Application Brief

envision : ensure

How to Use the IQ Fiber Master™ MT2780A to Diagnose PIM Problems on CPRI-Based Systems

Introduction

Passive intermodulation (PIM) is a growing problem within the wireless network industry. As more bands get turned up, the sub-6 GHz frequency spectrum gets increasingly crowded, more transmitters can mix with existing transmitters, and consequently more uplinks are vulnerable to intermodulation products that cause problems. The problem is also exacerbated by densification, whereby more antennas are being added to the network to improve coverage. This consequently introduces more RF power into the environment, further increasing the likelihood of RF mixing with non-linearities in the environment.

Current solutions lack a method to simply diagnose a PIM problem quickly, particularly for a multi-band site. A multi-band site is defined as having multiple transmitters and receivers, making the RF environment complex and difficult to analyze. When an RF engineer encounters a PIM problem on a particular uplink, there is critical information that must be gathered before deciding on a PIM troubleshooting path:

- Determining whether there actually is PIM versus just external RF interference
- Analyzing whether the PIM is internal or external to the system
- Measuring the amount of PIM (in dB) you have present in the system so you can get a quantified measurement of the severity
- The level of de-sensitivity of your Rx paths as a result of PIM
- The distance-to-PIM from the antenna to the PIM source
- A list of transmitters in your system that contribute the most to PIM

The IQ Fiber Master™ MT2780A PIM and RF analyzer is Anritsu’s newest CPRI-based solution that enables users to diagnose and monitor PIM problems on any LTE-based site, including ones that contain multiple bands within the same locations. It does its analysis by using the RF data from the CPRI link, which allows the analysis to be done while the site is live, using real-time cellular traffic.

This application brief will introduce a method that utilizes the IQ Fiber Master MT2780A to gather the required information quickly, without disrupting service or disassembling the site. A simple table of possible trouble-shooting methods are also discussed in the final section.

Test Equipment Components

To analyze PIM problems on a single or multi-carrier site, here are the test components required. All are available with the IQ Fiber Master MT2780A kit and accessories (Figure 1).

1. IQ Fiber Master MT2780A sensor module
2. PC software installed onto a laptop.
3. Optical tap with auxiliary fiber cables
4. PIM source (optional, used for distance-to-PIM calibrations)

In addition, access to the BBU/RRH will be required to control the radio output power of each radio. The OCNS, AILG, or equivalent command can be used for this purpose.

