ERS

RADIANODE ENGINEERING READINESS SERIES

ERS-2026-002

Engineering Readiness Assessment

Measurement Chain Readiness for Instrument-Grade Energy Characterisation of Cellular IoT Devices

INDEPENDENT ENGINEERING VALIDATION

Radianode Ltd · Company No. 17359155

PUBLICATION CLASSIFICATION

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Supporting artefacts	**github.com/radianode/ers-2026-002**

Executive Summary

This Engineering Readiness Assessment evaluates whether a laboratory measurement chain, assembled from commercially available instruments, is fit to produce defensible instrument-grade energy measurements of cellular IoT devices.

The assessment was conducted using the Radianode engineering validation methodology, focusing on the characteristics that determine whether a measurement can be trusted rather than on any device performance result. **No energy consumption result is reported in this assessment.** Its subject is the instrument, not the device.

The measured evidence demonstrates that the evaluated chain:

- Agrees with an independently derived reference to within **0.22 percent** in the primary path
- Places attenuation components within **0.3 dB** of nominal at the operating frequency
- Achieves branch balance of **0.38 dB** and no measurable inter-port leakage above the measurement floor
- **Does not** reproduce absolute RF level between sessions without in-session verification
- **Does not** permit module-level current attribution on the evaluated carrier board

> ENGINEERING DECISION
>
> **Is this measurement chain fit to produce defensible energy measurements of cellular IoT devices, and at what level of attribution?**
>
> This publication answers that question using measured engineering evidence.

Investigation scope

ITEM	DESCRIPTION
Engineering asset	Laboratory measurement chain for cellular IoT energy characterisation
Engineering objective	Determine whether the chain can produce defensible engineering measurements, and establish the level of attribution it supports
Instruments evaluated	Nordic Power Profiler Kit II; Anritsu MS2712E Spectrum Master; HP 6611C system DC supply; Keysight DSOX1102G; Mastech MS8268 bench digital multimeter
RF network evaluated	20 dB and 30 dB SMA attenuators; Wilkinson divider in combiner configuration
Device carrier evaluated	Waveshare SIM7080G Cat-M/NB-IoT HAT
Network emulation	Amarisoft Callbox, Band 25 FDD, separate Tx1 and Rx1 ports
RVP	RVP is Radianode's structured methodology for turning engineering evidence into defensible decisions. RVP connects the engineering question, expected behaviour, controlled evidence and resulting decision so that conclusions remain traceable to the evidence behind them.

ENGINEERING PROCESS

RVP · Radianode Validation Process

RVP is Radianode's structured methodology for turning engineering evidence into defensible decisions. It connects the engineering question, expected behaviour, controlled evidence and resulting decision so that conclusions remain traceable to the evidence behind them.

STAGE	DEFINITION	APPLICATION IN ERS-2026-002
RVP-01 Assess	Define the engineering problem by reviewing requirements, understanding system architecture, identifying constraints, and establishing the scope of assessment.	Defined the measurement objective, the attribution levels required by the intended campaign, and the constraints imposed by available instrumentation.
RVP-02 Simulate	Apply appropriate engineering analysis to evaluate expected system behaviour.	Computed expected current from an independently measured reference load; derived expected attenuation and combiner behaviour from component specification.
RVP-03 Validate	Verify engineering assumptions using objective evidence, performance evaluation, documented findings, and structured engineering review.	Measured every path against an independently derived reference; retested where a first result was implausible; withdrew three claims that did not survive challenge.
RVP-04 Decide	Evaluate the evidence against requirements, assumptions and remaining uncertainty to establish readiness.	Established the attribution level the chain supports, and the conditions under which its measurements are valid.

01

Current Measurement Accuracy

ENGINEERING QUESTION

Does the current measurement path agree with an independently derived reference value, and to what tolerance?

