BiTS

Burn-in & Test Socket Workshop

March 2 - 5, 2003
Hilton Phoenix East / Mesa Hotel
Mesa, Arizona

IEEE COMPUTER SOCIETY

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Session 7

Wednesday 3/05/03 8:00AM

Contact Technology

"Electroplated Palladium-Cobalt On Test Probe Plungers: An Improved Method For Reducing Solder Adhesion"

Therese Souza – Rika Denshi America, Inc.
Larre Nelson – Rika Denshi America, Inc.

"Contact Technology For 0.5mm Pitch And Below"

Prasanth Ambady – Texas Instruments
James Forster – Texas Instruments
Jason Cullen – Texas Instruments

"High Frequency Performance Of Various Test Contactor Geometries - 0.8mm Pitch"

Eric Fachon – QA Technology, Inc.

Electroplated Palladium-Cobalt on Test Probe Plungers

An Improved Method For Reducing Solder Adhesion

Authors:

Therese Souza, Rika Denshi America

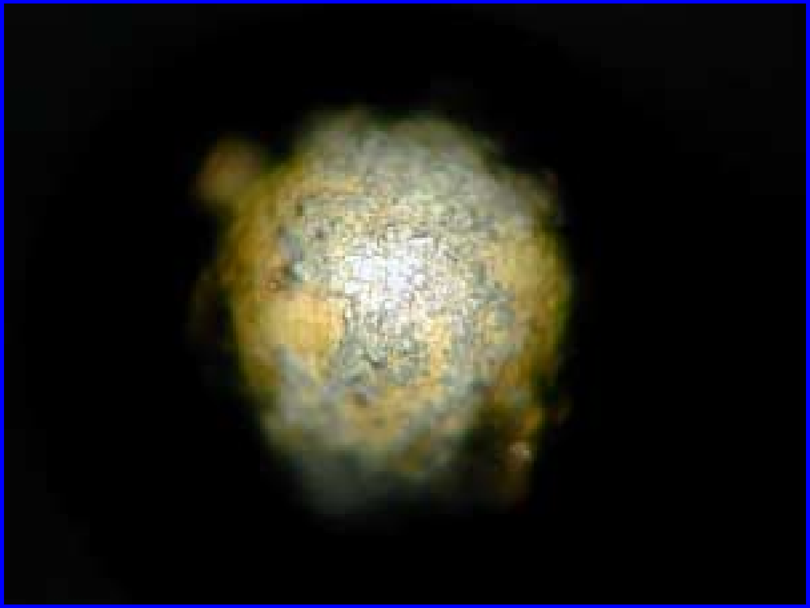
Larre Nelson, Rika Denshi America

Outline

- Problem description
- Potential solutions
- PdCo as a novel surface finish
- Experiment description
- Conclusions / references

Problem Description

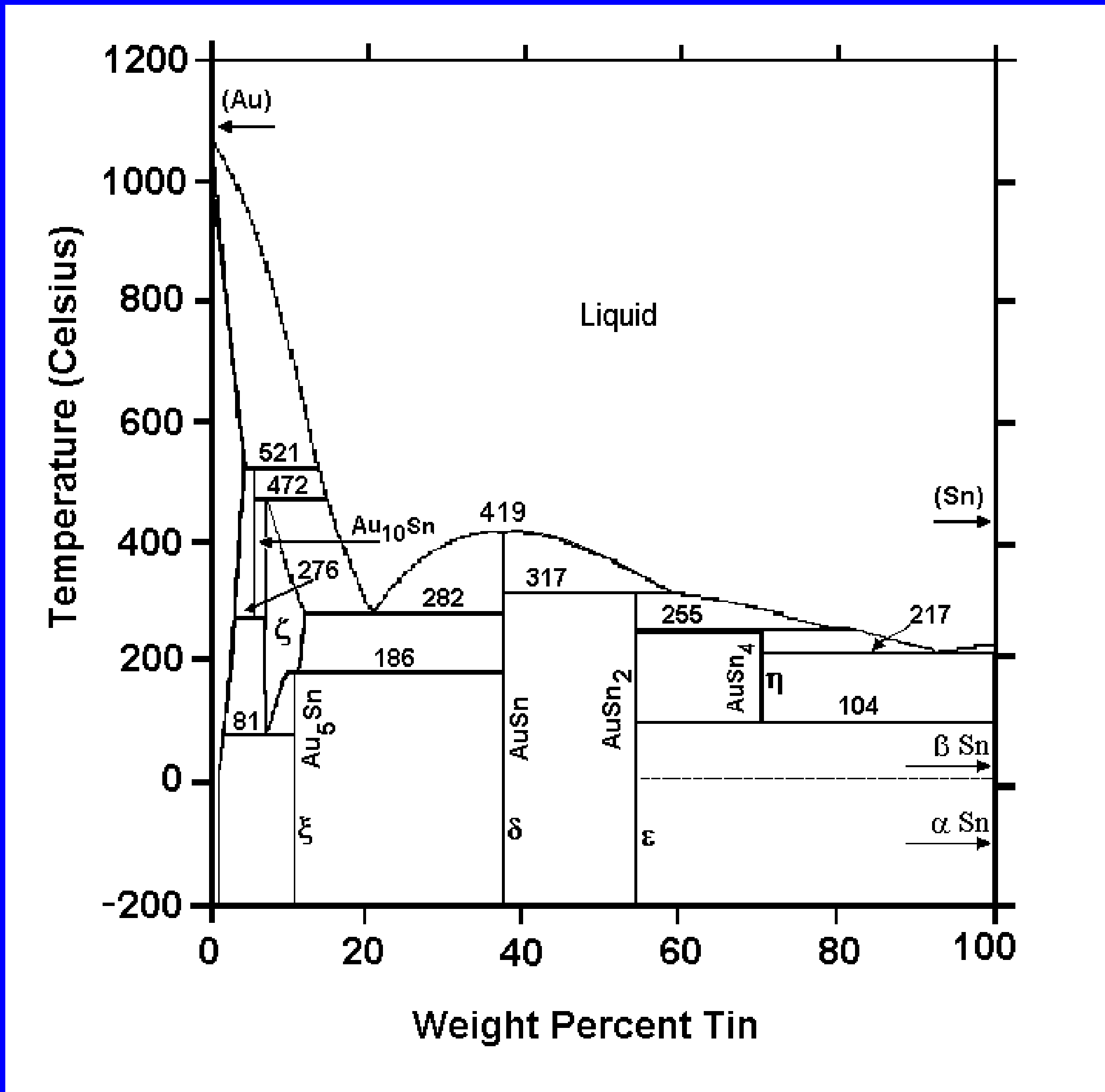
Solder sticks to contact area of test probe plunger



- Decreased yield
- Variability in resistance
- Open circuit condition
- Reduced life
- Increased maintenance
- Increased down time

Mechanism of Solder Contamination

- Solder transferred to plunger during use
- Solder bonds to gold
  - Intermetallics
  - Solder Oxides
- Contact area become contaminated
- Intermetallics / oxides have poor conductivity



Au-Sn Phase Diagram

Repair/Prevent Options for Contaminated Plungers

- Mechanical abrasion (scrubbing)
- Chemical cleaning
- Tip Design – self-cleaning
- Replaceable tips
- Other plated finishes

Palladium-Cobalt
Novel Test Probe Finish

- Palladium-Cobalt
  - Both are elements combined thru plating
  - Semi-noble plated finish
- Pd alloys
  - Commonly used on separable connectors & lead frames
- Properties

Why Palladium Cobalt Makes A Difference

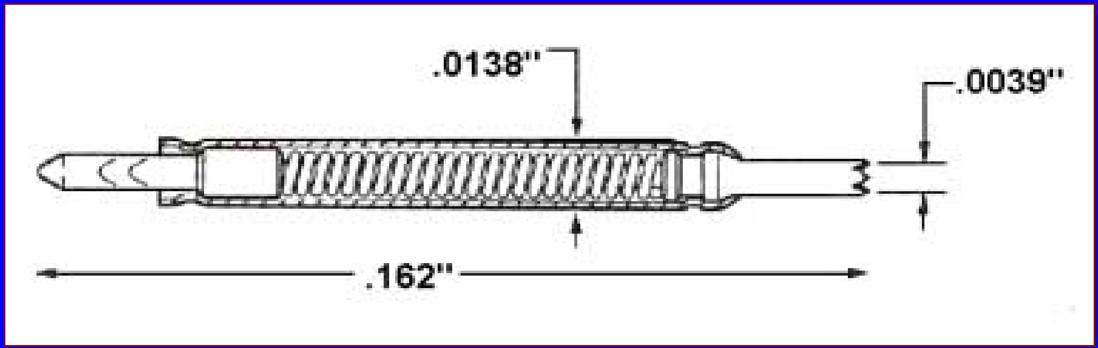
CHARACTERISTIC	WHY THIS IS GOOD FOR A TEST PROBE	SPECIFICATIONS
PdCo is very hard	A hard surface finish decreases wear and increases durability	Hard Gold hardness: Knoop 130-200 PdCo hardness: Knoop 600-650
PdCo is slippery	A low coefficient of friction makes the plunger motion smoother and makes it easier for foreign matter to slide off the surface of the plunger	Hard Gold coefficient of friction: .60 PdCo efficient of friction: .43
PdCo has a small grain size	It is less likely that a small grain size material will allow diffusion and the formation of intermetallic compounds	Hard Au grain size: 200-250 Angstroms PdCo grain size: 50-150 Angstroms
PdCo has low porosity	Low porosity does not allow corrosion to penetrate the plating and damage the base metal	Hard Gold porosity index: 3.7 PdCo porosity index: 0.2
PdCo has good ductility	A ductile plated surface is less likely to crack under mechanical stresses	Hard Gold: <3% elongation PdCo: 3-7% elongation
PdCo is thermally stable	When exposed to elevated temperatures over time, the contact resistance stays consistent	Hard Gold: up to 150^{0}C PdCo: up to 395^{0}C
Pd and Co have high melting points	A plating material with a high melting point will inhibit diffusion and the formation of intermetallic compounds	Gold melting point: 1,064^{0}C Palladium melting point: 1,554^{0}C Cobalt melting point: 1,495^{0}C
PdCo is an alloy	Alloys are good barriers to diffusion	Hard Gold chemistry: almost 100% Au PdCo chemistry: 80% Pd / 25% Co
PdCo has surface oxides	Surface oxides help deter solder adherence	To be determined

PdCo Studies

- Life Cycle Resistance Study
- Solder Ball Cycling Study
- Life Cycle Against Pure Tin
- Solder Dip Test Comparison Study

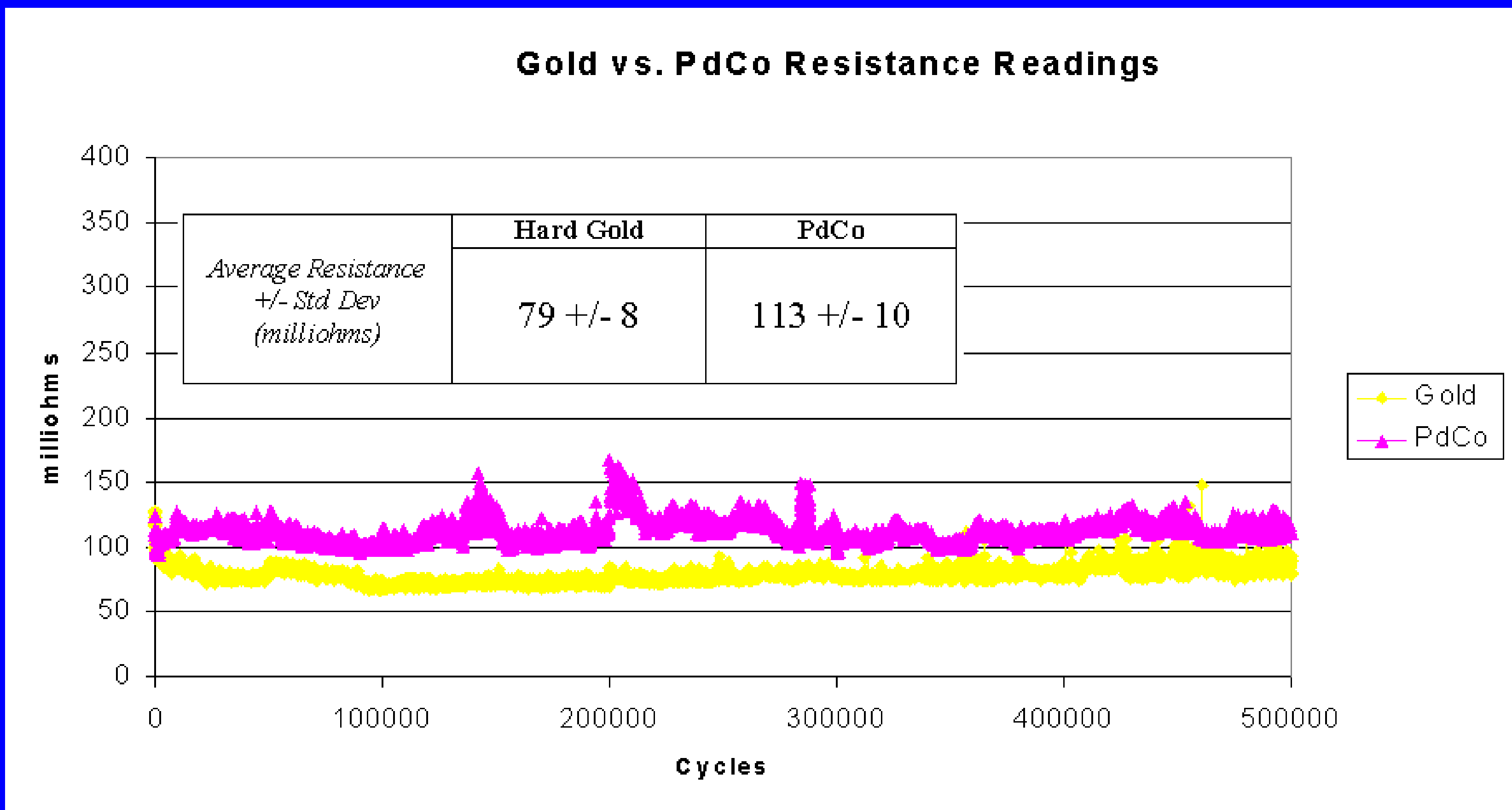
1. Life Cycle Resistance Study

- Test probe design (.162" x .0138"): double ended plunger, movable conical tip and stationary four point crown
- Comparison of Hard Gold plate vs. PdCo plate
- 500,000 cycles against gold surface



