Understanding Specs to Better Simulate Solder-to-Board Performance

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2012 BiTS Workshop
March 4 - 7, 2012

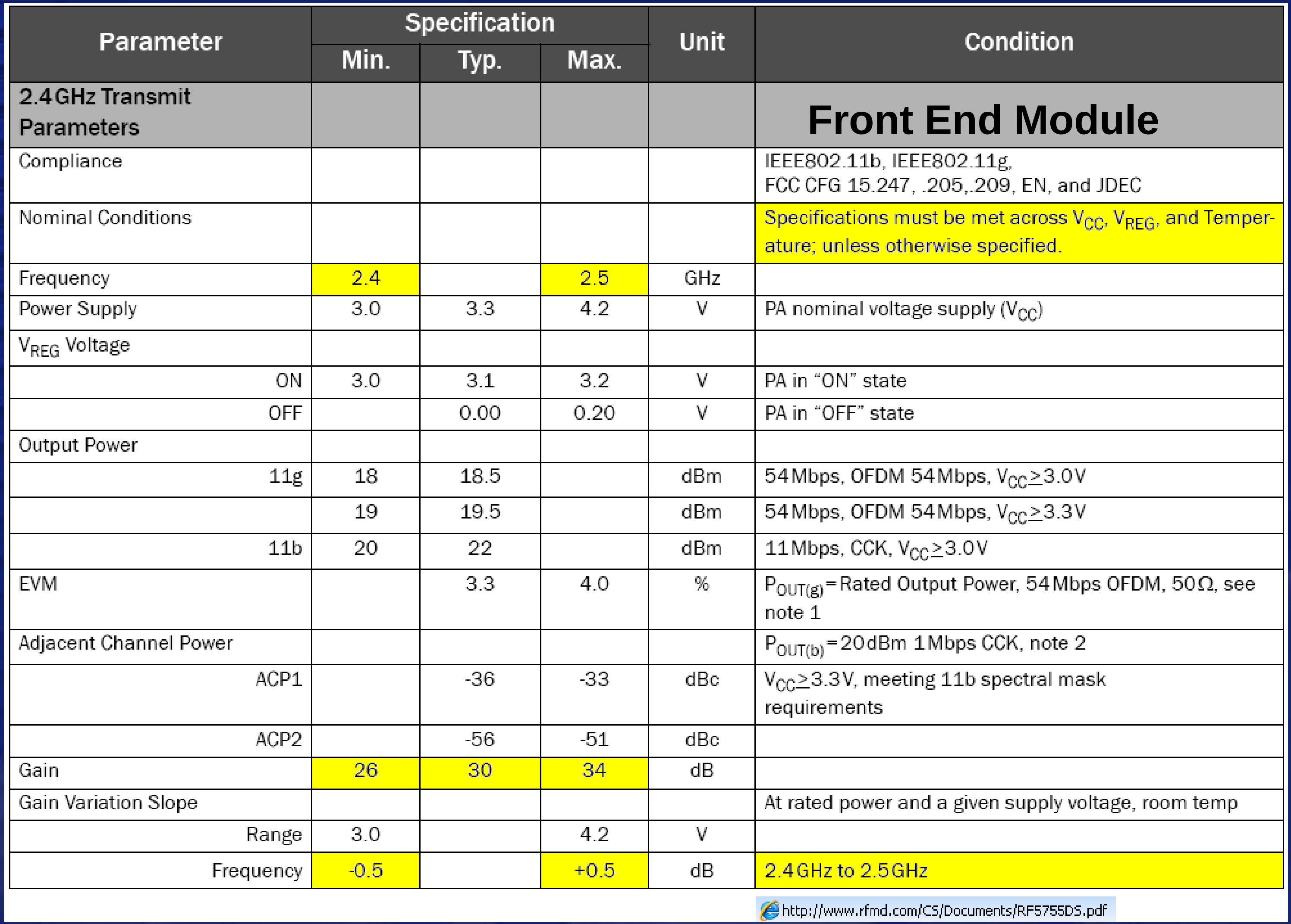
Agenda

- Changes in Contactor performance
  - Inductance effects
  - Thermal or current carrying effects
  - Cres and repeatability
- Importance of design margins
- Effects of device configurations
- Mechanical considerations
- Test methods
- Conclusion

Causes of Changes in Performance

- **Variations in signal path**
- **Variations in insertion position**
- **Variations in oxides and debris buildup**
- **Variations in package platings**
- **Variations in I/O pitch**
- **Variations in location of ground or return path**
- **Variations in insertion forces and speed**

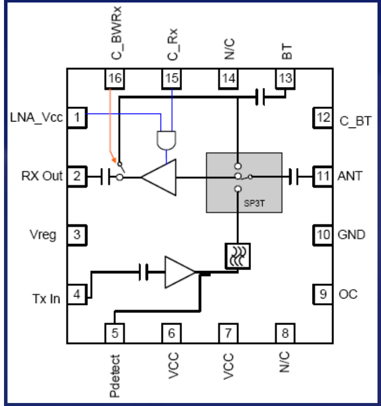
High Gain Amplifier Spec Sheet



Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
2.4GHz Transmit Parameters					**Front End Module**
Compliance					IEEE802.11b, IEEE802.11g, FCC CFG 15.247, .205,.209, EN, and JDEC
Nominal Conditions					Specifications must be met across V_{CC}, V_{REG}, and Temperature; unless otherwise specified.
Frequency	2.4		2.5	GHz	
Power Supply	3.0	3.3	4.2	V	PA nominal voltage supply (V_{CC})
V_{REG} Voltage					
ON	3.0	3.1	3.2	V	PA in “ON” state
OFF		0.00	0.20	V	PA in “OFF” state
Output Power					
11g	18	18.5		dBm	54Mbps, OFDM 54Mbps, $V_{CC} \geq 3.0V$
	19	19.5		dBm	54Mbps, OFDM 54Mbps, $V_{CC} \geq 3.3V$
11b	20	22		dBm	11Mbps, CCK, $V_{CC} \geq 3.0V$
EVM		3.3	4.0	%	$P_{OUT(g)}$=Rated Output Power, 54Mbps OFDM, 50Ω, see note 1
Adjacent Channel Power					$P_{OUT(b)}$=20dBm 1Mbps CCK, note 2
ACP1		-36	-33	dBc	$V_{CC} \geq 3.3V$, meeting 11b spectral mask requirements
ACP2		-56	-51	dBc	
Gain	26	30	34	dB	
Gain Variation Slope					At rated power and a given supply voltage, room temp
Range	3.0		4.2	V	
Frequency	-0.5		+0.5	dB	2.4GHz to 2.5GHz

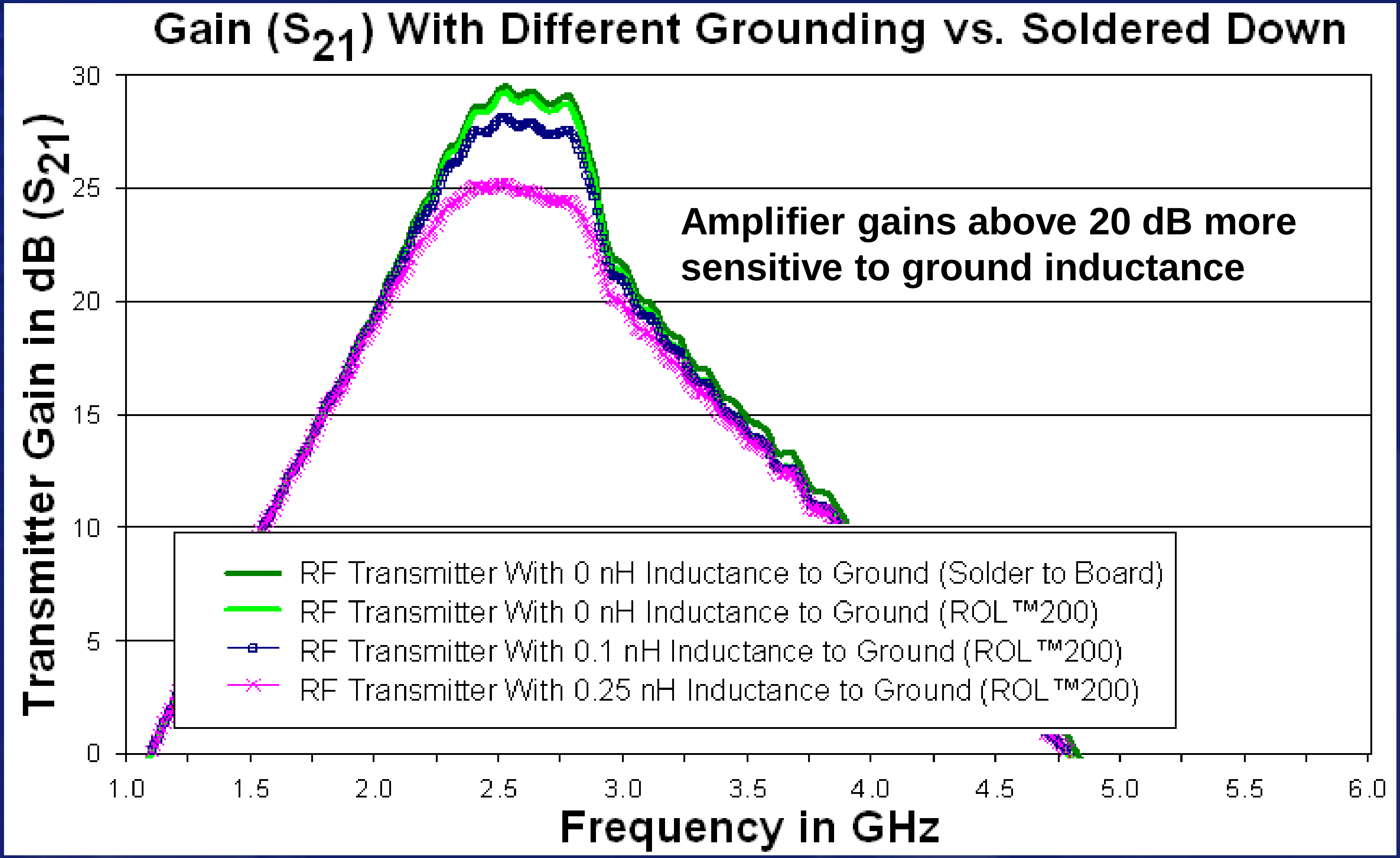
http://www.rfmd.com/CS/Documents/RF5755DS.pdf

