Diagnosing Passive Intermodulation

A field methodology for finding the real source

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EXECUTIVE SUMMARY

A PIM test does not tell you what is broken. It tells you that something, somewhere in the tested path, is generating intermodulation — and on a modern multi-band network, that path can run through a dozen connectors, several metres of cable, and whatever metalwork happens to be nearby.

A high PIM reading identifies a path, not a part.
The analyser, test leads, adapters, terminations, connectors, installation and surrounding environment all sit inside the measurement. Any one of them can produce the result in front of you.

The instinct, faced with a high reading, is to blame the jumper or cable under test. That instinct is usually premature. A high reading confirms that intermodulation exists somewhere in the measured path. On its own, it says nothing about which component is responsible.

This paper sets out a systematic method for closing that gap: verifying the test system, inspecting connections, substituting components one at a time, weighing installation and mechanical effects, and accounting for environmental PIM — in that order, before anything gets replaced.

Done properly, this cuts unnecessary returns, avoids repeat site visits caused by fixing a symptom instead of a cause, and gets the fault resolved the first time.

01 Introduction

Passive Intermodulation occurs when two or more RF signals meet a non-linear point in a passive system and generate additional frequencies. Where those products land inside a receive band, they raise the apparent noise floor and degrade system performance — invisibly, until someone runs a test.

Connectors, cable assemblies, antennas and filters can all generate PIM. So can poor electrical contact, contamination, corrosion, mechanical damage, and dissimilar metals working against each other at a junction.

Establishing that a high reading exists is rarely the hard part. Establishing where it is coming from is. A PIM test measures the complete path between the analyser and the termination, not a single component in isolation, so the result reflects everything sitting in that path [1].

That makes replacing the most obvious part an unreliable fix. If the replacement doesn't address the actual source, the fault comes back. And even where a reading does improve, changing several things in the same visit makes it impossible to say which change did the work — which means the next fault on the next site gets diagnosed with no more certainty than this one.

The more reliable approach: establish a known baseline, then change the system in a controlled, recorded sequence, one variable at a time.

02 Understanding the PIM Measurement

A PIM analyser injects two RF carriers into the system under test — per IEC 62037, typically +43 dBm (20 W) each — and measures the intermodulation products that result, expressed in dBc relative to the carrier power [1].

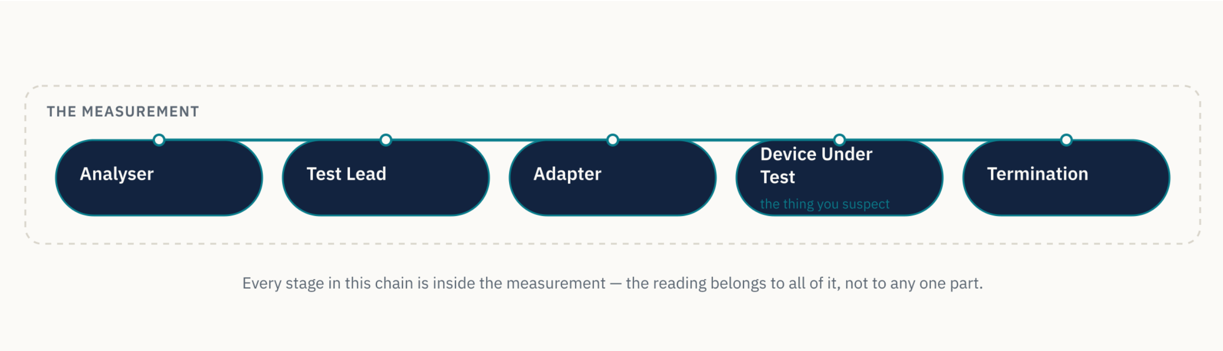

Figure 1 — The test path. Every stage between the analyser and the termination is inside the measurement.

