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Solution for mmWave wafer probe applications and field results

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Cohu

Overview

- Introduction / Background – cmWave and mmWave Market/applications and xWave
- Objectives / Goals – Move from package test to wafer test
- Methods / Materials / Procedures – design considerations, mechanical simulation, electrical simulation, characterization
- Results / Relevant Findings / Key Data – tip design, force, insertion loss, impedance
- Customer Results/Feedback – Initial DC and RF test results
- Summary / Conclusion - viable cmWave and mmWave wafer level test solution
- Follow-On Work – Beta sites

mmWave Market

- ADAS
  - Advanced Driver Assistance System (Automotive Radar)
  - Short Range 24GHz and Short and Long Range 80GHz versions
  - CMOS – Low cost, High integration, catching up with SiGe
  - SiGe – High power/frequency performance ,High cost ,Low integration
  - GaN – Highest frequency performance, high cost, low integration, being obosleted by SiGe
- 5G telecom
  - 5G Backhaul – routers behind the tower
  - 5G End Node – Handheld phones/tablets/devices
  - Contacted test – external antenna arrays
  - AIP – Antenna In Package – Over the air test
  - 28GHz and 39GHz bands popular
  - Eband/Vband expected as next generation

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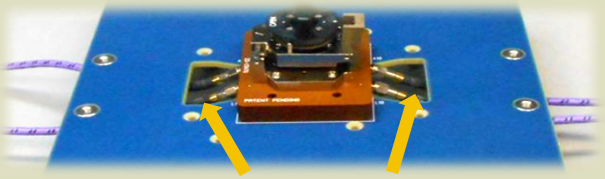
mmWave Market

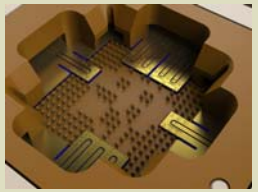
- UltraGig/WiGig
  - Fixed Wireless applications
  - Local area networks
  - Short range line of sight
  - beamforming
  - 57-64 GHz extended to 71 GHz
- Satellite Internet
  - Low orbit satellite internet systems
  - Global aircraft high speed internet connection
  - Terrestrial and orbiting devices
  - Ku (12-18 GHz) and Ka (26.5-40 GHz) bands
- High Speed Cloud Networks
  - SERDES - 54GBPS NRZ, 112GBPS PAM4
  - 3rd Harmonics reach 80GHz
  - RF theory applies to Digital applications

xWave Platform for mmWave Package Test

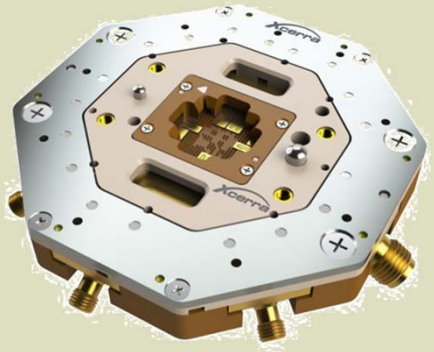
- Signal Integrity
  - Short impedance controlled coplanar waveguide (CPW)
  - 1 transition between Tester and DUT (connector to Leadframe)
  - DUT ball contacts CPW
- Integrated Solution (PCB/Contactor in One)
  - Includes RF Path from Tester to DUT
  - Pogo pins for Power and control signals
- Production Package Test Solution
  - Robust Leadframe lasts Millions of cycles
  - Mechanical assembly fully field maintainable
  - Includes calibration kit (s-parameters)
  - CTE matched materials for Tri Temp testing (-55 to 155°C)

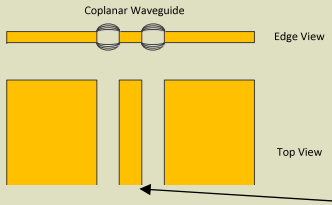


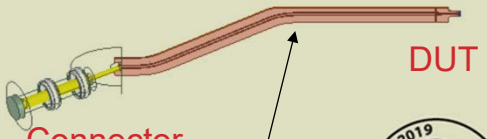
Holes in PCB for cable connections



DUT Pocket







CPW

Solution for mmWave wafer probe applications and field results

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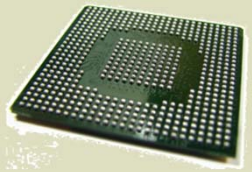
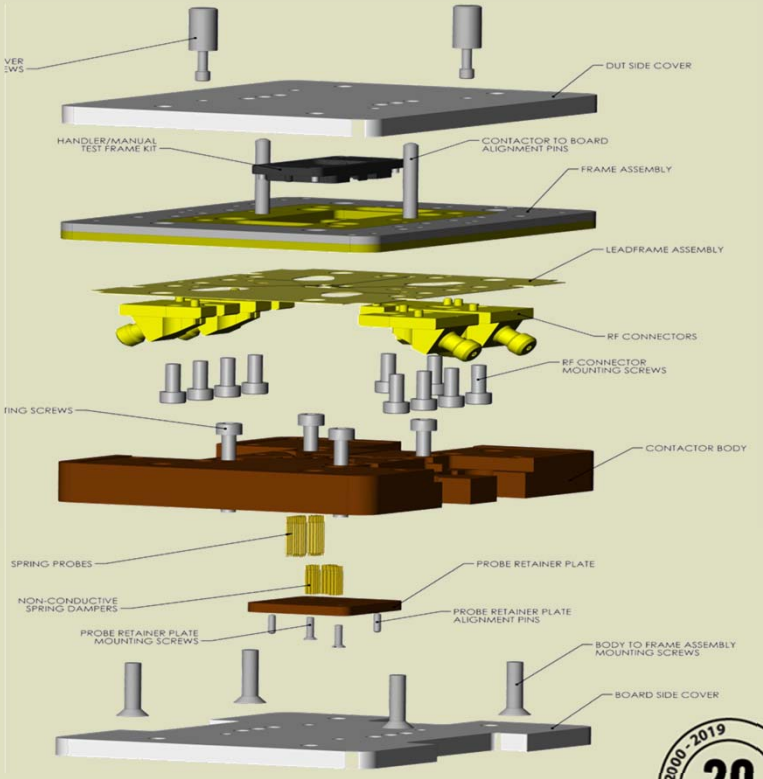
xWave Limitations for Wafer Test

- Frame limits xWave solution to Package test
  - Leadframe sandwiched between top frame and connectors
  - Top frame violates wafer infinite plane
  - Flat leadframe shorts adjacent sites



How to make xWave compatible with Wafer Test?



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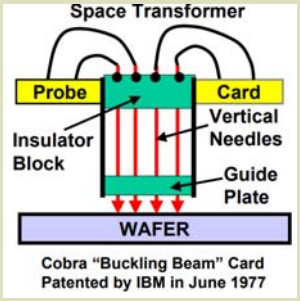
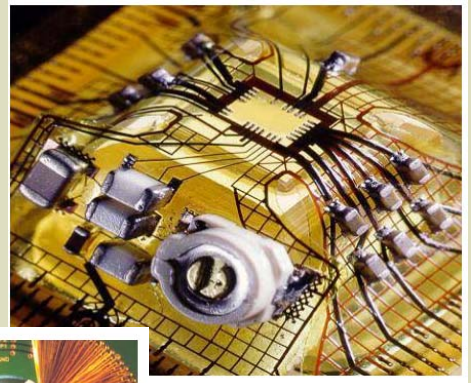
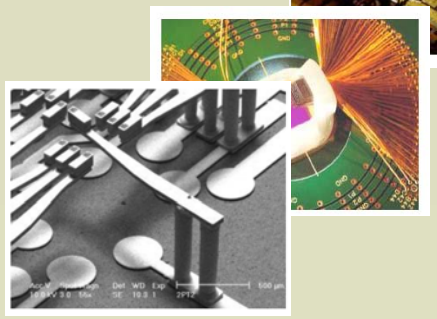
Current RF Probe Limitations

