Passive Intermodulation (PIM) in PCBs

Passive Intermodulation (PIM)

- Definition
- Sources
- PIM in PCBs
- Measurements

Passive Intermodulation (PIM)

Inputs

F_A, F_B

System (passive, non-linear)

Outputs

F_A, $2F_A$, $3F_A$, …

F_B, $2F_B$, $3F_B$, …

$k_A F_A + K_B F_B$

(linear combinations)

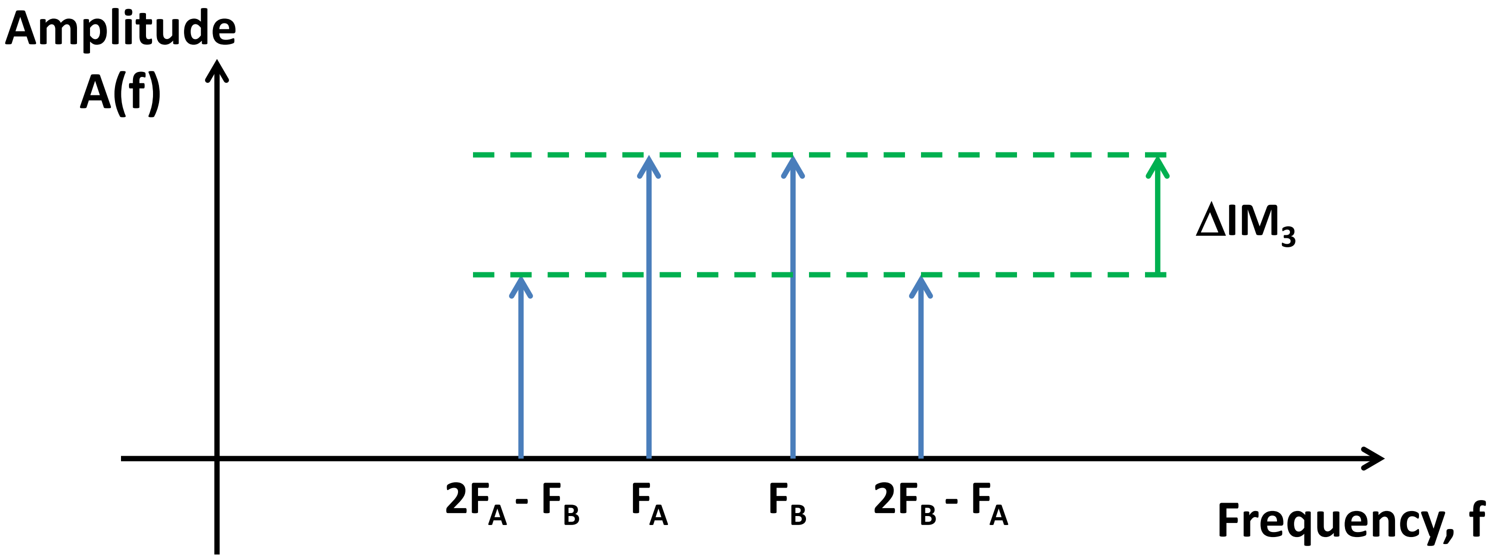
System Components

- PCB
- High Speed Package
- Antennas
- Cables and connectors
- …

Passive intermodulation products are generated when two or more signals are transmitted through a passive system having non-linear characteristics

PIM at the input port is called Reverse PIM
PIM at the output port is called Forward PIM

Passive Intermodulation (PIM)



IM_3 = third order intermodulation product

PIM is measured as the relative difference between the amplitude of the intermodulation product and the amplitude of the carrier

