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

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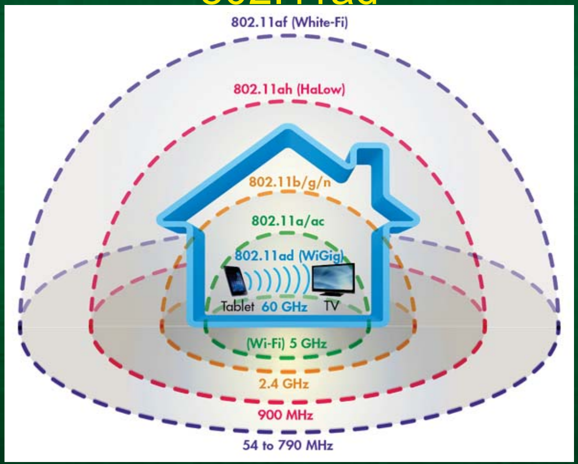
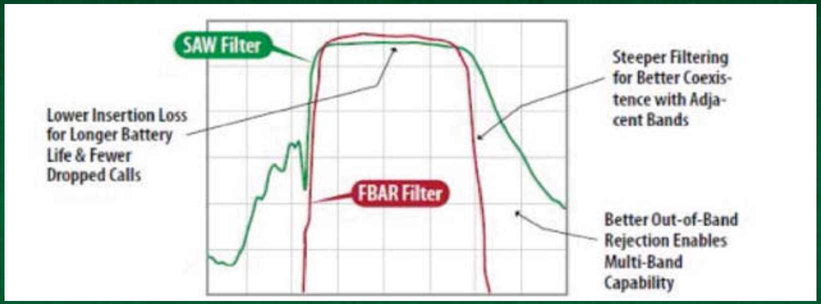


