MIM-104 Patriot PAC-3

Telemetry Test Procedures

PCM/Frame Encoder
Telemetry Transmitter
Group Demodulator & Recorder
Digital Data Recorder & Archiver

WARNING: This mock procedure intentionally omits all operational, classified, or safety-critical commands and numeric stimulation parameters. **This will not replace or act as a supplement for official information** for testing-program technical orders or cleared engineering documentation of the MIM-104 Patriot PAC-3.

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1. Purpose

The purpose of this manual is to establish standardized, repeatable procedures for the **testing, verification, and documentation of telemetry system components** within a controlled laboratory environment. These procedures define the step-by-step methods required to evaluate each device's functional integrity, signal performance, and interoperability within a simulated telemetry chain.

This manual serves as both a **training reference and a procedural standard**. It is intended to ensure that all personnel performing tests—whether engineers, technicians, or students—apply consistent methods, measurements, and safety practices. Each test sequence has been written to remove ambiguity, minimize operator error, and ensure that any qualified technician can perform the tests successfully using only the information contained herein.

The purpose of this manual extends beyond simple function checks. It provides a framework for:

- Demonstrating the relationships between hardware subsystems in a telemetry chain;
- Reinforcing discipline in procedural execution, data recording, and configuration control;
- Developing operator proficiency in using test instrumentation and interpreting measurement results; and
- Establishing traceable performance baselines that can be referenced during future calibration, maintenance, or instructional exercises.

By following the procedures outlined herein, the operator ensures that all telemetry subsystem elements are configured, tested, and evaluated in accordance with accepted engineering practices. The resulting data provides objective confirmation that each component performs within expected parameters and that the end-to-end data path maintains fidelity, synchronization, and reliability under standard operating conditions.

2. Scope

This section defines the operational boundaries, objectives, and component coverage of this Telemetry Component Test Procedure Manual. It ensures that all testing, documentation, and analysis are performed in a controlled, repeatable manner consistent with aerospace telemetry validation practices.

2.1 - System Context

The telemetry subsystem described in this manual represents a notional model derived from publicly available information about modern missile and aerospace telemetry architectures. It reflects a closed-loop data acquisition and transmission chain used for flight test instrumentation or training systems.

The following components are included under test (CUTs):

Compnent	Model	Primary Function
PCM Encoder	EC-2100	Converts analog and digital sensor signals into a formatted IRIG-106-compliant PCM stream for transmission.
RF Telemetry Transmitter	TT-308A	Modulates the PCM data onto an RF carrier for line-of-sight downlink to a ground station.
Telemetry Receiver/Decoder	GTR-500	Demodulates, decodes, and reconstructs the PCM data for recording, processing, and analysis.

2.2 - Scope of Testing

The procedures contained herein encompass functional bench-level testing only. Tests are intended to:

- Verify each component's standalone performance and conformance to nominal electrical and data specifications.
- Confirm interoperability between the encoder, transmitter, and receiver under standard IRIG-106 conditions.
- Validate data integrity by measuring bit-error rate (BER), frame synchronization, and timing accuracy.
- Assess RF transmission parameters such as carrier frequency, output power, and spectral purity under nominal lab conditions.
- Provide detailed operator guidance for safe setup, calibration, operation, and post-test data handling.

The procedures include explicit safety precautions, setup schematics, acceptance criteria, and documentation requirements to ensure zero ambiguity during execution.

All tests are repeatable and traceable to documented configurations and reference standards.

2.3 - Exclusions and Limitations

The telemetry component tests outlined in this document are limited to **bench-level functional and format validation**—verifying data framing, timing accuracy, and archive integrity per IRIG 106-20 standards.

To achieve full qualification and acceptance, **additional testing is typically required**. The following test types are acknowledged but are not included within this manual's scope:

- **Environmental Qualification Testing:** Thermal cycling, vibration, humidity, and shock testing as defined in MIL-STD-810
- **Electromagnetic Compatibility (EMC)**: Radiated emissions, susceptibility, and shielding effectiveness evaluations per MIL-STD-461.
- **Software Validation and Firmware Auditing**: Beyond basic verification of decoder and encoder operational versions.
- **System Integration Tests:** Any end-to-end validation involving live ordnance, propulsion systems, or guidance controls
- **Flight or Field Testing:** These procedures are strictly laboratory-based and are not authorized for use on active weapon systems.

Such activities are performed under separate documentation and authorization according to applicable organizational or DoD protocols.

2.4 - Use of References and Standards

All test methodologies are derived from open-source documentation and accepted engineering practice. The following standards and reference materials were consulted in developing the procedures:

- IRIG 106-20 Telemetry Standards, Range Commanders Council
- FM 3-01.11 — Air Defense Artillery Operations, U.S. Army
- DTIC Technical Report ADA405901 — Telemetry System Engineering Review
- Vendor Application Notes from Keysight Technologies, Rohde & Schwarz, and Mini-Circuits (publicly available) regarding PCM modulation, IRIG decoding, and RF power measurement.

These references guided the test structure, instrument configuration, and expected measurement tolerances. No proprietary or restricted data is reproduced.

2.5 - Intent and Audience

This manual is designed for engineering and technical personnel engaged in the assembly, verification, and maintenance of telemetry systems or their educational equivalents.
It serves as both a procedural reference and a training tool for technicians learning telemetry verification workflows, documentation discipline, and measurement accuracy.

While the structure and methodology emulate defense-grade testing standards, the content is entirely unclassified and suitable for academic or demonstration use.

3. Supplemental & Reference Materials

This section lists all reference documents, standards, and supporting materials that informed the preparation of this Telemetry Component Test Procedure Manual, and should be utilized as companion materials when operating the PAC-3 Interceptor Missile during testing.

3.1 - Primary Telemetry & System Context Standards

3.1.1 IRIG Standard 106-20 — Telemetry Standards (Range Commanders Council, Telemetry Group)

Provides the authoritative guidance for PCM/frame formatting, time-tagging, channel identifiers, archive file formats, and recommended telemetry test and recording practices. The mock procedures use IRIG 106-20 as the normative basis for frame integrity checks, time synchronization validation, and archive format expectations.

3.1.2 FM 3-01.11 — U.S. Army, Air and Missile Defense Operations

Offers unclassified operational context and component-level nomenclature (radar set, engagement control, launcher elements). This handbook was used to ensure component names and high-level telemetry roles in the mock procedures are realistic and understandable to non-specialists. (Do not use FM 3-01.11 as a substitute for program TOs or ICDs.)

