



**SW Test Workshop**  
Semiconductor Wafer Test Workshop

# Evaluation of RF Calibration Substrate Lifetime and Accuracy for mW Production Test Cells



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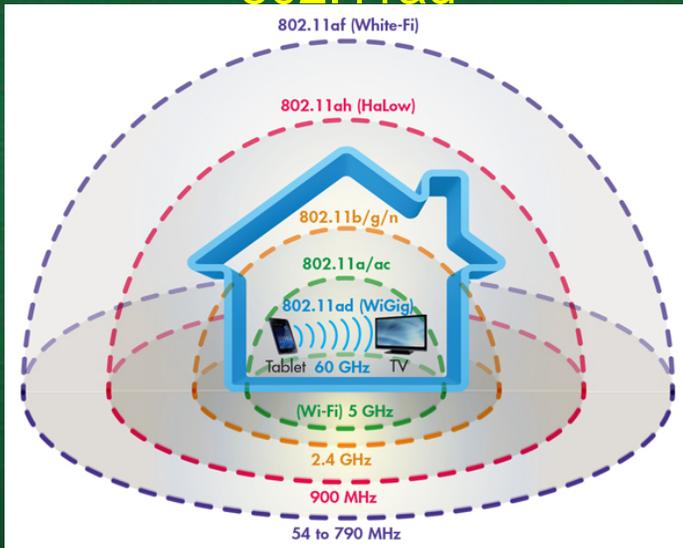
# Overview

- **What devices in production require RF calibration?**
- **Test Overview**
- **Data Results**
  - CRES vs DOE on Au Pads
  - TCR for NiCr on Calibration Substrates
  - Probe Mark depth
  - RF accuracy evaluation of Pyramid Probe post SOLR Calibration
- **Conclusions**

# RF Devices Driving Calibration in Production

- There are several production test application that require RF calibration to the probe tip

## 802.11ad



Ref: <http://www.electronicdesign.com/wifi/future-wi-fi-revealed>

## HighSpeed Digital



<http://pdf.directindustry.com/pdf/semtech/optical/13536-406035.html>

## RF Filters



REF: [http://www.eeweb.com/company-blog/avago\\_technologies/fbar-filter-technology-for-4g-lte-smartphones](http://www.eeweb.com/company-blog/avago_technologies/fbar-filter-technology-for-4g-lte-smartphones)

## Automotive Radar

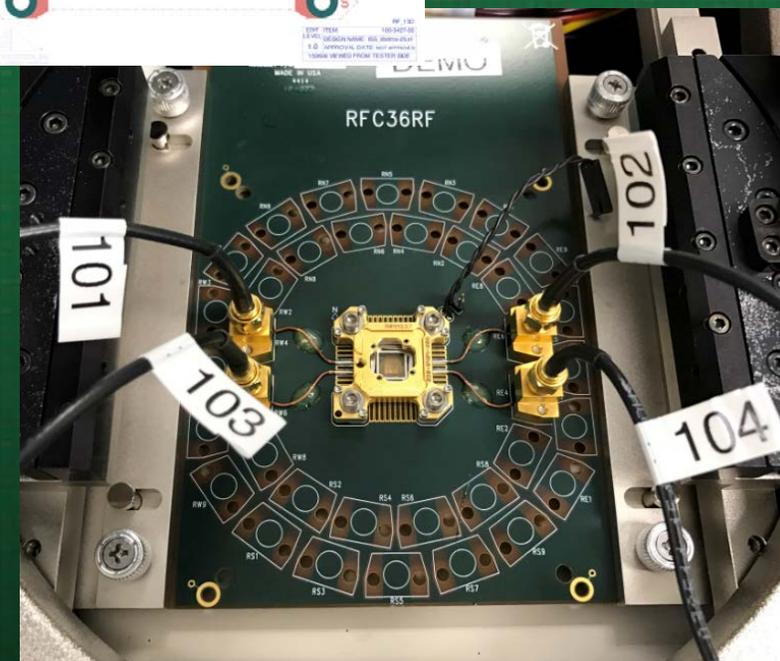
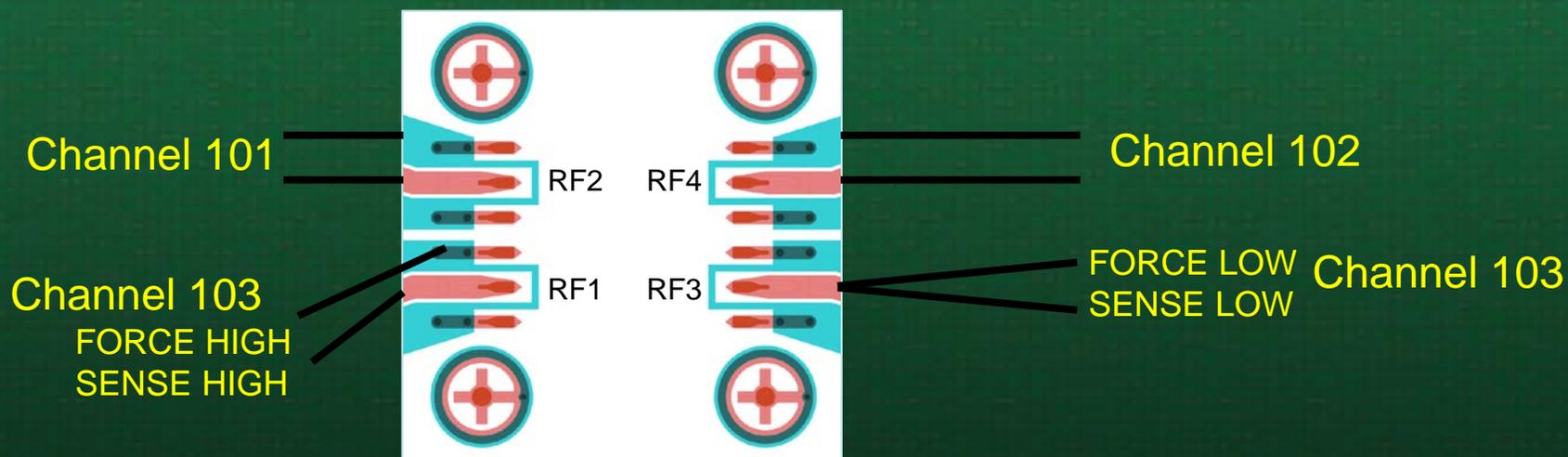
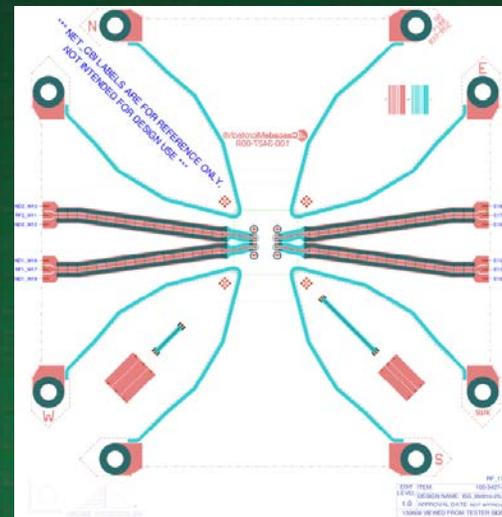


