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ATE Loadboard Layout for High Density RF Applications

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VERIGY

Abstract

The current success of smart-phones and the relentless trend to reduce cost and add capabilities every year are key drivers in the wireless semiconductor business. Combining various RF technologies into one device along with the desire for multi-site testing can easily increase the RF ATE test fixture port count to a range of 48 and beyond. While a few ATE vendors provide test equipment for this requirement, the question remains on how to manage the interfacing and the test fixture design for high density RF without losing performance.

The current interfacing and layout paradigm will undergo a significant change. The RF connectors are moved further away from the DUT to allow easier assembly and debugging, but with higher risk of performance degradation due to loss, crosstalk and interference. The increase in the number of matching networks makes hand tuning a significant bottleneck in delivery of a working loadboard. This paper evaluates new hardware and layout techniques to address both mechanical and electrical performance for high density RF ATE test fixtures and applies this knowledge to measurement based modeling techniques to minimize hand tuning of RF matching networks.

Outline

1. Motivation and Concept
2. RF Cables
3. RF Connectors and Mounting Options
4. London Bridge (RF Interface)
5. Trace Design
6. Impact on RF Matching Networks
7. Summary

1. Motivation and Concept

RF Port Count Continues to Increase with Integration of Multiple Wireless Standards

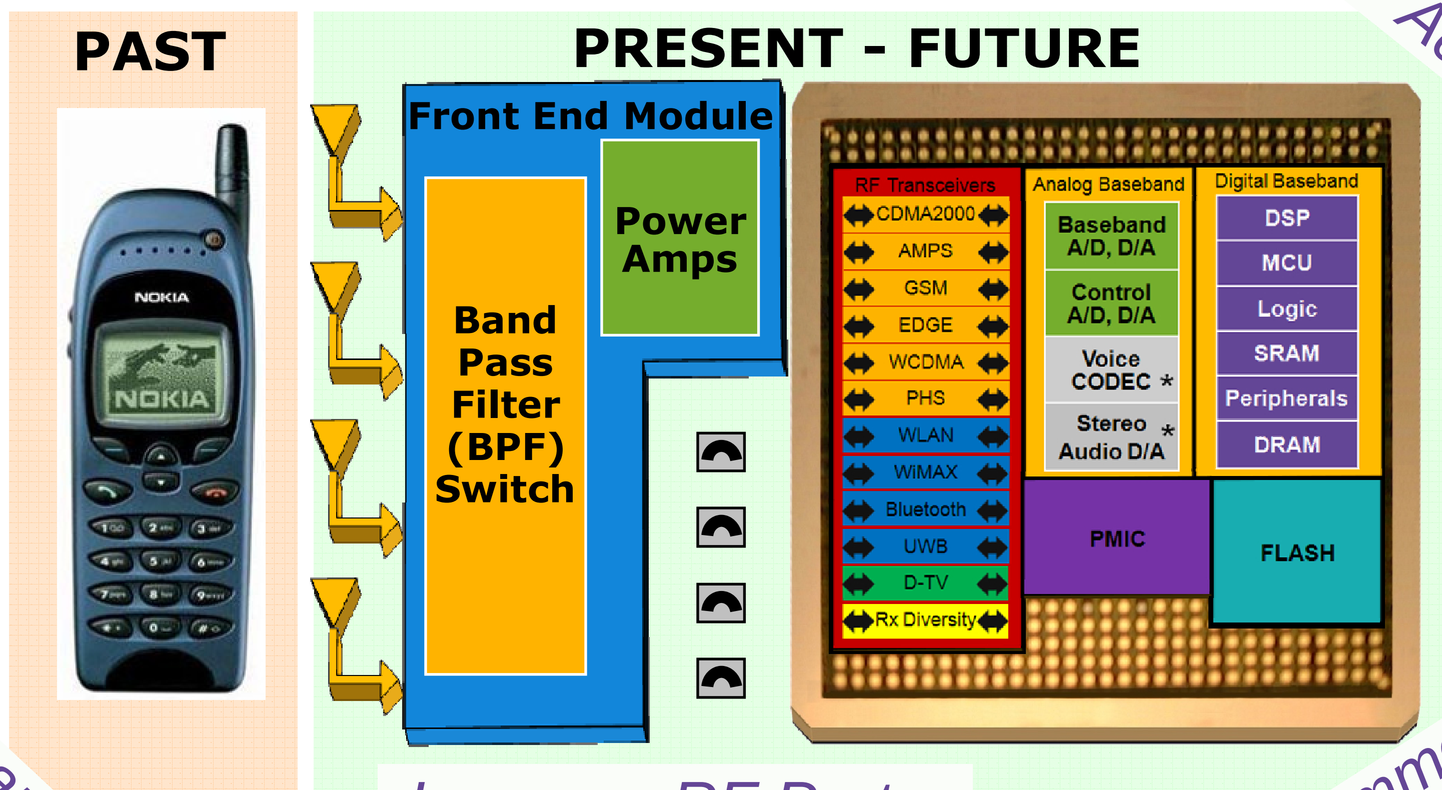
Longer Traces

Limited Component Space

DUT Access

Crosstalk

Tuning



Performance Degradation

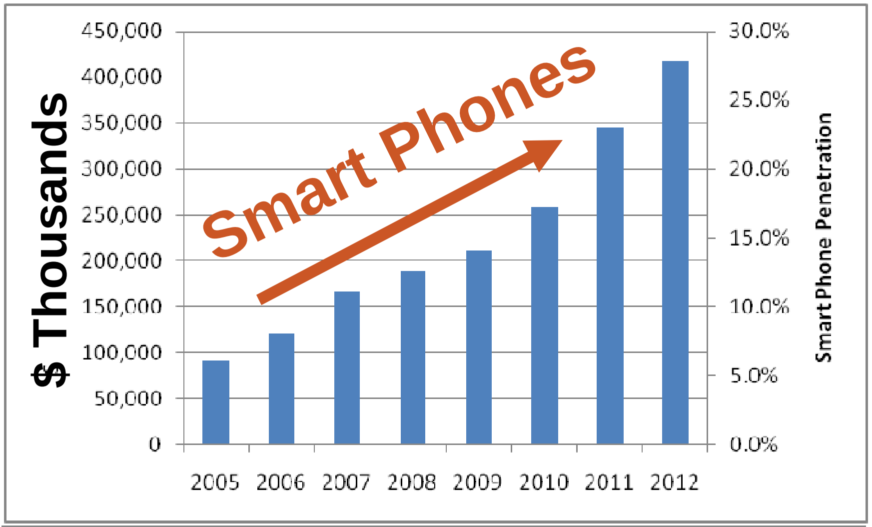
Increase RF Ports (connectors / cables)

Symmetric Device Layout

Market Reality and Test Implications

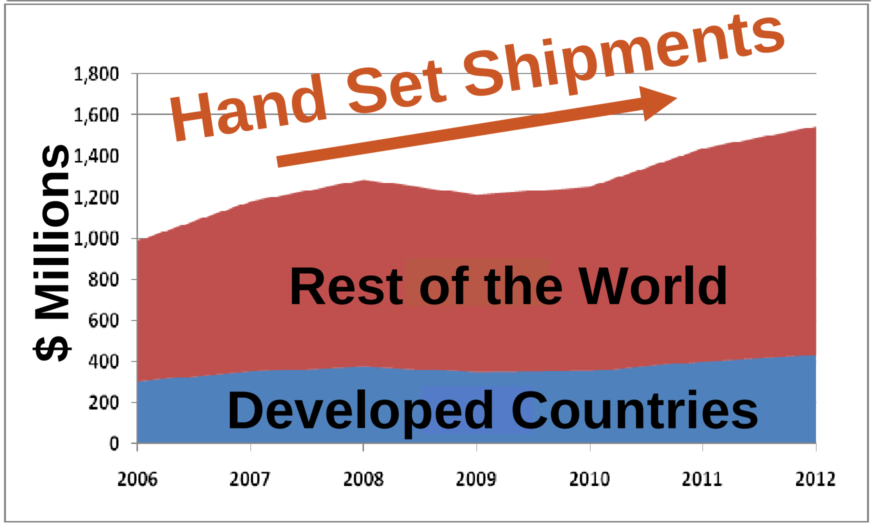
High End Handset

- Number of **RF ports increasing**
  - *Multi-band*
  - *Receive diversity*
  - *Additional radio interfaces (WLAN, BT, GPS, FM Tx/Rx)*
- **Smart phone** penetration accelerating
- Driving increase in RF port count for smart and high end feature phones
- **World phone** (3-4 bands) devices will drive multi-site **RF port count** requirements **above 24**