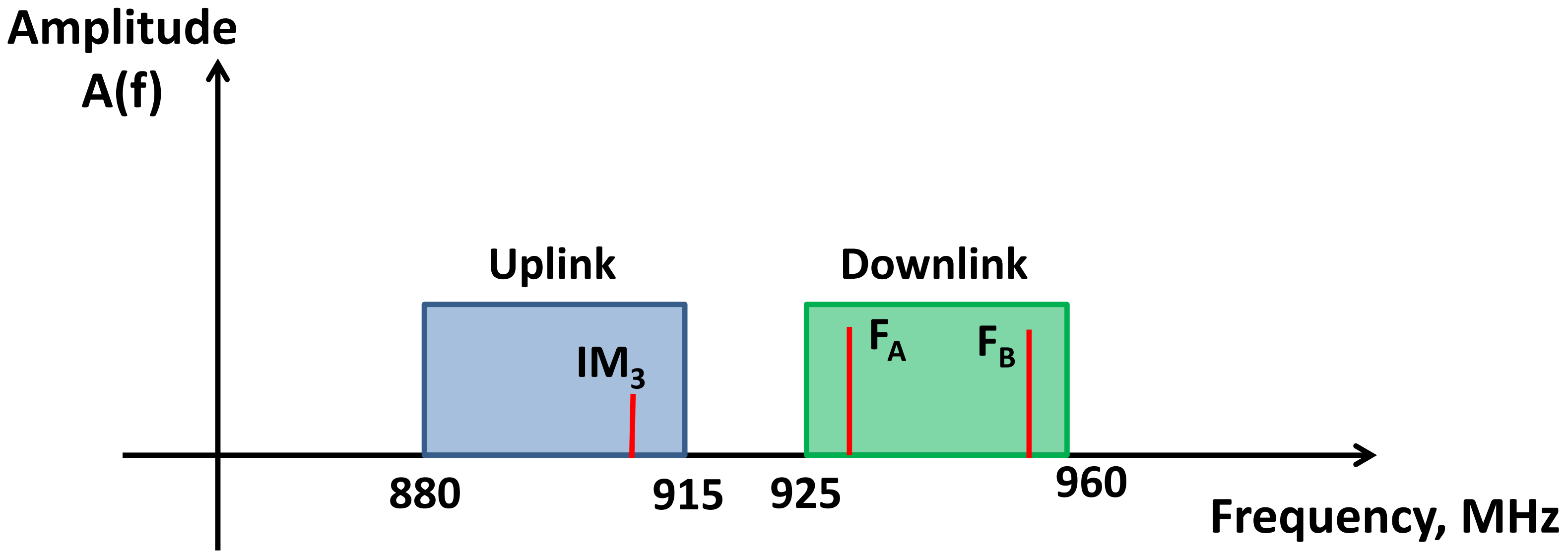
Units of ΔIM_3 are dBc: If you have a +43dBm carrier and IM3 measures -100dBm, ΔIM_3 is -143 dBc

PIM Sources

- Ferromagnetic materials (ferrites, nickel, steel, etc.) due to Hysteresis effect
- Contaminates including dirt, moisture or oxides on electrically conducting surfaces
- Inconsistent metal to metal contact
- Unmatched (galvanically) metals in contact
- Multipath with oxidized metal structures
- In PCBs, non-linear trace resistance and non-linear dielectric properties (second order)

Effect of PIM

- **E-GSM 900 Band as an Example**



If F_A = 930 and F_B = 950, IM_3 = 910MHz is within the uplink band and a source of interference

Implications of PIM

- **PIM produces signals in cell receive band which will raise noise floor and increase the BER resulting in reduction of cell coverage area and quality of service (dropped calls, slower data downloads)**
- **Field measurements show download speed decreased by 18% when PIM increased from -125dBm to -105dBm**
- **PIM can cause receiver blocking, effectively shutting down a sector**

PIM in PCBs

- **Number of technical papers have been published since the 1990s**
- **Yet, the mechanisms of PIM in PCBs are only partially understood**
  - Inconsistent measurements
  - Measurement-induced errors
  - Insufficient measurement device sensitivity
- **General conclusions can be drawn from research to date however**

