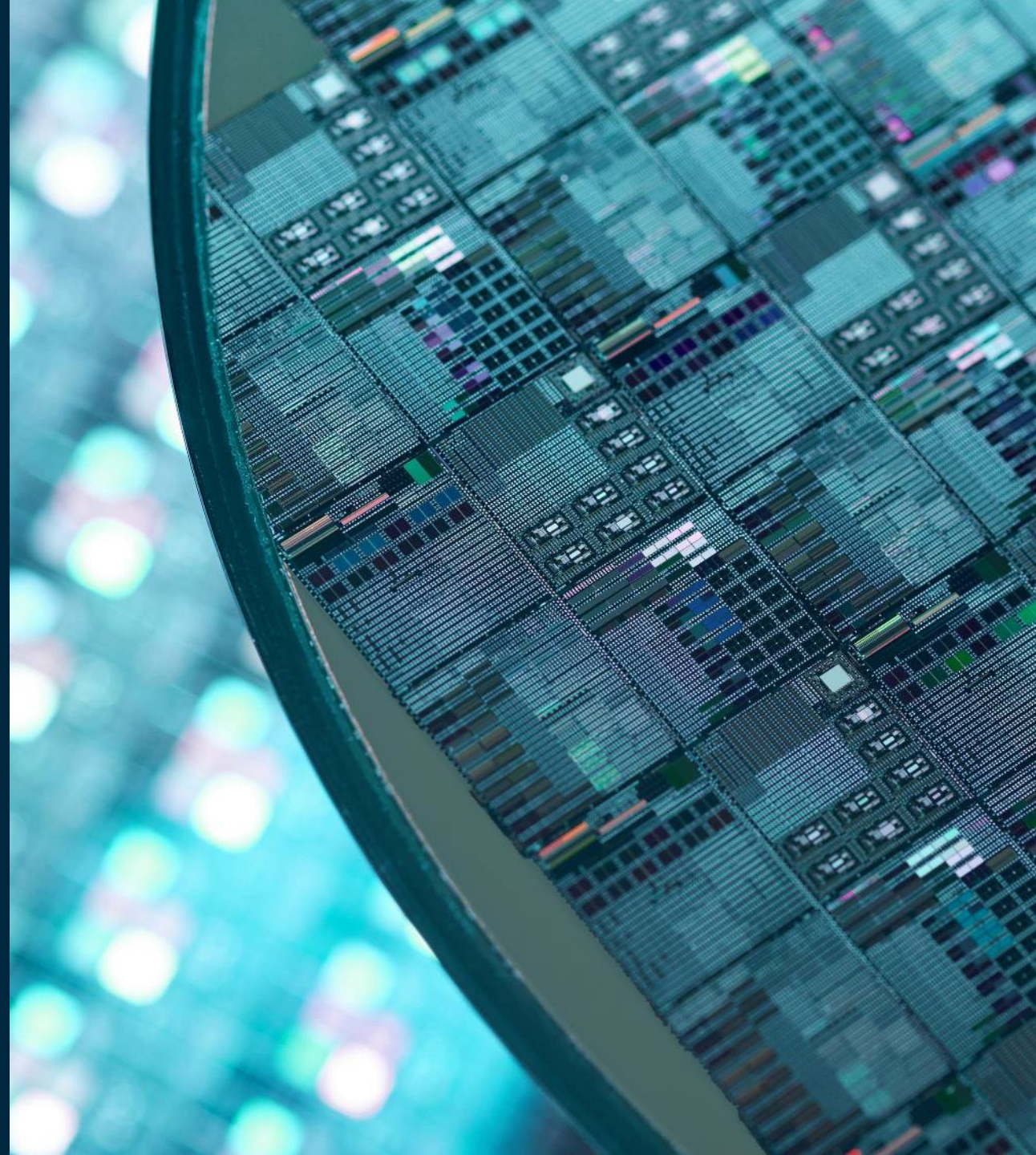




Designing RF/mmWave Passive Structures

Pratik Ghate, Ph.D.

02/22/2024



Agenda

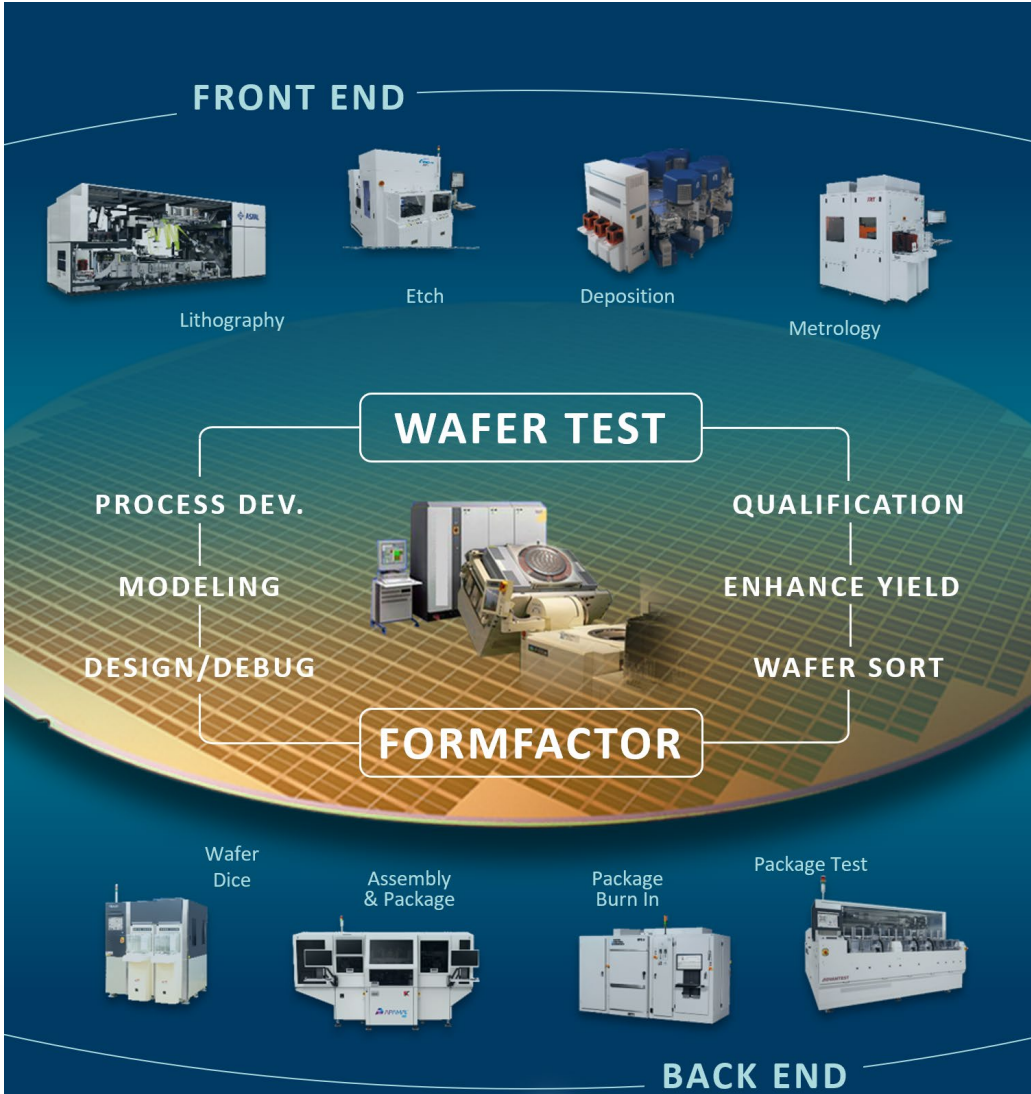
- About FormFactor
- RF Products
 - Pyramid Probe Technology
 - Analytical Probe
 - Impedance Standard Substrates (ISS)
- Need for RF and mmWave Devices
- RF/mmWave Frequency
- Passive Structures
- Simulation Examples
- Conclusion

