Anritsu Advancing beyond

Measuring PIM on the AT&T FirstNet Network with the Anritsu 2-Port PIM Master™

Introduction

In 2017, AT&T won a multibillion dollar contract from the United Sates Government to build and maintain a communications network for first responders, including police, firefighters, and emergency medical services. The purpose of the FirstNet service is to provide a modern voice and data network that allows seamless communications between services, and does not become overloaded during large scale emergency situations. FirstNet users will have priority network access during times of peak demand using dedicated FirstNet handsets. The FirstNet network uses standard LTE bandwidths and protocols in a new block of frequency spectrum.

AT&T's commercial LTE network is located in band 17, and the downlink occupies 734 MHz to 746 MHz. The band allocated for the FirstNet downlink is 758 MHz to 768 MHz and the uplink is 788 MHz to 798 MHz. These spectrum allocations lie adjacent to other commercial LTE networks from Verizon and T-Mobile as seen in figure 1 below.

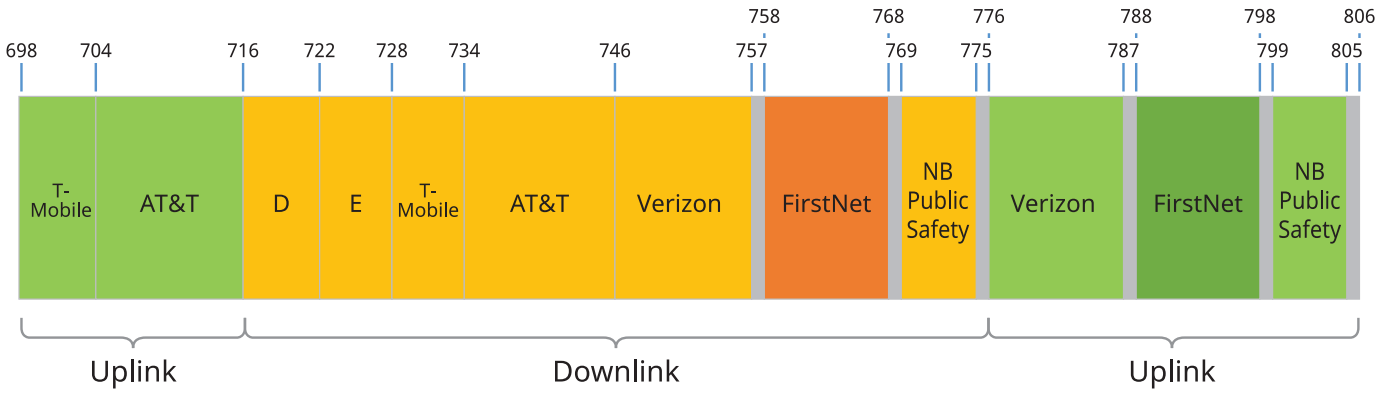


Figure 1. LTE 700 MHz Band

Adding the FirstNet network into the already crowded frequency plan around 700 MHz creates significant challenges for network performance. The uplinks of all cellular networks are very vulnerable to passive intermodulation (PIM) products. PIM occurs when RF signal components generate two or more signals that pass through any non-linear device that acts as a diode and generates intermodulation products. LTE 700 MHz band networks typically have 10 MHz modulation bandwidth and intermodulation products from LTE transmitters have even wider bandwidths. The most notable 3rd order (IM3) and 5th order (IM5) PIM products can have 30 to 50 MHz bandwidth. Figure 2 below highlights how PIM products from the FirstNet 700 MHz band 14 can fall into the bands of other users.

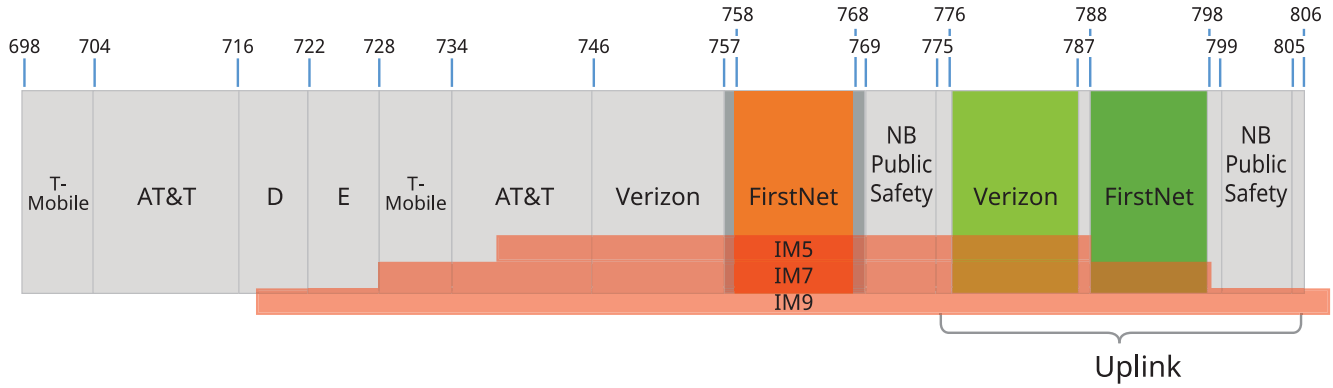


Figure 2. FirstNet Band 14

In addition to the new bands allocated to FirstNet, PIM products from the legacy AT&T LTE 700 MHz band 17 can fall into adjacent bands, normally IM5 and IM7, as shown in figure 3.

