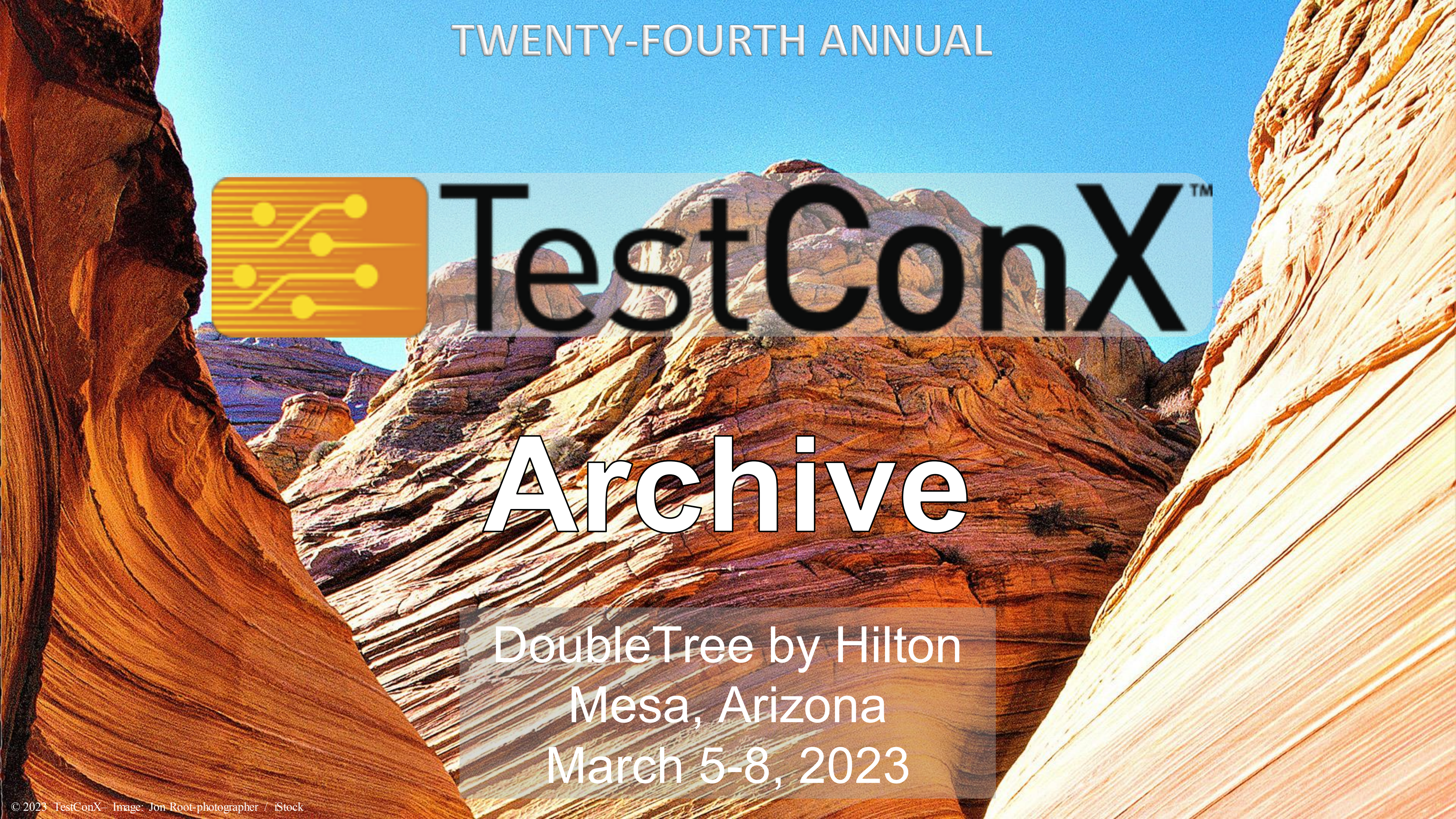

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Optimizing and Correlating a Spring Probe Contactor Electrical Performance Using RF Modeling

Jim Hattis
Johnstech International

TestConX™
Mesa, Arizona • March 5-8, 2023

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Agenda

- Define and discuss the benefits of optimizing the electrical performance using the J-Tuned™ process on Johnstech spring probes: YARI™, SHOTO™ and DAISHO™
- Examples to be discussed:

- **0.5mm Pitch Differential GSSG**: >40 GHz operation with SHOTO™ spring probes.
- **1mm Pitch Differential GSSG**: YARI™ spring probes in a digital application, being able to get 32-40 GHz of bandwidth with a 4.5mm probe in a 1mm pitch scenario.
- **400um Pitch Single-Ended GSG** - highlighting good correlations between simulation and measurement in a DAISHO™ application.

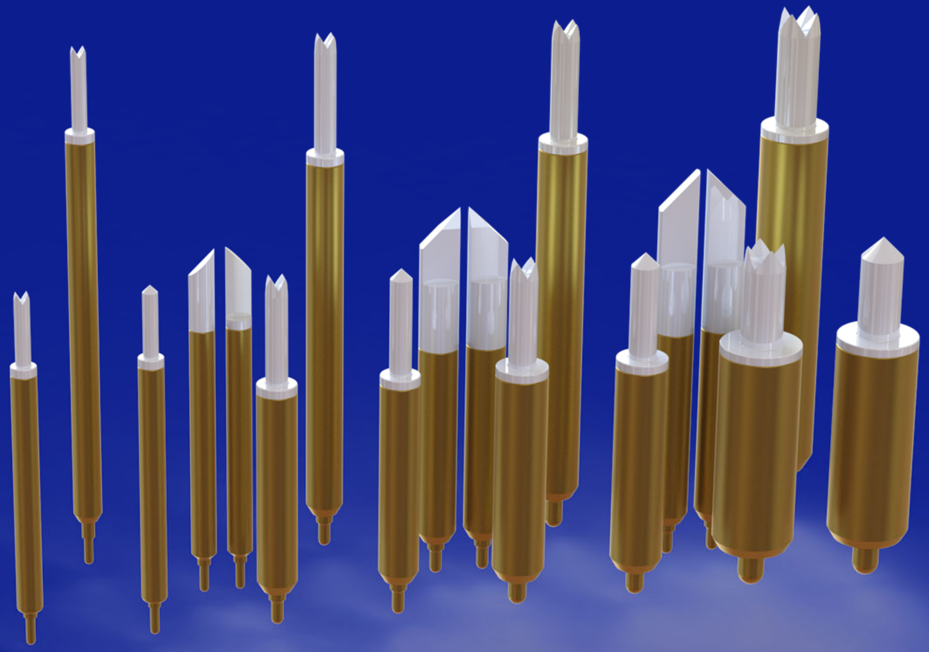
Spring Probe Family (YARI™ SHOTO™ DAISHO™)

Applications:

- Microprocessors
- LTE
- WiFi

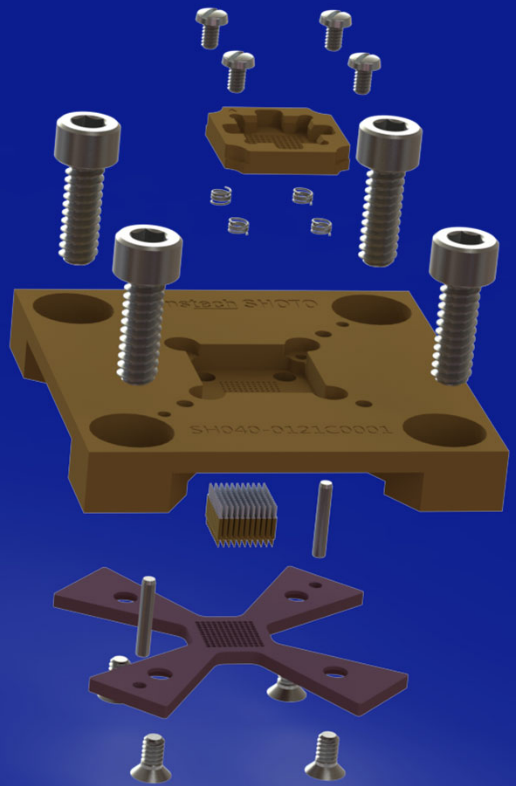
Device Thermal - Mechanical

- Multiple test height available including
    - Shoto @ 3mm
    - Yari @ 4.5mm
- Device Pitch down to 0.3mm
- Typical Cres: <50mΩ
- Environmental : -65°C to 175°C
- Total stroke from 0.25mm to 0.65mm
- Spear, Crown and Kelvin tips available
- BGA / QFN / LGA / WLCSP packages

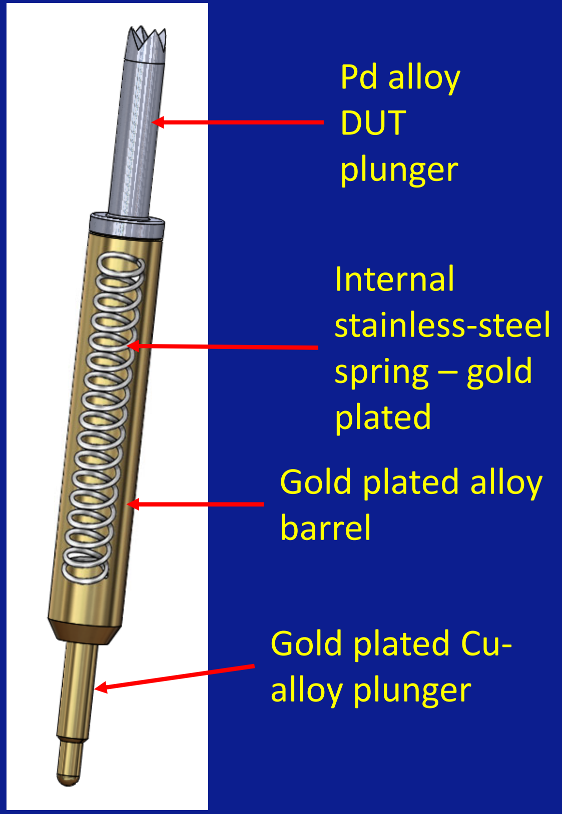


PATENT PENDING

Spring Probe Family - Features

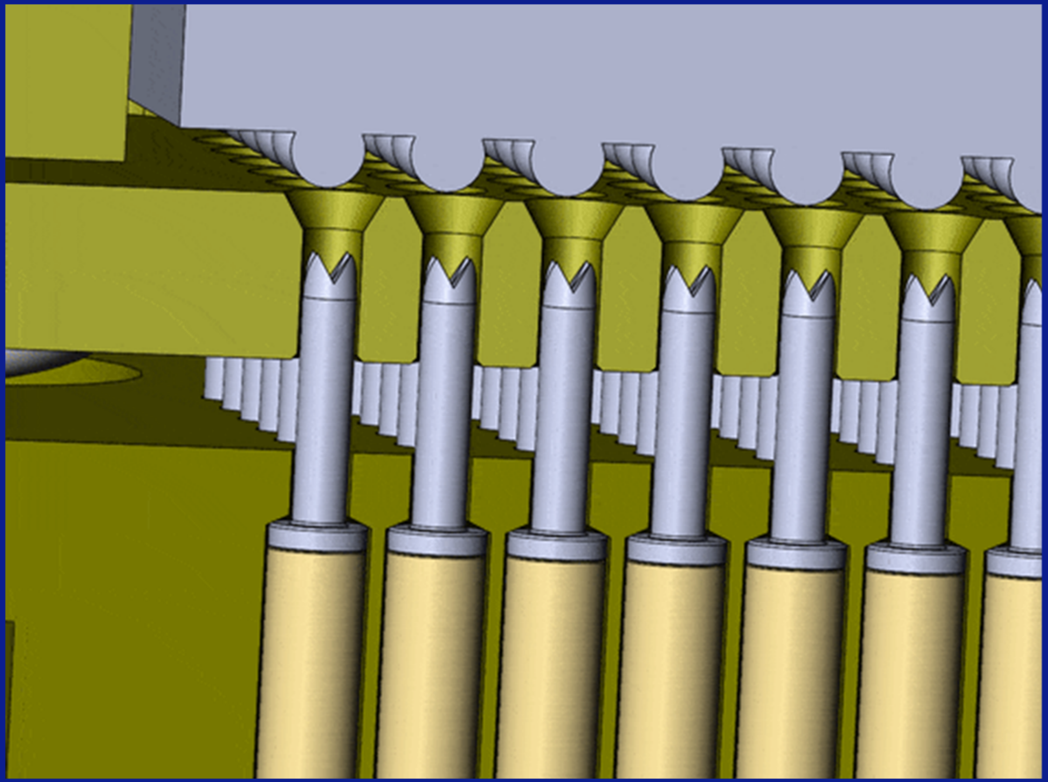


- Single-ended probe architecture for more consistent Cres performance
- Pd alloy tip
- Fully user serviceable contactor architecture – individually replaceable probes



Spring Probe DUT Alignment

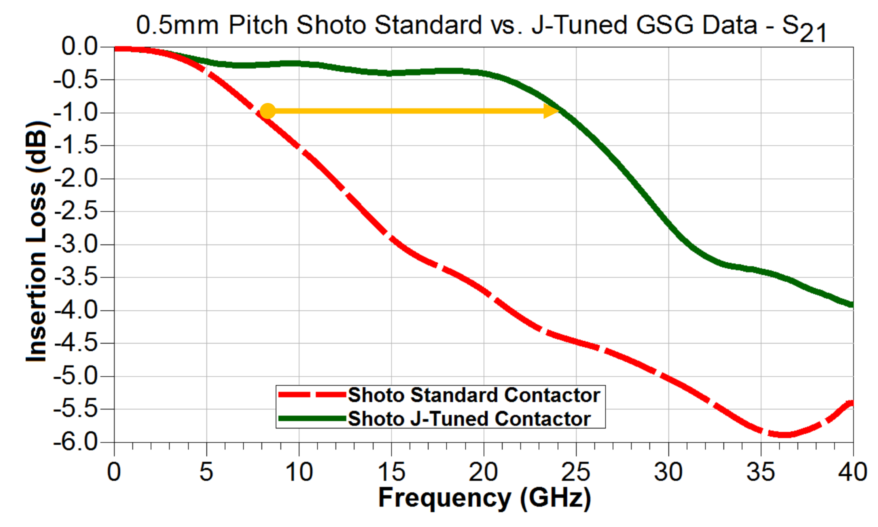
- The alignment plate first rough-aligns the BGA package on the sides
- Then the floating plate funnels the BGA balls and guides them precisely to the probe tips

