10/13

wireless pages

An AWT Global Publication

About PIM: Forward - Reverse - Residual

by Wolfgang Damm | AWT Global

Passive intermodulation (PIM) distortion is a growing concern for telecommunication network operators. They have to cope with limited bandwidths and at the same time, with highest data demand of their subscribers. Signal degradation caused by PIM reduces available bandwidth and can seriously impair mobile network quality. PIM analyzers play an important role in tackling the PIM problem, in the field but also in development labs.

PIM is an unwanted signal distortion caused by non-linear behavior of passive components in the RF path of telecommunication systems. PIM happens when these systems carry two or more RF signals simultaneously. Multi carrier systems are the norm with today's in-building DAS installations. Not only can PIM degrade signal quality, it can affect system performance so severely that it may even drop calls. Users become disgruntled about poor service, network operators lose revenue.

Modern telecommunication networks are challenged as never before with subscribers demanding huge data volumes for smart phones and tablets. To maintain the highest levels of network coverage, performance and reliability, all sources of interference that might affect signal quality need to be eliminated.

PIM can be caused by a number of sources, including:

- Junctions of dissimilar metals with different electrical properties
- Corroded components and structures
- Ferromagnetic metals like iron, nickel and steel
- Irregular contact areas, even on microscopic scale, that cause an inconsistent flow of electrons and generate inhomogeneous electrical fields
- Spark discharges caused by "hot" connections and disconnections, producing craters on connector surfaces and leading to chemical reactions.
- Rusty-Bolt- effects. This is PIM caused in the RF path between transmitter antenna and receiver antenna.

The need to minimize PIM effects makes testing for passive intermodulation (PIM) in components and cellular installations a mandatory task. This is especially important for systems that share more than one carrier, as it is the case with neutral-host distributed antenna systems (DAS).

AWT Global
117 Grand Avenue, Hackettstown, NJ 07840, USA
w: www.awt-global.com | e: info@awt-global.com | p: +1 973--321-3423

Forward & Reverse PIM

If PIM levels of telecommunication installation are too high, culprits are often found in components and connections. Dust or metal chips in the connector areas, scratched plating surfaces or dissimilar metals can induce PIM. Figure 1a shows a connection between two feeder cables. If the connection is causing PIM, it can be seen like the electrical model in Figure 1b. The RF source represents the PIM source in the connectors, generating low power signals at a frequency that correlates to the intermodulation signal. The generator injects the IM signal into the feeder cables in a way that it propagates in both directions: towards the system's output (antenna) and towards the systems input (receiver). PIM in the direction of the antenna is called forward PIM. Intermodulation power that is propagating towards the receiver is known as reflected or reverse PIM. The receiver of the base station is replaced by the receiver of the PIM analyzer during PIM tests.

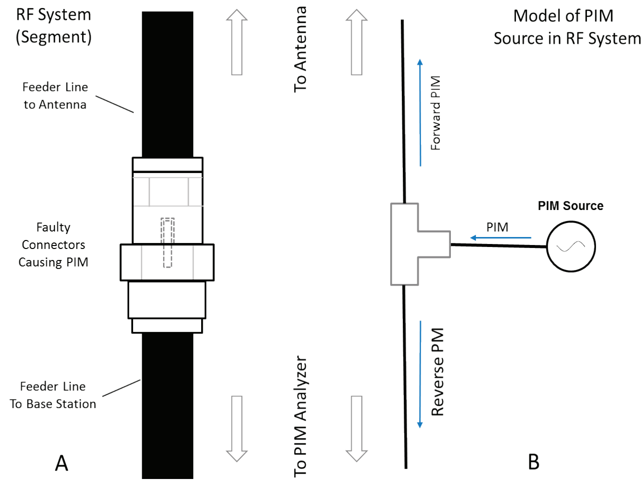

Figure 1. Electrical model of PIM source in RF system.

Incoming receiver signals are naturally very weak, and can go as low as -117 dBm. It does not take a lot of energy to interfere with these signals. If reverse PIM interferes with these incoming up-link signals, receivers get seriously distorted and the quality of wireless connections drops significantly.

