2010 Session 4

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MODELING THE REAL WORLD

Design of Experiment for Force vs. Current Evaluation of a 3x3mm Ground Insert

Harlan Faller—Johnstech International Corporation

An Improved Characterization Technique for Contactors

Ryan Satrom, Marcus Frey, Valts Treibergs—Multitest

Using Modeling to Simulate High Frequency Test Results

Jeff Sherry—Johnstech International Corporation
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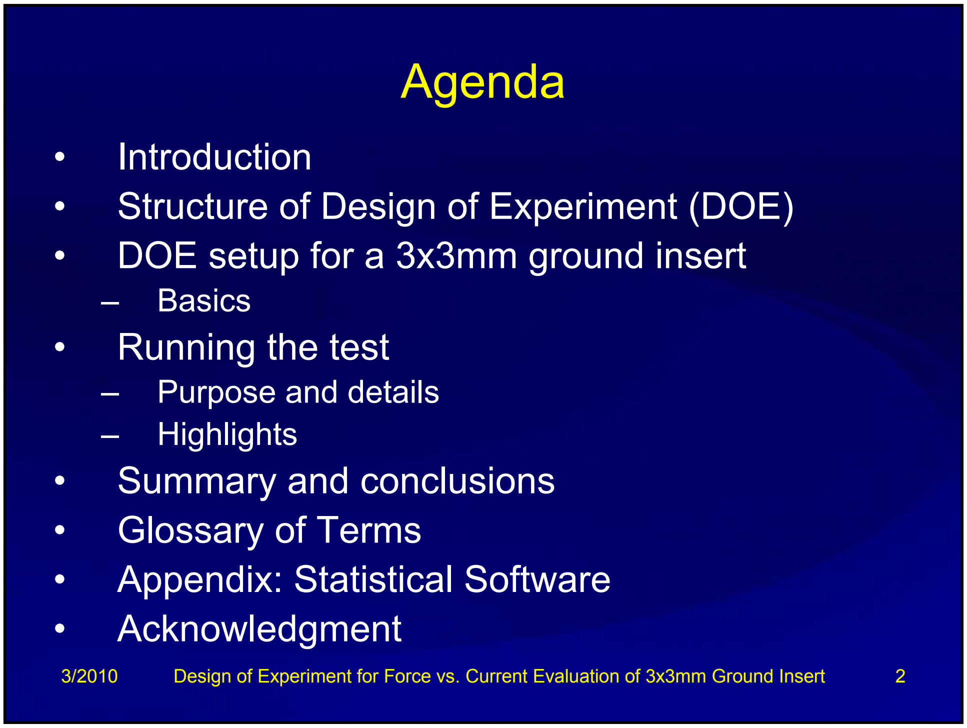
Design of Experiment for Force vs. Current Evaluation of a 3x3mm Ground Insert

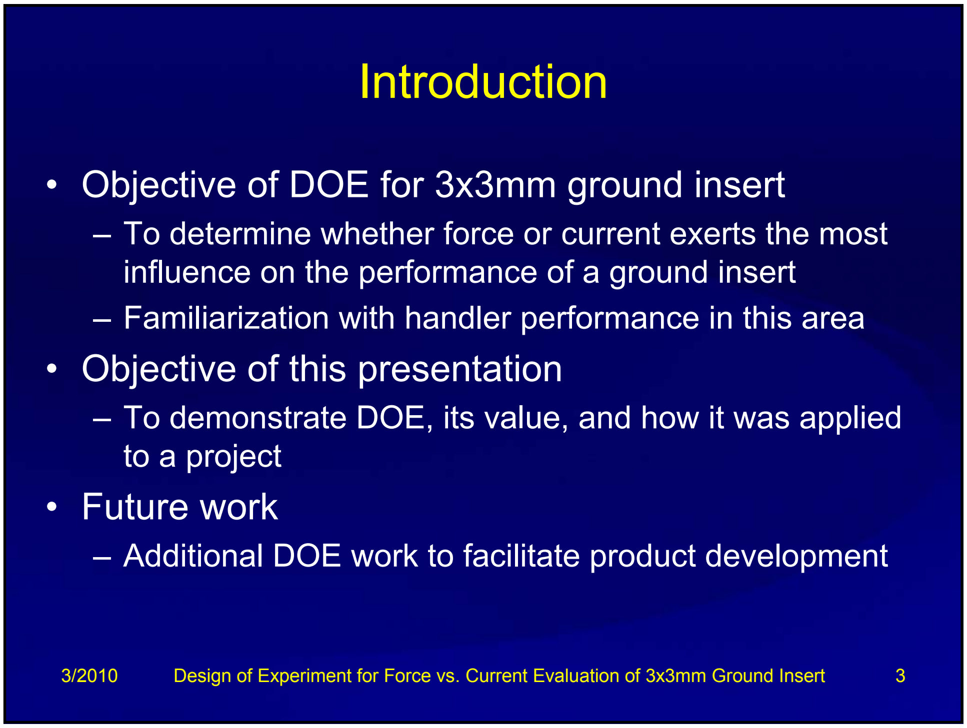
Harlan Faller, P.E.
Johnstech International

2010 BiTS Workshop
March 7 - 10, 2010



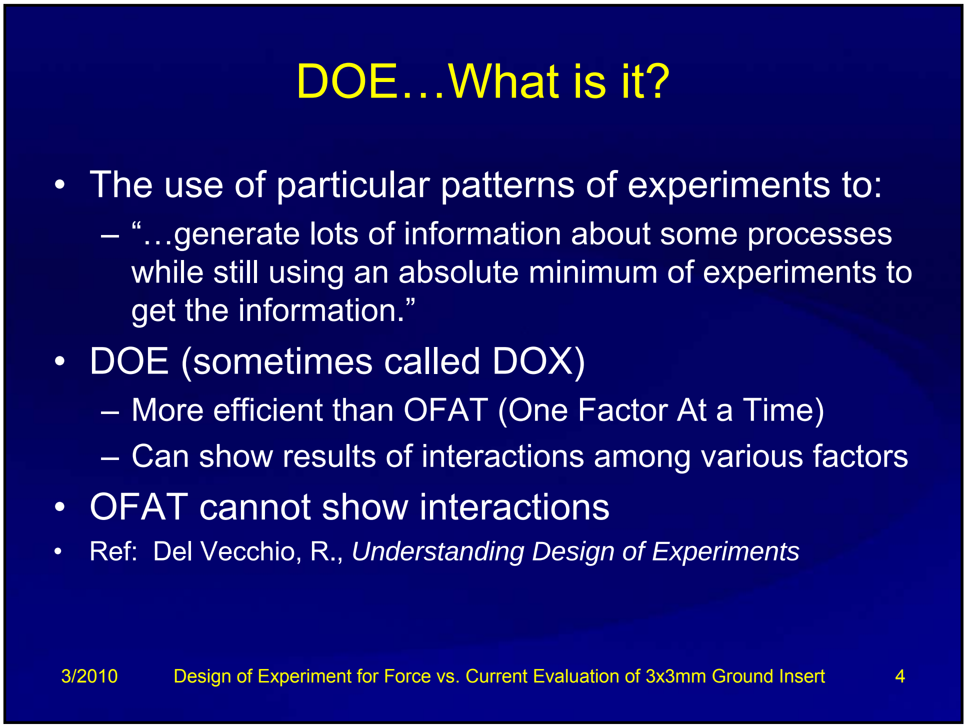
Agenda

- Introduction
- Structure of Design of Experiment (DOE)
- DOE setup for a 3x3mm ground insert
  - Basics
- Running the test
  - Purpose and details
  - Highlights
- Summary and conclusions
- Glossary of Terms
- Appendix: Statistical Software
- Acknowledgment



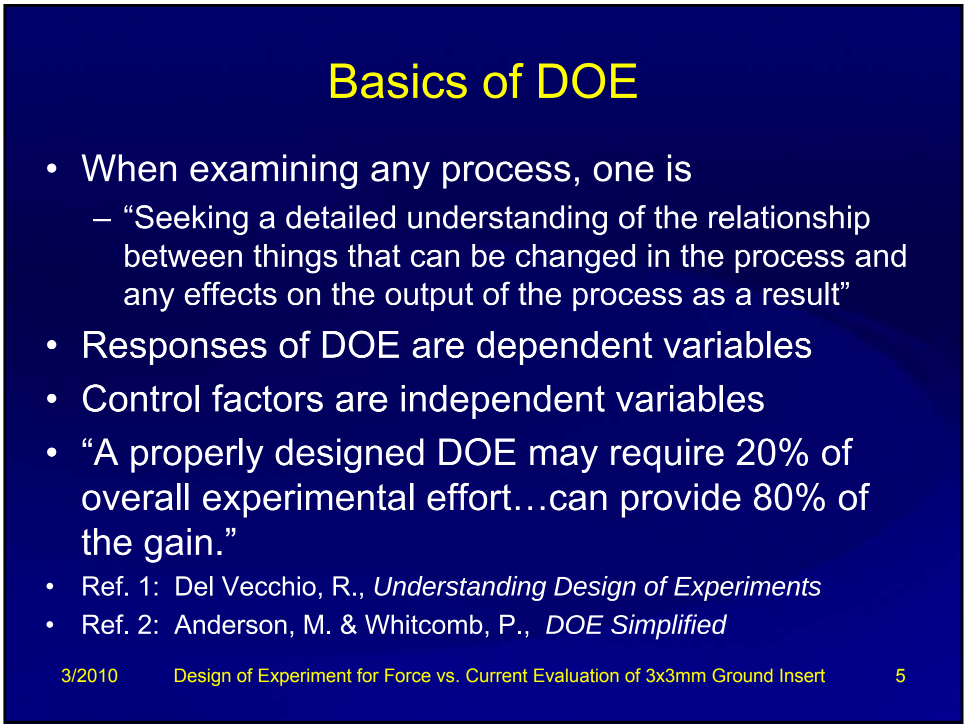
Introduction

- Objective of DOE for 3x3mm ground insert
  - To determine whether force or current exerts the most influence on the performance of a ground insert
  - Familiarization with handler performance in this area
- Objective of this presentation
  - To demonstrate DOE, its value, and how it was applied to a project
- Future work
  - Additional DOE work to facilitate product development



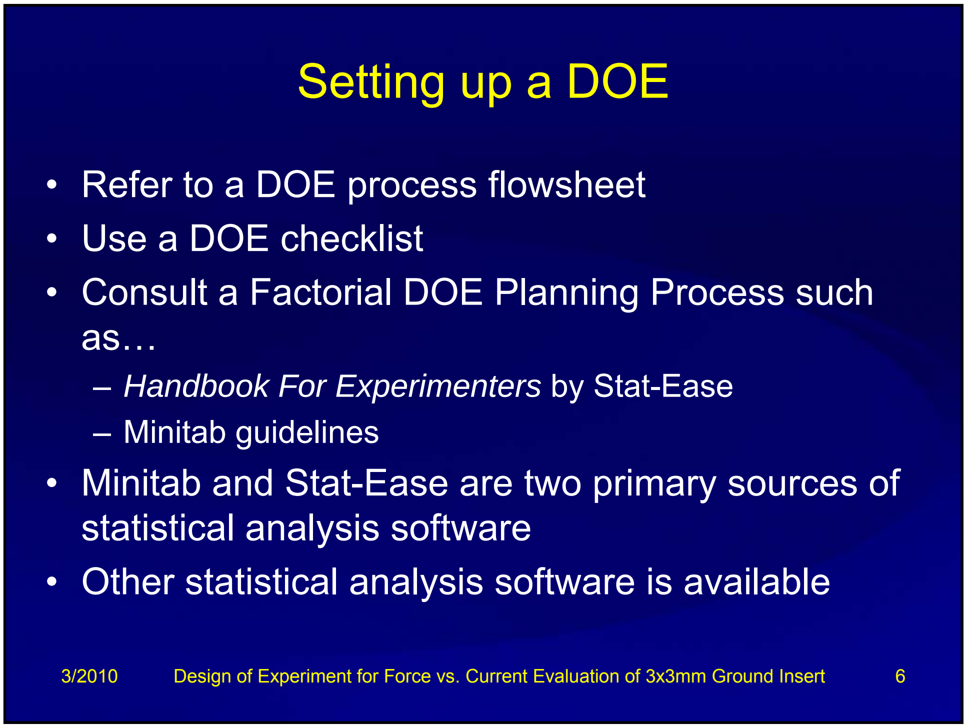
DOE…What is it?

- The use of particular patterns of experiments to:
  - "…generate lots of information about some processes while still using an absolute minimum of experiments to get the information."
- DOE (sometimes called DOX)
  - More efficient than OFAT (One Factor At a Time)
  - Can show results of interactions among various factors
- OFAT cannot show interactions
- Ref: Del Vecchio, R., *Understanding Design of Experiments*



Basics of DOE

- When examining any process, one is
  - “Seeking a detailed understanding of the relationship between things that can be changed in the process and any effects on the output of the process as a result”
- Responses of DOE are dependent variables
- Control factors are independent variables
- “A properly designed DOE may require 20% of overall experimental effort…can provide 80% of the gain.”
- Ref. 1: Del Vecchio, R., *Understanding Design of Experiments*
- Ref. 2: Anderson, M. & Whitcomb, P., *DOE Simplified*



Setting up a DOE

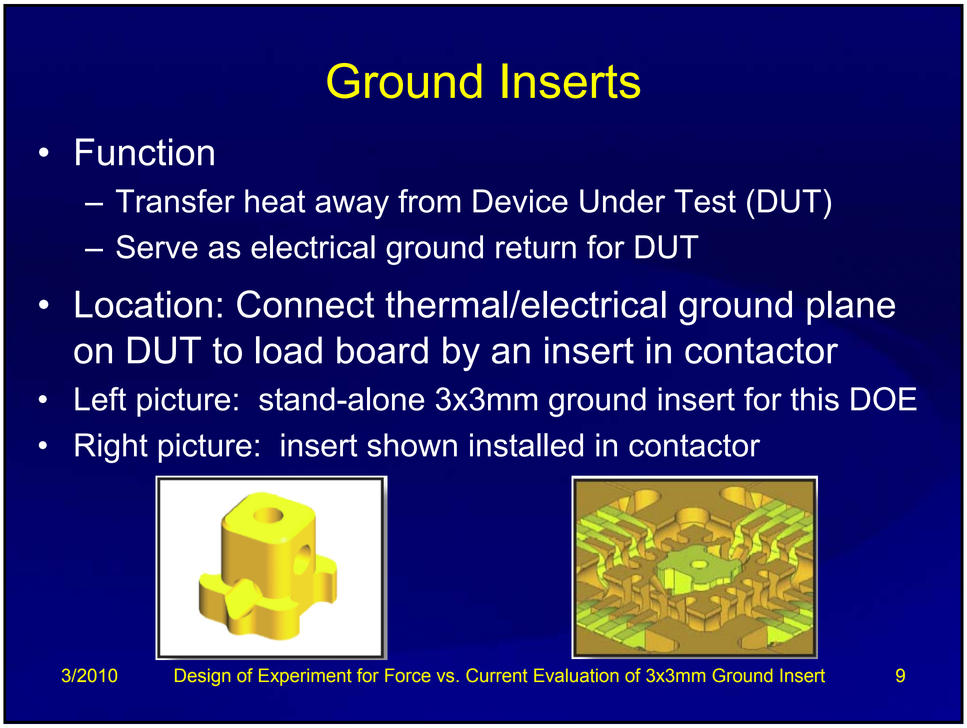
- Refer to a DOE process flowsheet
- Use a DOE checklist
- Consult a Factorial DOE Planning Process such as…
  - *Handbook For Experimenters* by Stat-Ease
  - Minitab guidelines
- Minitab and Stat-Ease are two primary sources of statistical analysis software
- Other statistical analysis software is available

Example: Pattern of Experiments

- "Full Factorial"
  - Most basic pattern of experiments
  - Uses every possible combination of factors and their levels
- DOE specifics
  - Computer-generated fraction of all combinations
  - Preserves vital estimates of main effects and interactions
- Performance goals:
  - Goal #1: What is the optimum applied force (F)
  - Goal #2: What is the optimum applied current (I)

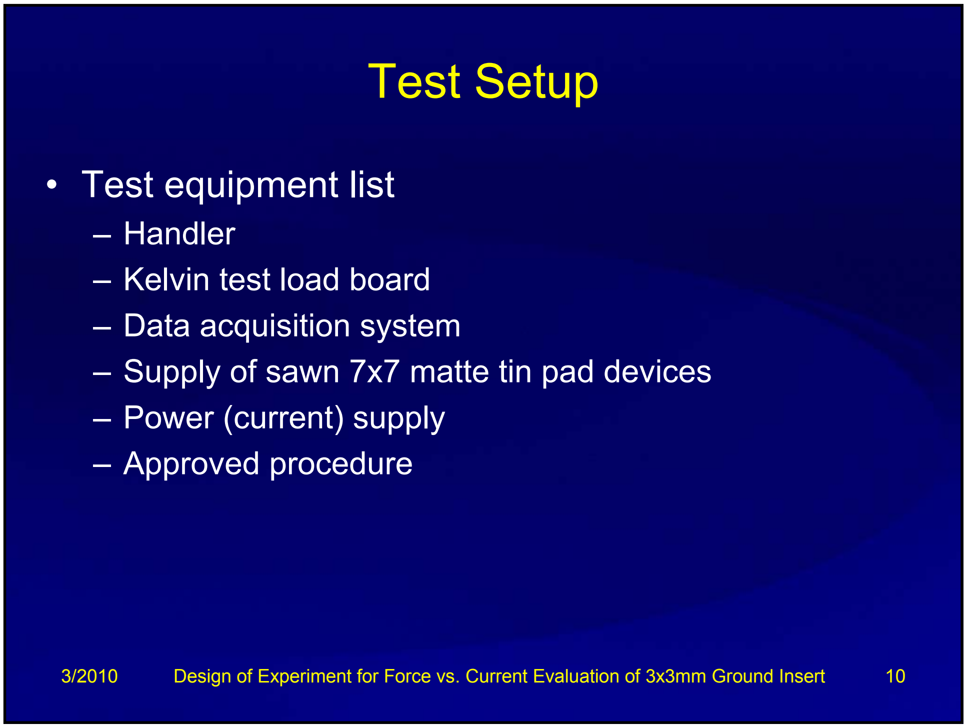
Ground Insert Factors & Responses

- Factor 1: Force applied (pounds)
  - 4.5, 18 and 30
- Factor 2: Current applied (milliamps)
  - 10, 100, 500, 2000 and 5000
- Main response: Contact resistance (CRES…mΩ)
- Secondary response: Debris and state of insert after each series of tests