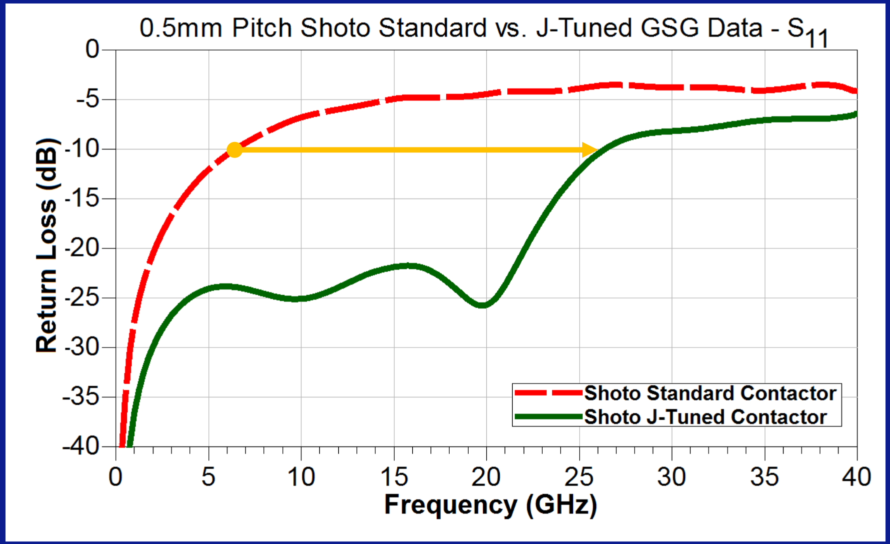


J-Tuned™ Capabilities*

Because the SHOTO™, YARI™, and other spring probe families Johnstech offers, the continuity through the families of the same test height for each probe allows us some greater degrees of freedom to impedance match.

* "Standard" results shown are for a specific customer I/O layout and do not necessarily represent the released product specifications



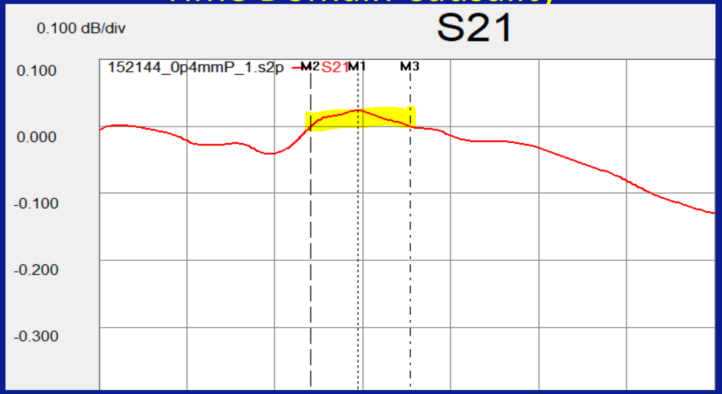


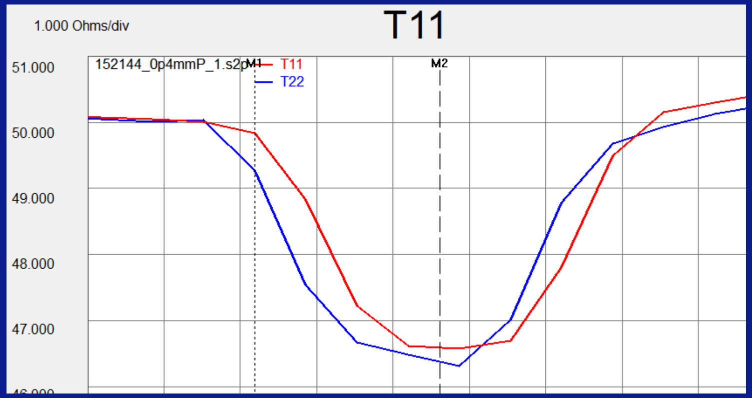
Passivity, Reciprocity, and Causality in S-Parameter Models

- ***Passivity***: (In A Passive Device):
- A network is passive if the energy absorbed does not generate additional energy
- he S-parameter always need to be between -1 and +1 in the matrix. For a passive device, there must be no energy of the propagating EM wave before t = 0 in the TDR plot.

Frequency Domain passivity

Time Domain Causality





- ***Reciprocity***: For a passive system, s12 = s21.
- ***Causality:*** Extrapolates to > sweep range. Not a real physical model. Used mainly for transient simulations, so optional.
  - 2 ways of determining / forcing causality.
    1. DFT (Discrete Fourier Transform) (Keysight)
    2. Causality estimation (Anritsu) using Smith Chart techniques of phase rotation

There is discussion over which method is better and for which type of application

Passivity, Reciprocity, and Causality in S-Parameter Models (cnt'd)

- Some post-processing software offered on the market can not only test for these 3 validity tests on a Touchstone File format (1.0 and 2.0) but can also CORRECT the S-parameter files by forcing the s parameter matrix to be valid.

EXAMPLE#1

Highlighting ~40 GHz operation with SHOTO™ spring probes and with field to edge measurements with J-Tuned™ optimization.