- Cantilever
  - No impedance control
  - Extremely High inductance
  - Limited to <2GHz
  - Decoupling components far from DUT
    - Vertical Probe
      - Shorter uncontrolled impedance path
      - Lower inductance than cantilever
      - Limited to <6GHz
      - Decoupling components ~1-2cm from DUT
      - Individually replaceable probes
        - Membrane
          - Impedance controlled to DUT
          - No additional inductance
          - Decoupling caps ~1-5mm from DUT
          - Limited compliance (~50um)
          - Fragile
          - Not field replaceable



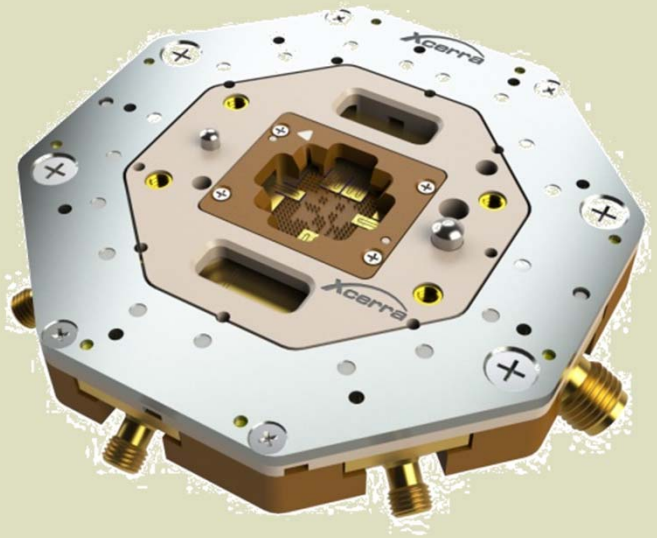




Images provided by William Mann Chair, Southwest Test Workshop

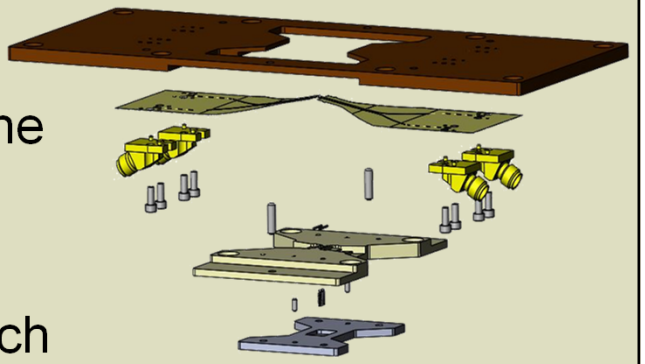
WLCSP xWave Design Goals

- Maintain as much as possible from package test xWave technology
  - mmWave Signal integrity
  - High compliance
  - Field maintainability
  - Robustness and longevity
  - Tri-Temp capability

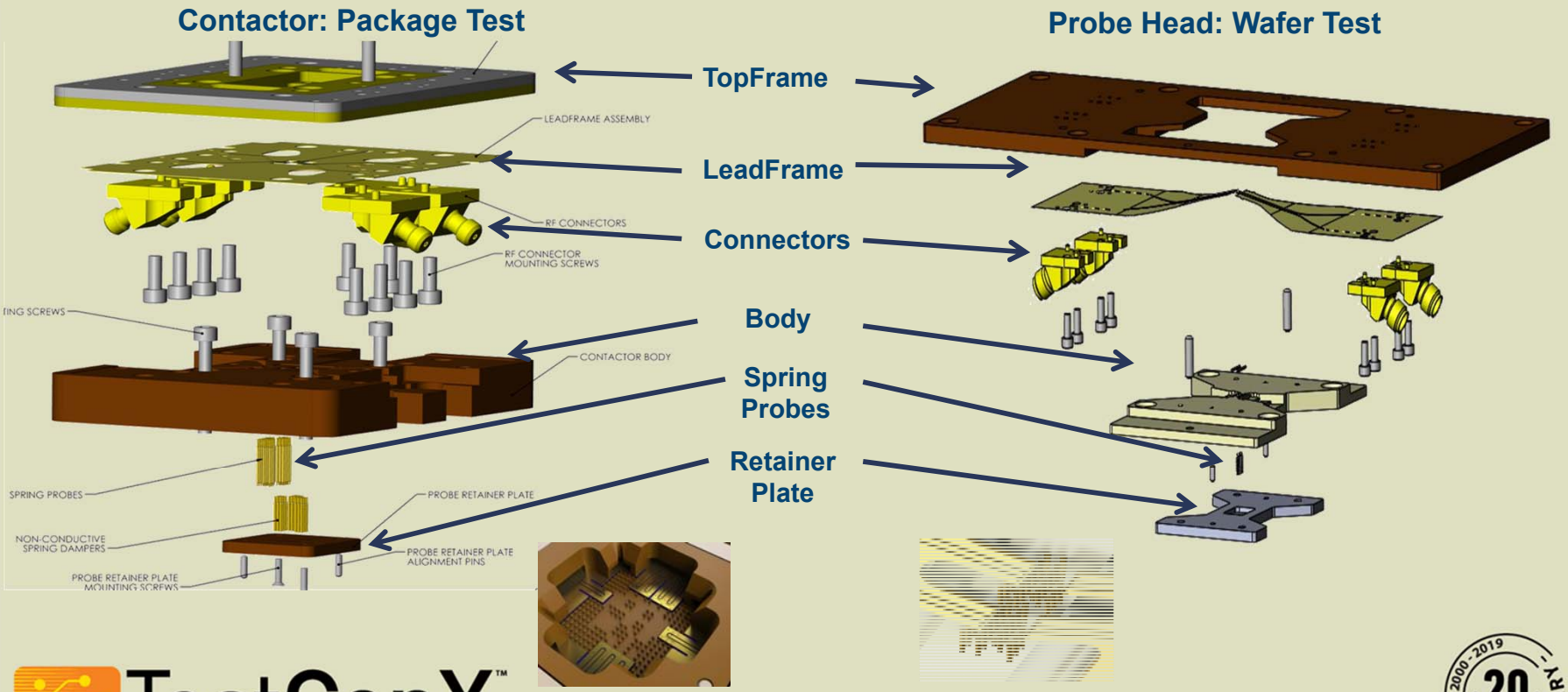


Objectives/Goals

- Move xWave Technology from package test to wafer probe
  - Move contact point of leadframe to infinite plane
  - Combine leadframe with fine pitch pogo technology
  - Reduce leadframe features to match bump pitch
  - Reduce leadframe force to limit contact marking on wafer bumps
  - Limit scrub to ensure no ball shear



xWave Wafer Level Final Test



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xWave: Wafer Level Final Test

- Signal Integrity
  - Short impedance controlled coplanar waveguide (CPW)
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- Integrated Solution (PCB/Contactor in One)
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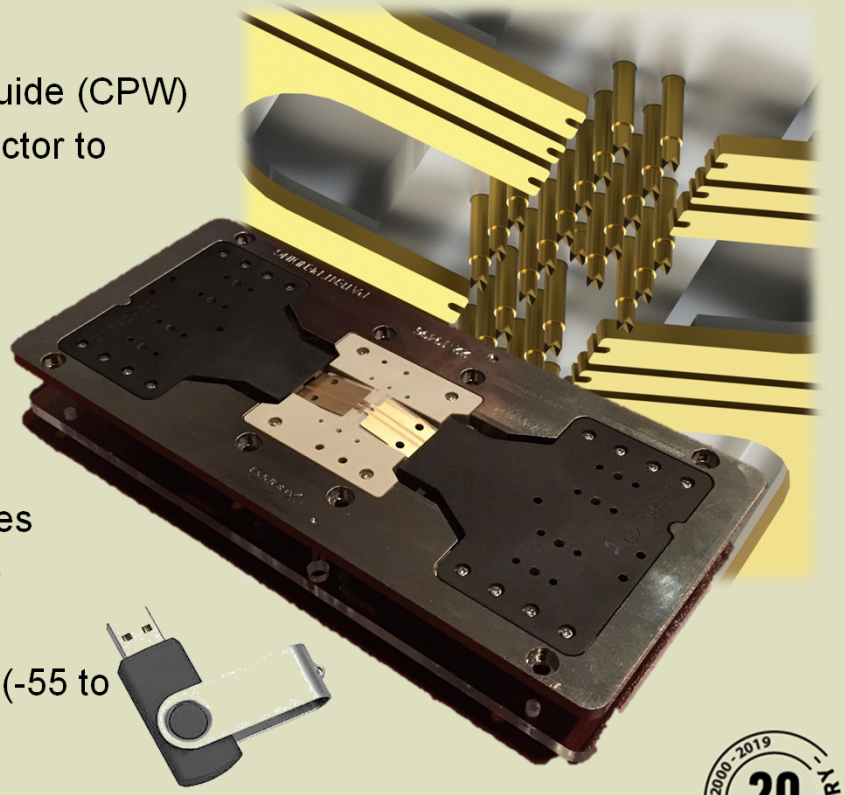

