kAelus

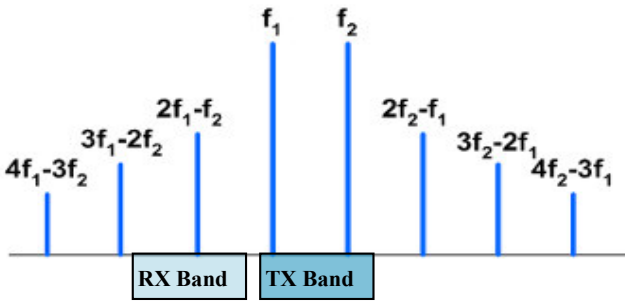
PASSIVE INTERMODULATION (PIM)
Testing Guidelines

smiths interconnect

PASSIVE INTERMODULATION (PIM)

Passive Intermodulation (PIM) occurs when two or more high power RF signals encounter non-linear electrical junctions or materials in an RF path. These non-linear junctions behave like a mixer causing new signals to be generated at mathematical combinations of the original RF inputs. In the figure to the right, f1 and f2 represent two Tx frequencies present at a typical cell site and ± m•f1 ± n•f2 are the PIM signals generated by those Tx frequencies.

When these PIM signals fall in the Rx band of the cell site the noise floor rises causing increased dropped calls, reduced data transmission rates and decreased system capacity. The impact of PIM on the network performance can be severe, especially for wideband systems such as CDMA, UMTS or LTE.



Example: f_1 = 869 MHz, f_2 = 894 MHz

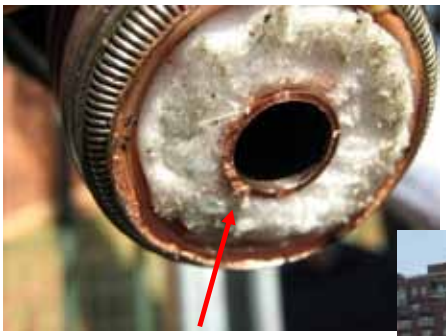
IM3 = 2x 869 MHz - 1x 894 MHz = 844 MHz
IM3 = 2x 894 MHz - 1x 869 MHz = 919 MHz
IM5 = 3x 869 MHz - 2x 894 MHz = 819 MHz
IM5 = 3x 894 MHz - 2x 869 MHz = 944 MHz

PIM SOURCES AT A CELL SITE

The primary sources of non-linear junctions at a cell site are inconsistent metal to metal contacts in high current density regions such as inside transmission lines, inside RF components or outside the system but in the main beam of the antenna. Clean metal surfaces with high contact pressure generally behave in a linear manor and do not generate PIM. Where there is loose contact between metal surfaces, a non-linear relationship develops between the applied voltage and the resulting current flow across the joint causing PIM to be generated.

In the field, non-linear junctions can be caused by:

- Contaminated surfaces or contacts due to dirt, dust, moisture or oxidation.
- Loose mechanical junctions due to inadequate torque, poor alignment or poorly prepared contact surfaces.
- Loose mechanical junctions caused transportation shock or vibration .
- Metal flakes or shavings inside RF connections.
- Poorly prepared RF connections
  - Trapped dielectric materials (adhesives, foam, etc.)
  - Cracks or distortions at the end of the outer conductor of coaxial cables caused by over tightening the back nut during installation.
  - Solid inner conductors distorted in the preparation process causing these to be out of round or tapered over the mating length.
  - Hollow inner conductors excessively enlarged or made oval during the preparation process.
- Nearby metallic objects in the main beam and side lobes of the transmit antenna including roof flashing, vent pipes, guy wires, etc.



PIM TEST EQUIPMENT

To find and eliminate sources of passive intermodulation in RF components Summitek Instruments developed factory PIM test equipment in 1996. This equipment has been used by RF equipment manufactures worldwide to validate the PIM performance of new designs and to verify PIM performance of the products they manufacture.

In 2005, Summitek's sister division Triasx developed a portable version of this equipment to enable PIM testing to be conducted at the cell site. The portable PIM test equipment performs the same function as the factory test equipment but has been miniaturized and ruggedized to meet field requirements. This equipment enables network operators to find and eliminate non-linear junctions at the cell site in order to improve site performance.

PIM test equipment works by transmitting two high power signals into the line or device under test. If the test signals encounter a non-linear junction mixing occurs causing the PIM frequencies to be generated. The PIM signals travel in all directions from the point of generation. In a coaxial system this means they travel out toward the antenna as well as back in the direction of the PIM test equipment. The PIM test equipment measures the magnitude of the PIM signal generated by the test signals and displays this information to the test operator.