3.1.3 ADA405901 — "Analysis of Telemetry Data Collection and Processing for Missile Systems"

Provides conceptual background and examples of telemetry processing chains, common data-handling pitfalls, and historical testing approaches. Useful for informing the logical flow of encoder > transmitter > receiver > archive tests in the mock procedures; cleared engineers should consult the document for ideas but rely on program-specific documents for numeric parameters. (User-supplied resource; public DTIC PDF.)

3.2 - Environmental, EMC, and Electrical Standards (for additional testing)

3.2.1 MIL-STD-810H — Environmental Engineering Considerations and Laboratory Tests

Justifies and standardizes environmental tests (temperature, thermal shock, vibration, humidity) that are described as additional qualification activities in the Scope section. Use MIL-STD-810 methods to design environmental test profiles and acceptance checks.

3.2.2 MIL-STD-461G — Requirements for the Control of Electromagnetic Interference (EMI)

Defines radiated and conducted emissions and susceptibility testing used to ensure telemetry components do not emit harmful interference and can survive hostile RF environments. Reference MIL-STD-461 when planning EMC/EMI tests that were listed as recommended in Section 2.5.

3.3 - Laboratory & Quality Management Standards

3.3.1 ISO/IEC 17025 — General requirements for the competence of testing laboratories

Why included / how used: Guides calibration traceability, test-lab competence, and measurement-reporting practices. Used to shape calibration, instrument ID, and archival traceability requirements in the Data Recording and Post-Test sections.

4. Safety, Security, & Personnel

4.1 - Core Safety & Personnel Rules

4.1.1 Authorization & Scope Control

No bench, ground, or integration test may be conducted without an approved Test Authorization form signed by the Test Director and the Program Safety Authority. The authorization must reference the approved procedure revision and list the components & permitted modes. (Program TOs/ICDs override.)

4.1.2 Roles & Minimum Staffing

- Test Director (TD): overall responsible for test execution and coordination.
- Safety Officer (SO): independent of TD; responsible for LOTO, electrical safety, and immediate test halt authority.
- Security/Data Custodian: responsible for classification marking, chain-of-custody and archive controls.
- Operator(s) & Recorder(s): execute instrument operations and data capture.
- Maintain a minimum of two trained personnel in the test area when powered hardware is present.

4.1.3 Training & Qualification

Personnel shall be trained on electrical safety, ESD handling, the specific decoder/recorder tools used, and data handling rules (including classification handling if applicable). Maintain training records and proof of currency. See OSHA electrical guidance and ISO/IEC 17025 (lab competence).

4.1.4 Permits & Approvals

Obtain range/airspace approvals for any tests that could affect RF emissions or involve real transmitters (TRMC / Range Office / AFMAN processes as applicable).

4.1.5 Lockout / Tagout (LOTO) & Electrical Controls

Apply LOTO procedures wherever test steps could expose personnel to hazardous energy. Follow OSHA high-voltage test rules for lab setups involving elevated voltages or currents.

4.1.6 Personal Protective Equipment (PPE)

Minimum PPE for bench tests: ESD grounding wrist straps, safety glasses, hearing protection (if acoustic or mechanical tests), insulated gloves when handling exposed conductors. Add PPE per site ESH handbook.

4.1.7 Facility & Equipment Controls

Calibrated instruments only (maintain calibration IDs/dates). House test equipment in certified labs; demodulators/recorders used for classified captures must run in accredited facilities with controlled access. See ISO/IEC 17025 for lab traceability.

4.1.8 Emergency & Incident Reporting

Safety Officer halts test on any safety/security incident. All incidents are logged in an Incident Report and routed to ESH and Program Security. Emergency evacuation and first-aid procedures per facility ESH. OSHA reporting thresholds apply for serious injuries.

4.2 - Security & Data Handling

4.2.1 Classification & Marking

All telemetry captures must be assessed for classification. Classified captures must be labelled, transported, and archived under program security rules (PSO guidance). Unclassified data still requires access control and audit logging. (Do not store classified data on unapproved systems.)

4.2.2 Chain-of-Custody & Archival Integrity

Record transfer metadata (session ID, operator, signer, checksum/hash, destination archive ID). Use cryptographic checksums for long-term integrity where authorized.

4.2.3 Access Control & Privileges

Limit access to test instruments and archives by role-based privileges. Maintain logs of all archive accesses and data exports.

4.2.4 Cryptography & Keying

Obtain range/airspace approvals for any tests that could affect RF emissions or involve real transmitters (TRMC / Any crypto or keying operations are controlled by PSO and must not be part of open lab procedures. Refer to program crypto handling SOPs.

4.2.5 Media Sanitization & Disposal

Follow program and facility policies for sanitization of removable media after use (secure erase or destruction) before release.

4.3 - Test-Specific Safety Considerations

4.3.1 No Live-Fire / Arming Actions

Explicitly prohibit any operational or arming sequences in the bench-level telemetry test procedure; those actions require separate, approved procedures and safety waivers.

4.3.2 RF Emissions

Do not enable RF transmitters for open-air tests without Range/Radio approval. Where RF testing is required, use shielded attenuated feeds and approved test connectors or anechoic chambers. Refer TRMC/range guidance and AFMAN.

4.3.3 Access Control & Privileges

For power-variation tests, ensure safe shutdown and file-system integrity checks are performed—uncontrolled power interruptions can corrupt archival files. Use instrument-rated power supplies and controlled brownout simulators in a lab.

4.3.4 Cryptography & Keying

If a recording failure is detected, preserve the test site and all equipment for forensic examination and log chain-of-custody; do not erase logs.

4.4 - Program Forms

For any live system or weapon-system hardware the program's Technical Orders, Range Safety regulations and Program Security Office (PSO) instructions take precedence over the guidance below. Do not substitute the templates below for approved program procedures.