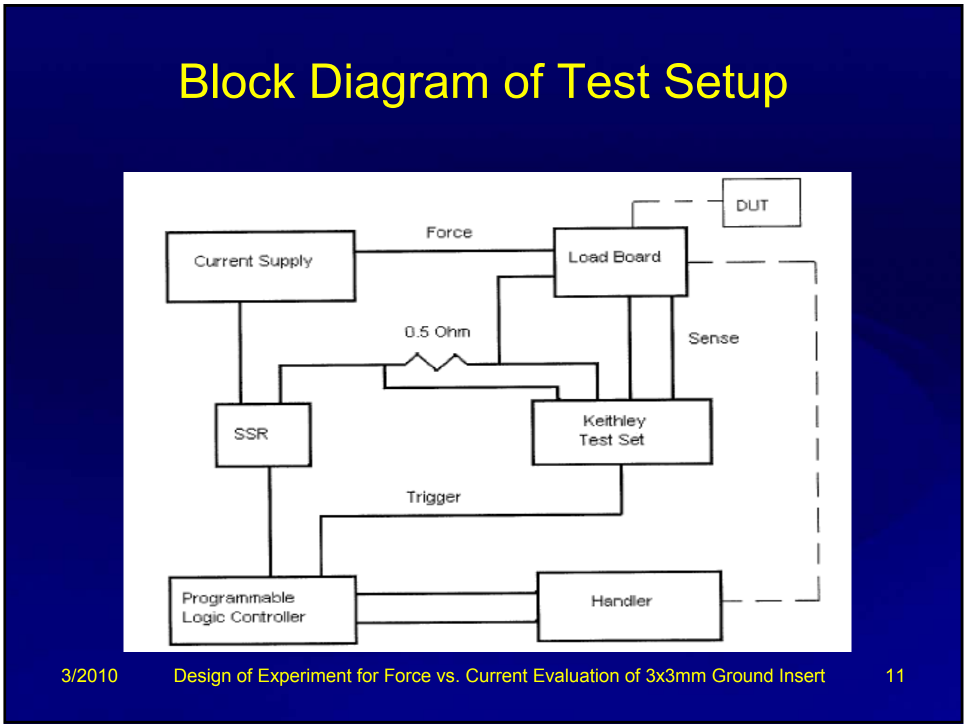
Ground Inserts

- Function
  - Transfer heat away from Device Under Test (DUT)
  - Serve as electrical ground return for DUT
- Location: Connect thermal/electrical ground plane on DUT to load board by an insert in contactor
- Left picture: stand-alone 3x3mm ground insert for this DOE
- Right picture: insert shown installed in contactor



Test Setup

- Test equipment list
  - Handler
  - Kelvin test load board
  - Data acquisition system
  - Supply of sawn 7x7 matte tin pad devices
  - Power (current) supply
  - Approved procedure



Block Diagram of Test Setup

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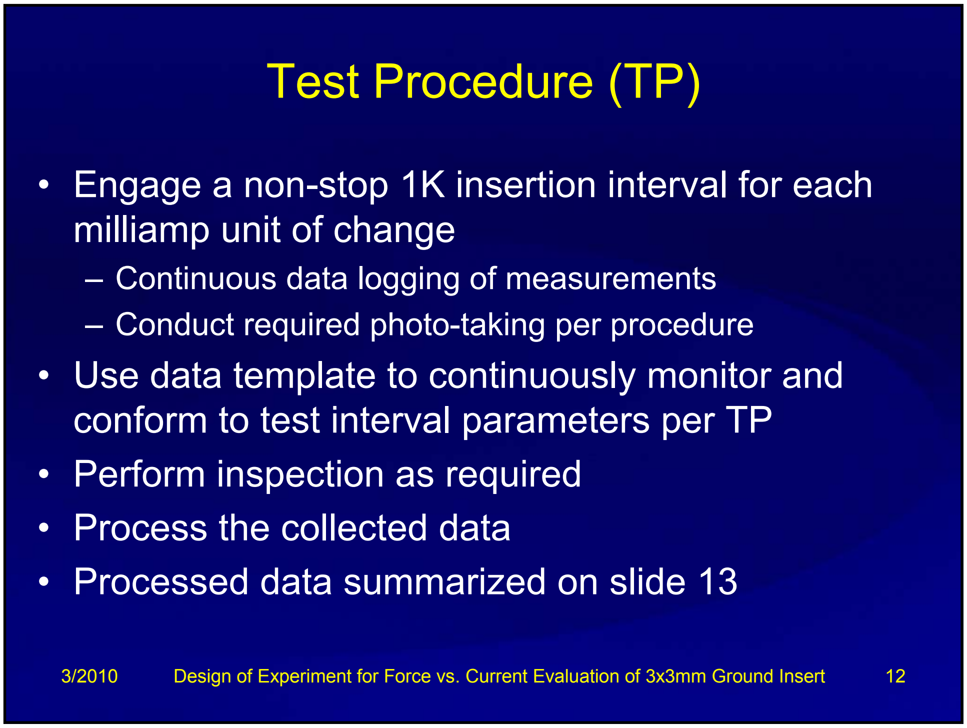

Test Procedure (TP)

- Engage a non-stop 1K insertion interval for each milliamp unit of change
  - Continuous data logging of measurements
  - Conduct required photo-taking per procedure
- Use data template to continuously monitor and conform to test interval parameters per TP
- Perform inspection as required
- Process the collected data
- Processed data summarized on slide 13

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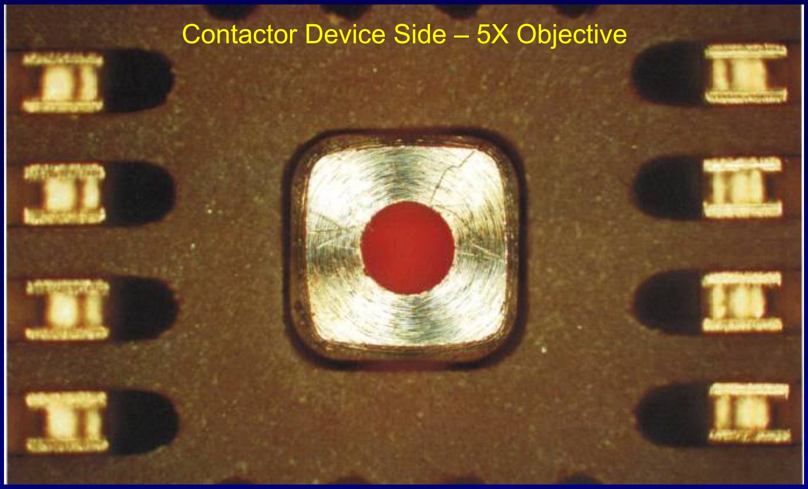
Table 1. Force/Current/CRES

Applied Force (lbs.)	10 mA Current	100 mA Current	500 mA Current	2000 mA Current	5000 mA Current
4.5	1.0 mΩ	2.0 mΩ	3.0 mΩ	6.0 mΩ	3.0 mΩ
18	0.7 mΩ	1.0 mΩ	0.8 mΩ	0.8 mΩ	0.9 mΩ
30	4.6 mΩ	4.3 mΩ	4.2 mΩ	5.9 mΩ	2.0 mΩ

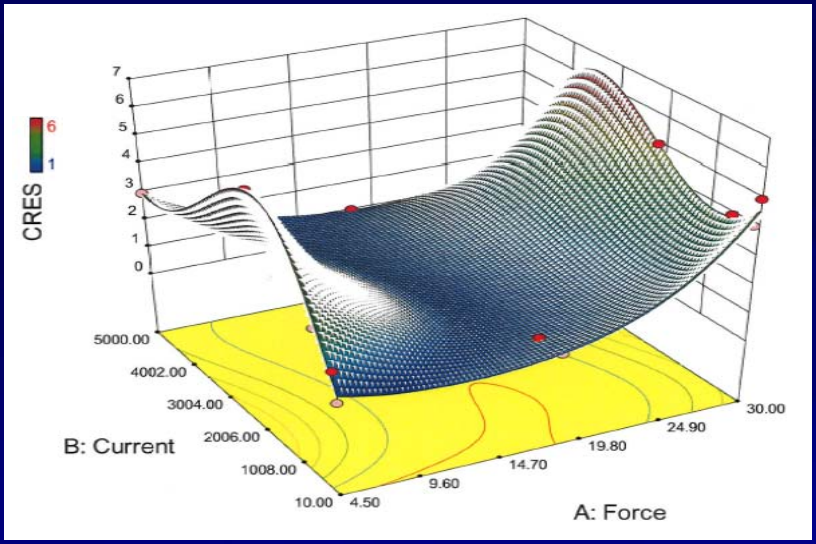
Ground Insert: @ 0 Actuations

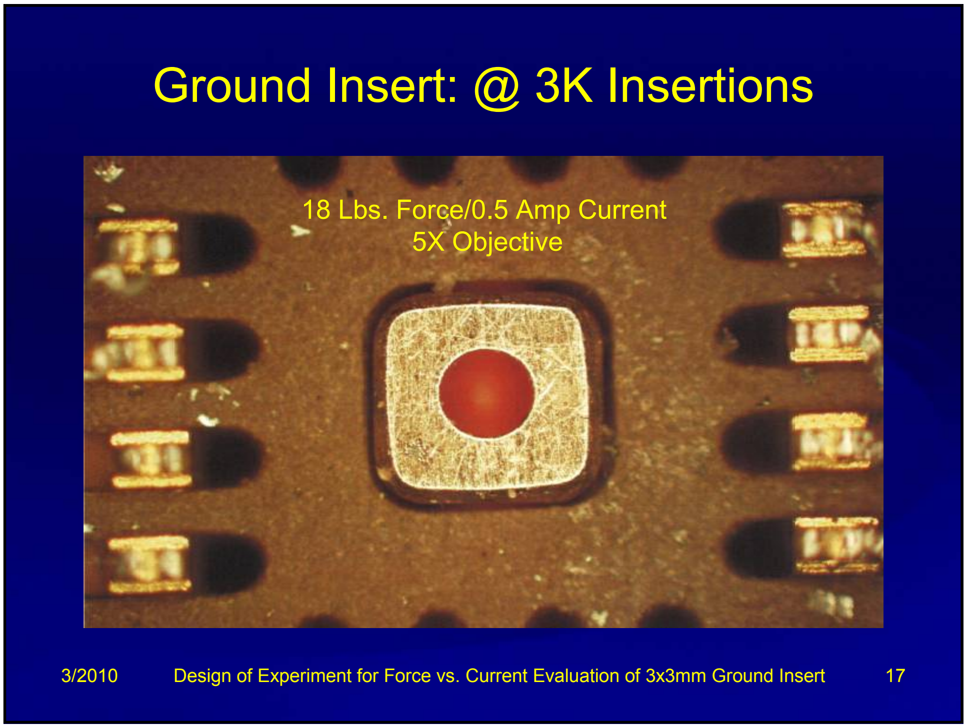


Analysis of Ground Insert DOE

- Insert size is 3x3mm
- Total of 15 standard runs
- Statistical analysis was done via DX8 software
- ANOVA
- Model of the result is shown on slide 16

3D Plot: Force/Current/CRES





Ground Insert: @ 3K Insertions

18 Lbs. Force/0.5 Amp Current
5X Objective

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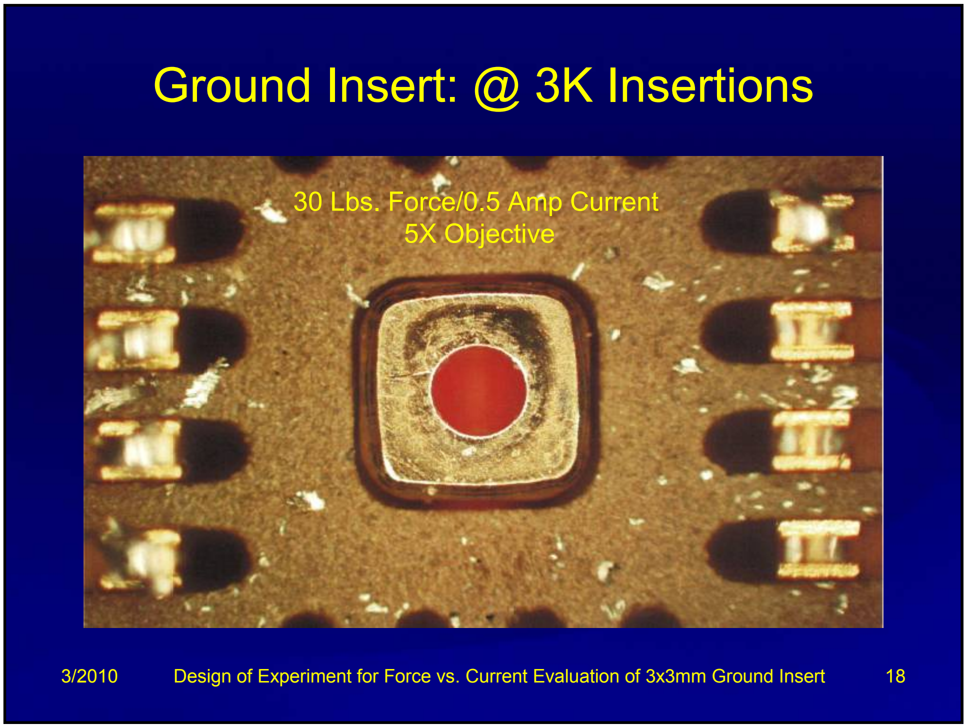

Ground Insert: @ 3K Insertions

30 Lbs. Force/0.5 Amp Current
5X Objective

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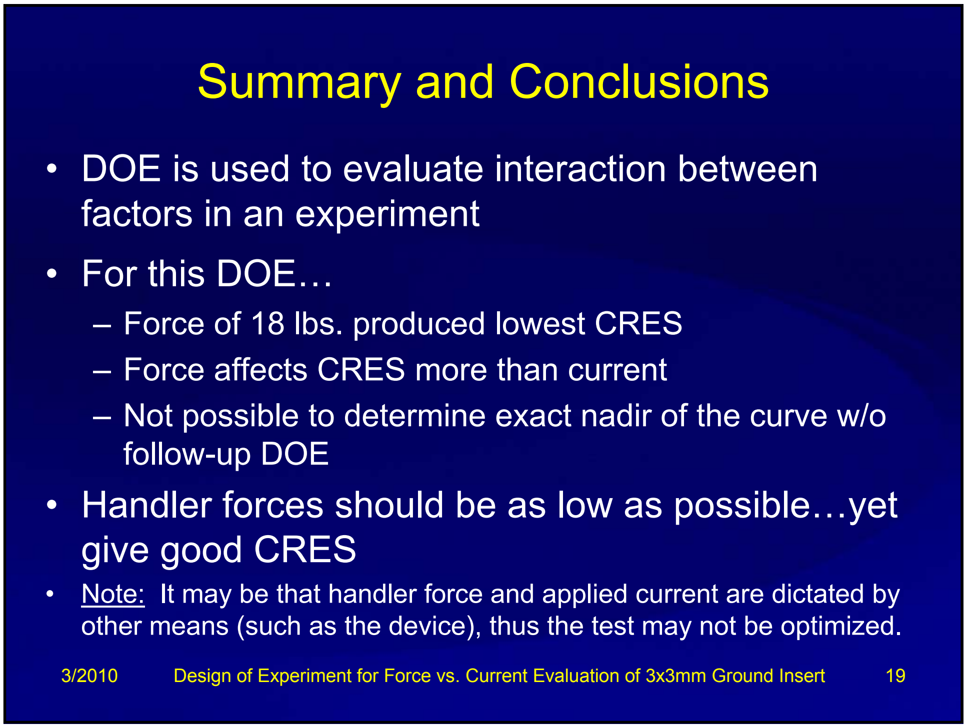
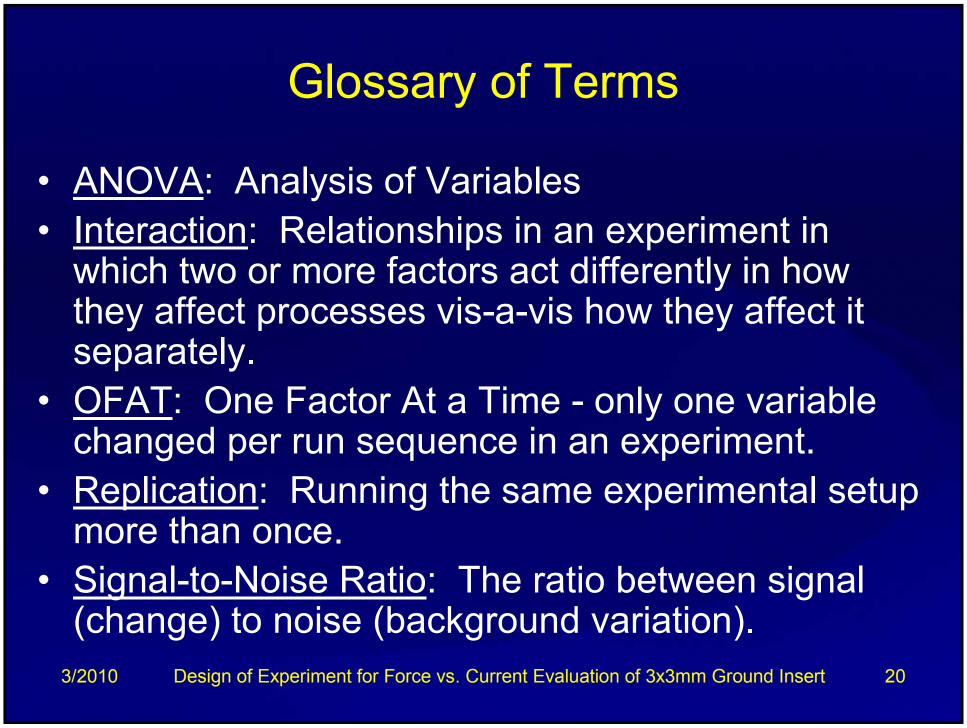


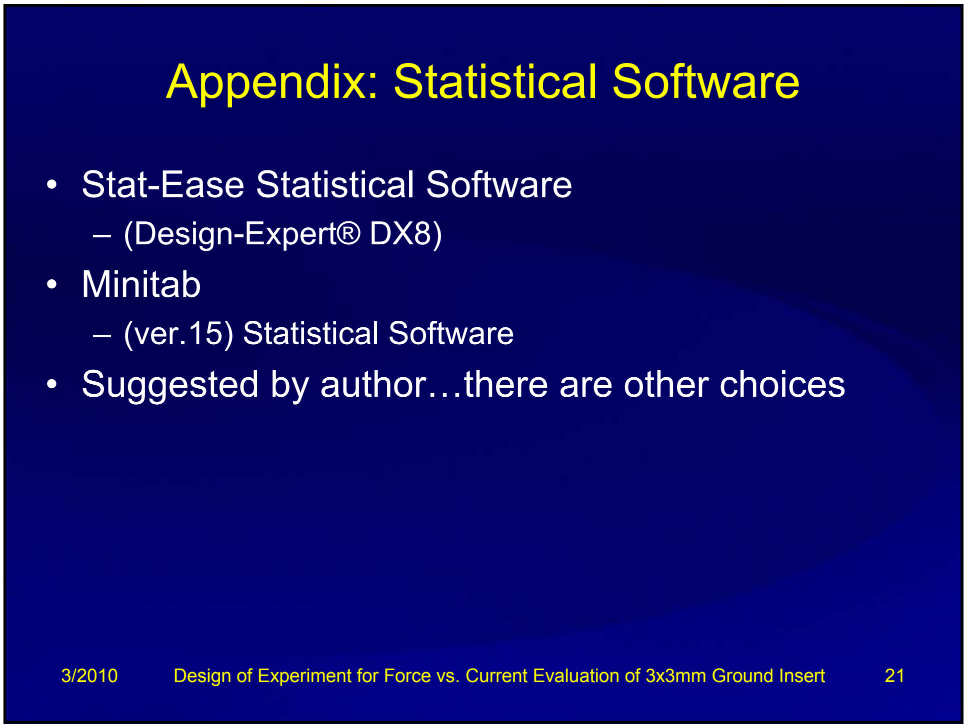
Summary and Conclusions

- DOE is used to evaluate interaction between factors in an experiment
- For this DOE…
  - Force of 18 lbs. produced lowest CRES
  - Force affects CRES more than current
  - Not possible to determine exact nadir of the curve w/o follow-up DOE
- Handler forces should be as low as possible…yet give good CRES
- Note: It may be that handler force and applied current are dictated by other means (such as the device), thus the test may not be optimized.



