Application Note

Anritsu
envision : ensure

Using Distance-to-PIM (DTP) and Distance-to-Fault (DTF) trace overlay to speed site repair

In today's competitive environment, consumers no longer have to tolerate inconsistent network performance. If their current provider has poor coverage and slow data throughput, customers can easily switch to a different operator offering faster speeds and better coverage. In order to grow their subscriber base and increase revenue, operators must continuously improve the quality of their network by adding new cell sites and deploying new spectrum.

To verify the quality of these new installations, operators now commonly require a Passive intermodulation (PIM) test as part of the site commissioning process. Passing a 3rd order intermodulation (IM3) test at a level below –97 dBm (–140 dBc) shows that the site has been constructed to high standards and that performance impacting non-linearities have been removed from the RF path. If the site fails the PIM test, additional work is required to find the offending PIM source(s) and make the necessary repairs.

Distance-to-PIM (DTP) technology

In 2010, Anritsu was first to introduce Distance-to-PIM (DTP) technology to identify the location of PIM sources both inside the feed system and beyond the antenna. Previously, finding and eliminating PIM required a process of elimination involving the movement of low PIM terminations in the feed line until the PIM problem disappeared. This process was time consuming and also meant that good connections might be opened (and potentially damaged) in the process of locating PIM faults. In addition, this process was not effective for locating PIM sources beyond the antenna. With DTP technology, the instrument performs a measurement and in seconds displays the locations of PIM faults both in the feed system as well as beyond the antenna. Contractors using DTP technology are able to achieve passing PIM results faster, reducing the overall labor cost to build a cell site.

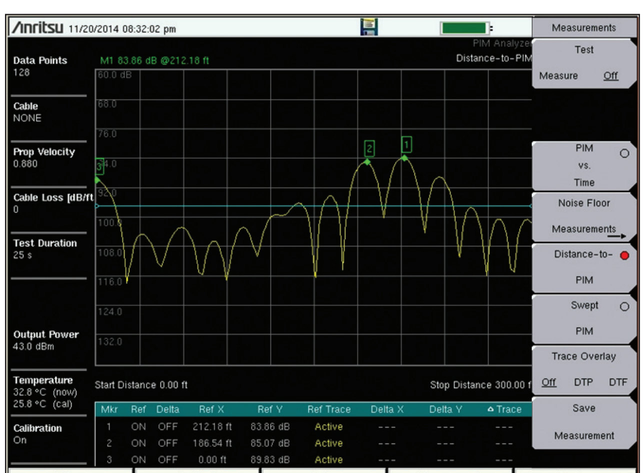


Figure 1: Distance-to-PIM (DTP) measurement

To enhance the usefulness of DTP technology Anritsu has developed two trace overlay functions that allow real-time comparison between the active DTP measurement and a previously recorded DTP or DTF (Distance-to-Fault) trace. Knowing where a PIM source is located relative to a known "PIM marker" or relative to a known RF connection simplifies troubleshooting, providing even faster site repairs.

DTP / DTP overlay

A DTP/DTP trace overlay is a feature allowing two different Distance-to-PIM (DTP) traces to be viewed at the same time on the PIM Master display. The active trace is the current DTP measurement while the overlay trace is a previous DTP measurement placed into memory. This capability is useful for identifying the location of an unknown PIM source relative to a known “PIM marker” placed in the system.

A practical application for DTP/DTP overlays is for identifying whether a PIM source is inside the feed system or beyond the antenna. This is an important capability since in many cases responsibility for repairing PIM beyond the antenna is the responsibility of the operator, not the installer. Supplying measured data to support claims not only avoids arguments, but also gives the operator an idea where to start looking to resolve the problem. The following procedure describes how to use the DTP/DTP overlay feature to evaluate external PIM:

1. Find a consistently strong PIM source, such as a bag of steel wool, and enclose it inside a plastic bag. Carry this and a roll of non-permanent tape, such as painter’s masking tape, with you when PIM testing cell sites.
2. If DTP indicates a PIM problem near the antenna location, stop the test and tape the strong PIM source to the center of the antenna radome. Run a DTP measurement with the PIM source at the antenna and store this measurement into memory by pressing the “Trace Overlay” submenu key. This strong PIM source creates a “PIM Marker” that accurately shows the electrical distance to the antenna radiating surface.