Ref: http://www.electronicdesign.com/wifi/future-wi-fi-revealed

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

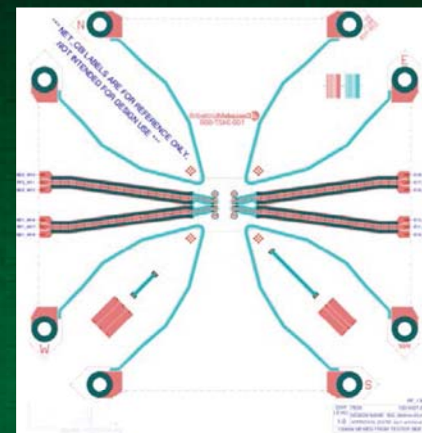
Automotive Radar

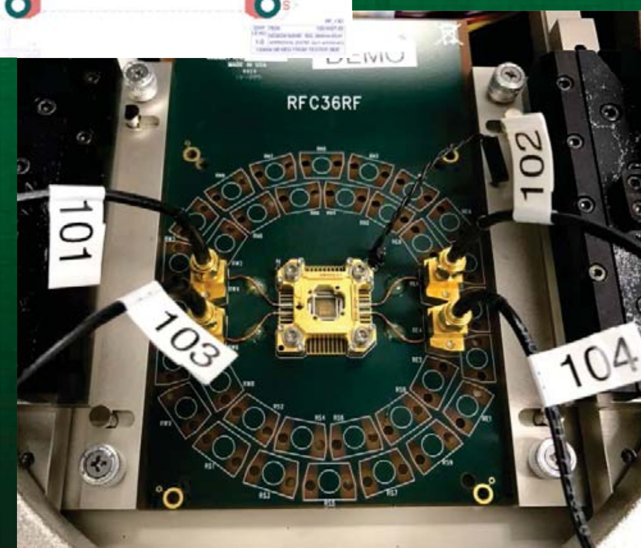
Production Test Cell Requirements

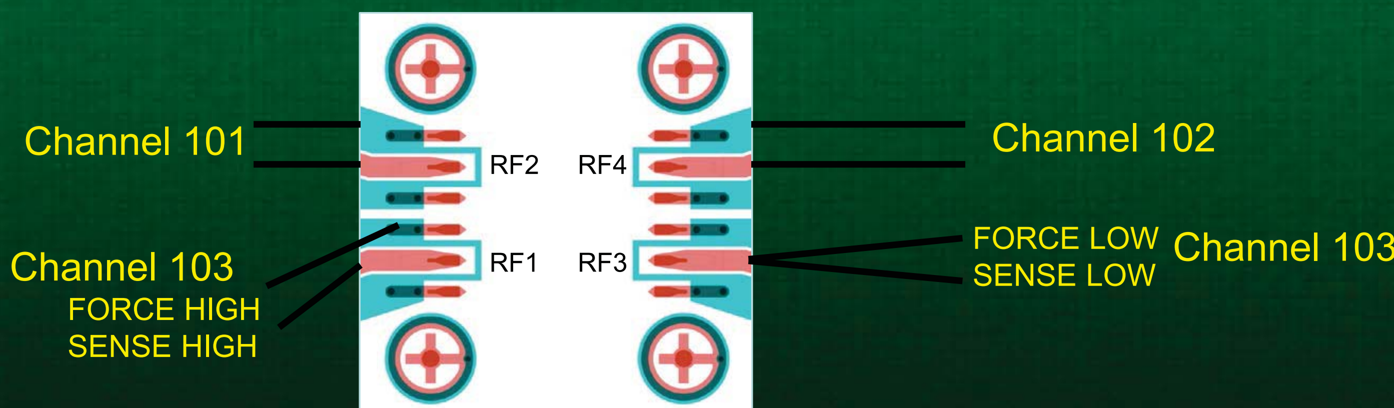
- **Calibration Substrate needs to provide:**
  - Long lifetime
    - Prefer that the calibration substrate lasts longer than a single probe card
  - Stable contact resistance
    - Helps with repeatable RF calibration
  - Temperature Characterization of the loads
    - If the load changes by a substantial 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 Ω 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 Ω 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

