Validation of 55GHz Octal-site Wafer Test Probecard for 5G mmWave devices

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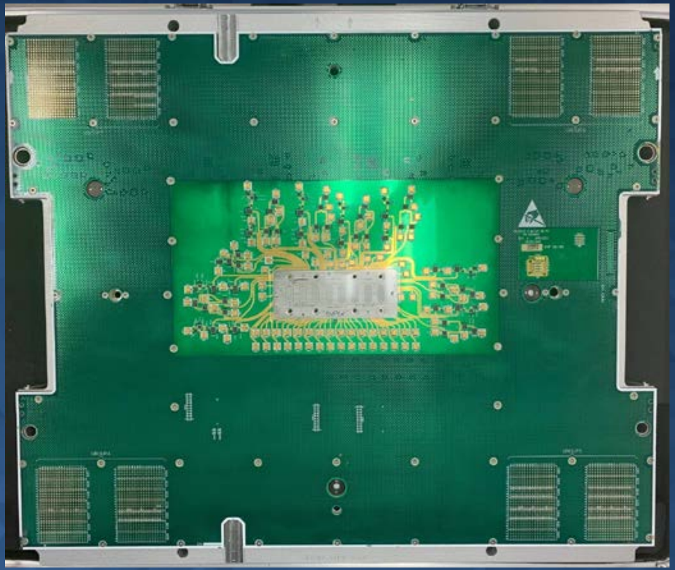
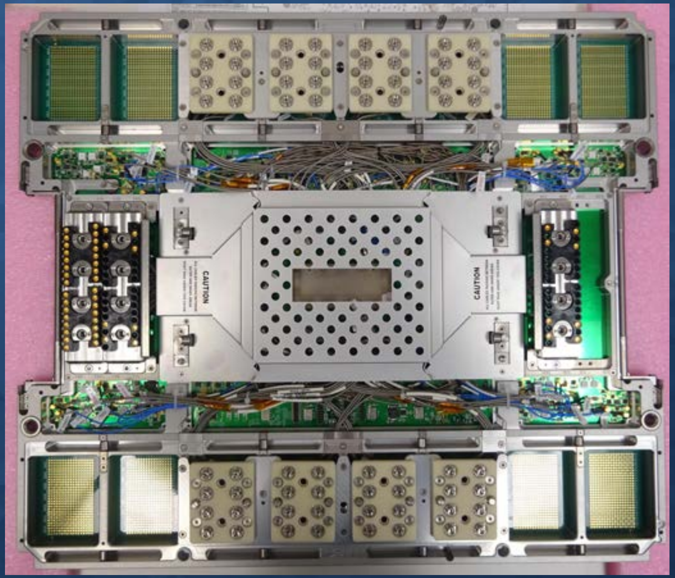
Overview

- **Introduction – 55GHz Octal-site Wafer Test Probecard for 5G mmWave devices**
- **Areas for Performance Improvement: Objectives, Methods, Results & Follow-On Work**
  – 35 Ω Impedance Change for MB Signals
  – Probehead – Probe Card Alignment
  – DOE and PCA Testing
  – More Compact Site Layout for Improved COT
- **Summary and Acknowledgements**

Validation of 55GHz Octal-site Wafer Test Probecard for 5G mmWave devices

- **In SWTest 2021, we presented a probecard for WLCSP mmWave devices** with some key requirements:**
  - 55GHz BW for mmWave MB signals (direct test + loopback)
  - 150um pitch, direct-attach PCB technology
  - Octal site with 600+ I/Os per site
  - Manual Test option for all eight sites
- **Design evolved to meet new customer needs, improve usability and test efficiency**
  - 35 Ω impedance for mmWave MB signals
  - Better probe head to probe card alignment
  - Denser multisite test pattern
- **Each design change requires a different validation process**

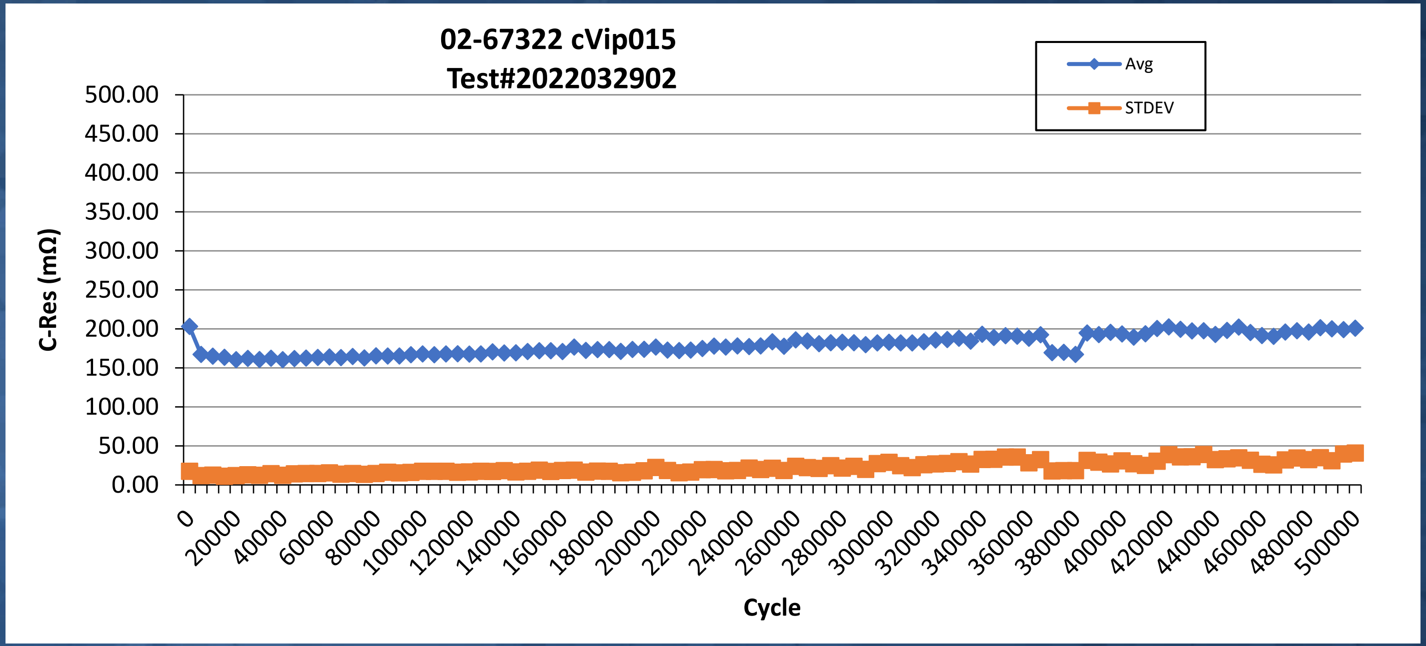




** SWTest 2021, Session #1 55GHz Octal-site Wafer Test Probecard for 5G mmWave devices; Jason Mroczkowski (Cohu – USA)

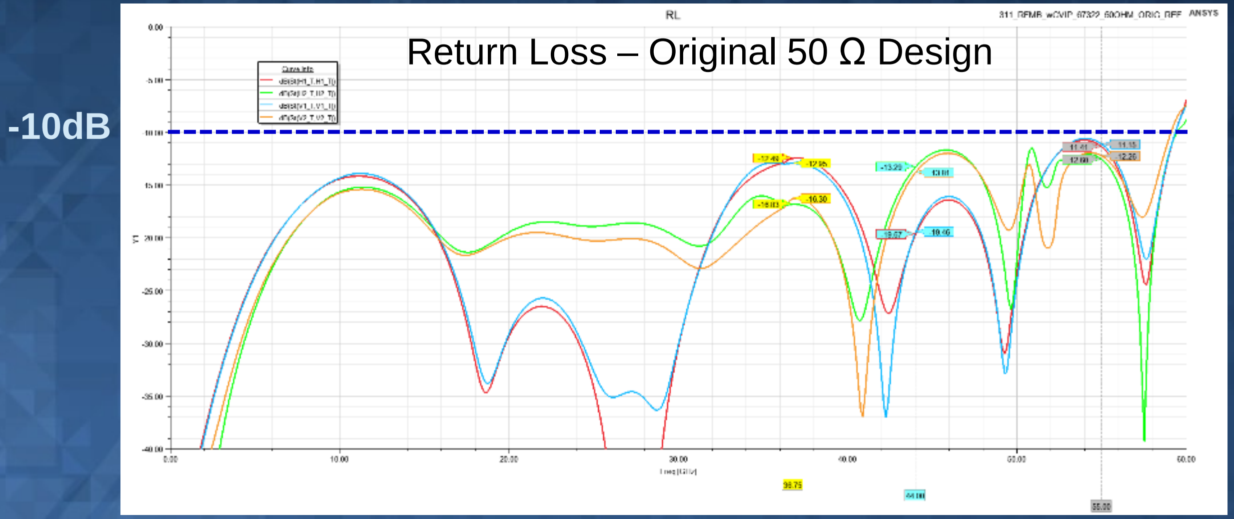
Why Use Radial Spring Probes?

