WHITE PAPER

External PIM Hunting Process

PIM SHIELD®

BACKGROUND

Noise rise due to passive intermodulation (PIM) is a significant problem for many network operators. Downlink signals at cell sites mix at passive, non-linear junctions in the RF path, creating new signals. If these new signals fall in an operator's uplink, they can elevate the noise floor and degrade system performance. When only a few frequency bands were deployed at sites, mobile operators typically experienced 7th or 9th order intermodulation products in their uplinks. As new frequency bands are added, it becomes increasingly common for 3rd and 5th order products to be present. These lower order intermodulation products are thousands of times higher in magnitude, resulting in elevated uplink noise when PIM sources are present.

PIM sources can be located inside the antenna feed system (internal PIM) or can be located beyond the antenna radome (external PIM). Internal PIM is typically caused by loose RF connections, metal flakes inside connectors or faulty RF components. Portable PIM test equipment first deployed in 2006 identified weaknesses in both product design and in installation quality. RF equipment manufacturers responded by improving the robustness and overall PIM performance of site components such as RF connectors, antennas, and jumper cable assemblies. Installation crews responded by developing the skills needed to ensure low PIM construction. Internal PIM problems do still occur, but much less frequently. When they occur, installers have the tools and knowledge needed to quickly locate and mitigate these internal sources.

Resolving external PIM issues has proven to be more complicated. Service impacting PIM can be generated by non-linear objects in any direction relative to the antenna. Sources may be located many meters in front of the antenna or may be located directly behind or beside the antenna. Efforts to locate external PIM using portable PIM analyzers and a PIM probe first began in 2016. Since 2016, network operators and test equipment manufacturers have worked together to develop improved tools and to refine the PIM hunting process. This paper presents an improved external PIM hunting process based on the latest tools available and based on lessons learned in the field.

PIM HUNTING PROCESS:

A high-level overview of the improved external PIM hunting process is shown in Figure 1. This process should be invoked after other potential noise sources have been ruled out, such as site set-up issues or external interference. The improved PIM hunting process includes two major paths. The first path involves using the site radios to excite PIM sources during the hunt and the second path involves using a PIM analyzer to excite PIM sources during the hunt. Each path has advantages and disadvantages that will be discussed.

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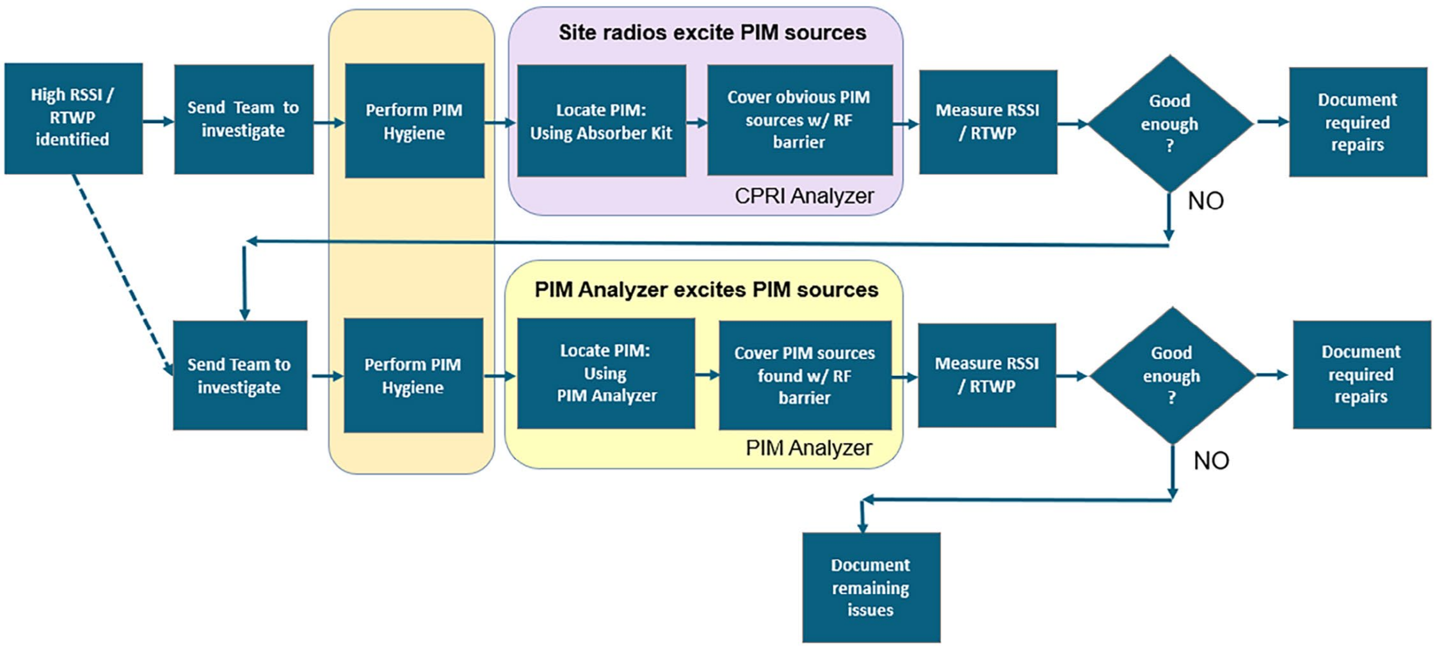