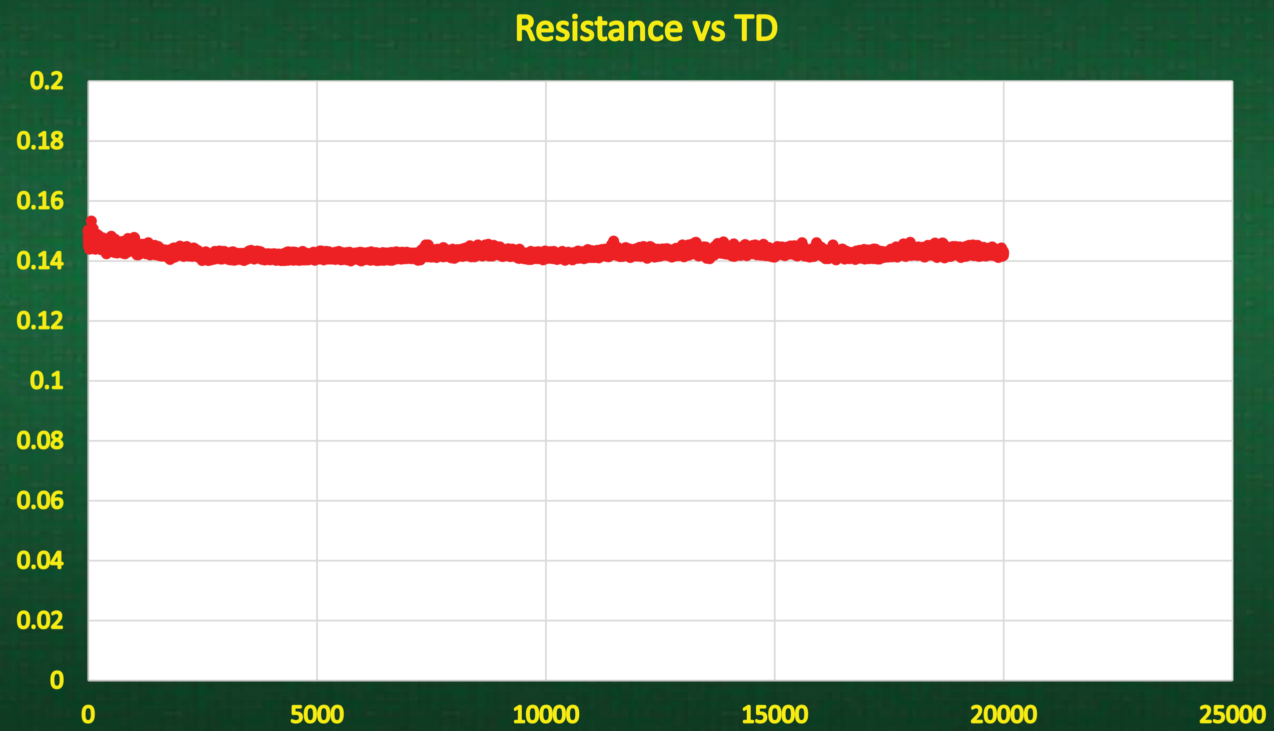
- **The test investigated the effect of:**
  - Probe tip size
    - 13 x 13 µm (marker 19)
    - 18 x 18 µm (marker 25)
    - 25 x 25 µm (marker 15)
  - OT
    - 100 µm (recommended)
    - 250 µm (max)
  - Cleaning/no cleaning
    - Test 1 no cleaning
    - Test 2 cleaning
  - Temperature (-40, 25, 125 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 µm	18 x 18 µm			25 x 25 µm	
Core Serial #				RO44157	RO44159	RO55489	RO55490	RO44160	RO44161
Cleaning	**Probing Pattern**	**Temp.**	**OT (µm)**						
No	Straight up and down	25°C	100	3	1				2
		-40°C	100	4	2				3
		125°C	100		5	2	3		
		25°C	250		3	1			
		-40°C	250			3	1		4
		125°C	250			4	5		5
	Box	25°C	100				2		1
yes	Straight up and down	25°C	100	1				1	
		-40°C	100	2				2	
		125°C	100					5	
		25°C	250					3	
		-40°C	250					4	
		125°C	250				4	6	

Note: the numbers indicated test order

Example Data: CRES vs TD

- **Representative data set**
  - 100 OT
  - Perfect PTPA
  - 25 C
  - 18 x 18 µm probe tip
  - No cleaning



A Little Statistics Information

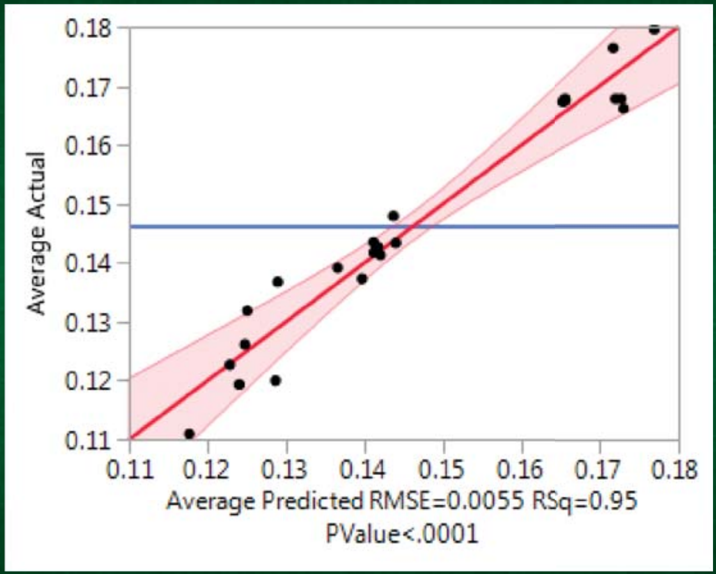
- **In order to evaluate the effects of the different parameters, we used a model analysis within the program JMP**
  - Used a Standad Least Squares Model
  - LogWorth values for the sources of variation above 2.00 are considered to be significant, as well as Pvalues <0.01