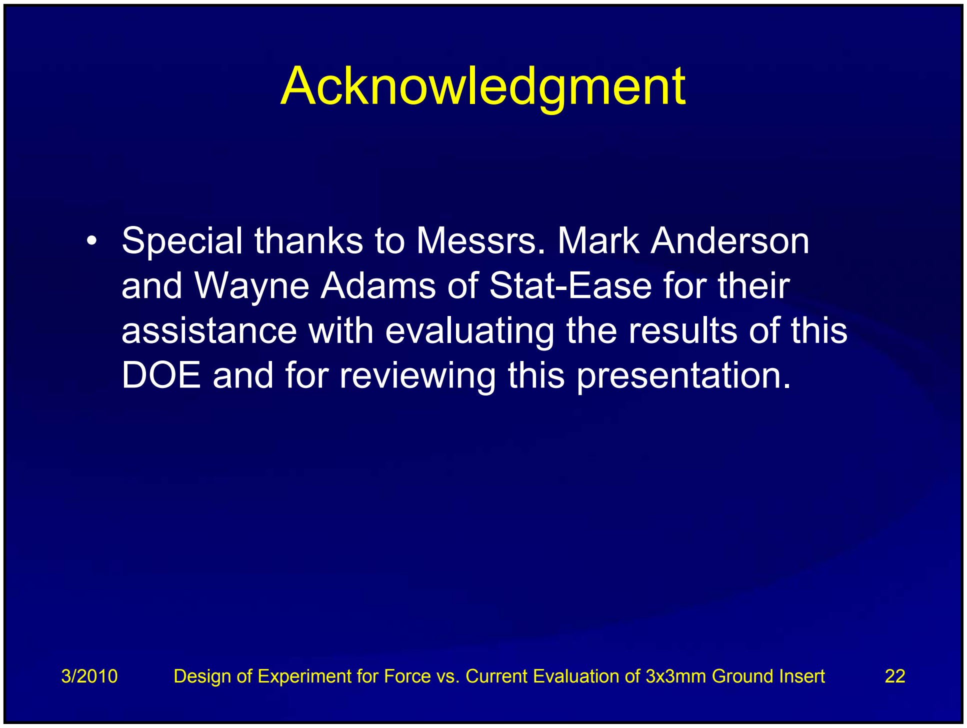
Glossary of Terms

- ANOVA: Analysis of Variables
- Interaction: Relationships in an experiment in which two or more factors act differently in how they affect processes vis-a-vis how they affect it separately.
- OFAT: One Factor At a Time - only one variable changed per run sequence in an experiment.
- Replication: Running the same experimental setup more than once.
- Signal-to-Noise Ratio: The ratio between signal (change) to noise (background variation).



Appendix: Statistical Software

- Stat-Ease Statistical Software
  - (Design-Expert® DX8)
- Minitab
  - (ver.15) Statistical Software
- Suggested by author…there are other choices



Acknowledgment

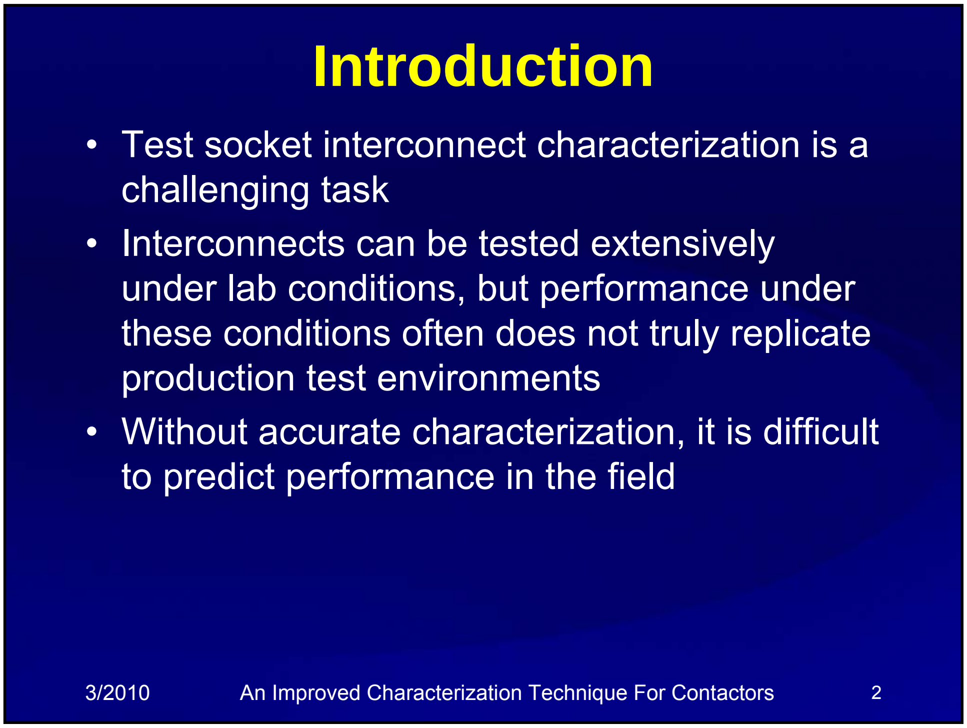
- Special thanks to Messrs. Mark Anderson and Wayne Adams of Stat-Ease for their assistance with evaluating the results of this DOE and for reviewing this presentation.

An Improved Characterization Technique For Contactors

Ryan Satrom
Marcus Frey, Valts Treibergs

Multitest Electronic Systems

2010 BiTS Workshop
March 7 - 10, 2010



Introduction

- Test socket interconnect characterization is a challenging task
- Interconnects can be tested extensively under lab conditions, but performance under these conditions often does not truly replicate production test environments
- Without accurate characterization, it is difficult to predict performance in the field

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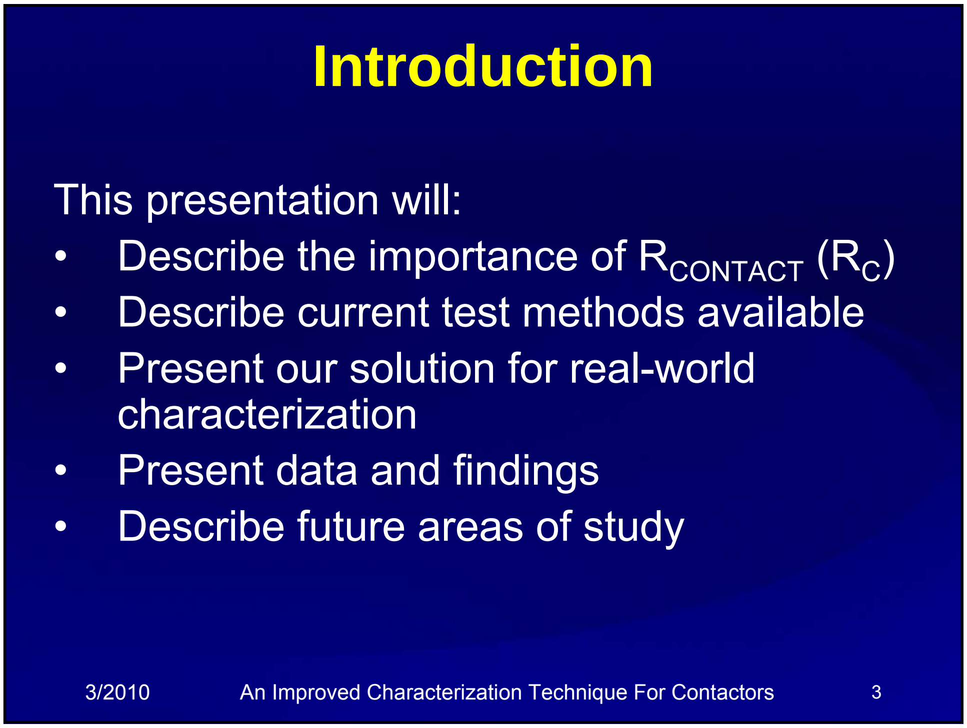
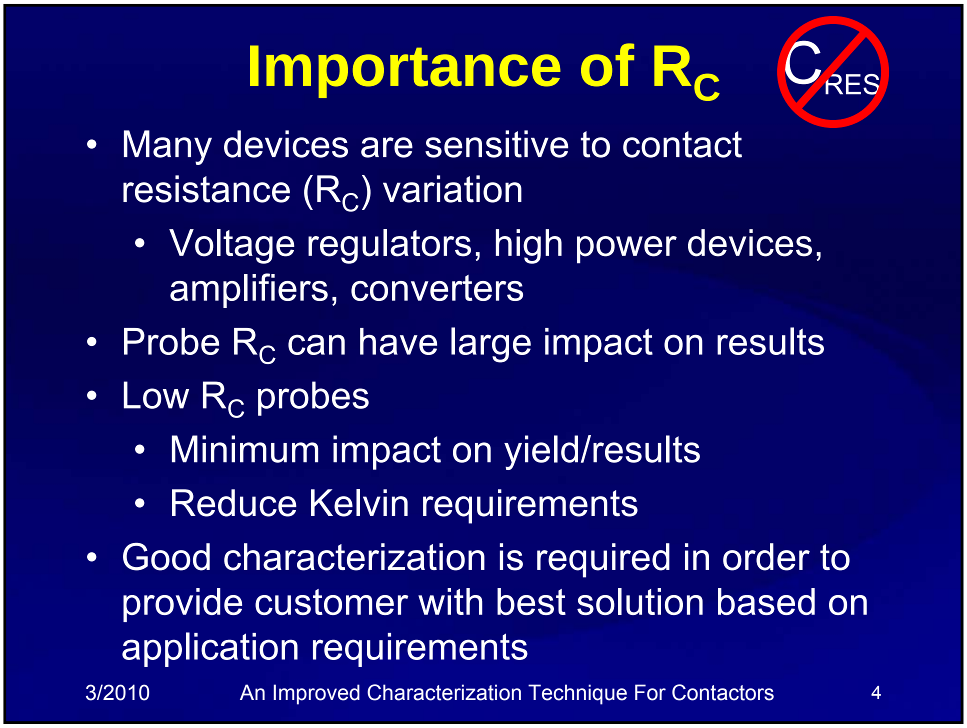


Introduction

This presentation will:

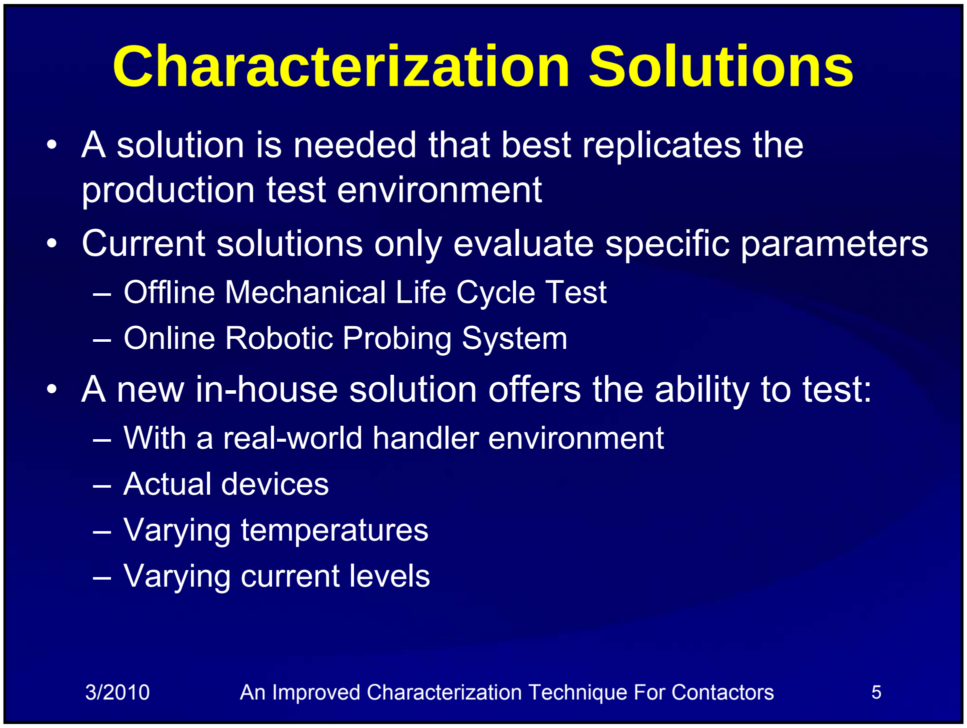
- Describe the importance of $R_{CONTACT}$ (R_C)
- Describe current test methods available
- Present our solution for real-world characterization
- Present data and findings
- Describe future areas of study



Importance of R_C

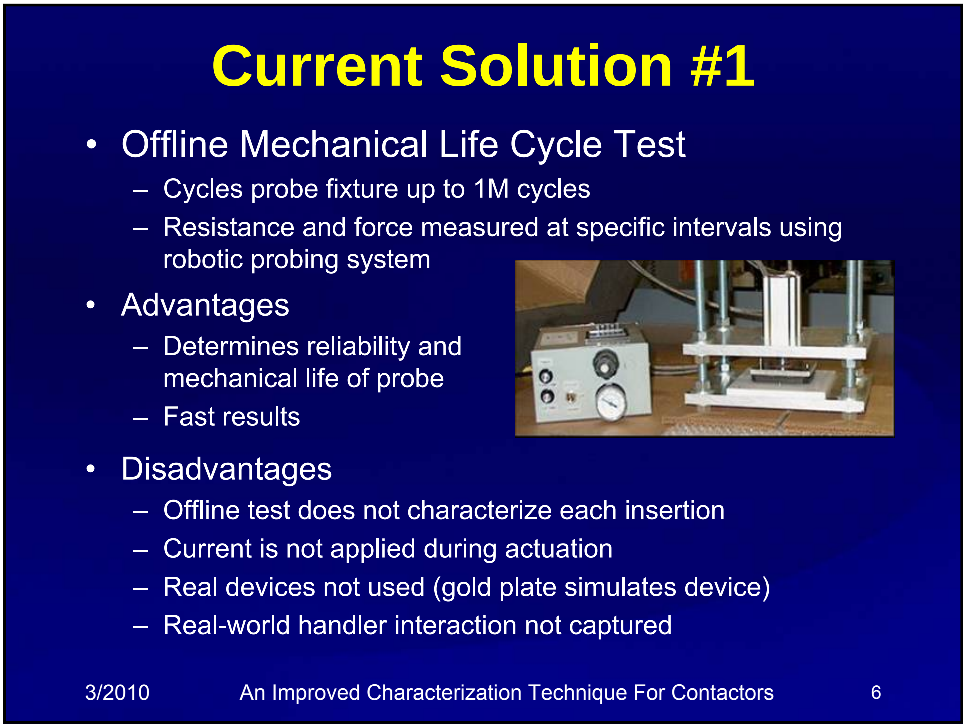
C_{RES}

- Many devices are sensitive to contact resistance (R_C) variation
  - Voltage regulators, high power devices, amplifiers, converters
- Probe R_C can have large impact on results
- Low R_C probes
  - Minimum impact on yield/results
  - Reduce Kelvin requirements
- Good characterization is required in order to provide customer with best solution based on application requirements



Characterization Solutions

- A solution is needed that best replicates the production test environment
- Current solutions only evaluate specific parameters
  - Offline Mechanical Life Cycle Test
  - Online Robotic Probing System
- A new in-house solution offers the ability to test:
  - With a real-world handler environment
  - Actual devices
  - Varying temperatures
  - Varying current levels



Current Solution #1

- Offline Mechanical Life Cycle Test
  - Cycles probe fixture up to 1M cycles
  - Resistance and force measured at specific intervals using robotic probing system
- Advantages
  - Determines reliability and mechanical life of probe
  - Fast results
- Disadvantages
  - Offline test does not characterize each insertion
  - Current is not applied during actuation
  - Real devices not used (gold plate simulates device)
  - Real-world handler interaction not captured

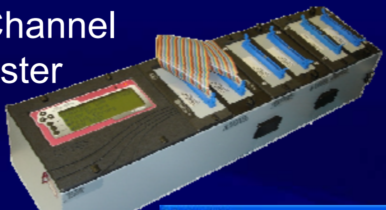
Current Solution #2

- Online Robotic Probing System
  - Resistance measured during each cycle
- Advantages
  - Contacts fresh simulated DUT surface each cycle
  - Simulated DUT surface can match device plating
  - Current applied during actuation
  - Fast results
- Disadvantages
  - Real devices not used (gold plate simulates device)
  - Real-world handler interaction not captured

New Characterization Solution

- Real-World Tester/Handler System
  - Replicates true production test environment
- Advantages
  - Tests actual devices
  - Accounts for probe-device interface
    - Solder migration, surface wear, oxidation
  - Tests various temperatures
  - Tests multiple current levels during each actuation
- Disadvantages
  - Slower results
  - Requires capital and ongoing investment

New Characterization Solution



512-Channel Tester

Multitest Handler & Delta Handler

The Denogginizer

Options Debug

Test Options
● Create Test ○ Open Test
Test Name: mer050_qfn_100K
ECT Probe: MER050
Tests per Device: 5

Test Mode
● Denogginizer Mode (Tester)
○ New Mode (Reed Switch)

Bin Failures?
● YES ○ NO
Failure Threshold 10 Ω

Test Type
● 32QFN ○ 100BGA ○ Other
Measurements Per Test: 44

Number of Tests
● Indefinite ○ Fixed

NOT READY Continue True

Test Info
Test Name: mer050_qfn_100K
ECT Probe MER050
Test Mode Denogginizer
Tests per Device 5
Measurements Per Test: 44
Bin Failures? YES

