White Paper

PIM over CPRI - Long Term Monitoring – a new approach with significant advantages over traditional PIM test solutions

Overview

Passive Intermodulation (PIM) is a growing and unpleasant side effect of the successful deployments of 4G and future 5G networks. PIM has the potential to degrade the efficiency of the cell site. This network degradation directly impacts the edge of cell performance and/or the throughput of the cell site. PIM will inevitably increase as more and more spectrum is utilised at a site.

PIM is created via three primary mechanisms;-

1 – Poor installation of the cell site, where dirty, loose or poor PIM quality components have been used at the cell site or just bad cell site configuration (for example how the antennas are positioned relative to other antennas or nearby metal infrastructure).

Figure 1 – example of antennas close to metal infrastructure

2 – Physical effects. If the antennas radiate into a PIM reflective material, for example, a rusty roof or rusty chain fence. With densification efforts ongoing it is increasingly difficult to find "clean" cell sites that are PIM free. Even tower mounted antennas commonly suffer from PIM due to the equipment mountings themselves. Rooftop sites inherently contain metal air-conditioning & plant equipment.

Figure 2 – rooftop cell site with a nearby rusty roof

3 – Adjacent RF bands. PIM is often viewed as an installation problem and whilst this is absolutely true that good site installation and antenna placement will minimize PIM, PIM is by its very nature is an ongoing and evolving problem. The industry has worked hard to address PIM at the cell site during installation. However, this does not mean that just because a site is PIM free today that tomorrow PIM will not occur. Today PIM is more likely to occur due to adjacent bands and/or physical effects in the vicinity of the cell site, for example, if a new RF band is added to an existing cell site; a new physical structure is added within the range of a cell site; or over time the cell site connectors corrode or work loose; then PIM will re-occur. Given this evolving and intermittent nature of PIM, it has become important to provide long-term monitoring capabilities to the operators to determine the actual impact of PIM on a cell site over days, weeks and even months to allow the Operator to fully quantify the PIM and prioritize next steps to mitigate PIM.

Why is long term monitoring important?

Simply, things change ! As previously mentioned an RF-based PIM test only identifies a persistent or permanent PIM issue. It is highly likely that a PIM issue is random, sporadic or traffic dependent. For example, a loose connector on an antenna may well show no signs of PIM until a strong wind blows that vibrates the cable, antenna or mounting and creates PIM. Likewise, zero or low traffic may not be sufficient to excite a PIM source, not until a site is heavily loaded does the PIM appear, or a combination of the right carriers and sufficient carrier loading would trigger PIM. Over time rooftop flashing, infrastructure, bolts and mounts exposed to the elements start to rust increasing the probability of PIM.

Figure 3 – PIMForensics – PIM over time

Current test methods for PIM monitoring and long term monitoring of PIM

Today there are two primary methods used to detect PIM:-

- **RF-based PIM testers** – Typified by the Anritsu PIM Master these are portable test boxes that allow the Engineer to generate two 20W (or 40W) RF tones at a set RF frequency and to measure the effects of PIM. These tools are useful for evaluating suspected PIM problems caused by poor installation (i.e. loose connectors) or with a PIM wand/probe to look for external PIM sources. They provide an instantaneous 'snapshot ' of the cell site PIM at the time of test, however, this method is unfeasible for long term monitoring as the cell site will remain out of service during the monitoring period (which could be days or weeks) and you would violate spectrum rules by transmitting CW tones over long periods of time.
- **Spectral analysis over CPRI** – A relatively new method using analysis of I/Q data on the fibre interface between the BBU and RF allow the user to measure the effects of PIM passively with no impact to the network. In addition measurements made represent true dB impact to the carrier providing the most accurate measure of PIM and also crucially the magnitude of PIM impact to the carrier.