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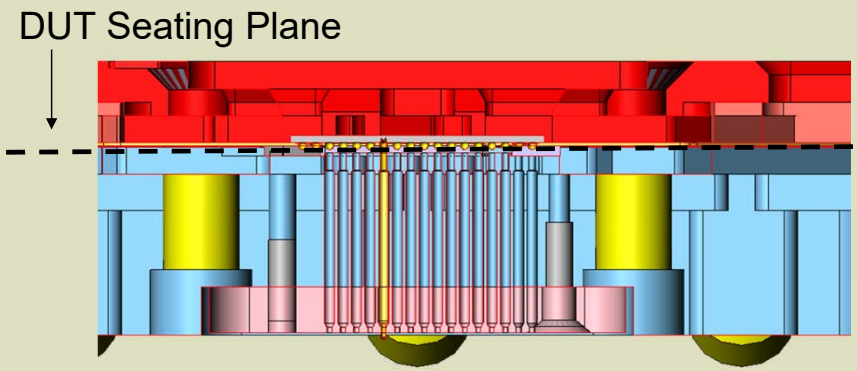
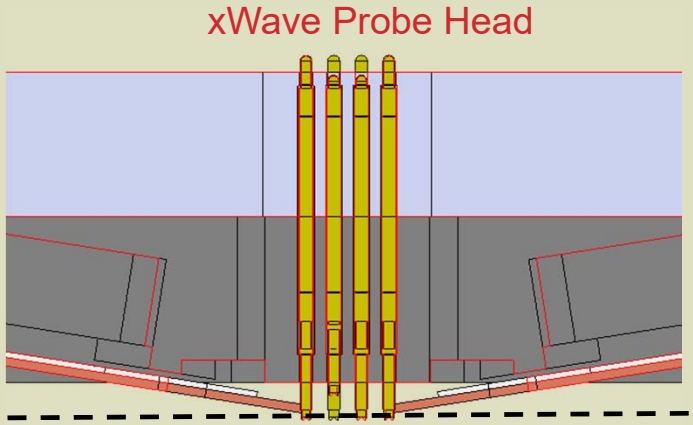
Move contact plane to infinite plane