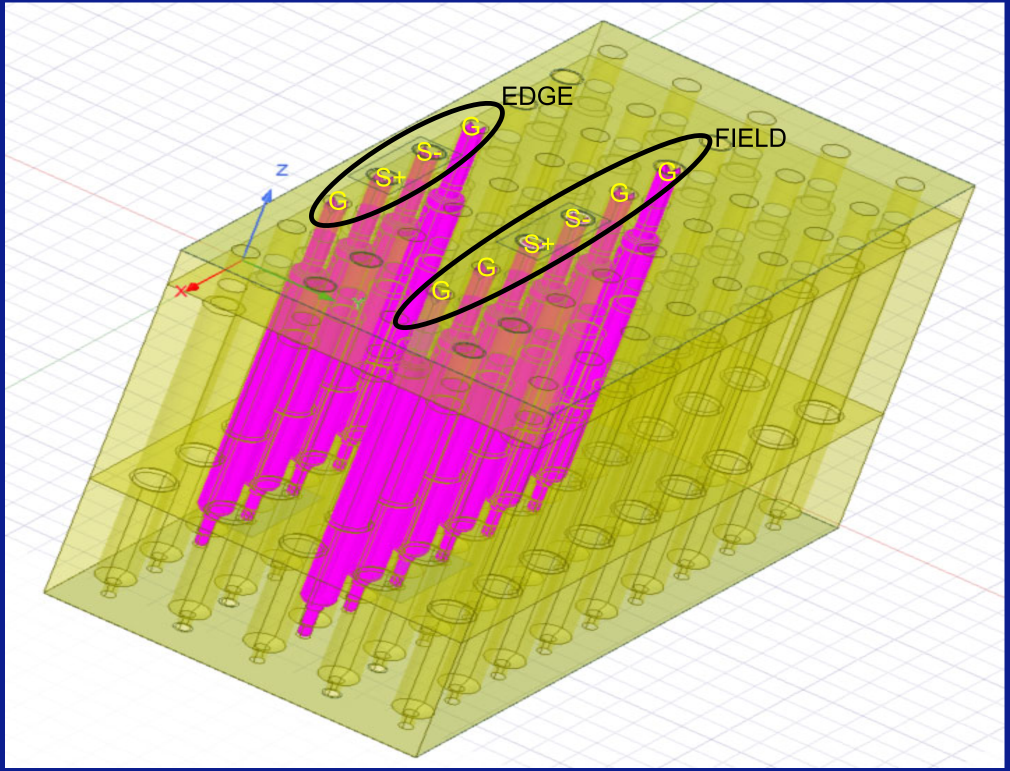
0.5MM PITCH DIFFERENTIAL GSSG SPRING PROBE

Simulation / Measurement Agenda

- Perform DOE of 6 simulation models with various combinations of J-Tuned™ processes applied
- Customer specs:
  - Pitch: 500 µm
  - Data rate of 10.56 Gbps serial data NRZ*, with a BW = 10.56 / 2 = 5.28 GHz
  - 3rd, 5th, and 7th harmonics:
    - Contactor Bandwidth (GSSG) for 5.28 x 3 = 15.8 GHz
    - Contactor Bandwidth (GSSG) for 5.28 x 5 = 26.4 GHz
    - Contactor Bandwidth (GSSG) for 5.28 x 7= 37 GHz
  - The eye diagram parametrics would show that the eye degrades as less power from the fundamental, 3rd, 5th, and 7th harmonics are passed (Decreasing -1 dB bandwidth)
- What we are trying to do is optimize the impedance across the spring probe geometry to match as close to 100 ohms differential, and 25 ohms Common mode impedance

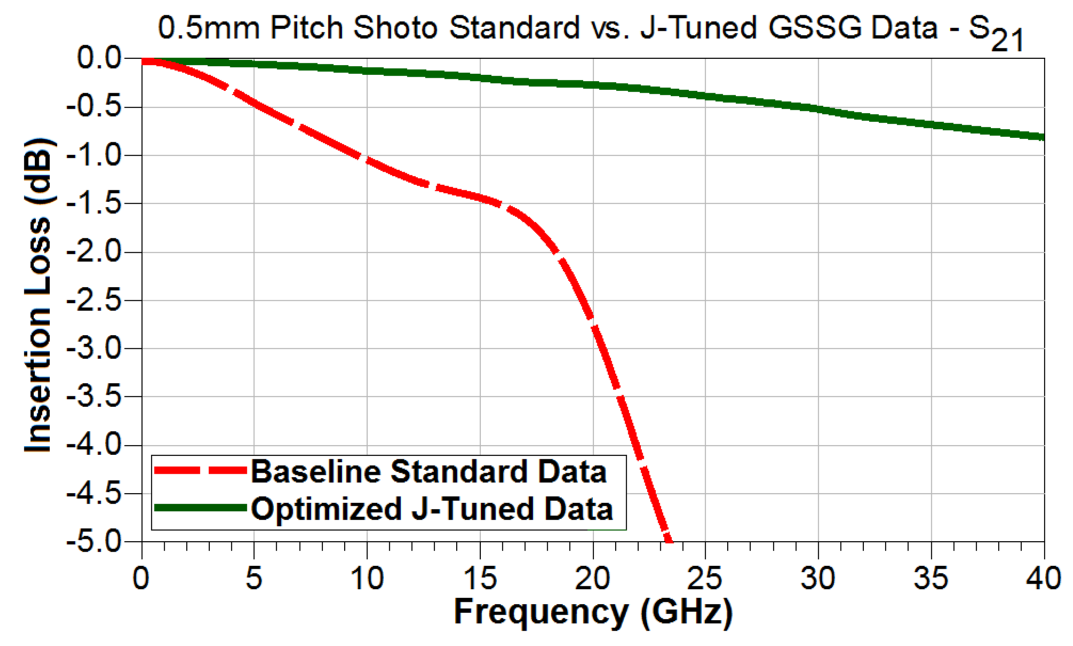
*NRZ = Not return to zero

Differential GGSSGG / GSSG Models

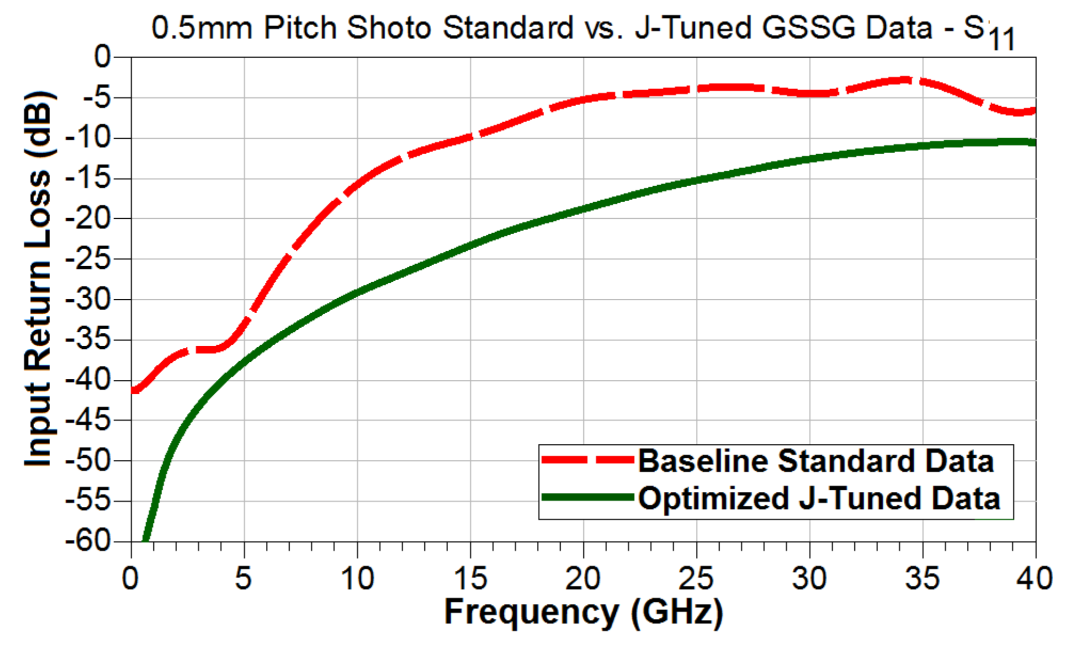


Differential FIELD GSSG Comparisons* S21

* “Standard” results shown are for a specific customer I/O layout and do not necessarily represent the released product specifications