Figure 2: Steel wool taped to antenna radome

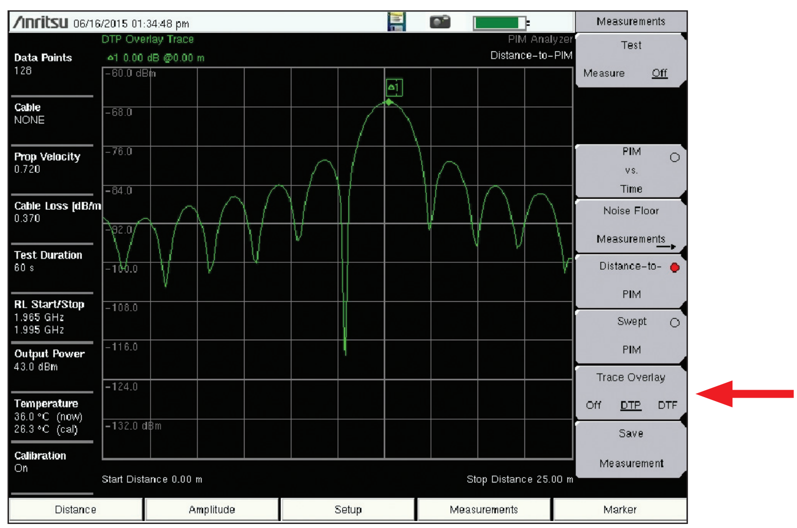


Figure 3: DTP with Steel wool taped to antenna radome

3. Remove the strong PIM source from the antenna radome and move it far away. On a tower top, move the PIM source at least 3 m behind or below the antenna.
4. Re-measure DTP on the antenna system, with the strong PIM source removed. The PIM Master will overlay the active trace (Site PIM) with the stored trace (PIM marker) and automatically insert a delta marker showing the relative distance between the two DTP peaks. The relative distance between peaks is displayed at the upper left corner of the measurement window. To make the value easier to read, select the “Large” option for the marker table in the Marker menu.

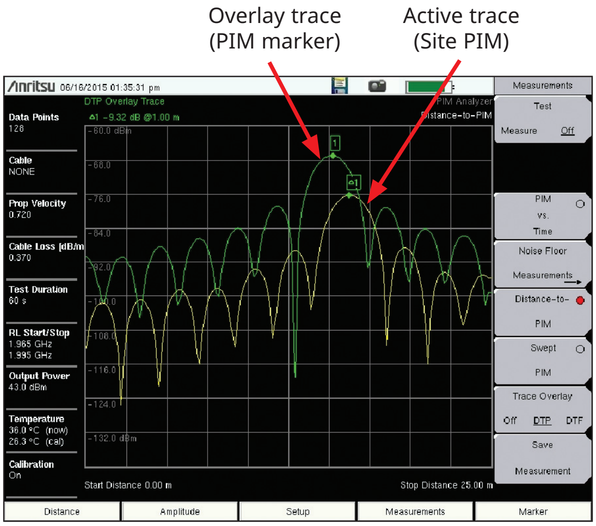


Figure 4: DTP/DTP overlay

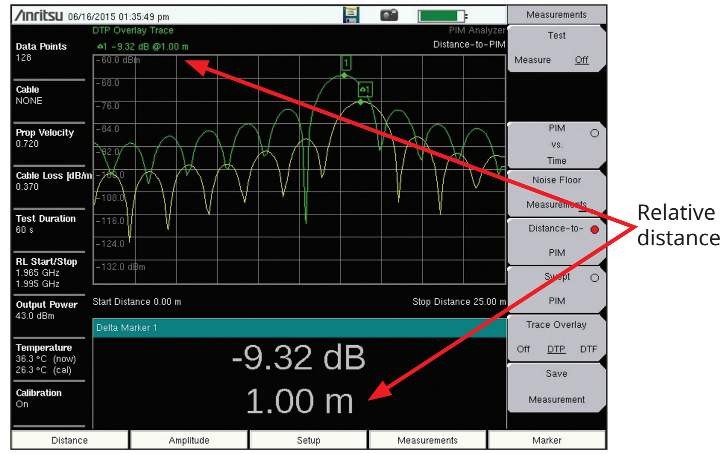


Figure 5: DTP/DTP overlay, marker table "Large"