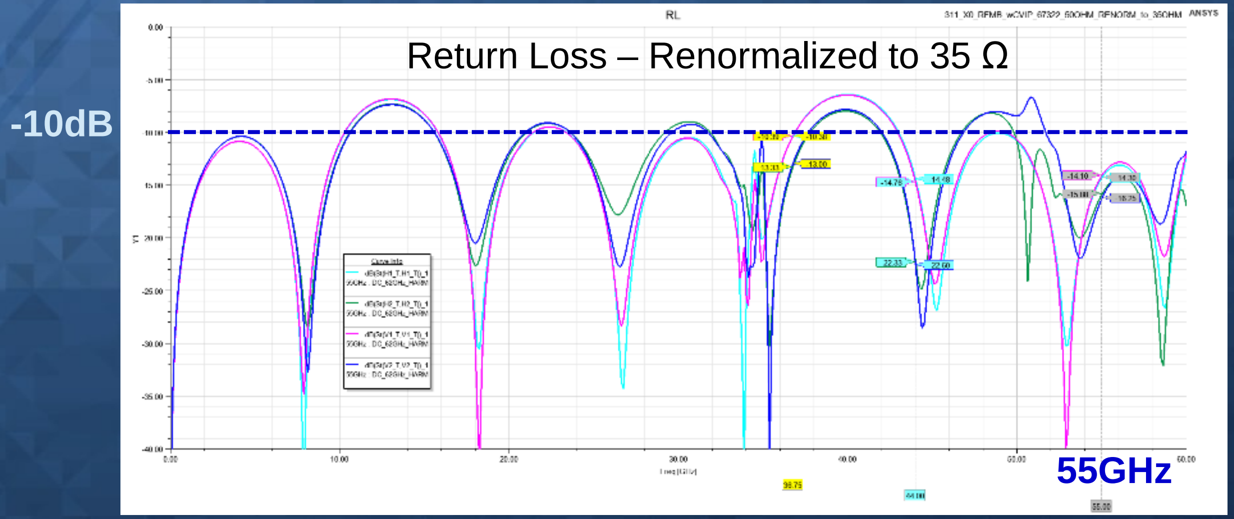
- Low and consistent cRes
- Long lifetime
- Individual replacement
- Manual Test of singulated WLCSP
- Standardized recipes for probes and cross sections at different pitch / impedance combinations



35 Ω Impedance Change for MB Signals

- **Original probe head cross-section and PCB layout optimized for 50 Ω impedance**
- **55GHz MB channels changing to 35 Ω impedance, requires:**
  - New PCB layout with DUT-launch trace structures matched to 35 Ω
  - New probe head design supporting both 35 Ω and 50 Ω signal impedances
  - PCB impedance transformer from 35 Ω to 50 Ω
- **Without modification, the performance will be degraded**



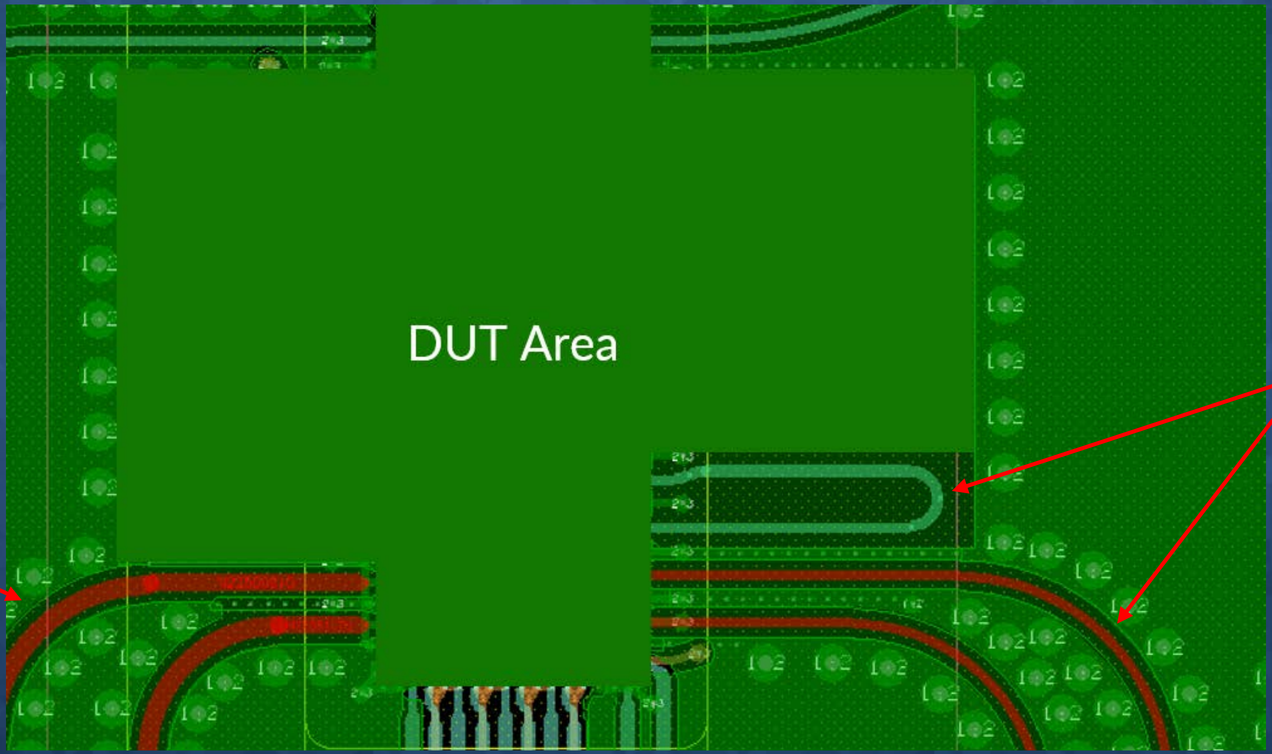


35 Ω Impedance Change for MB Signals

- **New coupon board layout implemented with 35 Ω matching**
- **Next step is to simulate performance and identify further optimizations required**

Loopback paths moved to L2 with new geometry for 35 Ω (not shown)

Direct paths on L1 using new geometry for 35 Ω



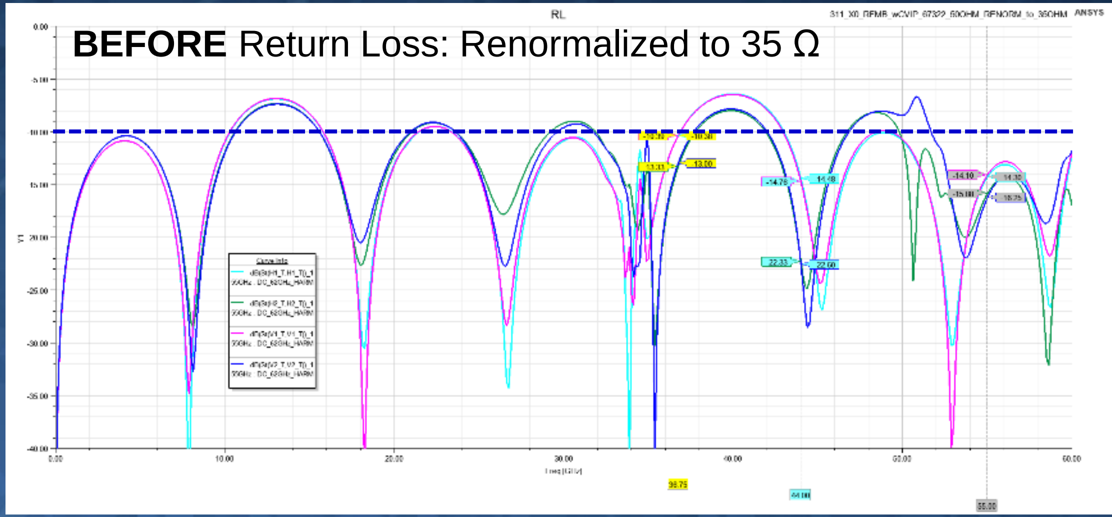
Original trace geometry for 50 Ω loopback and direct connections

35 Ω Impedance Change for MB Signals

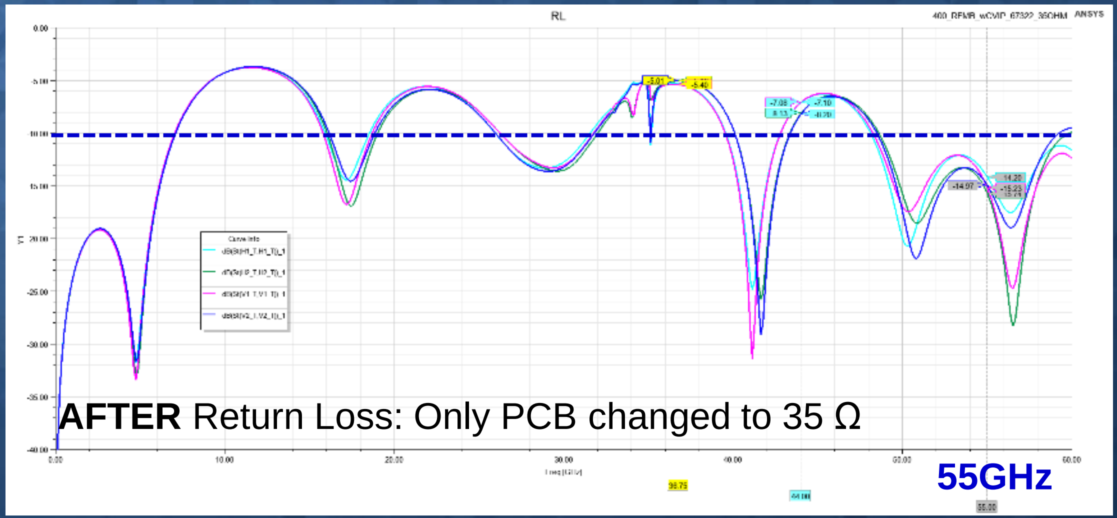
- **Initial simulation results for loopback path show that only changing PCB layout creates multiple impedance discontinuities in signal chain:**

