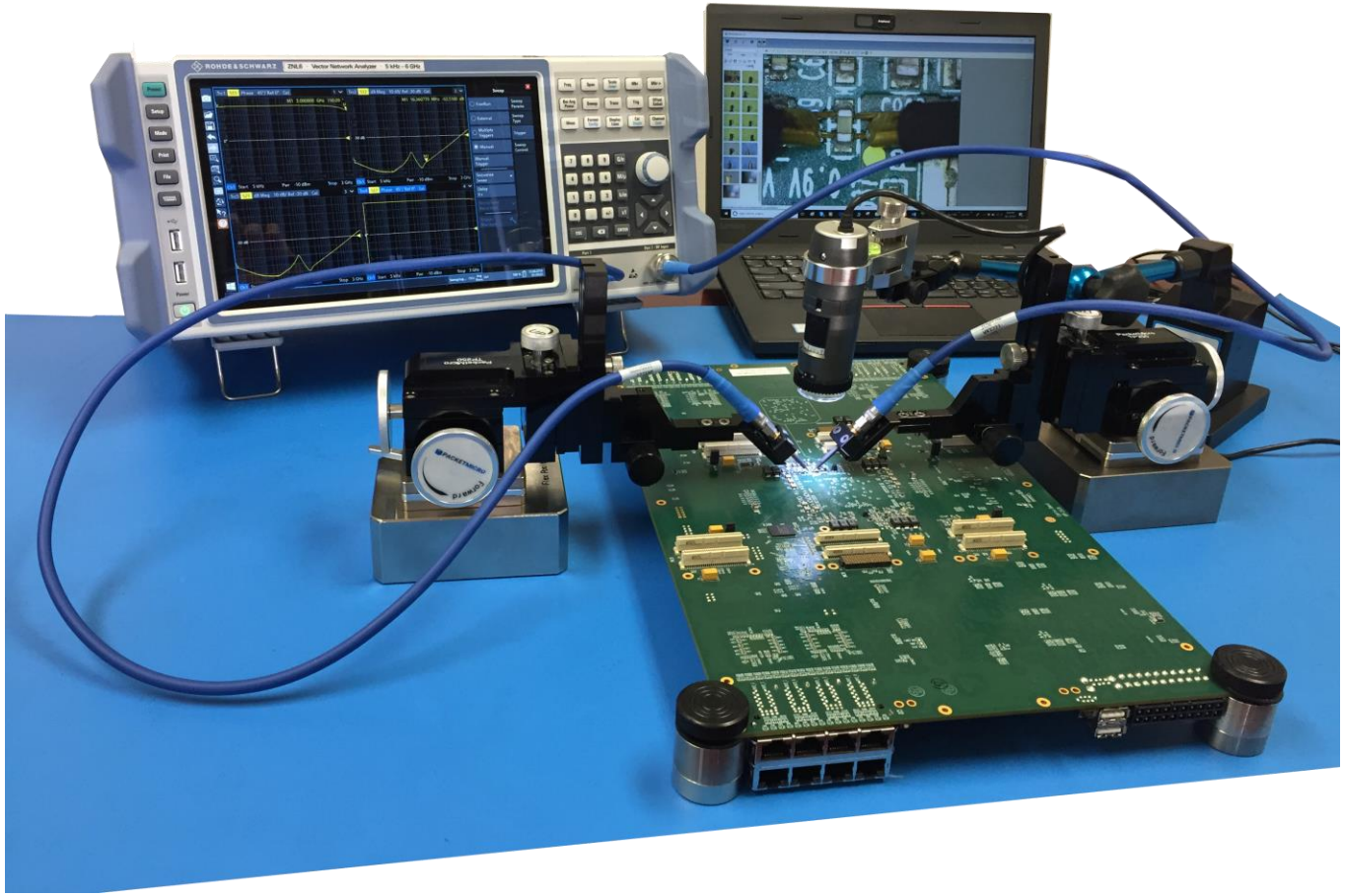
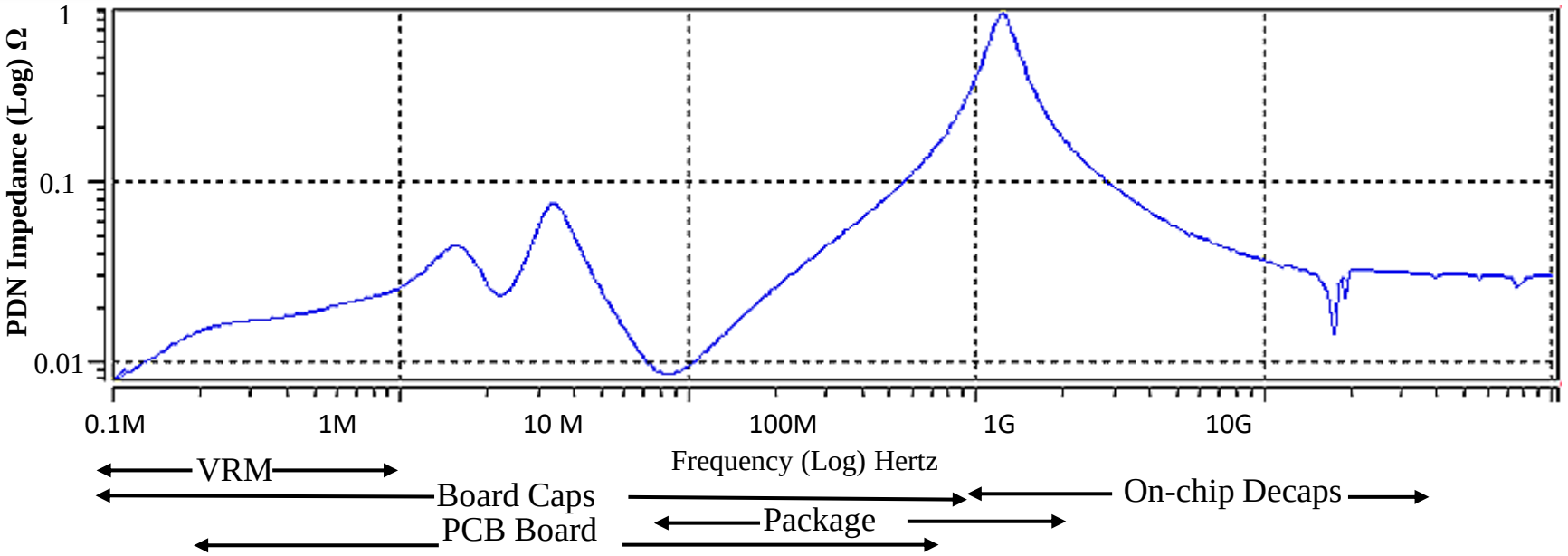
PACKETMICRO
Innovative Benchtop Probing Solutions

Power Integrity Measurement
With
Rohde & Schwarz VNA

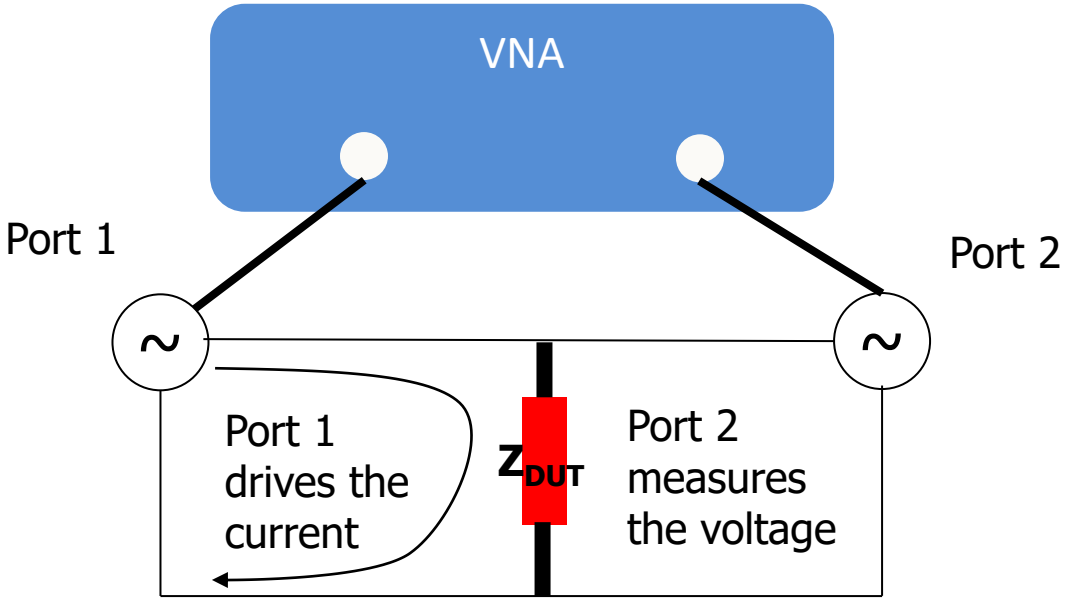


Typical PDN Impedance Profile



- Impedance profile formed by the interaction of various PDN components
- Impedance peak at package/chip resonance
- Peak impedance dependent on package, PCB, and on-chip parameters
- Typical impedance in the range of tens of milliohms

2-Port VNA Measurements of Low Z_{DUT}



- 1st order Analysis

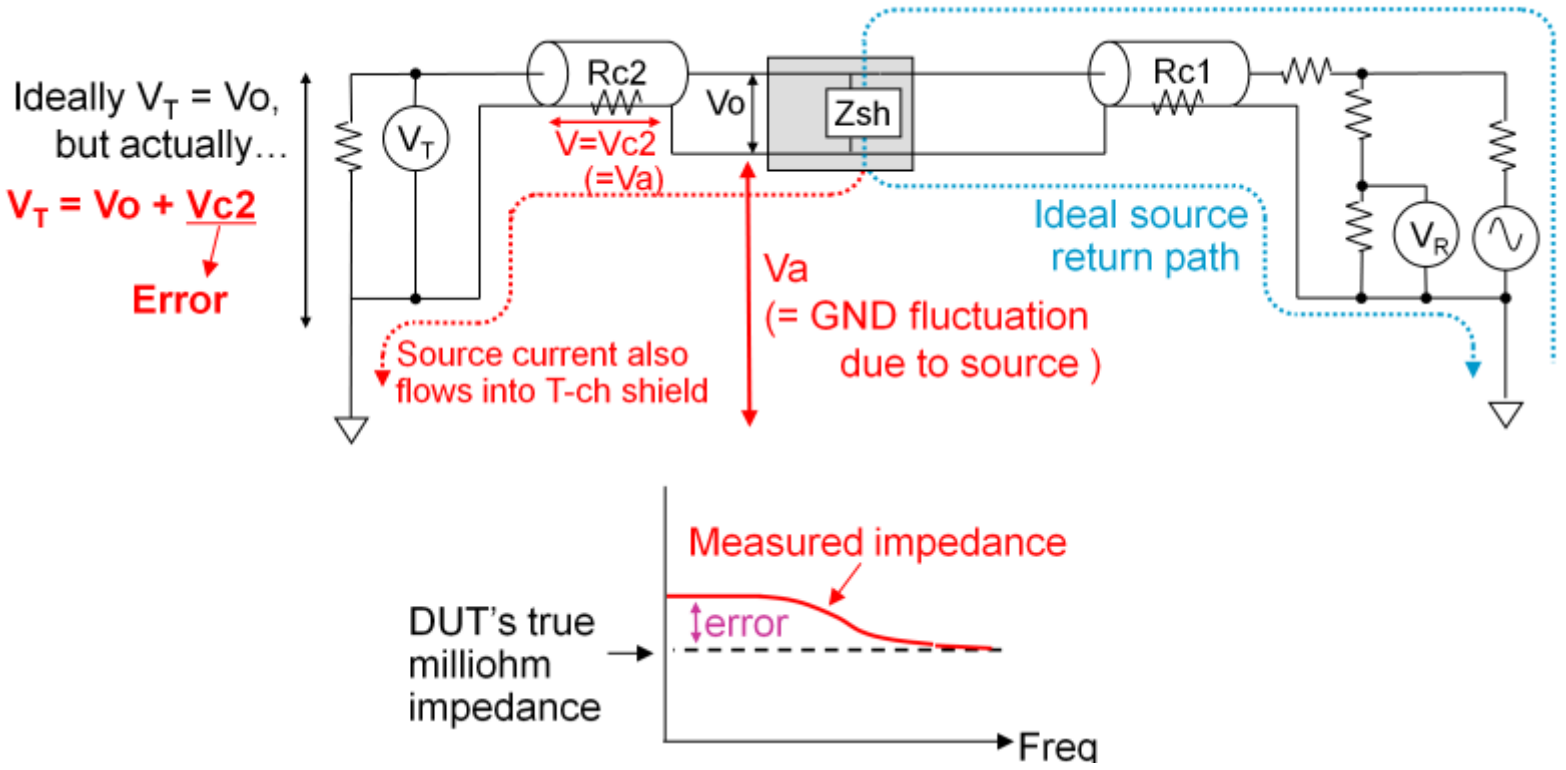
  ($Z_{DUT} << Z_o$)

  $$Z_{DUT} = 25\ S_{21}\ \Omega$$

- 2nd order Analysis

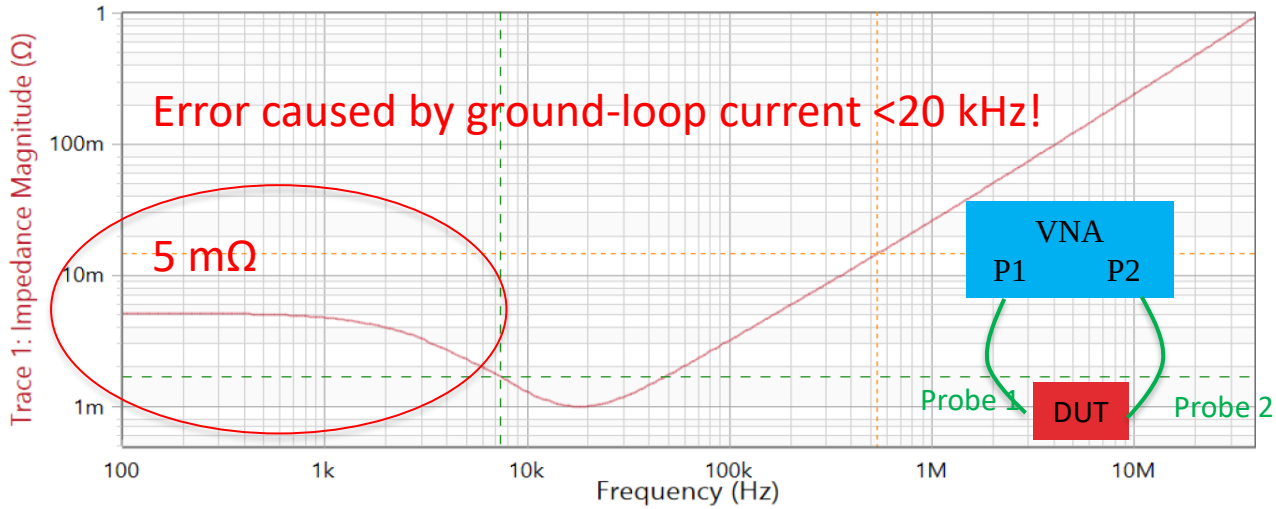
  $$Z_{DUT} = 25\ \frac{S_{21}}{1 - S_{21}}\ \Omega$$