# Production Test Cell Requirements

- **Calibration Substrate needs to provide:**
  - Long lifetime
    - Prefer that the calibration substrate lasts longer than a single probe card
  - Stable contact resistance
    - Helps with repeatable RF calibration
  - Temperature Characterization of the loads
    - If the load changes by a substantial amount, it can affect the final calibration accuracy
  - Good RF calibration Accuracy
    - Know that you are measuring the device and not the probe card

# Measurement Setup for CRES

- Custom ISS with Au floods, and some 50  $\Omega$  loads
- A Pyramid Probe for CRES testing has 4 measurement channels
  - Channel 101 and 102 were connected to measure contact resistance between the RF tip and GND
    - Used to measure the NiCr 50  $\Omega$  loads
  - Channel 103 was connected in 4-wire fashion to measure contact resistance of each tip plus the Au sheet resistance between the two tips
    - Used to measure Au CRES



# Test DOE

- The test investigated the effect of:

- Probe tip size
  - 13 x 13  $\mu\text{m}$  (marker 19)
  - 18 x 18  $\mu\text{m}$  (marker 25)
  - 25 x 25  $\mu\text{m}$  (marker 15)
- OT
  - 100  $\mu\text{m}$  (recommended)
  - 250  $\mu\text{m}$  (max)
- Cleaning/no cleaning
  - Test 1 no cleaning
  - Test 2 cleaning
- Temperature (-40, 25, 125 C)
- Type of alignment
  - Straight up and down vs box pattern

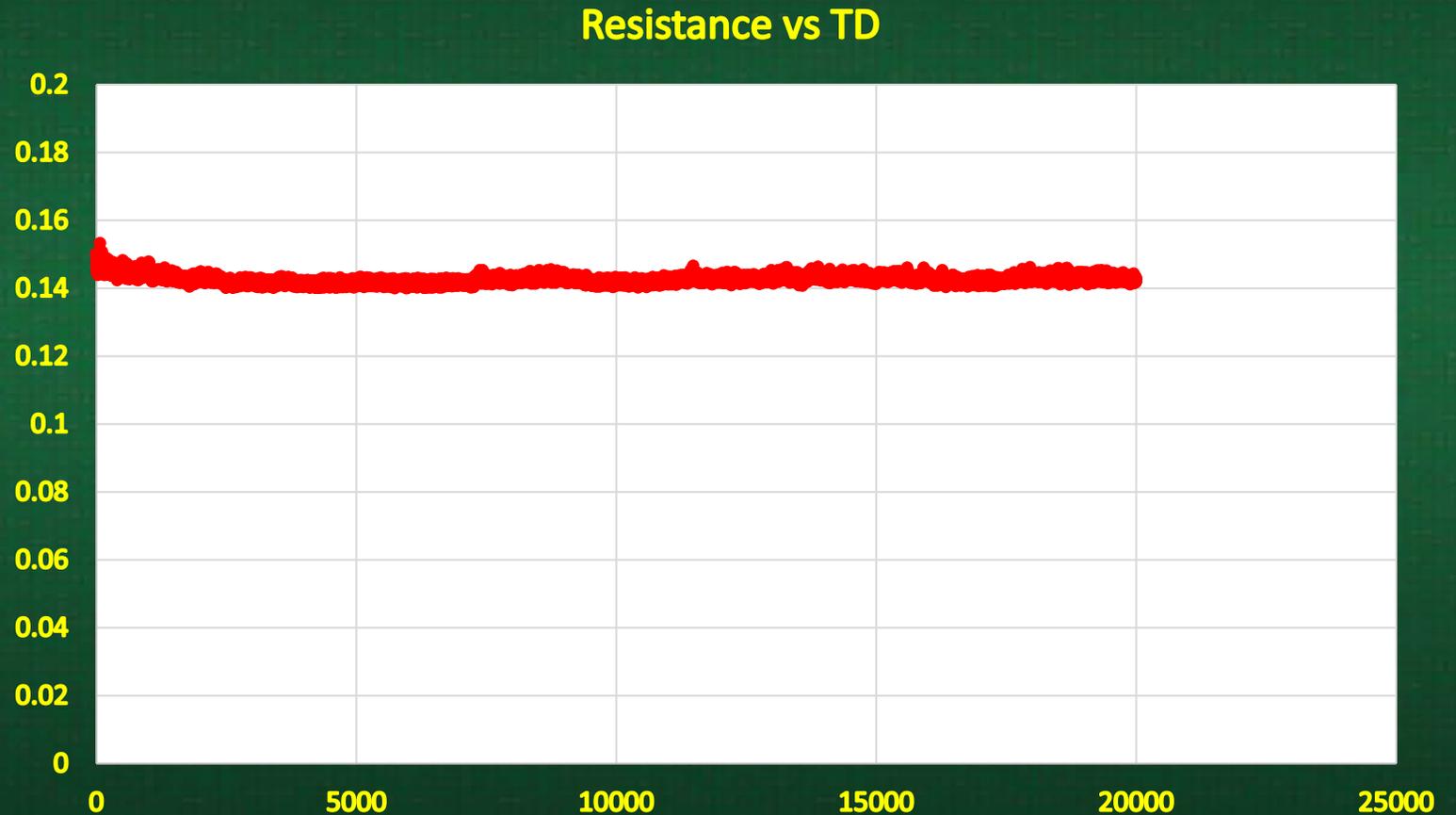
Core P/N				090-0404-00	090-0405-00			090-0406-00	
Probe Tip Size				13 x 13 $\mu\text{m}$	18 x 18 $\mu\text{m}$			25 x 25 $\mu\text{m}$	
Core Serial #				RO44157	RO44159	RO55489	RO55490	RO44160	RO44161
Cleaning	Probing Pattern	Temp.	OT ( $\mu\text{m}$ )						
No	Straight up and down	25°C	100	3	5				26
		-40°C	100	4	6				27
		125°C	100		8	10	15		
		25°C	250		7	9			
		-40°C	250			11	13		28
		125°C	250			12	17		25
	Box	25°C	100				14		24
yes	Straight up and down	25°C	100	1				18	
		-40°C	100	2				19	
		125°C	100					22	
		25°C	250					20	
		-40°C	250					21	
		125°C	250				16	23	

