SWTEST

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2022 CONFERENCE

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

Cohu

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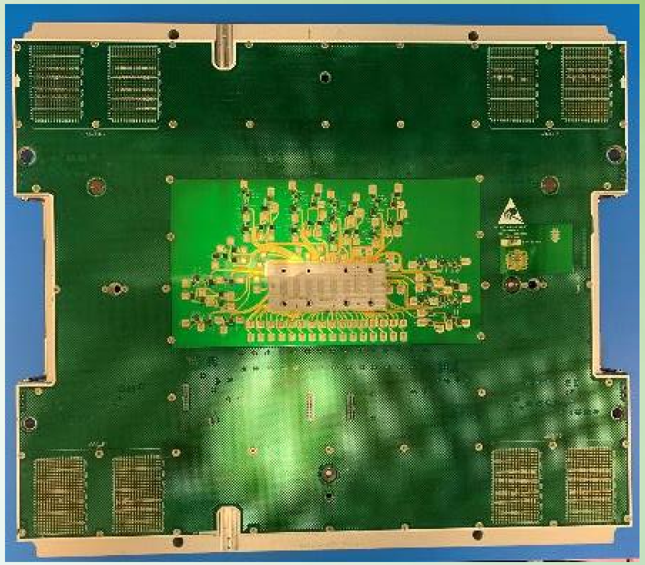
June 5 - 8, 2022

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
  - Multi-site Manual Actuator Performance
  - Probehead – Probe Card Alignment
  - More Compact Site Layout for Improved COT
- **Summary and Acknowledgements**

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

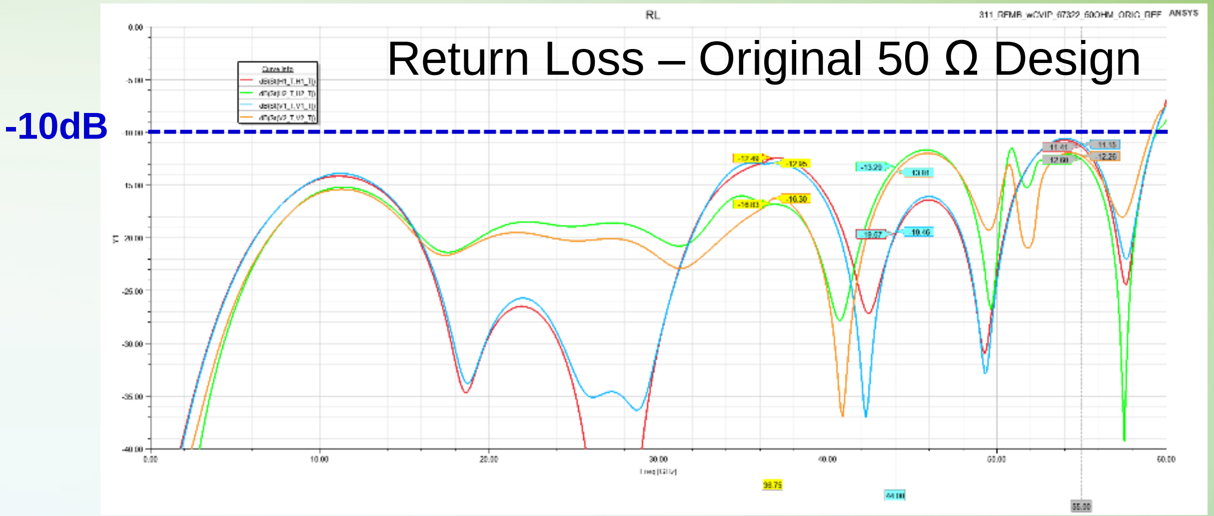
- **In SWTest 2021, we presented a probecard for WLCSP mmWave devices** with some key requirements:**
  - 55GHz BW for mmWave MB signals (direct test + loopback)
  - 150um pitch, direct-attach PCB technology
  - Octal site with 600+ I/Os per site
  - Manual Test option for all eight sites
- **Design 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
  - Improved multisite support using Manual Test option
  - Denser multisite test pattern