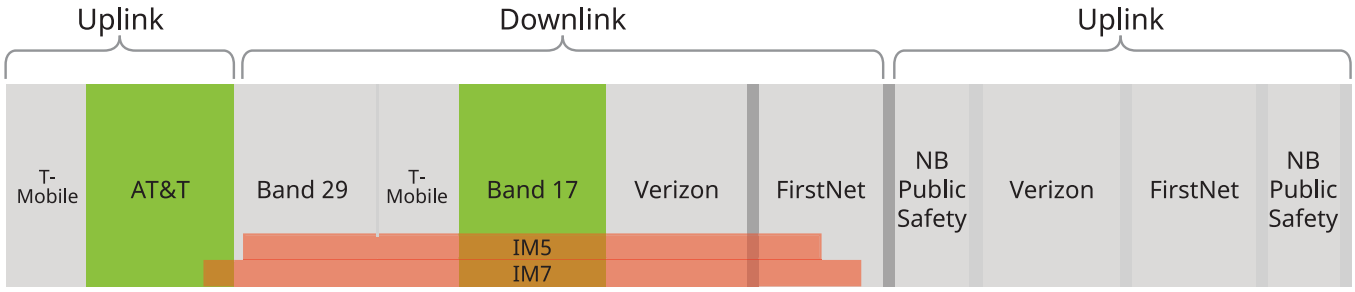


Figure 3. AT&T Band 17

When incident signals occur on PIM sources, the modulated transmitter in AT&T band 17 creates IM5 and IM7 PIM products, which are 20 dB to 35 dB below a corresponding IM3 PIM product. The FirstNet band 14 can also create IM5 and IM7 PIM products even without mixing with other bands. This PIM is typically created in RF cable feeds due to poor connector assembly, degradation due to weather exposure, and damage to the cables themselves. PIM generated in the RF feed from the radio to the antenna is often referred to as internal PIM. For the RF cable feeds to the antenna for band 14 or band 17 systems, the most significant PIM products to the antenna would be IM5 or IM7. The system noise floor to this point would be 20 to 35 dB lower than an IM3 PIM product and less likely to cause interference problems.

External PIM is defined as PIM generated by PIM sources in front of the antenna or when the signals from two separate antennas intermodulate. When band 14 and band 17 signals interact with each other beyond the antenna, or IM3 PIM products are created. This is much higher than the noise floor (about 20 dB on average) or an IM5 PIM product, as illustrated by figure 4 below.

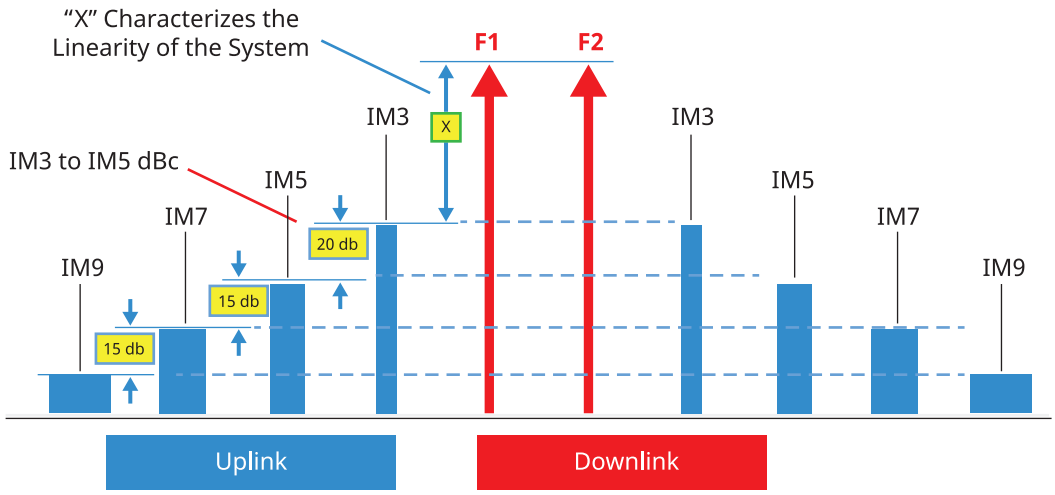


Figure 4. IM Amplitudes

The addition of FirstNet band 14 in the upper 700 MHz LTE spectrum has now created IM3 products between bands 14 and 17, and this is a much more powerful interfering product in the 700 MHz uplink band that is affecting customers. See figure 5 below.

