
TestConX™
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DoubleTree by Hilton
Mesa, Arizona
March 3-6, 2024

Optimal Spring Probe Solutions for Every Application

Valts Treibergs
Johnstech International

Mesa, Arizona ● March 3–6, 2024

Agenda

- Background
- Testing Application Challenges – Overview
- Electrical Challenges
  - Existing predominant solutions available
- Next Generation HF testing solution using the HF Spring Probe family
  - Internal electrical and mechanical qualification
  - RF Applications and field performance
- Mechanically challenging applications
  - Introduction to the robust ‘bread and butter’ HC solution

Application Challenge – Electrical or Mechanical? (or both?)

- Electrical challenges:
  - High data rate – digital
  - High frequency
  - High power
- Mechanical challenges
  - Large package(s) – planarity
  - Multi-site testing
  - Overcome large stack-up tolerances
  - Old handlers & kits – very loose tolerances – imprecise DUT presentation
  - Thermal control

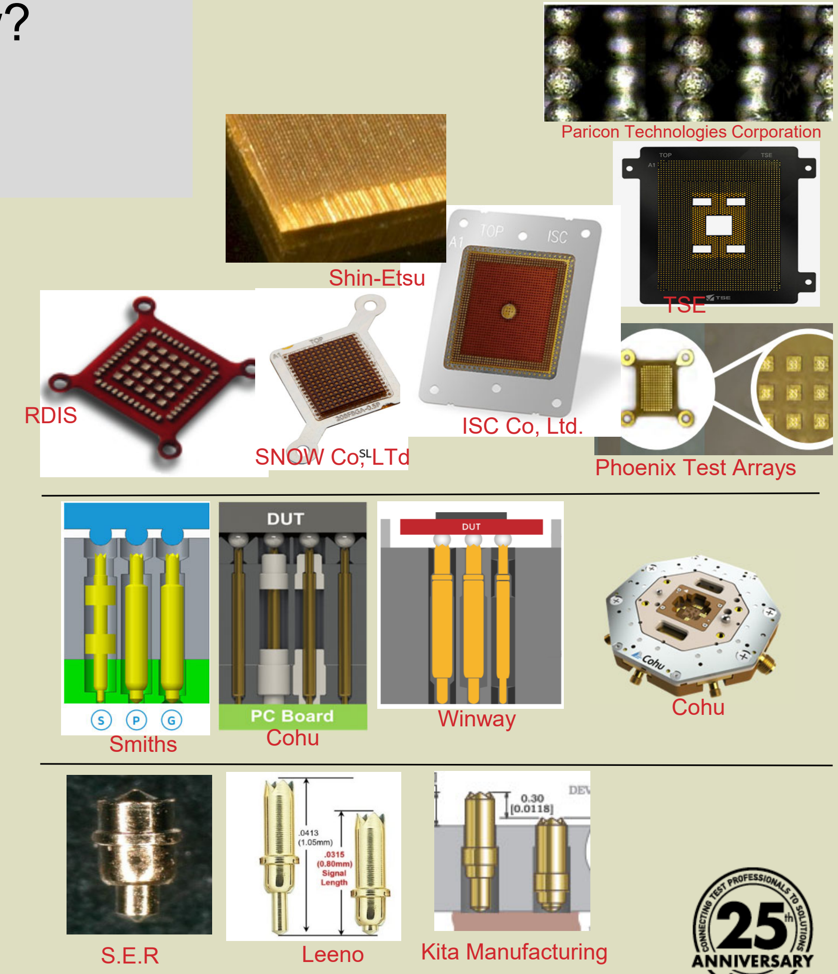
- PAM-4
- 5/6 G
- RADAR
- Amplifiers
- Filters

- Low Inductance
- Matched Impedance
- Low Insertion Loss
- Low Return Loss

- Big BGA modules
- Package warp
- Worn out kits
- Strip test

Electrical Challenges & Existing Solutions

- Maximize data rate or frequency response – how?
  1. Low inductance with short test height
  2. Matched impedance to the test environment
- Z-axis Conductive Elastomers
  - Very short signal path:
    - Low inductance
    - Good S_{11}, S_{22}
- Coaxial or coplanar waveguide
  - Good impedance match
  - Good isolation
- Short spring probes
  - Low inductance



