Application Note

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The Importance of Testing 600 and 1900 MHz Receiver Channels When Installing 600 MHz LTE Base Stations

As mobile technology has evolved, cellular networks have drastically increased the density of the RF spectrum. This necessitates that the transmit power increases as the noise floor of receivers decreases. Due to the greater demands on the entire communication network, the quality of all aspects of the network have had to improve (including mobile devices and base stations). All interference signals related to the mobile network have a growing effect on the quality of the network. While interfering signals can be generated by a variety of things – such as active modulation, rouge communication signals, known low-level interfering sources, adjacent channel noise, etc. – this application note will take a close look at passive intermodulation (PIM). PIM can be generated either internally (before the antenna) or externally (beyond the antenna) to a communication system. These PIM sources can be caused by poor quality base station construction (e.g. loose or poorly constructed connectors, pinched or damaged cables, poor quality or damaged antennas, etc.) or generated externally to the base station within the pattern of the antenna as well as minor antenna lobe patterns (e.g., rusty bolts, fencing, poor cable or antenna clamps, and any metal to metal contact point). PIM test and measurement equipment is designed to locate and help mitigate these interfering sources. After using PIM test equipment to identify, locate, and mitigate PIM sources, the improvement of the communication link increases the base station's reliability, data throughput, and call quality.

Defining PIM

PIM is a form of intermodulation distortion that occurs in passive components normally thought of as linear or non-reactive. These components include cables, connectors, antennas, splitters, adaptors, etc. With the high-power transmitters found in mobile communication systems, these components can generate PIM signals greater than –80 dBm, which is significantly above a receiver's noise floor.

Figure 1 shows the spectrum view of two intermodulated signals, F1 and F2, which are generating 3rd, 5th, and 7th order products. These unwanted intermodulation signals produced within the communication system can be in the receive bandwidth of the communication link causing unwanted interference with the desired received mobile signals.

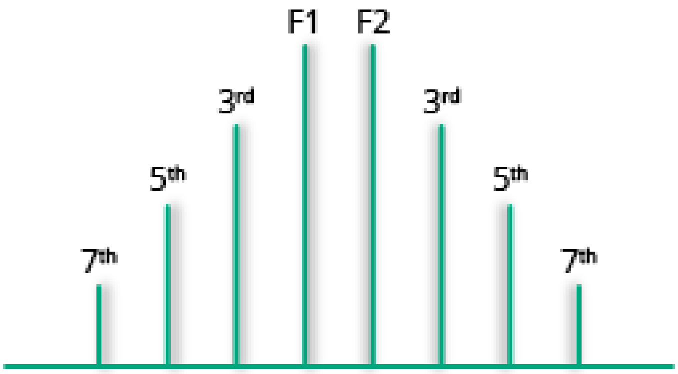

Figure 1. FCarriers F1 and F2 with 3rd through 7th order products

Figure 2 shows the same spectrum view as Figure 1 while increasing the spectral power density of F1 and F2. The figure shows how the increased spectral power of F1 and F2 affect the intermodulation signature of the 3^{rd}, 5^{th}, and 7^{th} mixing products. If the transmit signal contains an amplitude modulation component, the spectral power of intermodulation products spreads significantly with the order of the intermodulation index.

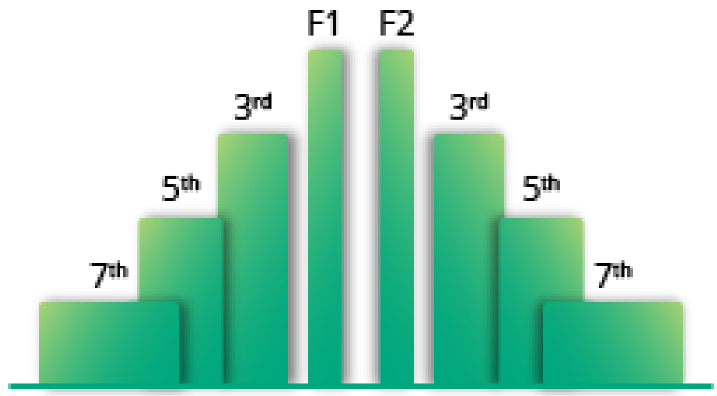

Figure 2. PIM bandwidth increases with the order of the product

This pair of formulas can predict PIM frequencies for two carriers:

Equation 1: nF1 ± mF2

Equation 2: nF2 ± mF1

F1 and F2 are carrier frequencies, and the constants n and m are integers. When referring to PIM products, the sum of n + m is called the product order, so if m is 2 and n is 1 the result is referred to as a third-order product. Typically, the third-order product is the strongest and causes the most harm, followed by the fifth- and seventh-order products. Since PIM amplitude becomes lower as the order increases, higher order products typically are not strong enough to cause receiver problems.