  DUT @ 35Ω → Probe @ 50Ω → PCB @ 35Ω → Probe @ 50Ω → DUT @ 35Ω

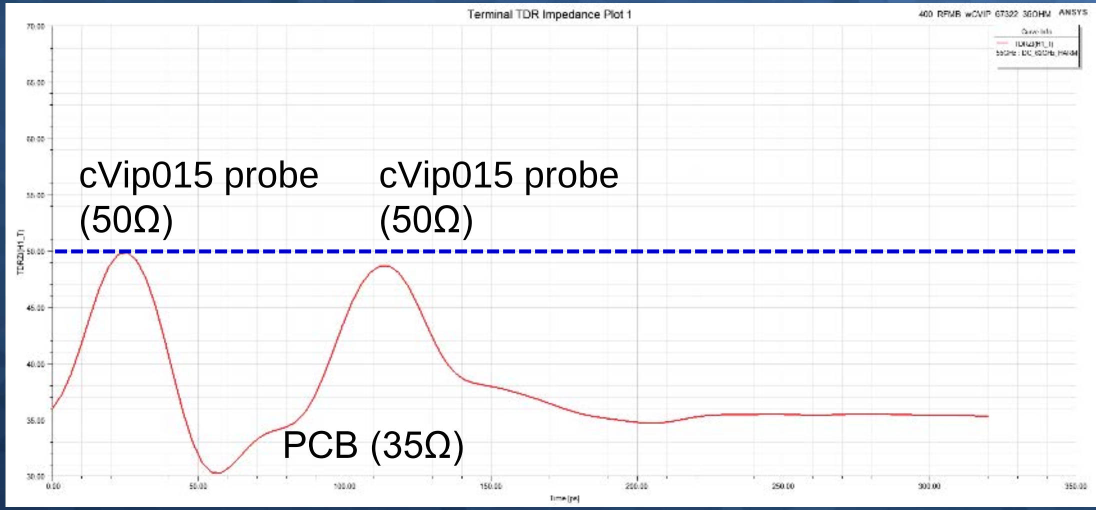
-10dB



-10dB



50Ω



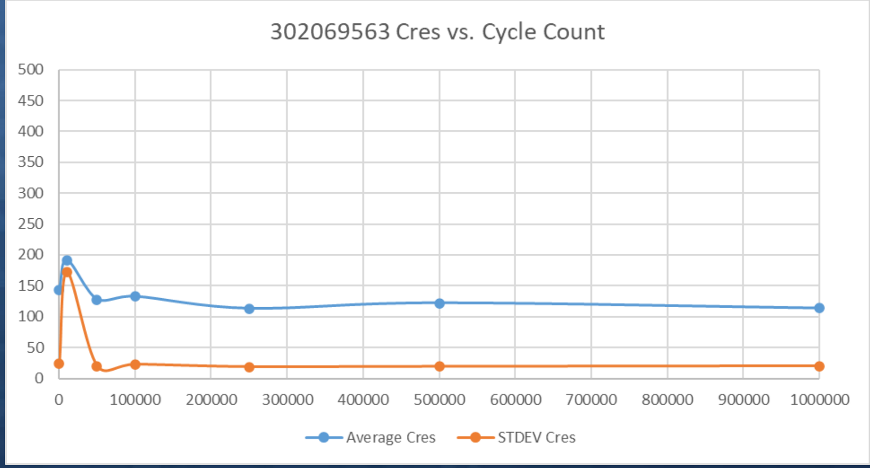
Performance is even worse than before starting redesign!

35 Ω Impedance Change for MB Signals

- **Requirement: reduce impedance of probehead cross-section to match 35Ω PC trace impedance**
- **Possible solution: reduce gap between cViper 0.15mm pitch signal probe and ground probe(s) using larger diameter probe**
- **Problem: Signal pin probe and ground probe behind signal pin are at maximum diameter due to spacing, and cannot be enlarged**
- **Preferred Solution: Increase diameter of ground probes shown circled in red**

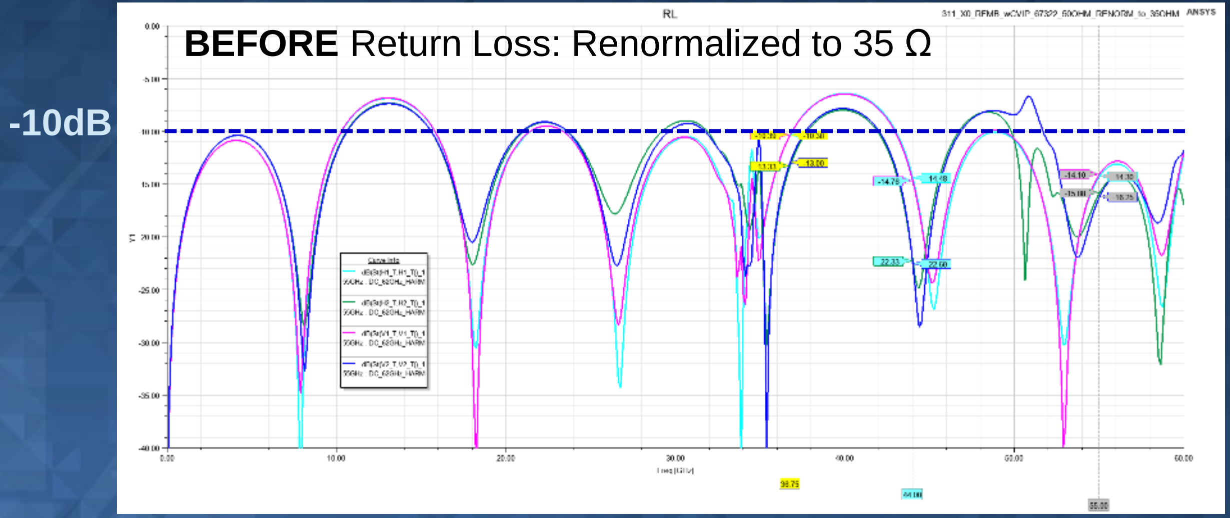
35 Ω Impedance Change for MB Signals

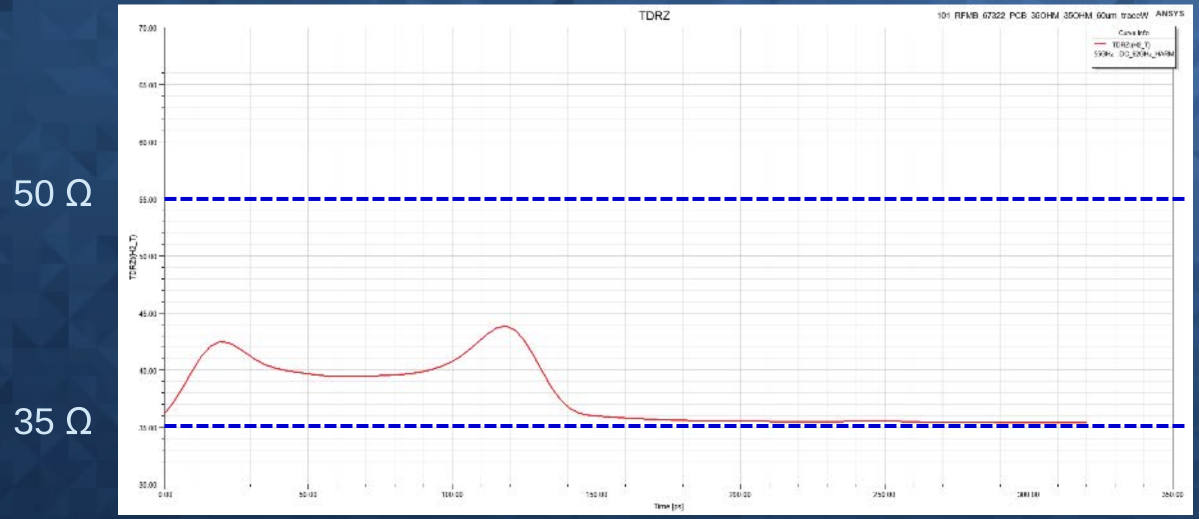
- **New wider Ground probe compares with original cViper signal / Ground probe:**
  - Same 3.1mm test height and compliance range
  - Same crown tip dimensions and geometry
  - Same spring force at test height
  - Wider barrel diameter
  - Wider plunger diameter
  - Equivalent or better Cres performance