Figure 1: External PIM hunting process

PIM HYGIENE:

PIM Hygiene is the name given to the process of eliminating known sources of Passive Intermodulation at a site without the use of test equipment. Site mounting hardware should be tight, loose metal-to-metal contacts should be eliminated and galvanic mismatches should be removed in the high-risk PIM zone close to the site antennas. Crews armed with knowledge, low PIM cable support hardware and common hand-tools can perform this task quickly and efficiently. For additional information on the PIM Hygiene process, please refer to ConcealFab's PIM Hygiene Application Note.

PIM hunting should not begin before PIM Hygiene is completed. In some cases, PIM Hygiene alone can improve site performance to an acceptable level. Even if the site is not 100% fixed, eliminating the obvious PIM issues in a single pass will speed up the overall hunting process.

Figure 2: Examples issues to be resolved during PIM Hygiene

PIM HUNTING USING SITE RADIOS

There are significant benefits to using the actual site radios to generate the PIM you are hunting. With the site radios, downlink signals from all contributing frequency bands and all contributing antenna ports will be present at the PIM sources. The RF power arriving at each PIM source will be the actual power from the site radios, not a simulated test value. This is as "real world" as it gets! Confidence will be very high that performance improvements seen with temporary mitigation in place will equate to similar KPI improvements when a permanent solution is deployed.

Temporary mitigation typically involves covering potential PIM sources with a PIM Blanket or PIM Foil. These temporary RF barrier materials prevent RF energy from reaching the covered PIM source, thus preventing PIM from being generated. If the RSSI (Receive Signal Strength Indicator) or RTWP (Receive Total Wideband Power) reduces when an object is covered, that object is a PIM source that will require permanent repair.

Similar to PIM Hygiene, some external PIM sources may be obvious. If you temporarily cover the obvious PIM sources such as the parapet wall in front of an antenna with an RF barrier material and achieve the desired level of noise reduction, you are done. There is no need to continue hunting. For this reason, it is recommended to start with the radio PIM hunting process first before proceeding to the PIM analyzer hunting process.

Figure 3: PIM Foil deployed on parapet wall in front of site antennas

While this process offers many benefits, it also presents challenges. First, the PIM interference generated (and resulting RSSI increase) fluctuates based on the site downlink traffic loading. The lower the site traffic, the lower the RSSI. It may be impossible to tell if changes in RSSI are due to traffic changes or due to objects being temporarily covered at the site. Second, the radio provides noise level information but does not provide distance or direction information to help guide the hunt. Third, access to the RSSI data used to make decisions may not be fast. A crew working on the site may have to wait a long time between covering an object and receiving results. In the following sections, solutions are presented to address these concerns.