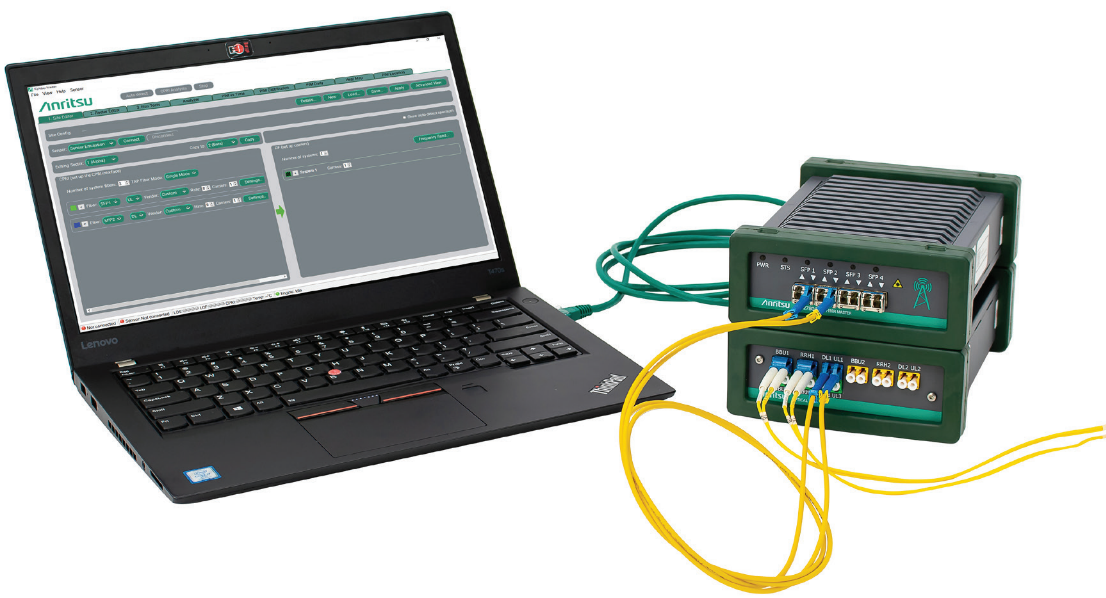

Figure 1 – IQ Fiber Master MT2780A sensor, optical tap, PIM source, and laptop PC (Note: laptop PC is not included with the product and must be supplied separately)

6 Steps to PIM Analysis

There are 6 major steps to analyzing PIM using the IQ Fiber Master MT2780A.

Step 1: Site Assessment

Certain information about the site is required before embarking on a PIM analysis exercise. This aids in not only the physical connection in Step 2, but also in understanding the results. Operators normally have this information readily available.

Below is a checklist of items required for the site assessment:

1. Which sector needs to be analyzed?
2. Who is the manufacturer of the base station and radio?
3. What are the bands for the transmitters you wish to analyze (up to 3)? This information should include the center frequency, the bandwidth, and the EARFCN.
4. Do the carriers exist on separate CPRI links or are they concatenated onto a single links? This is where it can get tricky. Often times drawing a picture is a good way to understand which downlink carrier is mapped to which CPRI link.

In most situations, this information is available through either operator documentation and/or polling the base station for this information. When all of this information is filled in, you will have a clear picture of which fiber contains which band. This is critical before moving onto to Step 2.

Step 2: Physical Connection

The next step is physically connecting the IQ Fiber Master MT2780A to the system. This is a relatively simple exercise if you have completed Step 1. For each CPRI fiber link, follow the steps below.

1. Turn off/lockdown the radio with the uplink that has the suspected PIM problem. This must be done using the network software that controls the BBU. Please consult your company's operating instructions before executing this step.
2. With the radio locked down, insert the optical tap inline between the RRH and BBU. This normally involves taking the fiber cable coming from the RRH and plugging it into the RRH1 port of the optical tap. An additional duplex fiber cable is then connected form the BBU1 port on the optical tap to the BBU.
3. The radio can now be turned on. If there are any problems, the optical tap and/or additional fiber cable needs to be checked for proper operation.
4. Connect power to the sensor.
5. Connect the uplink tap port (UL1) to the sensor SFP 1 using a single-plex fiber cable. Make sure to connect to the right side (input) of SFP in the sensor module.
6. Repeat steps 1 – 4 for each of the downlink radios that need to be analyzed. Use the DL1, DL2, and DL3 ports as necessary.

At this point, your set up may look similar to the diagram in Figure 2. This figure shows a multi-carrier scenario with 3 CPRI links for 3 separate carriers.