About FormFactor, Inc



**A Leader in
Semiconductor
Test and Measurement
from Lab to Fab**

We enable our customers to revolutionize semiconductors with advanced packaging bringing tomorrow's electronics to life



FormFactor Probe Card Portfolio

ENGINEERING

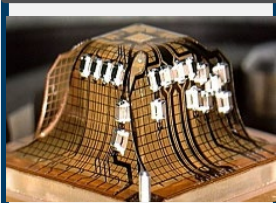


Analytical Probes

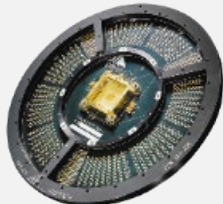


Probe Systems

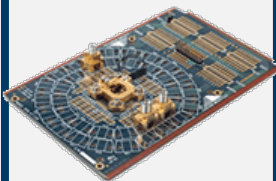
RF



Pyramid

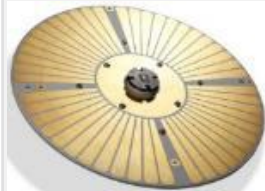


Pyramid-RF

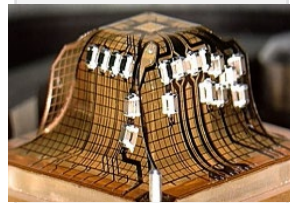


Pyramid-MW

PARAMETRIC



Takumi

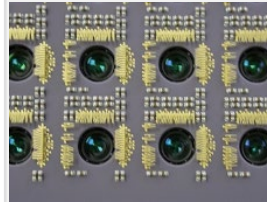


Pyramid

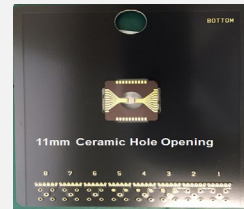


Cantilever

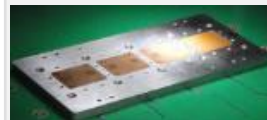
SoC WLCSP/Specialty



Hikari: CIS Image Sensor

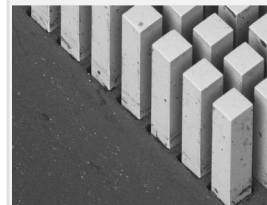


Akari: LED

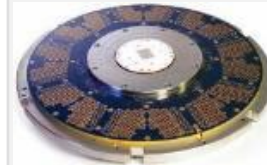


QiLin: WLCSP

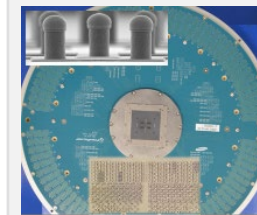
SoC Grid Array



Vertical Springs

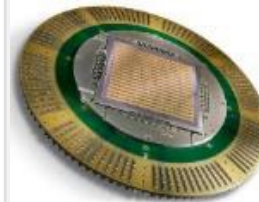
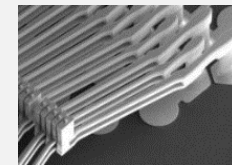


