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Increasing Broadband Interconnect Characterization

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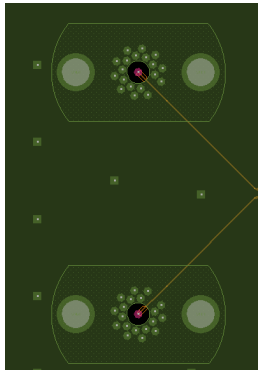
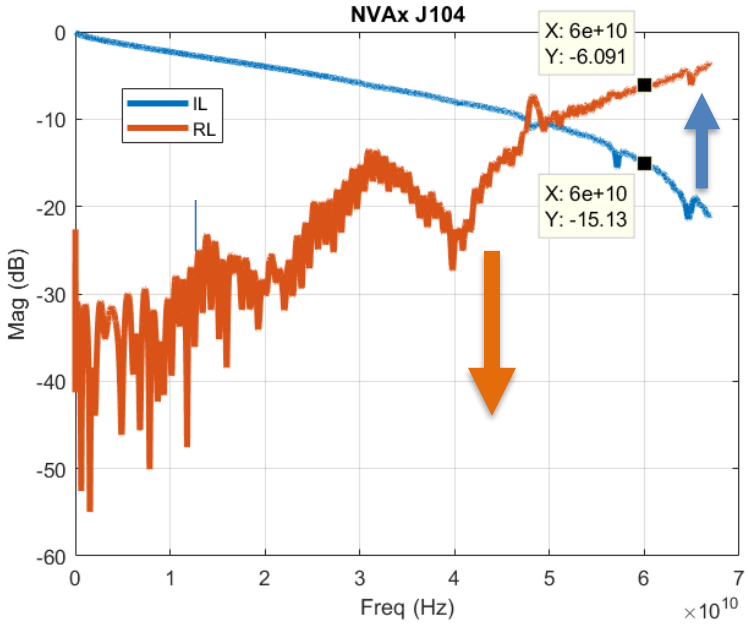
Calibrations

Anatomy of the DUT

- Calibration traces consists of:
  - 2.4mm or 1.85mm connector and mating interface
  - PCB launch structure
  - Small section of single ended traces
  - Differential trace
- Higher BW calibration means:
  - **Decreasing insertion loss (push up)**
  - **Decreasing return loss (push down)**

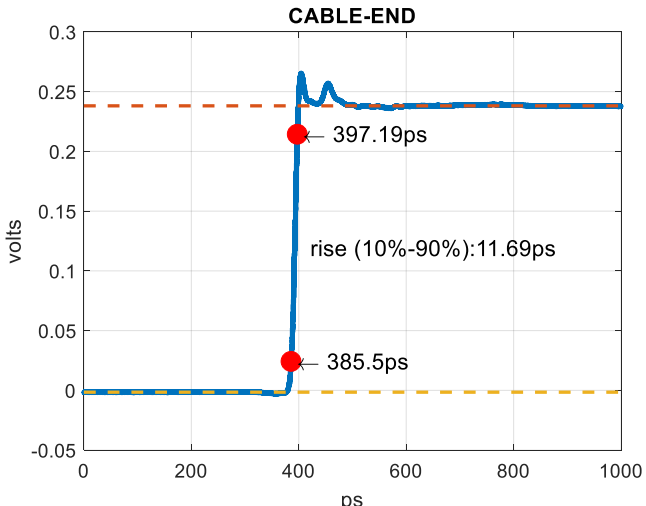


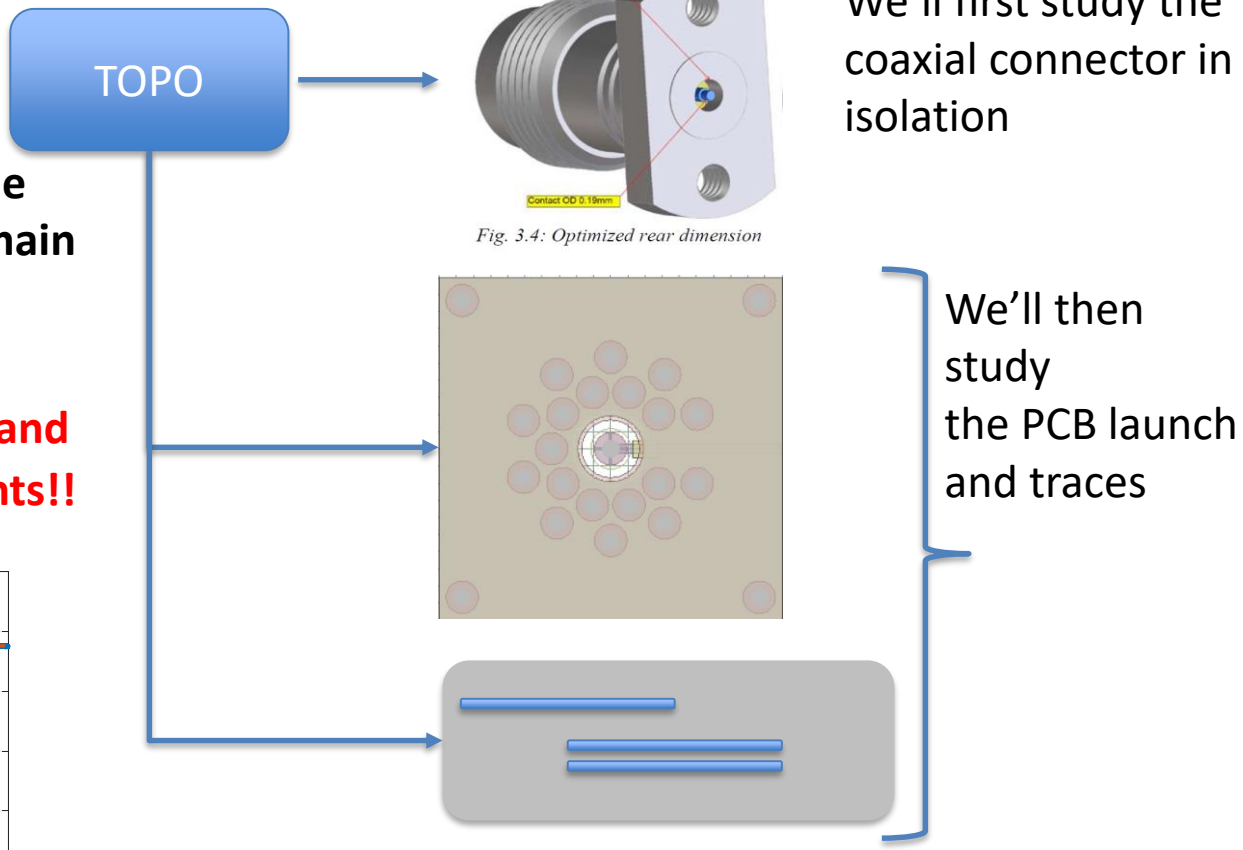


Topology Components

Measurements done in the time (TDR) and frequency (VNA) domain

Important to establish equivalence between time and frequency domain measurements!!





Coaxial Connector Preparation

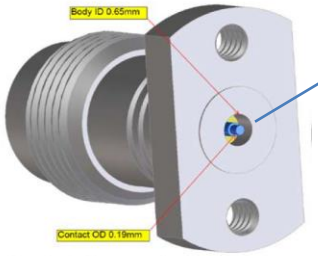
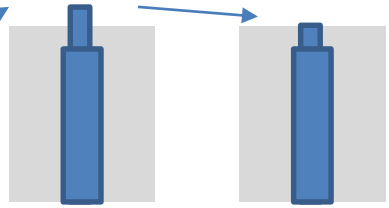


Fig. 3.4: Optimized rear dimension



DUT

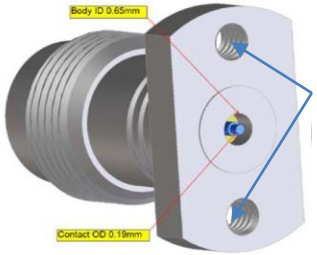
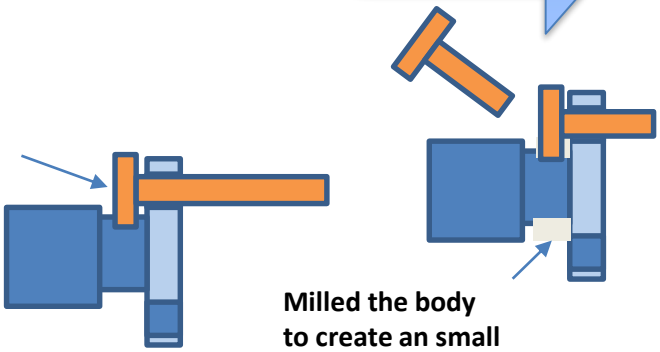
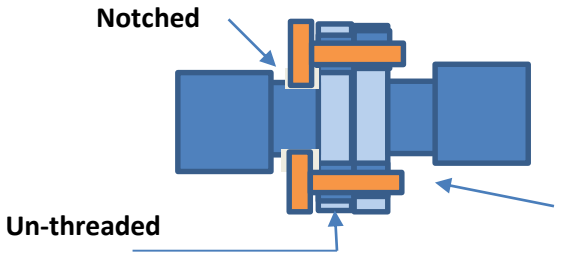