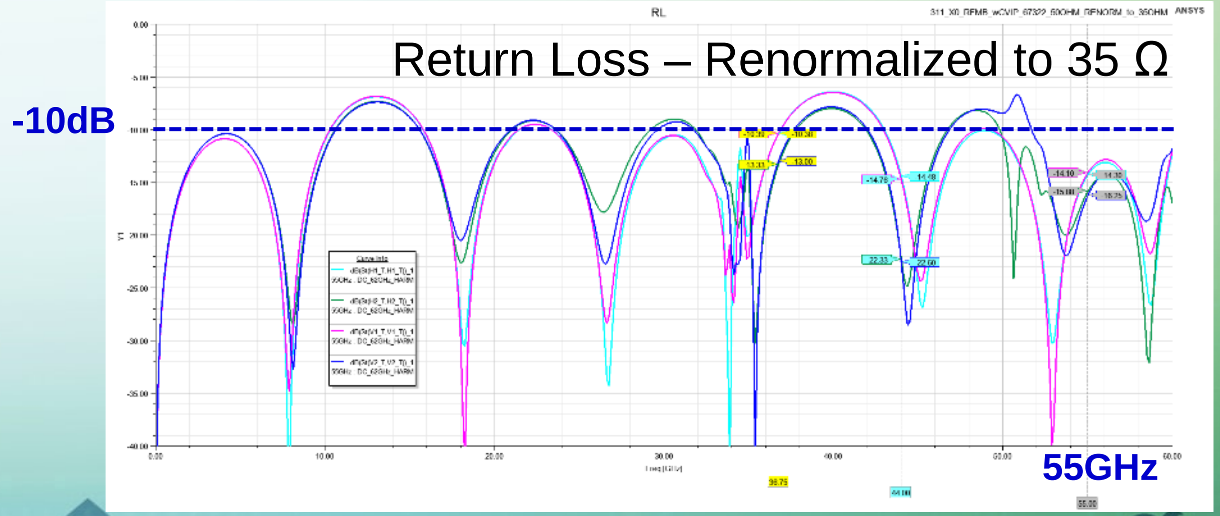


** SWTest 2021, Session #1 55GHz Octal-site Wafer Test Probecard for 5G mmWave devices; Jason Mroczkowski (Cohu – USA)

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**



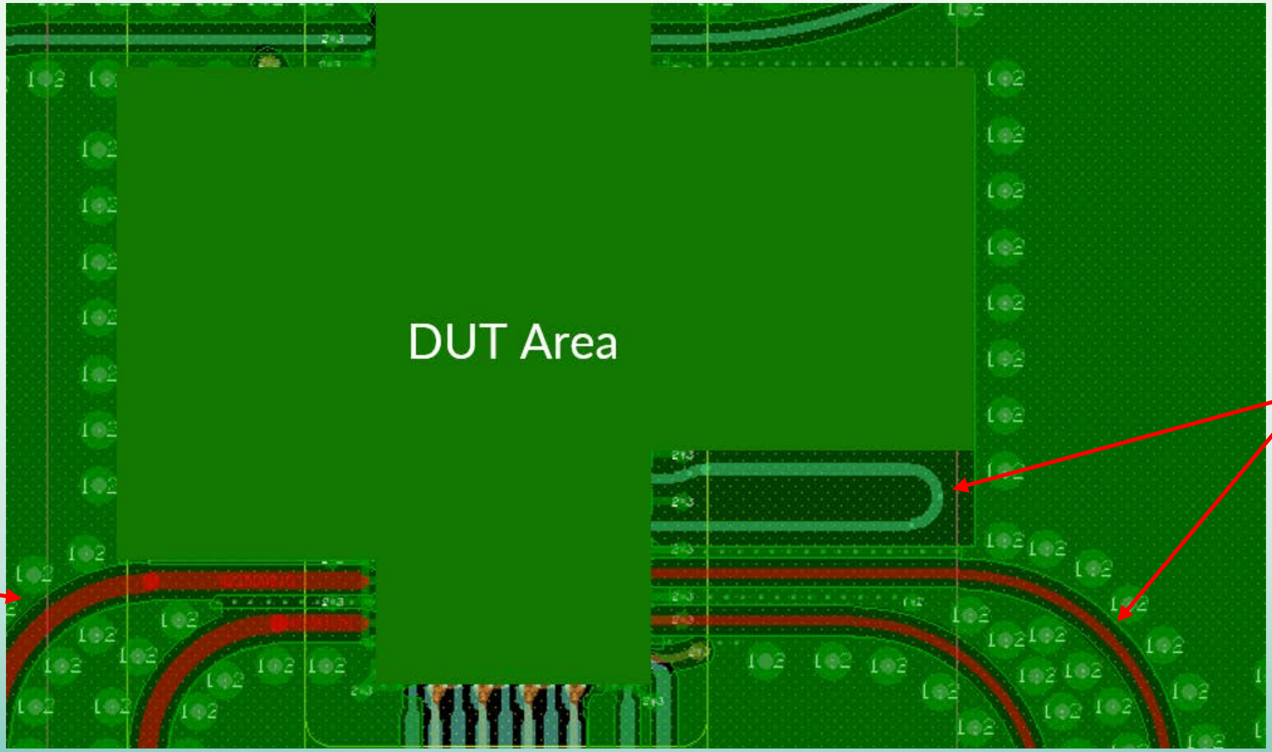


35 Ω Impedance Change for MB Signals

- 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

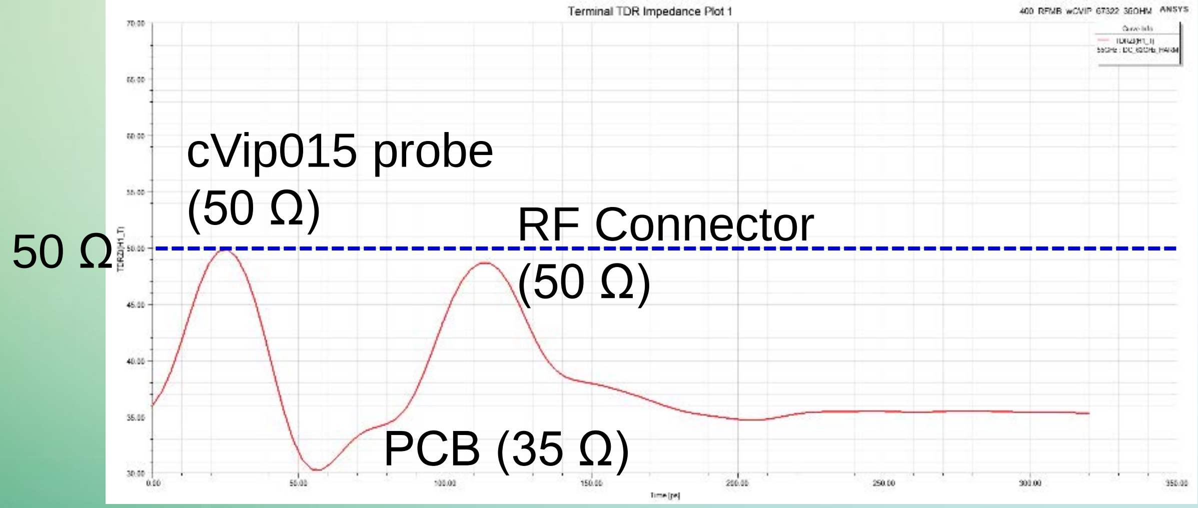


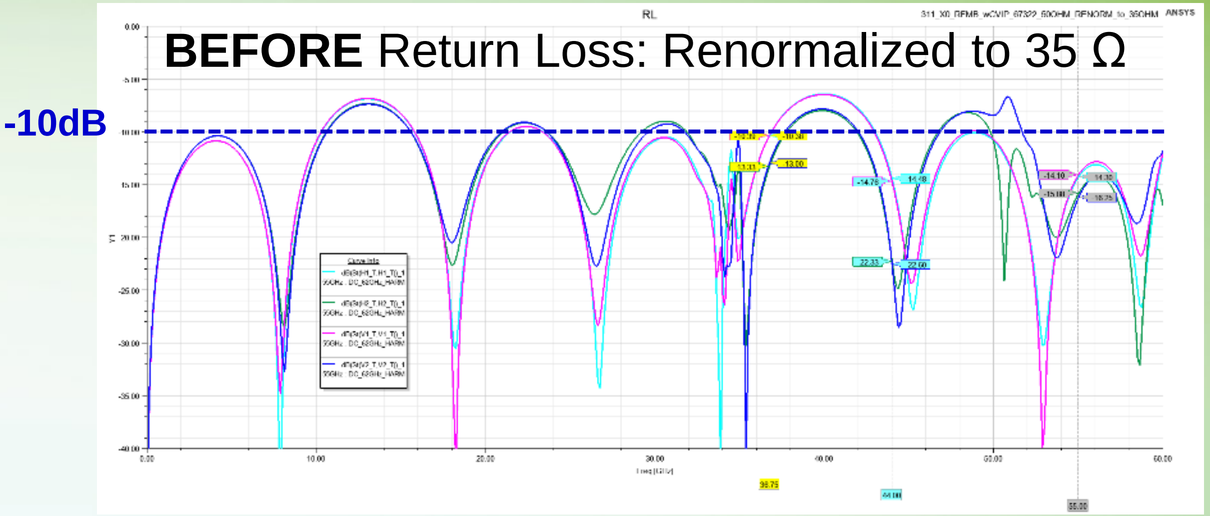
Original trace geometry for 50 Ω loopback and direct connections