Note: the numbers indicated test order

# Example Data: CRES vs TD

- **Representative data set**

- 100 OT
- Perfect PTPA
- 25 C
- 18 x 18  $\mu\text{m}$  probe tip
- No cleaning



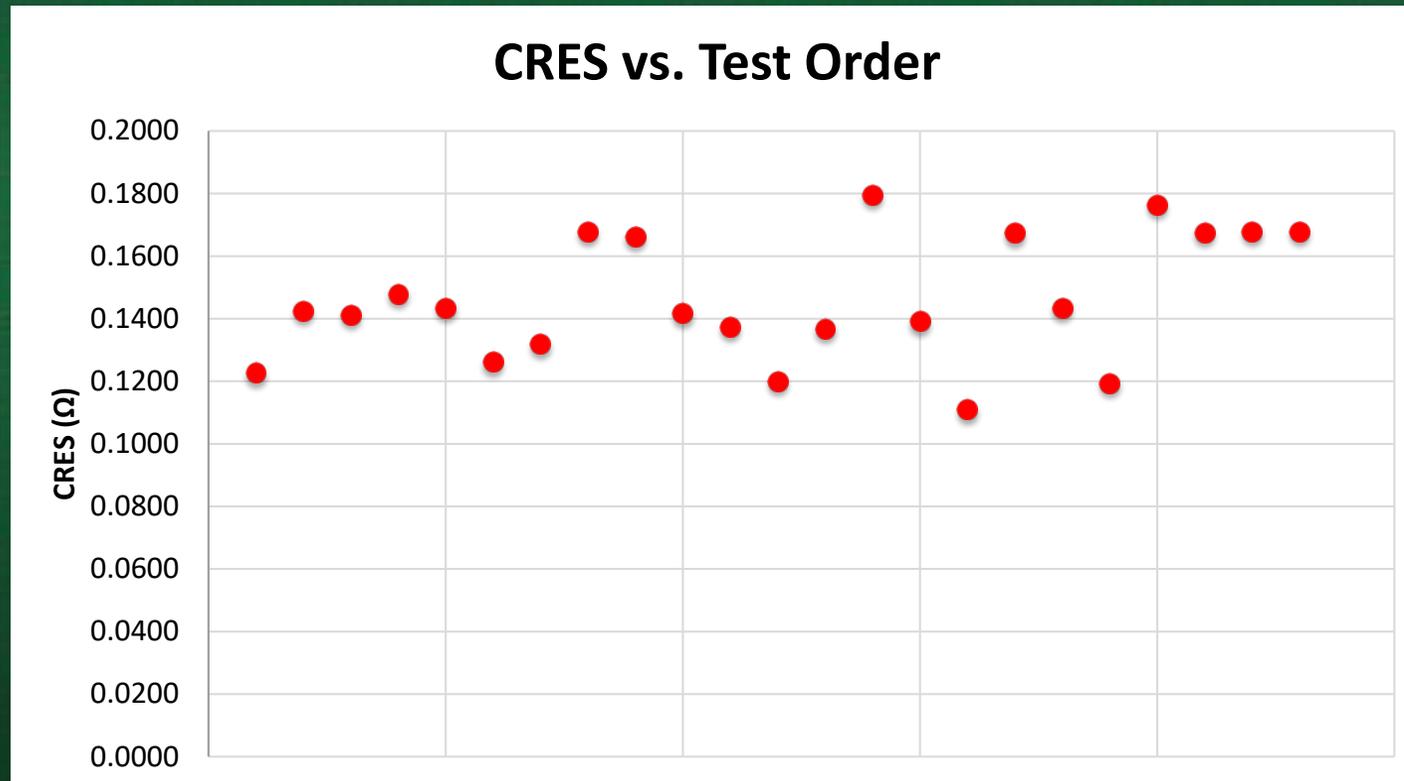
# A Little Statistics Information

- In order to evaluate the effects of the different parameters, we used a model analysis within the program JMP
  - Used a Standard Least Squares Model
  - LogWorth values for the sources of variation above 2.00 are considered to be significant, as well as Pvalues <0.01

Source	LogWorth	PValue
Temp of test	-	-
Test Descip	-	-
OT	-	-
Note	-	-
Core	-	-
Marker	-	-

# Summary of Mean Results

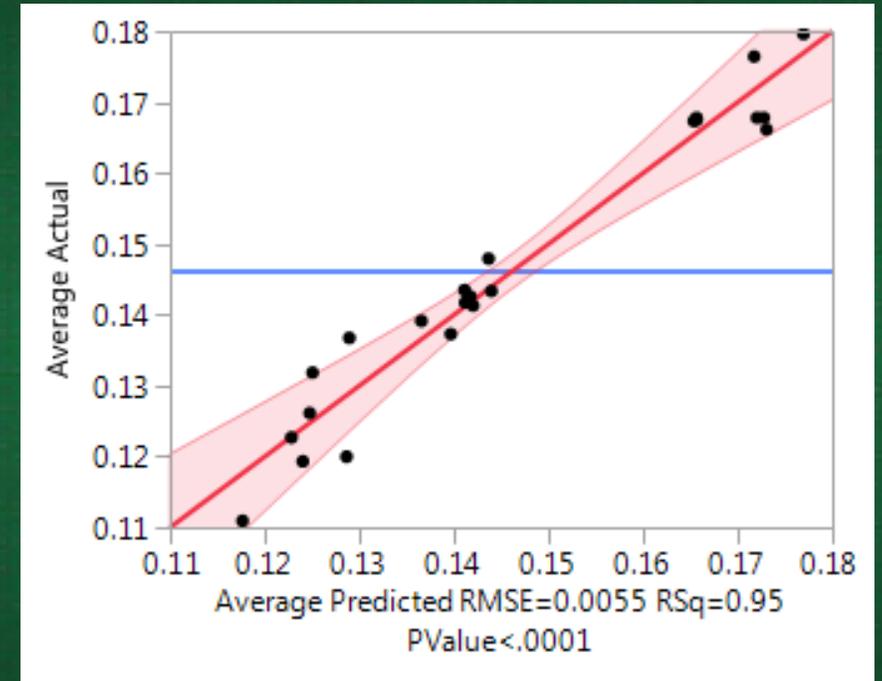
- The average CRES overall is 146 mΩ
- Data is plotted in test order