4.4.1 Test Authorization Form

Test Authorization Form (TAF)

Form ID: ____________ **Rev:** ________ **Date:** ________

Sec 1. *Test Overview*

Test Procedure Title ____________________ **Test Procedure Number** ____________

Component Under Test ____________________ **Serial / Lot Number** ____________

Test Location ____________________ **Scheduled Test Date** ____________

Sec 2. *Authorization*

Role	Name	Signature	Date
Test Requestor			
Lead Test Engineer			
Quality Assurance Rep			
Safety Officer (if required)			
Program Manager / Technical Director			

Sec 3. *Approval to Proceed*

☐ Authorization Granted ☐ Authorization Denied

Notes / Conditions:

____

____

Authorized By: ____________________ **Signature:** ____________________

Date: ____________

4.4.2 Incident Report

Incident Report Form (IRF)

Form ID: ________________________ Rev: ____ Date: ________________

Section 1 – Basic Information

Reported By	____
Role / Position	____
Incident Date & Time	____
Test Procedure / Component	____
Location	____

Section 2 – Incident Description

Provide a concise but complete description of the event, sequence of actions, equipment involved, and any immediate consequences.

____
____
____
____
____

Section 3 – Immediate Actions Taken

____
____
____

Section 4 – Personnel Involved / Witnesses

Name	Role / Affiliation	Contact Information

Section 5 – Preliminary Assessment

■ Equipment Malfunction ■ Human Error ■ Procedural Error ■ Environmental Factor ■ Other

Brief Assessment:

____
____
____

Section 6 – Authorization & Follow-Up

Role	Name	Signature	Date
Test Engineer			
Safety Officer			
Program Manager			

5. Test Procedures

This section defines how all test procedures in this manual are organized and presented. The standardized structure ensures consistency, repeatability, and clarity for every engineer and technician performing telemetry component verification.

Each test follows the same core structure:

1. Purpose – States what the test verifies and why.
2. Required Equipment – Lists all necessary tools, instruments, and software.
3. Test Setup – Describes how equipment and components are arranged.
4. Pre-Test Conditions – Lists environmental and readiness checks before testing.
5. Test Method – Summarizes the testing approach and measurement strategy.
6. Procedure – Provides the ordered steps for conducting the test.
7. Acceptance Criteria – Defines the limits or conditions for a successful result.
8. Data Recording and Reporting – Outlines documentation and archiving requirements.
9. Post-Test Actions – Covers equipment shutdown, reset, and data backup steps.

All test procedures adhere to this format to promote clarity and reliability. When adding or revising procedures, maintain this structure and document any deviations in the revision log. This uniform approach ensures that every test—regardless of complexity or personnel—meets consistent standards for quality, repeatability, and safety.

5.1 - PCM Encoder Functional Test

Model: M-PCM-1000

Output Format: IRIG-106 PCM, NRZ-L

Input Channels:8 Analog + 4 Discrete

Bit Rate: 1 Mbps nominal

5.1.1 Purpose

This procedure verifies the correct operation of the M-PCM-1000 Pulse Code Modulation (PCM) Encoder, ensuring it accurately converts analog and digital input signals into a properly formatted IRIG-106-20 compliant data stream.

Specifically, this test confirms:

- All analog channels respond linearly and encode without distortion.
- Digital inputs are sampled correctly.
- Frame synchronization words, bit timing, and word alignment conform to IRIG 106-20 requirements.
- Output signal levels and bit integrity meet telemetry data link standards.

Successful completion of this test demonstrates the encoder is ready for integration into the telemetry transmitter subsystem.

5.1.2 Required Equipment

Equipment	Minimum Specification	Model	Notes
Regulated DC Power Supply	28 VDC ± 0.2 V, ≥ 5 A	BK Precision 1687B	Must include ovwer-voltage protection
Function Generator	Dual-channel, up to 1 MHz sine/square	Keysight 33500B Series	Outputs test waveforms to encoder inputs
Digital Oscilloscope	≥ 500 MHz bandwidth, 2 GSa/s	Tektronix MDO3034	Monitors signal integrity and synchronization
Telemetry Data Analyzer	IRIG-106-20 compliant	Curtiss-Wright TTC DAS Studio	Decodes and verifies telemetry stream
Digital Multimeter (DMM)	6½-digit accuracy	Fluke 8846A	Verifies supply voltage and continuity
Shielded Coaxial Cables	RG-58 or better	N/A	For telemetry output connections
ESD Ground Strap and Mat	ANSI/ESD S20.20 compliant	N/A	Required for handling all electronics
Computer with Data Capture Software	Windows 10+	N/A	For file storage and analysis

