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Ground Inductance Modeling of Test Contactor

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TestConX

Mesa, Arizona ● May 2-5th, 2021

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Agenda

- Why is ground inductance important?
- Devices that are Susceptible to Ground Inductance in Test System
- How to simulate ground inductance in contactor
- Back of envelope ground inductance calculation
- Comparison of SIG-GND-SIG and GND-SIG-GND in passive coupler
- Examples of ground inductance effect on device performance
- Methods to improve grounding (Device, Contactor, Board)
- Conclusion

Why is Ground Inductance Important?

- Ground inductance acts as a low impedance return path
- Lower inductance allows decoupling of high frequency currents
- Important for digital signals with fast BIT rates
- Minimizes EMI/RFI emissions
- Lower ground Inductance is needed to support higher frequency devices and devices with increased gain

Devices that are Susceptible to Ground Inductance in Test System

- Power Amplifiers
- High Gain Amplifiers (Above 20 dB)
- Filters Surface Acoustic Wave (SAW) and Bulk Acoustic Wave (BAW)
- High Frequency Designs – Above 3 GHz
- High Speed Digital Designs – Above 10 GBits/sec
- High Gain Devices (above 20 dB)
- Voltage sensitive devices – (i.e. High BIT count DACs and ADCs - Voltage per BIT small)

Capacitances and Inductances in Test System

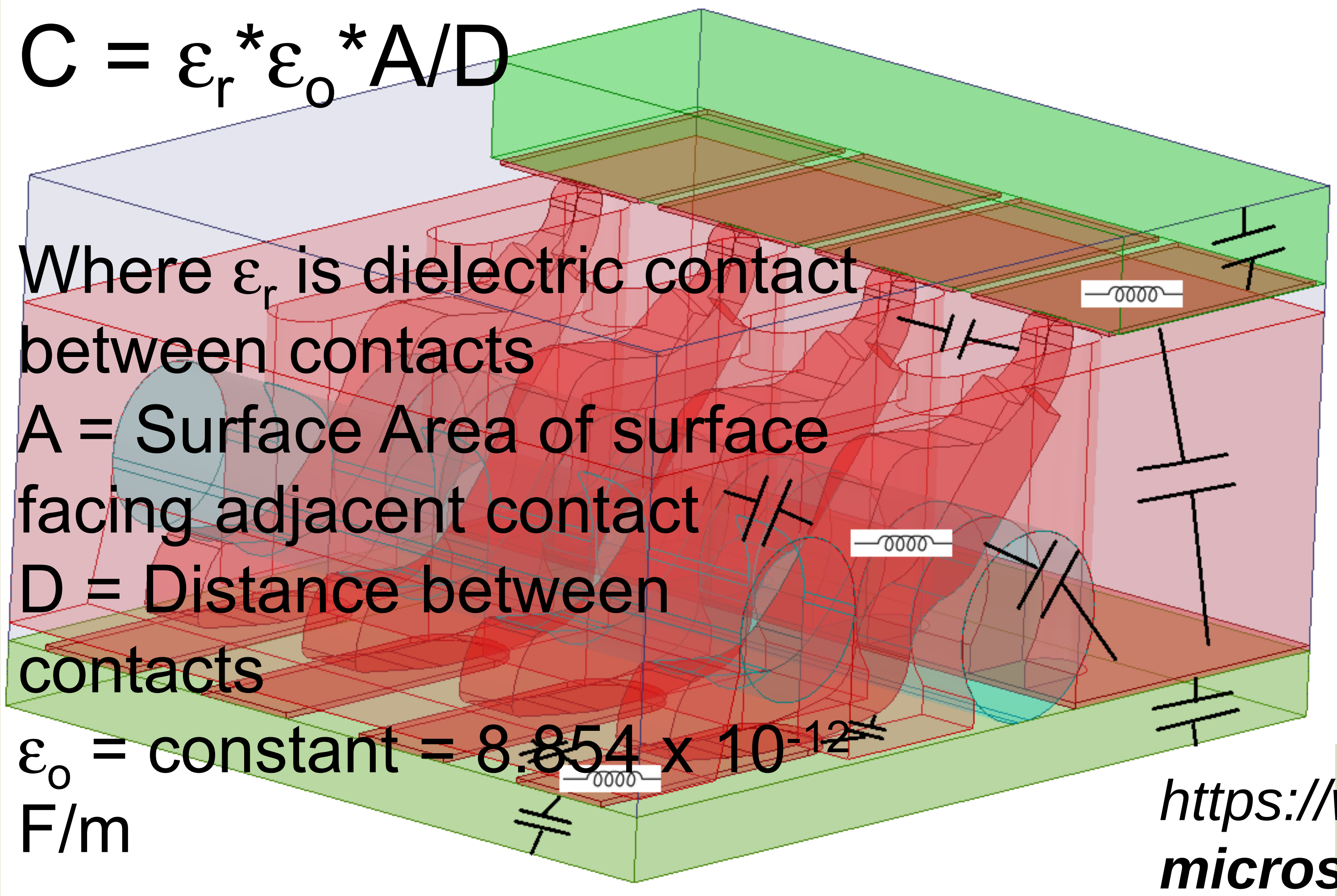
$C = \varepsilon_r * \varepsilon_o * A/D$

Where ε_r is dielectric contact between contacts

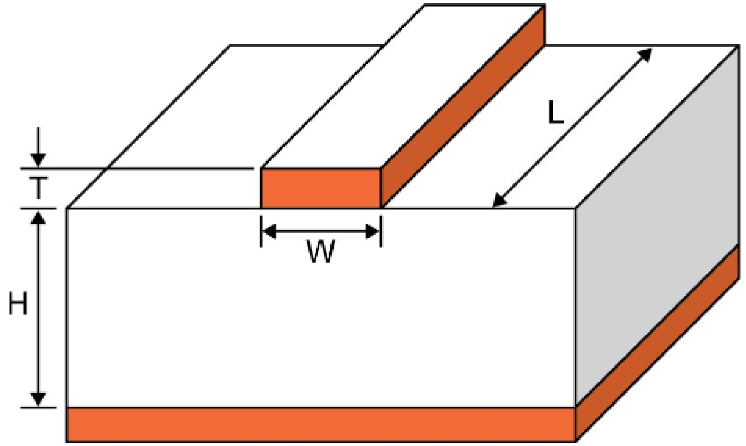
A = Surface Area of surface facing adjacent contact

D = Distance between contacts

ε_o = constant = 8.854×10^{-12} F/m



Inductance of Trace Formula



Equation

$$L_{ms} = 0.00508L\left[ln\left(\frac{2L}{W+H}\right) + 0.5 + 0.2235\frac{(W+H)}{L}\right]$$

where:

L_{ms} = inductance of the microstrip in microhenries (μH)

W = width of the strip in inches

L = length of the strip in inches

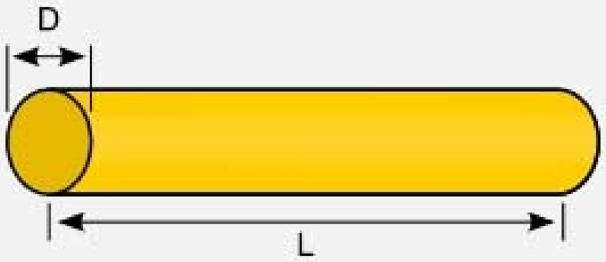
H = distance between the strip and the ground plane

*https://**www.allaboutcircuits.com**/tools/**microstrip-inductance-calculator***

Self Inductance of a Wire (Contact)

Wire Self Inductance Calculator

Wire Self Inductance Calculator



Inputs

Diameter of Wire	D	3	mm
Length of Wire	L	1	mm

Outputs

Wire Self Inductance: *0.114 nH*

	Length	
Wire Diameter	**2mm**	**1mm**
0.1mm	1.46 nH	0.598 nH
0.2mm	1.20 nH	0.469 nH
0.3mm	1.04 nH	0.397 nH
0.4mm	0.937 nH	0.349 nH
0.5mm	0.857 nH	0.313 nH
1.0mm	0.626 nH	0.215 nH
2.0mm	0.430 nH	0.143 nH
3.0mm	0.339 nH	0.114 nH

Converting rectangular area to effective diameter is a good predictor of inductance

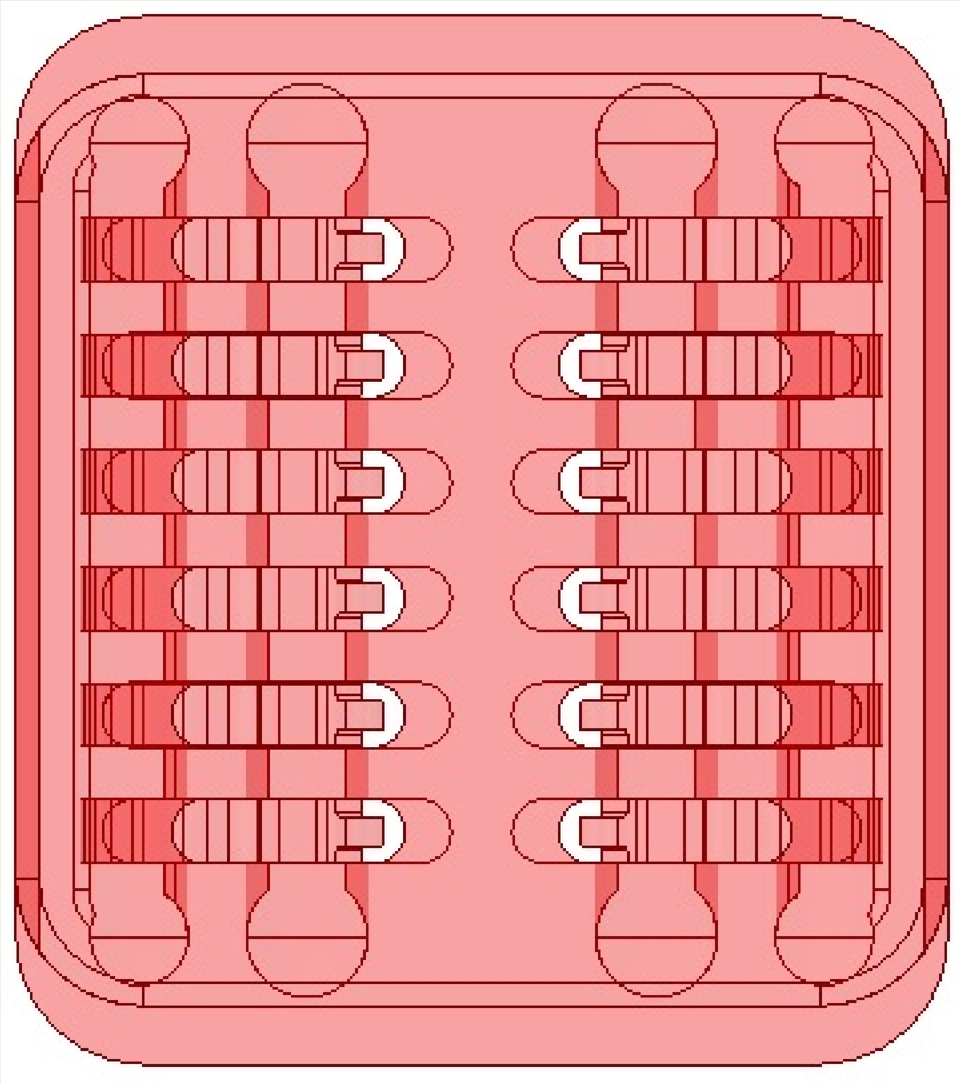
*Courtesy of https://www.eeweb.com/tools/**wire**-self-**inductance-calculator***

