

Pinpointing Sources of PIM on Rooftops and Macro Cell Sites

Introduction

Passive intermodulation (PIM) is one of the primary causes of interference in today's multi-band cellular networks. The first indication that a site may be suffering from PIM is typically the network monitoring software sensing a rise in the uplinks' noise floor at a cell site. This causes a failure in the key performance indicators (KPIs) of the site and results in a field technician being sent out to validate the presence of PIM and mitigate the source when possible. Once a technician has tested a sector and found that it contains PIM above their specified pass/fail limit, they need to determine if the PIM is internal or external to the antenna system. The process for identifying distance from antenna to PIM source is now well established. Using a PIM test set, like the Anritsu PIM Master™ MW82119B, the technician starts off by conducting a distance-to-PIM (DTP) measurement by placing a PIM source on the antenna surface. This DTP measurement allows a technician to determine the location of the antenna on a DTP plot. The technician can then re-measure DTP without the PIM source on the antenna to determine if the strongest intermodulation (IM) source is internal or external to the antenna system.

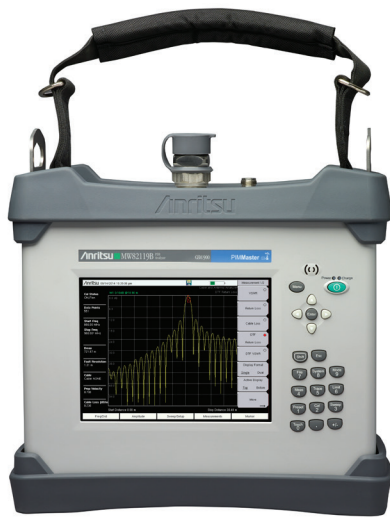
This application note focuses on finding PIM that is located on a rooftop or tower external to the antenna, also known as PIM hunting. These external PIM sources are much harder to resolve as they require searching over a rooftop or even beyond the edge of the roof.

PIM Hunting Equipment

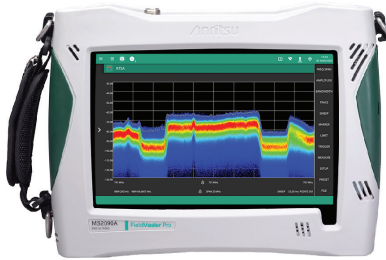
Once the technician determines that the strongest IM source is external to the antenna system, they will conduct a PIM hunt using the DTP plot to note the distance from the antenna to that source. Because the DTP plot can only estimate the distance of the IM source from the antenna and not the direction, the technician will then need to look for PIM source(s) at that distance, in an arch, from the antenna. Due to the radiating patterns of the antenna, the further away the IM source is from the antenna the larger the search area becomes and the more difficult it can be to find.

To conduct a successful PIM hunt, technicians will need a number of tools typically contained in a PIM hunting kit (Figure 1). First, a PIM test set is used to illuminate the rogue PIM source with RF energy by generating the necessary F1 and F2 frequencies for the desired IM product being investigated. A spectrum analyzer is used to search for intermodulation signals at the IM frequency. The search is achieved by connecting either a directional antenna, for example, Log periodic antenna (2000-2107-R) connected to an Interference Hunter, or a PIM probe to the spectrum analyzer with an inline bandpass filter. The filter must cover the uplink frequency band where the IM signal is present and reject any signals outside the wanted intermodulation frequency. The PIM probe is a specially designed antenna for finding PIM sources. Its sensitivity is such that it responds to the proximity to the PIM source (i.e., closer the PIM source, louder the indicator). PIM blankets are also an essential part of the PIM hunting kit. These are used to temporarily cover discovered IM sources in order to find the next strongest one. Since stronger IM sources will mask weaker ones, it is necessary to cover known PIM sources until all have been located and the required PIM level has been reached.

Note: Portable PIM analyzers output a pulsed signal for their F1 and F2 frequencies, so a spectrum analyzer with very fast response is required to detect the pulsed IM product. The optional RTSA in the MS2090A and MS2080A is ideal for this purpose, but the standard spectrum analyzer sweep is also practical.