Cycle Tester

Life Cycle Resistance Study

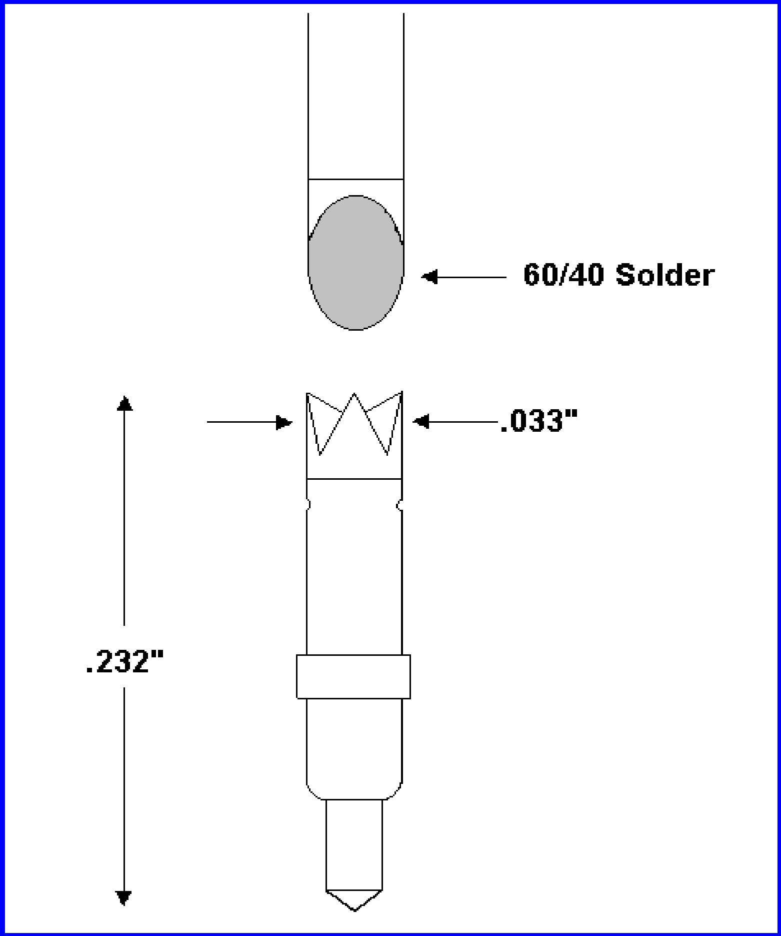


	Hard Gold	PdCo
Average Resistance +/- Std Dev (milliohms)	79 +/- 8	113 +/- 10

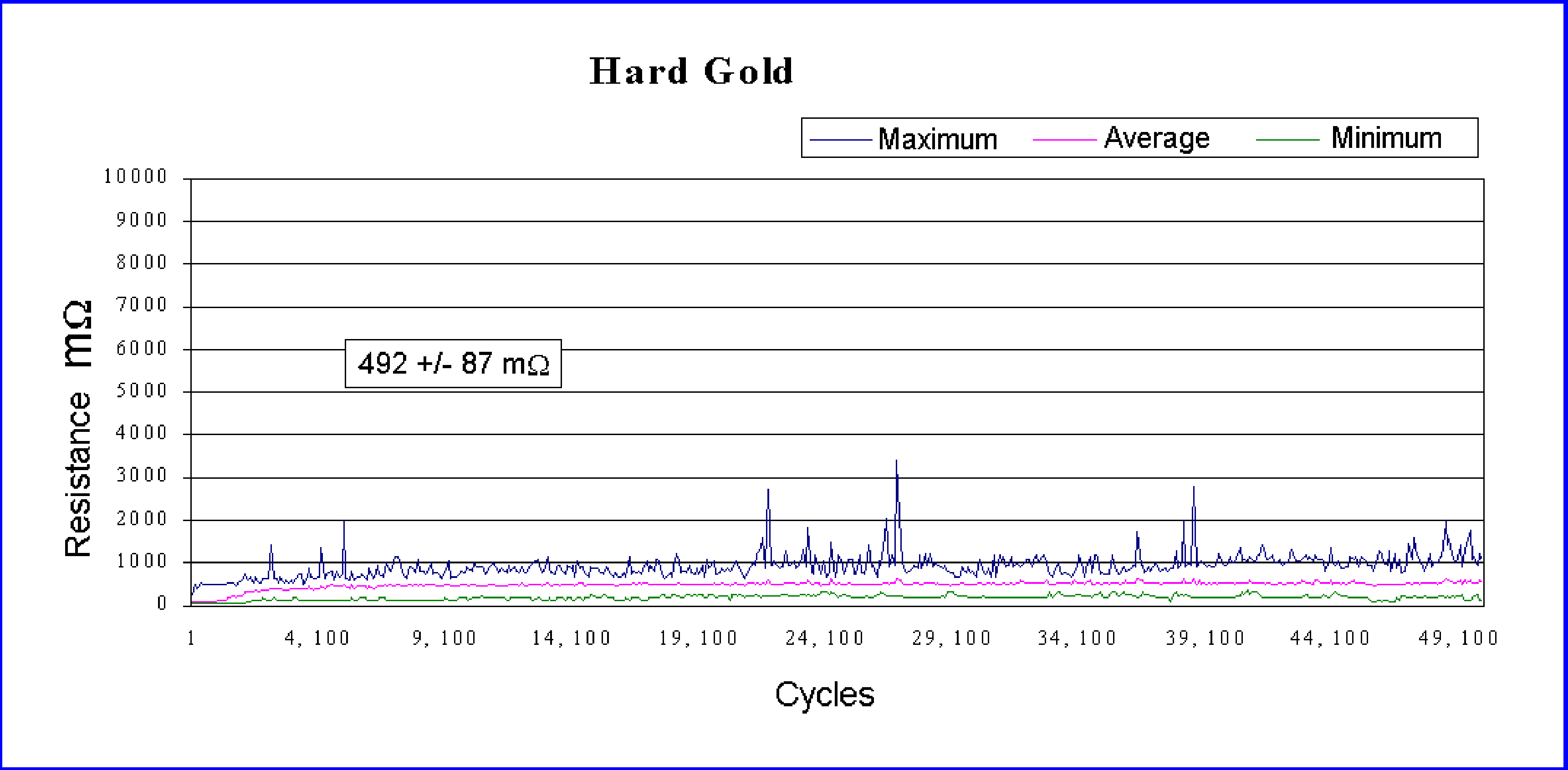
2. Solder Ball Cycling Study

- Cycle to a 60/40 solder ball
- 50,000 cycles
- Ambient

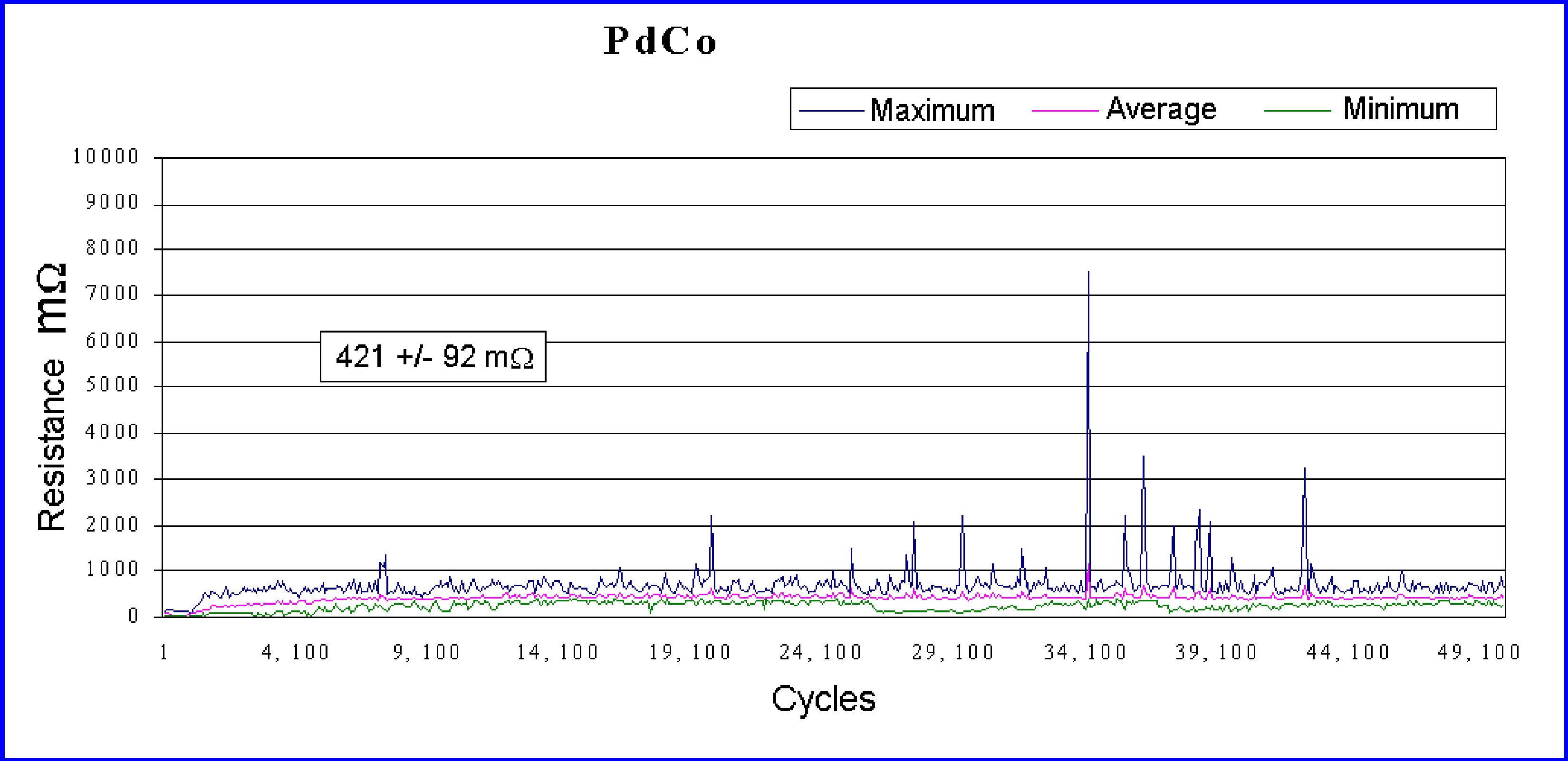
  temperature
- PdCo vs. Hard Gold



Solder Ball Cycling Study

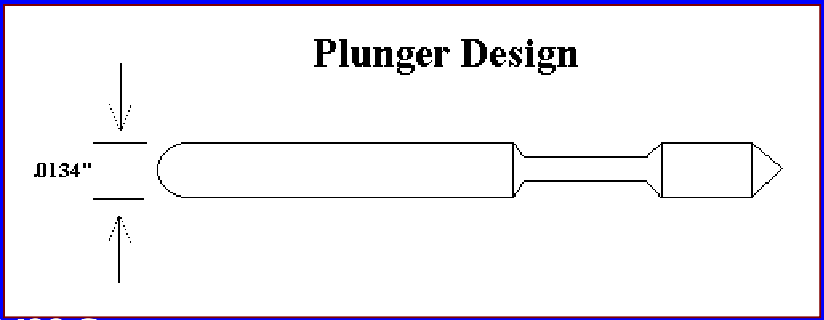


Solder Ball Cycling Study



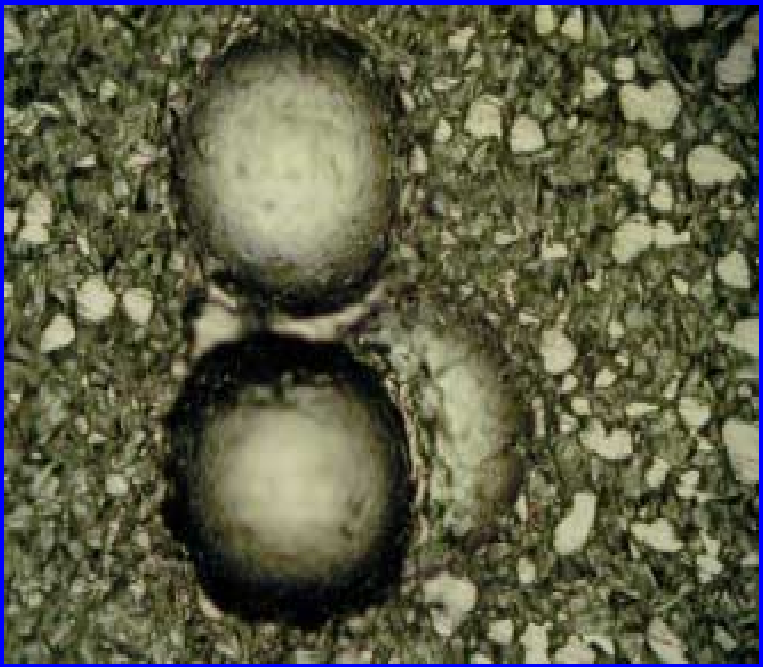
3. Life Cycle Against Pure Tin

- Spherical plunger cycled against pure electroplated tin
- Tin contact resurfaced every 5,000 – 10,000 cycles
- Hard gold vs PdCo
- Multiple tests conducted
- Cycled 150-200 k
- Contact force 40/80 grams
- Plunger tips frequently examined for transferred tin



Observations

- Plunger force deformed tin on contact surface
- Tin build-up on gold more obvious



Dimple in Tin

Palladium-Cobalt

Post Plating Treatment

Options

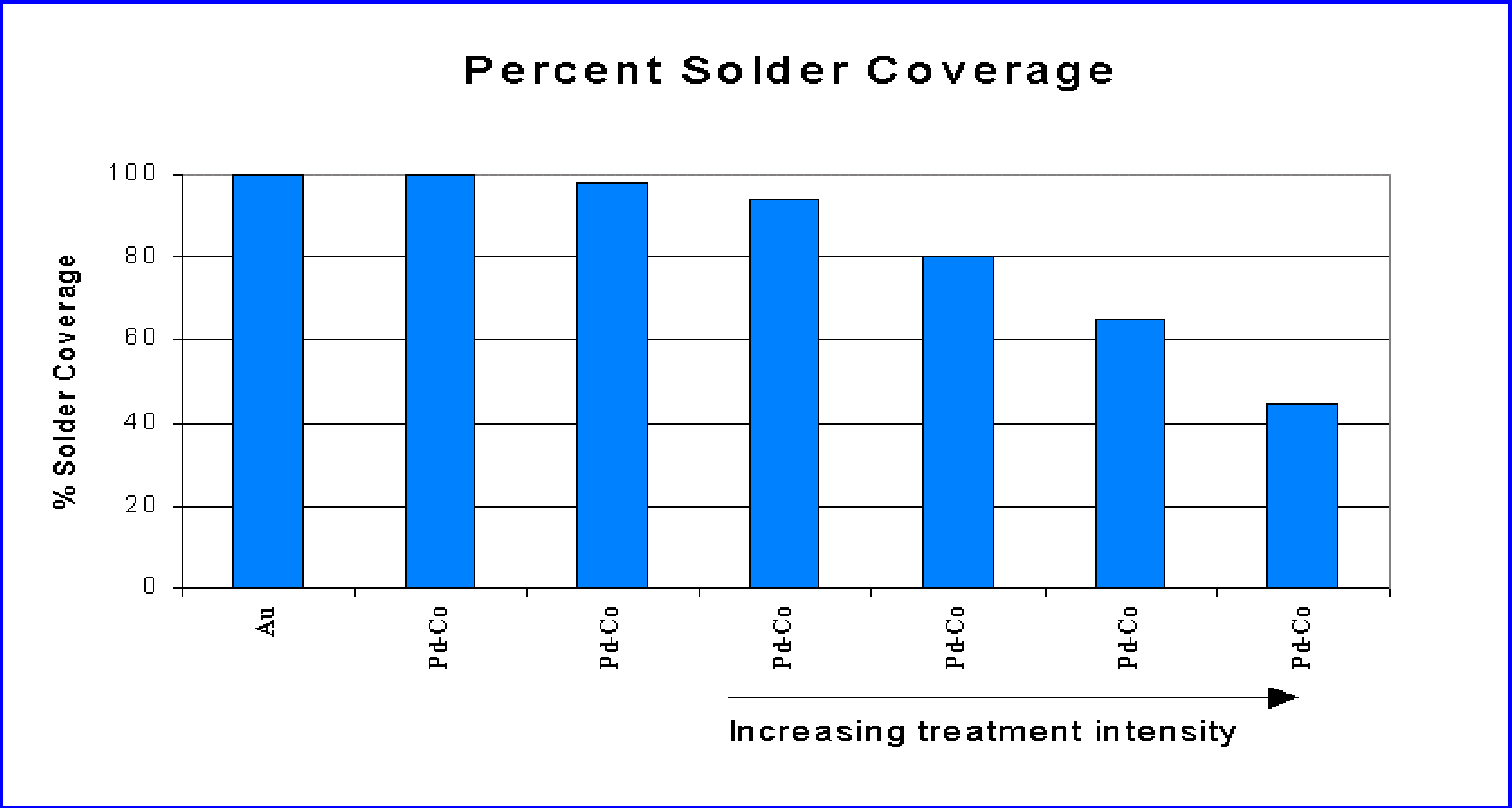
Palladium-Cobalt can be treated

- To provide increased protection from solder sticking
- To increase hardness of deposit
- To increases ductility
- May alter other properties

4. Solder Dip Comparison Study

- Test samples prepared from copper foil and preplated with electroless nickel
- Post plating treatment
- 20-30 microinches PdCo
- Solder dip using 60/40 solder & 5 second dwell time

Solder Dip Comparison Study



Conclusions

- PdCo can be used as a test probe finish
  - Alternative to gold
  - Consistent resistance readings when mated against tin
  - A reduced tendency to form adhesions to solder
- PdCo has the potential for increased contact resistance

References

- Whitley, J.H., *The Tin Commandments,* Plating & Surface Finishing, October, 1981, pp. 38-39.
- Brock, Edward, *Mateability of Tin to Gold, Palladium, and Silver,* AMP Inc. Technical Report, 7/31/96
- Kudrak, Abys, Chinchankar, Maisano,*Porosity Evaluation of Composite Palladium, PdNi and Gold Electrodeposits*, AT&T Bell Laboratories,
- Moore, R.L., *Investigations of Tin Diffusion in Gold Contacts by Auger Electron Spectroscopy,* Evans East
- *http://klara.met.kth.se/pd/element/Au-Sn.html*

Contact Technology For 0.5 mm Pitch and Below

Prasanth Ambady
James Forster
Jason Cullen

Texas Instruments,
Interconnection Business Unit
Sensors & Controls
Attleboro, MA

BURN-IN & TEST SOCKET WORKSHOP

REV 1.2

TEXAS INSTRUMENTS

INTRODUCTION

The Communications Age

The ability to communicate is changing the way we live, our freedoms, and making the world a smaller place.

SAMSUNG MOBILE

1973
56.3 cubic inches
38.4 oz.
15 minutes talk
$2,000

1999
5.5 cubic inches
3.1 oz.
140 minutes talk
Free

TODAY

OVERVIEW

- **Introduction To Different Contact Technologies**
- **Discussion Of Currently Available Technologies**
- **Design Issues With Current Technology**
- **Future Design/Cost Challenges**

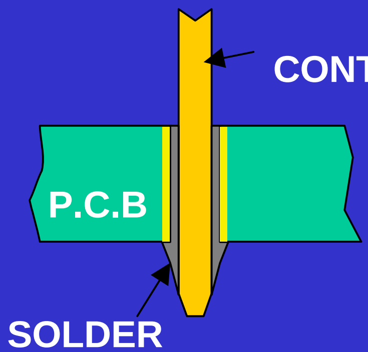
BURN-IN SOCKET REQUIREMENTS

- Temperature: Up To 150 °C
- Life: 4,000 to 10,000 Cycles
- Hand Loading/ Auto Loading Capabilities
- Insulation: 500 V DC, 1000 M Ohms Between Pins
- Resistance : Less Than 1 Ohm Per Pin
- Acceptable Capacitance & Inductance

DEFINITIONS

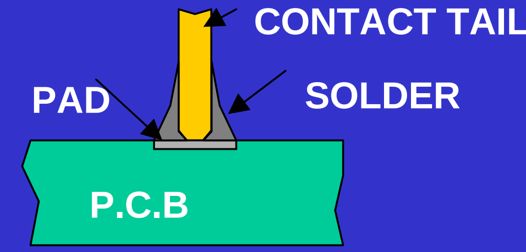
Through Hole Sockets:

Sockets Mounted By Soldering
The Contact Leads Through A
Plated Hole In The Board.



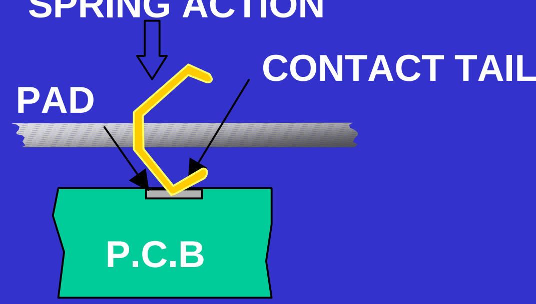
Surface Mount Sockets:

Sockets Mounted By Soldering
The Lead To A Pad On The Board.



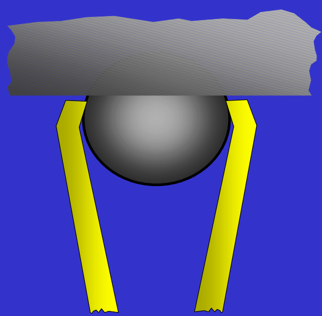
Compression Mount Sockets:

Socket Contact Lead Presses
Vertically Against The Board.
Spring Force Provides
Interconnection between The Pad
And The Contact