Ultra Low Cost Handset

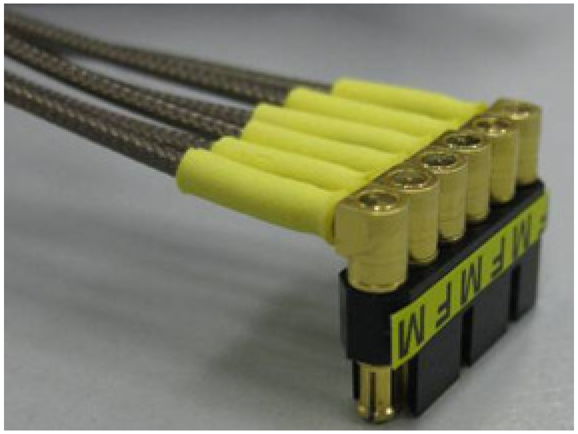
- **1.8B new subscribers** from 2008 to 2012, 93% from developing countries
- **ULC Handset ($20 BOM)** driving single chip SOC devices for entry level phones
- Limited RF port count required (<24)
- Cost goals driving **increase in multi-site (X4 → X8)**



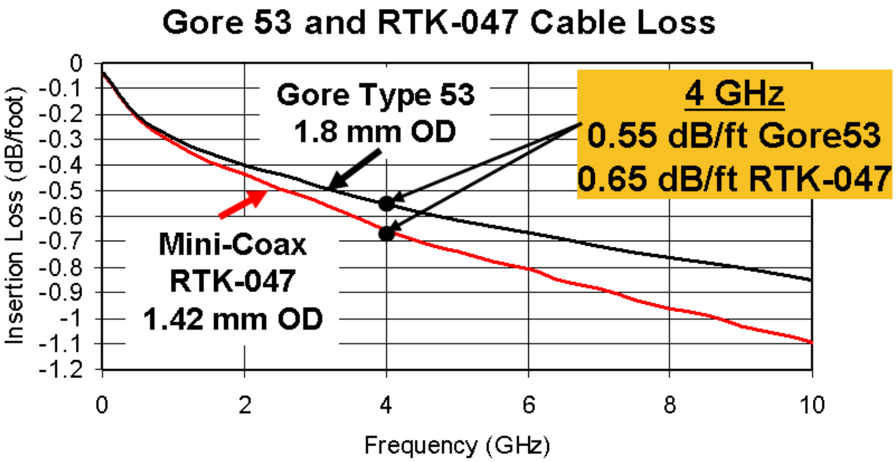
iSuppli data Q408

2. RF Cables

High Density RTK-047 Tempflex Cable

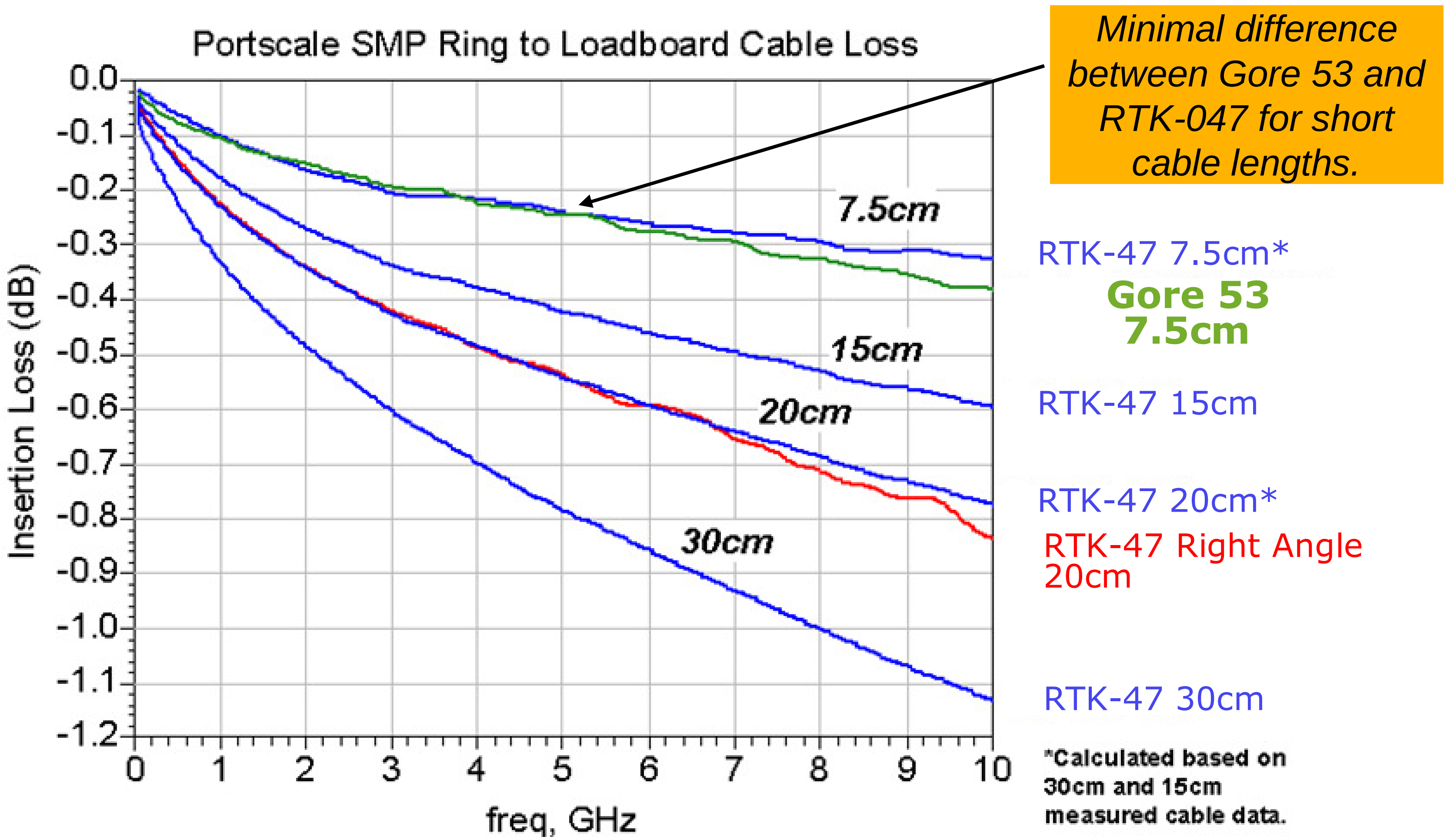


- Small: 1.42mm Diameter vs. 1.8mm for Gore 53
- Low Loss Dielectric: dK=1.25
- Flexible: 6.4mm Bend Radius vs. 10.2mm for Gore 53
- Different lengths: 15cm / 20cm / 25cm
- Robust: Ganged housing with strain relief
- Less space:
  - Increases routing flexibility
  - Enables smooth operation with RF interface ring



Measured Cable Performance

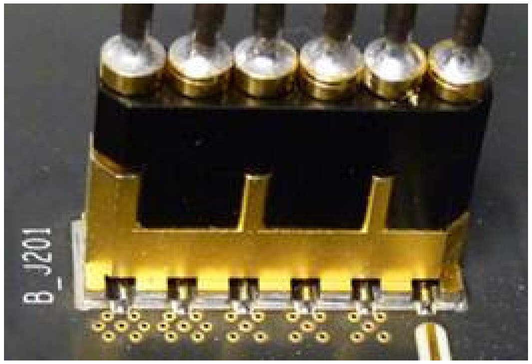
Full S-Parameter data includes cable loss and connectors



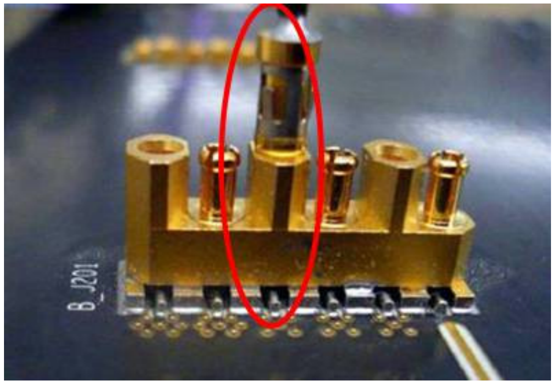
*Calculated based on 30cm and 15cm measured cable data.