Fig. 3.4: Optimized rear dimension

Removed threads by drilling a bigger hole

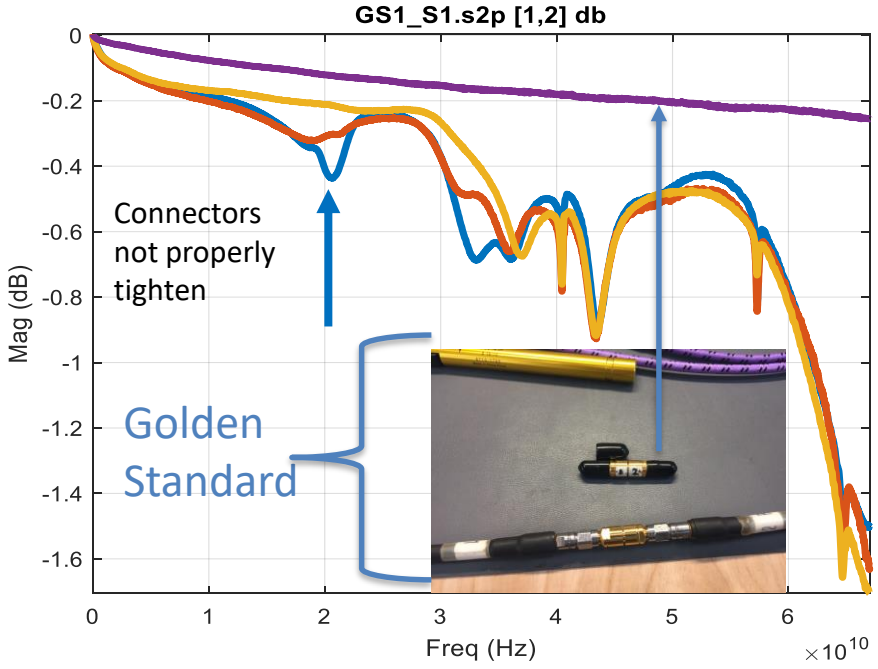


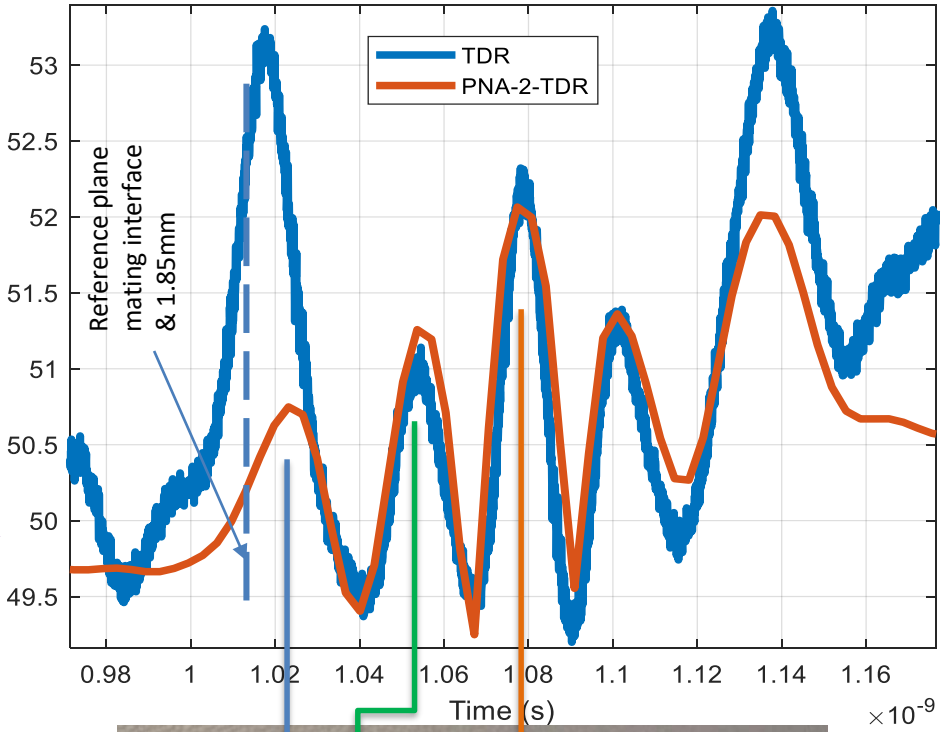
Milled the body to create an small notch

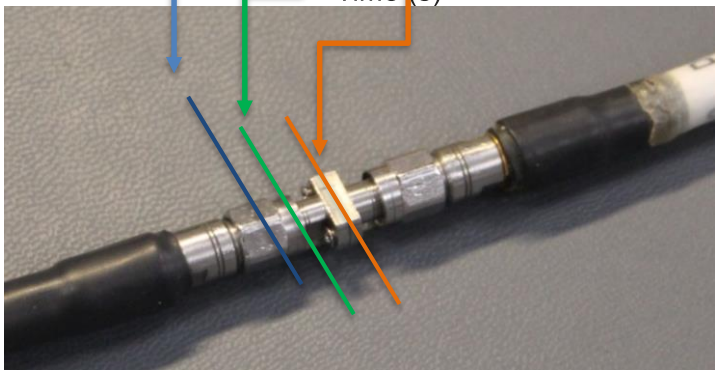


2.4mm Connectors back-2 back

- B2B connectors have low losses, but reflective IL as compared to the golden standard (cal piece)
- Very good correlation between measurement on TDR and VNA (equivalence)
- Whole mating interface present in TDR
- Partial mating interface present in VNA

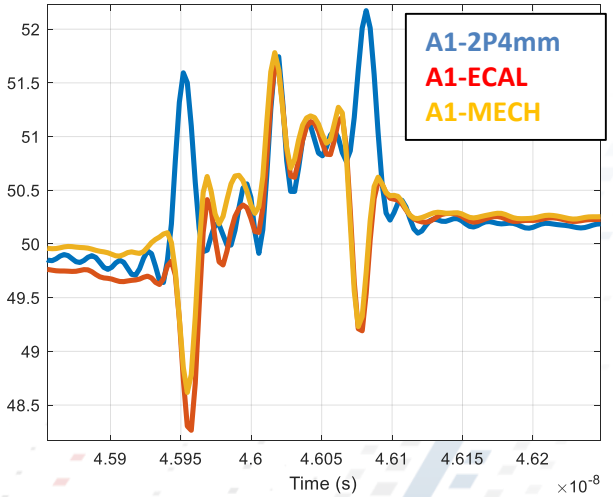


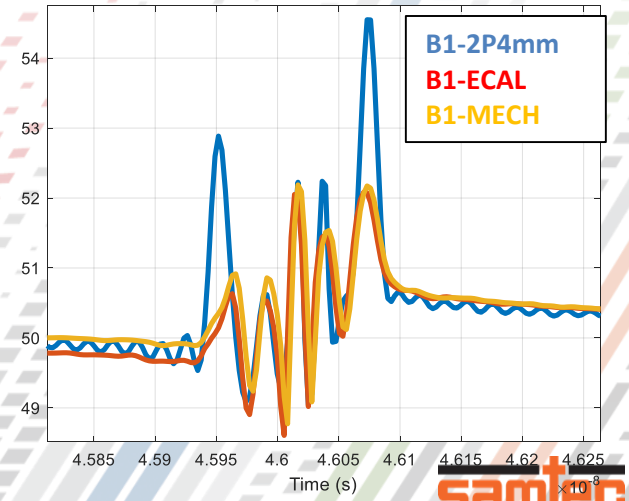




Back-2-Back 2.4mm on different mating interfaces (2 vendors)

- Measurements of 2.4mm back to back pair connected to either 1.85mm or 2.4mm terminated cables
- Blue case: DUT connects to a 2.4mm cable.
- Red and Yellow case: DUT connects to a 1.85mm cable
- Vendor-A1
  - Small inductive peak when connected to 2.4mm mate
  - Small capacitive dip when connected to 1.85mm mate
- Vendor-B1
  - Bigger inductive peak when connected to 2.4mm mate
  - Smaller inductive peak when connected to 1.85mm mate

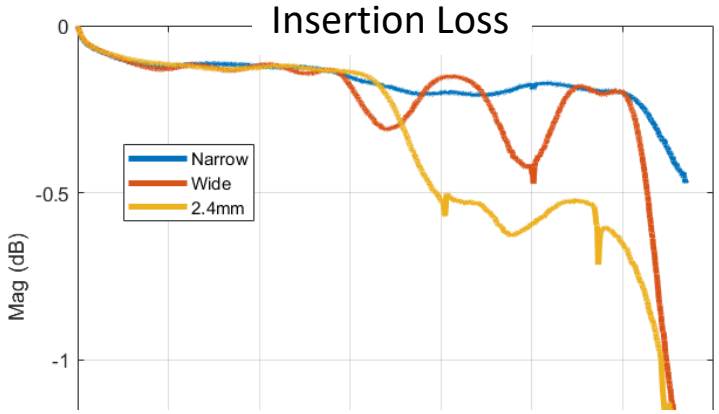


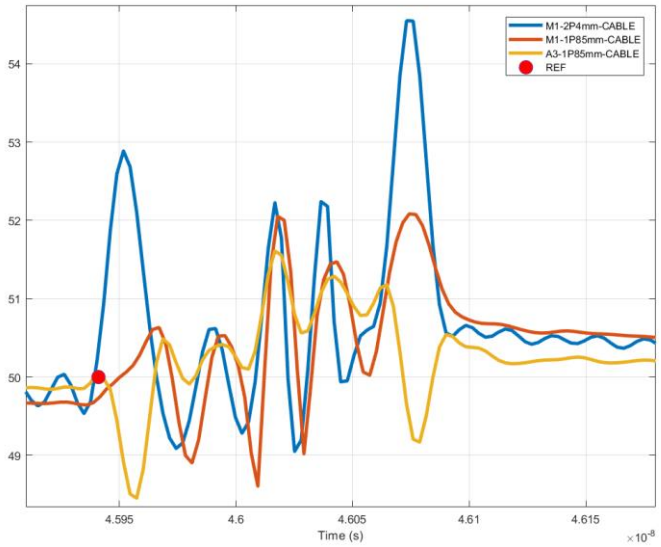


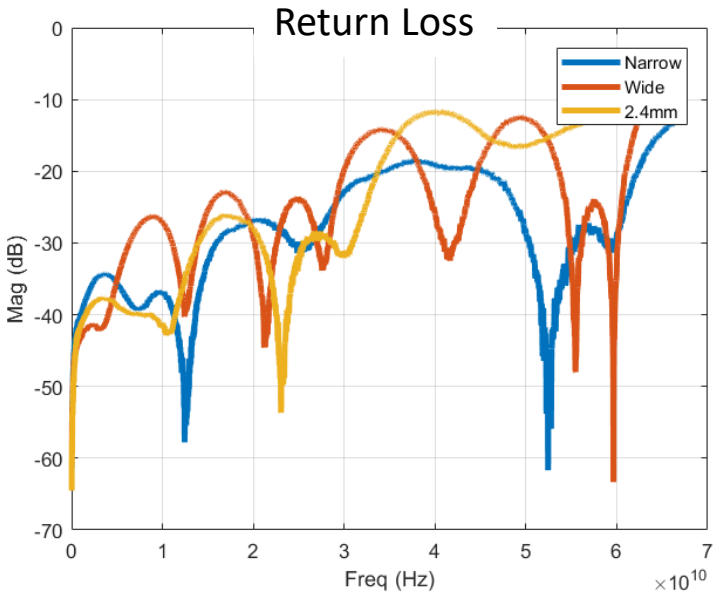
1.85mm vs 2.4mm

Two version of 1.85mm found in my lab: (Narrow and Wide pin)