That measured value belongs to the whole arrangement, not to any single part of it. The analyser, test leads, adapters, load, connectors and device under test are all inside the loop. On an installed system, cable routing, mechanical condition and nearby metalwork join them too.

This is the detail that gets missed when a result is read too quickly. A high reading proves intermodulation is present under the conditions tested. It does not locate the source within them. A jumper measured against one test arrangement can produce a materially different result against another, not because the jumper changed, but because the configuration, the connections, or the conditions around it did.

PIM should therefore always be measured against a known, repeatable arrangement. Without one, two genuinely identical components can appear to perform completely differently, and neither reading can be trusted.

03 Establishing a Test-System Baseline

Check the test system before the assembly under test. If the analyser, leads, adapters or termination are generating PIM of their own, nothing measured downstream of them means anything.

A verified low-PIM load establishes this baseline: measure the test system's residual PIM before the device under test goes anywhere near it, and hold that baseline to a tighter limit than the one you're actually trying to meet. Hughes' own precision test loads, for reference, are independently rated to an absolute minimum of −165 dBc while handling 50 W continuous [7] — that is the kind of margin a baseline load needs below whatever limit the job specifies, so the load itself is never in question.

RESIDUAL PIM
Measure the test system against a verified low-PIM load before the device under test is introduced.

EQUIPMENT CONDITION
Check calibration status, and inspect connectors, test leads and adapters for wear or damage.

TEST CONFIGURATION
Record the exact equipment and configuration so later measurements can be compared against this one.

REPEATABILITY
Confirm the baseline holds steady when the measurement is repeated, not just on the first pass.

If residual PIM drifts between repeats, or sits higher than expected, that is the test system to investigate — not the assembly under test. Chasing a fault through the device under test while the analyser's own leads are the actual source wastes a site visit before it has properly started.

04 Inspecting Connections and Interfaces

Once the test system is verified, the connections within the test path come next.

Connector interfaces get investigated early because their performance depends on two separate things: the condition of the mating surfaces, and how well the connector was assembled in the first place. Either one alone can cause a fault. Most real faults on site are some combination of both.

Torque — connectors should be installed to the torque the connector manufacturer specifies. For 7/16 DIN interfaces, that figure is commonly around 25 N·m [3]. Under-torqued connections leave separations at the mating surface that generate PIM directly; over-torqued ones can deform that same surface and cause the identical problem from the opposite direction.

Cleanliness — mating surfaces should be clear of dirt, grease, metal particles and other contamination before assembly, not inspected for it afterwards.

Mechanical condition — threads, mating surfaces and connector bodies should be checked for deformation, cracking or other physical damage.

Material interfaces — dissimilar metals at a junction are worth noting, particularly wherever corrosion or poor contact pressure is already present.

None of these findings, on their own, prove a source. A worn thread or a dissimilar-metal junction is a condition to weigh against the rest of the investigation, not a verdict to close it on.

05 Controlled Substitution

If the test system and the connections both check out and the reading is still high, the next step is substitution — one component at a time.

Change one thing at a time.

Changing several components together may improve the result. It will not tell you which one was responsible.

01
Record
The original PIM result and the complete test configuration, before anything changes.

02
Substitute
One component.

03
Repeat
The measurement, under identical conditions.

04
Confirm
Restore the original component and confirm the original result returns.

Repeat the cycle for each remaining component in the path.

> ILLUSTRATIVE EXAMPLE
>
> *A jumper feeding a shared sector antenna measures −142 dBc against a −150 dBc site limit. It is swapped for a new unit from stock. The retest still reads −142 dBc. A second jumper, from a different batch, goes in next — no change. Only when the test lead between the analyser and the test point is reseated does the reading move, settling at −151 dBc. Neither jumper was ever the fault. Both had already been logged as defective and sent back before the test lead was checked.*

This is precisely what controlled substitution is for. Swap a jumper, reseat an adapter, alter the cable route and adjust connector torque all in the same pass, and an improved reading afterwards tells you nothing about which of the four changes actually did the work. The more variables move at once, the less the result can tell you — and the more likely a working component gets condemned in place of the real fault.