- From Flat leadframe in DUT pocket to Angled leadframe at infinite plane

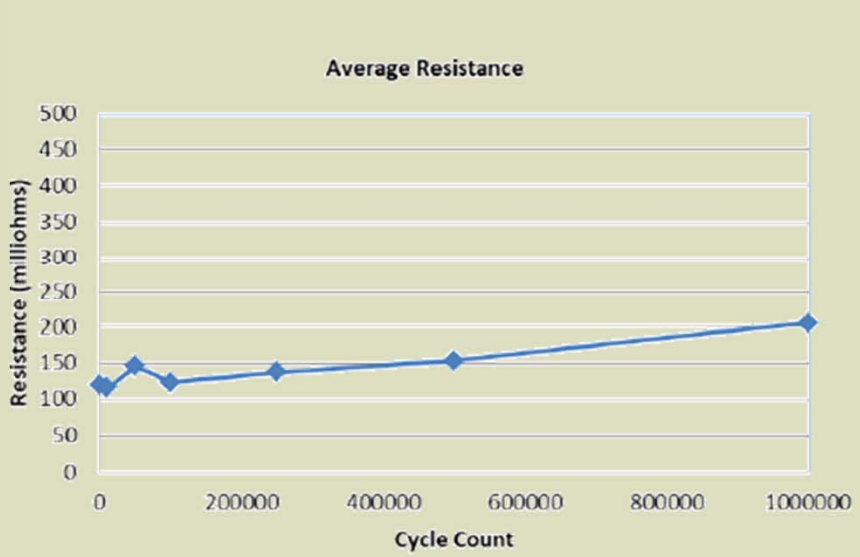




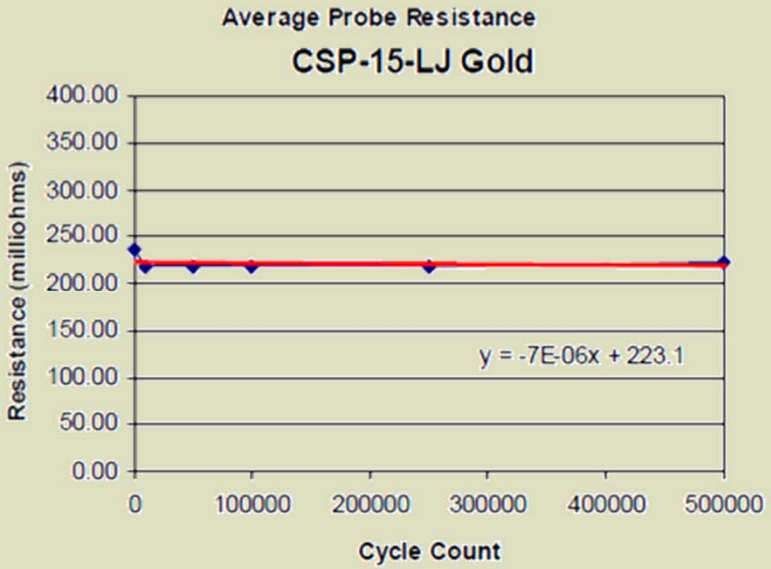
- From 0.5mm probe to 150um probe

Probe comparison

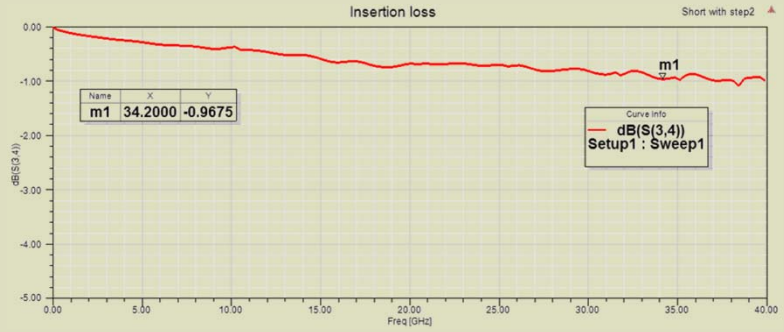
- xWave Contactor Probe

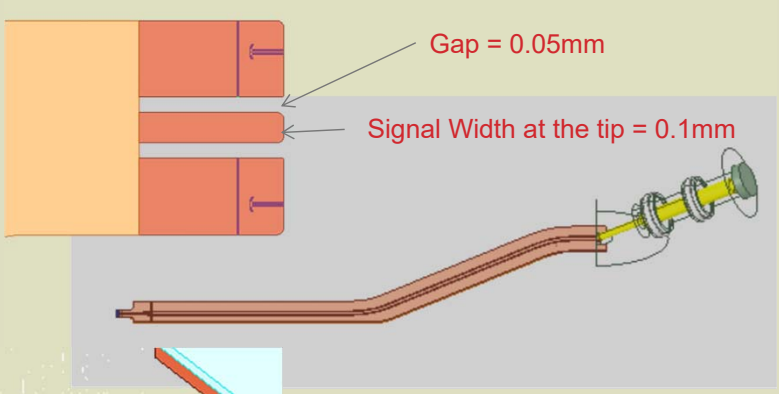


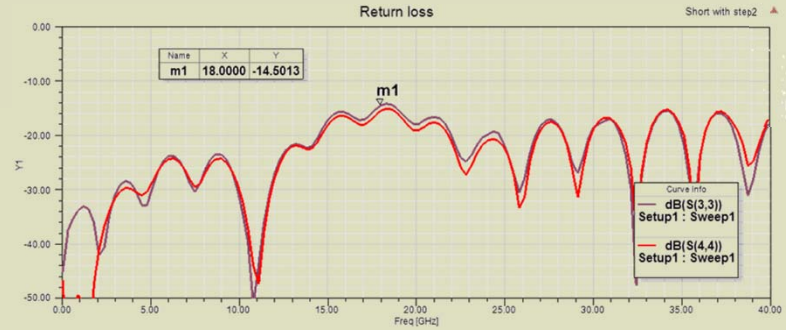
xWave Wafer Probe

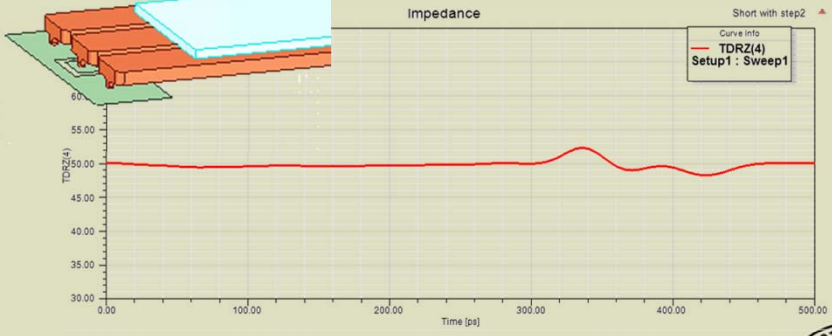


Electromagnetic Simulation









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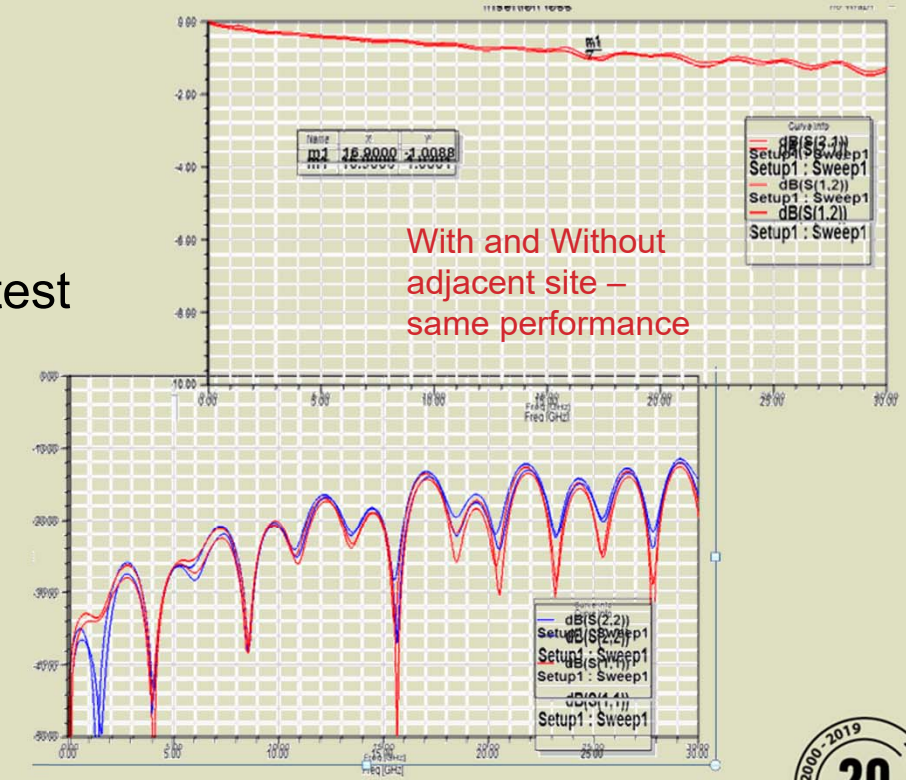
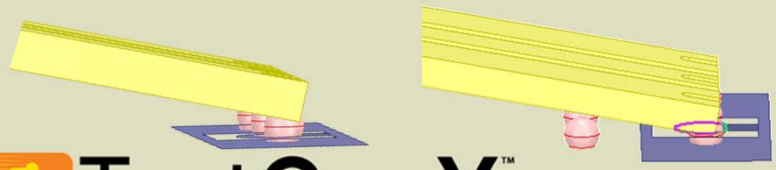
WLCSP xWave Signal Integrity

- Impact of Adjacent site
  - 15deg angle at free height
  - 5deg angle at test height
  - Proximity of adjacent site to test site
  - Same performance with and without adjacent site



No adjacent site

with adjacent site



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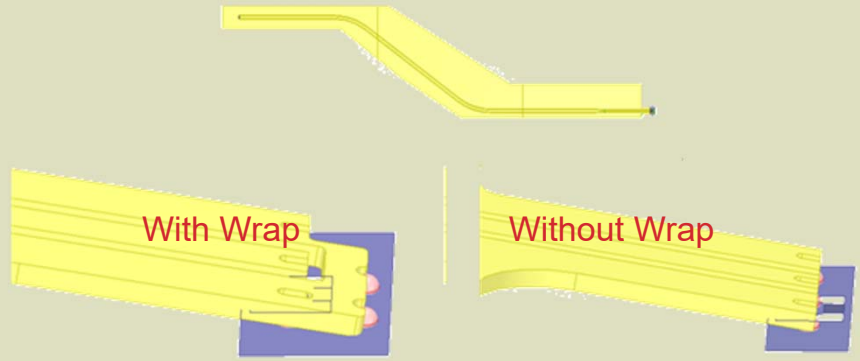
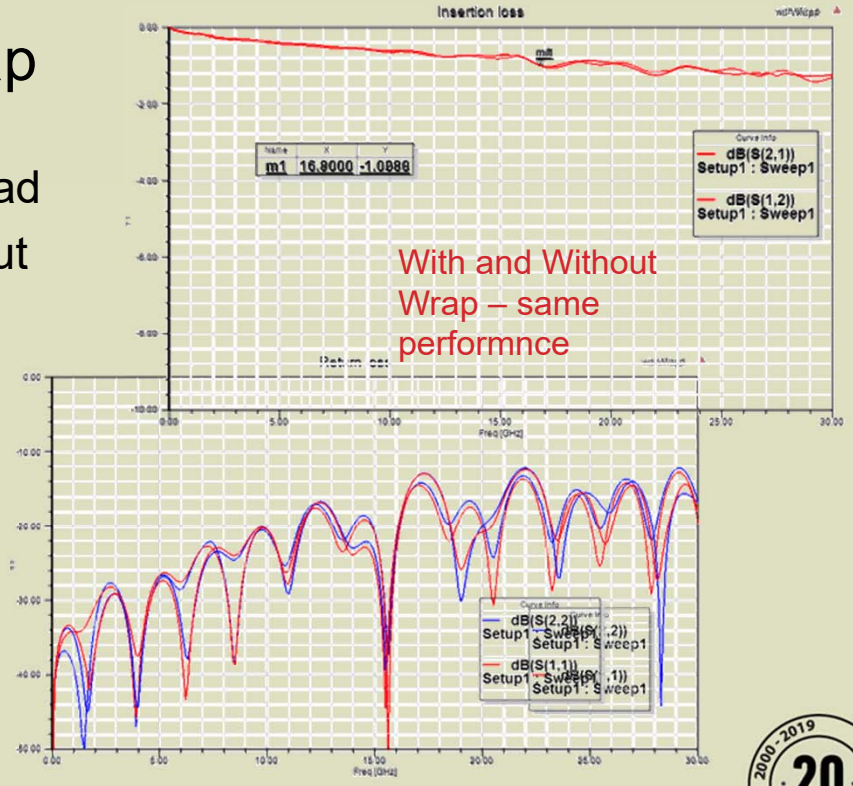
WLCSP xWave Signal Integrity