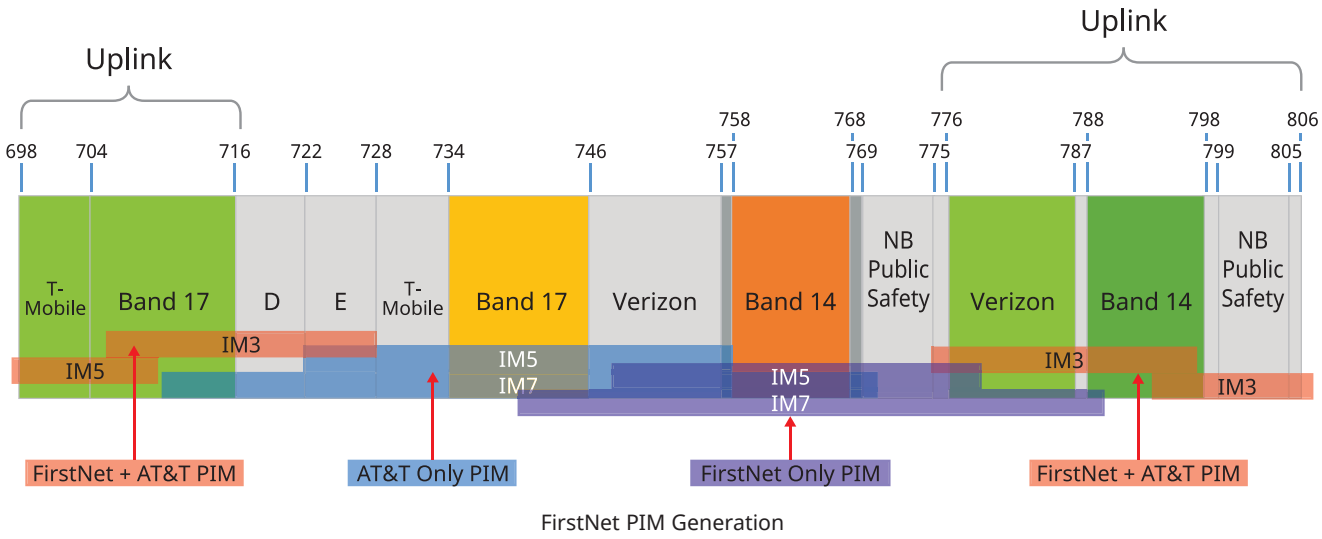


Figure 5. Bands 14 and 17 and IM Products

The higher the IM product (on the uplink), the higher the noise floor of the receive band (affecting both band 14 and 17). This higher uplink noise floor will affect coverage (at the edge of the sector), data throughput (use of lower modulation rate), and increase dropped and blocked calls for end users.

The majority of FirstNet installations use separate antennas for band 17 (commercial LTE) and band 14 (FirstNet). The transmitters will transmit out of separate antennas, this means that the IM3 product created by the mixing (non-linearity's) of band 14 and 17 will happen to the two external antennas.