Apollo

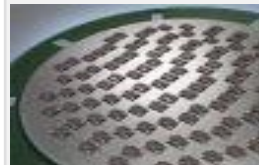


Altius for HBM

SoC Peripheral Pads



PH

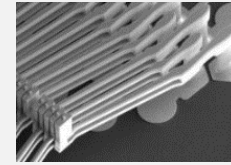


TrueScale



Kepler

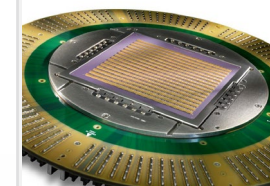
DRAM



SmartMatrix

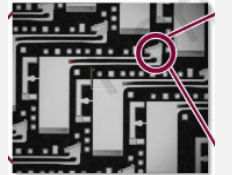


HFTAP



PH

FLASH



TouchMatrix



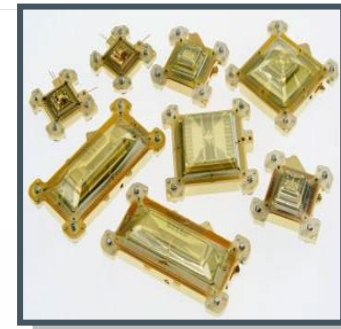
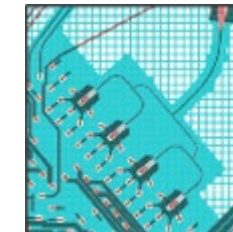
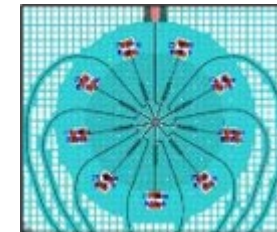
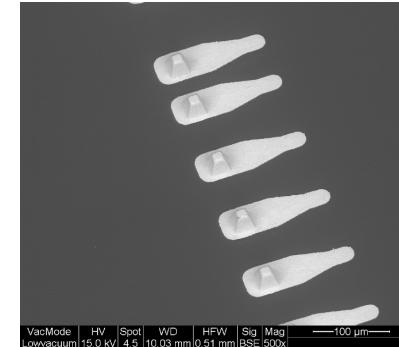
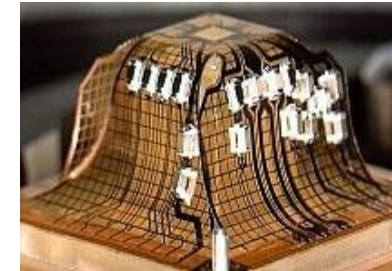
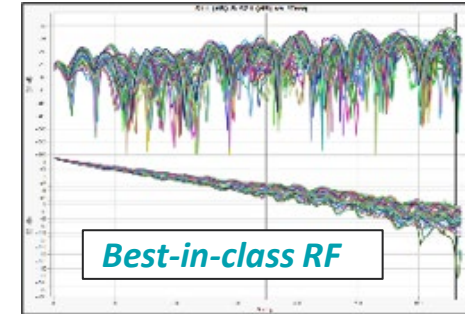
Genus



HFTAP

Pyramid Probe Technology

- Frequency range to 81+ GHz with better than -10 dB Return loss to maximize test accuracy out to specified frequency
- Multi-site 5G antenna and RFFE die testing
- Short probe lengths and controlled impedance lines minimize overall loss in the measurement
- Probe geometries engineered for low contact resistance on pads and solder
- Most widely qualified Wafer Test solution for RF Filters worldwide
 - Lowest controlled Ground Inductance (<5pH)
 - Isolation >70dB @6GHz for most die layouts
 - Expedited Delivery to meet 1st Silicon with Design/Build/Ship in 14 days



Pyramid Probe Thin Film

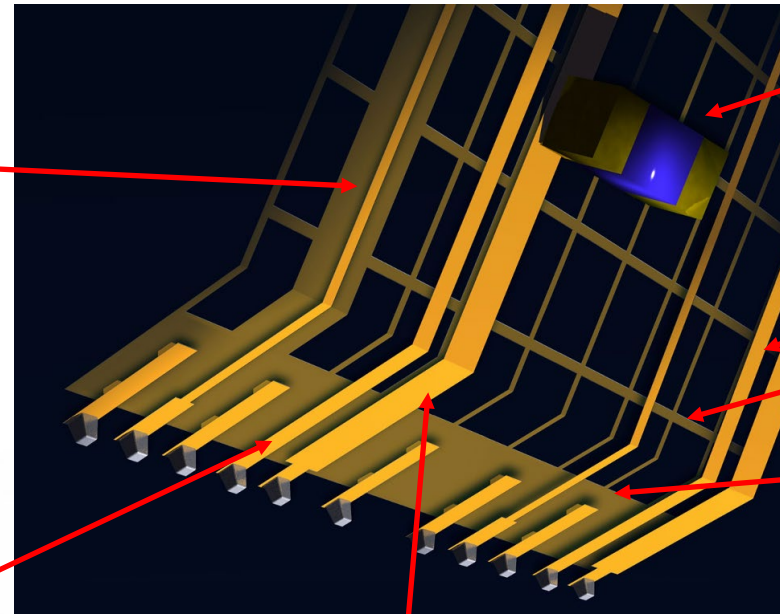
- The Pyramid Probe is a multi-layer membrane that can handle a large variety of different signal types
- mmWave transmission lines use coplanar waveguide transmission lines because of their low loss

RF

50 Ω microstrip or
coplanar waveguide

Low speed

Power supply



Components within 30
ps of DUT depending on
design

Two metal layers:

wafer side layer is signal
tester side layer is ground

Ground inductance 0.04
nH or less to the plane

Analytical Probes

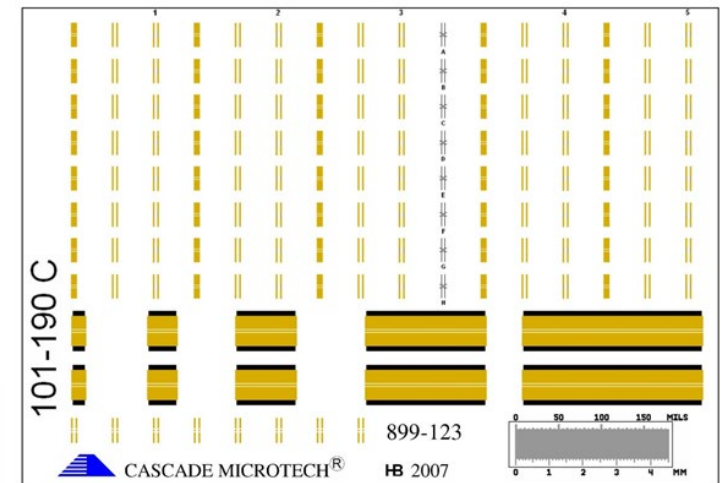
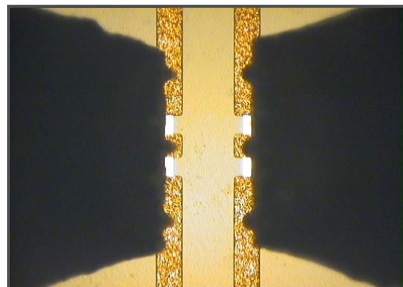


- These are high performance RF and DC probes used for precision S-Parameter, DC and other measurements.
- Used for validating models, device characterization, load pull, noise parameter, precision IV, etc.
- Also used for validating circuit debug and characterization.
- Examples of high-performance analytical probe.