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

Effect to Mean

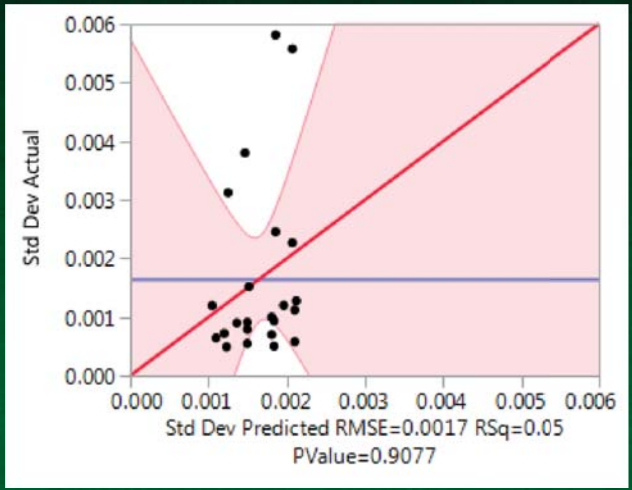
- **We evaluated the affects in the CRES data from each variable in the DOE**
  - Only temperature of test appears to have a strong effect in the measurements

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



Effect to Std Dev

- Using the same methods, there appears to be no strong correlation to any of the tested parameters

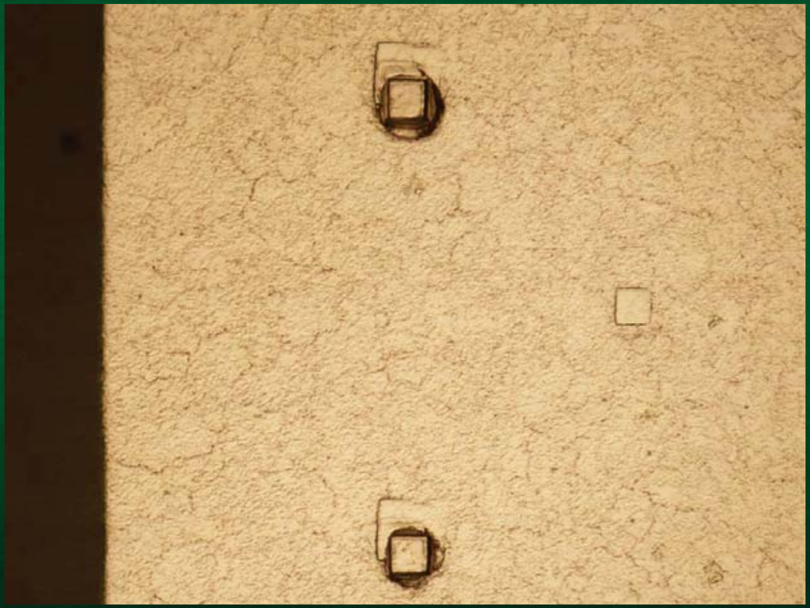


- ISS CRES is stable under a wide variety of operating conditions

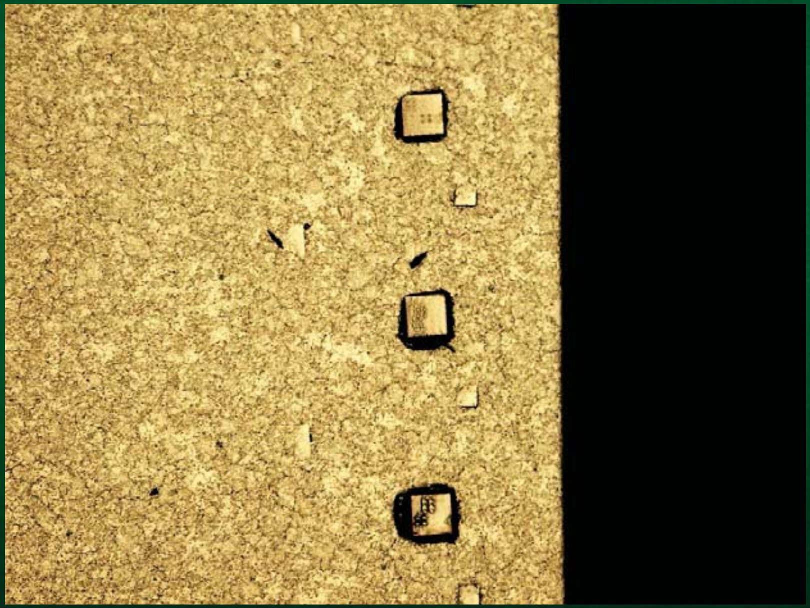
Source	LogWorth	PValue
OT	0.564	0.27282
Note	0.51	0.3088
Core	0.44	0.3634
Temp of test	0.235	0.58202
Test Descip	0.118	0.76231
Marker	0	1