MEASUREMENT	RESULT
Reference load, Mastech MS8268-measured	216 to 217 Ω (nominal 220 Ω, ±5 percent)
Source meter mode, supply output	4.036 V
Source meter mode, voltage across load	3.992 V
Source meter mode, measured current	18.25 mA average, 18.66 mA maximum, 182.47 mC over 10.00 s
Source meter mode, independently calculated	18.15 mA
Ampere meter mode, measured current	18.14 mA average
Ampere meter mode, theoretical	18.18 mA
Deviation against theory	**0.22 percent**
Deviation against supply indication	0.71 percent (18.27 mA indicated)

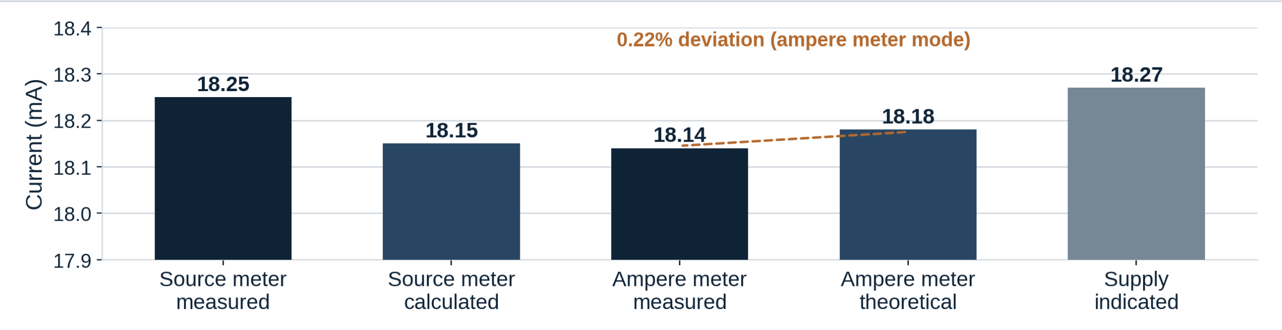

FIGURE 1 Current measurement path validation against an independently derived reference value. The observed deviation is adequate for resolving the current transitions relevant to this campaign.

ENGINEERING INTERPRETATION

The primary current measurement path agrees with an independently derived expectation to within 0.22 percent, and with the supply's own indication to within 0.71 percent. Both figures are considered adequate to resolve the current transitions of interest in cellular IoT devices.

A first attempt in ampere meter mode returned 0.43 µA against an expected 18.2 mA — a discrepancy of four orders of magnitude. This was diagnosed by continuity and voltage checks at the instrument terminals as a **connection topology fault, not an accuracy limitation**, and corrected by adopting the manufacturer's documented configuration. The failure and its diagnosis are recorded because the distinction matters: an instrument that reads implausibly is not necessarily an instrument that reads inaccurately.

✓ **Engineering Finding -** Current measurement accuracy is confirmed against an independent reference in both operating modes.

02

RF Network Behaviour

ENGINEERING QUESTION

Do the attenuation and combining components behave as specified at the operating frequency?

COMPONENT	NOMINAL	MEASURED	DEVIATION
Attenuator 1	20.00 dB	20.28 dB	+0.28 dB
Attenuator 2	30.00 dB	30.15 dB	+0.15 dB

COMBINER MEASUREMENT	RESULT
Branch A to B	–51.77 dBm at 1.979936 GHz
Branch A to C	–52.15 dBm at 1.979936 GHz
Branch imbalance	**0.38 dB**
Inter-port leakage, B to C	–92.77 dBm displayed, with port A terminated

