TWENTIETH ANNUAL

TestConX™

March 3 - 6, 2019

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive

Testing of High Frequency 5G Applications and Why Simulation is Critical to Success

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Johnstech International

TestConX
Mesa, Arizona • March 3 - 6, 2019

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Agenda

- Introduction to 5G Bands and purpose of paper
- ROL100A - Measured vs. Modeled
- Performance Plus ROL100A - Grounding Effects
- BGA Device Contactor – Measured vs. Equivalent Circuit
- Verticon II – Effects of Materials – Metals
- Verticon II – Effects Of Materials – Non-Metals
- Waveguide – Tolerance Analysis
- Conclusion

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Purpose of Paper

- The purpose of this paper is to show how simulation tools can predict measured results accurately
- This means mechanical dimensions should be simulated as built
- Models run at expected tolerances to assure every contactor built performs with consistent and repeatable performance
- Non-metals should be tested to assume specifications provided by suppliers are accurate at all frequencies
- Many suppliers only provide dielectric constant (ε_r) and loss tangent (lt) or dissipation factor (df) at one frequency (many times this is at 10 MHz).
- Some materials vary by more than 30% or have issues at certain frequencies

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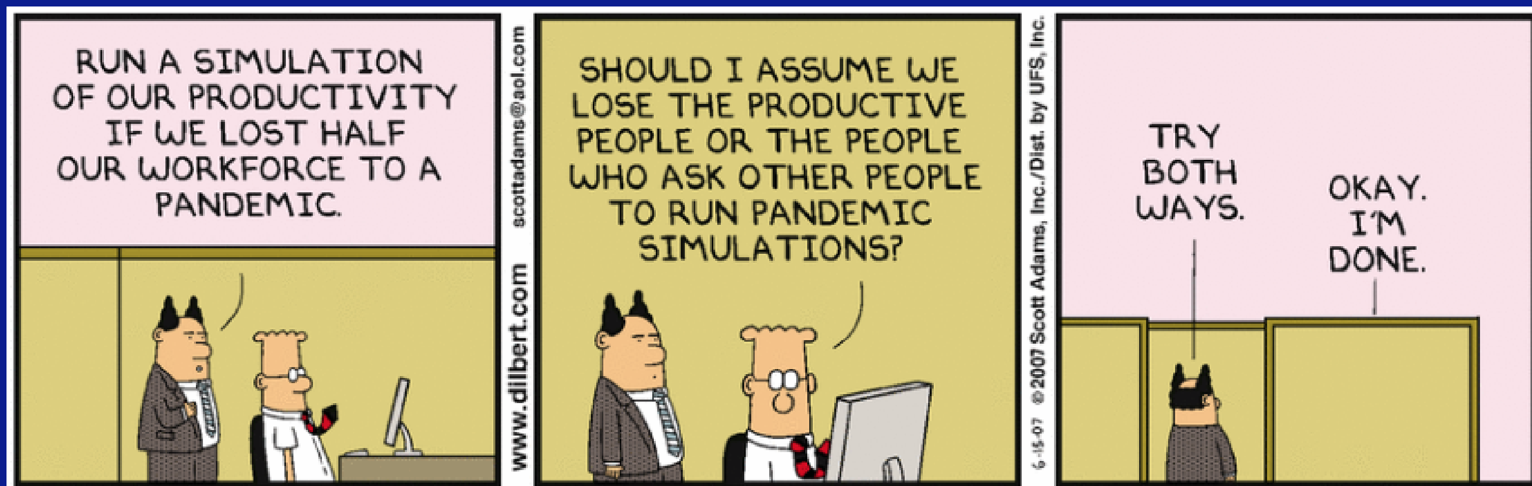
Introduction to 5G Bands

Band	Downlink/Uplink
n77	3.3 - 4.2 GHz
n78	3.3 - 3.8 GHz
n79	4.4 - 5.0 GHz
n257	26.5-29.5 GHz
n258	24.25 - 27.5 GHz
n260	37 - 40 GHz
n261	27.5 - 28.35 GHz

* Wireless Standards 2018 Microwave & RF

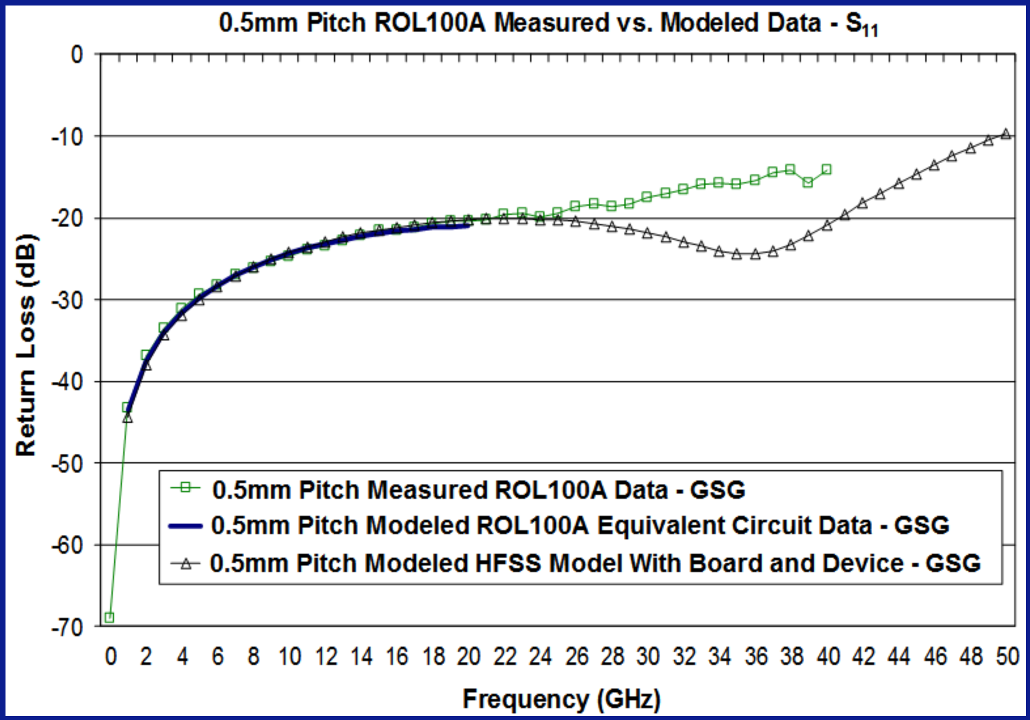
Potential 5G Communications Bands According to 2018 Wireless Standards (Microwaves and RF)