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RSSI FLUCTUATIONS DUE TO MOBILE TRAFFIC:

Radio OEMs offer the functionality to artificially load unused resource elements with white noise to simulate user traffic. (AILG with Ericsson equipment, DLIG with Nokia equipment, etc.) With the downlink resource elements artificially loaded at 100%, the PIM noise generated in the uplink will be more consistent. If the PIM level is high, the RSSI level reported will have little fluctuation. As the PIM level is reduced, fluctuations will start to increase again due to mobile traffic. Observing the spectrum with a CPRI analyzer, as discussed later in this section, and recording RSSI values when traffic is very low can help address this issue.

USING ABSORBER KITS TO "GUIDE THE HUNT"

ConcealFab offers a patent pending Absorber Kit System to help "guide" PIM hunts. The Absorber kit system consists of three components: Front Absorber Kit (PN 901124), Rear Absorber Kit (PN 901125 or 901162) and Side PIM blanket (PN 007640-2400008). The Front Absorber kit attaches to the front of the antenna and blocks energy radiating in the forward direction with minimum increase in VSWR and minimum increase in PIM. The Rear Absorber kit consists of individual absorber panels housed in rugged vinyl material that are secured behind the antenna to block radiation in the rear direction. The Side PIM blanket drapes down the sides of the antenna to block radiation in the side directions.

Figure 4: ConcealFab Front Absorber Kit installed on a site antenna

The recommended process for using the Absorber Kit system is shown in Figure 5. When all three components are installed over the site antenna, the antenna is effectively isolated from its environment. If high RSSI is still present with the full system installed, the PIM source is likely internal. Internal PIM sources must be resolved before external PIM sources can be located. If the RSSI level reduces significantly with the Absorber System installed, you have confirmed that the noise source is external. By systematically removing components of the kit in accordance with the flow chart, the direction of the site PIM sources can be determined.

When the Absorber Kit system is installed on an antenna, RF energy transmitted by the radios will be absorbed by the Absorber Kit System pads and converted to heat. It is extremely important for users to follow the guidelines presented in the Absorber Kit User Guide to ensure safe operating temperatures are not exceeded.