Both 1.85mm vendors looks similar and with higher BW than 2.4mm as expected

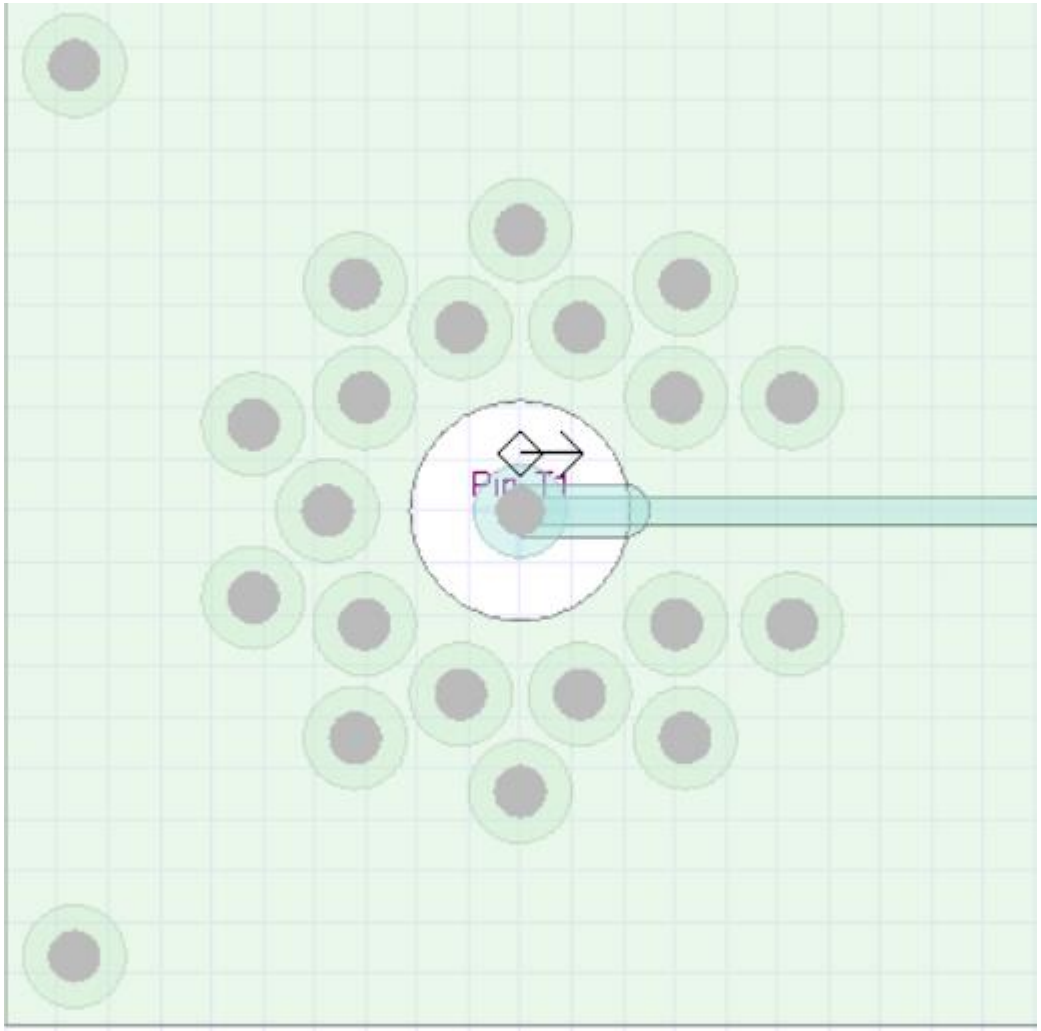






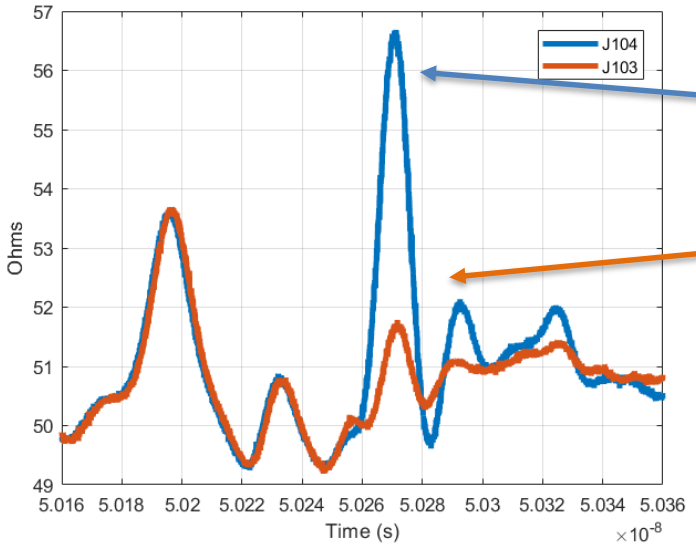
PCB Launch

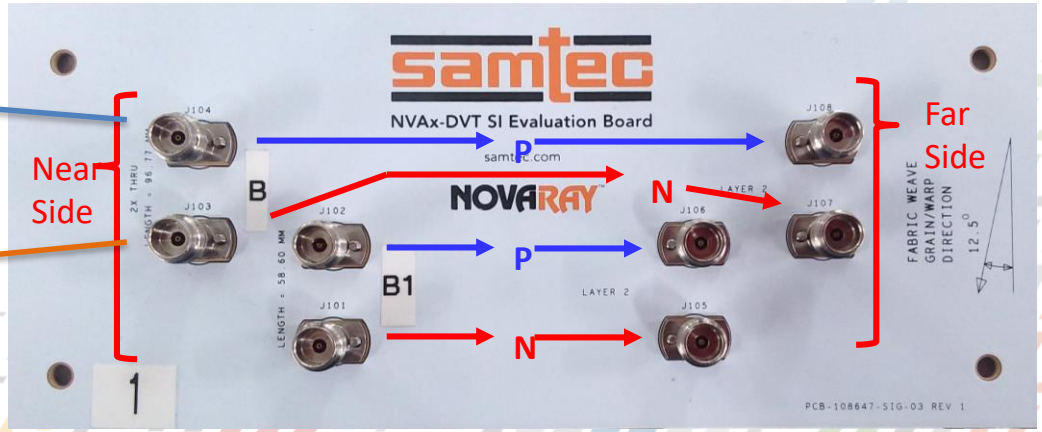
- Architected to mimic as much as possible a coax structure
  - Two concentric rings of GND vias to contain and direct the fields
  - Drill size adjustments
  - Pad and anti-pad sizes adjustments per layer
  - Exit trace width dimension adjustments
  - Design dependent on stack-up construction and exit layer



PCB Launch Test Case

- Launch From TOP to SIG02
- *Asymmetrical Impedance Profile – ~59 ohms SE max.*
  - ***P*** *side launch vias have a higher impedance than the* ***N*** *side*

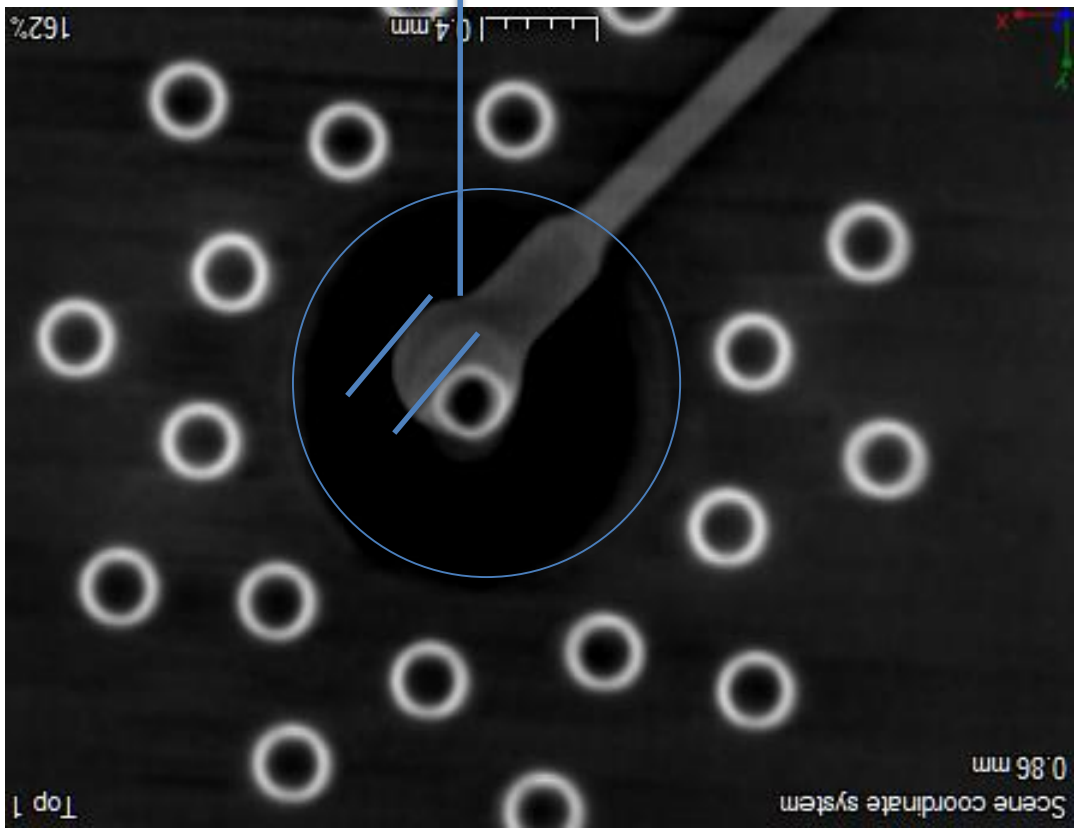




Layer Registration

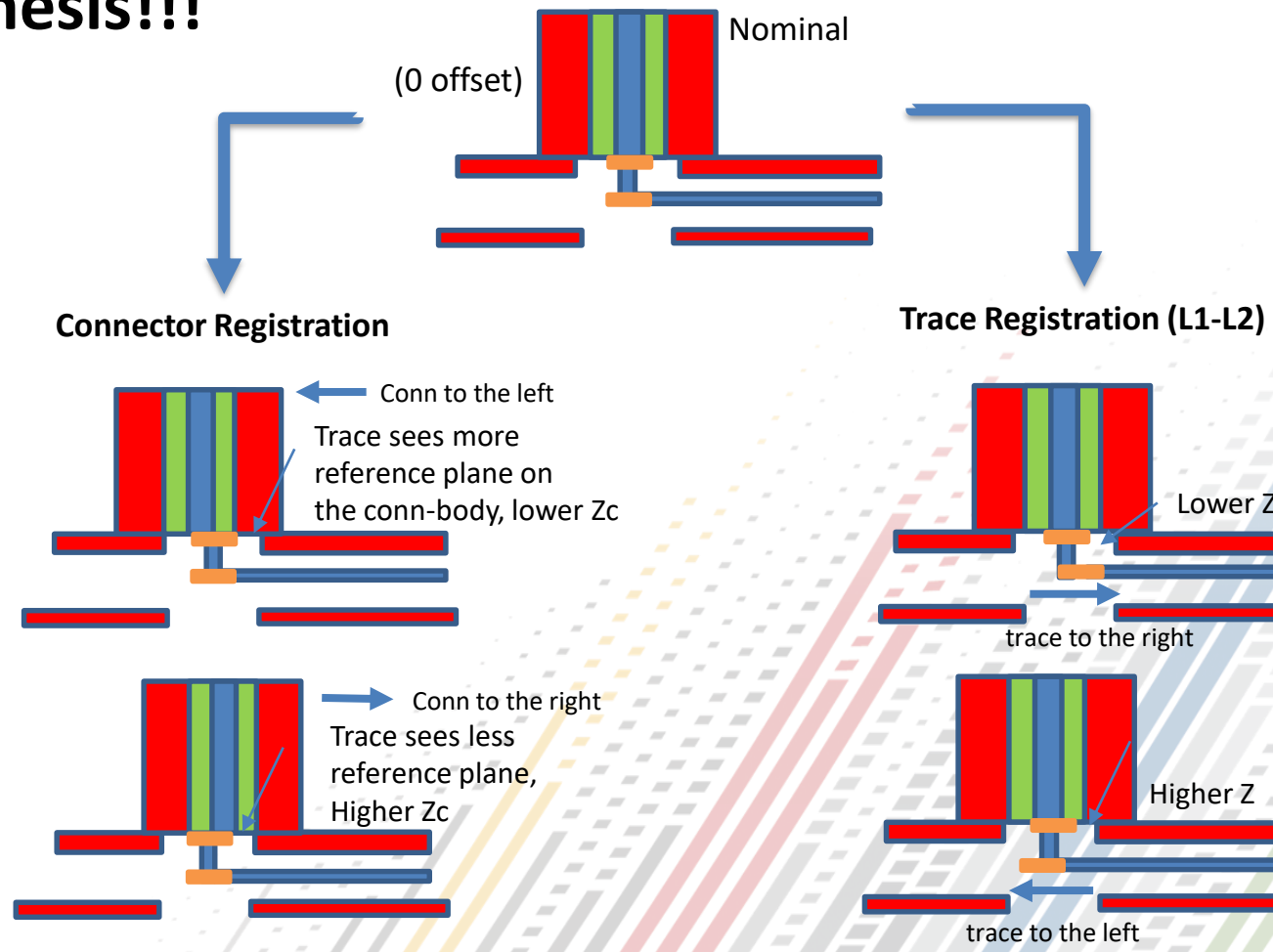
- 3.5mils (more than expected)