Things That Affect Accuracy of Simulation



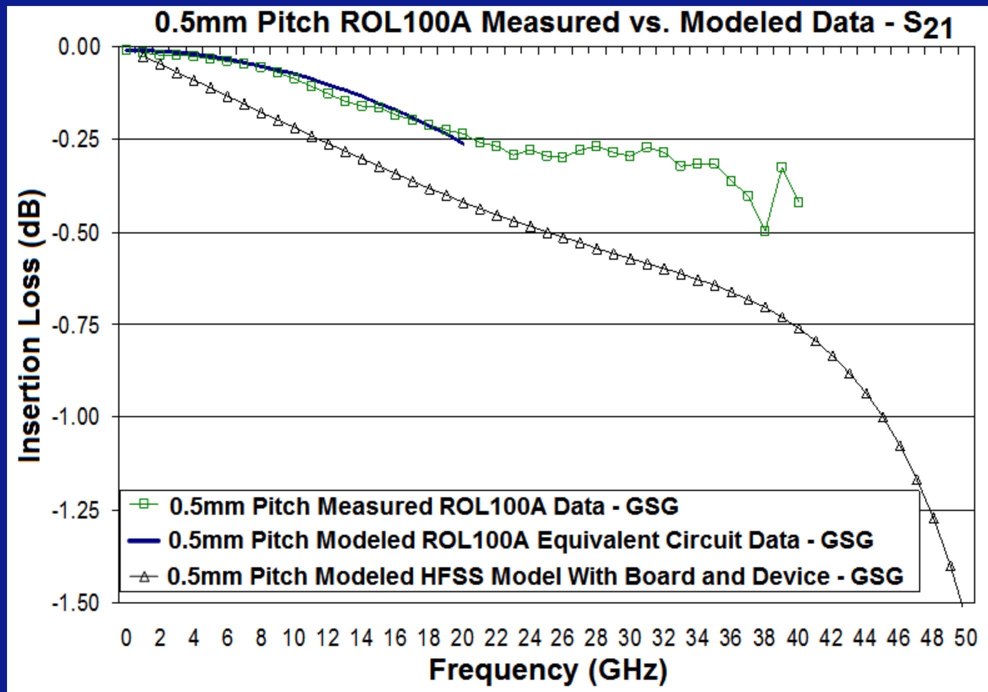
- Assumptions need to be correct
- Inputs to model need to be correct

0.5mm Pitch ROL100A Measured vs. Modeled Results - S_{11}

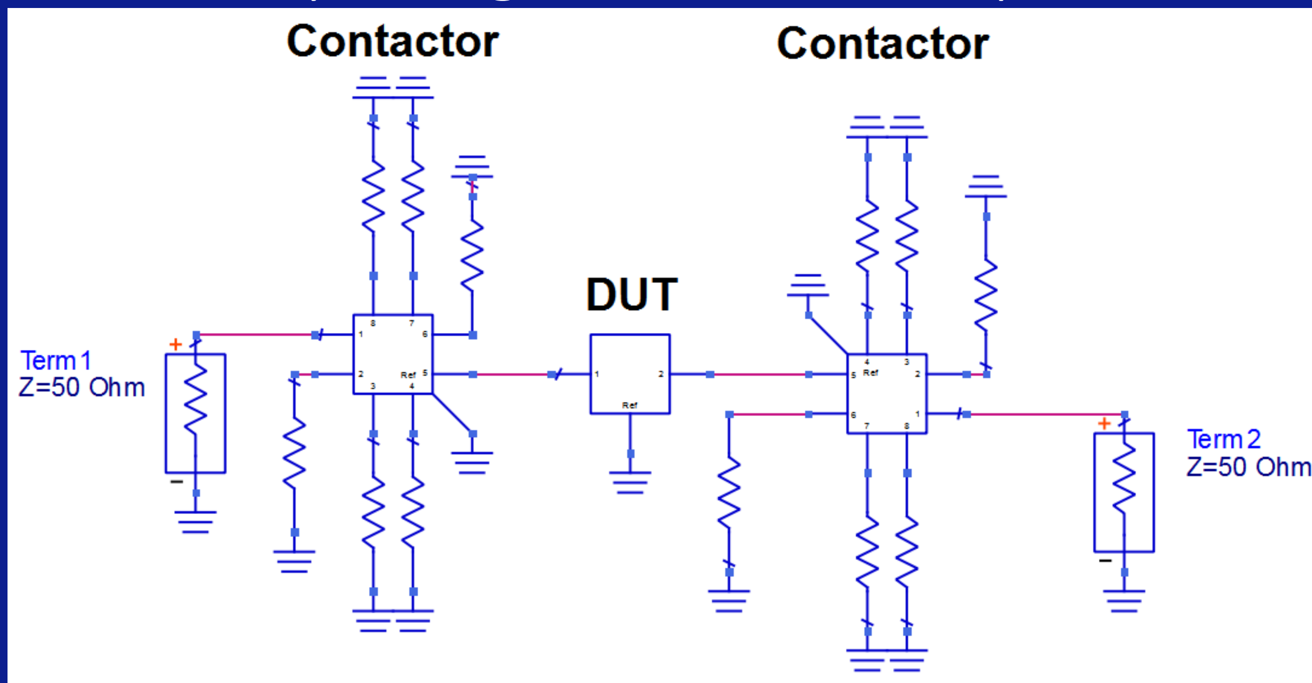


With 50 Ohm Board Matching Return Loss of Contact Matches System

0.5mm Pitch ROL100A Measured vs. Modeled Results - S_{21}



Case Study Using 50 Ohm RF Amplifier DUT



For devices with input and outputs total performance should include two contacts

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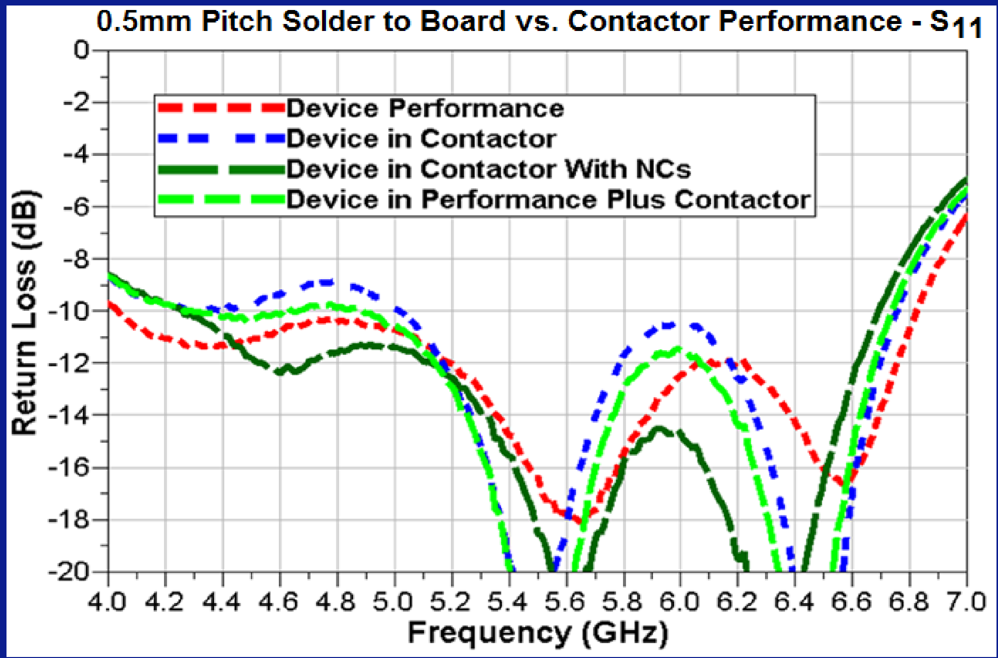
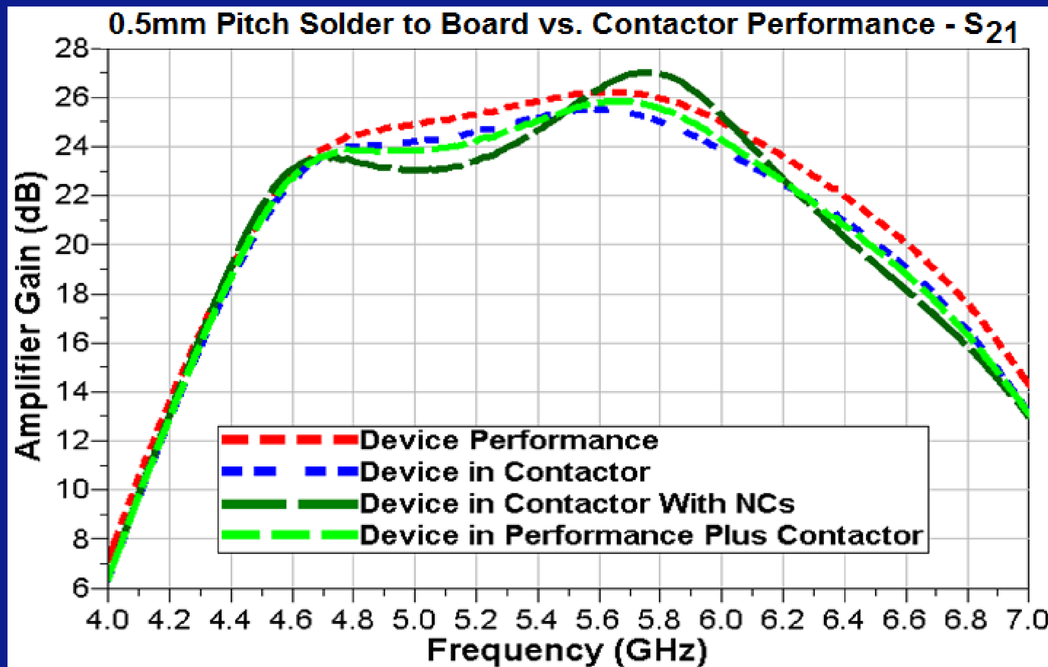
0.5mm Pitch ROL100A Performance Plus Measured vs. Modeled S-Parameter Results – S_{11}