3. RF Connectors and Mounting Options

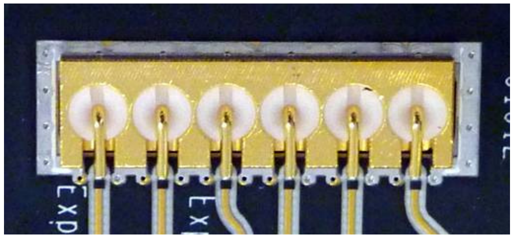
High Density Ganged Mini-Coax Connector



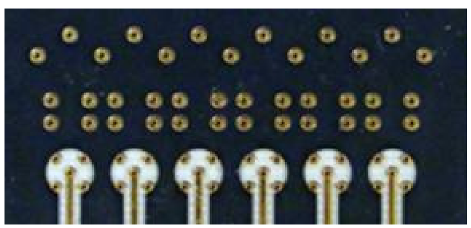
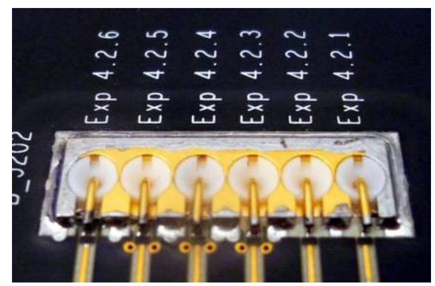
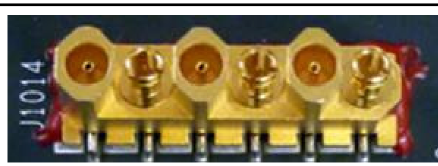
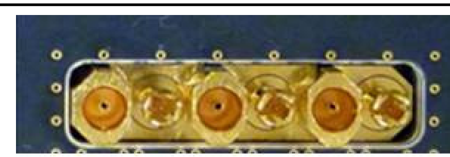
- 6x Ganged
- Share mechanical structure:
  Reduces the size by 30%
- Increased mechanical robustness
- Individually replaceable cable by removing from housing



- Disengagement force < 24 N
  vs. single Mini-SMP full detent connector < 29 N
- Engagement force < 12.5 N
  vs. single smooth bore Mini-SMP < 11 N
- Mating cycles > 500 vs.
  500 cycles SMA connectors.
  100 cycles Mini-SMP connectors

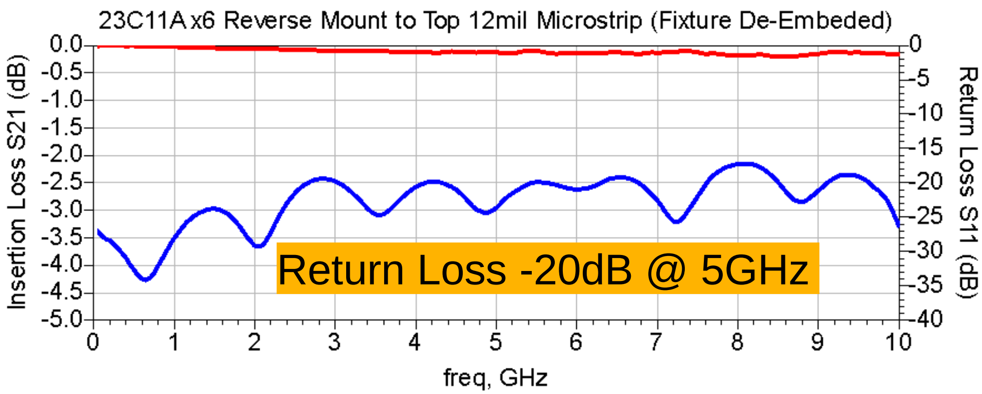


Mounting Options

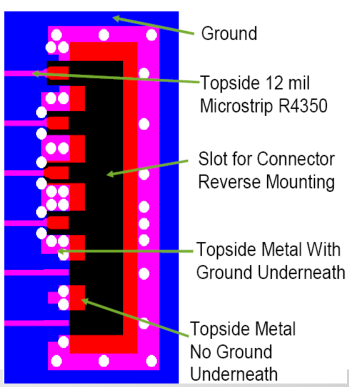
<table>
<tr><th>Standard Mount topology</th><th>Reverse Mount topology</th></tr>
<tr><td>Signal pin to bottom layer microstrip</td><td>Signal pin to top layer microstrip</td></tr>
<tr><td>Vias required to connect to an inner or to the Top layer Microstrip</td><td>No Via required for Top layer Microstrip</td></tr>
<tr><td>Blind vias under the connector body can completely open up the space for digital routing layers.</td><td>Through hole slot completely blocks routing on all layers</td></tr>
<tr><td>Cable connection on bottom side of PCB</td><td>Cable connection on bottom side of PCB</td></tr>
<tr><td colspan="2">Top Side</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td colspan="2">Bottom Side</td></tr>
<tr><td>
</td><td></td></tr>
</table>

Reverse Mount RF Performance

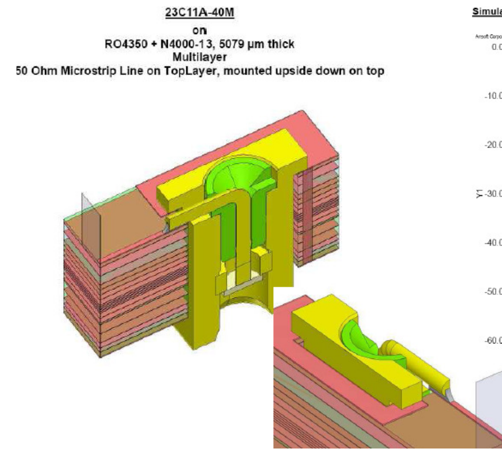
Full S-Parameter Data for
Mini-Coax Connector to PCB Transition

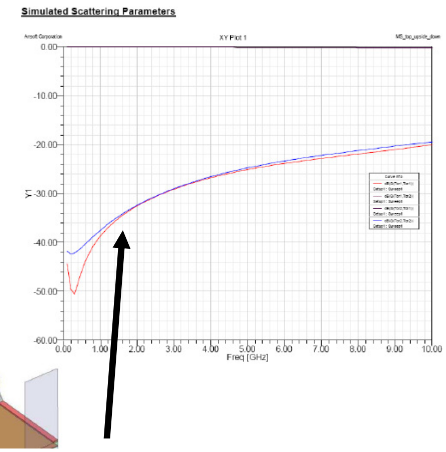


PCB footprint experiments to compare mechanical and electrical signal pin trade-offs.



Simulations





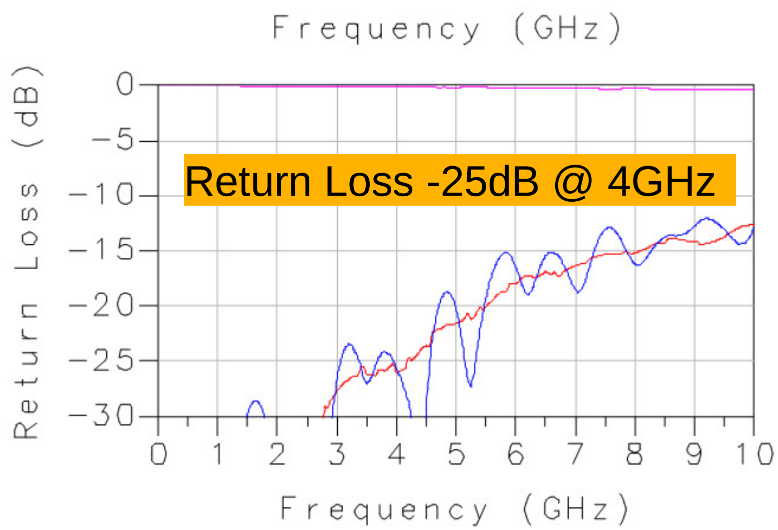
Return Loss -26dB @ 5GHz

V0015_Rosenberger_23C11A_40M_MiniCoax_x6_Reverse_Top_SMT.zip

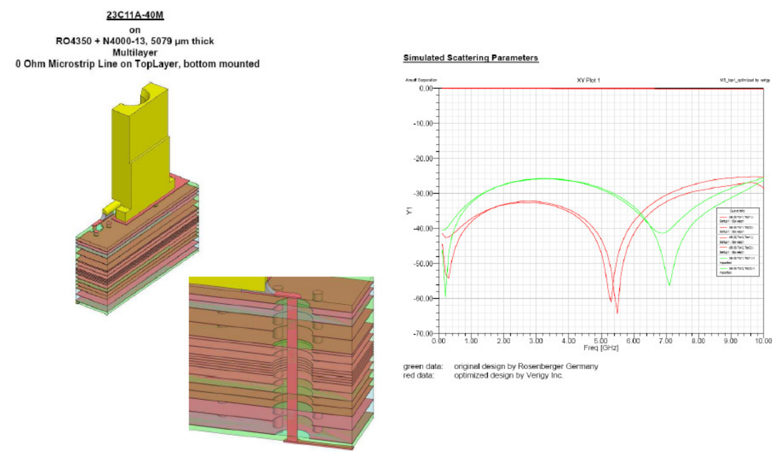
PCB footprints in dxf and Gerber format

Standard Mount RF Performance

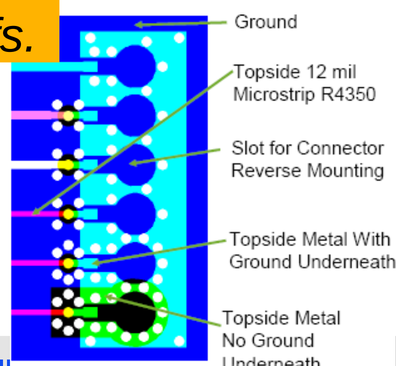
Full S-Parameter Data for Mini-Coax Connector to PCB Transition