- Eliminated CPW ground wrap
  - Relies on DUT to maintain ground potential on either side of signal lead
  - Same performance with and without ground wrap





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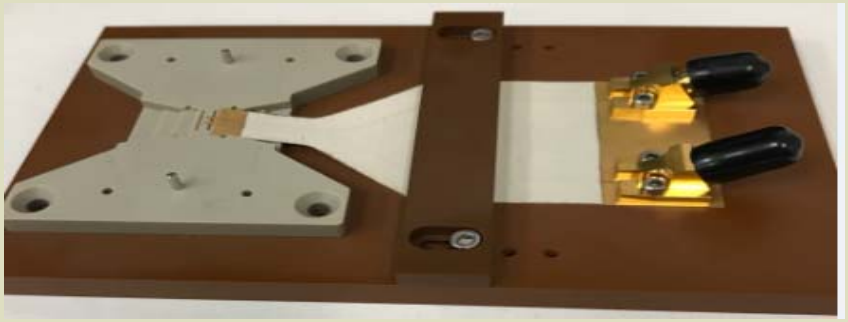
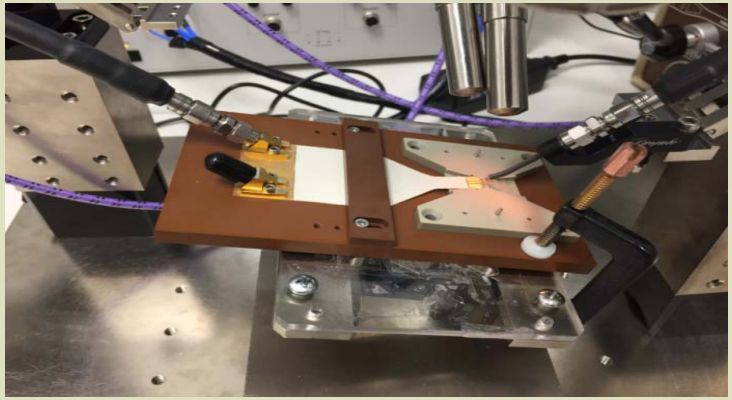
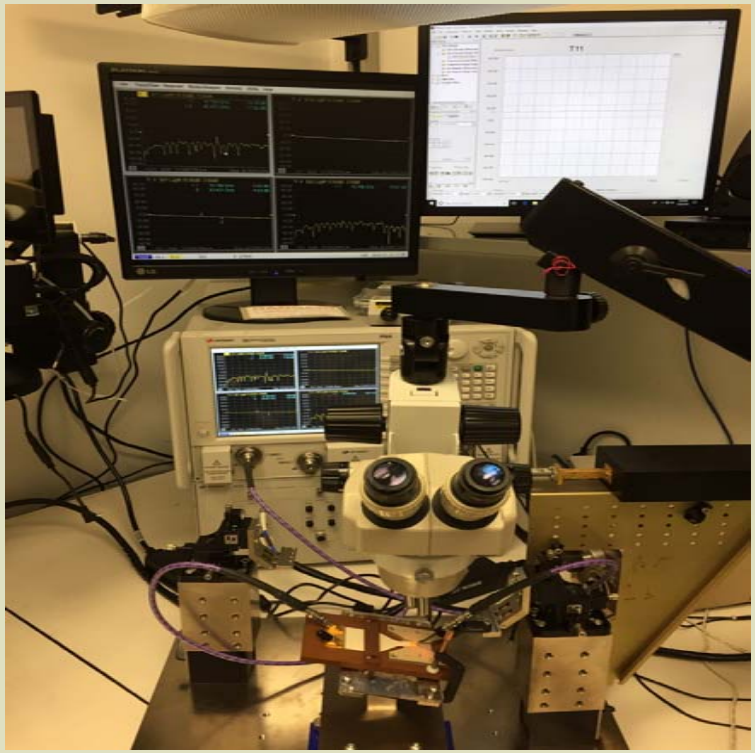
xWave Dual Site Probe Card Prototype RF Lab Measurement







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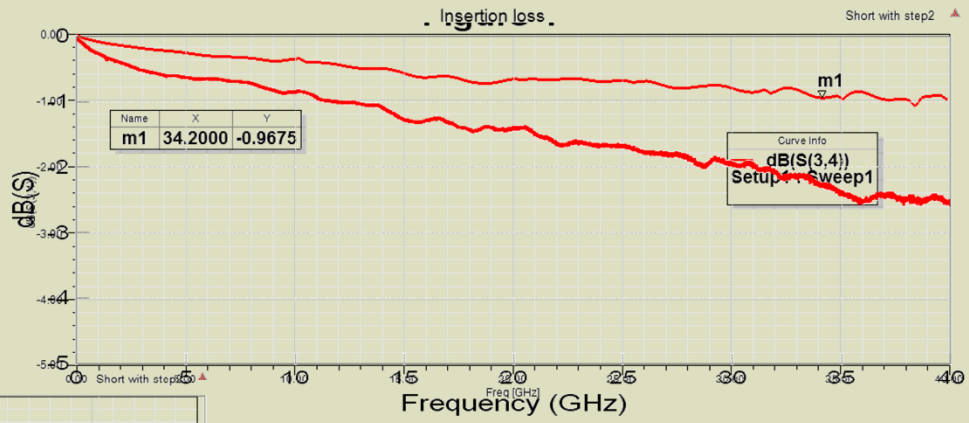
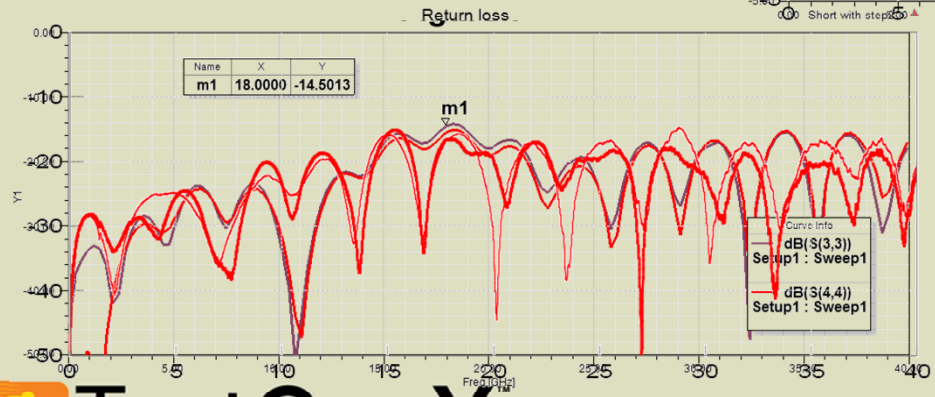
Simulation to Measurement Correlation

- Simulation and Measurement linear
- More insertion loss in measurement
  - Longer path length in measurement
- Return loss correlates and <-15dB





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Solution for mmWave wafer probe applications and field results