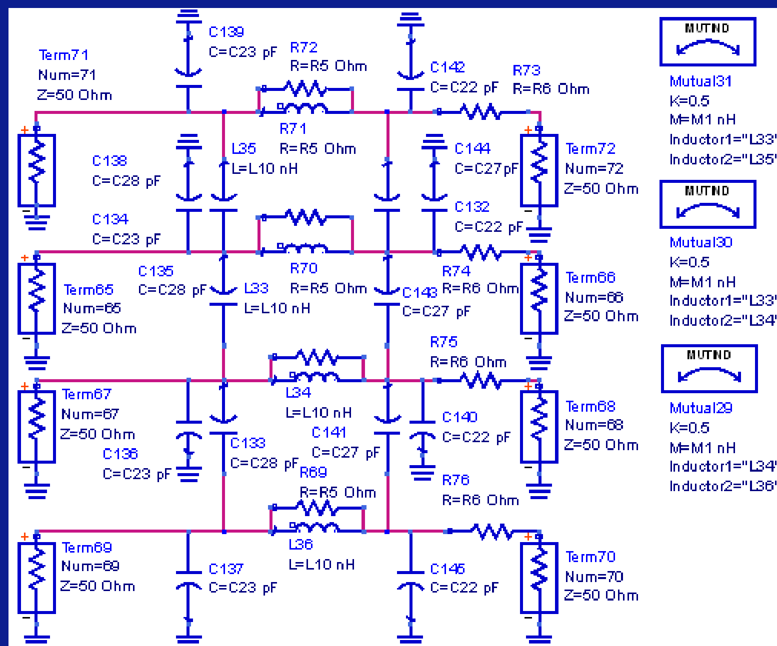
Testing in contactor changes the ground reference plane from solder-to-board results

0.5mm Pitch Device Solder to Board Performance – S_{21}



Extra Contactor Inductance Does Affect Gain Performance

0.4mm Pitch BGA Device Contactor – Equivalent Circuit (80 GHz Model)



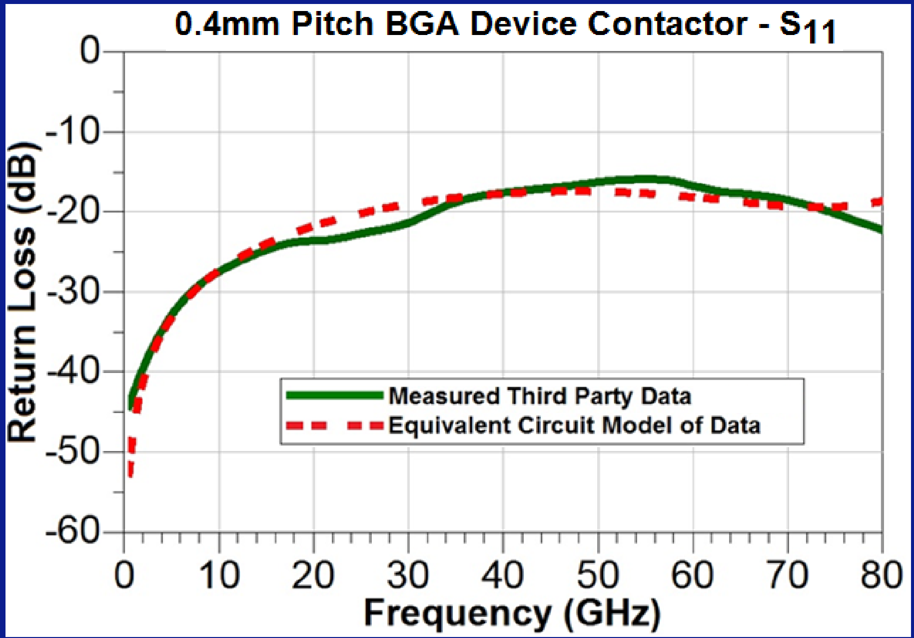
Board Side **Device Side**

Equivalent Circuit Model
Ls = 0.103nH
Lm = 0.003nH
Cgnd = 0.043pF
Cm = 0.013pF
Cres = 0.08 Ohms

Var Eqn
VAR
VAR1
C22=0.014
C23=0.029
C27=0.006
C28=0.007
R1=500
R6=0.08
L10=0.103
M1=0.003

Equivalent circuit should include Cres element and using discrete components is really only good for low frequencies

0.4mm Pitch BGA Device Contactor Measured Vs. Modeled Equivalent Circuit – Center or Field – S_{11}