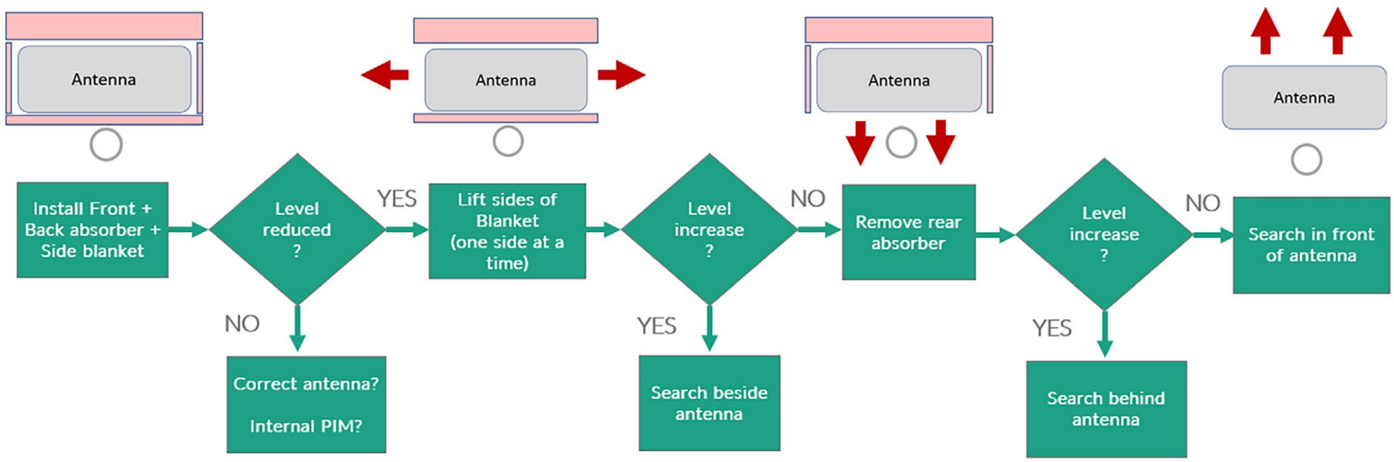


Figure 5: Absorber Kit system testing process

USING A CPRI ANALYZER FOR FAST RSSI LEVEL FEEDBACK

CPRI analyzers are able to decode the I/Q data stream between the Base Band Unit (BBU) and a Remote Radio Head (RRH) and display the RF spectrum that the radio sees for each radio branch. "Seeing" the spectrum is very useful when resolving uplink noise issues. PIM as well as other sources of external interference can be identified based on their signature appearance in spectrum view.

To access the CPRI data stream, an optical tap must be installed between the RRH and the BBU. Some sites may have optical taps permanently installed near the BBU to support CPRI testing. If a permanent tap is not available, a temporary tap must be installed. Radios on the sector under test must be locked down prior to disconnecting the fiber. After the optical tap is installed, the radios can be unlocked and returned to normal operation.

CPRI analyzers provide a real time view of the RF spectrum for each branch. Changes in RSSI value are seen immediately for each radio branch eliminating the wait time between covering an object and seeing results. With this fast feedback, technicians can try many things very quickly to try to isolate PIM sources.

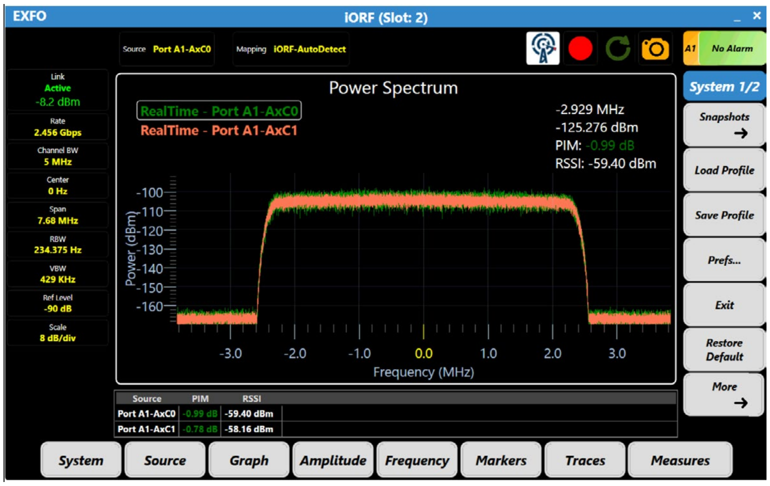


Figure 6: Spectrum view obtained using a CPRI analyzer

Another advantage of using a CPRI analyzer is that all receive ports (all polarizations) can be monitored simultaneously. Changes impacting only one port or one polarization can be seen during the test, eliminating the need to perform multiple tests to clear a sector.

The primary limitation of PIM hunting using the site radios is that you do not have a Distance-to-PIM (DTP) feature to help guide the hunt. If covering the obvious sources does not achieve the desired results, move to the second path in the external PIM hunting process to take advantage of the capability of a PIM analyzer to continue the hunt.

It is worth mentioning that operators always have the option of skipping the 1st path and immediately sending a PIM analyzer crew to locate the PIM sources. For difficult sites this may be a better approach. Be sure to set clear "dB reduction" goals for the PIM analyzer team to prevent "over fixing" the site as discussed in the next section.

PIM HUNTING USING PIM ANALYZER

PIM analyzers are designed to measure linearity. These analyzers do not directly measure the uplink noise level seen by the radio receiver. PIM analyzers inject two narrow bandwidth CW test signals into the system under test and measure the magnitude of the 3rd order intermodulation product (IM3) generated by the test signals. When IM3 is high, the linearity of the system is poor, which can result in high uplink noise. When IM3 is low, the linearity is good, which may resolve increased uplink noise caused by PIM.