CT Scan of boards show quite a bit of TOP to SIG2 registration



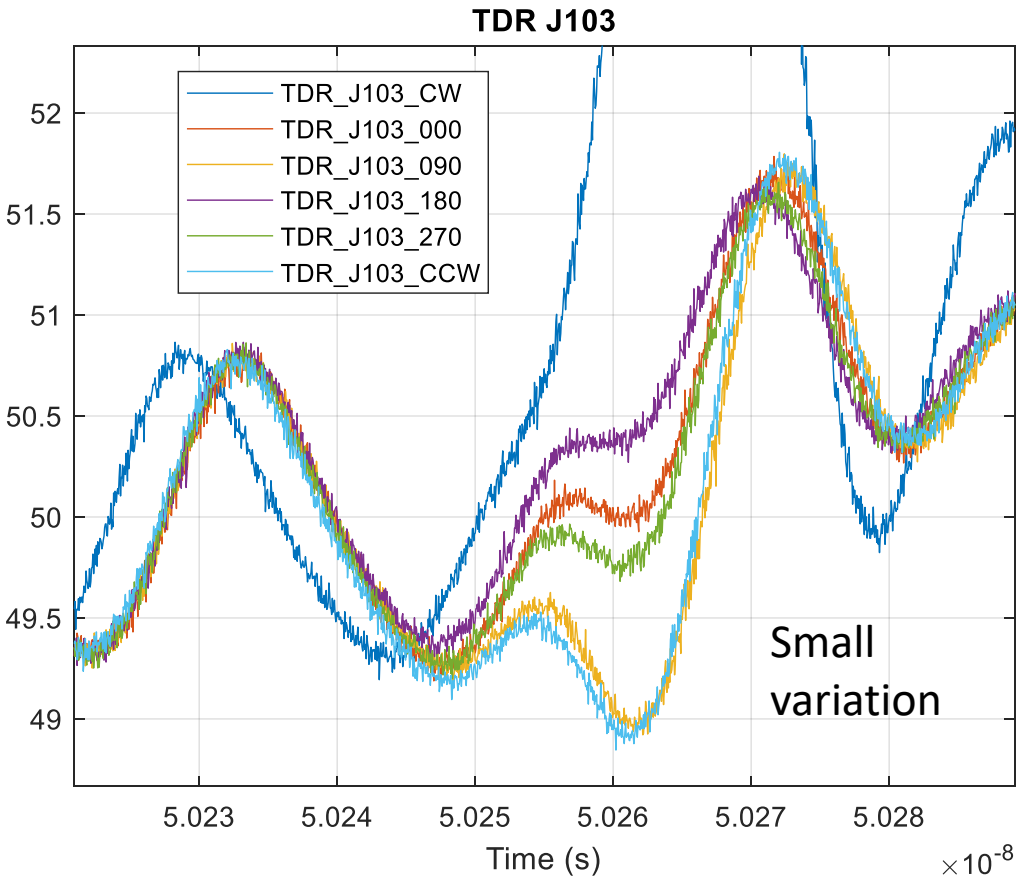
Registration direction

Hypothesis!!!

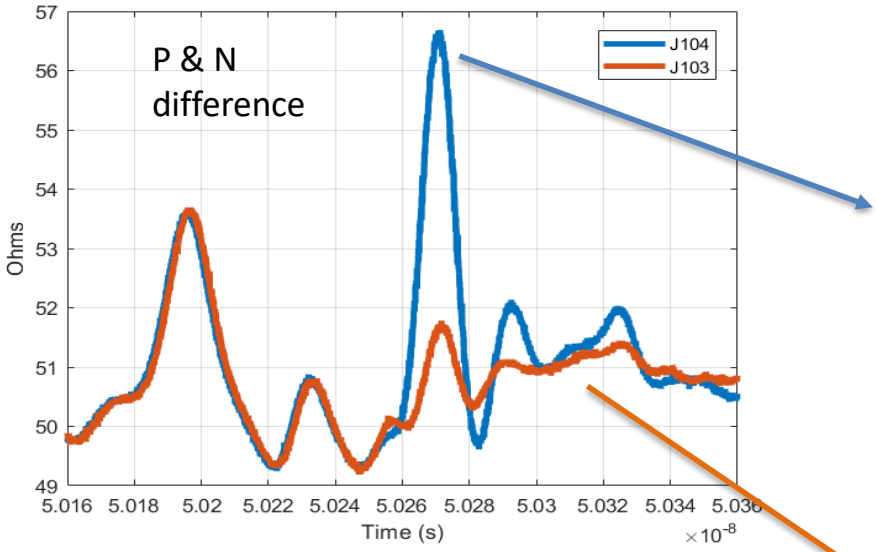


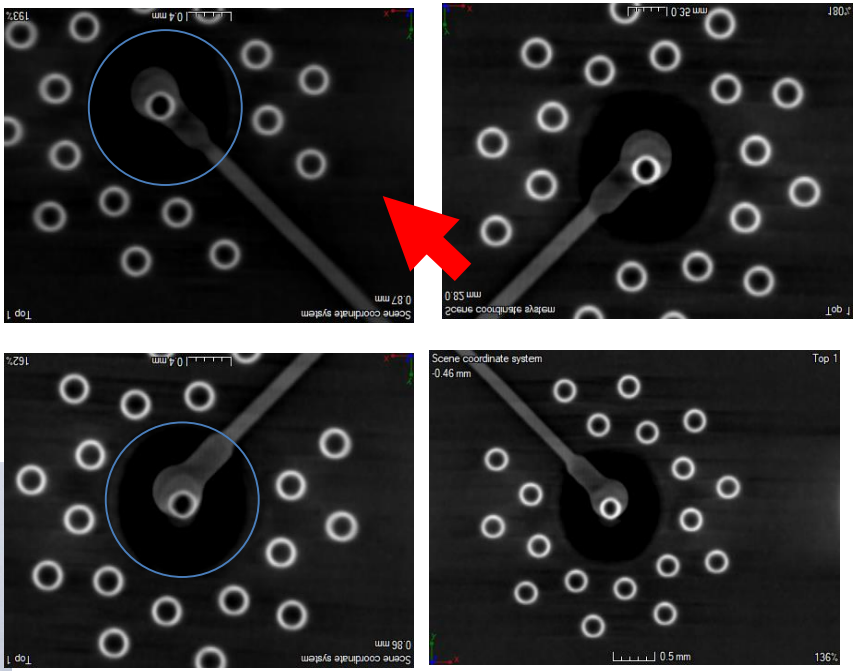
Connector Registration

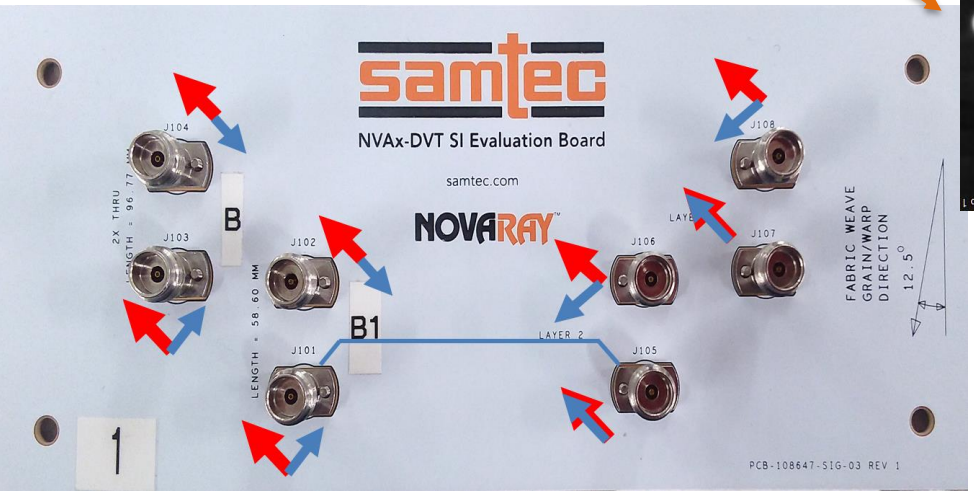
Opened the mounting holes and offset the connector as much as possible in all directions.



Layer Registration



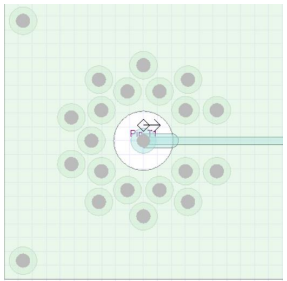


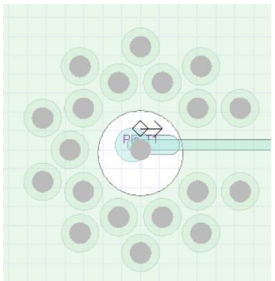


- In cases of misregistration perpendicular to the exit trace, we would expect relatively small impedance effects
- The main impact is from miss registration along the axis of the launch trace exit

Modeling to Measurement Correlation

- Feature sizes adjusted per CT Scan
- Layer registration offsets per CT Scan
- Sim TDR rise time adjusted to match measurement rise time
- **Impedance bimodality confirmed**