5. Analysis:
   a. Relative distance > 0 : PIM source is beyond the antenna
   b. Relative distance = 0 : PIM source is at, or very near the antenna
   c. Relative distance < 0 : PIM source is inside the antenna or feed system

Distance-to-PIM (DTP) accuracy

The system tested in the previous example was an indoor antenna installed at the end of a 15 m long test cable (propagation velocity = 0.72) with an external PIM source approximately 5 ft (1.52 m) beyond the antenna. The relative distance displayed by the PIM Master between the external PIM source and the antenna radome is 1.00 m when the actual distance is 1.52 m. This is an error of 0.52 m, or 30%! The majority of this error is due to the propagation velocity used for the measurement. A propagation velocity of 0.72 (matching the propagation velocity of the cable) was used to accurately show the distance to RF connections in the feed system. Repeating steps 2 – 4 above with the propagation velocity set to 1.0 (matching the propagation velocity of air) will more accurately indicate the physical distance between external PIM sources and the antenna radome, as shown in Figure 6. With this change, the measurement error is reduced to 0.1 m (3.9 inches).

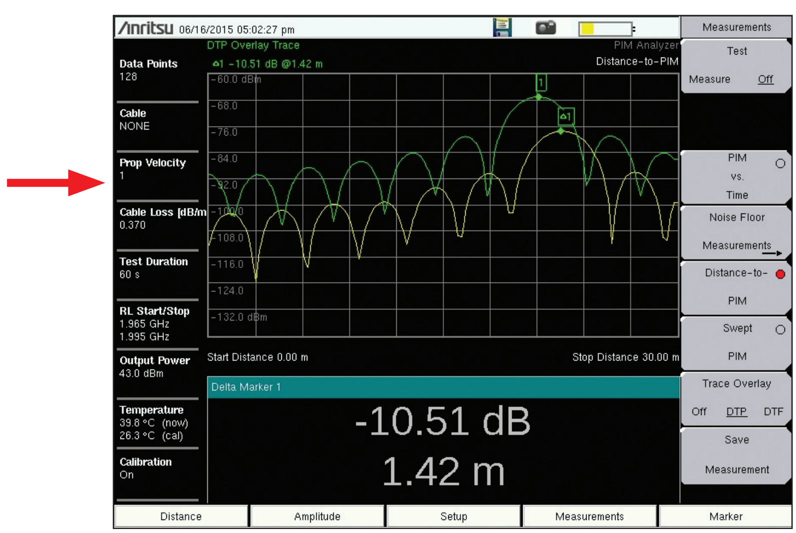


Figure 6: DTP/DTP overlay, propagation velocity = 1.0

DTP / DTF overlay (manual method)

Anritsu provides two methods to overlay the active DTP trace with a Distance-to-Fault (DTF) trace. DTP/DTF overlays are useful for identifying the location of PIM sources relative to known reflections in the antenna feed system.

The first method is a “manual” method, where a previously measured DTF trace is selected in the Trace menu (Shift 5) and overlaid with the active DTP measurement. DTF measurements overlaid this way can be created using a Site Master (transferred to the PIM Master via USB memory stick) or can be created using Option 331 on a B-series PIM Master (loaded directly from internal memory). These high-resolution DTF measurements are typically made using 100’s of MHz of swept bandwidth, enabling clear identification of all RF connections in the feed system. Since PIM often occurs at RF connections, these DTF traces provide an accurate “connector location map” that can be used as a guide to assist PIM fault troubleshooting.

