SWTEST

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30TH ANNIVERSARY

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

Cohu

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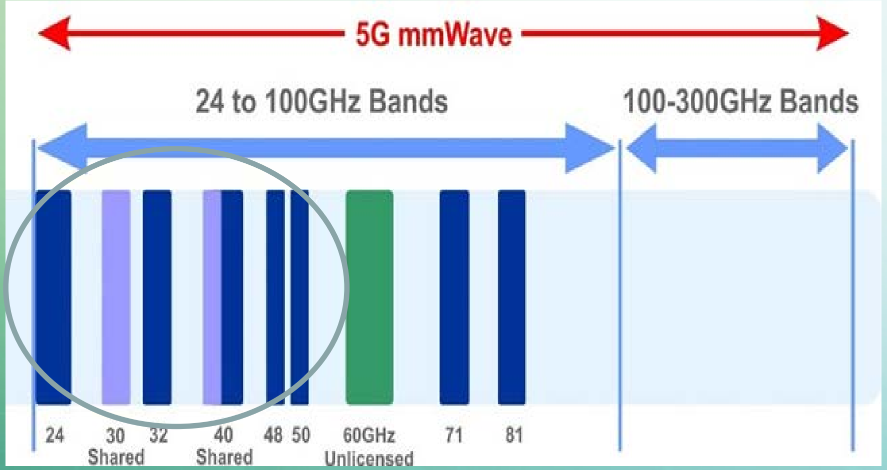
Intro: 5G mmWave Drivers

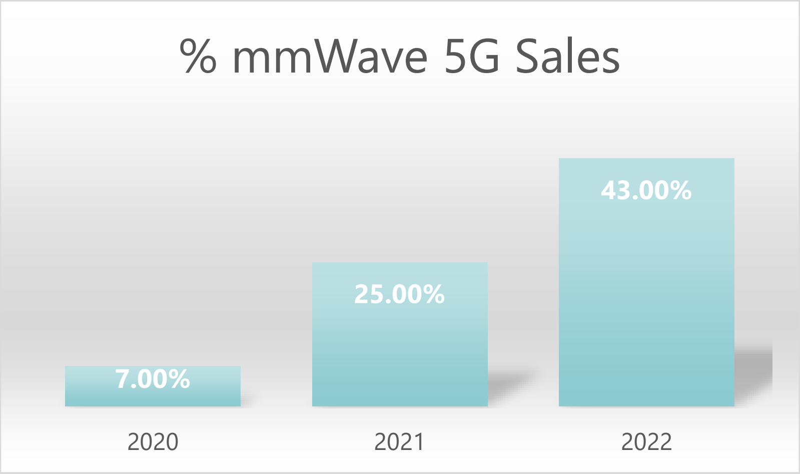
- **Demand**
  - Urban area capacity, fixed wireless broadband (FWA), video streaming, AR/VR, Critical IOT such as autonomous vehicles and mobile healthcare
- **Frequency**
  - 5G FR2 (frequency range 2) (24.25GHz to 52.6GHz)
  - Bandwidth up to 3.4GHz

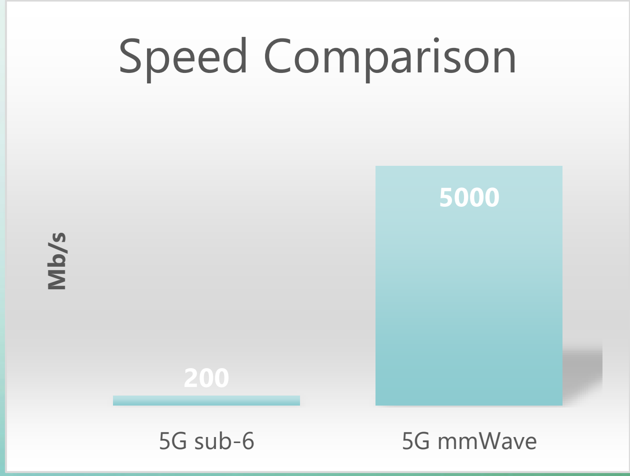
- **5G Comparison:**
  - 5G sub-6Ghz 200Mb/s
  - 5G mmWave 5Gb/s
- **Percentage mmWave sales**
  - 43% phones by 2022

https://www.macrumors.com/guide/mmwave-vs-sub-6ghz-5g/



www.5gmmwave.com/5g-mmwave/5g-mmwave-nsa-or-sa/





Introduction – RF Probing Challenges

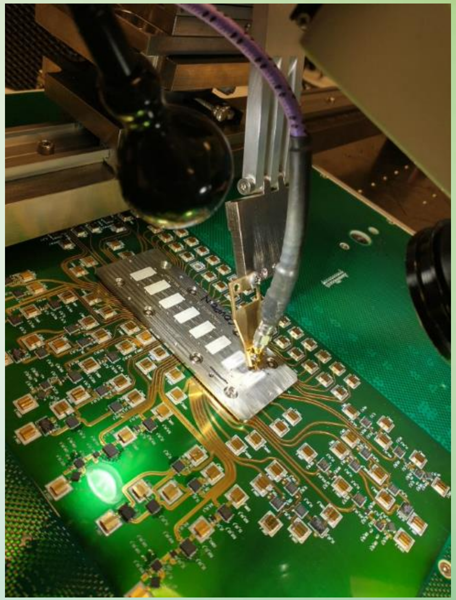
- **General probing challenges**
  - Planarity
  - Overdrive
  - Maintenance
  - Initial Cost
  - COT
  - Throughput
  - Yield
  - Routing
  - Temperature
- **RF probe card challenges**
  - Higher Initial Cost
  - Exotic Space transformers
  - Multisite limitations
  - Loss
  - Reflections
  - Repeatability
  - Tester resource Limitations
  - Components, connectors, switching, cabling

WLCSP Objectives / Goals

- **Mechanical targets**
  - 600+ i/o die
  - 150um pitch
  - Octal Site Probecard
  - ~5000 contacts
  - <50um planarity
  - >100 RF connectors/cables
  - >100 01005 components (capacitors, resistors)
  - >80 RF mmWave switches
  - Full probecard including stiffener, cabling, docking, RF brackets, etc.
- **Electrical targets**
  - 55GHz to tester
  - 55Ghz loopback
  - 44GHz switching
  - Low impedance power supplies
  - -10dB max return loss
  - 50ohm impedance match
  - Simulated and measured full path from tester to DUT for calibration and de-embedding

Methods/Materials

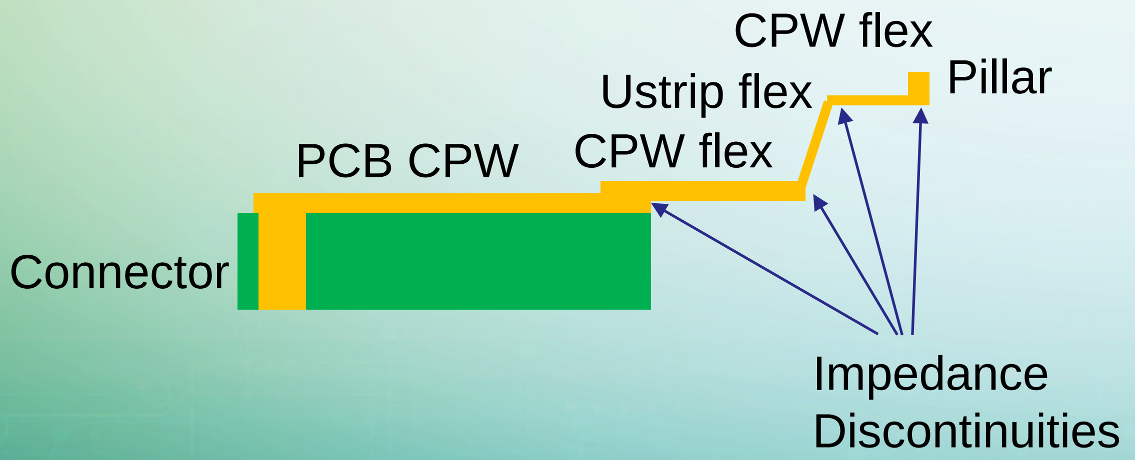
- **cRacer Probehead**
  - 3mm test height spring probe, 150um pitch, 6g, 150um overdrive (DUT side)
  - Metal frame, stiffener, 8 site MA
  - Simulated and optimized signal integrity, bowing/stress analysis
  - Measured life cycle, cRes, CCC, RF, planarity, force
- **Direct Attach PCB**
  - Fanout in PCB (no space transformer/MLO/MLC required)
  - 100+ RF channels (5GHz-55GHz RF paths)
    - Simulated signal integrity (HFSS, SI Wave)
    - DUT side: surface, internal
    - Tester side: surface, internal
  - 25 Power supplies
    - Simulated IR drop and impedance (SI Wave) all 8 sites
- **Connectors/Cabling**
  - SMPM connectors, Cabling
    - Simulated launch geometries
- **Switching**
  - 44GHz dual pole switches
  - Simulated launch geometries
- **Components**
  - 01005 capacitors and resistors for signal integrity and space savings
  - Simulated footprints
- **Simulation and Measurement equipment**
  - Ansys CFD, HFSS, SI Wave
  - PCA (Cohu FReD machine)
  - VNA (67GHz Keysight)
  - Cycler (Kita)