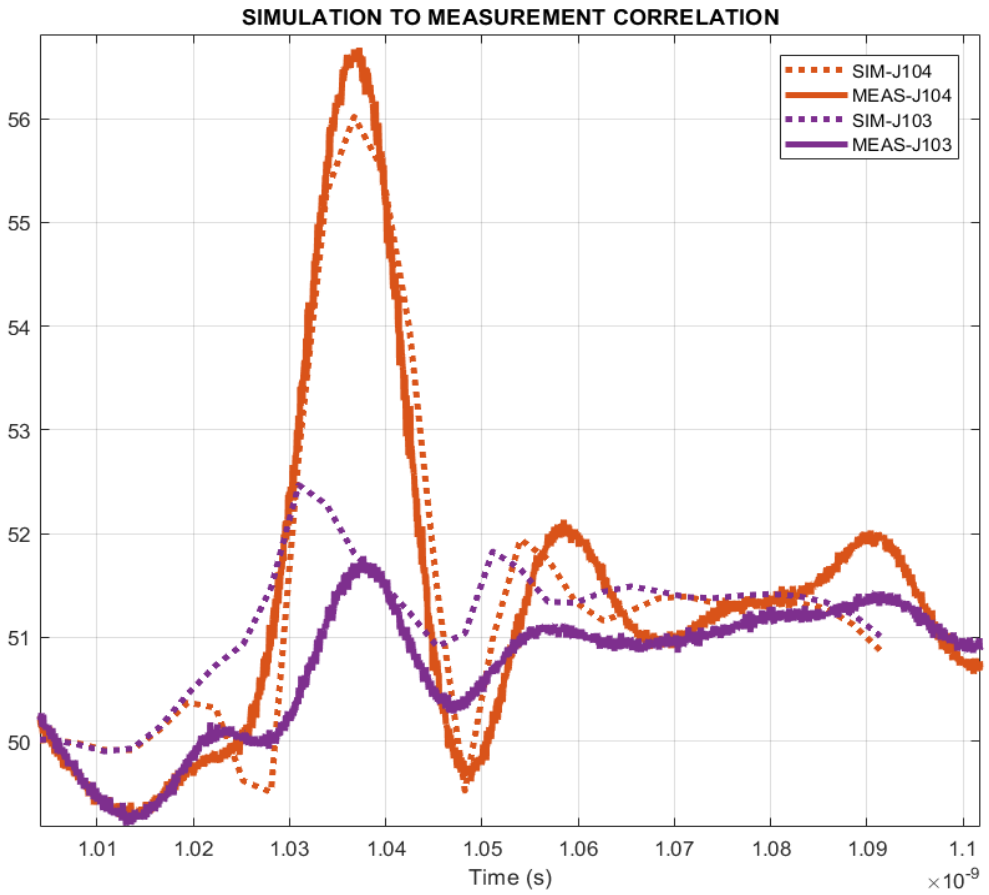
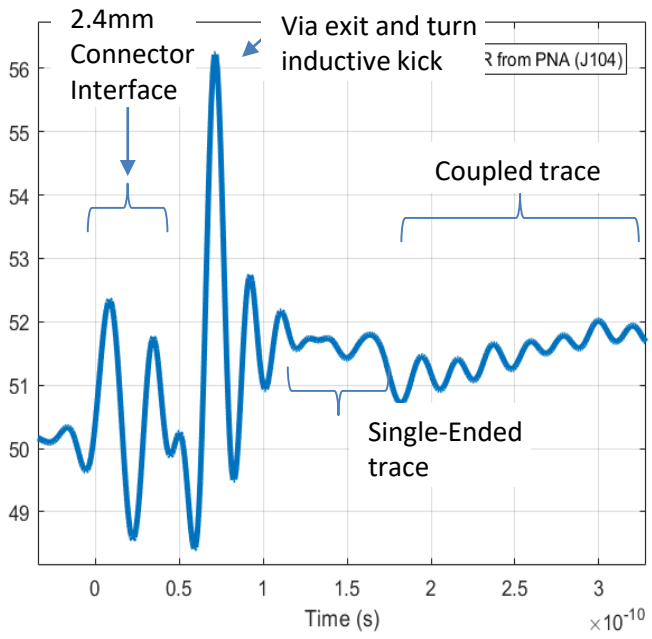
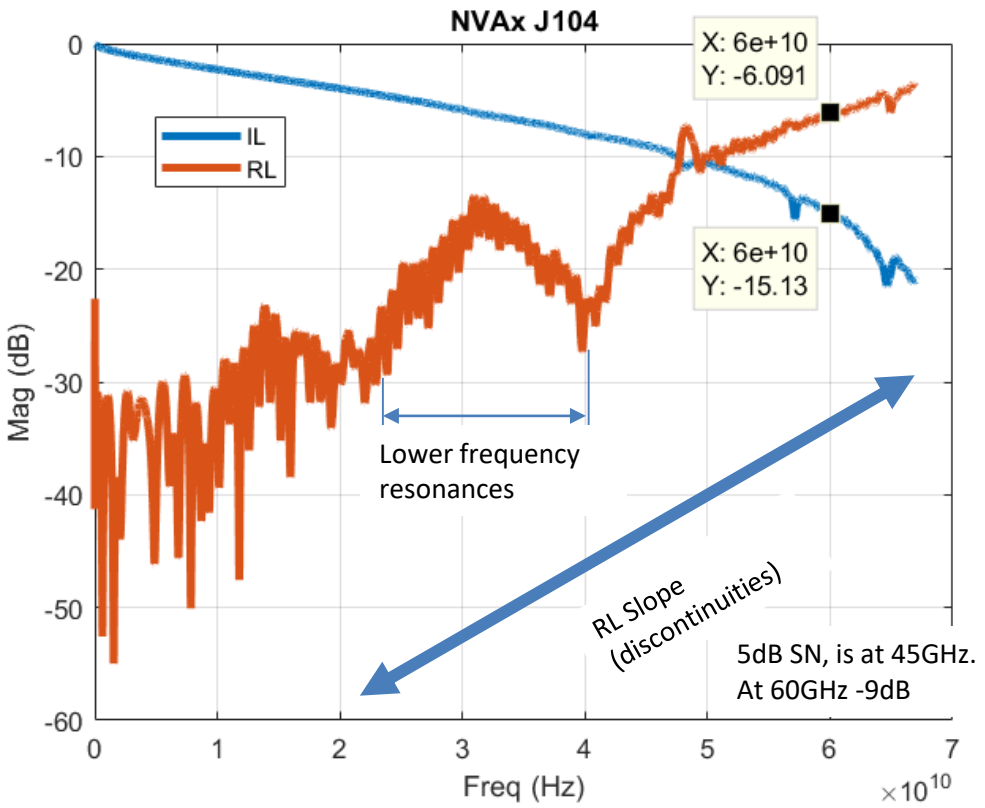


Figure of Merit Definition

Application dependent

For our calibrations we'll define a figure of merit of 5dB
(IL-RL >= 5dB)





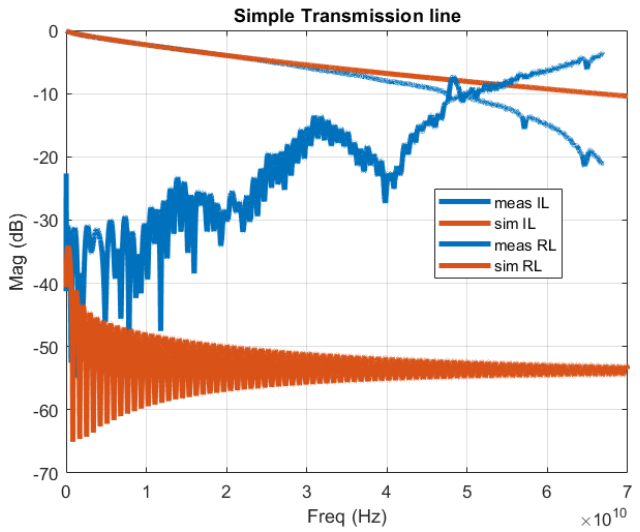
Launch Anatomy

Discontinuity Impact

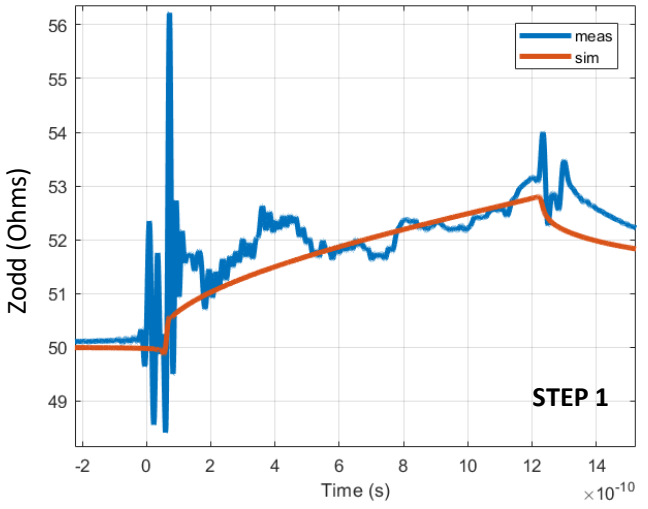
- Mathematical model developed to understand **(gut feel!!)** launch discontinuity effects
- With a mathematical model we can:
  - Understand launch behaviors
  - Sensitivity analysis
  - What if scenarios

Zc=50.5Ohms,99.7mm,
tand=0.004,dk=3.2,w=5.5mils

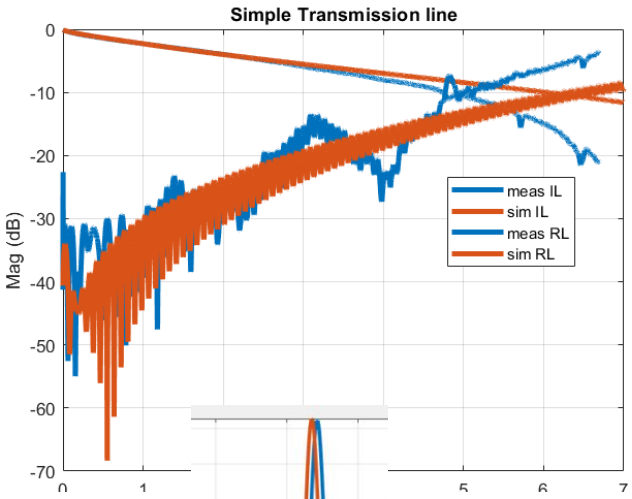
Frequency Domain

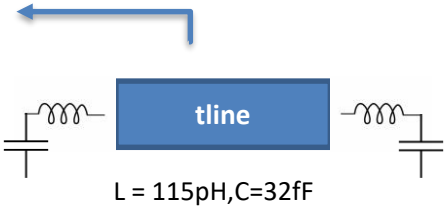


Time Domain

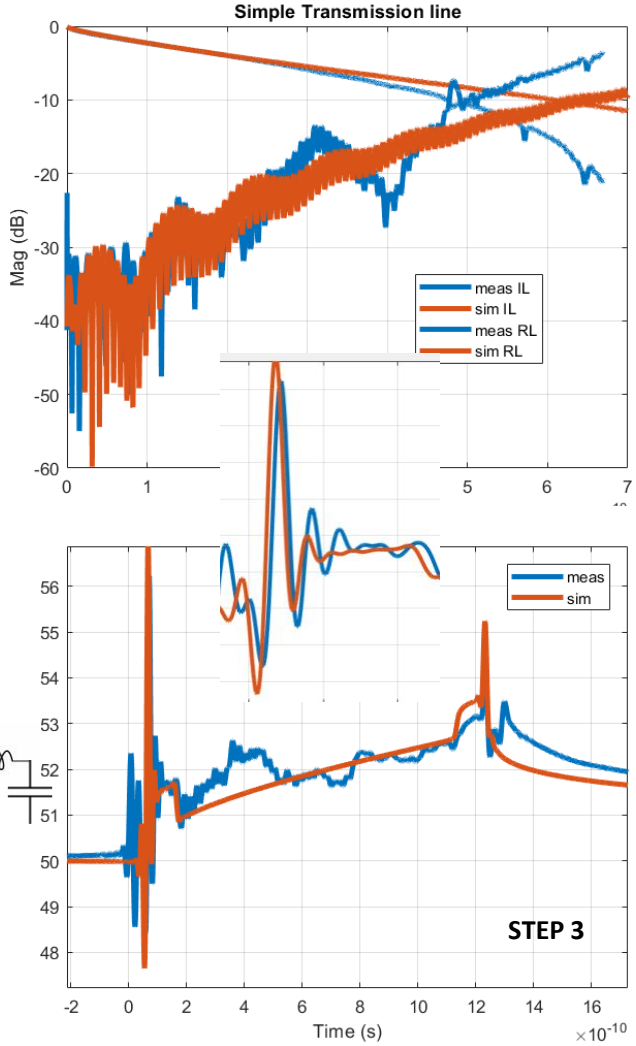


Launch Anatomy (2)