06 Installation and Mechanical Effects

PIM performance is also shaped by how an assembly is installed. A jumper that performs correctly on the bench can produce a different result once it is under mechanical stress in situ.

Cable condition — check for excessive bending, crushing, distortion or jacket damage.

Connector stress — look for strain at the connector body, excessive clamp pressure, or inadequate cable support.

Environmental exposure — check for water ingress and other conditions that could be affecting the assembly.

Movement — factor in vibration and movement where either is present in the installation.

Controlled mechanical testing

A defined section of cable or a connection can be lightly flexed or tapped, within sensible limits, while the PIM reading is monitored. If the reading moves when a particular section is disturbed, repeat the test to confirm the change is consistent rather than incidental. A repeatable change points to a problem associated with that cable, connector, termination or its mounting — worth investigating further, not treating as proof in itself. Any mechanical stimulus applied during testing should stay well within the equipment's and the installation's limits.

07 Environmental and Alien PIM

The source of a PIM reading does not always sit inside the electrical circuit being tested. Metallic objects in the surrounding environment can interact with RF energy and contribute to the measured result — commonly referred to as alien PIM.

METALWORK
Loose structures, brackets and other metallic objects near the RF path.

CABLE TRAYS
Nearby trays and supporting structures introducing unwanted metallic interfaces.

FASTENERS
Bolts and other metal-to-metal contacts within the installation.

CORROSION
Rust and degraded metallic interfaces forming non-linear contacts of their own.

This is worth weighing whenever a result shifts with the position or movement of the installation, or when a reading taken on site cannot be reproduced under lab conditions. The surrounding environment shouldn't be assumed to be the source by default — but where the measured behaviour points toward it, it belongs in the investigation rather than outside it.

08 Test Records and Reproducibility

PIM troubleshooting stands or falls on being able to compare measurements. Record test conditions in enough detail that the result could be reproduced by someone who wasn't on site.

Equipment — identification and calibration status for everything used.

Test conditions — frequencies, power levels and full test configuration.

Connections — test leads, adapters, connector torque and cable routing.

Evidence — PIM results, photographs, and a record of exactly what was substituted and when.

The sequence matters more than any single reading: the initial result, the change made, and the result that followed. Where a component looks like a genuine candidate, keep it rather than cleaning, re-terminating or disposing of it before the investigation is finished — that component may be the only evidence that explains the fault.

> **Repeatability matters.**
> If identical tests produce meaningfully different results, look at the test system, the connections, the installation and the surrounding environment before concluding that a component is defective.