Back of Envelope Ground Calculation

Ground Inductance is insert inductance in parallel with contact inductance = $L_{insert} * L_{contacts} / (L_{insert} + L_{contacts})$

- $L_{contacts}$ = Inductance of Contact / # Contacts in parallel where
  - Inductance of Contact = $L_{self} + L_{mutual}$ where
    - L_{mutual} = 0 in metal housing or metal insert
    - L_{self} = from contact testing
- L_{insert} Inductance of Insert found using on-line calculator by searching "wire inductance" where
  - wire diameter = convert insert surface area from device interface to board into an equivalent wire diameter
  - wire length = height of insert

Back of Envelope Inductance Calculation



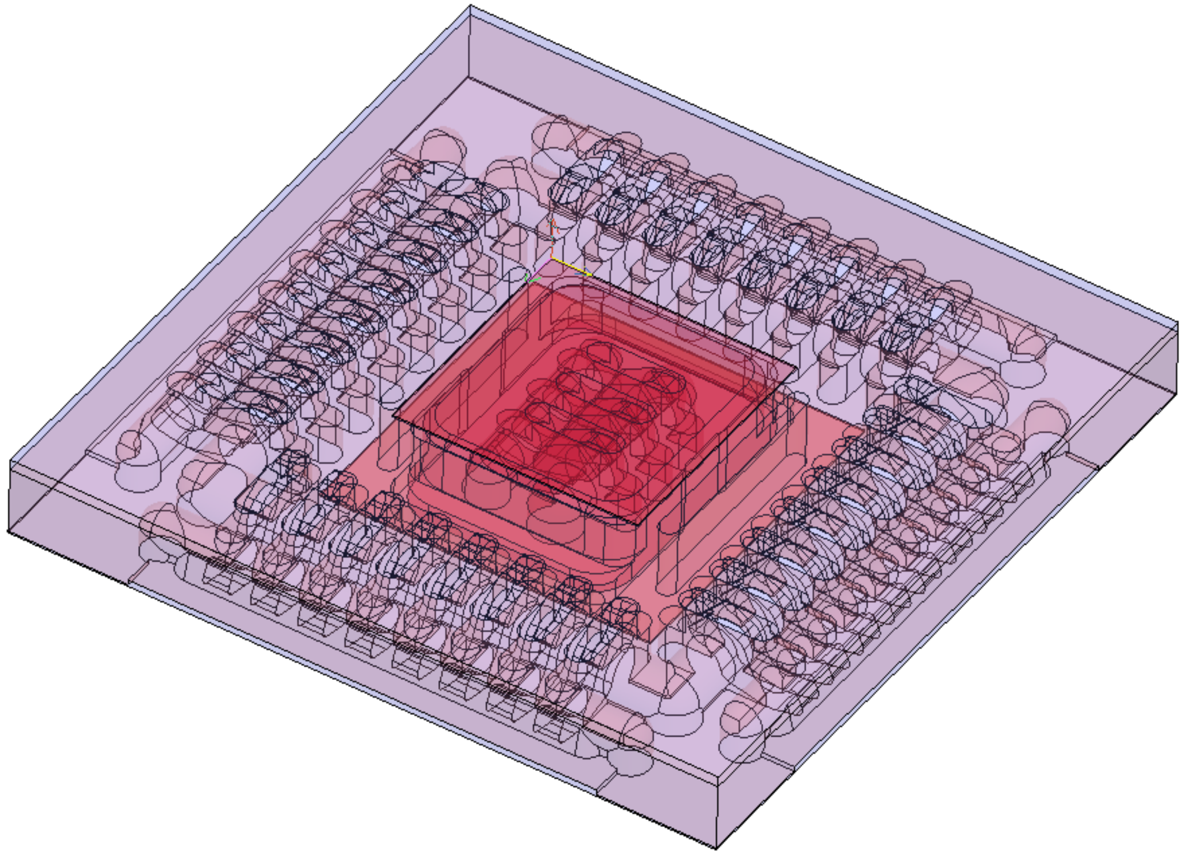
- Contact Self Inductance = 0.233 nH*
- Contact Mutual Inductance = 0.143 nH*
- Number of Contacts in Insert = 12
- Insert Height = 0.763mm

$L_{contacts}$ = Inductance of 12 contacts in ground
$L_{contacts}$ = Self inductance / # of contacts
$L_{contacts}$ = 0.233nH / 12
$L_{contacts}$ = 0.0194nH

Total surface area = 54.4mm^2; $d^2 = 54.4 * 4 / \pi$
With equivalent wire diameter of 8.322 mm for insert and height L_{insert} = 0.0521 nH
$L_{gnd} = L_{insert} * L_{contacts} / (L_{insert} + L_{contacts})$ = 0.014 nH

* Data from third party test report

ROL100 5mm x 5mm Copper Insert Model - Isometric View



Capacitive Structures

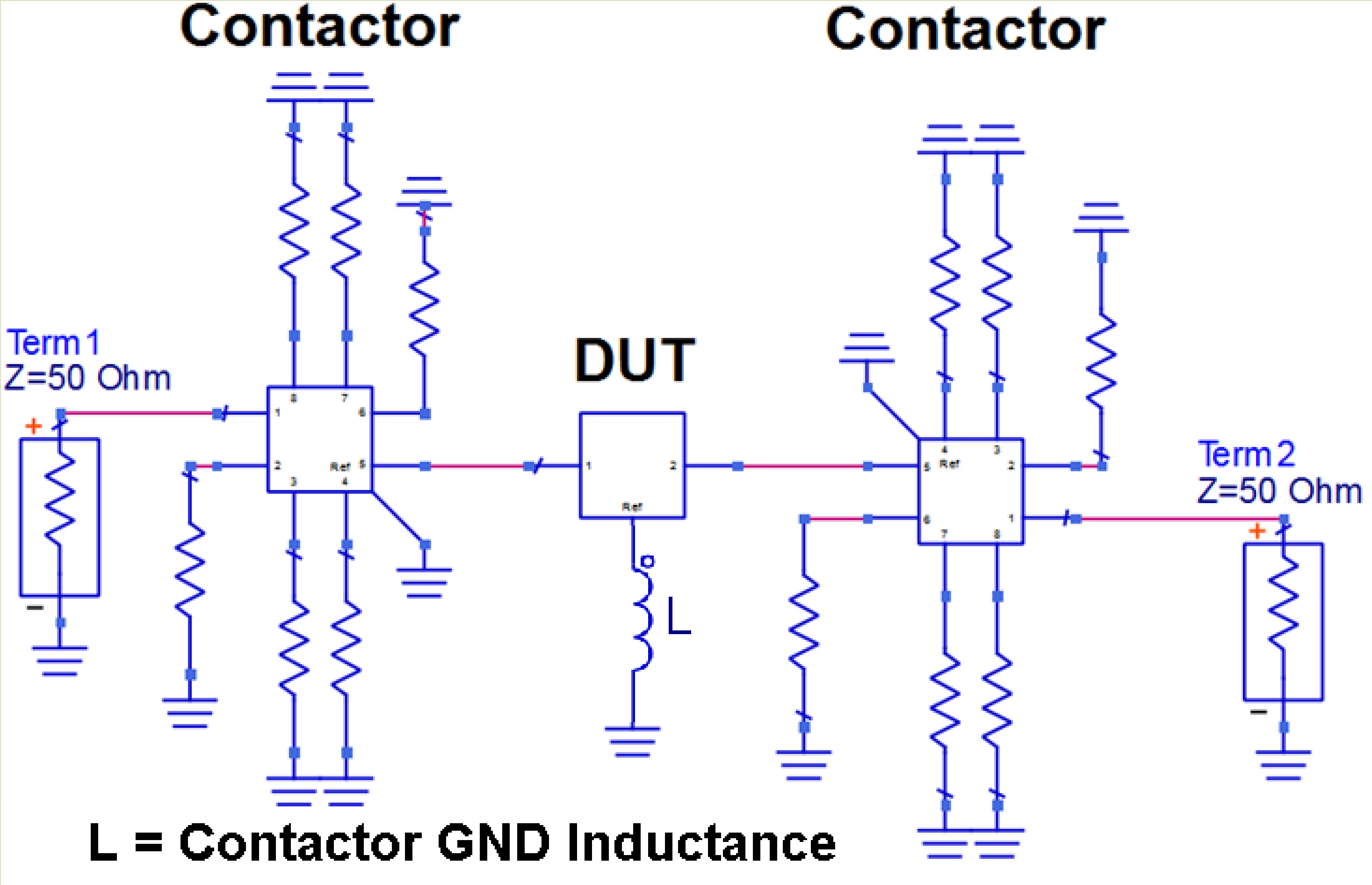
- Device pads to load board pads
- Insert to peripheral contacts
- Insert contacts to ground pad
- Device pads to insert pad