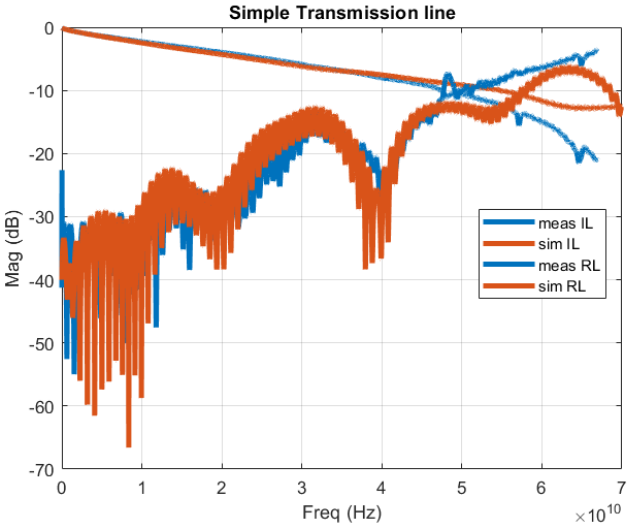


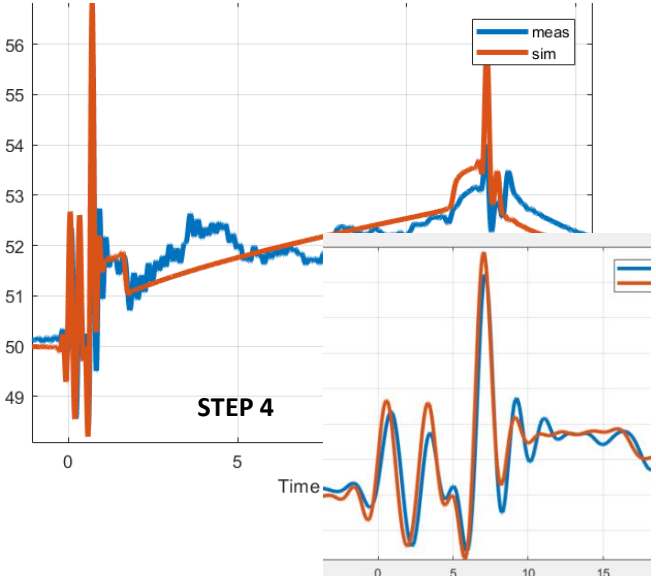


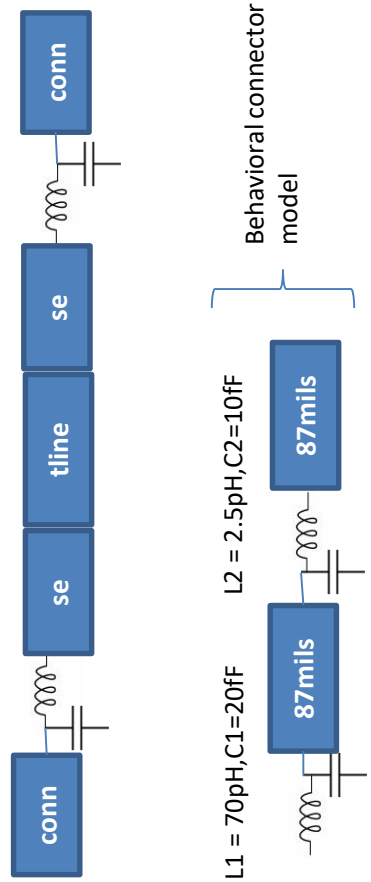
Remarkable how very simple models allows us to match very closely a complex physical structure

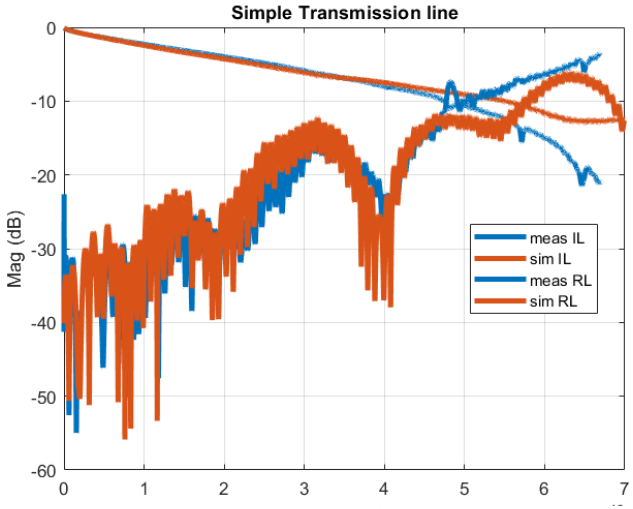


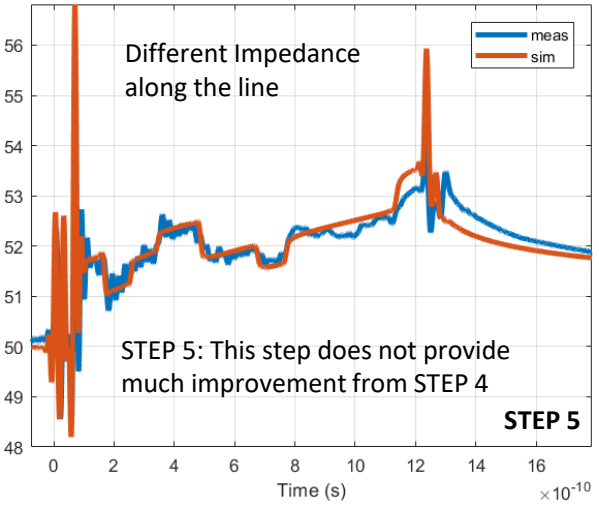
Launch Anatomy (2)