The 3rd order product (IM3) is primarily used to characterize PIM performance both in the factory and in the field. The IM3 signal generated by a non-linear junction is usually higher magnitude than the other PIM products enabling higher measurement accuracy. The higher order products (IM5, IM7, IM9, etc.) typically drop in magnitude by 5 to 10 dB for each successive PIM product. By controlling IM3 to a specified level, the higher order products are held well below that level, often by 10's of dB's.

Factory PIM Test Equipment

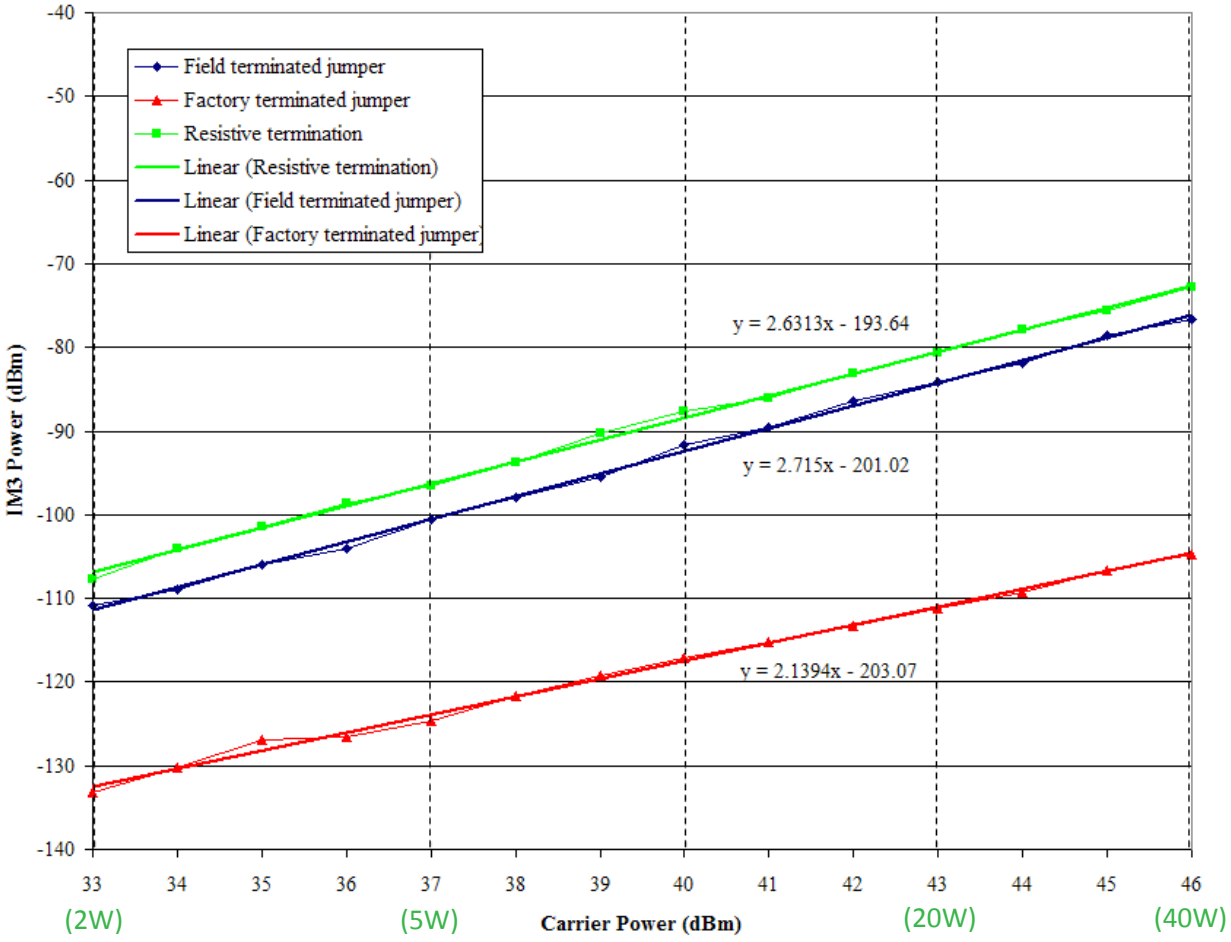
Field PIM Test Equipment

PIM MEASUREMENT POWER

The magnitude of the PIM signal generated by a given defect is highly dependent on the power level of the two RF signals interacting with that defect. A 3rd order PIM product, for example, will change between 2.2 and 3.0 dB in magnitude for every 1 dB change in test power. As shown in the figure below, this rate of change, or PIM slope, remains fairly constant across a wide range of applied Tx power levels.