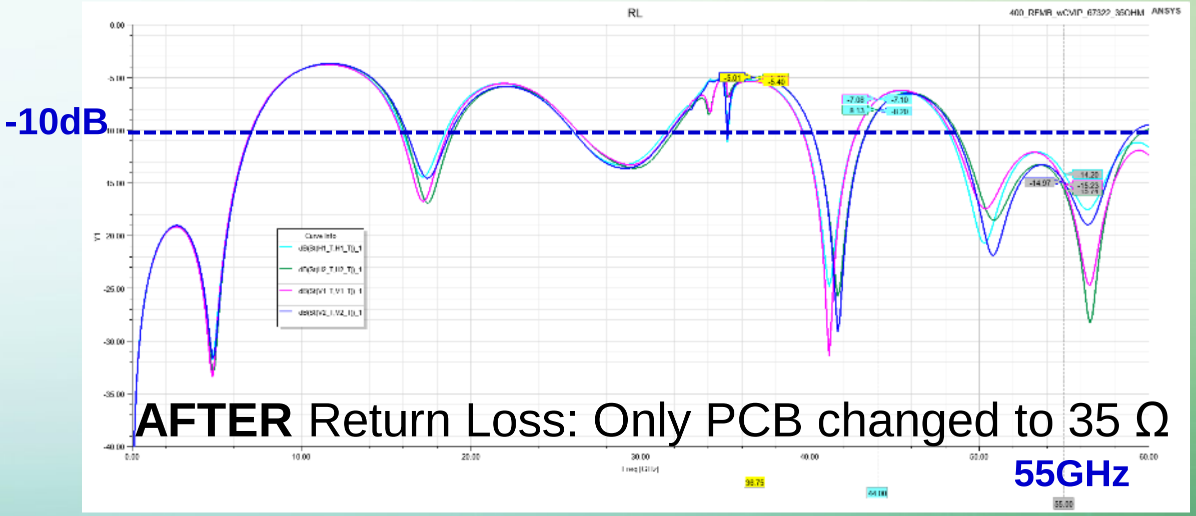
35 Ω Impedance Change for MB Signals

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

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



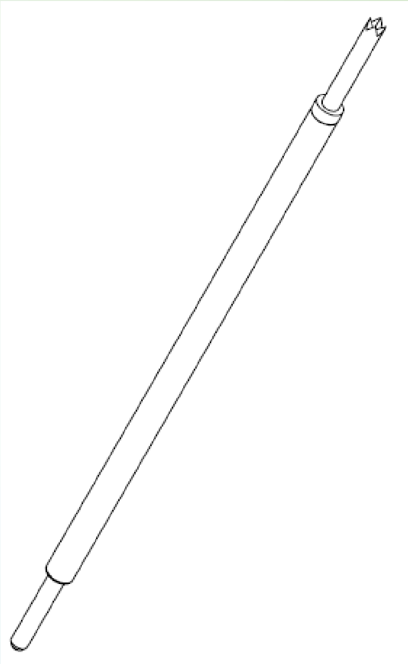


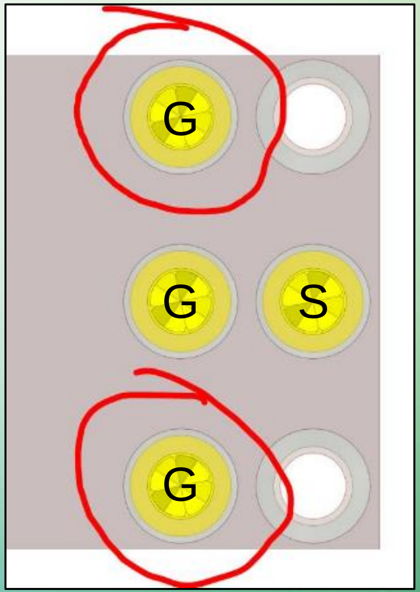


Performance is even worse than before starting redesign!

35 Ω Impedance Change for MB Signals

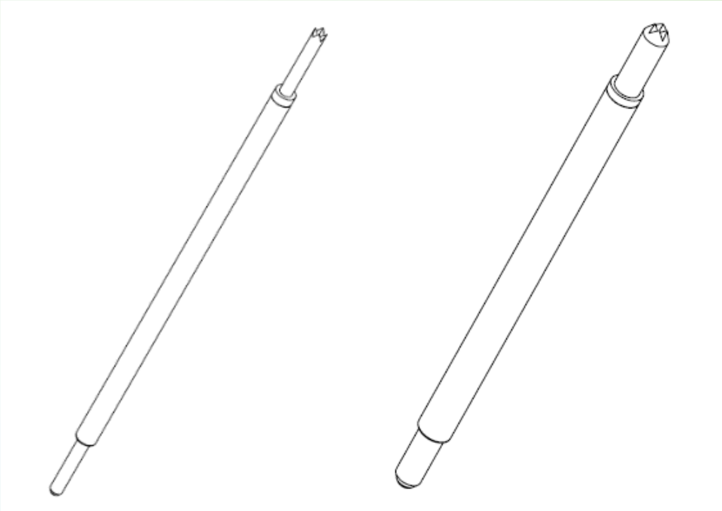
- Requirement: reduce impedance of probehead cross-section to match 35Ω PC trace impedance
- Possible solution: reduce gap between cViper 0.15mm pitch signal probe and ground probe(s) using larger diameter probe
- Problem: Signal pin probe and ground probe behind signal pin are at maximum diameter due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

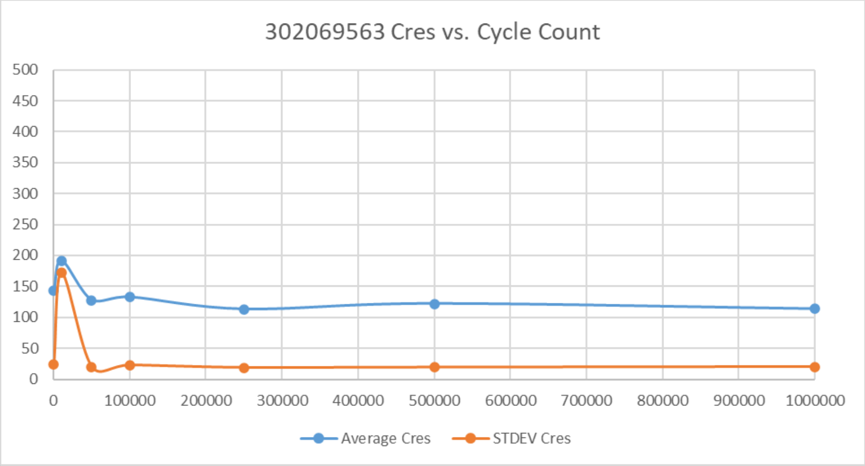




35 Ω Impedance Change for MB Signals

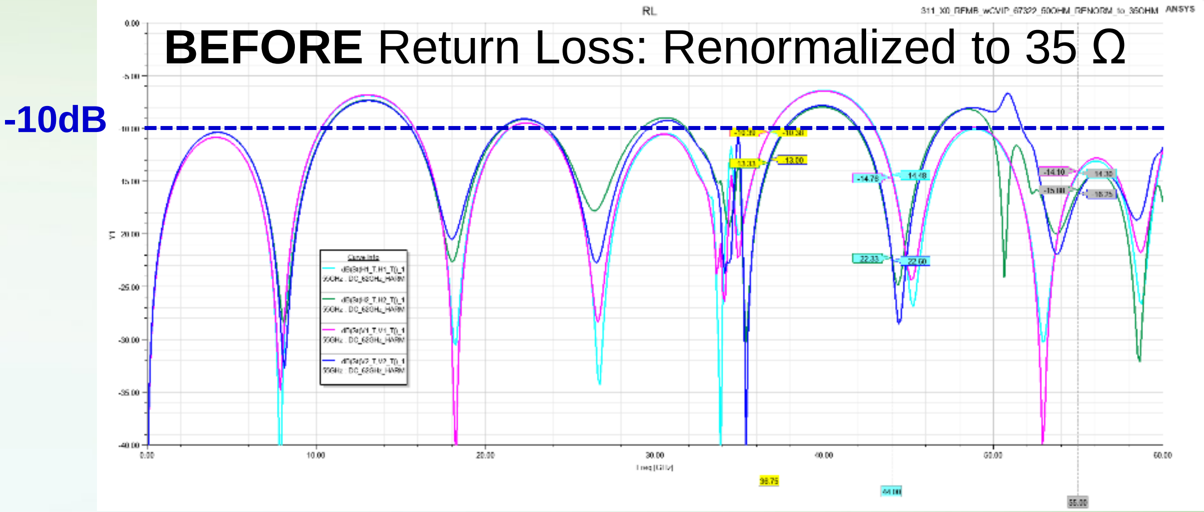
- **New wider Ground probe compares with original cViper signal / Ground probe:**
  - Same 3.1mm test height and compliance range
  - Same crown tip dimensions and geometry
  - Same spring force at test height
  - Wider barrel diameter
  - Wider plunger diameter
  - Equivalent or better Cres performance