# Effect to Mean

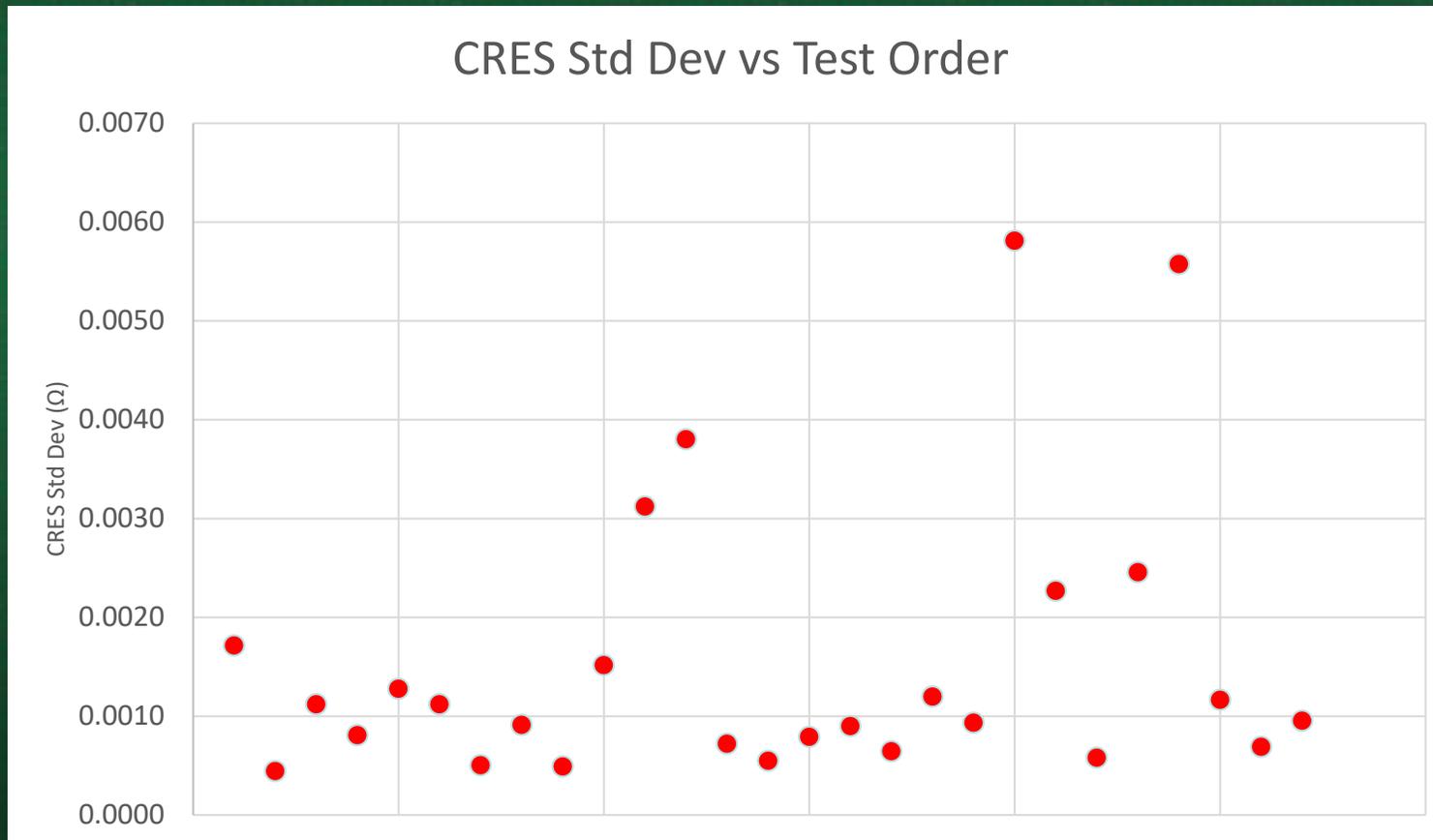
- We evaluated the affects in the CRES data from each variable in the DOE
  - Only temperature of test appears to have a strong effect in the measurements

Source	LogWorth	PValue
Temp of test	9.554	0
Test Descip	0.86	0.13806
OT	0.564	0.27282
Note	0.51	0.3088
Core	0.44	0.3634
Marker	0	1



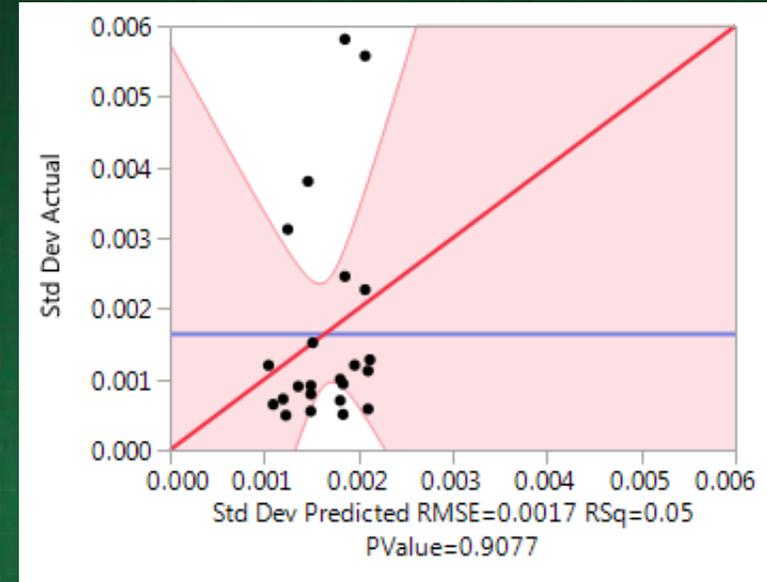
# Summary of CRES Std. Dev.