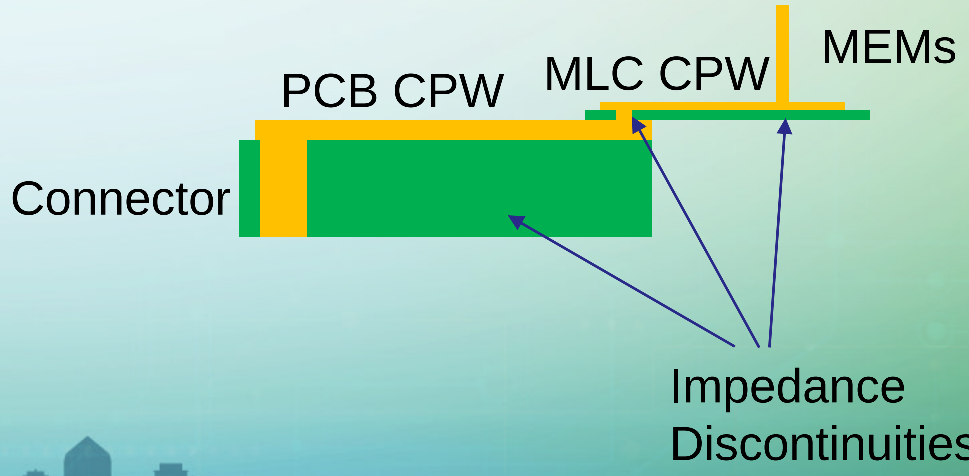


Signal Integrity Difference

cRacer Direct Attach Signal Path

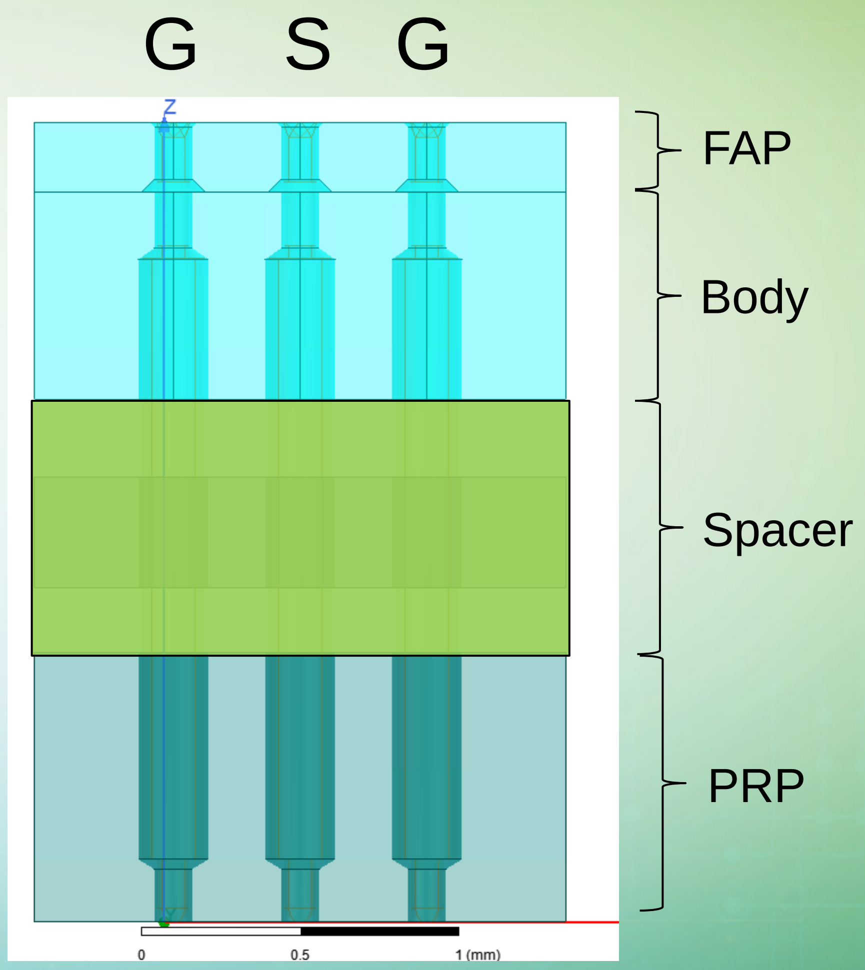
Other Signal Path Options





cRacer Optimization Process (Patent Pending)

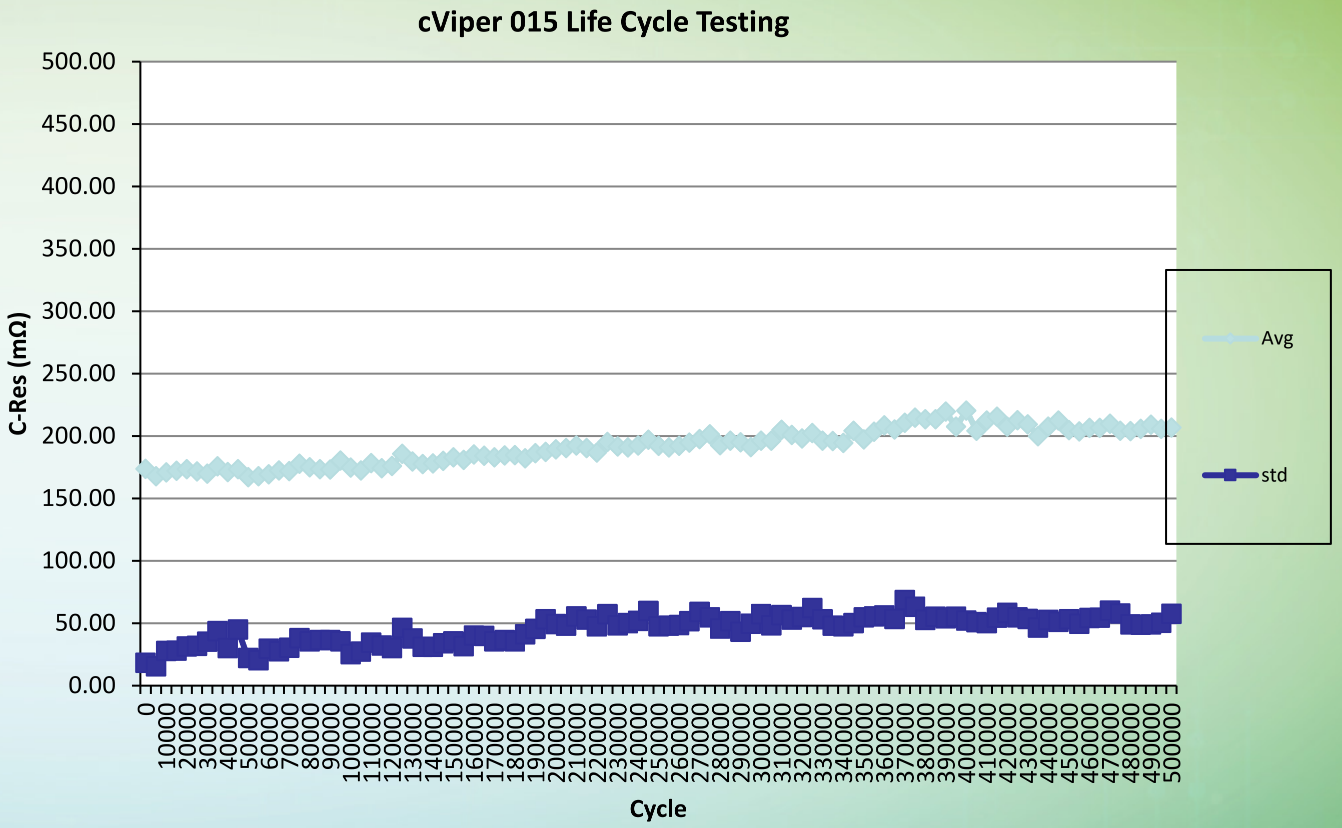
- Select pin based on required pitch and tip profile (150um crown tip in this case)
- Select contactor materials for PRP, Spacer, Body and FAP to provide required mechanical strength and dielectric performance
- Simulate RF performance in GSG or GSSG configuration
- Tune performance by matching to required impedance (typically 50 Ohms) across bandwidth of interest

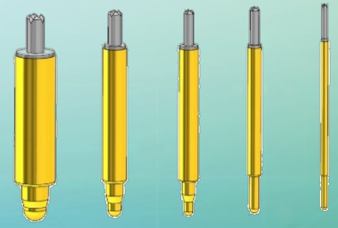


PRP = Probe Retainer Plate
FAP = Floating Alignment Plate

Radial Probe cRes Optimization

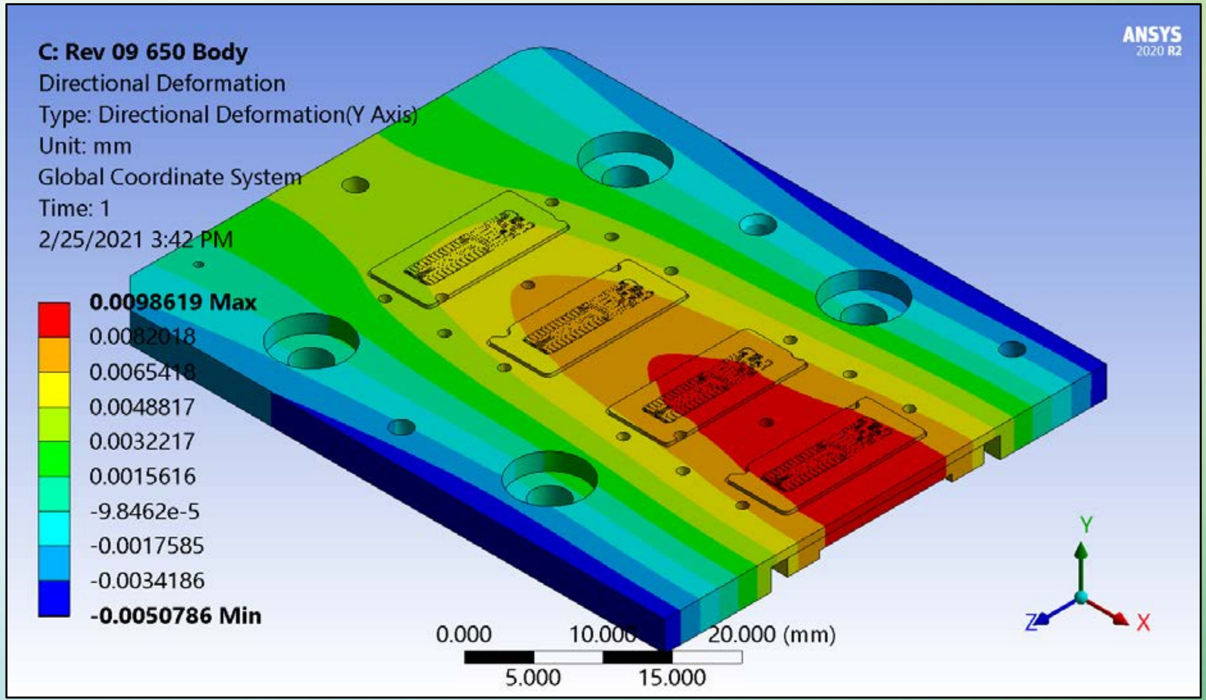
- **Expertise leveraged for performance**
- **Back to the Basics**
  - Low and consistent cRes
  - Lot-to-lot stability
  - Long lifetime
  - Optimized "Guts"
- **Standardized Recipe for probes and cross sections**