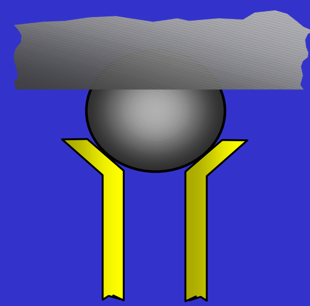


CONTACT OPTIONS

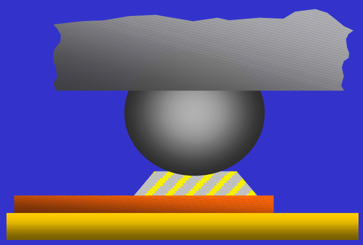
a) Metal Pinch Contact



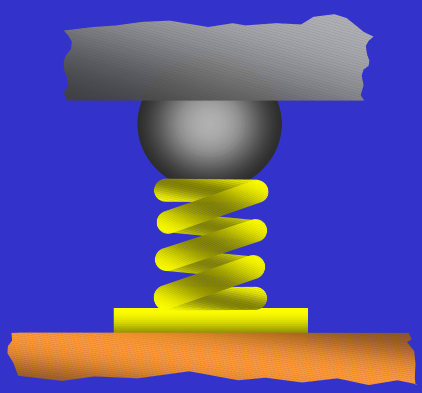
b) Metal 'Y' Contact



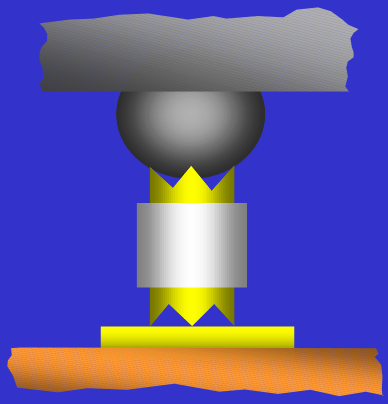
c) Conductive Polymer



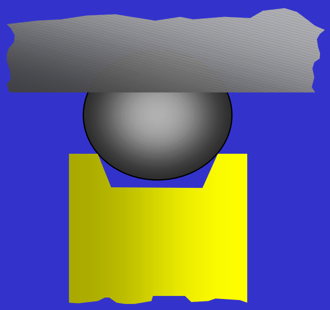
d) Coil Spring



e) Pogo Pin

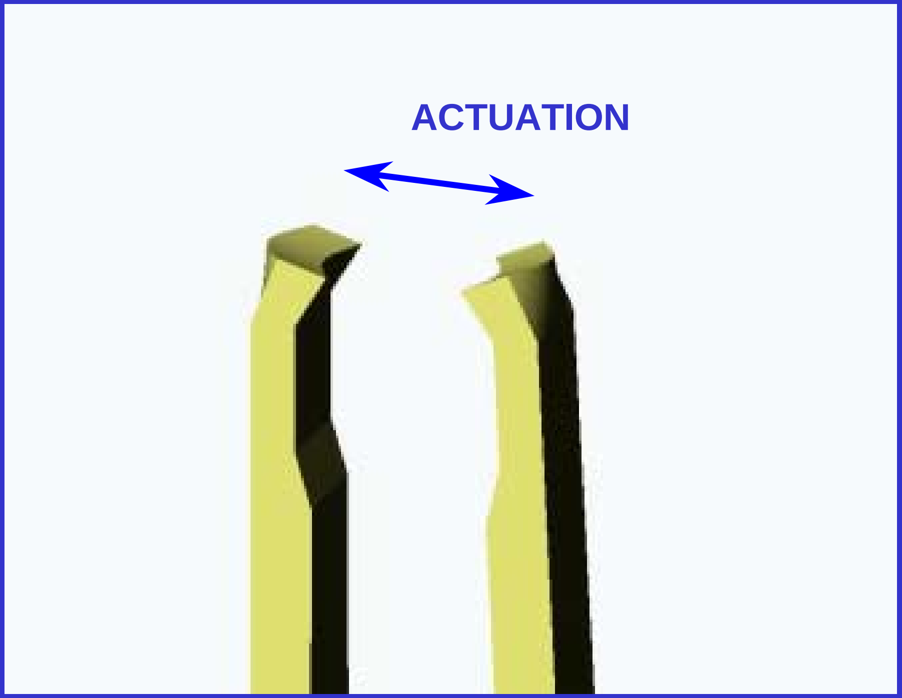


f) Metal Probe - Buckling Beam

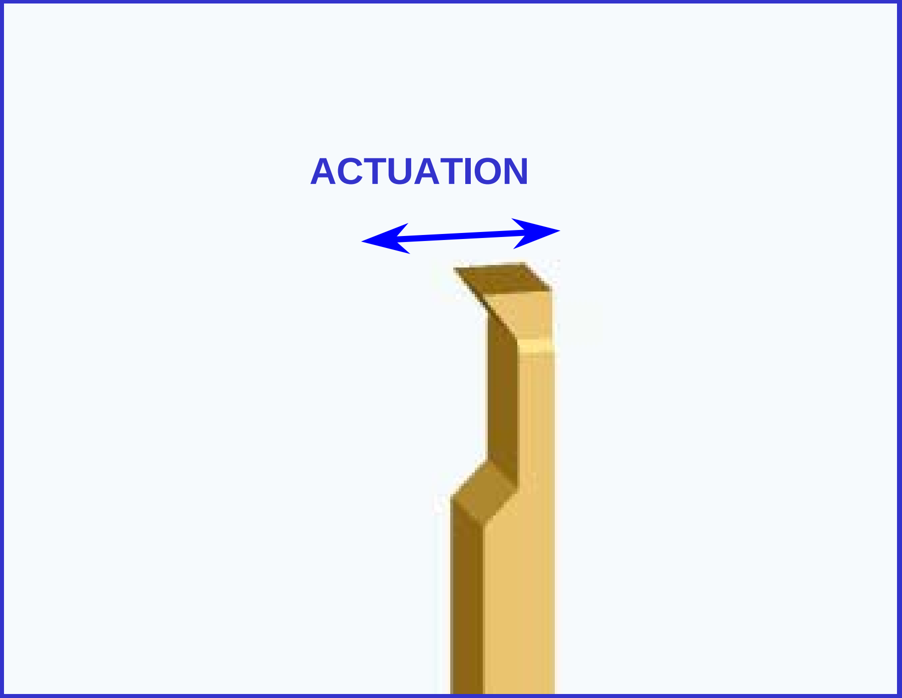


CONTACT TYPES
HORIZONTALLY ACTUATED

Dual Pinch Style

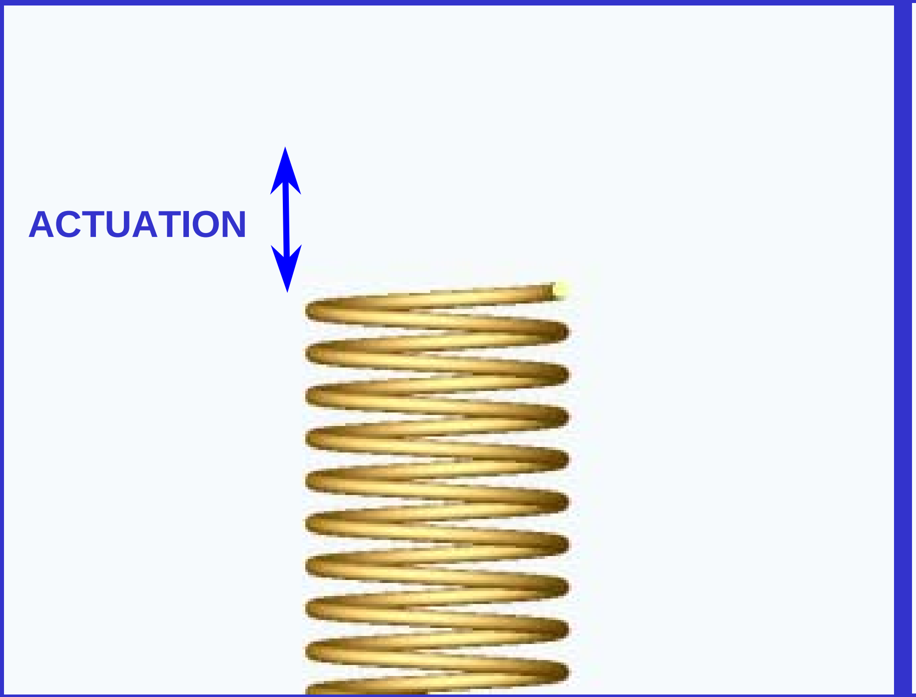


Single Beam Style

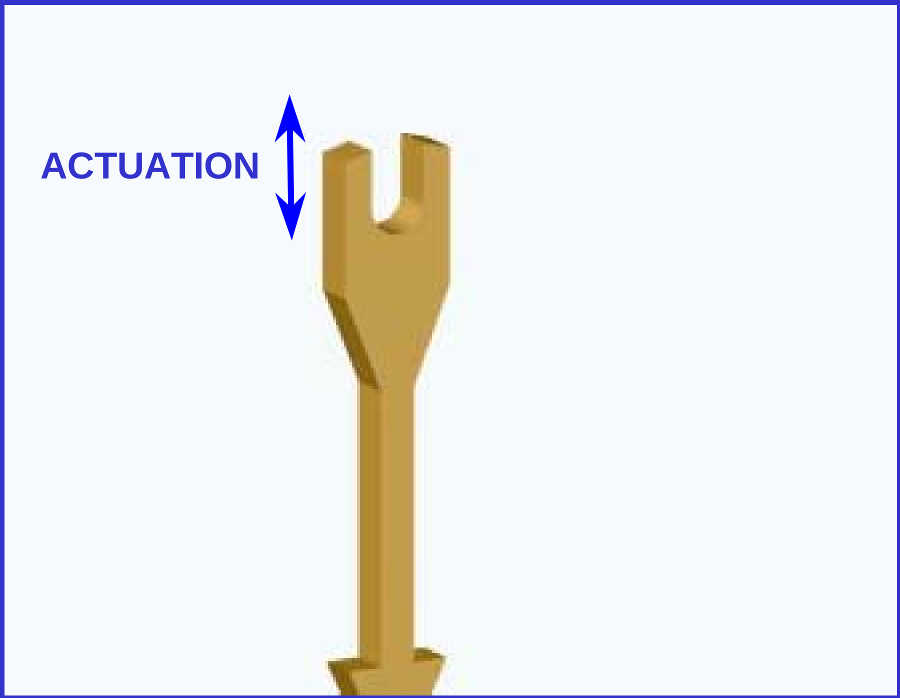


CONTACT TYPES
VERTICALLY ACTUATED

Helical Coil Spring



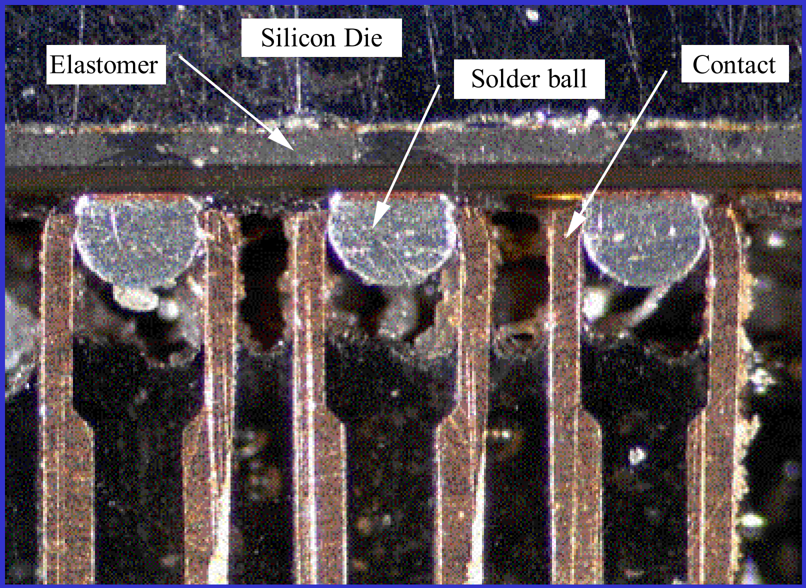
Buckling Beam

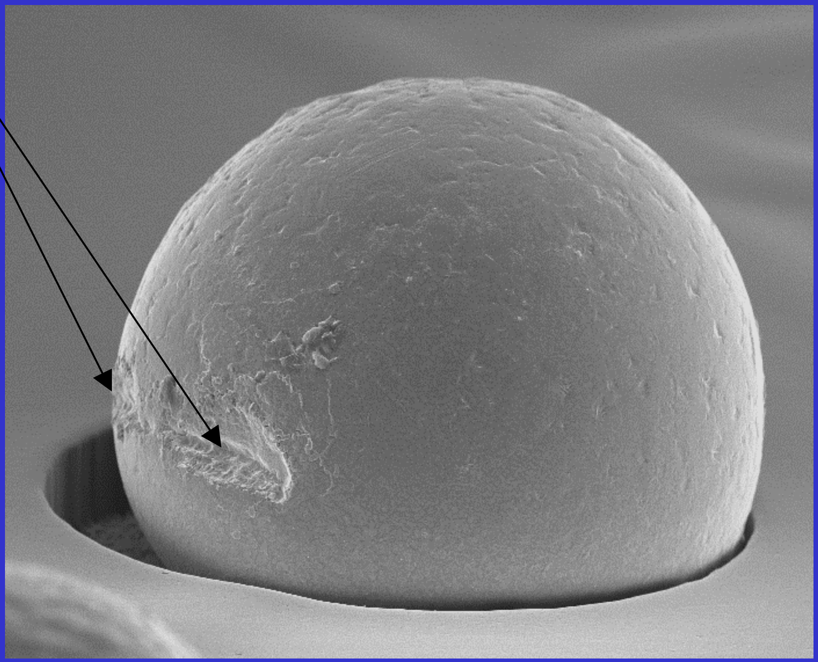


SOLDER BALL - CONTACT INTERFACE
PINCH STYLE

- Location of witness marks
- Ball deformation

Dual Beam Pinch Style Witness Marks



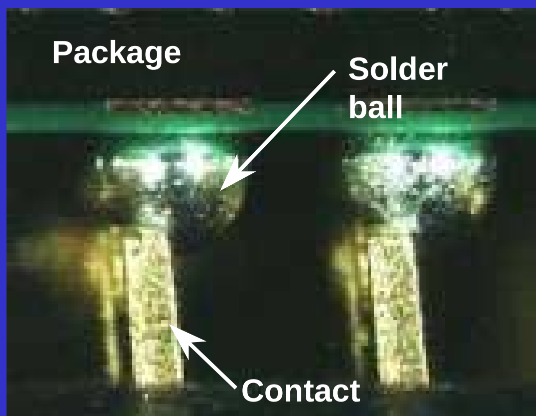


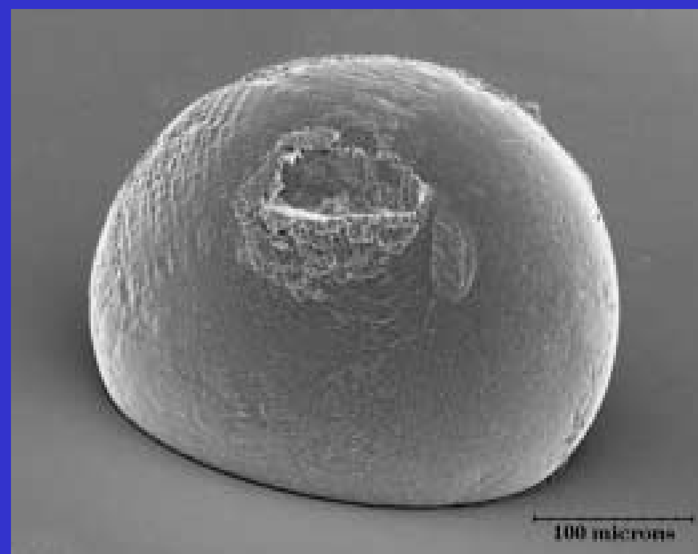
Example of Witness Mark - Dual Pinch Contact - 140° C for 12hr
0.4mm Dia Ball , 0.75mm Pitch. Typical of 1.00mm to 0.5mm pitch

SOLDER BALL - CONTACT INTERFACE
BUCKLING BEAM STYLE

Contact Witness Mark

Bottom Of Ball





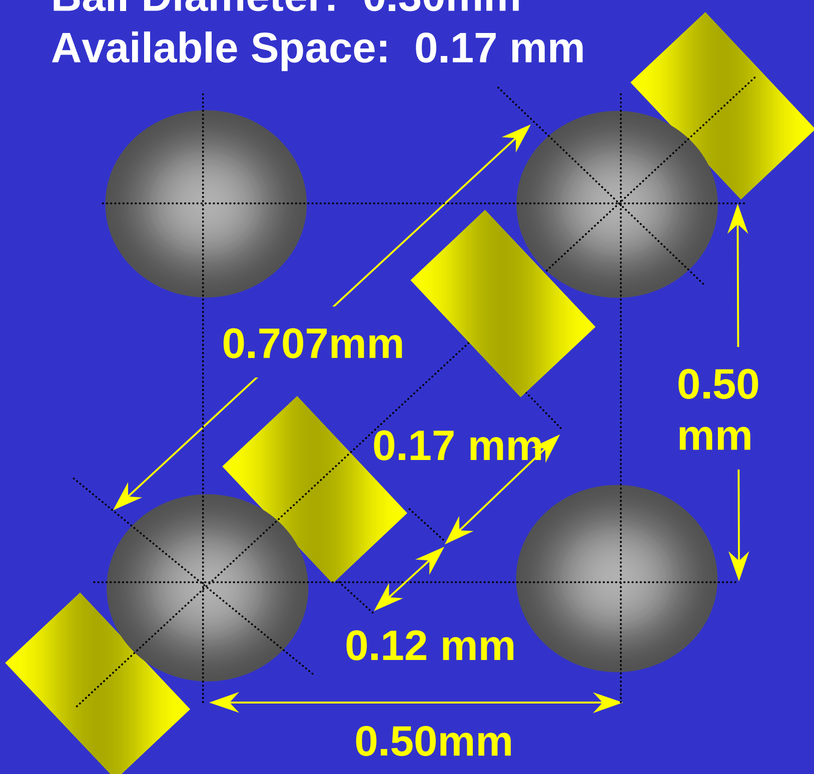
Example of Witness Mark - Buckling Beam Contact - 140° C for 12hr
0.3mm Dia Ball, 0.50mm Pitch.

FINE PITCH DUAL PINCH CONTACT

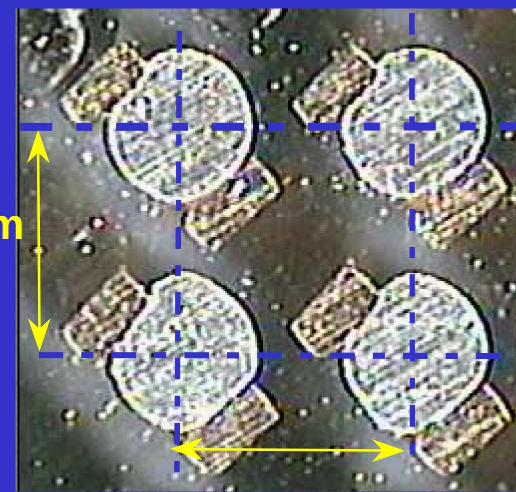
Issue

- **Make A Mechanical Contact With Metal Less Than 0.12 mm Thick**

Pitch: 0.50mm ;
Ball Diameter: 0.30mm
Available Space: 0.17 mm



NOT TO SCALE – SHOWN EXPANDED FOR CLARITY



- **As Pitches Shrink Below 0.5mm, The Space For The Arms Of A Pinch Style Contact Is Limited.**
- **Solutions Favor Single Beam, Buckling Beam Or Pogo Pin For Pitches Less Than 0.5mm.**

FINE PITCH - MOLDED COMPONENTS

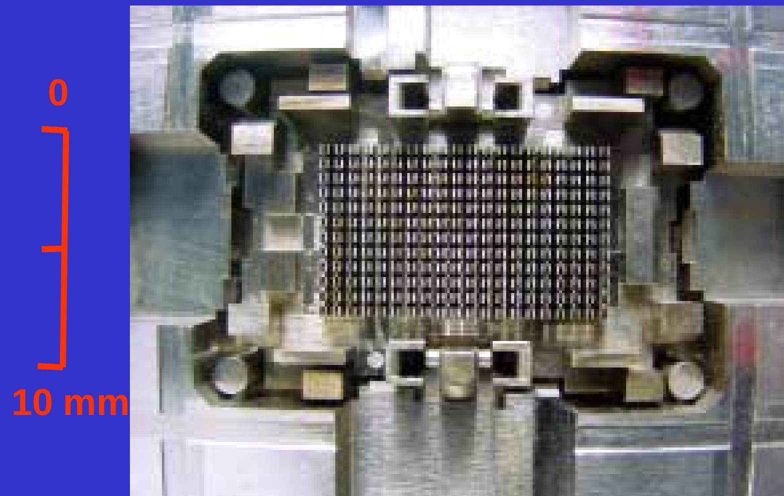
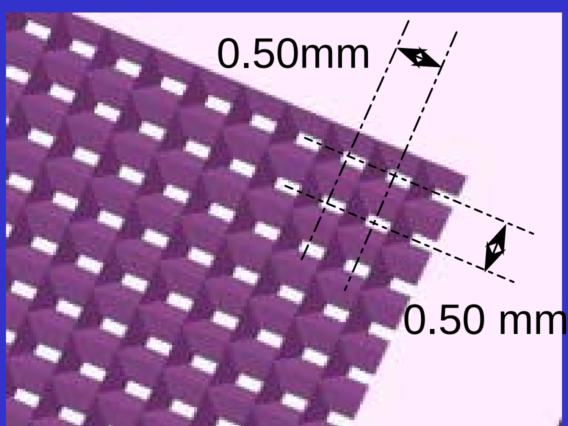


PHOTO OF MOLD CORE PINS FOR 0.8mm PITCH



- **Tooling Difficulties For Fine Pitch Core Pin Arrays.**
- **Longer Lead Times For Tool Qualification.**
- **Uniform Fill And Mold Stability.**
- **Cost.**

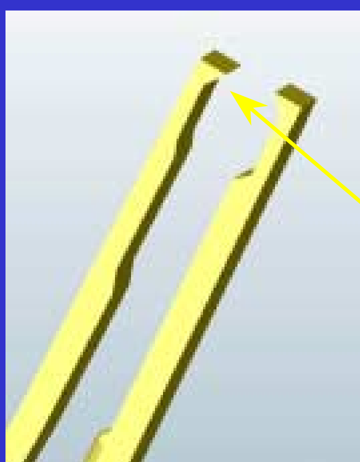
ASSEMBLY ISSUES

- **Automation**
- **Handling Of Small Components**
- **Contact Loading**
- **Time For Assembly: Cost Of Labor**
- **Increase with Higher I/O Sockets**

DESIGN ISSUE: CONTACT TIP GEOMETRY

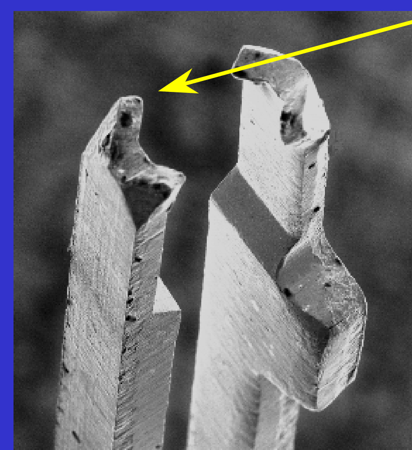
Witness Marks And Contact Resistance: Trade Off

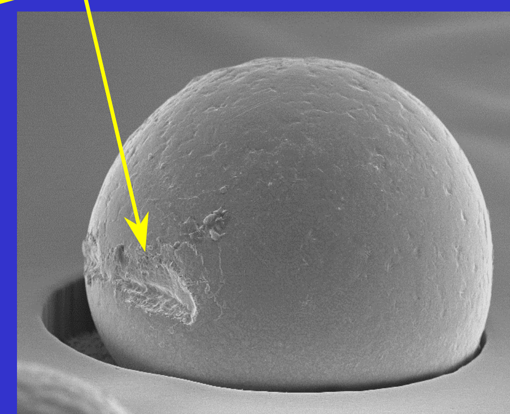
A Sharper Contact Tip Allows Better Penetration Of The Oxide Layer And Lower Contact Resistance ….. But Increases The Solder Ball Witness Mark Size.