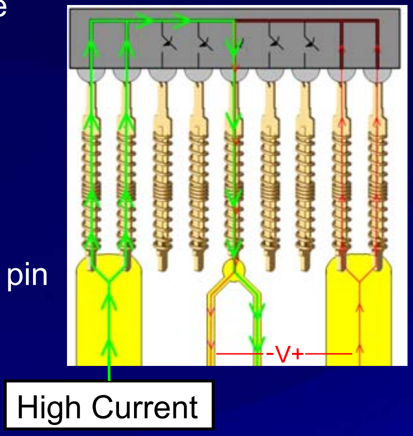
Real-time Data
Current Test Cycles: 48635
Tests to be run: INDEFINITE
Status: 2048
Test Site Temperature: 25.4

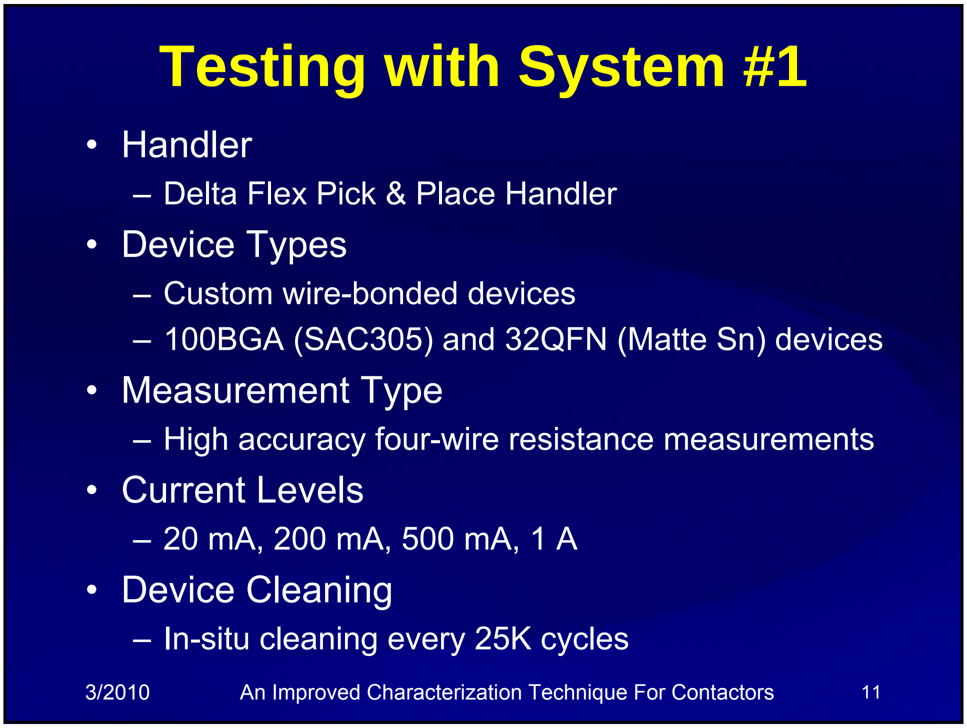
Test Controls
START TEST
STOP TEST
● Continuous
○ Single Test
○ Manual Test

Customized "Denogginizer" Software

Tester Four-Wire Measurement

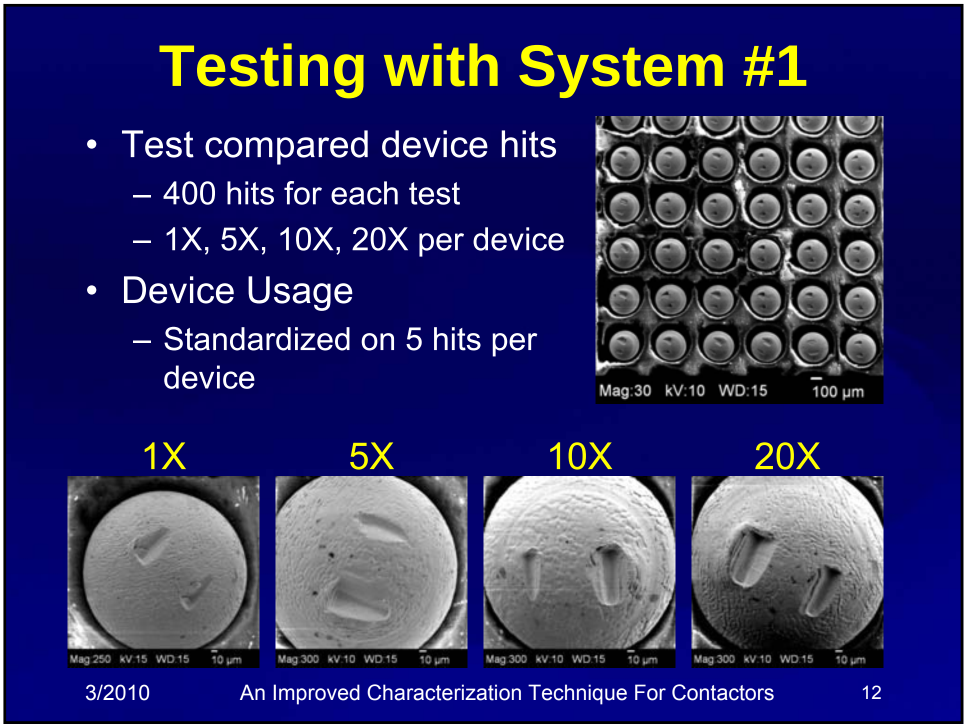
- Power bussed through multiple probes
- Green – High current signal
  - 20 mA-1 A
- Red – Voltage measurement
  - ~10 pA
- Measures voltage drop across pin and small length of wire bond
- Resistance = Voltage/Current





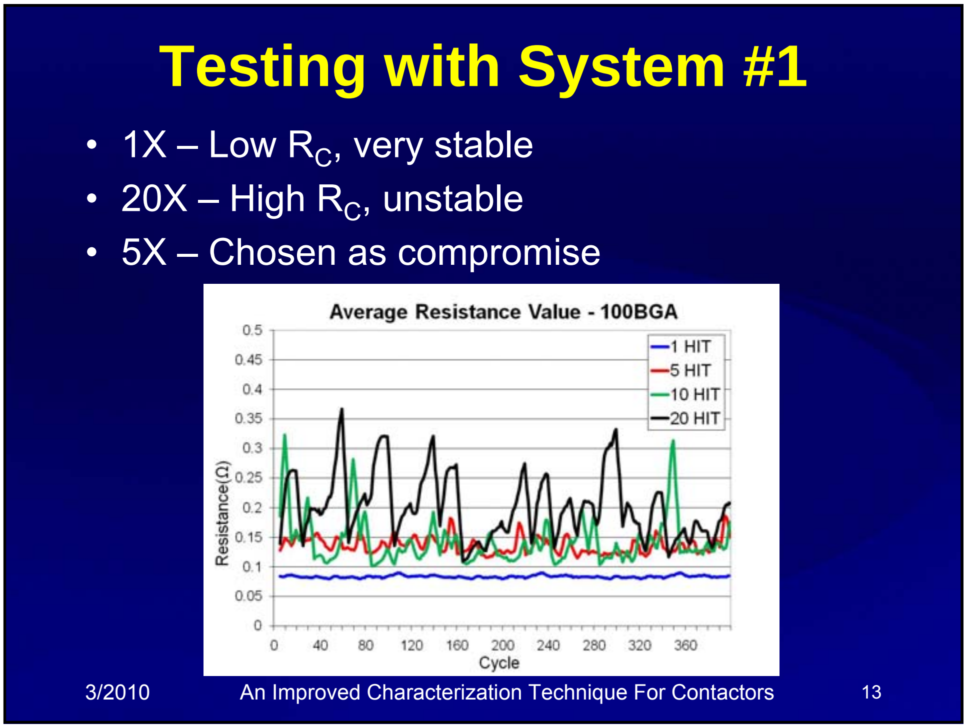
Testing with System #1

- Handler
  - Delta Flex Pick & Place Handler
- Device Types
  - Custom wire-bonded devices
  - 100BGA (SAC305) and 32QFN (Matte Sn) devices
- Measurement Type
  - High accuracy four-wire resistance measurements
- Current Levels
  - 20 mA, 200 mA, 500 mA, 1 A
- Device Cleaning
  - In-situ cleaning every 25K cycles



Testing with System #1

- Test compared device hits
  - 400 hits for each test
  - 1X, 5X, 10X, 20X per device
- Device Usage
  - Standardized on 5 hits per device



Testing with System #1

- 1X – Low R_C, very stable
- 20X – High R_C, unstable
- 5X – Chosen as compromise

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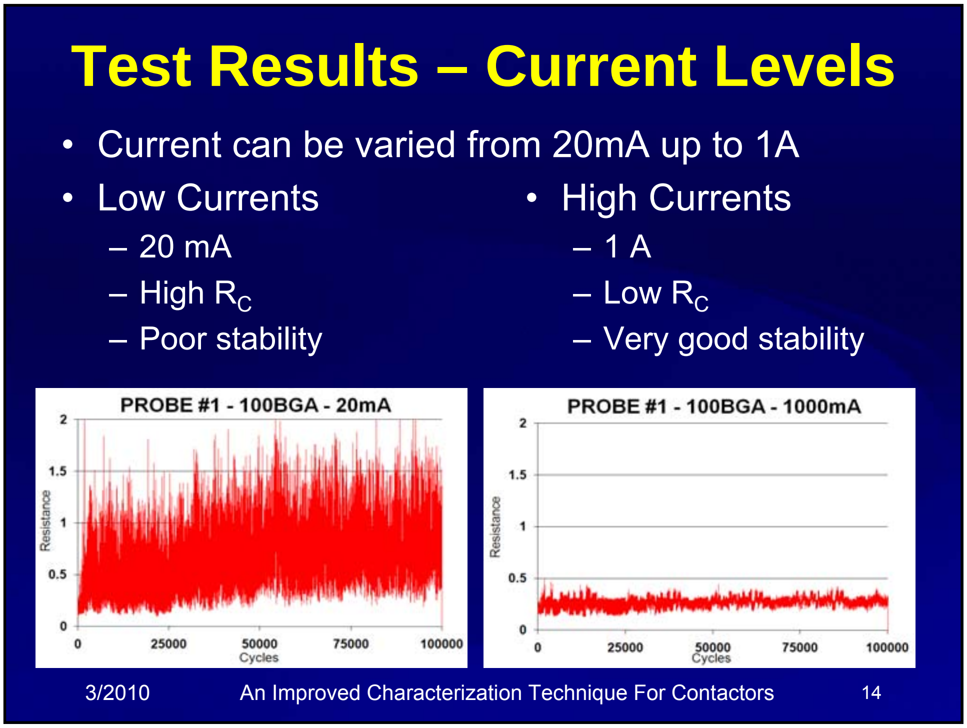

Test Results – Current Levels

- Current can be varied from 20mA up to 1A
- Low Currents
  - 20 mA
  - High R_C
  - Poor stability
- High Currents
  - 1 A
  - Low R_C
  - Very good stability

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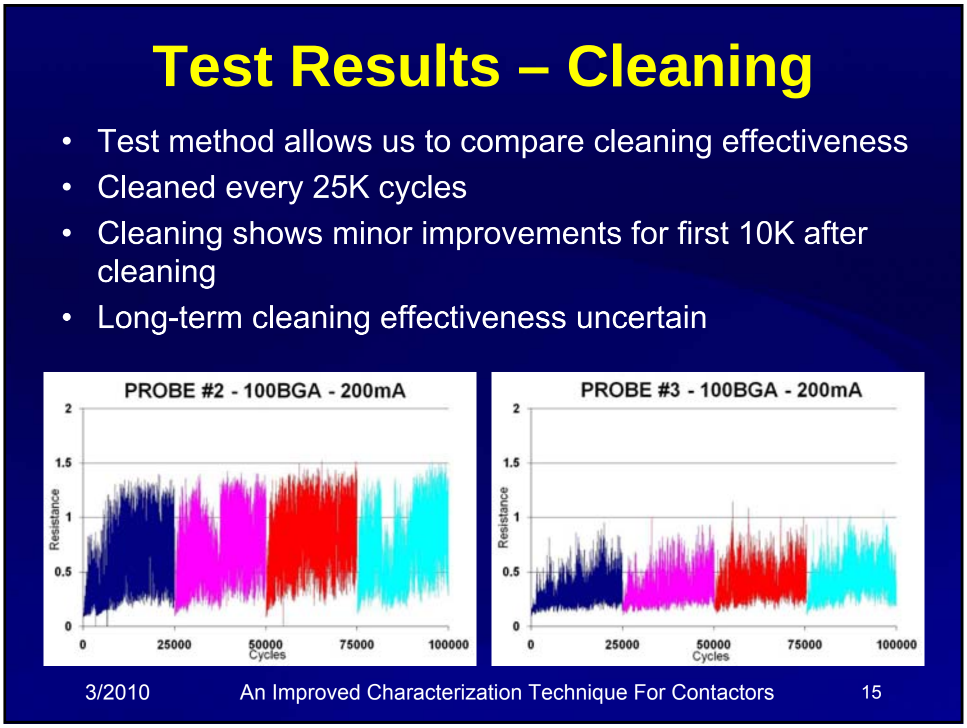

Test Results – Cleaning

- Test method allows us to compare cleaning effectiveness
- Cleaned every 25K cycles
- Cleaning shows minor improvements for first 10K after cleaning
- Long-term cleaning effectiveness uncertain

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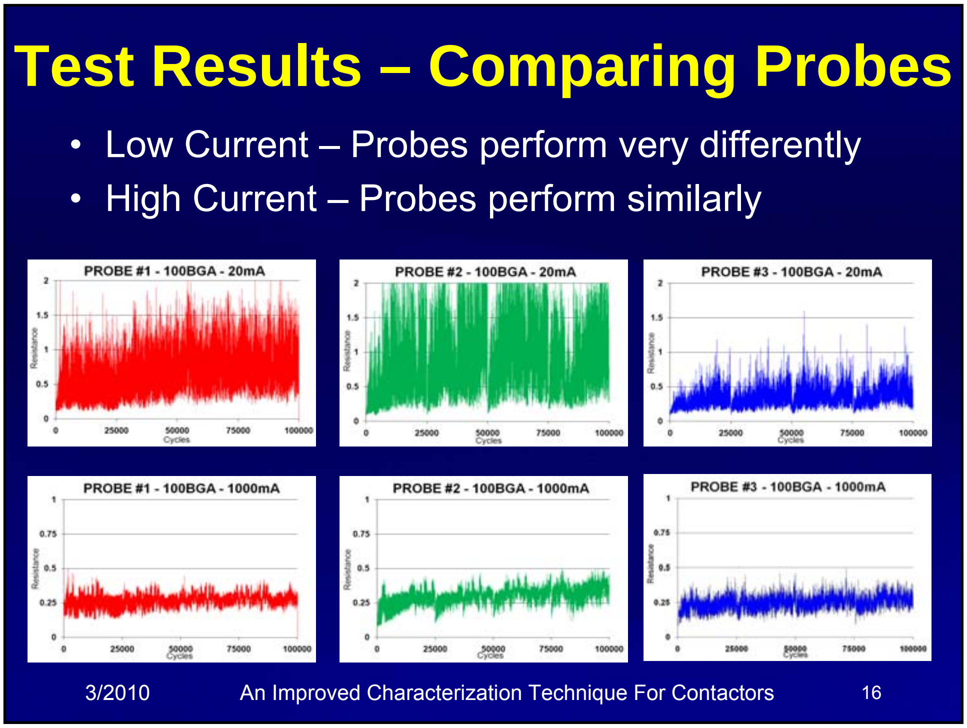

Test Results – Comparing Probes

- Low Current – Probes perform very differently
- High Current – Probes perform similarly

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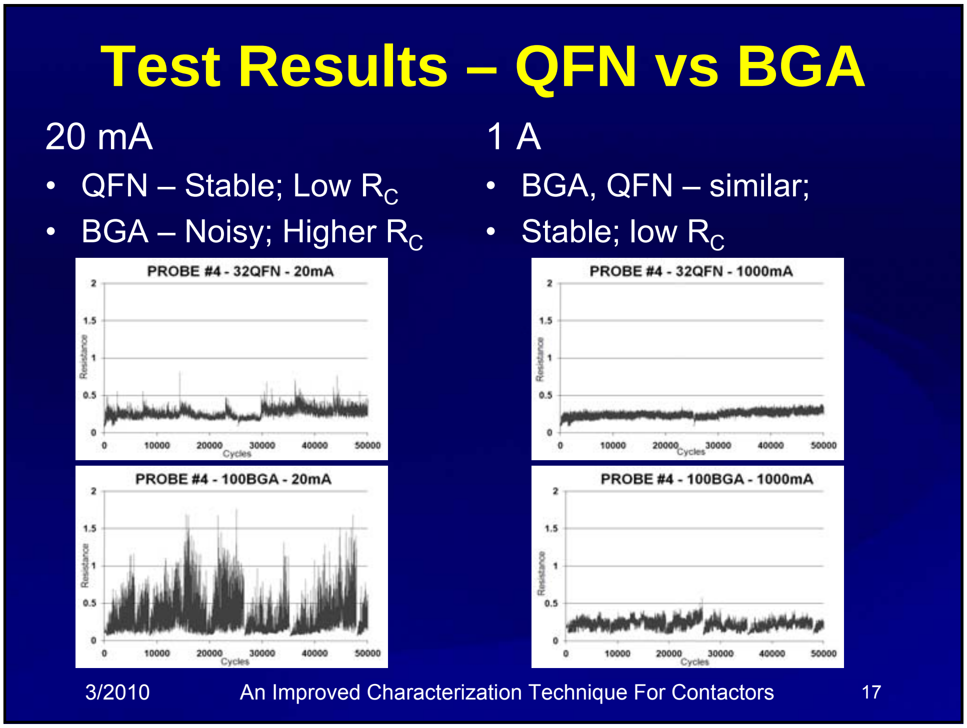