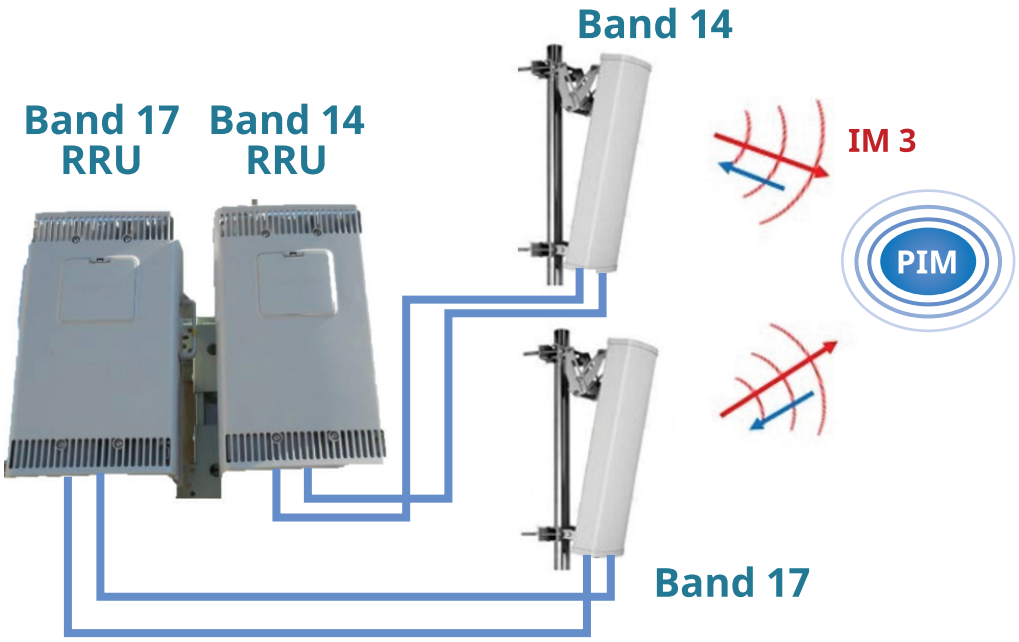


Figure 6. Bands 14 and 17 External IM Products

Antenna systems exclusive to band 14 or band 17 can only create IM5 and IM7 PIM internal to the antenna system from their respective transmitted signals. The IM3 products are due to PIM sources in front of the antenna where the RF signal from the two transmitters (Bands 14 and 17) are incident on a common PIM source. This will occur mainly on rooftop sites where there may be many PIM sources such as guard rails, air-conditioning units, or roofing materials that create PIM. Even traditional tower-mounted radios and antennas can experience external PIM from large advertising boards erected around a construction site and metal fences in the path of the transmitted signal.

When installing new FirstNet base stations, it is essential to validate that the site is "PIM Free", otherwise the new FirstNet system and existing commercial LTE networks will experience a rise in the RF noise floor and a consequent degradation of network performance.

Testing PIM During New FirstNet Site Rollout

This application note details the additional PIM testing that is required at new FirstNet sites, specifically focusing on the need for 2-port PIM testing. Familiarity with the Anritsu PIM Master for standard 1-port PIM testing is required. Users unfamiliar with the Anritsu PIM Master should refer to Anritsu's "Understanding PIM" application note, 11410-00629, that can be found at www.anritsu.com.

FirstNet PIM Testing Procedure

For the initial PIM testing, 1-port testing is still needed. Connect the PIM test equipment to the coax cable using the connector that is normally connected to the radio and run the PIM vs. Time and Swept PIM tests to determine if PIM is present. PIM vs. Time is a good test for finding PIM with fixed F1 and F2 CW signals. PIM vs. Time will give you quick PIM pass/fail results (based on limits defined in the Method of Procedure [MOP]). PIM vs. Time is also used for tap testing. Tap testing is where the likely sources of PIM in the RF feed, such as connectors, are tapped with a heavy item such as a wrench while running a PIM vs. Time test. This method is used to verify that loose connectors are not causing PIM in the cable system. Swept PIM will test PIM with one fixed frequency while sweeping the second frequency. Different F1 and F2 frequencies can have higher or lower PIM amplitudes based on the F1 and F2 combinations. A swept PIM measurement covers a broad frequency range by sweeping one of the CW tones, therefore better simulating the 10 MHz LTE carrier sub-channels interaction that may cause IM products.

If the above tests show that PIM is present, run distance-to-PIM (DTP) to determine the location of PIM. If it is internal to the cable and antenna system, go through normal troubleshooting procedures to clear the PIM problems. If it is external to the antenna, then it is now necessary to use a 2-port PIM test to measure and locate the source of PIM.

Why 2-Port PIM Test?

As mentioned before, IM3 products will only show up after band 14 and 17 signals mix externally from their respective antennas.

If a 1-port PIM test is used for external PIM hunting instead of a 2-port PIM test, there is the possibility of finding IM3 products at the antenna since both band 14 and 17 CW signals are being transmitted through the antenna, as seen in figure 7. In real world conditions, the antenna would only get one of band 14 or band 17 LTE carriers, which could only produce IM5 or IM7 products 20 dB to 35 dB lower in amplitude to an IM3 product, and this is less likely to impact customer service. The 2-port PIM test is to troubleshoot and fix customer impacting PIM problems.

By separating the F1 and F2 signals through two ports in the PIM test equipment (F1 through port 1 and F2 through port 2), the antennas will only transmit one of the signals, and then F1 and F2 will only mix with each other after being transmitted through the antenna, creating IM3 products external to the antenna and similar to real world conditions. Figure 8 shows the procedure required for measuring PIM at AT&T sites.