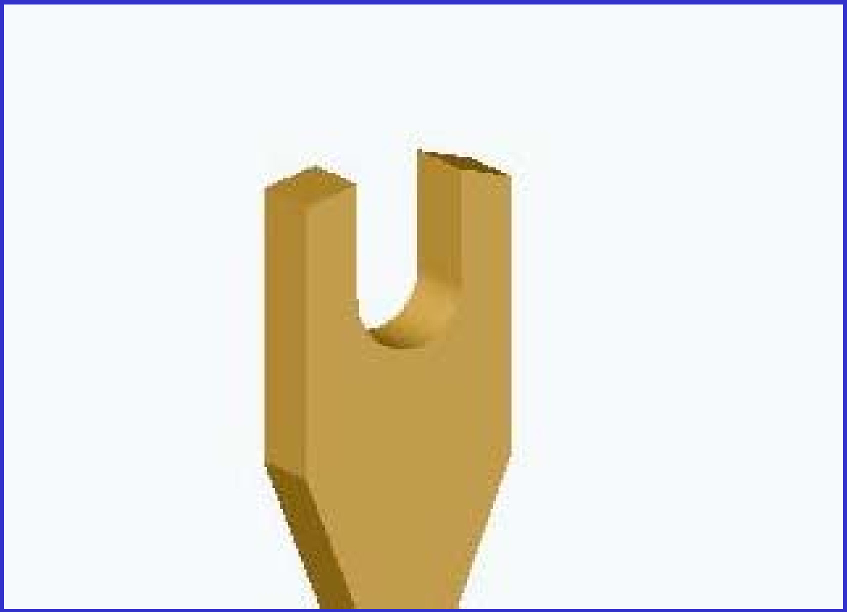
More contact tip area:
Lower resistance
Large witness mark

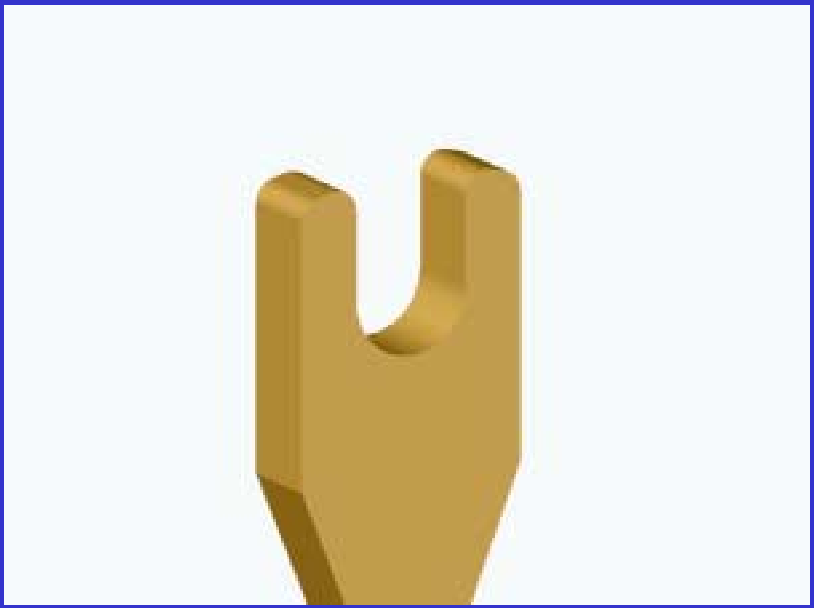
Less contact tip area:
Higher resistance
Small witness mark





DESIGN ISSUE:
CONTACT TIP GEOMETRY



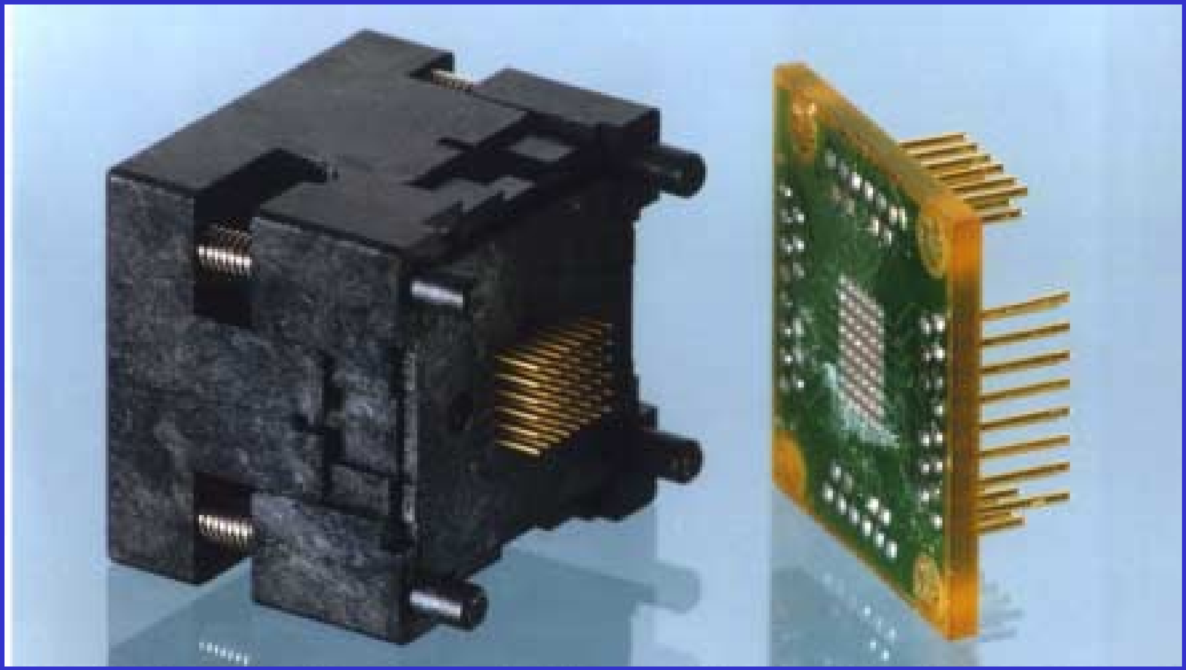


Sharp Tip With Aggressive Bite
- Suitable For Short Burn In Time And Programming Applications

Blunt Tip With Softer Bite
- Suitable For Longer Burn In Time And Hast Applications.

BIB MOUNTING

Fan Out Interposer Allows BIB To Be Drilled At Pitches Of 1.27 or 1.00 mm – Lower Overall Cost



- **Concept Works Well For 0.75mm Pitch**
- **Being Applied to 0.5mm Pitch**

COMPRESSION MOUNTING OF SOCKETS

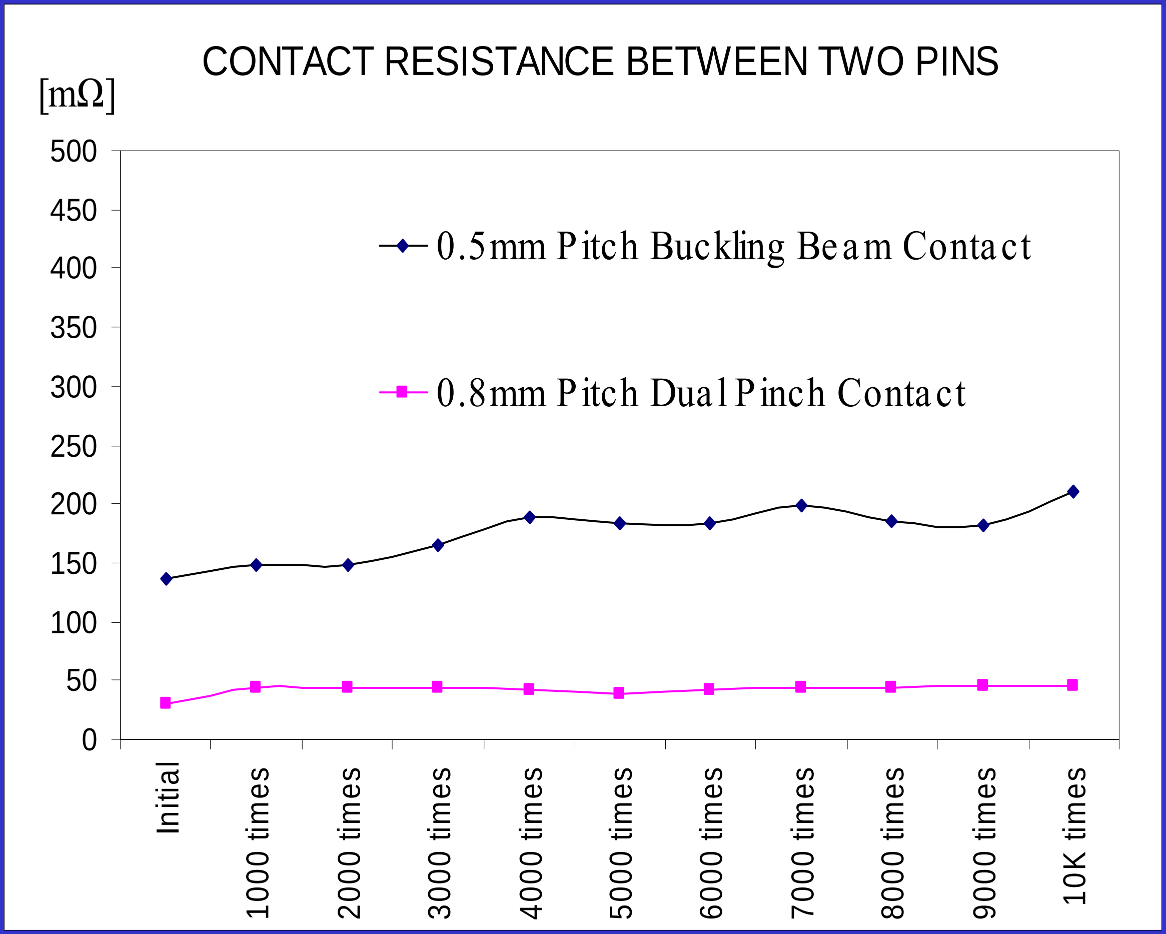
- **Spring Loaded Contact Tail - Eliminates Problems Drilling Fine Pitch Holes.**
- **Concern - Reliable Interconnect In Harsh Testing Conditions Esp. BIB To Contact .**
- **Possibility Of Contamination - Can Increase Overall Resistance**

FINE PITCH LIMITATIONS

- As Pitches Go Below 0.5 mm, The Ball Diameter And Ball Height Are Also Reduced.
- Poses Difficulties When Targeting Specific Areas Of The Solder Ball Where The Contact Can Touch.
- Smaller Metal Contacts Have Lower Fatigue Life And Are More Difficult To Manufacture.
- Tighter Package Tolerances Are Required. Critical Dimension On Molded Plastic Parts Can Be Held Within +/-0.01mm (0.0004”) In Production.

CONTACT RESISTANCE

Contact Resistance As A Function # Of Cycles

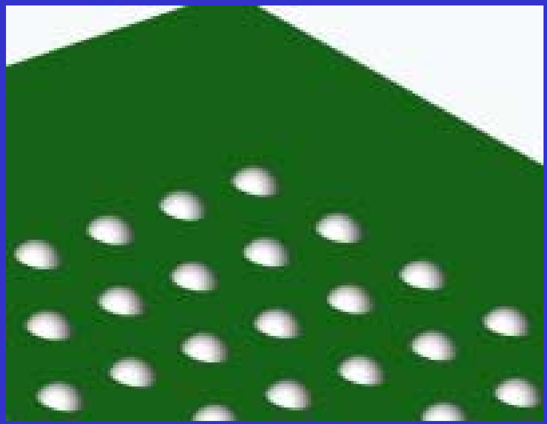


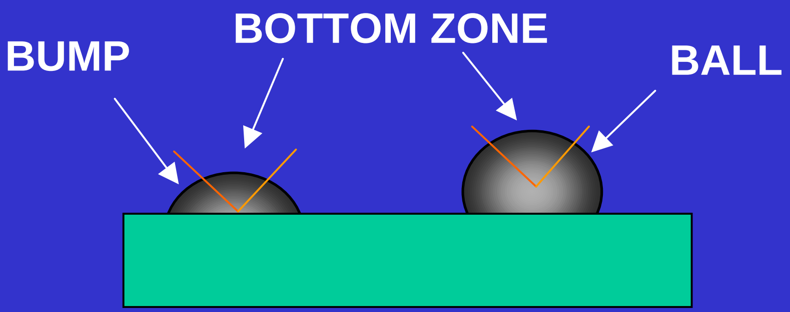
- **Increases With Socket Actuations: Solder Buildup, Contact Wear Etc.**
- **Increase As Contact Size Decreases For Fine Pitch Applications.**

FUTURE DESIGN CHALLENGES

- **Emergence Of Low Profile Bumps As An Alternative To Solder Balls.**
- **LGA Compression Style Contacts Have To Be Used.**
- **Requires Large Latching Force And Bigger Socket Sizes**
- **Witness Marks On Sides - Bottom Of Ball Not Compromised .**

SOLDER BUMPS





FUTURE DESIGN CHALLENGES

- **Low Cost And Reliable Contacts For 0.4mm & 0.3mm Pitch.**
- **Small Open Top Socket Outline.**
- **Contact Life.**
- **Manufacturability Of Fine Pitch Sockets.**
- **Handling Of Multiple Solder Ball Profiles.**
- **Moldability Issues Of Plastic Parts For Fine Pitch.**

ACKNOWLEDGEMENTS

- Work presented here was the result of much effort by many people - especially the following: …….

    - Design Team in Japan
    - Design Team in Korea
    - WW Manufacturing Team
    - Technical Services Lab

DISCUSSION

High Frequency Performance of Various Test Contactor Geometries

0.8 mm Pitch

Eric Fachon

QA Technology, Inc.

BiTS Workshop, March 2003

Test System

- Hewlett Packard: 8720ES Vector Network Analyzer, 50MHz-20GHz
- GigaTest Labs: GTL 4040 Wide Area Probing Station & Custom Test Fixture
- GGB Industries: Microwave Probes and Calibration Substrate

Test System

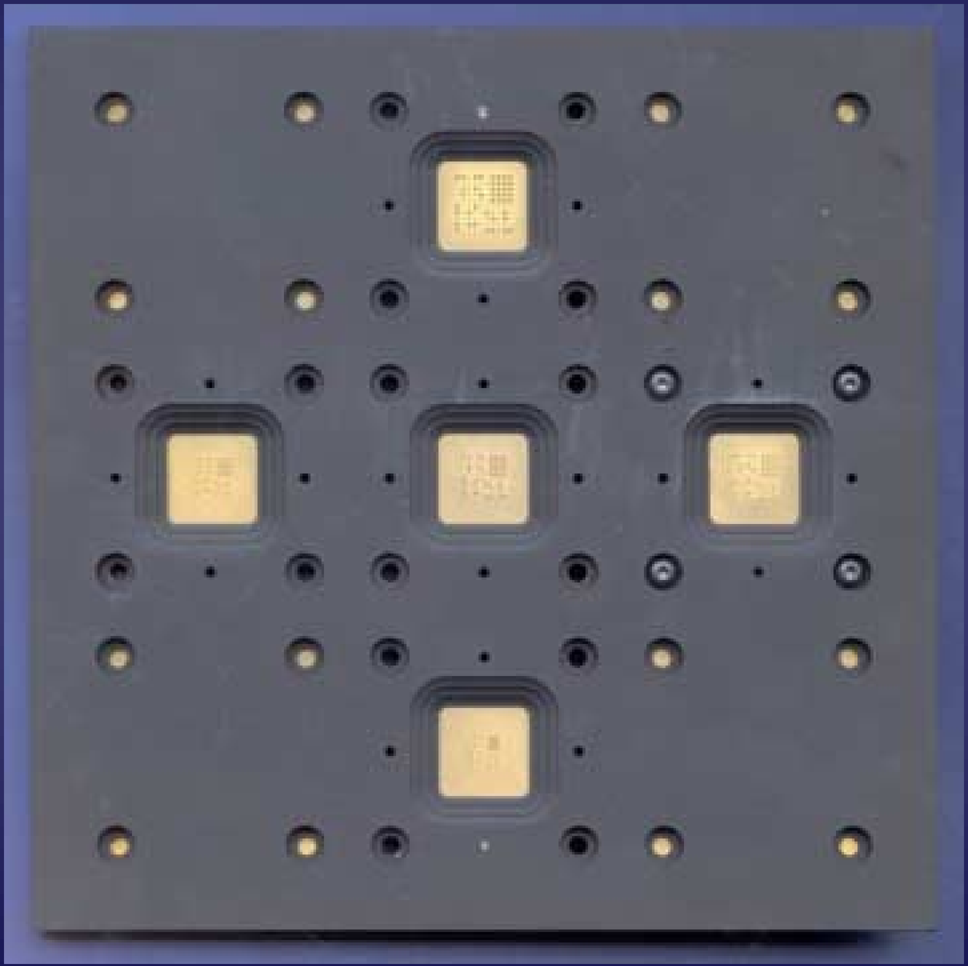
Custom Test Fixture

- Designed by GigaTest Labs
- Allows the use of a simple, symmetrical surrogate contactor
- Provides for Open, Short and Loop-thru measurements
- Allows measurements of different pin locations
- Provides for measurements on various pitches

Test Fixture

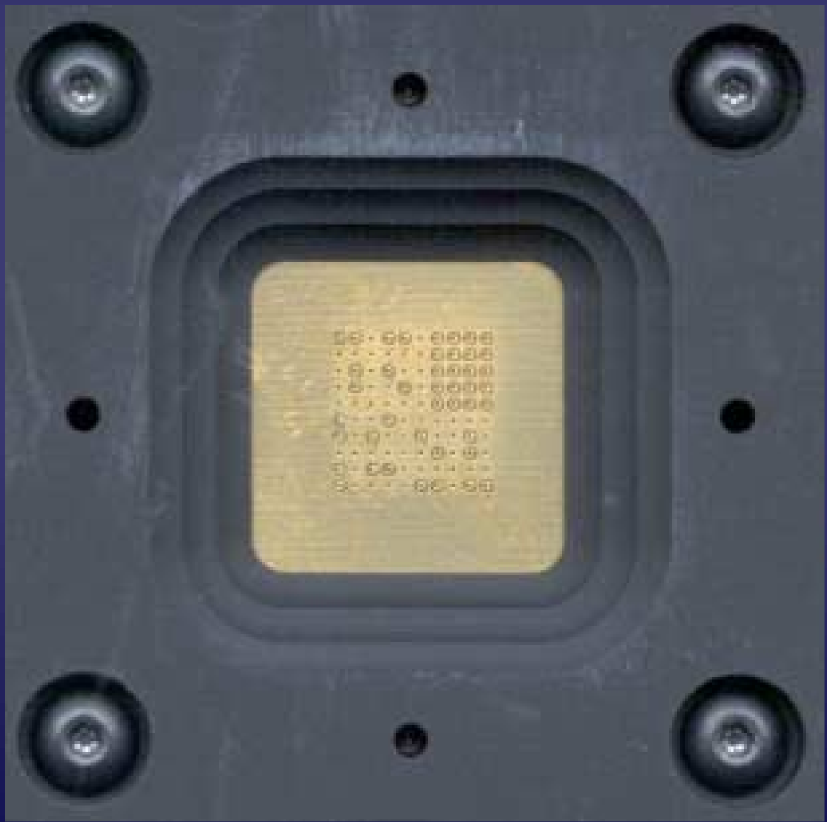
- Test arrays for probe pitches of:

  1.0 mm
  0.8 mm
  0.75 mm
  0.65 mm
  0.5 mm



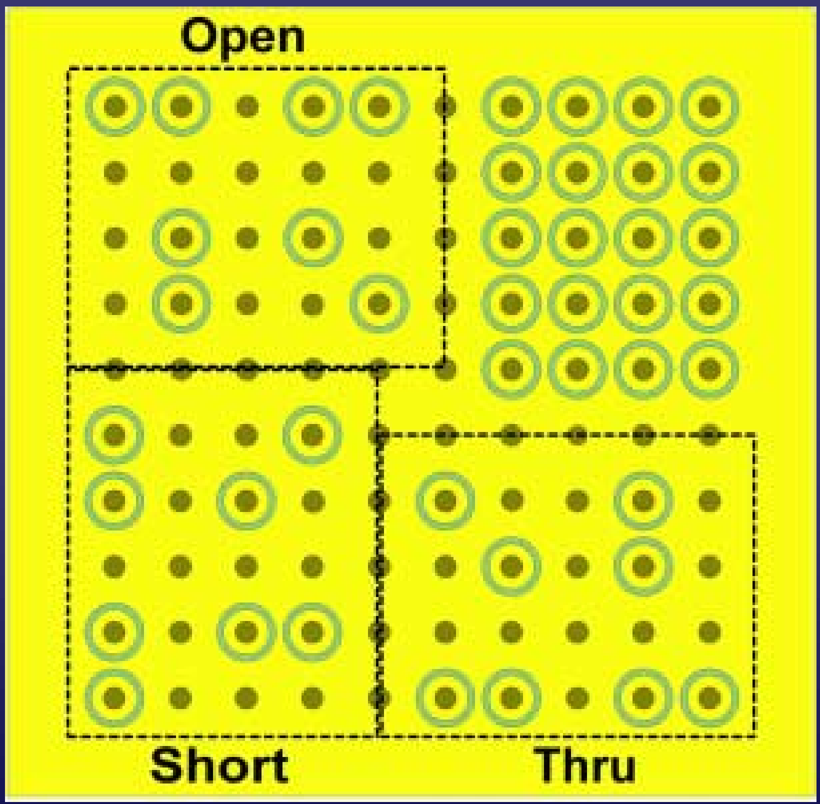
Test Fixture

- Top board
- Surrogate package

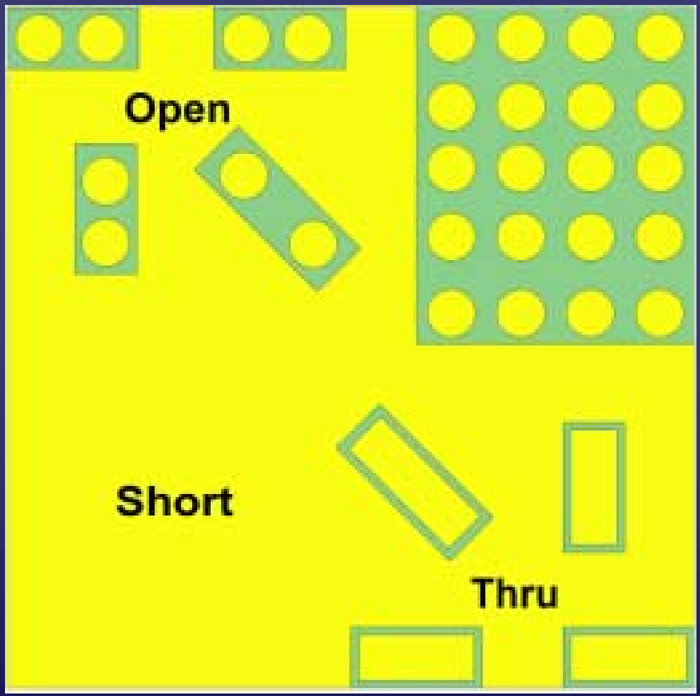


Test Fixture

- Top board

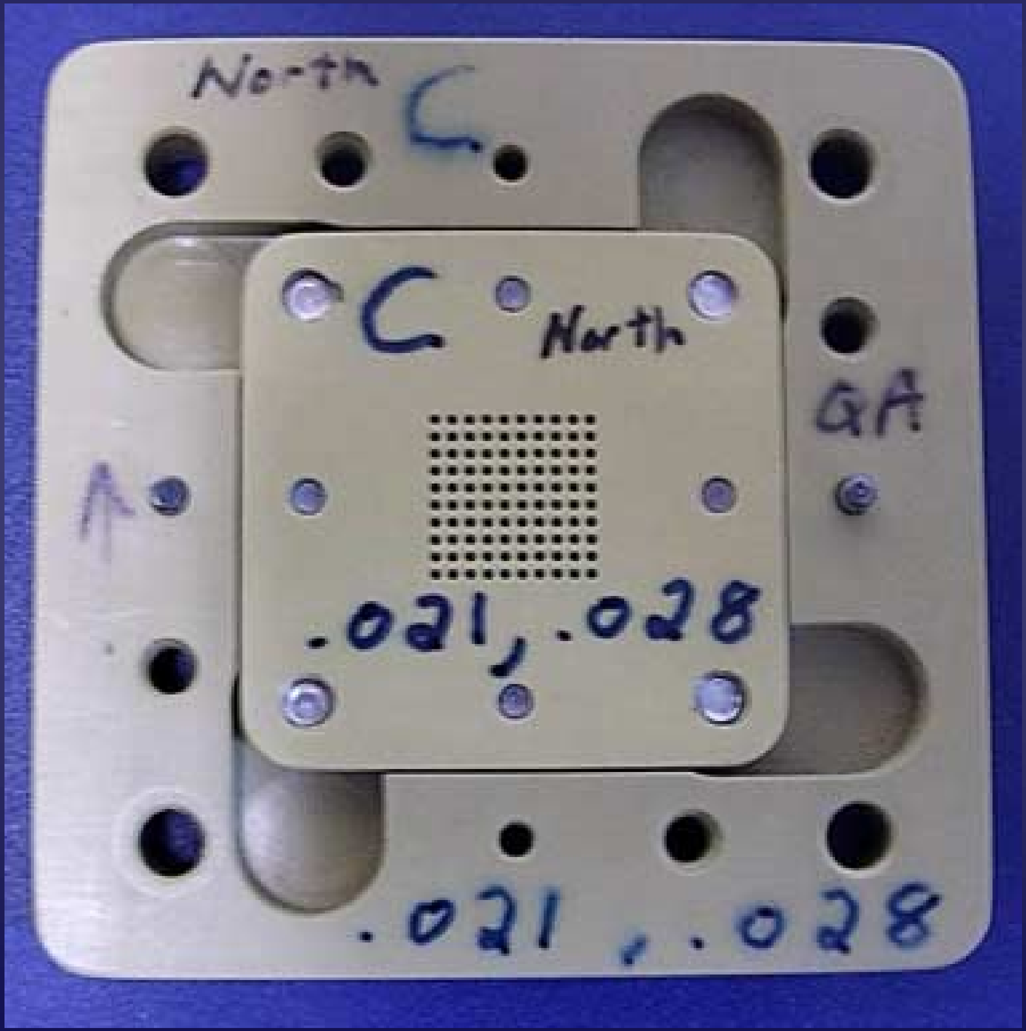


- Surrogate package



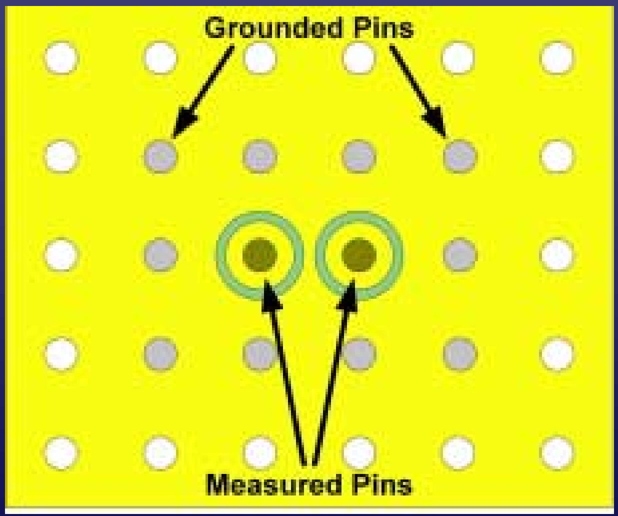
Test Fixture: Surrogate Contactor

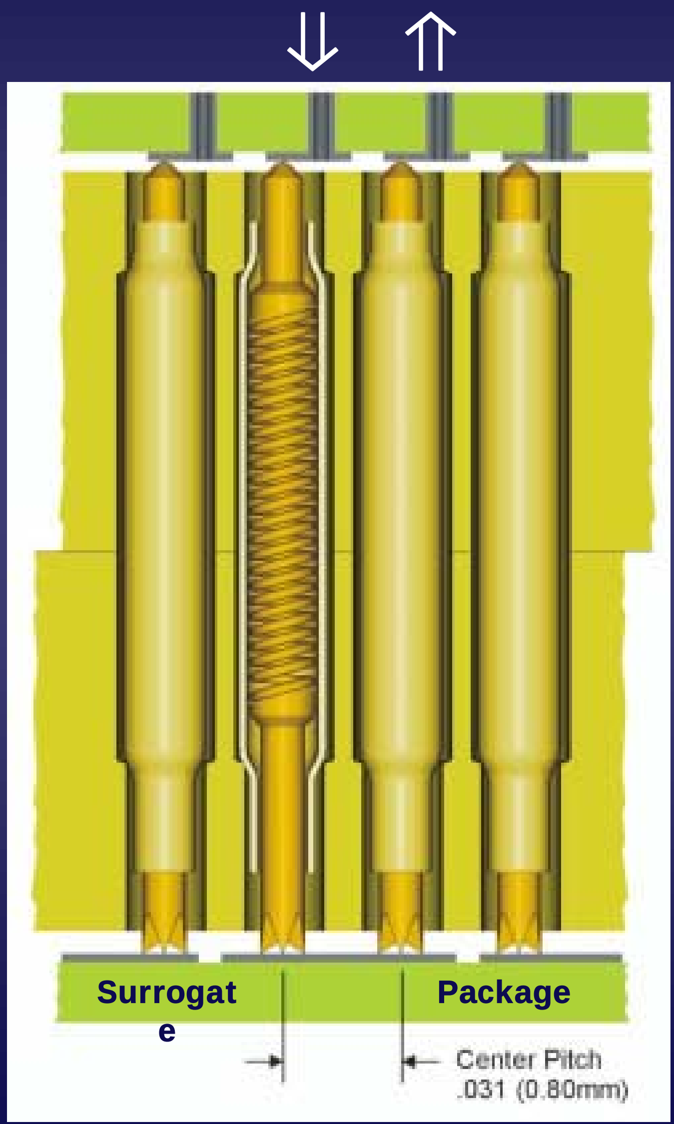
- Torlon 4203
- 10 x 10 Array



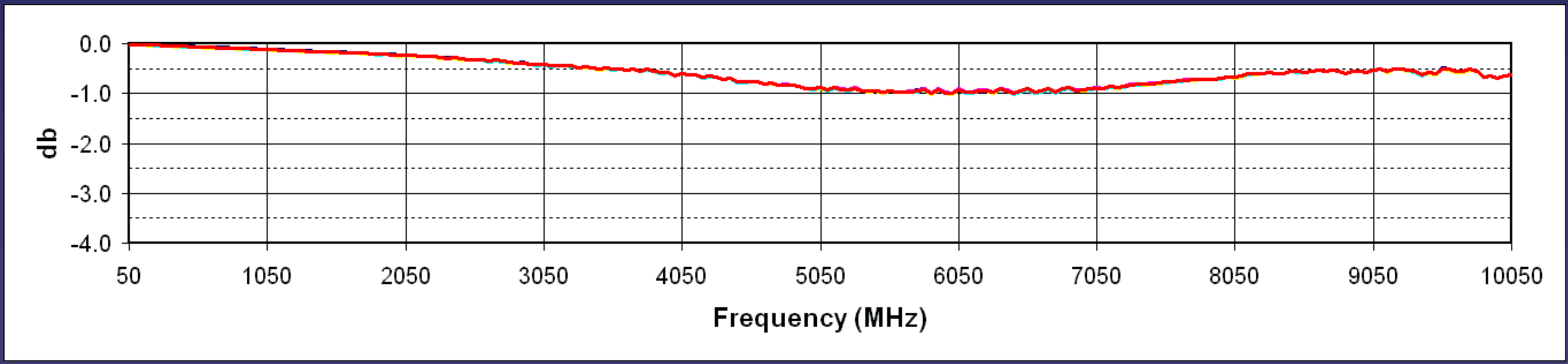
Test Fixture: Loop-thru

- Round trip through two adjacent probes and surrogate package
- Surrounding probes are grounded

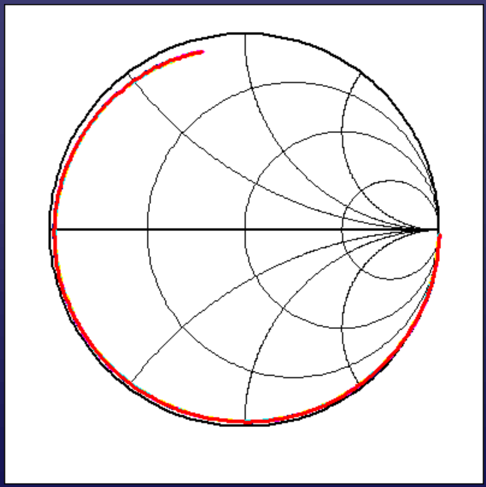




Test System Repeatability

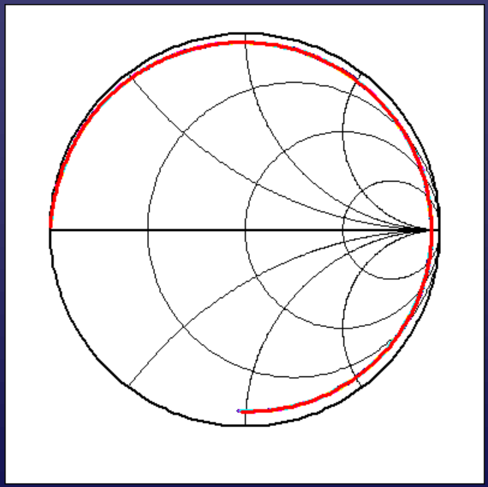


Insertion Loss (S_{21})



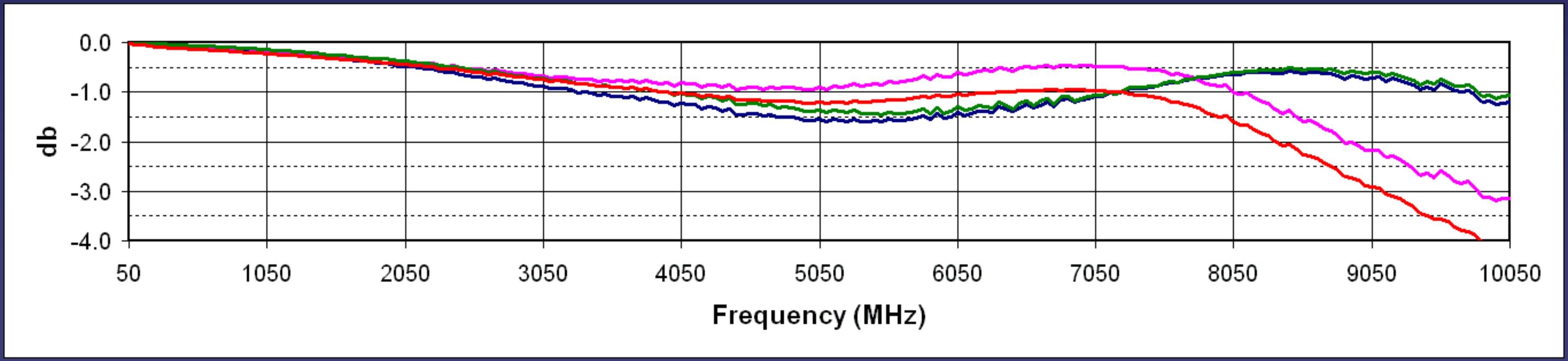
S_{11} Open

Composite of Five Data Sets

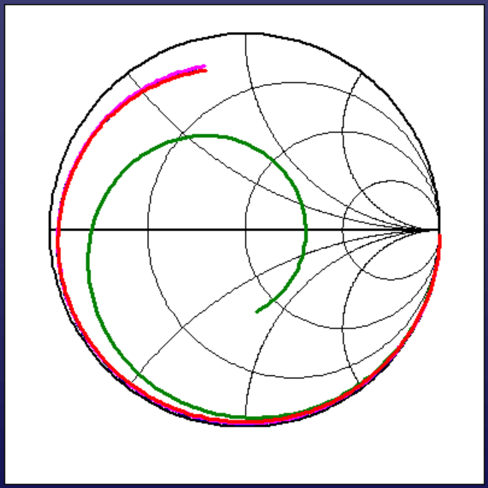


S_{11} Short

Early Contactor Repeatability

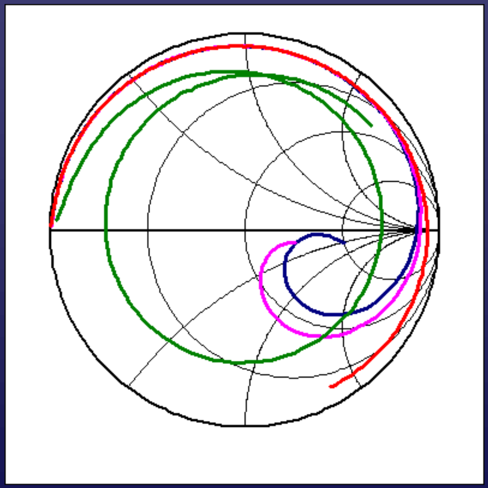


Insertion Loss (S_{21})



S_{11} Open

Selected Data



S_{11} Short

General Test Methodology:

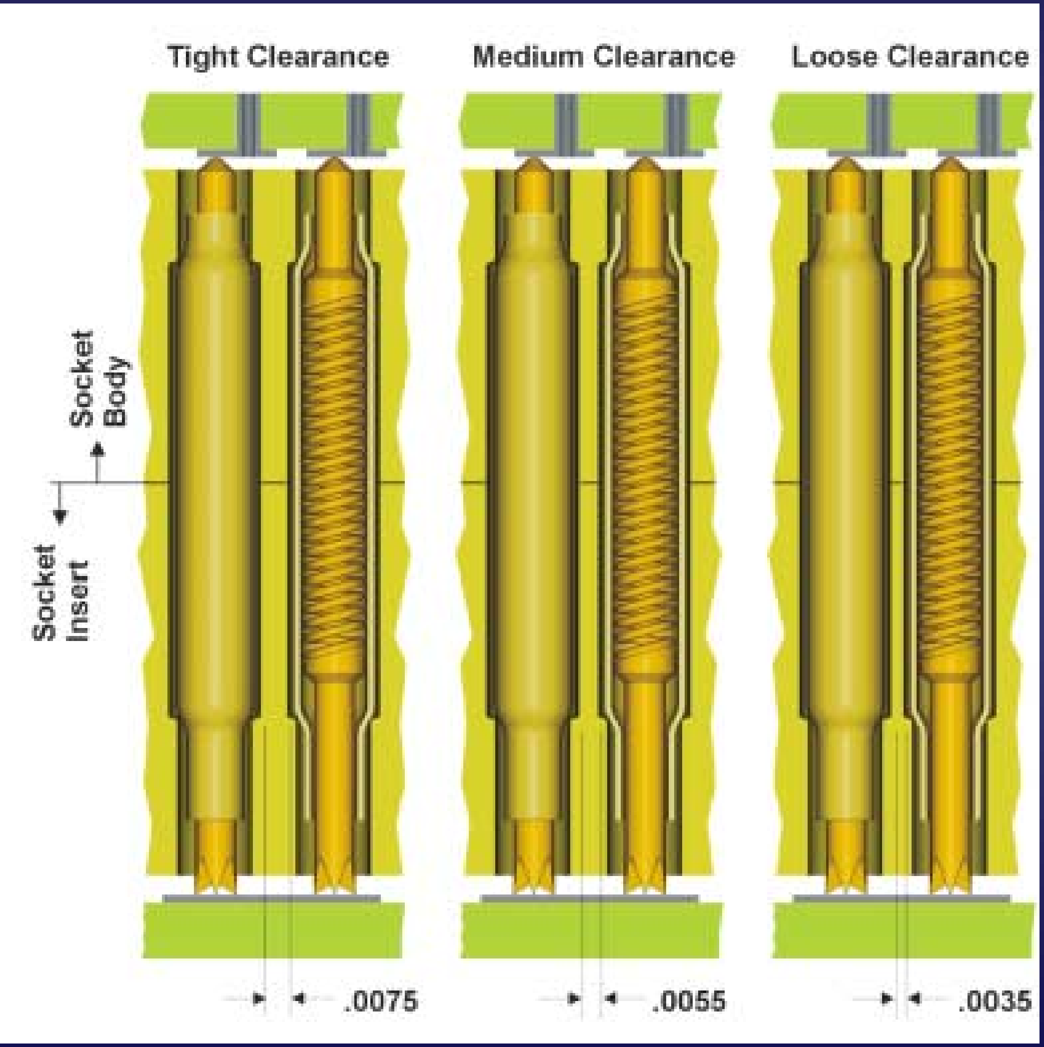
- Fabricate surrogate contactor
- Perform system calibration (SOLT)
- Make Open/Short/Thru measurements for all four probe pair locations
- Repeat for each of four contactor orientations
- Import measurement data to Excel
- Generate Smith Charts and Bandwidth Plots
- Generate averaged S-parameter data for model extraction by GigaTest

Contactor Geometry Variants

- Our earliest surrogate contactors were of a simple one piece design
- Subsequent versions captured the probe via a two piece design
- Clearances were varied in these later designs to evaluate the effect on high frequency performance

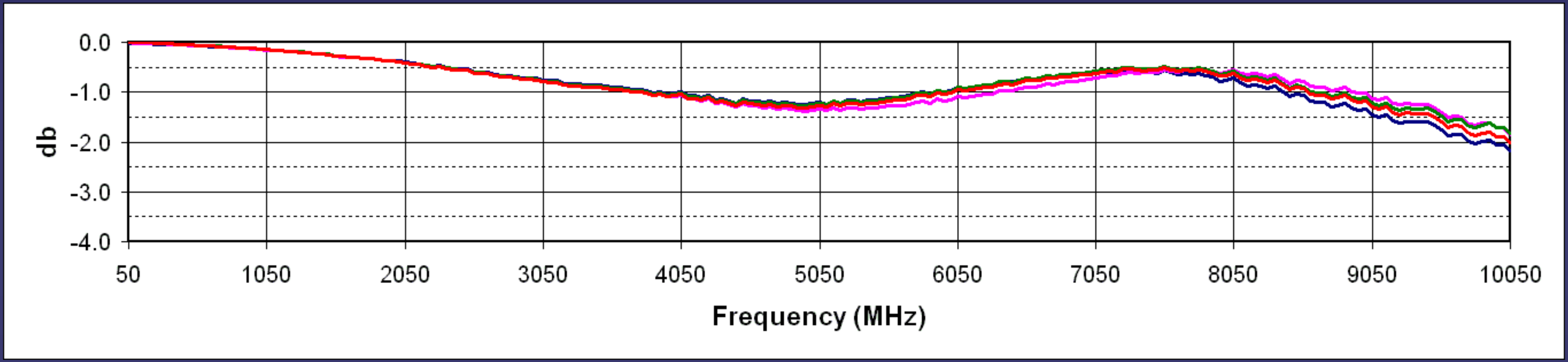
Contactor Geometry Variants

- Minor Diameter x
  Major Diameter
- Probe:
  .0166” x .0224”
- Tight Clearance: .018” x .024”
- Medium Clearance:
  .021” x .026”
- Loose Clearance: .021” x .028”

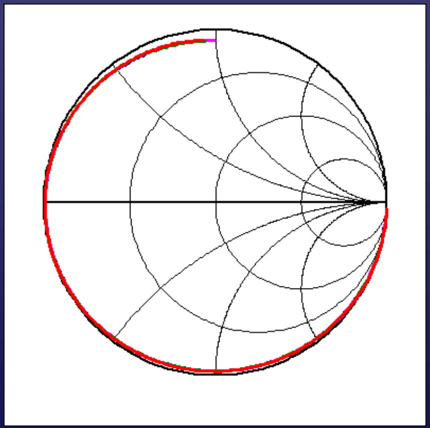


S-Parameter Measurements

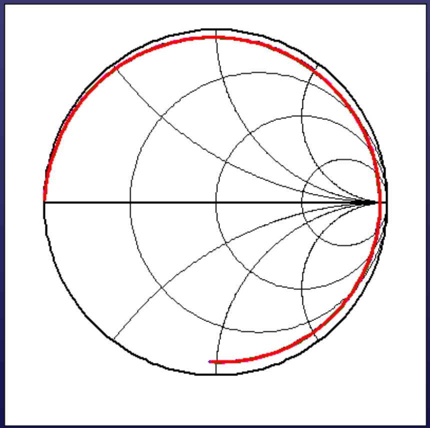
- Tight Clearance
- -1db at 3.7 GHz



Insertion Loss (S_{21})



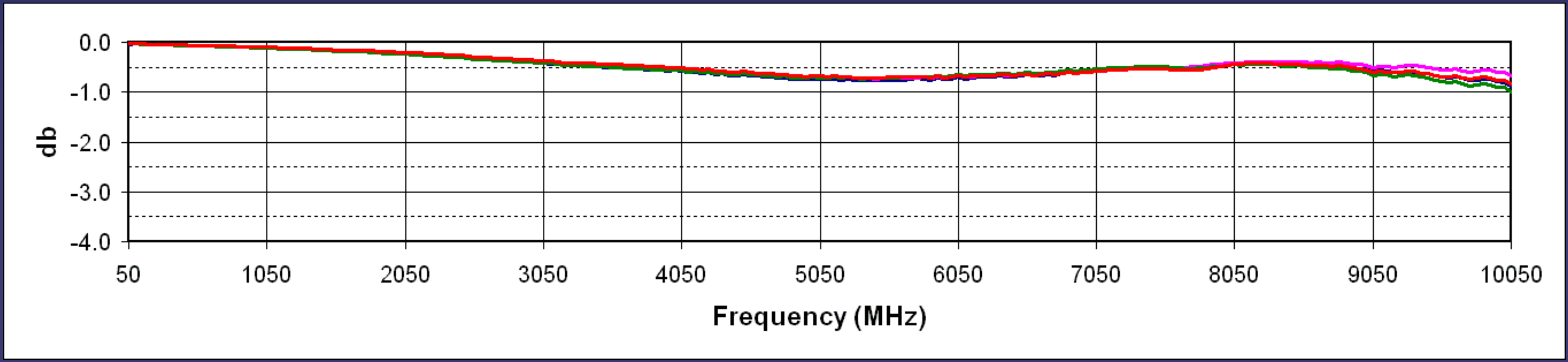
S_{11} Open



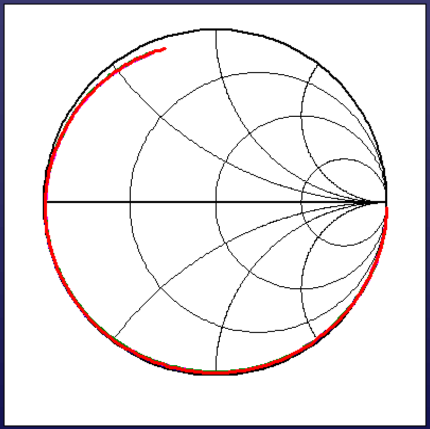
S_{11} Short

S-Parameter Measurements

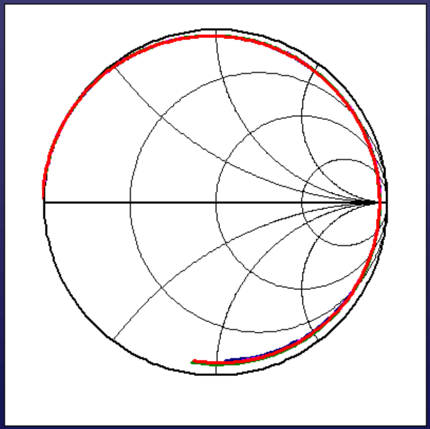
- Medium Clearance
- -1db at 10.0 GHz



Insertion Loss (S_{21})



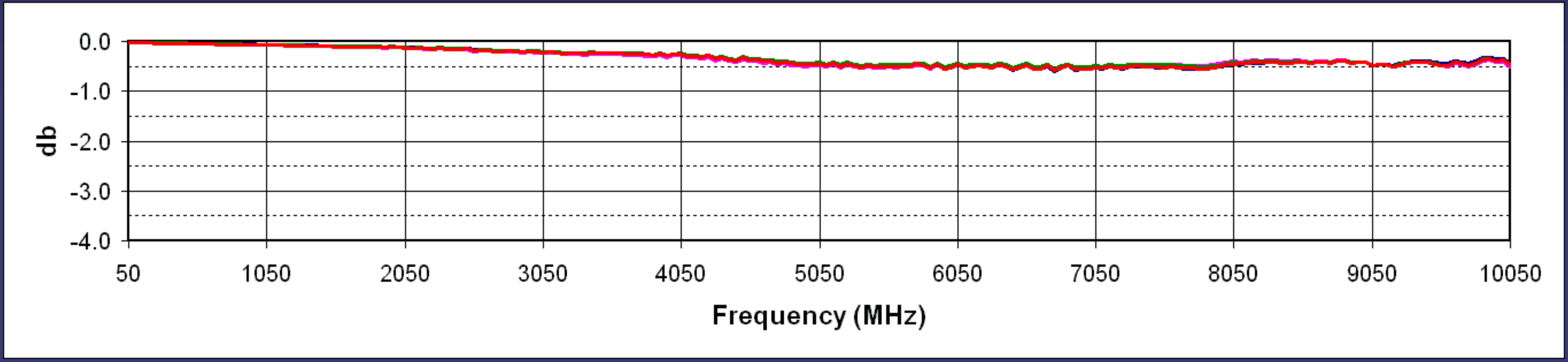
S_{11} Open



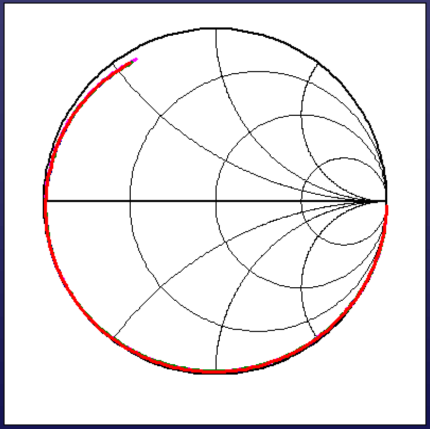
S_{11} Short

S-Parameter Measurements

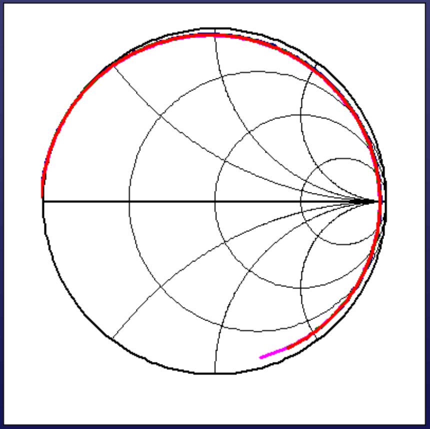
- Loose Clearance
- -1db at >10.05 GHz



Insertion Loss (S_{21})



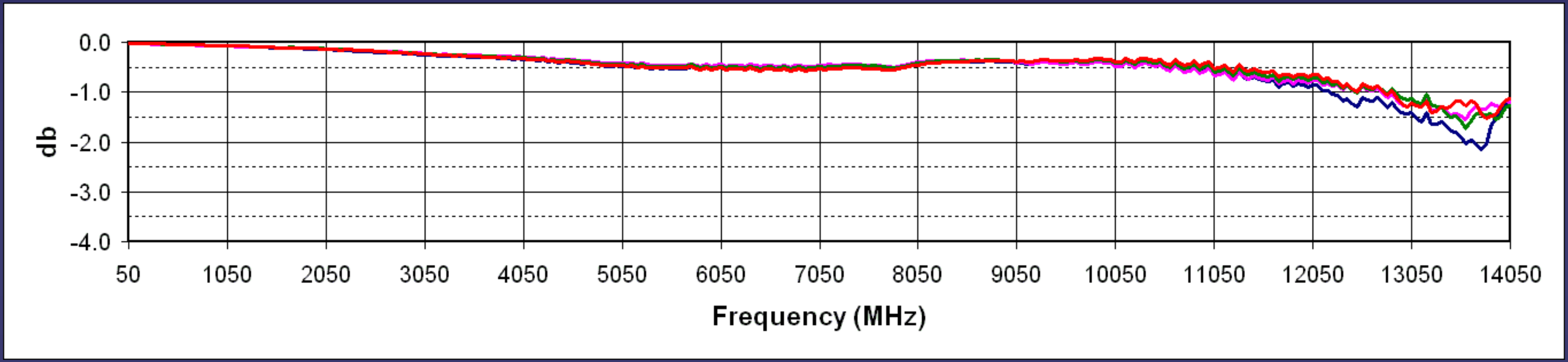
S_{11} Open



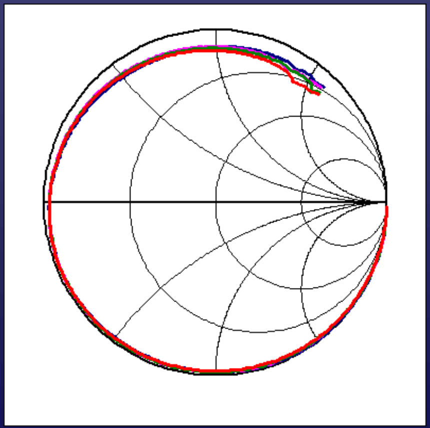
S_{11} Short

S-Parameter Measurements

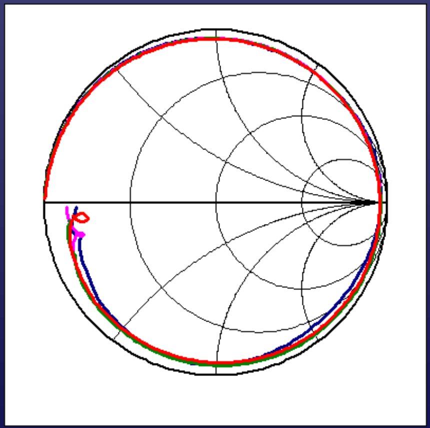
- Loose Clearance
- -1db at 12.25 GHz



Insertion Loss (S_{21})