Simulations



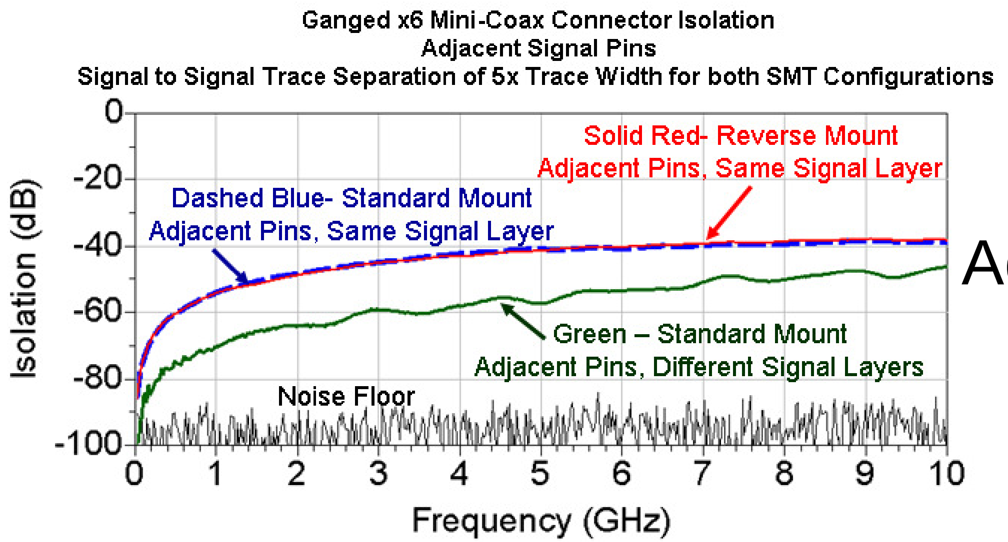
PCB footprint experiments to compare mechanical and electrical signal pin trade-offs.



PCB footprints in dxf and Gerber format

V0016_Rosenberger_23C11A_40M_MiniCoax_x6_Bot_SMT.zip

Ganged Connector Isolation

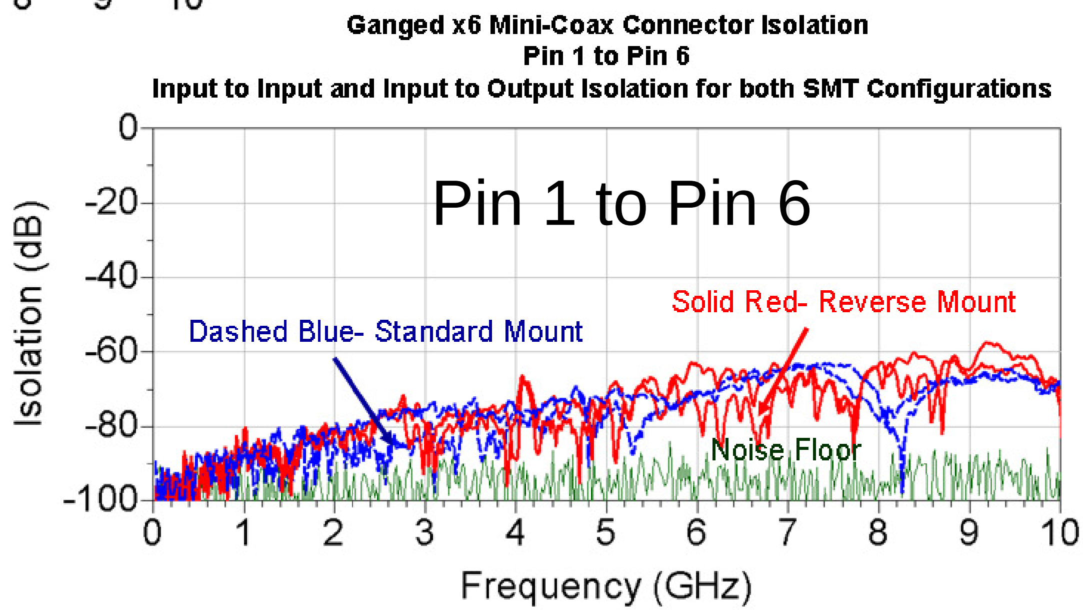


3 mm Signal Pin to Signal Pin Spacing

Adjacent Signal Pins

Standard Mount with vias to topside and reverse mount with no vias show similar performance for isolation.

Stripline routing on different layers but adjacent connector pins improves isolation by >10 dB.



4. RF Interface: London Bridge

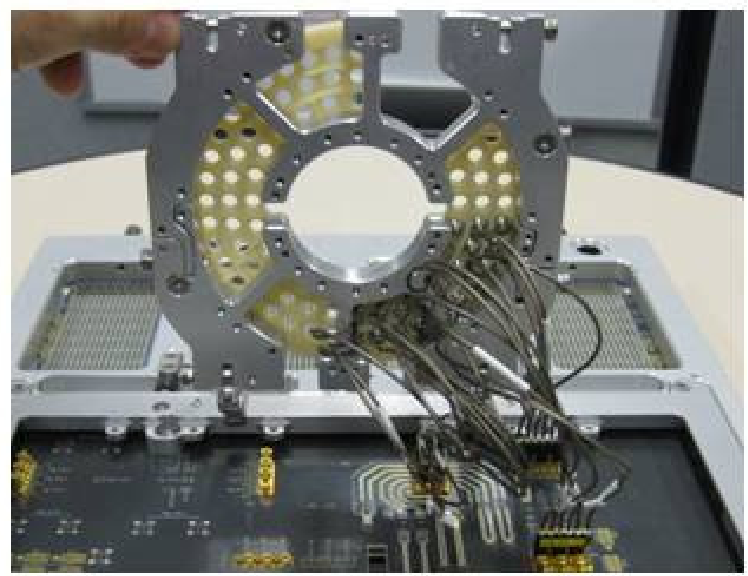
London Bridge RF Interface Ring (1/2)

- Access to component area:
  - can be opened in the middle
  - can be lifted on either side and completely disengaged

- RF cables can be shorter for lower loss and less cable congestion

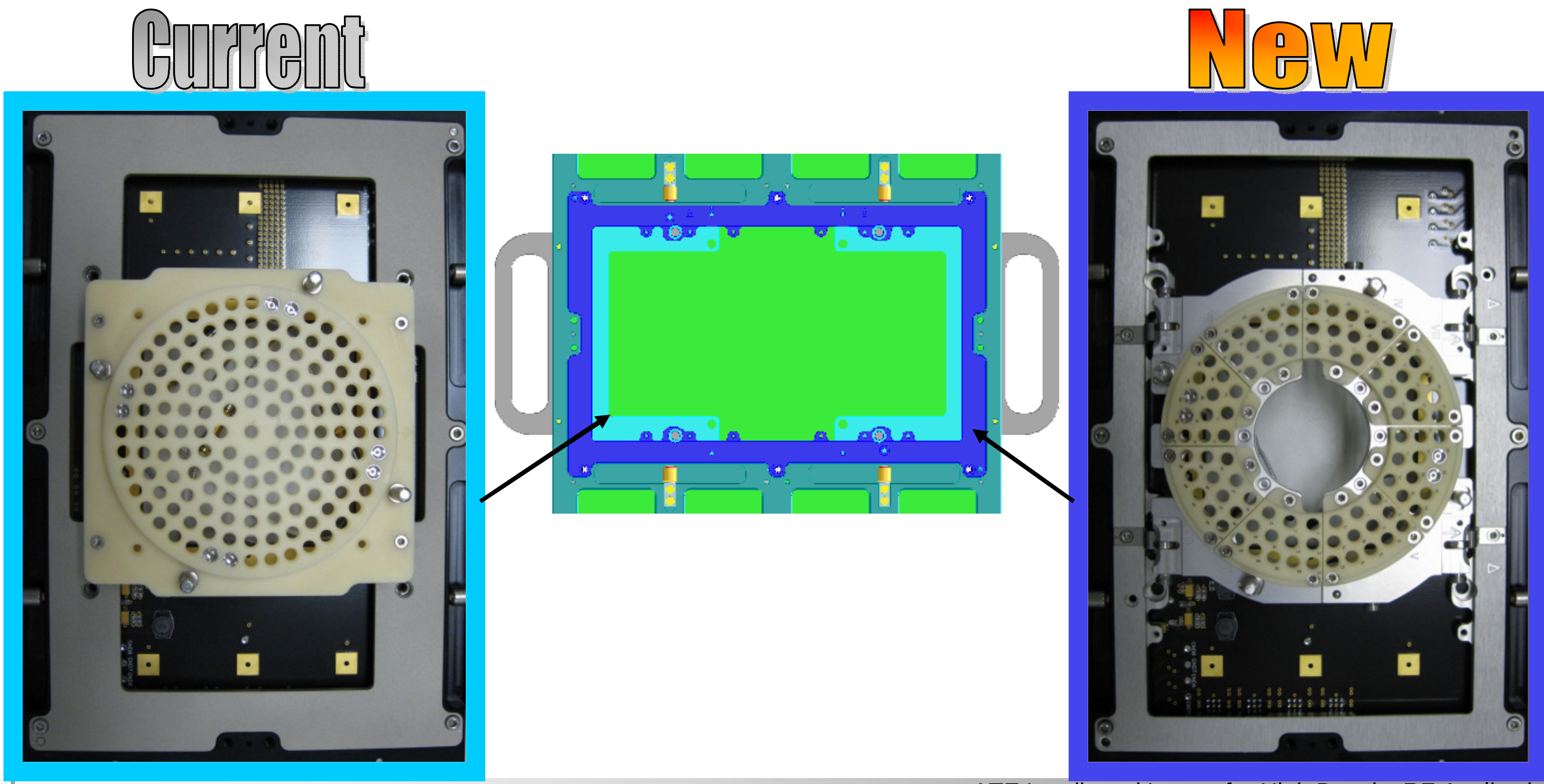
- Divided into 8 segments with 12 RF connections each. Easier assembly and better cable arrangement.