Schematic



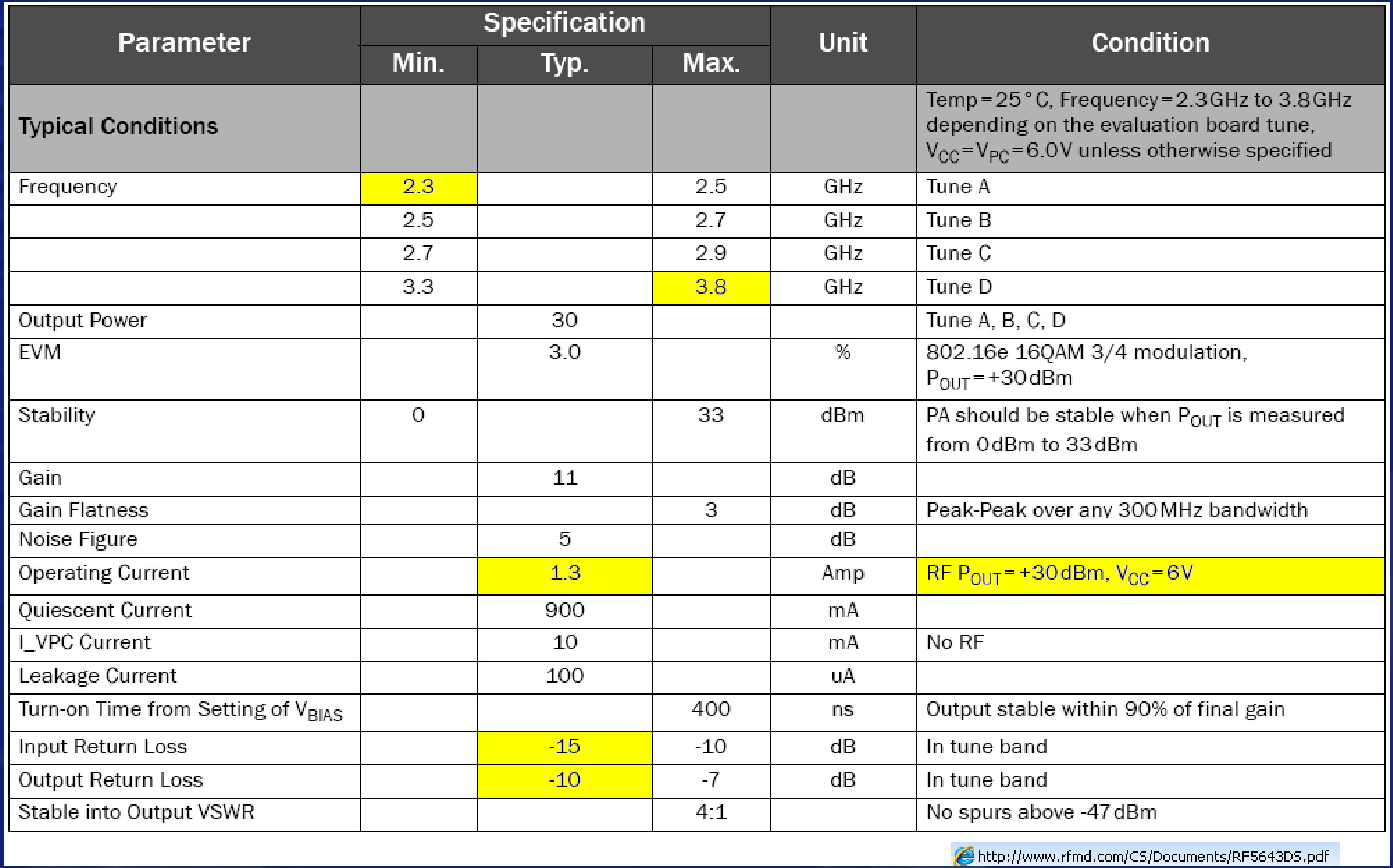
Testing at hot will stress device if die temperature is exceeded!

Effects of Inductance



Higher amplifier gains require lower ground inductance!!

High Power Amplifier Spec Sheet

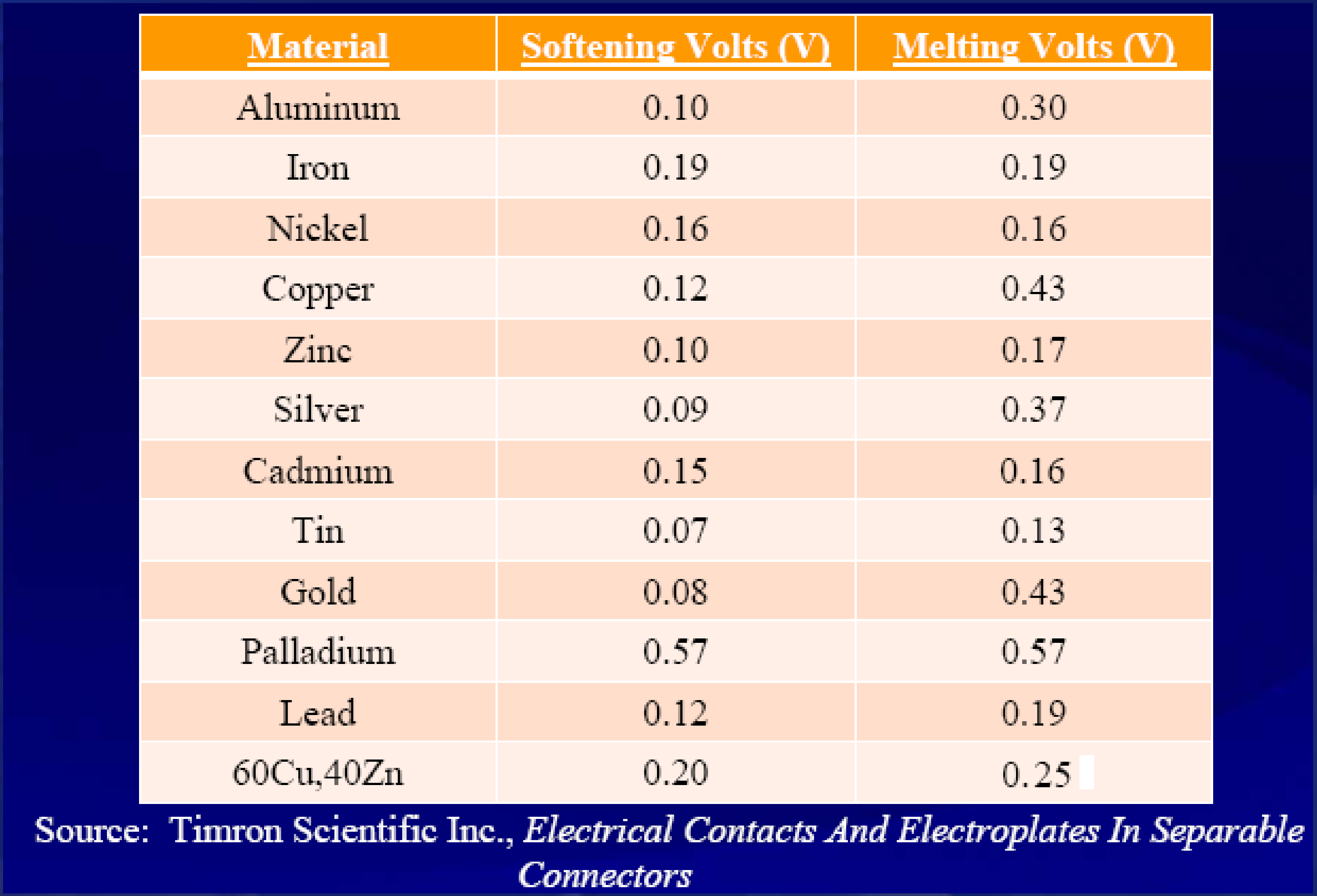


Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Typical Conditions					Temp=25°C, Frequency=2.3GHz to 3.8GHz depending on the evaluation board tune, $V_{CC}=V_{PC}=6.0V$ unless otherwise specified
Frequency	2.3		2.5	GHz	Tune A
	2.5		2.7	GHz	Tune B
	2.7		2.9	GHz	Tune C
	3.3		3.8	GHz	Tune D
Output Power		30			Tune A, B, C, D
EVM		3.0		%	802.16e 16QAM 3/4 modulation, $P_{OUT}=+30dBm$
Stability	0		33	dBm	PA should be stable when P_{OUT} is measured from 0dBm to 33dBm
Gain		11		dB	
Gain Flatness			3	dB	Peak-Peak over any 300MHz bandwidth
Noise Figure		5		dB	
Operating Current		1.3		Amp	RF $P_{OUT}=+30dBm$, $V_{CC}=6V$
Quiescent Current		900		mA	
I_VPC Current		10		mA	No RF
Leakage Current		100		uA	
Turn-on Time from Setting of V_{BIAS}			400	ns	Output stable within 90% of final gain
Input Return Loss		-15	-10	dB	In tune band
Output Return Loss		-10	-7	dB	In tune band
Stable into Output VSWR			4:1		No spurs above -47dBm

http://www.rfmd.com/CS/Documents/RF5643DS.pdf

Amplifiers have large bandwidths so it is difficult to optimize performance! Large DC power, 1W RF out -> rest is heat!!