Modern mobile communication systems have a wide transmit signal spread over the entire transmit band. This transmit signal pattern will mix with itself to generate a similarly wide intermodulation signal centered at the same intermodulation frequencies predicted by the equations. These patterns can overlap with each other centered at different intermodulation orders. By using PIM test equipment to mitigate PIM sources, the wide spectral pattern of the intermodulation source will decrease and not interfere with the wanted received mobile signal.

New 600 MHz Spectrum

In April 2017, T-Mobile made its largest network investment by purchasing the 600 MHz spectrum sold by the U.S. government. In September 2018, T-Mobile announced it had installed 600 MHz Extended Range LTE in 1,254 cities and towns in 36 states, including the island of Puerto Rico. The deployment of this 600 MHz LTE network lays the foundation for T-Mobile’s nationwide 5G rollout in 2020.

600 MHz Spectrum PIM Issues

From a PIM perspective, if operators in the 600 MHz band utilize their own 5 or 10 MHz spectrum blocks, they should experience few PIM issues, as IM21 or IM9 generated by these blocks are most likely well below the receiver noise floor and not strong enough to cause interference in the 600 MHz uplink bands (Figures 3a and 3b). However, operators will experience PIM issues – IM5 – if utilizing their own 20 MHz spectrum blocks (in isolation) (Figure 3c).

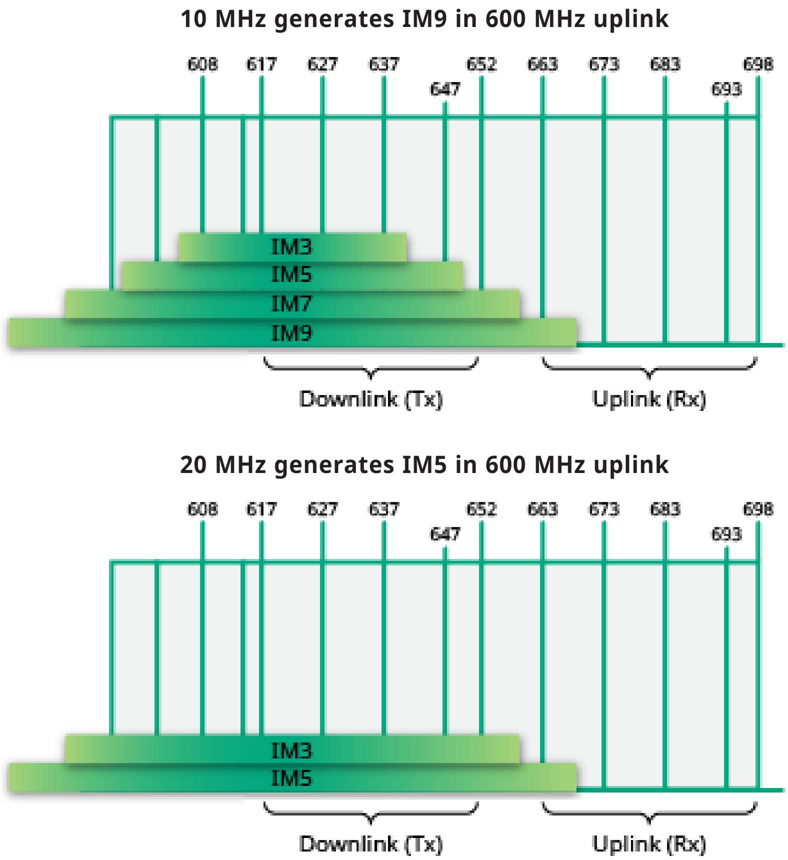

Figure 3. 600 MHz spectrum

It is rare that individual operators are able to utilize their spectrum in isolation of other operators' spectrum. Co-location on macro sites and within distributed antenna systems (DAS) means multiple frequency bands are likely to be combined at the same site. IM3 signals that can cause significant interference are possible when multiple 600 MHz blocks are combined at the same site.

