TWENTY THIRD ANNUAL

TestConX™

May 1 - 4, 2022

DoubleTree by Hilton
Mesa, Arizona

Archive

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

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Cohu

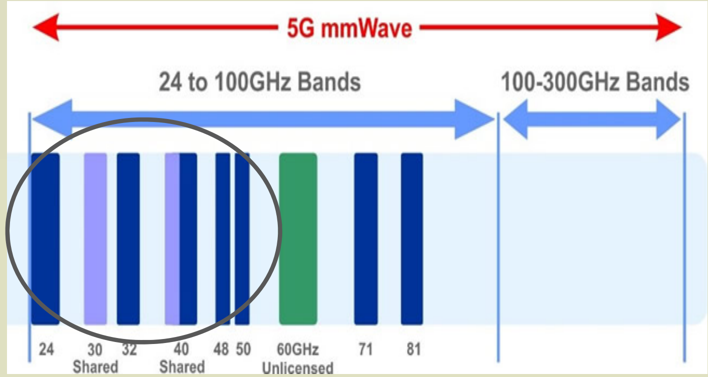
TestConX

Mesa, Arizona • May 1–4, 2022

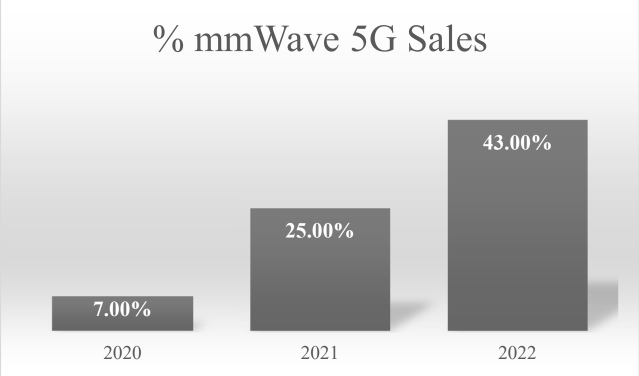
Intro: 5G mmWave Drivers

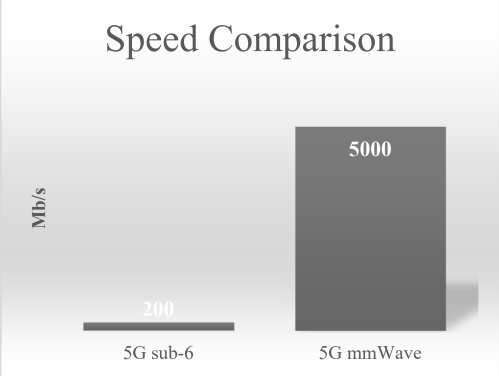
https://www.macrumors.com/guide/mmwave-vs-sub-6ghz-5g/

- 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



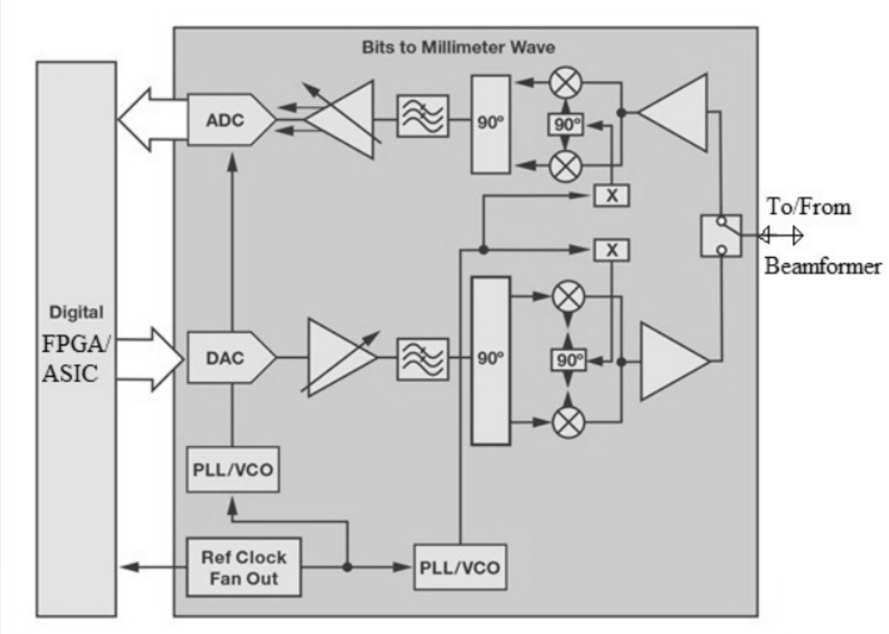
www.5gmmwave.com/5g-mmwave/5g-mmwave-nsa-or-sa/





5G transceivers

- mmWave 5G radio
  - Transmitter
    - DAC
    - Power Amplifier
    - Up-conversion
  - Receiver
    - Low Noise Amplifier
    - Down-conversion
    - ADC
- Possible Vendors
  - Anokiwave, ADI, Nokia, Qualcomm, Ericsson, etc.



Mmwave Radio Transceiver Block Schematic

Mmwave 5G Radio | 5G mmwave transceiver manufacturers or vendors (rfwireless-world.com)

Introduction – RF Probing Challenges

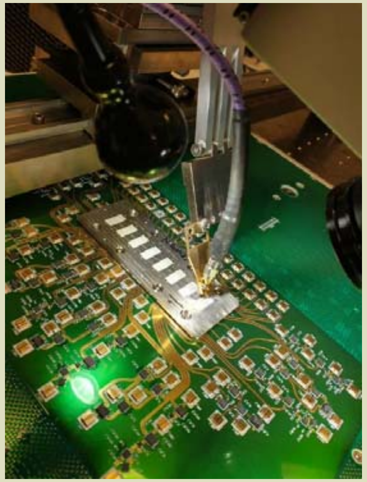
- General probing challenges
  - Planarity
  - Overdrive
  - Maintenance
  - Initial Cost
  - COT
  - Throughput
  - Yield
  - Routing
  - Temperature
- RF probe card challenges
  - Higher Initial Cost
  - Exotic Space transformers
  - Multisite limitations
  - Loss
  - Reflections
  - Repeatability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

Wafer probe Objectives / Goals

- Mechanical targets
  - 600+ i/o die
  - 150 um pitch
  - Octal Site Probecard
  - ~5000 contacts
  - <50 um 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
  - 55 GHz to tester
  - 55 Ghz loopback
  - 44 GHz switching
  - Low impedance power supplies
  - -10 dB max return loss
  - 50 ohm impedance match
  - Simulated and measured full path from tester to DUT for calibration and de-embedding

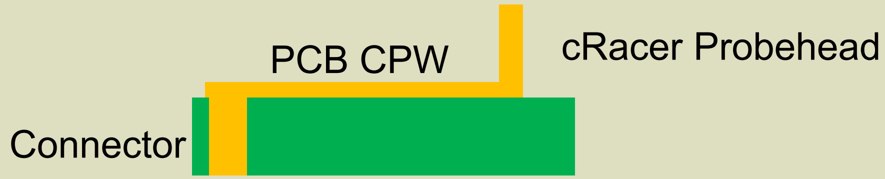
Methods/Materials

- cRacer Probehead
  - 3mm test height spring probe, 150 um pitch, 6g, 150 um 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 (5 GHz-55 GHz RF paths)
    - Simulated signal integrity (HFSS, SI Wave)
    - DUT side: surface, internal traces
    - Tester side: surface, internal traces
  - 25 Power supplies
    - Simulated IR drop and impedance (SI Wave) all 8 sites
- Connectors/Cabling
  - SMPM connectors, Cabling
    - Simulated launch geometries
- Switching
  - 10-44 GHz SP4T 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)