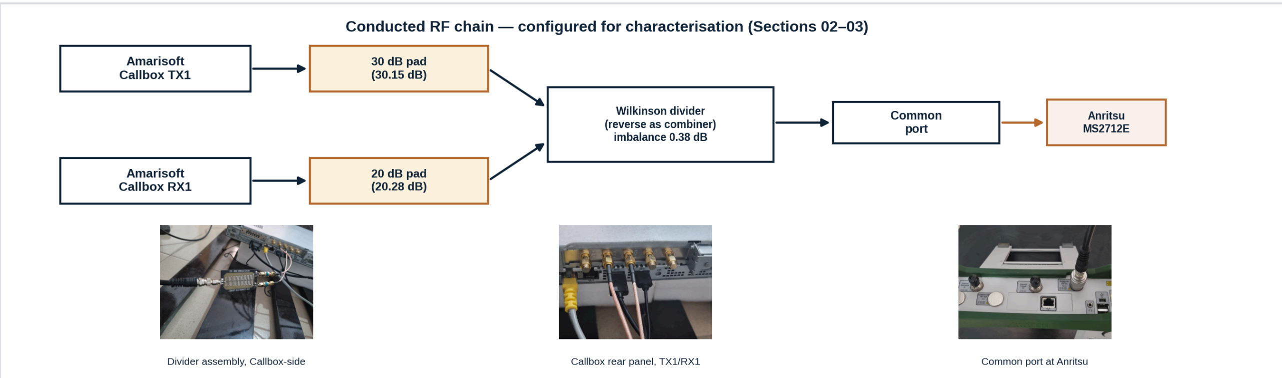

FIGURE 2 *Conducted RF chain architecture with measured component values* Measured values annotated. Divider used in reverse as a combiner for Band 25 FDD.

ENGINEERING INTERPRETATION

Both attenuators track nominal within 0.3 dB at the operating frequency, and the divider is well balanced at 0.38 dB. Inter-port leakage was tested in the topology that is operationally relevant — branch to branch, with the common port terminated — rather than in the split configuration, which characterises balance rather than isolation.

The leakage result is recorded as **no measurable leakage above the displayed measurement floor**, not as an isolation figure of 92.77 dB. The distinction is material: the measurement was floor-limited, and the true isolation may be considerably better. Reporting a non-detection as a measured value would overstate what the evidence supports.

✓ **Engineering Finding -** RF network components behave within specification at the operating frequency, with inter-port leakage below the measurement floor.

03

Link Level Repeatability

ENGINEERING QUESTION

Can the radio-frequency level presented to the device be set predictably and reproduced between sessions?

CONFIGURATION	MEASURED LEVEL
Transmit gain 60 dB	–82.24 dBm
Transmit gain 45 dB, receive gain 40 dB	–95.78 dBm (first session)
Transmit gain 45 dB, receive gain 40 dB	**–96.79 dBm (retest, working reference)**
Session-to-session drift observed	**+2.44 dB and –1.01 dB** at nominally identical configurations

Configured TX Gain (dB)	Measured Level (dBm)	Configured Step (dB)	Measured Step (dB)
60	-80.51	-	-
55	-85.58	5.00	5.06
50	-90.84	5.00	5.26
45	-95.04	5.00	4.20
40	-99.78	5.00	4.74

FIGURE 3 TX Gain-Step Response and Session Repeatability

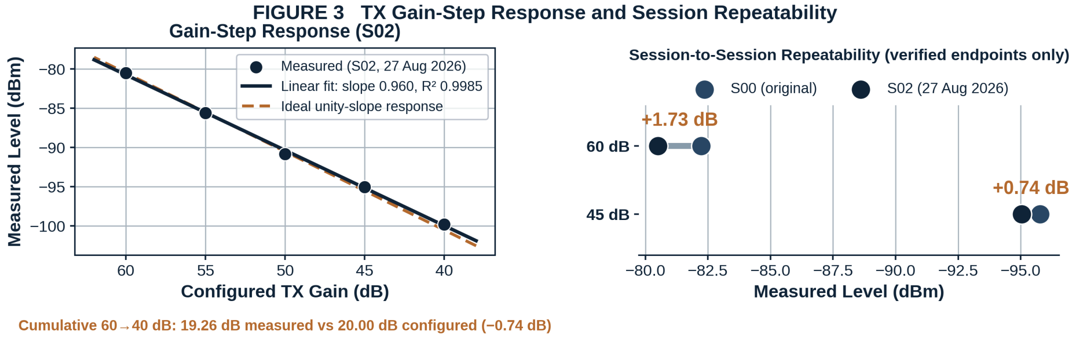

FIGURE 3 TX Gain-Step Response and Session Repeatability, session S02 (27 Aug 2026). Slope 0.960 (R^2 0.9985), opposite in sign to the discarded S01 sweep.