Because the magnitude of PIM generated by a defect changes depending on the applied test power, it is important that all specifications clearly state what power level to use when performing the test. IEC 62037 recommends that +43dBm (20W) test tones be used when performing PIM tests on communications systems. Using a common test power across the industry both in the factory and in the field provides a consistent method to characterize and compare PIM performance to a common specification.

Low power, battery operated test sets are available for testing in locations where AC power is not available or where transporting a 20W test set is not feasible. These low power systems are useful for finding gross PIM failures in components and are useful for troubleshooting sites to determine the location of PIM problems. Absolute results may vary, however, when compared to 20W test results due to differences in measurement accuracy (S/N ratio) between low power testing and 20W testing.



PIM MEASUREMENT FREQUENCY

PIM test equipment is used to find and eliminate non-linear junctions and materials at the cell site. The specific test frequencies used to identify these defects are not critical as long as the following criteria are met:

- All RF components in the path (Cables, Antennas, TMA's, etc.) must be able to pass the two test frequencies, f1 and f2, and be able to pass the IM frequency you are measuring.
- The two test frequencies must be within the operator's licensed spectrum or be guard band frequencies between licensed spectrum blocks. This applies to all system level tests where the test frequencies will be broadcast through the antenna.
- The two test frequencies need to be selected so that they will produce the specified IM product within the receive band for that system. When IM3 is specified this will typically require test tones with wider frequency spacing than can be achieved within the licensed frequency block for a given market. For this reason, guard band frequencies will typically be selected.

Some test equipment provides the ability to sweep the two transmit frequencies across a range of frequencies during the test. Swept frequency modes will transmit frequencies outside of the operator's licensed spectrum. *For this reason, swept frequency modes should only be used to test systems terminated into a low PIM load.*

DYNAMIC VS. STATIC PIM TESTING

During a PIM test, all components and interconnections on the line should be subjected to light mechanical stress or "dynamic" test conditions. If the component or RF connector has loose internal connections or internal debris that can result in increased PIM (as identified during dynamic testing) there is a high probability that the condition will present itself in the future and invariably at the most inconvenient time.

Tap Test Guidelines

- Tap RF components such as TMA's, Filters and Antennas using a hard plastic or rubberized metal object to prevent nicking or damaging protective finishes.
- Lightly tap the nut and/or back shell of RF connectors using a hard plastic or metal object. Do not tap the coaxial cable itself as this could cause dents in the line.
- Tap with sufficient force to excite PIM problems if they exist but do not tap with excessive force. A good rule of thumb is that if you tapped your unprotected palm with the same force, it should not hurt.
- Tap before weatherproofing is installed on RF interconnections. If weatherproofing is in place, substitute a "flex test" to apply stress to the interconnection.

Flex Test Guidelines

- For stiff cables, rock the RF connector back & forth in two orthogonal directions while holding the cable rigid.
- For flexible cables, hold the RF connector rigid and flex the cable back & forth in two orthogonal directions. Hold the cable approximately 12 inches (300mm) away from the connector and flex the cable ±1 inch (25mm) in each direction.

ANTENNA PIM MEASUREMENT

When performing a PIM test, high power RF energy will be radiated from the antenna. Care must be taken to ensure that people near the test are not exposed to RF field levels in excess of the maximum allowable exposure limits and that the test environment must be free of PIM sources that could invalidate the results. The following guidelines should be followed:

- Do not PIM test antennas indoors. (Unless an anechoic chamber is available designed to absorb the RF energy.)
- Place the antenna on non-metallic supports at least 1 foot (300mm) off the ground with the front of the antenna pointing to the sky.
- Position the test equipment to the top or bottom of the antenna (not to the sides.) Typical sector antennas have minimum radiation along the vertical axis.
- Position the antenna so that no metallic objects obstruct the view of the sky within the antenna's half-power beamwidths (both azimuth and elevation.)

  Note: Omni directional antennas typically must be mounted at the top of a tower during PIM testing to prevent "seeing" metallic objects within the antenna beam.
- Stay away from the front and sides of the antenna during test.
- Make sure the correct band PIM test equipment is used for each antenna port tested. The test equipment Tx signals + IM signal must fall within the operating band of the antenna port under test.

About Kaelus

Kaelus www.kaelus.com, a Smiths Interconnect business formed by the combination of Summitek Instruments, Allrizon Communications, Triasx Pty Ltd and the telecom division of Trak Microwave Ltd, designs and manufactures a wide range of innovative RF and microwave solutions for the wireless telecommunications sector. Products include specialized filters, combiners, tower mounted amplifiers, Passive Intermodulation (PIM) test solutions, radio link diplexers, ferrite isolators and circulators. Kaelus' experience and understanding of the radio environment enables it to excel by developing technically differentiated offerings that improve network performance.

For more information visit us online at www.kaelus.com.