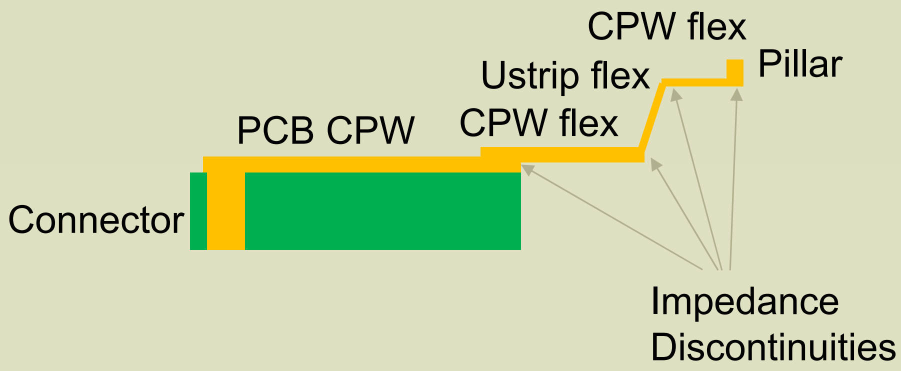


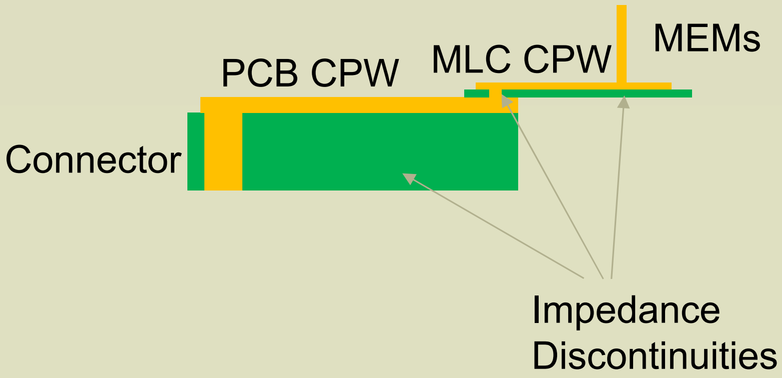
Signal Integrity Difference

cRacer Direct Attach Signal Path



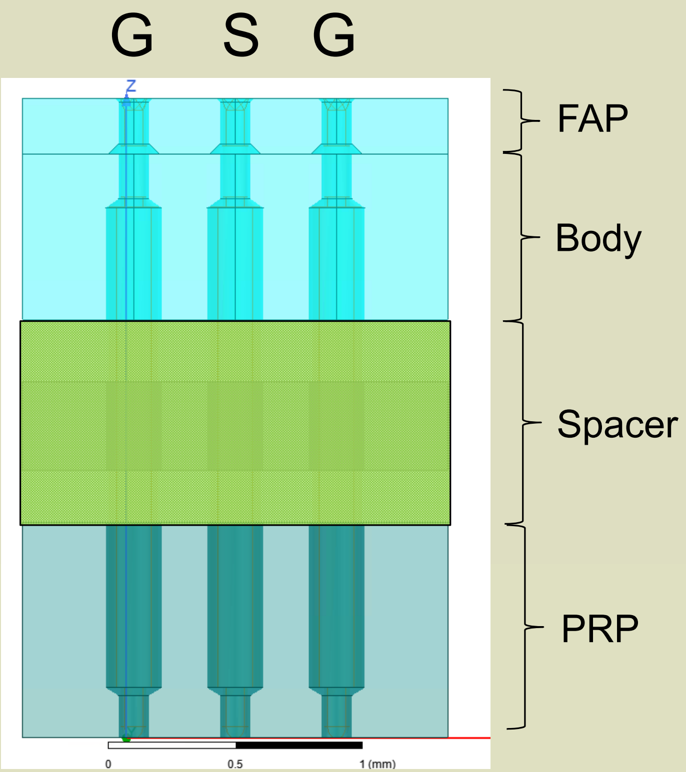
Other Signal Path Options





cRacer Optimization Process (Patent Pending)

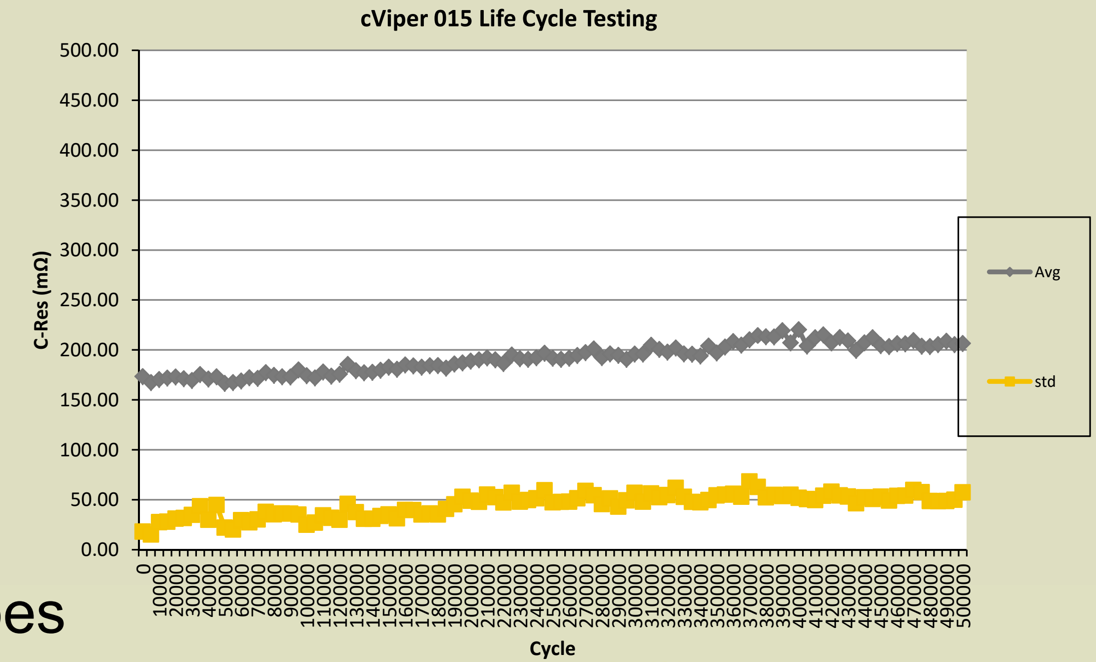
- Select pin based on required pitch and tip profile (150 um crown tip in this case)
- Select contactor materials for PRP, Spacer, Body and FAP to provide required mechanical strength and dielectric performance
- Simulate RF performance in GSG or GSSG configuration
- Tune performance by matching to required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