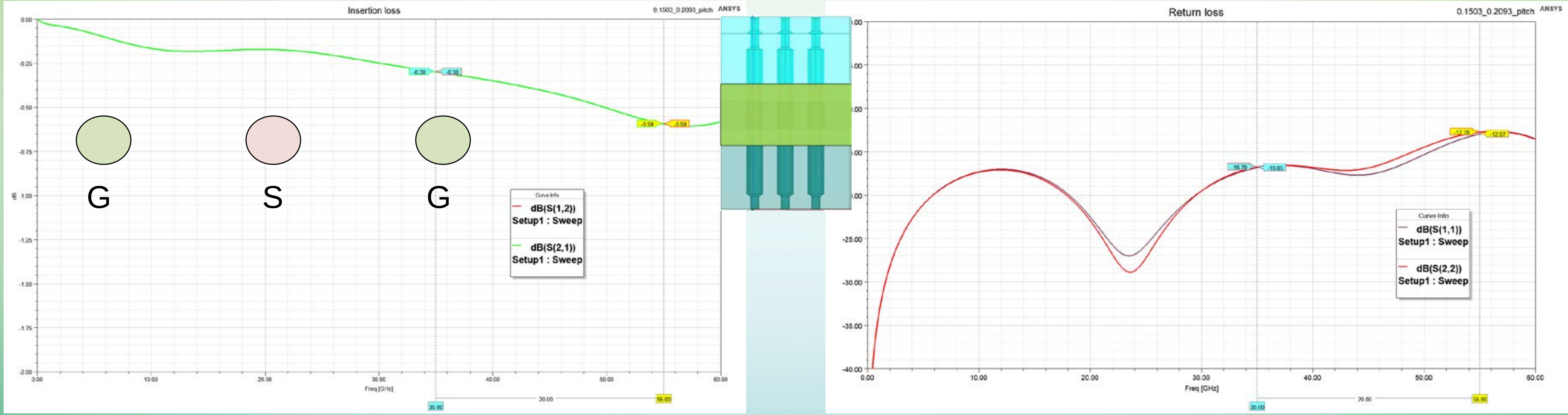
Bowing Simulation – Rev 04

- **Predict the bowing deflection due to probe preload that can be expected from Probehead using Ansys simulation**
- **Max Y-Directional Deformation: 10.3 µm**



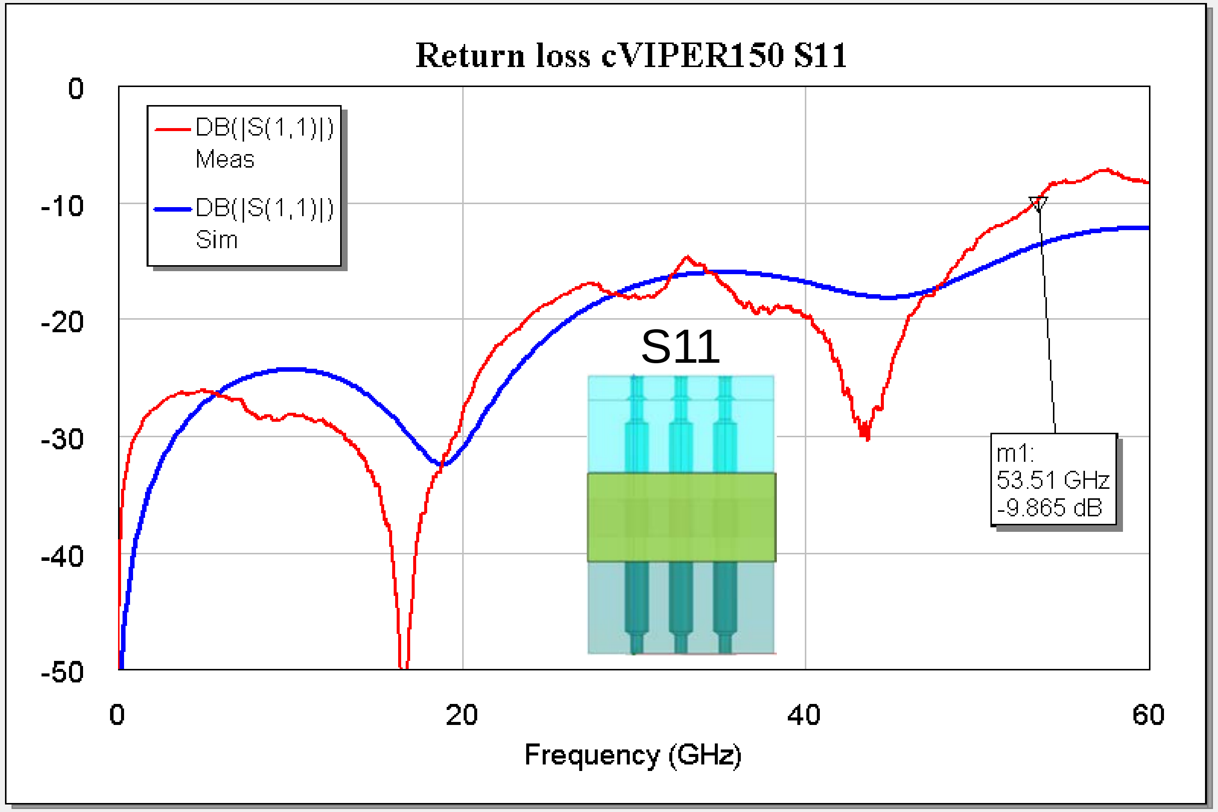
cRacer Probehead Simulated Insertion Loss

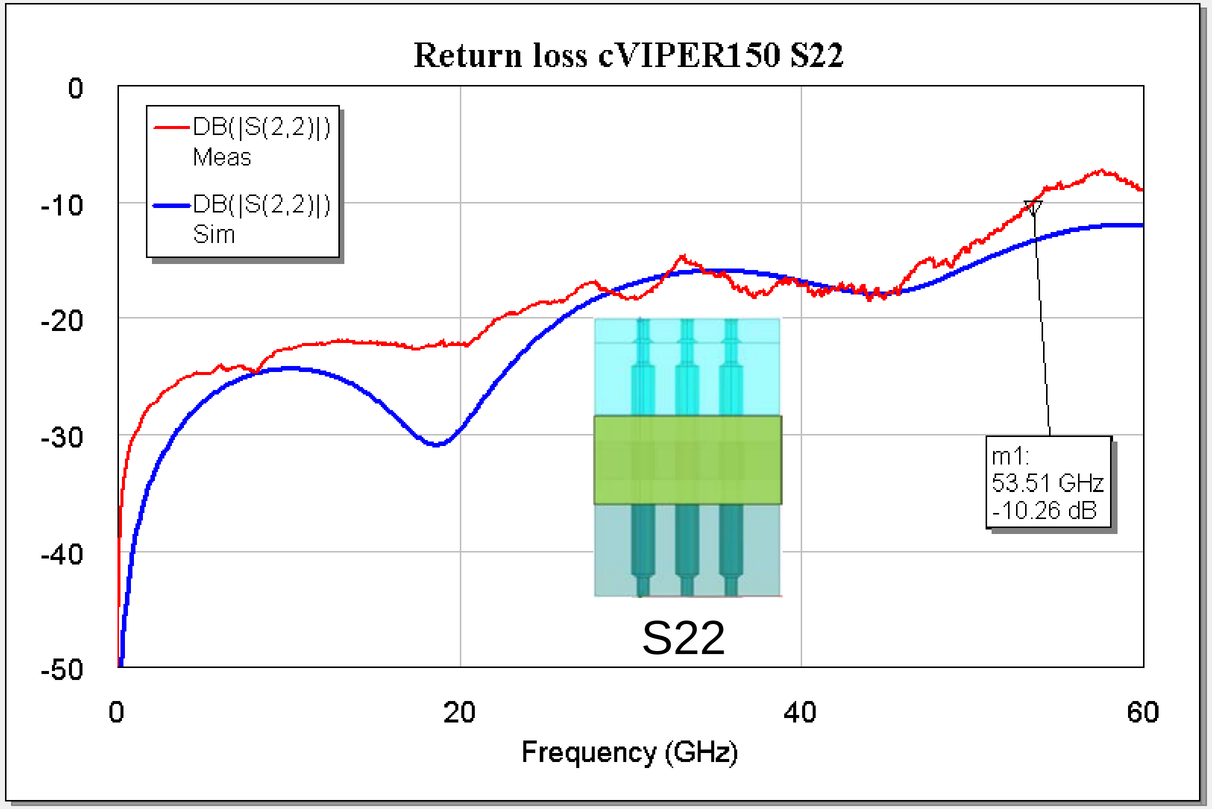
- **Predict the insertion loss and return loss expected from Probehead using Ansys simulation out to 55GHz**
  - Great performance with <1dB Insertion loss, <-12dB return loss through 60GHz



cRacer 150 Return loss Correlation

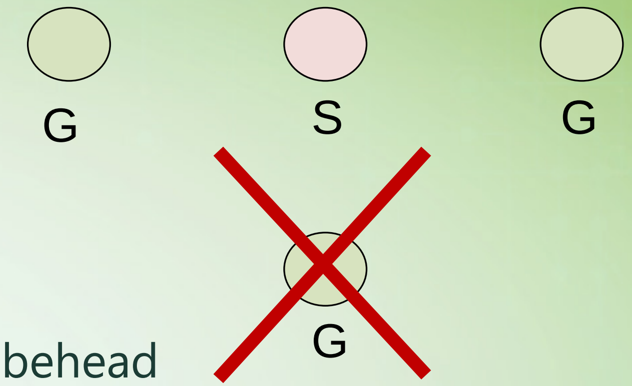
- **cRacer150 GSG Probehead RF Measurement to RF Simulation correlation**
  - Great correlation between simulation and measurement
  - simulation -12dB, measurement -10dB @ 53GHz