- The average Std. Dev. over all runs is 1.6 mΩ



# Effect to Std Dev

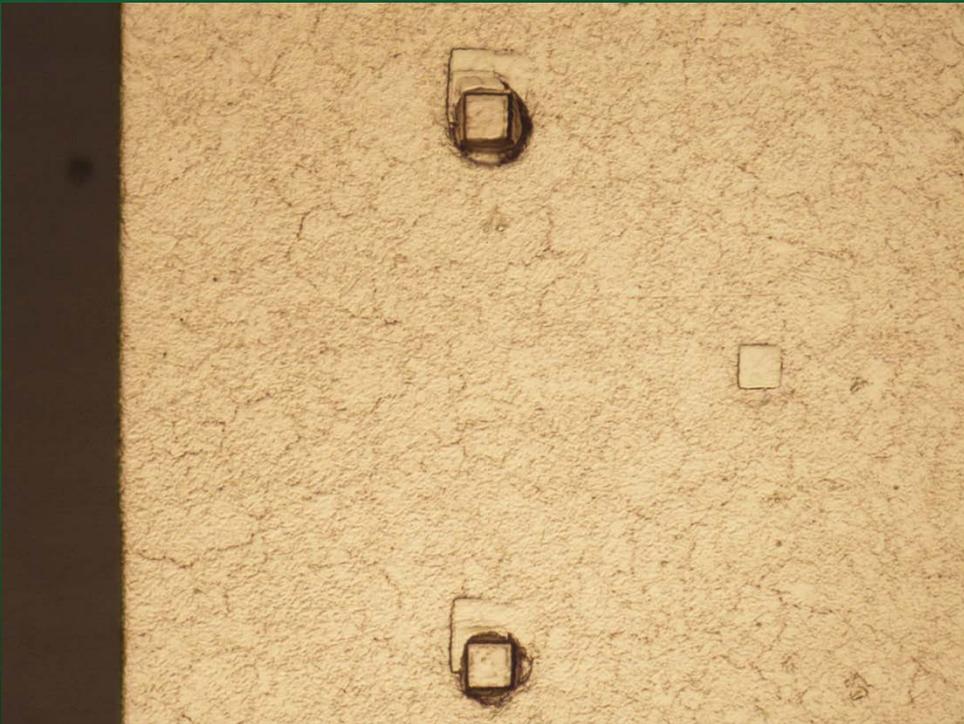
- Using the same methods, there appears to be no strong correlation to any of the tested parameters
- ISS CRES is stable under a wide variety of operating conditions



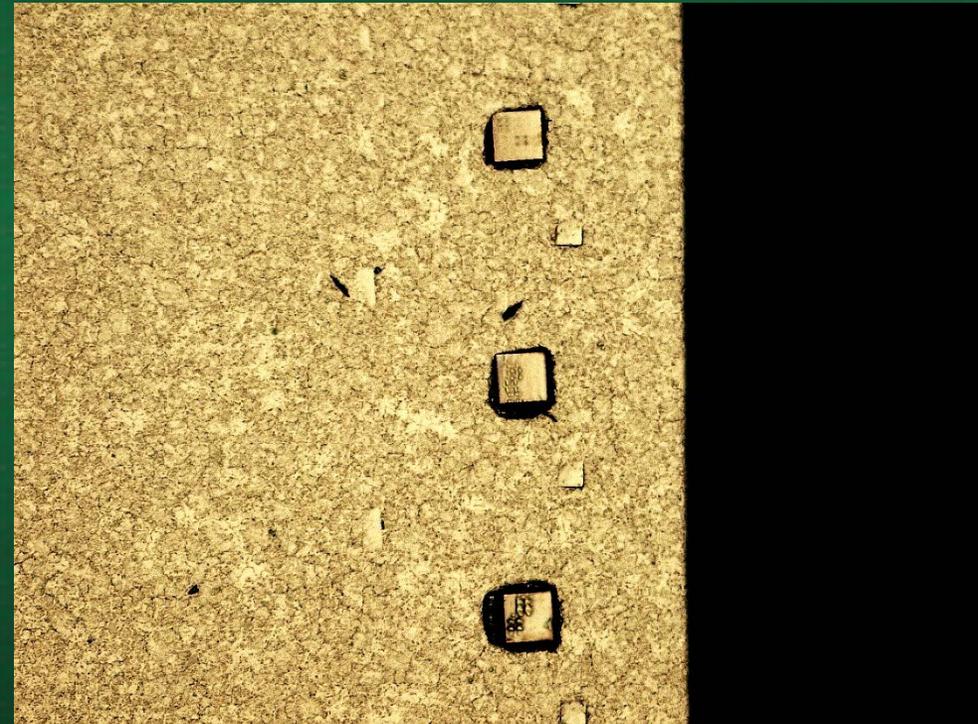
Source	LogWorth	PValue
OT	0.564	0.27282
Note	0.51	0.3088
Core	0.44	0.3634
Temp of test	0.235	0.58202
Test Descip	0.118	0.76231
Marker	0	1

# Probe Mark Measurements

- We measured the probe mark depths on all of the ISSs in order to evaluate the ISS Au durability after 20k TDs



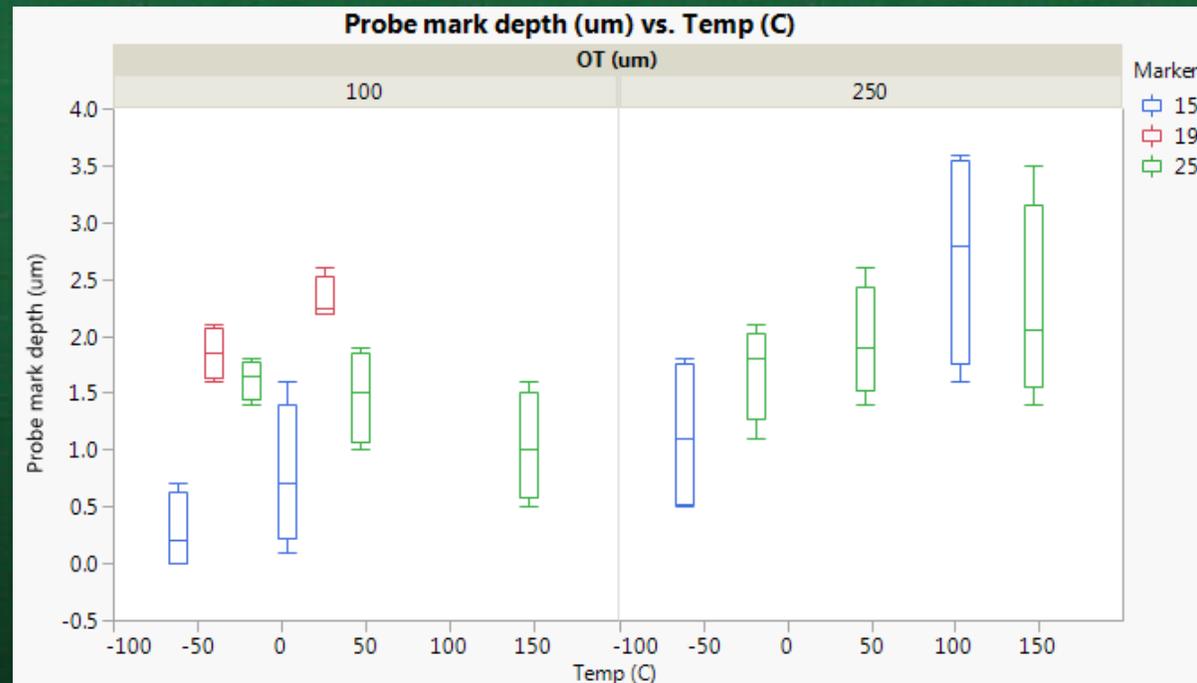
Straight up and down at 100  $\mu\text{m}$  OT  
at 25°C