Two DTF measurements that are typically required at a site that should be available for overlay are:

- DTF-RL-Load: Distance-to-Fault measurement made on the feed line with a precision load installed at the end of the feed system. This measurement verifies connector attachment quality and looks for any cable issues between connectors.
- DTF-RL-Short: Distance-to-Fault measurement made on the feed line with a short installed at the end of the feed system. This measurement shows a very high reflection at the end of the cable that is used to identify the cable length.

The following two screen shots show DTP/DTF measurements made by manually overlaying the two typical DTF measurements made at a site for the antenna system measured previously. The PIM source appears farther away in each case due to the electrical length of the antenna. Indoor antennas typically have a very short electrical length (<< 1 m) so the error is very small. If a high gain panel antenna had been used, the relative distance error between the end of the cable and the external PIM source would be much greater. For this reason, DTP/DTP overlays are more accurate and are the preferred measurement for locating PIM sources beyond the antenna.

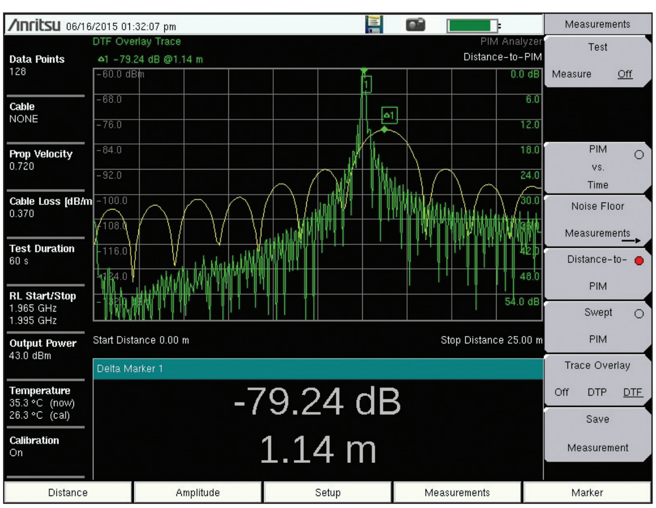


Figure 7: DTP/DTF overlay using short circuit DTF

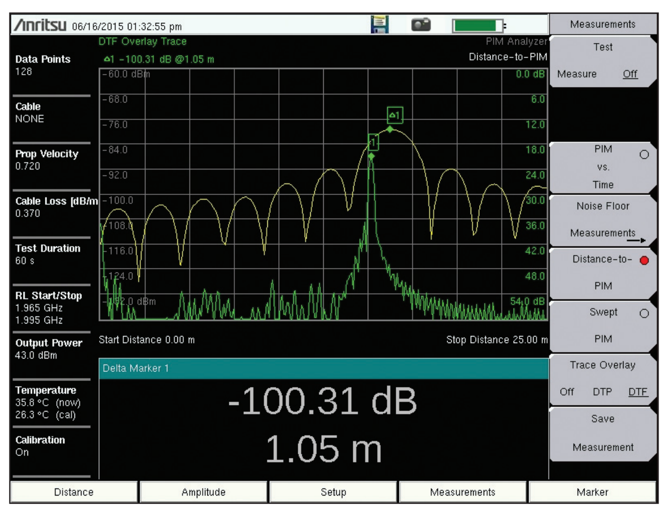


Figure 8: DTP/DTF overlay using antenna system DTF

For PIM sources inside the feed system, DTP/DTF overlays are preferred. Figures 9 and 10 show DTP/DTF overlays made on a system consisting of two 15 m cables with a PIM source installed either at the middle or at the end of the system. DTF clearly identifies the connector locations using either a high frequency sweep (Figure 9) or a low frequency sweep (Figure 10). In each case, the DTP/DTF overlay clearly identifies the PIM fault location. As long as DTF and DTP are both measured using the same propagation velocity, the actual distance displayed by the PIM Master is not important. In Figure 9, it is obvious that the PIM fault is located at the last connector and in Figure 10, it is obvious that the PIM fault is located at the middle connector. This saves time in the field locating PIM sources since a list of exact cable lengths is rarely available.