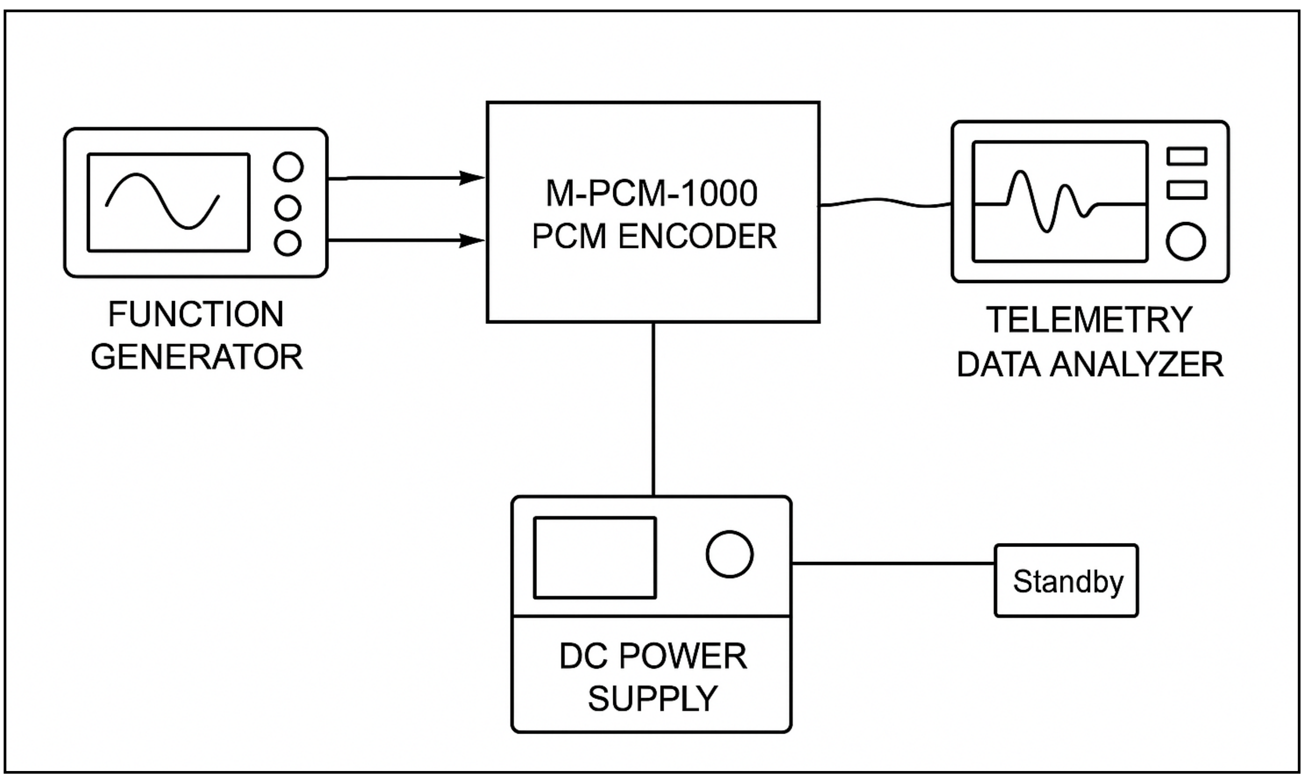
5.1.3 Test Setup

Perform setup exactly as follows:

1. Place the M-PCM-1000 encoder on an ESD mat.
2. Connect the positive (+) output of the 28 VDC power supply to Pin A of the encoder power connector, and the negative (–) lead to Pin B (Ground). Leave the power supply OFF.
3. Connect Function Generator Channel 1 to Encoder Input Channel 1 using a 50 Ω coaxial cable.
4. Connect Function Generator Channel 2 to Encoder Input Channel 2 using a second coaxial cable.
5. Connect the Encoder Telemetry Output to the Telemetry Data Analyzer Input using a 50 Ω shielded coax cable no longer than 1 m.
6. Connect the Oscilloscope across the telemetry output (use a high-impedance probe in parallel) to monitor waveform quality.
7. Verify that all instruments share a common electrical ground.
8. Power on the oscilloscope, function generator, and telemetry analyzer.
9. Confirm calibration stickers are present and valid (within 12 months).

(Reference Figure 5.1-A for typical setup layout.)

Figure 5.1-A



5.1.4 Pre-Test Conditions

Check	Specification	Operator Initials
Ambient temperature	20 °C ± 5 °C	
Relative humidity	< 65 %	
Power supply output (no-load)	28.0 V ± 0.2 V	
Ground continuity from encoder chassis to bench	< 0.1 Ω	
Analyzer and function generator warm-up time	≥ 30 minutes	
Encoder connectors and cables inspected	No visible damage	

5.1.5 Test Method

The encoder will be stimulated with two known input signals:

- Channel 1: 1 kHz sine wave at 1 Vpp.
- Channel 2: 5 kHz square wave at 5 Vpp.

The encoder's telemetry output will be captured and decoded. The resulting data will be analyzed for:

- Correct frame synchronization pattern.
- Stable bit rate and word alignment.
- Low bit-error rate (BER).
- Accurate amplitude-to-digital conversion.

5.1.6 Procedure

Perform all steps sequentially. Do not skip or reorder any step.

Power-On and Baseline Verification

1. Set the power supply output to 28.0 VDC, current limit 5.0 A.
2. Switch the supply ON, confirm 28.0 ± 0.2 V appears at encoder input.
3. Observe that the encoder status LED (green) illuminates within 5 seconds.
   - If LED fails to illuminate: power down immediately and report anomaly.

Signal Input Configuration

4. On Function Generator Channel 1, select Sine Wave, 1 kHz, 1 Vpp, 0 V offset, 50 Ω output impedance.
5. On Channel 2, select Square Wave, 5 kHz, 5 Vpp, 0 V offset, 50 Ω output impedance.
6. Confirm both waveforms using the oscilloscope before connecting to the encoder.

5.1.6 Procedure (cont...)

Encoder Configuration

7. Using encoder control software (if applicable), set parameters as follows:
   - Frame rate: 512 kbps
   - Frame length: 128 words
   - Word length: 12 bits
   - Sync pattern: 0x1ACFFC1D (mock example)
   - Channel assignment: CH1 = Analog 1, CH2 = Analog 2
8. Save configuration file as `PCMENC_Config_512Kbps.cfg.`

Telemetry Stream Verification

9. Start data acquisition on the Telemetry Data Analyzer.
10. Observe oscilloscope output: verify square-edged digital waveform with nominal amplitude of ±1.5 V.
11. Confirm analyzer reports continuous frame synchronization within 2 seconds of data start.
12. Record the following from analyzer:
    - Frame rate (target = 512 kbps ± 0.5 %)
    - Frame sync word recognition count (≥ 95 %)
    - BER after 60 seconds (target ≤ 1×10^{-6})
13. Save telemetry data to file `PCMENC_TestRun1.dat.`
14. Stop acquisition and review decoded data plots for analog channels.
15. Confirm CH1 data represents a sine wave; CH2 data represents a square wave with correct frequency ratio (1:5).

Functional Repeatability Test

16. Change CH1 waveform to 2 kHz and CH2 waveform to 10 kHz.
17. Repeat Steps 9–15.
18. Confirm results are consistent within ±2 % of previous test parameters.

Frame Alignment and Word Integrity

19. Enable bit-level view on analyzer.
20. Verify that sync word occurs every 128 words exactly.
21. Check random sample of 10 consecutive frames for bit errors or dropped words.
22. Capture screenshot showing valid frame structure and save as `PCMENC_FrameVerify.png`

Power-Off

23. Stop all waveform generation.
24. Turn off power supply.
25. Wait 30 seconds for all capacitive discharge.
26. Disconnect all cables and label encoder as "Tested."

5.1.7 Acceptace Criteria

Parameter	Requirement	Pass Criteria
Output bit rate	512 kbps ± 0.5 %	Analyzer confirms within range
Frame synchronization	Continuous lock	No loss > 1 s
Bit error rate (BER)	$\leq 1 \times 10^{-6}$	Analyzer BER log confirms
Frame word count	128 ± 0	Analyzer matches config
Analog accuracy	± 2 % deviation from expected input	Within limits
Power draw	< 2.5 A @ 28 VDC	Measured ≤ limit

If any parameter fails to meet the above criteria, the test shall be halted, the failure documented in the **Incident Report Form**, and the encoder quarantined for engineering review.