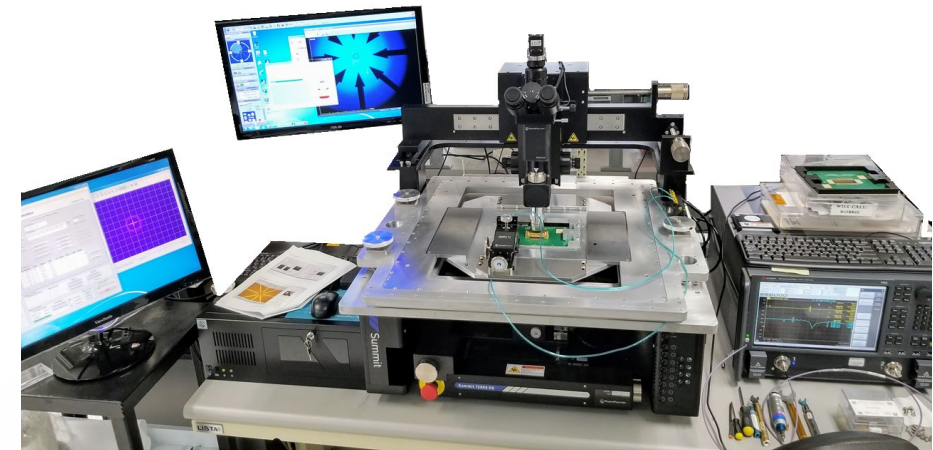
On Wafer Calibration for Precision S-Parameter Measurements

- To achieve precision on wafer S-Parameter measurements we need to go beyond coaxial calibration standards.
- There is a need to calibrate to the probe tips / contact pad to remove the effects of the probe from measurements.
- To achieve this, FFI offer two sets of tools.
 - WinCal calibration software with wafer specific calibration algorithms
 - On substrate planar calibration structures / standards
 - These substrates are specific to probe tip config & Pitch



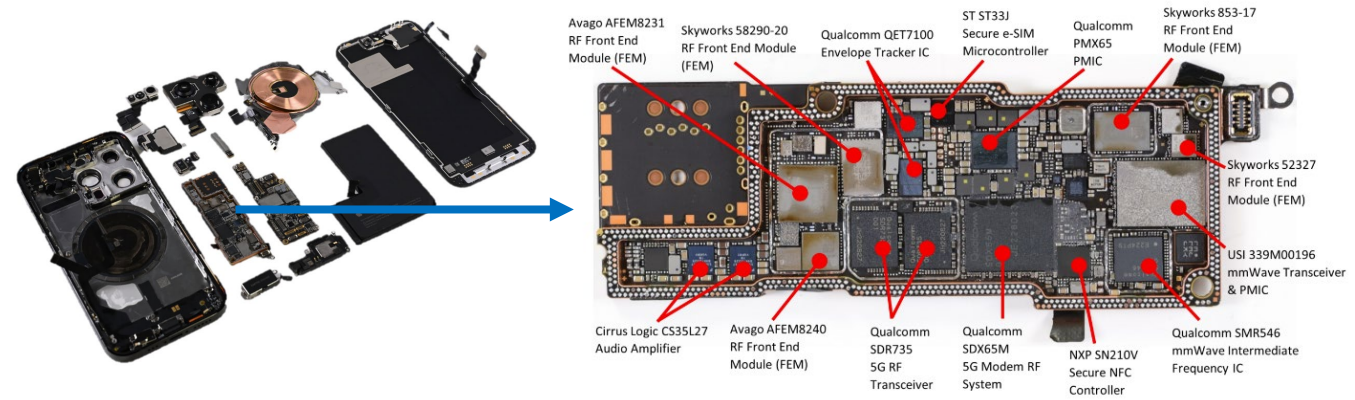
Test Capabilities

- FFI Summit 12000 semi-auto station
- Keysight PNA with 4-port capability
 - 50 MHz – 126 GHz
- Keysight eCal for cable calibration
- Different calibration techniques for probe calibration

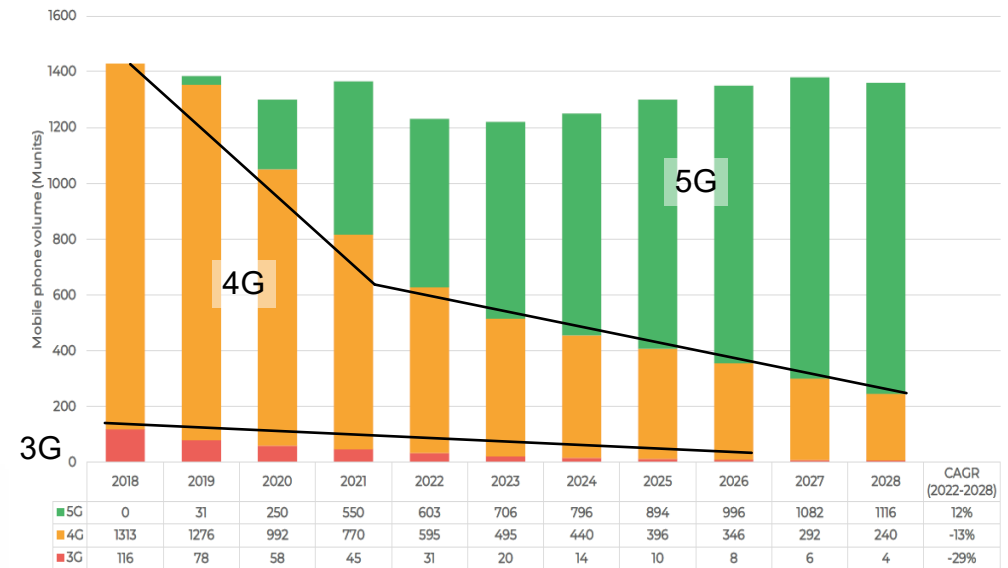


Need for RF and mmWave Devices

- The world's leading economies are actively deploying 5G coverage
- Demand ramp is soaring and will continue
- Advantages of 5G
 - High Speed
 - Large Capacity
 - Wide Spectrum
 - Low Latency
 - More Security



2018-2028 mobile phone volume forecast per air standard (Munits)