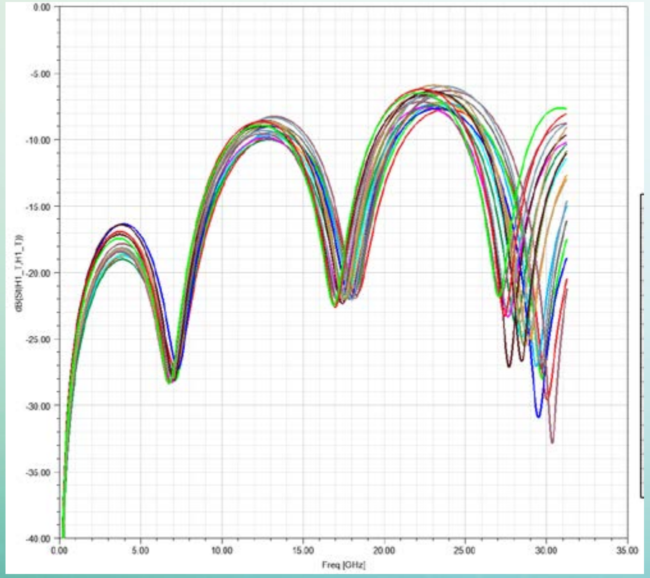


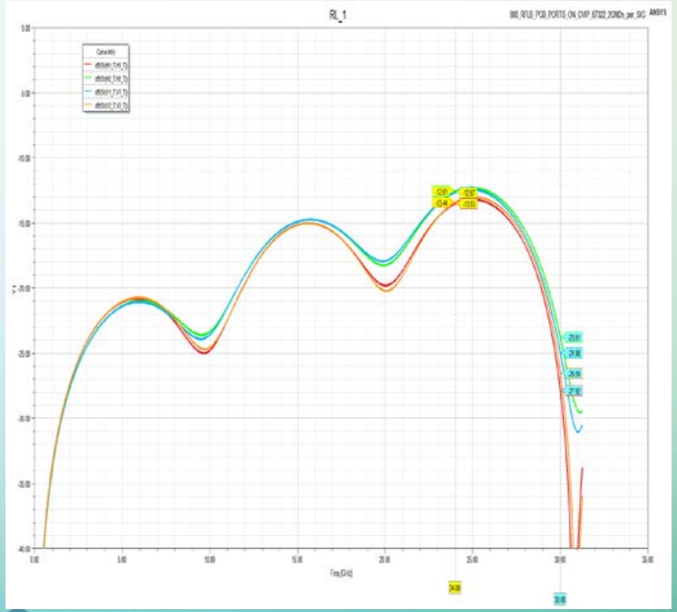


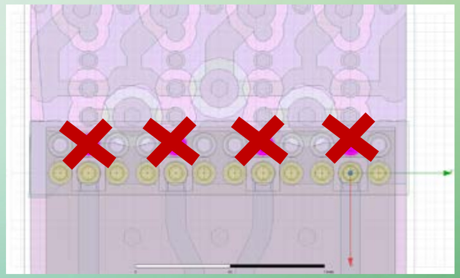
RL issue for mmWave signals

- **High return loss found for mmWave signals on device**
- **Alternative materials attempted**
- **Impedance is still too low (approx. 40Ω)**
  - Recommended Solution - > De-Populate the 3rd GND Probe in the Probehead
  - Return loss before -7dB, Return loss after -12dB