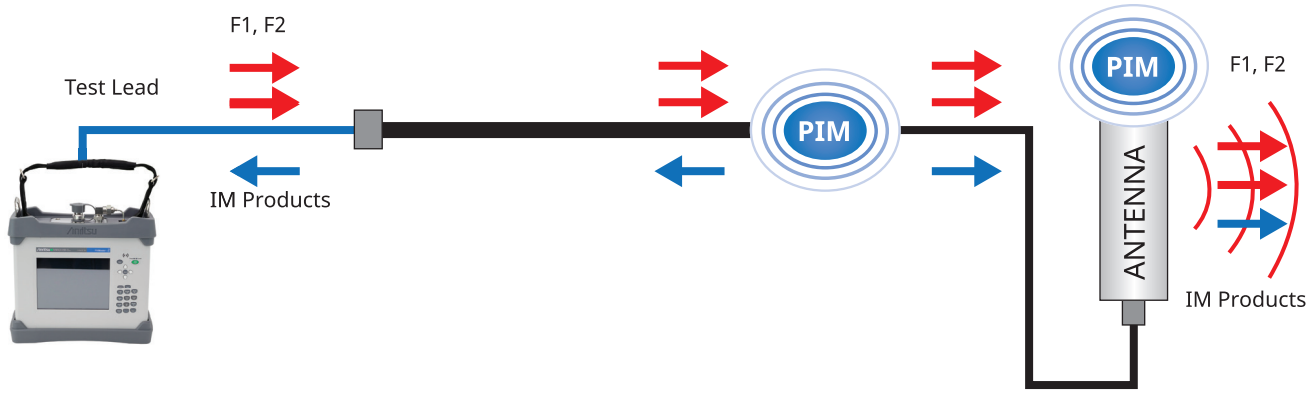


Figure 7. 1-Port Test Scenario

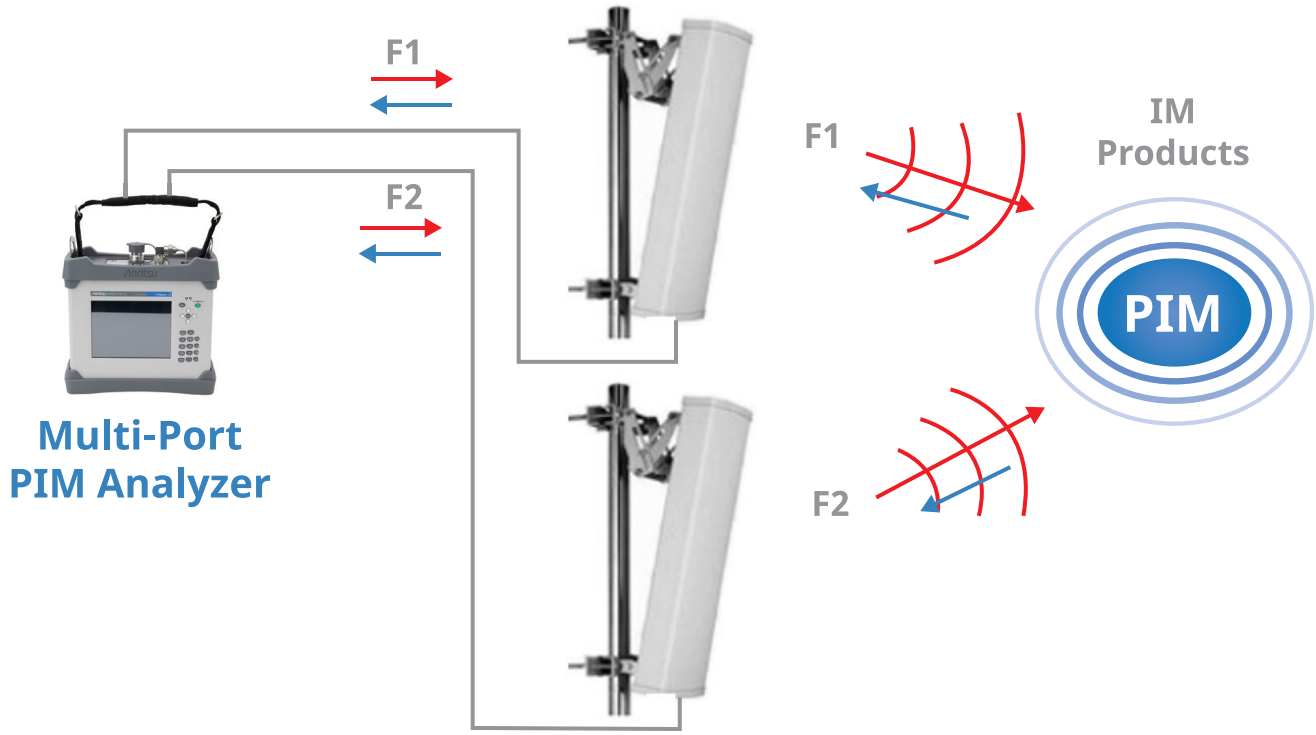
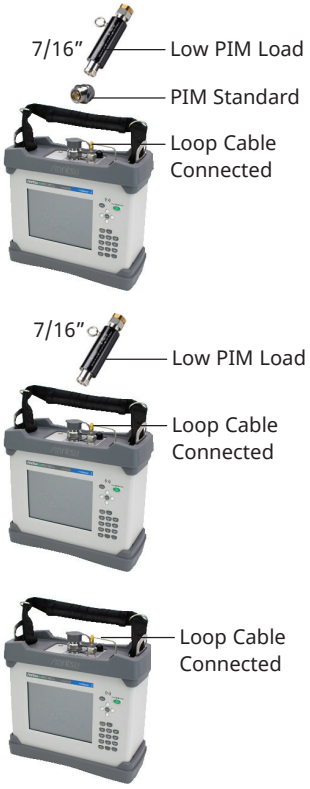


Figure 8. 2-Port Test Scenario

Procedure for Performing 2-Port PIM Tests

To perform a 700 MHz 2-port PIM test, you will need an Anritsu PIM Master 2-port LTE 700 MW82119B-0703. The PIM Master MW82119B-0703 can perform both traditional 1-port PIM tests as well as 2-port PIM tests based on its configuration and set up.The 2-port measurement mode is mainly intended for external (to the antenna) PIM Hunting and PIM mitigation.