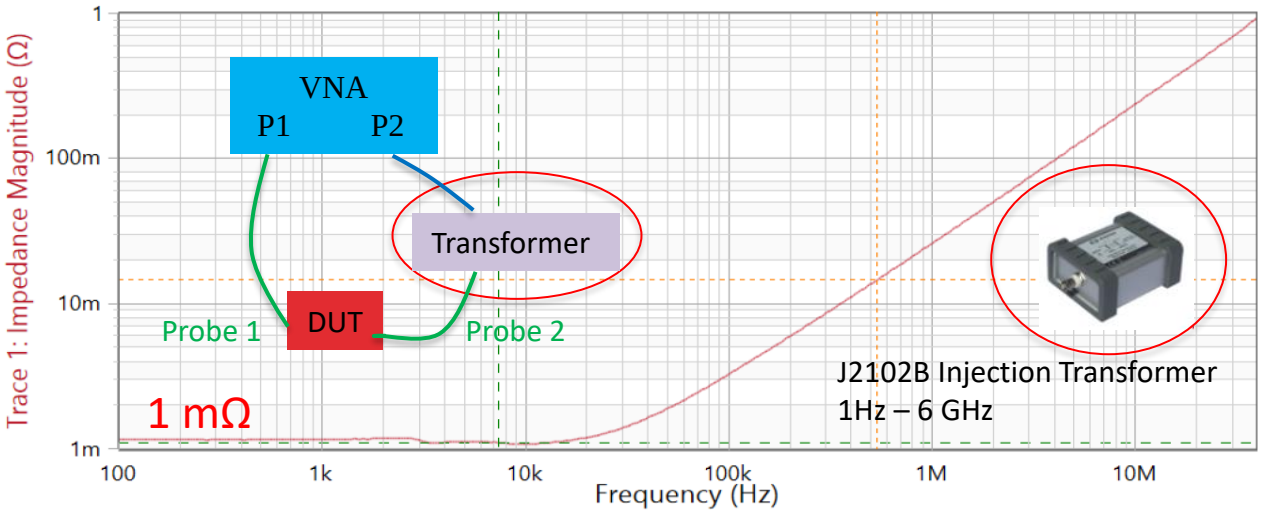
Low-Freq Errors Caused by Ground Loop



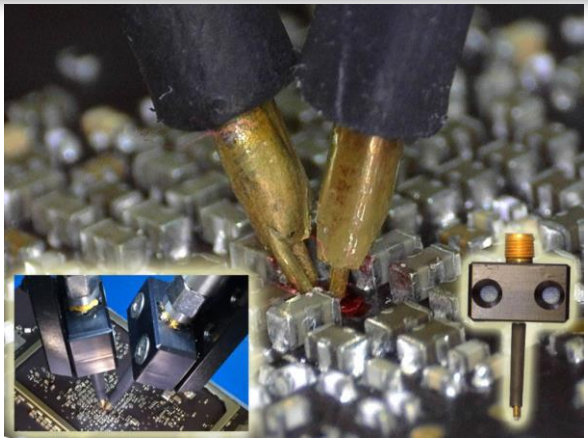
If the DUT's impedance is very small (ZDUT < tens of milliohms)
Source current flows into source-to-receiver cable GND loop.
Measurement errors occur at LF range (<20kHz)

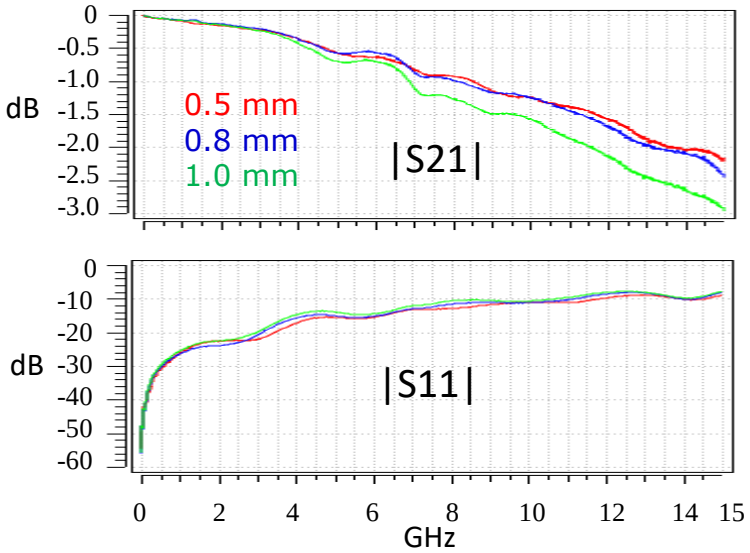
Use Transformer to Break the Ground Loop





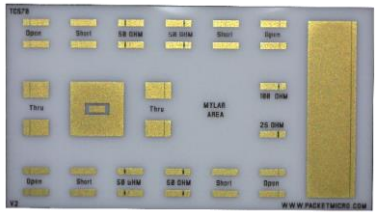
18 GHz R-Probe





R-Probe is ideal for probing a populated board with test points surrounded by components because of its 30-mil probe tips. Typical R-Probe applications are PDN and RF measurements.

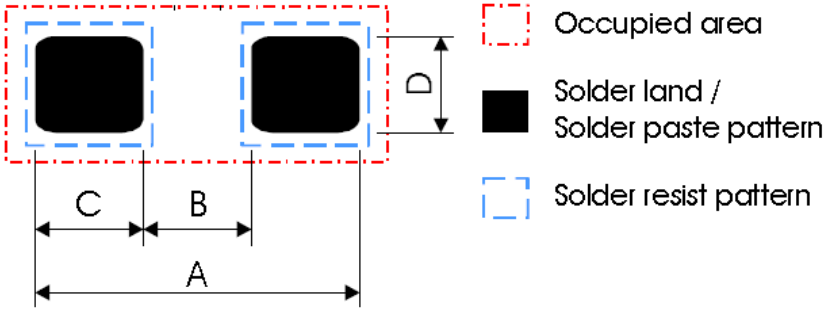
TCS70 Calibration Substrate



Specifications:
Substrate: Polished alumina
Structure: Open, short, thru, 25 Ω, 50 Ω, 100 Ω
Contact Material: Gold
Accuracy: 25 Ω, 50 Ω < 0.5%, 100 Ω < 1%
Size: 17.3 x 9.4 x 0.6 mm (0.68 x 0.37 x 0.025 in)

R-Probe Part No.
- **RP-GR-151502** – 18 GHz, 0.2 mm/ 8 mil pitch
- **RP-GR-151503** – 18 GHz, 0.3 mm/ 8 mil pitch
- **RP-GR-151504** – 15 GHz, 0.4 mm/16 mil pitch
- **RP-GR-151505** – 15 GHz, 0.5 mm/20 mil pitch
- **RP-GR-121508** – 12 GHz, 0.8 mm/32 mil pitch
- **RP-GR-121510** – 12 GHz, 1.0 mm/40 mil pitch

Probe-Pitch Selection



R-Probe Part Number:

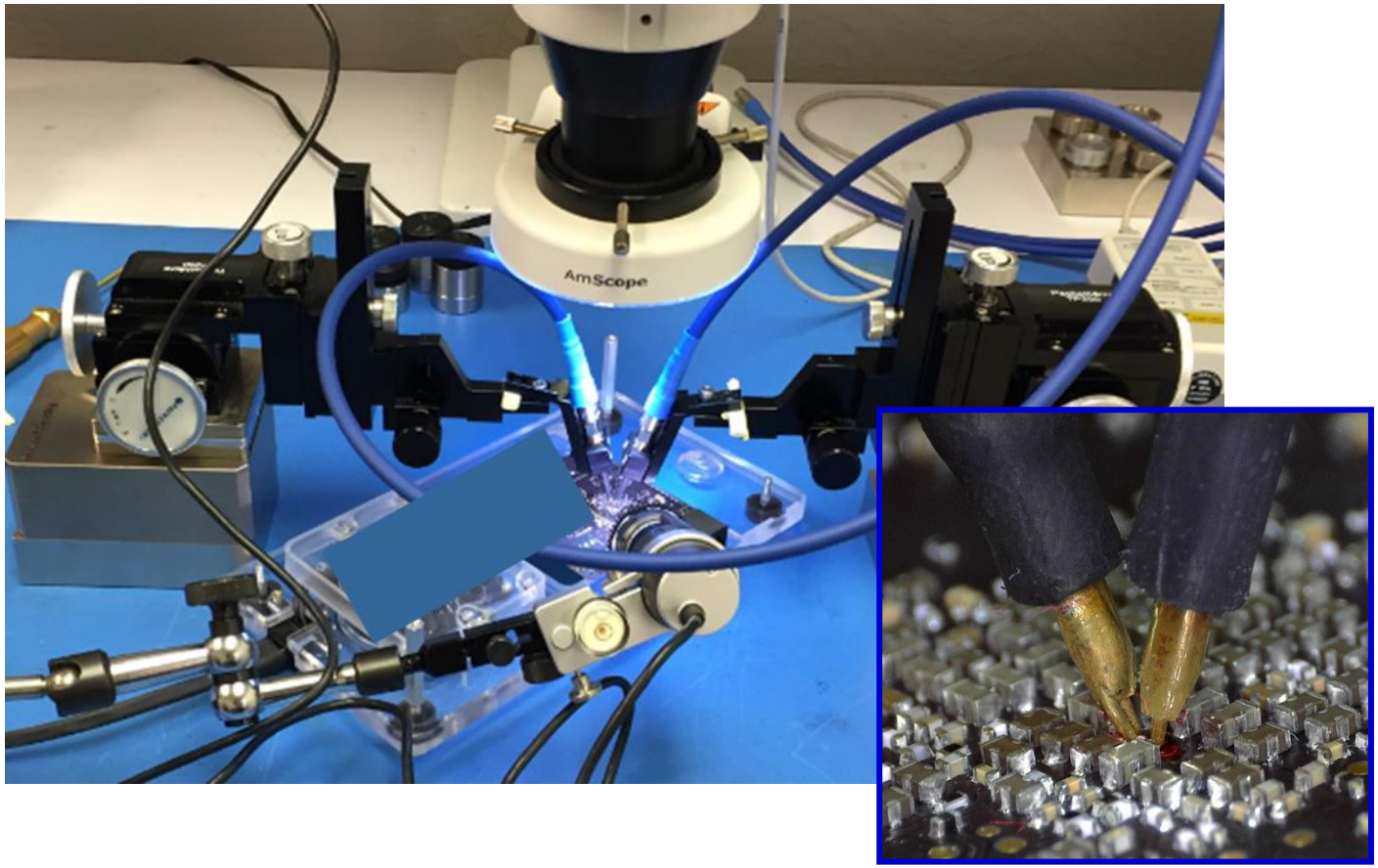
- **RP-GR-181502** – 18 GHz, 0.2 mm/ 8 mil pitch
- **RP-GR-181503** – 18 GHz, 0.3 mm/ 12 mil pitch
- **RP-GR-151504** – 15 GHz, 0.4 mm/ 16 mil pitch
- **RP-GR-151505** – 15 GHz, 0.5 mm/ 20 mil pitch
- **RP-GR-121508** – 12 GHz, 0.8 mm/ 32 mil pitch
- **RP-GR-121510** – 12 GHz, 1.0 mm/ 40 mil pitch

Recommendation: B + 0.2 mm < Probe Pitch < A – 0. 2mm

Size	Probe Pitch	A	B	C	D	Component Size
01005	RP-GR-181503	0.48	0.12	0.18	0.20	0.4 x 0. 2
0201	RP-GR-151505	0.75	0.30	0.30	0.30	0.6 x 0.3
0402	0.7mm < Pitch <1.3mm	1.50	0.50	0.50	0.60	1.0 x 0.5
0603	0.8mm < Pitch <1.9mm	2.10	0.60	0.90	0.90	1.6 x 0.8
0805	1.2mm < Pitch <2.8mm	3.0	1.0	1.0	1.25	2.0 x 1.25

Typical Reflow Soldering Footprint and Component Size in mm

Power Integrity Probing

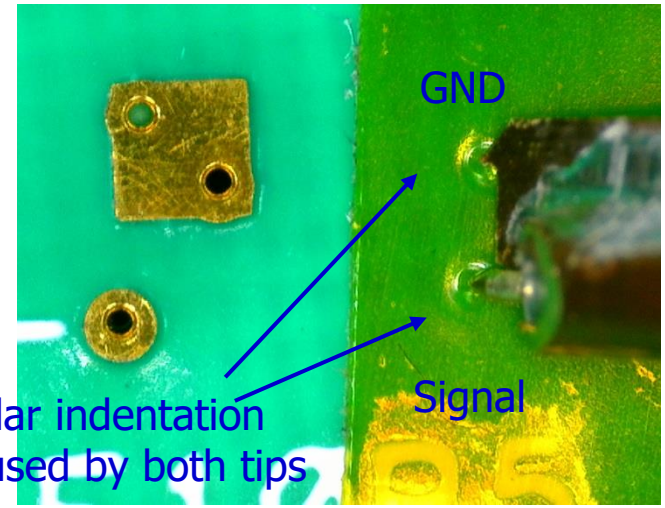


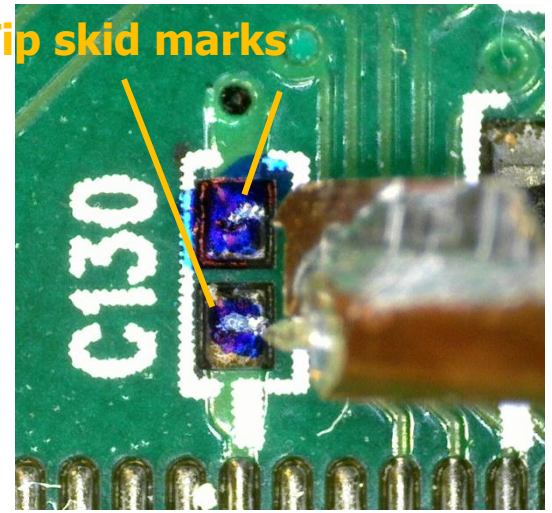
- PI Probing amid surrounding components is challenging

Milliohm PDN Measurements

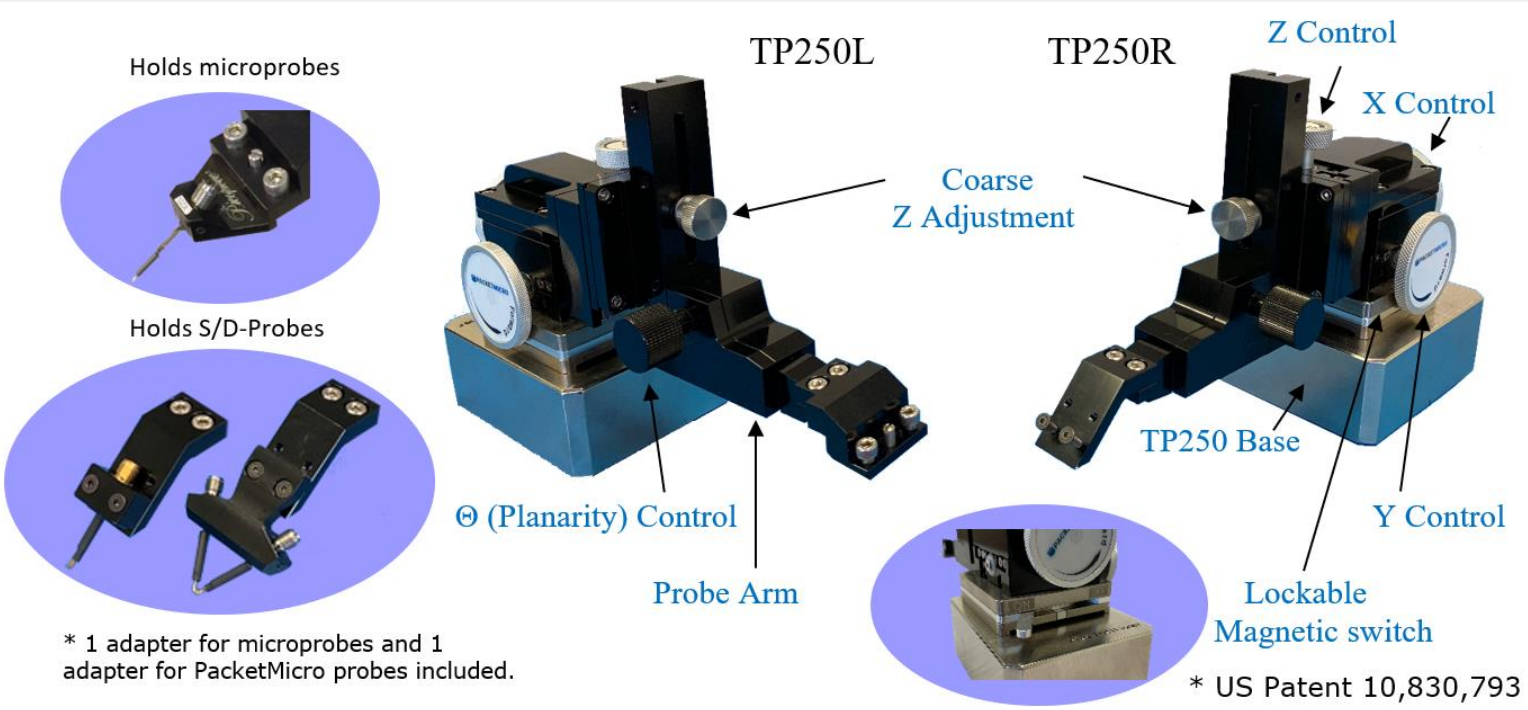
Probe Planarization Tips

- Good contact of both probe tips with the DUT is essential to accurate calibration and measurements.
- Mylar tape provides leveling guidance on flat, even surface (bare PCB).
- Color marker helps on uneven surface (solder bump).
- A good microscope is important. You might damage the probe if you cannot see its tips well.