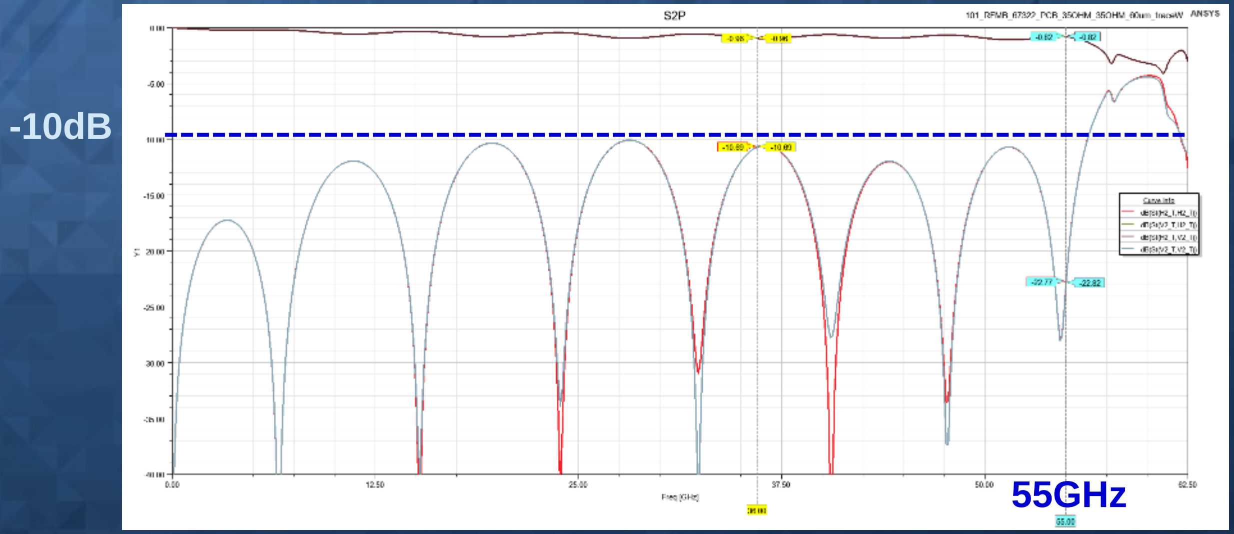


35 Ω Impedance Change for MB Signals

- **Simulations of RFMB Loopback with model of new cViper Ground probe show more uniform impedance match and improved Return Loss**
- **Minimum cViper Impedance: ~42 Ω**
- **Reduced stripline trace width to better match cViper impedance**

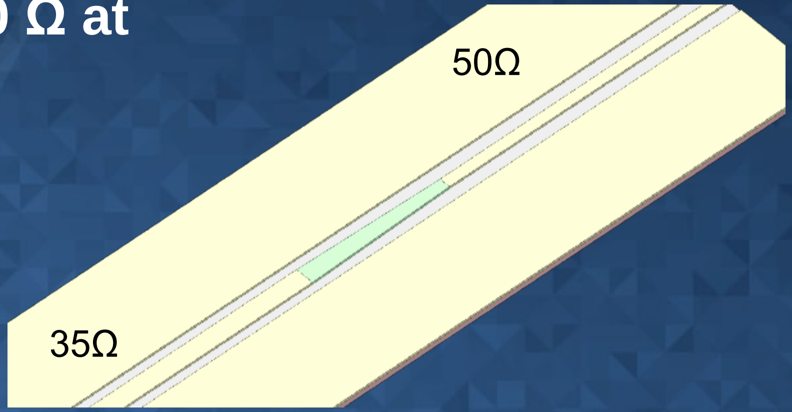


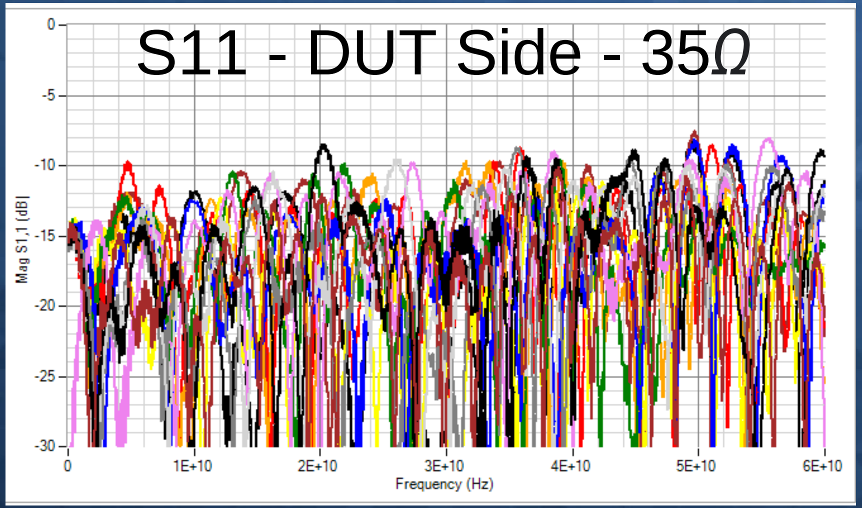


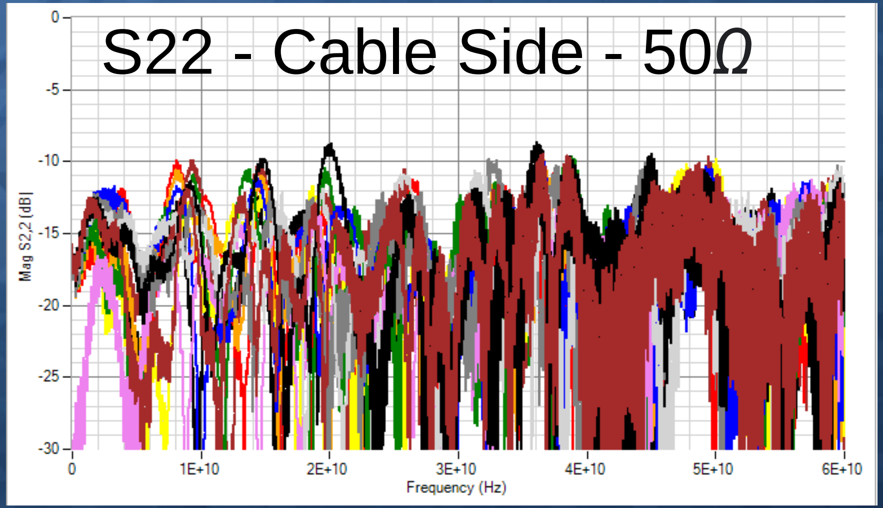


35 Ω Impedance Change for MB Signals

- Final addition: space transformer on PCB to return to 50 Ω at connector
- 35 Ω cViper stackup + PCB redesign for 35 Ohm was implemented and measured
- Measurements (including probe head and cables) confirm that simulated performance is achieved

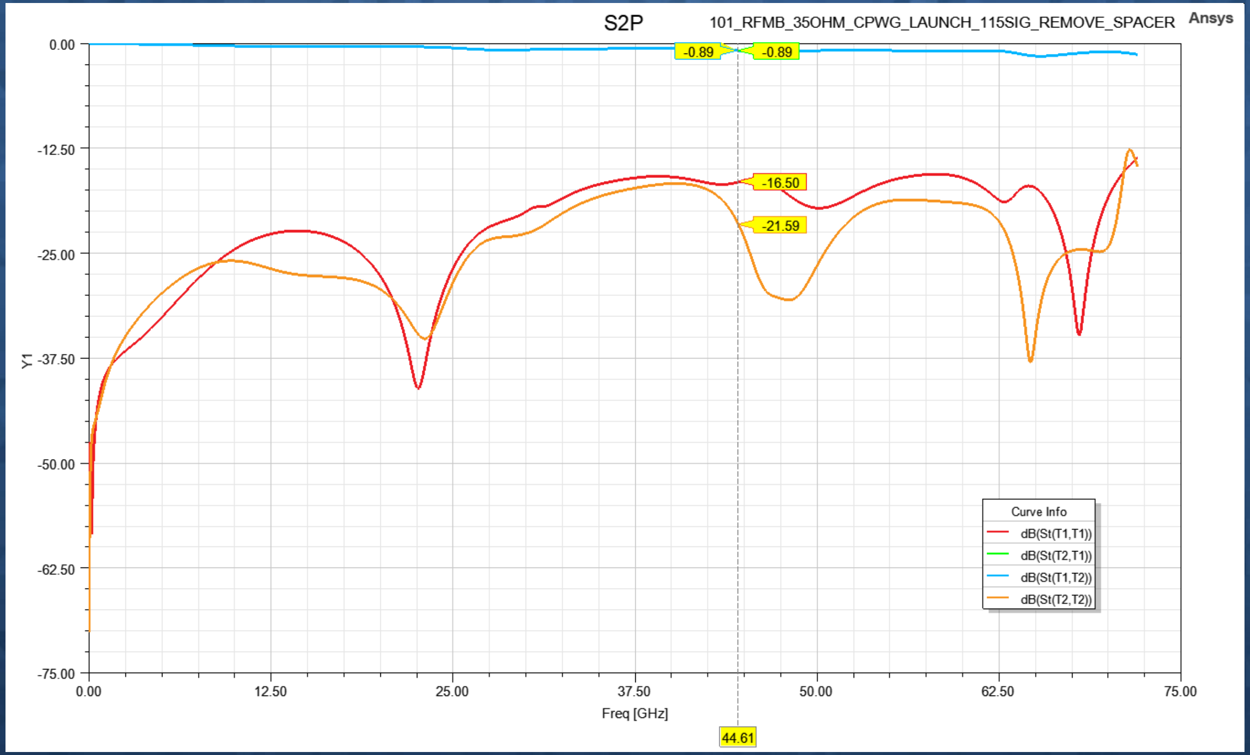






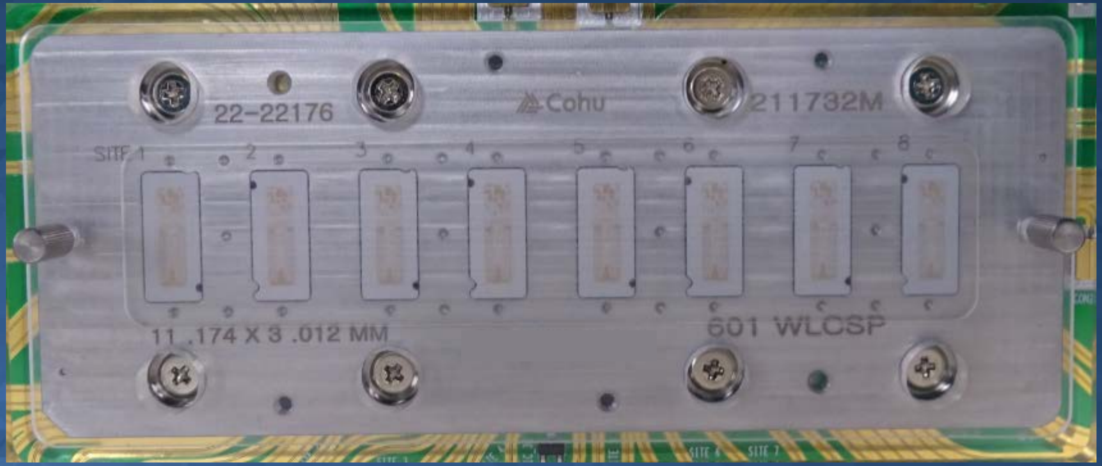
35 Ω Impedance Change for MB Signals: Next Steps