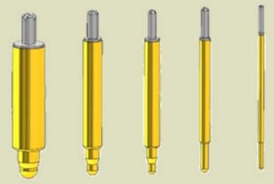


PRP = Probe Retainer Plate
FAP = Floating Alignment Plate

Radial Probe cRes Optimization

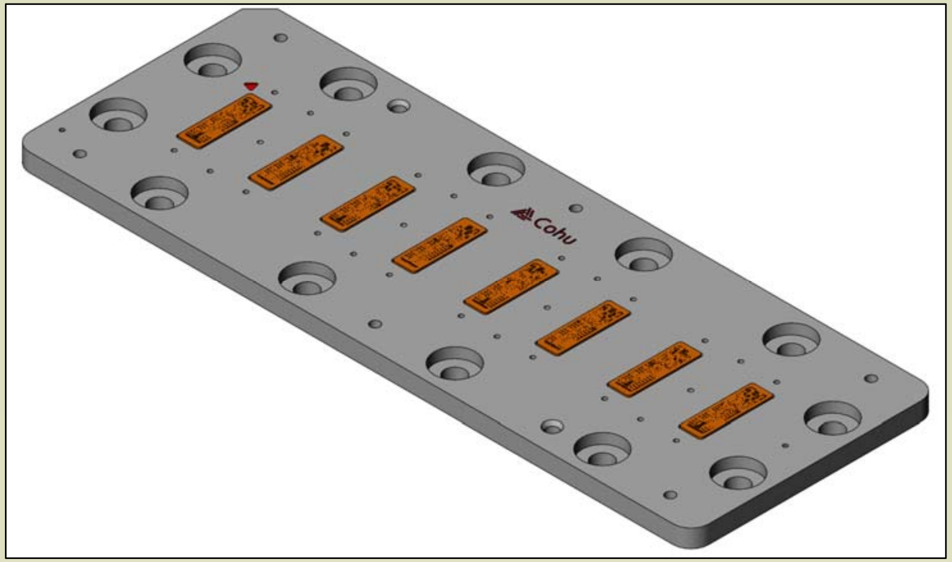
- Expertise leveraged for performance
- Back to the Basics
  - Low and consistent cRes
  - Lot-to-lot stability
  - Long lifetime
  - Optimized "Guts"
- Standardized Recipe for probes and cross sections

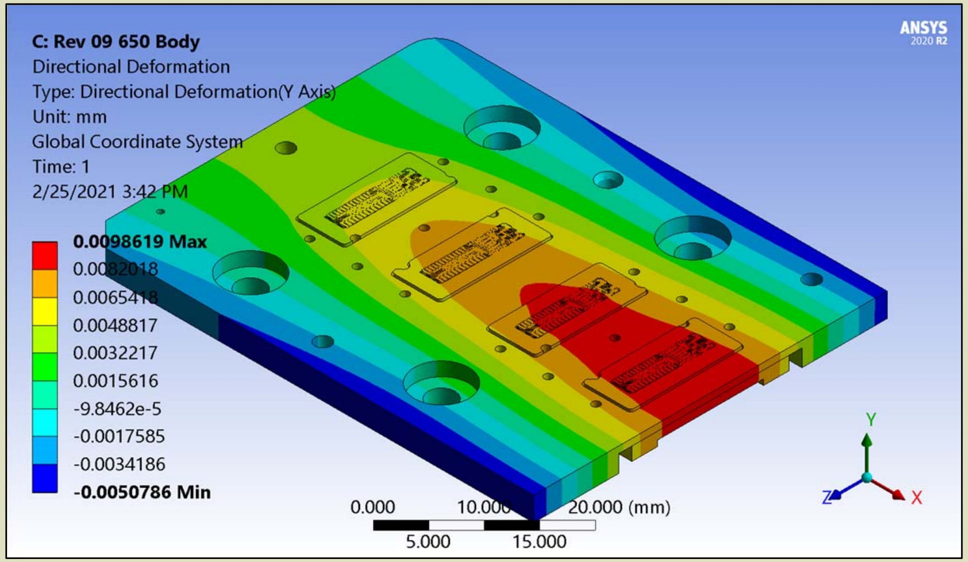




Bowing Simulation – Rev 04

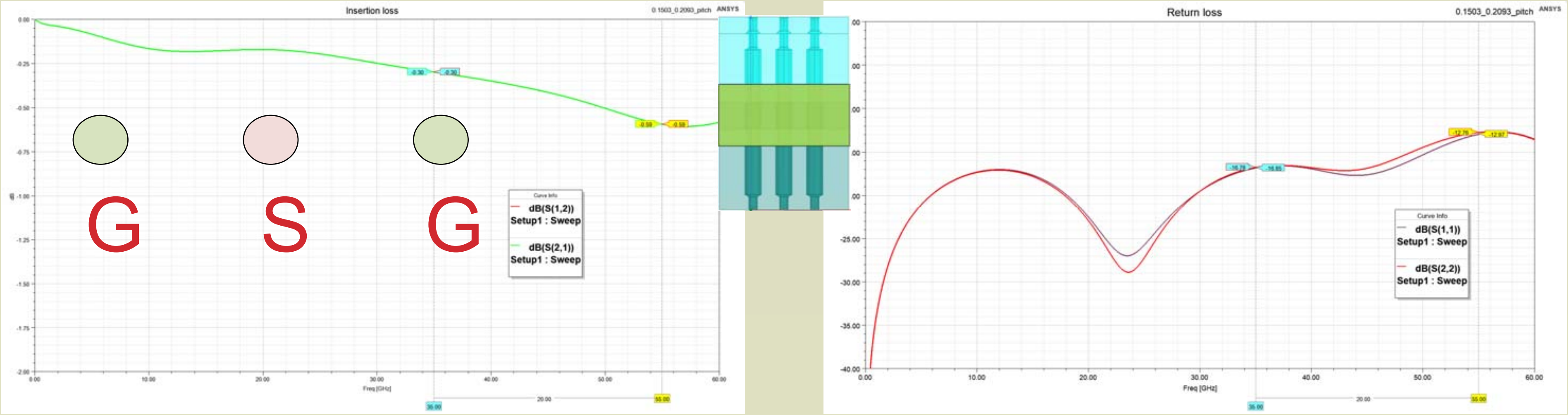
- Predict the bowing deflection due to probe preload that can be expected from Probehead using Ansys simulation
- Max Y-Directional Deformation: 10.3 µm





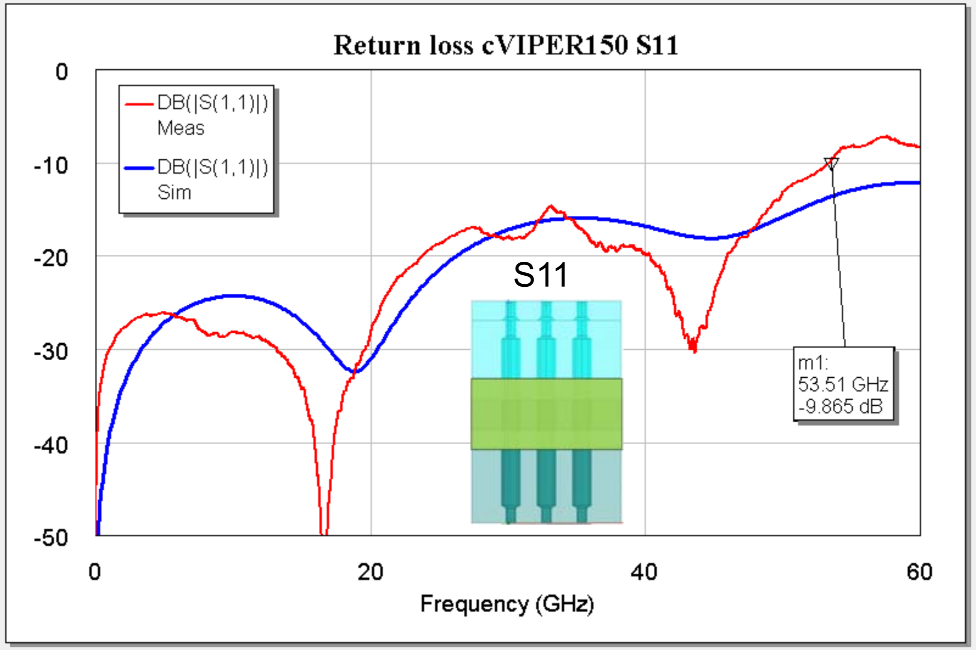
cRacer Probehead Simulated Insertion Loss