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**



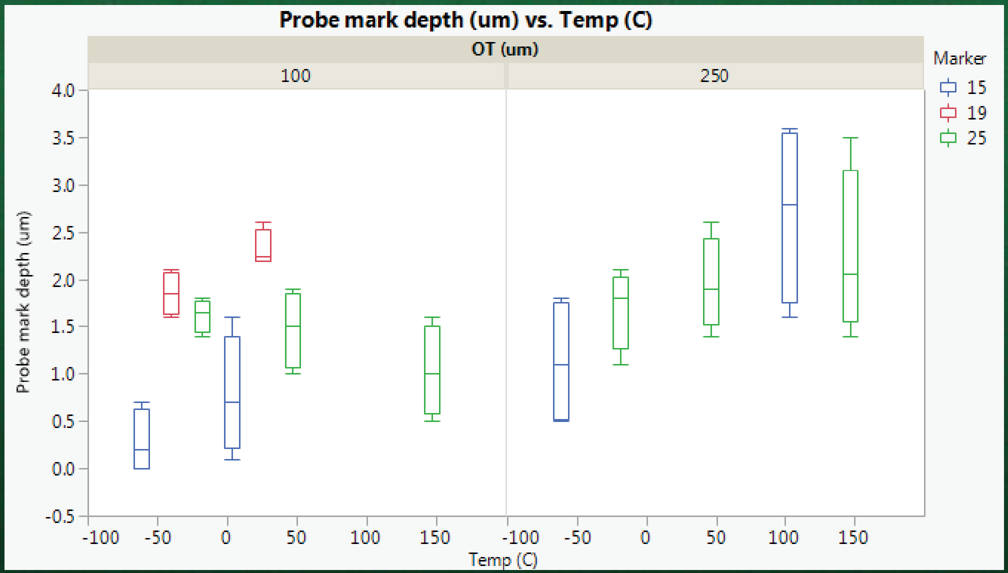
Straight up and down at 100 µm OT at 25°C