Material Softening/Melting Voltages



Material	Softening Volts (V)	Melting Volts (V)
Aluminum	0.10	0.30
Iron	0.19	0.19
Nickel	0.16	0.16
Copper	0.12	0.43
Zinc	0.10	0.17
Silver	0.09	0.37
Cadmium	0.15	0.16
Tin	0.07	0.13
Gold	0.08	0.43
Palladium	0.57	0.57
Lead	0.12	0.19
60Cu,40Zn	0.20	0.25

Source: Timron Scientific Inc., *Electrical Contacts And Electroplates In Separable Connectors*

The low melting voltage of Matte Tin can cause test problems!!

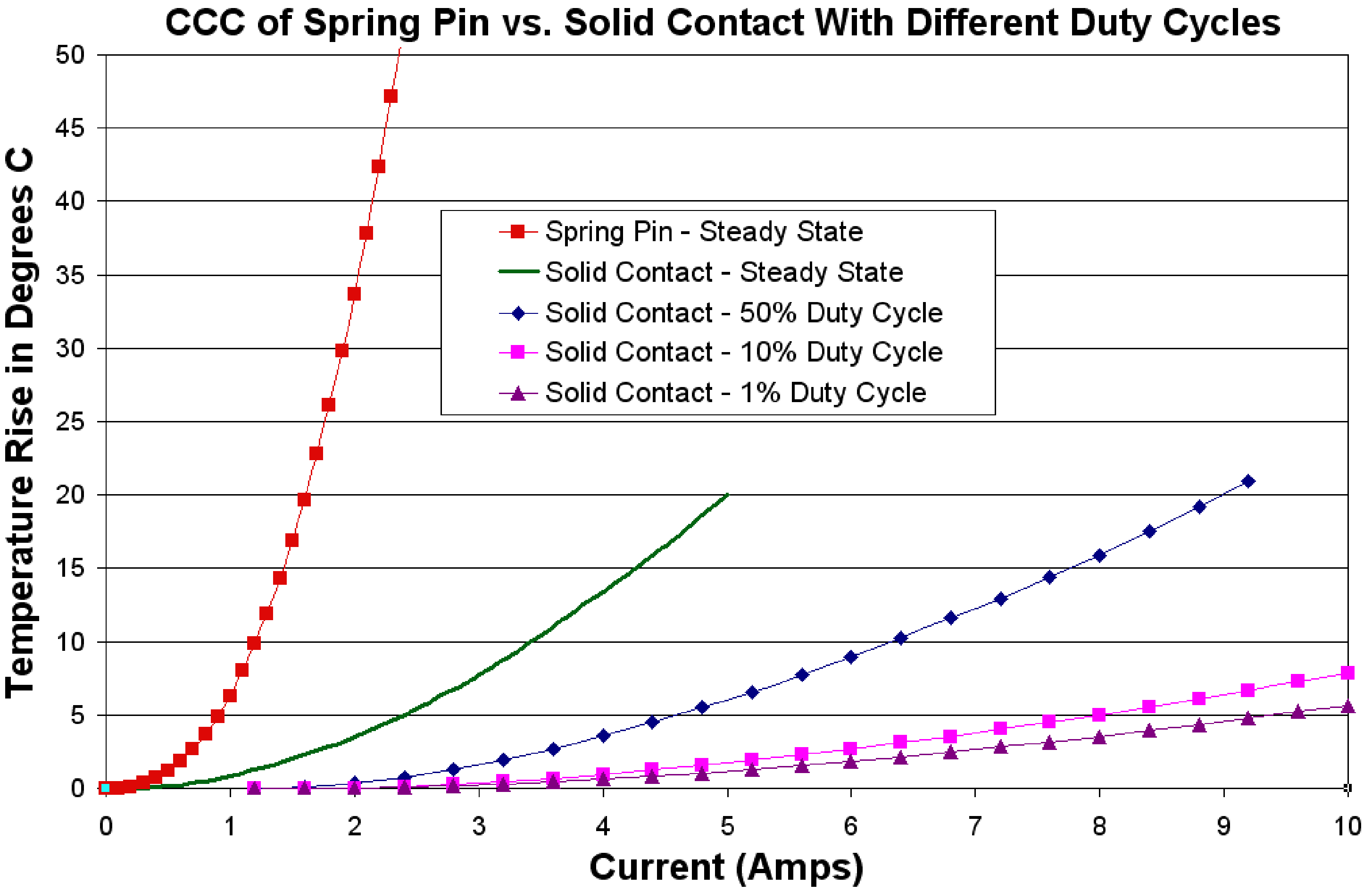
Current Carrying Example Calculations

For Matte Tin Plated Device

Contact Resistance	Current to Soften	Current to Melt
20 mOhms	3.5 A	6.5A
50 mOhms	1.4 A	2.6 A
100 mOhms	0.7 A	1.3 A
150 mOhms	0.47 A	0.87 A
200 mOhms	0.35 A	0.65 A
250 mOhms	0.28 A	0.52 A
500 mOhms	140 mA	260 mA

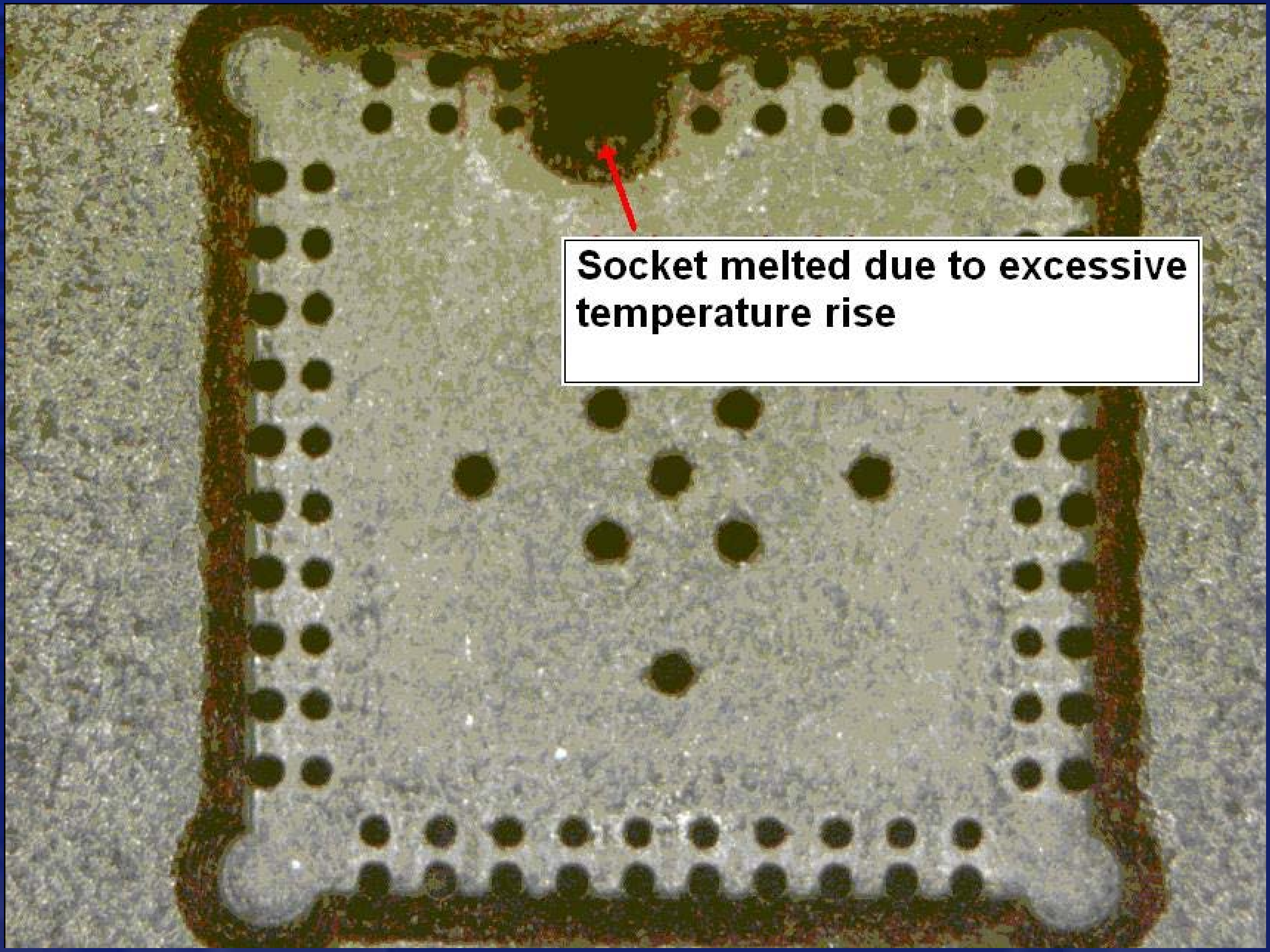
Lower C_{res} solutions enable higher current carrying capability!!

0.5mm Pitch Socket Contacts Current Carrying Capacity



Test times can be longer with less current carrying capability!!