1-Port PIM Master™ Calibration



1. Connect Port 2 Out to Port 2 Return with supplied cable
2. Connect a PIM Standard to the PIM Test Port
3. Connect a Low PIM Termination device to the PIM Standard device
4. Press ENTER to calibrate or ESCAPE to exit calibration
5. Remove the PIM Standard from the PIM Test Port
6. Connect a low PIM Termination device to the PIM Test Port
7. Press ENTER to calibrate or ESCAPE to exit calibration
8. Remove Termination device from instrument
9. Leave PIM Test Port open
10. Press ENTER to calibrate or ESCAPE to exit calibration

Figure 9. 1-Port Calibration

2-Port PIM Master™ Calibration

1. Connect Port 2 Out to Port 2 Return with supplied cable
2. Connect a PIM Standard to the PIM Test Port
3. Connect a low PIM Termination device to the PIM Standard device
4. Press ENTER to calibrate or ESCAPE to exit calibration
5. Remove the PIM Standard from the Termination device and the PIM Test Port
6. Remove the loop cable
7. Connect a low PIM Termination device to the PIM Test Port and to the Port 2 Out port
8. Press ENTER to calibrate or ESCAPE to exit calibration
9. Remove Termination devices from instrument
10. Leave PIM Test Port open
11. Press ENTER to Calibrate or ESCAPE to exit calibration

Figure 10. 2-Port Calibration

In order to run a calibration, the user would need to turn ON 2-port, under the frequency menu as seen in figure 11. When the 2-port models is turned on, a red 2-port indicator is shown at the bottom of the graph.

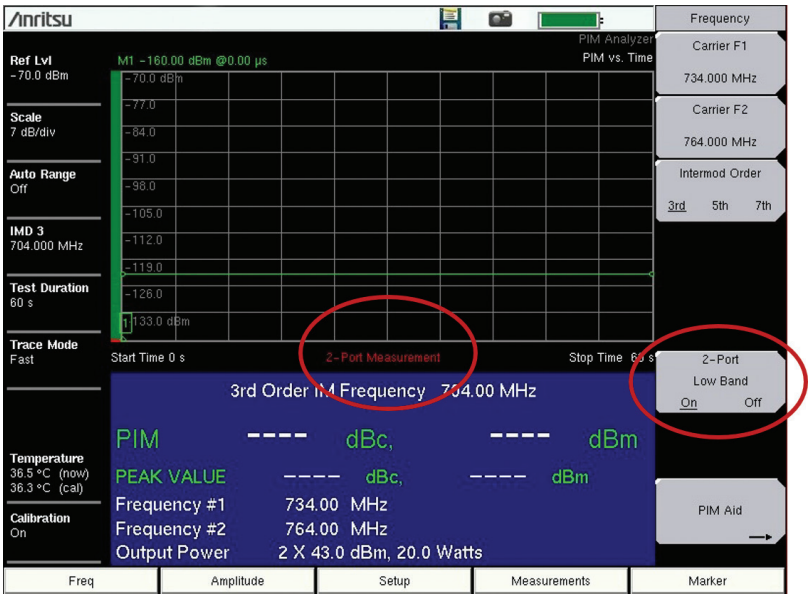


Figure 11. 2-Port Setup Menu

After 2-port mode is enabled, calibrate the PIM Master MW82119B-0703 by following the on screen instructions.