- **Customer requesting further performance enhancements**
- **Additional probe/cross-section changes expected to provide better than -15dB RL up to 75GHz**



Probehead – Probe Card Alignment: Objectives and Methods

- **Objective: ensure that probe head can be removed and exchanged between PCBs without requiring manual re-alignment process**
- **Methods:**
  - Monte Carlo analysis of stack-up tolerances in existing design
  - Implement more robust alignment pins with reduced alignment error
  - Add fiducial features on PCB to improve drilling accuracy of alignment holes
  - Simplify assembly to reduce errors across multiple site locations



Probehead – Probe Card Alignment Improvement: Methods

1. **Holes to verify alignment with PCB fiducials**
2. **Simplified, more robust and asymmetric alignment pins**
3. **Single-piece Probe Retainer Plate for improved alignment consistency across all sites**
4. **Improved tolerances in key areas affecting alignment**

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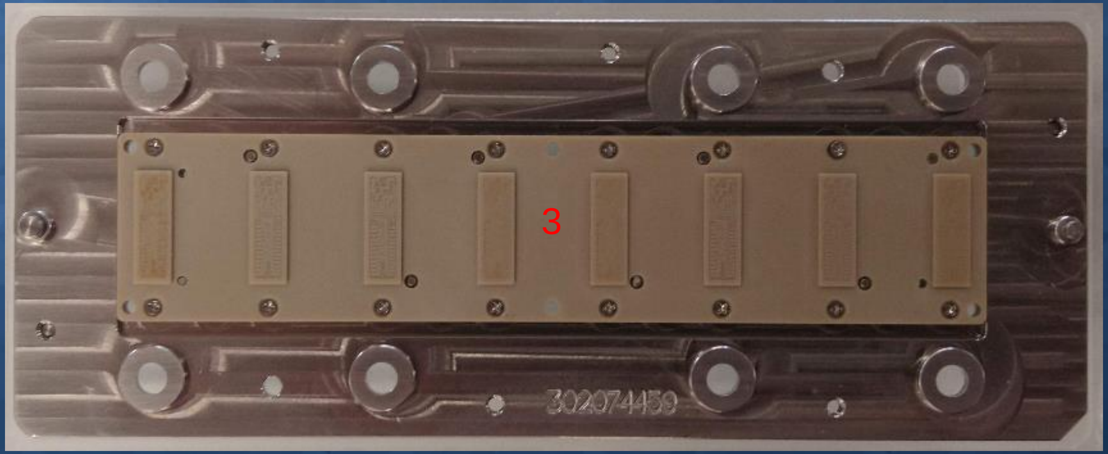

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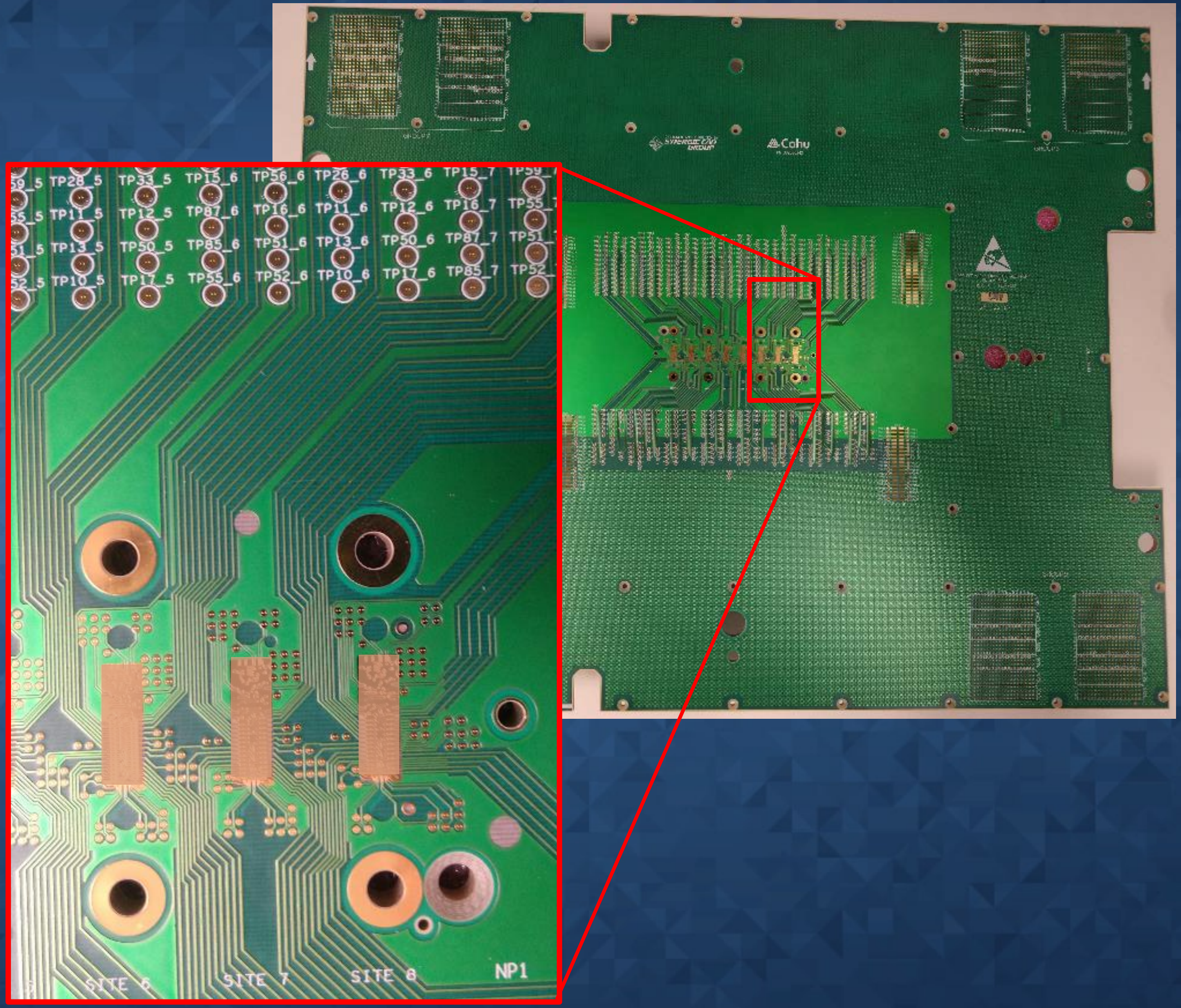
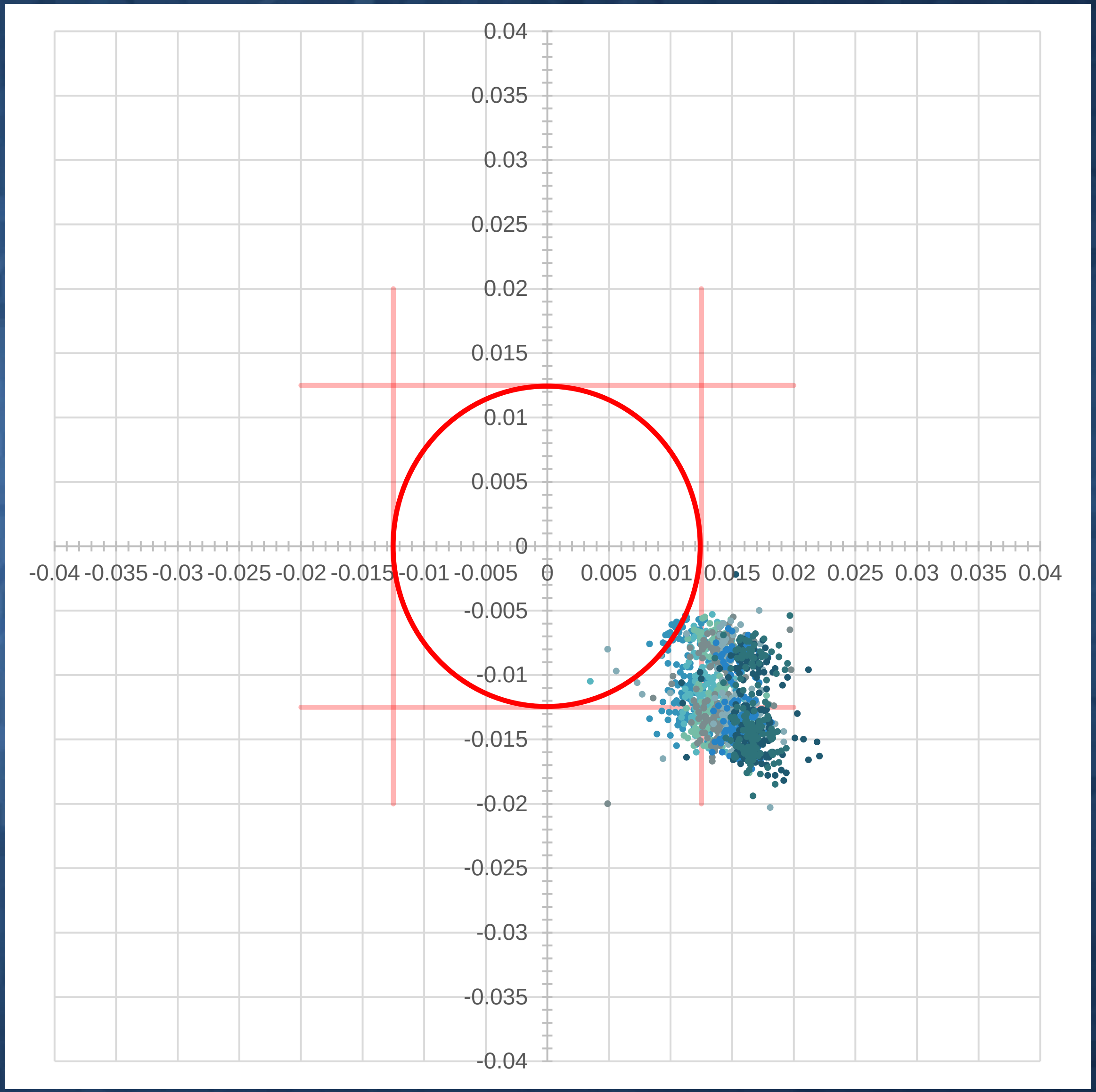
Probehead – Probe Card Alignment: Results