- Additional cavities in the ring frame allow unthreading the segment together with the cables.



London Bridge RF Interface Ring (2/2)

- New metal inlay frame with increased application routing area by 30%.

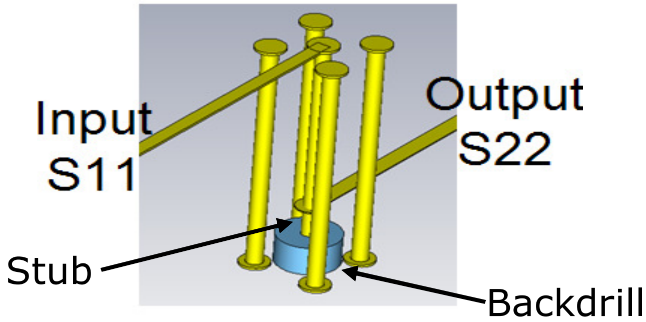


5. Trace Design Experiments

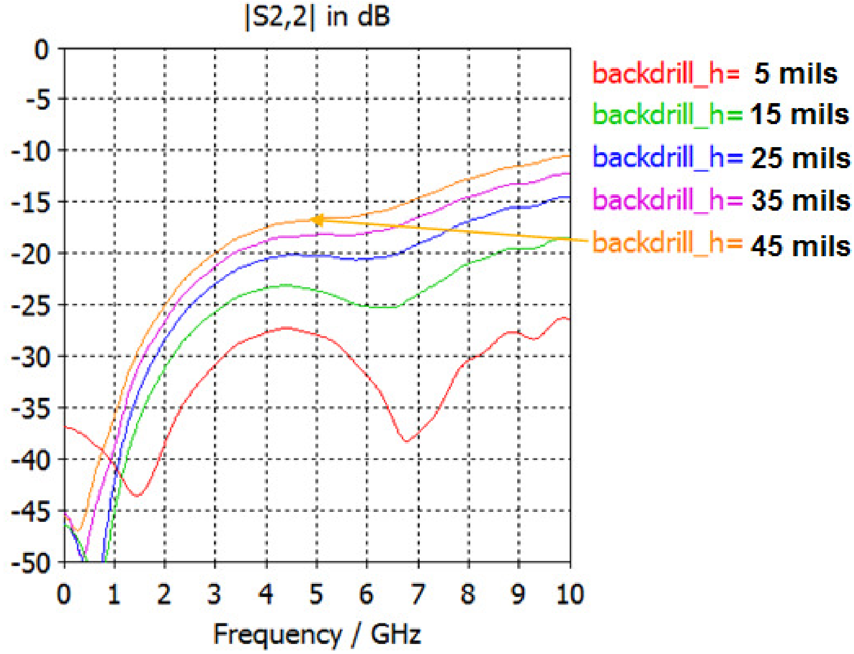
- ✓ Vias
- ✓ PCB Materials
- ✓ Isolation for Striplines and Microstrip Routing

Importance of Backdrilled Vias

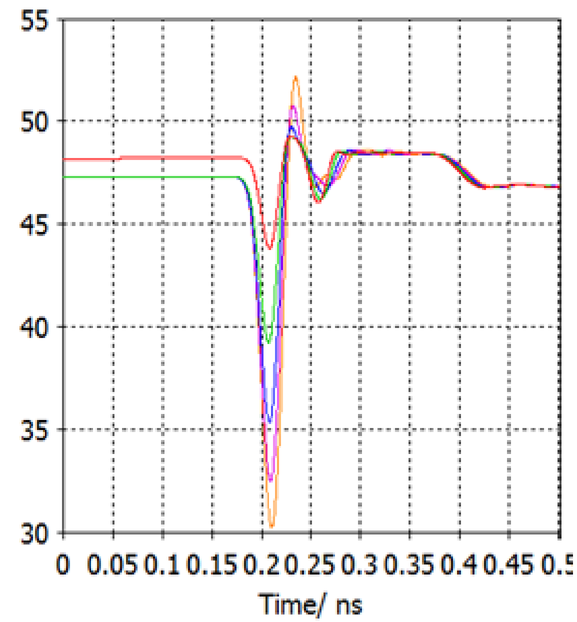
PCB Via
4 Ground Topology
50 Ohms



Return Loss vs Stub Length

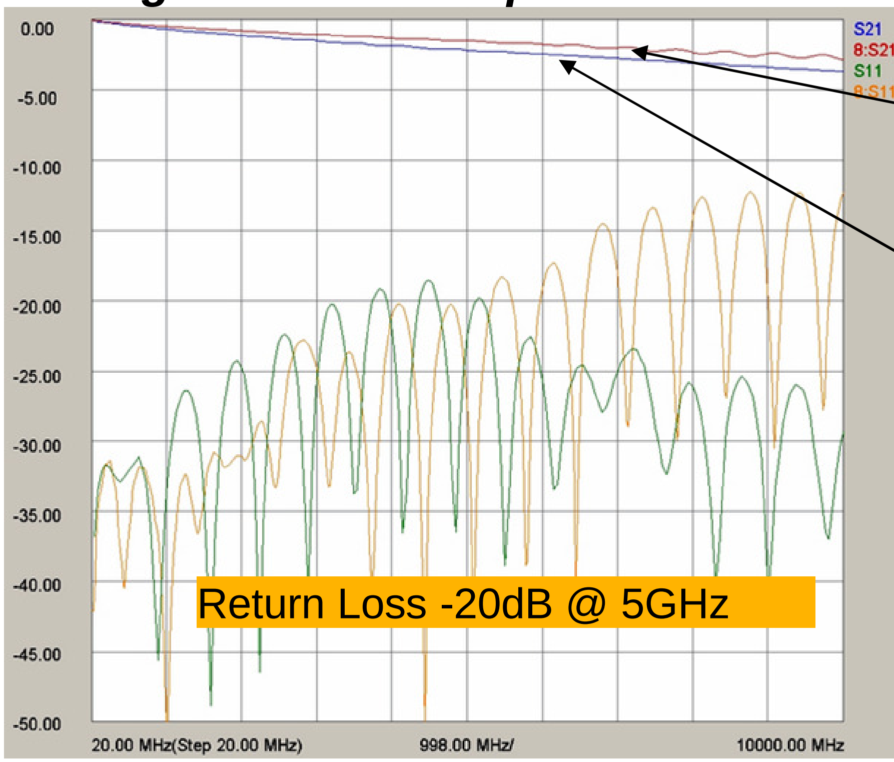


Via Impedance vs Stub Length



Signal Path with 2 Optimized 50 Ohm Vias

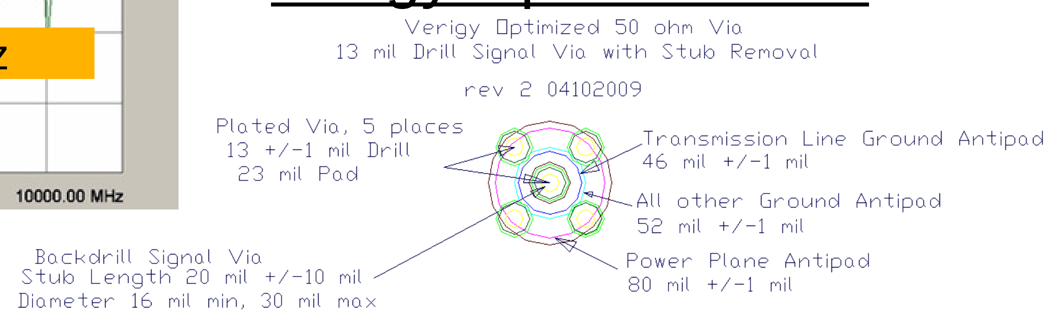
TRL Calibration Thru-Line with Southwest Microwave 2.4 mm edge launch and optimized 50 ohm Vias.