09 A Practical PIM Troubleshooting Procedure

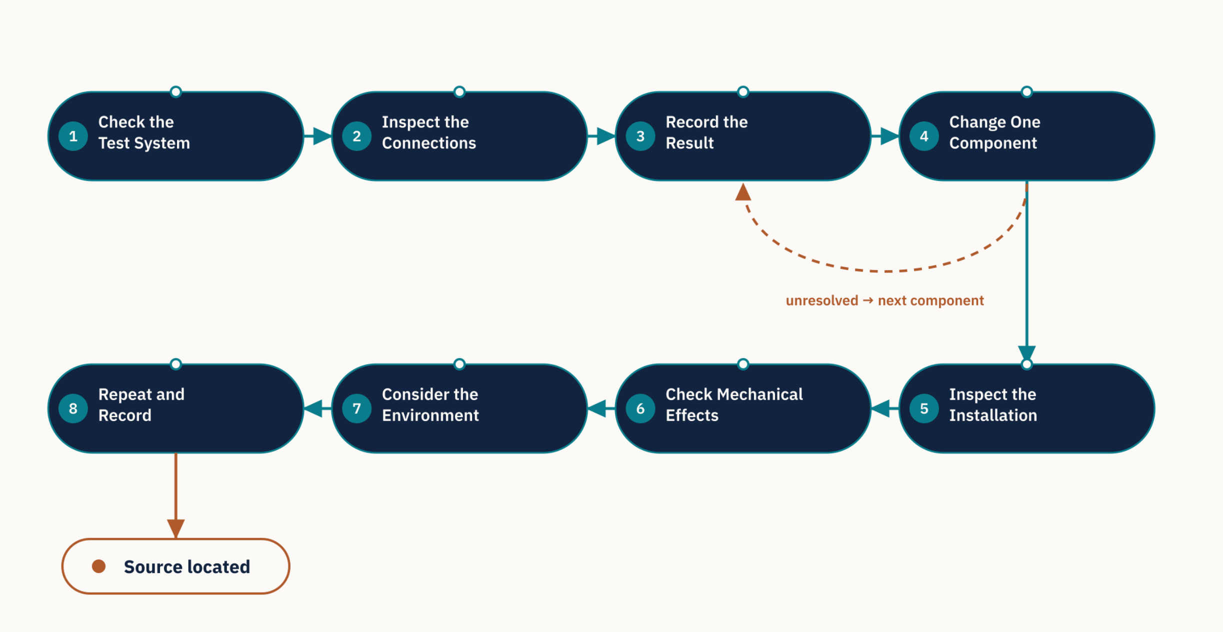

Figure 2 — The troubleshooting sequence. Unresolved readings return to substitution for the next component rather than moving on early.

1 Check the test system

Measure residual PIM against a verified low-PIM load. Confirm the analyser, leads, adapters and termination are within limits before anything else is assessed.

2 Inspect the connections

Check torque, cleanliness, threads, contact surfaces, contamination, corrosion and general mechanical condition.

3 Record the original result

Capture the PIM reading and the full test configuration before making any change.

4 Change one component

Substitute a single item, repeat the measurement, and confirm by restoring the original.

5 Inspect the installation

Check for excessive bending, crushed cable, clamp pressure, connector strain, water ingress and related mechanical conditions.

6 Check mechanical effects

Where appropriate, apply controlled movement to defined sections while monitoring the result, and repeat any change that appears.

7 Consider the environment

Investigate nearby metalwork, fasteners, cable trays, corrosion and other potential sources of alien PIM.

8 **Repeat and record**
Re-run the measurement under the established configuration and retain the records needed to support the diagnosis.

If step 4 doesn't resolve the reading, the cycle returns to step 3 for the next component rather than moving on to installation and environment prematurely — substitution is exhausted before the investigation broadens.

THE BASIC PRINCIPLE

Test the system → Inspect the connections → Change one thing at a time → Check the installation → Consider the environment → Repeat the result

10 Conclusion

A high PIM result does not, by itself, indict a cable or a jumper. The measurement spans the complete test path, and the equipment, the connections, the installation and the surrounding environment all sit inside it.

Replacing the most visible component is rarely the fastest way to resolve that — it is usually the slowest, once the return shipping, the re-test, and the second site visit are counted.

A reliable investigation starts with a known test-system baseline, moves through the connections, and substitutes components one at a time while recording the effect of each change. Where the evidence points there, it extends to mechanical condition and environmental PIM. What holds the whole process together is reproducibility: without a result that repeats, there's no way to know whether a change fixed the fault or just coincided with it.

For network operators, that discipline is the difference between a fault fixed once and the same fault revisited on a second callout. It is also, over enough sites, a meaningful reduction in components returned that were never actually at fault — see Hughes' companion papers on connector-related PIM and VSWR in cellular networks for the mechanisms behind two of the most common culprits [6, 8].

Before replacing the cable, test the system.

Establish the baseline. Isolate the components. Reproduce the result.

References

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[3] IEC 61169-4, Radio-frequency connectors — Part 4: RF coaxial connectors with inner diameter of outer conductor 16 mm, screw coupling — Type 7/16

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[6] Hughes Electronics Ltd, Connector Related PIM

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