Capacitance between two plates:

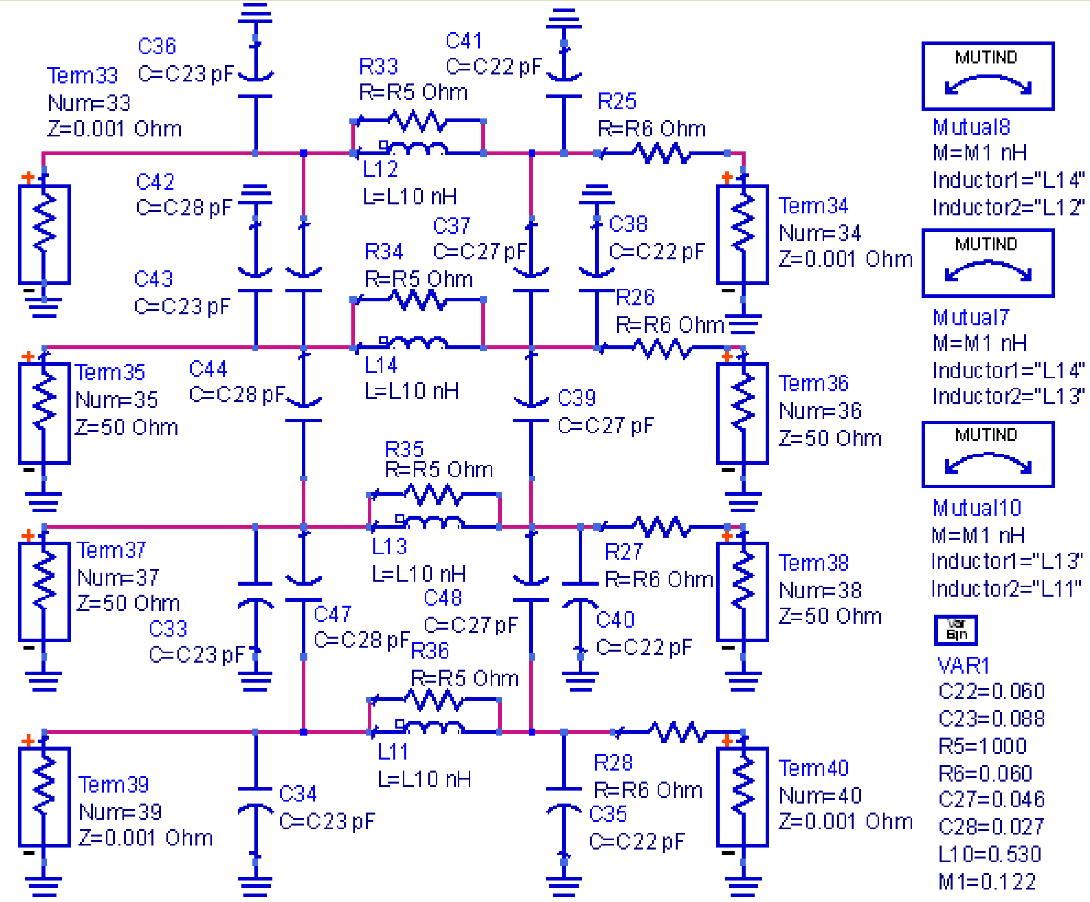
$$C = \varepsilon_r \varepsilon_o A/D$$

A = surface area, D = distance between surfaces

ADS Model of Device in Test Contactor Showing Ground Inductance Effects of Contactor