Box Pattern at 100 µm 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



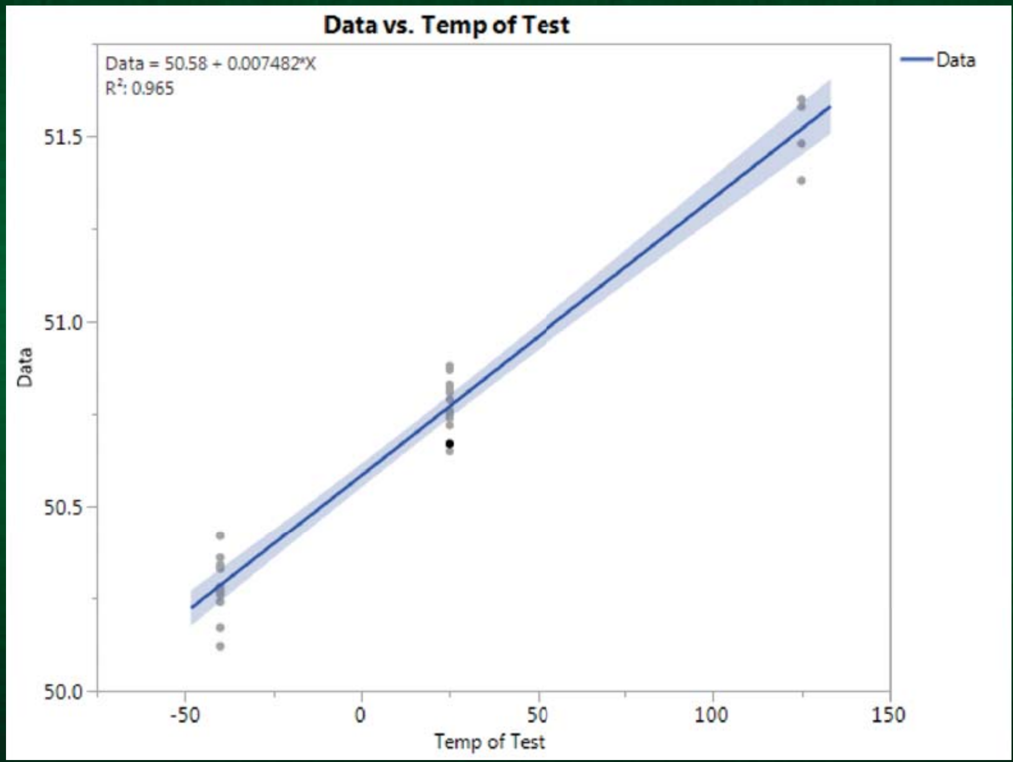
Expected Lifetime of ISS

- **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

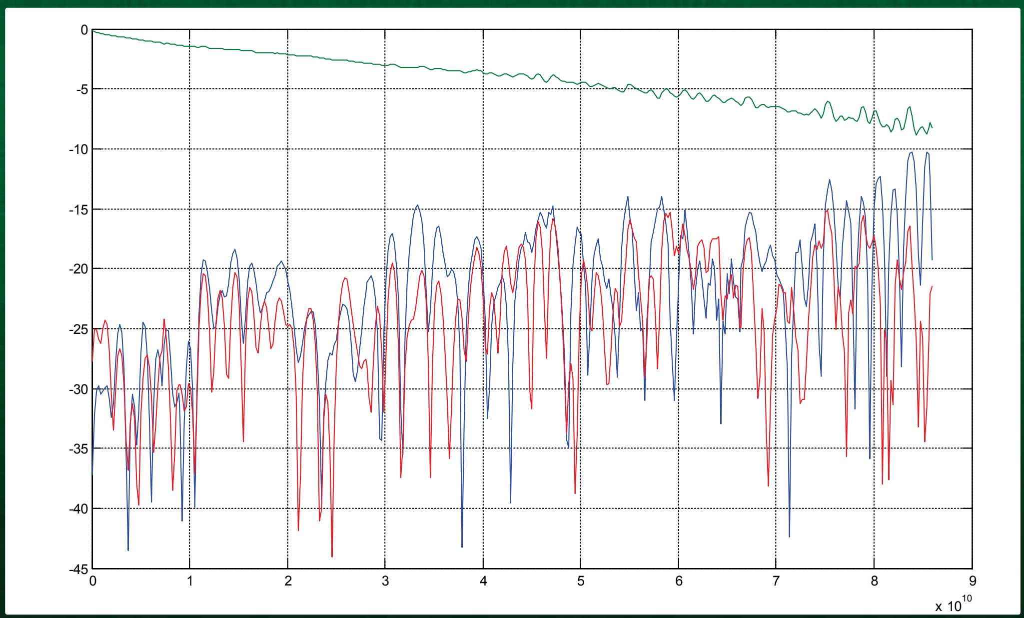


Accuracy Evaluation of RF Calibration

- **We made two Accuracy Standards to test Pyramid Probe Calibration to 86 GHz**
  - 75 Ω load
  - Beatty Standard
- **Test Hardware**
  - Used a custom ISS to do SOLR calibration to the Probe tips
  - P800S with 500 µm pitch GSG
  - 1 mm connectors on a 4.5” probe card