Typically, 20W or 40W CW test tones are transmitted into a single antenna port while PIM hunting at the site. A swept PIM test should be conducted on each antenna port first to determine which port (polarization) is seeing the highest IM3 level. The highest IM3 level port should be selected to begin the PIM hunt. After hunting is concluded on the first port, a second port of opposite polarization should be tested. External PIM sources are often polarization sensitive meaning two orthogonal polarizations must be tested to eliminate all service impacting PIM sources on the sector.

The resulting IM3 signal generated by the test tones is also a CW signal of relatively high magnitude. As a result, the IM3 signal is very easy to detect using a traditional spectrum analyzer attached to a PIM Probe or to a Yagi antenna. A bandpass filter must be included between the PIM probe and the spectrum analyzer to prevent the test tones from reaching and overloading the spectrum analyzer front end. An overview of the test equipment used during a PIM analyzer external PIM hunt is shown in Figure 7.

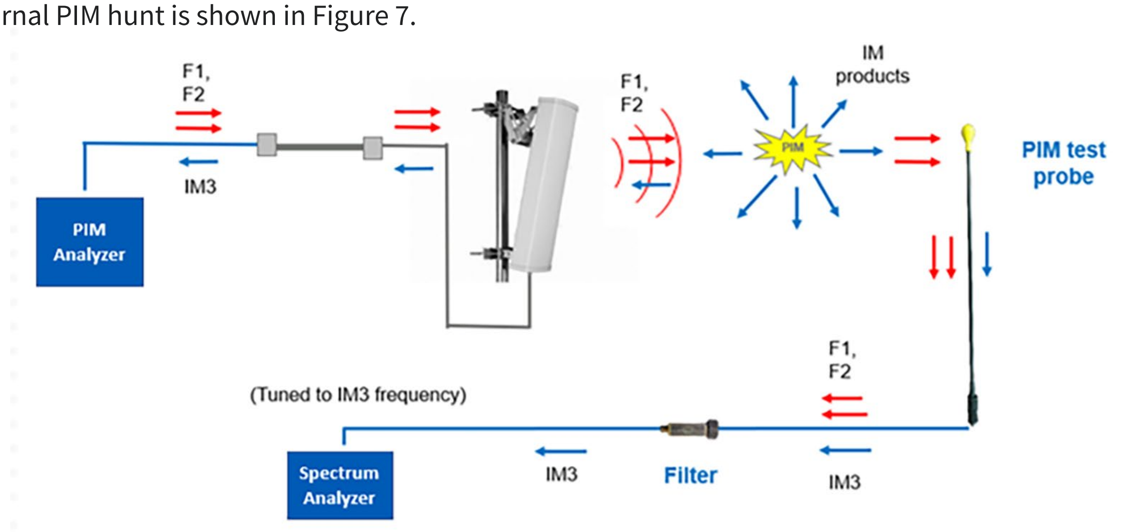
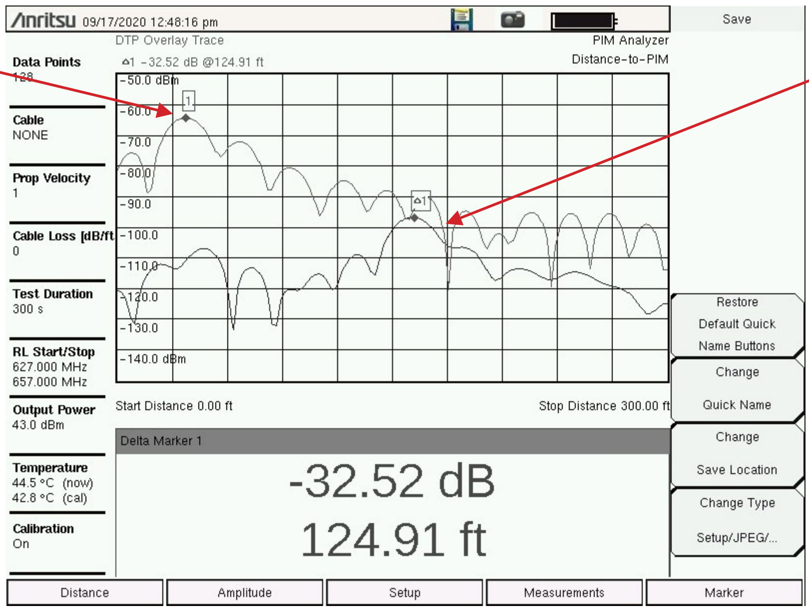