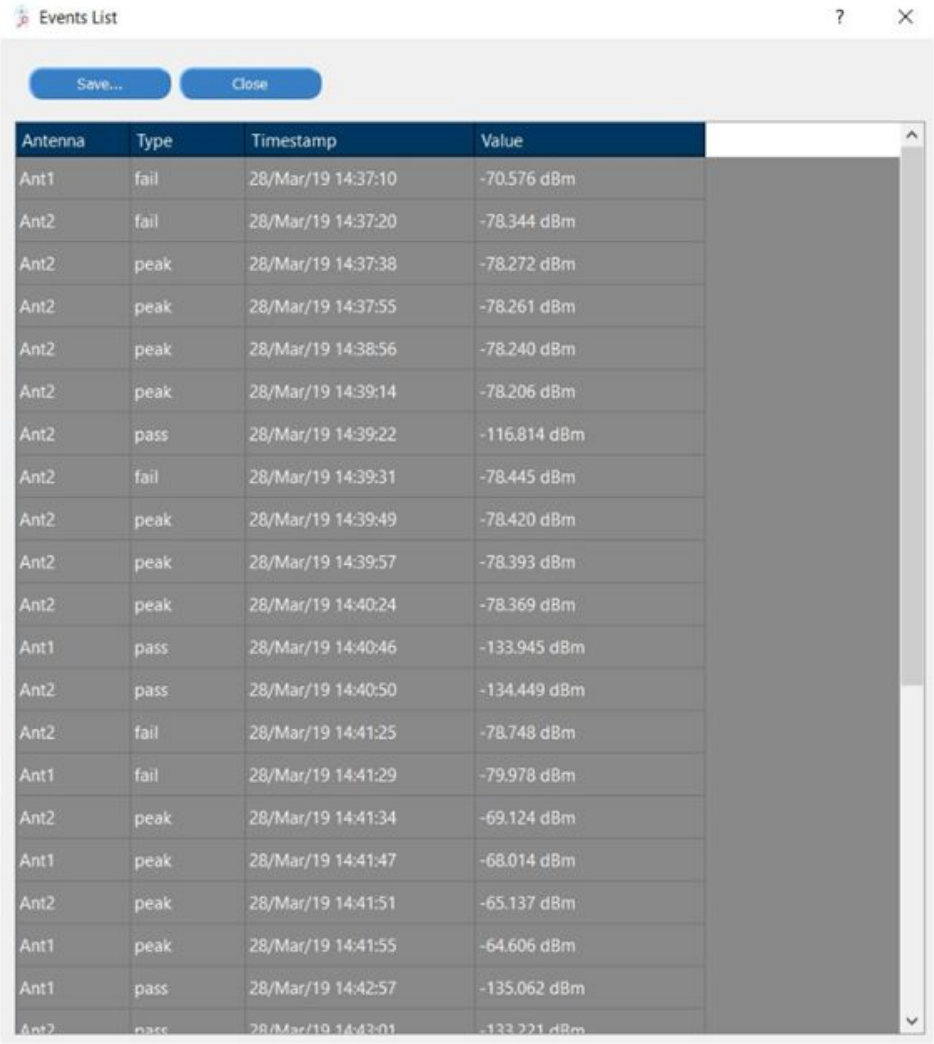
Both of the methods listed here cannot test for long term impacts of PIM. An RF PIM tester by creating an artificial CW tone by definition cannot monitor cell site traffic for the effects of PIM. A spectral analysis over CPRI cannot distinguish between PIM and noise in the uplink and hence cannot be used for long term PIM Monitoring. Only by using PIM over CPRI can the user get an accurate measure of the PIM impact over time.

Using PIM over CPRI, measured modes

- **Single measurement** – the downlink resource blocks are forced to be fully utilised (for example by using the OCNS function). Because the downlinks then have maximum power as set for that sector, a single measurement will capture the worst case PIM that sector will ever see. In addition to the PIM level measurement itself, an indication of internal or external PIM is provided.

Figure 4 – PIMForensics – single PIM measurement

- **Monitoring mode** – the equipment is left at the cell site to monitor the rise and fall of PIM level with the actual traffic at the cell site. This allows the identification of sites where PIM is actually causing a problem under normal operating conditions. An event log is created to allow the Operator to quickly and precisely see the time, duration and amplitude of the PIM and make a quick decision to invest money & resources to fix (or leave) the PIM problem.