R4350 Stripline (18mil) in red and orange

Nelco 4000-13SI Stripline (19mil) in blue and green

Verigy Optimized Via



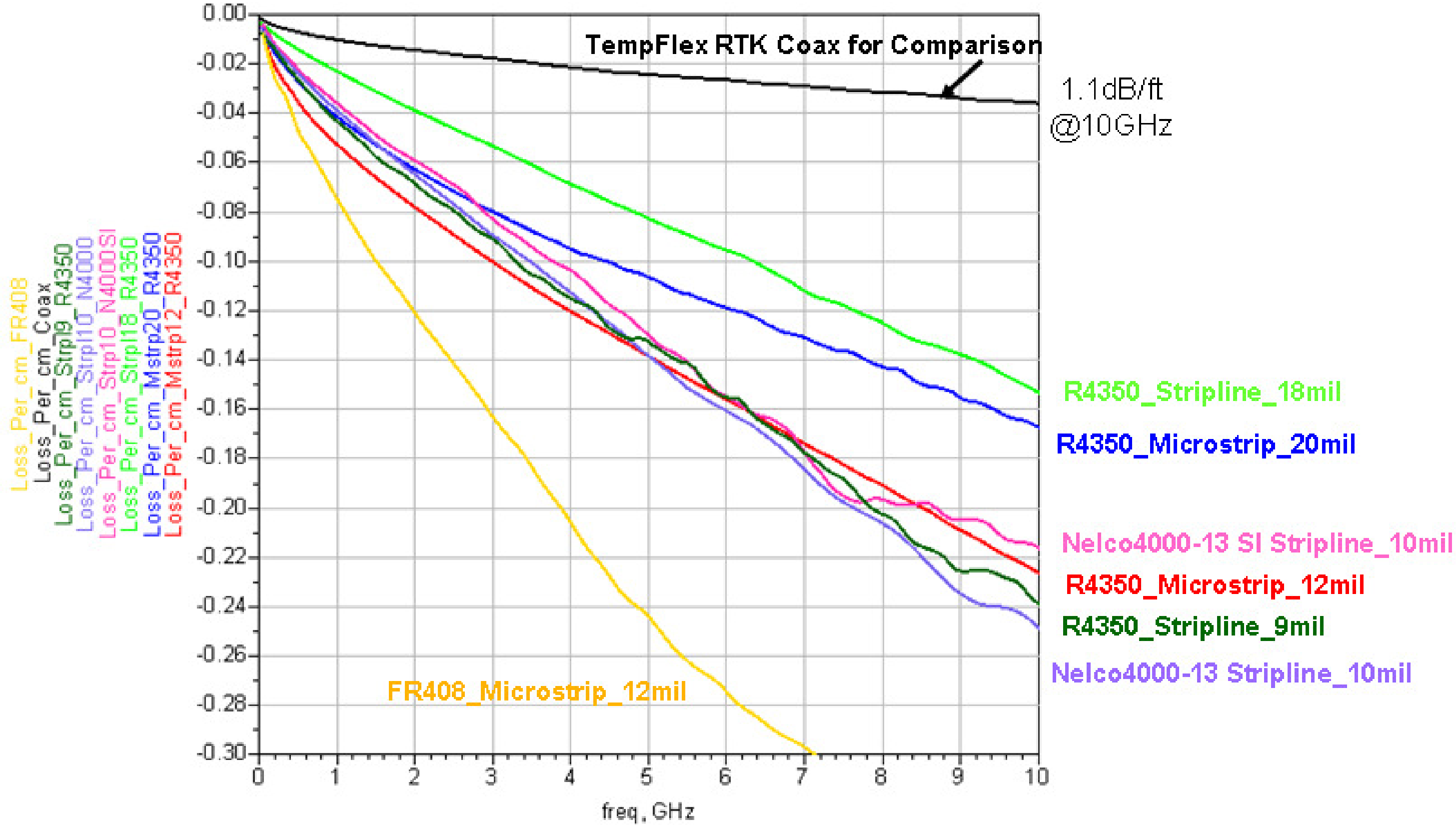
4-ground vias on the optimized via provide better isolation and robust implementation.

Outline (5. Trace Design Experiments)

- ✓ Vias
- ✓ PCB Materials
- ✓ Isolation for Striplines and Microstrip Routing

PCB Materials for Longer High Density Routing

Fixture Removed, Loss Per Centimeter Data



Outline (5. Trace Design Experiments)

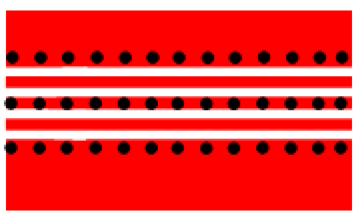
- ✓ Vias
- ✓ PCB Materials
- ✓ Isolation for Striplines and Microstrip Routing

Ground Via Stitching to Fence Off X-Talk

Isolation by separation (no via stitching)

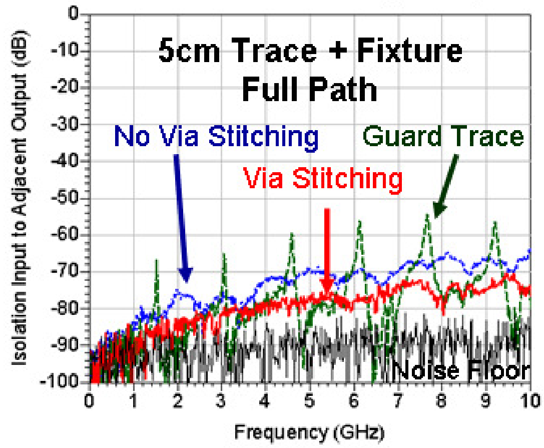
Isolation by Guard Trace

Isolation by Via Stitching

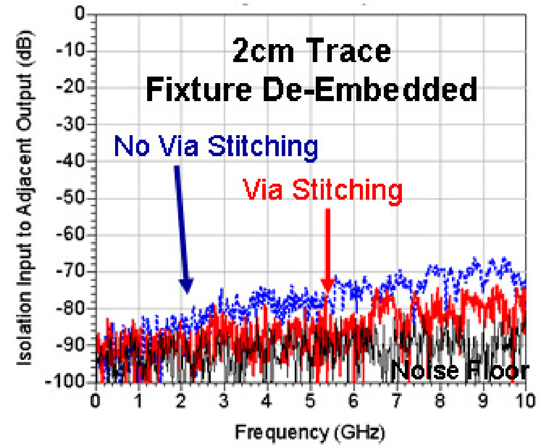


Stripline

Stripline Isolation
5x Trace Width Spacing

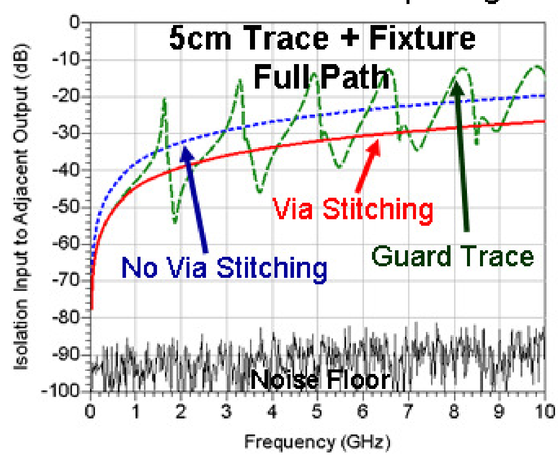


Stripline Isolation
5x Trace Width Spacing

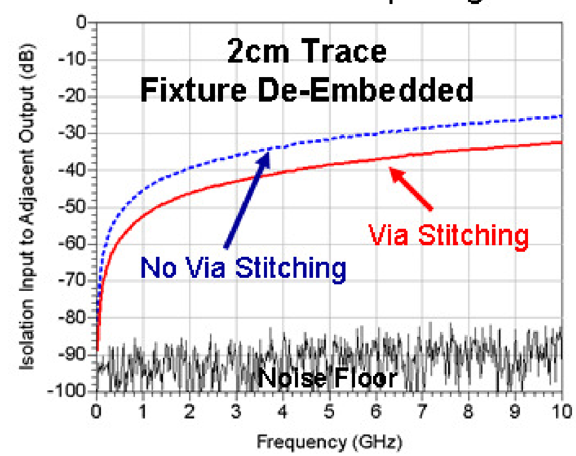


Microstrip

Microstrip Isolation
5x Trace Width Spacing



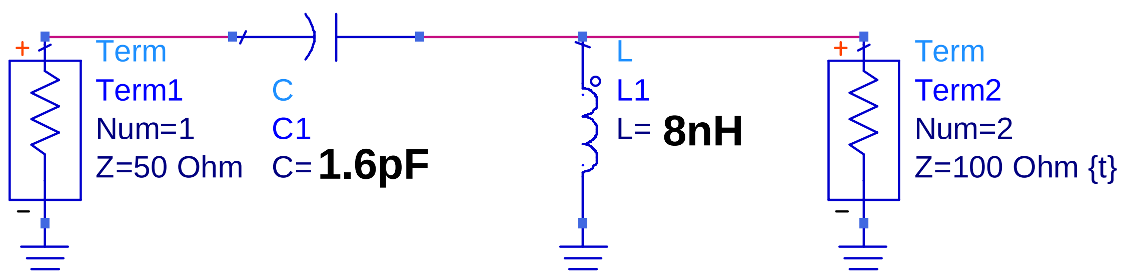
Microstrip Isolation
5x Trace Width Spacing