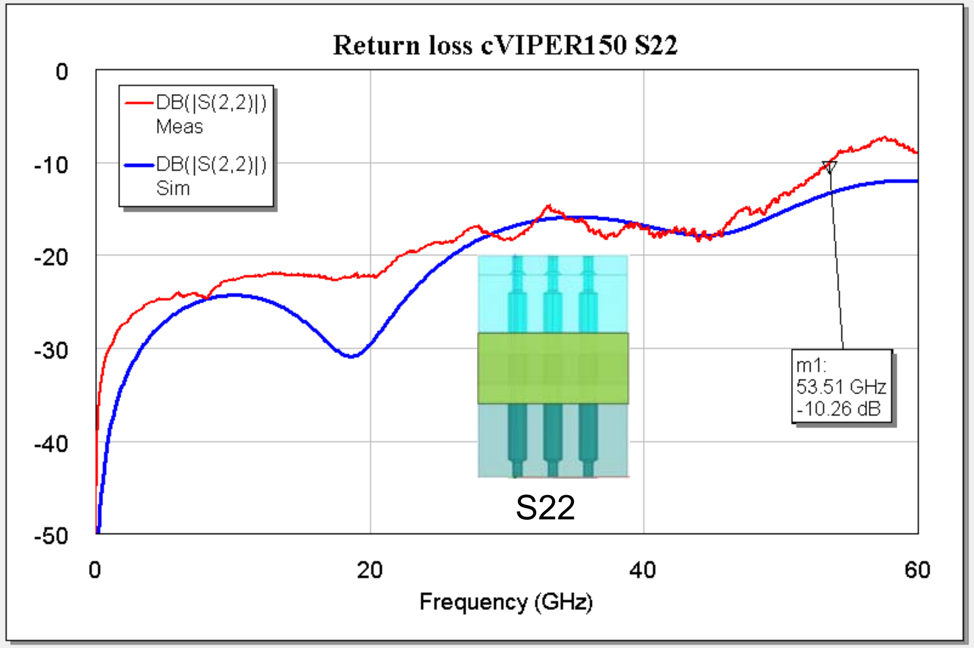
- Predict the insertion loss and return loss expected from Probehead using Ansys simulation out to 55 GHz
  - Great performance with <1 dB Insertion loss, <-12 dB return loss through 60 GHz



cRacer 150 Return loss Correlation

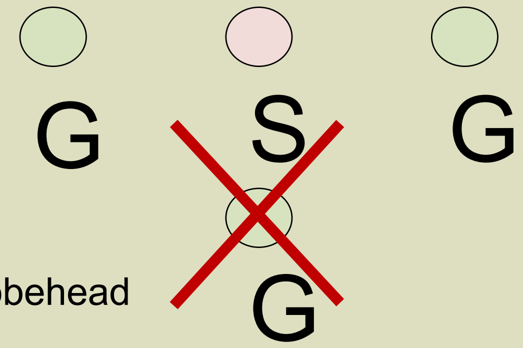
- cRacer150 GSG Probehead RF Measurement to RF Simulation correlation
  - Great correlation between simulation and measurement
  - simulation -12 dB, measurement -10 dB @ 53 GHz