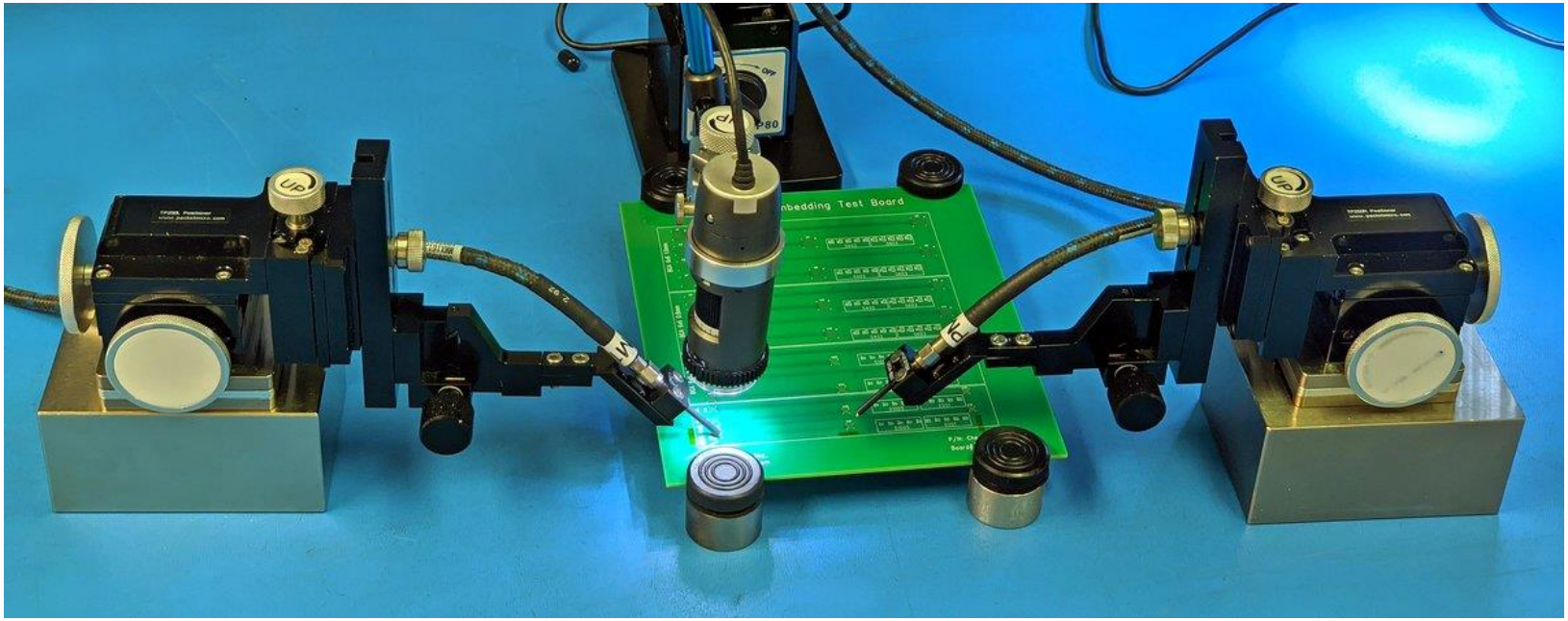


TP250 Precision Positioner



- **XYZ-axis travel**: 16 mm with 500 μm/turn (50 TPI, 5μm resolution)
- **Height coarse adjustment**: 5 mm/step (14 steps)
- **Θ (Planarity) control**: ±10° with 2.5° /turn and 0.025° resolution
- **Dimension**: 9” L x 2.7” W x 4.3” H
- **Weight**: 2.86 lb./1.30 kg

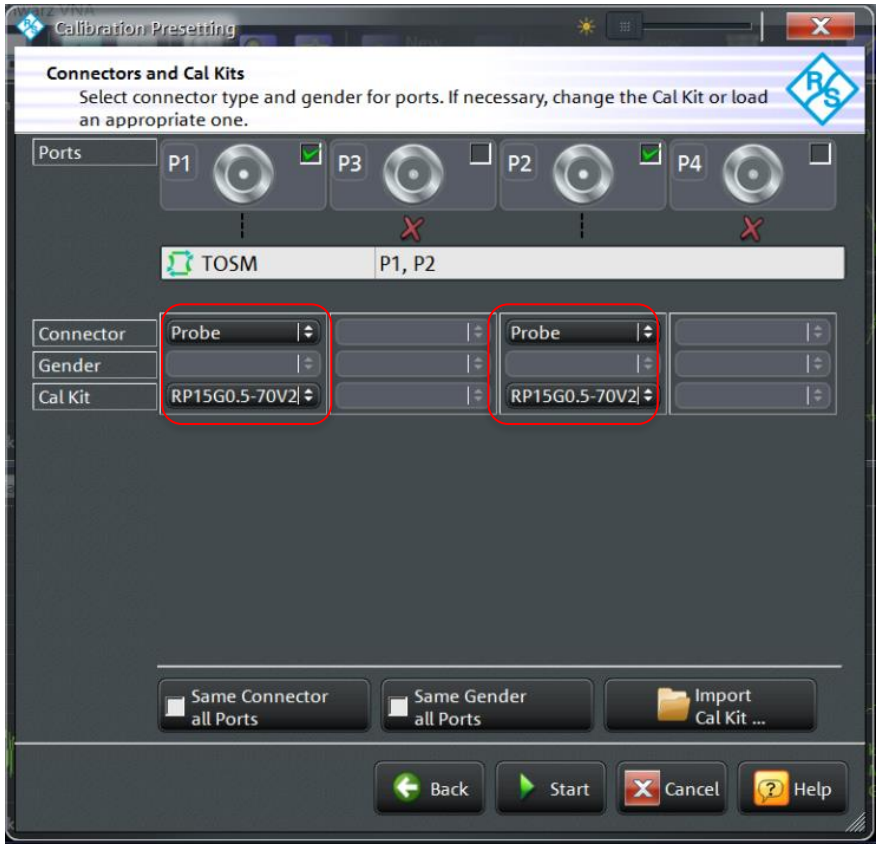
Probe Planarization with TP250



Probe Planarization Video:
https://packetmicro.com/Videos/PacketMicro_Probe_Planarization.mp4

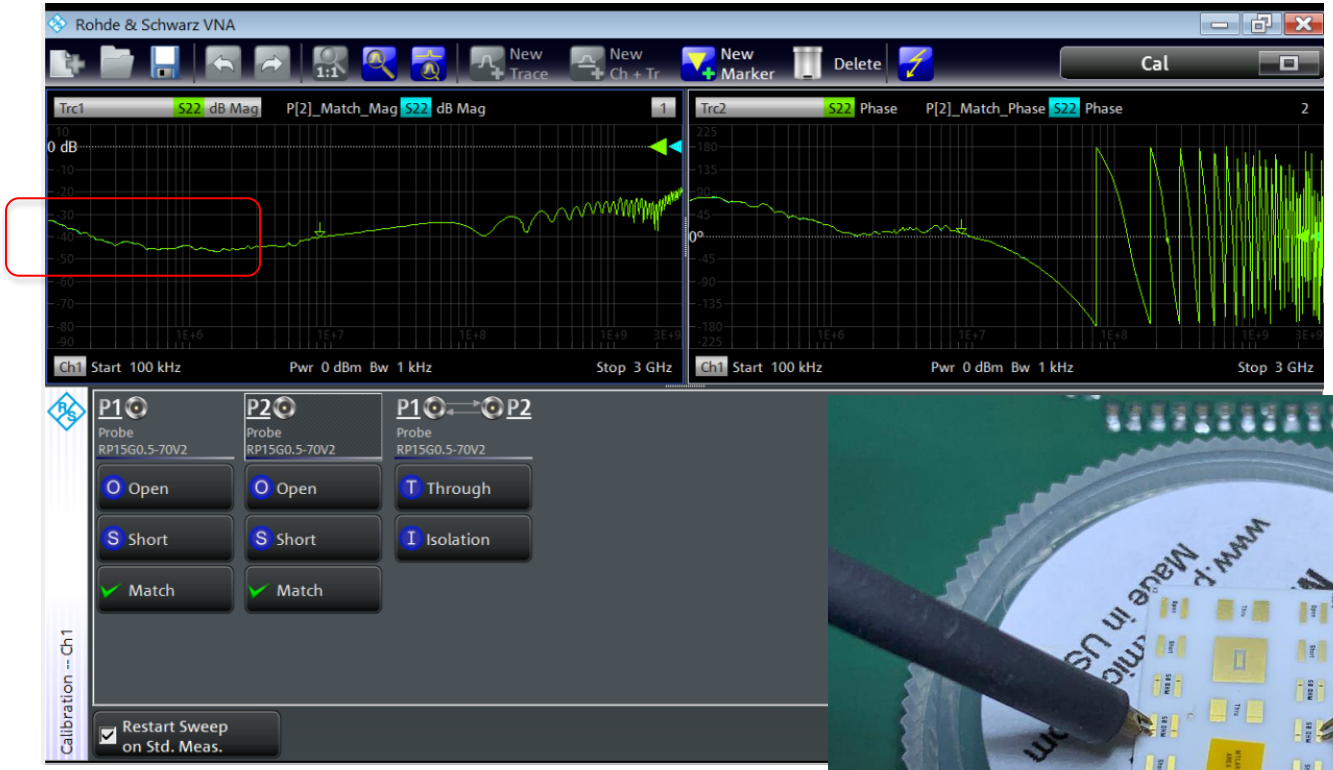
Probe-tip SOLT Cal

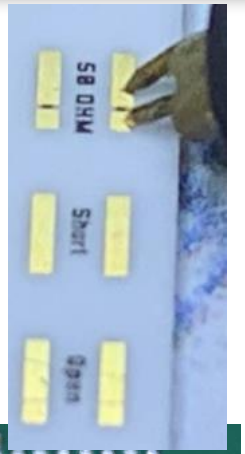
Probe-tip SOLT Cal – cont.

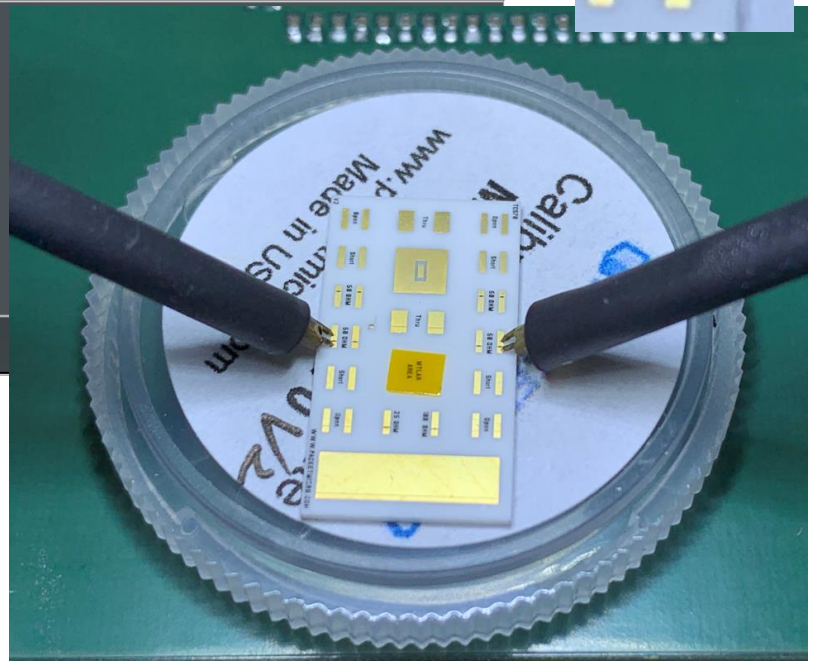


- Make sure to use the right .calkit file that is probe pitch dependent.