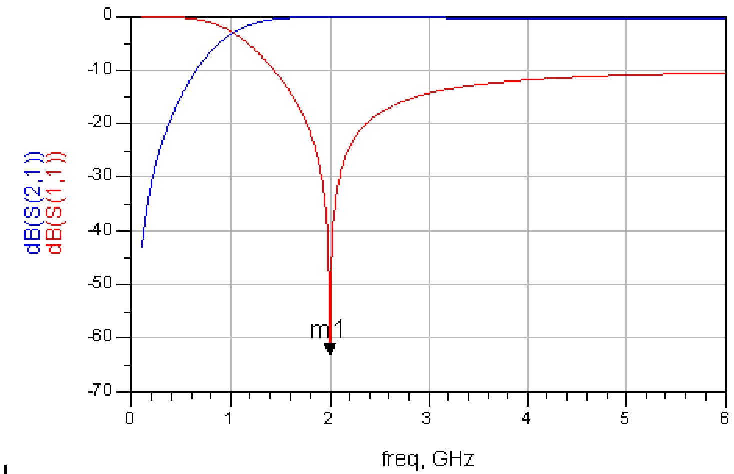
Outline

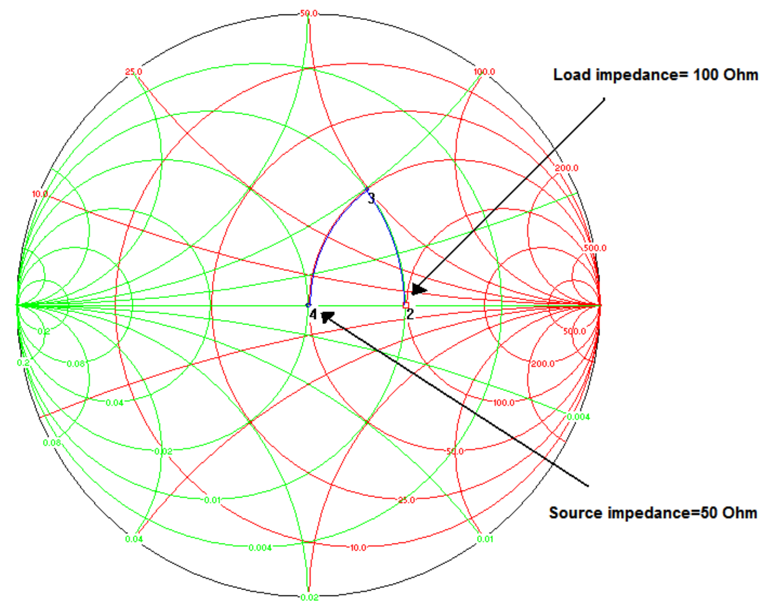
6. Impact on RF Matching Networks

Simple Matching Network Example



Lumped Model Design for 2 GHz Match





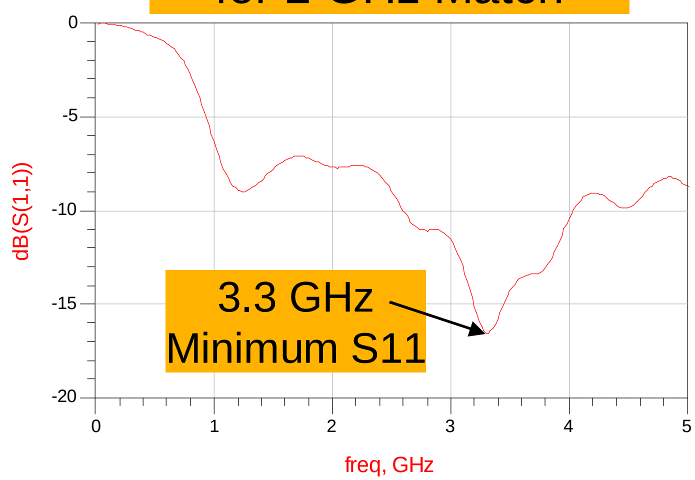
T-Line Affects on the Matching Network

The real load is complex 98-J10.9

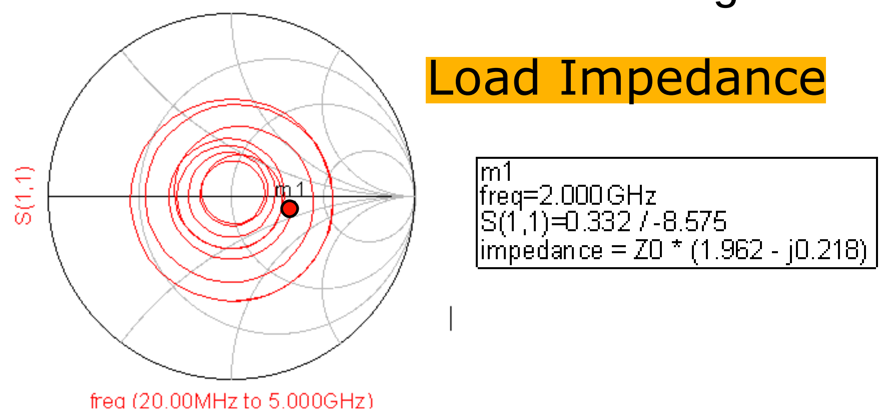
Rotation by Transmission-Line distances places the load on the other side of the SMITH Chart making it impossible to get a good match with the Series C followed by Parallel L Network.

Simulations need accurate load measurements and flexibility in matching network design to allow for phase rotation of the load to the matching network.

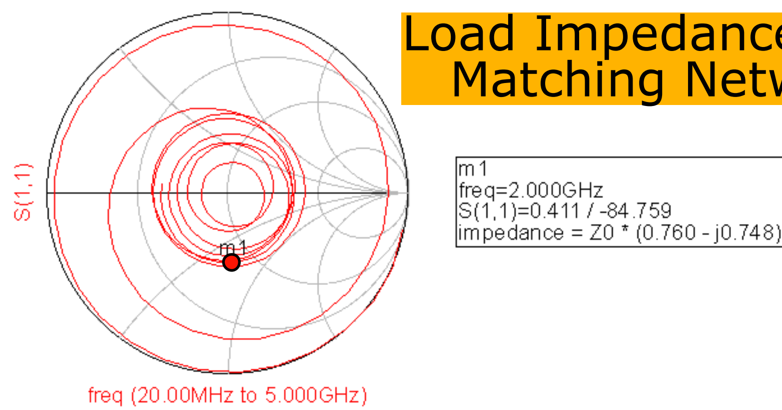
Measurement of Lumped Model Design for 2 GHz Match