Box Pattern at 100  $\mu\text{m}$  OT at 25°C

# Probe Mark Depth Analysis

- Probe mark depths in the Au ISS pad were measured optically, using a high magnification scope
- At 250um OT, probe mark depth increases with temperature



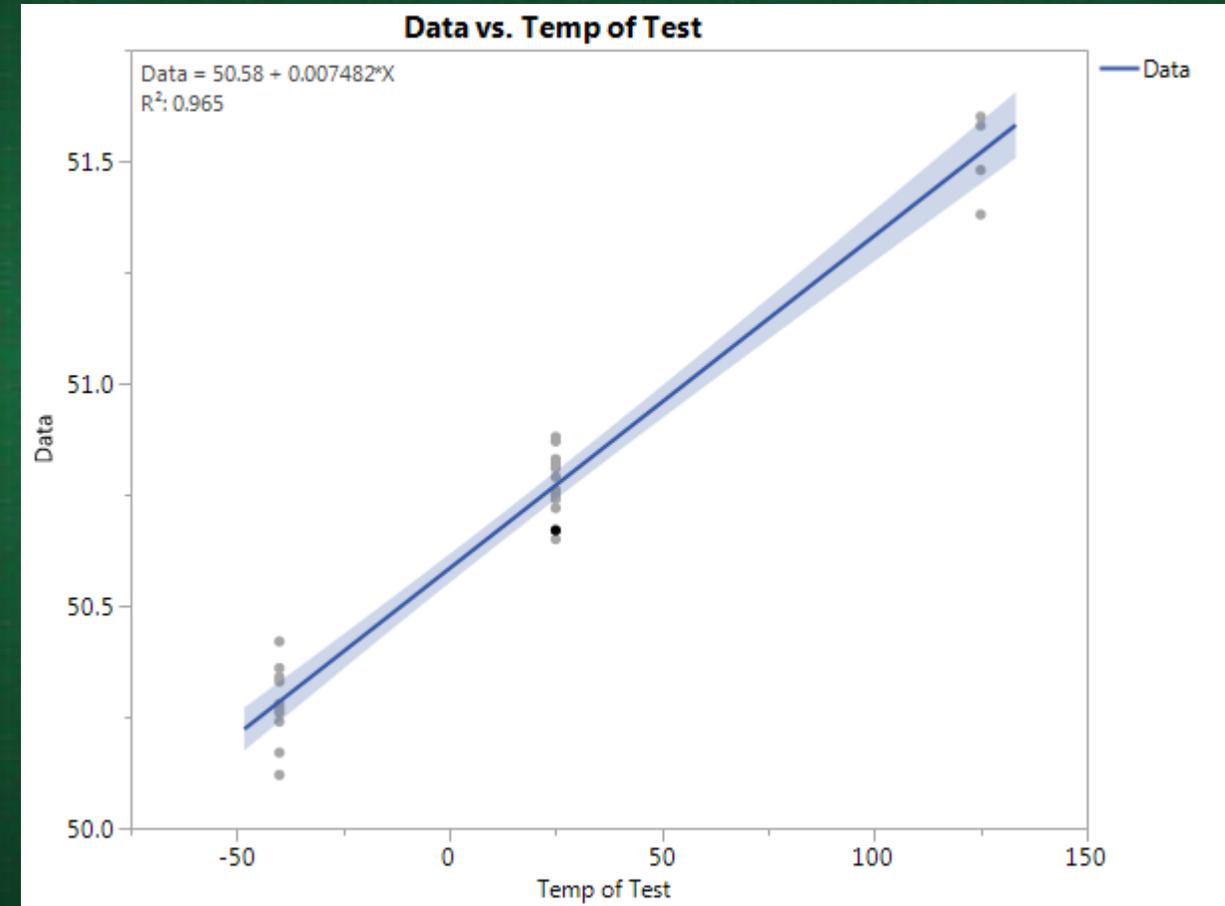
# Expected Lifetime of ISS

- **The ISSs will be able to last for at least 20k TDs before each site needs to be removed from use when used with a Pyramid Probe**
  - If you do RF calibration 12 times a day, the ISS site will last 4.5 years
  - If a LONG test time of 1 minute per device is assumed, then a total of 2.4M die can be tested

**EACH ISS WILL LAST LONGER THAN A SINGLE PROBE CARD!**

# Temperature Coefficient of Resistance for NiCr

- Using measurements across different temperatures, we characterized the change in resistance vs. temperature
  - The average TCR is:
    - 0.00015 / °C for ISS NiCr
    - NiCr bulk is 0.00017 /°C