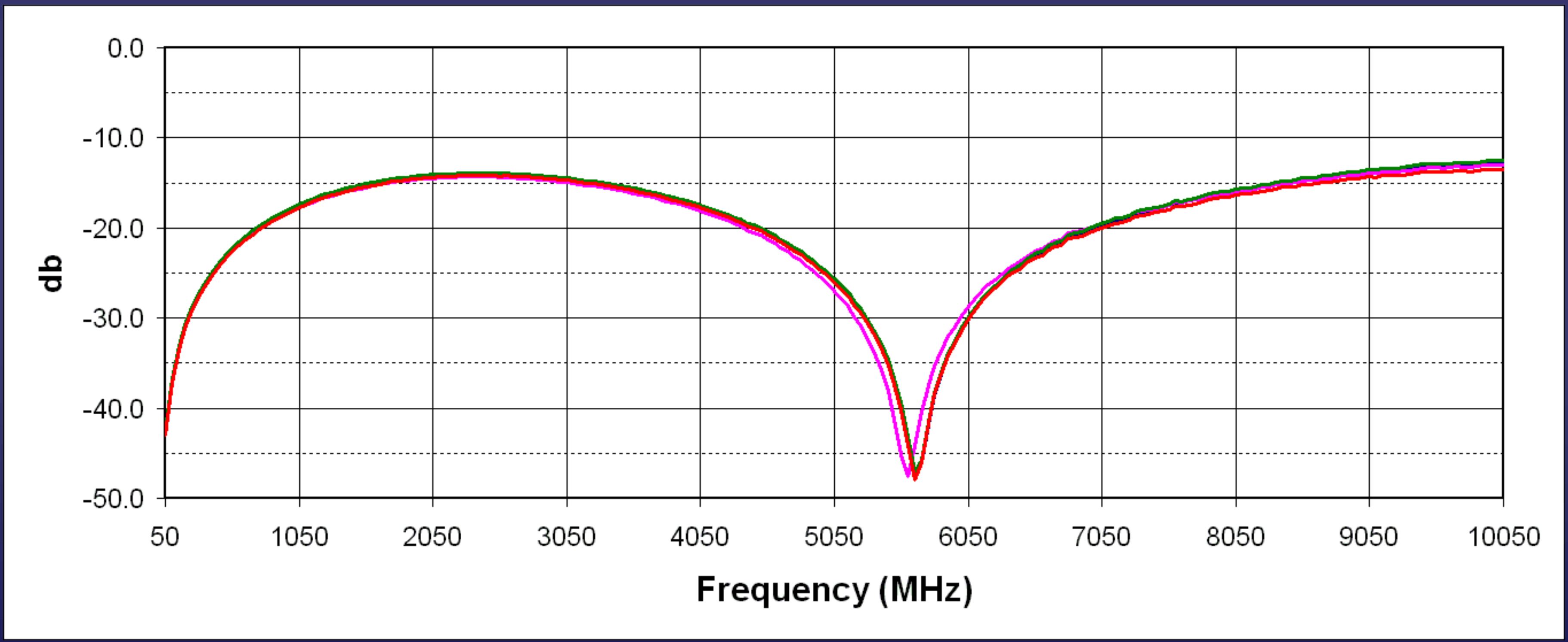
S_{11} Open



S_{11} Short

S-Parameter Measurements

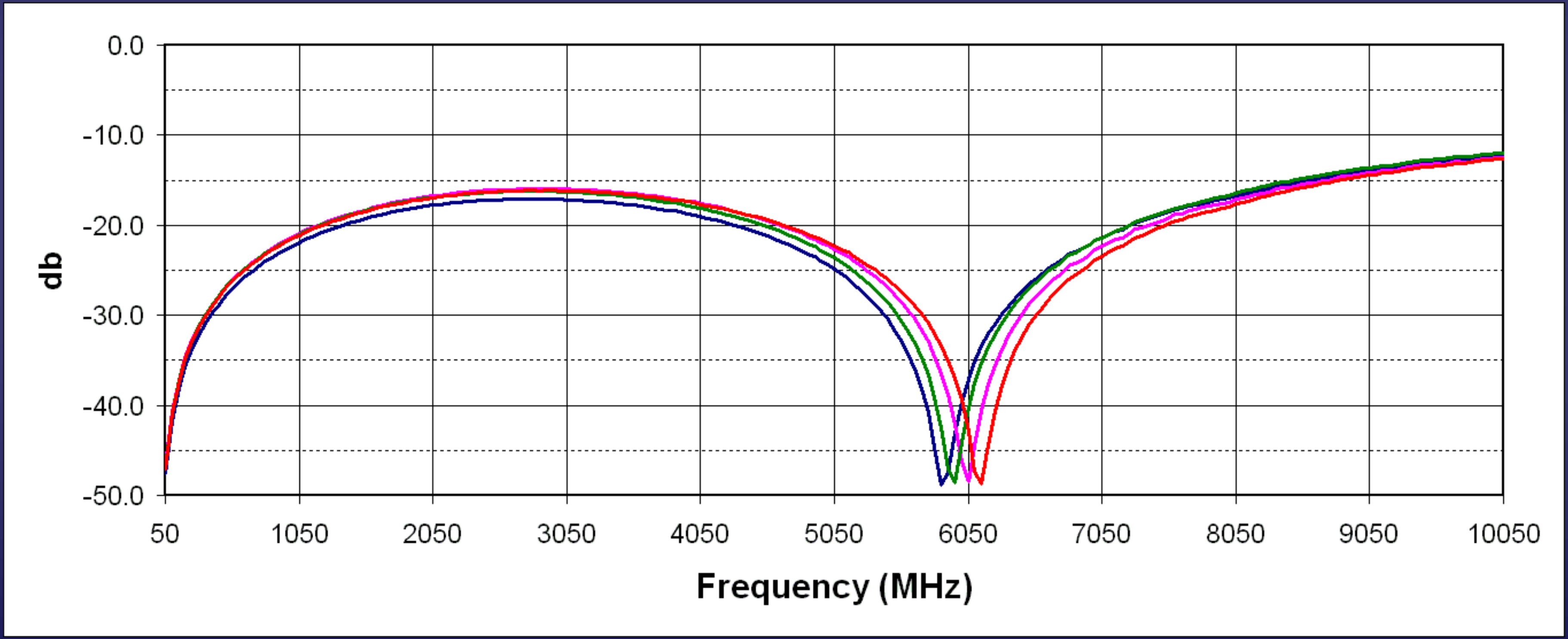
- Tight Clearance
- Crosstalk



S_{21} Open

S-Parameter Measurements

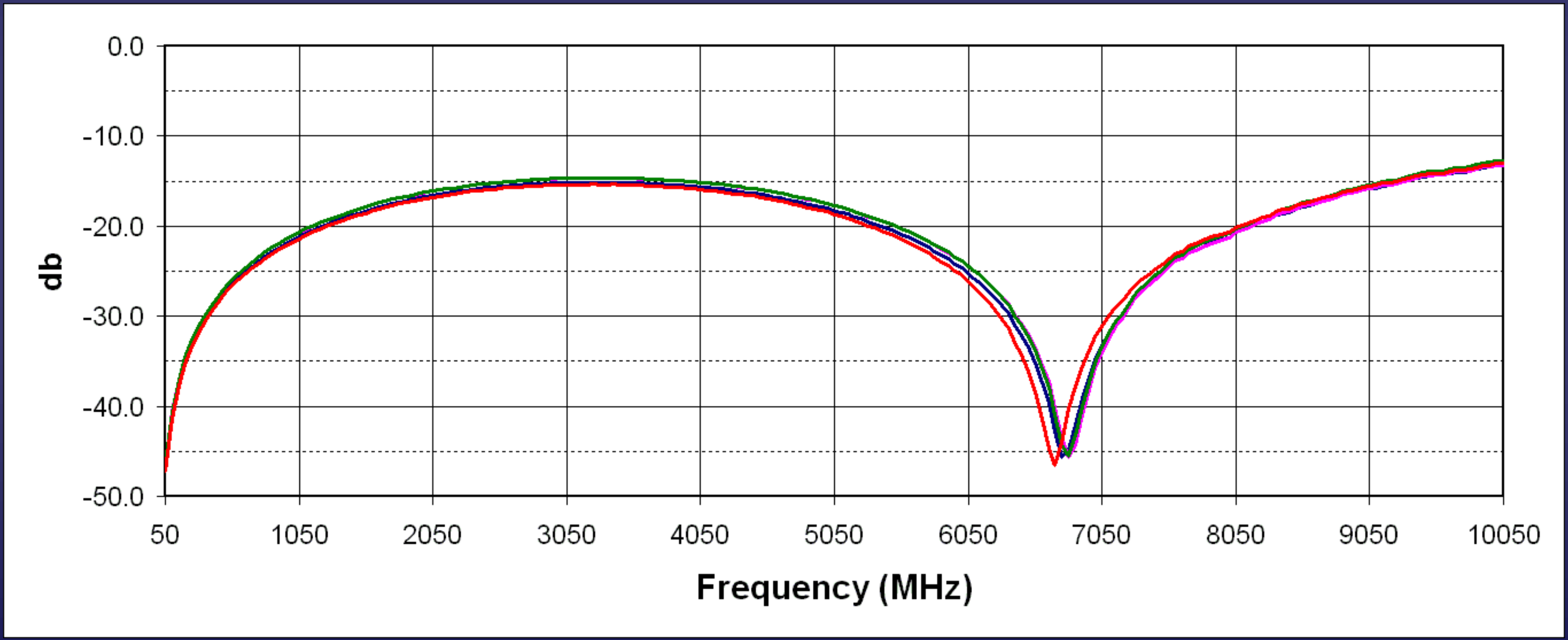
- Medium Clearance
- Crosstalk



S_{21} Open

S-Parameter Measurements

- Loose Clearance
- Crosstalk

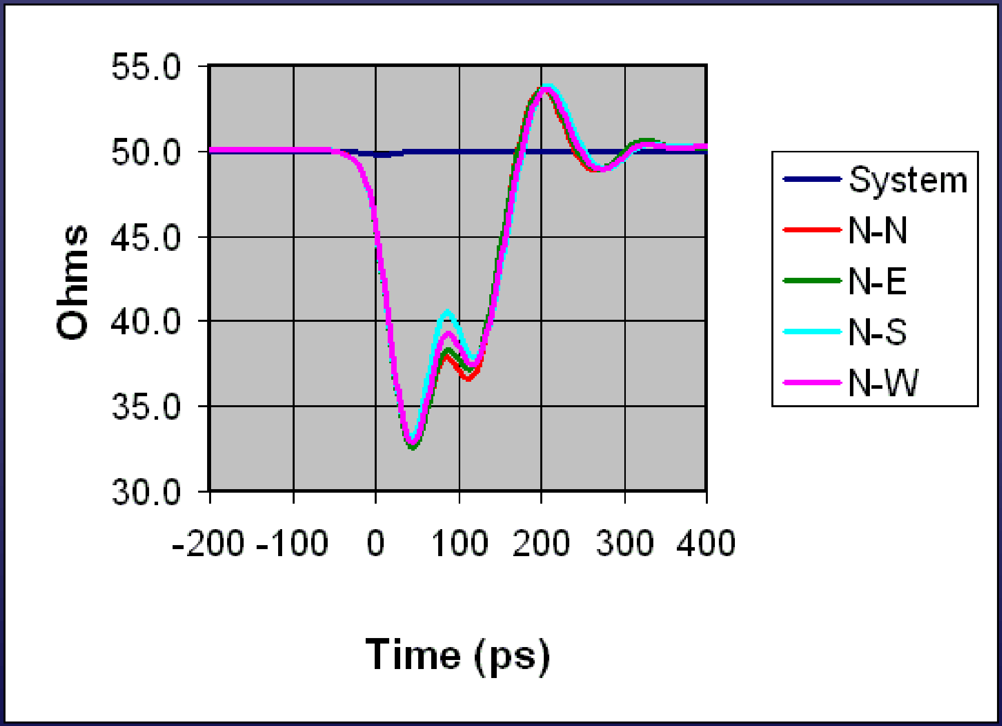


S_{21} Open

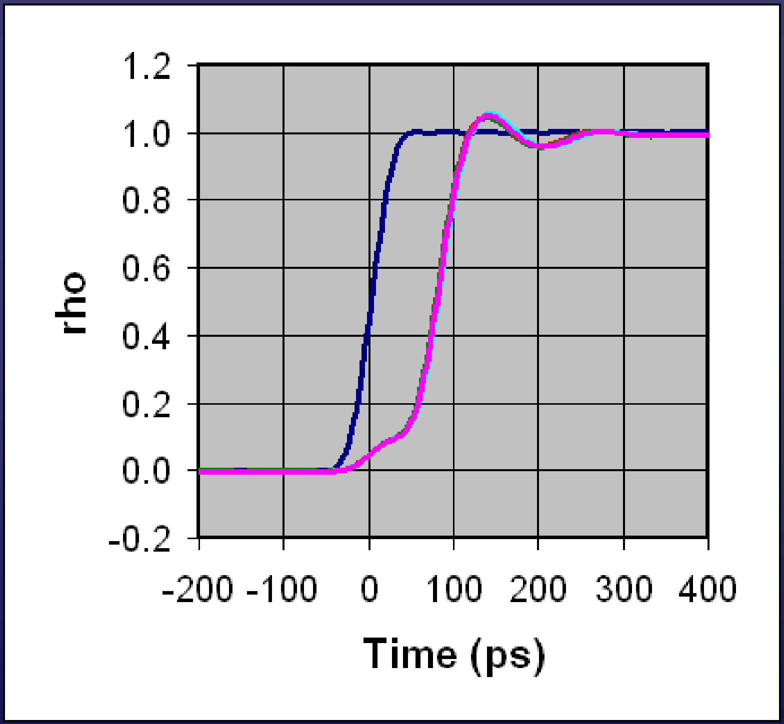
Time Domain Measurements

- Close Clearance
- Loop-thru

- Rise Time = 53 ps
- ½ Delay = 40 ps



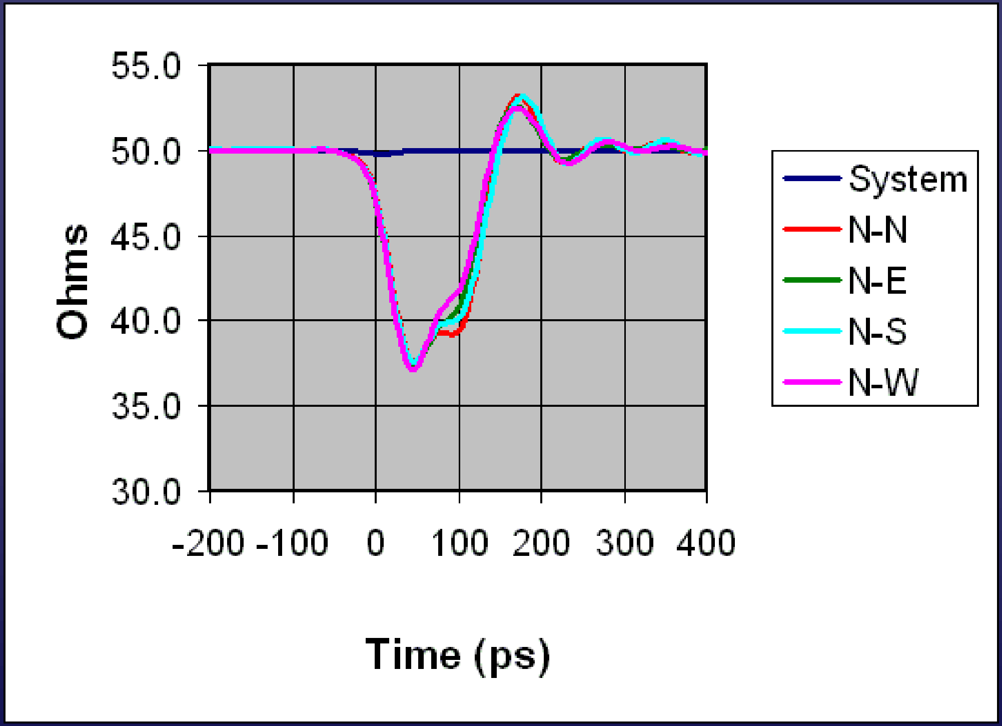
TDR



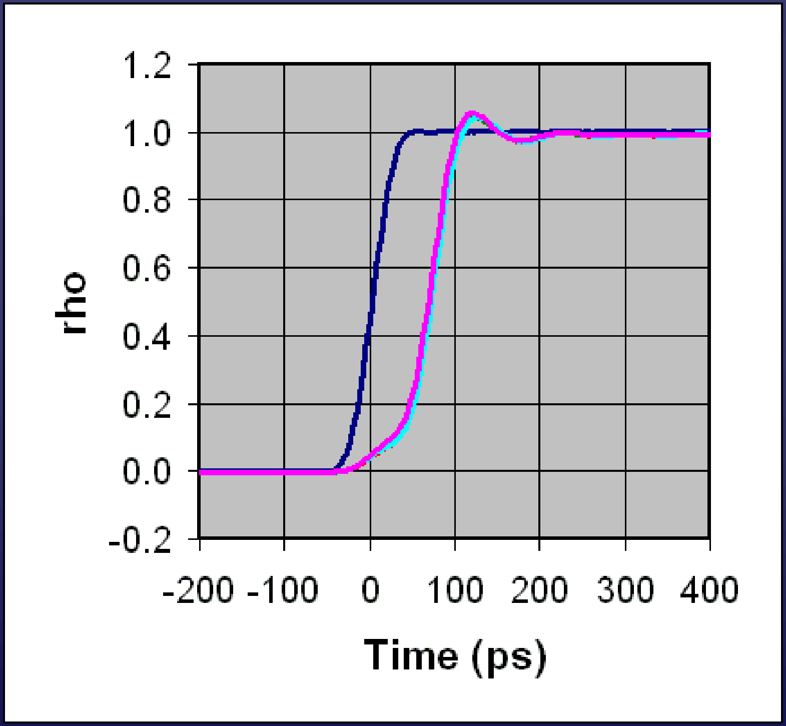
TDT

Time Domain Measurements

- Medium Clearance
- Loop-thru
- Rise Time = 38 ps
- ½ Delay = 35 ps



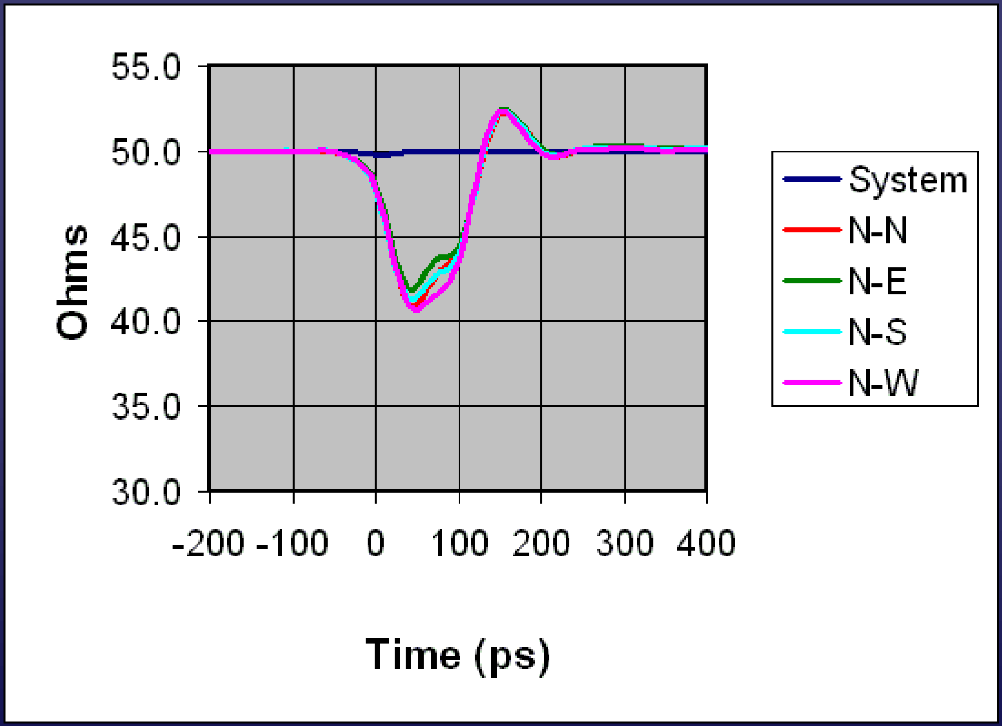
TDR



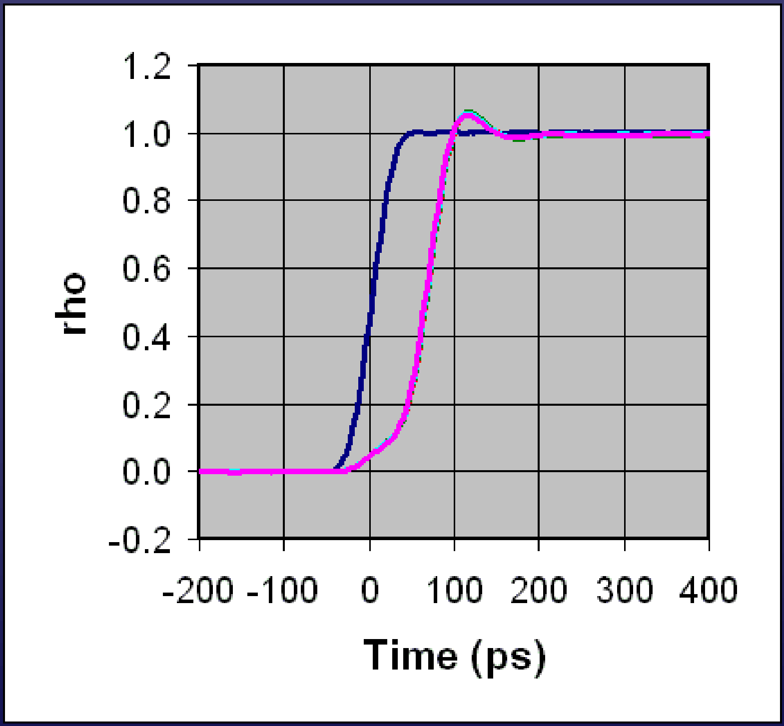
TDT

Time Domain Measurements

- Loose Clearance
- Loop-thru
- Rise Time = 37 ps
- ½ Delay = 33 ps



TDR

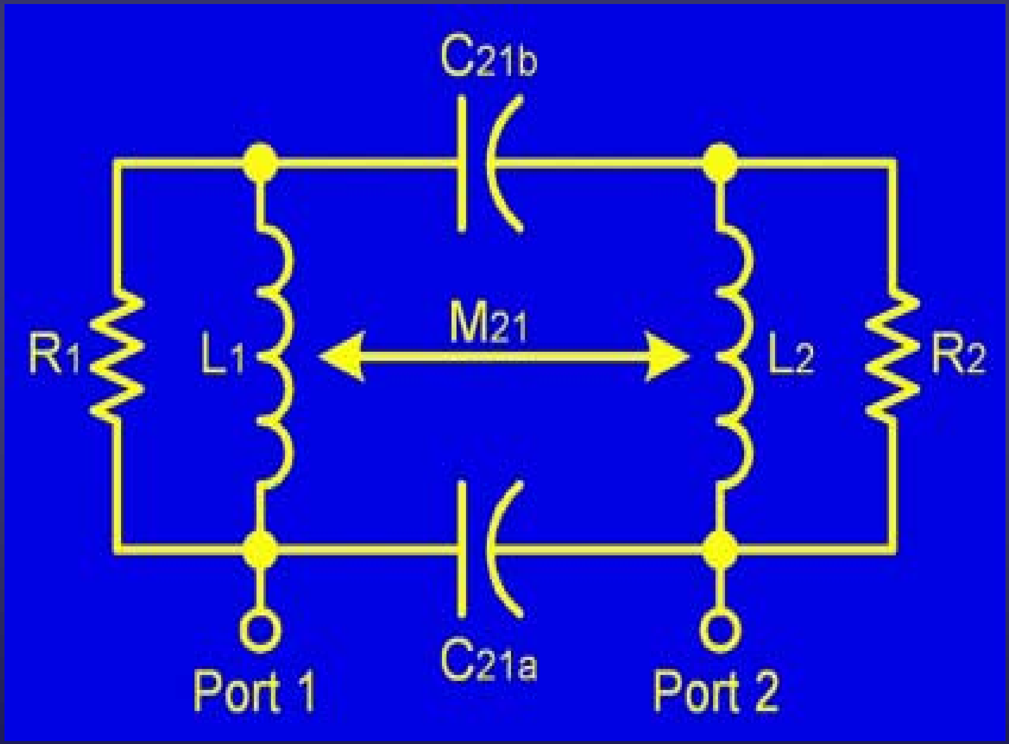


TDT

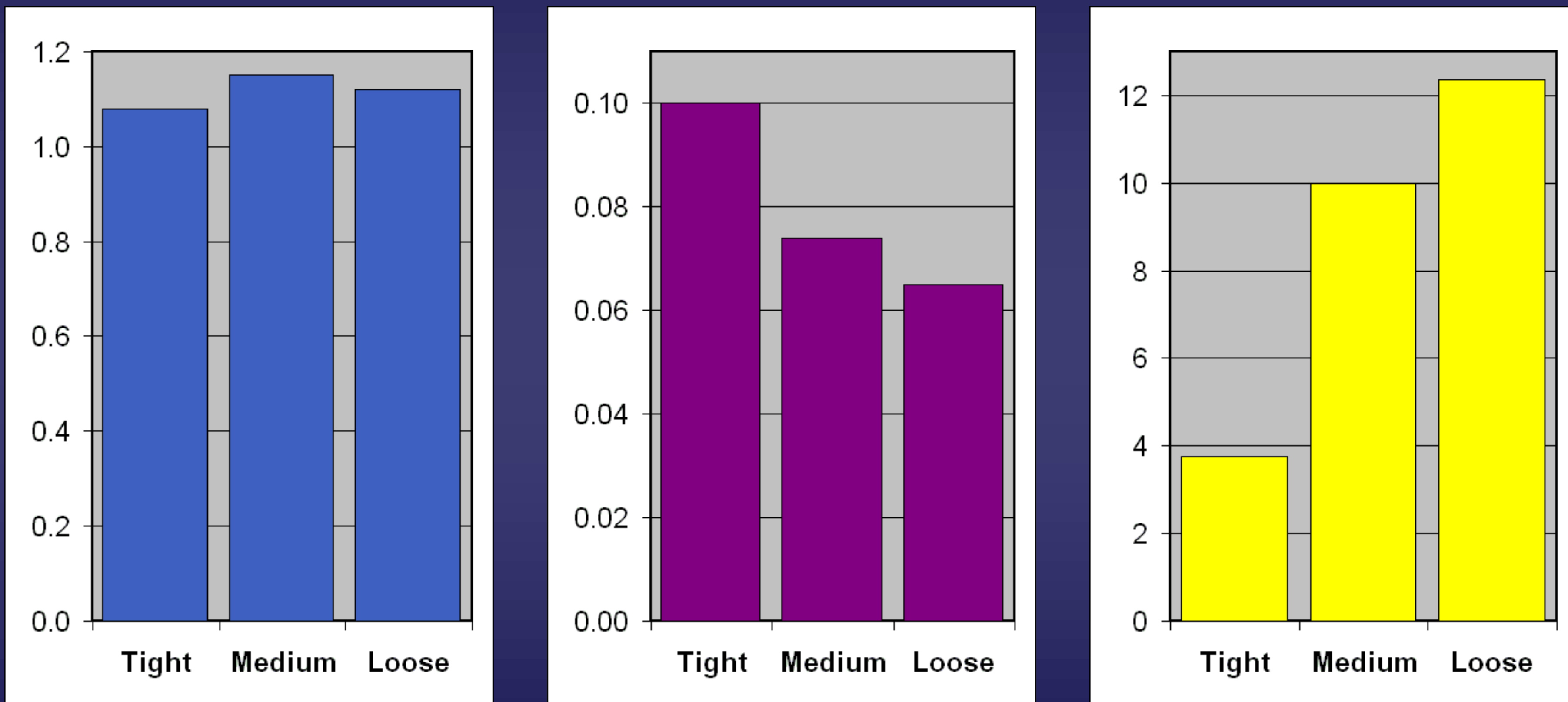
Equivalent-circuit Model Extraction

- Model data extracted by GigaTest Labs

- L_1, L_2: pin self inductance
- M_{21}: mutual inductance between adjacent pins
- R_1, R_2: shunt resistance of inductors L_1 and L_2