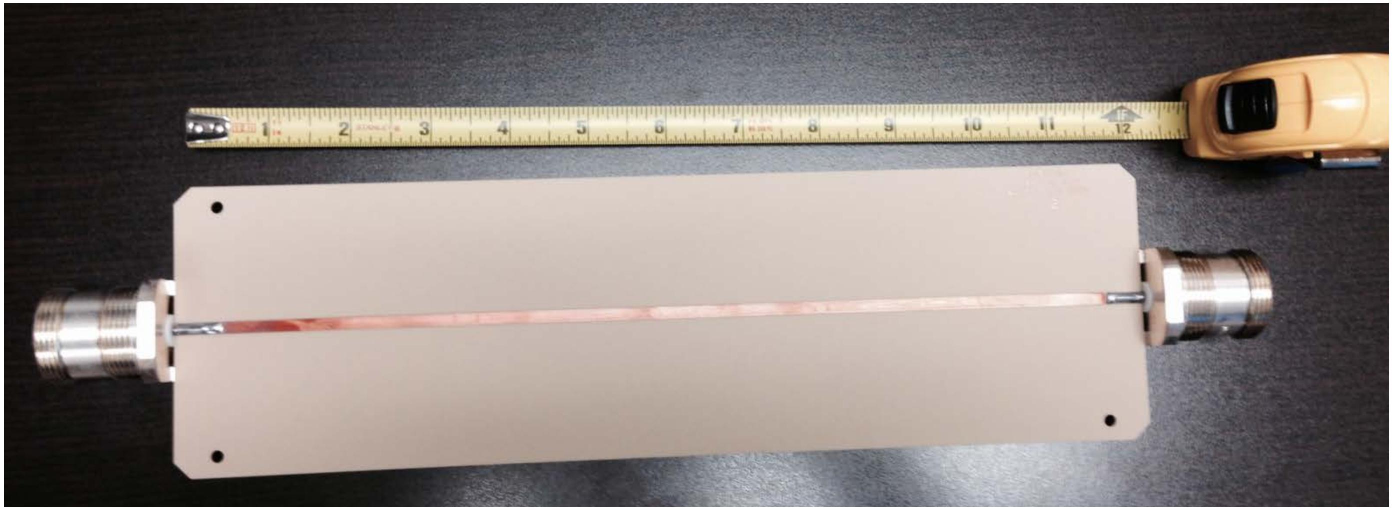
Consensus on PIM in PCBs

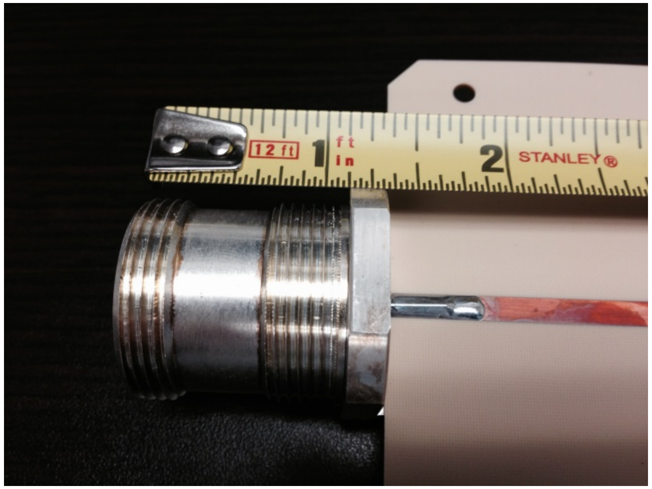
- **Primary source of PIM generation in microstrip lines is believed to be non-linearity of the traces**
- **Speculation on sources of non-linearity include**
  - Roughness of cladding underside
  - Roughness of copper crystalline structure
  - Finish material (hysteresis mechanisms) and its structural properties (wetability, adhesion, structural fineness)
- **Dielectric loss appears to be a second order effect on PIM – effects of non-linearity in dielectrics are weaker**
- **Use of surface bonding layer yields better PIM performance –**
  - Likely results in interface improvement for materials considered
  - If interface is good (free of contaminates and defects) this might not be necessary
- **Materials with high moisture absorption have worse PIM performance**
- **Forward PIM performance decreases with increasing line length whereas reverse PIM is largely dependent on input port matching**
- **Wider trace widths produce better forward PIM performance due to lower current density in presence of artifacts producing non-linearity**

Measurements

- **IEC 62037 is the PIM measurement standard**
- **Two tones at 43dBm (20W) each are injected into the device under test and magnitudes of IM products are measured**
- **Measurements are typically performed in shielded enclosure to prevent interference but are also done in the field on cell towers**
- **Equipment**
  - Kaelus (Summitek) Instruments PIM analyzer
  - Anritsu PIM Master
- **High quality coax to microstrip transitions are required to evaluate PIM performance of PCB laminates**
- **On the same PCB Reverse PIM can vary by 10dB based on the transition type – cable launch vs edge connector**
- **Near-field field-probe is alternate test method**

PIM Test Board





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