Equivalent Circuit matches well to measured data making it more accurate

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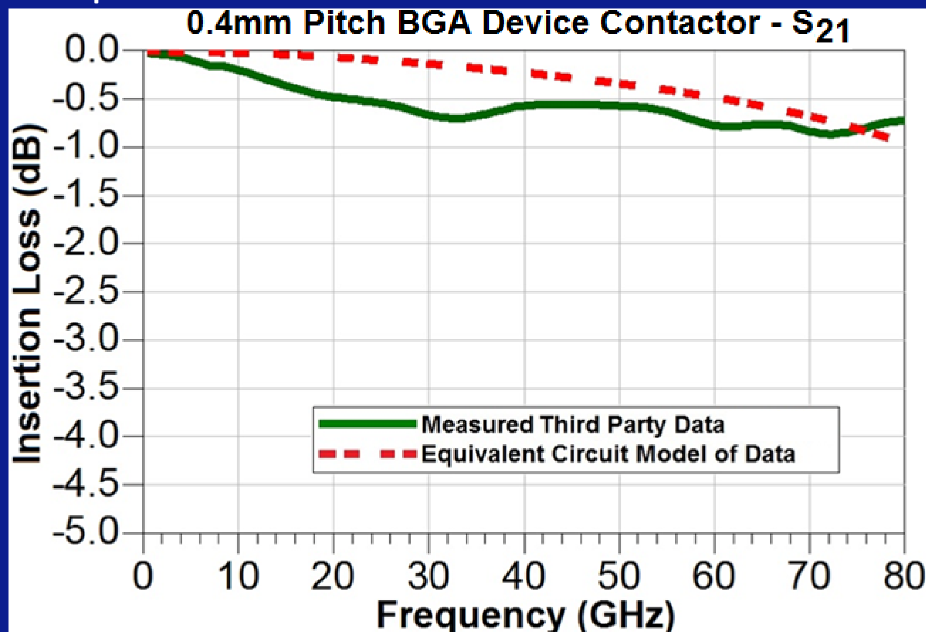
0.4mm Pitch BGA Device Contactor Measured Vs. Modeled Equivalent Circuit for Center or Field – S_{21}



The shorter the contact the lower the inductance and higher the -1 dB bandwidth

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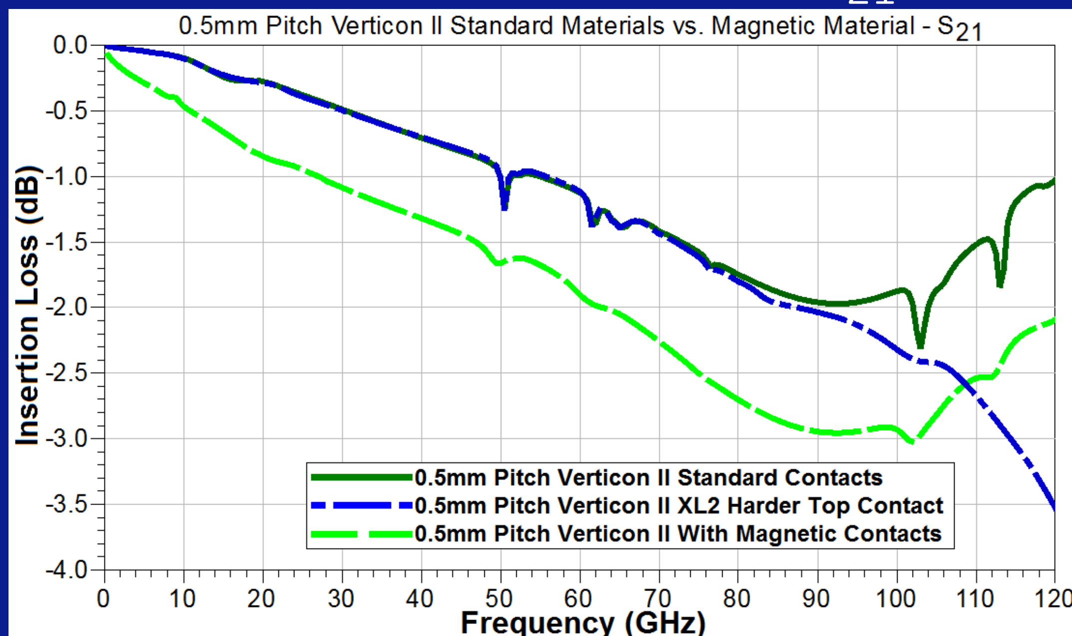
Results of Contact Materials on High Frequency Testing – S_{21}



Contact magnetic properties affect electrical performance

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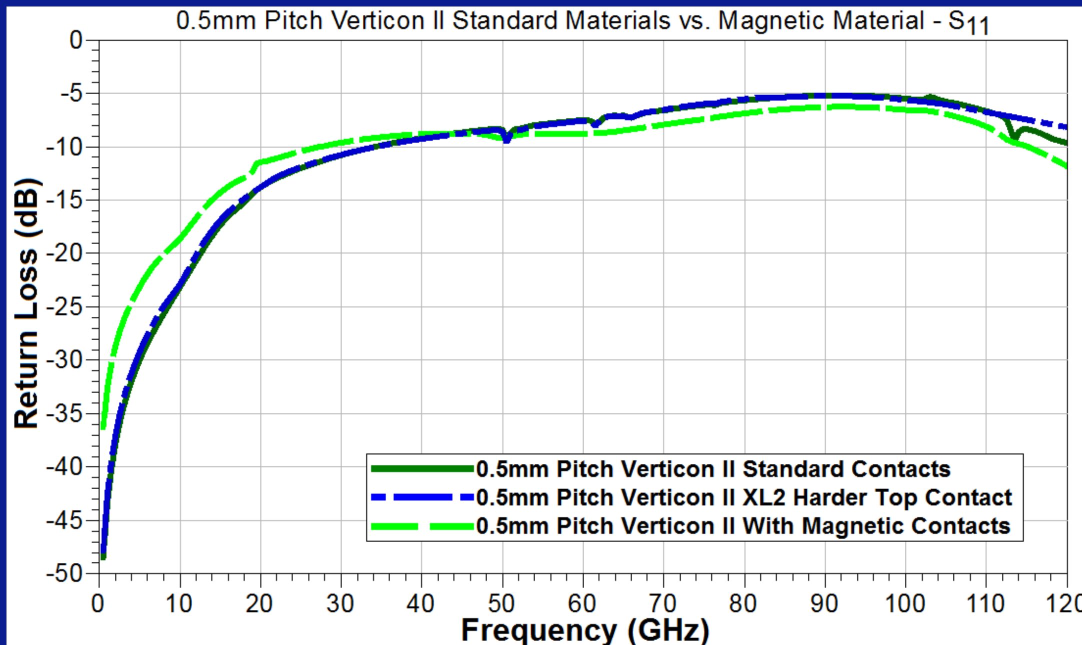
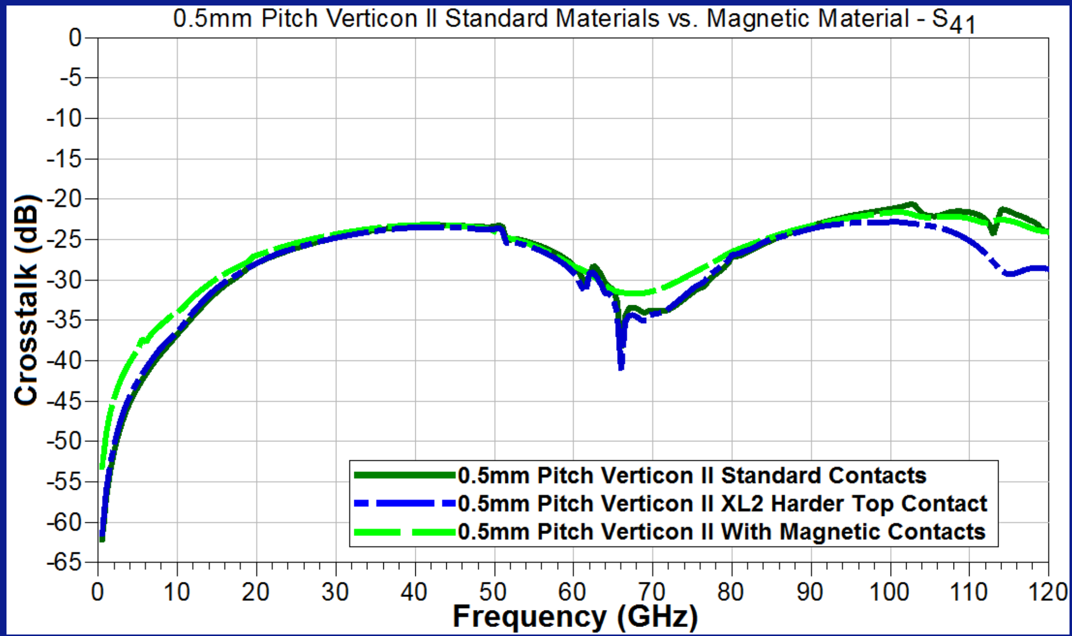
Results of Contact Materials on High Frequency Testing – S_{11}