Socket With Too Much C_{res}

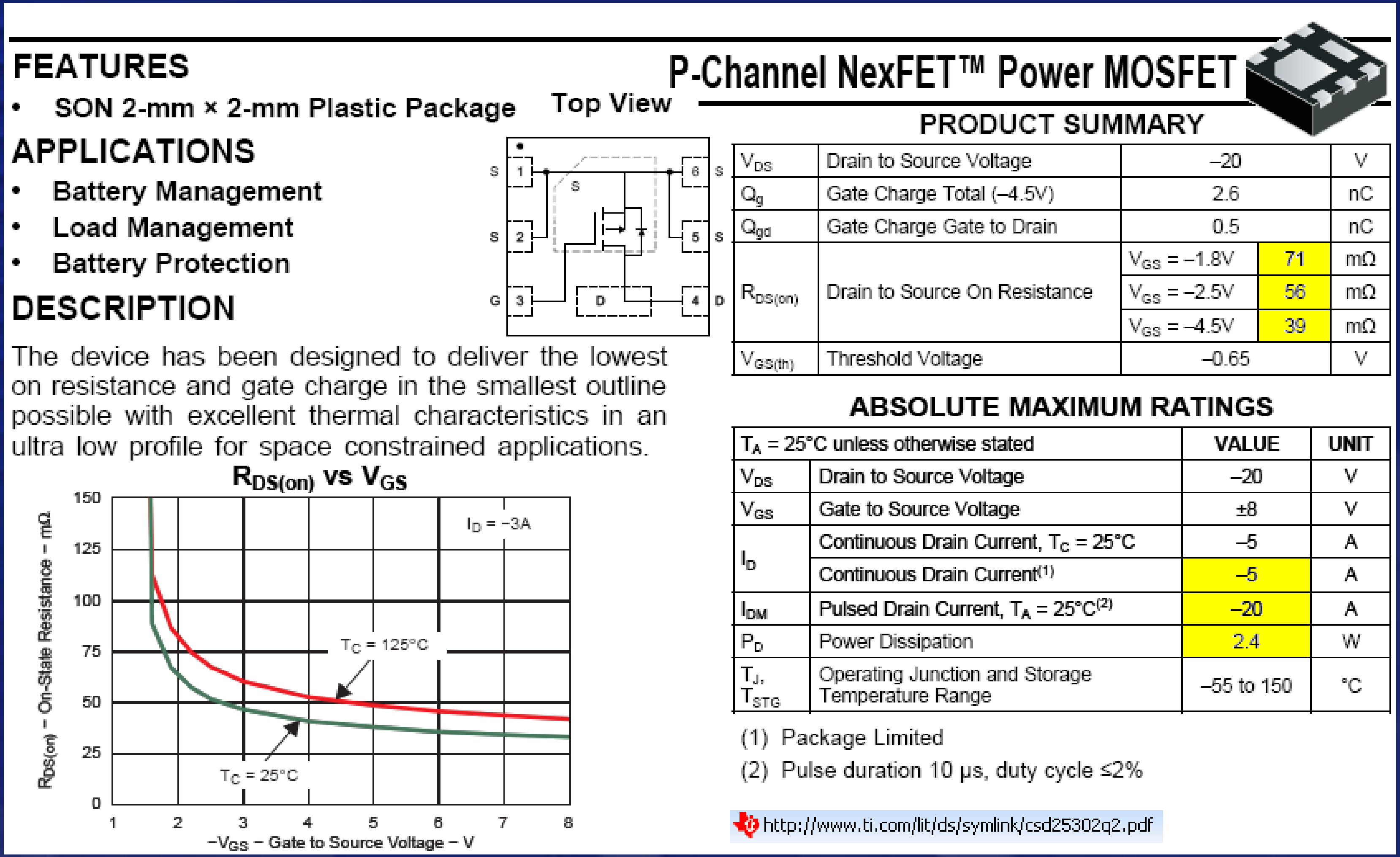


Socket melted due to excessive temperature rise

Customer later switched to Contactor using solid contacts to dissipate heat required to achieve desired test times.

Oops!! Excessive heat caused by normal increases in C_{res} and not considering required production duty cycles can melt sockets!!

RDSon Measurements Needs Low C_{res}



FEATURES

- SON 2-mm × 2-mm Plastic Package

APPLICATIONS

- Battery Management
- Load Management
- Battery Protection

DESCRIPTION

The device has been designed to deliver the lowest on resistance and gate charge in the smallest outline possible with excellent thermal characteristics in an ultra low profile for space constrained applications.

P-Channel NexFET™ Power MOSFET

Top View

PRODUCT SUMMARY

V_{DS}	Drain to Source Voltage	–20		V
Q_g	Gate Charge Total (–4.5V)	2.6		nC
Q_{gd}	Gate Charge Gate to Drain	0.5		nC
$R_{DS(on)}$	Drain to Source On Resistance	V_{GS} = –1.8V	71	mΩ
		V_{GS} = –2.5V	56	mΩ
		V_{GS} = –4.5V	39	mΩ
$V_{GS(th)}$	Threshold Voltage	–0.65		V

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C unless otherwise stated		VALUE	UNIT
V_{DS}	Drain to Source Voltage	–20	V
V_{GS}	Gate to Source Voltage	±8	V
I_D	Continuous Drain Current, T_C = 25°C	–5	A
	Continuous Drain Current(1)	–5	A
I_{DM}	Pulsed Drain Current, T_A = 25°C(2)	–20	A
P_D	Power Dissipation	2.4	W
T_J, T_{STG}	Operating Junction and Storage Temperature Range	–55 to 150	°C

(1) Package Limited

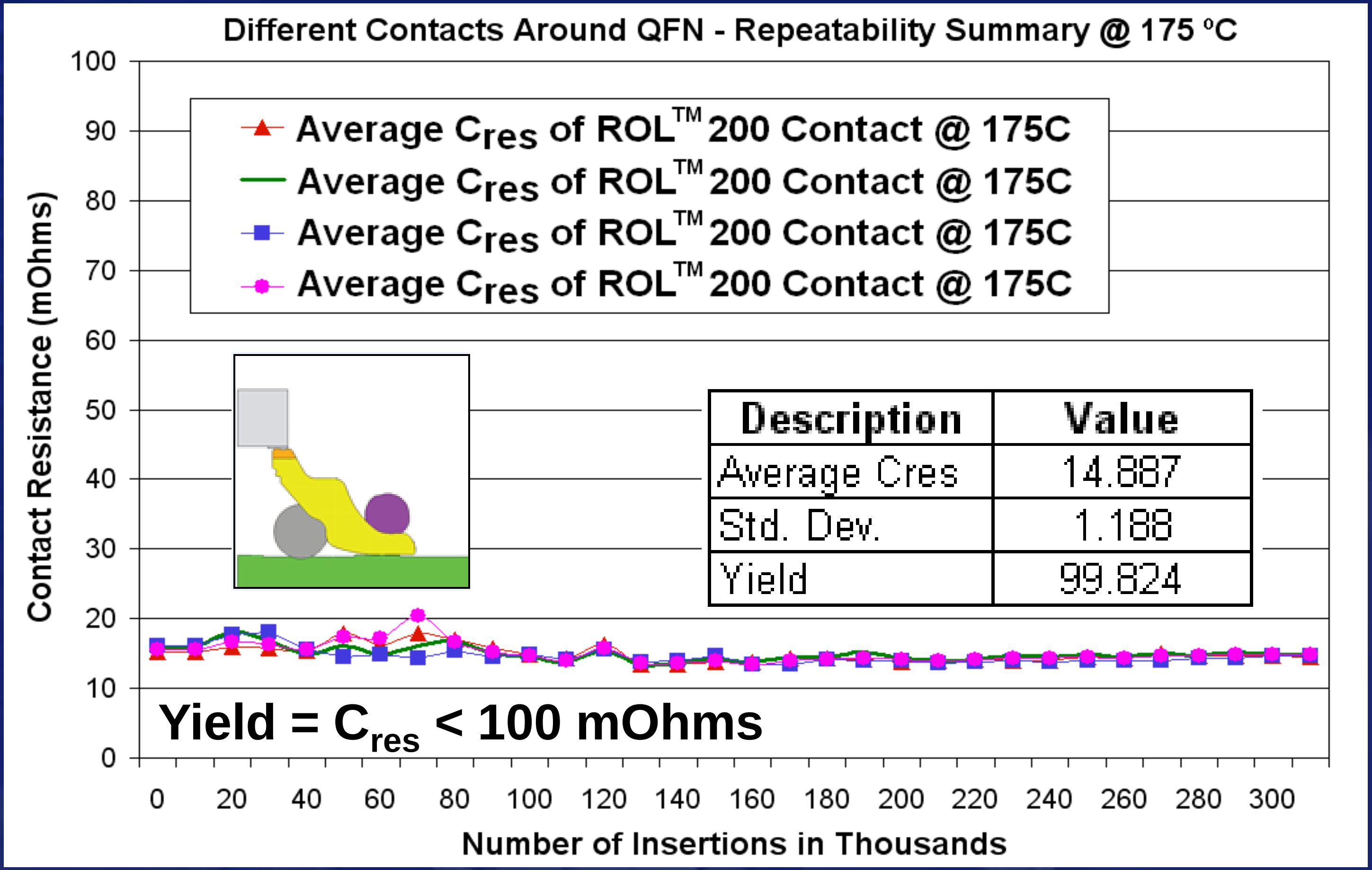
(2) Pulse duration 10 μs, duty cycle ≤2%

$R_{DS(on)}$ vs V_{GS}

http://www.ti.com/lit/ds/symlink/csd25302q2.pdf

Wide variations in Contact C_{res} cause excessive false failures!!