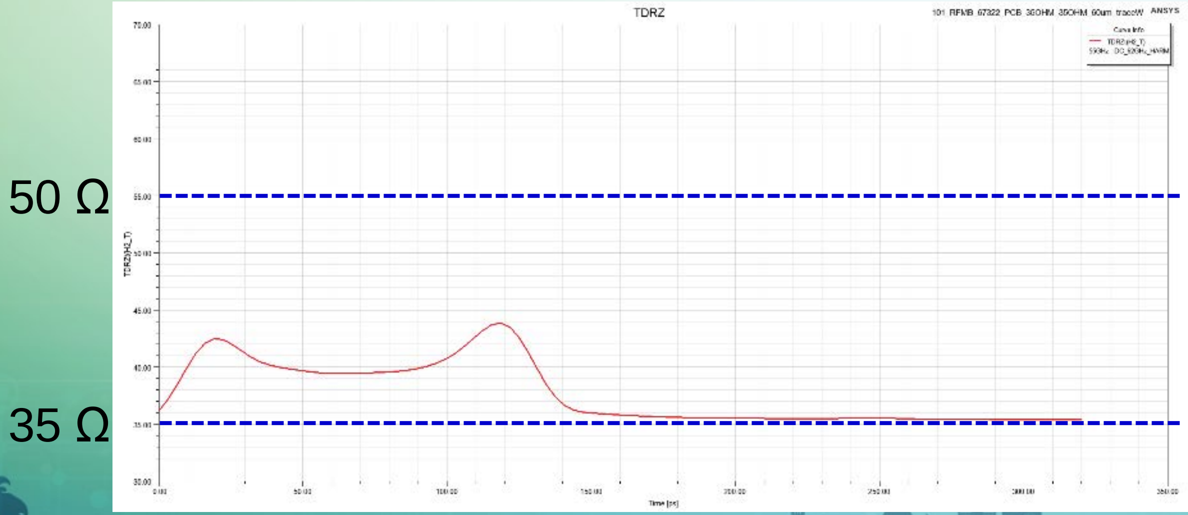


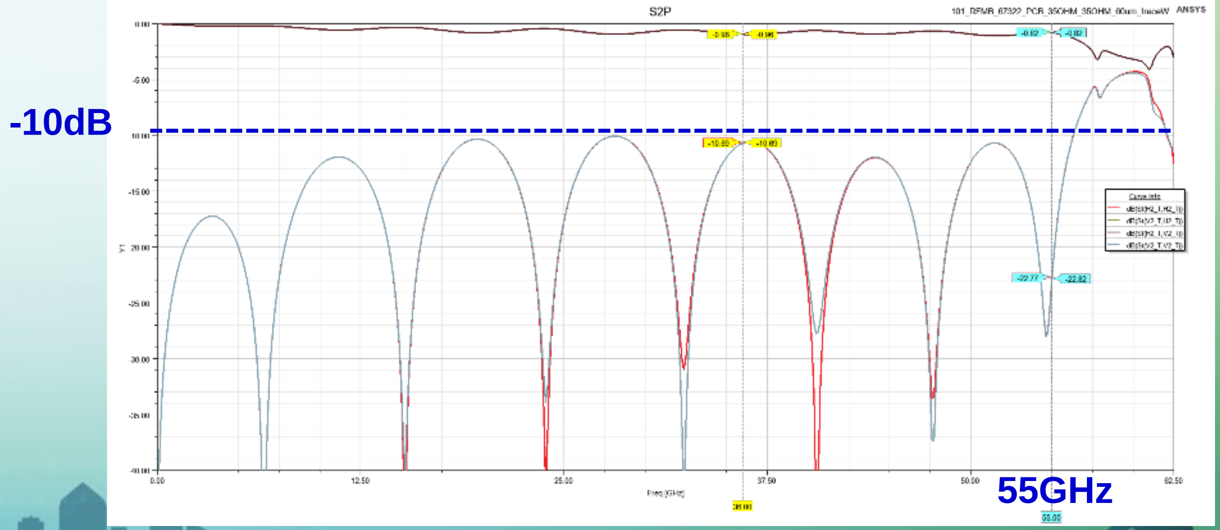


35 Ω Impedance Change for MB Signals

- 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

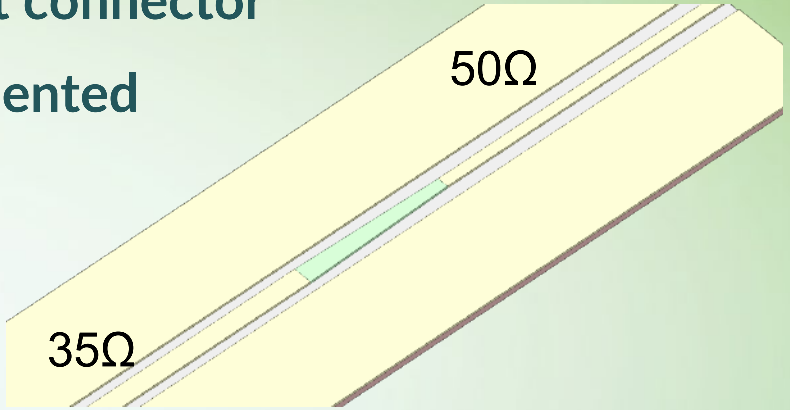


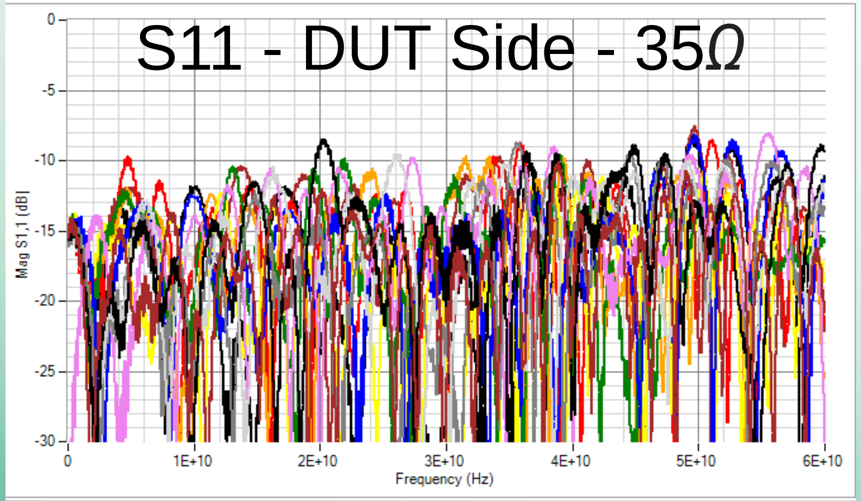


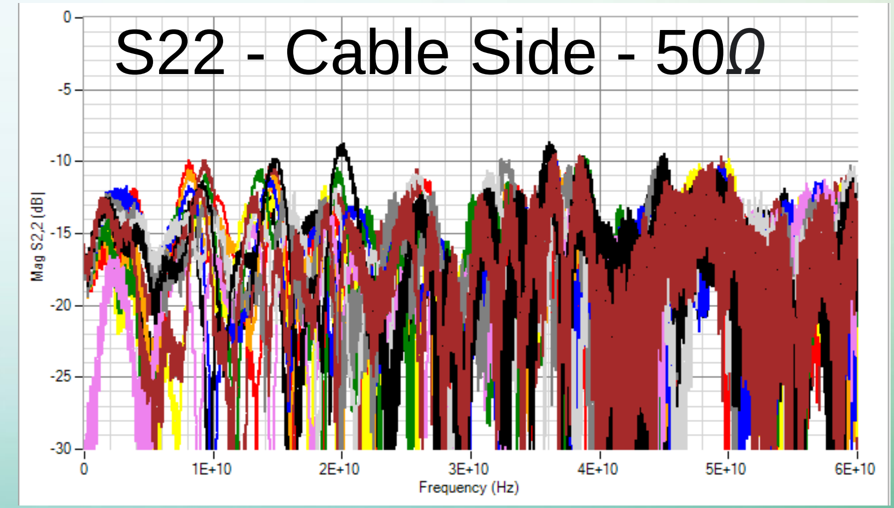


35 Ω Impedance Change for MB Signals

- **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 confirm that simulated performance is achieved**

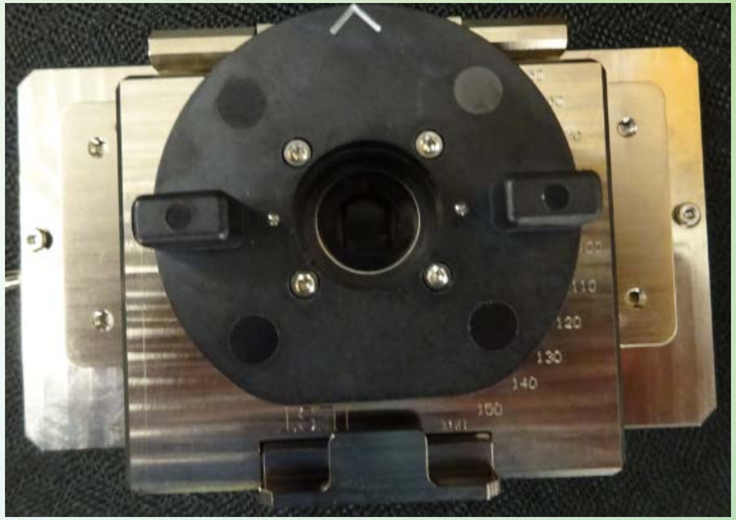


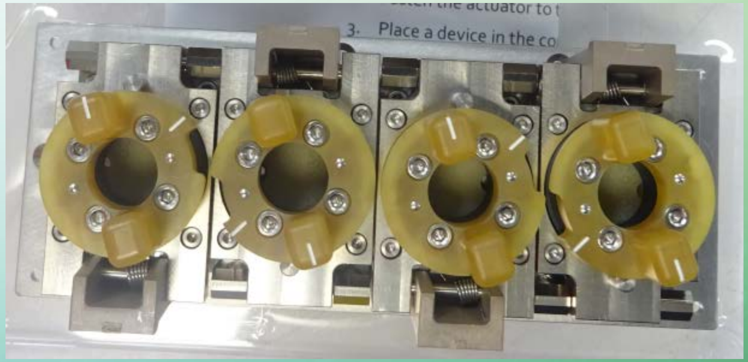




Manual Actuator: Objective

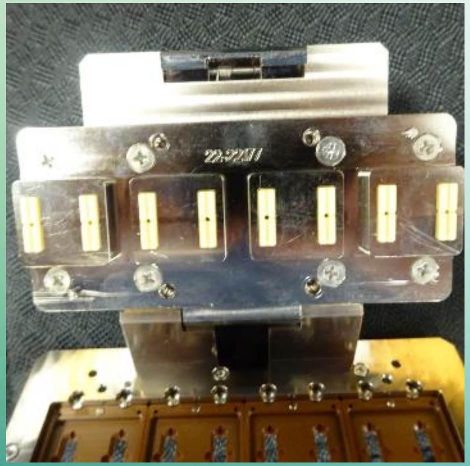
- Customer requirement to be able to test singulated die, e.g. at locations where wafer prober is not available