MW82119B PIM Master™



MS2090A Field Master Pro™



MS2080A Field Master™



RF Cable



Bandpass Filter



PIM Hunter Test Probe



MA2700A InterferenceHunter
and 2000-2107-R
Log Periodic Antenna

Figure 1. PIM Hunting Equipment

Figure 2 shows a typical PIM hunting scenario utilizing the tools contained in a PIM hunting equipment.

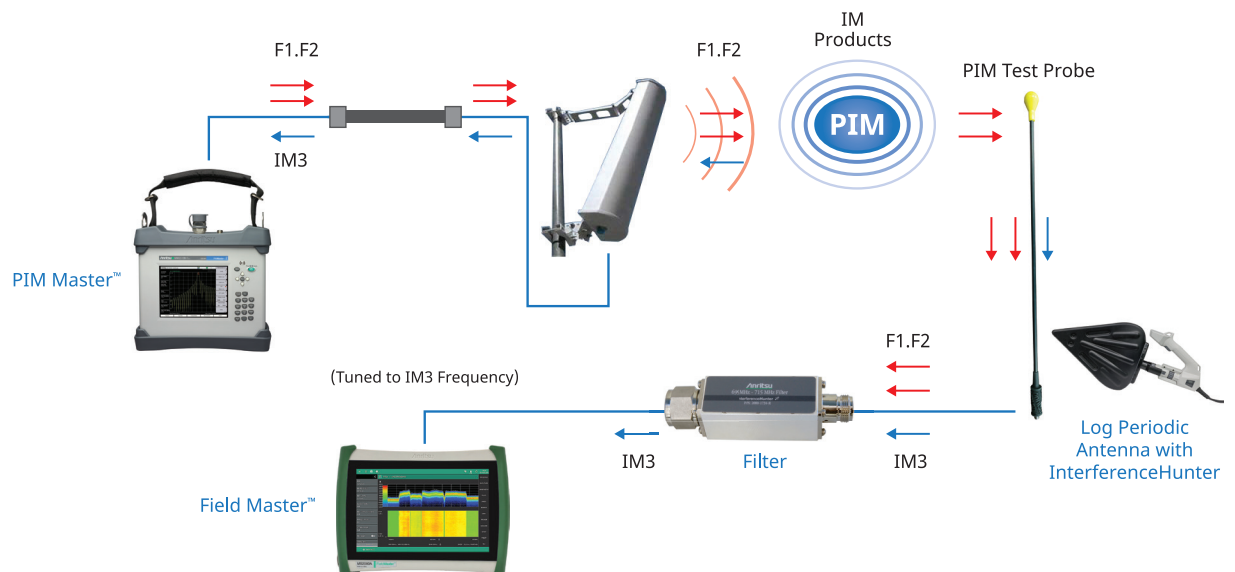


Figure 2. PIM Hunting Scenario

Figure 3 shows an example of how a PIM blanket is utilized.