Figure 7: Equipment used to isolate PIM sources using a PIM analyzer

The F1 and F2 test frequencies used to excite PIM sources while hunting can be adjusted to place the IM3 frequency being measured into a guard band between uplinks. The lack of active transmitters in the guard band provides clear spectrum for hunting that is not impacted by mobile traffic.

A key advantage of using a PIM analyzer to locate PIM sources is the Distance-to-PIM (DTP) feature. This feature reports the electrical distance between the point of calibration and the highest magnitude PIM source. Placing a strong PIM source, such as ConcealFab PN 900643, on the front face of the antenna and measuring DTP will clearly identify the distance to the front of the antenna. When the strong PIM source is removed and the system PIM is measured, the relative distance between the antenna and the worst PIM source on the sector is revealed. While the absolute distance displayed by the PIM analyzer is not perfect, it does provide guidance on the general location to look for the highest magnitude PIM source. When the distance to the highest magnitude PIM source is “off-the-sector”, DTP lets technicians know to “stop looking” and document the likely source. No additional covering of sources on the sector in front of or behind the antennas will improve performance if the largest remaining PIM source is the power lines 38 meters (125 feet) in front of the antennas, as shown in Figure 8.

Measurement with strong PIM source on face of antenna



Measurement with strong PIM source removed showing worst case PIM is located 125 FT (38 m) in front of the antenna

Figure 8: Distance-to-PIM measurement

The primary disadvantage of using a PIM analyzer to guide the hunt is not knowing when to stop. With the high signal-to-noise-ratio achieved using PIM test equipment and a spectrum analyzer it is possible to continue making improvements in linearity that the site receiver is not able to detect. The time and effort spent driving the IM3 level further and further below the receiver noise floor adds cost, not value to the mobile operator.

A good way to limit the problem of “over fixing” the site is to define the number of dB’s improvement needed at the end of the site radio hunting process and use that as the target improvement level to achieve when hunting using the PIM analyzer. The RSSI level achieved with artificial loading activated and the full Absorber Kit System installed on the antenna can be used to establish a best-case level. If PIM hunting using the site radios gets you to an RSSI level that is 10 dB away from the ideal level, use 10 dB as the target number of dBs reduction to achieve using the PIM analyzer process. Once an improvement of 10 dB is achieved, regardless of the IM3 level being measured, reconnect the jumper cables to the radio and measure RSSI to see if you are done.

CONCLUSIONS

Finding and mitigating sources of external PIM at cell sites can be a challenge. Starting with PIM Hygiene and following with a PIM hunt using the site radios to excite the PIM sources has yielded positive results at many sites. Incorporating a CPRI analyzer to provide fast feedback of RSSI levels allows test technicians to evaluate many potential sources quickly and efficiently. For sites that are not able to be resolved using the site radios, deploying a team armed with PIM test equipment is a logical next step. Establishing a "dB of improvement needed" goal rather than a specific IM3 target level will focus the PIM analyzer team to achieve the appropriate level of site linearity and prevent wasted effort. Using the combination of tools and processes described herein, external PIM sources can be identified efficiently. RSSI reductions achieved during the testing process using temporary mitigation will agree closely with improvement that can be obtained with permanent repairs.