ROL™ Technology C_{res} With NiPdAu Plated Device @ 175 °C

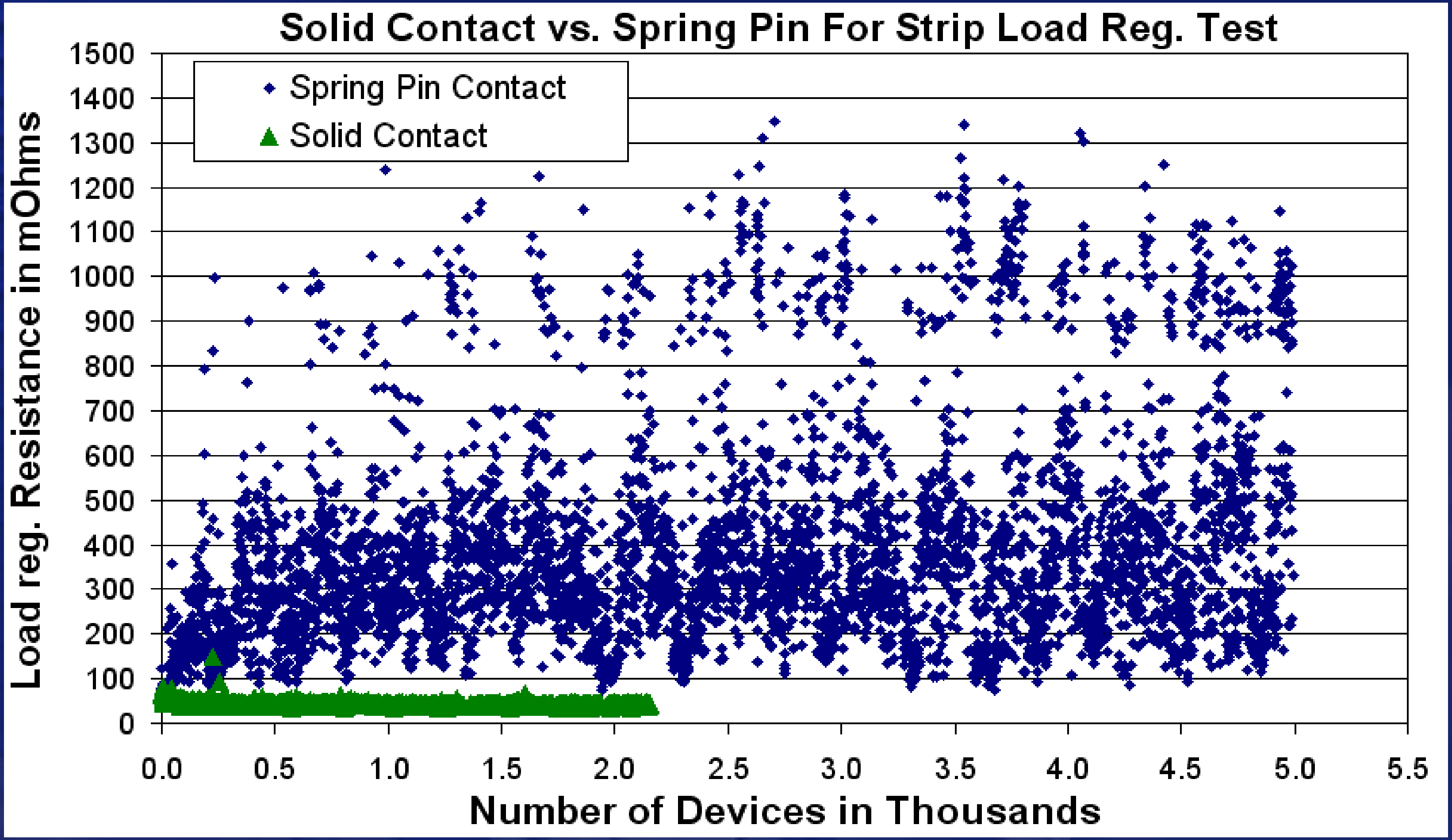


Description	Value
Average Cres	14.887
Std. Dev.	1.188
Yield	99.824

Yield = C_{res} < 100 mOhms

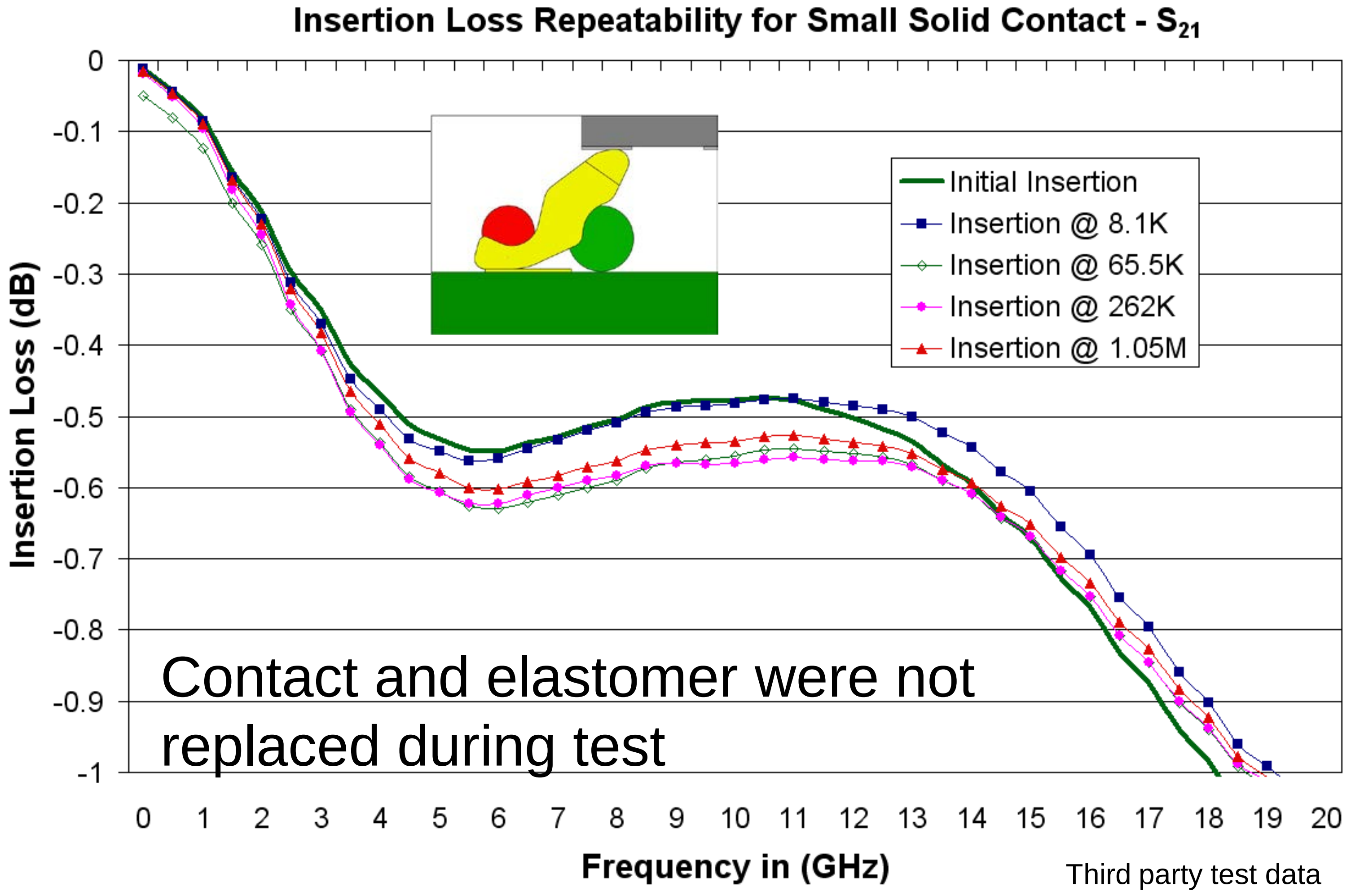
Solid contacts provide low and stable C_{res}!

Contact Resistance Repeatability – Solid Contact vs. Spring Pin



Actual production data shows C_{res} variability causing false failures!

Contactor RF Repeatability – Solid ROL™ Technology

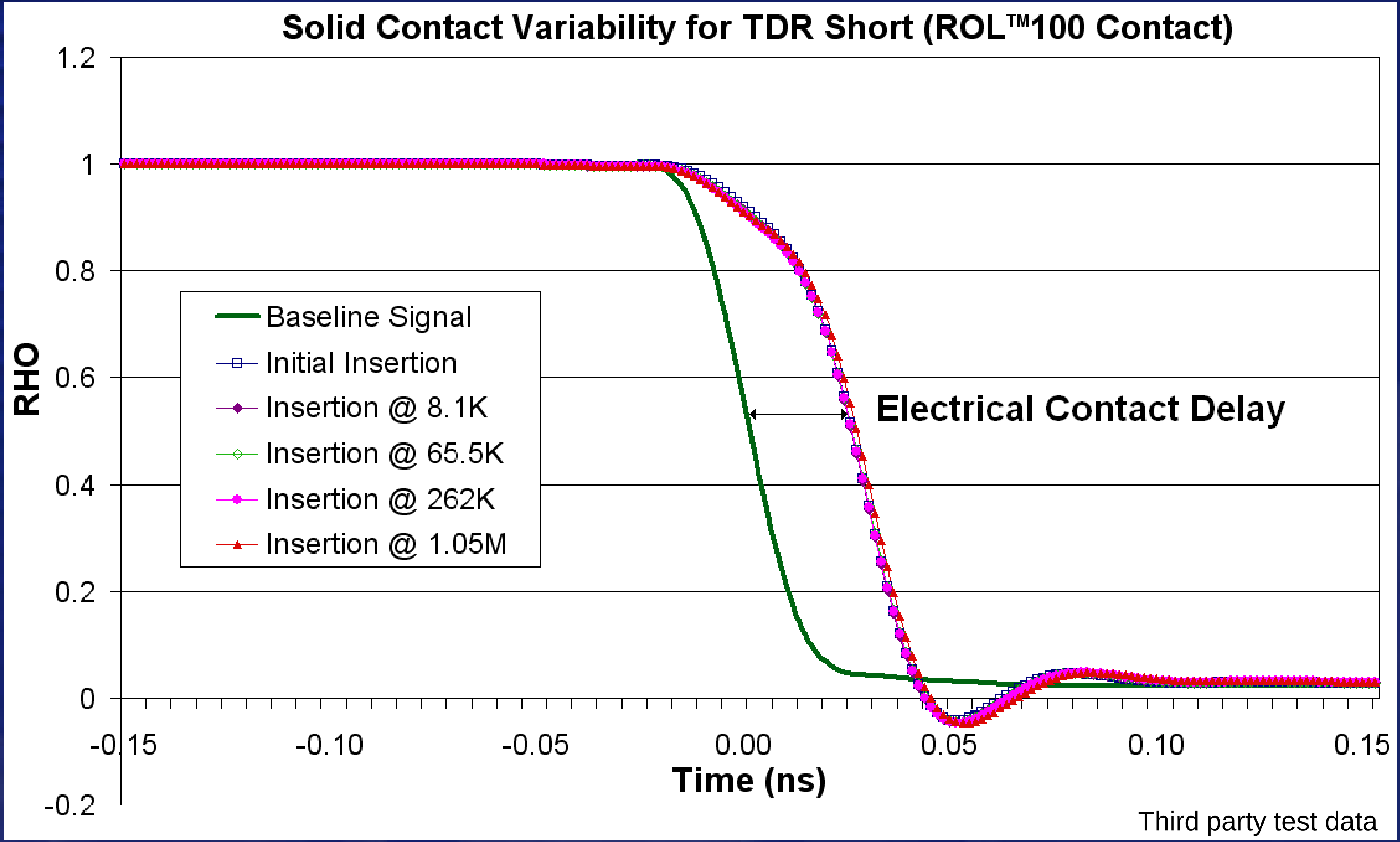


Contact and elastomer were not replaced during test

Third party test data

Solid contact has very good RF repeatability!