Test Results – QFN vs BGA

20 mA
- QFN – Stable; Low R_C
- BGA – Noisy; Higher R_C

1 A
- BGA, QFN – similar;
- Stable; low R_C

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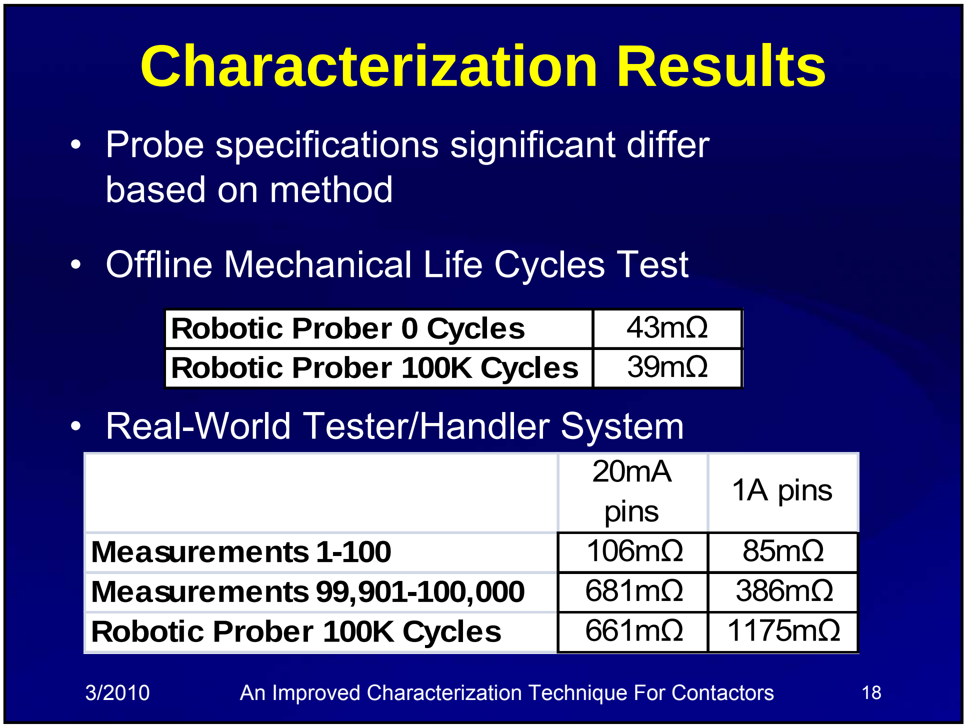

Characterization Results

- Probe specifications significant differ based on method
- Offline Mechanical Life Cycles Test

Robotic Prober 0 Cycles	43mΩ
Robotic Prober 100K Cycles	39mΩ

- Real-World Tester/Handler System

	20mA pins	1A pins
Measurements 1-100	106mΩ	85mΩ
Measurements 99,901-100,000	681mΩ	386mΩ
Robotic Prober 100K Cycles	661mΩ	1175mΩ

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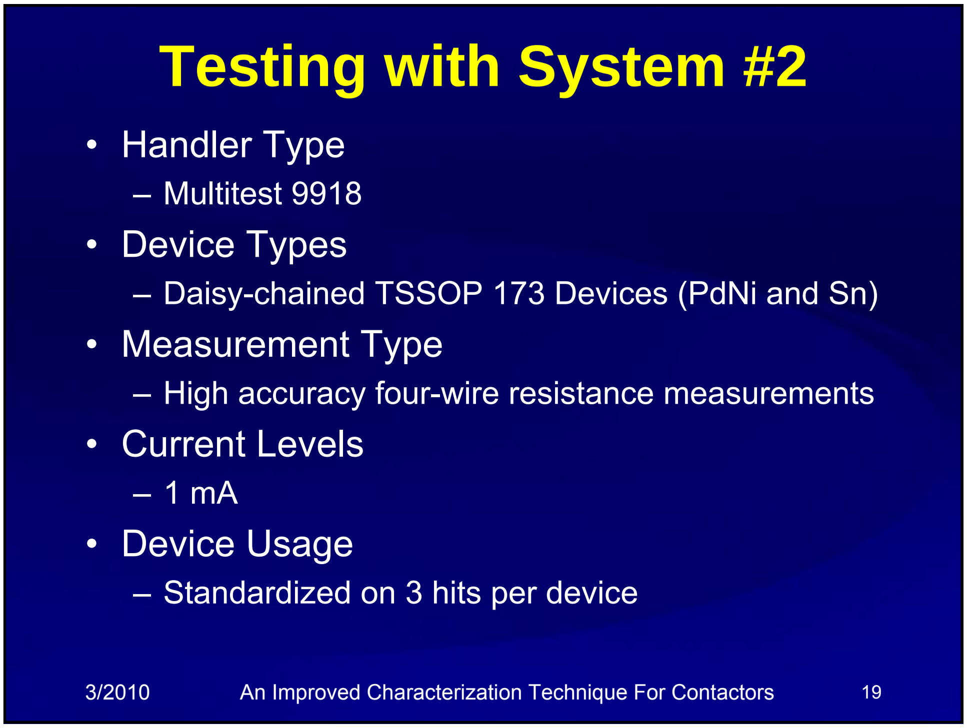
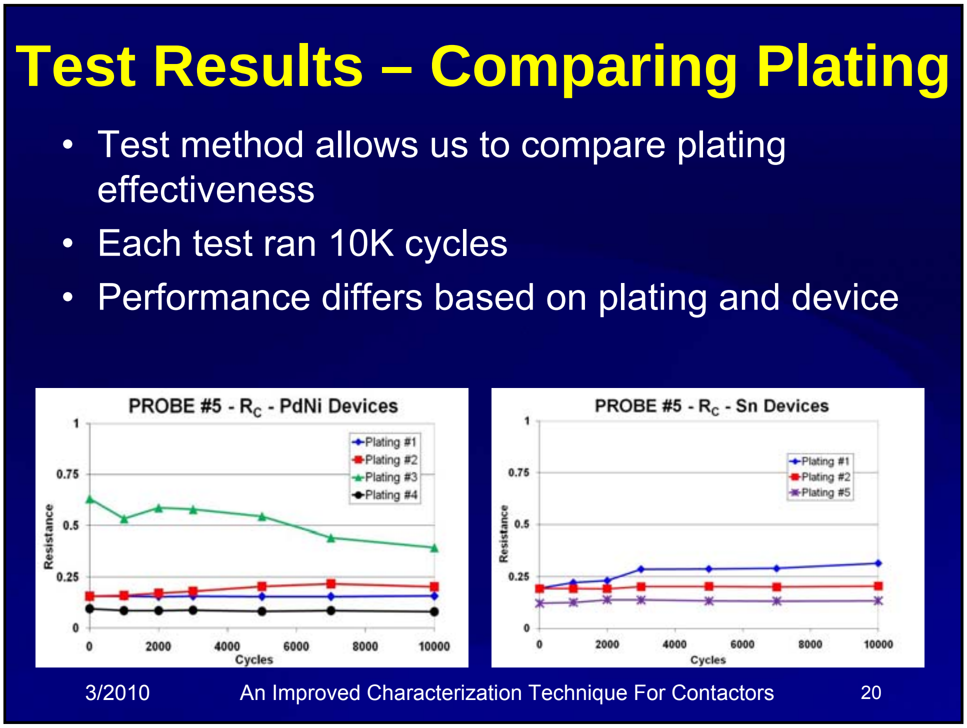


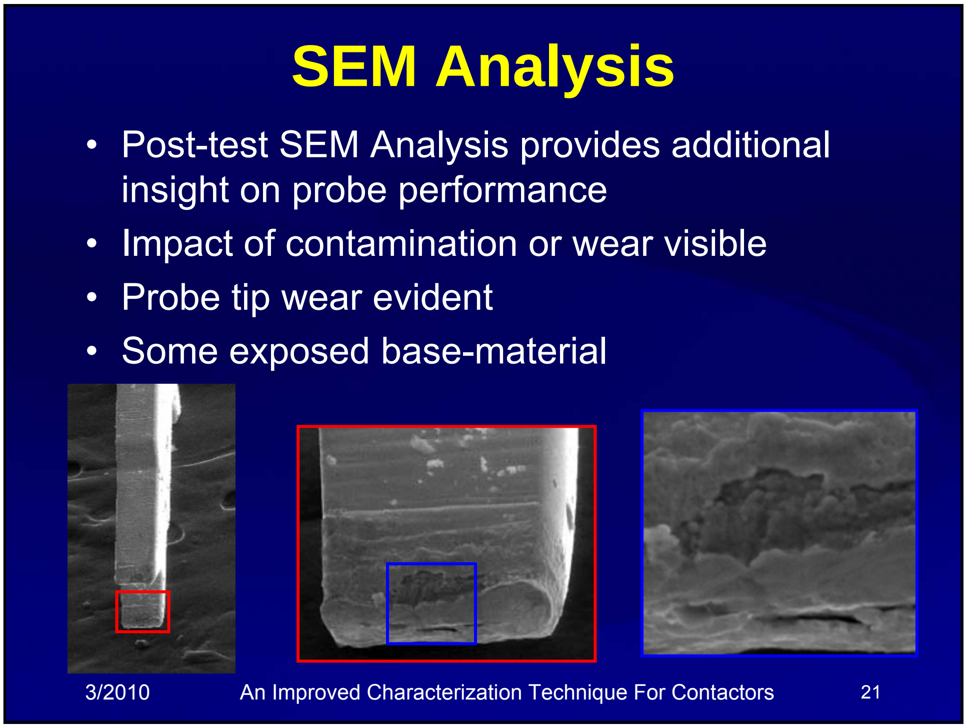
Testing with System #2

- Handler Type
  - Multitest 9918
- Device Types
  - Daisy-chained TSSOP 173 Devices (PdNi and Sn)
- Measurement Type
  - High accuracy four-wire resistance measurements
- Current Levels
  - 1 mA
- Device Usage
  - Standardized on 3 hits per device



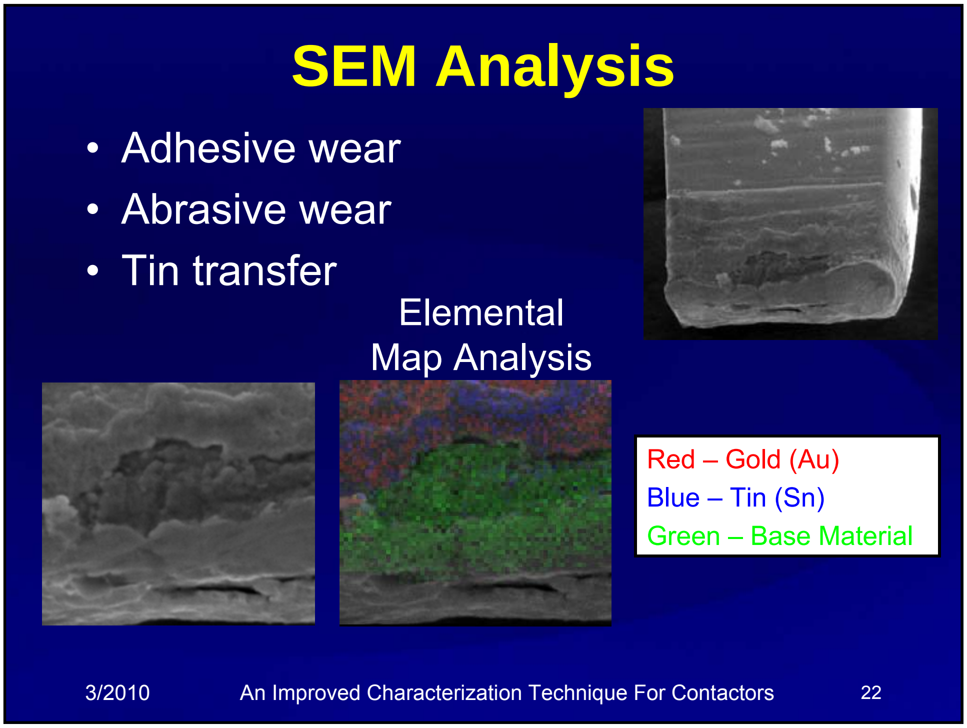
Test Results – Comparing Plating

- Test method allows us to compare plating effectiveness
- Each test ran 10K cycles
- Performance differs based on plating and device



SEM Analysis

- Post-test SEM Analysis provides additional insight on probe performance
- Impact of contamination or wear visible
- Probe tip wear evident
- Some exposed base-material

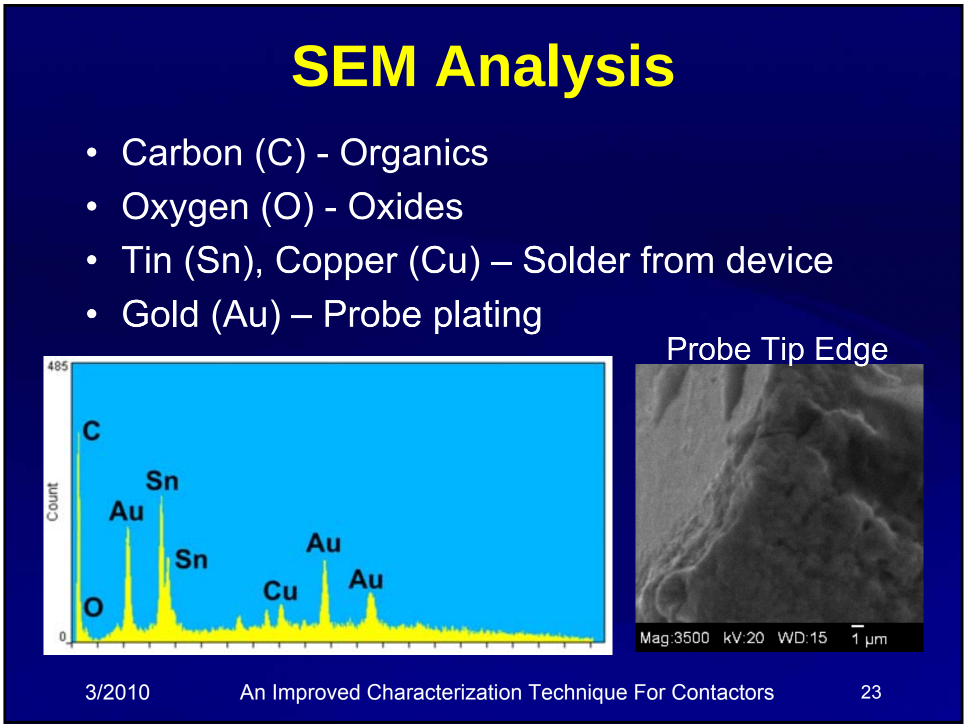


SEM Analysis

- Adhesive wear
- Abrasive wear
- Tin transfer

Elemental
Map Analysis

Red – Gold (Au)
Blue – Tin (Sn)
Green – Base Material



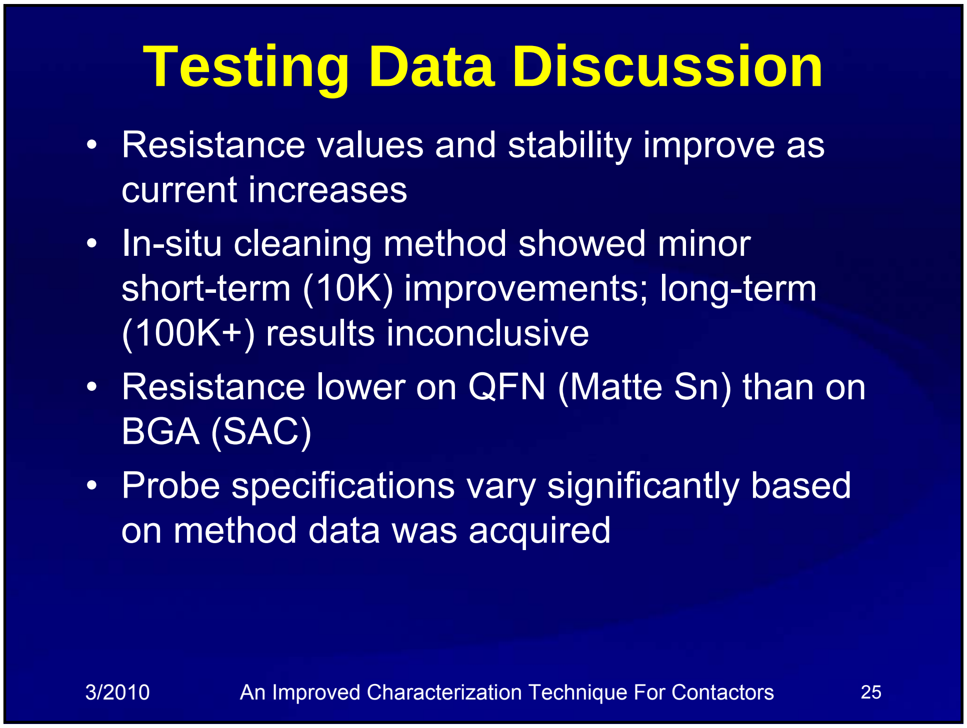
SEM Analysis

- Carbon (C) - Organics
- Oxygen (O) - Oxides
- Tin (Sn), Copper (Cu) – Solder from device
- Gold (Au) – Probe plating

Probe Tip Edge

New Method Discussion

- New solution improves characterization by replicating a real-world production test environment
- New method offers ability to test variables that were previously not possible
  - Cleaning methods on various device types
  - Probe plating on various device types
  - Testing at various temperatures
  - Testing with various current levels applied
  - Validate various alignment methods (direct vs indirect)
- New solution provides accurate performance characteristics across life of probe



Testing Data Discussion

- Resistance values and stability improve as current increases
- In-situ cleaning method showed minor short-term (10K) improvements; long-term (100K+) results inconclusive
- Resistance lower on QFN (Matte Sn) than on BGA (SAC)
- Probe specifications vary significantly based on method data was acquired

Future Goals

- Qualification of new probes
  - Verify mechanical reliability and R_C stability
- Determine contactor attributes that affect R_C results
- Characterize probe performance at various temperatures
- Define thresholds for recommending Kelvin solutions

Using Modeling to Simulate High Frequency Test Results

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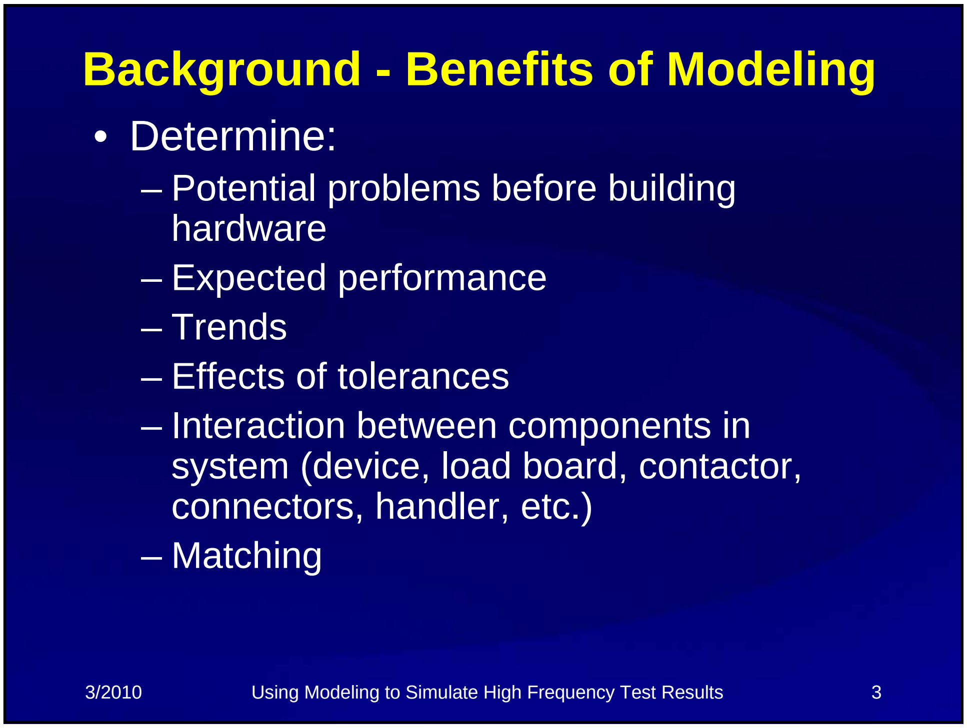
2010 BiTS Workshop
March 7 - 10, 2010