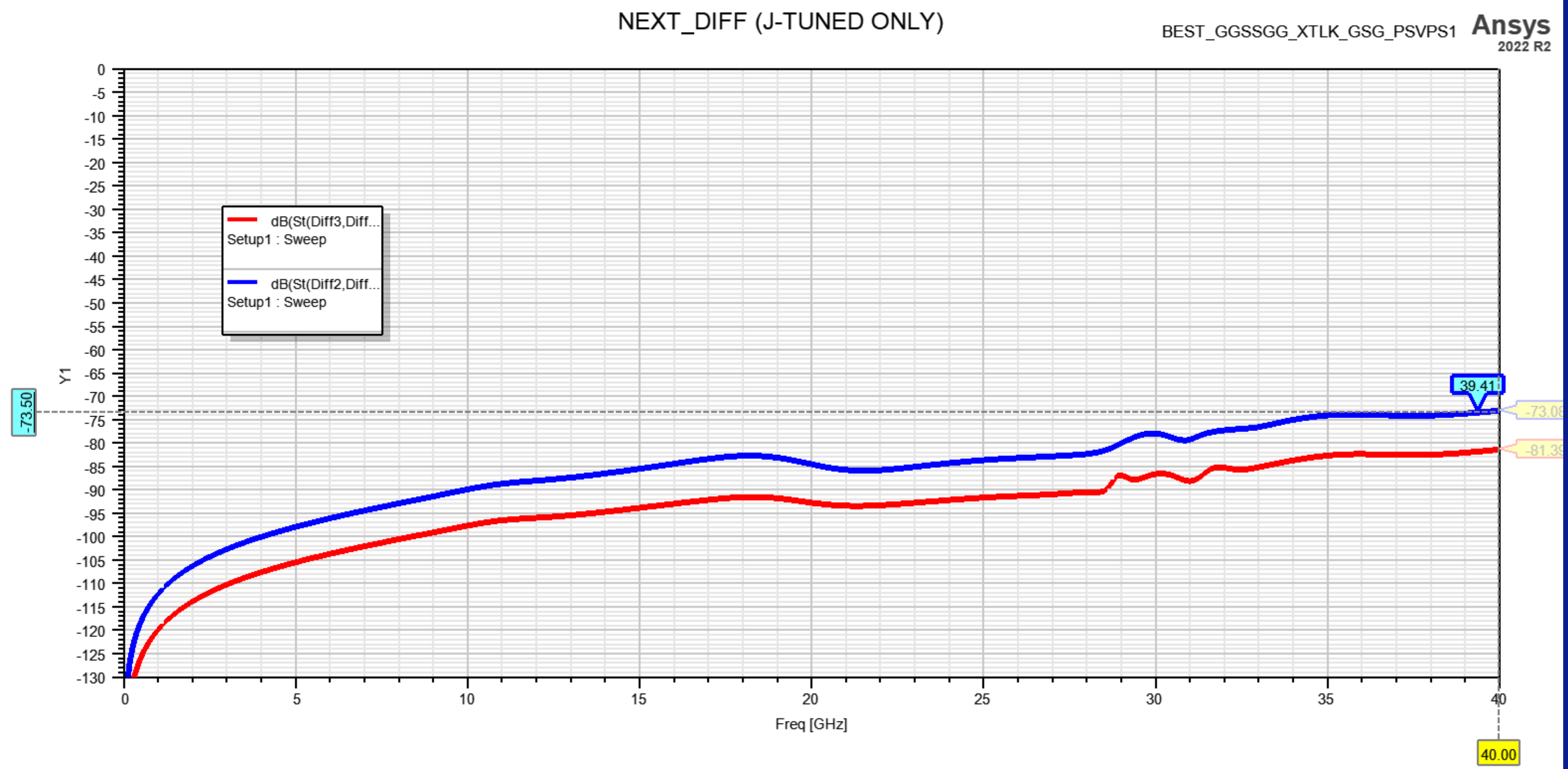


Differential FIELD GSSG Comparisons S11



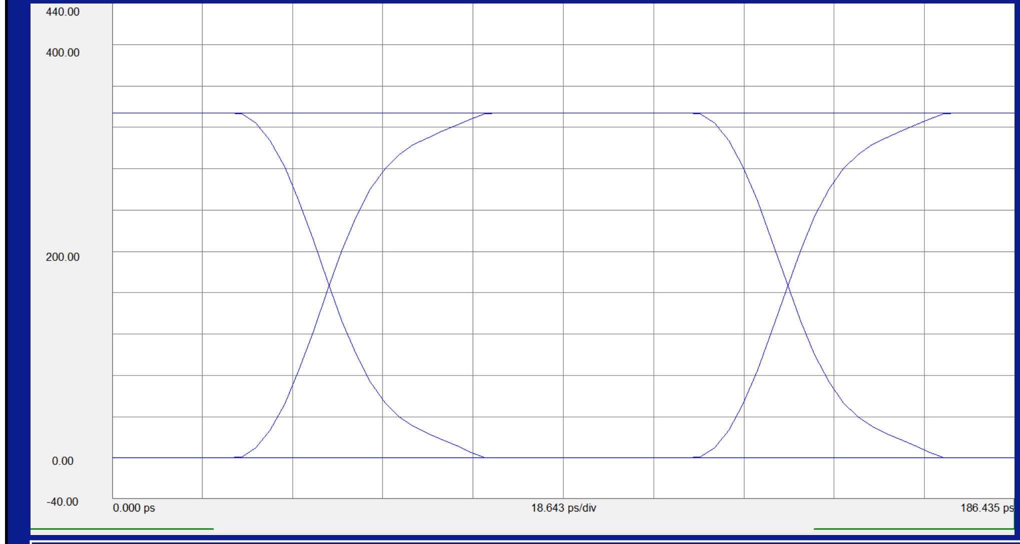
Differential FIELD GSSG Crosstalk NEXT

(J-Tuned™ Model Only)