5.1.8 Data Recording and Reporting

1. Save all analyzer data, screenshots, and configuration files to:
   `\\TelemetryTests\PCM_Encoder\YYYYMMDD\TestID\`
2. Record test summary in the Test Data Record Sheet with operator signature.
3. Verify file integrity by confirming file size > 0 kB and checksum log matches expected CRC.
4. Submit digital copy to Quality Control within 24 hours of test completion.

5.1.9 Post-Test Actions

1. Inspect encoder connectors for bent pins or residue.
2. Apply protective dust caps to all ports.
3. Return encoder to storage container labeled "Validated."
4. Disconnect and power down all lab equipment.
5. Update test status in the project tracking spreadsheet.
6. File physical logbook entry under section "Telemetry – PCM Encoder Tests."

5.1.10 Operator Sign-Off

Role	Name	Date	Signature
Test Operator			
QA Witness			
QA Witness			

5.2 - RF Transmitter Integrity and Link Verification Test

Model RFT-2100 Telemetry Transmitter

Output Power: 1.0 W nominal

Frequency Range: 2.2 – 2.3 GHz

Modulation: PCM/FM (per IRIG 106-20)

5.2.1 Purpose

This procedure validates the RFT-2100's ability to accept an IRIG-106-formatted PCM stream, modulate it onto an RF carrier, and transmit the signal at the correct frequency, power level, and spectral purity. It also confirms end-to-end data integrity when received by a compatible ground telemetry receiver.

5.2.2 Required Equipment

Equipment	Minimum Specification	Model	Notes
DC Power Supply	28 V ±0.5 V, 5 A	BK Precision 1688B	Power source for the transmitter
PCM Signal Source	IRIG 106-20 compliant PCM output	M-PCM-1000 or equivalent	Provides valid PCM input stream
RF Power Meter	10 MHz–26.5 GHz, ±0.02 dB accuracy	Keysight N1913A	Measures transmitter output power
Spectrum Analyzer	2 Hz–26.5 GHz, < 1 Hz RBWFSW-26	Rohde & Schwarz FSW-26	Verifies carrier frequency and spectral purity
Telemetry Receiver	PCM/FM demodulation, BER measurement	GRX-5000 or equivalent	Confirms reception and data integrity
Coaxial Cables	RG-400, SMA male-to-male	Pasternack PE3R125	RF signal routing between instruments
Attenuator	30 dB, 2 GHz rated, 2 W max	Mini-Circuits HAT-30+	Protects receiver and test instruments
RF Splitter	2 GHz bandwidth, 50 Ω	Mini-Circuits ZAPD-2-252-S+	Divides RF signal between analyzer and receiver

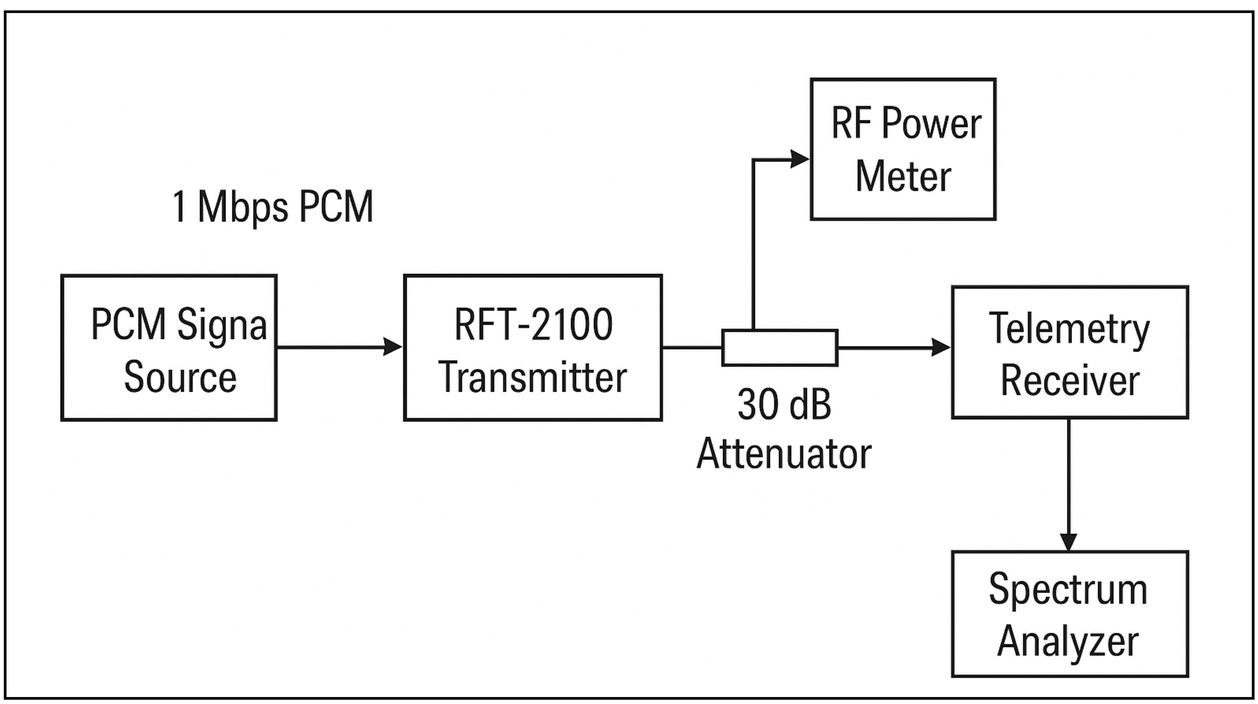
5.2.3 Test Setup

Perform all connections with the system powered OFF.
Follow this exact order:

1. Place all instruments on an antistatic workbench with sufficient spacing for cooling and cable routing.
2. Connect the **PCM Signal Source** output to the **RFT-2100 PCM Input** port.
3. Connect the **RFT-2100 RF Output** to the **30 dB Attenuator Input**.
4. Connect the **Attenuator Output** to the **RF Splitter Input**.
5. From the splitter:
   - Connect **Port A** to the **RF Power Meter Input.**
   - Connect **Port B** to the **Spectrum Analyzer Input** using a short coax jumper.
   - Connect the Telemetry Receiver in parallel using the analyzer's RF Through/Loop port.
6. Connect the **DC Power Supply** to the transmitter's power input using 16-AWG leads :
   (red = positive, black = return)
7. Ensure all test instruments and the transmitter share a common ground.
8. Visually inspect all RF connectors—hand-tighten only; do not overtorque.