0.5mm Pitch ROL100A Contact Equivalent Circuit Model



Load Board Side

Device Side

Equivalent Circuit Model

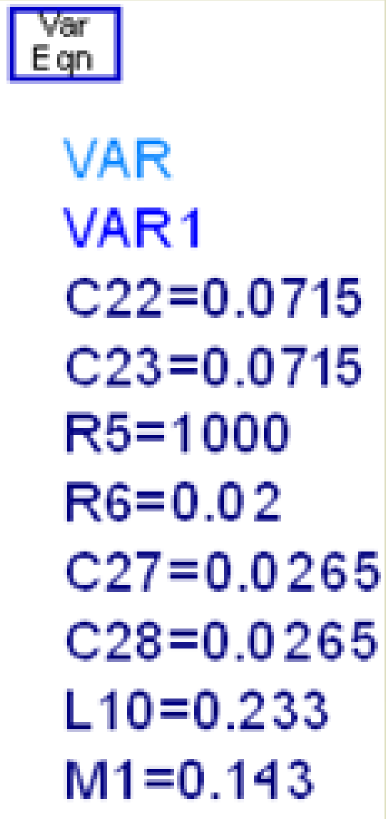
L_{self} = 0.233nH

L_{mutual} = 0.143nH

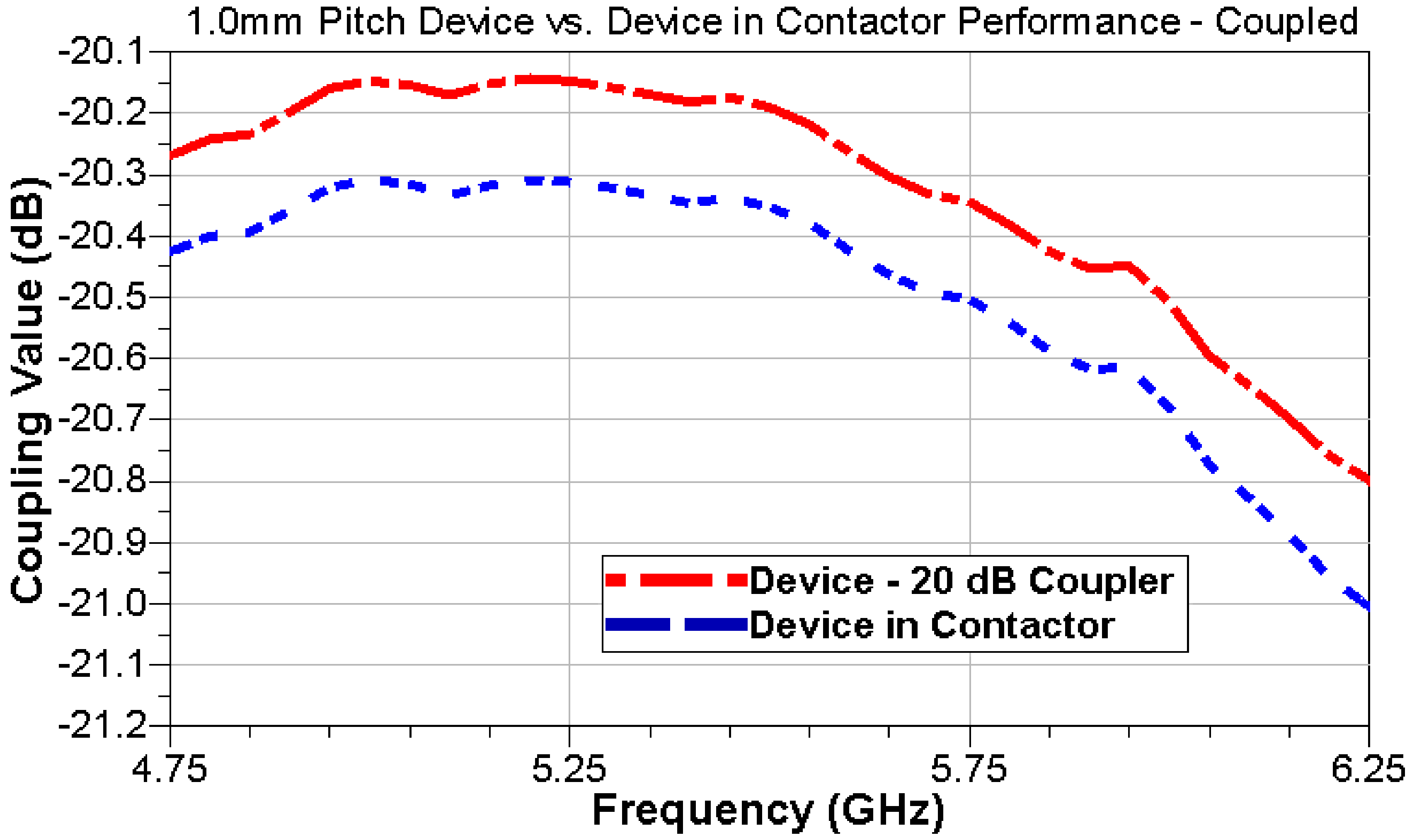
C_{gnd} = 0.153pF

C_{mutual} = 0.053pF

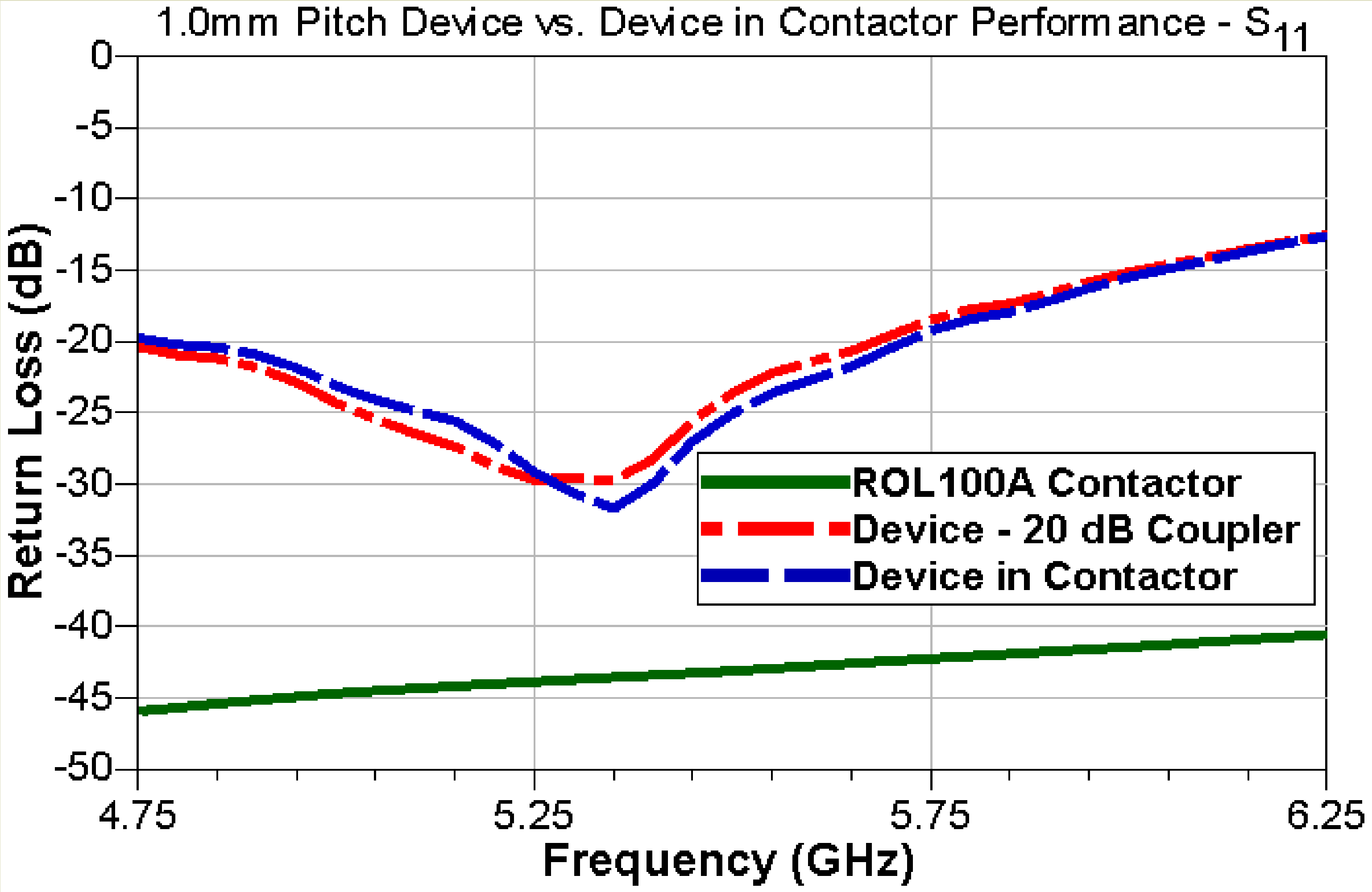
C_{res} = 0.02 Ohms



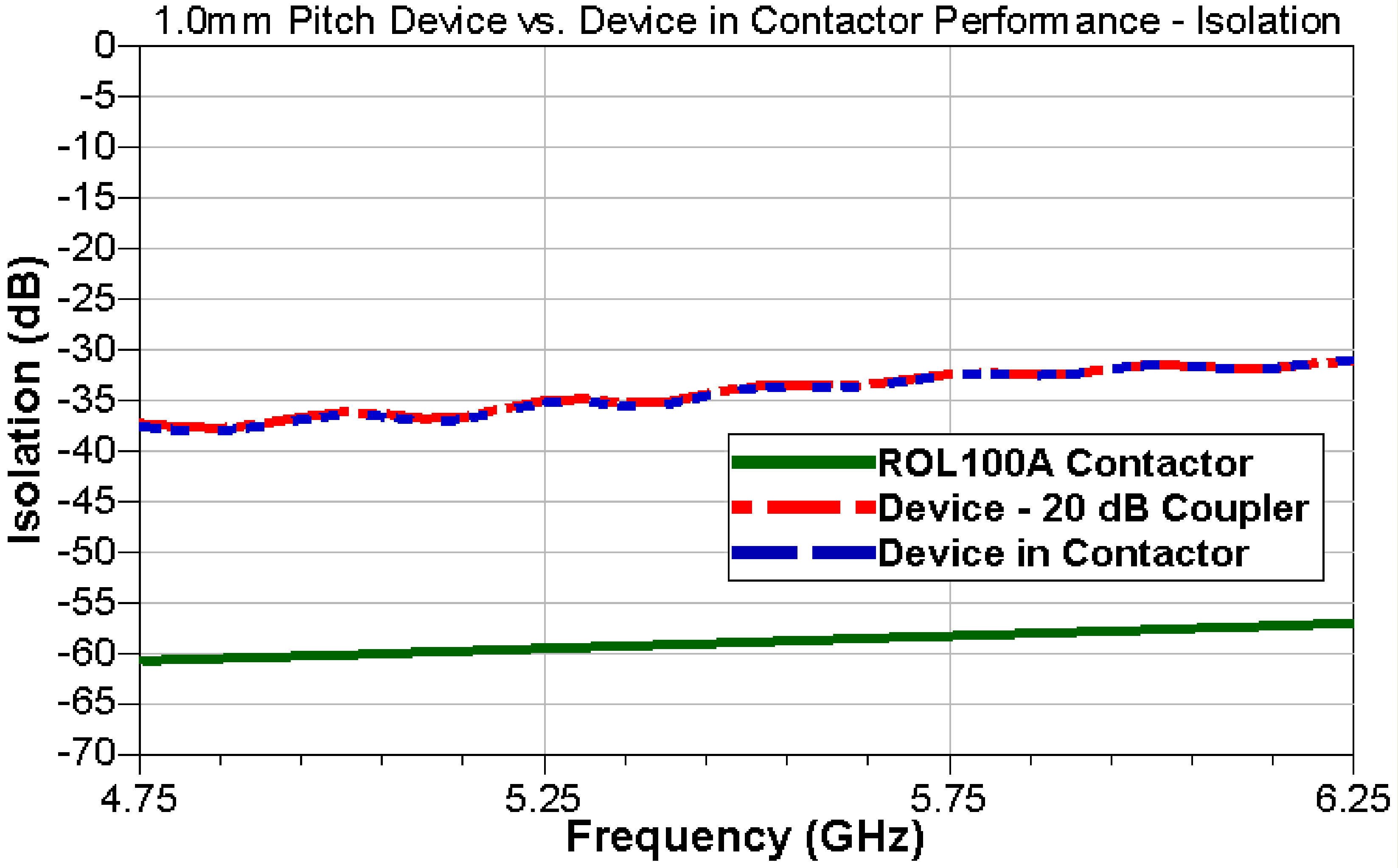
1.0mm Pitch GSG 20 dB Coupler With and W/O Contactor – Coupling - S_{21}



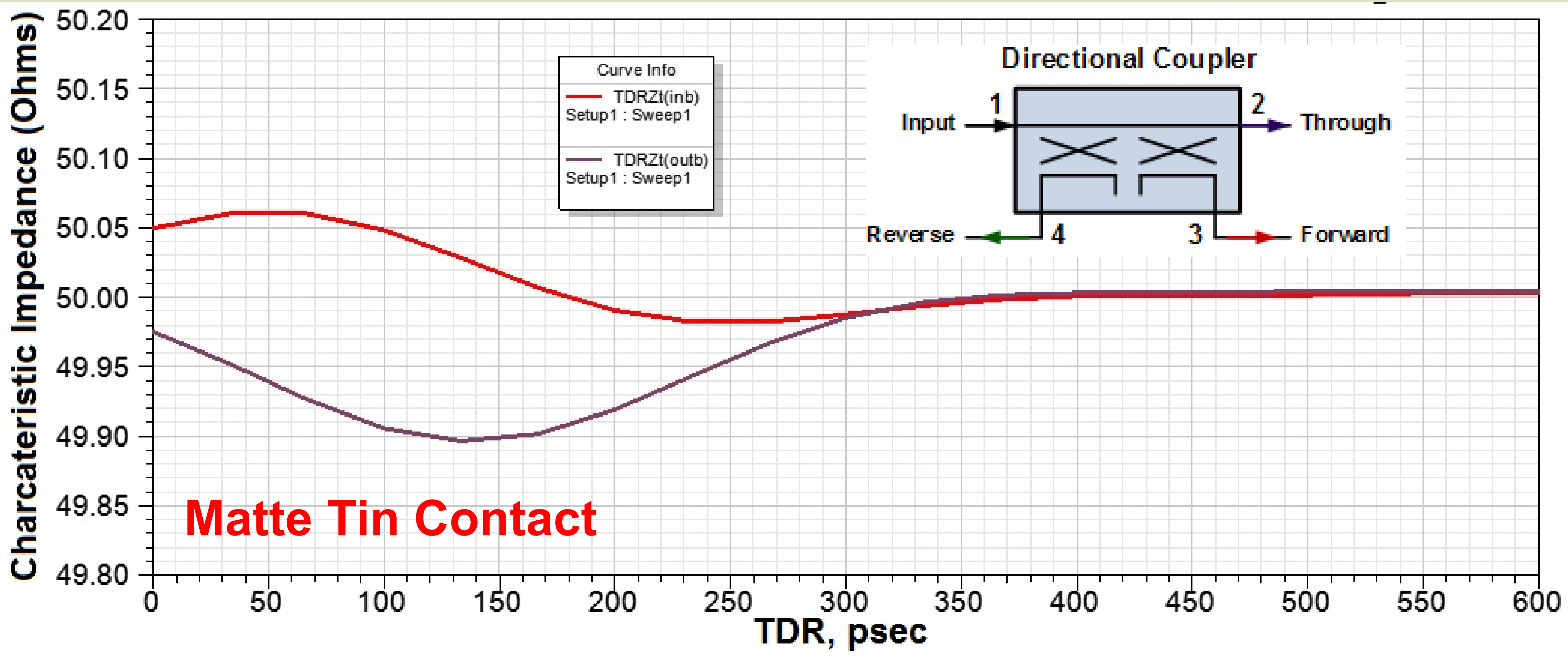
1.0mm Pitch GSG 20 dB Coupler With and W/O Contactor – S_{11}



