PIM Workshop

Passive InterModulation

Dublin 13/10/2015

Agenda

- PIM Fundamentals
- About Field Measurements
- Anritsu PIM Master™
- Hands On
Intermodulation distortion (IMD) is a multi-tone distortion product that results when two or more signals are present at the input of a non-linear device.

Intermodulation is caused by non-linear behavior.
PIM Fundamentals

- Linear/Non Linear Device

Linear device: A device for which the output is, within a given dynamic range, linearly proportional to the input

Non Linear device: Introducing frequencies

- Active/Passive Device

An active component must be biased (Amplifier)

A passive device does not require a source of energy for its operation
PIM Fundamentals

- Ideal Infrastructure
  - Minimum loss
  - Linear Infrastructure
  - Incident signals
  - Reflected signals

- Non-Ideal Infrastructure
  - Reflected + interference signals
  - Non-Linear Infrastructure
What are the mixing products created by PIM?

\[ IM_{n+m} = nF1 - mF2 \] (low side)
\[ IM_{n+m} = nF2 - mF1 \] (high side)

IM3, 3rd order is the strongest product

\[ IM_3 = 2F1 - F2 \] (low side)
\[ IM_3 = F2 - 2F1 \] (high side)

E-GSM Case

<table>
<thead>
<tr>
<th>EU Bands</th>
<th>Rx</th>
<th>Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 (20)</td>
<td>832</td>
<td>862</td>
</tr>
<tr>
<td>900 (F/T)</td>
<td>870</td>
<td>880</td>
</tr>
<tr>
<td>900 (B)</td>
<td>880</td>
<td>915</td>
</tr>
<tr>
<td>1800 (1)</td>
<td>1710</td>
<td>1785</td>
</tr>
<tr>
<td>1900 (2)</td>
<td>1710</td>
<td>1785</td>
</tr>
<tr>
<td>2100 (1)</td>
<td>1920</td>
<td>1980</td>
</tr>
<tr>
<td>2600 (7)</td>
<td>2500</td>
<td>2570</td>
</tr>
</tbody>
</table>

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Is PIM frequency dependent?

**NO!**

Value of PIM will change, but PIM effect stays

Is PIM power dependent?

**YES!**

As the transmitter power increases, the importance of PIM on the overall system performance becomes of increasing concern.

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**PIM Fundamentals**

- Bandwidth of mixing products
PIM Fundamentals

- PIM Amplitude: dBm or dBc

PIM Amplitude: dBm VS Watts

- dBm VS Watts

Anritsu
PIM Fundamentals

- **PIM Load**
  
  A 50 Ohm termination designed to produce very little or no PIM. Used to replace an antenna when testing the cable at a site.

- **PIM Source**
  
  A 50 Ohm device designed to produce a known amount of PIM. Used to check the PIM Test Set.

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- **Shall we sweep the line or PIM test it?**
  
  Sweep test measures efficiency of signal propagation.

  PIM test measures ability to propagate signals without generating interference.

  **Both tests** are important and necessary to ensure quality site construction.
!! PIM is not the same as VSWR and Return Loss !!

- Return Loss (or VSWR) Measures:
  - Impedance Mismatch vs. Frequency
- DTF (Distance to Fault) Measures:
  - Impedance Mismatch vs. Distance

These are all essential measurements of cables/antennas, but they don't measure PIM.

- PIM Measures:
  - Non-Linearity and Loose Connections
- DTP (Distance To PIM) Measures:
  - PIM Location

Environmental Diodes, what?

Name used for elements outside the BTS in the nearby environment that are acting like diodes in mixing signals.

This due to physical properties of materials.

Corroded objects are one of the main problems, "Rusty Bolt Effect"
Where is my PIM?

A US mobile operator says that 50% of their network PIM problems are not related to the base stations

Anritsu Distance-to-PIM™ can tell you

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PIM looks like interference to the system, lowering the C/I ratio and the data rate

Source: Qualcomm, “HSDPA for Improved Downlink Data Transfer,” Oct 2004
Indicators of PIM Problems – Case 1

PIM often shows up as poor statistics from the affected sector. One of the first and most direct indications of PIM can be seen in cells with two receive paths. If the noise floor is not equal between the two paths, the cause is likely PIM generated inside the noisy receive path.