- Original “One-piece” design allowed for all eight sites to be clamped in a single operation
- Fine pitch requirements created challenges achieving good alignment and connectivity on all eight sites
- Original design was modified to simplify alignment, reduce tolerance stack-up across multiple sites and allow for package size variation

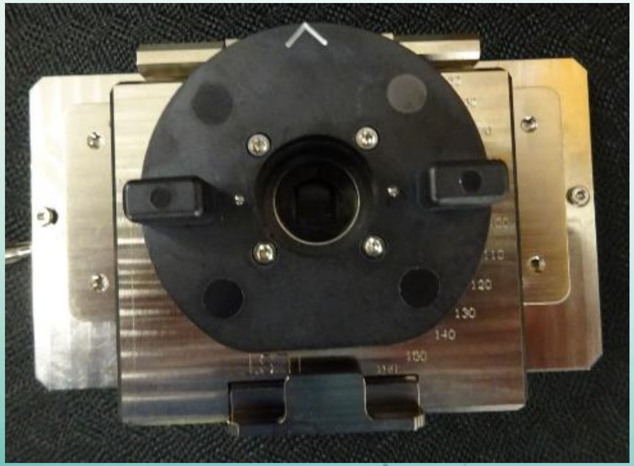




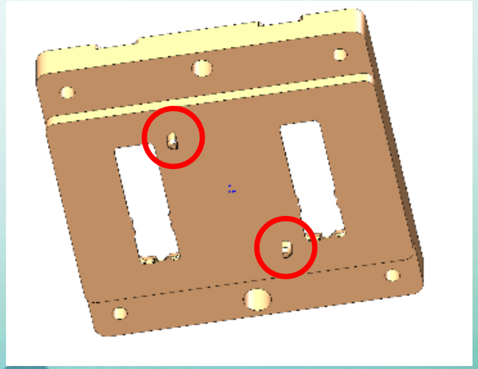
Manual Actuator: Methods / Results

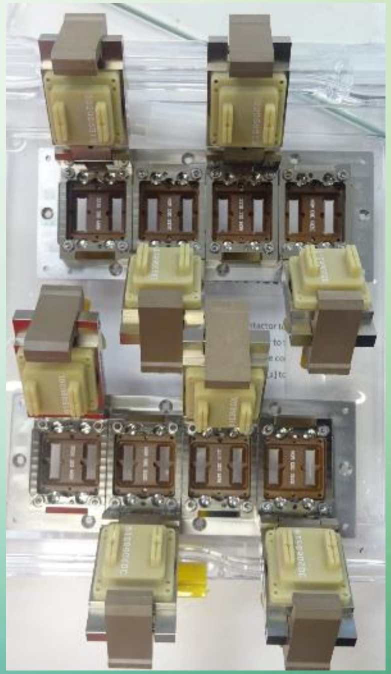
- Problem: Original MA design included Floating Alignment Plate (FAP) to ensure probes are shielded when no device is installed
- Spring-loaded FAP has inherent variation in Z-travel and X-Y position which is problematic at such a fine pitch