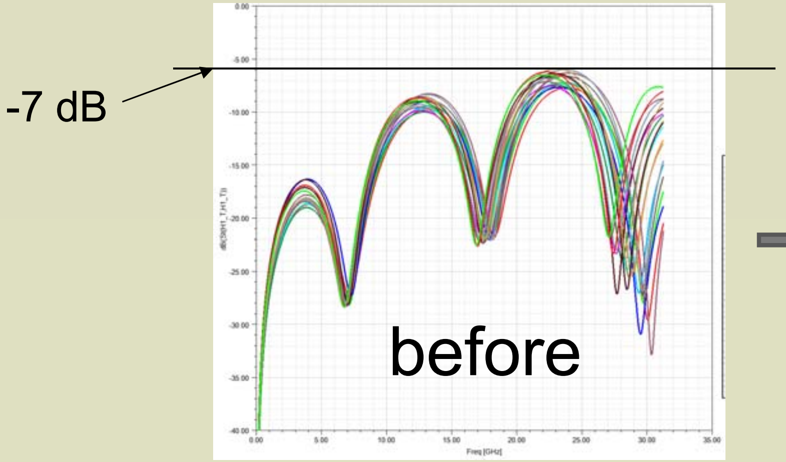


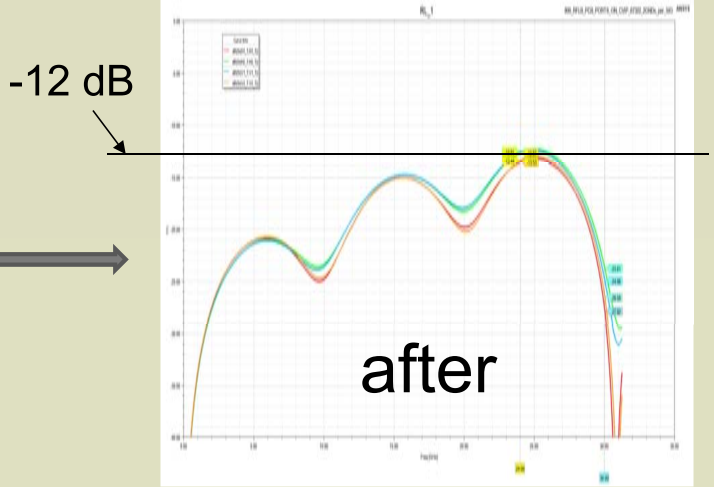


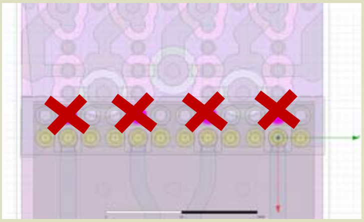
RL issue for mmWave signals

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

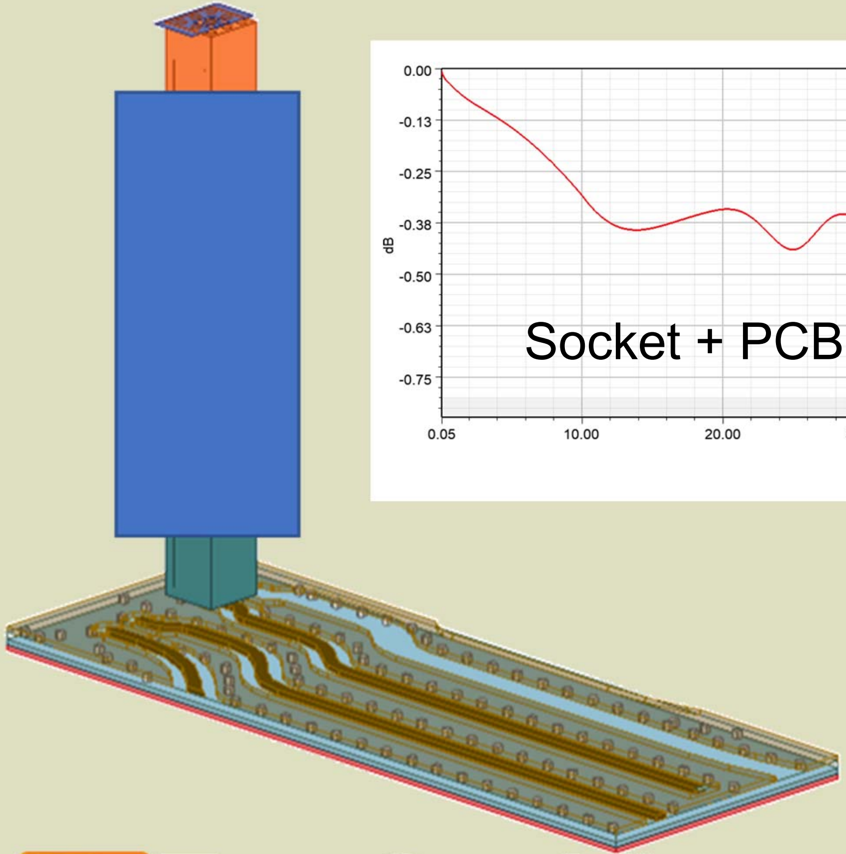


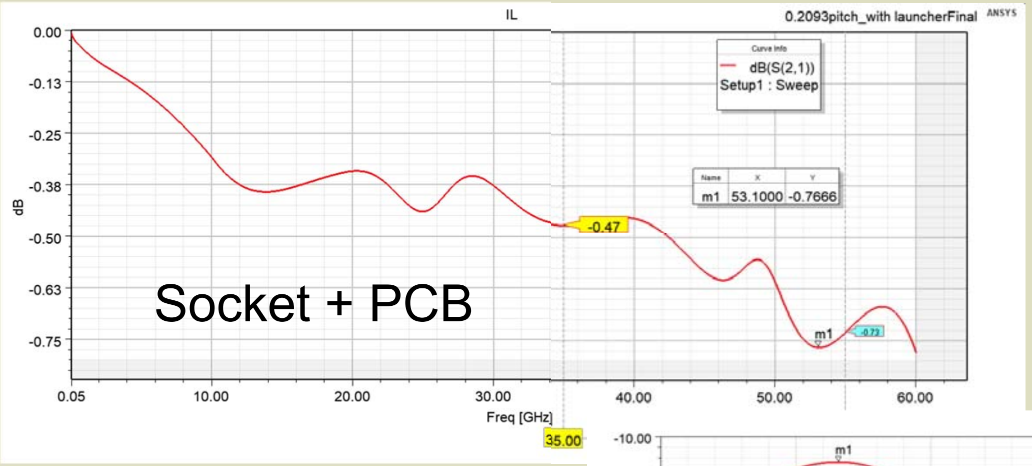


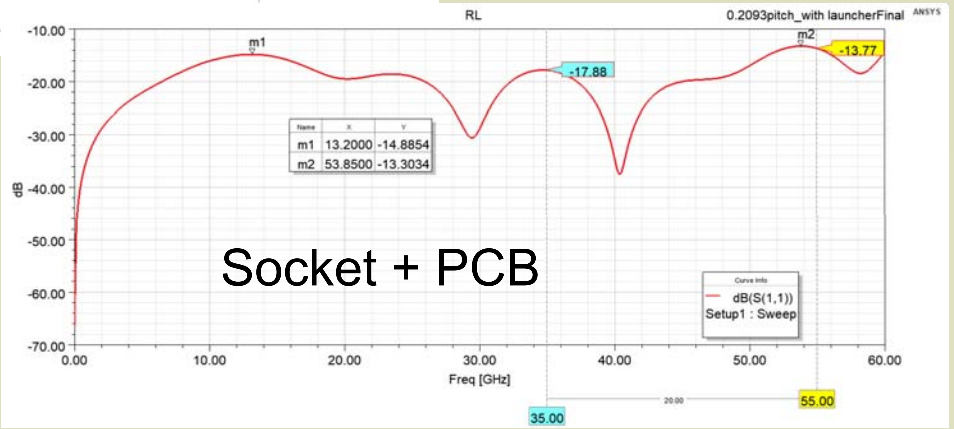




mmWave Simulation: cRacer with PCB Launch





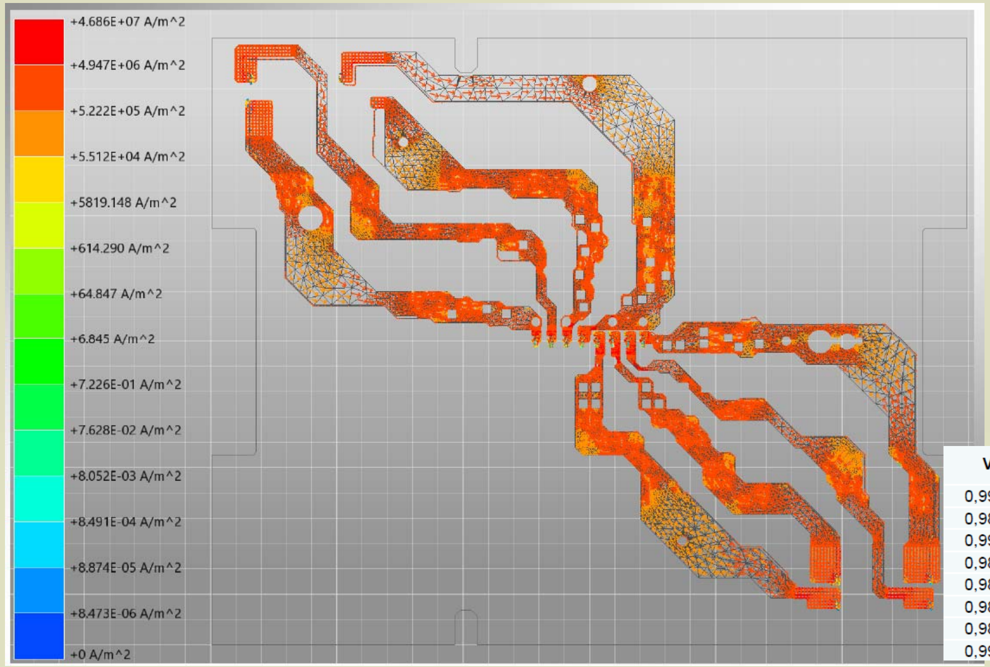


- Insertion loss
  - <1 dB to 60 GHz
- Return loss
  - <-13 dB to 60 GHz

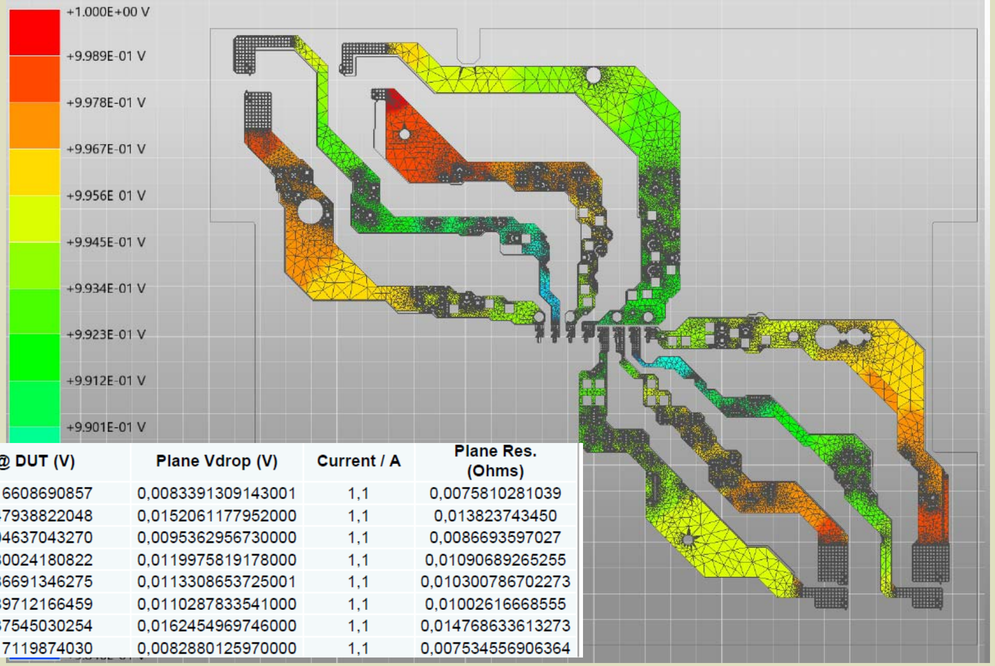
DC Voltage Drop Simulations (1V supply)