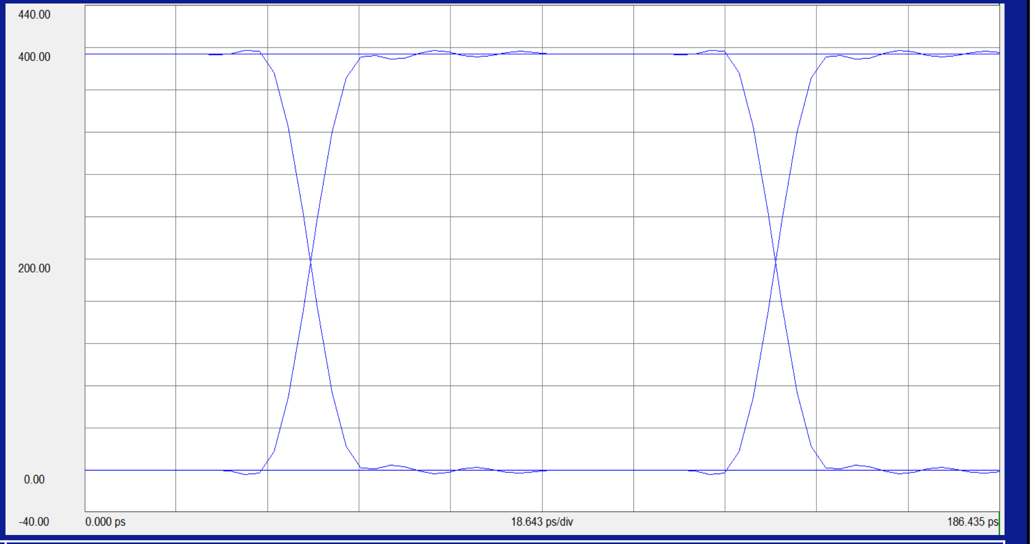
GSSG Eye Diagrams 10.56 Gbps / Channel NRZ

Baseline Standard Design



Height = 333.6 mV
Width = 95 ps
Signal to Noise (linear) = 0
Rise/Fall Time = 28.46 ps
Jitter = 2.96 ps PP

J-Tuned™ Design



Height = 391.9 mV
Width = 95 ps
Signal to Noise (linear) = 227.09
Rise/Fall Time = 12.33 ps
Jitter = <1ps PP

EXAMPLE#2

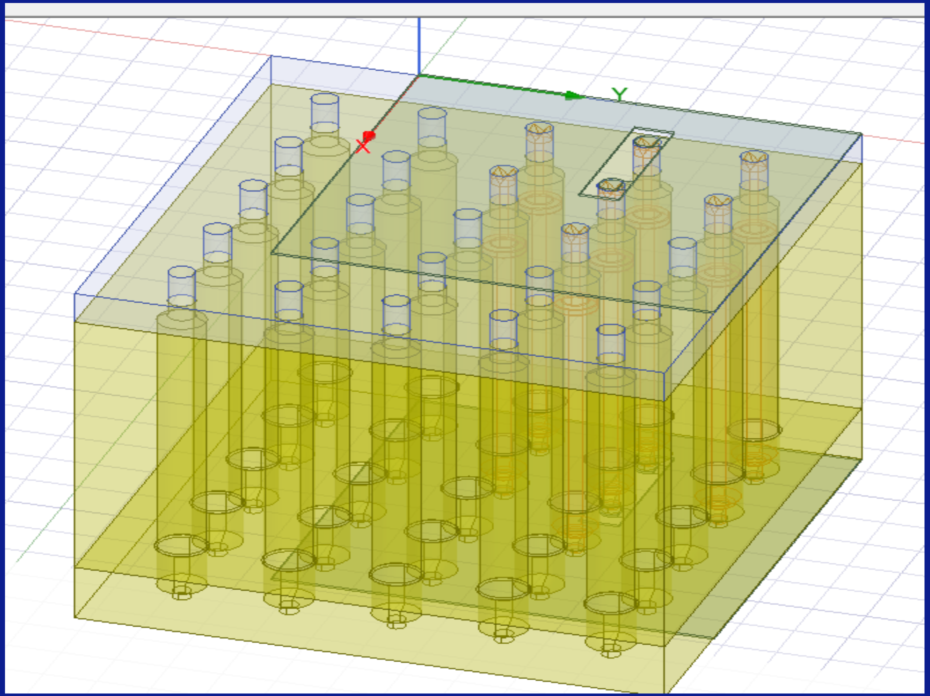
Highlighting ~40 GHz operation with YARI™ spring probes highlighting digital application with J-Tuned™ optimization.

1.0MM PITCH DIFFERENTIAL GSSG SPRING PROBE

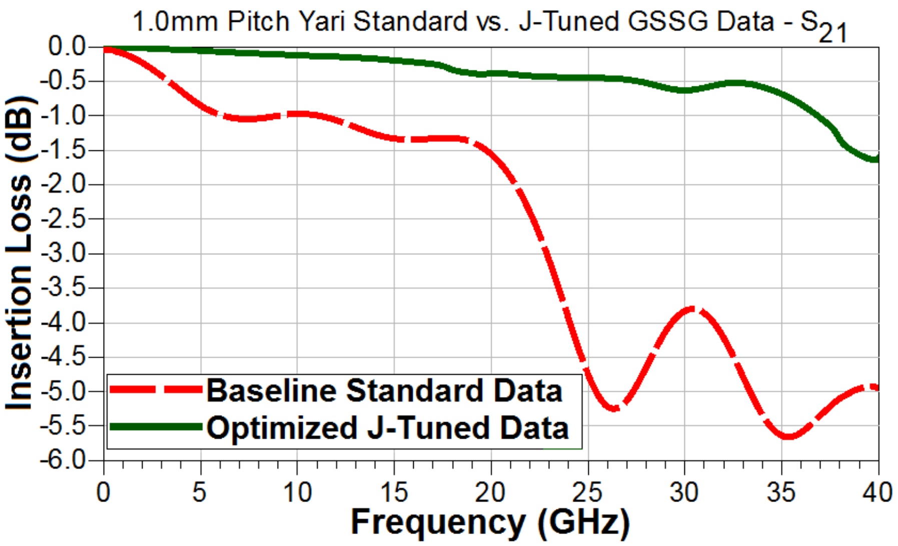
Simulation / Measurement Agenda

- Perform DOE of 6 simulation models with various combinations of J-Tuned™ processes applied
- Customer specs:
  - Pitch: 1000 µm
  - Data rate of 10.56 Gbps serial data NRZ, with a BW = 10.56 / 2 = 5.28 GHz
  - 3rd, 5th, and 7th harmonics:
    - Contactor Bandwidth (GSSG) for 5.28 x 3 = 15.8 GHz
    - Contactor Bandwidth (GSSG) for 5.28 x 5 = 26.4 GHz
    - Contactor Bandwidth (GSSG) for 5.28 x 7= 37 GHz
  - The eye diagram parametrics would show that the eye degrades as less power from the fundamental, 3rd, 5th, and 7th harmonics are passed (Decreasing -1 dB bandwidth)
- What we are trying to do is optimize the impedance across the spring probe geometry to match as close to 100 ohms differential, and 25 ohms Common mode impedance