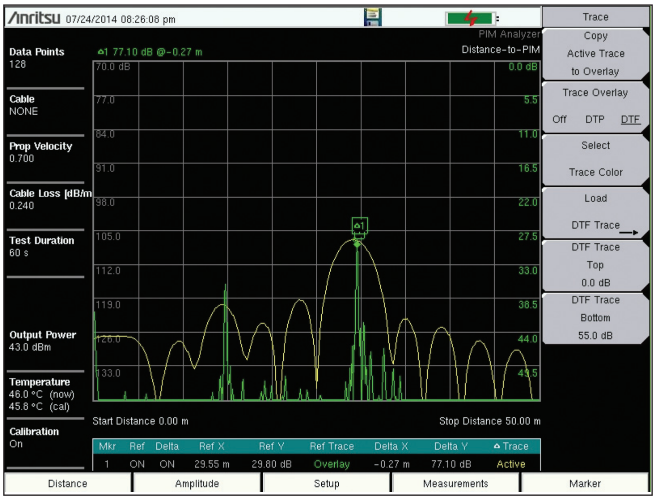


Figure 9: DTP/DTF using 1710-2170 MHz DTF

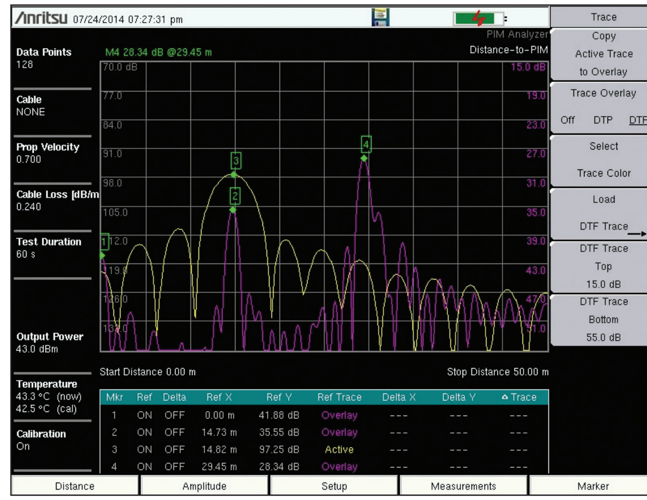


Figure 10: DTP/DTF using 880 – 960 MHz DTF

DTP / DTF overlay (automatic method)

The second method available from Anritsu for creating DTP/DTF overlays is an "automatic" method, where DTF is measured through the PIM test port prior to each DTP measurement. This capability is available starting with firmware version v1.21 for the A-series PIM Master and firmware version v2.12 for the B-series PIM Master. The benefit of this method is that no additional steps are required by the operator to generate the overlay. Whenever "low resolution DTF" is turned "ON" in the Distance-to-PIM Set-up menu, a DTF measurement is automatically conducted prior to each DTP measurement and displayed with the DTP measurement.

The only limitation of the "automatic" overlay is that the DTF resolution is reduced compared to the "manual" method. Since the "automatic" method is restricted to using frequencies that can pass through the Tx/Rx filtering inside the PIM Master, only 10's of MHz of spectrum can be used to produce the DTF plot, compared to 100's of MHz available for the "manual" method. Reducing the swept frequency range reduces the resolution as defined by the following formula:

DTF resolution (m) = (150 * V_p) / Bandwidth (MHz)

Where:

DTF resolution (m)	= smallest fault spacing in meters that DTF can resolve
V_p	= Propagation velocity
Bandwidth (MHz)	= Swept frequency range in MHz used to conduct DTF measurement

Figures 11 and 12 demonstrate the difference between “automatic” and “manual” DTF resolution using a MW82119B-0194 PIM Master. In the automatic mode, the MW82119B-0194 analyzer uses a swept frequency range of 1965 MHz to 1995 MHz (30 MHz total). Substituting Vp = .72 (for the cable used in this example) and 30 MHz swept bandwidth, we get a resolution of 3.60 m (11.81 FT). For the manual method, the DTF bandwidth is limited by the bandwidth of components installed in the system. In many cases, the antenna is the limiting component, which for a “high frequency” BTS antenna port is typically 1710-2170 MHz (460 MHz total). Substituting Vp = .72 and 460 MHz swept bandwidth, we get a resolution of 0.23 m (0.77 FT). For short cable lengths with closely spaced RF connections, the higher resolution “manual” DTP/DTF overlay offers an advantage. For longer cable lengths with widely spaced RF connections, either DTP/DTF overlay method will be effective. In the case shown below, the same conclusion is drawn from each plot; the PIM source is approximately 3 m beyond the antenna.