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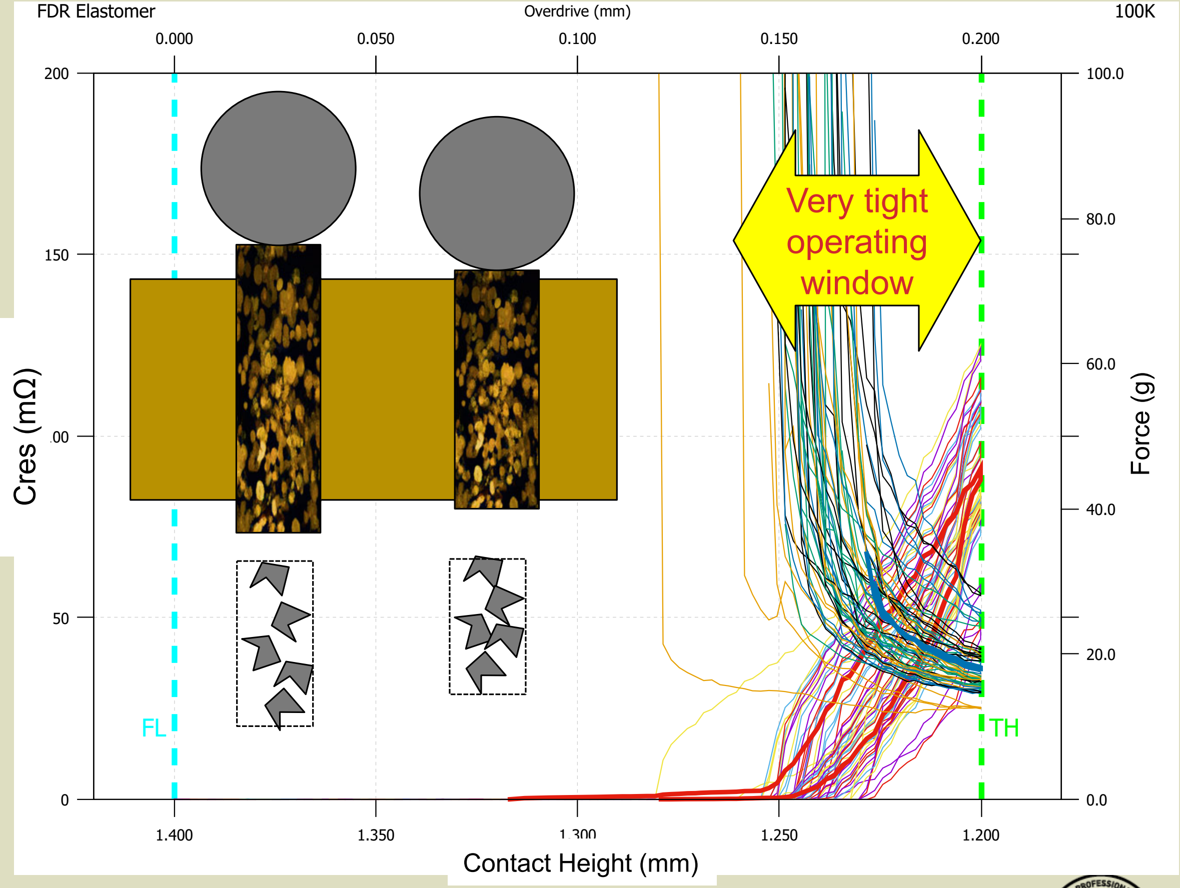
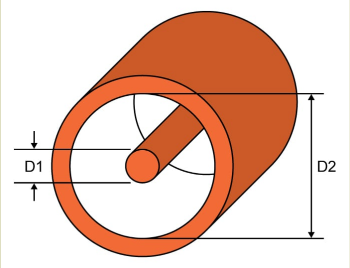
Electrical Challenges – Elastomer Solutions & Limitations

- Benefits:
  - Very short signal path (low inductance)
- Problems:
  - Less compliance
  - Performance at hot/cold temperatures
  - High force to DUT – possible damage
  - Variable contact resistance – conductive particle contact variability
  - No preload to PCB



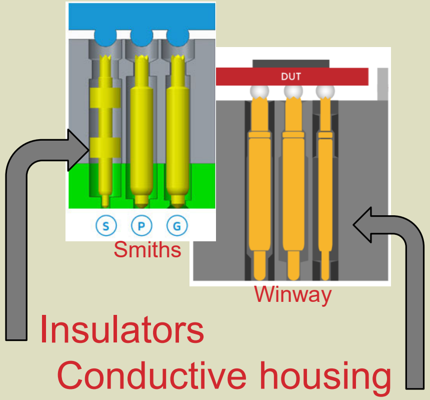
Electrical Challenges – Impedance Controlled Solutions & Limitations

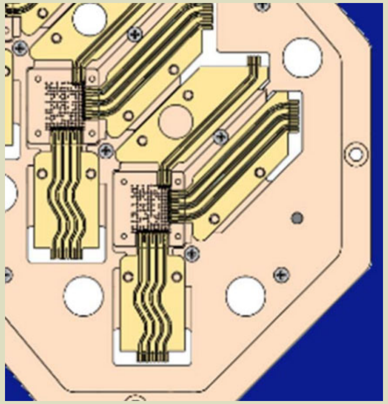
- Coaxial
  - Complex structure – maintenance - insulators
  - Center signal conductors – very small for DUT pitch – low force/high Cres/low CCC
- Coplanar Structures
  - Accessible to outer perimeter of DUT only
  - Required mixed technologies (spring probes, etc.)