- **New test PCB layout created with fan-out to tester pads; allows full electrical testing using either:**
  - Flying prober
  - Probe Card Analyzer (configured with 93k Probe Card Interface)
- **Includes fiducial features to improve accuracy for drilling alignment holes**
- **DOE process used to verify interchangeability of multiple PCBs and probe heads**
- **Zeiss visual inspection used to verify accuracy of feature placement**



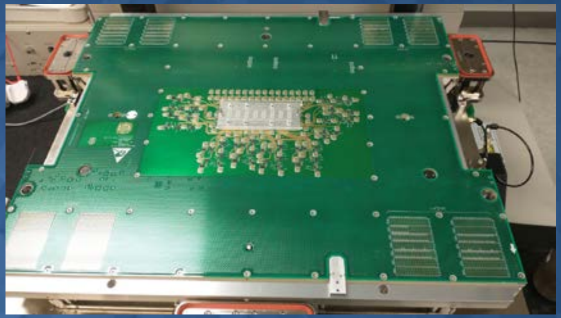
Probehead – Probe Card Alignment: Results

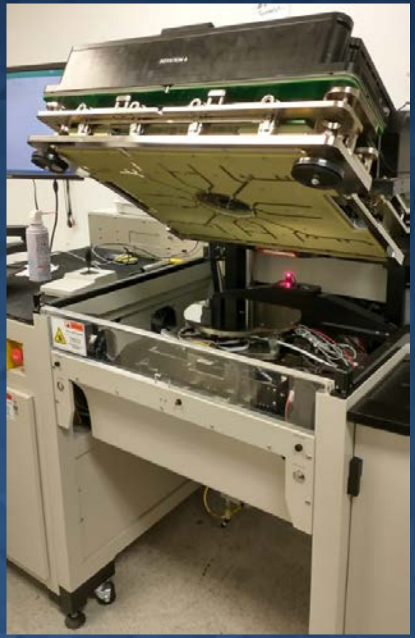
- Measurement of pad locations vs. alignment hole locations shows X-Y offset resulting from incorrect drilling process
- Distribution of pad locations is within required tolerances
- Correcting drill offset issue results in expected alignment on all pads

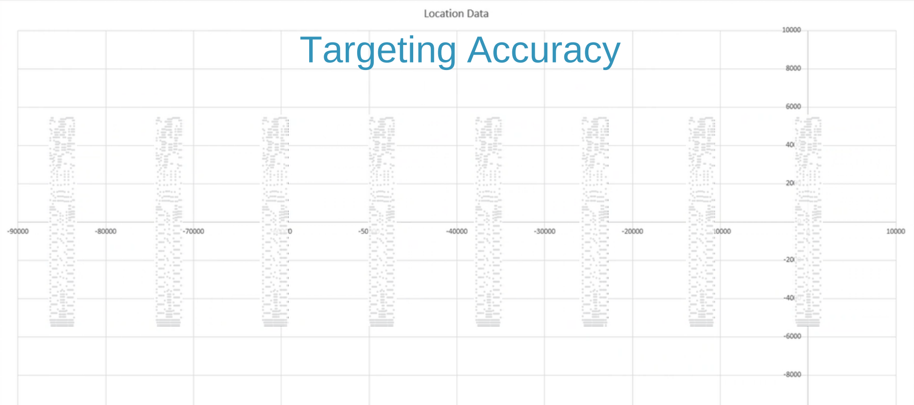


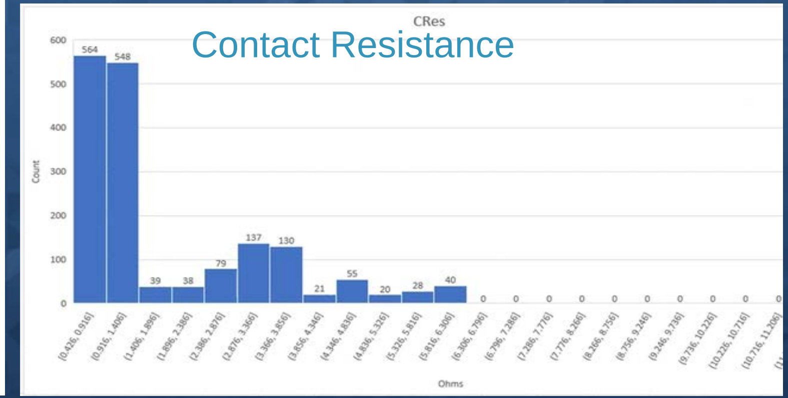
Probecard Analyzer (PCA) Implementation

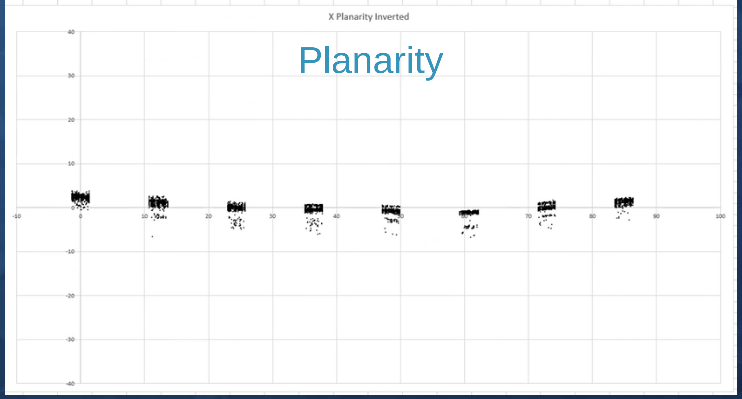
- ITC Probilt with custom PCI for mmWave probe card design
- Provides full Probecard testing coverage prior to shipment
- Probecards evaluated on PCA and correlated to internal probehead testing
- 90% reduction in test time for targeting accuracy, contact resistance and planarity measurements