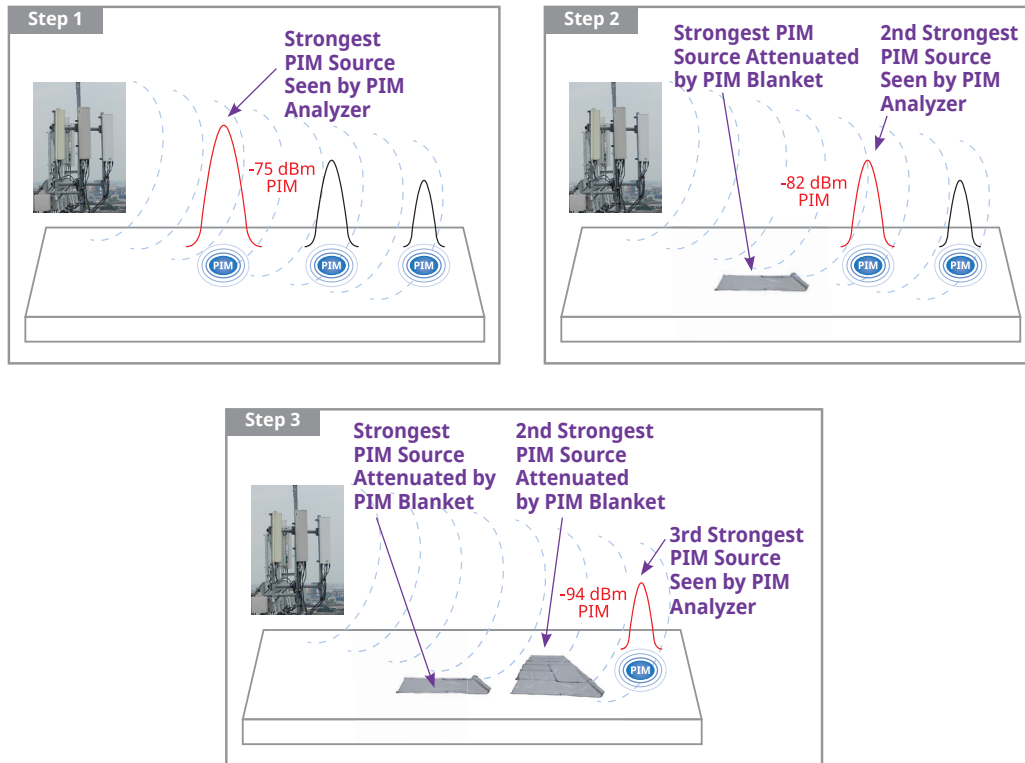


Figure 3. PIM Blankets Covering IM Sources, Showing Next Strongest IM

Going on a PIM Hunt

Note: Prior to conducting any PIM test, it is always good practice to clean all PIM test equipment connectors and adapters with alcohol swabs in order to make sure that loose metal flakes are not present. These can raise the PIM test equipment's residual noise floor, thereby limiting its ability to test low into the antenna system's noise floor.

Before a PIM hunting operation begins, it is a good practice to perform preliminary PIM mitigation. First, the technician should pick up any obvious loose items around the antenna system. Next, they should check to make sure that the clamps holding the antennas to their mounting brackets are correctly torqued and not damaged. Most antennas have multiple minor radiation lobes (though lower power) that create IM products behind the antenna within a shorter distance. For this reason, it is always important to inspect all clamps supporting the radio and cable feed leading up to the antenna. Often the prime source of PIM can be behind the antenna. Next, the technician will connect the PIM test set to the antenna port that the carrier's network monitoring software has identified as failing minimum uplink noise performance. Some carriers require an initial swept PIM measurement to determine the IM condition across the frequency band under test (the swept PIM measurement is done with a fixed F1 frequency and a sweep of F2 across a frequency range, then it will fix the F2 frequency and sweep F1 across a different frequency range). The PIM analyzer or a spectrum analyzer can be used to check the noise floor of the RF environment to be tested (IM product spectrum based on F1 and F2 frequencies). If there is too much noise in the RF environment (usually due to uplink user equipment [UE] signals), it can limit the ability to find IM sources at the level of the pass/fail limit. If this happens, choose F1 and F2 frequency combinations (band edge; PIM vs. Time measurement) to avoid interferers. Once a suitable F1 and F2 pair with low noise floor has been identified for the IM under test, perform a PIM vs. Time measurement. This is the measurement that will be used for PIM hunting.

Note: PIM vs. Time uses fixed F1 and F2 frequencies, which creates a fixed IM frequency (in the uplink band) that is used for PIM hunting. After preliminary PIM mitigation at the site, there is now a clean noise floor measurement and the initial swept PIM measurement and PIM vs Time measurements have been completed. The technician is ready to start PIM hunting. A DTP measurement (discussed at the beginning of this application brief) will determine a starting distance from the antenna for PIM hunting.

PIM Hunting for Rooftop Sites

To conduct a rooftop PIM hunt, the technician will begin by connecting the PIM Master output to the RF port of the antenna experiencing high noise due to PIM. The PIM Master is used in PIM vs Time mode which causes it to continuously transmit the two fundamental high power tones.