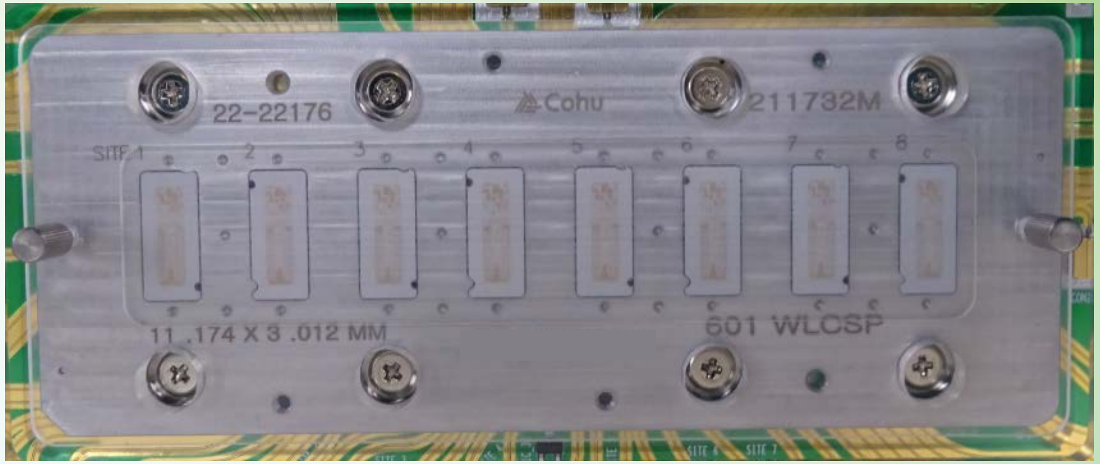
- The floating alignment plate is now a Manual Test Frame (MTF)
- To remove tolerance stackup between the probehead and MA, the MTFs have alignment bosses that align directly with the probehead body (shown below)
- New multisite design has localized alignment of each dual-site MTF to the probehead body





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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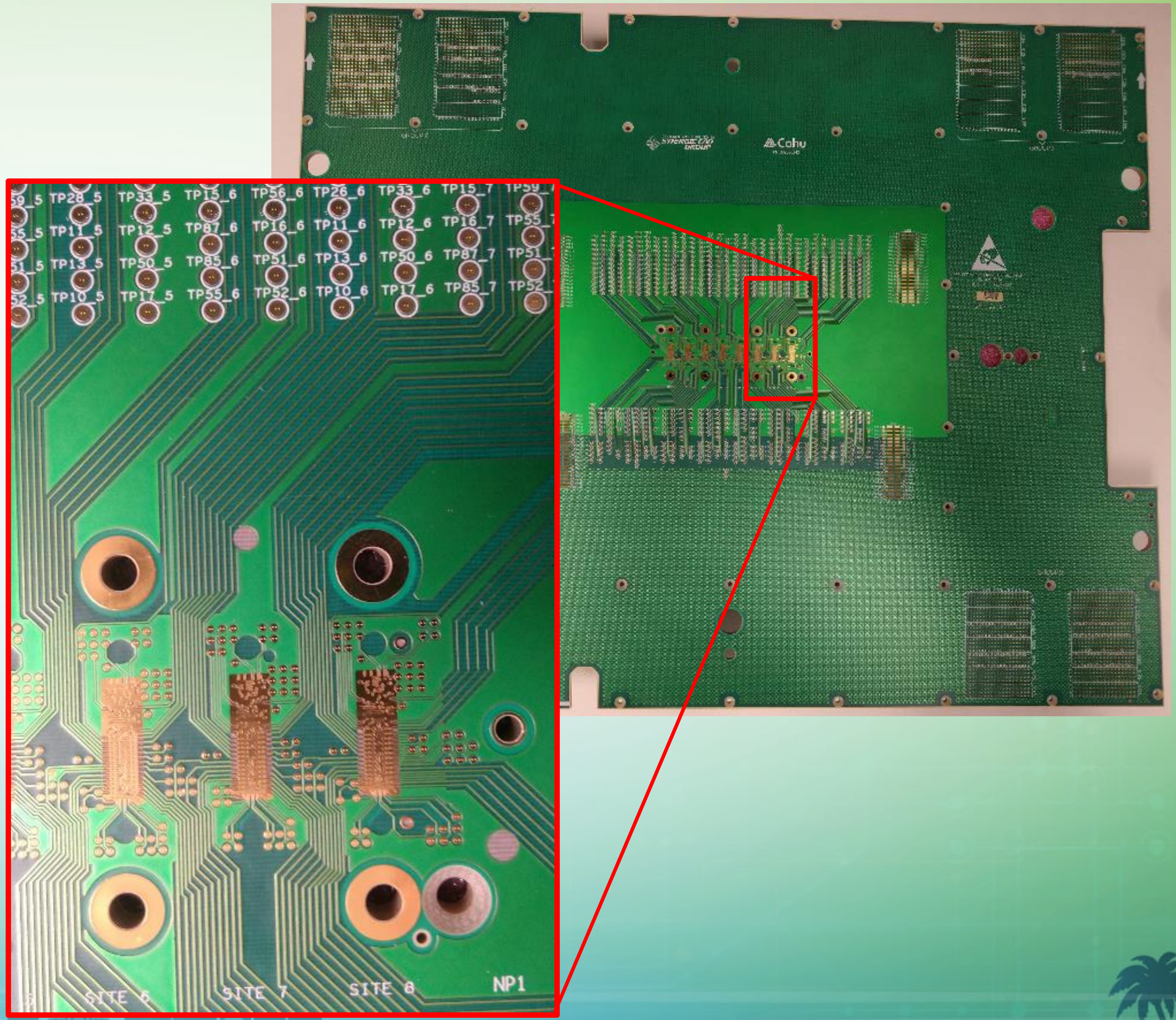
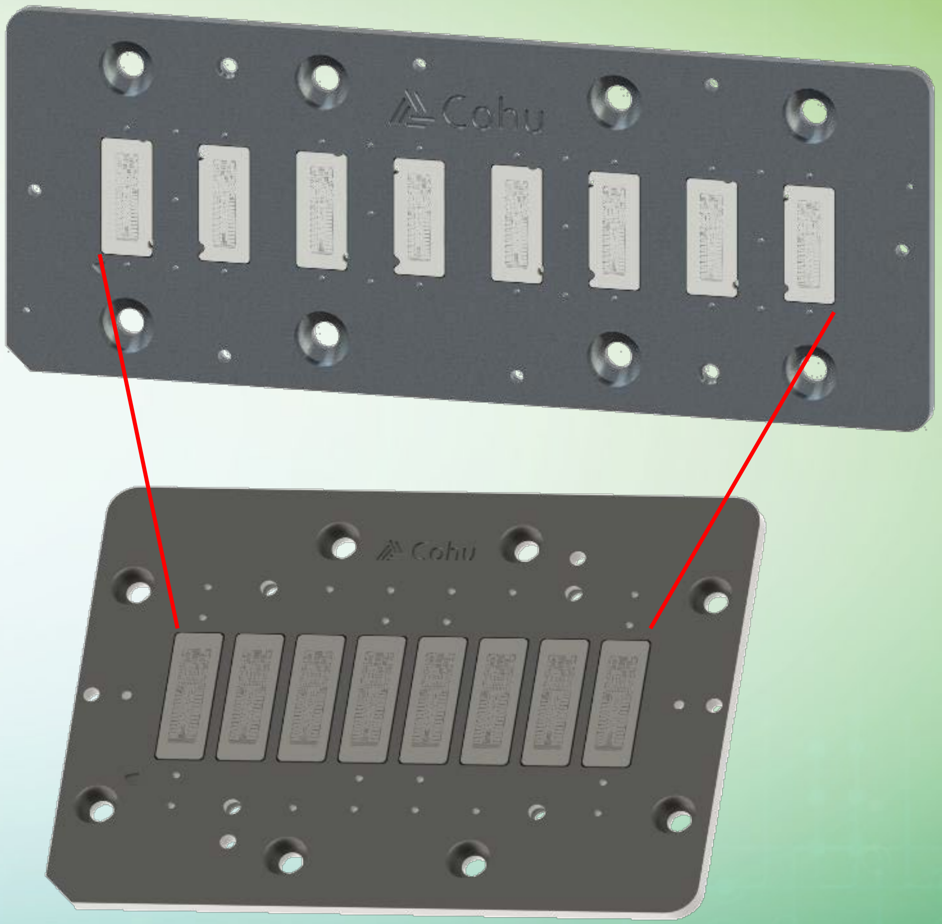
Probehead – Probe Card Alignment: Results