Of possibly even greater concern with the new 600 MHz spectrum are the IM3 products generated by a single operator that may cause interference in the PCS 1900 and AWS 2100 MHz uplink bands. When accounting for all IM3 products, even those that fall far away from the transmit signals, the problem becomes evident. The 5, 10, or 20 MHz blocks of the 600 MHz spectrum are able to generate IM3 covering the entire PCS or AWS receive bands (as shown in Figure 4), therefore, it becomes imperative to conduct the appropriate testing to ensure the possibility of PIM is minimized. Let us review three common scenarios.

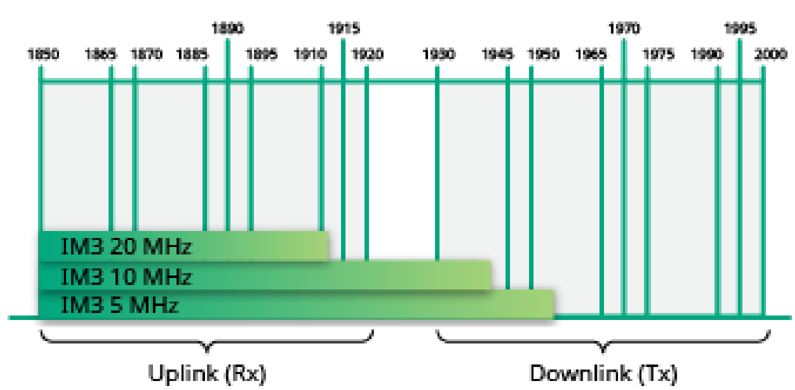

Figure 4. Third harmonic of 600 MHz downlink falls in PCS band uplink

Scenario #1: PIM vs. Frequency

This test measured a variety of standard RF components to see how their static PIM levels varied at different frequencies. Each device was measured using 700, 800, 900, 1800, 2100, and 2600 MHz PIM test equipment; the results are plotted in the Figure 5. Because PIM sources behave differently at various frequency, the value for some devices increased while other decreased. This reinforces the importance of testing at multiple frequency bands, as testing with only one frequency band instrument does not guarantee that all problems will be caught.