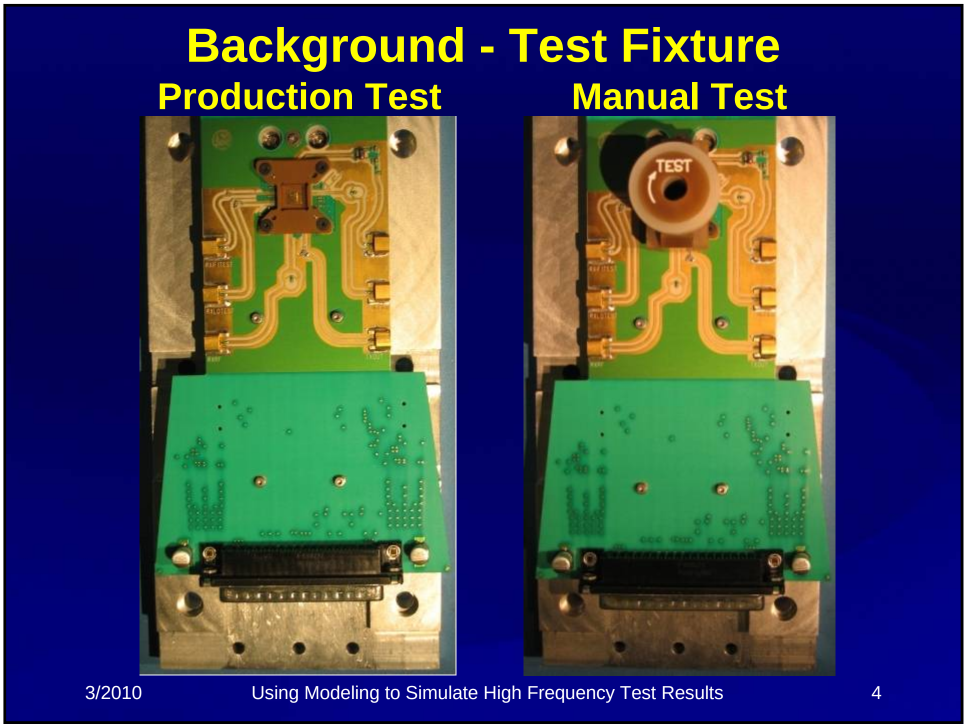
Agenda

- Background
- Modeling of test system components
  - Device
  - Load board (Effects of stubs)
  - Contactor
  - Interfaces
- Testing and de-embedding
- Comparison of modeled to measured data
- Conclusion



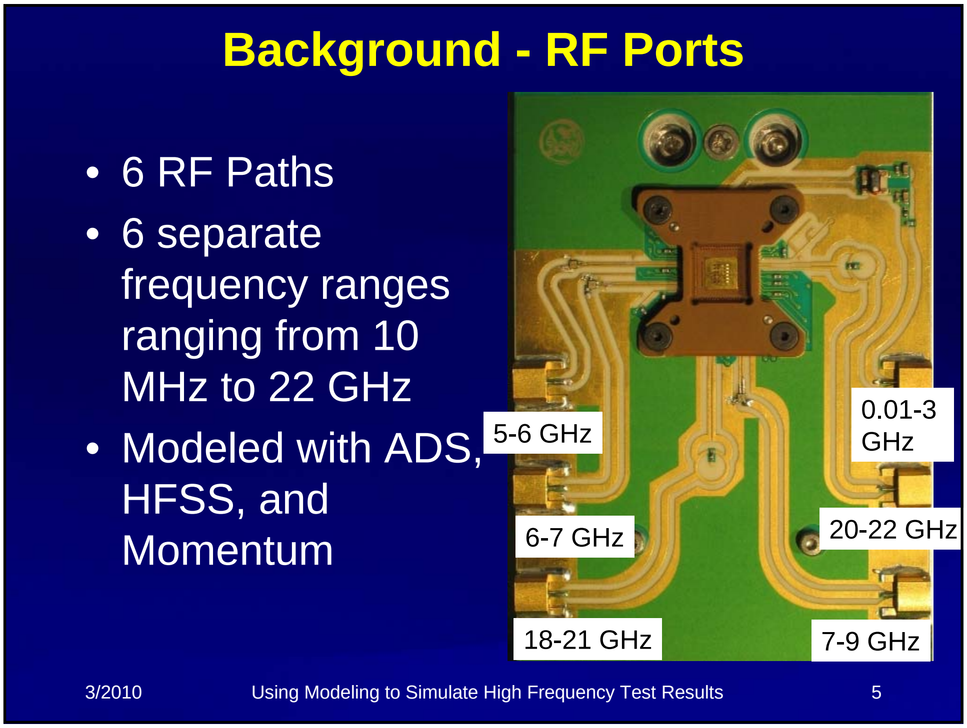
Background - Benefits of Modeling

- Determine:
  - Potential problems before building hardware
  - Expected performance
  - Trends
  - Effects of tolerances
  - Interaction between components in system (device, load board, contactor, connectors, handler, etc.)
  - Matching



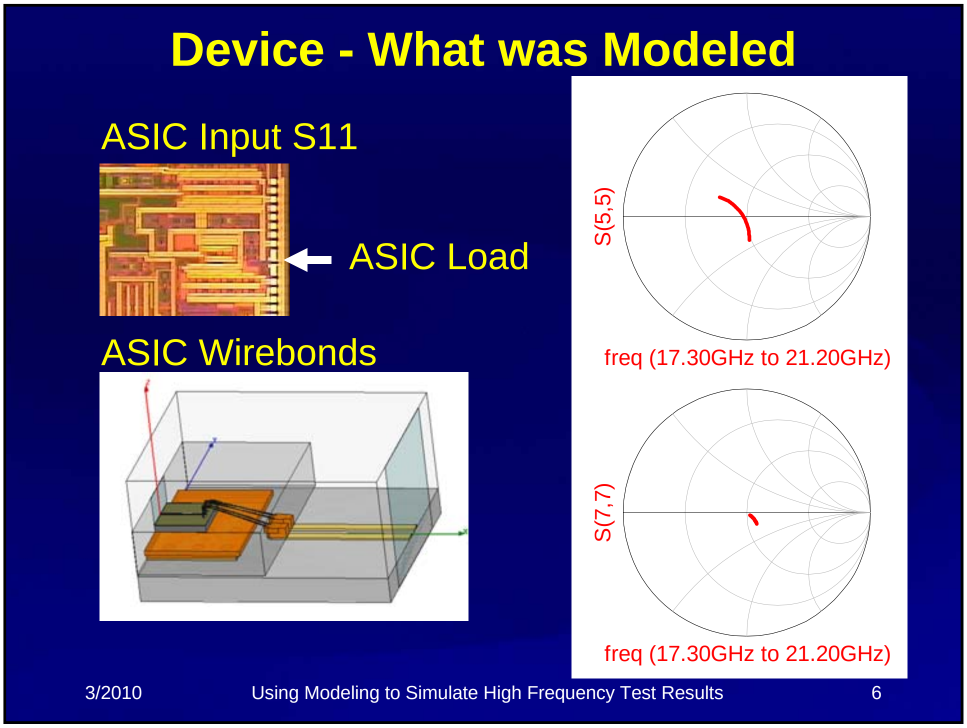
Background - Test Fixture

Production Test **Manual Test**



Background - RF Ports

- 6 RF Paths
- 6 separate frequency ranges ranging from 10 MHz to 22 GHz
- Modeled with ADS, HFSS, and Momentum



Device - What was Modeled

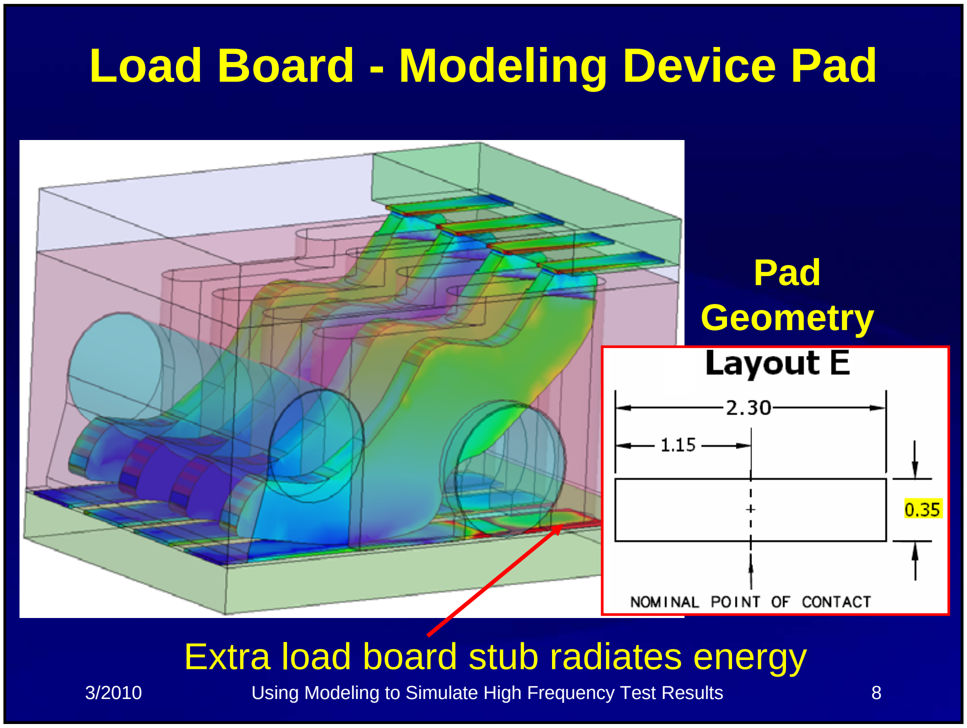
ASIC Input S11

ASIC Load

ASIC Wirebonds

Load Board - Factors That Affect System Performance

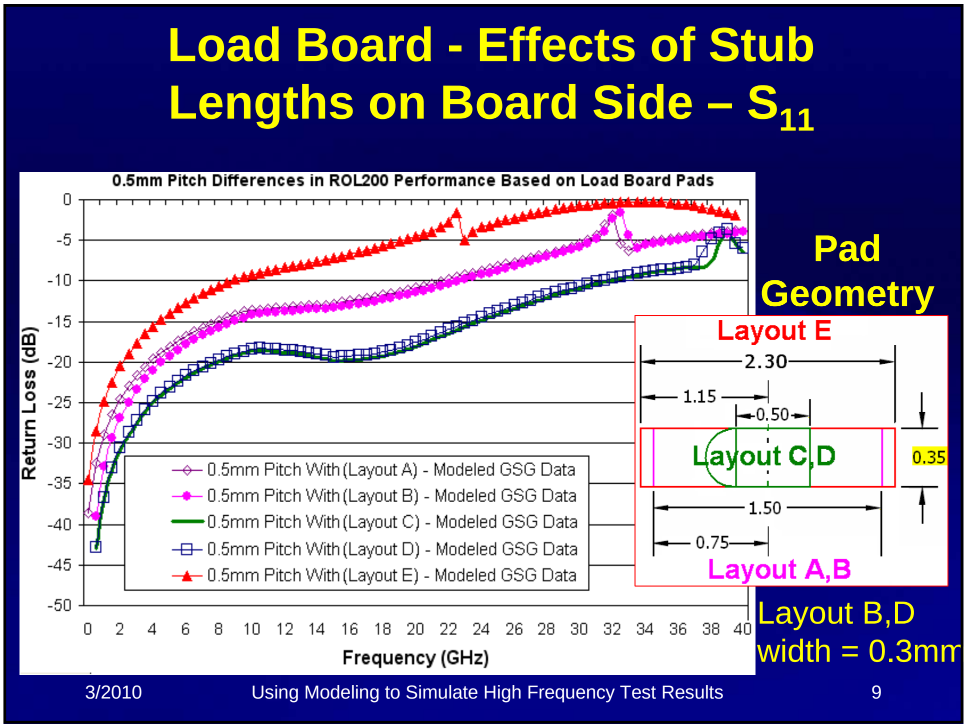
- Avoid changes in trace widths and spacing changes to ground plane
- Placement of vias and choice of substrate materials
- Thickness of load board and vias to ground plane
- Matching of load board to device parameters
- Solder to board vs. optimized pads
- Solder mask areas
- Avoid parallel traces – (GSSG)
- Connector types (RF – coaxial)
- Decoupling components close to device