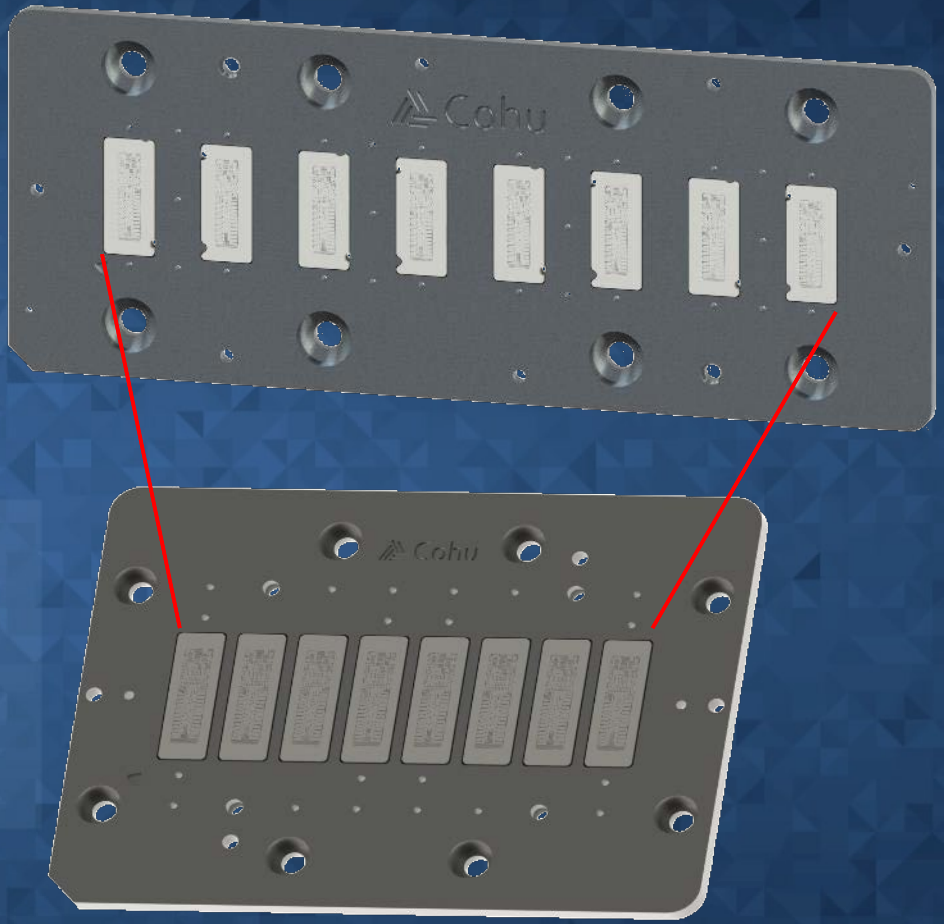




Peter Cockburn

Probehead Layout: Objective

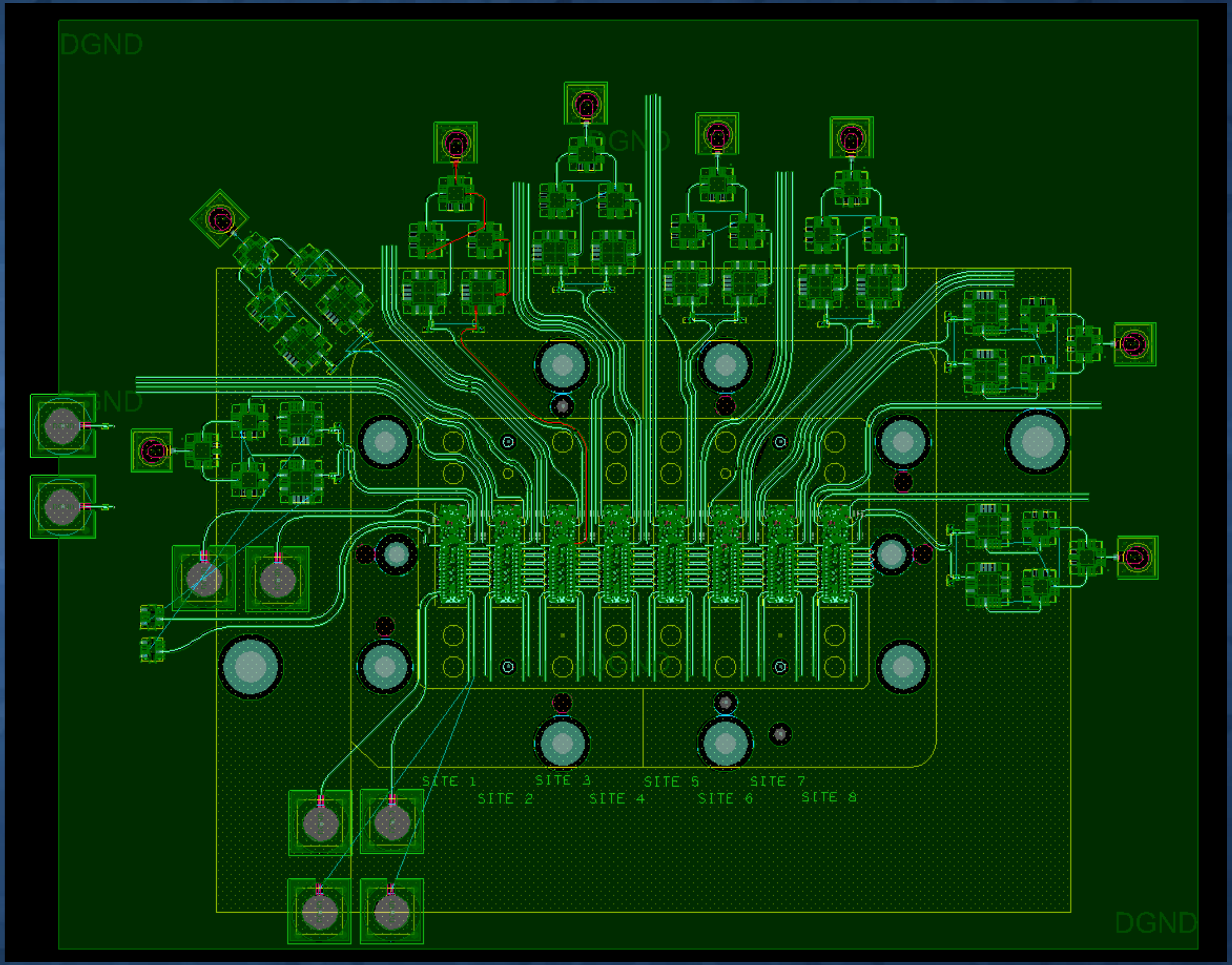
- **Original Probehead layout created was 1x8 with 3 skipped die between sites**
  - Required for routing of RF direct connection and loopback paths
- **Problem: reduced touchdown efficiency at edge of wafer**
- **Goal: production-optimized layout 1x8 with 1 skipped die**
  - Simplified layout required
  - Benefit of improved touchdown efficiency and lower COT



29 die → 15 die span = 48% shorter

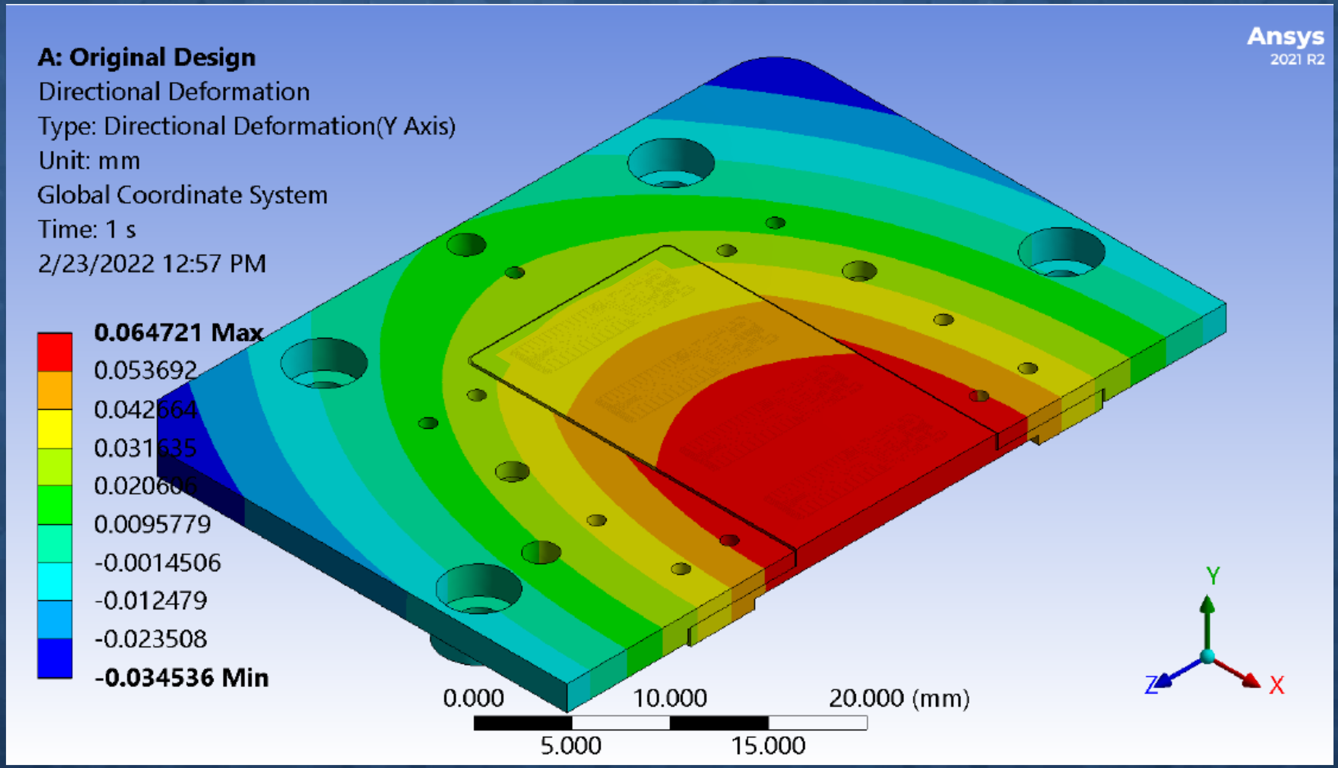
Probehead Layout: Methods

- Agreed simplified schematic and performance goals with customer, e.g. minimize losses on IF receive path
- New probehead layout optimized to meet bowing requirements
- PCB layout feasibility study confirmed routing for key RF signals can be accommodated within new DUT spacing and probehead constraints
- Overall, 1x8 with 1-skipped die implementation looks possible!