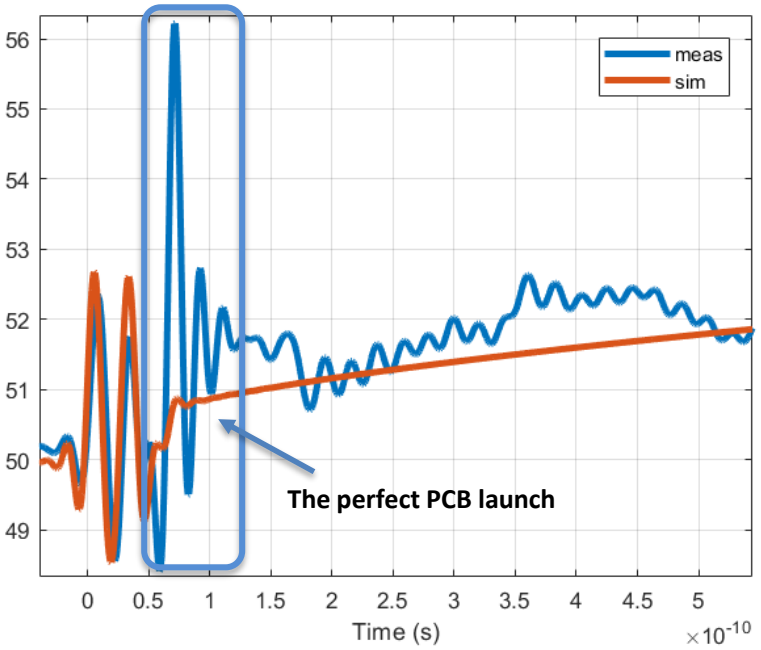


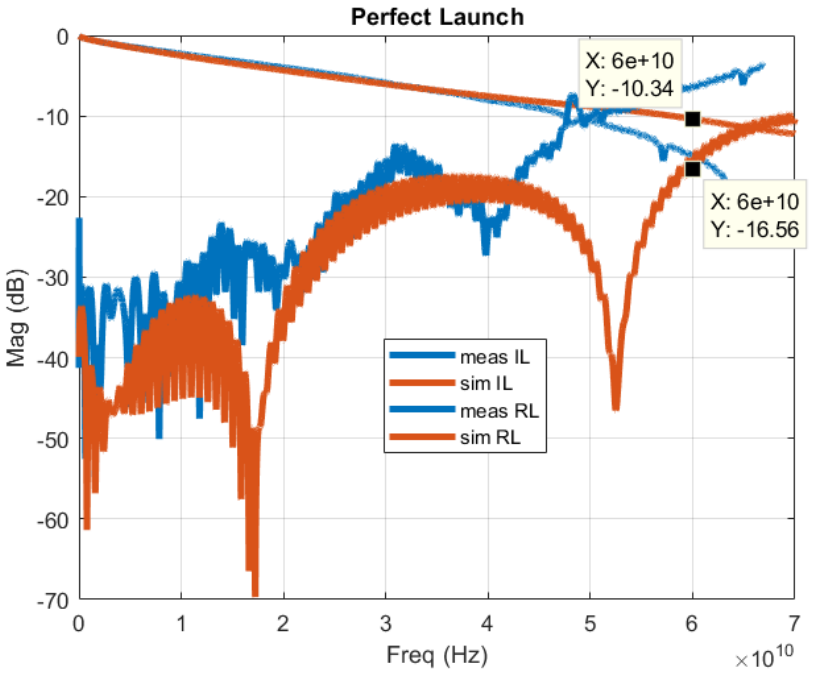




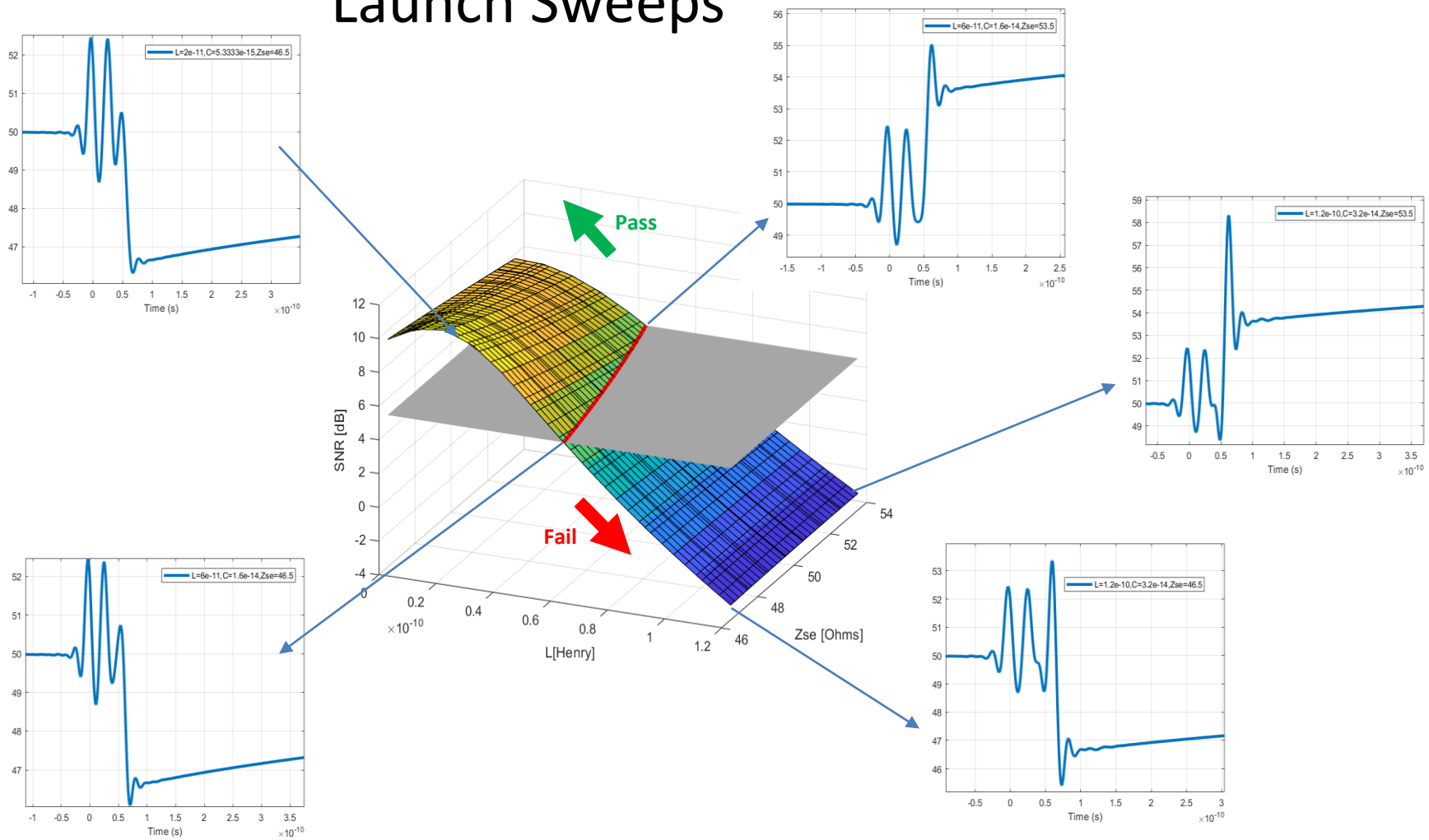
Connector Only Impact

- Even with a perfect launch we achieve only 6.22dB & only 1.22dB of margin



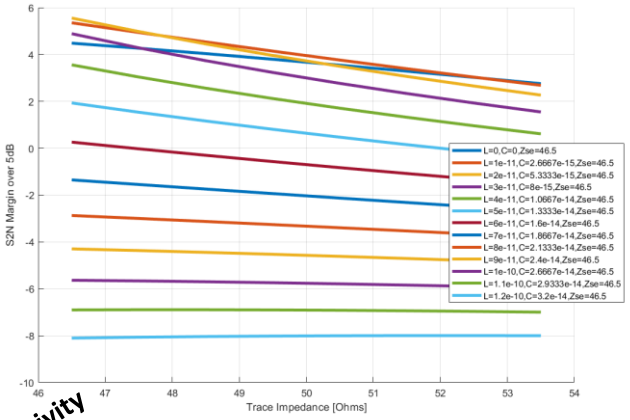


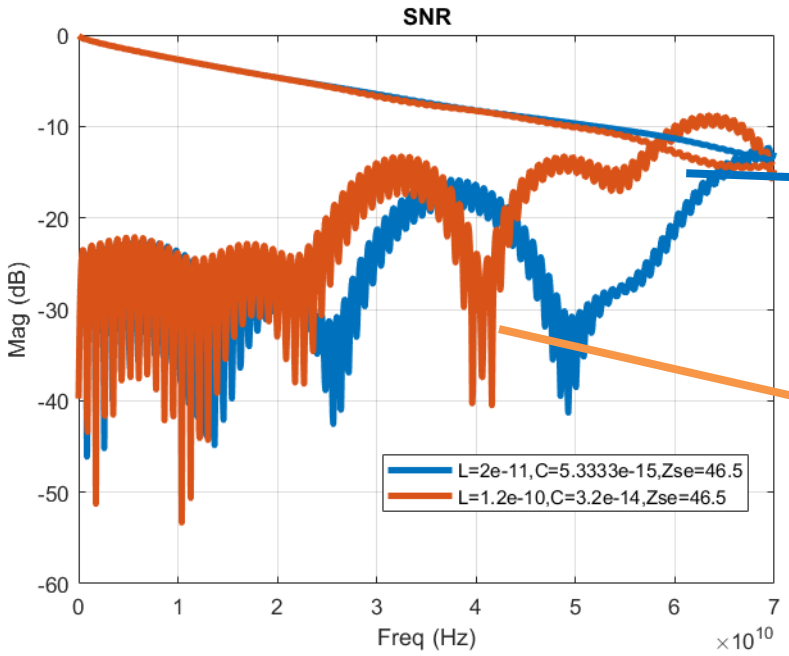
Launch Sweeps



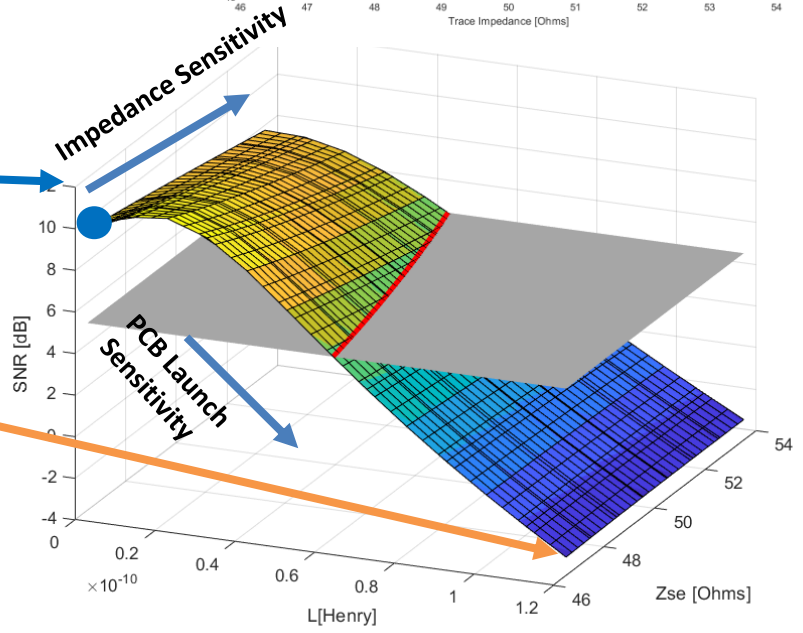
5dB Sensitivity

- The best the launch, the higher the impedance sensitivity
- Higher ½ resonance, better margin why?



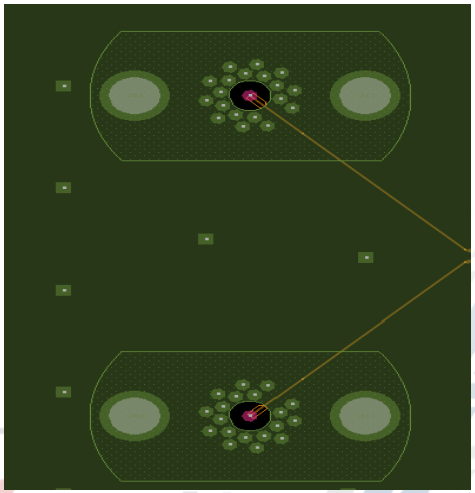


5dB



Typical SMA Launch routing implementation

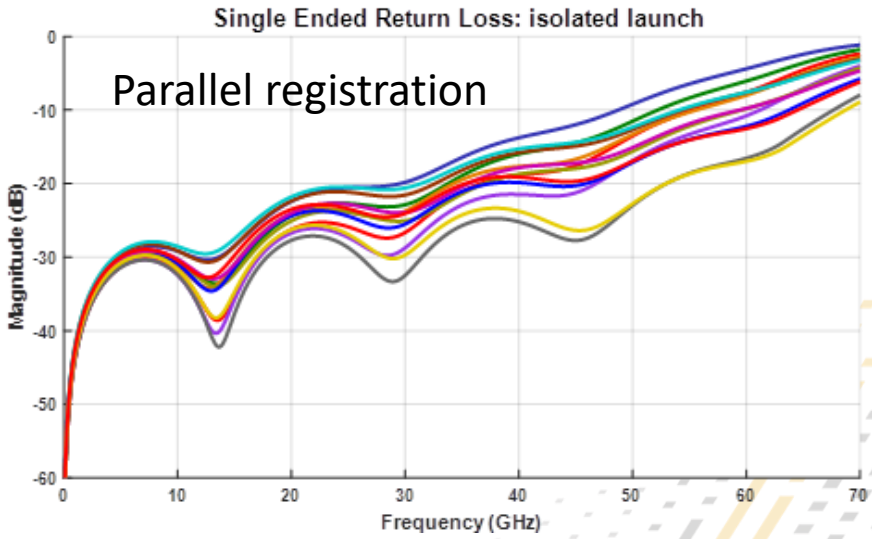
- One launch is 90 degrees rotated from the other
- Layer misregistration and drill placement tolerances are directional
- What affects the X-axis for P-launch is impacting the Y-axis for the N-launch
- X/Y impacts are not the same!
- This is the key SI issue for the L1→L2 SMA launch