At lower frequencies magnetic contacts degrade performance

Results of Contact Materials on High Frequency Testing – S_{41}

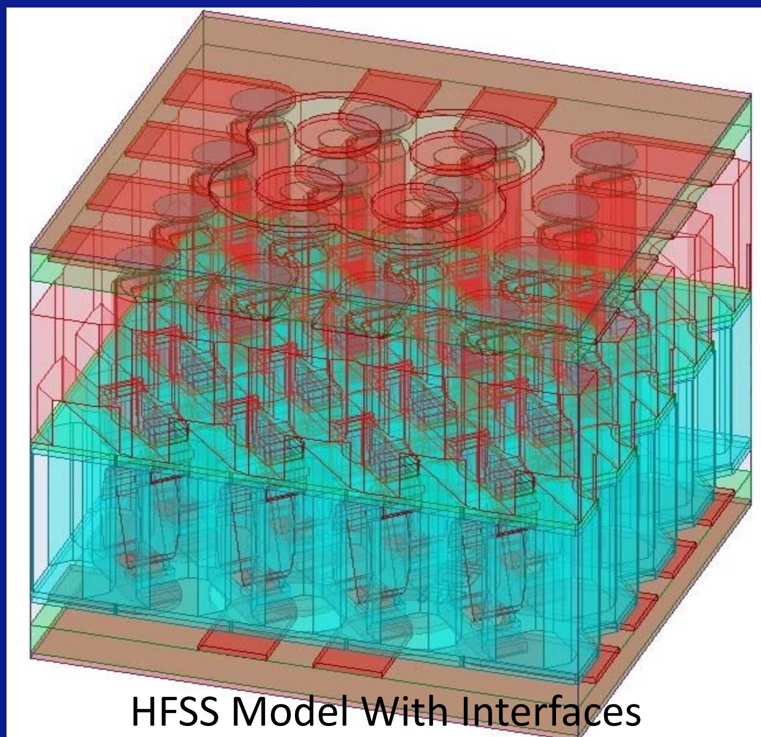


Crosstalk is affected more by distance between contacts than magnetic contacts

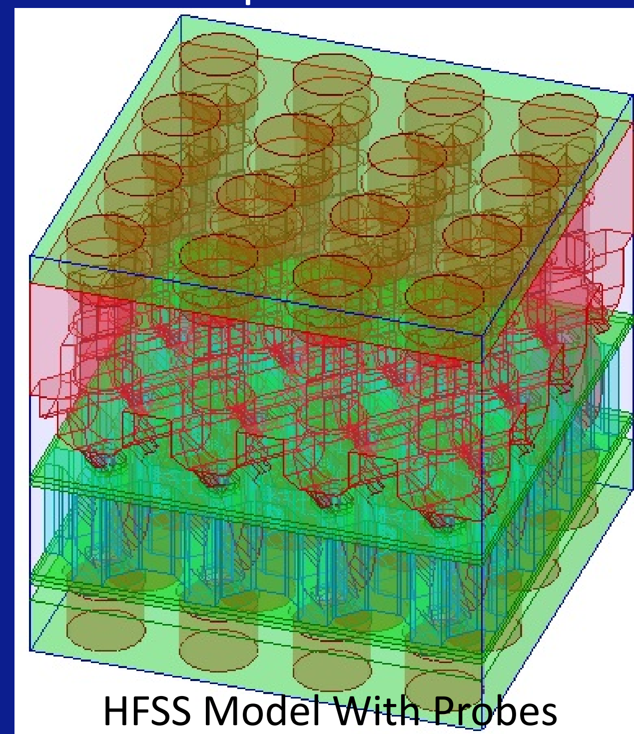
Example Material Data Sheet – Torlon 4203

Type	Property	UOM	Value	Testing Method
Thermal	Flammability, UL94	-	V-0	-
Thermal	Coefficient of Linear Thermal Expansion (-40°F to 300°F)	M in/in-°F	17	E-831 (TMA)
Thermal	Heat Deflection Temperature @ 264 psi	°F	532	ASTM D648
Thermal	Tg-Glass Transition (Amorphous)	°F	527	ASTM D3418
Thermal	Continuous Service Temperature in Air (Max.) (1)	°F	500	-
Thermal	Thermal Conductivity	BTU-in/hr-ft^2-°F	1.8	ASTM F433
Electrical	Dielectric Strength, Short Term	kV/in	580	ASTM D149
Electrical	Surface Resistance	ohms/sq.	>= 1.00e+16	ANSI/ESD STM 11.11
Electrical	Dielectric Constant, 10^6 Hz	-	4.2	ASTM D150
Electrical	Dissipation Factor, 10^6 Hz	-	0.026	ASTM D150