$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \ln \frac{D_2}{D_1}$$

50Ω Example
DUT Pitch: 0.5mm
D2=0.45mm
ϵ_r=2.1 (Teflon)
D1=0.134mm





Production Wafer Probe of 77-81 GHz Automotive Radar Applications TestConX 2021 - Cohu

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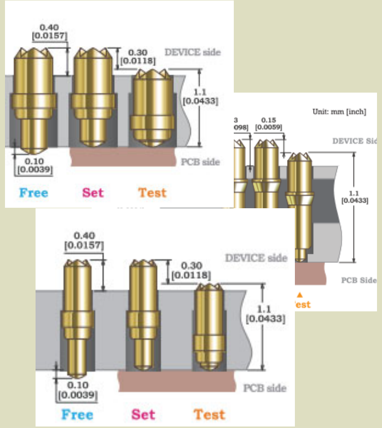
Electrical Challenges – Short Spring Probe Solutions & Limitations

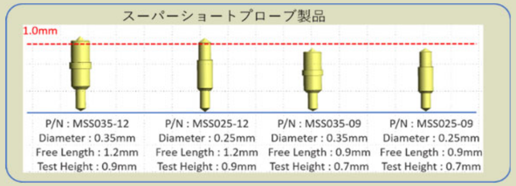
- Available from quite many suppliers
- All of different designs and test heights
- Limited pitch variations from any given supplier
- Spring material – may limit temperature performance
  - Music wire limited to 120°C

2.0mm, 1.1mm, 0.8mm, 0.9mm, 0.7mm ???

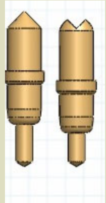


Kita Manufacturing

Test Tooling Solutions



SER Corporation



Signal Integrity

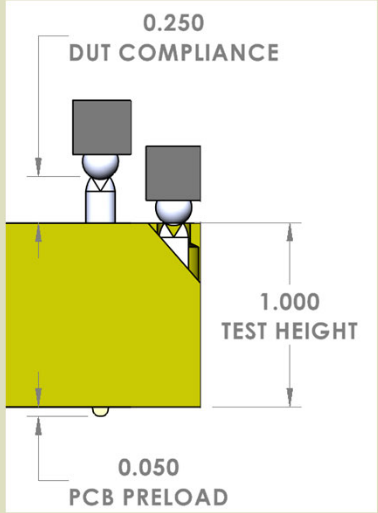
Leeno

Electrical Challenges → Solution Opportunity

- Compliance:
  - Maximize - 0.300mm or more
  - Predictable and reliable spring force
  - PCB preload – eliminate PCB wear
- Operating Temperature
  - Want consistent force and Cres at -65° to +175° C
- RF performance
  - Low inductance
  - Good S_{11}, S_{22} response
- Simple contactor maintenance

The Solution:
HF Probe Family

- 4 Pitches: 0.3, 0.4, 0.5, 0.8mm
- Standardized 1.0mm Test Height
- 0.30-0.35 probe compliance
- Pd Alloy radial DUT plunger
- Designed for maximum RF configurability: J-Tuning