Measuring PIM

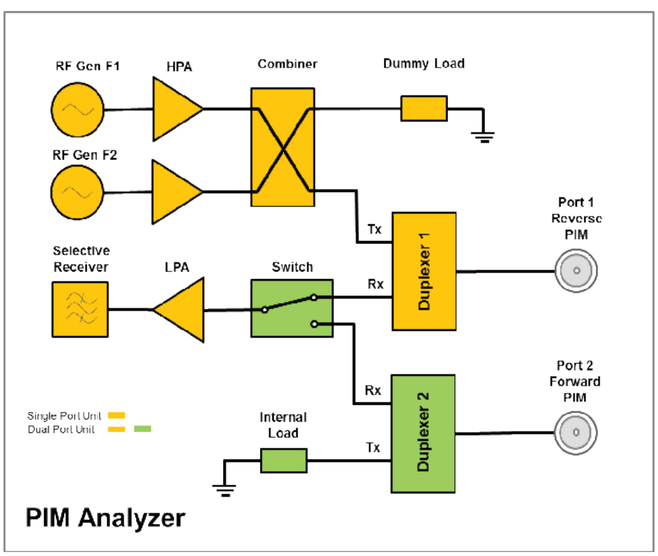

Figure 2. Block diagram of single port and dual port PIM analyzers.

Many passive RF components, like attenuators, can be utilized in both directions. Forward and reverse PIM measurements of components may display slightly different results. Therefore, PIM ratings on manufacturers' data sheets should include both forward and reverse PIM characteristics.

International standard for PIM measurements is IEC 62037. Only PIM testers fully conform to this standard guarantee that measurements are conducted in a meaningful, comparable and repeatable manner. PIM analyzers are vital tools for both, R&D engineers and field installation crews. Analyzers used by field personal are typically single port systems, while dual port analyzers are used at production floors. Dual port analyzers are not to be confused with dual band PIM analyzers. What is the difference? The latter have the capability to measure two different frequency bands; the former provide two ports, one to perform reverse PIM measurements, the other for forward PM measurements.

Single- and dual port PIM analyzers share the larger part of their architecture (Figure 2). Both incorporate two variable, independent RF generators which drive two high-power amplifiers (HPAs). The generated signals are variable in frequency and level. The generators can be set to any frequency in the specific band for which the PIM analyzer has been designed. An ultra low PIM combiner brings the amplified signals together and delivers the combined carriers to the Tx port of a duplexer. The duplexer has to provide very high separation between its high power Tx and very low power Rx ports. As better this duplexer is designed, as better the dynamic range of the PIM test system. The output of the duplexer is basically the reverse PIM port of the PIM analyzer. With the exception of antennas and loads, all Devices Under Test (DUTs) require external terminations to perform PIM measurements. Antennas radiate the transmitted RF power directly into the air, loads convert it into heat. Any test cable and load that is used for PIM testing, must have significantly better PIM ratings than the actual DUT to allow for accurate measurements.

Figure 3. Portable PIM analyzer with constant 2x20 W output power, conform to PIM specification IEC 62037.

PIM signals that arrive at the analyzer port are channeled to the duplexer's Rx leg. The duplexer frequency correlates with the receiving band of the wireless system. A highly selective receiver measures now the power of the intermodulation signal.

Dual-port analyzers consists of all these elements, but have a second duplexer (identical to the first), an additional internal high power, low PIM termination and a low PIM switch. The second port feeds into the second duplexer, which has a terminated Tx port. Since an internal termination is provided, dual-port analyzers do not require external loads to terminate 2-port DUTs. The Rx port of the second duplexer measures forward PIM power. A low PIM switch toggles between reverse and forward PIM measurements.

Field technicians use single-port analyzers like the one shown in Figure 3. During PIM measurements, system PAs and receivers of the RF systems are disconnected and instead PIM analyzer are connected. The analyzers will now generate two high-power CW tones within the transmit band of the measured system. It is important to apply enough energy during PIM measurements to ensure the RF system is tested under conditions similar to the actual utilization. Only measurements conducted with 2x20W systems apply realistic thermal load to connectors, allowing pinpointing (future) PIM issues.

Single or Dual Port Analyzers?

For many measurement applications in telecommunications, single-port analyzers are suitable for both, reverse and forward PIM analysis. Figure 4 shows forward and reverse PIM measurements for a simple two-terminal DUT; a cable in this example. Forward and reverse PIM will not differ much, and can easily be measured in two steps. Reverse PIM is measured by connecting one end of the DUT (A) to the PIM analyzer, while the other end is terminated with a low PIM load (B). Forward PIM is measured with the direction of the DUT reversed (B-A). The resulting PIM measurements are quite similar.