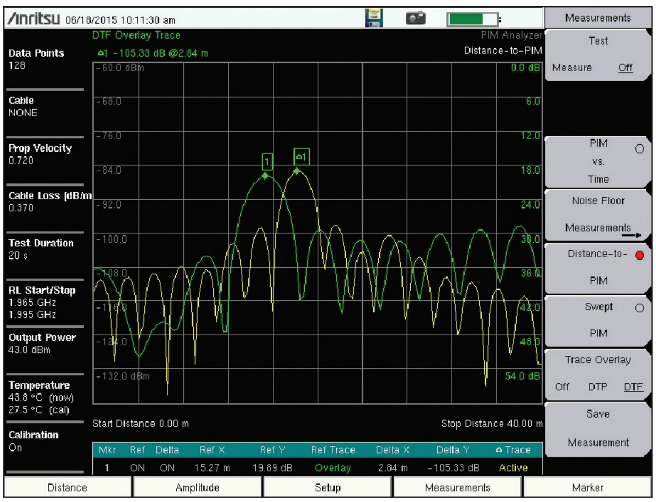


Figure 11: Automatic DTP/DTF - 30 MHz bandwidth

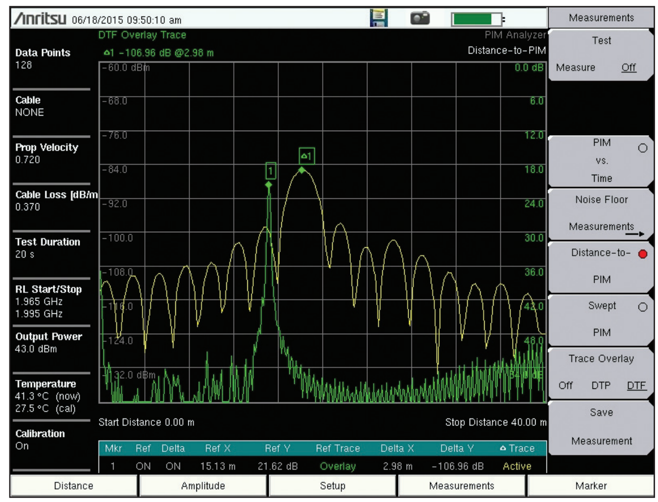
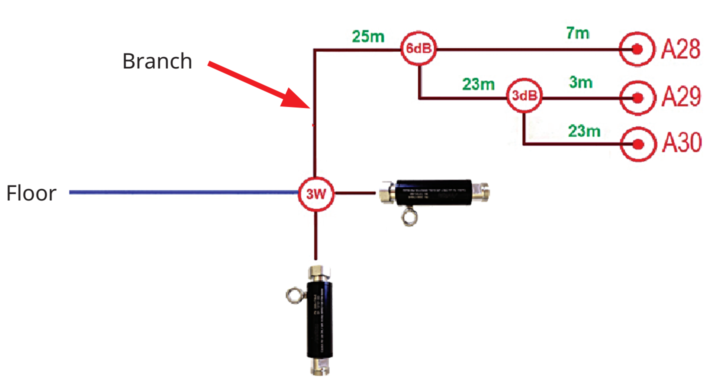


Figure 12: Manual DTP/DTF - 460 MHz bandwidth

Inbuilding DAS example

Inbuilding Distributed Antenna Systems (DAS) can have hundreds, if not thousands of RF connections at cables, splitters and antennas in the power distribution system. DTP and DTF are powerful tools for helping installers isolate problems in these complex systems. The example below is from a 30-story office building with 9 antennas installed on each floor.