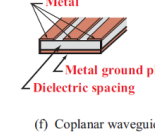
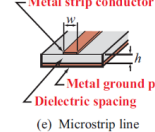
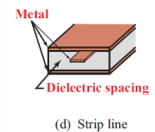
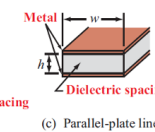
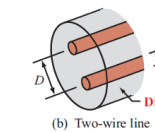
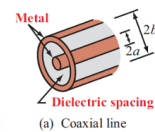
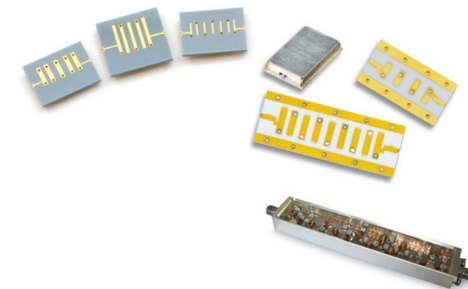
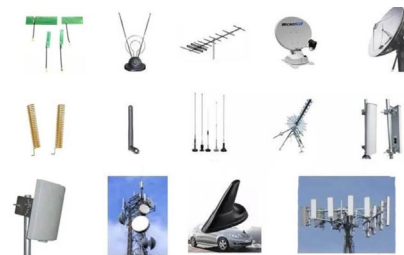
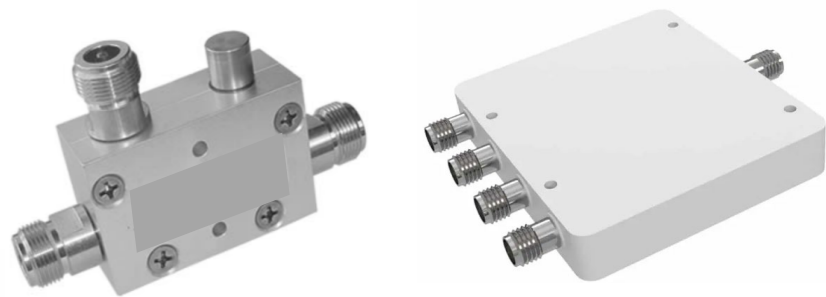


RF and mmWave Frequency

- Radio Frequency (RF):
 - RF frequencies typically refer to the range of frequencies from around 3 kHz (kilohertz) to 300 GHz (gigahertz).
 - Applications include AM and FM radio, television broadcasting, cellular networks, Wi-Fi, Bluetooth, and many other wireless communication systems.
- mmWave Frequency:
 - mmWave frequencies are a subset of RF frequencies, specifically referring to the range from about 30 GHz to 300 GHz.
 - Applications include high-speed data transfer such as 5G networks, point-to-point wireless links, and some types of radar systems.

Passive Components

- Any Electrical, Electronic and Electromechanical (EEE) components which do not require electrical power to operate are called passive components.
- Passive RF components include, filters, couplers, power dividers, waveguides, antennas, transmission lines etc.

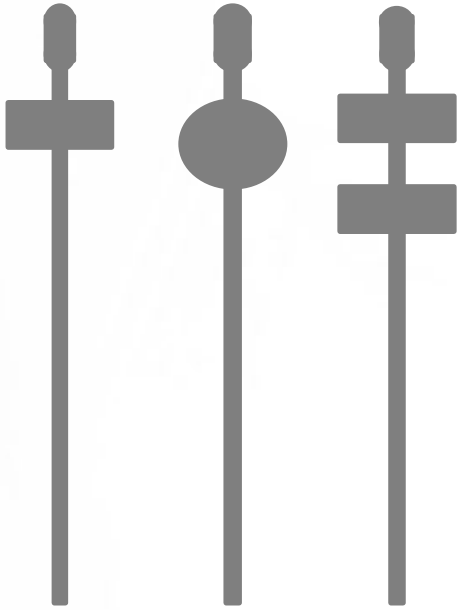


How Ansys is Helpful to Us?

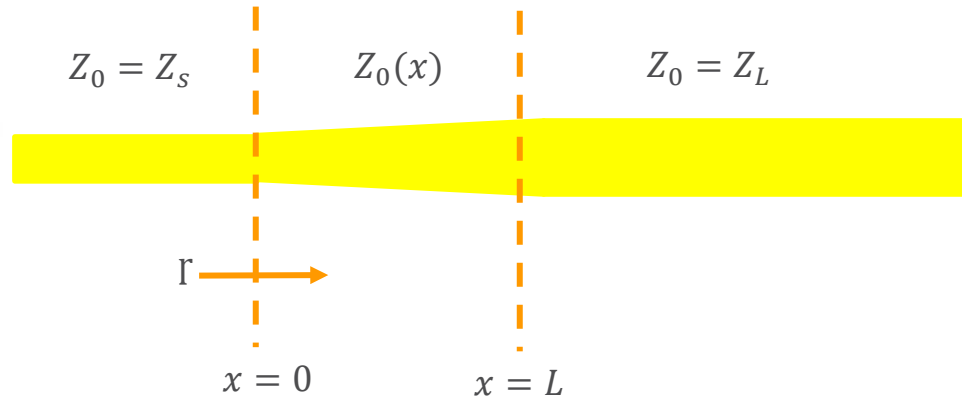
- Simulations provide guiding path for a new design.
- They help in new developments, design optimizations, design validations, cost reductions etc.
- Simulations help
 - Transmission Line Designs and Analysis
 - Waveguide Designs and Analysis
 - Design and Optimizations
 - Circuit, Probe Simulations
 - Electromagnetic Field Analysis