Load Calibration

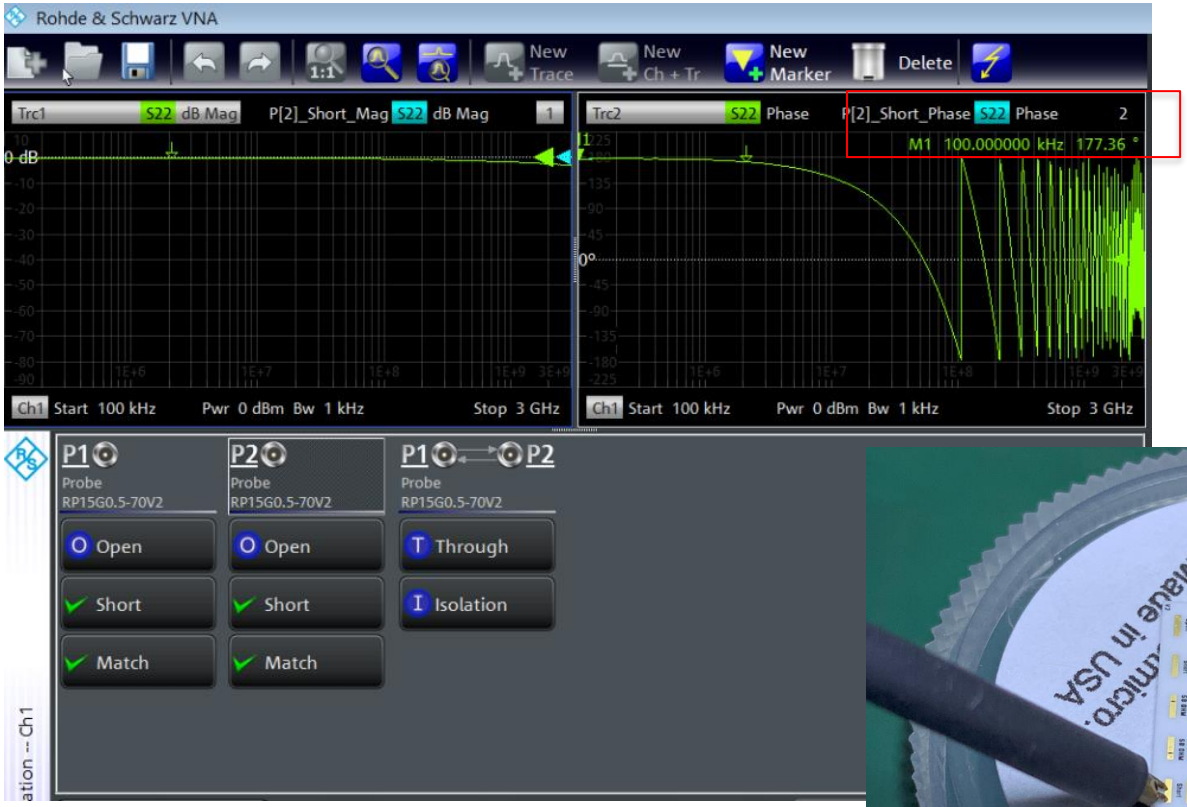


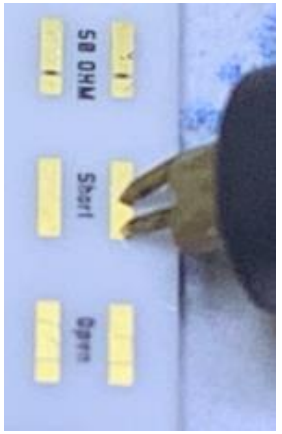


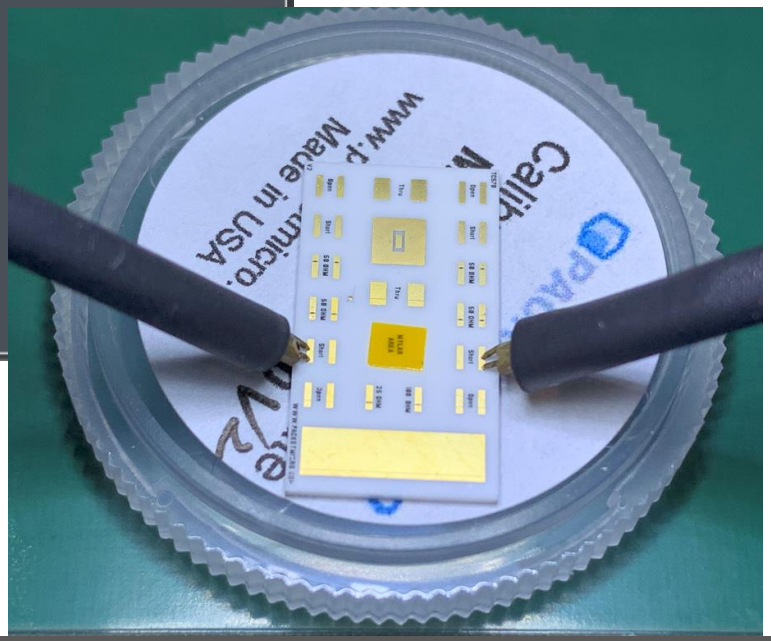


- S11 and S22 should be less than -20 dB at low frequencies

Short Calibration

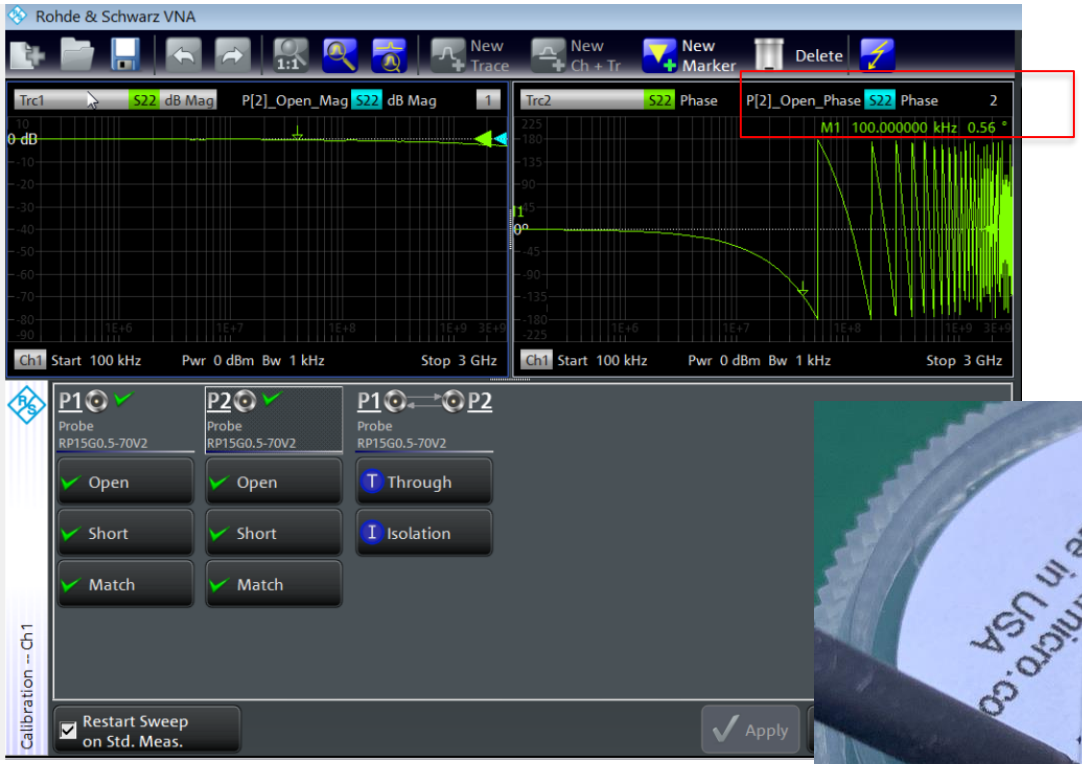


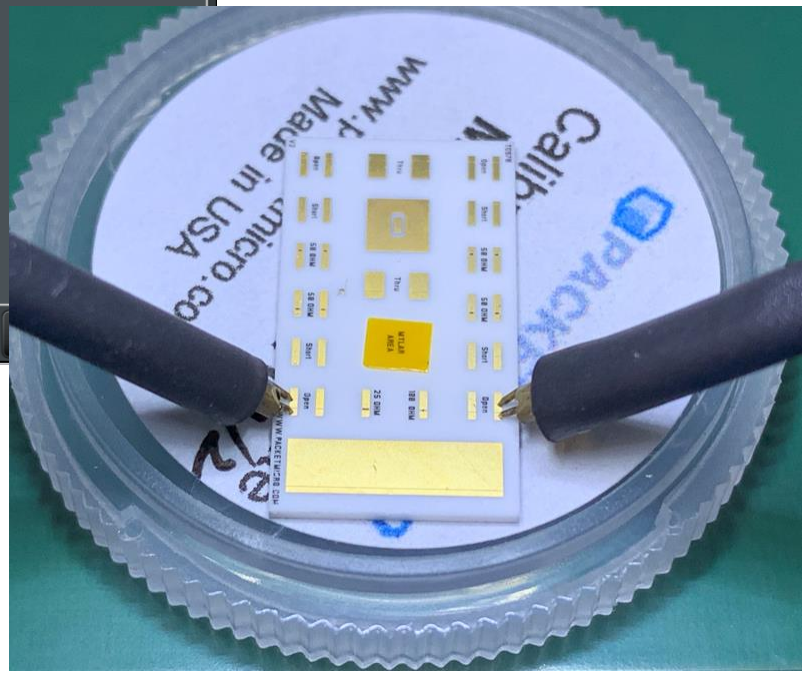




- Set the phase marker to the lowest frequency
- Good short contact makes phase change ~ 180 deg

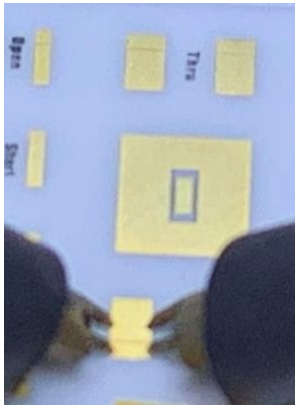
Open

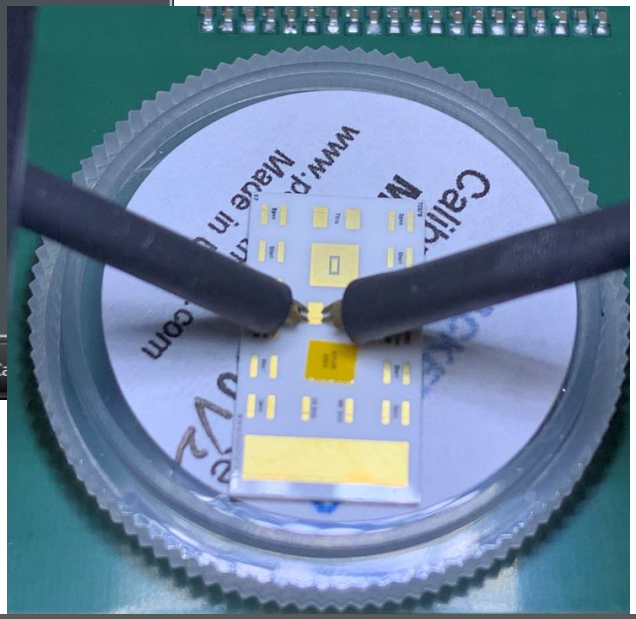




- Make sure that probe tips contact the open pattern.

Thru



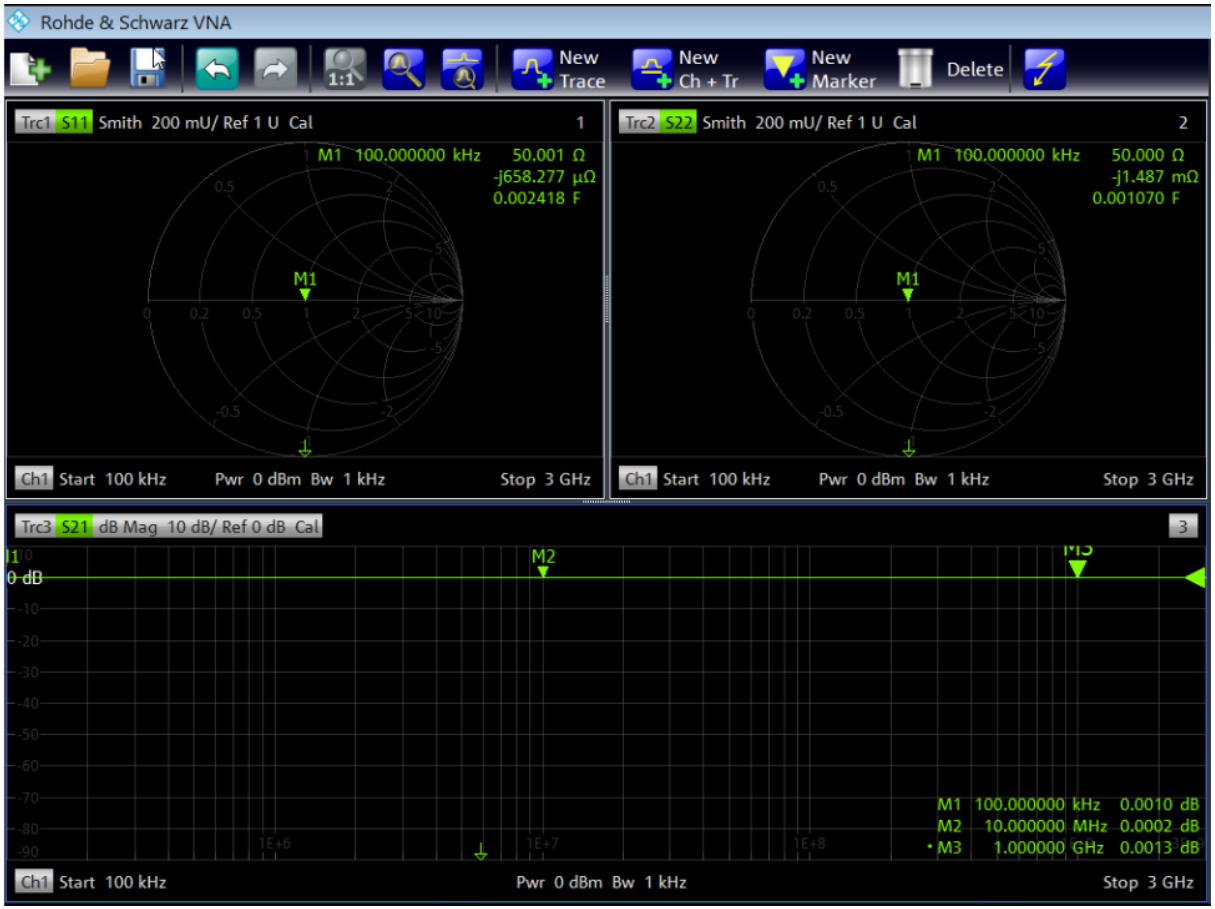


- S21 should be around 0 dB at lowest frequency

Apply Calibration

- S21 should be close to a flat line after calibration is applied

Use Thru for calibration verification

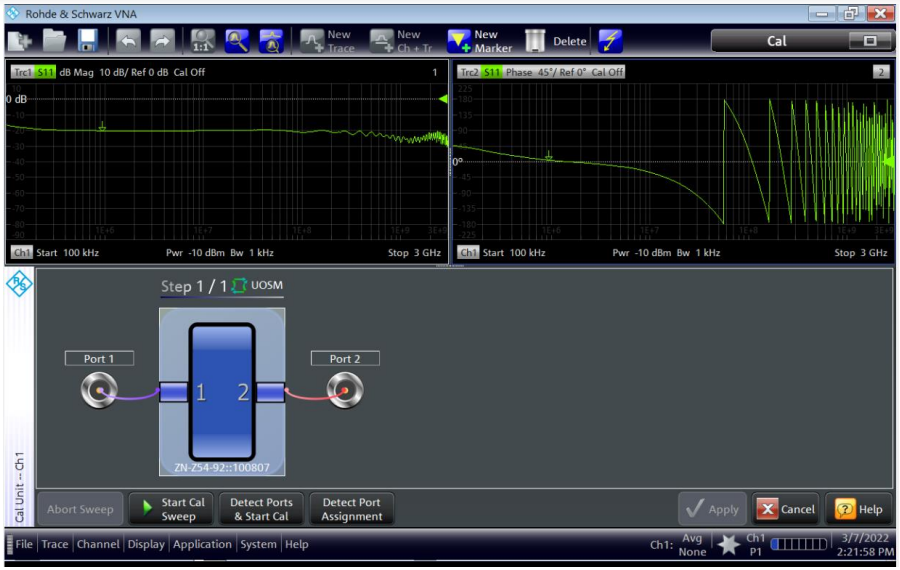


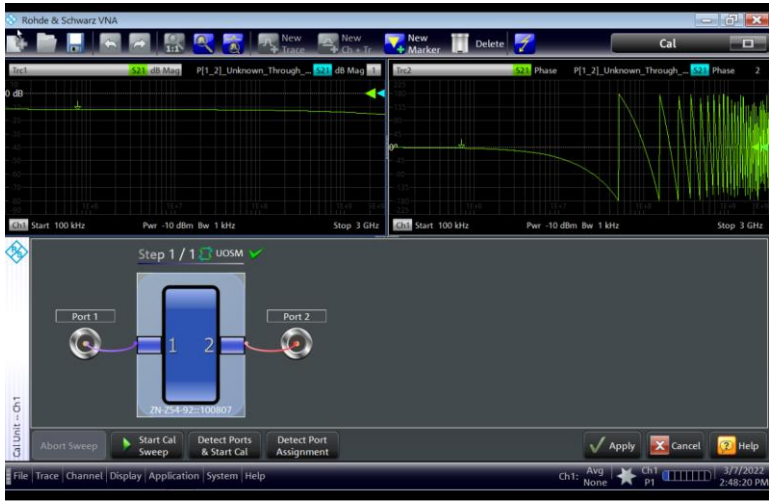
- After lifting up and then lowering down the probe tips, S21 should be flat around 0 dB up to 50% of probe bandwidth.