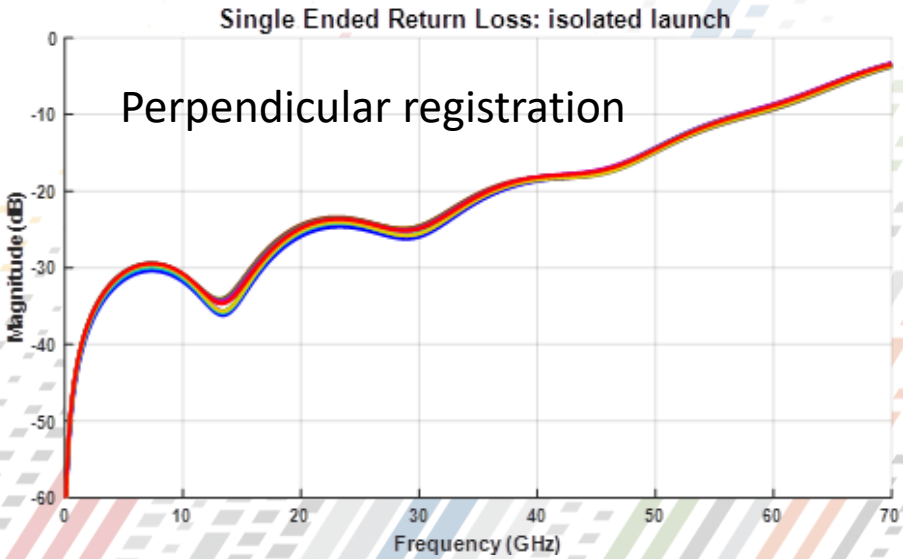


Impact of fab tolerances

Return loss variation

Big difference when registration aligns with the trace exit

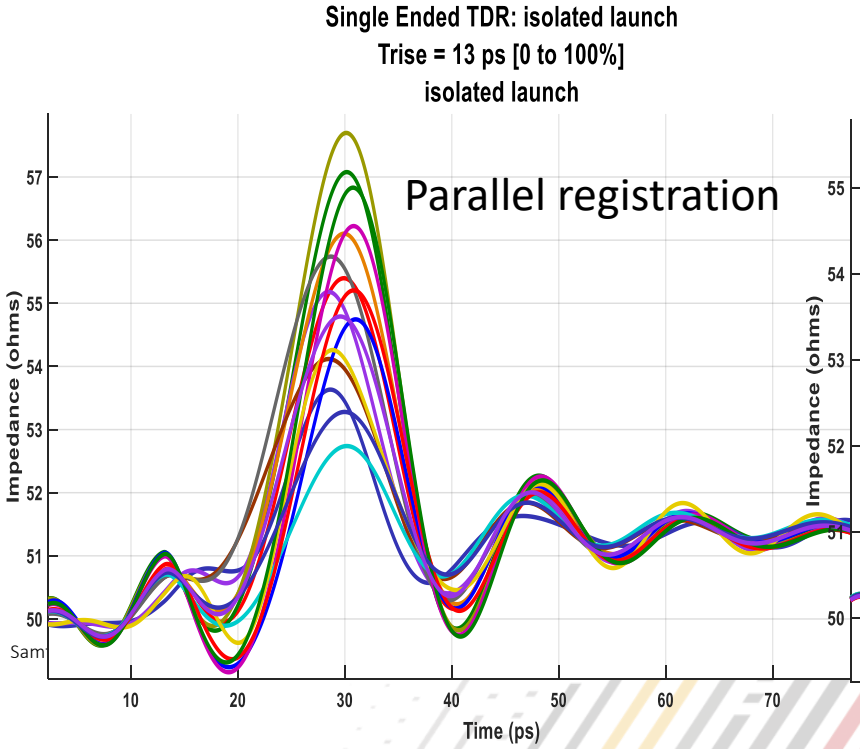


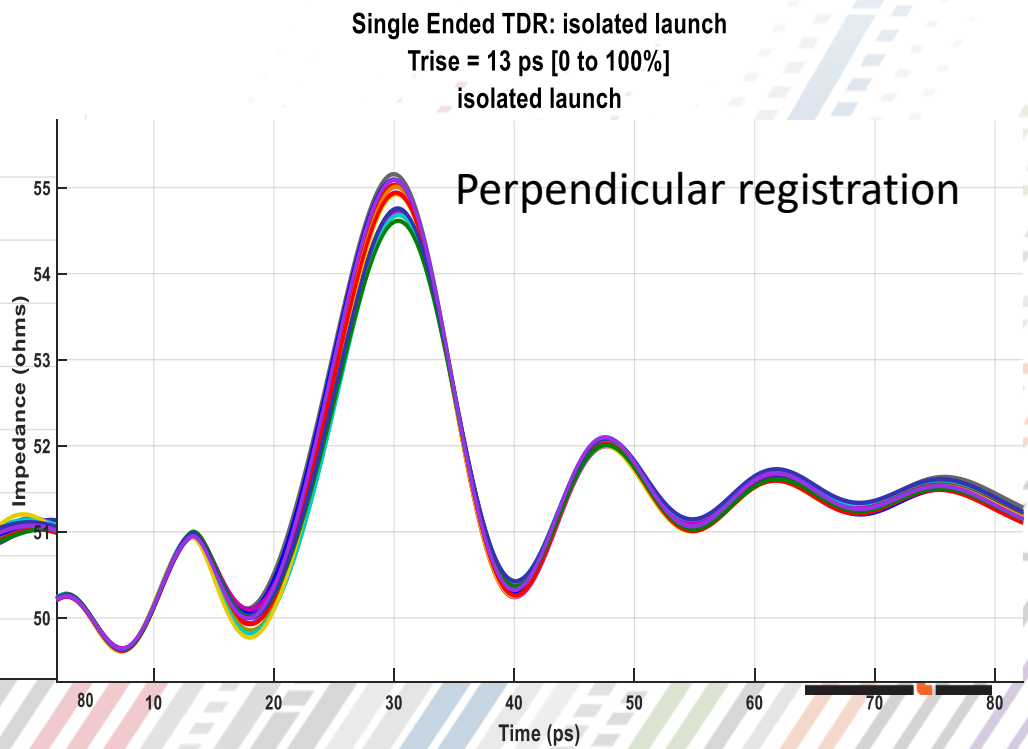


Impact of fab tolerances

TDR Variations

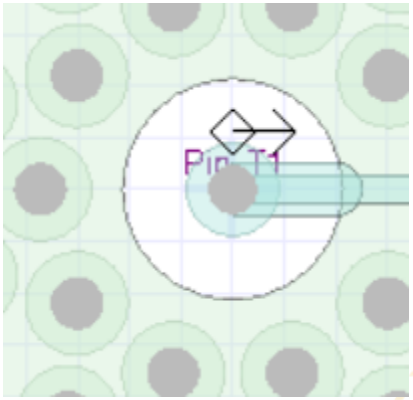
TDR impacts broken out between the P and N launch orientations





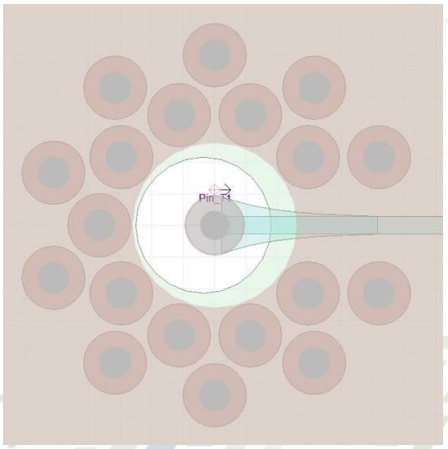
PCB Launch Design Improvements

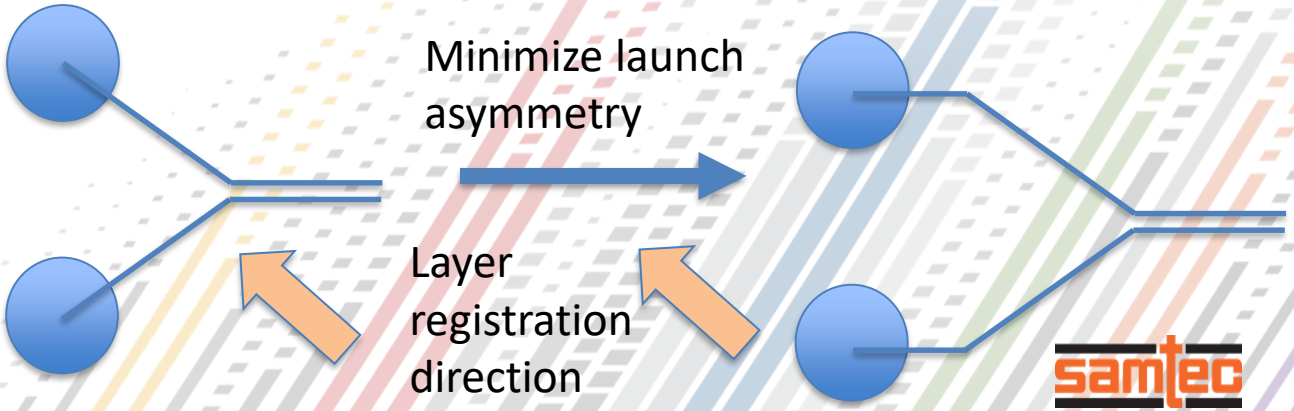
- Ideas to improve registration sensitivities and asymmetries
- There are other parameters that can be tweaked to improve on sensitivities



Reduces registration sensitivity

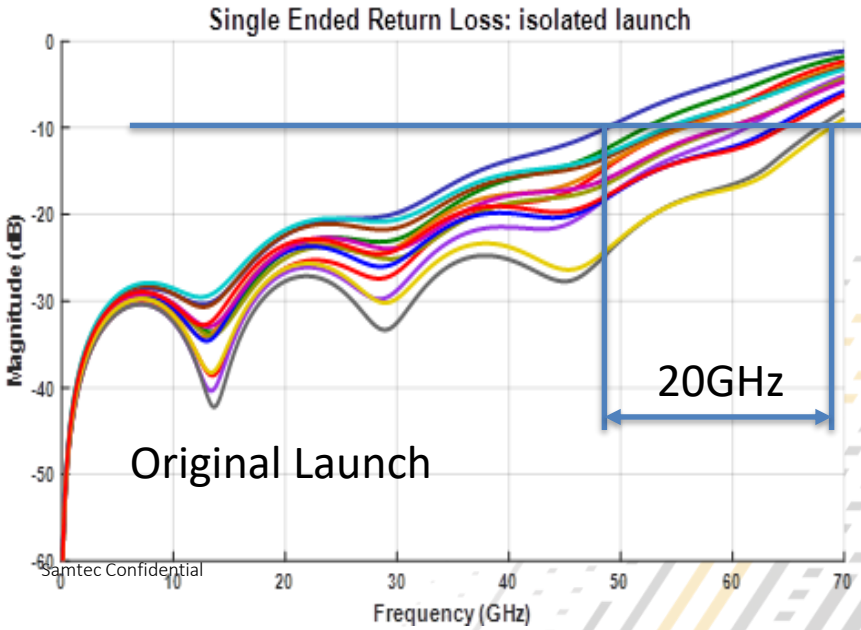
Offset anti-pad, exponential taper

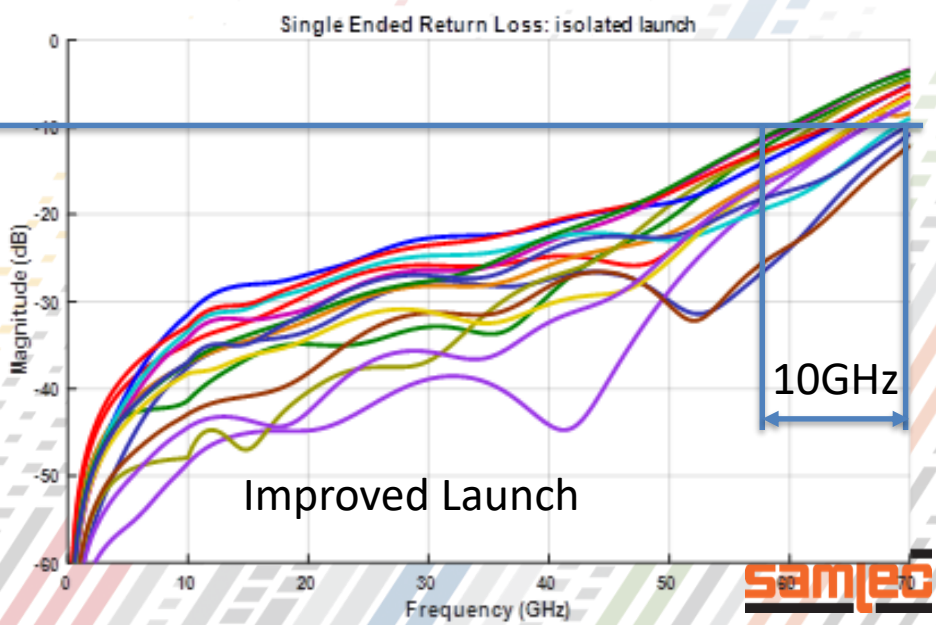




Comparison of the OLD AND NEW

- Put TDR and RL comparison between both implementation (New and OLD)





Conclusions

- Weak sensitivity to impedance, but high sensitivity for discontinuities at the end, **(important to keep a clean launch)**
- 2.4mm connectors produce resonances that rises the S11, leaving only a few dB of margin for the PCB launch, *1.85mm connectors would help*
- Connector movement with respect to TOP landing pad has an small effect on the launch
- High manufacturing layer registration have a high impact above 40GHz
- Look to design with registration in mind, apply methods that minimize launch sensitivity