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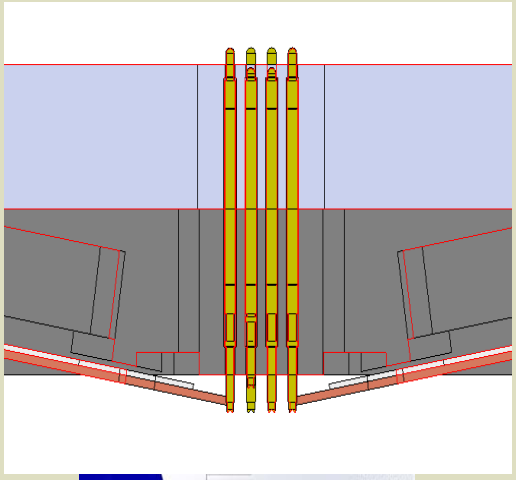
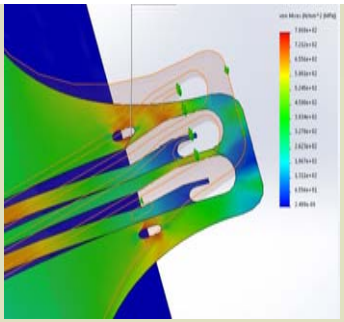
WLCSP xWave Mechanical Design

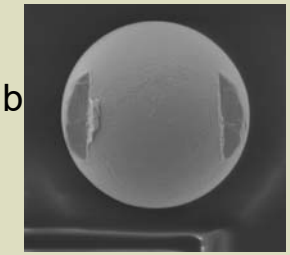
- Force
  - Leadframe – 8g @ 150um overtravel
  - 250um total leadframe compliance
  - Adjustable based on leadframe cross section and cantilever anchor point
  - Sufficient force without spring damper
- Thermal
  - Designed for Tri-Temp
  - Same materials as standard xWave
  - All materials are matched coefficient of thermal expansion (CTE)



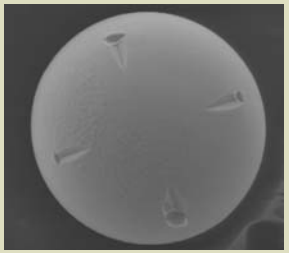


WLCSP xWave Mechanical Design

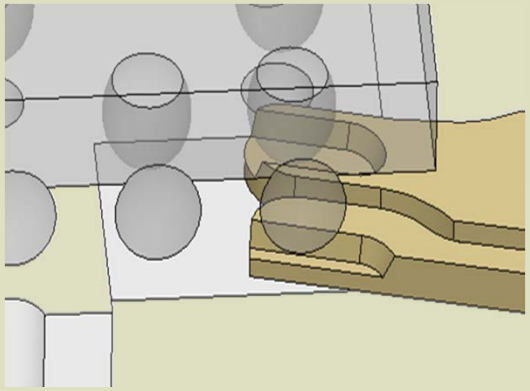
- BGA Contact feature
  - Leadframe - U shape edge contact to b
  - ~10um knife edge scrub
  - Pogo – 4 point crown
  - 250um compliance

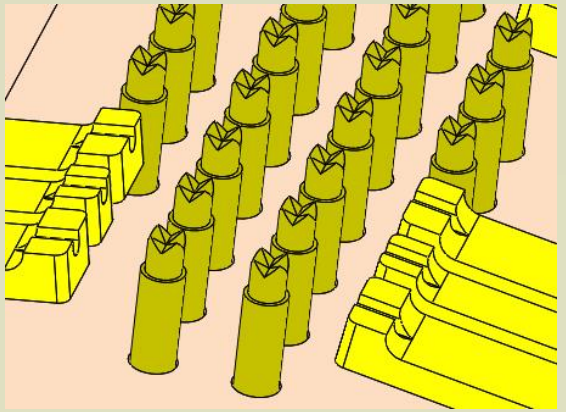


Leadframe



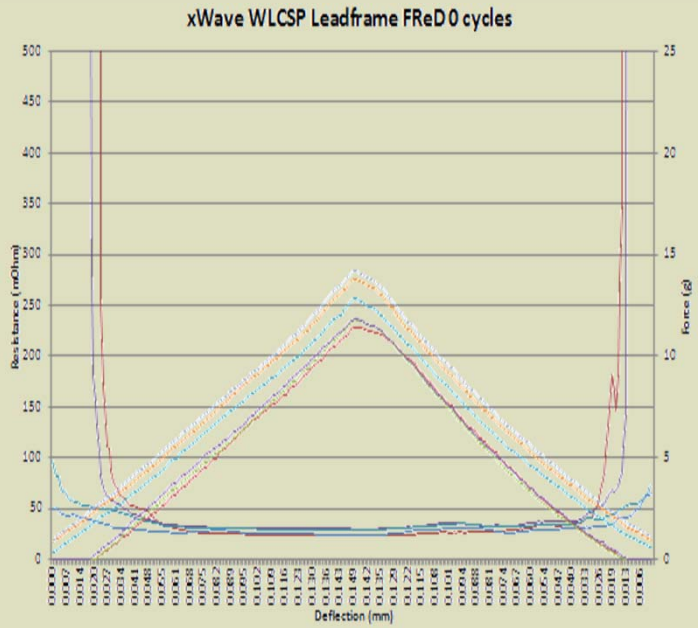
probe

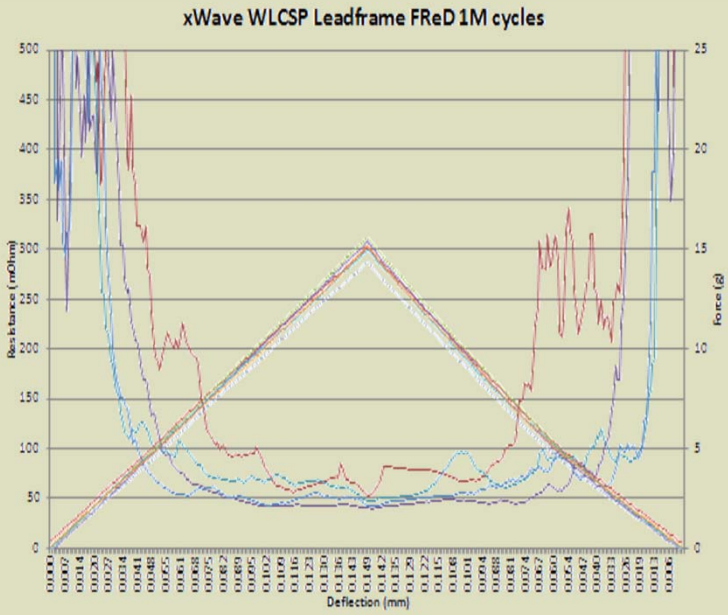




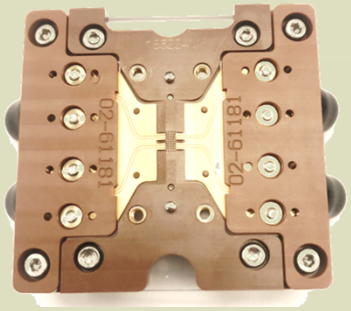
WLCSP xWave Life Cycle

- Stable low contact resistance through 1M cycles
- No force degradation over 1M cycles