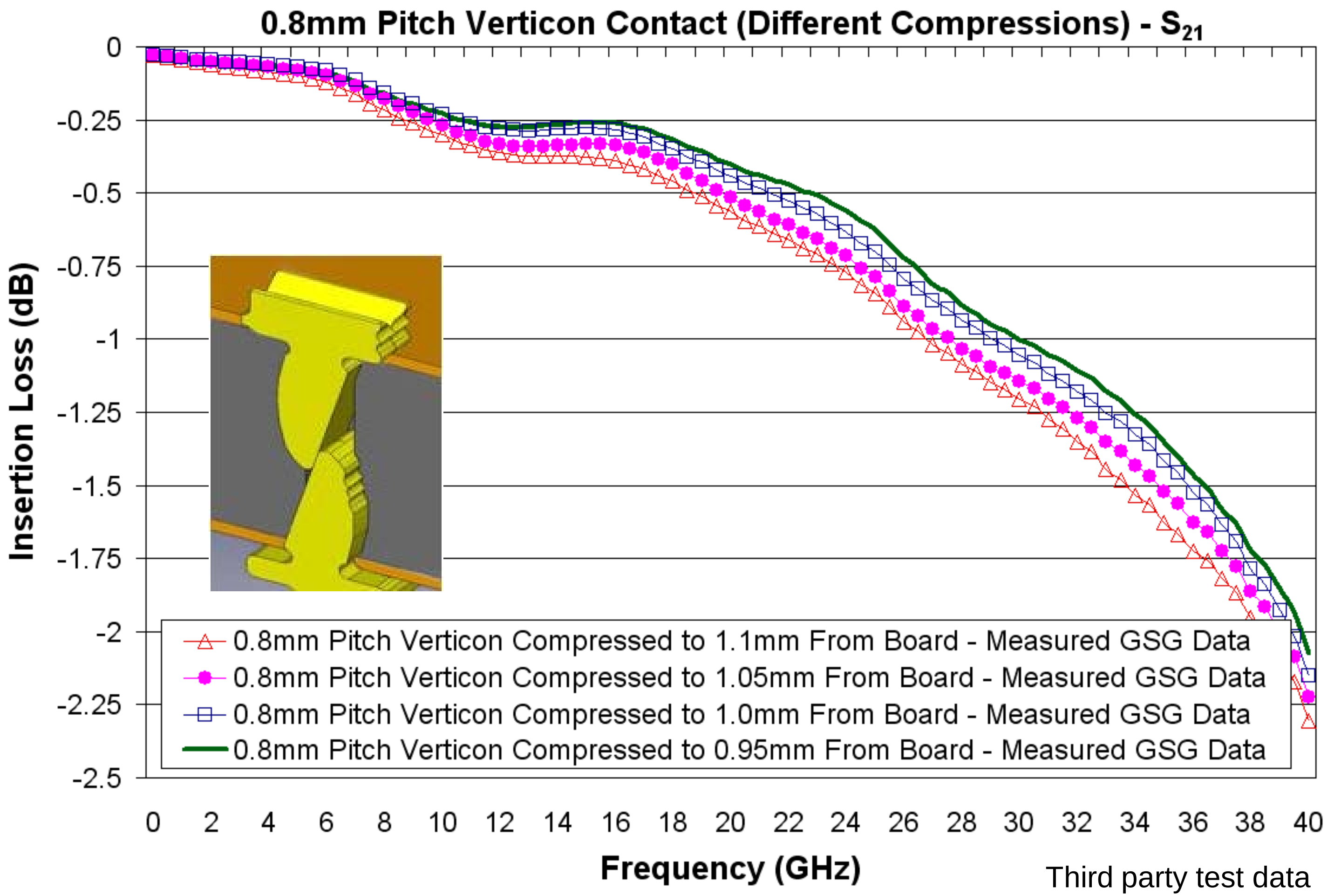
Contactor Digital Repeatability – Solid ROL™ Technology



Third party test data

Solid contact has consistent repeatable delay!

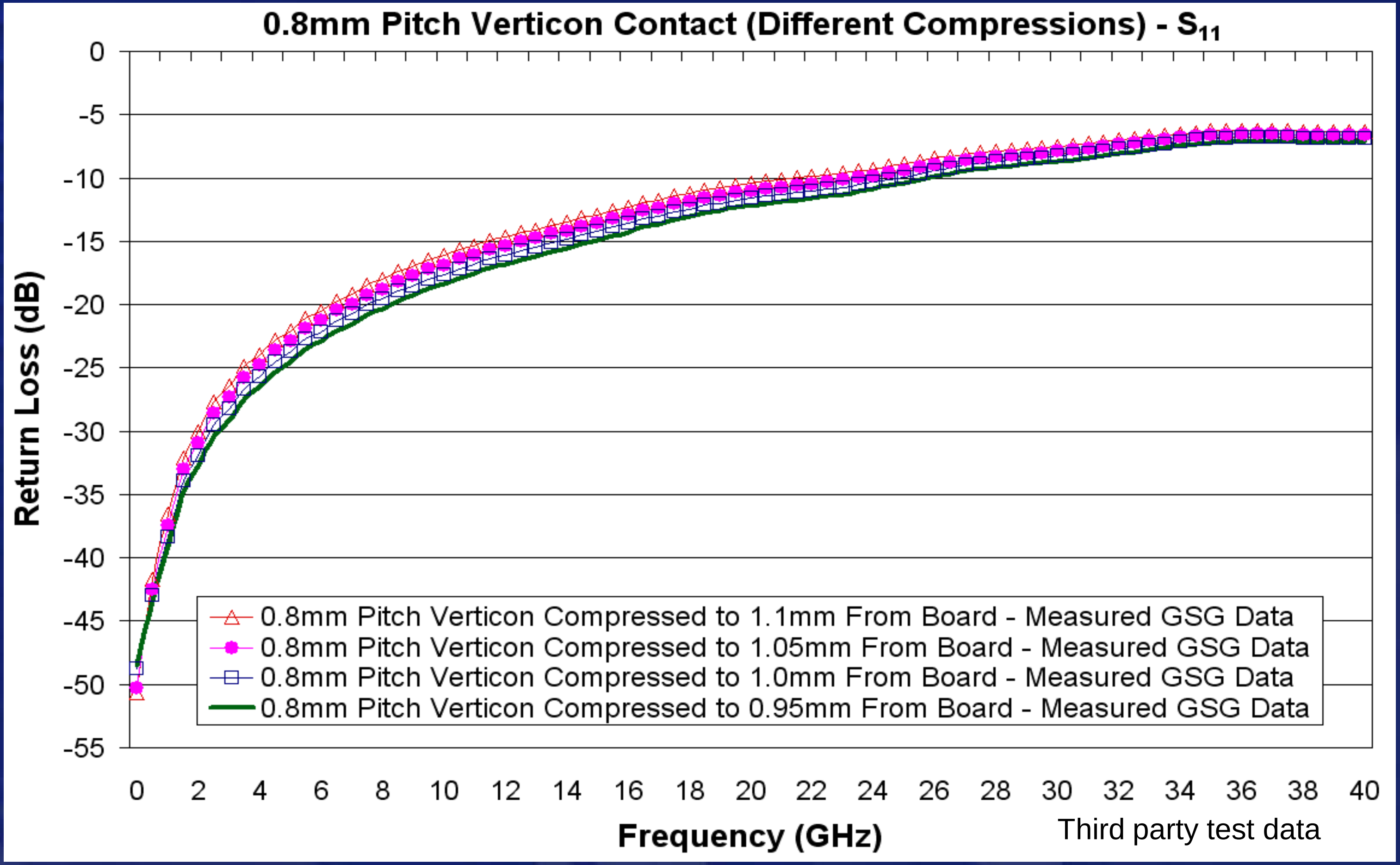
0.8mm Pitch Verticon® 100 BGA Insertion Loss vs. Compression – S_{21}



Third party test data

Shorter Contact lengths improve RF performance!

0.8mm Pitch Verticon® 100 BGA Return Loss vs. Compression – S_{11}



Third party test data

Increasing contact interfaces increases variation in RF performance during compression!