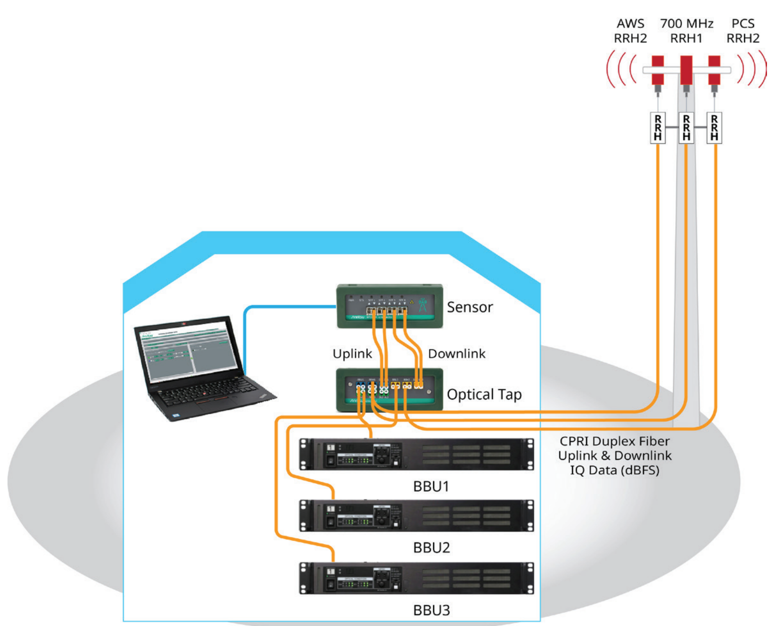

Figure 2 – Multi-band IQ Fiber Master MT2780A connection diagram

Step 3: Define Site Parameters and Test Combinations

With the IQ Fiber Master MT2780A now physically connected and the radios turned back up and fully operational, we can proceed to defining the site parameters of the system. For the analysis, the information required includes frequency bands used in the system and the network equipment manufacturer. Specifying the network equipment manufacturer is necessary so the software can account for certain vendors who use non-standard CPRI configurations.

Since CPRI RF data comes across as IQ data at baseband, the RF frequency band information is not present so this must be input by the user as well. Most operators will have this information available.

To simplify entering this data, the tool has an Auto-Detect feature that configures both the network equipment manufacturer parameters and frequency band information. This is done by reading the IQ streams and looking at the LTE BCCH information to derive the information, as well as analyzing the occupied bandwidth and other data in the CPRI bit stream.

In instances where the information is not available, this information must be input manually. An example of a 4 branch antenna on Band 71 is shown in Figure 3.