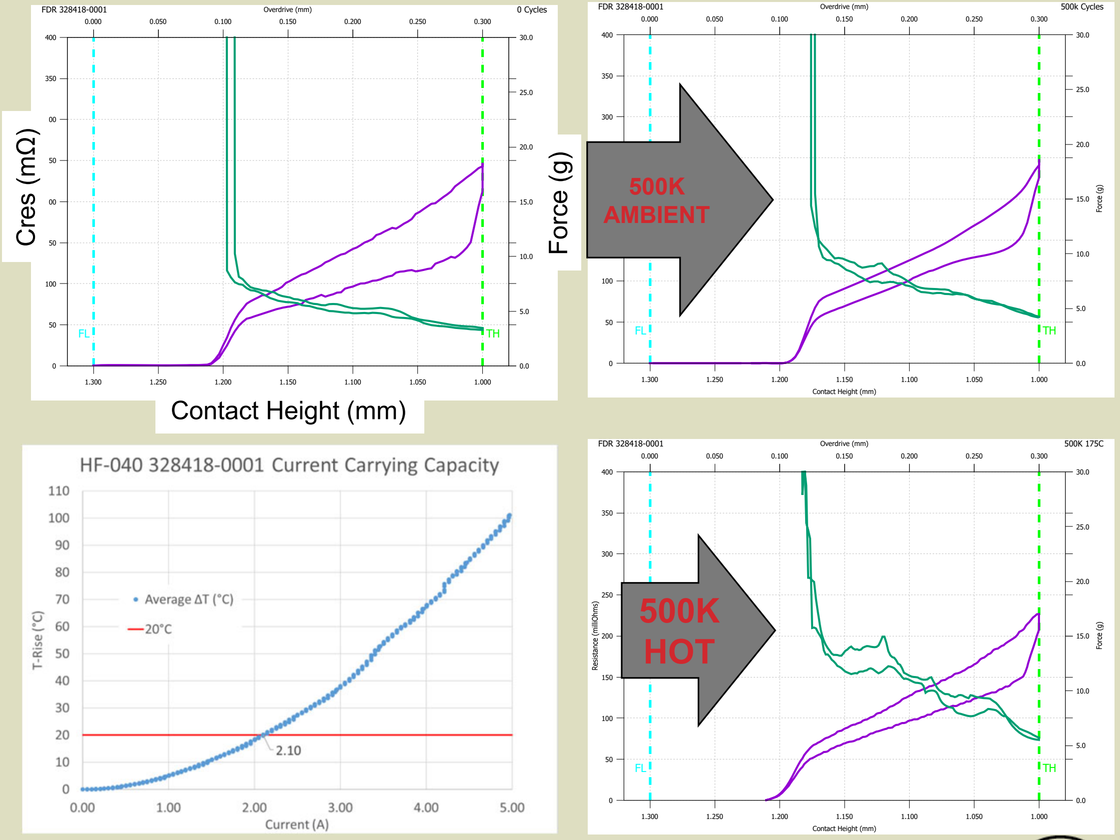
HF Family Solution

- Contactor construction
  - Standard CNC machined housing components for quick fabrication – no special tooling required
  - BGA / LGA / QFN – any configuration
  - Spear or crown tip probe option available
- Probe
  - Individually user replaceable
  - Cleanable Pd alloy – inline or manual cleaning
  - Patent-pending innovative probe architecture
- True configurability
  - Socket design improved with optimal probe size for application – *J-tuned*TM
    - Optimize for RF performance (match impedance)
    - Optimize for power – use largest pin
    - Optimize for signal isolation

HF Probe Performance – In-house Qualification

Qualification regimen – done for each probe configuration:

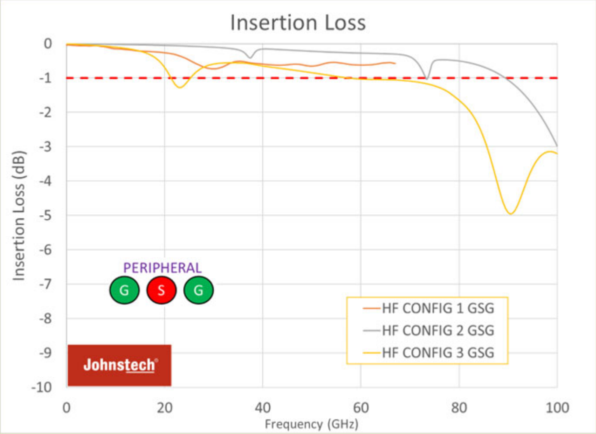
- Life cycle testing to 1M insertions
  - FDR testing periodically
  - Cres repeatability
- Life cycle testing at 175°C to 500K insertions
  - FDR testing periodically
  - Cres repeatability
- CCC T-Rise
- RF testing – GSG
  - HFSS model correlation



Example data for HF 040 variant

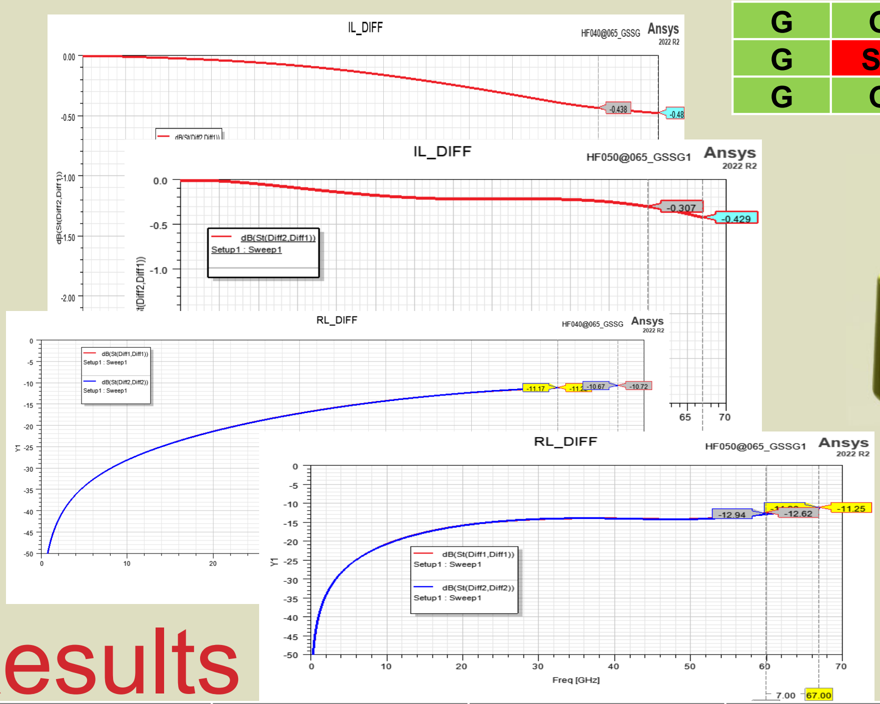
RF Qualification

- Vector Network Analyzer Measurement
  - Keysight 67GHz N5227B PNA
  - Direct probing using CPW microwave probes
- Measurement correlation to HFSS models
  - All probe configurations
  - Certifies that simulation will be accurate



mmWave Transceiver Application

- 0.65mm FC-CSP package
- HFSS Modeling:
  - 4x3 Probe matrix
  - Tx and Rx Differential RF signals deep in BGA array
  - DC-67 GHz sweep
- Goal:
  - Differential Insertion loss <1 dB or better @67 GHz
  - Differential Return loss better than -10 dB @67 GHz
  - Find optimal HF probe configuration