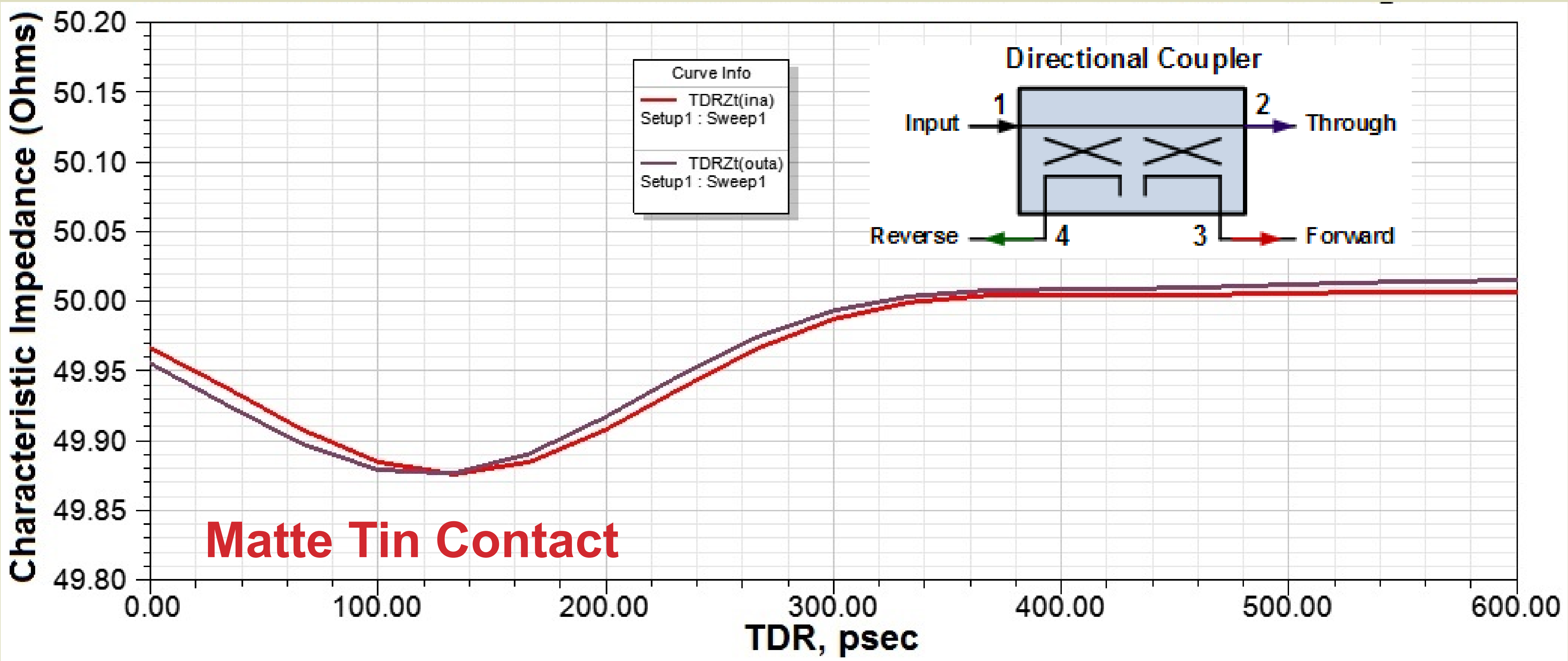
1.0mm Pitch GSG 20 dB Coupler With and W/O Contactor – Isolation - S_{41}



6 GHz Coupler Contactor – SGS Config. – TDR

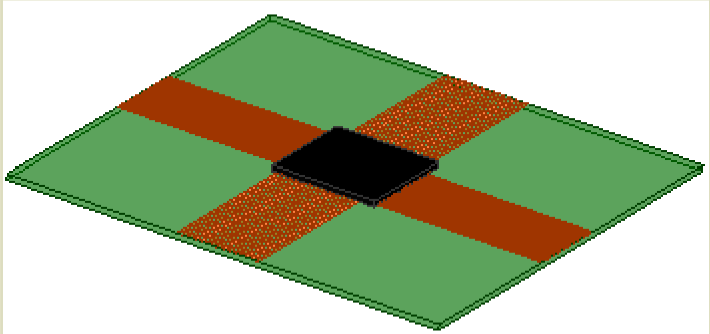


6 GHz Coupler Contactor – GSG Config. - TDR

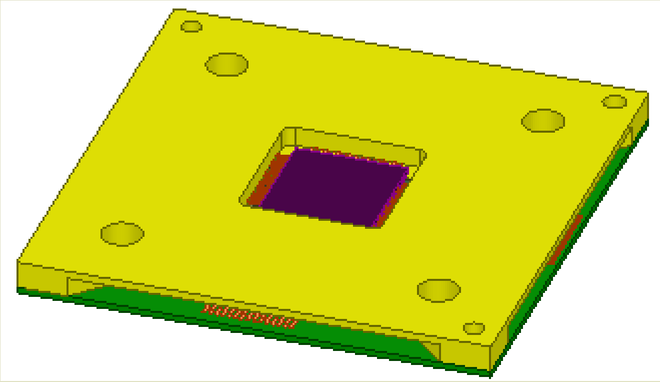


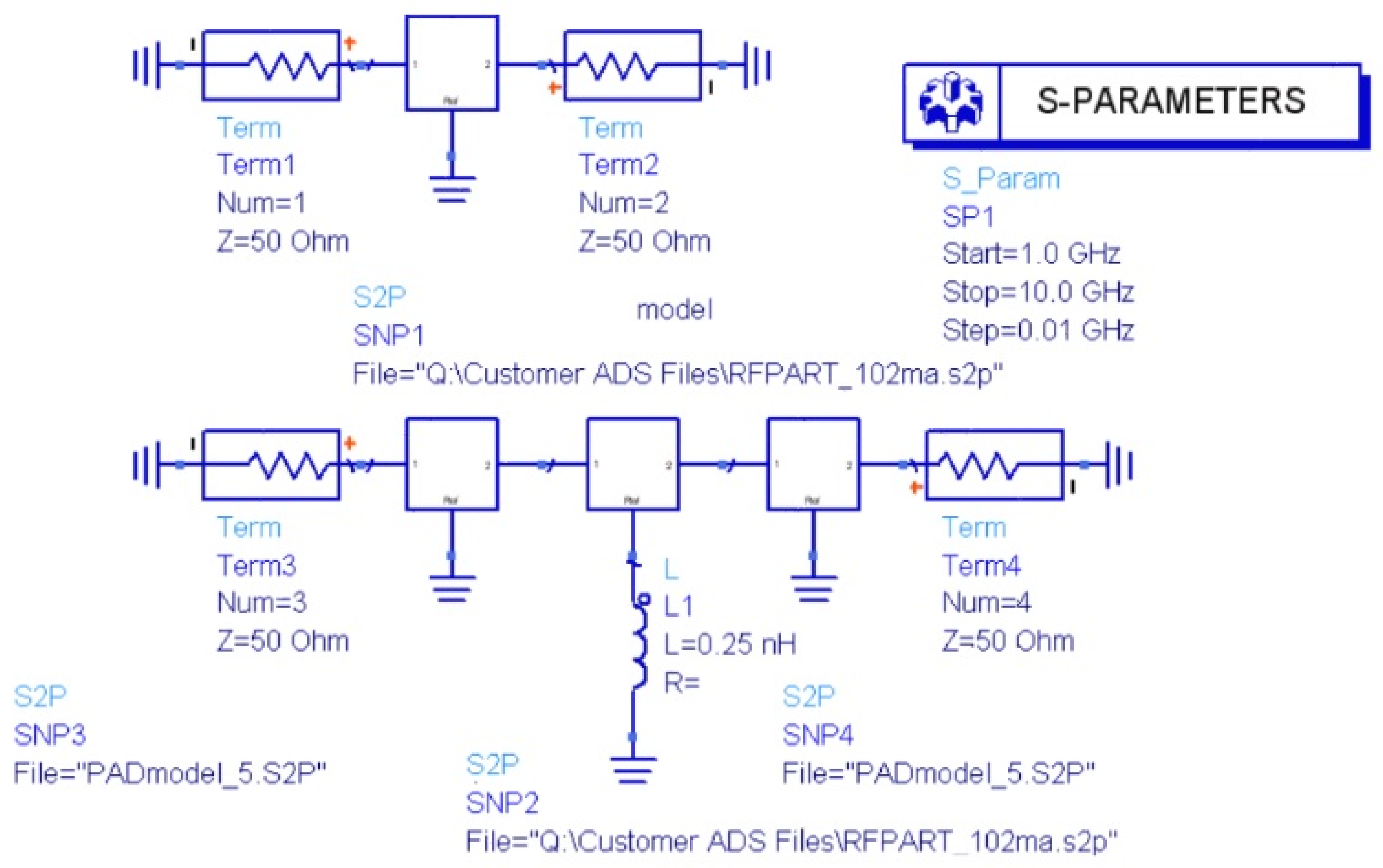
Ground in ADS Model for Determining Effects of Amplifier-to-Ground Inductance Paths