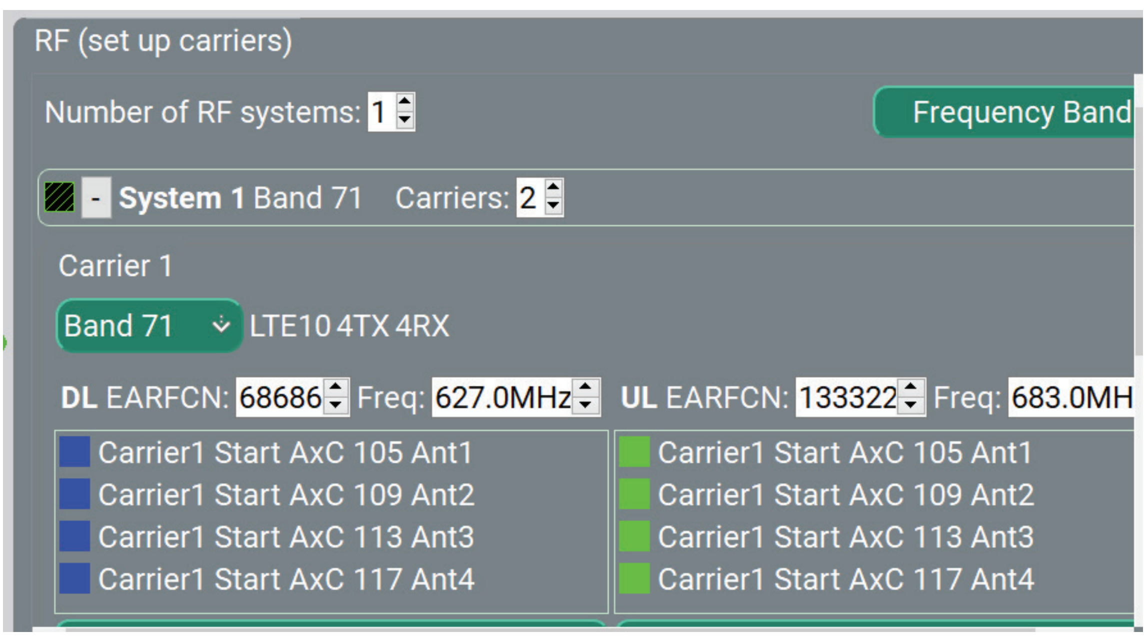

Figure 3 – Carrier definition example

In this step, it is also important to set up the different combination of transmitters that will be analyzed for PIM. This list is called a test roster. In analyzing PIM, two transmitters must interact with a non-linearity in the RF path to produce PIM. IM1, IM3, and IM5 products are calculated for each scenario so that the user can gain insight into which ones may produce the highest PIM levels. Tests can be run either individually or as a complete set.

The tool can either auto-generate all possible combinations of transmitters based on the definition of the frequency bands defined earlier in this step or it can be done manually by the user. Whichever method is used, the end result is a list of tests that will be run in Step 5. However, before we run any of these tests, we must analyze the RF spectrum as described next in Step 4.

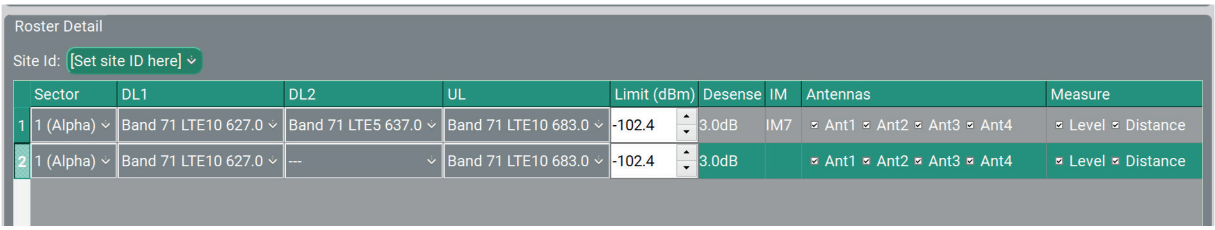

Figure 4 – An example of a test roster. The IM column provides helpful information about PIM products produced at the defined frequencies.

Step 4: Analyze the RF Spectrum

Now that we can read all the RF data streams required, we can look at the different RF spectrum graphs both for the uplink and downlink. We can look at the spectrum by simply clicking on the CPRI Analysis button at the top of the window. Here we can see exactly with the antenna sees for both uplink and downlinks. Any RF stream can be seen individually by clicking on its listing in the carrier tab.

This analysis window has several functions to enhance interpretation of the RF spectrum, including peak hold, a spectrogram, and a persistence setting. You can adjust the parameters and markers as needed to suit your visualization of the RF spectrum.

If you encounter a suspected PIM problem, often times you will see it manifested in the RF spectrum. A slope or “shark fin” may alert you to which uplink can have possible PIM.

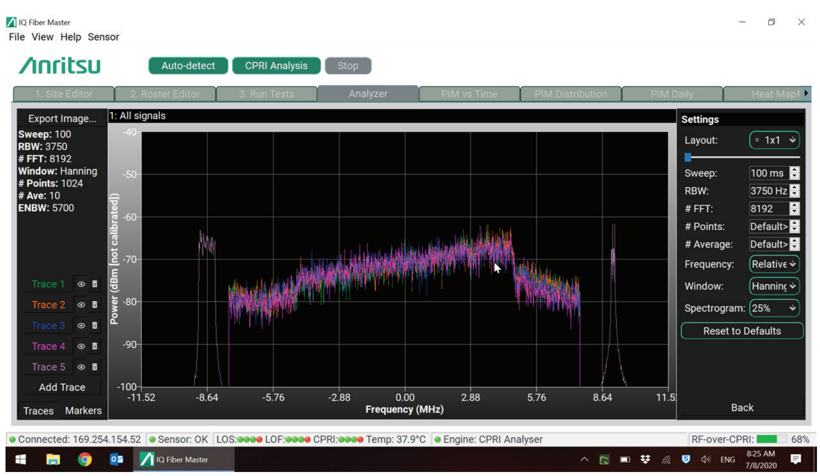

Figure 5 – Example of a sloped RF noise floor, indicating a probable PIM problem

Regardless of whether an actual shark’s fin is visible or not, if the uplink in question is experiencing performance issues due to suspected PIM, the next step will give you definitive answers on whether PIM is actually present and where it is located.