ENGINEERING INTERPRETATION

Gain-step response. Session S02 (27 Aug 2026) shows a monotonic, approximately linear TX-gain response over 40 to 60 dB: successive 5 dB steps measured 5.06, 5.26, 4.20 and 4.74 dB, a cumulative 19.26 dB against 20.00 dB configured (-0.74 dB), linear fit slope 0.960 (R^2 0.9985).

Session-to-session drift. Verified endpoints across two sessions (S00, S02) differ by +1.73 dB at 60 dB and +0.74 dB at 45 dB. A separate sweep from 26 Aug (S01) is excluded from evidence: it held a 40 dB capture conflict and an unverified 45 dB point, and is fully superseded by S02.

Slope-sign reversal. The discarded S01 sweep's slope exceeded unity; S02's falls short of it. Opposite-signed deviation across two sessions argues against a fixed instrument non-linearity, which would be expected to reproduce with consistent sign and shape, and supports describing this as gain-control response and repeatability variation still under investigation.

Withdrawn claim, restated. The original 13.54 dB vs 15 dB claim of confirmed gain non-linearity remains withdrawn. S02 gives 14.53 dB measured against the same 15 dB change (-0.47 dB), consistent with gain-control response and repeatability variation, not a fixed non-linearity.

Engineering Finding - Link level is **not** reproducible between sessions from configuration alone. In-session verification against a calibrated instrument is required before every measurement.

04

Attribution Level

ENGINEERING QUESTION

Can current drawn by the cellular module be attributed to the module alone, or only to the carrier board as a system?

OBSERVATION	RESULT
Carrier board VBAT access	Single breakout header. No dedicated test point adjacent to the module
Header topology	**Series versus parallel tap unresolved.** A printed-circuit artwork question that the schematic alone cannot settle
Module-off baseline at the header	2.06 mA average, 2.15 mA maximum over 10.00 s
Module datasheet power-saving floor	3.2 µA
Implied contamination ratio	**Approximately 600 to 1** if the tap is parallel
Constraint applied	No hardware modification. No trace cuts, no component lifts

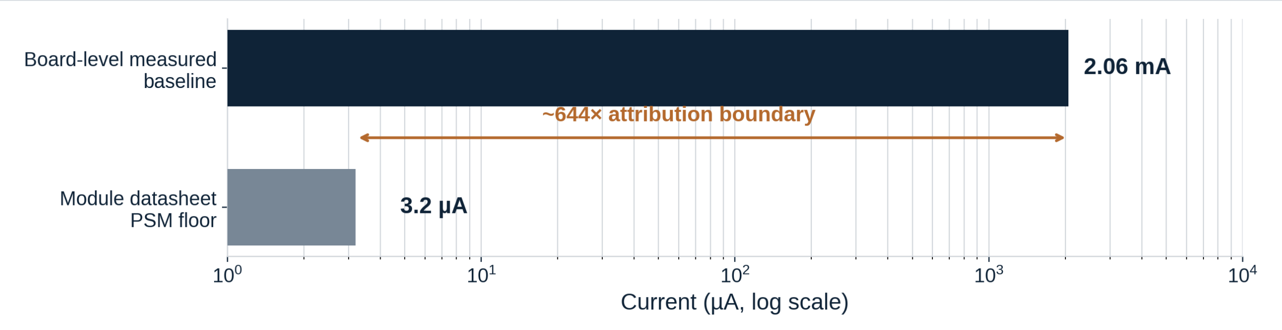

FIGURE 4 *Attribution levels available on the evaluated carrier board* The quantity of interest sits far below the board-level floor.

ENGINEERING INTERPRETATION

Under a no-modification constraint, the only available current access point on the evaluated carrier board is a breakout header whose connection topology is unresolved. If the header is a parallel tap, current measured there includes board-level draw from the on-board regulator and its associated circuitry.

The measured board-level baseline of 2.06 mA is approximately six hundred times the module's specified power-saving floor. At that ratio the module's own low-current behaviour is **unrecoverable by measurement** at this access point.

Differential subtraction does not rescue the measurement. Subtraction is valid only for a static baseline, whereas the intended campaign requires per-phase energy across a dynamic event during which the board-level load itself varies with supply droop. There is no constant quantity to subtract.