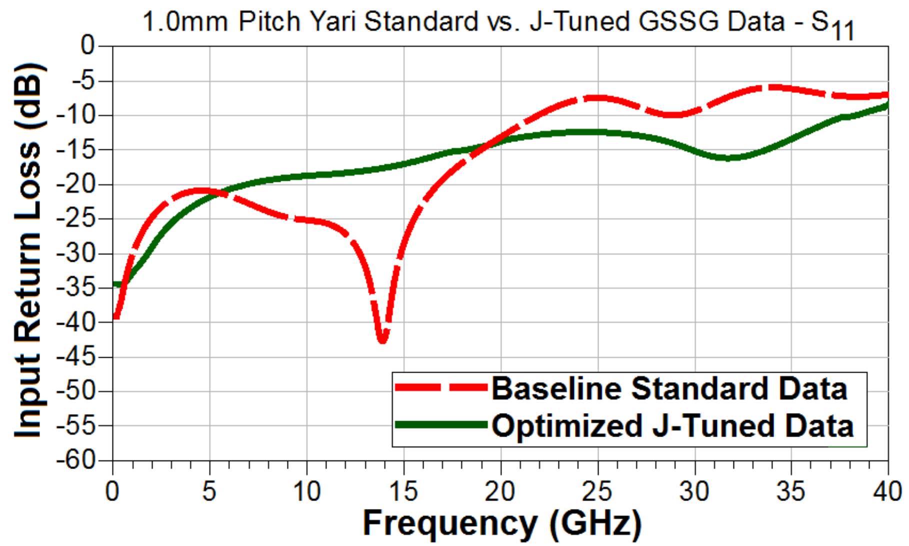
1mm Pitch Model



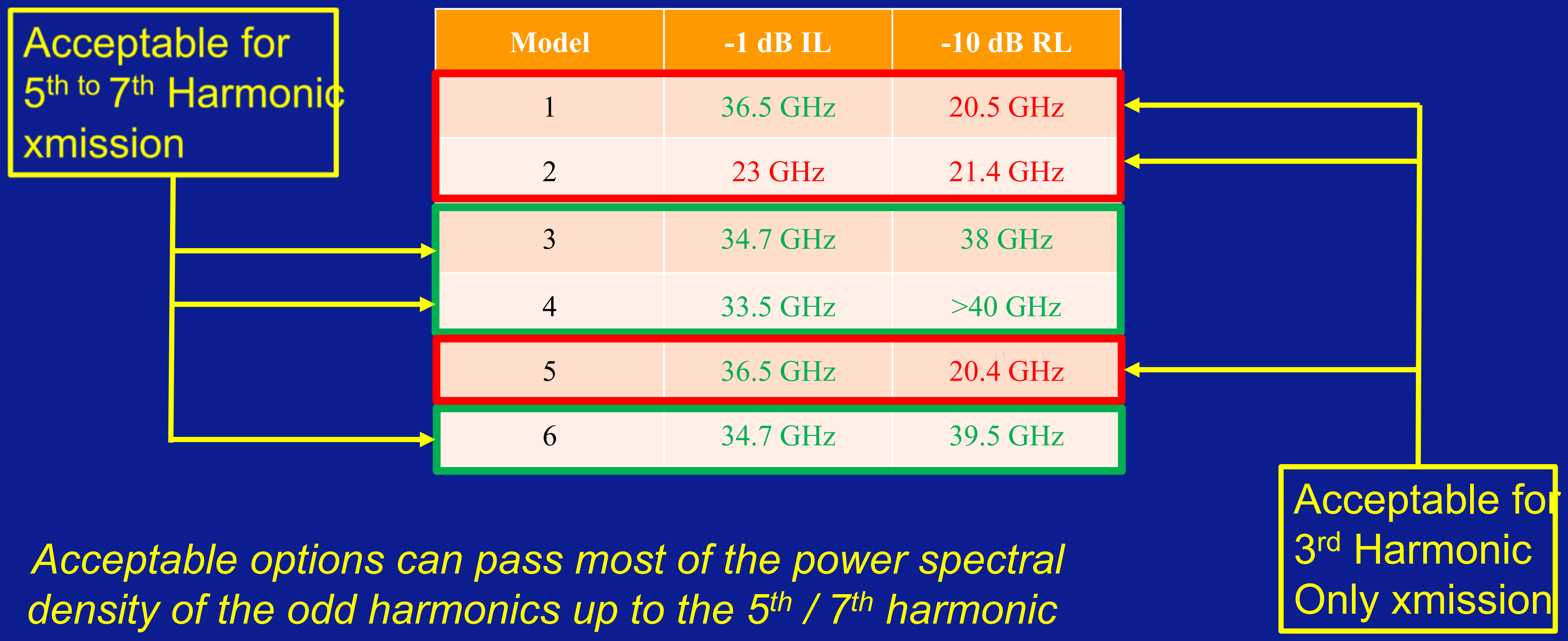
Differential FIELD GSSG Comparisons S21



Differential FIELD GSSG Comparisons S11



Summary of DOE Results



Model	-1 dB IL	-10 dB RL
1	36.5 GHz	20.5 GHz
2	23 GHz	21.4 GHz
3	34.7 GHz	38 GHz
4	33.5 GHz	>40 GHz
5	36.5 GHz	20.4 GHz
6	34.7 GHz	39.5 GHz

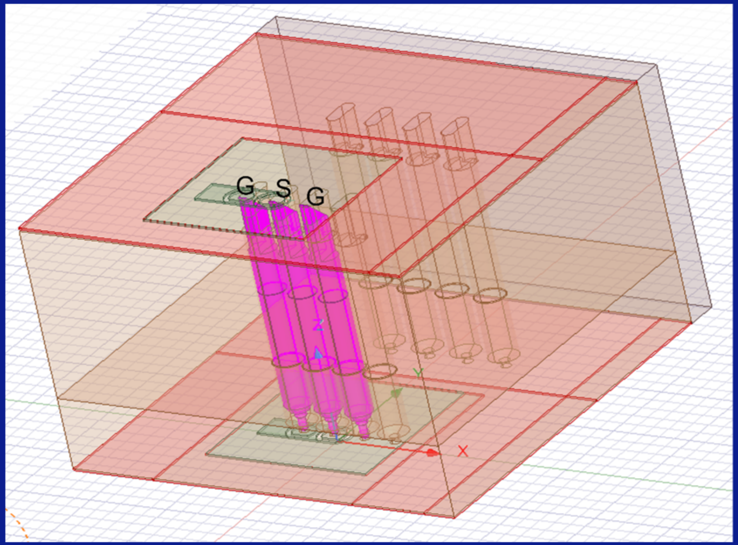
Acceptable options can pass most of the power spectral density of the odd harmonics up to the 5th / 7th harmonic (improves eye diagram and BER [bit error rate])