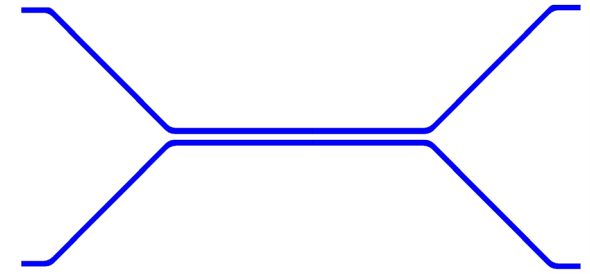
Simulation Examples



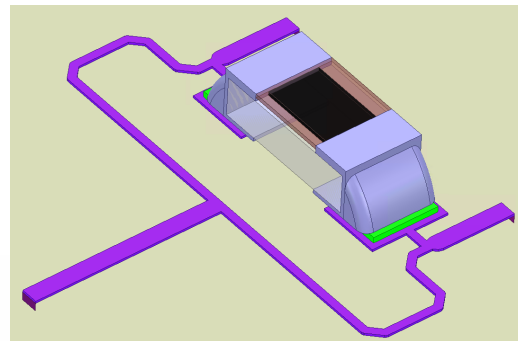
Complex Impedance Matching Structures



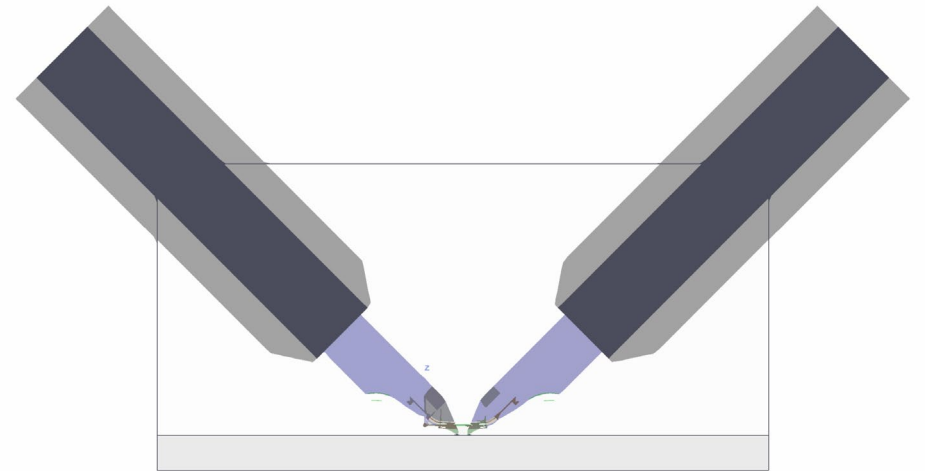
Tapered Impedance Match



Coupler

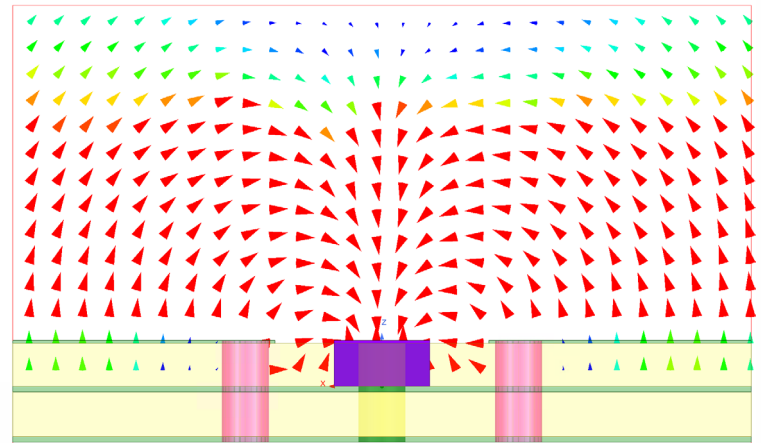
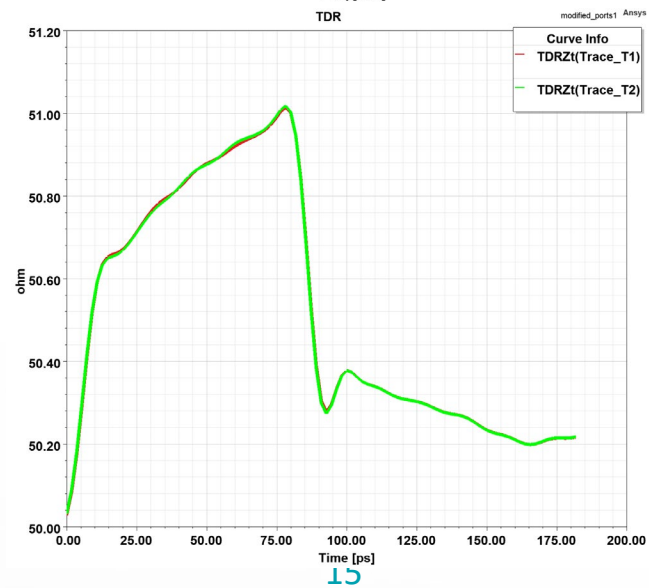
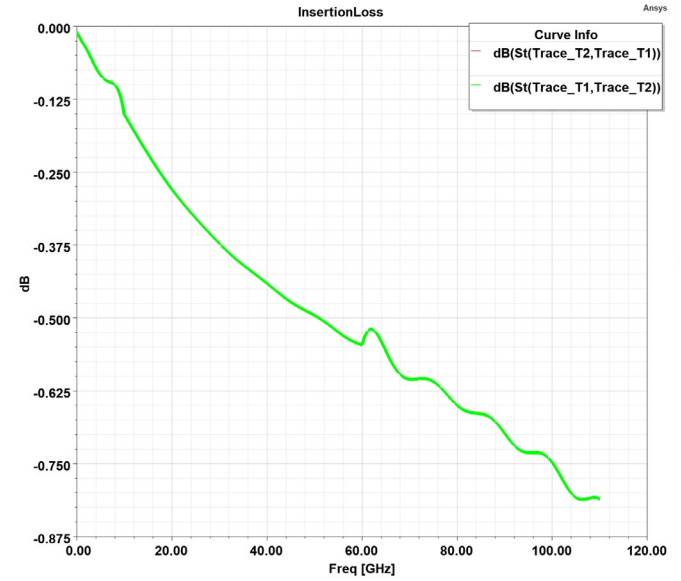
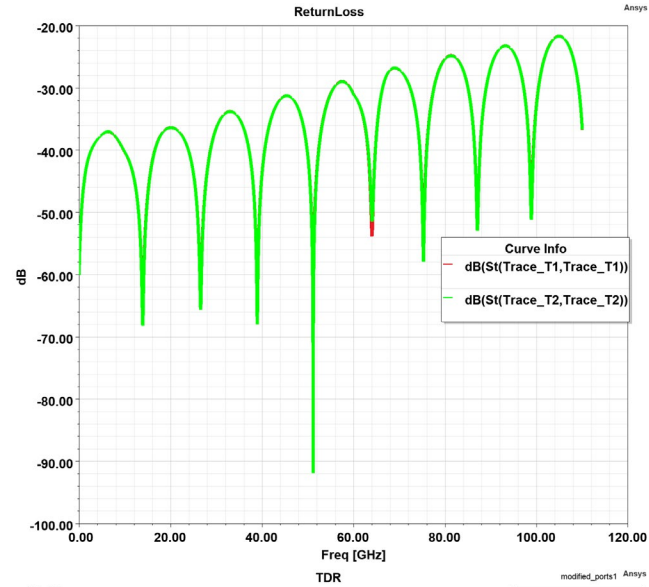
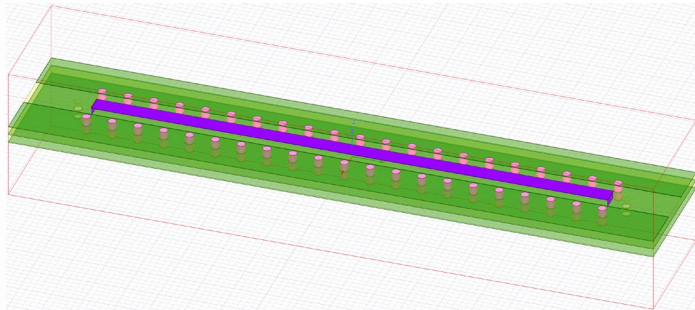