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

- Current Density



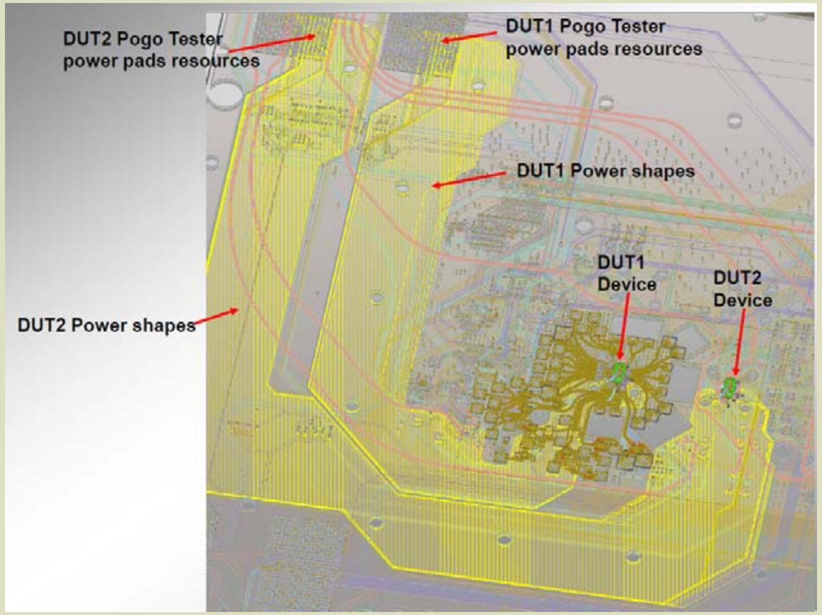
- Voltage Drop

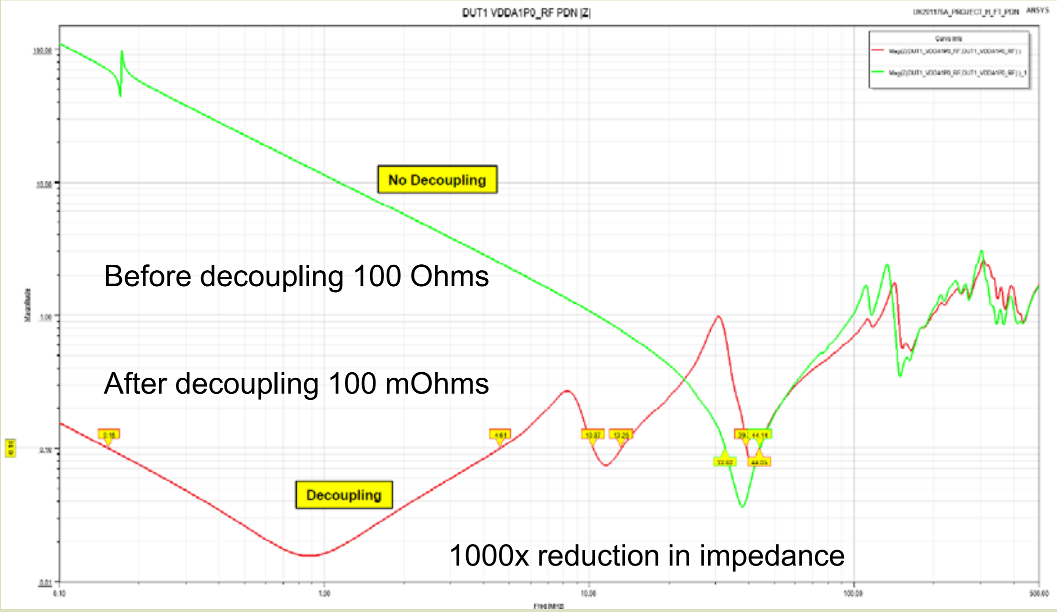


V @ DUT (V)	Plane Vdrop (V)	Current / A	Plane Res. (Ohms)
0,9916608690857	0,0083391309143001	1,1	0,0075810281039
0,9847938822048	0,0152061177952000	1,1	0,013823743450
0,9904637043270	0,0095362956730000	1,1	0,0086693597027
0,9880024180822	0,0119975819178000	1,1	0,01090689265255
0,9886691346275	0,0113308653725001	1,1	0,010300786702273
0,9889712166459	0,0110287833541000	1,1	0,0100261668555
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