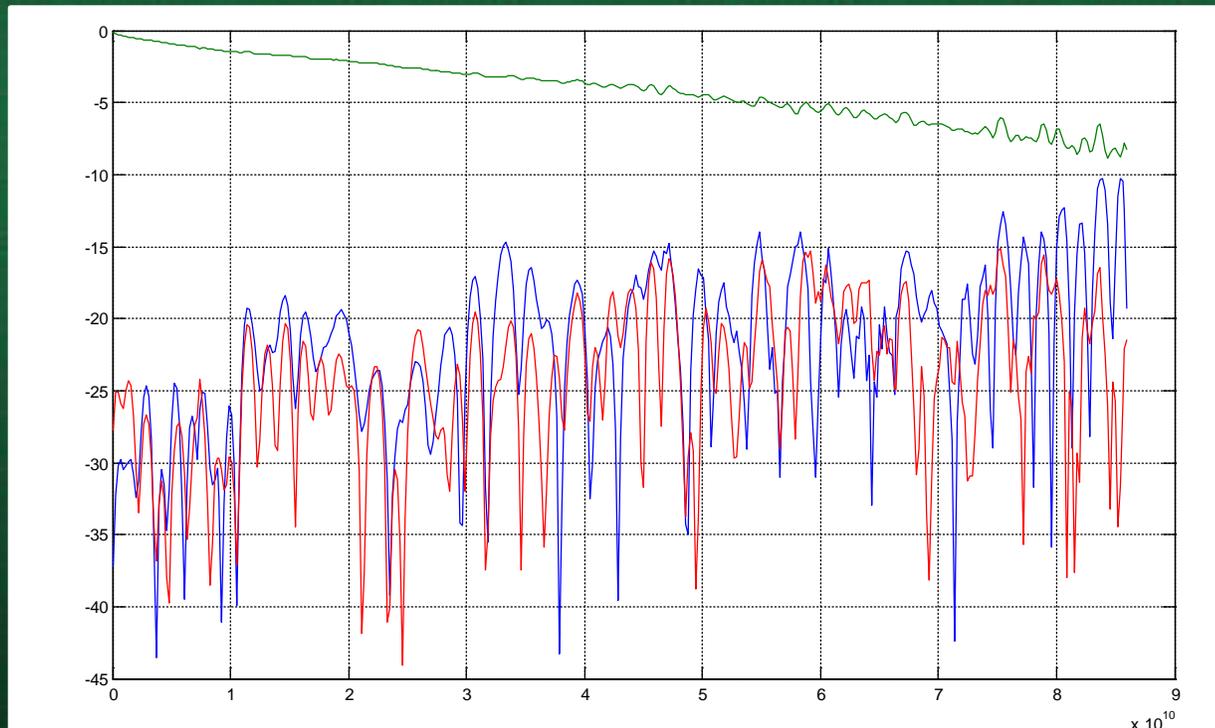


# Accuracy Evaluation of RF Calibration

- **We made two Accuracy Standards to test Pyramid Probe Calibration to 86 GHz**
  - 75  $\Omega$  load
  - Beatty Standard
- **Test Hardware**
  - Used a custom ISS to do SOLR calibration to the Probe tips
  - P800S with 500  $\mu\text{m}$  pitch GSG
  - 1 mm connectors on a 4.5" probe card

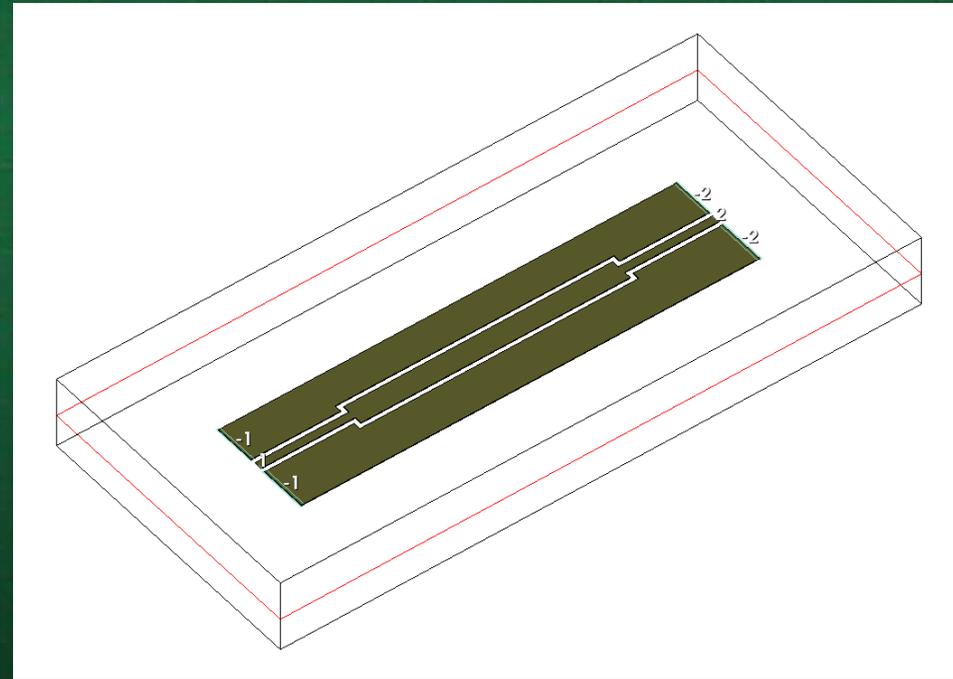
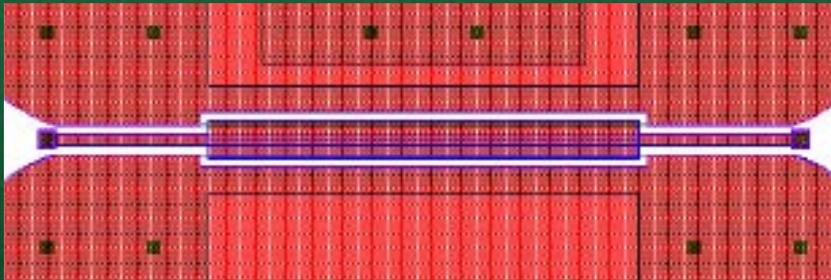
# Pyramid Probe layout

- The membrane is a CPW transmission line, with a 500  $\mu\text{m}$  pitch layout
  - 3.5 mm distance between signal probe tips