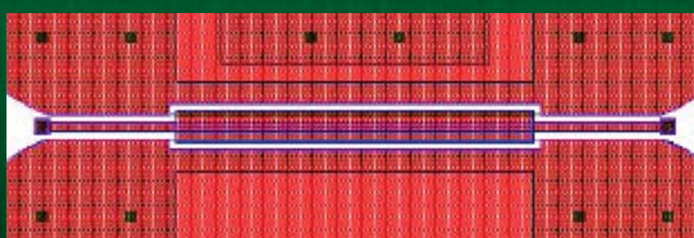
Pyramid Probe layout

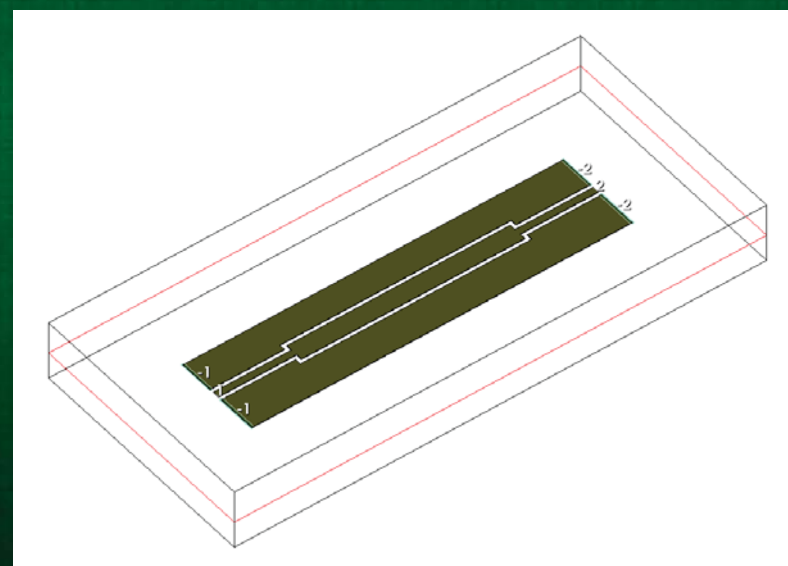
- **The membrane is a CPW transmission line, with a 500 µm pitch layout**
  - 3.5 mm distance between signal probe tips



Beatty Standard

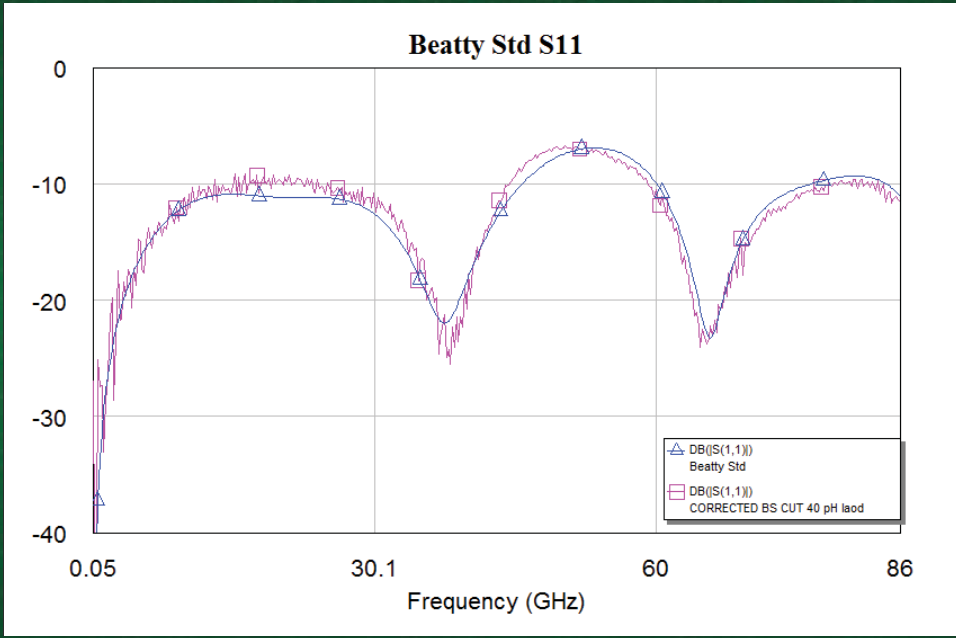
- **A Beatty Standard is a transmission line of a known length that is not 50 Ω**
  - They can easily be simulated for comparison to measurement