To isolate PIM problems on a particular floor, a PIM test was conducted with low PIM terminations installed on all three outputs of the 3-way power divider feeding the floor. This verified that the feed cable from the telecommunications equipment room and the 3-way power divider had low PIM. Next, PIM tests were performed with individual branches attached to the 3-way divider, one at a time, until the failing branch was identified. Then, a DTP measurement (with automatic DTF overlay) was made to identify the locations of problems on the branch. Figure 13 shows the test configuration of the failing branch.



Feature	Distance
3-way splitter	76 m
6 dB tapper	101 m
Antenna A28	108 m
3 dB tapper	124 m
Antenna A29	127 m
Antenna A30	147 m

Figure 13: Inbuilding DAS branch configuration

Figure 14 shows the DTP/DTF overlay as seen by the operator in the telecommunications equipment room. The PIM Master in this example was a MW82119A-0900 with “automatic” DTF overlay through the PIM test port. Given the length of the system under test and the long physical distance between connections, the “automatic” DTF overlay had sufficient resolution to identify the key features. By radio, the operator was able to direct the team working on the floor above to make PIM repairs at antenna locations A28 and A30. In this case, the repair involved re-working the RF connectors near each antenna to remove foam & glue that was preventing good metal-to-metal contact. Without the DTP/DTF overlay feature, resolving these problems would have taken much more time and effort.

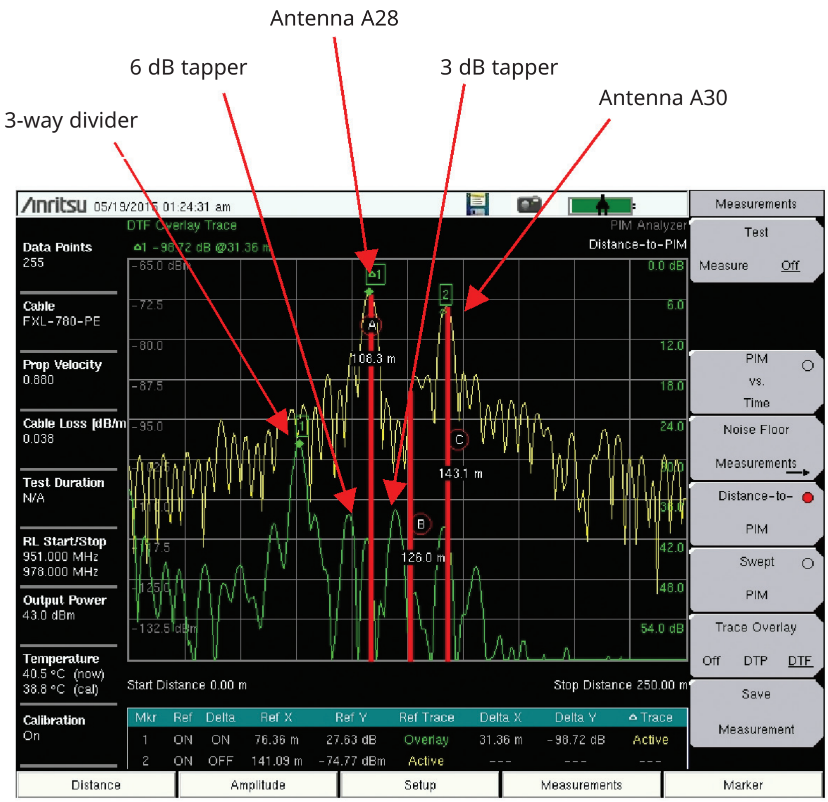


Figure 14: DTP/DTF overlay used to troubleshoot DAS branch

Figure 15: Telecommunications equipment room

Conclusion

Distance-to-PIM (DTP) technology from Anritsu greatly reduces the time required to resolve PIM issues at macro sites as well as inbuilding systems. Real-time trace overlay on the PIM Master enables technicians in the field to understand more clearly what they are seeing by comparing PIM fault locations to known “PIM markers” and known reflections in the system. Together, these features simplify the Passive Intermodulation (PIM) troubleshooting process, enabling faster site repairs.

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11410-00869, Rev. A Printed in United States 2015-06