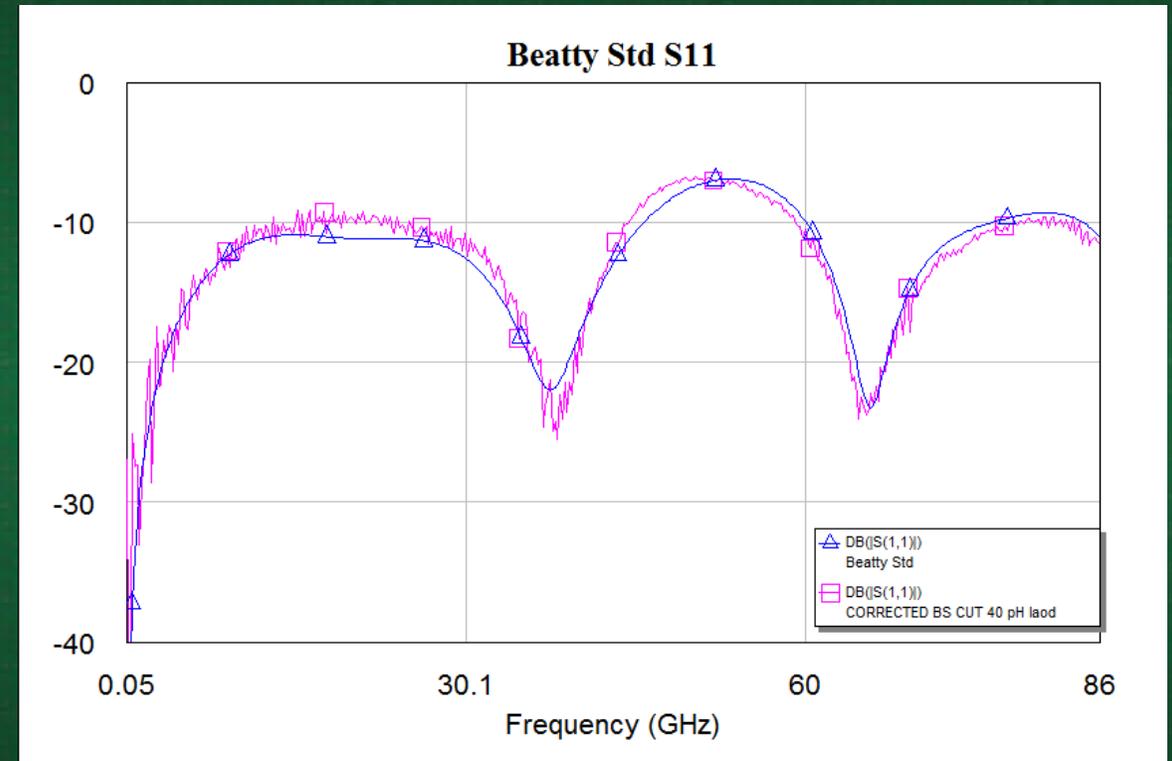
# Beatty Standard

- A Beatty Standard is a transmission line of a known length that is not  $50 \Omega$ 
  - They can easily be simulated for comparison to measurement



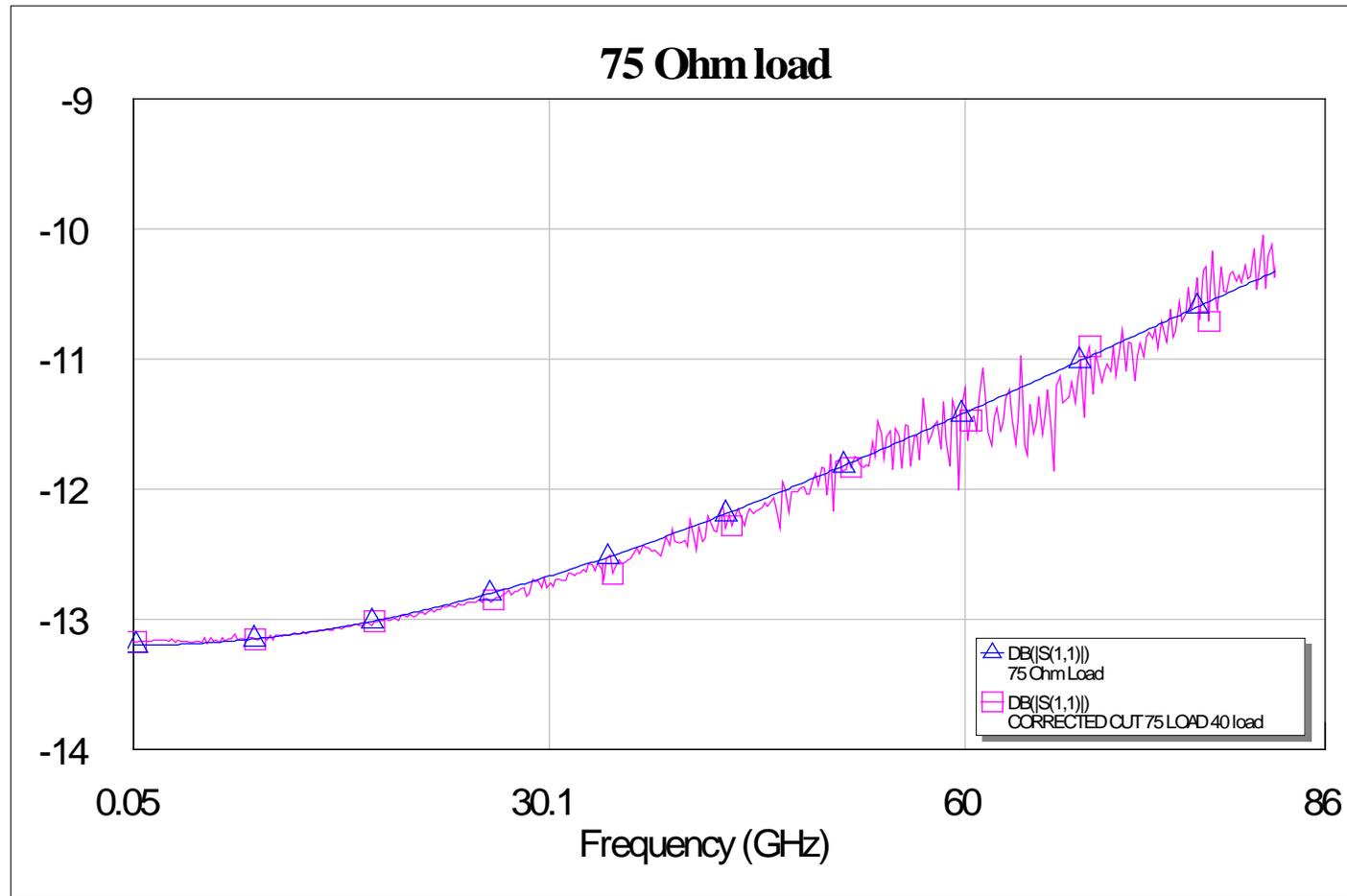
# Comparison of Beatty Standard to Simulation

- **Simulating the Beatty in MWO, there is good correlation between measurement and simulation**
  - We had to include non-ideal effects in the model because of coupling between the probe and the standard



# 75 $\Omega$ compared to Simulation

- Looking at the 75  $\Omega$  load, the match with simulation to measurement is really tight
  - 55 pH inductance of the load is what we have seen in other measurements



# Conclusions/Recommendations

- **Based on the data, the average Std Dev is less than 2 mΩ**
  - Does not have a strong correlation to probing temperature or cleaning
- **The lifetime of the ISS should be able to last for 20k TDs per RF standard, outlasting the probe card**
- **RF calibration Accuracy using SOLR is very good when compared to RF simulation of the standards**