- C_{21a}: mutual capacitance between pins (PCB side)
- C_{21b}: mutual capacitance between pins (BGA side)



Model Data Comparison



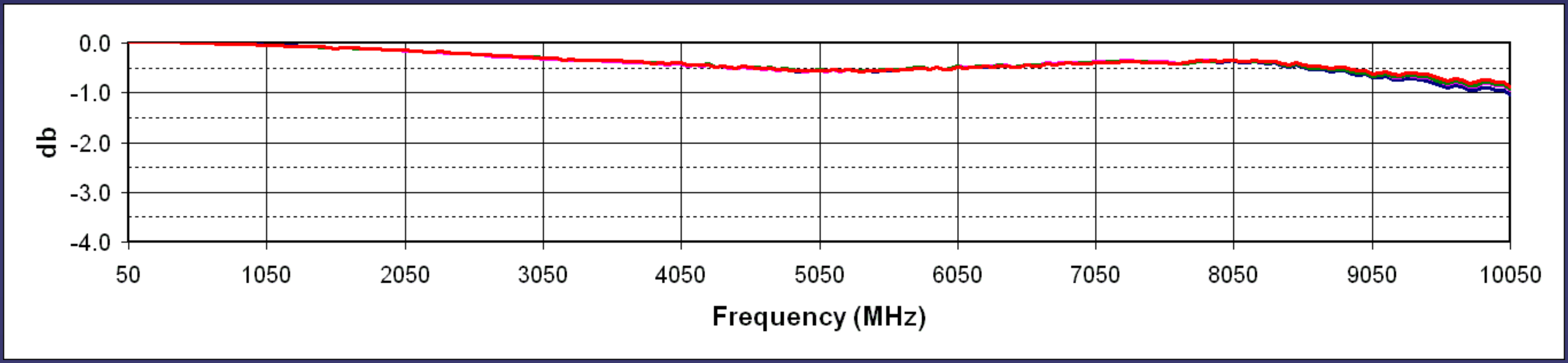
Self Inductance (nH)

Mutual Capacitance (pF)

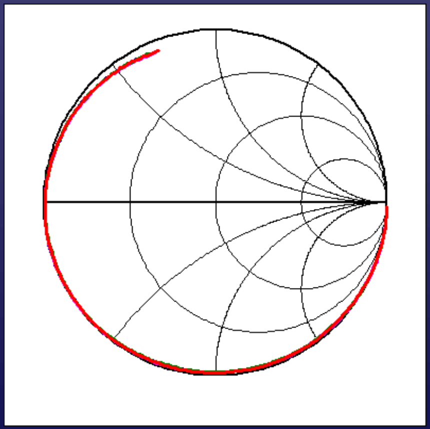
-1db Bandwidth (GHz)

Alternate Material: Torlon 5530

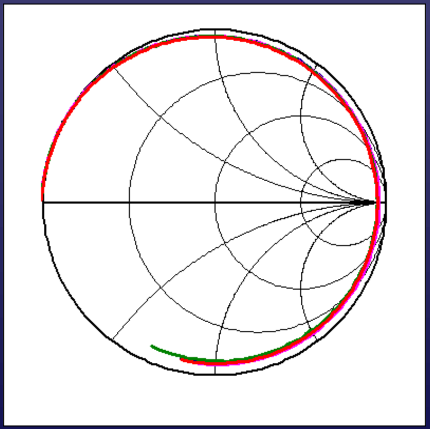
- Medium Clearance
- -1db at 10.0 GHz



Insertion Loss (S_{21})



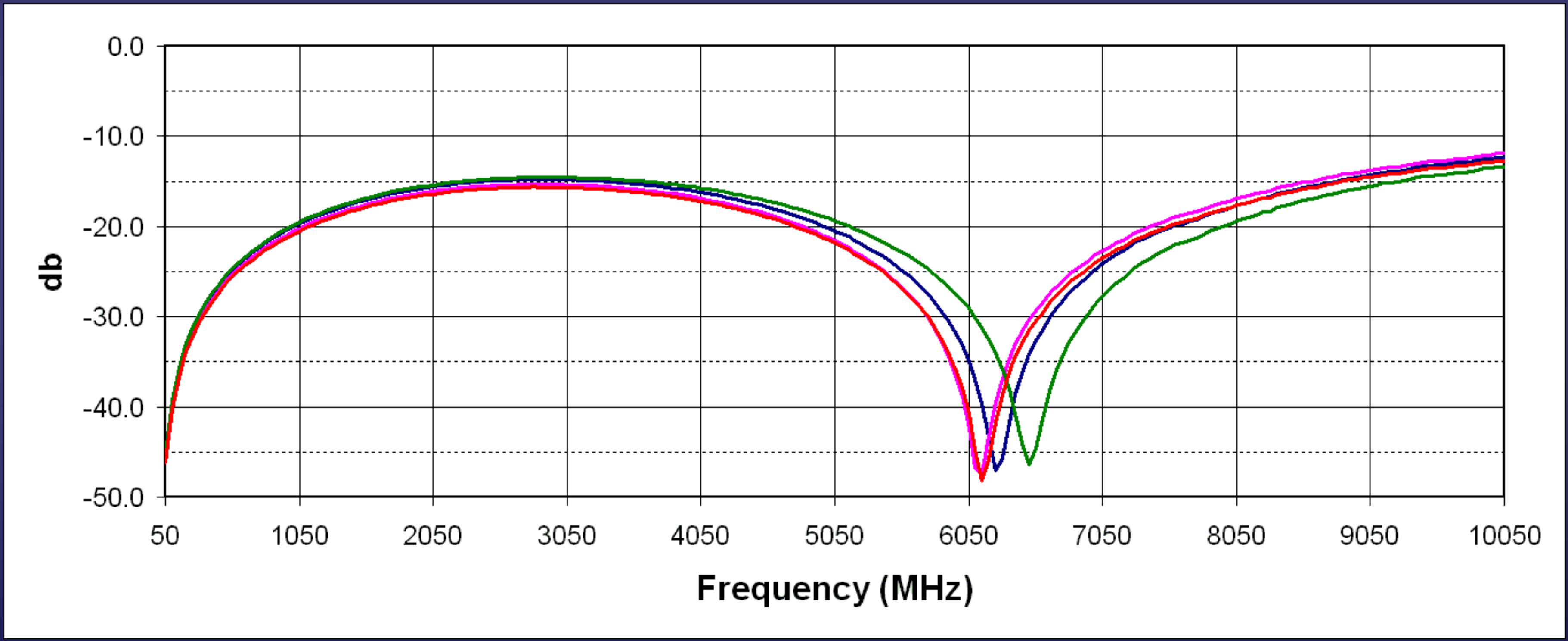
S_{11} Open



S_{11} Short

Alternate Material: Torlon 5530

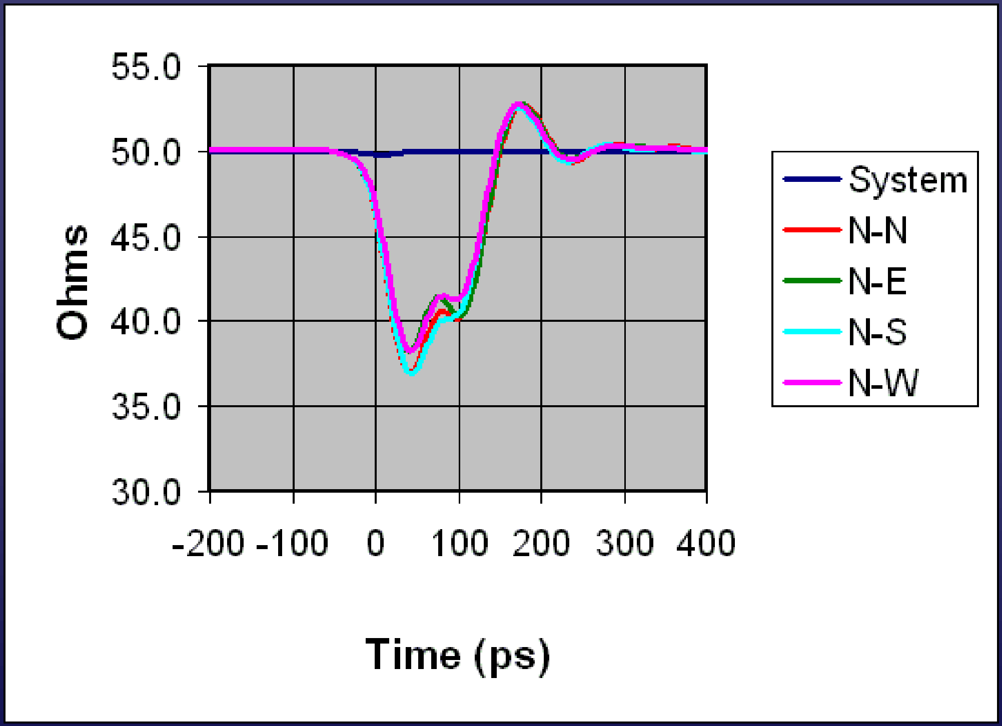
- Medium Clearance
- Crosstalk



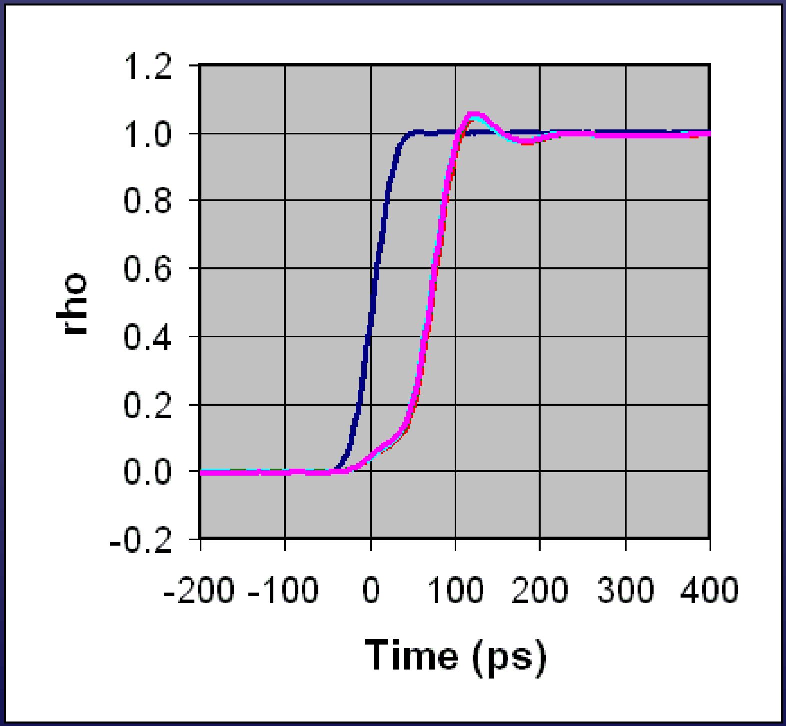
S_{21} Open

Alternate Material: Torlon 5530

- Medium Clearance
- Loop-thru
- Rise Time = 39 ps
- ½ Delay = 35 ps

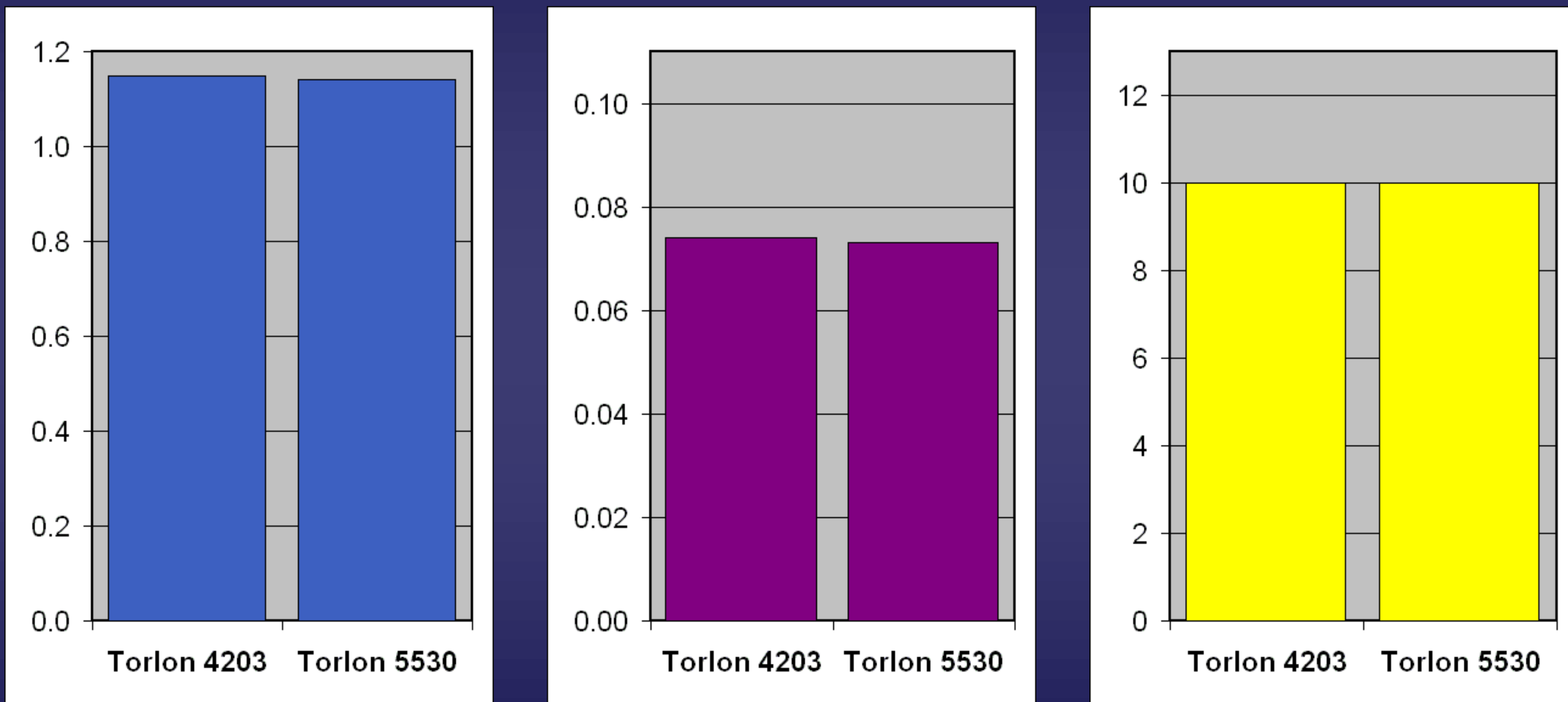


TDR



TDT

Alternate Material: Model Data



Self Inductance (nH)

Mutual Capacitance (pF)

-1db Bandwidth (GHz)

Conclusions

- Contactor housing geometry plays a significant role in the high frequency performance of a test contactor
- Small variations in geometry can have a large effect on loop-thru bandwidth, a popular figure of merit for contactors
- Probe contact consistency is a vital contributor to repeatable high frequency performance (and DC performance as well)