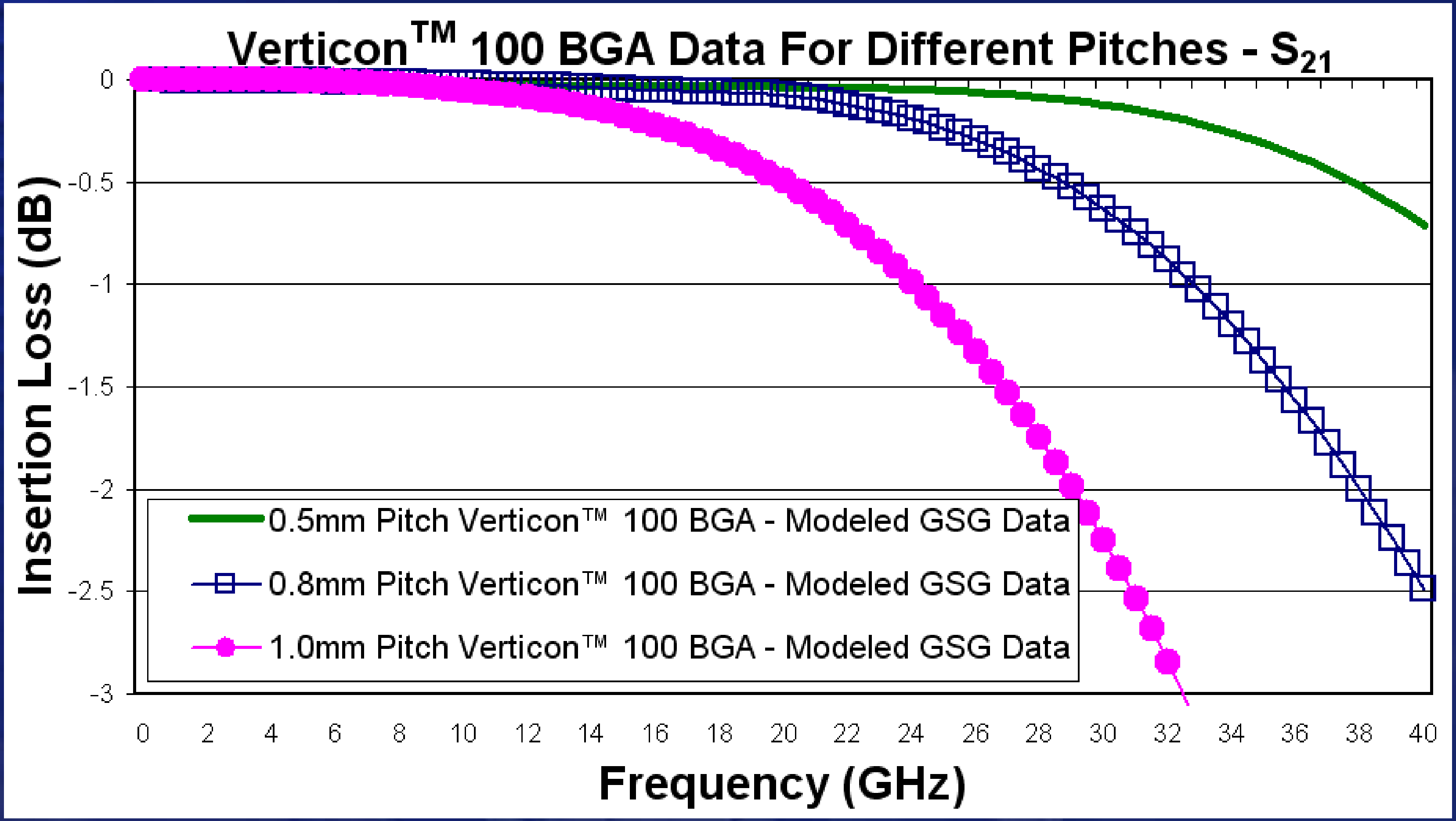
Importance of Design Margin

- Contact resistance will increase over time
- Debris or oxides may impact C_{res} or ground inductance path
- IR drop across interfaces could cause softening or melting of device plating
- Variation in signal path and ground location will vary electrical performance

All of these will affect Guard Bands and Test Limits

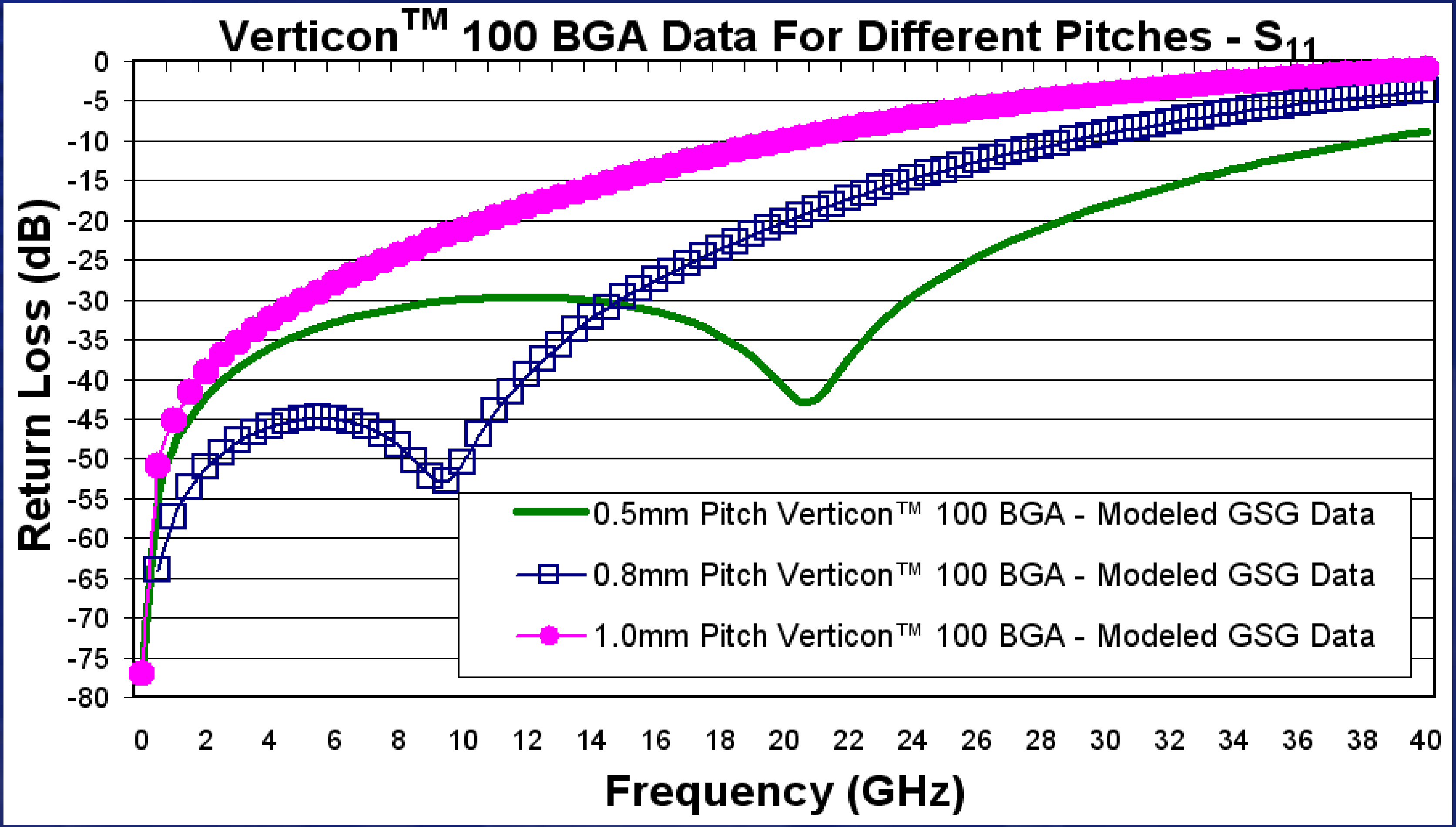
NOTE: The contactor will always add more ground inductance and resistance to the path than solder-to-board performance!

Verticon® 100 BGA Modeled Data For Different Pitches – S_{21}



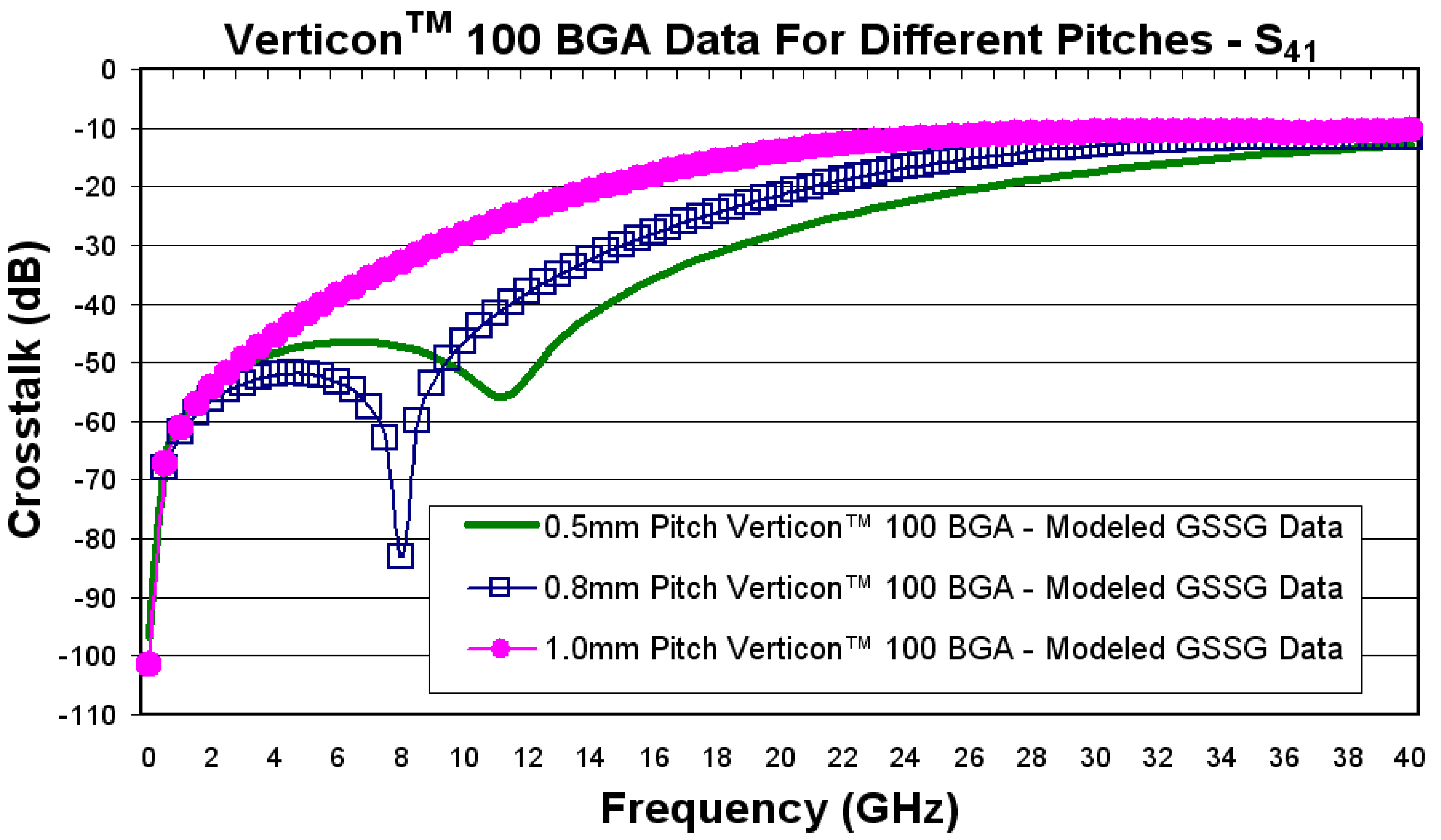
Proximity of grounds affects performance at higher frequencies!