(A schematic of this configuration is shown in Figure 5.2-A.)

Figure 5.2-A



5.2.4 Pre-Test Conditions

Pre-Test Condition	Verification Method	Operator Initials
All RF interconnects are secure; SMA/BNC connectors tightened to specification.	Visual and tactile inspection.	
Attenuator (HAT-30+) and RF splitter correctly installed per Figure 6.2-A.	Cross-check orientation and labeling.	
DC power supply set to 28 VDC ± 0.5 V, current limit 2 A max.	Power supply digital display reading.	
Transmitter output connected to 50 Ω termination or test instrument.	Verify RF path continuity.	
Spectrum analyzer, power meter, and receiver warmed up for ≥ 15 minutes.	Timer or instrument self-check.	
PCM signal source active and producing valid IRIG 106-20 format.	Observe bit pattern via oscilloscope or BER monitor.	
All equipment properly grounded; ESD wrist straps in place.	Ground continuity check.	
Safety and authorization documentation (TAF-01, Section 4) verified.	Review and signature confirmation.	

5.2.5 Test Method

This test verifies the operational integrity of the TT-308A Telemetry Transmitter by transmitting a known PCM data stream through its RF chain and measuring the resulting signal characteristics.

The method evaluates carrier frequency accuracy, output power level, and modulation fidelity using calibrated test equipment under controlled laboratory conditions.

By analyzing the transmitted signal on a spectrum analyzer and power meter, engineers can confirm that the transmitter correctly amplifies and modulates the input PCM stream in compliance with IRIG-106 telemetry standards.

Successful completion of this test ensures the transmitter can reliably convey encoded telemetry data over a designated RF channel without degradation, distortion, or frequency drift.

5.2.6 Procedure

***Safety**: Never apply DC power to the transmitter without a properly rated attenuator connected. RF output at full power into an open load can permanently damage both the transmitter and test instruments.*

Perform all steps sequentially. Do not skip or reorder any step.

Power-On Sequence

1. Verify all instrument power switches are OFF.
2. Turn ON the DC Power Supply, set to **28.0 VDC**, current limit **5 A**.
3. Power ON the PCM Signal Source, Power Meter, Spectrum Analyzer, and Receiver.
4. Allow 2 minutes for all equipment to stabilize.

Input Signal Verification

5. Set the PCM Source to **2.000 Mbps** NRZ-L format, IRIG 106 frame.
6. Observe its output on the source's monitor scope; confirm stable clock and data.

Transmitter Activation

7. Apply **28 VDC** to the transmitter.
8. Wait 30 seconds for internal regulation to stabilize.
9. Enable RF Output switch.

Power Measurement

10. On the Power Meter, record the measured power in watts.
11. Convert to dBm ($10 \times \log_{10}(P \times 1000)$).
12. Note reading in Table 6.2-1, Row 1.

Telemetry Stream Verification

13. On the Spectrum Analyzer:
    - Center Freq = 2.250 GHz
    - Span = 10 MHz
    - Resolution BW = 1 kHz
    - Video BW = 3 kHz
    - Detector = Peak Hold
        a. Observe the carrier; measure peak frequency and occupied bandwidth.
        b. Confirm no spurious components above –50 dBc.
        c. Record all values.

5.2.6 Procedure (cont...)

Receiver Verification

14. On the Telemetry Receiver, tune to 2.250 GHz, FM mode, 1 MHz deviation.
15. Confirm frame lock and bit sync lock indicators illuminate.
16. Observe real-time BER readout; measure for 60 seconds
17. Record BER reading.

Stability Check

18. Monitor output power and frequency for 5 minutes.
19. Ensure variation ≤ ±0.1 dB (power) and ≤ ±2 kHz (frequency).

Power-Down Sequence

18. Disable transmitter RF output.
19. Switch OFF the transmitter's DC power.
20. Turn OFF measurement instruments in reverse order of setup.
21. Allow transmitter to cool 5 minutes before disconnecting cables.

5.2.7 Acceptace Criteria

Parameter	Requirement	Pass Criteria
RF Output Power	+30 dBm ± 1 dB at 2.2 GHz	Output within range; stable over 60 seconds of transmission
Carrier Frequency Accuracy	±5 kHz from nominal 2.2 GHz	Frequency remains within specified tolerance throughout test
Modulation Integrity	BER ≤ 1×10^{-6}	Clean modulation and error-free data recovery
Power Supply Current	≤ 1.5 A at 28 VDC	Stable current draw; no transients >10%
PCM Lock Stability	Continuous for ~30 seconds	Lock indicator does not drop during transmission
Spectral Purity	Spurious outputs ≥ 60 dB below carrier	No spurious tones or harmonics above threshold

If any parameter fails to meet the above criteria, the test shall be halted, the failure documented in the Incident Report Form, and the encoder quarantined for engineering review.

5.2.8 Data Recording and Reporting

Record all readings on Form 6.2-T (RF Transmission Verification Record).
Each entry must include:

- Date and Operator Name
- Instrument Models and Serial Numbers
- Power and Frequency Readings
- BER Result
- Environmental Conditions (Temperature, Humidity)
- Operator Signature

Digital copies shall be saved under
`/Telemetry_Tests/RFT2100/YYYYMMDD/`

Each entry must include:
`PowerFreqLog.txt` , `BERReport.csv` , and `SpectrumTrace.png.`

5.2.9 Post-Test Actions

1. Inspect all connectors for wear or debris; apply dust caps.
2. Verify that all instruments return to standby or default states.
3. Review data for outliers exceeding ±5 % tolerance; if found, repeat test.
4. Attach completed Form 6.2-T and a printed spectrum plot to the Test Authorization Form.
5. If abnormal readings, spurious > –50 dBc, or BER > 1×10^{-6} occur, file an Incident Report (Appendix B) and quarantine the transmitter.
6. Store the RFT-2100 in its ESD-safe container at ambient temperature (20 ± 5 °C).

5.2.10 Operator Sign-Off

Role	Name	Date	Signature
Test Operator			
QA Witness			
QA Witness			

5.3 -Ground Telemetry Receiver & Decoder Functional Test

Model GTR-500 Ground Telemetry Receiver/Decoder

Receive Band: 2.2–2.3 GHz

Nominal Input Sensitivity: –60 dBm

Supported PCM formats: NRZ-L, Bi-Φ, PCM per IRIG-106

5.3.1 Purpose

Verify the GTR-500 correctly demodulates an incoming RF telemetry signal, recovers PCM frames, decodes IRIG-106 formatted data, and reports data integrity metrics (BER, frame loss, and channel mapping). The test confirms end-to-end receive chain operation under controlled lab conditions and ensures archive output files are complete, correctly time-stamped, and checksum-verified.