Step 5: PIM Analysis

If PIM problems are suspected, a PIM analysis will give insight into the degree and location of the PIM problem. In order to maximize accuracy of test results, the radio must be left in high-power mode, meaning leaving on the aforementioned AILG or OCNS mode.

The PIM analysis can now be run by pushing the Run Test button on the GUI. The tool will initiate the analysis for each scenario defined in the test roster and produce results as shown below. The analysis results will report whether or not PIM is detected, what the PIM levels are, the desensitization of the receiver due to PIM, and whether the PIM is internal or external to the system.

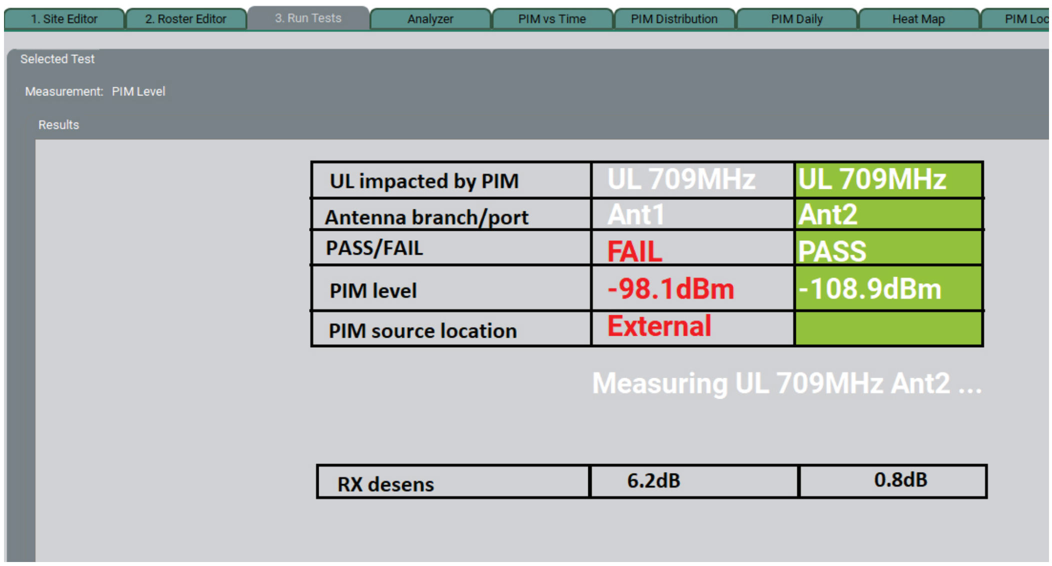

Figure 6 – Example PIM analysis results

Distance-To-PIM Calibration if PIM is Detected

If PIM is detected and the antenna is accessible, a distance-to-PIM (DTP) analysis can be performed to help locate the non-linearity(ies) in the RF path to aid in the troubleshooting and mitigation phase. This will give the software a zero reference point so it can report accurate DTP measurements.

The calibration involves attaching a PIM source to the radome of the antenna. A solid PIM source is available as an accessory to the IQ Fiber Master MT2780A kit. Please observe all safety precautions when performing this step. This normally means turning off the radio before having a technician attach the PIM source.

Once the source is attached, the next step is to turn up the radio to full power by utilizing the radios AILG, OCNS, or whatever the equivalent command is for your particular brand of radio to maximize the power output from unused PRB blocks. When this is done, simply push the Calibration button on the GUI. Software will record its required reference point where it finds the strongest PIM, which will be right at the location of the antenna. Thus, all DTP results will be with respect to this point.