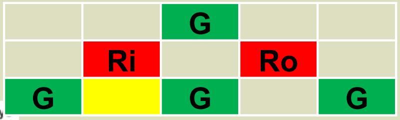


G	G	G	G
G	S+	S-	G
G	G	G	G

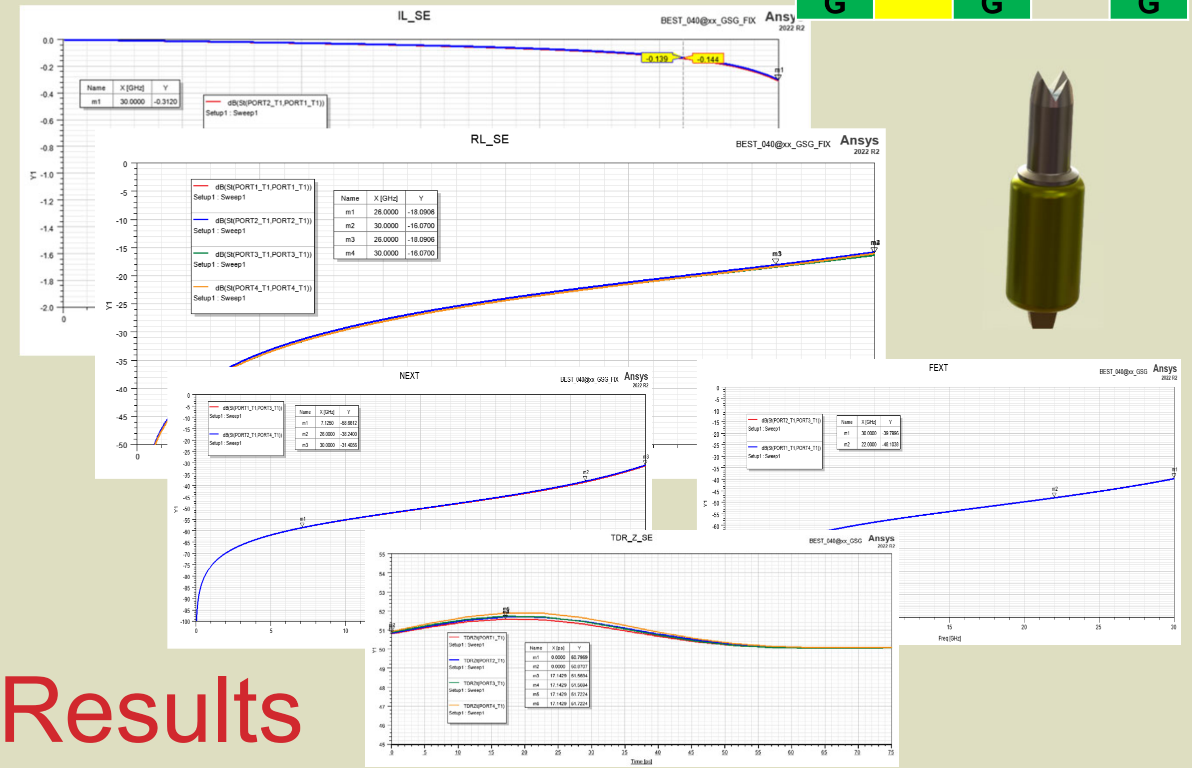
Results

Configuration	Insertion Loss at 67 GHz	Return Loss	Impedance (Diff)
HF A	-0.48 dB	-10.7 dB	107-114 Ω
HF B	-0.43 dB	-11.2 dB	86-100 Ω

RF Switch Application



- Variable pitch WLCSP package
- HFSS Simulation:
  - Variable pitch bump (.38mm min)
  - Internal RF_{in} and RF_{out} ports
  - DC-26 GHz sweep
- Goal:
  - Single-ended GSG insertion loss <1dB
  - Single-ended return loss better than -10 dB @30 GHz
  - Good isolation between RF_{in} and RF_{out}



Results

Insertion Loss at 26 GHz	Return Loss at 26 GHz	Impedance (Hanning)	Isolation NEXT at 26 GHz	Isolation FEXT at 26 GHz
-0.144 dB	-10.7 dB	51.4 Ω	-38.24 dB	-44.00 dB

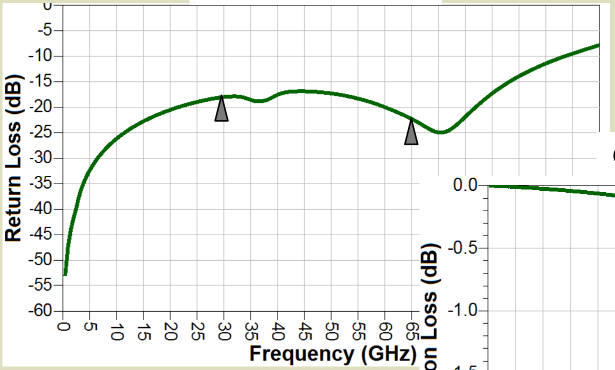
Optical DSP Transceiver Application

- Large 800 ball+ 0.5mm FCBGA package
- HFSS Modeling:
  - Tx and Rx 100Ω differential embedded in BGA array
  - 30GHz and 65GHz bandwidth signals
  - DC-100 GHz sweep
- Mechanical FEA Modeling:
  - Full design mechanical simulation – housing deflection
- Goals:
  - Differential Insertion loss <1 dB or better @30&65 GHz
  - Differential Return loss better than -10 dB @ 30&65 GHz
  - Find optimal HF probe configuration
  - Verify BGA array will not deflect housing beyond probe preload capabilities