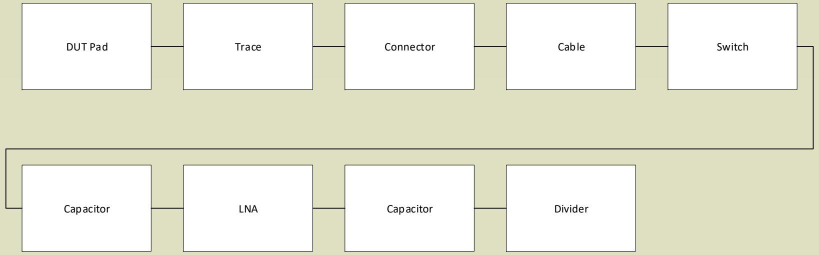


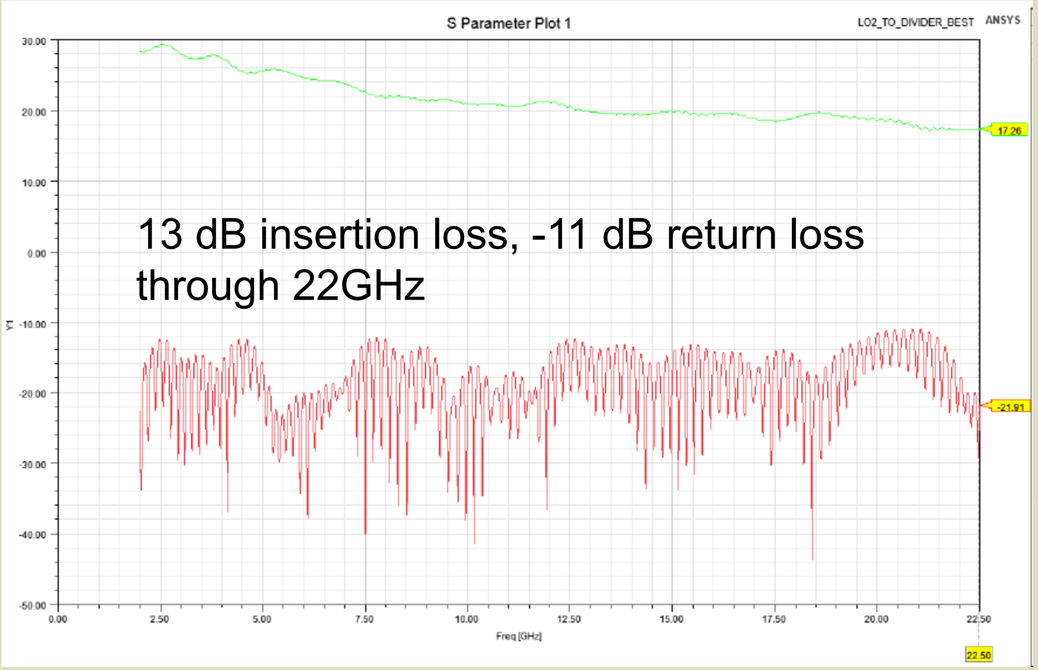


LO Full Path Simulation example

- 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

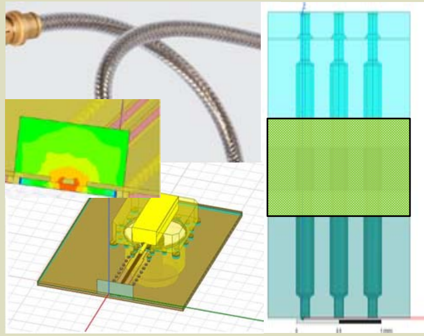
Schematic

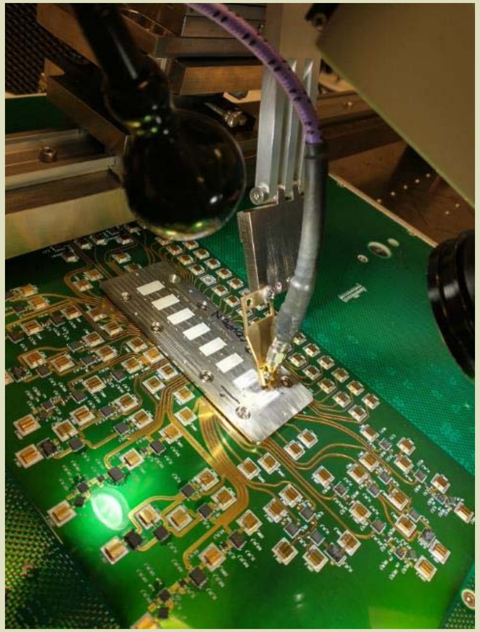


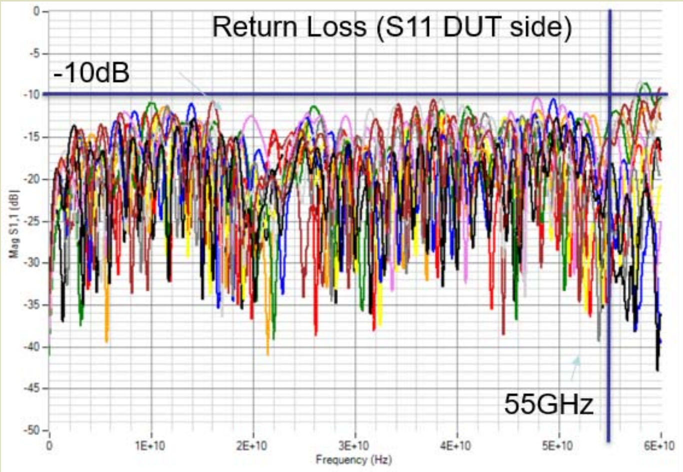


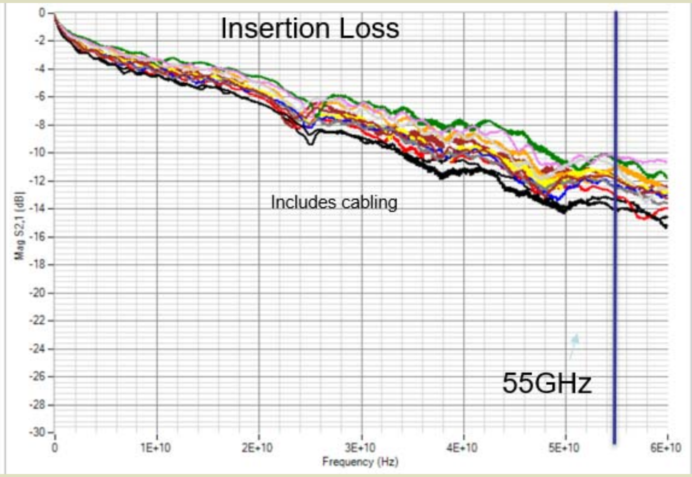
Full Path S-parameter measurement to 55GHz

- Tester to DUT full path loss (12x 55 GHz paths)
  - Return loss below -10 dB and linear insertion loss thru 55 GHz
  - Includes socket, vias, traces, connector, 18” coax cable

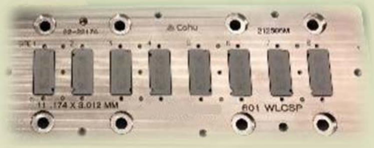






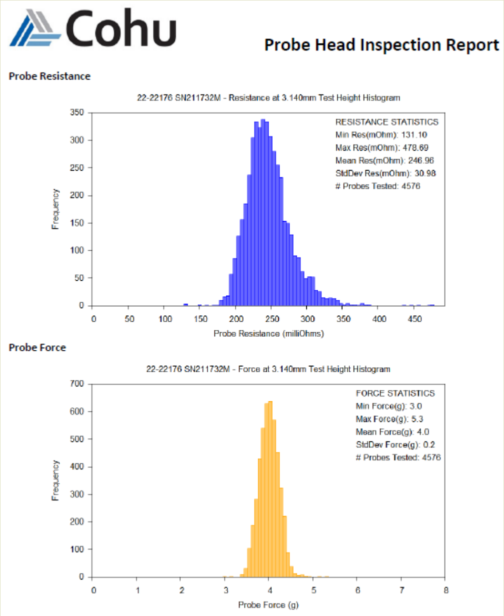


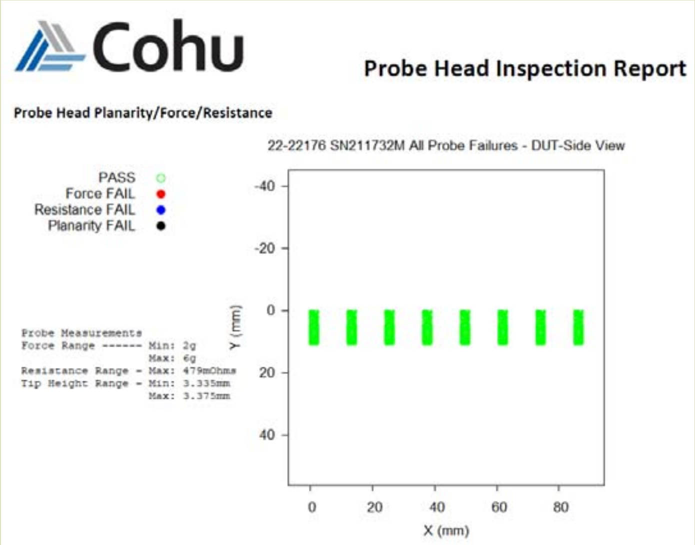
Probehead Inspection

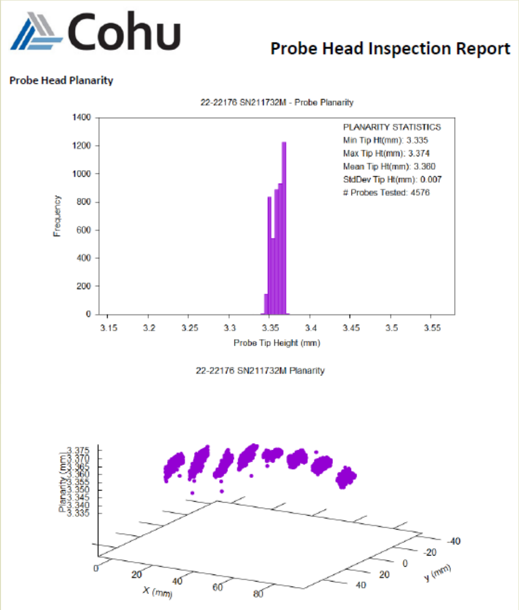


- Resistance Average: 250 mOhm
- Resistance STD: 30 mOhm
- Force Average: 4 g
- Force STD: 0.2 g