Load Board - Modeling Device Pad

Pad Geometry

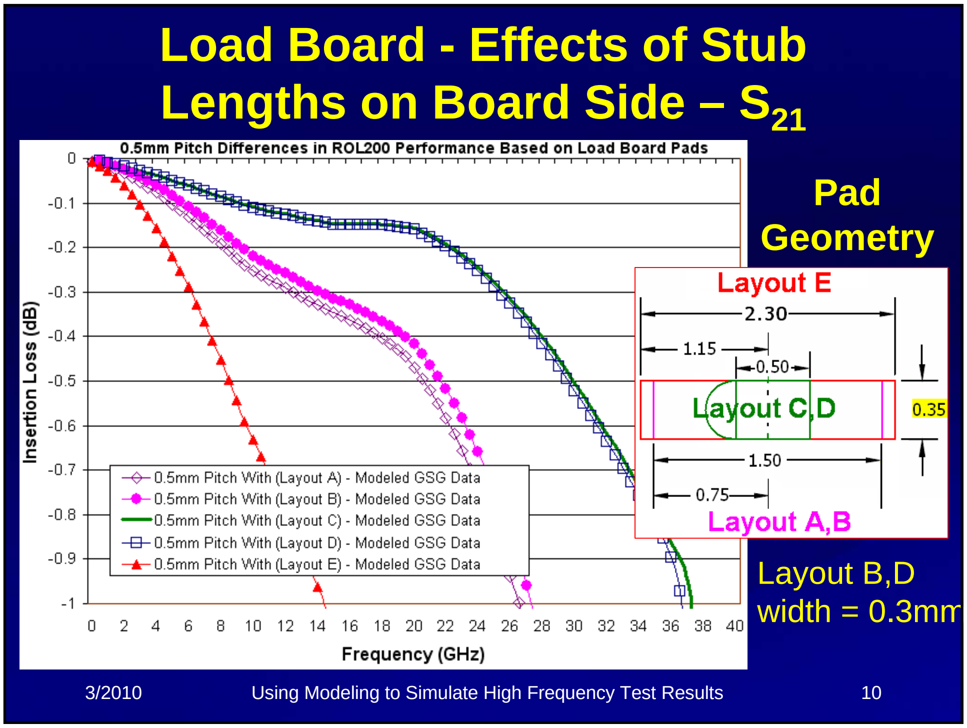
Extra load board stub radiates energy



Load Board - Effects of Stub Lengths on Board Side – S_{11}

Pad Geometry

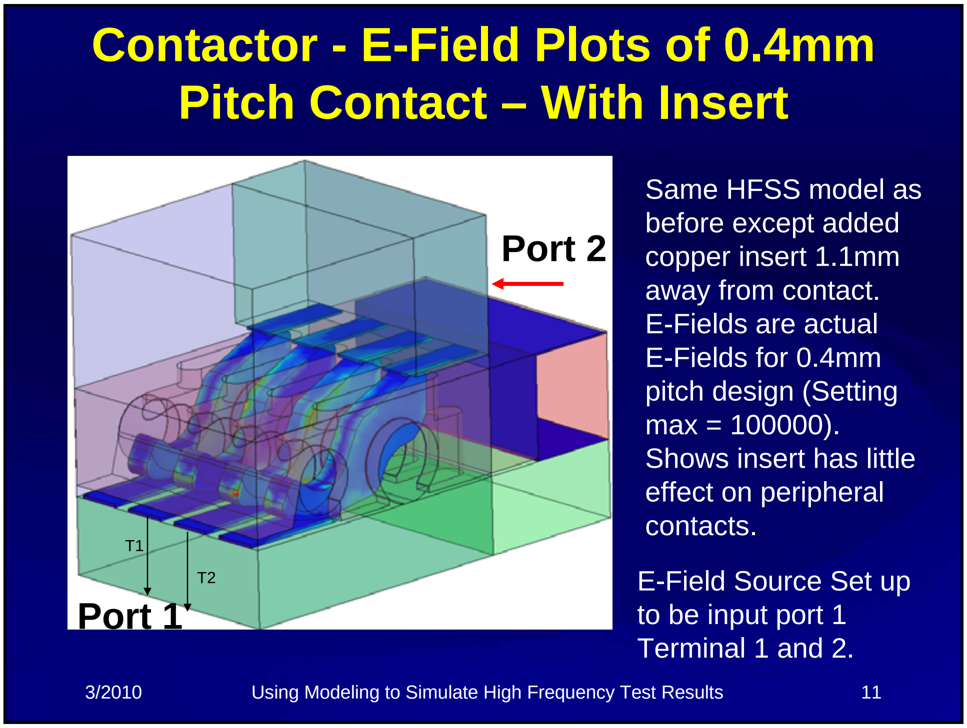
Layout B,D width = 0.3mm



Load Board - Effects of Stub Lengths on Board Side – S_{21}

Pad Geometry

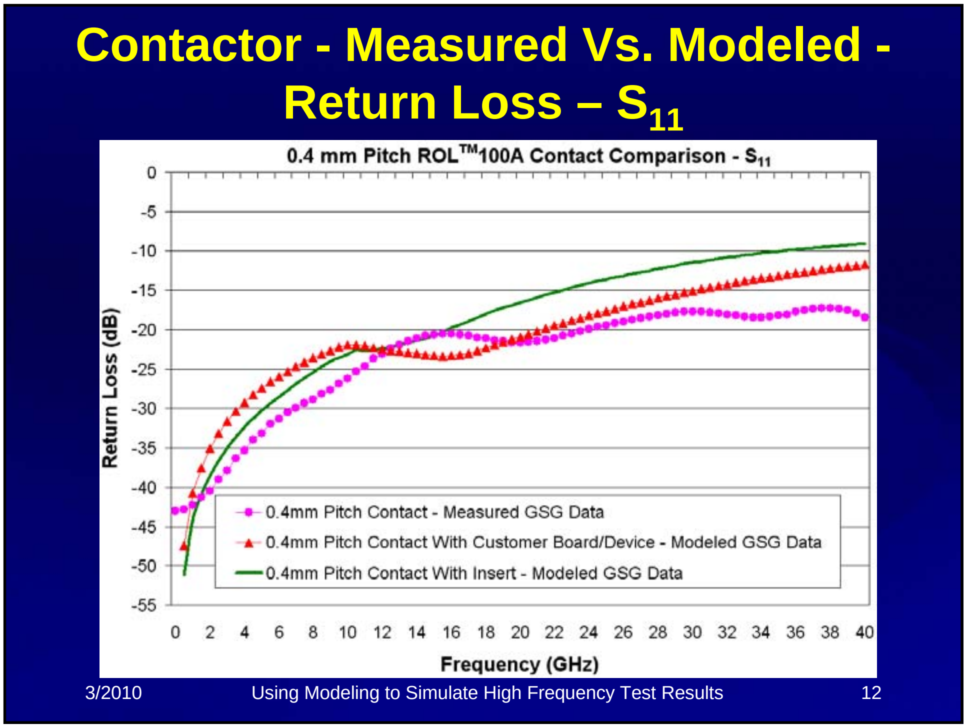
Layout B,D width = 0.3mm



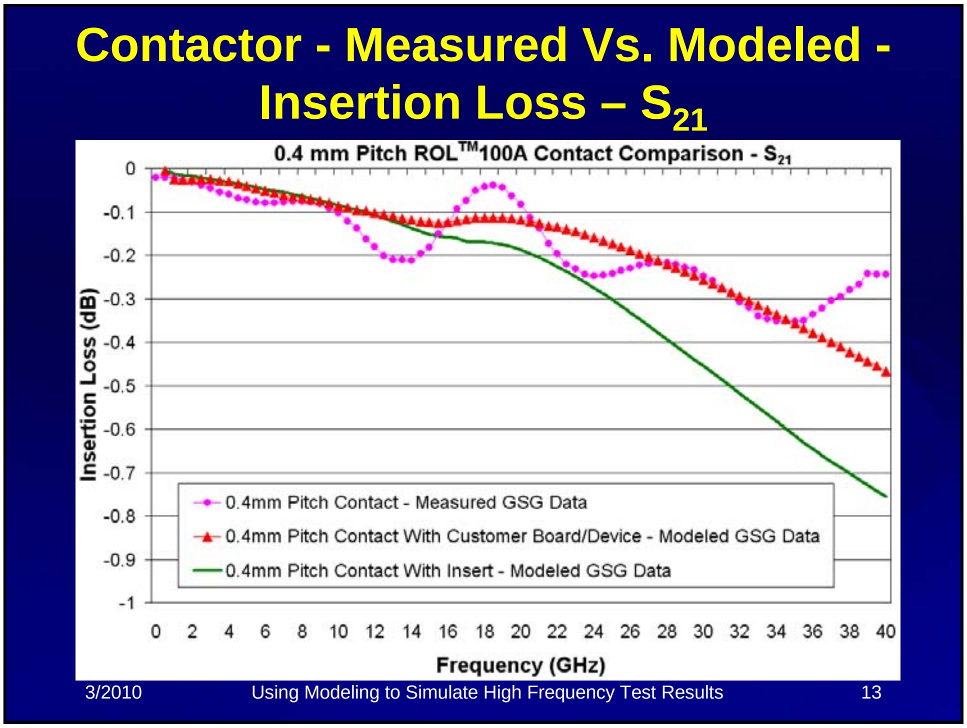
Contactor - E-Field Plots of 0.4mm Pitch Contact – With Insert

Same HFSS model as before except added copper insert 1.1mm away from contact. E-Fields are actual E-Fields for 0.4mm pitch design (Setting max = 100000). Shows insert has little effect on peripheral contacts.

E-Field Source Set up to be input port 1 Terminal 1 and 2.



Contactor - Measured Vs. Modeled - Return Loss – S_{11}



Contactor - Measured Vs. Modeled - Insertion Loss – S_{21}

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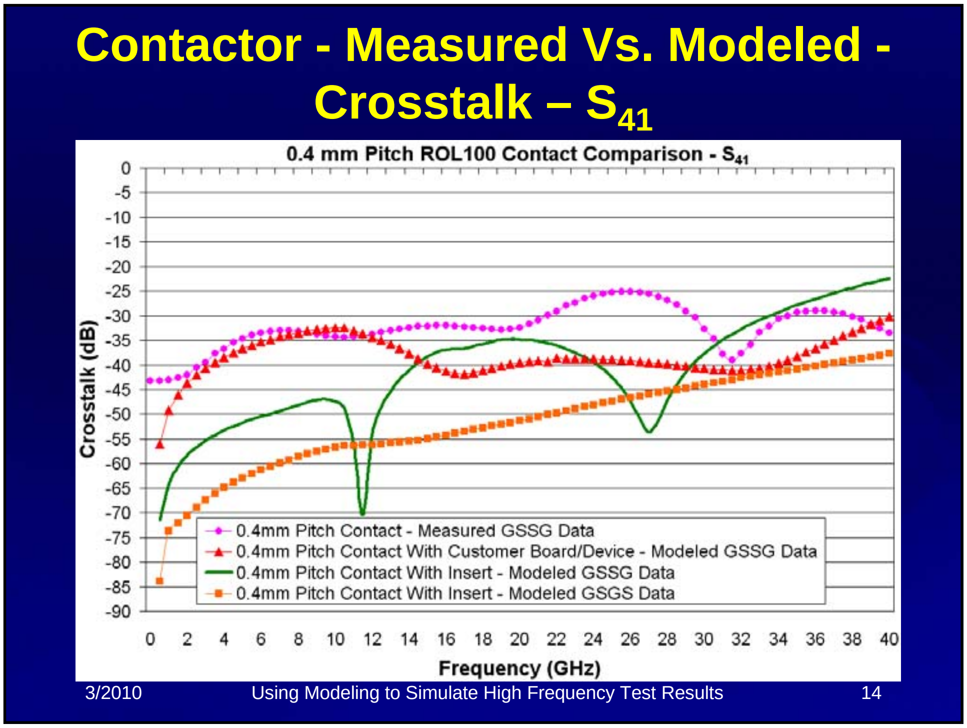

Contactor - Measured Vs. Modeled - Crosstalk – S_{41}

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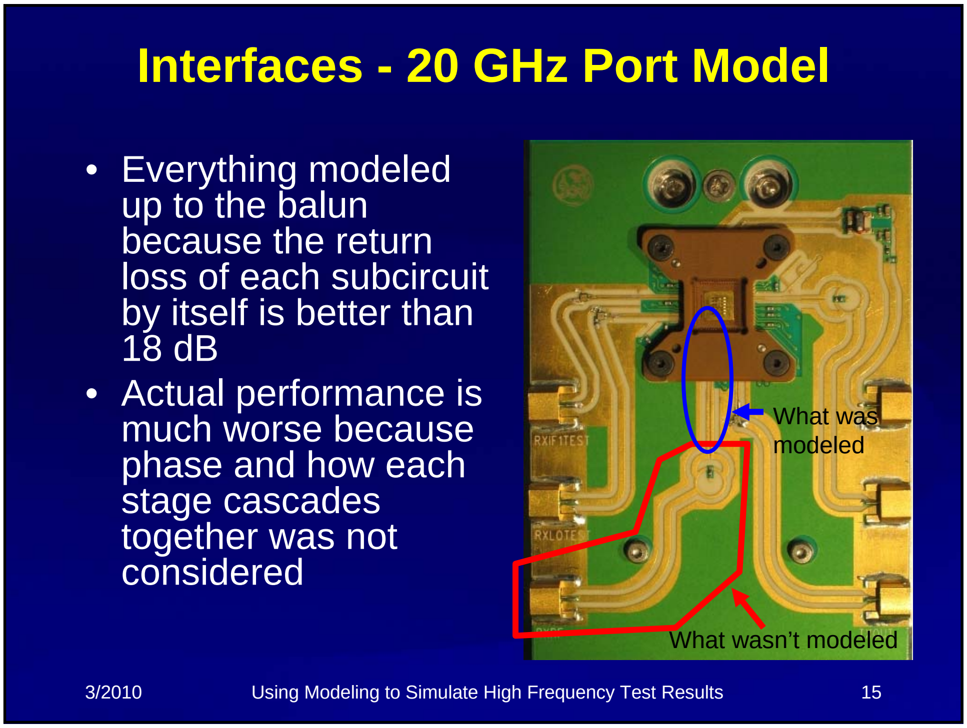
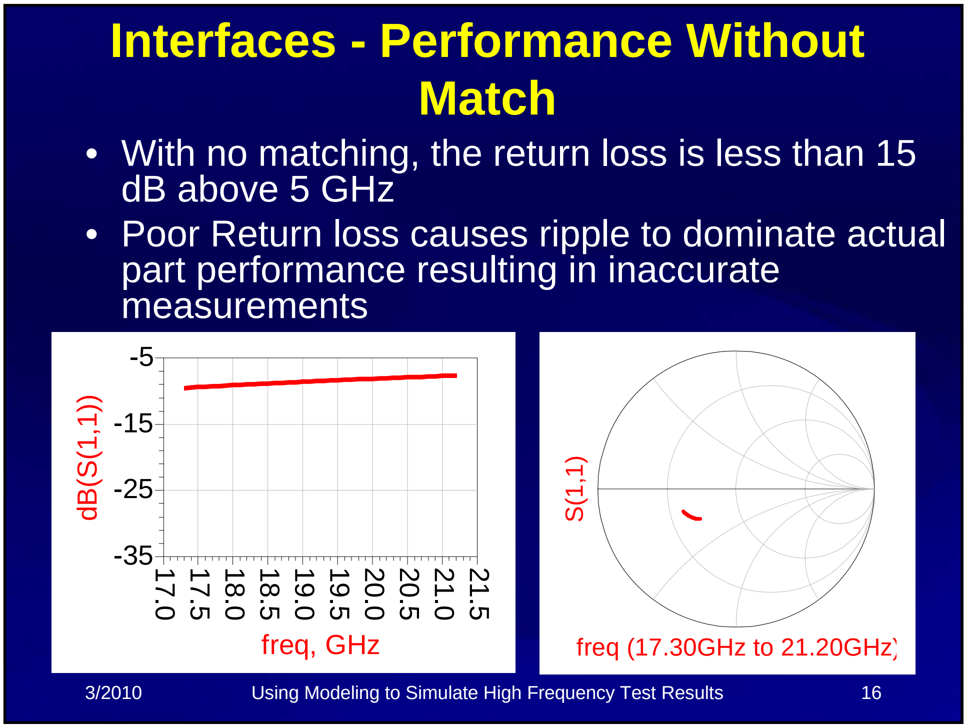


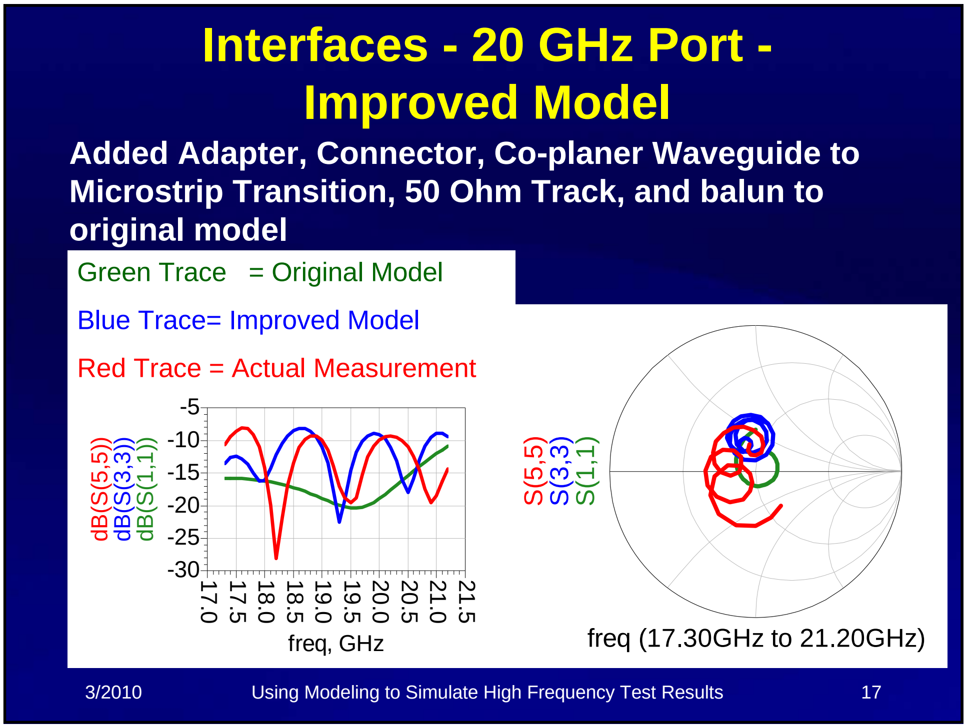
Interfaces - 20 GHz Port Model

- Everything modeled up to the balun because the return loss of each subcircuit by itself is better than 18 dB
- Actual performance is much worse because phase and how each stage cascades together was not considered



Interfaces - Performance Without Match

- With no matching, the return loss is less than 15 dB above 5 GHz
- Poor Return loss causes ripple to dominate actual part performance resulting in inaccurate measurements



Interfaces - 20 GHz Port - Improved Model

Added Adapter, Connector, Co-planer Waveguide to Microstrip Transition, 50 Ohm Track, and balun to original model

Green Trace = Original Model

Blue Trace= Improved Model

Red Trace = Actual Measurement

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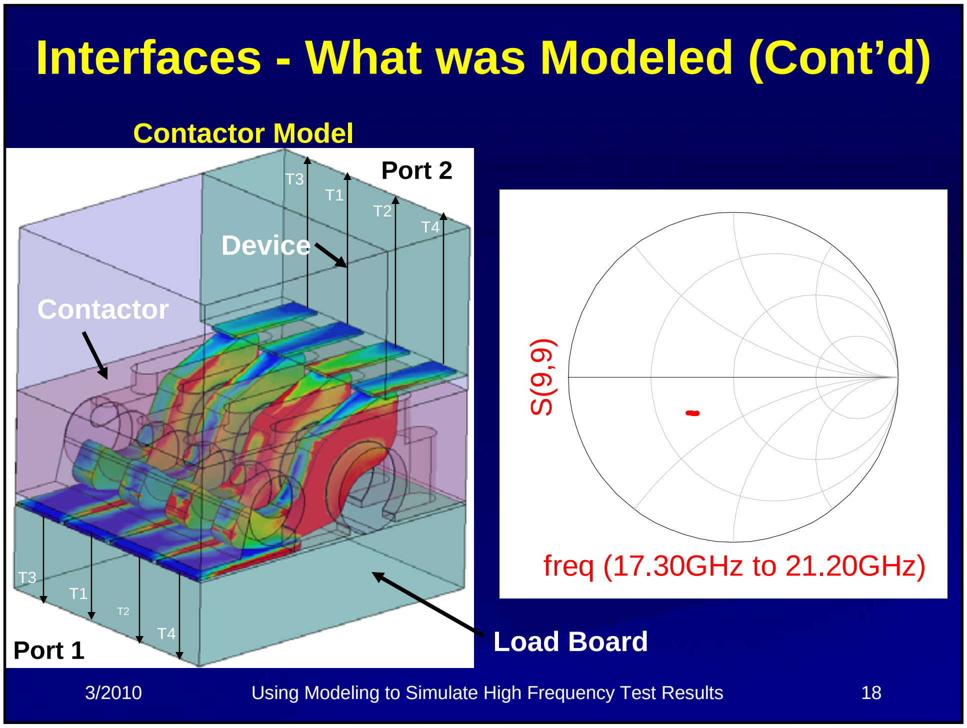

Interfaces - What was Modeled (Cont'd)

Contactor Model

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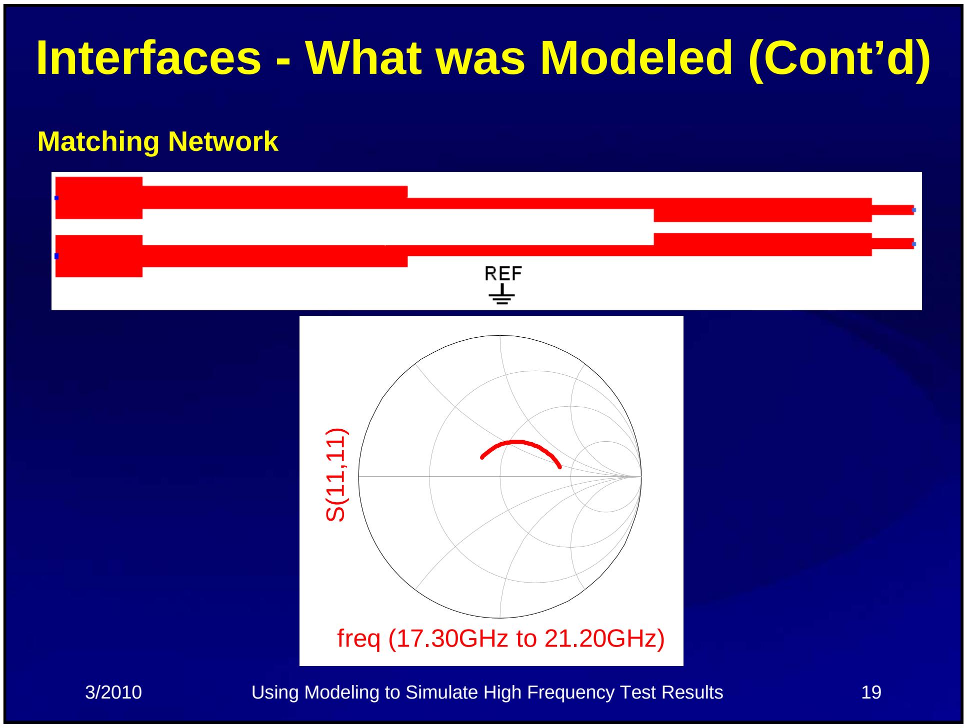
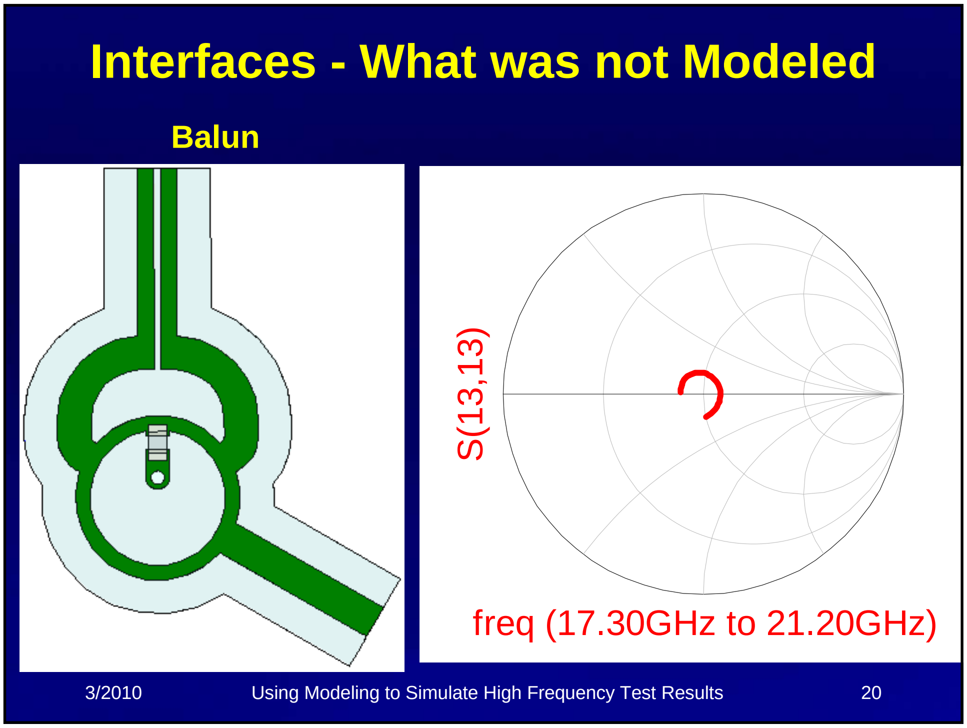