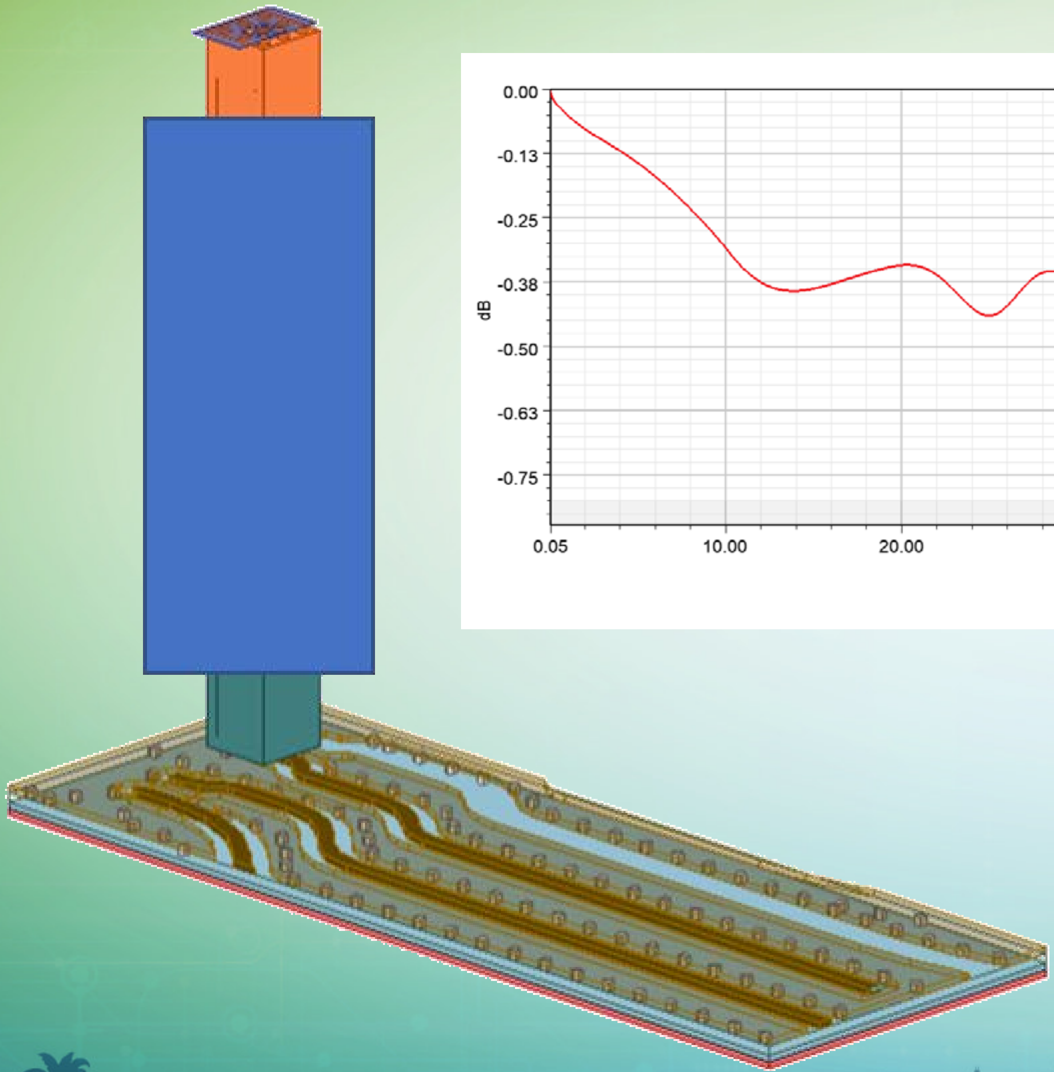


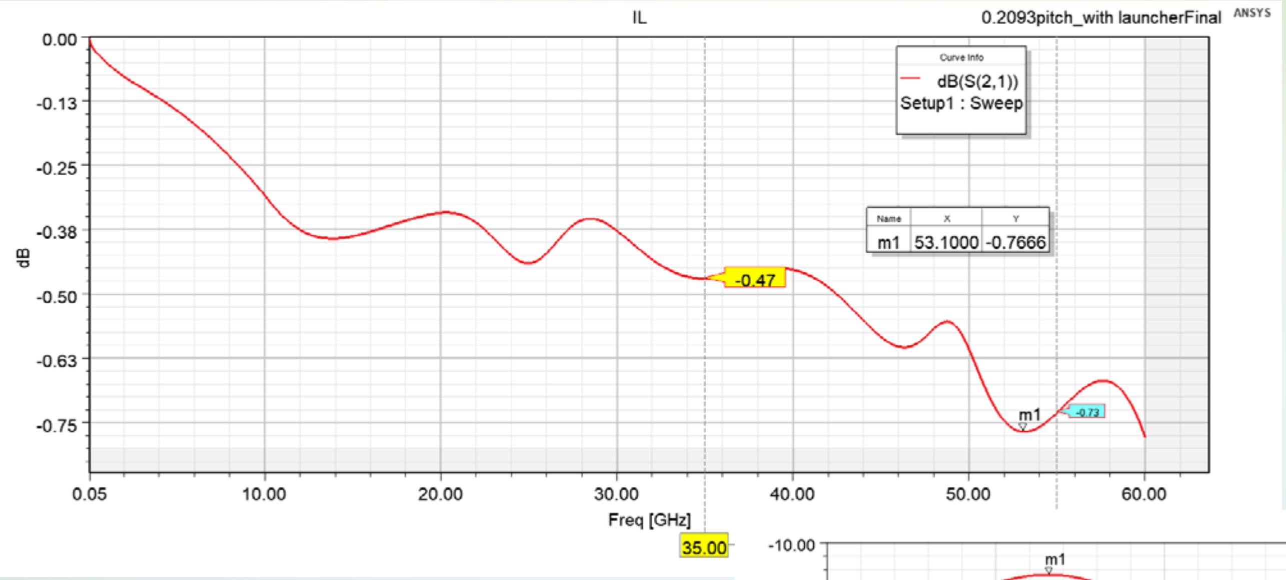


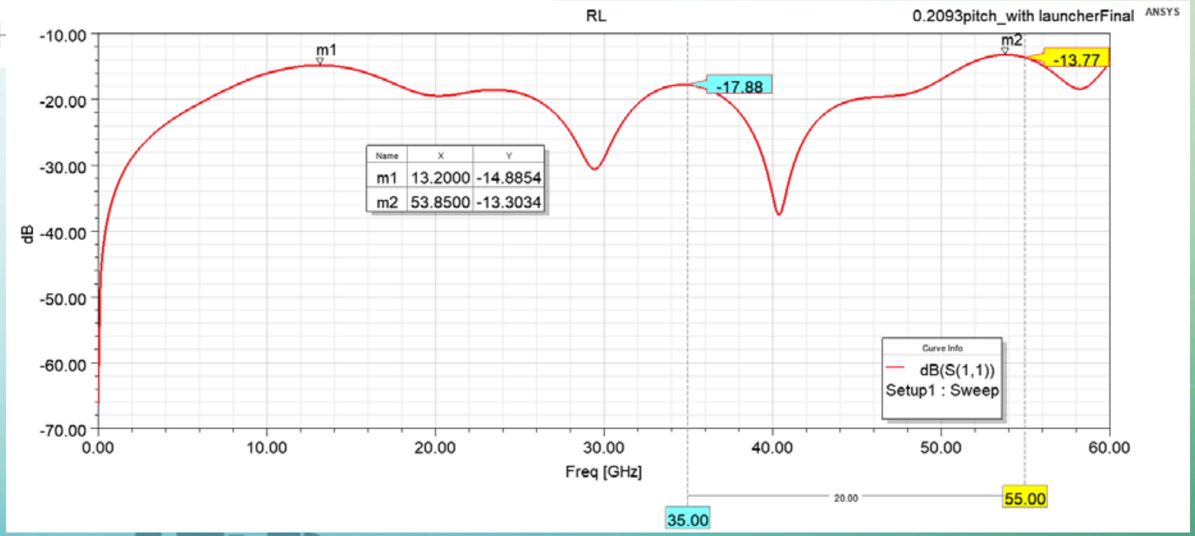




mmWave Simulation: cRacer with PCB Launch





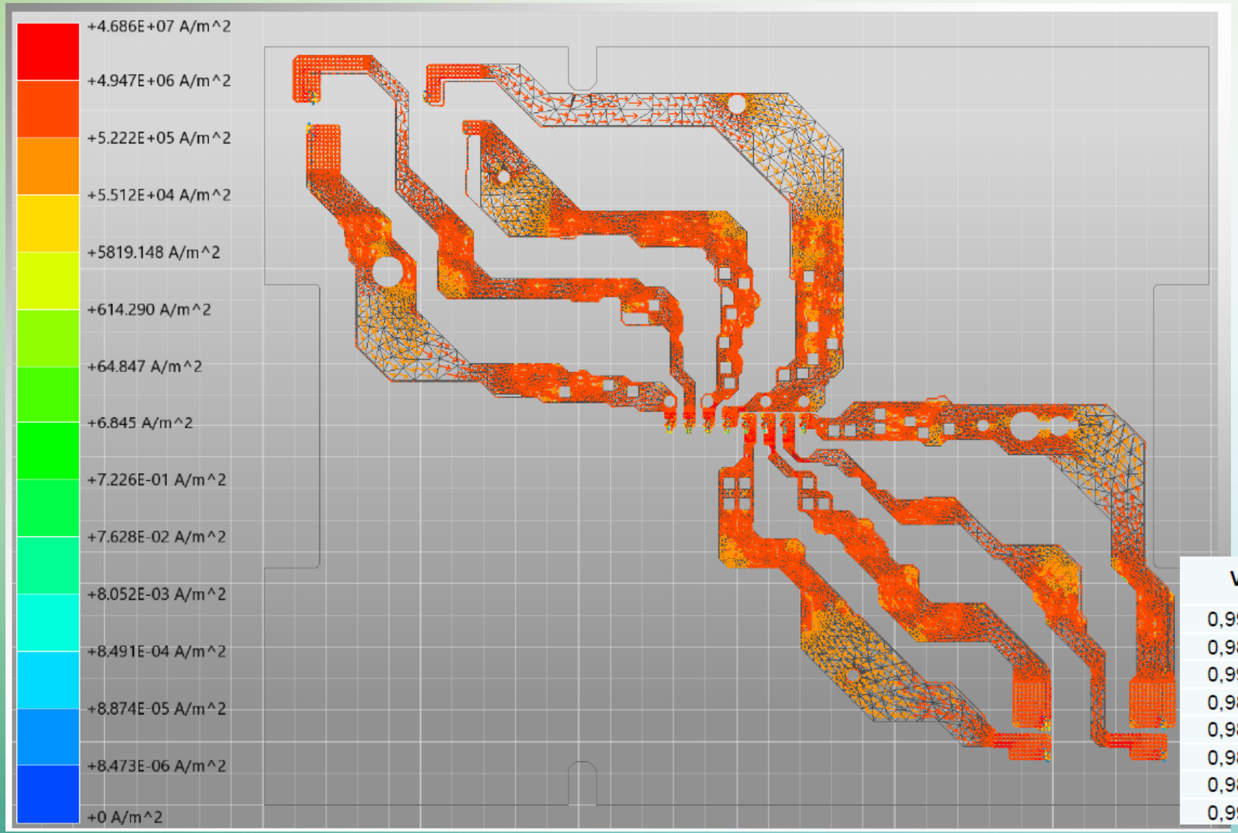


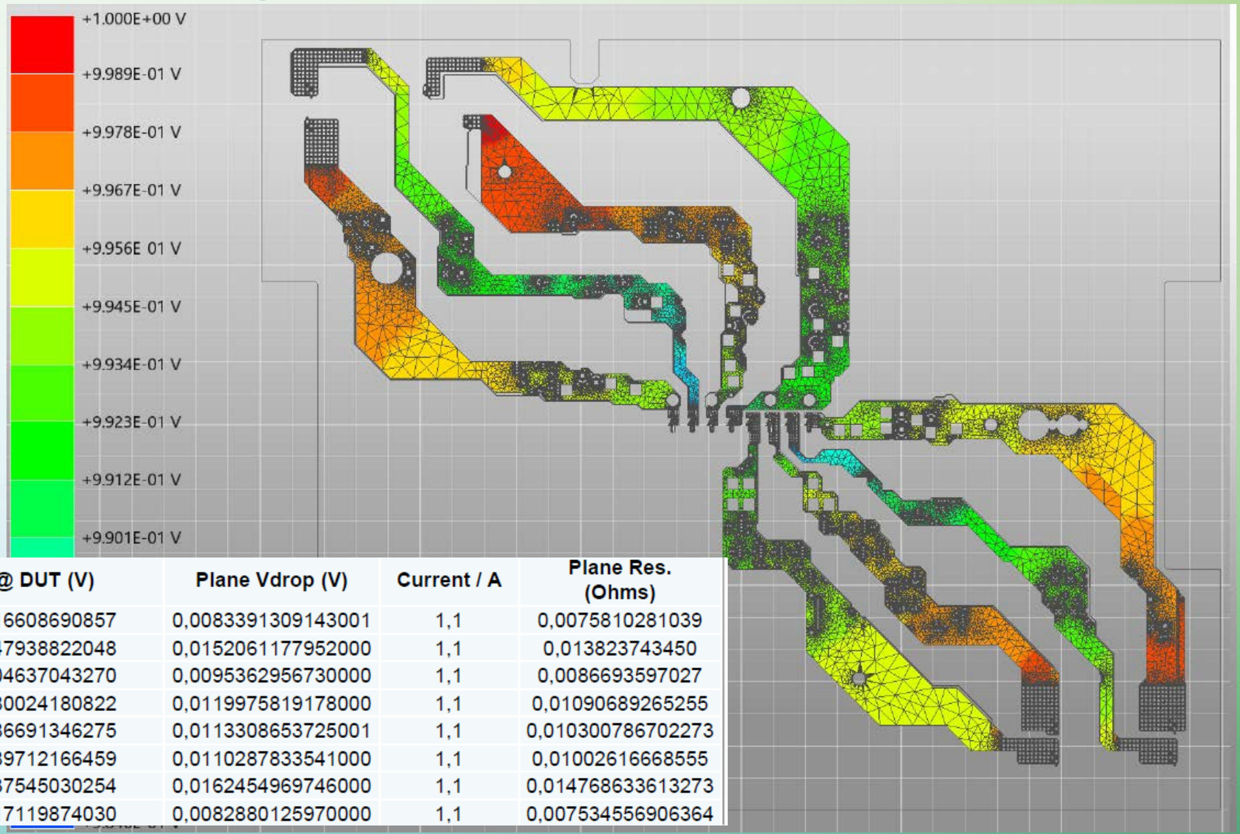
- **Insertion loss**
  - <1dB to 60GHz
- **Return loss**
  - <-13dB to 60GHz

DC Simulations (1V supply)

Target IR drop less than 24mV (16mV Max simulated) achieved thru Ansys SI Wave simulation