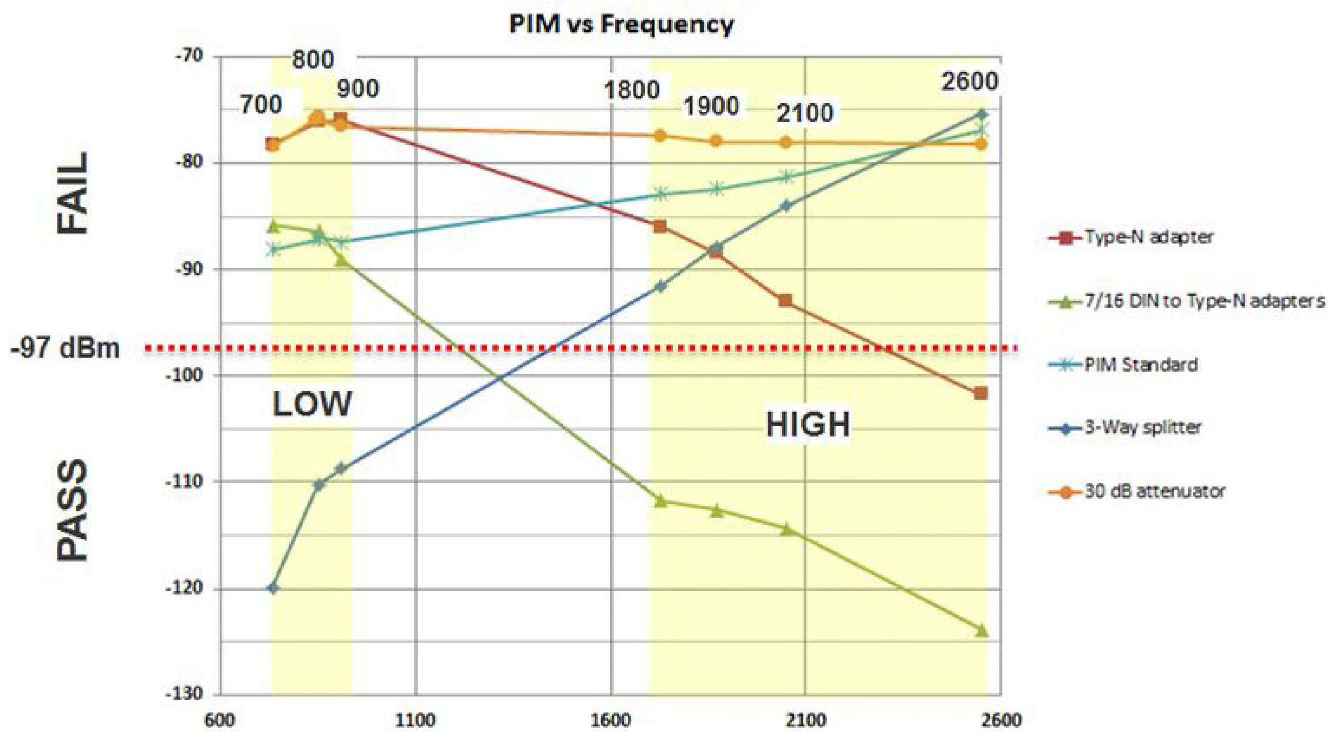

Figure 5. PIM vs. Frequency diagram

Scenario #2: 600 and 1900 MHz PIM Issue

To further illustrate the importance of testing at both low and high bands, a 600 MHz antenna is used in the following measurements to illustrate how PIM varies between the 600 and 1900 MHz receive channels.

Antenna Information

The 600 MHz antenna used in the following measurements was an 8-port dual-band antenna with dual-polarization and 4.3-10 female connectors. Table 1 shows specified frequency bands.

Frequency range	Antenna Connector (Array)
617 - 746	R2
1695-2200	B2

Table 1. Specified frequency bands of 8-port dual band antenna pictured in Figure 6