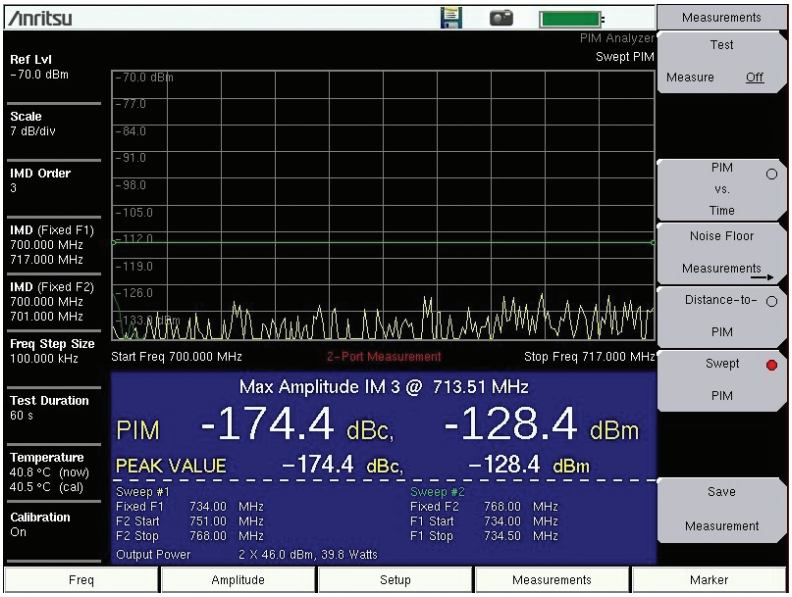


Figure 12. 2-Port PIM 40 W Residual PIM After Calibration

After calibration, connect the PIM test port to the antenna port with the highest IM results based on the LTE-M Pilot results. (LTE-M Pilot is the internal AT&T network monitoring tool that identifies PIM within the antenna system) Connect port 2 out to the same phase port on the opposite antenna (ex., PIM test port to +45 band 14 antenna, port 2 out to +45 band 17 antenna) as seen in figure 13. The PIM test port (port 1) has both the receiver and F1 transmitter, port 2 out transmit F2, see figure 14.

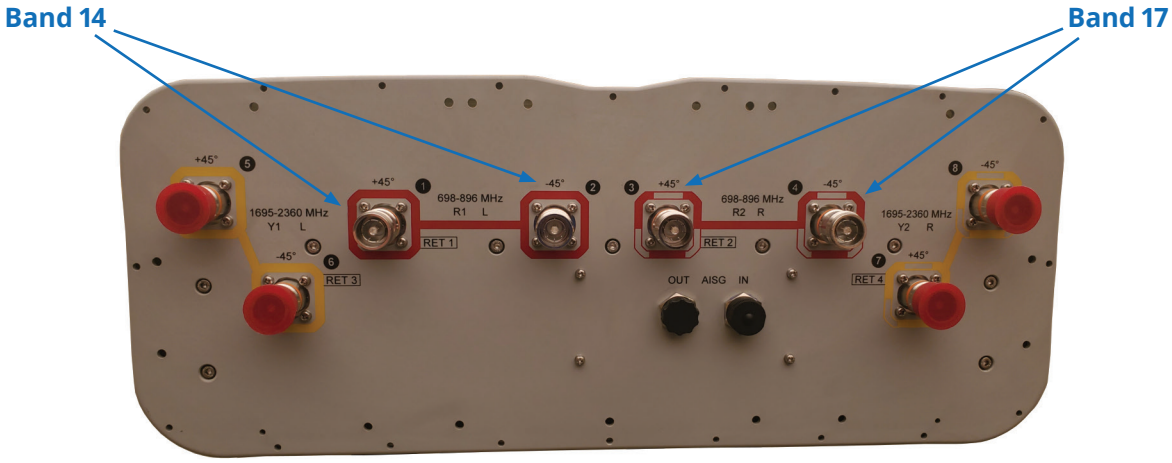


Figure 13. Antenna Port

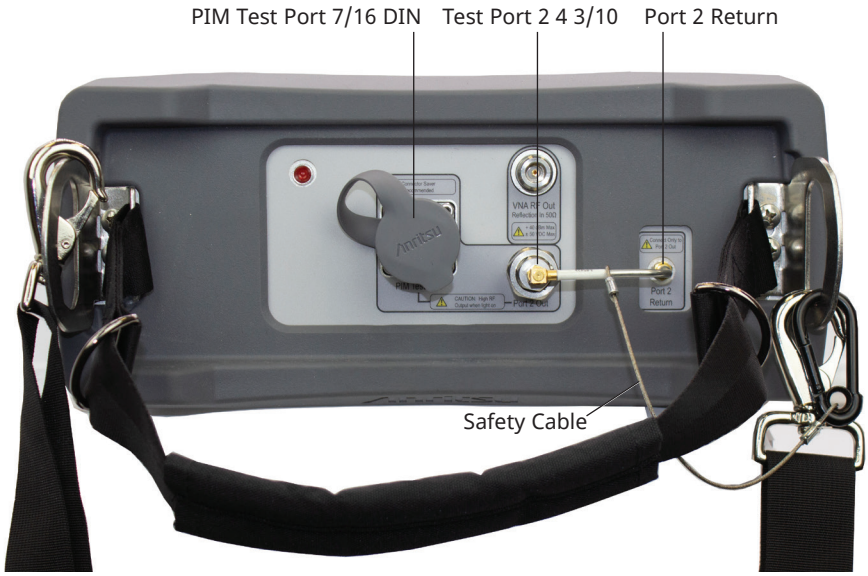


Figure 14. Top View of PIM Master MW82119B-0703

Measurements can be made once the necessary connections are made between the appropriate ports. 2-port PIM testing is identical to normal 1-port PIM testing. Run either a PIM vs. Time measurement as shown in figure 15 or a Swept PIM measurement as seen in figure 16. Examine the results to determine if PIM is present based on the AT&T MOP Pass/Fail values.