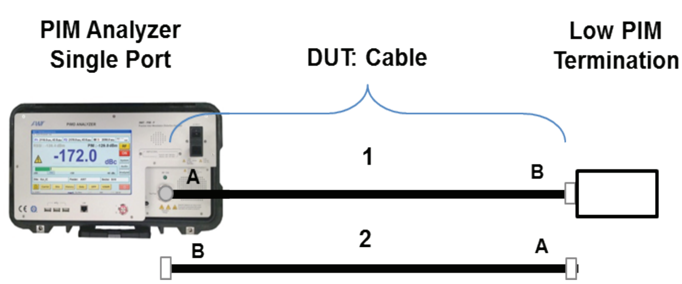

Figure 4. Forward and reverse PIM measurement of cable, as simple dual-port DUT (cable).

Dual-port units help measure forward and reverse PIM of components in less time. This is very beneficial for complex components with more than two ports. The example in Figure 5 shows a power splitter under test. Single-port units require three test steps, feeding the analyzer's measurement signals sequentially into the splitter ports IN, OUT1 and OUT2. Ports that are not connected to the PIM analyzer need to be terminated for accurate measurements. Dual port analyzers offer more convenient testing. During the first test step, measurement signals are fed into IN port of the splitter, while the forward port is connected to OUT1, with OUT2 terminated. For the second test step, only OUT1 and OUT2 have to be swapped to complete the test; the IN port stays connected as is.

This saves time and labor, and it reduces the number of connection / disconnection cycles. Connector mating causes wear, resulting in microscopic metal chips on the connectors surfaces. These chips are a strong source of PIM. Even with the mandatory alcohol swipe before connectors are mating, the fewer cycles the better.

Residual PIM

Residual PIM is unrelated to the DUT, but it is a characteristic of the PIM analyzer. Analyzers are built with components that are far superior to the ones used in network operations. Still, PIM analyzers generate internal PIM. Even if the amount of PIM generated by these special internal components is small, it sums up and can influence the measurement. Manufacturers provide residual PIM specs in their data sheets.

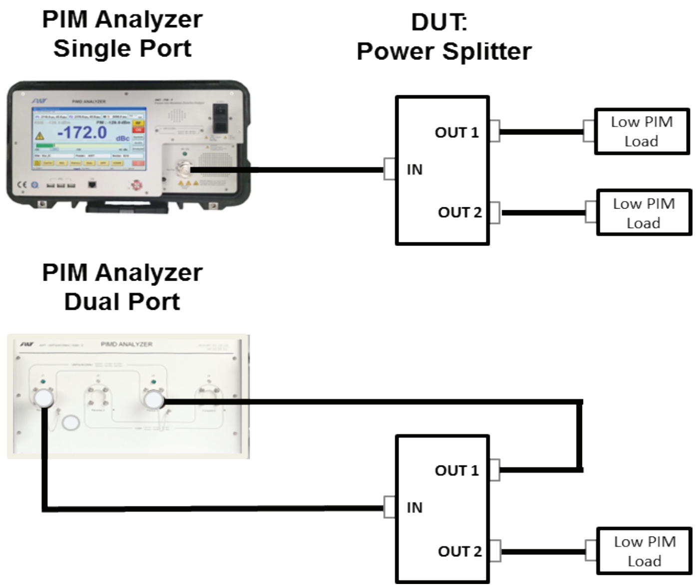

Figure 5. Forward and reverse pim measurement of a 3 port DUT (power splitter)

To ensure meaningful PIM measurements, residual PIM should be at least 10 dB below the measurement range of the analyzer. Modern PIM analyzers use not only ultra-low PIM components, but minimize possible residual PIM readings with sophisticated digital signal processing (DSP) technology.

Conclusion

The demands on mobile network infrastructure evolve continuously towards faster data rates, which are achieved through more complex modulation technologies. Unfortunately, complex modulation schemes are more susceptible to interference. PIM can seriously degrade system performance. PIM is caused when two or more carriers share one RF path. Telecommunications operators are determined to prevent any loss of capacity due to signal degradation. To minimize PIM effects, every new installation is tested for low PIM. All PIM rated components have to be tested as well. Field installation crews use single port PIM analyzers providing reverse PIM capabilities. Component manufacturers have to be concerned about both, reverse and forward PIM ratings.