Modeled vs. Measured HFSS Depiction



HFSS Model With Interfaces



HFSS Model With Probes

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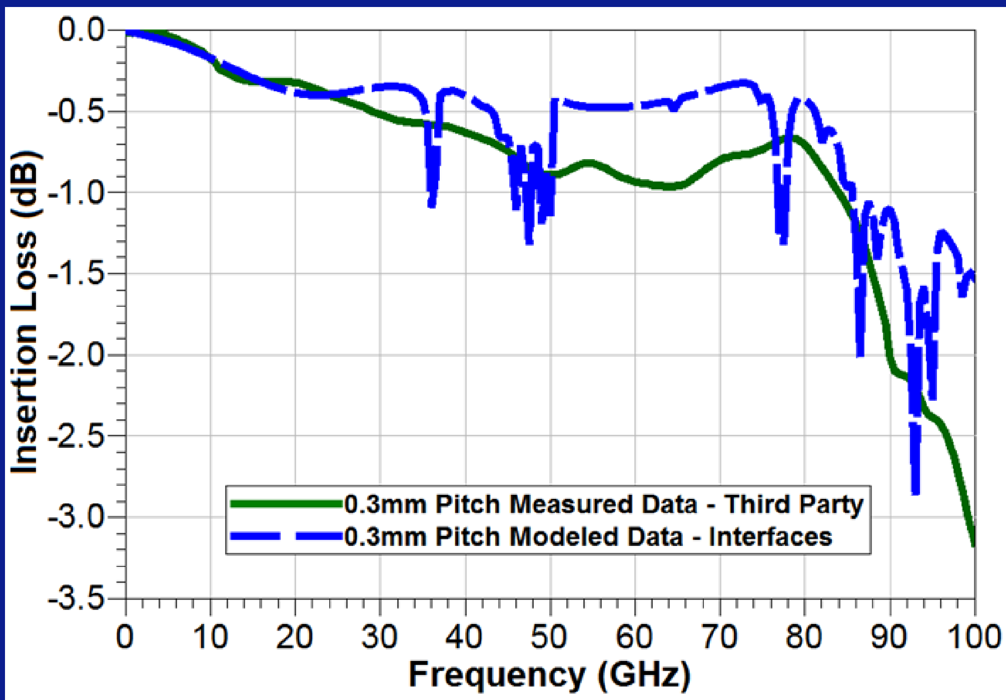
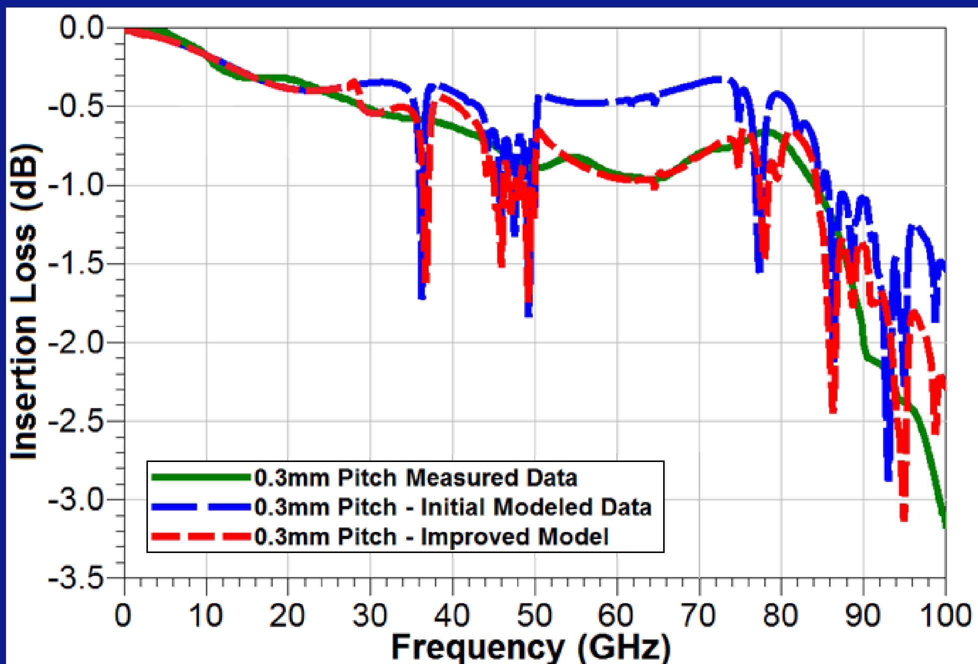
0.3mm Pitch BGA Device Measured vs. Modeled Data – S_{21}



- Simulated with probes similar to measured test setup
- No right angle device and board connections

Higher Frequency differences due to material properties changing for non-metal materials

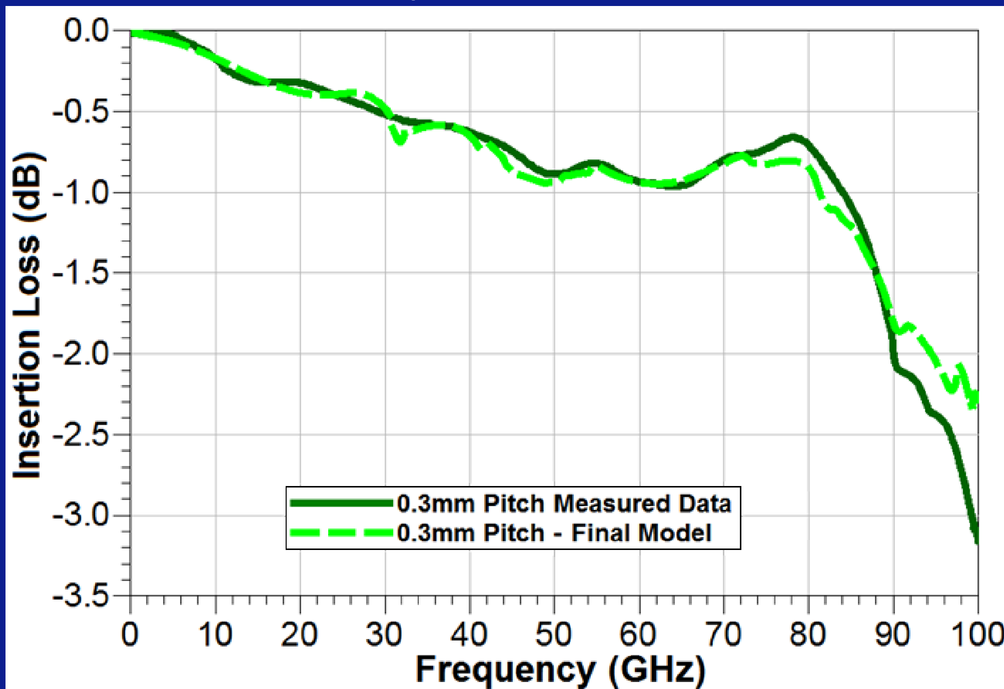
0.3mm Pitch BGA Device Contactor Measured vs. Improved Modeled Data – S_{21}



- Simulated with probes similar to measured test setup
- No right angle device and board connections
- (Red) Modeled with tested material properties to 80 GHz

Variations between measured and modeled due to S-parameter convergence being too high

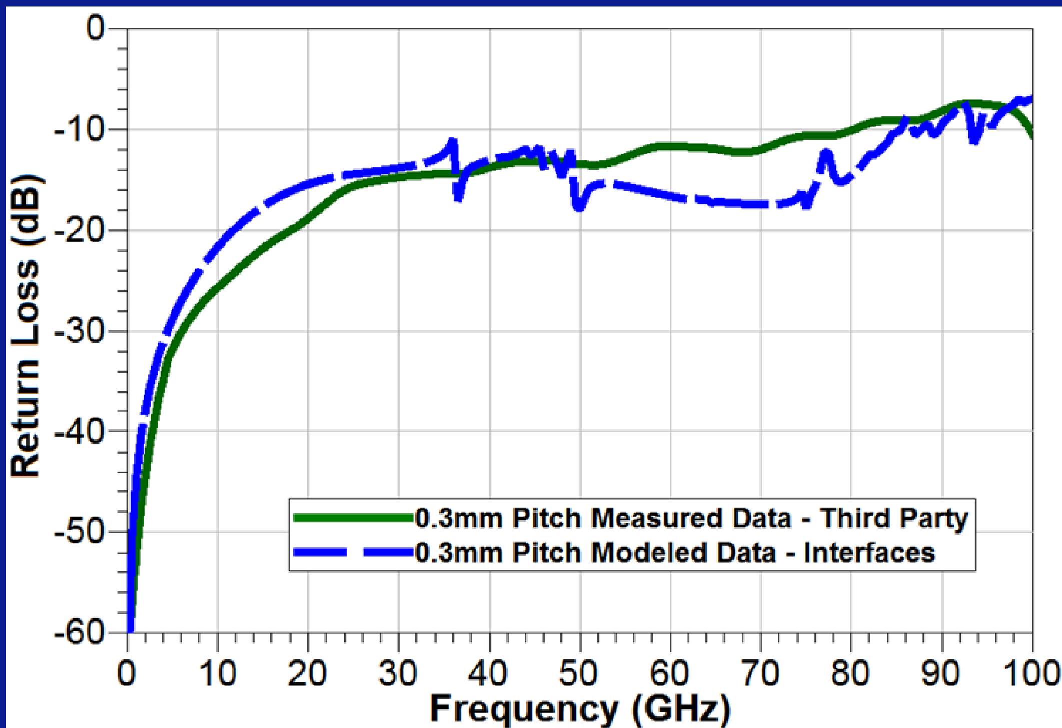
0.3mm Pitch BGA Device Contactor Measured vs. Improved Final Modeled Data – S_{21}