5.3.2 Required Equipment

Equipment	Model	Specifications	Notes
RF Signal Generator	Rohde & Schwarz SMB100A (or equivalent)	9 kHz – 6 GHz, modulation capable	Generates controlled RF telemetry with PCM input
Variable Attenuator	Mini-Circuits HAT-30+	0–30 dB, 2 GHz rated	Simulates path loss; protects receiver
Spectrum Analyzer	R&S FSW-26 (or equivalent)	2 Hz – 26.5 GHz	Verify RF input and monitor spurious
Telemetry Source / PCM Encoder	M-PCM-1000 (or equivalent)	IRIG-106 PCM output	Provides canonical PCM test stream
Time Source / IRIG Generator	TSG-IRIG-10 (or equivalent)	IRIG-B or GPS time reference	Time sync & stamp verification
Desktop PC with Decoder Software	Windows 10+, IRIG-106 decoder tool	Runs decode and saves archive files	Decoding, BER logging, file archiving
Coaxial cables & attenuators	RG-400 or equivalent	50 Ω RF connections	Interconnects
Calibrated Power Meter & Probe	Keysight N1913A (or equiv.)	Verify generator output	Instrument verification

5.3.3 Test Setup

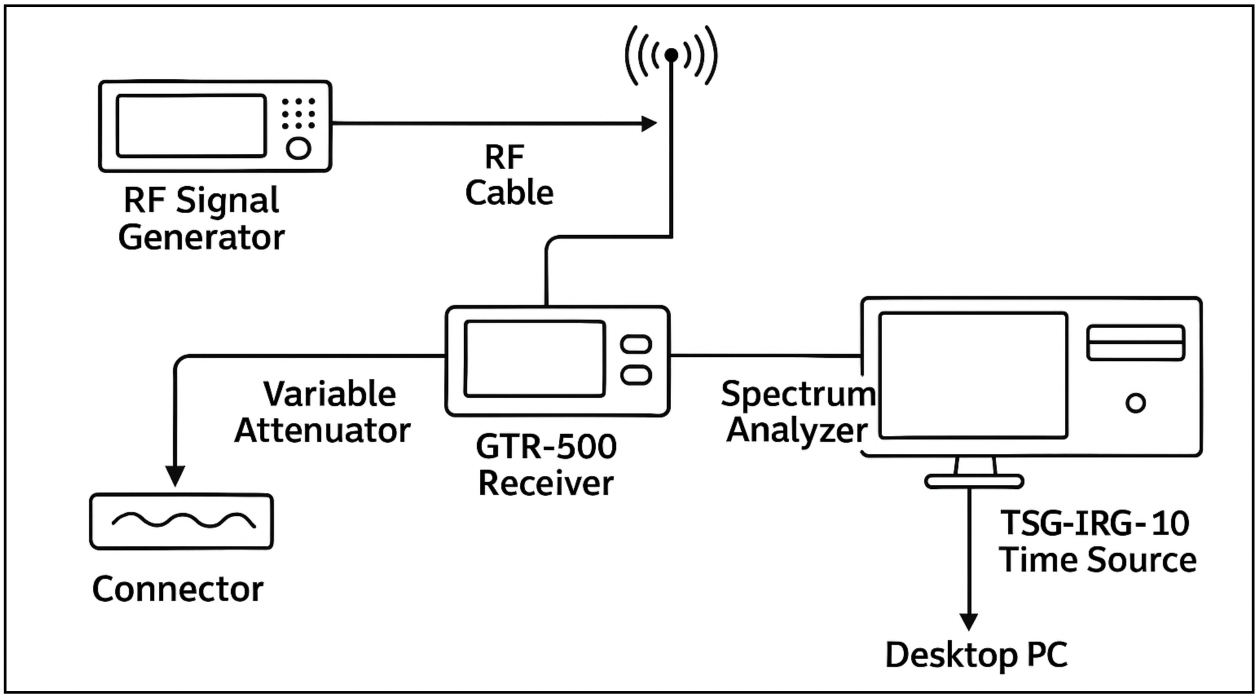
Perform setup exactly in this order, with equipment powered OFF:

1. Place GTR-500 on ESD mat and connect to common ground.
2. Connect **RF Signal Generator** output > **Variable Attenuator** > **GTR-500 RF Input** using short coax (≤ 1 m).
3. Connect **Telemetry Source / PCM Encoder** data output to the RF Signal Generator modulation input (or directly feed the signal generator a pre-encoded RF input per instrument capability).
    - If using direct RF modulation: ensure the generator is set to carrier 2.250 GHz and modulated with the PCM encoder output.
4. Connect **GTR-500 data output** (Ethernet or USB as applicable) to the **Decoder PC.** Confirm network settings (static IP or DHCP as lab uses).
5. Connect **IRIG time source** to the Decoder PC (if required) or ensure the decoder PC is synchronized to GPS/ IRIG time.
6. Connect **Spectrum Analyzer** in parallel (via splitter or monitor tap) to observe the RF input.
7. Confirm the **Variable Attenuator** is initially set to high attenuation (e.g., 30 dB) to protect the receiver during first power-up.
8. Power ON the Spectrum Analyzer, Signal Generator, PCM Encoder, Decoder PC, and finally the GTR-500 (leave RF generator output OFF until ready).

Warning: *Do not apply RF to the receiver until Pre-Test Conditions below are complete and initialed.*

(A schematic of this configuration is shown in Figure 5.3-A.)

Figure 5.3-A



5.3.4 Pre-Test Conditions

Pre-Test Condition	Verification Method	Operator Initials
Receiver physical inspection (no bent connectors, no visible damage)	No physical defects, antenna ports covered	
All instrument calibrations current	Calibration stickers dated ≤ 12 months	
RF attenuator installed and set to max attenuation	Attenuator reading = maximum / protective	
Signal generator configured for IRIG-106 PCM modulation	2 Mbps NRZ-L, known frame sync pattern active	
Decoder PC has adequate disk space (> 5 GB) and correct decoder software version	Free space ≥ 5 GB; decoder version logged	
IRIG/GPS time source available and synchronized	Time sync within 1 ms (if used)	
Common grounding confirmed	Ground continuity < 0.1 Ω	
Authorization form signed and on file	Test Authorization completed	

5.3.5 Test Method

Stimulate the receiver with a known, canonical PCM stream carried on an RF carrier. Gradually reduce RF level (via the variable attenuator) to the nominal input sensitivity and observe receiver lock, frame recovery, and decoder output.