Electronic Calibration

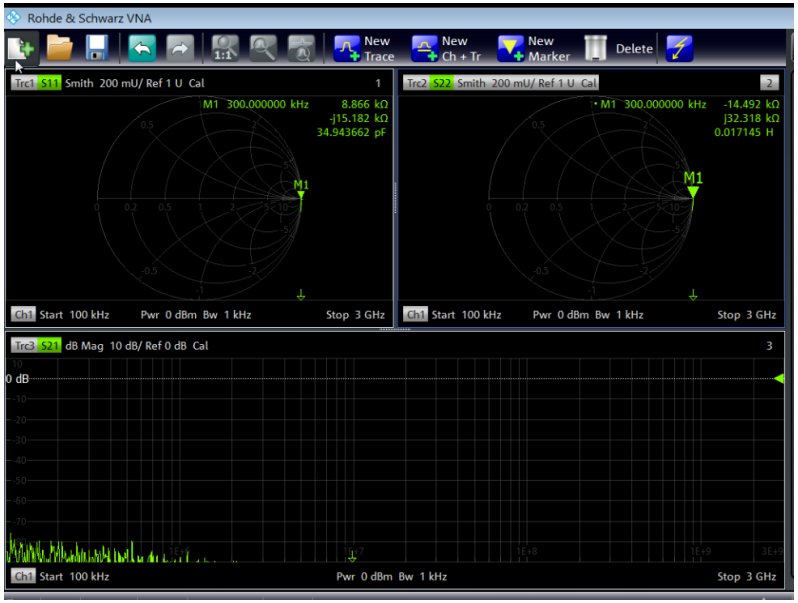
- For many applications, you may be able to use electronic calibration

Electronic Calibration – cont.

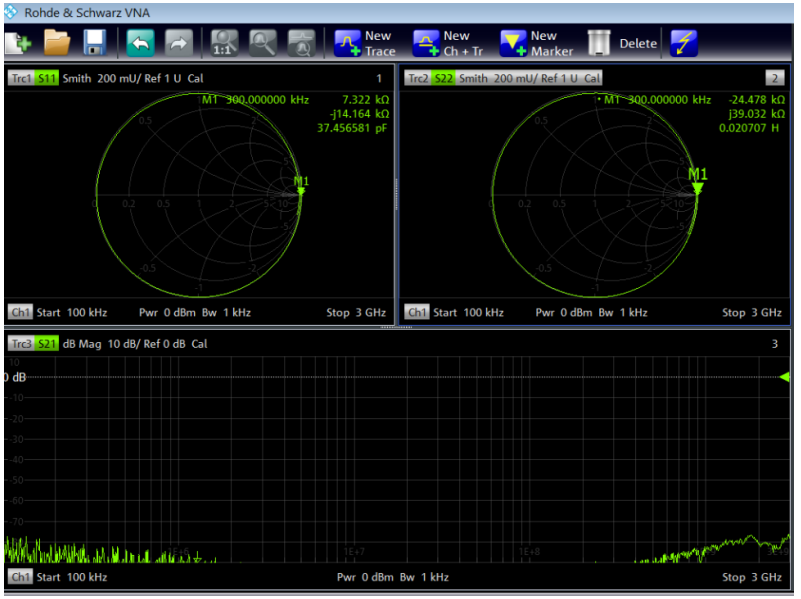




Electronic Calibration – cont.

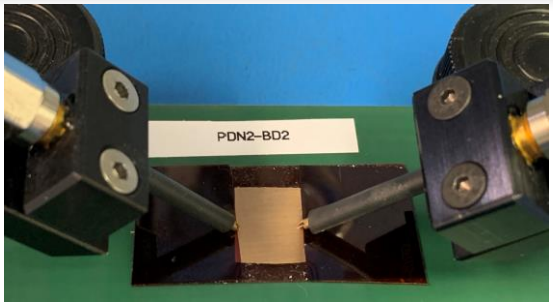


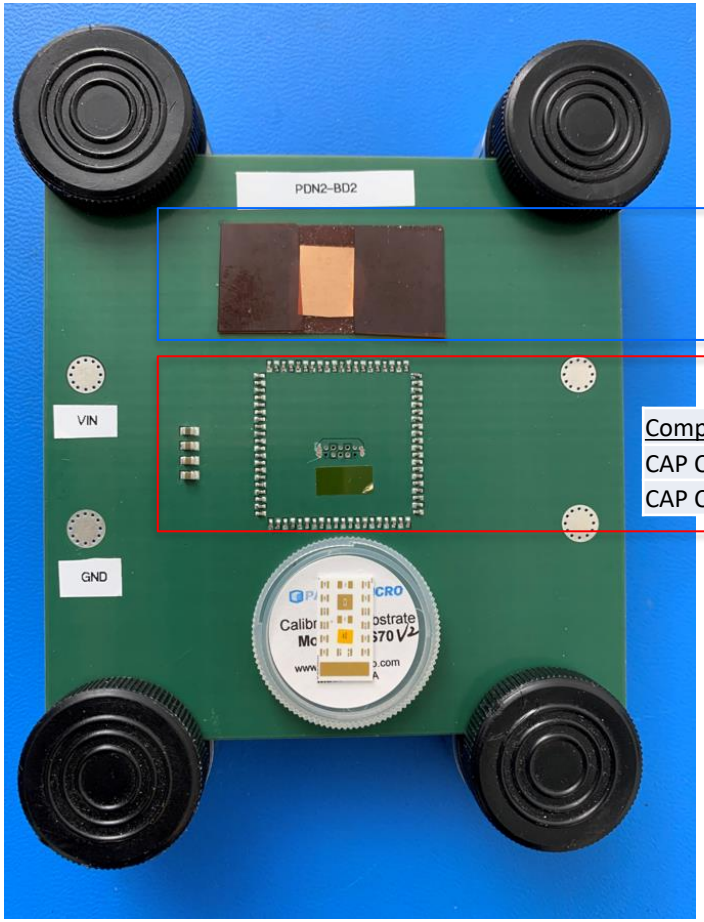
- Both cables are left open



- Both cables are connected to probes that are lifted up in the air.

Test Cases

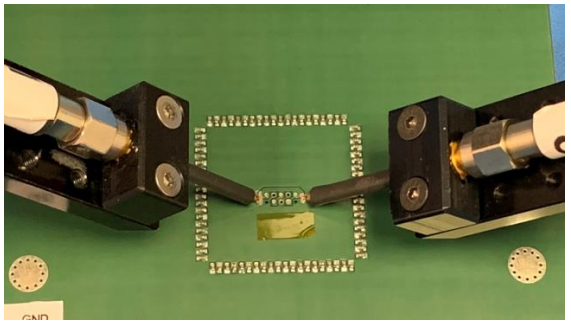




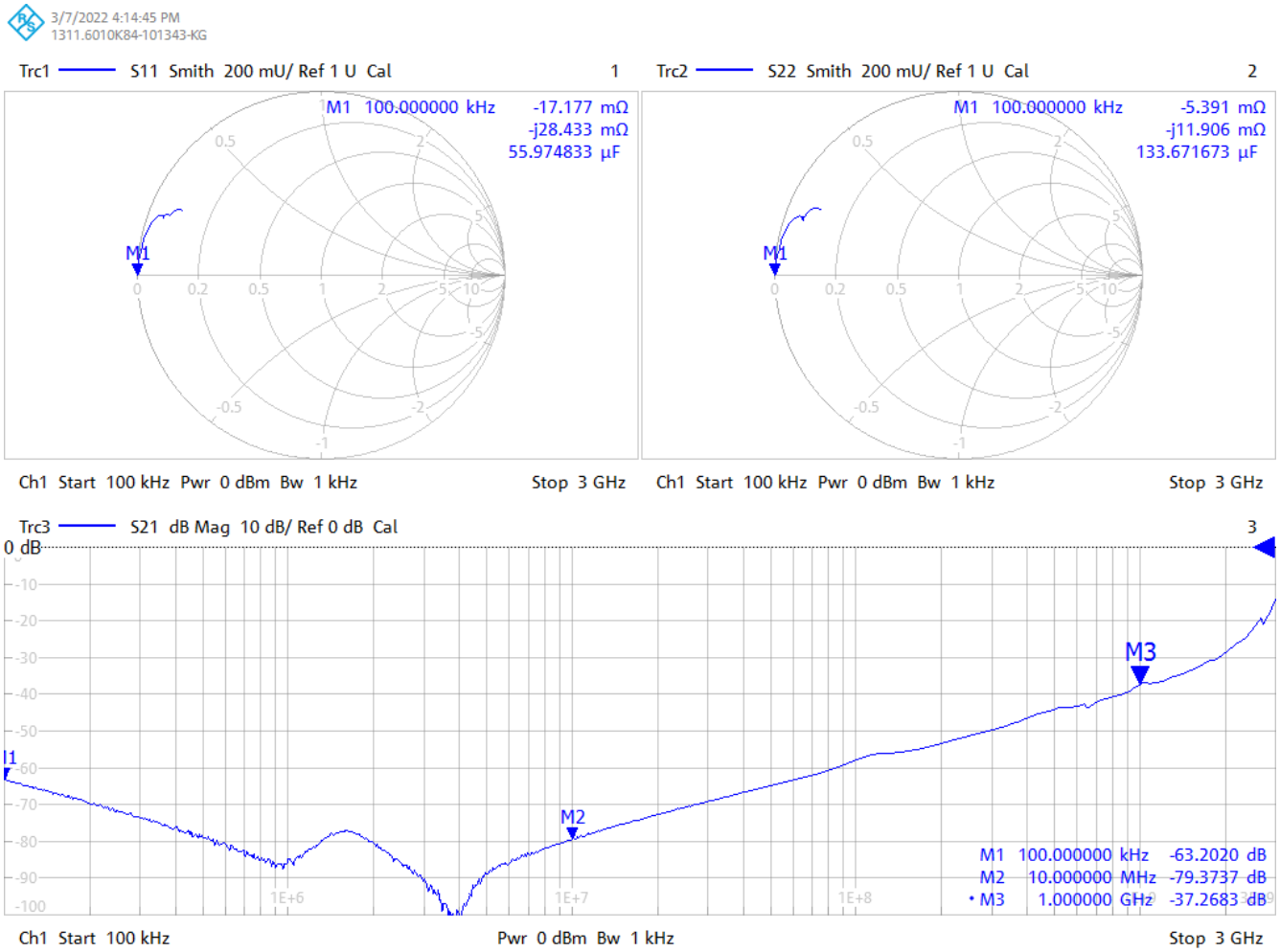
Copper: 50x40x4 mils

PDN

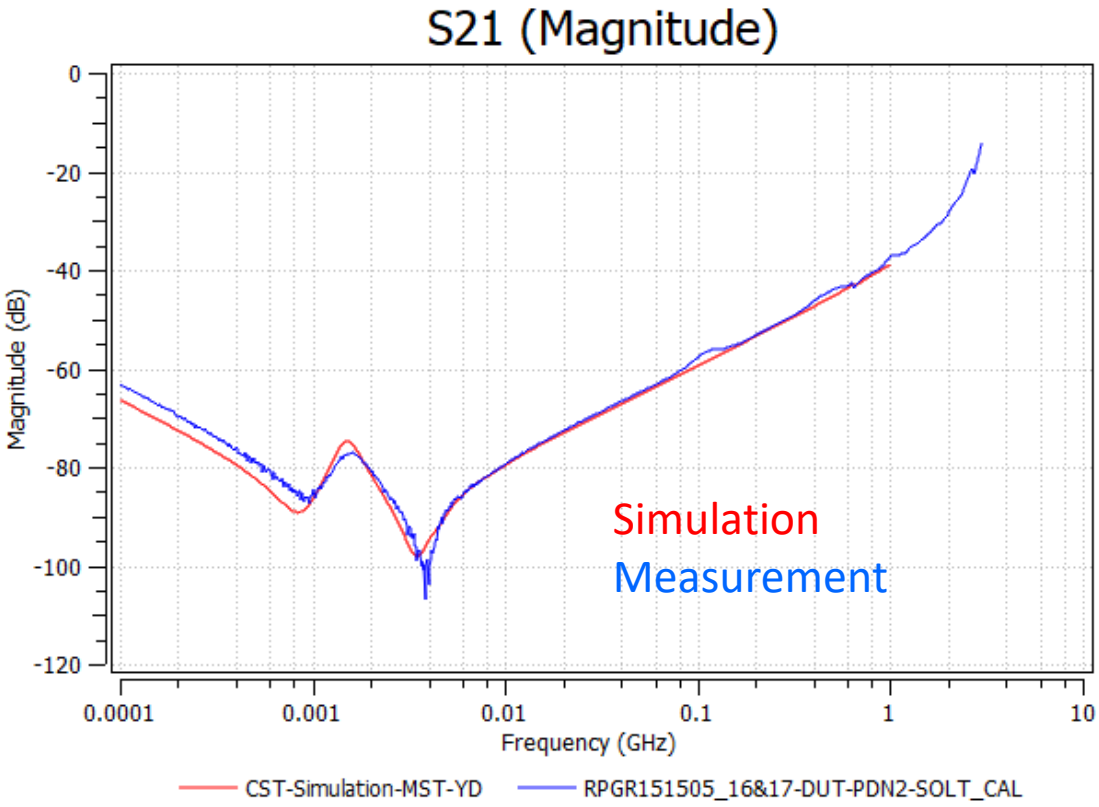
Component Description	QTY	Ref Des	Mfg P/N #
CAP CER 22UF 6.3V X5R 0805	4	C1,C2,C3,C4	C0805C226M9PACTU
CAP CER 1UF 6.3V X6S 0402	80	C5-C84	GRT155C80J105ME01D