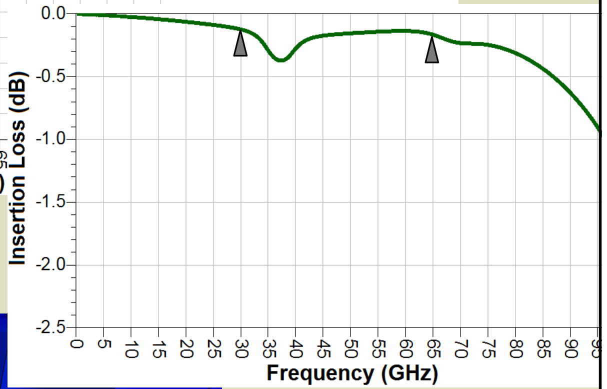
G	G	G
G	S	G
G	S	G
G	G	G

G	G
G	S
G	S
G	G

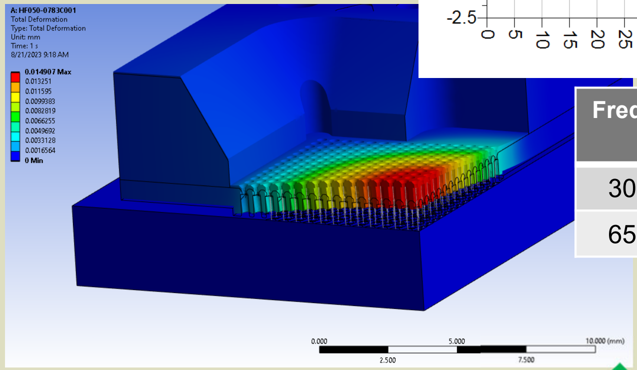
GSSG Return Loss



GSSG Insertion Loss



Results

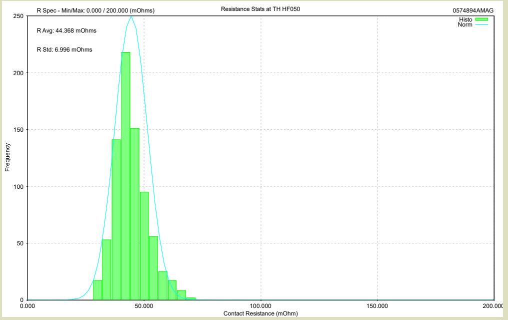


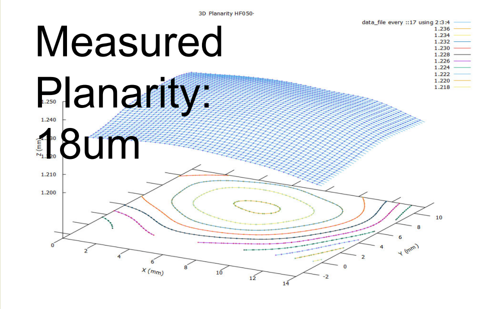
Frequency	Insertion Loss	Return Loss
30 GHz	-0.15 dB	-17 dB
65 GHz	-0.20 dB	-22 dB

Max HSG Bowing
15 um

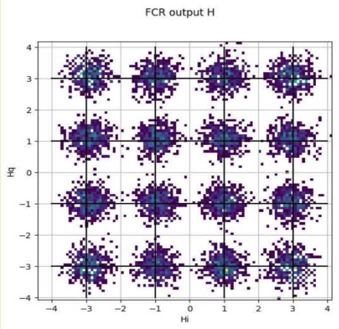
Optical DSP Transceiver Application

- Outgoing Measurements:
  - Probe Cres
  - Probe Force
  - Socket Probe Planarity
- Customer RF Performance
  - Digital 800G/16-QAM loopback test vs POR elastomer socket

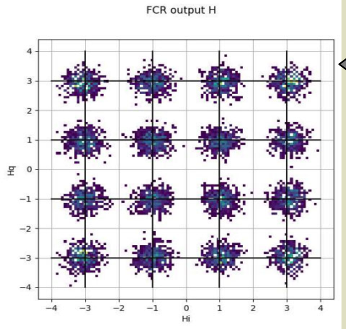




Probe Force (g)	Cres (mΩ)	Housing Deformation - Planarity (um)
13.9 Avg	44.4 Avg	18
1.3 St Dev	7.0 St Dev	