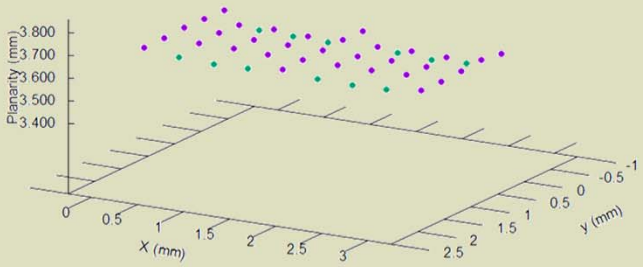


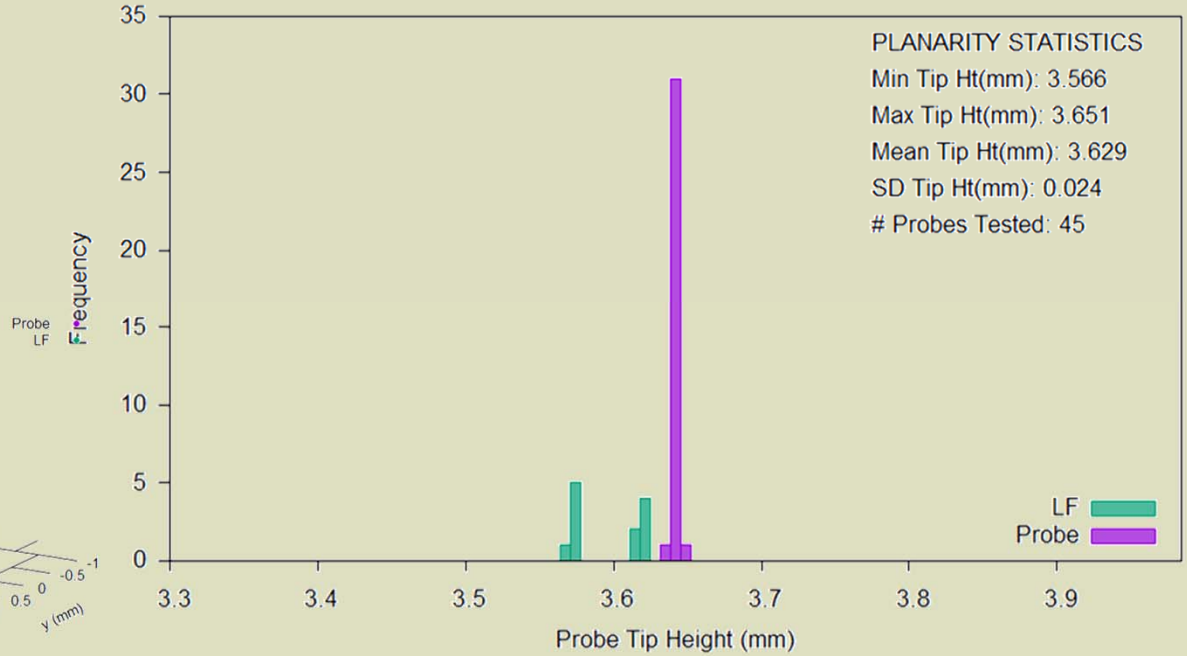


Probe Head Planarity



22-20236 SN185573M Planarity (Full Skew)





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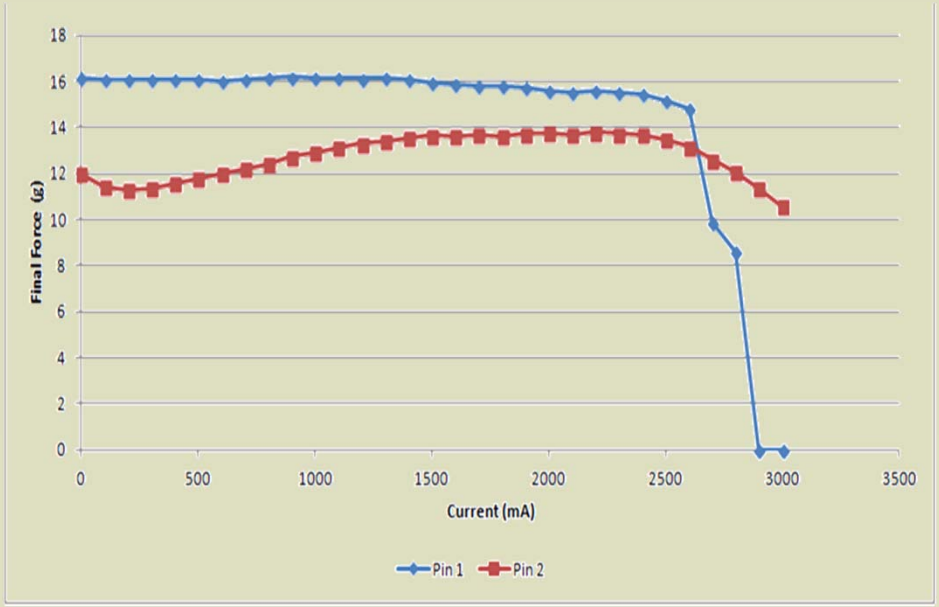
WLCSP xWave DC Performance

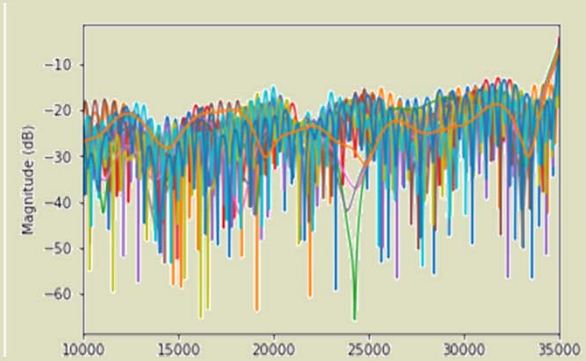
- Current Carrying Capacity
  - 2.6A based on ISMI method
  - Limited testing
  - Pressure applied to signal lead only
  - Expect higher current carrying capacity when deflecting grounds and signals

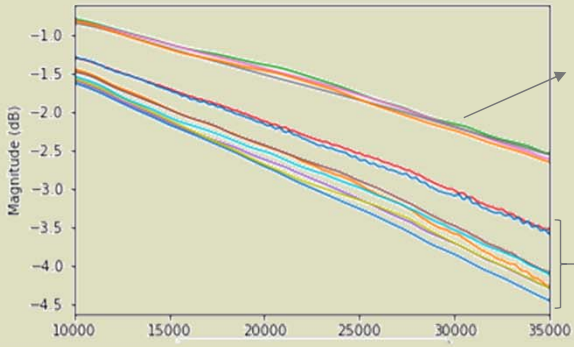


Package Test and Wafer Test in One

- Same hardware can be used for both packaged test and wafer test
  - Manual Alignment Frame (MAF) attaches to Probe head to convert to final test
  - Manual Actuator (MA) attaches to MAF
  - Simple change over from Wafer to Packaged parts for QA or RMA's

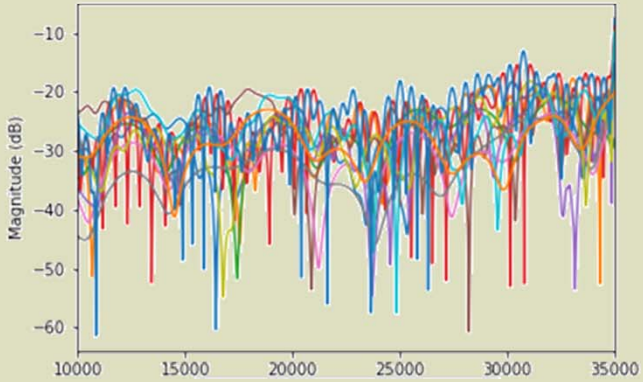
Customer Results: S11, S21 TDR 1 port AFR 0-35GHz





Only probe head, no cabling

Main difference is cable length



Correlates to Cohu Internal measurements

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Solution for mmWave wafer probe applications and field results

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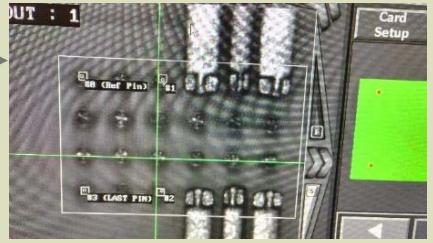
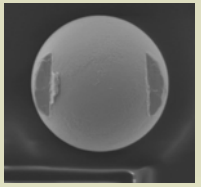
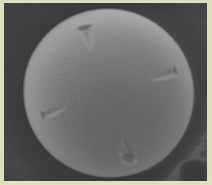
Customer Results: First trials

- Day 1
  - Prober setup OK(single only)
    - Site and bump pitch/location is OK
  - DC trials: both sites OK
    - No overdrive needed to get contact
    - DC measures analysis on going for different overdrive steps
    - No obvious DC probe mark on bump, or very slight (prober camera)
  - RF trials : site 1 OK
    - Requires ~100um overdrive to get RF contact
      - Prober measured 55um difference height DC vs RF
      - Cohu expecting 60um overdrive RF vs DC for contact. Nominal 150um would be ok for most cases.
    - No obvious RF probe mark on bump, or very slight (prober camera)