This is a limitation of the carrier board, not of the measurement chain. The chain resolves current correctly, as established in Section 01. What is unavailable is a point at which to apply it.

✕ **Engineering Finding -** Module-level current attribution was **not achieved** on the evaluated carrier board under the no-modification constraint applied in this assessment. System-level attribution is available and valid.

Scope of Evaluation

Clearly defining the limits of this assessment strengthens the credibility of the engineering conclusions presented.

THIS ASSESSMENT EVALUATES	THIS ASSESSMENT DOES NOT EVALUATE
Current measurement accuracy against an independent reference	Frequency response across the operating band — no tunable source was available
Attenuation and combining component behaviour at the operating frequency	Any energy consumption result for any device
Inter-port leakage in the operationally relevant topology	Any device performance, battery life or deployment claim
Link level setting and session-to-session repeatability	Thermal effects and long-term instrument drift
The attribution level available on the evaluated carrier board	Carrier boards other than the one evaluated
	Radiated measurement of any kind

A DECLARED LIMITATION

Attenuation was characterised at a single frequency within the downlink block. The available spectrum analyser has no tracking generator and no independent tunable source was available, so the frequency response across the band was not measured.

This is recorded as a deferred item, not an addressed one. Band flatness is carried as a specification-bounded term rather than a measured one, and any future operation at a different frequency within the band should not assume the measured values apply without re-verification.

Engineering Evidence Summary

ENGINEERING CRITERION	OUTCOME
Current measurement accuracy	✓ **Confirmed** — 0.22 percent against theory
RF network behaviour	✓ **Confirmed** — within 0.3 dB of nominal; 0.38 dB imbalance
Link level repeatability	■ **Qualified** — requires in-session verification
Module-level attribution	✗ **Not achieved** under the applied no-modification constraint
System-level attribution	✓ **Available**

Radianode Engineering Position

Following independent engineering evaluation, Radianode considers the assessed measurement chain fit to produce defensible energy measurements of cellular IoT devices **at system level**, subject to two operating conditions.

#	OPERATING CONDITION
1	**Link level is verified against a calibrated instrument in every session**, at the device connector, and never set from a previously recorded gain configuration alone
2	**Measurements are labelled at the attribution level they support.** System-level results are not presented as module-level results

Module-level attribution requires a carrier board that exposes the module supply rail in series, or a modification to the evaluated board that the applied constraint excludes. Verification on an alternative carrier board is recommended before module-level claims are made.

Frequency response across the operating band remains unmeasured and is recommended for characterisation should a tunable source become available.

ENGINEERING READINESS OUTCOME

READY FOR SYSTEM-LEVEL ENERGY MEASUREMENT

Subject to in-session link level verification

Module-level attribution not achieved under the no-modification constraint applied in this assessment

Reproducibility Statement

This Engineering Readiness Assessment is an implementation of the Radianode Validation Process. Supporting engineering artefacts, reproducibility resources, implementation workflows and publication assets are available through the official Radianode GitHub repository: **github.com/radianode/ers-2026-002**

REPOSITORY CONTENTS	
Instrument configuration records	Model, serial, firmware and calibration date per instrument
Measured component values	Reference load, attenuators, with measurement dates
Raw instrument captures	Current measurement traces and spectrum analyser trace files
Session records	Full session metadata including ambient conditions
Correction history	Claims made, challenged and withdrawn, with their resolutions
Figure generation scripts	Every published figure regenerable from raw data

Appendix A — Figure Traceability

Every published figure is traceable to the engineering workflow that generated it.

REPORT FIGURE	ENGINEERING WORKFLOW	SOURCE EVIDENCE
Figure 1 — Current measurement validation	Measurement chain validation	Instrument capture records, reference load determination
Figure 2 — RF chain architecture	Conducted chain characterisation	Spectrum analyser trace files, assembled-chain photograph
Figure 3 — Gain repeatability	Link level characterisation	Five-point sweep record, cross-session retest
Figure 4 — Attribution levels	Carrier board current assessment	Board-level baseline capture, manufacturer specification

Continue the Conversation

Every connected system presents different engineering constraints. The question is rarely whether a technology can work. The real question is whether it is ready for your deployment.

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