Wilkinson Power Divider

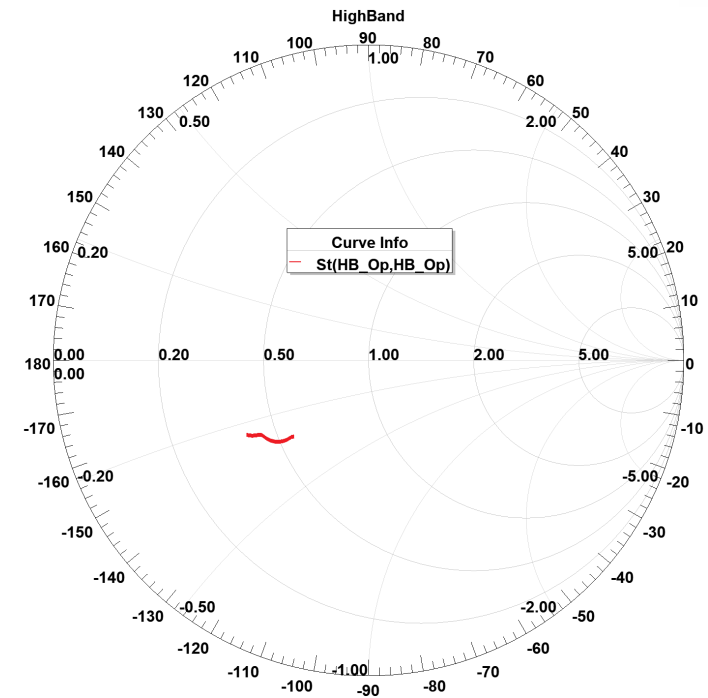
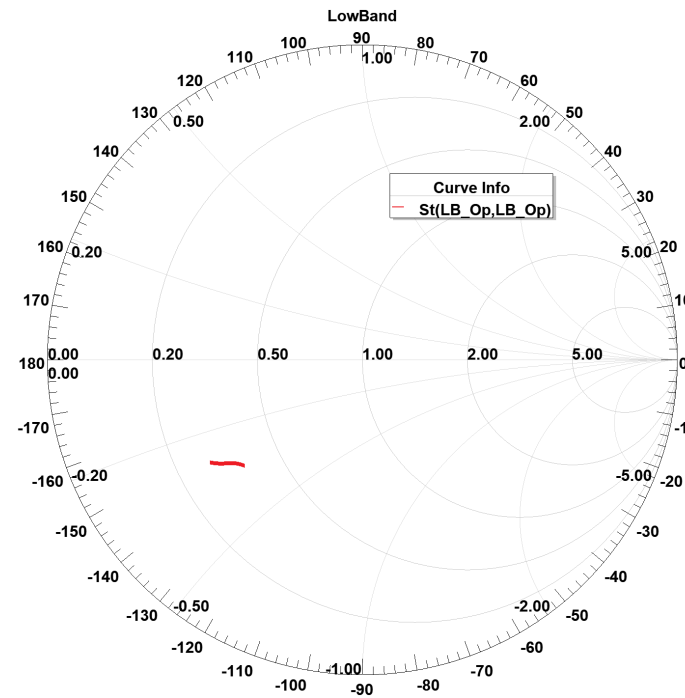
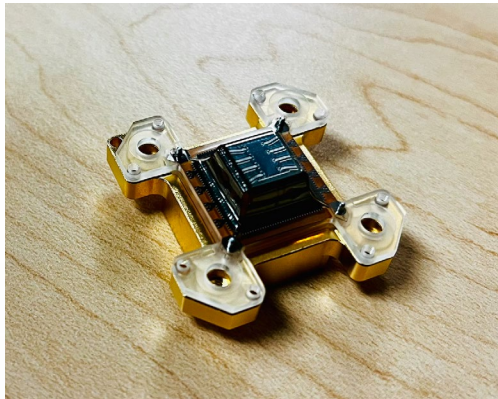
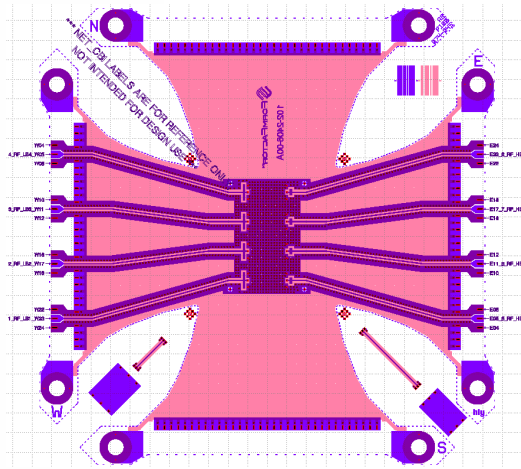