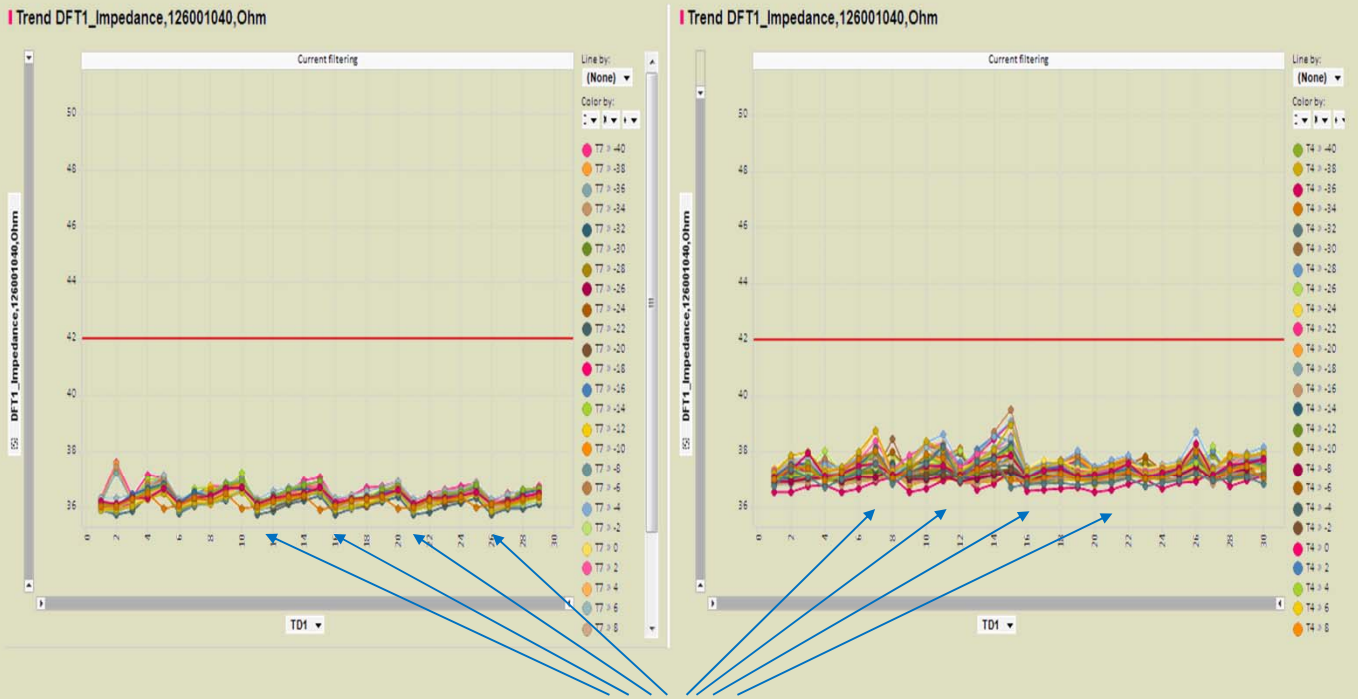
Customer Results DFT1 impedance: Existing vs Cohu

Existing probe card

Pos Y=-26, cleaning, 30 Run, OD=200

Cohu probe card

Pos Y=-98, cleaning, 30 Run, OD=190



Cleaning every 150 touch down

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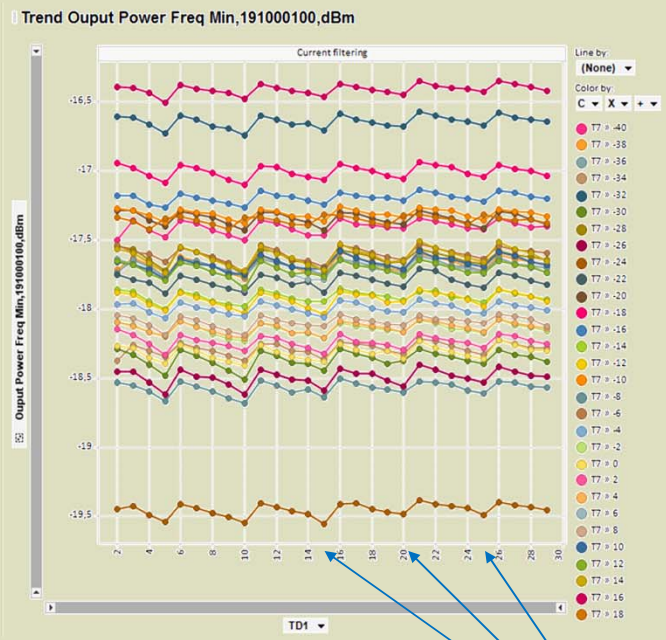
Customer Results: RF measure: Existing vs Cohu

Existing probe card

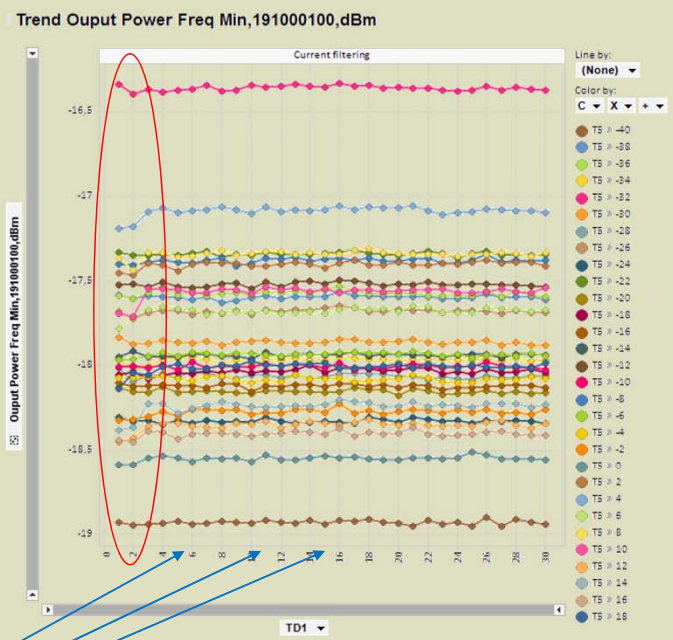
Pos Y=-26, cleaning, 30 Run, OD=200



Need of cleaning for RF measure

Cohu probe card

Pos Y=-74, cleaning, 30 Run, OD=150



- No impact of cleaning on RF
- Small drift seen on first runs (to be checked)

TestConX™ Cleaning every 150 touch down

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Customer Results: Wrap-Up / X-Wave Pros & Cons

- Excellent Insertion Loss and Return Loss performance.
  - IL < 4dB @ 30GHz (including cable),
  - RL < 15dB @ 30GHz,
  - X-Wave design up to 110GHz.
- X-Wave is designed to reduce probe mark.
  - Avoid hitting center of ball,
  - May remove need for ball re-flow.
- Fully repairable on Field at low cost.
  - Part maintenance has been demo'ed.
- Good RF Repeatability
  - < 0.05dB over 30 program loops.
- Good RF Repeatability on multiple touch-down
  - About 0.2dB variation observed on 30 cycles.
- Capability to perform manual retest of singulated die.
  - Need microscope to insert the tiny device,
  - Good unit at first test.

- Probe core is more expensive than current solution.
- Lead-frame alignment is made manually (few tens of um).
  - Need to assess stability during prober operation,
  - Need to understand what it means for production.
- During trial a larger drift has been observed on DFT1 Impedance test.
  - When pogo hits multiple times at same place, the electrical contact is degraded,
  - Behavior seems no more true when prober steps or when pogo hit more the center of the ball.
  - Need more investigation.

Summary / Conclusion

- 5G, ADAS, Wireless, Satellite cmWave and mmWave markets growing rapidly and moving from package to WLCSP at speed
- Overcame infinite plane and force profile to take the mmWave technology from final test applications to wafer test.
- WLCSP test data shows same electrical and mechanical performance as package test data
- Customer trials shows positive results