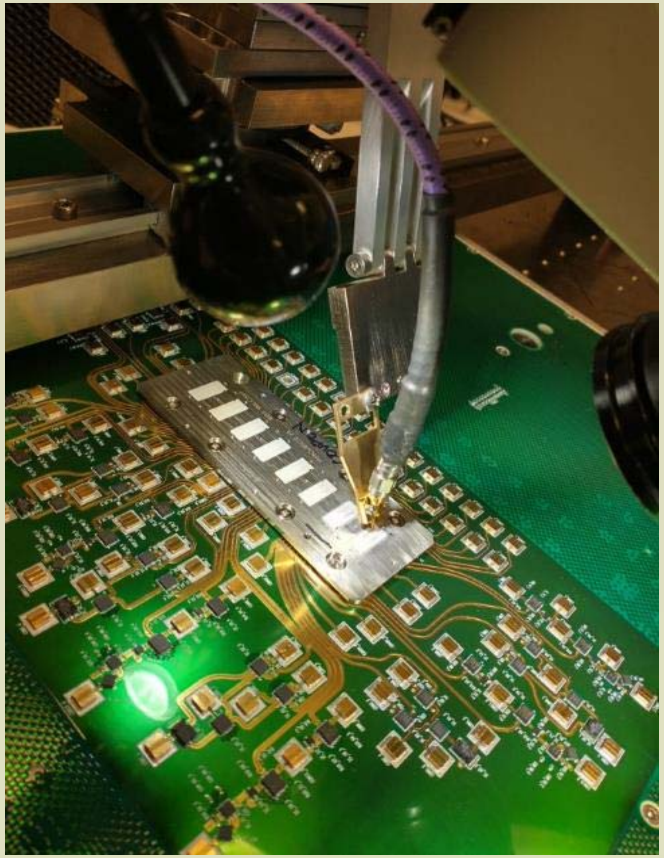
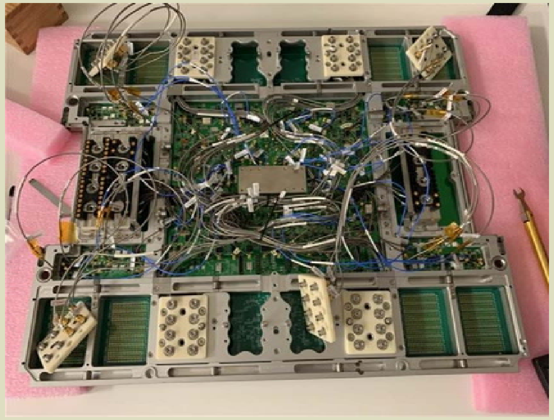
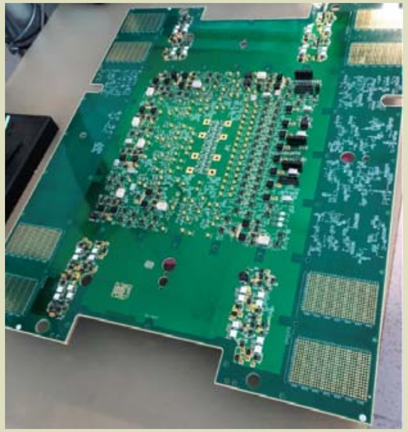
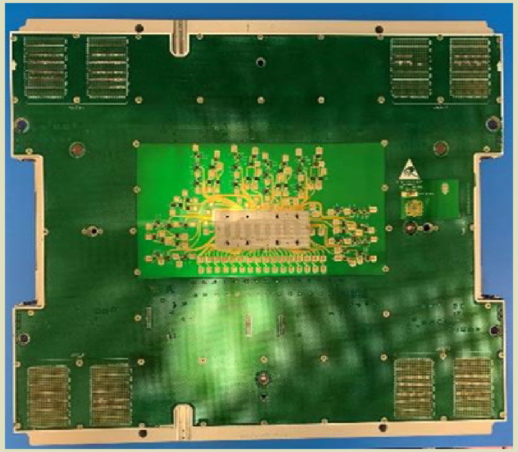
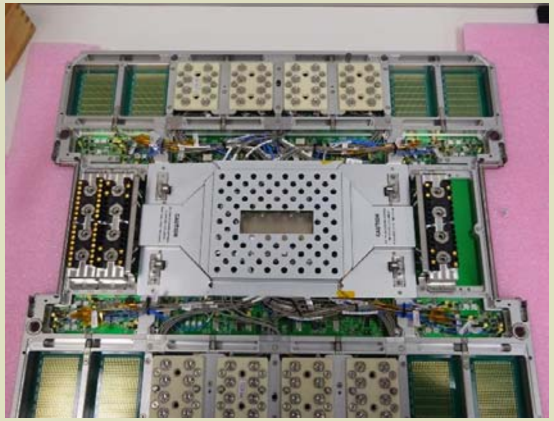
- First touch average: 3.36 mm
- First touch STD: 7 um
- Min tip height: 3.335 mm
- Max tip height: 3.374 mm
- Coplanarity: 41 um





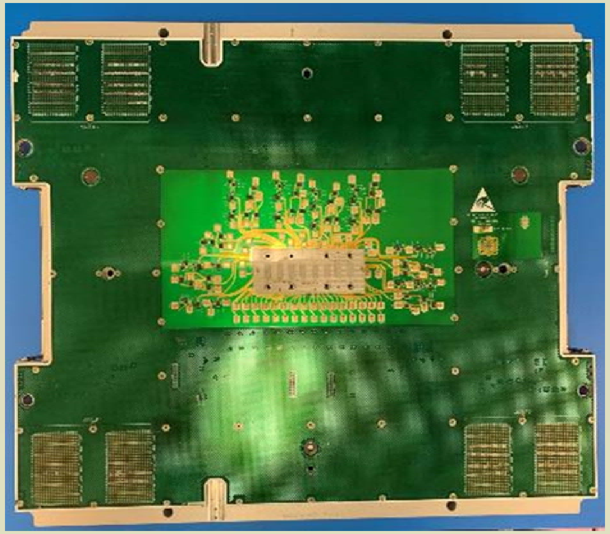


cRacer 55 GHz Octal-Site Direct Attach Probe Card

Discussion of Results

- Advantages
  - 8+ site capable mmWave Vertical 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
  - PCB registration and lamination
  - High BOM count/cost and assembly complexity
  - Long-leadtime mmWave components



Summary / Conclusion

- Proven performance of a cRacer probecard
  - Multisite (8+) spring probe probecard for 150 um pitch applications
  - RF performance through 55 GHz
  - Design, simulation, prototype and production builds completed
  - Platform developed for generations of mmWave die and package test
- Turnkey Production Probe solution
  - Mechanical/electrical design, supply-chain management, assembly and test coordination, and global logistics management
  - Product and processes developed for high-volume probecard applications

Follow-On Work

- Redesign for alternative impedance profiles
  - Printed impedance transformers, High-Power cRacer socket
- Optimize cable lengths and routing for lower loss
  - Initial design used 19" cables for simplicity
  - Optimized design can cut half the loss and half the length
- Add fiducial alignment for finer pitches
- Simplify test for high-volume orders
  - Automated PCA and RF test Stations to increase capacity by 10x+


PCA


RF test

Thanks to:

- Synergie CAD
  - Mahmoud Mesgarzadeh (Design Team Manager)
  - John Holmes (PCB CAD Engineer)
  - Paul Holland (RF Simulation Engineer)
- Cohu
  - Aaren Lonks (RF Product Development Manager)
  - Peter Cockburn (Senior Product Marketing Manager)
  - Anne Krantz (Product Development Engineering Manager)

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