Solder to Board



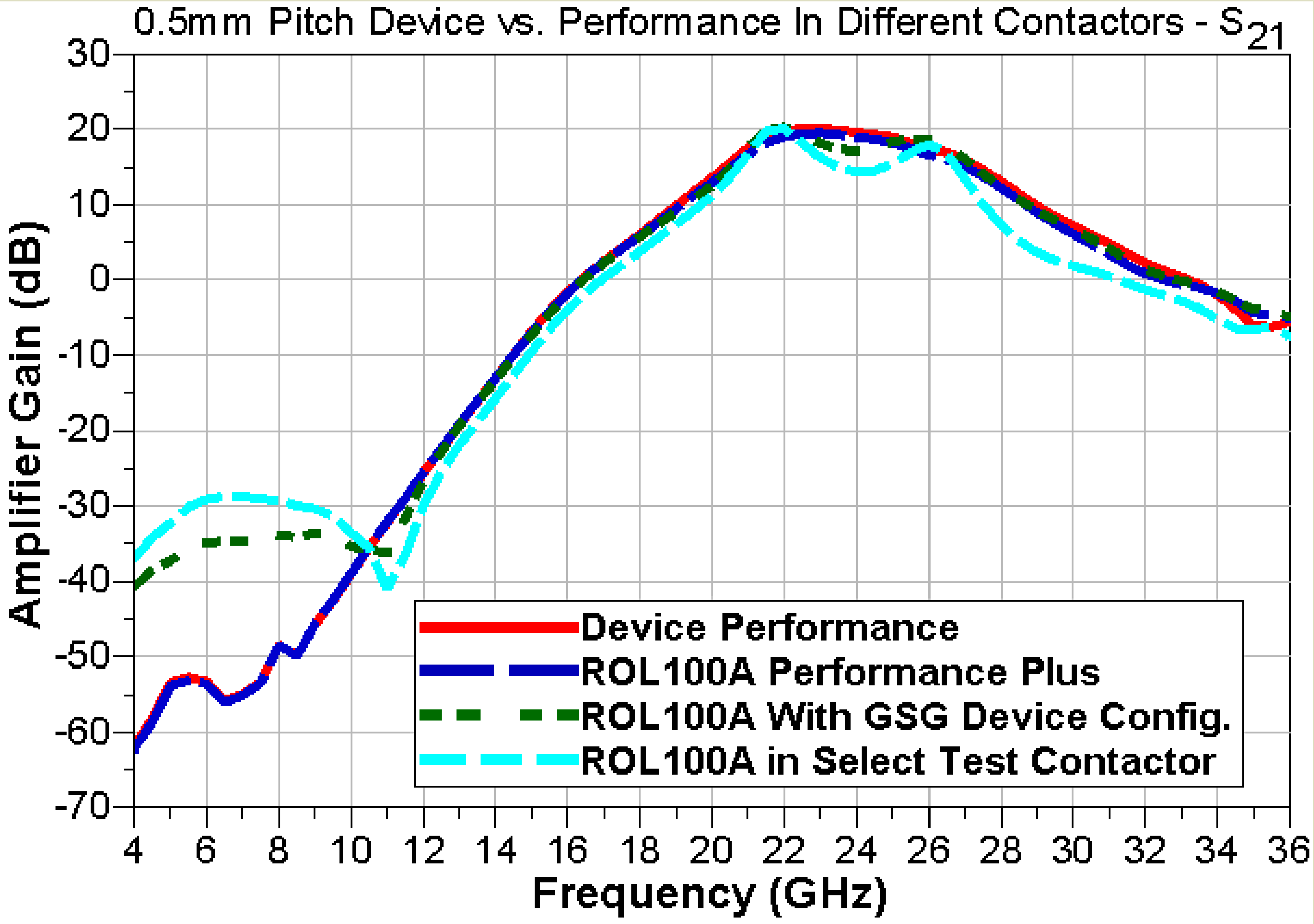
Device in Contactor



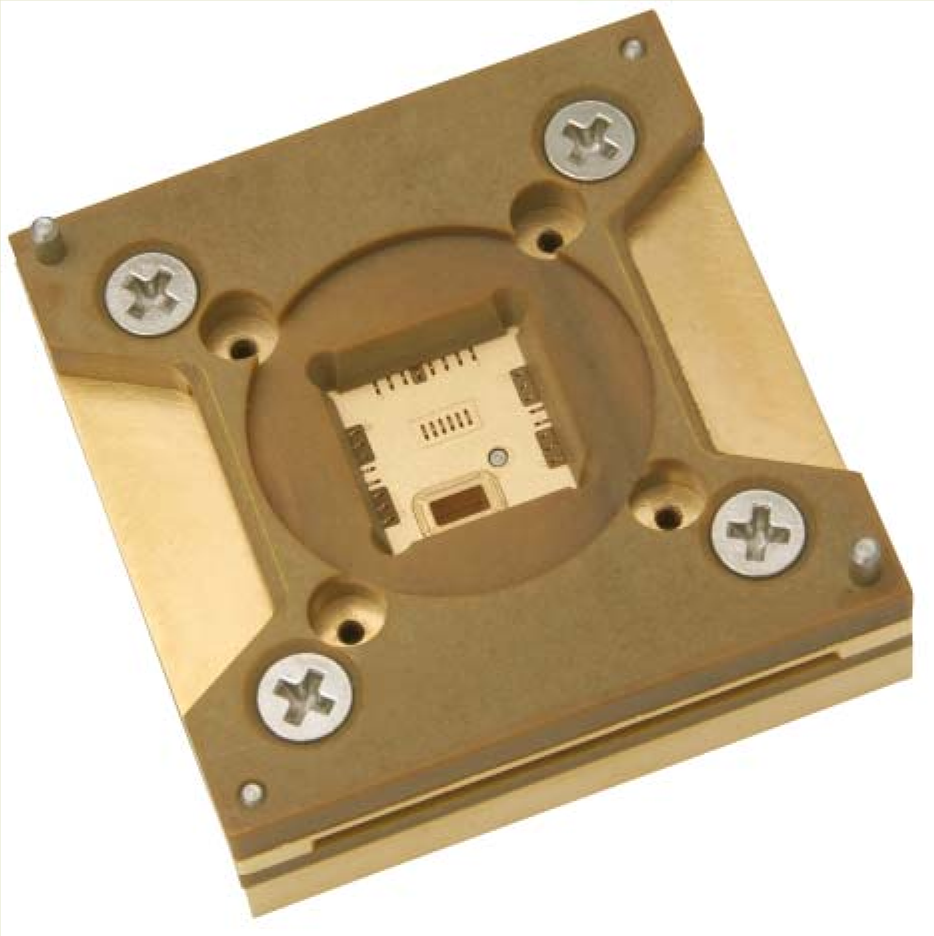


Basic model to determine contactor ground inductance affect on device

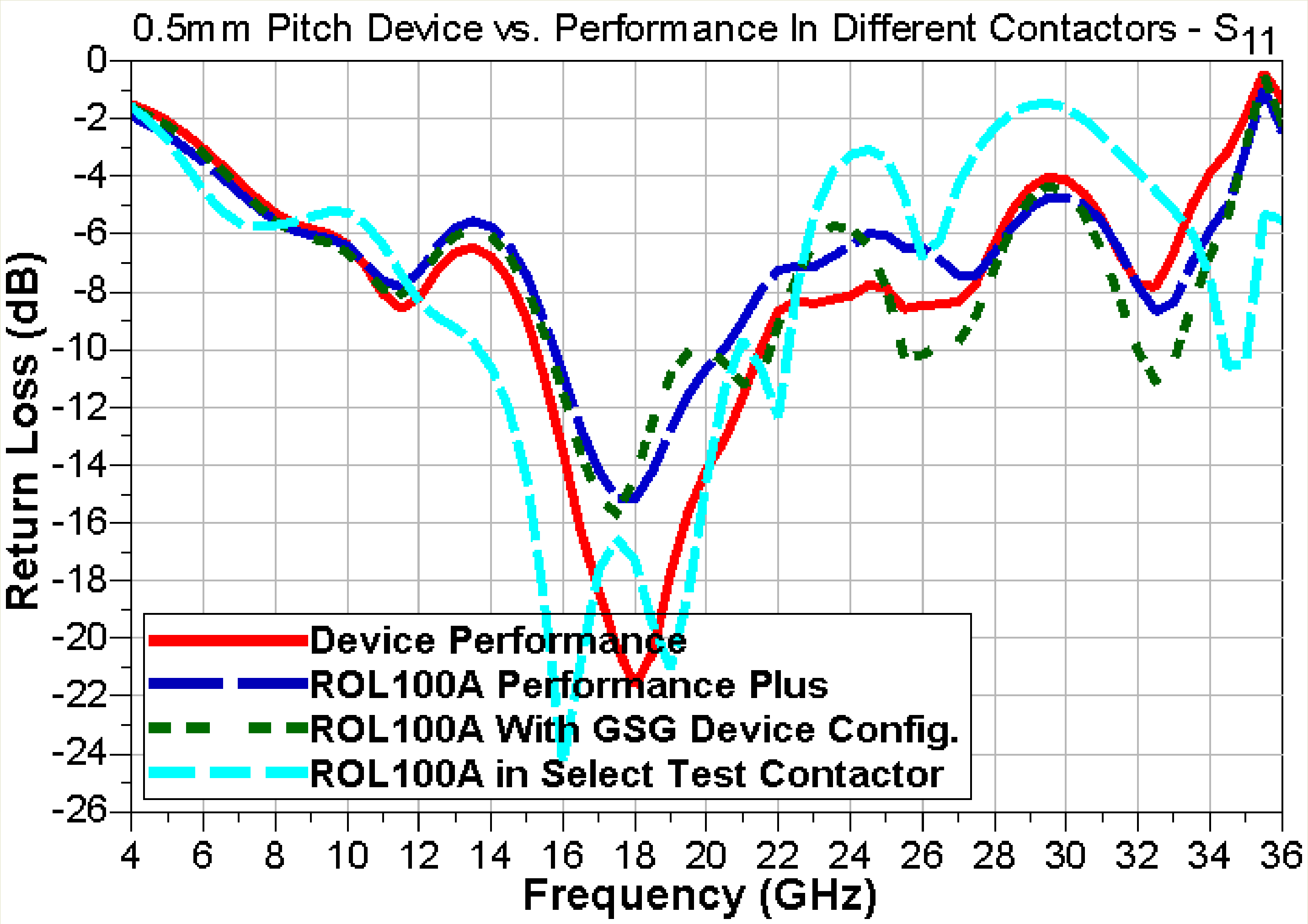
0.5mm Pitch Amplifier vs. Performance in Different ROL100A Contactors – Amplifier Gain