Load Impedance

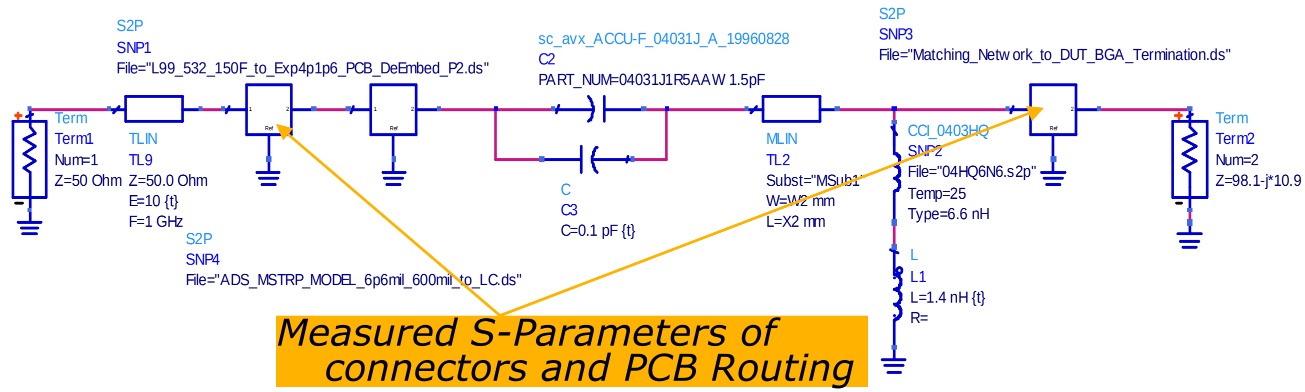


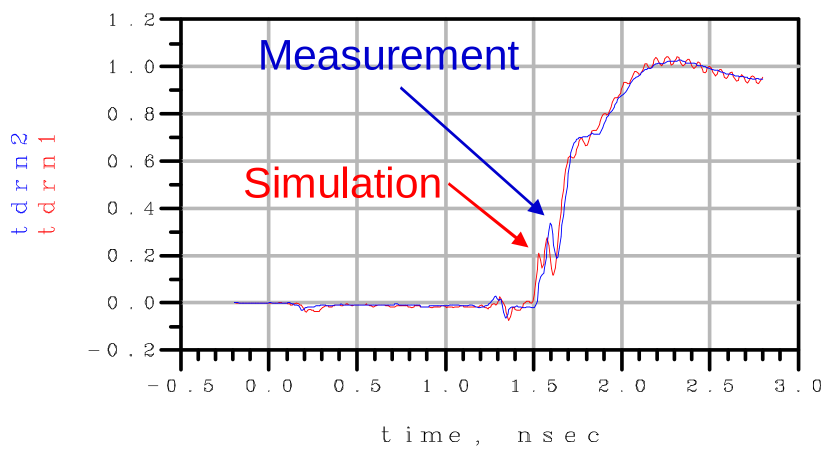
Load Impedance at the Matching Network

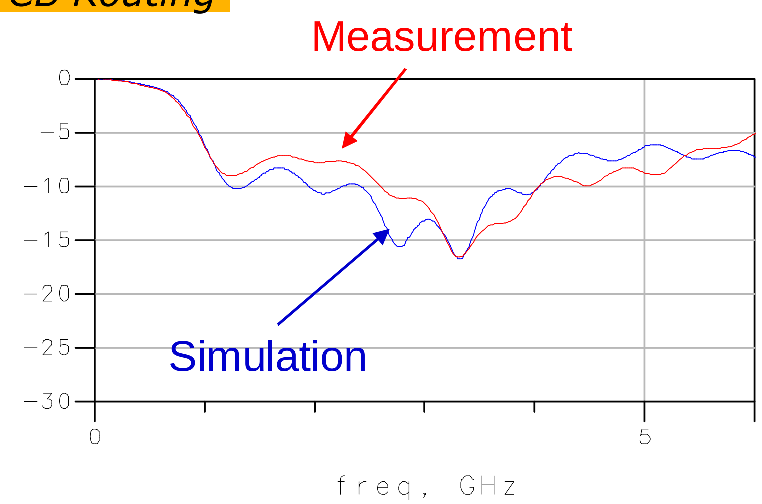


Measurement Based RF Tuning Approach

Verification of Measurement Based Model with Measured Data

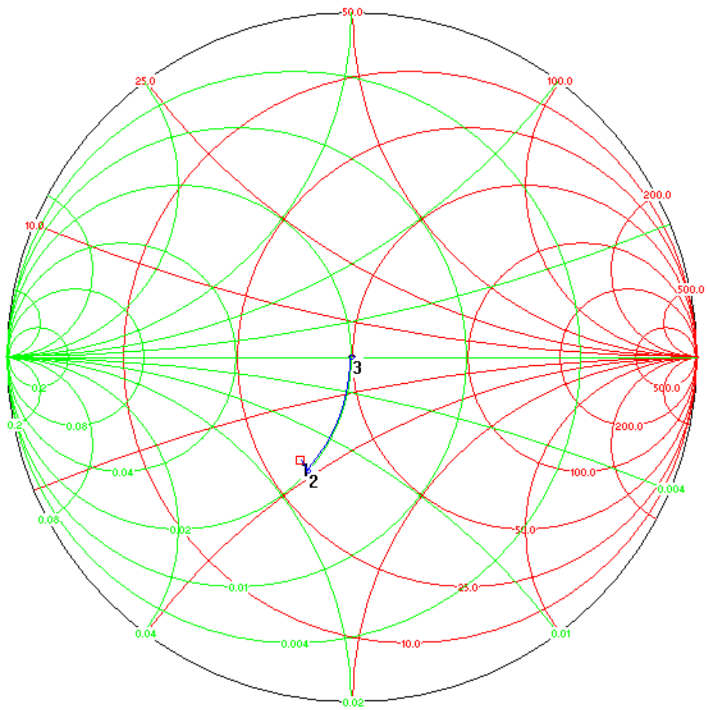


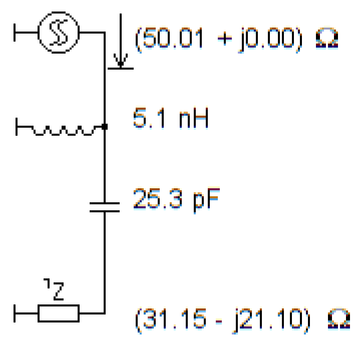




New Matching Network Topology for Rotated Load Impedance

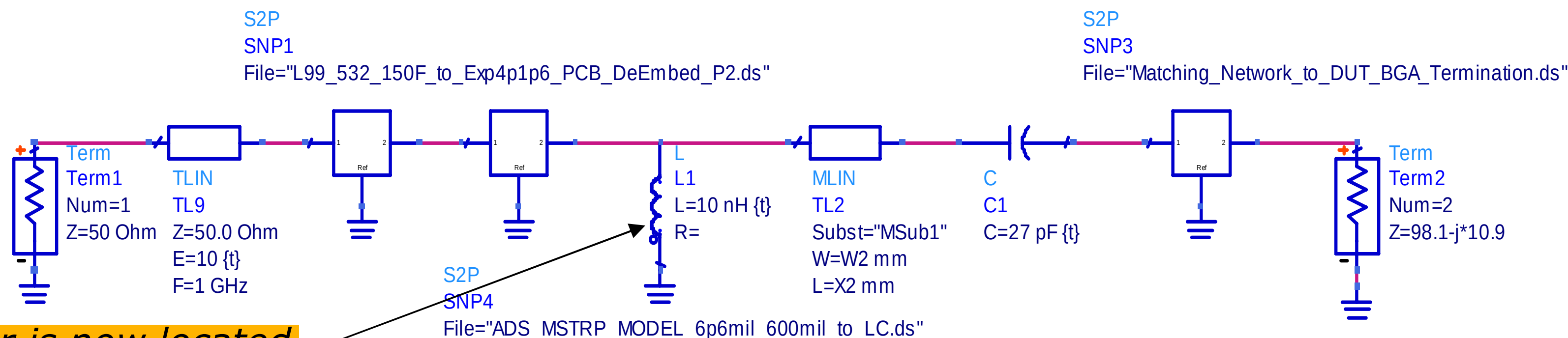
Impedance matching on the Smith Chart:





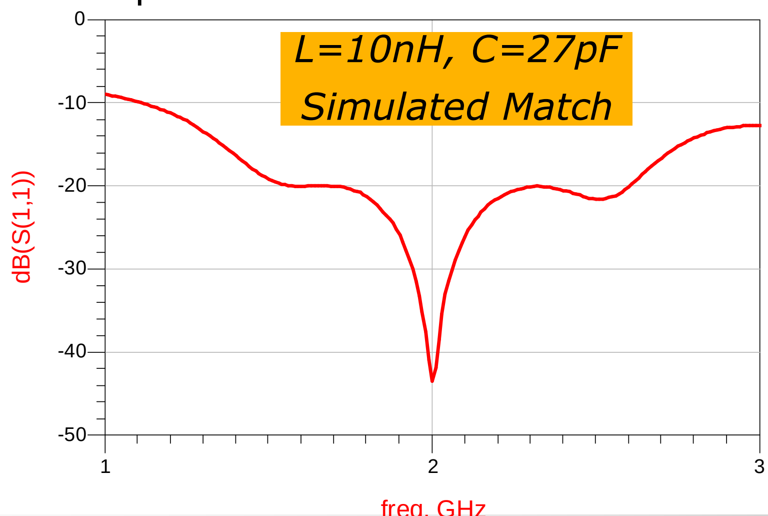
→correct topology!

Prediction vs. Measurement for the Tuned Matching Network

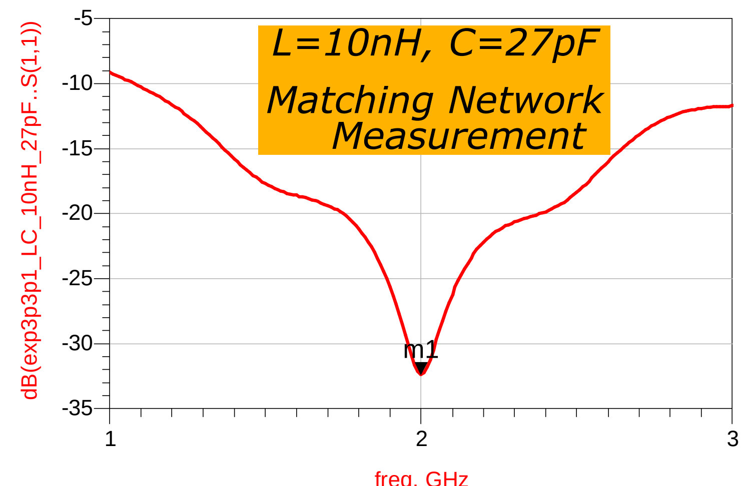


Inductor is now located before the capacitor on the source side

Optimized Prediction for 2 GHz Match



Measured Data, M1=2.00 GHz



7. Summary

- Higher density Mini-Coax connector topology maintains electrical and improves mechanical performance.
- Optimized 50 ohm vias and stripline routing have the potential to significantly improve isolation and routing densities.
- RF matching networks are already affected by T-Line affects at 2GHz, so moving them further out for high density applications will not change the difficulty of tuning.
- The key to RF tuning is flexible matching network design and accurate measurement techniques for signal path and DUT S-Parameters.

Acknowledgements

•Verigy managers Markus Rottacker, Kosuke Miyao, and Adam Smith for supporting the High Density Loadboard Investigation Project.