- **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**



Probehead Layout: Objective

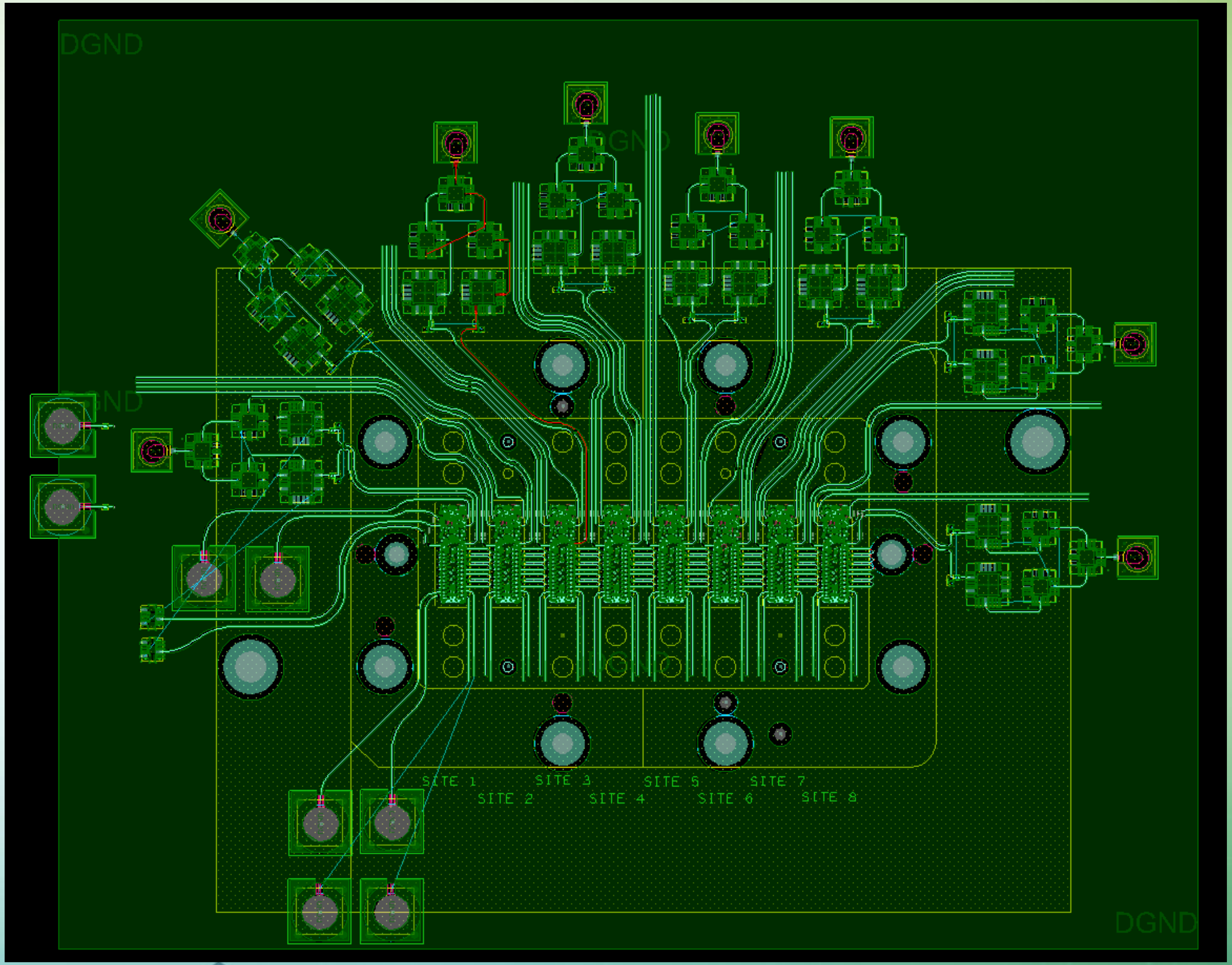
- **Original Probehead layout created was 1x8 with 3 skipped die between sites**
  - Required for routing of RF direct connection and loopback paths
- **Problem: reduced touchdown efficiency at edge of wafer**
- **Goal: production-optimized layout 1x8 with 1 skipped die**
  - Simplified layout required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