Antenna	Type	Timestamp	Value
Ant1	fail	28/Mar/19 14:37:10	-70.576 dBm
Ant2	fail	28/Mar/19 14:37:20	-78.344 dBm
Ant2	peak	28/Mar/19 14:37:38	-78.272 dBm
Ant2	peak	28/Mar/19 14:37:55	-78.261 dBm
Ant2	peak	28/Mar/19 14:38:56	-78.240 dBm
Ant2	peak	28/Mar/19 14:39:14	-78.206 dBm
Ant2	pass	28/Mar/19 14:39:22	-116.814 dBm
Ant2	fail	28/Mar/19 14:39:31	-78.445 dBm
Ant2	peak	28/Mar/19 14:39:49	-78.420 dBm
Ant2	peak	28/Mar/19 14:39:57	-78.393 dBm
Ant2	peak	28/Mar/19 14:40:24	-78.369 dBm
Ant1	pass	28/Mar/19 14:40:46	-133.945 dBm
Ant2	pass	28/Mar/19 14:40:50	-134.449 dBm
Ant2	fail	28/Mar/19 14:41:25	-78.748 dBm
Ant1	fail	28/Mar/19 14:41:29	-79.978 dBm
Ant2	peak	28/Mar/19 14:41:34	-69.124 dBm
Ant1	peak	28/Mar/19 14:41:47	-68.014 dBm
Ant2	peak	28/Mar/19 14:41:51	-65.137 dBm
Ant1	peak	28/Mar/19 14:41:55	-64.606 dBm
Ant1	pass	28/Mar/19 14:42:57	-135.062 dBm

Figure 5 – PIMForensics long-term monitoring event log

Advantages of PIM over CPRI testing for long term monitoring

Here is a comparison of 'old' (RF-based) versus 'new' (CPRI based) PIM testers:-

Metric	RF based (old)	PIM over CPRI based (new)	Comments
Equipment set-up, verification and calibration.	>1 hour	<30 minutes	Significant time)and cost) savings with new method.
NO sector or cell outage	✗	✔	ZERO outage with new method (or less than 5 minutes if tap needs to be installed). Long-term (>30 minutes) required for old method. No restriction to testing during maintenance period only.
NO requirement to evaluate test frequencies (with spectrum analyser).	✗	✔	New method requires no 'test' frequencies, uses actual licensed carriers at site.
NO broadcast of potentially 'unlicensed' CW signal.	✗	✔	New method does not require test/ unlicensed frequencies to be broadcast.
Multi-frequency capability (all 4G & 5G bands) - frequency.	✗	✔	New method supports ALL 3GPP bands, old method requires dedicated test sets for specific frequency bands.
Cross-band PIM testing with single piece of equipment.	✗	✔	Cost and time saving with ONE piece of test equipment for new method.
True, accurate PIM measurements under 'live' traffic conditions.	✗	✔	New method evaluates PIM level against actual traffic levels, allowing a very quick determination of it's impact to service.
Long Term PIM monitoring with event log.	✗	✔	New method can be left to collect data for hours or days, can be remotely monitored in real time. RF based testing requires cell site outage for entire test duration- not feasible for hours, days or weeks of monitoring.
Heatmaps (isolate PIM to internal/ external antenna port(s)).	✗	✔	Only product to offer patented 'heatmap' evaluation of PIM location.
Event log.	✗	✔	New method produces real-time event log of date, time, duration and PIM level.
No certification required to use equipment.	✗	✔	Savings in training and upfront product use costs.

Summary

What is often forgotten in the battle with PIM is that all multiband 3/4/5G networks have PIM but that the impact of that PIM is highly variable. In some networks the effect of PIM is negligible and in others it can impact 10-20% of cell sites in a measurable and meaningful way.

To date there has been no accurate way to assess PIM impact relative to the carrier and hence no easy way to calculate the cost of PIM and thus define effective ROI based strategies to address PIM.

PIM Forensics provides tools to help the operator quickly and cost effectively test for PIM and to identify only those sites that have a severe enough problem to merit resolution.