The next step is to precisely determine the location of the PIM sources. This can be done with either a directional antenna or using a PIM probe. Connect the directional antenna or PIM probe to the spectrum analyzer (using a suitable length RF cable and inline bandpass filter), then methodically sweep the rooftop area in front of the antenna looking for PIM sources (Figure 4).

For the best real time response to detecting PIM signals, a MS2090A or MS2080A Field Master spectrum analyzer with the RTSA (Option 199) and Interference Finder (Option 24) is required. Select the IA RTSA mode.

The spectrum analyzer is used to locate PIM by detecting the IM3 product signal level. The PIM Master transmits two high power CW tones which cause IM3 products to be generated when they are incident on a PIM source such as a metallic junction that acts as a diode. With the spectrum analyzer in RTSA Interference Analyzer mode, the following sequence outlines a typical configuration.

FREQ/SPAN

- Set the center frequency to the IM3 frequency
- Set the span to 100 kHz

AMPLITUDE

- Set the Ref Level to -30 dBm
- Preamp ON
- Auto Attenuation OFF
- Attenuation Level 0 dB

MEASURE

- MEASUREMENT: PIM/Interference
- SETUP
 - Integration bandwidth 10 kHz
 - Max level -40 dBm
 - Min level -80 dBm
 - Volume 100%
 - Mute OFF



Figure 4. Technician Performing PIM Hunting Exercise with Anritsu Field Master Spectrum Analyzer and PIM Hunter Probe

Note: Tap the padlock icon above the amplitude scale to prevent manual changes to the maximum level line unintentionally adjusting the amplitude scale.

For the following PIM hunting example, we will use the PIM Probe for determining the precise location of PIM sources. This can also be done using a directional antenna, in which case, the technician can sweep an area by pointing the antenna at a precise spot. The PIM Master and spectrum analyzer are now ready to start the PIM hunt. In this mode, in addition to showing the results on the screen, the Field Master spectrum analyzers generate an audio tone whose pitch and volume matches the strength of the PIM level detected (so it basically acts like a metal detector for PIM). As the probe tip is passed closer to a PIM source, the audio tone increases in volume and pitch, indicating the precise location of the possible PIM source. The use of the audio tone also helps ensure the technician's safety as now they do not need to continually watch the level of the IM signal on the screen of the spectrum analyzer, and can remain more aware of their surroundings.