Analytical Probes

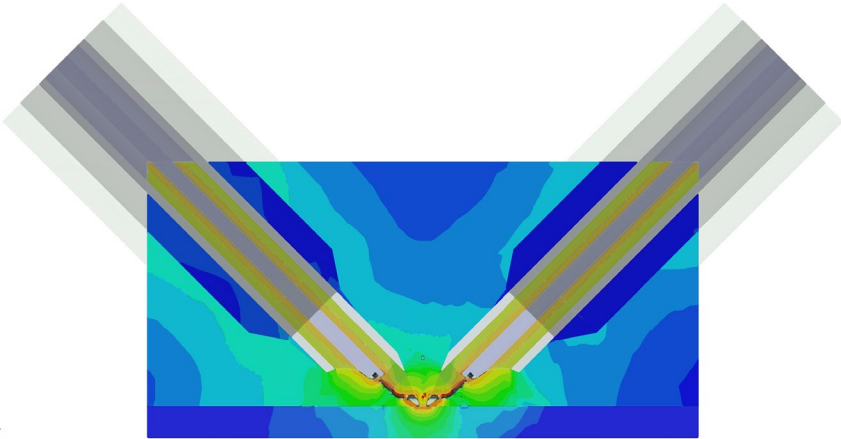
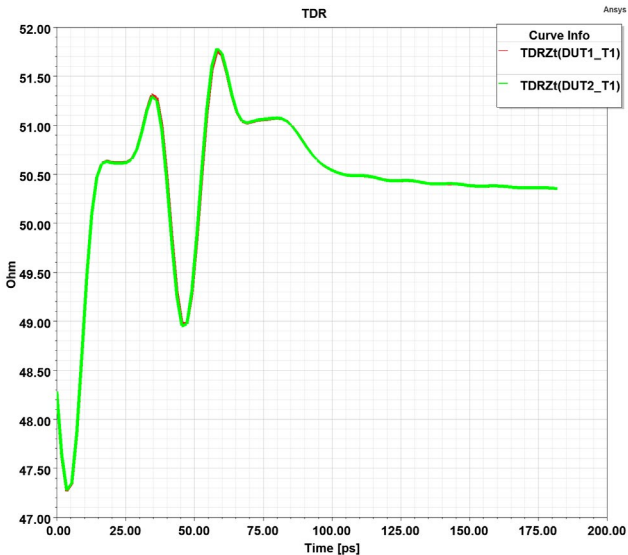
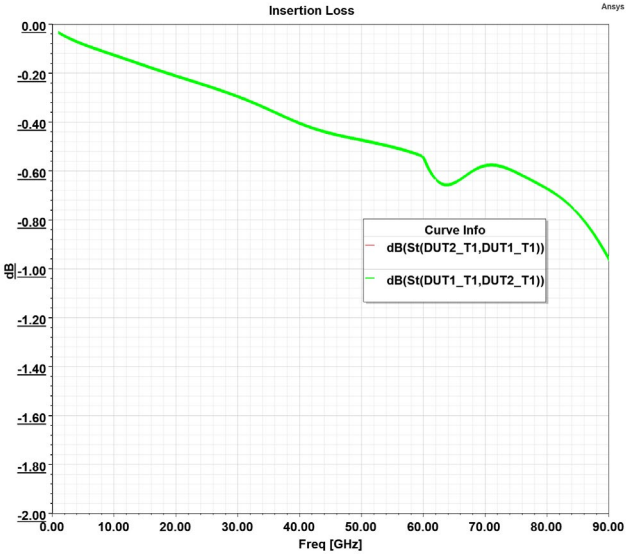
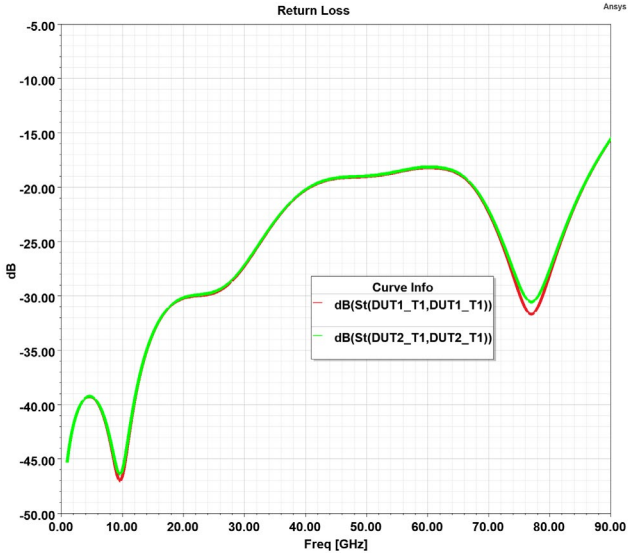
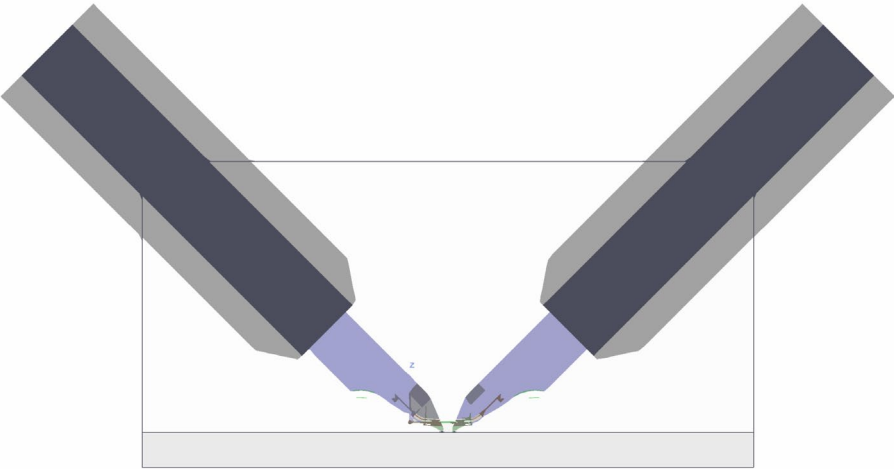
Board Transmission Line Simulations



Complex Impedance Matching Simulations



Analytical Probe Simulations



Summary

- Ansys has been a tremendous help in designing and optimizing the passive RF structures such as:
 - Transmission lines models
 - Waveguide structures
 - Optimizing circuit board stackups for proper impedance matching
 - Pyramid Probes and Analytical Probe designs
 - EM Field Analysis

Questions?