- Simulated with probes similar to measured test setup
- No right angle device and board connections
- (lt. Green) Modeled with tested material properties to 80 GHz
- (lt. Green) S – Parameter convergence half normal model

S-parameter convergence 4X better than previous slide. Lower Convergence -> better accuracy -> longer solve time

0.3mm Pitch BGA Device Contactor Measured vs. Modeled Data – S_{11}



- Simulated with probes similar to measured test setup
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Higher Frequency differences due to material properties changing for non-metal materials

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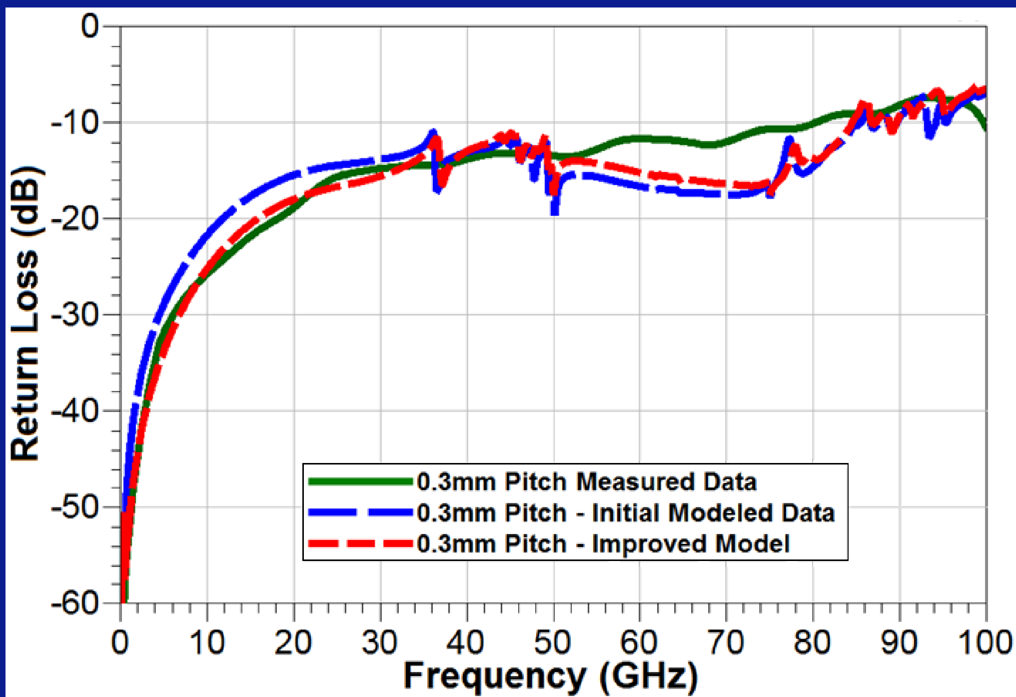

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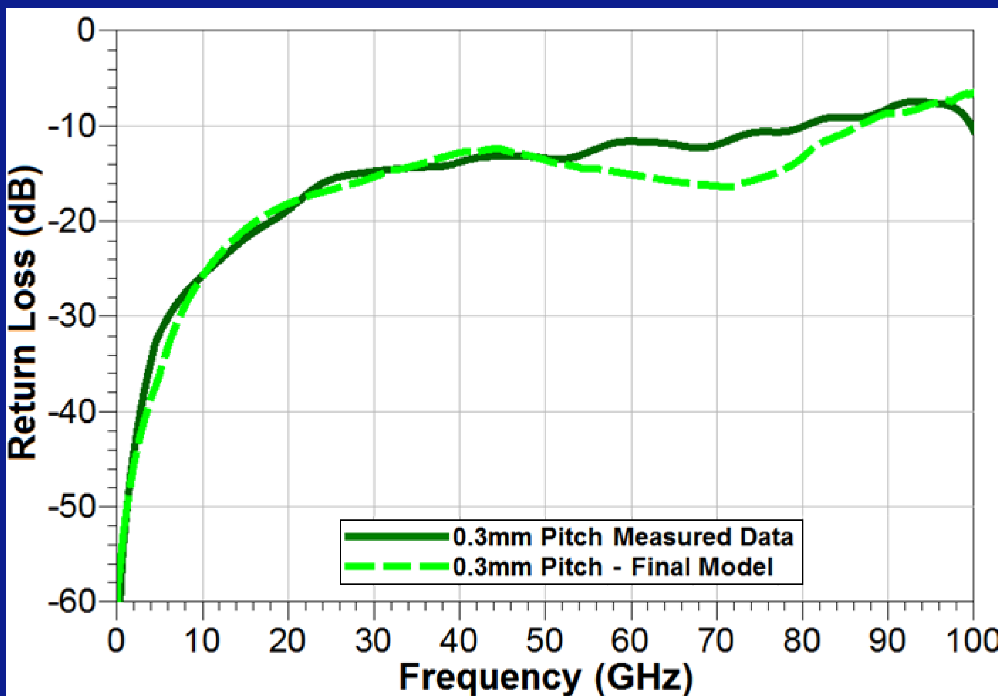

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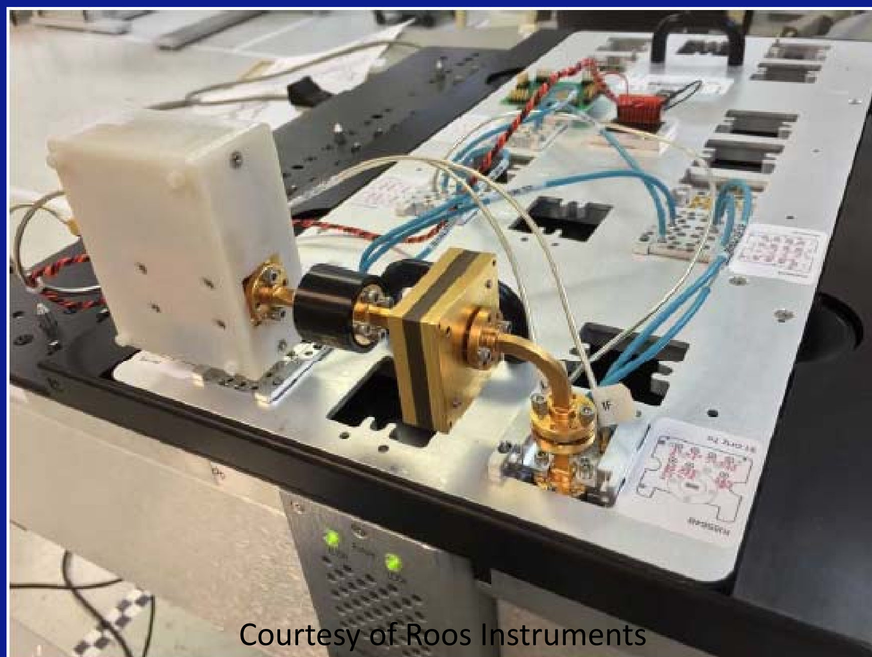
Compliant Waveguide Design Comparison of Different Compressions – S_{11}