- **Current Density**
- **Voltage Drop**

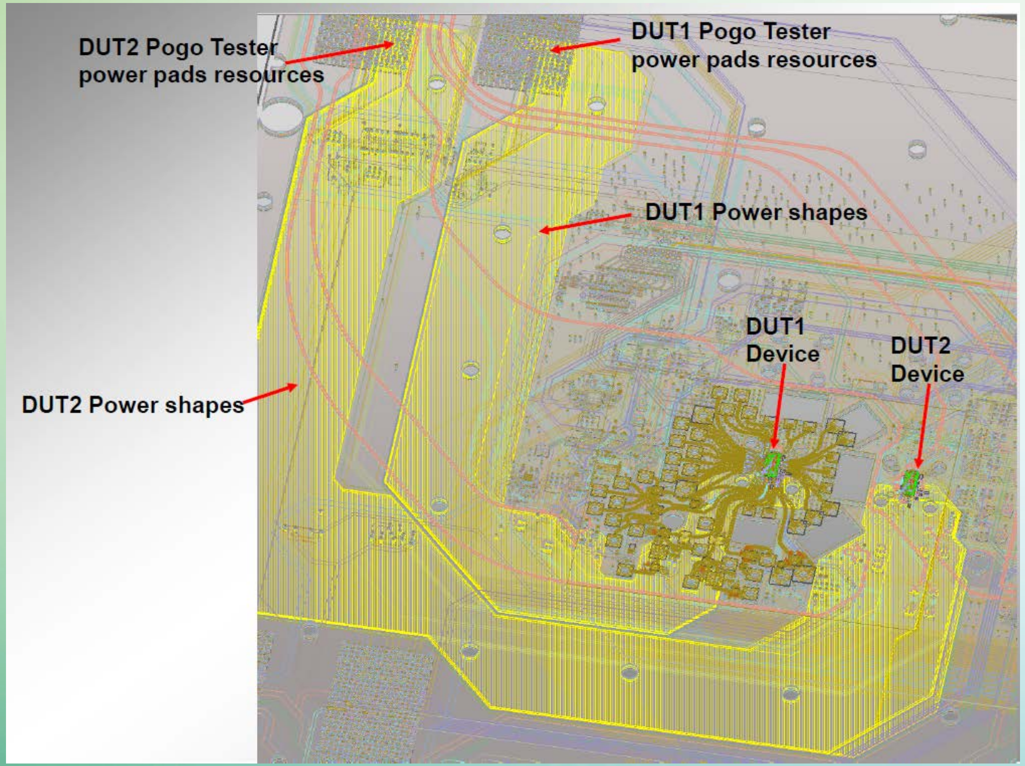




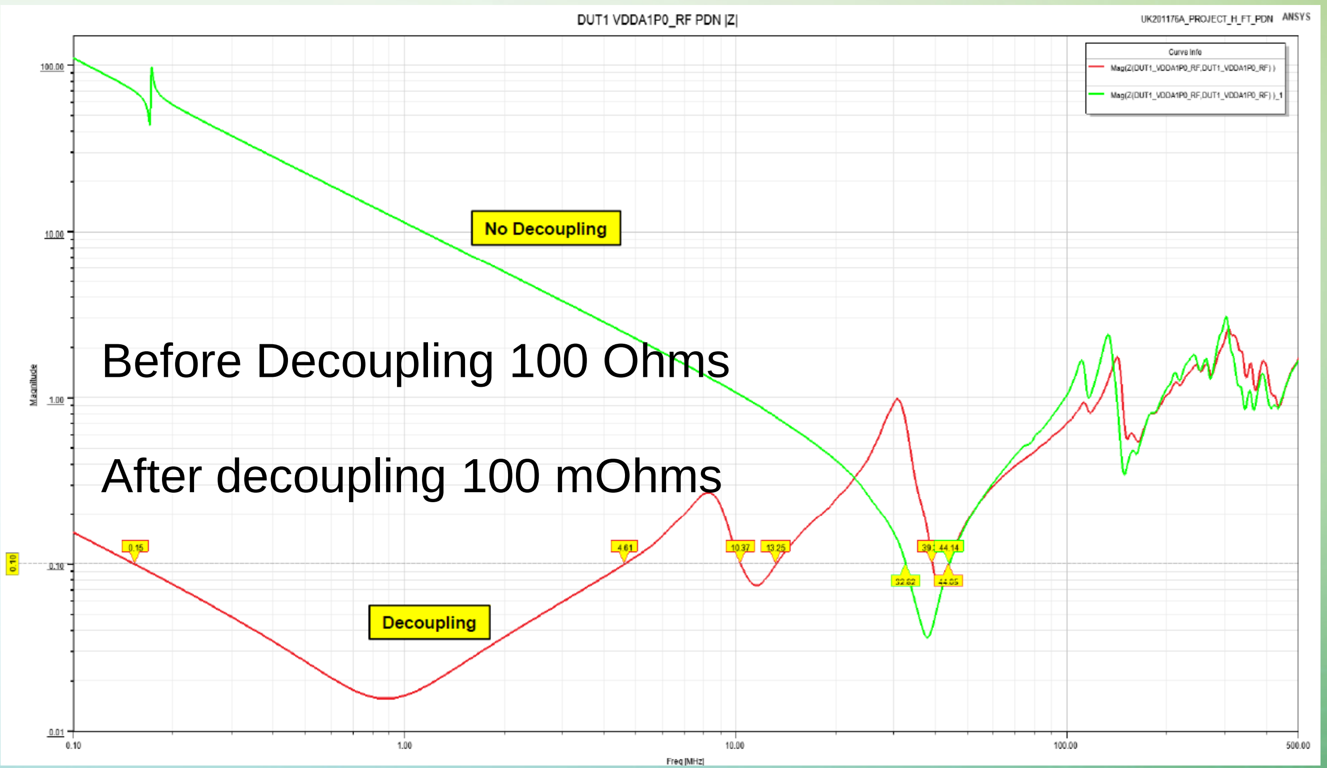
V @ DUT (V)	Plane Vdrop (V)	Current / A	Plane Res. (Ohms)
0,9916608690857	0,0083391309143001	1,1	0,0075810281039
0,9847938822048	0,0152061177952000	1,1	0,013823743450
0,9904637043270	0,0095362956730000	1,1	0,0086693597027
0,9880024180822	0,0119975819178000	1,1	0,0109068926525
0,9886691346275	0,0113308653725001	1,1	0,010300786702273
0,9889712166459	0,0110287833541000	1,1	0,01002616668555
0,9837545030254	0,0162454969746000	1,1	0,014768633613273
0,9917119874030	0,0082880125970000	1,1	0,007534556906364

Power Supply Impedance modeling

- **Site 1, 2 power supply configuration**



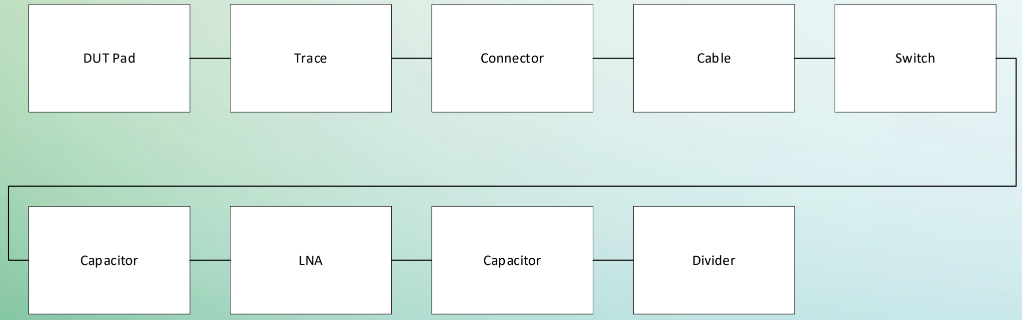
- **Impedance improvement after Decoupling**

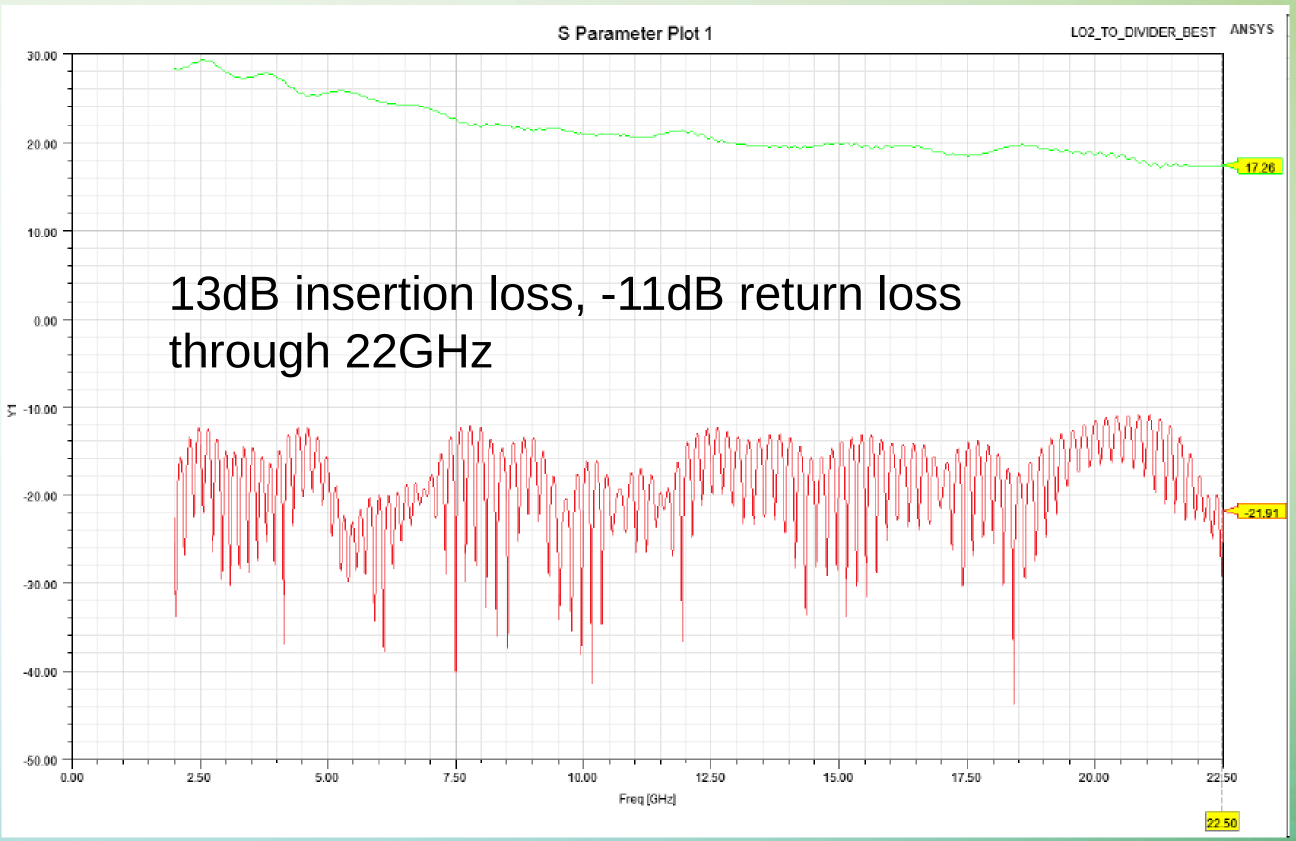


LO Full Path Simulation example

- **Simulation Includes:**
  - DUT pad (HFSS), CPW trace (W-element), connector(HFSS), coaxial cable(2D) , bias-T (s-param) , switch (s-param), bypass caps (s-param), LNA (HFSS, s-param), divider (HFSS, s-param)
  - Used for de-embedding in test program prior to full path s-parameter measurements