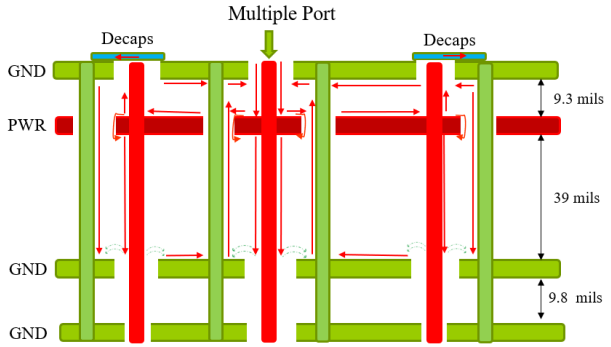


PDN DUT – SOLT Calibration



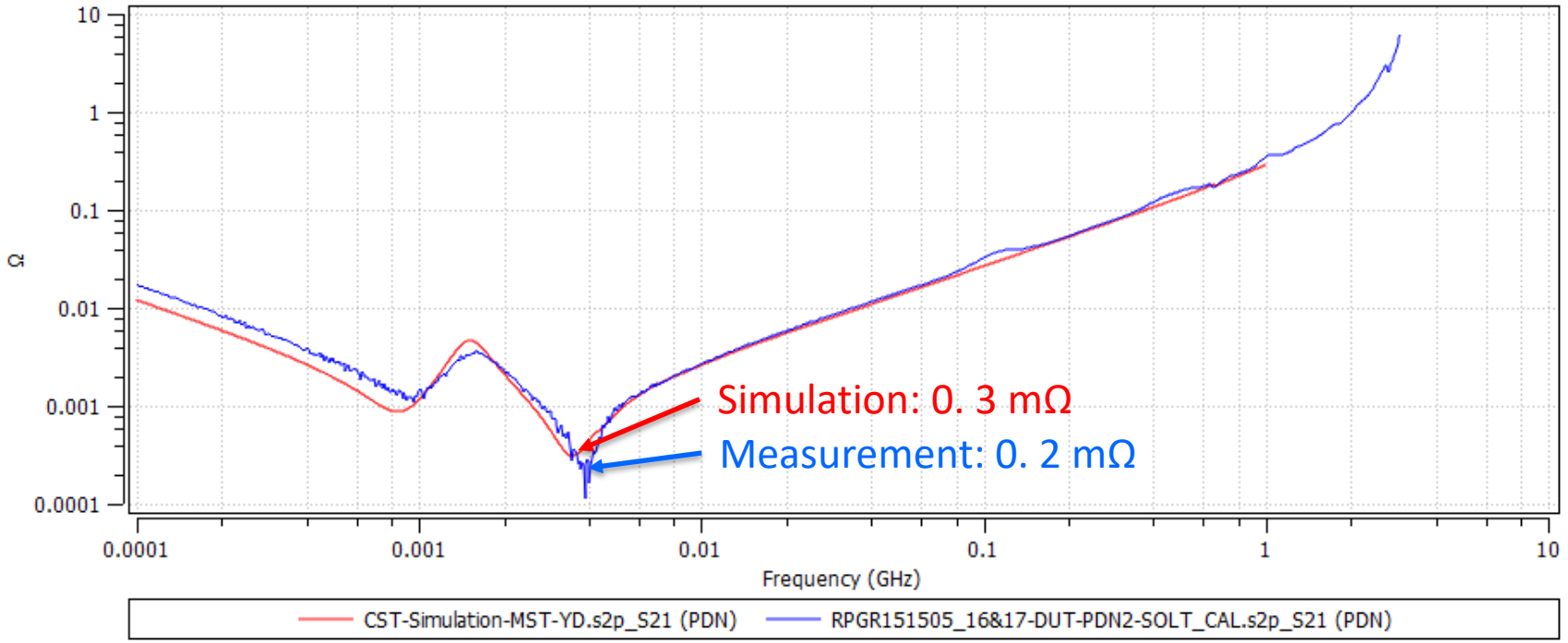
Measurement vs. Simulation



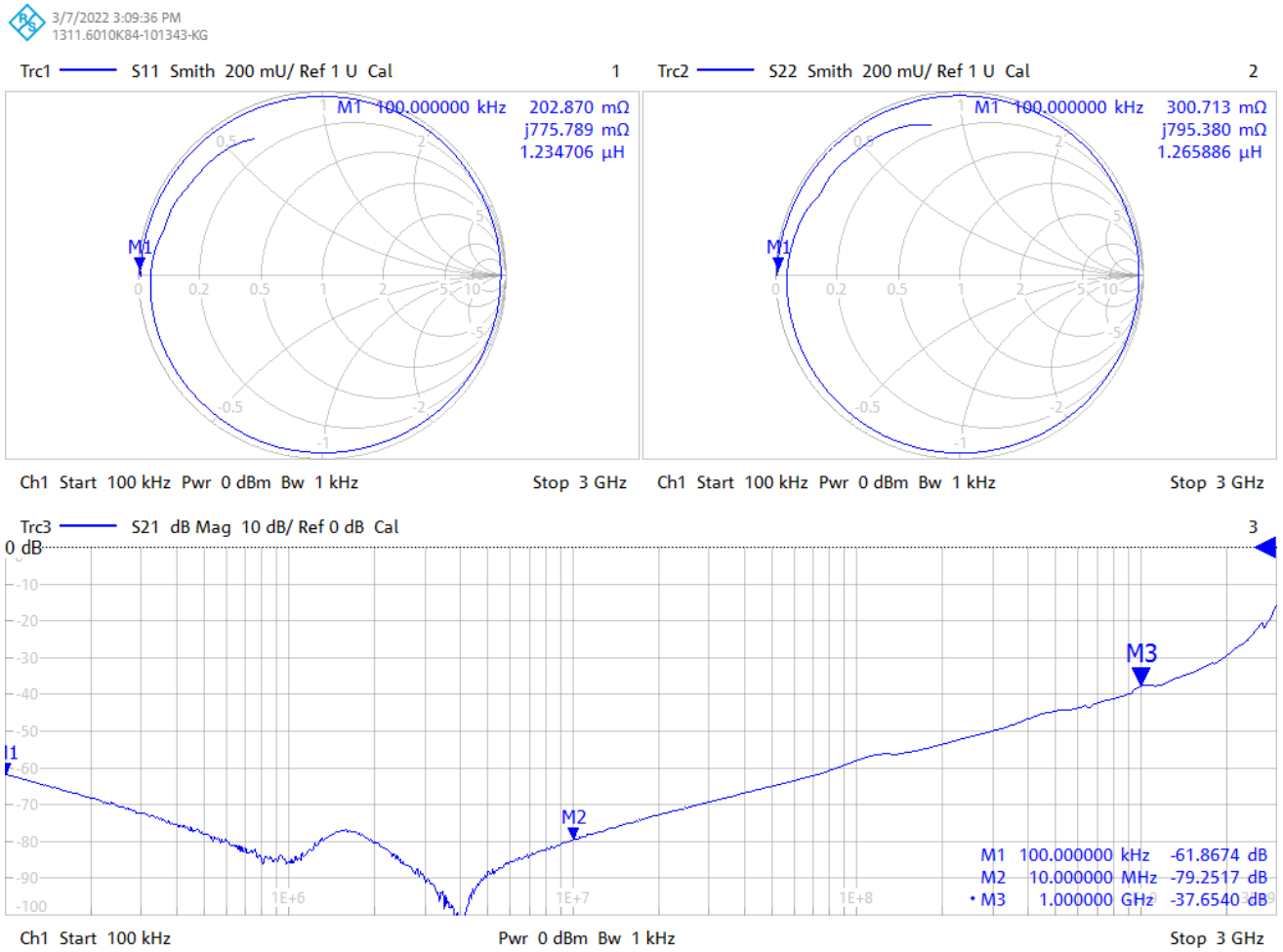


CST Simulation was provided by Yifan Ding of Univ. of Missouri Science & Technology

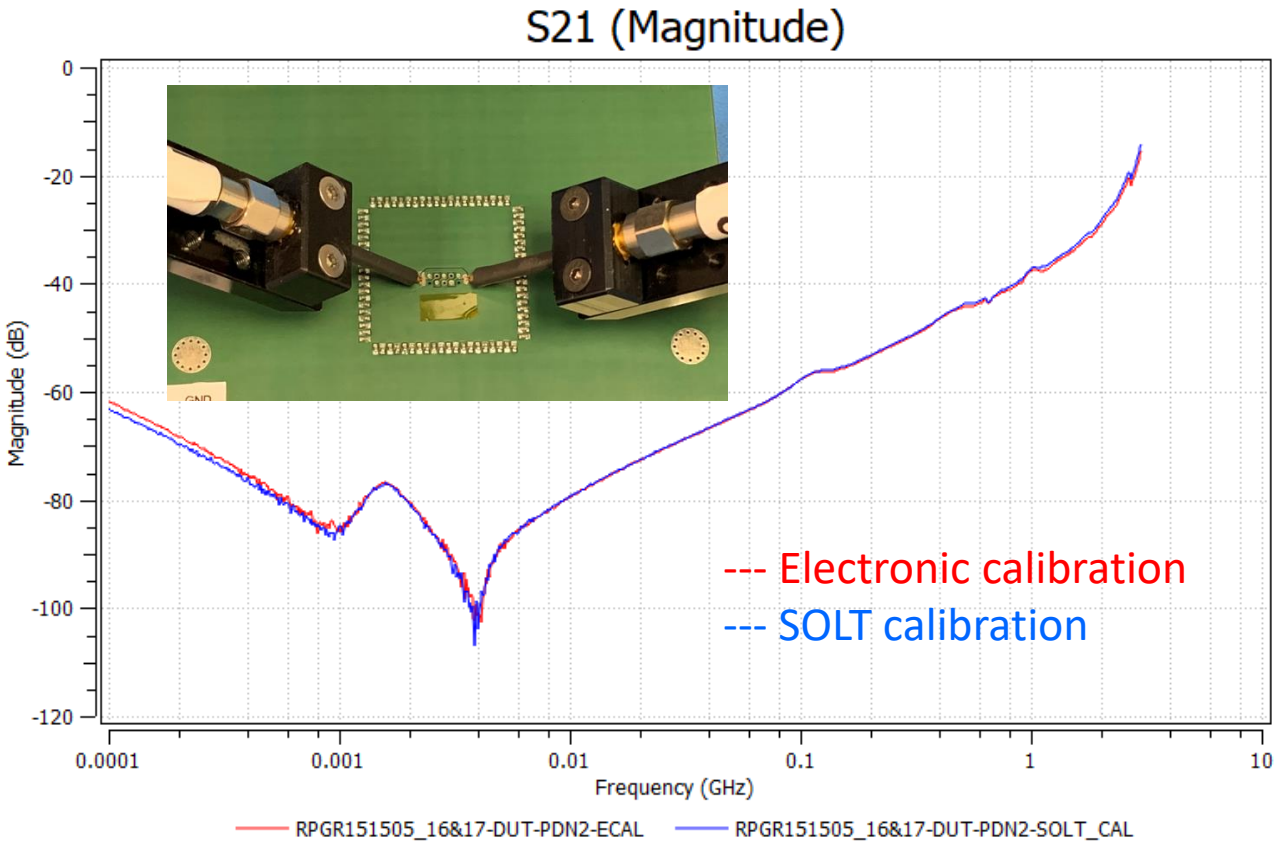
Measurement vs. Simulation – cont.