Indicators of PIM Problems – Case 2

If a cell site performs poorly when dry conditions exist but improves dramatically when a rainstorm passes through the region, the technician should immediately inspect the surrounding area for items that have rusty mounts.
Causes of PIM - 1

Mechanical Considerations
Metallic Contact
Tunneling Effects
Rusty Bolt Effect
Fritting
Ferromagnetic Materials

such as iron, nickel, cobalt, and some alloys of magnesium, aluminum and copper

Causes of PIM - 2

Connectors

Poor connector attachment causes electrical Arcing
Arcing creates serious interferences

Types of poor connectors attachment
Loose connector body
Improper soldering of center Pin
Recessed center Pin
Cable cut at an angle
Rough hacksaw cut
Causes of PIM - 3

Connectors/Cables Termination

- Loose Mating of connectors
  - Should be tightened to spec
  - Sometimes loosened by installer to achieve RL spec

- Over tightened connectors
  - Causes center contact to fracture or bend
  - Sometimes over-tightened by installer to achieve RL spec

- Poor weatherproofing
  - Water in cable causing corrosion

- Dirty connectors/cables
  - Use alcohol swabs

Causes of PIM - 4

Manufacturing Defects in:

- Cables
  - Bad weld in cable sheath
  - Missing foam inside cable

- Antennas
  - Internal failures

- Other Passive Devices
  - Directional couplers
  - Diplexers
  - Lightning protectors
PIM Fundamentals

 Causes of PIM - 5

Adapters

Use quality adapters
Test them to be sure they have low PIM
Discard adapters with high PIM
Clean with denatured Alcohol

Adapters are for testing
Should never ne in-circuit when actually providing service

Keep them clean!

PIM Fundamentals

 Causes of PIM - 5

Cable bent near connector

A bend close to connector can cause PIM
Some antennas have poorly placed connectors, the connector is obstructed by the mounting pipe
This difficult access results in a bend near the connector

The minimum distance between the connector and the first bend should be two fist widths or more

Observe the manufacturer’s minimum bend radius, excessive bend pull the center conductor out the connector
About Field Measurement

- Safety

PIM Test Sets generate 80 Watts of RF Power (2 x 40 W).

This amount of power is required to find PIM Problems and is safe when the cable is terminated with a Load.

This amount of power may be unsafe when applied to an antenna that has a person close by.

<table>
<thead>
<tr>
<th>Test Power</th>
<th>Frequency</th>
<th>Gain (dB)</th>
<th>Distance (m)</th>
<th>Gain (dB)</th>
<th>Distance (m)</th>
<th>Gain (dB)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 W</td>
<td>710-950</td>
<td>6</td>
<td>1.99</td>
<td>12</td>
<td>3.18</td>
<td>20</td>
<td>7.98</td>
</tr>
<tr>
<td>40 W</td>
<td>710-950</td>
<td>6</td>
<td>2.25</td>
<td>12</td>
<td>4.43</td>
<td>20</td>
<td>11.28</td>
</tr>
<tr>
<td>20 W</td>
<td>1930-2150</td>
<td>6</td>
<td>0.99</td>
<td>12</td>
<td>1.96</td>
<td>20</td>
<td>4.97</td>
</tr>
<tr>
<td>40 W</td>
<td>1930-2150</td>
<td>6</td>
<td>1.40</td>
<td>12</td>
<td>2.86</td>
<td>20</td>
<td>7.03</td>
</tr>
</tbody>
</table>
About Field Measurement

- Things NOT TO DO
  - No Standing over antenna during test!

About Field Measurement

- Things NOT TO DO
  - No tools on antenna during test
About Field Measurement

Things NOT TO DO

One at a time! NO nearby antennas during test

About Field Measurement

Things NOT TO DO

No metal table during test – set antenna on plastic, wood or cardboard
About Field Measurement

- Things NOT TO DO

1. No dirty connectors during test
2. Over tightening the connector will break these small screws

About Field Measurement

- Things NOT TO DO

1. No leaning the antenna against a chain link fence during test
About Field Measurement

- Things NOT TO DO

No leaning the antenna against a wall during test

About Field Measurement

- Things NOT TO DO

No nearby metal chains during test
The right way to do it

1. Start with **VSWR and DTF** if needed to check transmission
2. **PIM test** the cable with the antenna connected, 2x40W
3. If PIM fails, use **DTP** to locate hot spots
   - Establish location of the antenna by connecting a PIM Standard after the cable
   - You can then see if PIM is caused by external sources
4. Remember to tap (dynamic) test all Hot Spots as well as the Lightning Protector, Current Injector (Bias Tee), Connectors and ground at attachment points
5. Correct any PIM Hot Spots
6. If nearby objects (rusty objects near antenna) are causing PIM failure, report these to the antenna owner for resolution
About Field Measurement

- PIM Limits

Antennas that were installed 10 years ago were probably not manufactured with PIM performance in mind, so it would be unrealistic to set a PIM level greater than -80 dBm because very few would measure favorably.

A standard figure used around the world is a pass level of -97 dBm.

With the overlay of LTE services now beginning, a pass value of -97 dBm may not be enough, and it would be wise to achieve the specified receiver sensitivity level (usually around -107 dBm) with PIM testing.