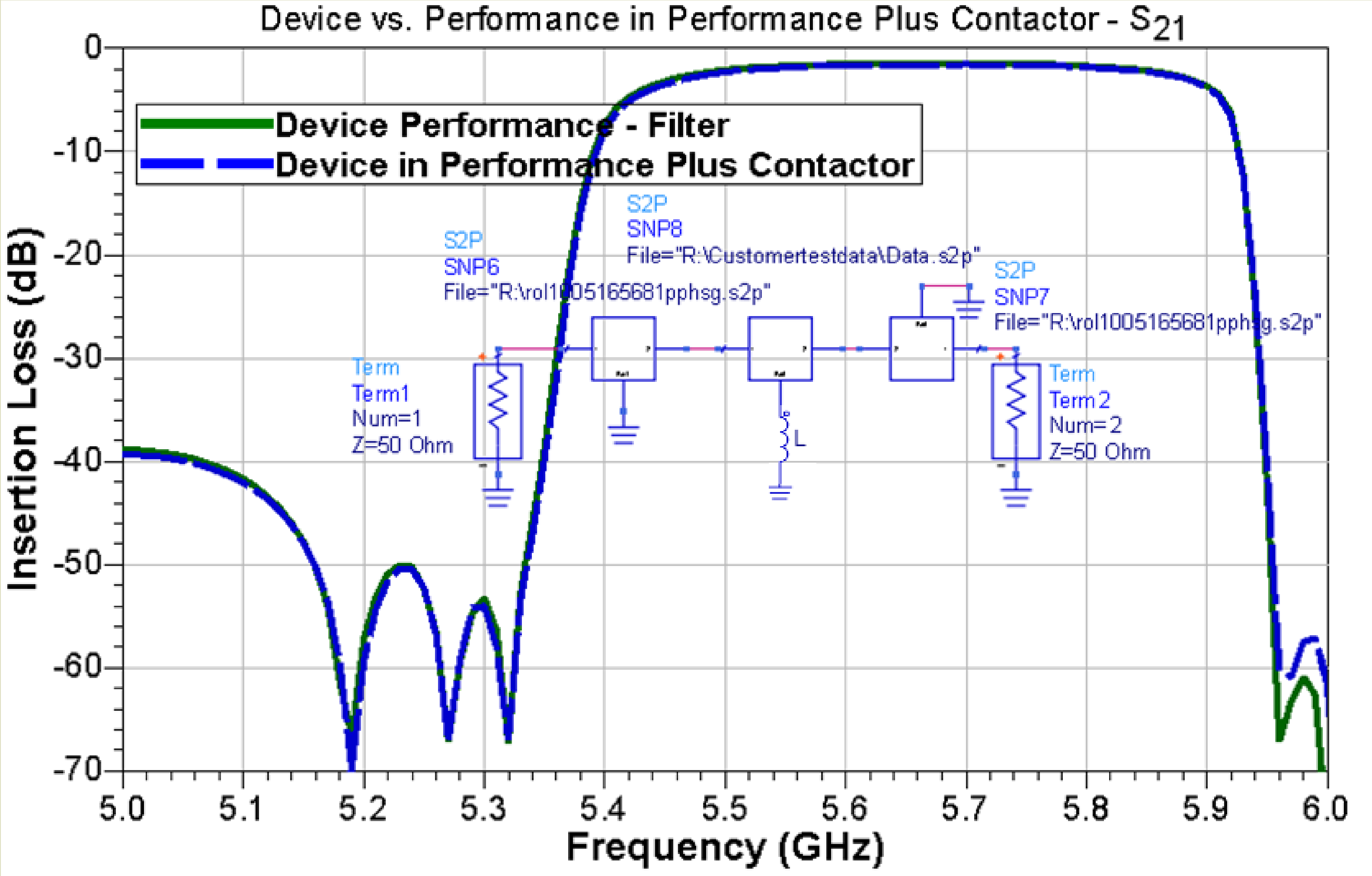
Performance Plus Housing



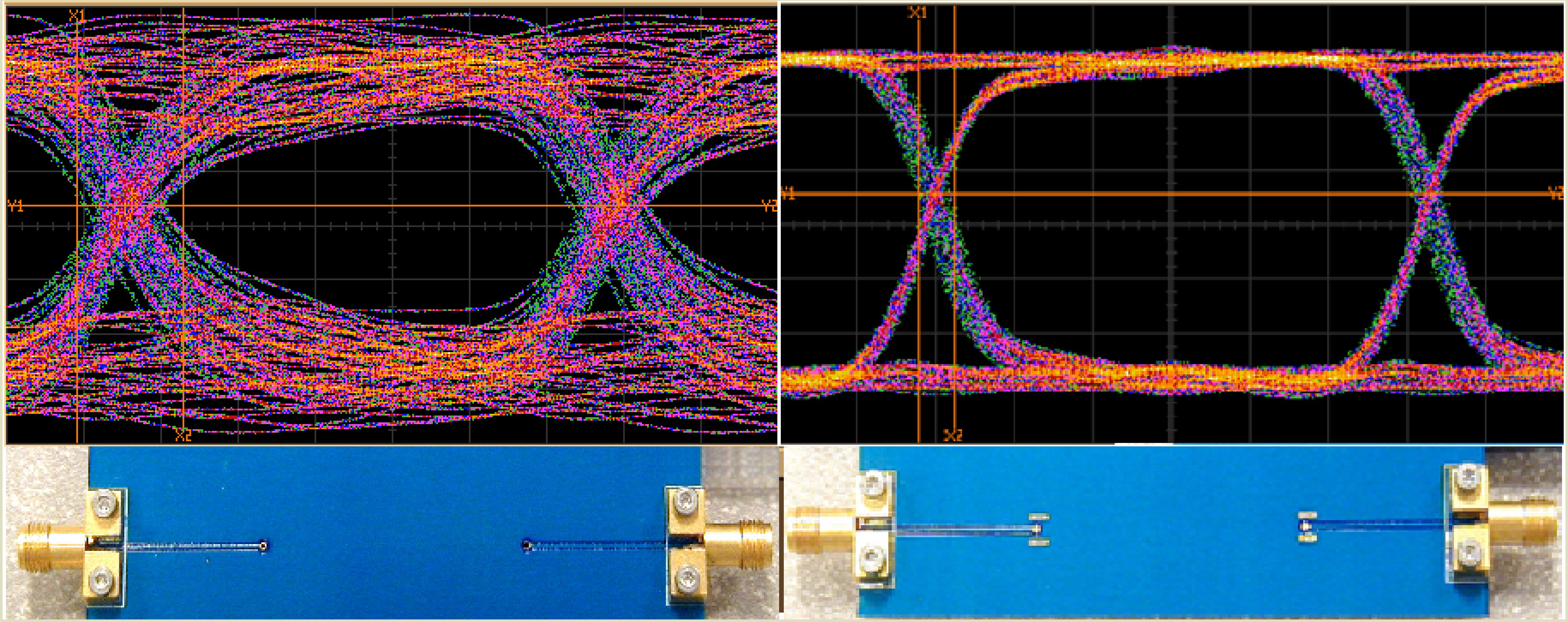
0.5mm Pitch Amplifier vs. Performance in Different ROL100A Contactors – S_{11}