Elastomer Socket 16QAM mode 121 800G



Johnstech Socket 16QAM mode 121 800G

Tighter distribution

Optimal Spring Probe Solutions for Every Application

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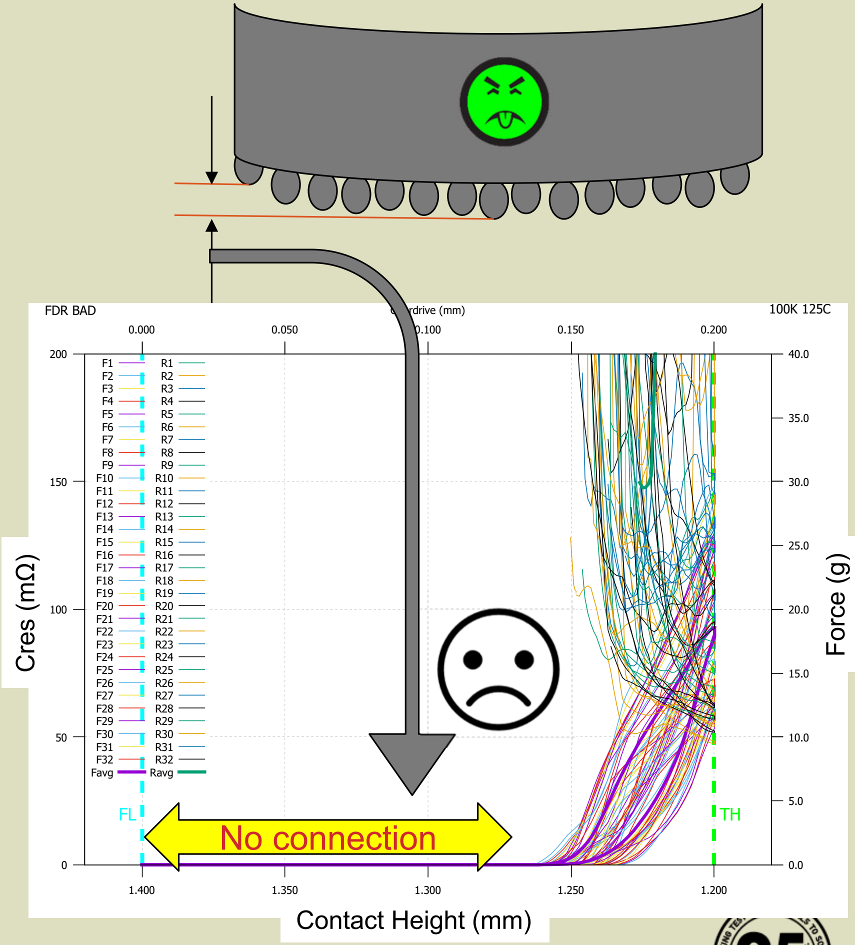
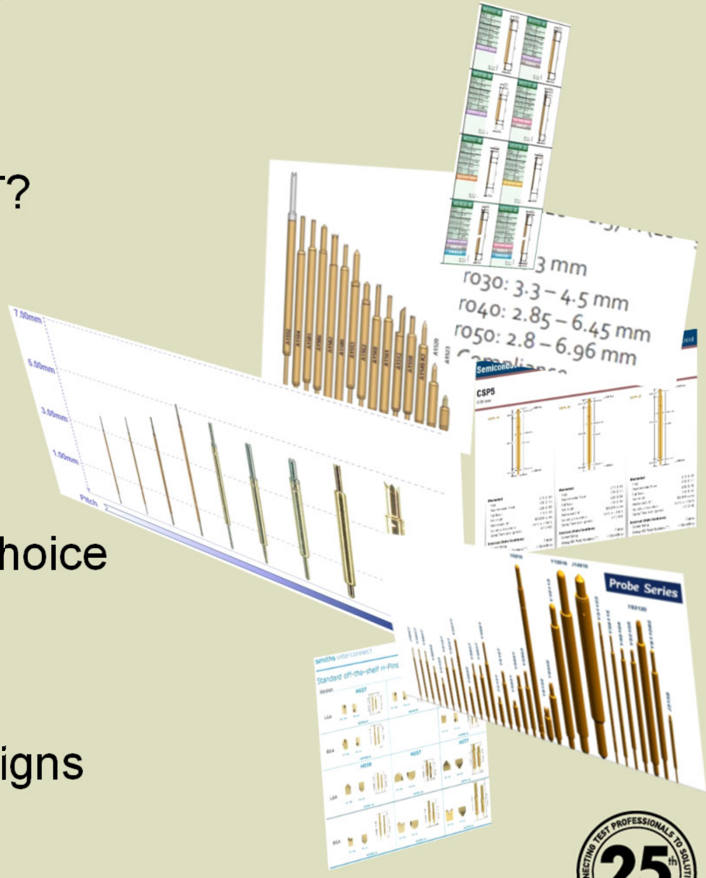
Mechanical Challenges – Limitations

- The vast majority of applications do not need 60+ GHz performance
  - 30 GHz is adequate
  - Run very high volumes and have world-wide established test cell infrastructure
- Most existing spring probe solutions
  - Different compressed test heights of every probe – limits the selection
  - Spring materials used limit testing below 155°C
  - Old designs use barrel and plunger fits that do not provide good biasing
  - Do not provide a wide operating window



Mechanical Challenges & Existing Solutions

- Maximize mechanical compliance to overcome handler and package shortcomings
  - Package specs – planarity/ball size/thickness
  - Handler stack-up – kit tuned to optimally compress DUT?
- Many spring probes to choose from many suppliers:
  - Double-ended
  - Single-ended
  - Many are temperature range is limited due to material choice (music wire)
- Way too long: poor electrical performance
  - 5.05mm? 7mm? 3.2mm? More? Many are legacy designs