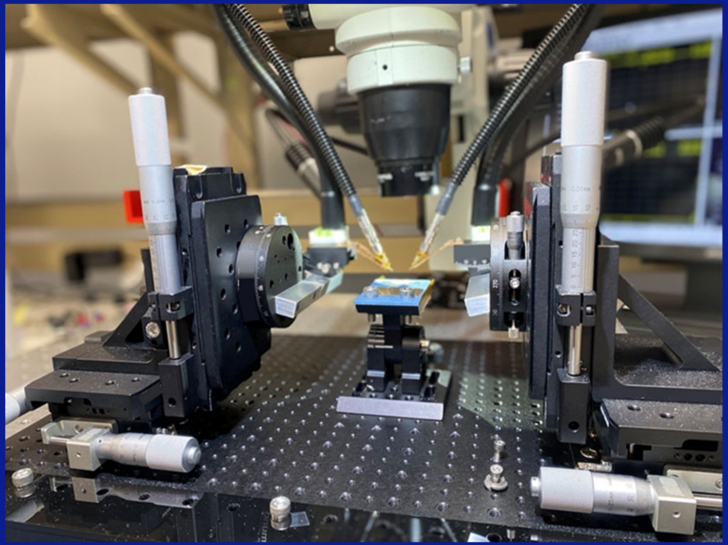
EXAMPLE#3

Highlighting 40 GHz operation with DAISHO™ spring probes highlighting good correlations between simulation and measurement

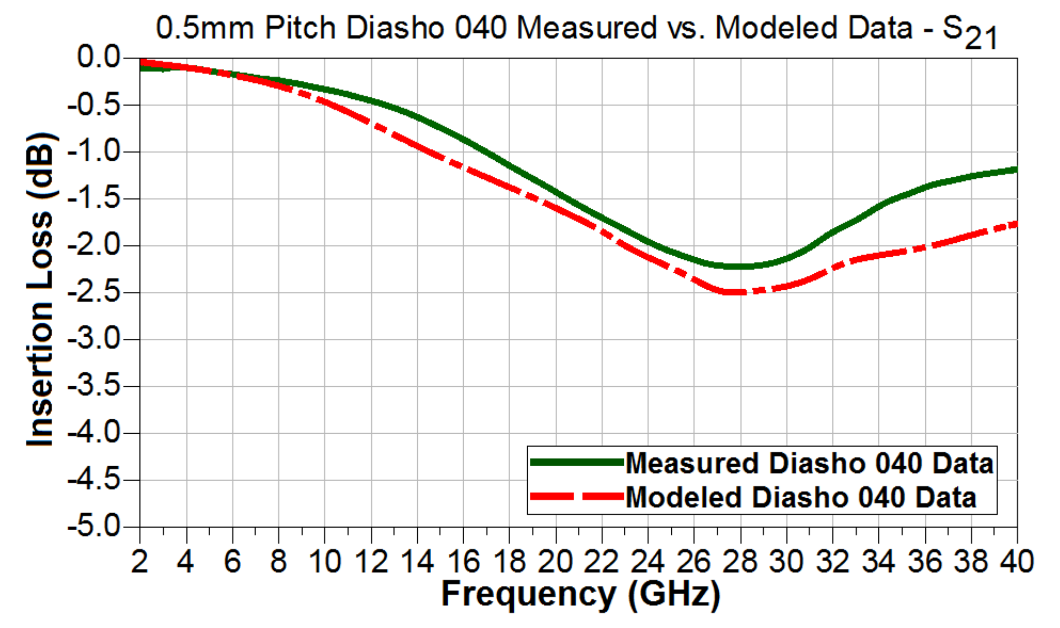
0.4MM PITCH DIFFERENTIAL GSG SPRING PROBE

DAISHO™ Simulation and Measurement

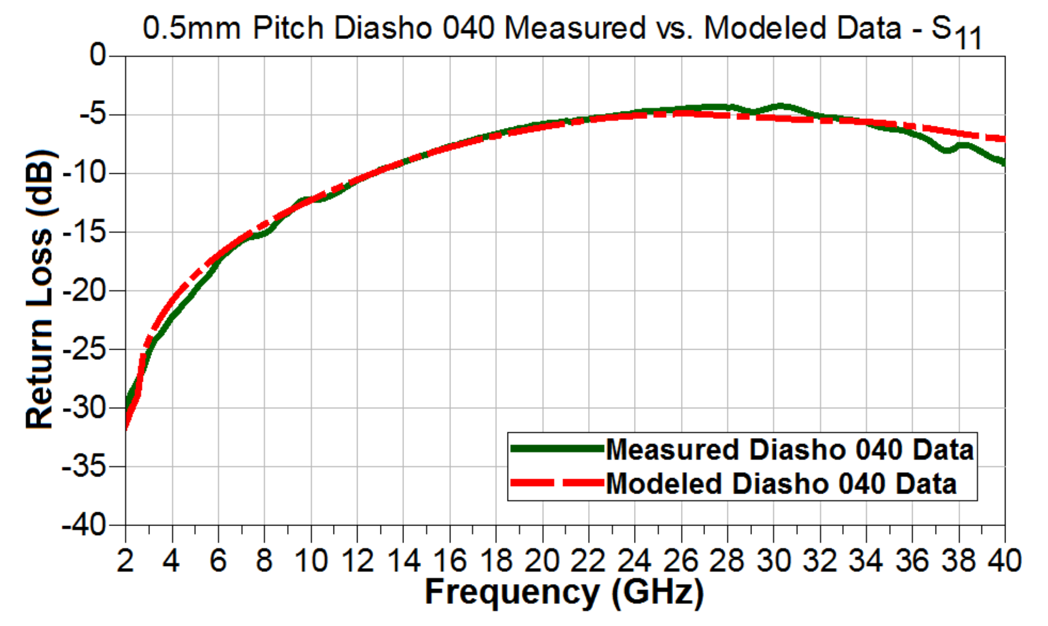




GSG Comparisons S21 – Measured vs. Simulated



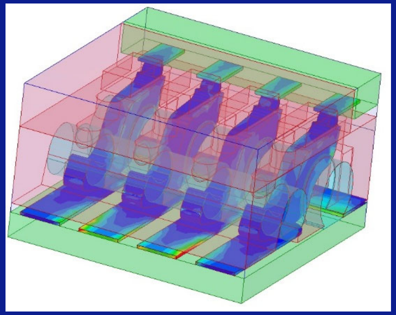
GSG Comparisons S11 – Measured vs. Simulated



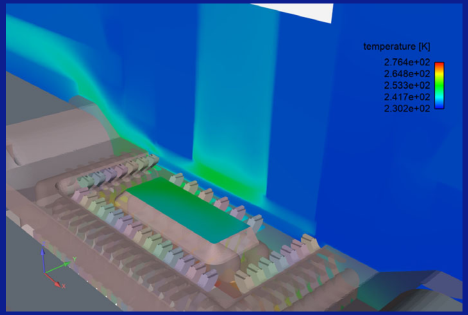
Conclusions

- With J-Tuning, a much higher bandwidth, and better impedance match can be achieved without having to go to more expensive coaxial contactor designs.
- All S-Parameter results have been verified for Passivity, Reciprocity, and Causality (both measured in-house and simulated)
- Also, J-Tuned™ is possible not only with the electrical performance but can also be applied in the thermal and mechanical space as well.

ELECTRICAL



THERMAL



MECHANICAL