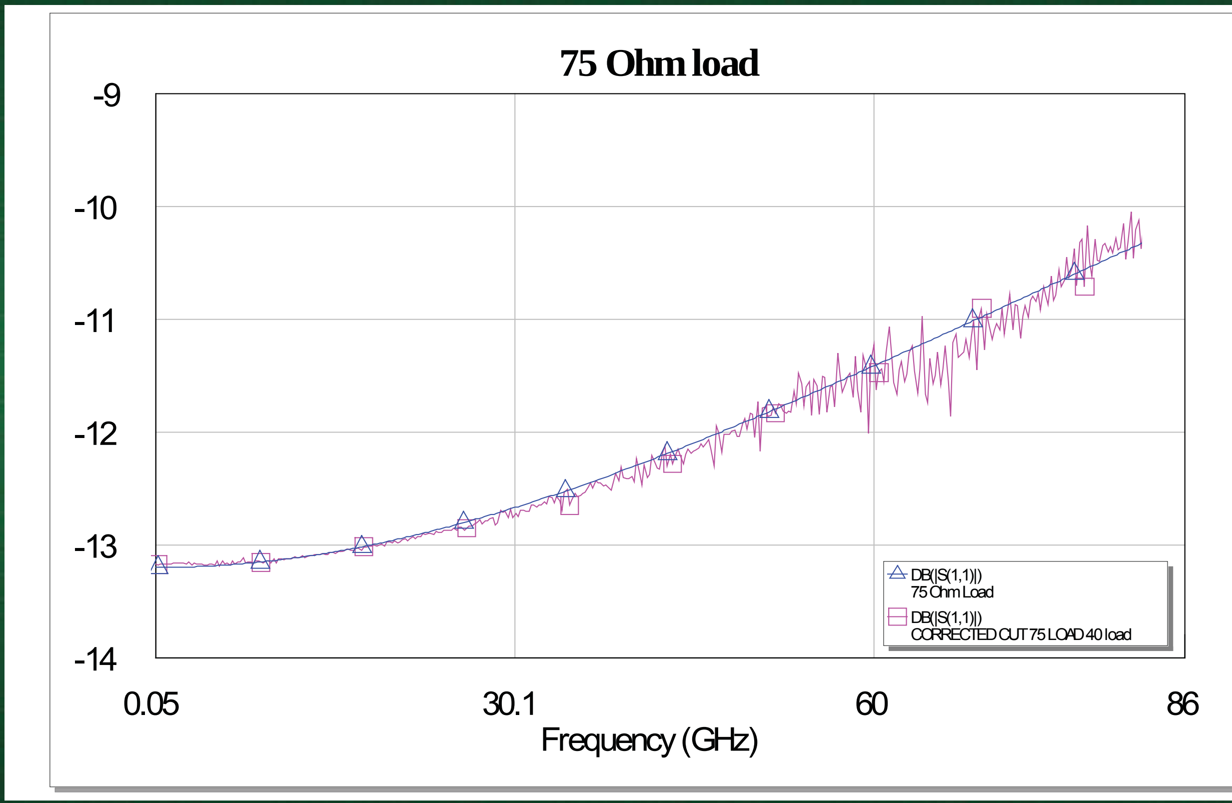
Comparison of Beatty Standard to Simulation

- **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 Ω compared to Simulation

- **Looking at the 75 Ω 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**