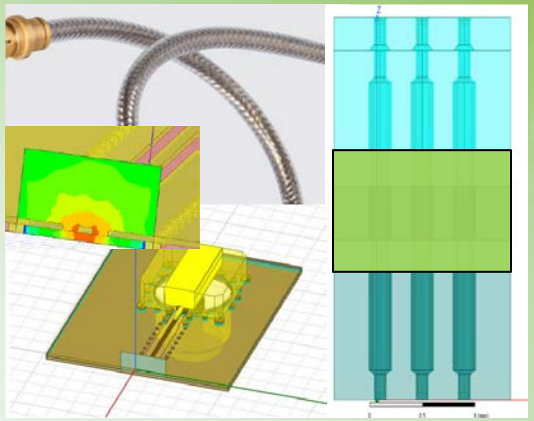
Schematic

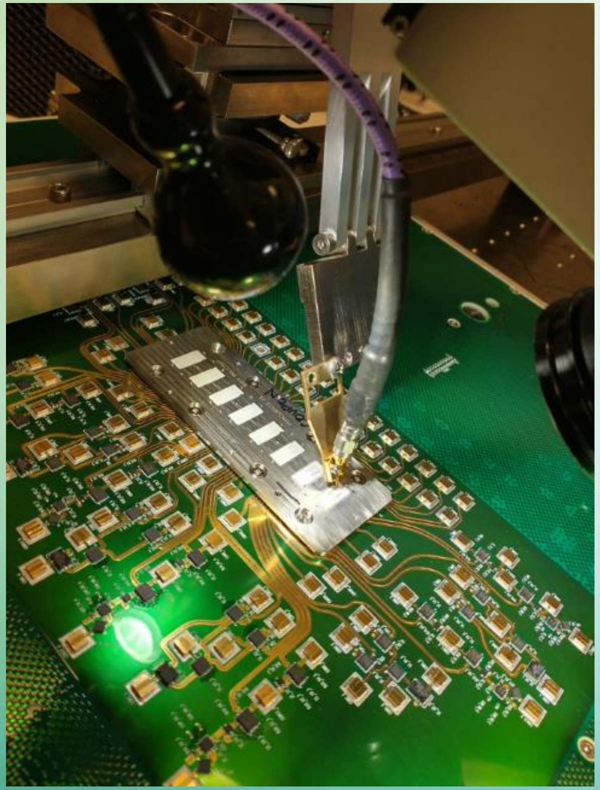


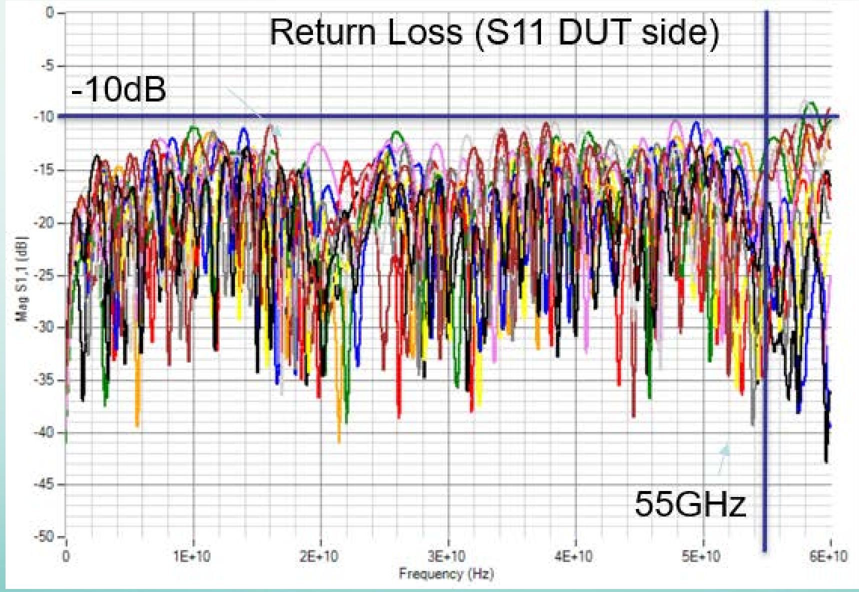


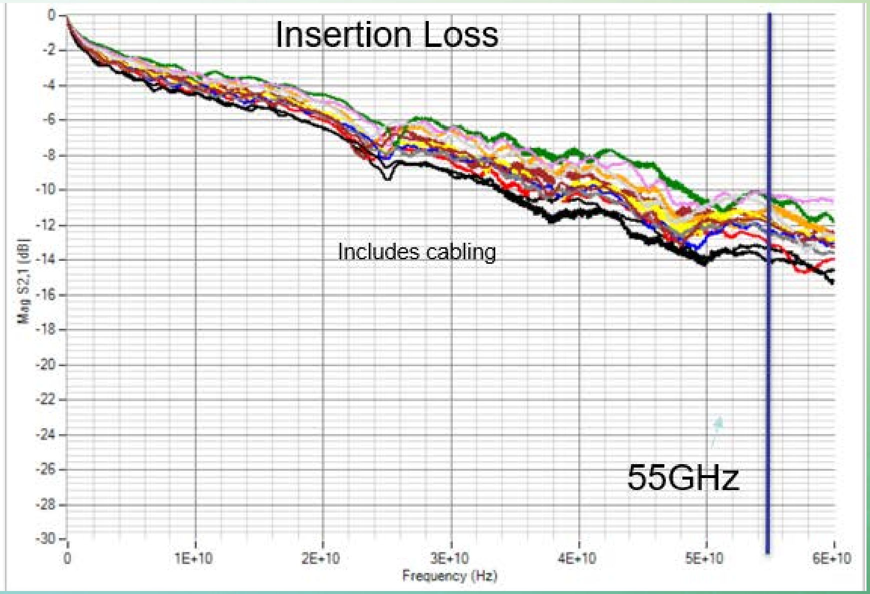
Full Path S-parameter measurment to 55GHz

- **Tester to DUT full path loss (qty12 55GHz paths)**
  - Return loss below -10dB and linear insertion loss thru 55GHz
  - Includes contactor, vias, traces, connector, 18" coax cable

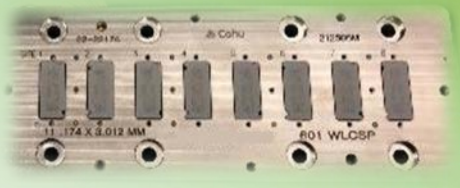






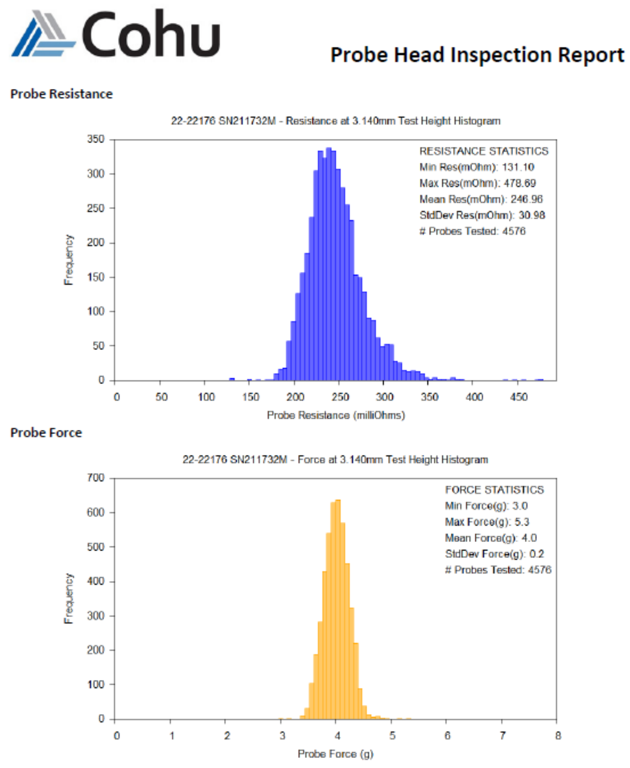


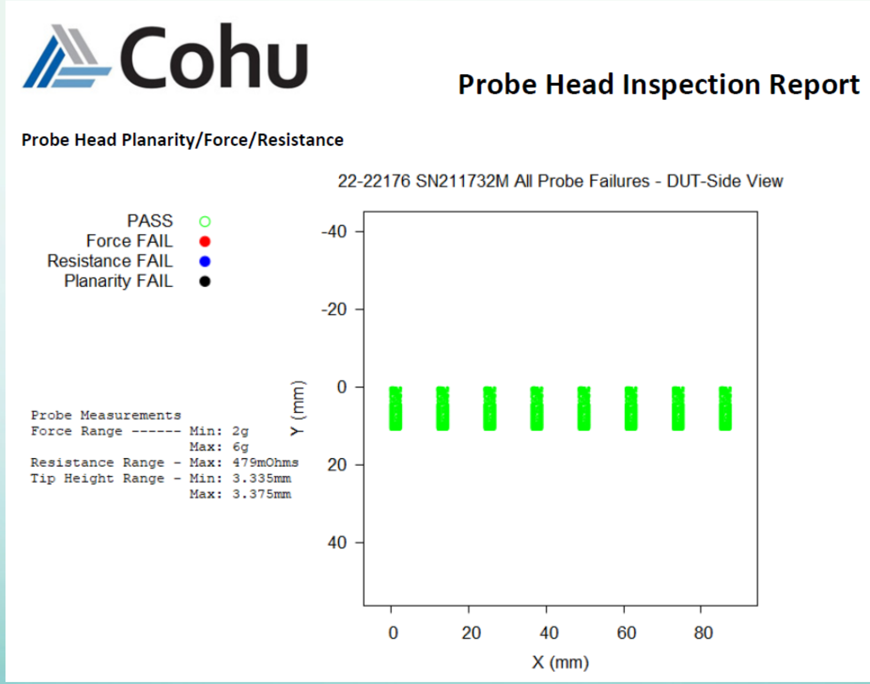
Probehead Inspection

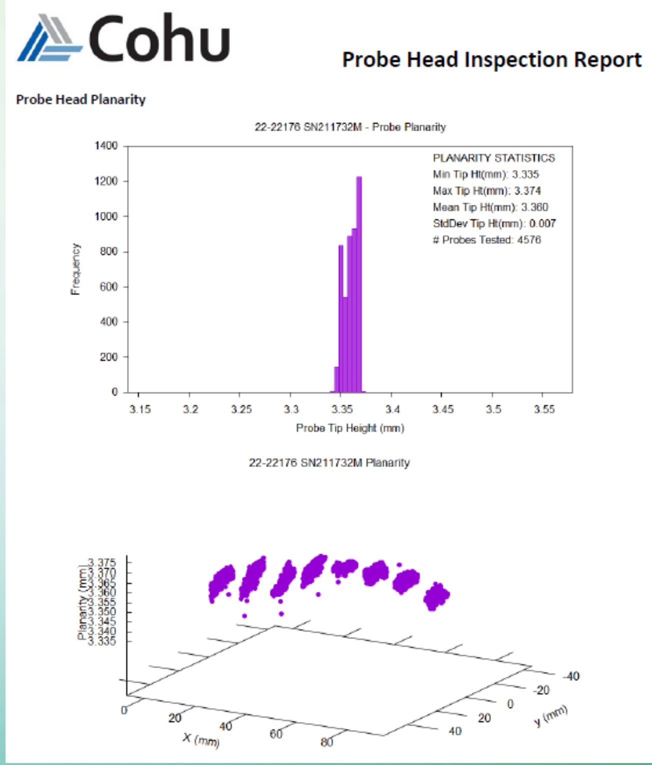


- Resistance Average: 250mOhm
- Resistance STD: 30mOhm
- Force Average: 4g
- Force STD: 0.2g