Figure 6. Commercial dual-band antenna

Figure 7. PIM source is placed on the antenna

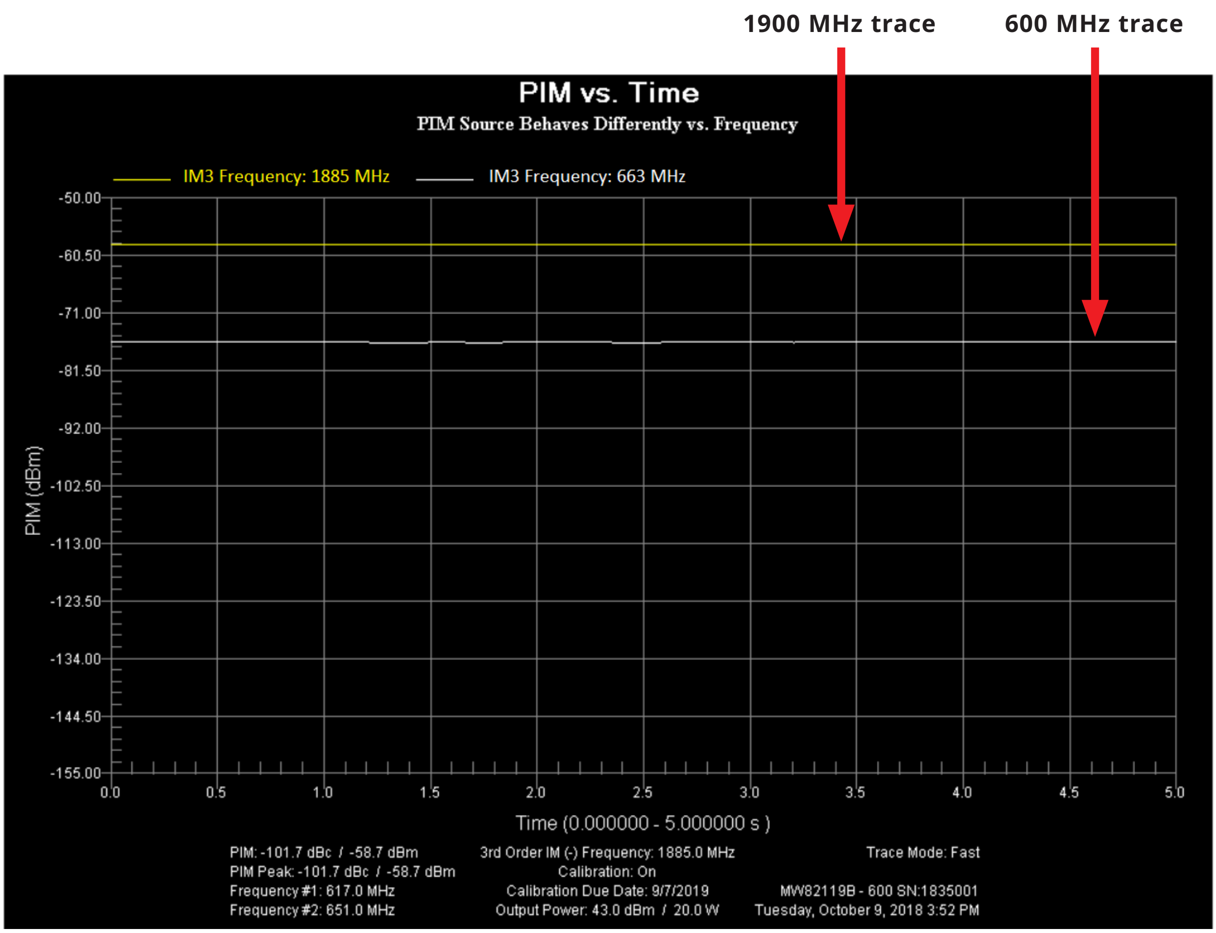

Figure 8. PIM vs. Time for both 663 and 1885 MHz receive channels

To measure the same PIM source at different IM3 bands (600 MHz and 1900 MHz), the Anritsu PIM Master™ MW82119B with PIM vs. Time feature was used. In Figure 8, the yellow trace shows the IM3 1885 MHz band and measures –62 dBm, whereas the green trace shows the IM3 663 MHz band and measures around –85 dBm. With the same 20W 600 MHz transmit tones, there is approximately a 13 dB difference between the measured PIM values at the 600 and 1900 MHz band antennas. This could mean pass or fail at a cell site. The result shows that for the 600 MHz spectrum, T-Mobile networks should be PIM tested at both 600 MHz and 1900 MHz bands. Mitigating one frequency band is not a guarantee for the other band. Testing PIM at both frequency bands is a necessity in order to mitigate PIM issues in the field.

Scenario #3 Evaluating 40W test power

With the more stringent requirements of 4G and 5G systems, demand for higher linearity (lower PIM) construction is needed. With this need, it is time to reassess the historical test power level recommended by IEC 62037 and determine if 40W (46 dBm) test power might better serve modern mobile communications networks.

A diagram of the PIM hunting process is shown in Figure 9. The process begins with the PIM Master MW82119B-0600 injecting two high-power test signals (F1 = 617 MHz, F2 = 636 MHz) in to the system under test. The test signals broadcast through a 600 MHz antenna, exciting the PIM source in the RF path. The PIM source behaves like CW transmitters radiating the IM3 frequency in all directions. The following linearity measurements were conducted on one PIM source with two test powers: 20W and 40W. The PIM Master MW82119B measurements were made with the 600 MHz antenna connected to the output port of the instrument. The test measures the Distance-to-PIM (DTP) at each test power.