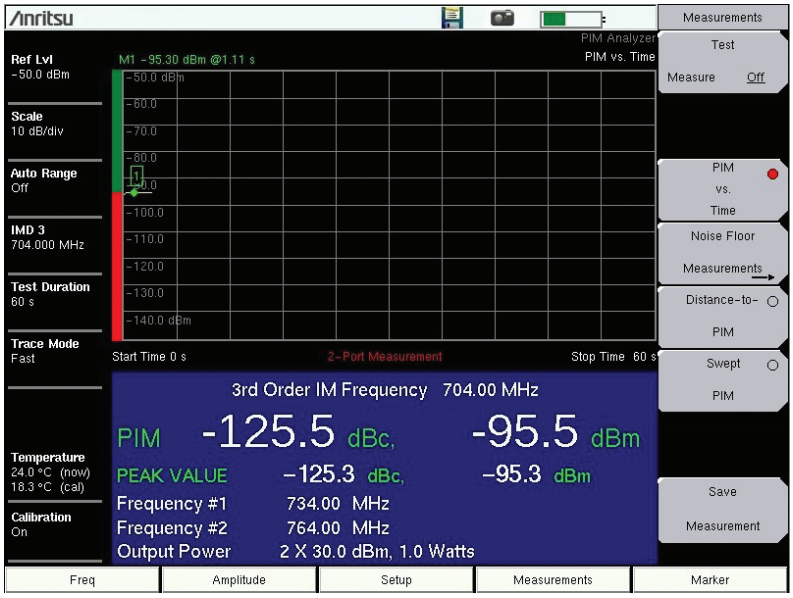


Figure 15. 2-Port PIM vs. Time

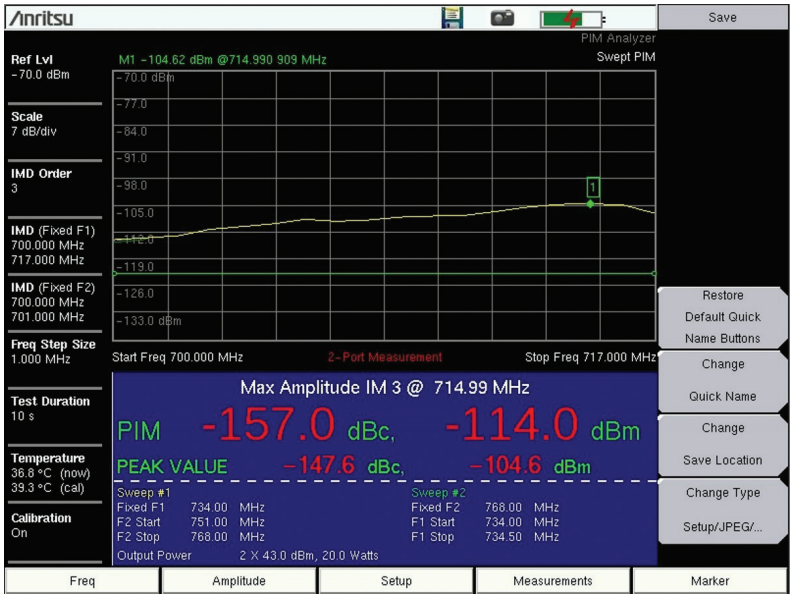


Figure 16. 2-Port Swept PIM

If PIM is present, run DTP to determine a starting point for PIM hunting. See ‘Pinpointing Source of PIM on Rooftops and Macro Cell Sites’ application note, 11410-02839, for PIM hunting procedures. This screen can be seen in figure 17. For PIM Hunting information, please see our ‘How to Use the IQ Fiber Master MT2780A to Diagnose PIM Problems on CPRI-Base Systems’ application brief, 11410-02831. Repeat the PIM testing and PIM Hunting process until the sector passes the LTE-M Pilot test criteria or until all IM products within the testing area have been mitigated. Document all mitigated IM products and IM issues physically beyond the rooftop of the tower.

Figure 17. 2-Port DTP

Summary

The 2-port PIM testing simulates real world conditions of FirstNet and AT&T 700 MHz LTE bands 14 and 17, and highlights customer IM problems beyond the antennas similar to normal LTE service. This process helps to minimize troubleshooting non-customer IM issues that would show up using a traditional 1-port PIM test set. The concept is to maximize time and effort into troubleshooting the IM issues that affect customer service within the MOP pass/fail values and ignore non-customer affecting issues, making PIM troubleshooting a more efficient process.

The PIM Master MW82119B has been specially developed to enable testing in compliance with the AT&T MOP. It is the latest instrument in Anritsu’s portfolio of PIM solutions and delivers accurate measurement results using a familiar user interface in a portable, rugged instrument designed for field use.

Anritsu Advancing beyond

Specifications are subject to change without notice.

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11410-02865, Rev. A Printed in United States 2021-09