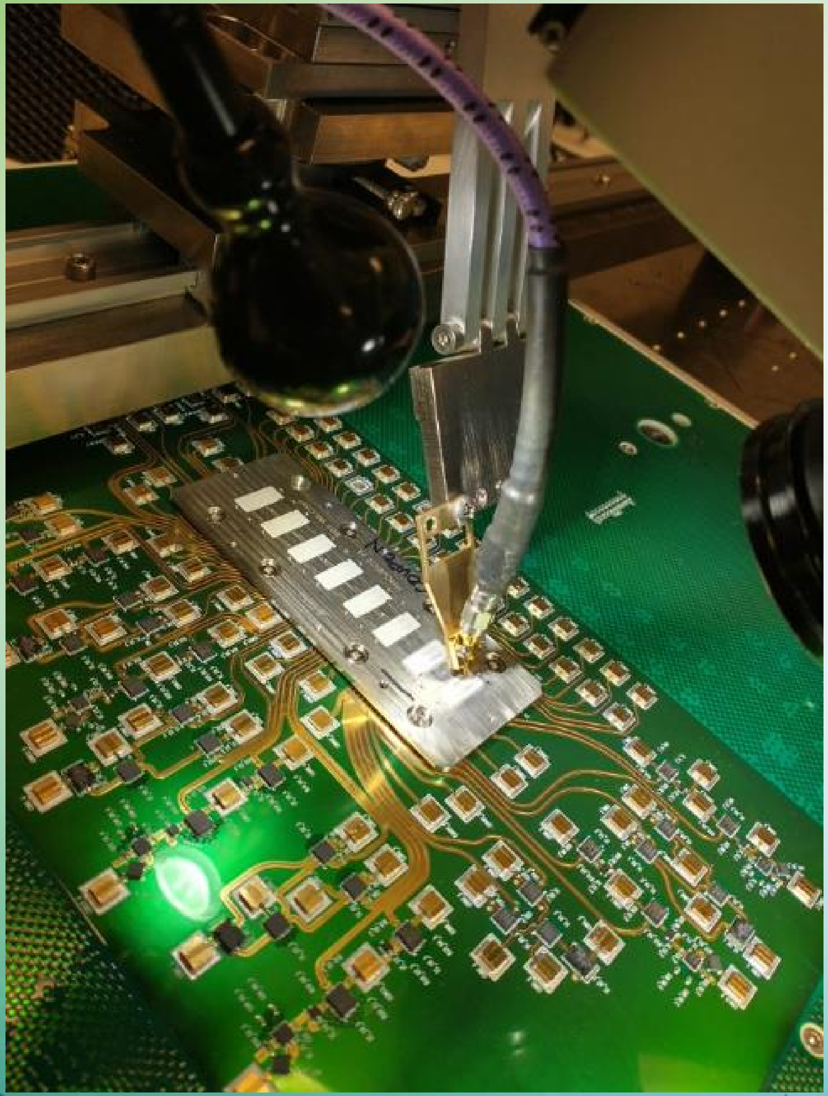
- First touch average: 3.36mm
- First touch STD: 7um
- Min tip height: 3.335
- Max tip height: 3.374
- Coplanarity: 41um

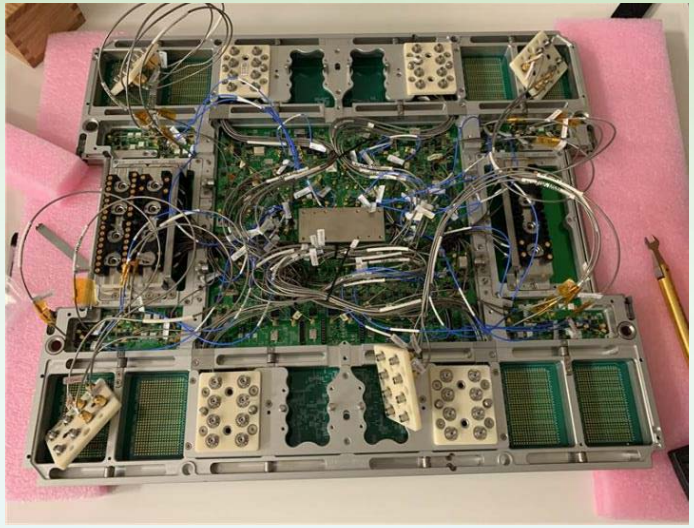


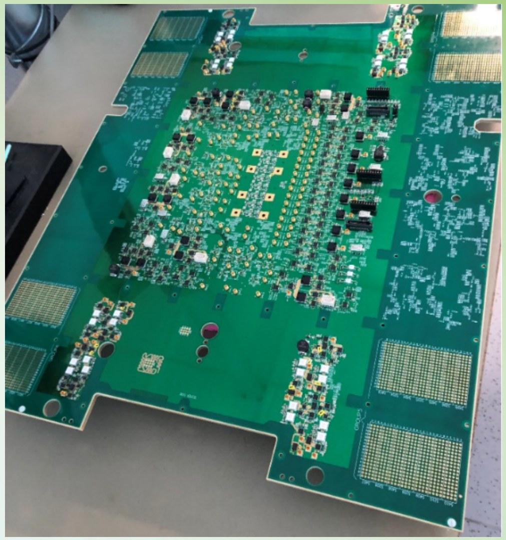


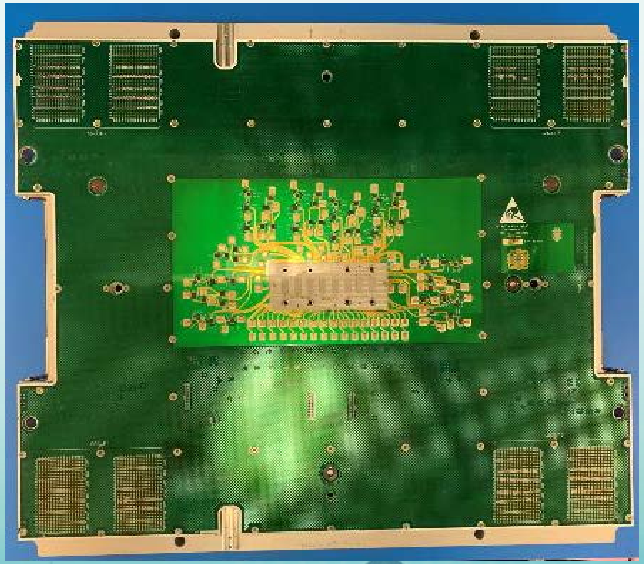


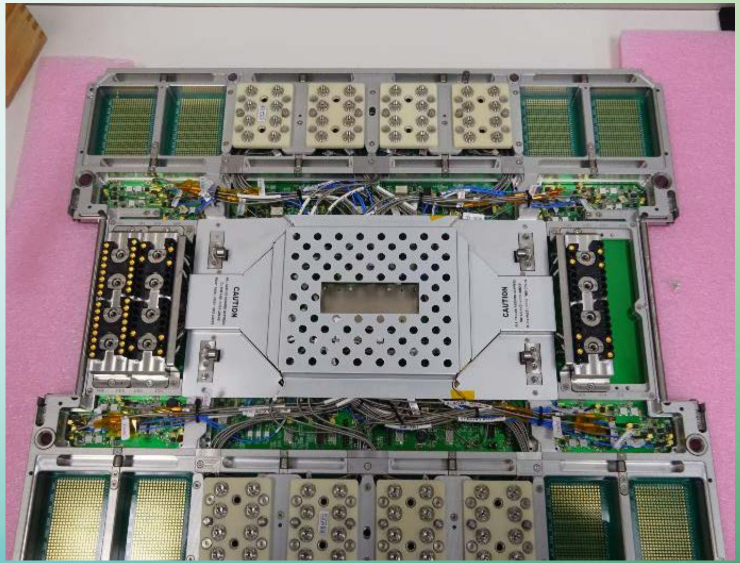
cRacer 55GHz Octal-Site Direct Attach Probe Card





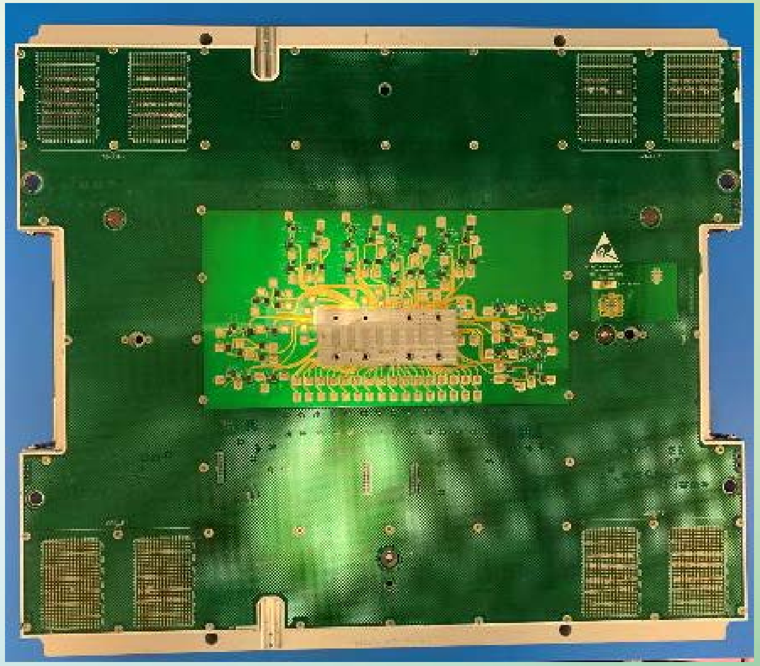






Discussion of Results

- **Advantages**
  - 8+ site capable mmWave Probecard Solution
  - Traditional Spring Probe Technology
  - Direct Attach (no MLO/MLC)
  - Field maintainable
  - Lower Cost of Test
- **Challenges**
  - Significant Engineering Design effort
  - Limited real-estate limits optimal RF Routing
  - Complex PCB stackup
  - High BOM count/cost and assembly complexity
  - Long-leadtime mmWave components



Summary / Conclusion

- **Proven performance and parallelism of a cRacer probehead+Direct attach PCB for up to mmWave and down to 150um pitch**
  - Turnkey Production Probe solution for any RF application from DC to Daylight
- **Design, Simulation, Prototype and Final build efforts to deliver**
  - Required mechanical and electrical expertise, supply chain management, assembly and test coordination, and logistics management to get the job done right the first time

Follow-On Work

- Redesign for alternative impedance profile
- Optimize cable lengths and routing for lower loss
- Improve manual actuator for singulated die testing
- Simplify logistics for High Volume Deliveries

Thanks to:

- **Synergie CAD**
  - Mahmoud Mesgarzadeh (Design Team Manager)
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