This method yields:

- RF lock threshold and margin (how much attenuation before lock loss).
- BER and frame loss under nominal and marginal conditions.
- Verification that decoded channel data matches the known stimulus (functional correctness).
- Confirmation that decoder archives are complete, timestamped correctly, and checksummed.

5.3.6 Procedure

Follow these steps in exact sequence. Do not skip or reorder.

Initialization & Baseline Capture

1. Confirm pre-test checklist complete and signed.
2. Ensure Variable Attenuator = maximum attenuation (protective mode).
3. Configure Signal Generator: Carrier = 2.250 GHz, modulation source = PCM Encoder output, modulation depth per encoder setting. Keep RF output OFF.
4. On the Decoder PC, launch the decoder application and set the capture directory to: `\\TestDrive\Telemetry\GTR500\YYYYMMDD\TestRun_##\`
5. Create the directory and note the full path.
6. In the decoder, set session ID: `GTR500_TR1_<YYYYMMDD>_<OperatorInitials>.`
7. On the PCM Encoder, verify the transmitted test pattern is the canonical test sequence (e.g., alternating PRBS or known numeric channel ramps) and log the sequence ID to correlate later.
8. With attenuator still high, power ON the RF Signal Generator output (low level) and verify on the Spectrum Analyzer that a carrier is present and centered at 2.250 GHz.
   - If no carrier, troubleshoot generator/modulation chain before proceeding.

Receiver Lock & Decode Verification (Nominal Input)

9. Reduce attenuator to present **–60 dBm ± 1 dB** at the receiver input (use the power meter to measure level at receiver input if available). Record measured input level.
10. On the GTR-500, verify **RF Lock** indicator is active. On the Decoder PC, click **Start Capture**.
11. Allow the decoder to capture **60 seconds** of continuous data. During capture, monitor:
    - Frame sync count (expect continuous sync).
    - BER display (should be below threshold).
    - Any decoder error/warning flags.
12. After 60 seconds, stop capture and save raw file `GTR500_TR1_raw.dat` and decoded CSV `GTR500_TR1_decoded.csv`
13. Verify decoded channel values (a sample of channels) match the PCM encoder's known test pattern (compare numeric values or waveform plots). Note discrepancies.

Sensitivity Margin & Robustness

14. Increase attenuation in 3 dB steps. At each step:
    - Wait 10 seconds for the receiver/decoder to settle.
    - Record whether RF Lock persists.
    - Record BER and frame loss over a 30-second capture.
    - Continue until lock is lost or attenuation reaches the maximum defined test limit (e.g., +30 dB beyond nominal).
15. If lock is lost, reduce attenuation 3 dB and verify re-lock occurs within 5 seconds. Record time to re-lock.

Time-Stamp & Archive Integrity

16. Verify that raw file headers include time stamps (UTC) from IRIG/GPS source or decoder PC clock.
17. Compute and record checksum (e.g., SHA-256) of `GTR500_TR1_raw.dat` and `GTR500_TR1_decoded.csv` Store checksum in the session log.
18. Verify decoded CSV contains a header row with field names and timestamp column. Validate there are no NULL rows in required fields.

Edge Cases & Recovery

19. While continuous capture is running at nominal input, simulate a short interruption by increasing attenuation to lose lock for 2–3 seconds, then restore.
20. Observe decoder behavior: it should log frame loss events and resume capture without file corruption.
21. Capture the event and save as `GTR500_TR1_interrupt1.dat.`
22. Verify that all files remain readable and decodable after the interruption.

Shutdown

23. Stop capture, close decoder application, and safely power down Signal Generator (RF OFF), then GTR-500, then decoder PC peripherals.
24. Label and secure all recorded files and session log per data handling rules. Ensure chain-of-custody form is initiated if the data is controlled.

5.3.7 Acceptace Criteria

Parameter	Requirement	Pass Criteria
RF Lock at Nominal Input	Lock at –60 dBm ± 1 dB	Receiver locks and maintains lock for 60 s
BER (Nominal)	$\leq 1 \times 10^{-6}$ measured over 60 s	Decoder BER display ≤ threshold
Frame Loss	< 0.01 % frames lost over capture	Frame count matches expected within tolerance
Decode Accuracy	Decoded channel samples match source pattern within ±2 %	Numeric or waveform match confirmed
Time-Stamp Presence	UTC time stamps present in raw file headers	Time stamps recorded and match IRIG/GPS source
Archive Integrity	Raw and decoded files checksum match computed values	SHA-256 or CRC verified and logged
Recovery Behavior	Re-lock within 5 s after 3 dB reduction from loss	Receiver/decoder resumes without file corruption

If ANY criterion fails, stop further testing, document the failure using the Incident Report Form, and quarantine the receiver until engineering review.

5.3.8 Data Recording and Reporting

1. Store raw and decoded files to the session directory created in Step 4.
2. In the Test Data Record Sheet, record: session ID, operator, start/stop times (UTC), RF input levels, BER values, frame counts, file names, and checksums.
3. Attach a spectrum analyzer screenshot showing the carrier and any spurs. Save as: `GTR500_TR1_spectrum.png`
4. Email the session report (encrypted if required) to the QA inbox and copy the Test Director within 24 hours.

Suggested file naming convention:

```
GTR500_TR1_raw_YYYYMMDD_HHMMSS.dat
GTR500_TR1_decoded_YYYYMMDD_HHMMSS.csv
GTR500_TR1_spectrum_YYYYMMDD_HHMMSS.png
```

5.3.9 Post-Test Actions

1. Ensure all files have a verified checksum recorded in the session log.
2. Complete the Chain-of-Custody form for any removable media used.
3. Power down and cap the receiver RF port.
4. Return equipment to designated storage locations and note serial numbers in the log.
5. Sign and date the Test Data Record Sheet and obtain QA witness signature

5.2.10 Operator Sign-Off

Role	Name	Date	Signature
Test Operator			
QA Witness			
QA Witness			