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Mechanical Challenges – Opportunities

- Compliance:
  - Maximize – provide best in class
  - Wide operating range to maximize yields
- Operating Temperature
  - Want consistent force and Cres at -65° to +175° C
- RF performance
  - Still plenty of RF margin – Measured probe performance to 30 GHz
  - < 1nH inductance
- Simple maintenance

The Solution: HC Probe Family

- 4 Pitches: 0.3, 0.4, 0.5, 0.8mm
- Standard 2.5mm Test Height
- **0.65-0.75mm** probe compliance - most compliance & spring force per test height
- Pd Alloy DUT plunger
- Stainless steel alloy spring for +175°C performance
- Also designed for maximum RF configurability and *J-tuning*™

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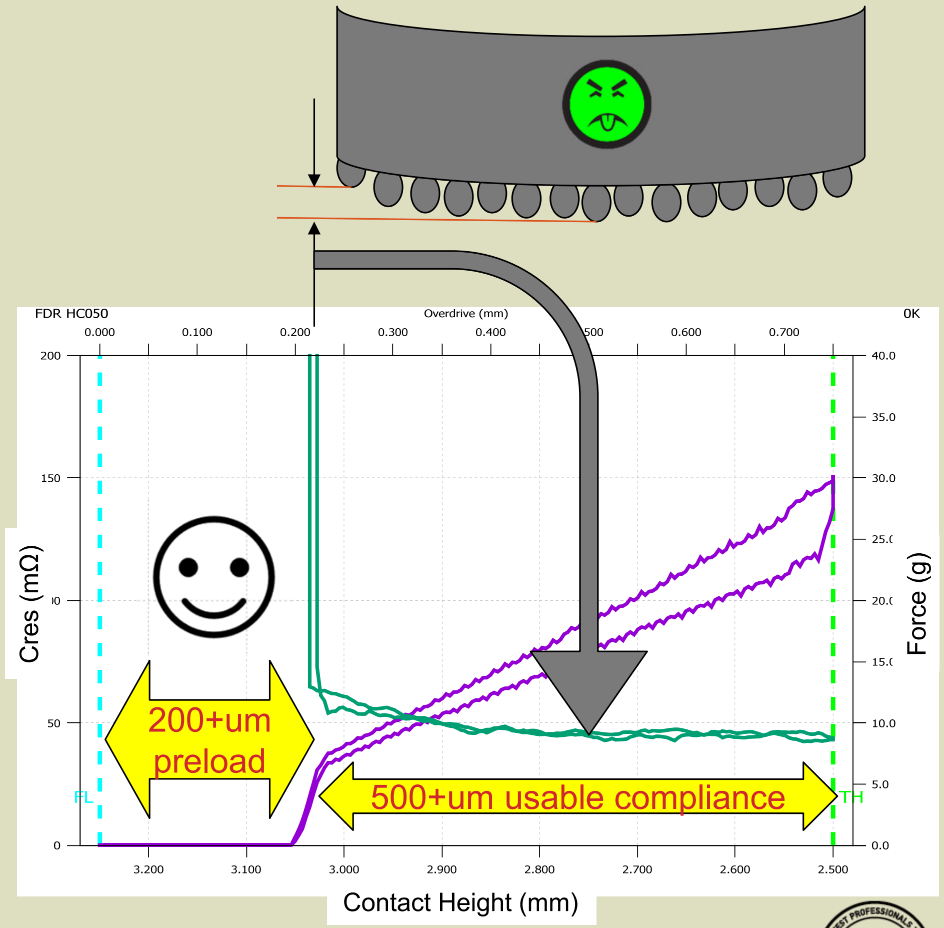
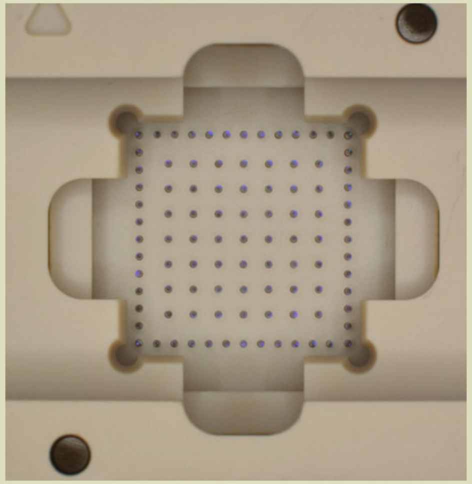
Everyday HC Solution

- The HC spring probe family:
  - Uses same patent-pending architecture as HF
  - Up to 0.750 mm total probe compliance
    - Allows for an extreme range of test robustness
    - 2.5mm testing height
    - 175°C
  - Same RF configurability
- *MORE TO COME…….*



Summary



- For ‘bleeding-edge’ electrical challenges
  - Standardized 1mm short compressed height spring probes (HF)
    - Provide low inductance – maximize RF signal performance
    - Are flexible for optimal RF configurations
    - Provide the best mechanical compliance at 1mm TH
- For ‘bleeding-edge’ mechanical challenges
  - Standardized 2.5mm compressed height spring probes (HC)
    - Best in class compliance to accommodate mechanical stack-ups
    - Yet offer good RF performance and configurability