Verticon® 100 BGA Modeled Data For Different Pitches – S_{11}



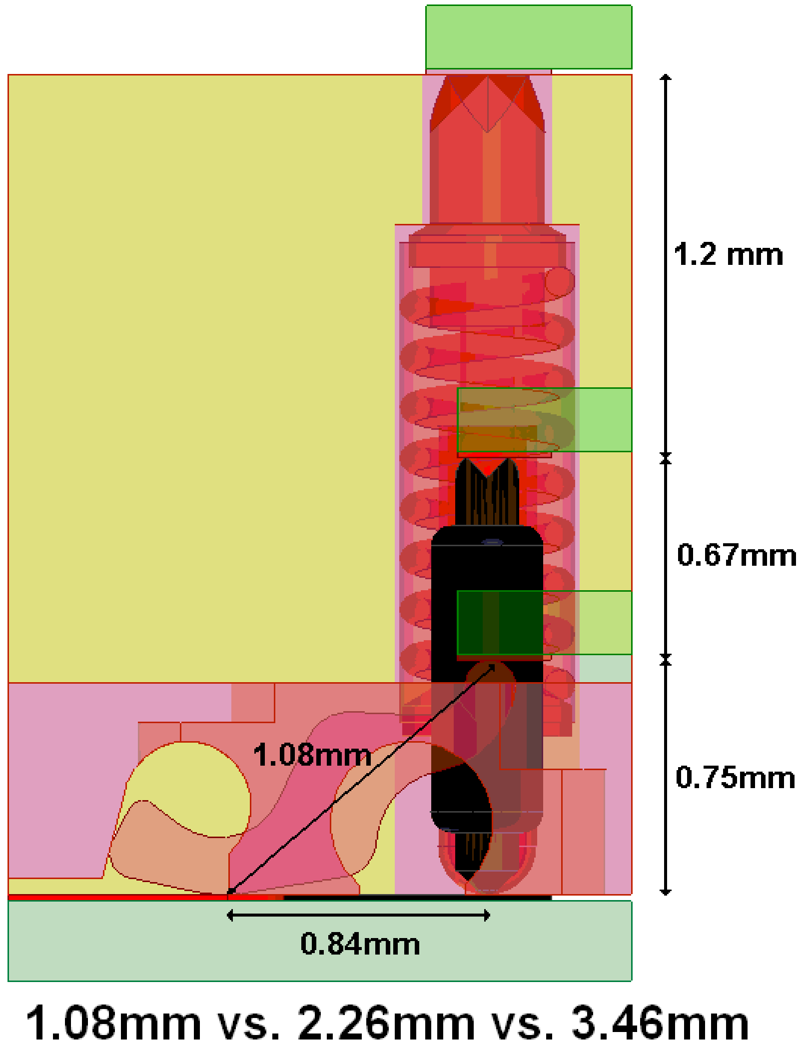
Both pitch and contact design impacts characteristic impedance!

Verticon® 100 BGA Modeled Data For Different Pitches – S_{41}



Return loss is correlated to Crosstalk!

Signal Transition Comparison
RF Signal Launch vs. Airplane Take Off



1.08mm vs. 2.26mm vs. 3.46mm

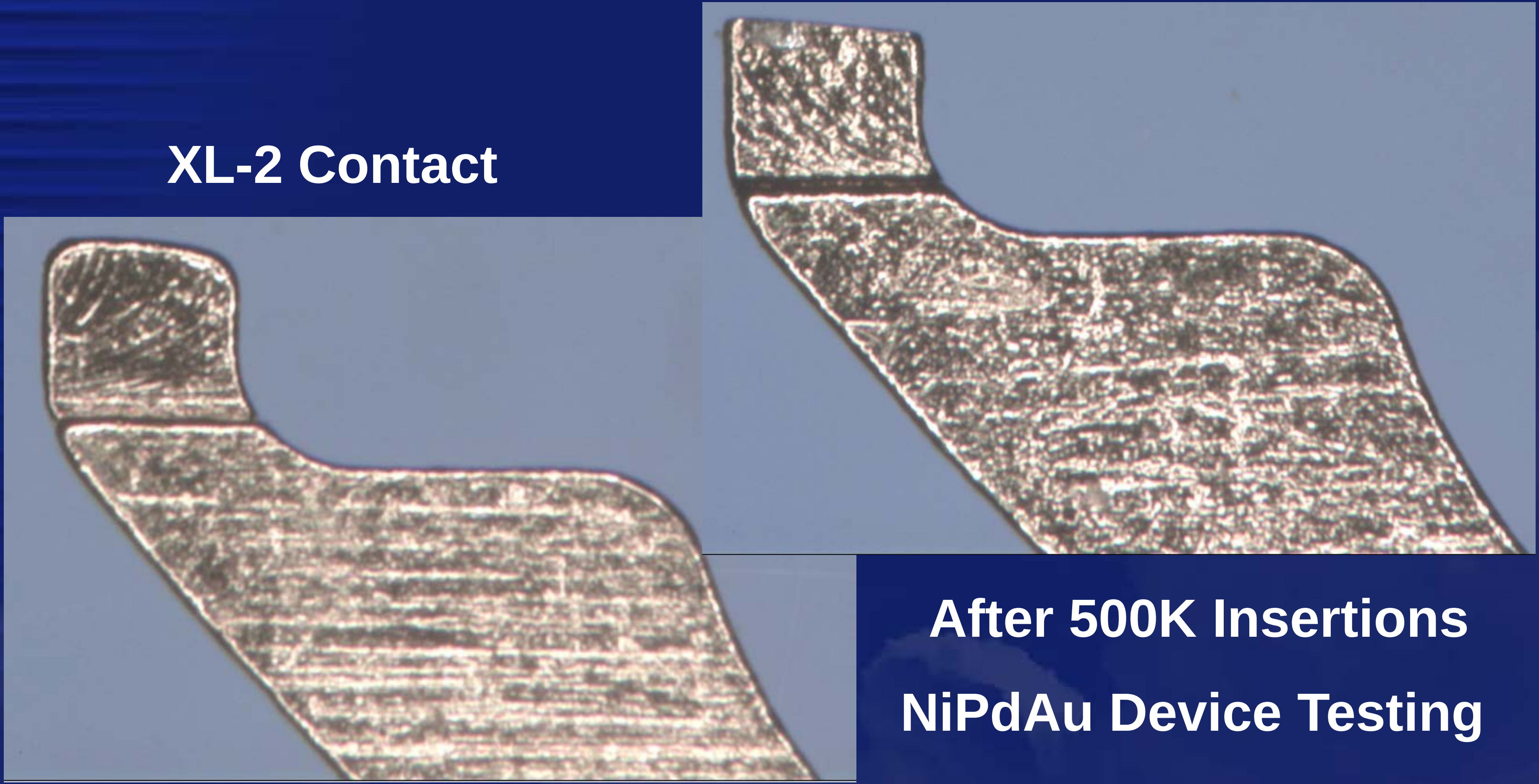
RF performance degrades with every right angle connection!!

Mechanical Considerations

- Wiping action vs. no wiping action effects MTBA and cleaning intervals
- One piece vs. multiple parts : more parts = more variability
- Handler interface issues – insertion speed
- Maintenance of parts
- Test conditions affect performance

Mechanical features also affect RF performance!

Solid Contact Shows Minimal Wear After 500K Insertions



XL-2 Contact

After 500K Insertions

NiPdAu Device Testing

C_{res} Test Method Differences

- Testing with correct device plating
  - Gold on gold gives best results. Majority of packages use other platings (i.e. Matte Tin and NiPdAu)
  - Hardness of plating affects performance
  - Oxide level affects performance
  - Wear and contaminants affect life
  - Wiping or self cleaning action affect MTBA
- Testing at correct forces and insertion speeds
  - Higher the force the lower the C_{res}
  - Higher the force the shorter the contact life and MTBA

Conclusion

- Ground inductance is extremely important when measuring high frequency signals and devices with high gain
- Shorter paths result in better electrical performance (hypotenuse shorter than sum of legs)
- Solid contacts have current carrying advantages over contacts with multiple parts
- Fewer contact interfaces result in lower C_{res}
- Repeatability improves both electrical and mechanical data accuracy resulting in higher yields
- Not all specifications are created equal