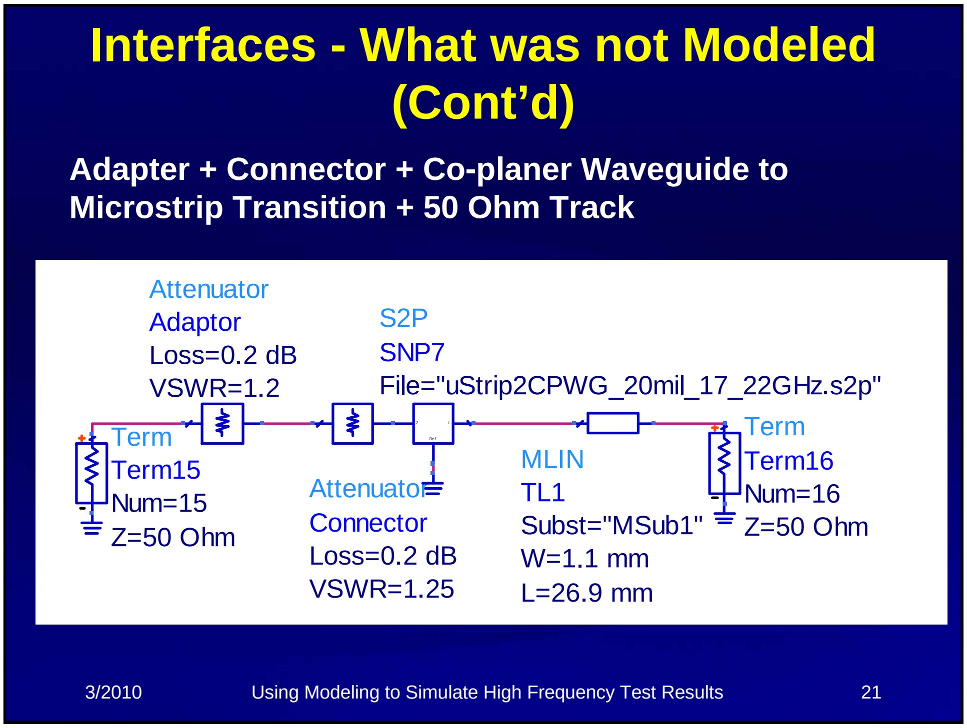
Interfaces - What was Modeled (Cont’d)

Matching Network



Interfaces - What was not Modeled

Balun



Interfaces - What was not Modeled (Cont'd)

Adapter + Connector + Co-planer Waveguide to Microstrip Transition + 50 Ohm Track

Attenuator
Adaptor
Loss=0.2 dB
VSWR=1.2

S2P
SNP7
File="uStrip2CPWG_20mil_17_22GHz.s2p"

Term
Term15
Num=15
Z=50 Ohm

Attenuator
Connector
Loss=0.2 dB
VSWR=1.25

MLIN
TL1
Subst="MSub1"
W=1.1 mm
L=26.9 mm

Term
Term16
Num=16
Z=50 Ohm

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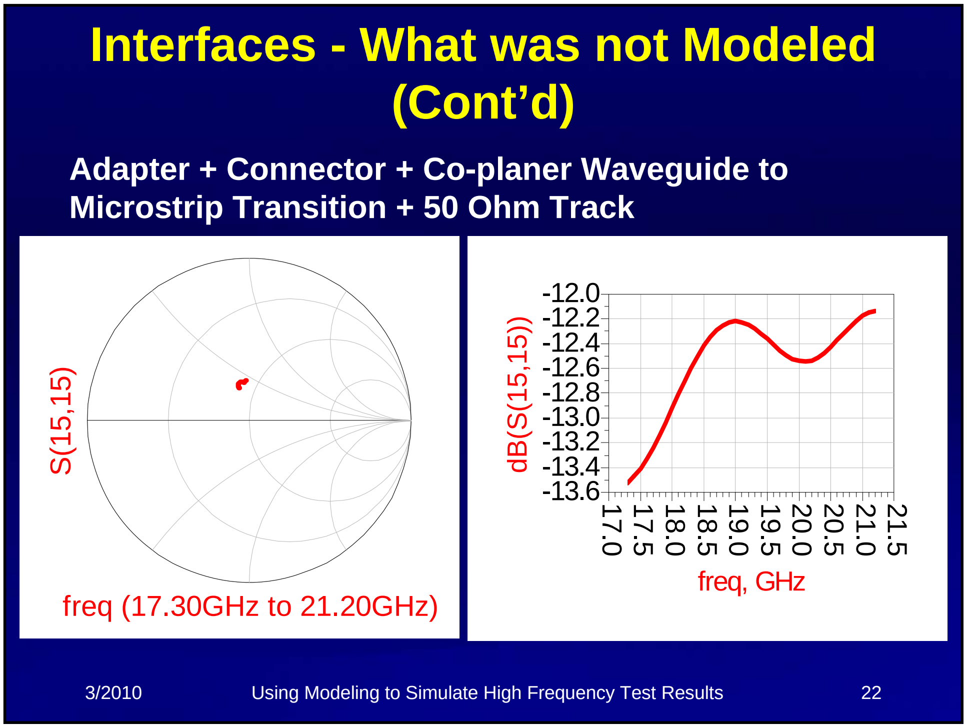

Interfaces - What was not Modeled (Cont'd)

Adapter + Connector + Co-planer Waveguide to Microstrip Transition + 50 Ohm Track

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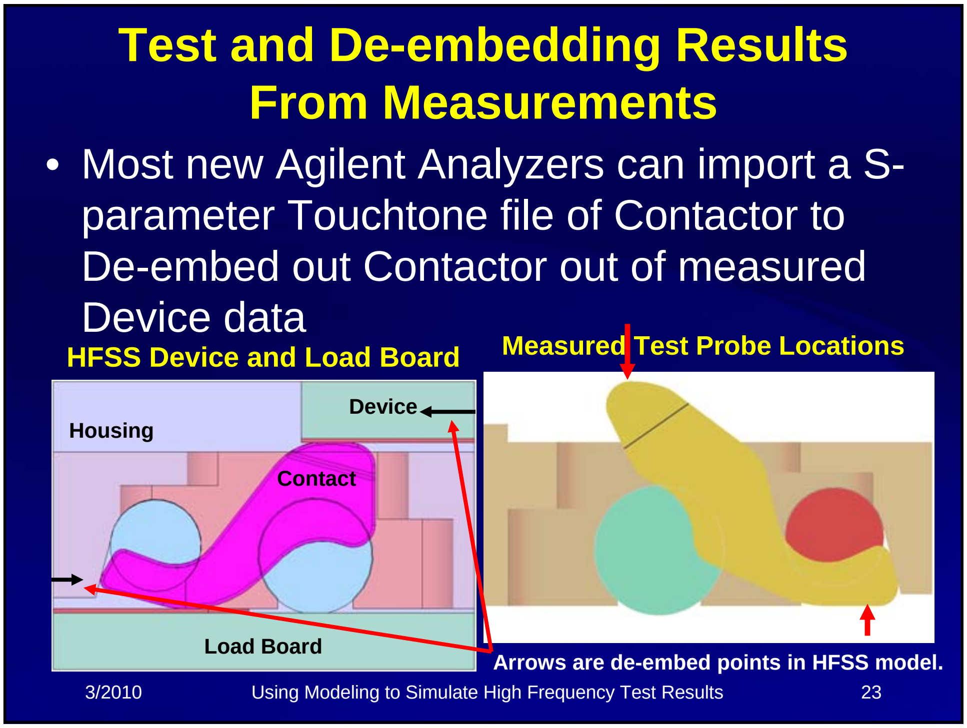
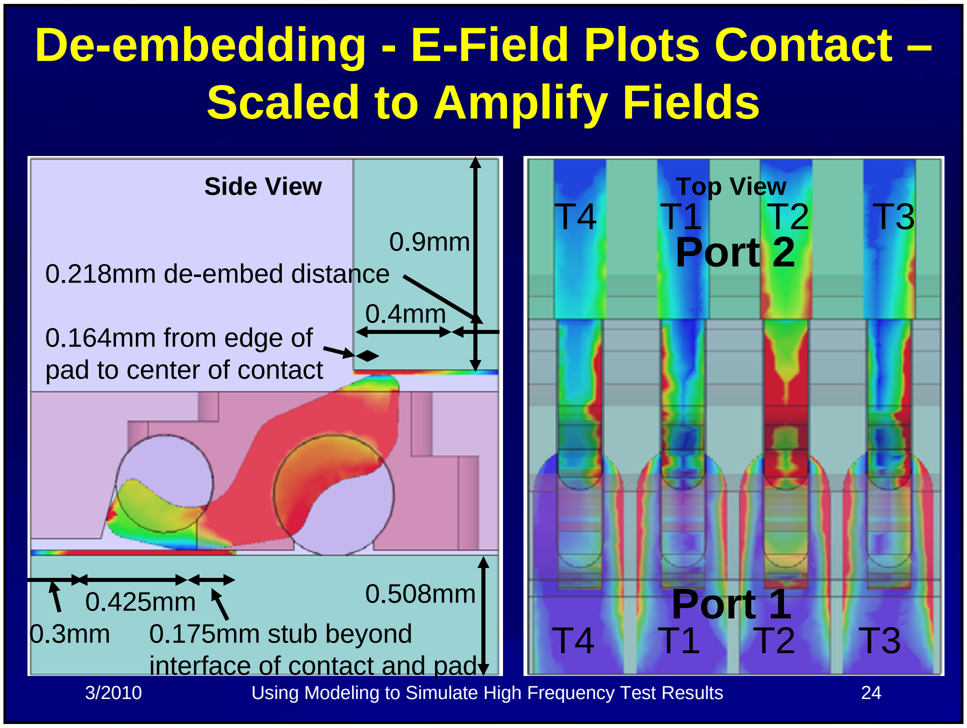


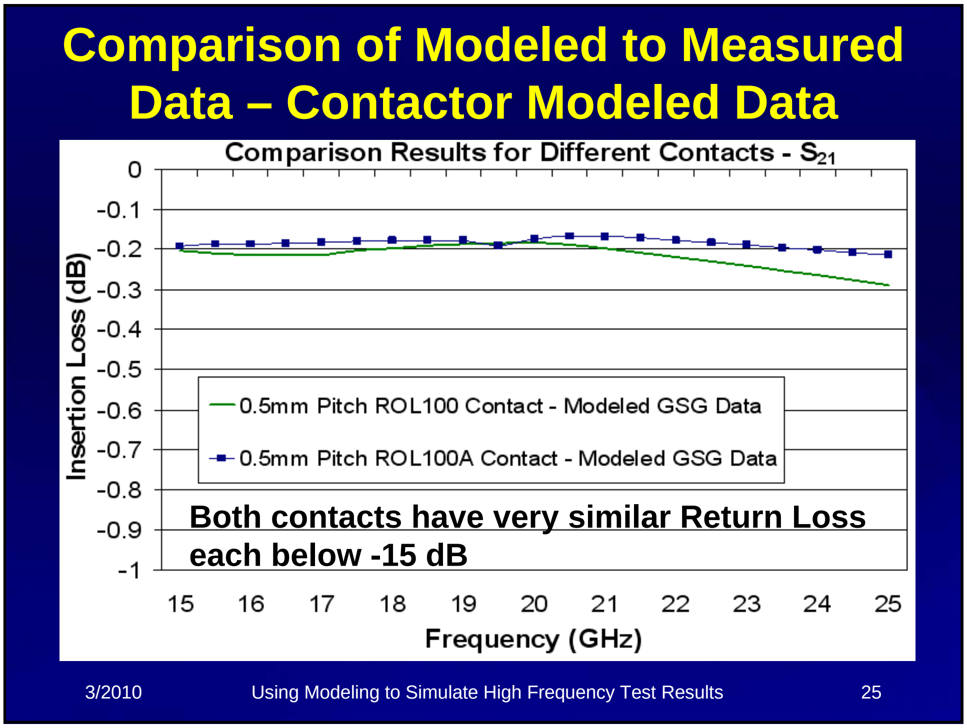
Test and De-embedding Results From Measurements

- Most new Agilent Analyzers can import a S-parameter Touchtone file of Contactor to De-embed out Contactor out of measured Device data

Arrows are de-embed points in HFSS model.

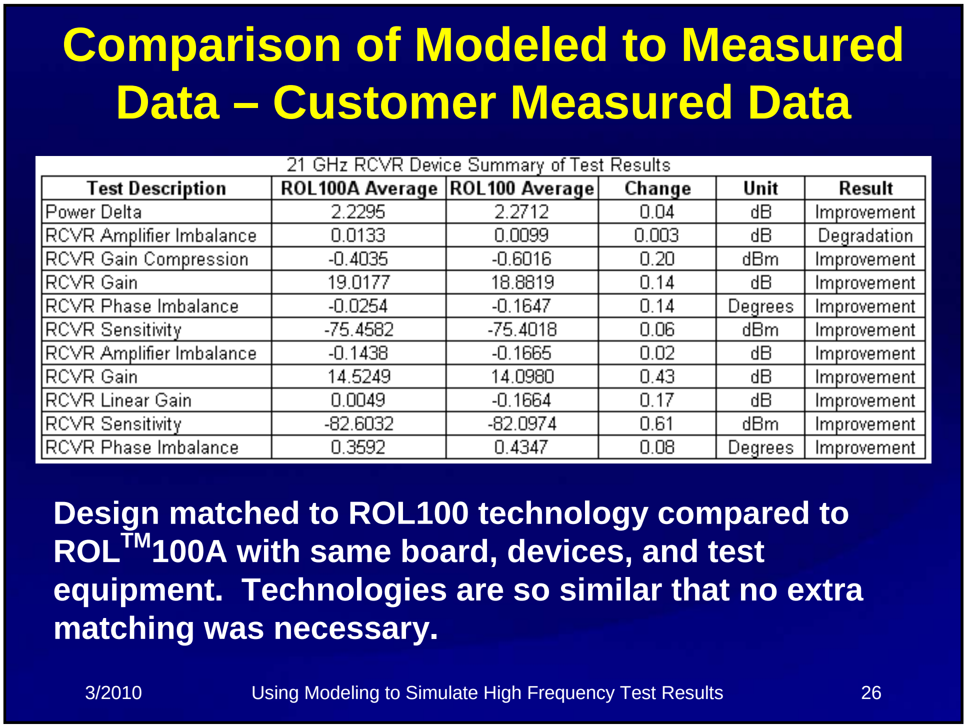


De-embedding - E-Field Plots Contact – Scaled to Amplify Fields



Comparison of Modeled to Measured Data – Contactor Modeled Data

Both contacts have very similar Return Loss each below -15 dB



Comparison of Modeled to Measured Data – Customer Measured Data

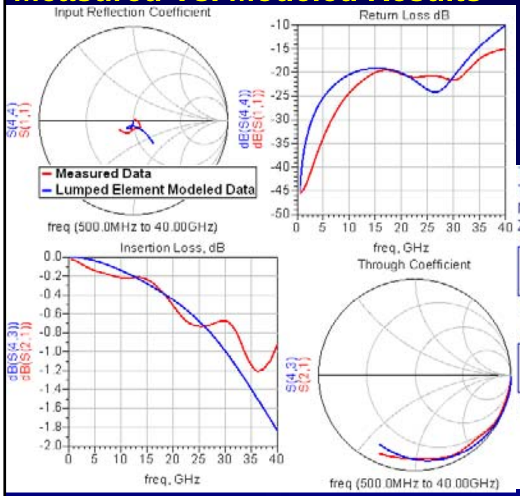
21 GHz RCVR Device Summary of Test Results

Test Description	ROL100A Average	ROL100 Average	Change	Unit	Result
Power Delta	2.2295	2.2712	0.04	dB	Improvement
RCVR Amplifier Imbalance	0.0133	0.0099	0.003	dB	Degradation
RCVR Gain Compression	-0.4035	-0.6016	0.20	dBm	Improvement
RCVR Gain	19.0177	18.8819	0.14	dB	Improvement
RCVR Phase Imbalance	-0.0254	-0.1647	0.14	Degrees	Improvement
RCVR Sensitivity	-75.4582	-75.4018	0.06	dBm	Improvement
RCVR Amplifier Imbalance	-0.1438	-0.1665	0.02	dB	Improvement
RCVR Gain	14.5249	14.0980	0.43	dB	Improvement
RCVR Linear Gain	0.0049	-0.1664	0.17	dB	Improvement
RCVR Sensitivity	-82.6032	-82.0974	0.61	dBm	Improvement
RCVR Phase Imbalance	0.3592	0.4347	0.08	Degrees	Improvement

Design matched to ROL100 technology compared to ROL^{TM}100A with same board, devices, and test equipment. Technologies are so similar that no extra matching was necessary.

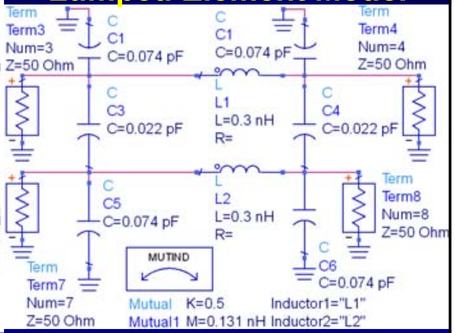
Comparison of Modeled to Measured Data – ADS

Measured Vs. Modeled Results



- Lumped elements are not as good as measured data and are worse the higher the frequency modeled

Lumped Element Model



High Frequency Design and Modeling Conclusions

- At high frequencies everything should be modeled
- Modeling:
  - Should include grounding
  - Can be used to determine effects of device configuration
  - Can be used to help determine expected yield and guard bands for testing
  - Can be used to de-embed contactor performance from device measurements
- Using actual measured data in models is best