Probehead Layout: Results (1)

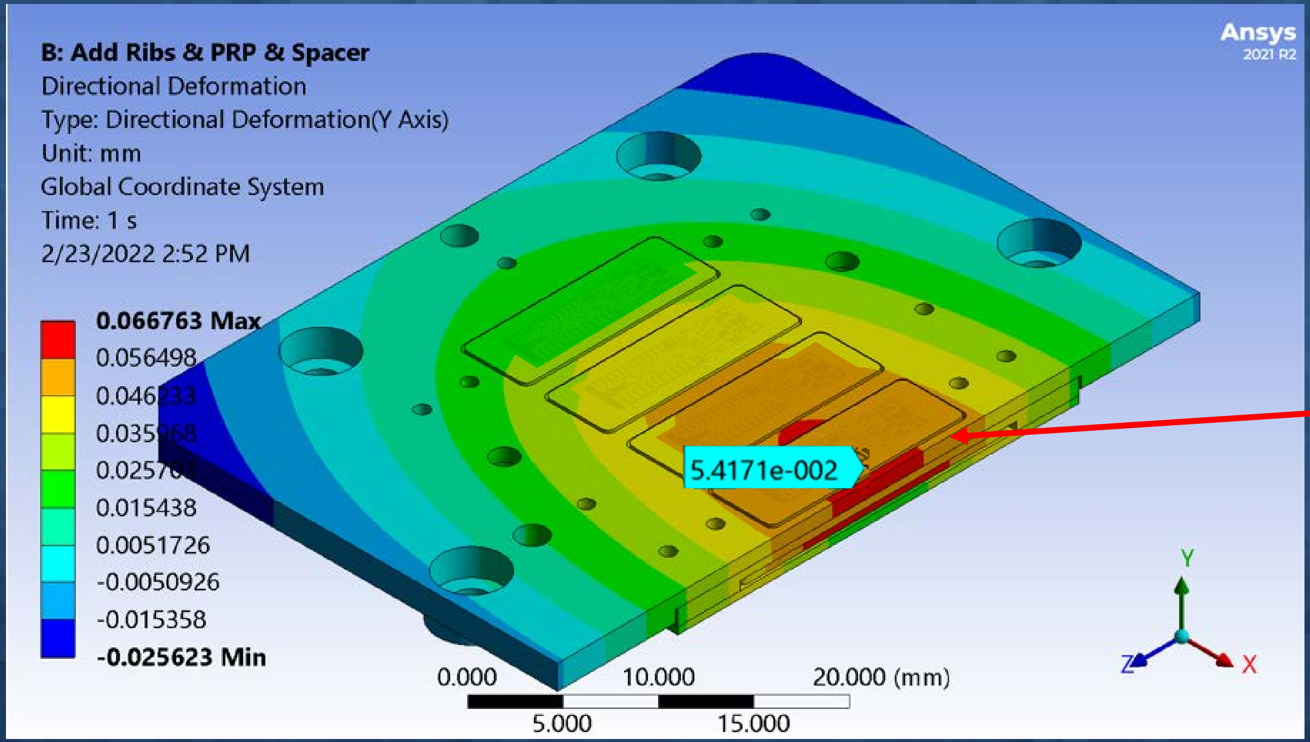
- **Initial Bowing Analysis confirmed Max Y directional deformation 65 µm: goal is <50µm**



Design uses 1-piece ceramic body across all sites and stainless steel frame

Probehead Layout: Results (2)

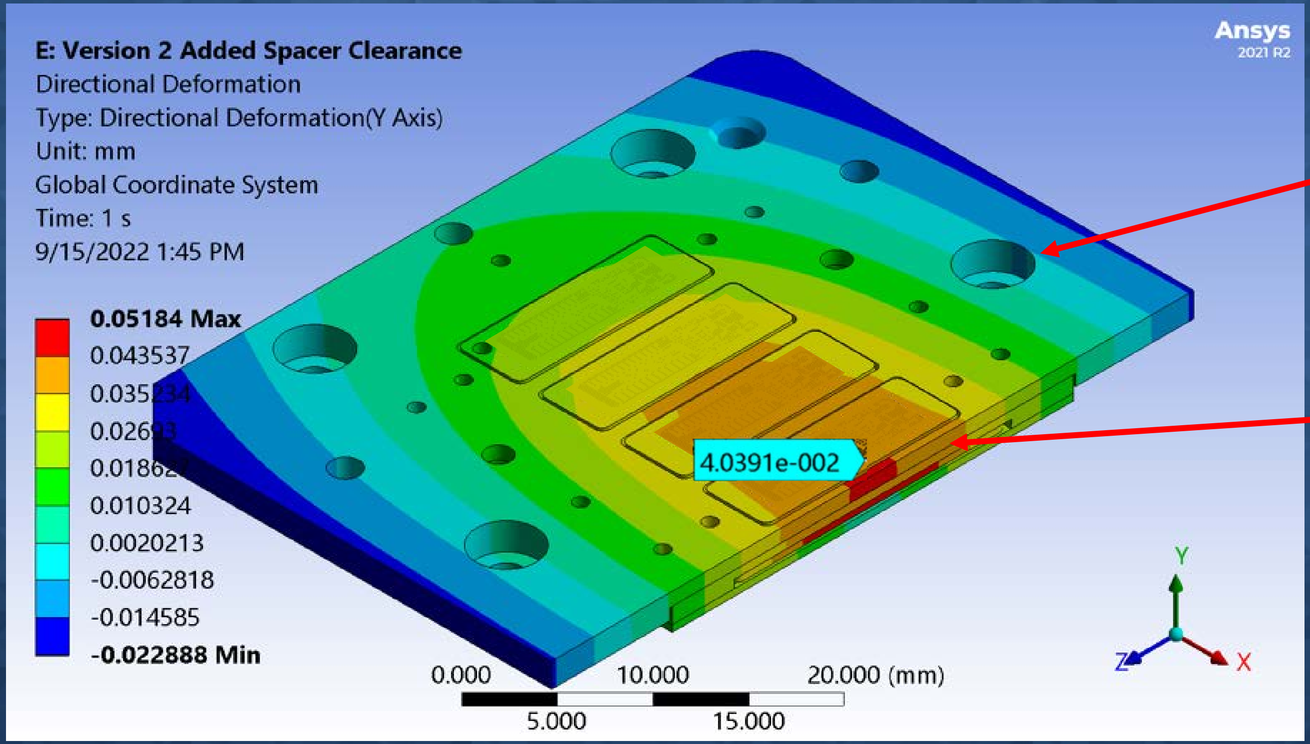
- **Bowing Analysis after initial redesign to add strengthening ribs: Max Y directional deformation 67 µm, 54 µm at body**



Additional SS support structures between DUT sites

Probehead Layout: Results (3)

- **Bowing Analysis after further redesign:**
  Max Y directional deformation 52 µm, 40 µm at body

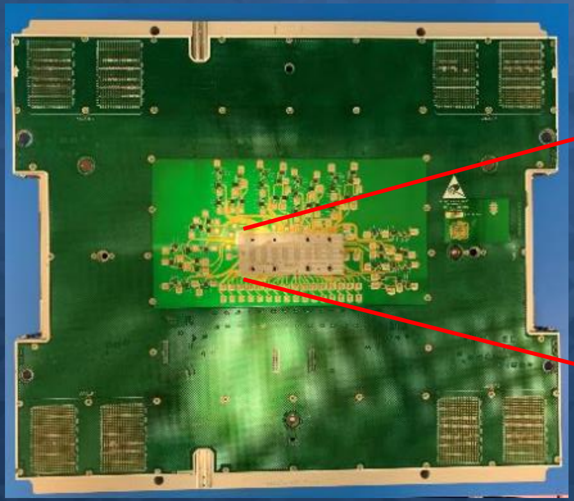


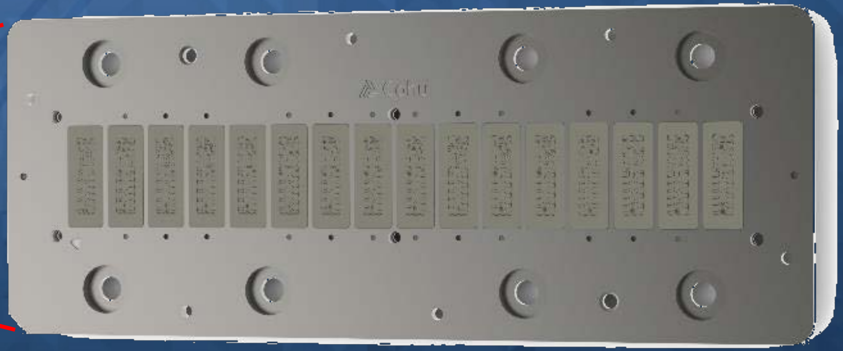
Move attachment points closer to DUT sites

Additional SS support structures between DUT sites

Probehead Layout: Follow-On Work

- Complete signal routing for all 8 sites
- Tune spacing between loop-back structures and probehead attachment features
- Design shorter RF cables to meet IF loss budget
- Routing and component placement for 16-site layout





Summary

- **Initial mmWave probe card design has been deployed and successfully used**
- **Design has evolved to meet new customer needs, improve usability and test efficiency**
  - 35 Ω impedance for mmWave MB signals
  - Better probe head to probe card alignment
  - Denser multisite test pattern
- **Each enhancement requires specific validation activities**
- **Additional design improvements are ongoing to further improve RF performance**
- **Thanks to all the Cohu and Synergie-CAD team members for their significant contributions to this project!**