Filter Performance in Performance Plus Contactor vs. Device Performance – S_{21}

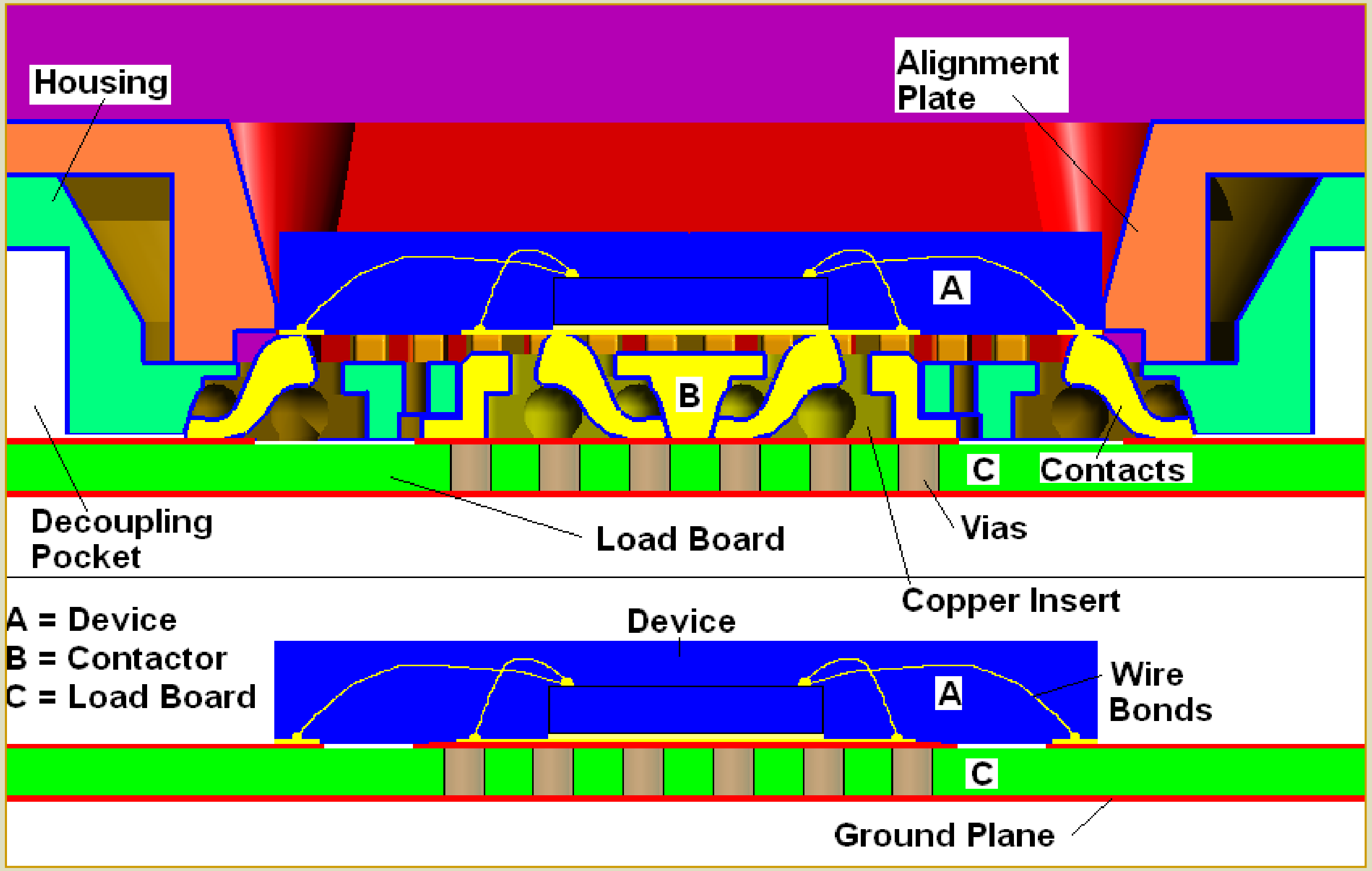


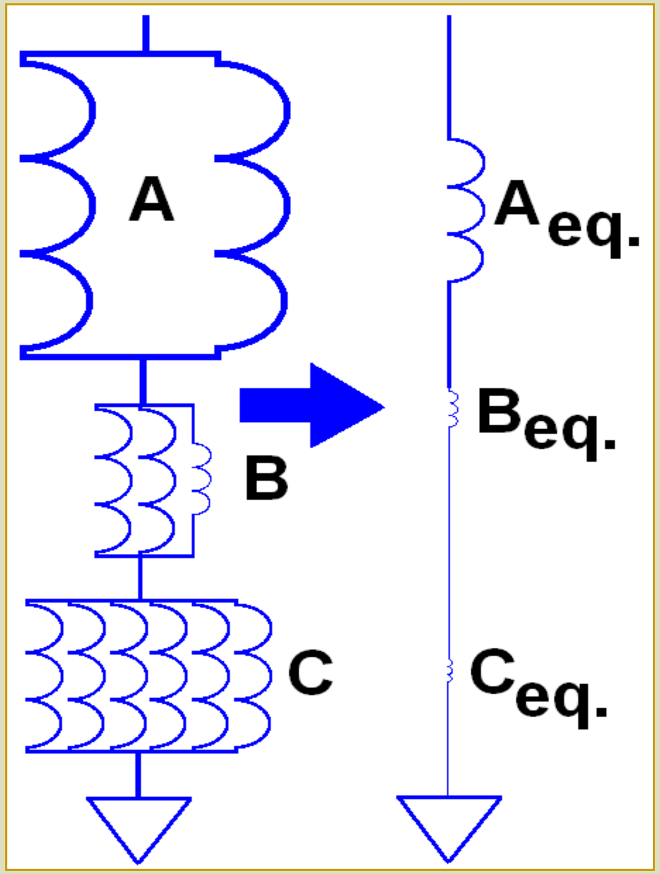
Sample of Affects of Good Digital Grounding



Vias attach ground planes and significantly improves signal integrity

Ground Inductance Paths





The ground inductance the device can handle is dependent on inductance of package, contact solution, and load board.

Improving Grounding in Package

- More wire bonds or ground connections to ground plane
- Shorter ground paths
- Flip chip to reduce path lengths
- Thin substrates with vias to ground pad
- More ground on peripheral, especially around high frequency or clock signals
- Differential signals (GND-SIG-SIG-GND) vs. single ended (GND-SIG-GND)

Improving Ground in Contactor

- Increase size of ground scheme (Optimal Metal Housing)
- Increase number of connections to ground plane (i.e. more contacts in parallel)
- Reduce height of housing to shorten ground path and shorter contacts (ROL100 better than ROL200)
- Since RF signals route on face of surface increase surface area from device ground to board ground

Improving Ground in Contactor - Continued

- Thicker contacts better than thinner contacts, but more thinner contacts better than thicker contacts
- Make contact to device where package ground connections are to reduce path to board ground plane
- Make sure insert and contacts are making good contact to ground pad on board

Improving Grounding on Load Board

- Decrease substrate thickness to ground plane
- Increase number of vias to ground plane
- Add via fences between critical signals
- Make sure vias are not under contact interfaces
- Via placement to ground plane should be close to contact interfaces to reduce ground paths
- Route ground planes between traces

Conclusion

- Decreasing ground inductance of system makes it easier to test device
- Grounds closer to RF signals provide a shorter return path
- Grounds close to RF signals tend to lower impedance of RF signals
- Ground inductance becomes more important the higher the frequency of device or the more gain the device exhibits
- If device is designed with no ground margin it becomes harder to test device accurately
- Calculation of ground inductance in this paper is just an estimate that typically overstates the real ground inductance by a small amount but this provides a margin for different test conditions

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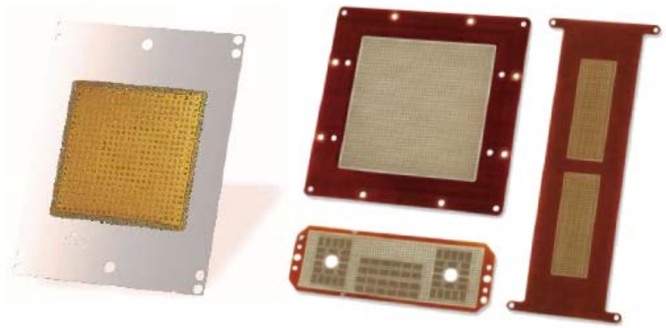
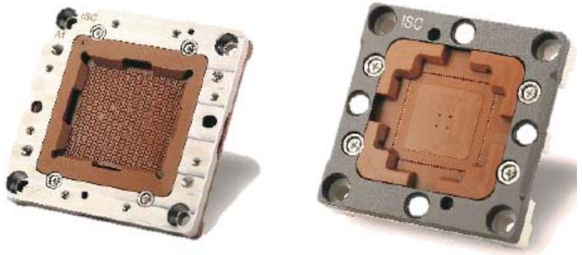


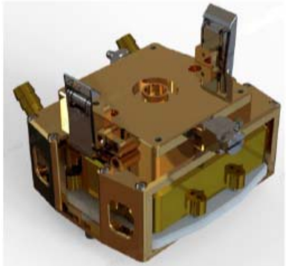
POGO SOCKET SOLUTIONS

- Excellent gap control & long lifespan
- High bandwidth & low contact resistance



THERMAL CONTROL UNIT

- Extreme active temperature control
- Safety auto shut-down temperature monitoring of the device & thermal control unit
- Full FEA analysis & Price competitiveness



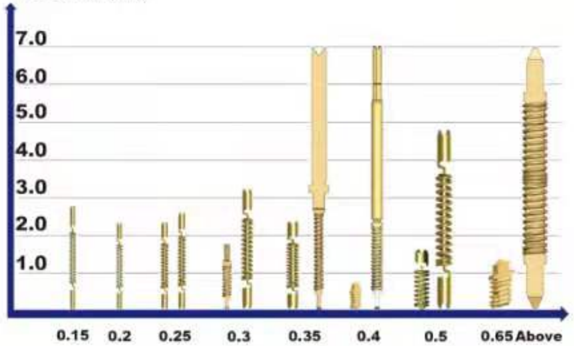
BURN-IN SOLUTIONS

- Direct inserting on the board without soldering
- Higher performance BIB solution

CONTACT ISC CO., LTD	ISC HQ Seong-nam, Korea	ISC International Silicon-valley, CA	**Tel**: +82-31-777-7675 / **Fax**: +82-31-777-7699 **Email:** sales@isc21.kr / **Web:** www.isc21.kr

The test probe for high signal integrity at extremely high speed test

Spring probe by stamping



250 kinds of spring probe pin

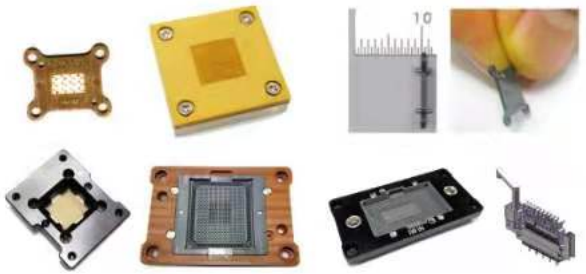
300 kinds of test socket (44,000 Pin count socket possible)

One piece spring probe

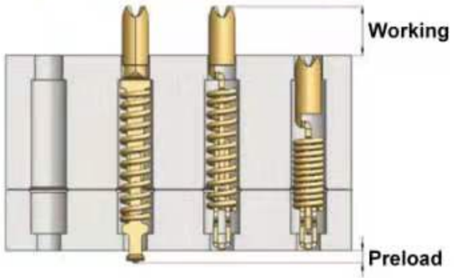
Three piece spring probe

High speed product → 0.63mm free length spring probe pin available

Finest Pitch → 0.15mm Pitch



Spring probe by stamping

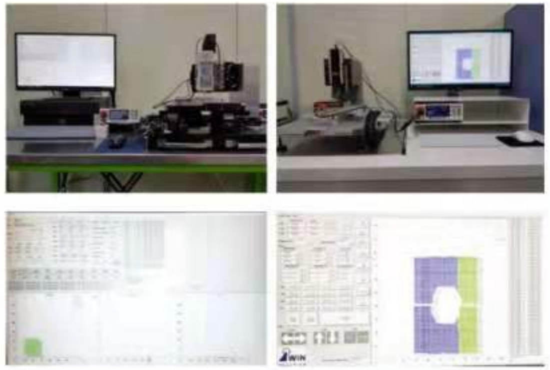


Patented

Pitch(mm)	Free Length(mm)	Current Carrying(Amps)
0.15/0.2/0.25	2.17~	0.5~
0.3	1.5~	1.5~
0.35	2.08~	1.8~
0.4	0.8~	2.5~
0.5	1.5~	3.0~
0.65	1.13~	9.0~
0.8	3.14~	3.0~

Automation

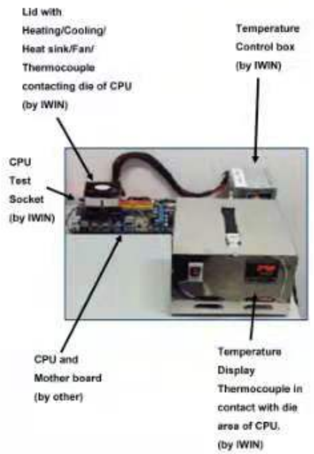
Pin assembly and Quality control



Top Figure: Socket CRES, Force, Stroke test
Bottom Figure: Data displayed

Top Figure: Socket CRES test
Bottom Figure: Data display 5,903 pins socket

Socket and Lid



Pin assembly

(Fully automated machines)

- Stamped piece parts attached to a reel fed into the assembly machine

- Assembled pins can be attached to a reel, or, supply in separate for socket assembly.

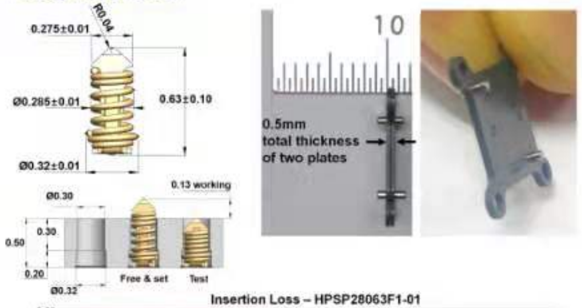
Spring probe pins for High speed

Extremely short spring probes by stamping

One piece spring probe

Three piece spring probe

Design approach



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High Performance Probe solution