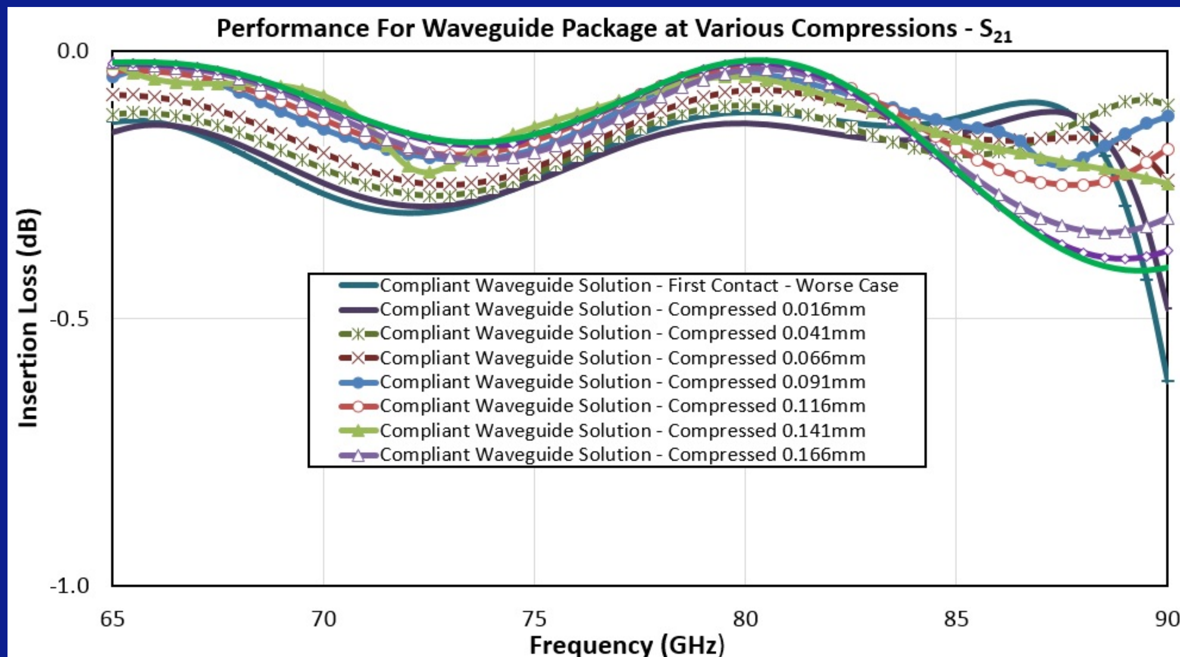

Courtesy of Roos Instruments

Test Procedure

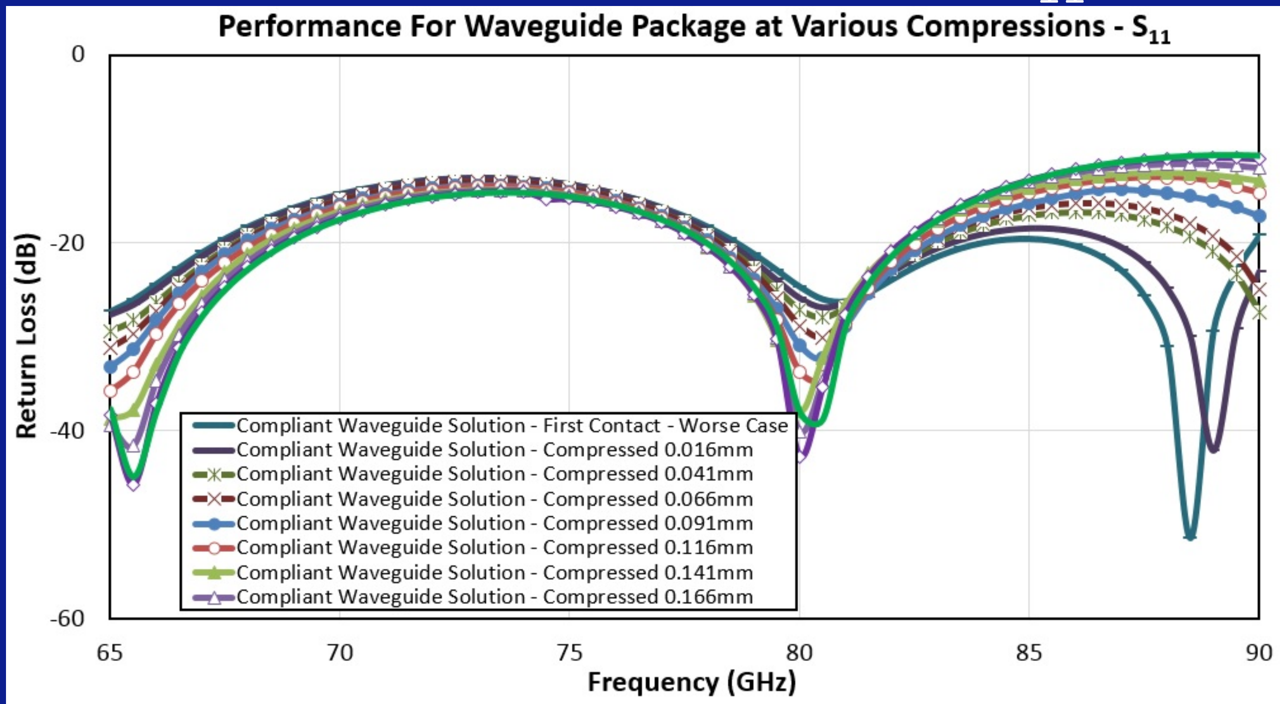
- **Measured Setup**
- **Two assemblies inserted into system**
- **Tested assemblies back-to-back**
- **Used standard waveguide flange dimensions**

Calibrating Measurement path extremely important to getting accurate results

Compliant Waveguide Design Comparison of Different Compressions – S_{21}



Compliant Waveguide Design Comparison of Different Compressions – S_{11}



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Things That Affect Accuracy of Simulation

- Material Dielectric Constant (ε_r) and Loss Tangent are not accurate over Frequency
- Frequency dependent material properties should predict results for different technologies and configurations if they are accurate
- Mechanical accuracy of model
- Making sure simulation is mechanically correct and model reflects configuration of what is actually built (Tolerancing)
- Determining S-parameter convergence to balance accuracy with model run time
- Configuration of device (pitch, location of GNDs, load board, etc.)

Conclusion

- Simulating exact configuration of device predicts measured results better
- The higher the frequency and complexity of system the more simulation is needed
- More accurate models lead to modeled results predicting measured results
- Most non-metal materials used in contactors have electrical properties (ε_r and loss tangent) measured at a low frequency – many of these properties vary over frequency (Need to model the frequency dependency of materials)
- Making sure simulation is mechanically correct and material properties over frequency are accurate leads to more accurate simulation results