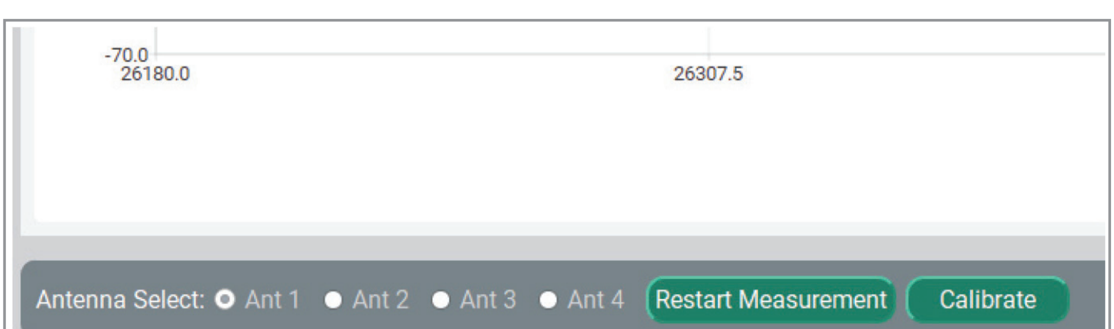

Figure 7 – The Calibrate button runs the DTP calibration

The PIM source can now be removed, again being careful to observe the proper safety protocols. The radio can then be returned to full power and a DTP test can be run to determine the exact location of the non-linearity causing the PIM. Since the zero reference point is the antenna, any negative DTP numbers will refer to a location inside the system. Conversely, positive DTP numbers will refer to a location beyond the antenna.

Step 6: Interpreting the Results

While a detailed PIM hunting exercise discussion is beyond the scope of this application brief, here are a few basics when using the analysis results to help direct your PIM hunting exercise. Reference the list of PIM debugging criteria introduced at the beginning of this application brief. We have added the specific reporting mechanisms that will answer the question, as well as suggestions on mitigating PIM when located.

DIAGNOSTIC TEST	TEST REPORT	MITIGATION TECHNIQUE
Determining whether there actually is PIM versus just external RF interference	The results are reported as a simple Pass/Fail in the software application	Determination of whether PIM is present or not moves troubleshooting crews in a direction of either PIM problem or RF interference problems
Analyzing whether the PIM is internal or external to the system	Software will report specifically whether PIM is internal or external to the system	Internal PIM points to cables, connectors, or other system components as the cause. External PIM points to non-linearities in the environment as the PIM source.
Measuring the amount of PIM (in dB) you have present in the system so you can get a quantified measurement of the severity	The results are presented as a measured dB level of PIM	The PIM levels reported are more for users to understand the severity of the PIM problem. Since PIM problems are often due to multiple PIM sources, this number can be monitored as suspected sources are mitigated.
The level of desensitivity of your Rx paths as a result of PIM	The Rx desense is reported as a measured dB level of loss in Rx sensitivity	Similar as the PIM dB level, this level can be monitored to observe improvement as PIM sources are mitigated
The DTP of the PIM source	This valuable metric is reported as distance in meters	With this information, a technician can examine the area around the antenna at the distance reported
Listing which transmitters in your system are contributing the most to PIM	This is reported as the top transmitters contributing to PIM in the form of a heatmap	Knowing which transmitters are contributing to the most PIM will open other mitigation techniques, such as adjusting antenna position on either the transmitter itself or the uplink antenna suffering from PIM

Conclusion

This application brief has discussed the procedure for diagnosing PIM using the IQ Fiber Master MT2780A PIM and RF analyzer. There are many unknowns when first trying to discover how to mitigate PIM problems at a particular site, and the IQ Fiber Master MT2780A allows technicians and RF engineers to quickly determine not only if there is actually PIM and its severity, but also which transmitters contribute to PIM and the distance to the exact location of the PIM source.

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