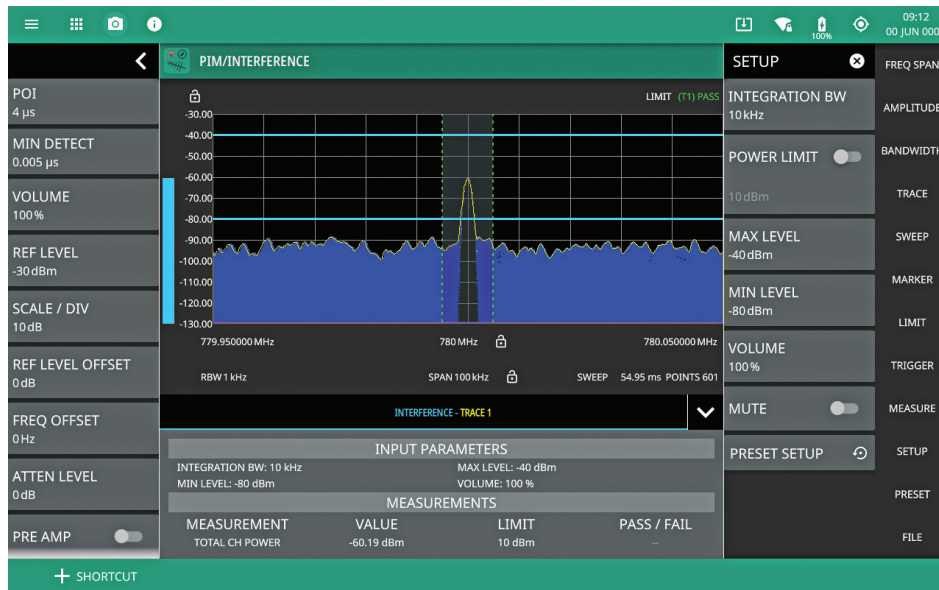


Figure 5. PIM Hunting with Field Master Spectrum Analyzer in IA RTSA Mode

As the PIM vs. Time measurement is transmitting the F1 and F2 frequencies, the technician will set up their spectrum analyzer to measure the IM3 (or IM5, depending on the scenario) frequency shown on the PIM instrument screen (the measured IM product). Then they will set the limit line roughly 3 to 5 dB lower than the measured PIM amplitude (dBm) of the IM product (this is an estimated start point, adjusted up or down as needed). The technician will walk out to an area based on how far the DTP measurement determined the location of the IM source was from the face of the antenna. Next, they turn up the audio volume on the spectrum analyzer and proceed to walk the coverage area of the antenna pattern parallel to the PIM probe.

As the probe gets close to an IM source, the RF power (dBm) will go up and the audio tone on the spectrum analyzer will go up in pitch. It is recommended that the technician walk past the IM source to see where the tone starts going down and then returns. This will reduce the area of the IM source(s). Once the area is narrowed down to a single location, place a PIM blanket on top of the IM source and check the reading on the PIM vs Time measurement. If the source masked by the PIM blanket was a significant source of PIM, the PIM level will go down. It is common for there to be multiple sources of PIM, especially on a rooftop, with the same amplitude level as the first IM source. The next step is to rerun DTP to determine the distance to the next IM source. Reset the pass/fail limit line on the spectrum analyzer if the amplitude level changed, then start the PIM hunting process at the new distance from the antenna determined by DTP. Restart the PIM hunting process from the beginning for each new IM source. If DTP determines that the distance is beyond the edge of the roof, it is recommended to use a golf range finder and directional antenna to identify possible long range PIM sources. If one is found, it is often not something that can be easily mitigated, for example, if it is a fence or advertising billboard. In this case, the potential source should be noted in any close out report. If the PIM problem is high enough, RF network engineering may choose to change the antenna coverage angle to avoid the PIM source beyond the roofline.

Typical Rooftop PIM Sources:

- Loose flashing on the top of the parapet (edge of roofline)
- Roofing screws underneath roofing membranes (possibly rusted or wind movement)
- Loose connectors on the antenna clamps
- Where multiple antennas are mounted on the same mounting post, metal clamps can touch creating a non-linearity creating PIM (there are new low PIM clamps that reduce the amount of metal and reduces clamps as a PIM source)
- Air conditioning units
- Billboard signs and their structure are other common sources of PIM on rooftops
- Rust on metal objects
- Rooftop lighting



■ = Antenna ● = IM Source

Figure 6. Rooftop Scenario

PIM Hunting for Tower-Mounted Antennas

PIM hunting is less practical on tower-mounted antennas. PIM sources are either within the tower structure or beyond. If the IM source is beyond the tower structure, use a golf range finder and directional antenna to identify the potential source of PIM. For shorter DTP distances, PIM can be in the vertical plane in front or behind the antenna.

Possible Tower-Mounted PIM Sources:

- Check the clamping screws with the PIM probe to see if they are a source of PIM
- Check to see if there are any loose cables
- Check to see if adjacent equipment (other sectors, other carriers) could be IM sources

Use the spectrum analyzer with the PIM probe in order to determine the location of the PIM source. Some carriers will also require a swept PIM measurement at close out to verify that the entire band passes the pass/fail limit. It is good practice to do a Noise Floor measurement at the end to document the improvement. On a tower, it is important to follow all safety protocols. Use of a PIM blanket in a tower situation is less likely to be practical. PIM mitigation can often be as simple as torquing down a clamp to improve PIM levels. As IM sources are identified and mitigated, the technician should repeat the PIM measurement steps outlined in the rooftop scenario above, until the pass/fail limit determined by the carrier is reached (see Figure 7).



● = IM Source

Figure 7. Tower Mounted Antennas



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