PDN DUT – Electronic Calibration

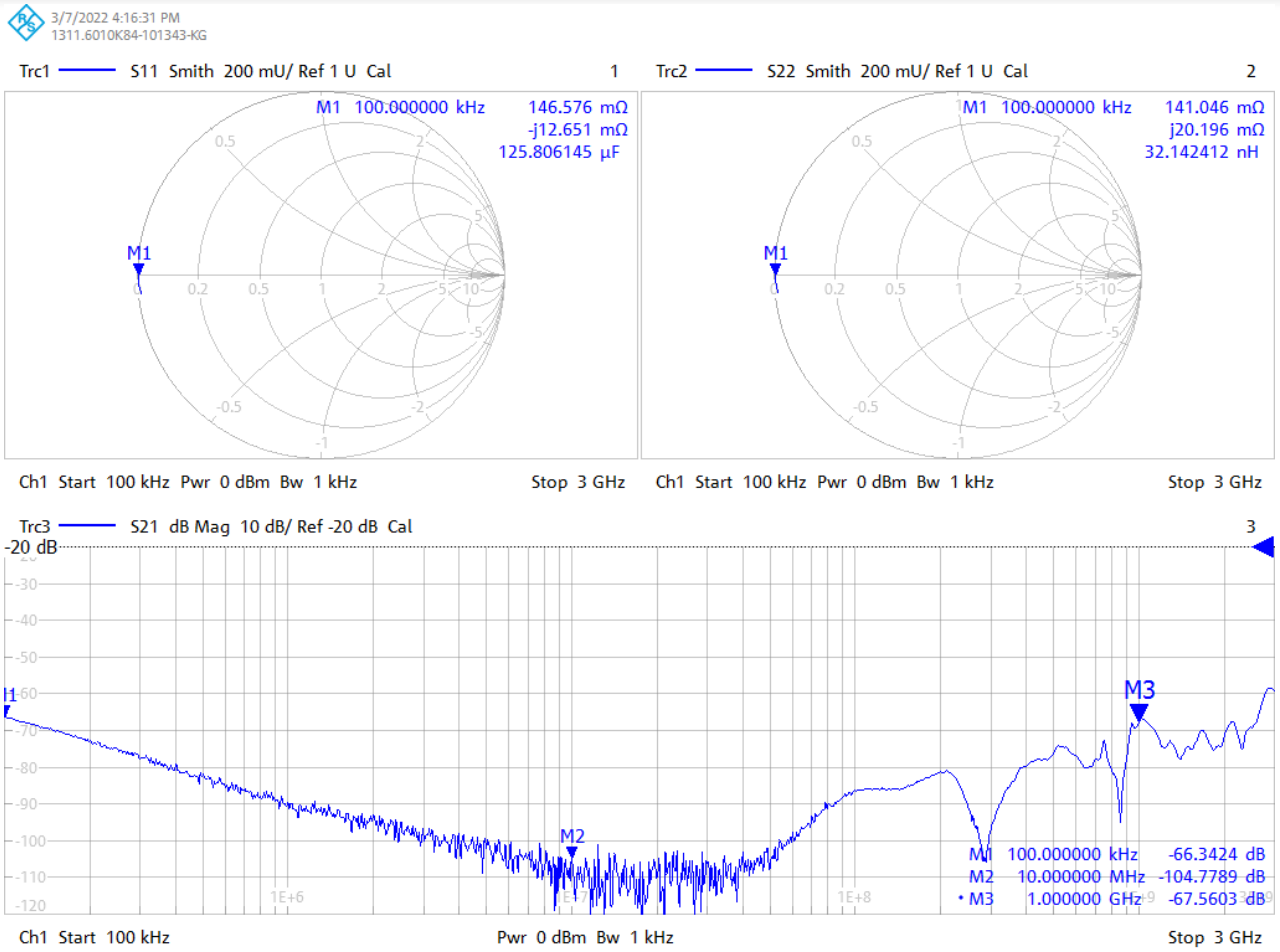


Comparison – PDN DUT

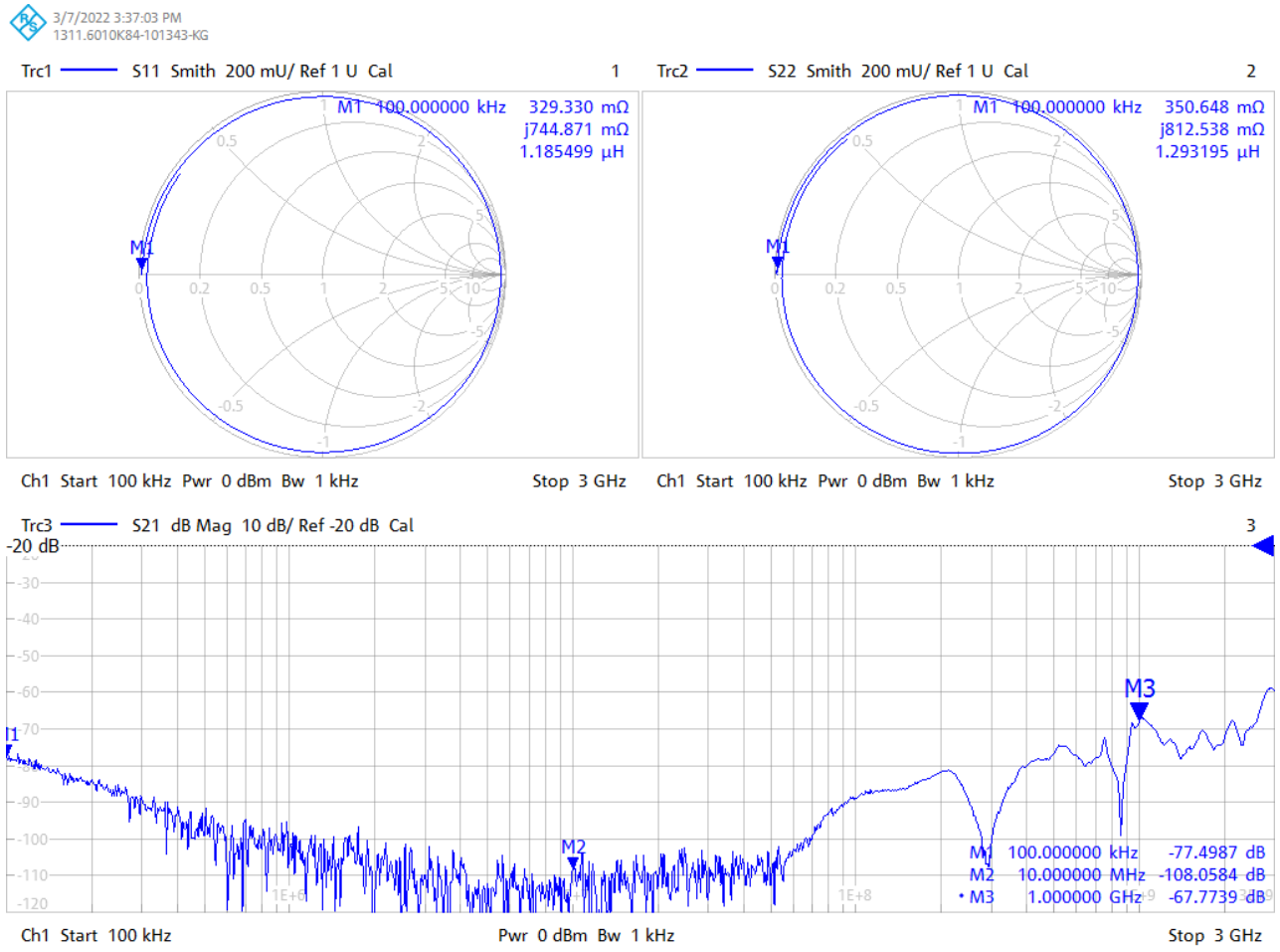


- SOLT calibration is slightly better than electronic calibration.

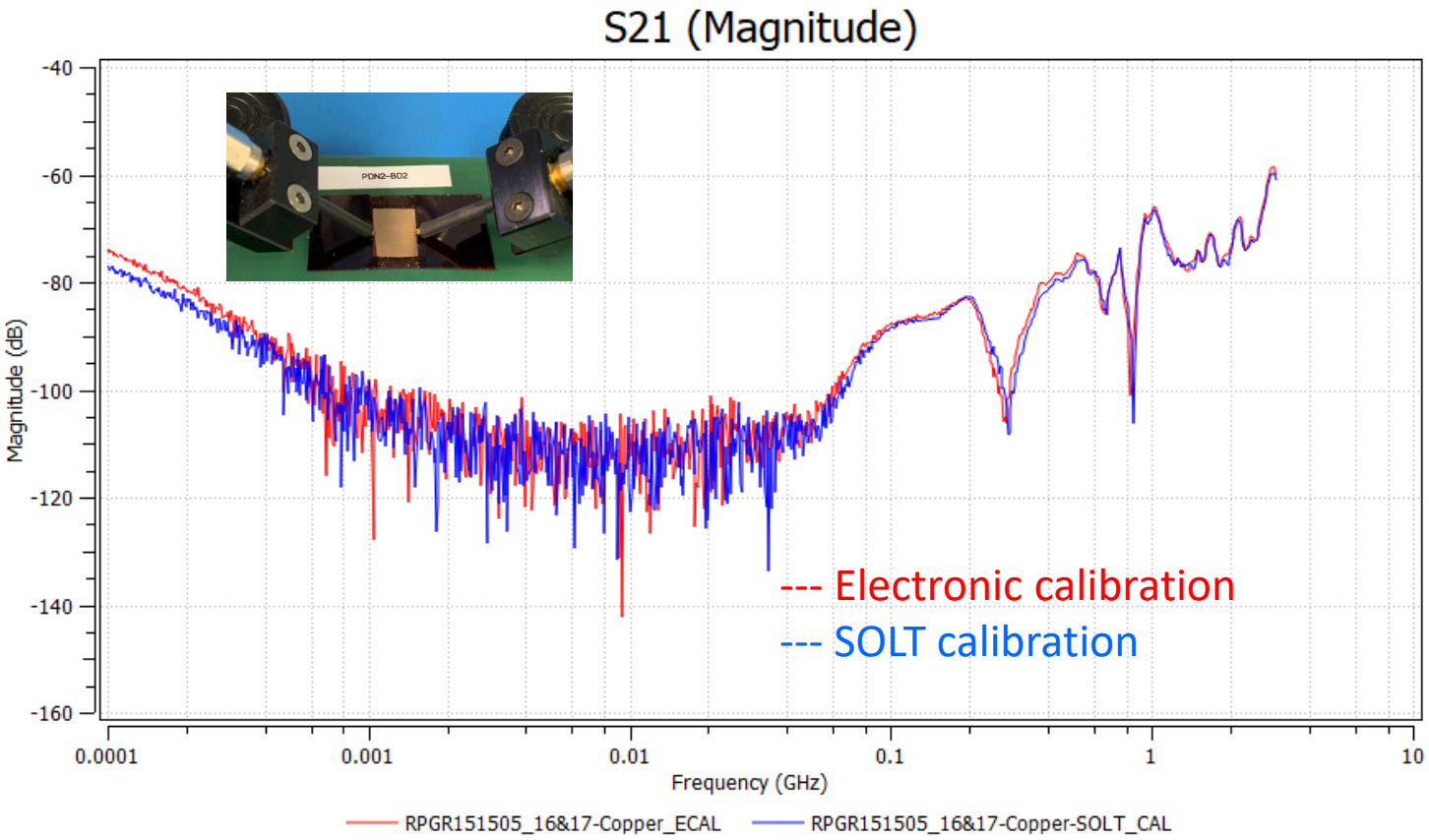
Copper DUT – SOLT Calibration



Copper DUT – Electronic Calibration

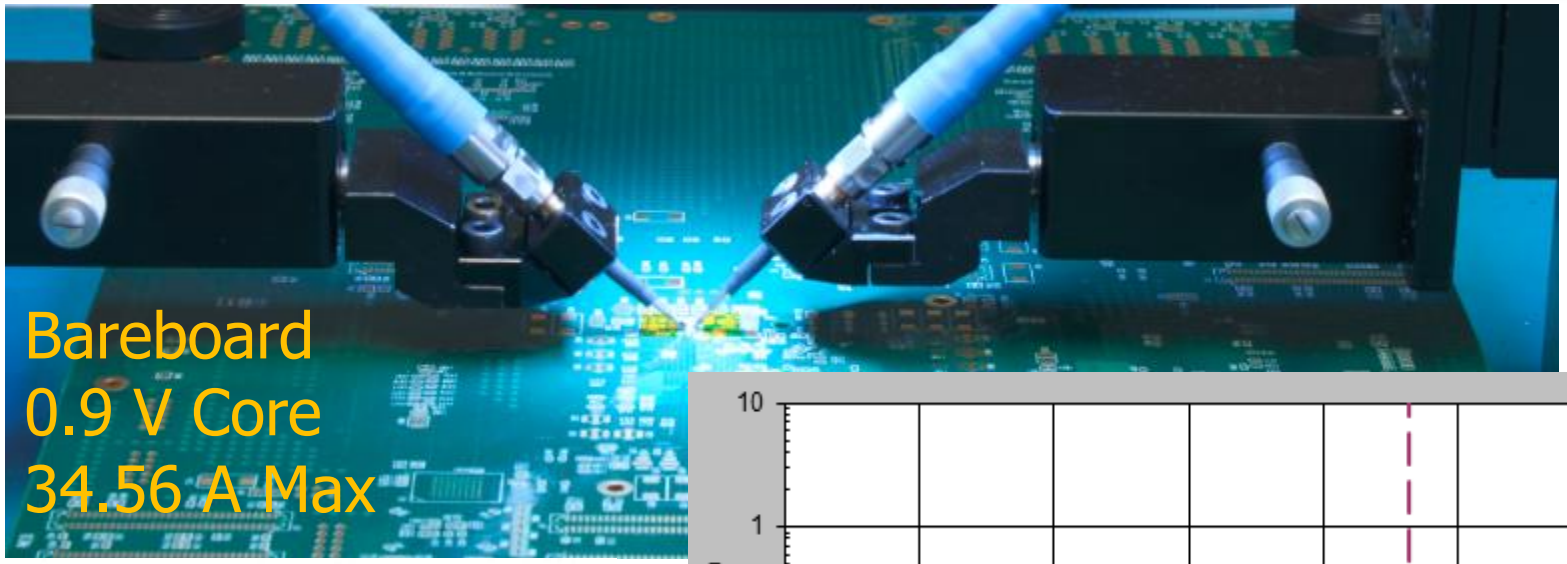


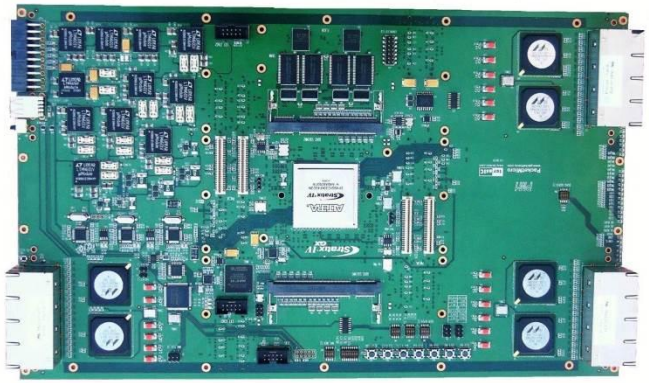
Comparison – Copper DUT



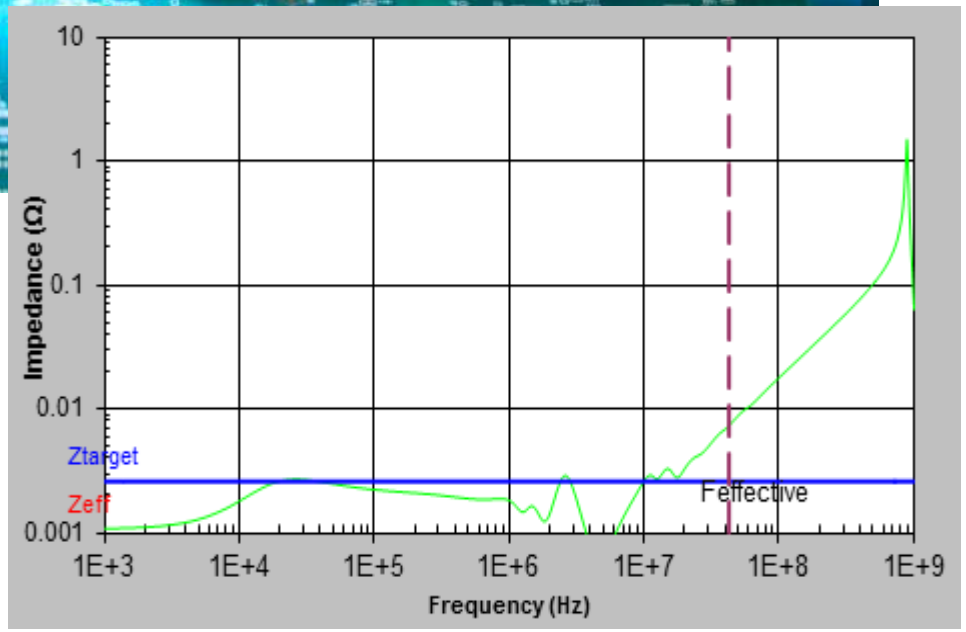
- SOLT calibration is slightly better than electronic calibration.