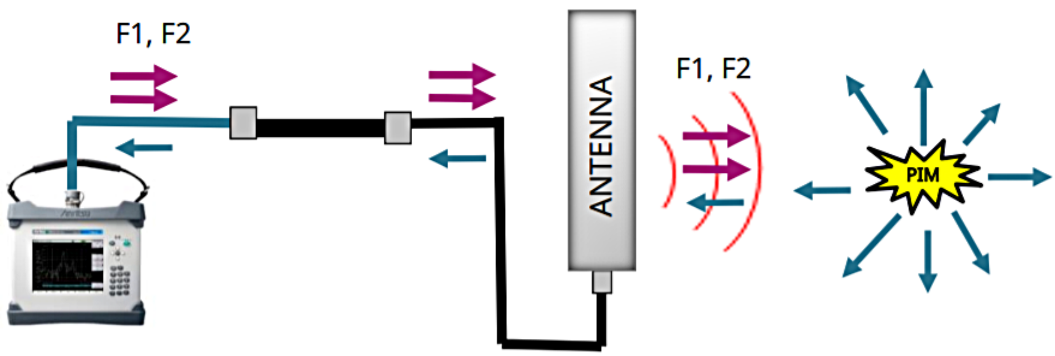

Figure 9. PIM hunting process

Figure 10. PIM source is positioned 5 meters away from antenna

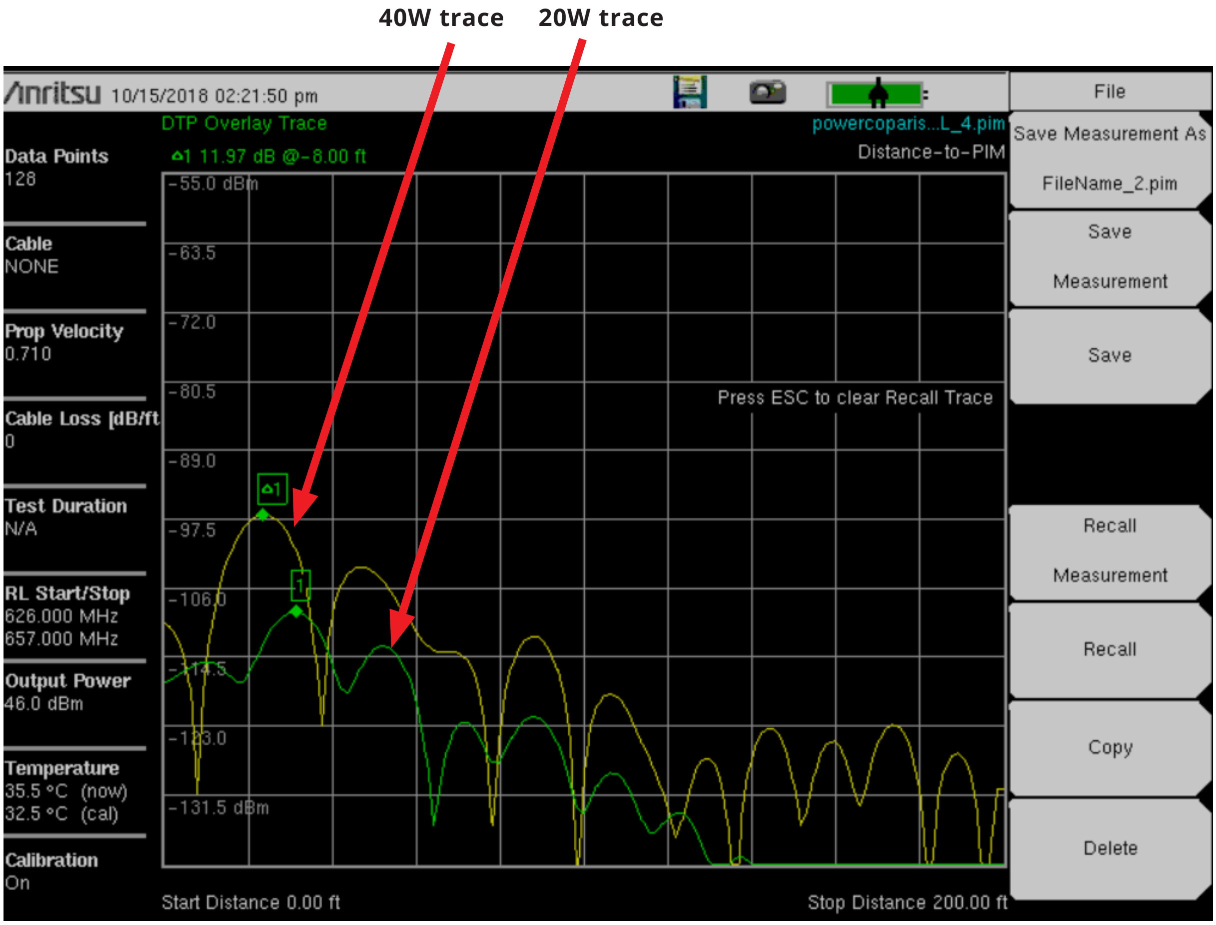

Figure 11. 20W PIM test failed to display true severity of PIM source

Using the Anritsu PIM Master MW82119B DTP-to-DTP trace overlay feature allows two different DTP traces to be viewed at the same time on the PIM Master analyzer display. In this instance, the yellow line is the 40W DTP trace and the green line is the 20W DTP trace. In Figure 11, the green trace measures < -107 dBm, which failed to identify external PIM source that is placed 5 meters away from the antenna. When measured at 40W, a rapid increase in PIM was observed and detected.

Conclusion

In the 600 MHz spectrum plan, PIM issues are found in both the 600 MHz uplink and co-located PCS band at 1900 MHz. To ensure good network performance, operators or technicians must verify PIM performance at both the 600 and 1900 MHz uplink frequencies when transmitting two 600 MHz tones. Testing outlined in this document shows that mitigating PIM issue on 600 MHz band does not guarantee the same for the 1900 MHz band. Testing PIM at both frequency bands is imperative in order to mitigate PIM issues in the field. Doubling the test power from 20W to 40W improves measurement accuracy and provides a way to thoroughly test mobile communications systems and devices. When troubleshooting and PIM hunting, Anritsu's PIM Master MW82119B analyzer with 40W capability provides more insight in to possible failure due to PIM at cell sites.

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