29 die → 15 die span = 48% shorter

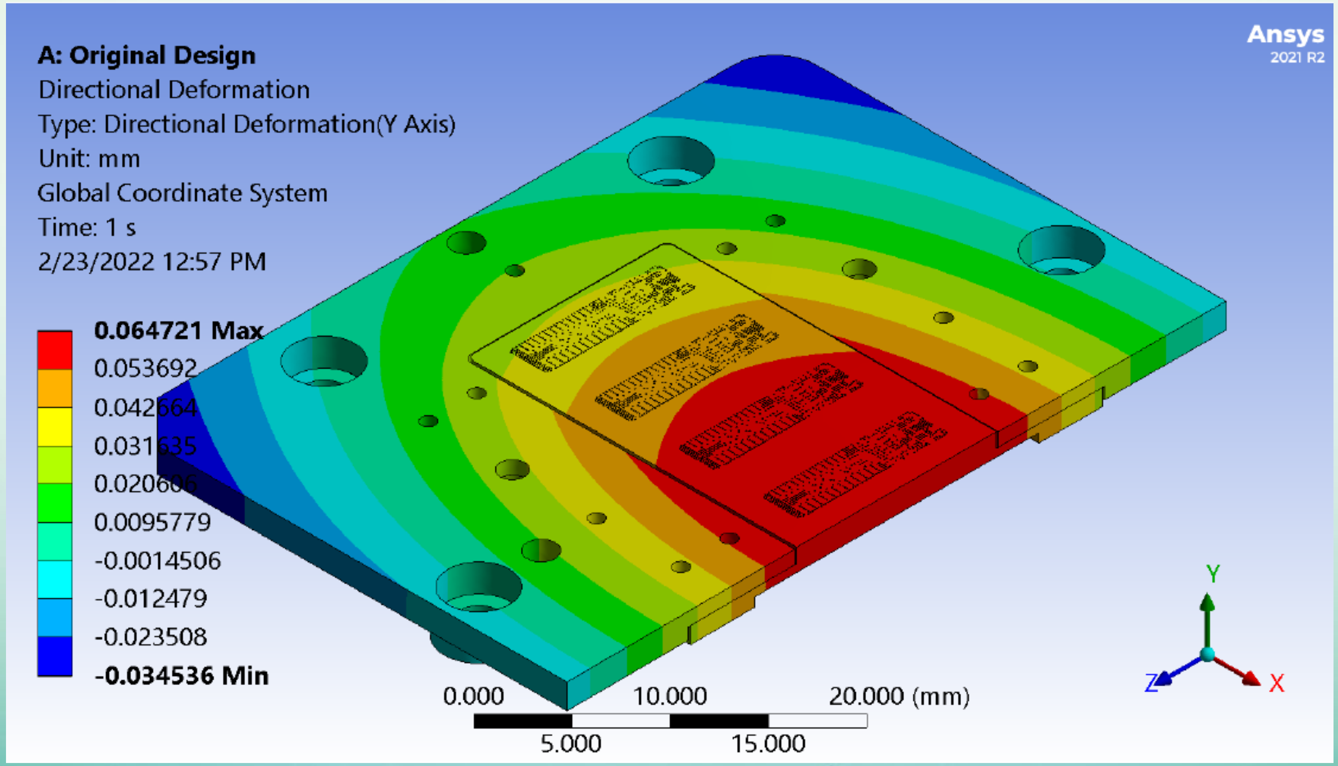
Probehead Layout: Methods

- 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)

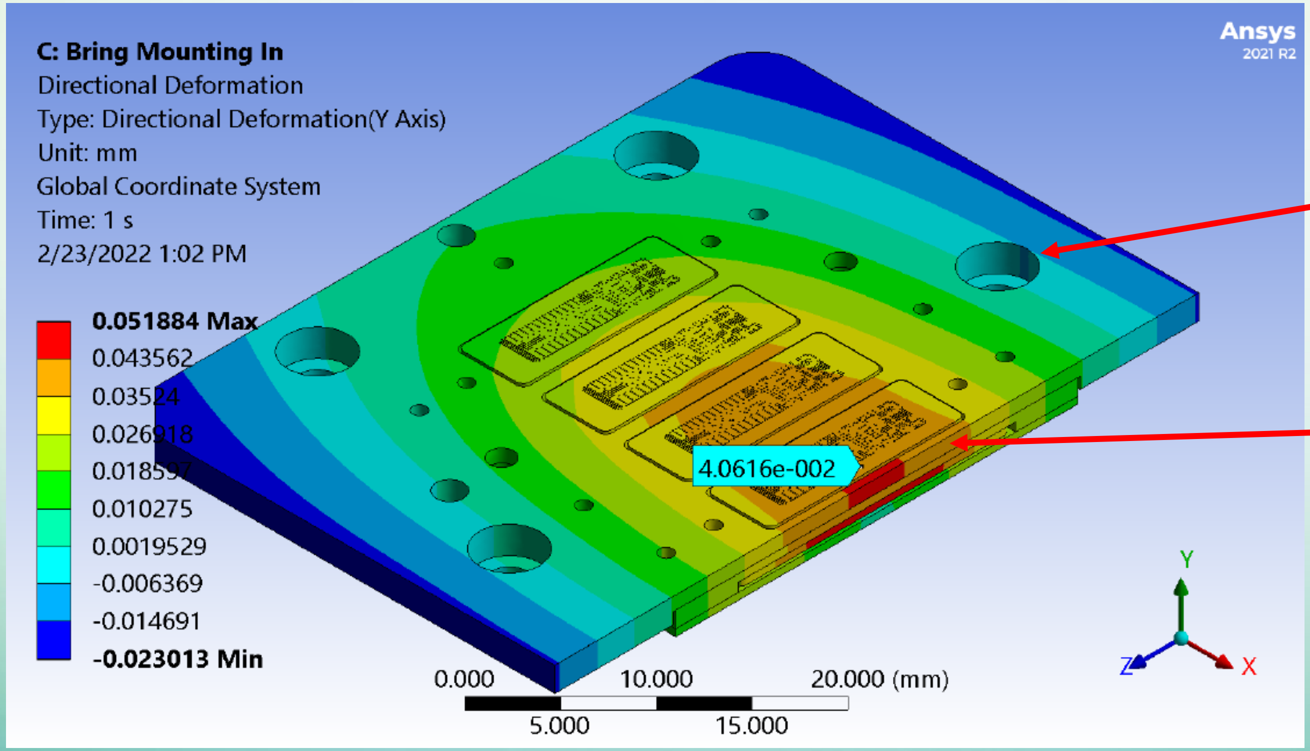
- **Initial Bowing Analysis confirmed Max Y directional deformation 65 µm: goal is <50µm**



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

Probehead Layout: Results (2)

- **Bowing Analysis after redesign: Max Y directional deformation 52 µm, 41 µm at body**

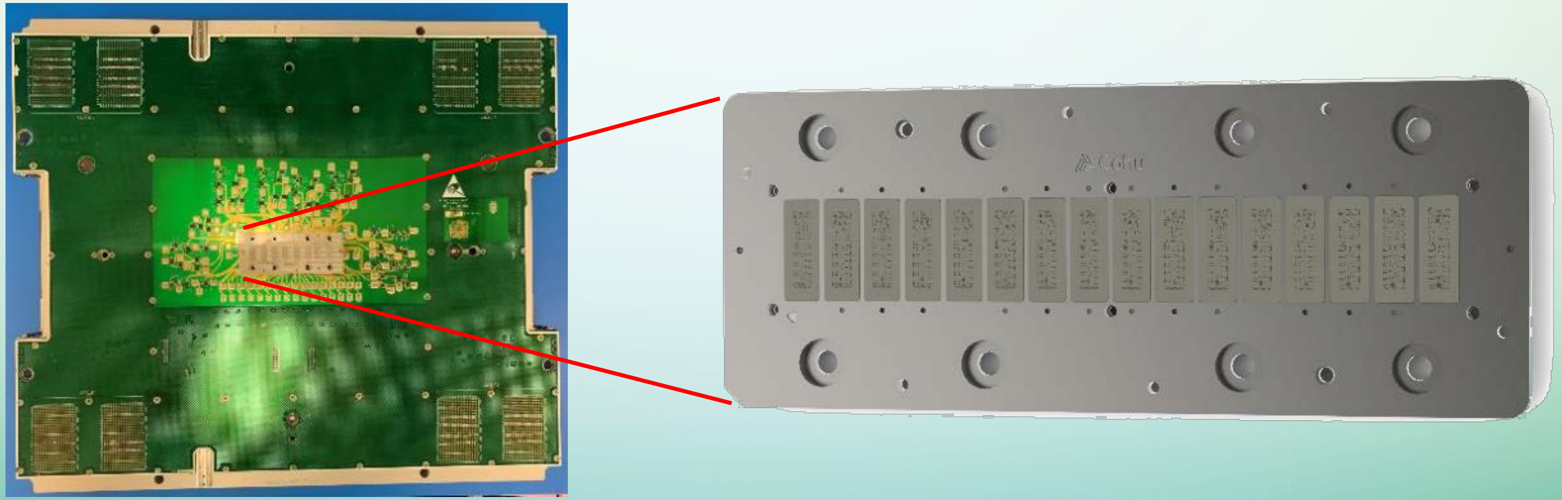


Move attachment points closer to DUT sites

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
  - Improved multisite support using Manual Test option
  - Denser multisite test pattern

- **Thanks to all the Cohu and Synergie-CAD team members for their significant contributions to this project!**