22-Layer Stratix III Test Board



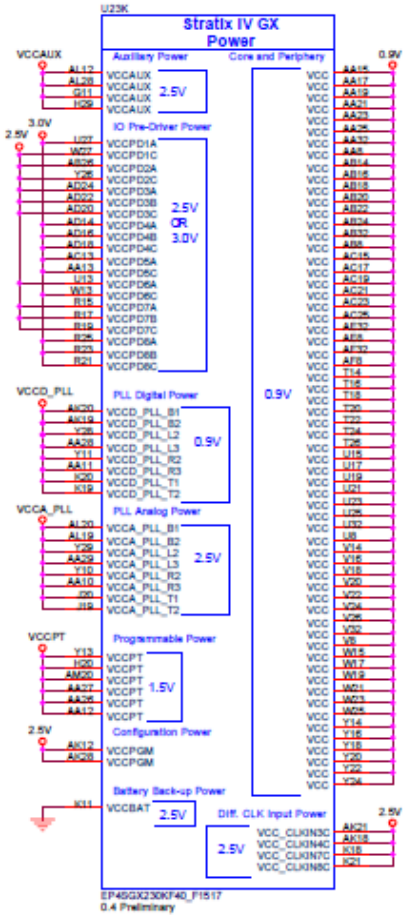


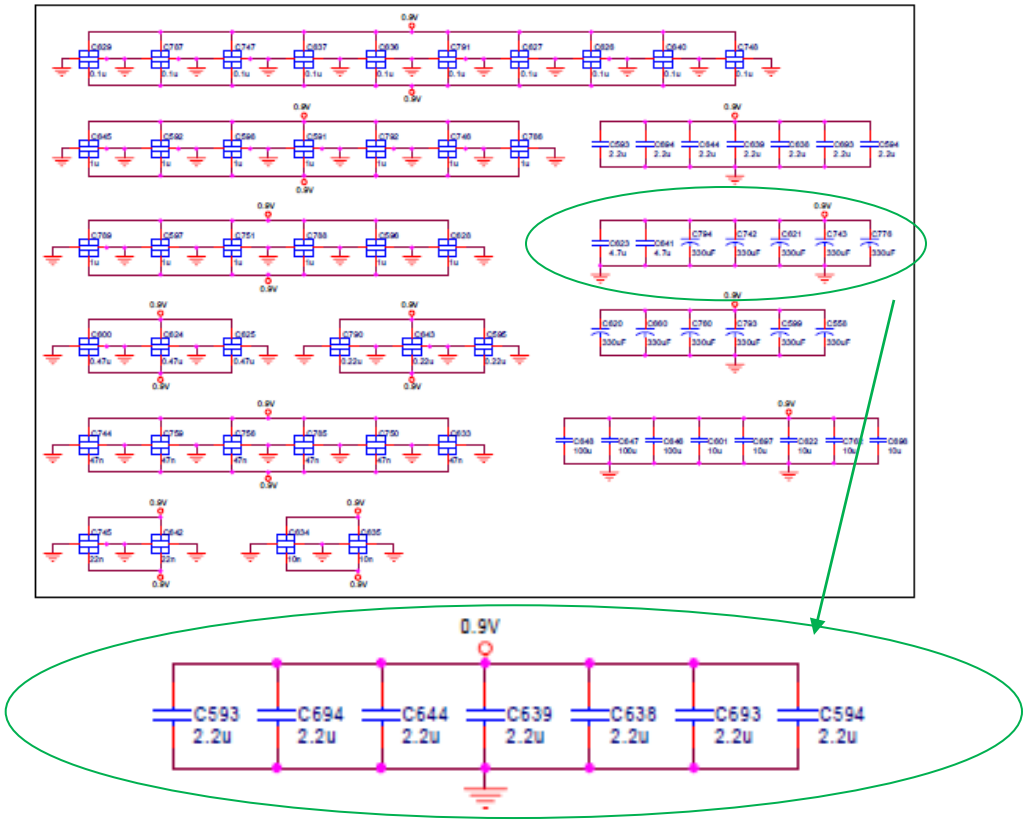
22-layer Stratix III board



PDN Impedance Requirement

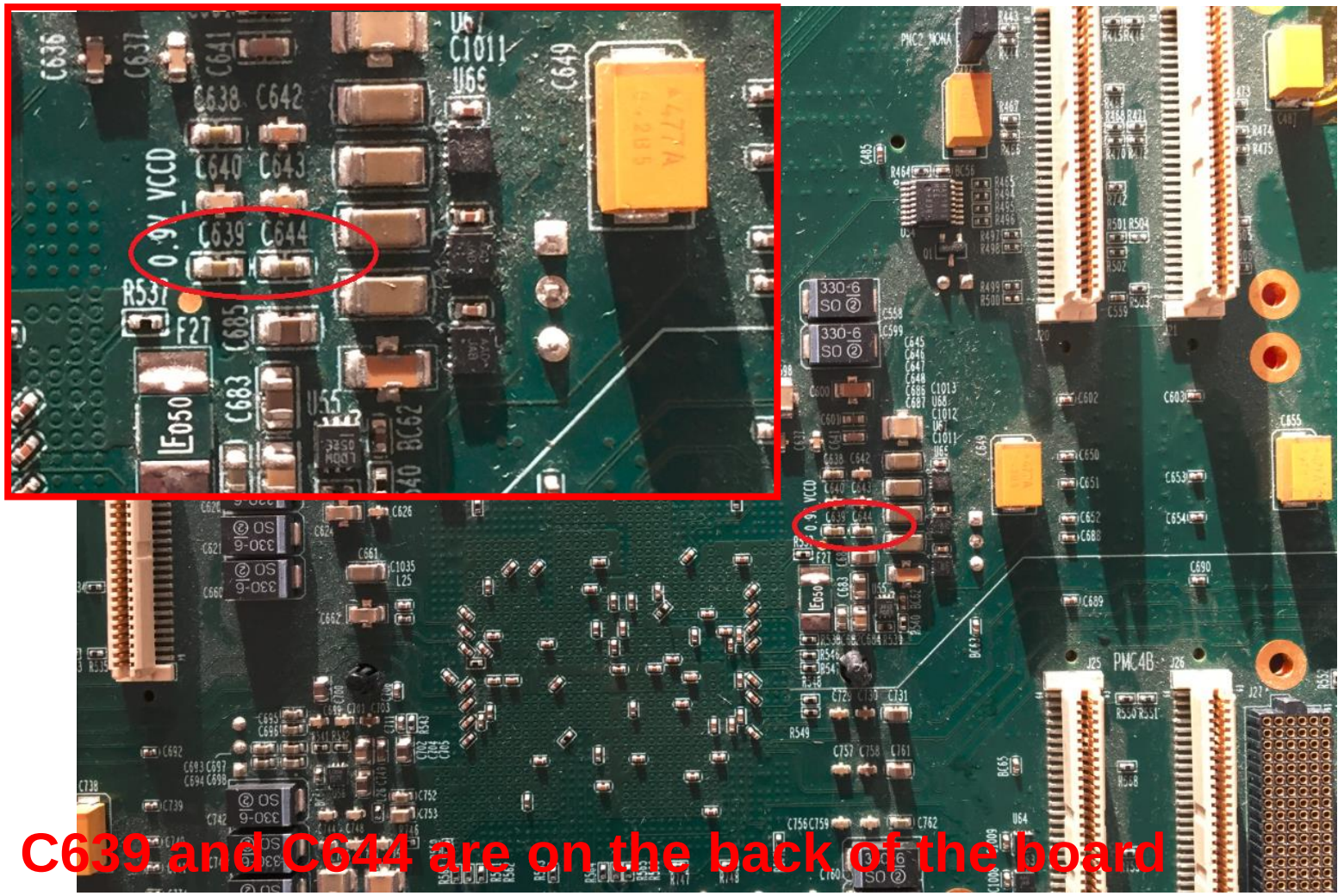
PI Probing Demo



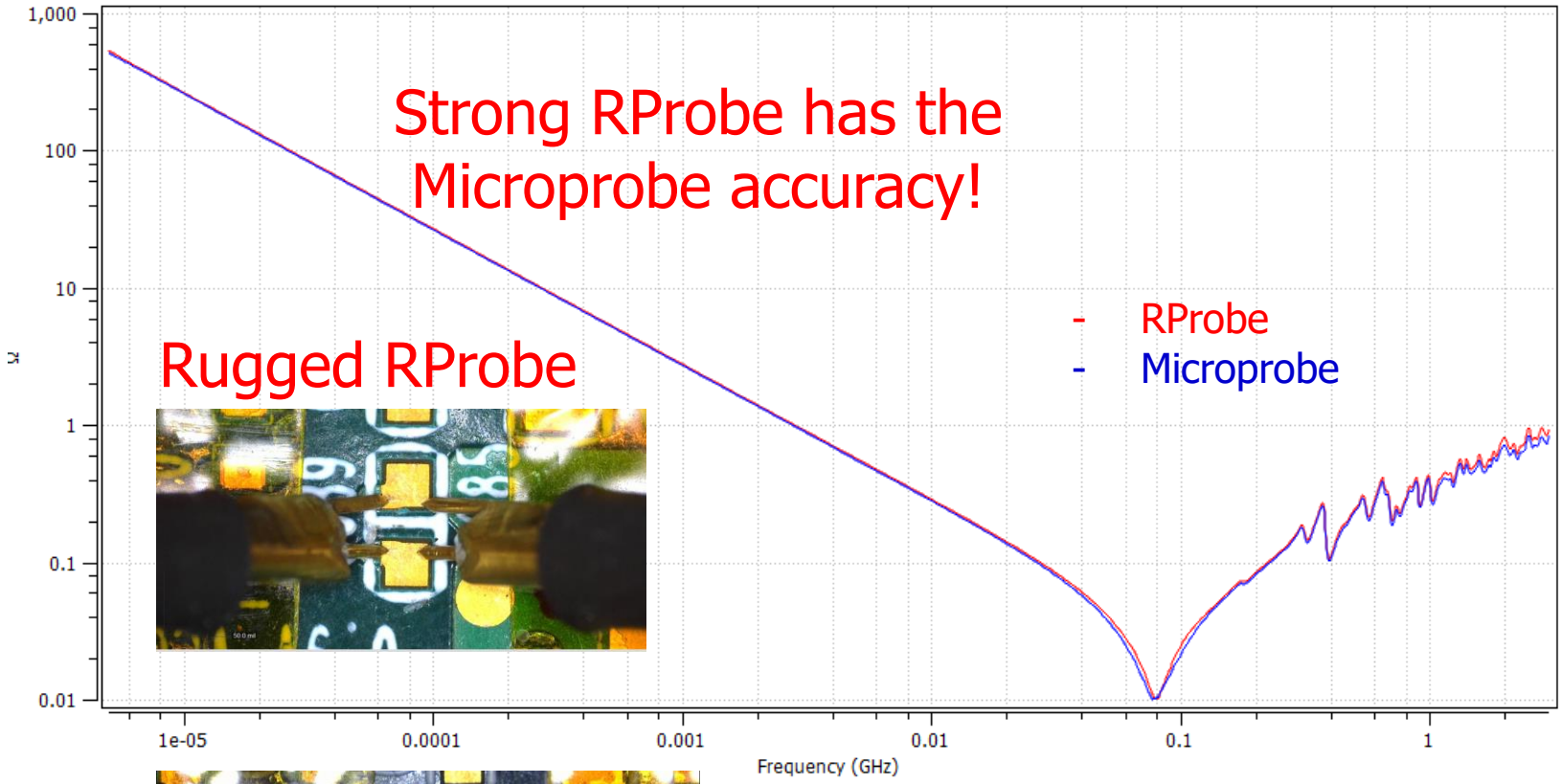


- **Measure impedance of 0.9 V core voltage**
- **Probe on C639 and C644**

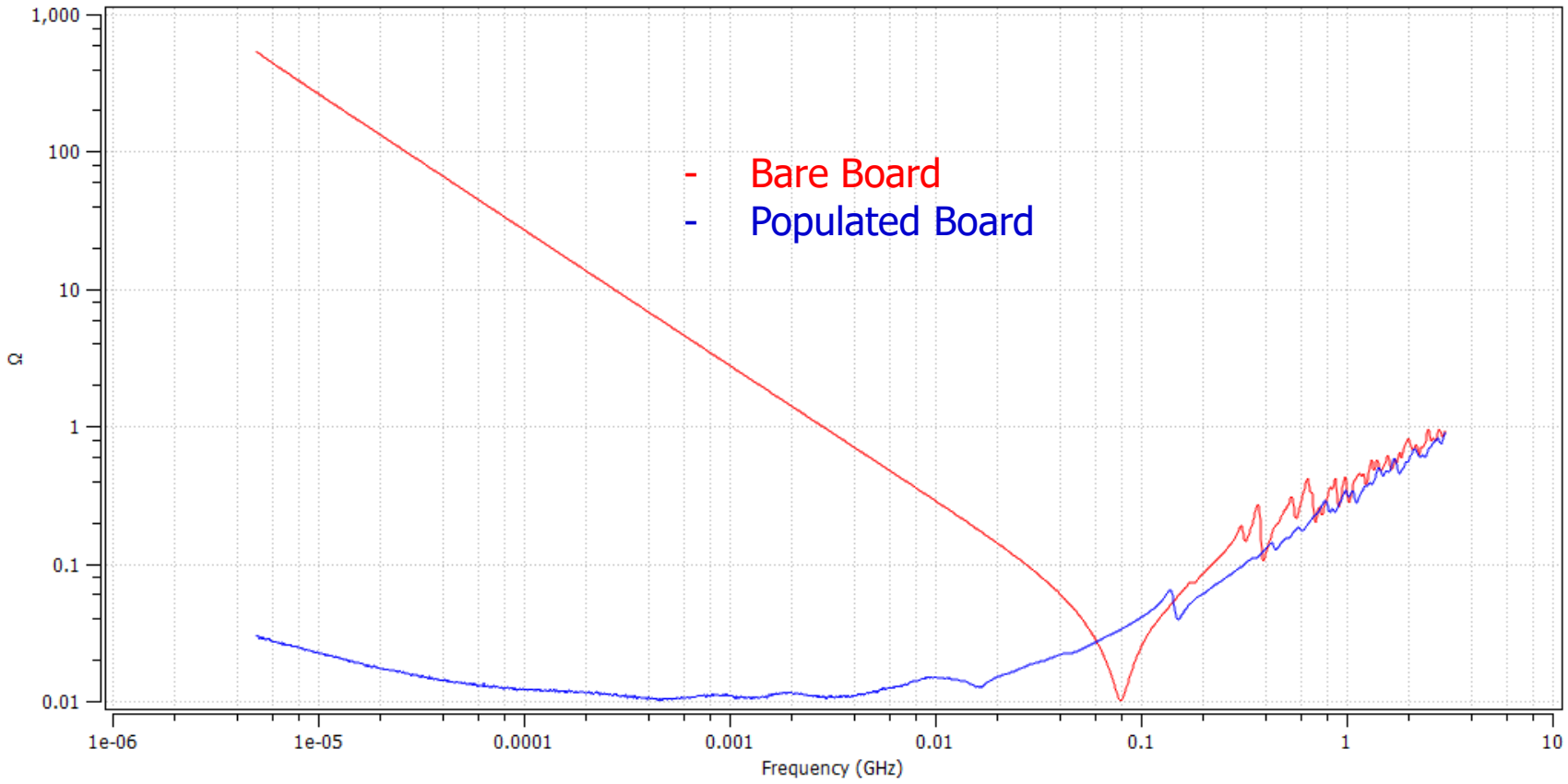
PI Probing Demo



R-Probe & Microprobe Comparison



Impedance Between Bare and Populated Boards



References

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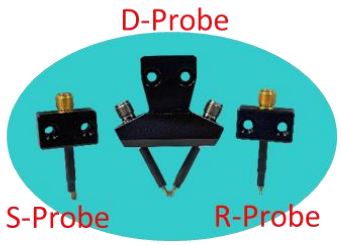
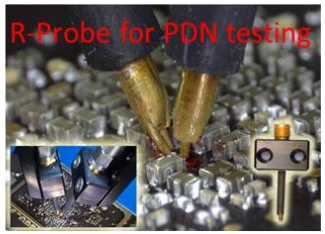
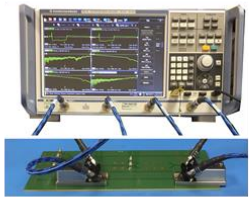
- Istvan Novak, “Measuring Milliohms and Pico Henrys in Power Distribution Networks” (http://electrical-integrity.com/Paper_download_files/DC00_MeasuringMiliohms_slides.pdf)
- Istvan Novak, “PDN Measurements: Reducing Cable-Braid Loop Error” (http://www.electrical-integrity.com/Quietpower_files/Quietpower-3.pdf)

PacketMicro Product Offering






Delta-L 4.0 Solution

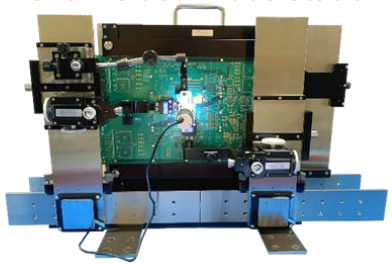

TCS70
Cal Substrate

Precision Positioners


TP250


TP150

VPS10 2-Sided Probe Station



Flex Positioners

F80

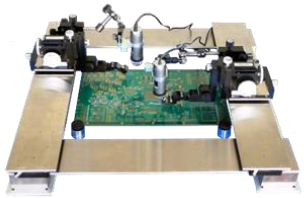

FP40

FP160MS

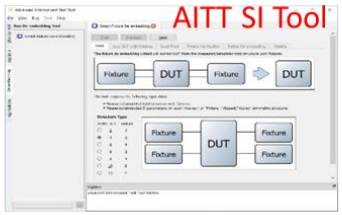

FP160

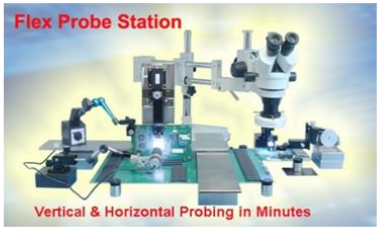
USB Type-C Fixtures

HPS24 Probe Station



AITT SI Tool





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