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Dynamic height adjustment using Vector Network Analyzer based contact sensing using FormFactor WinCal XE 4.9™ and Velox 3.4 - THMA6

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Thanks also to Pranav Shrivastava

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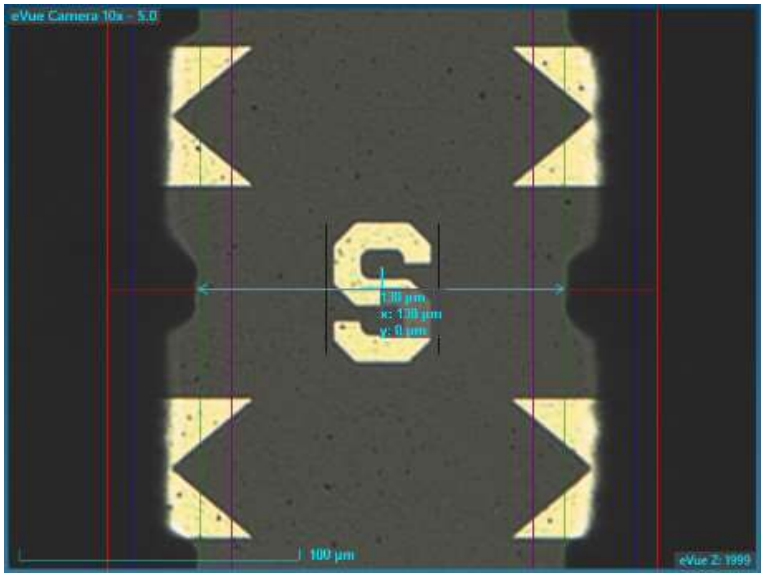
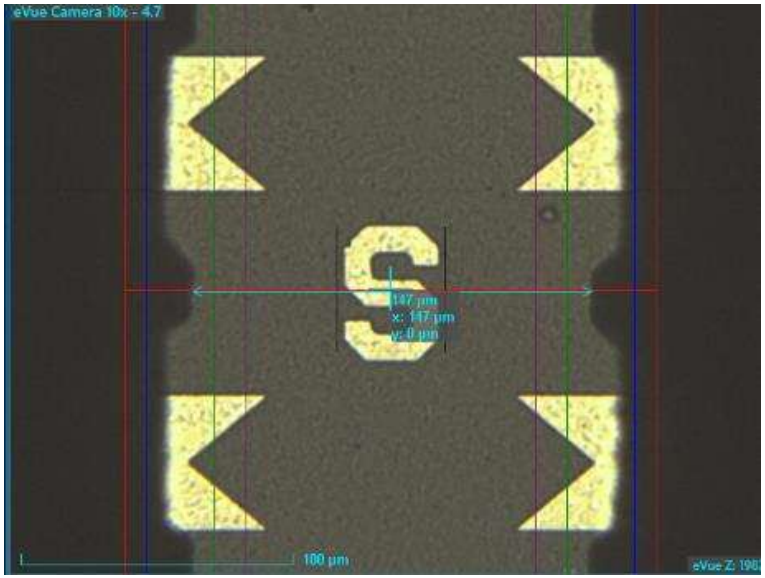
The Coolest Ideas Under the Sun
SAN DIEGO 2023

The problem – Contaminants can affect planarity

- In WinCal XE the probe geometry is set at a single reference location in terms of XYZ
- During calibration, the system steps using iss co-ordinates assuming the planarity is perfect
- Contaminants under the substrate can cause planarity to change, and results in more or less overtravel affecting probe final position at the standards away from the reference





- Augmented alignment Green lines set to be 130 um – probe geometry set to this spacing at alignment Mark A
- Stage move to location H – Less skate and probes now spaced to 140 um

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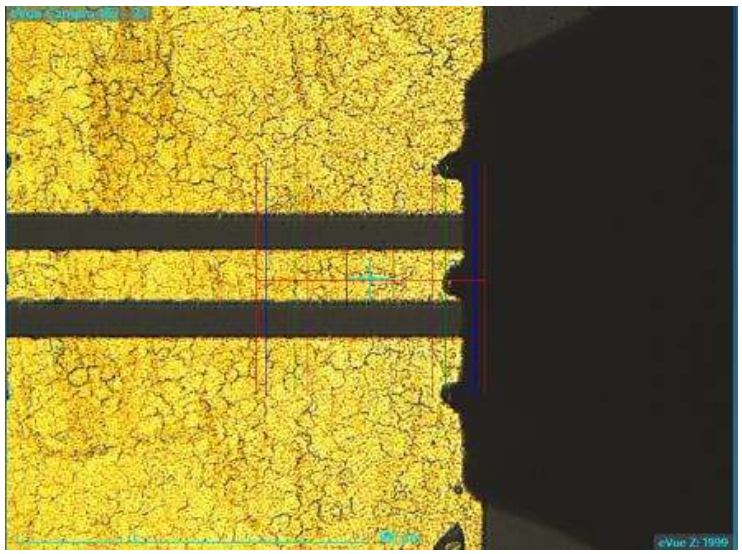
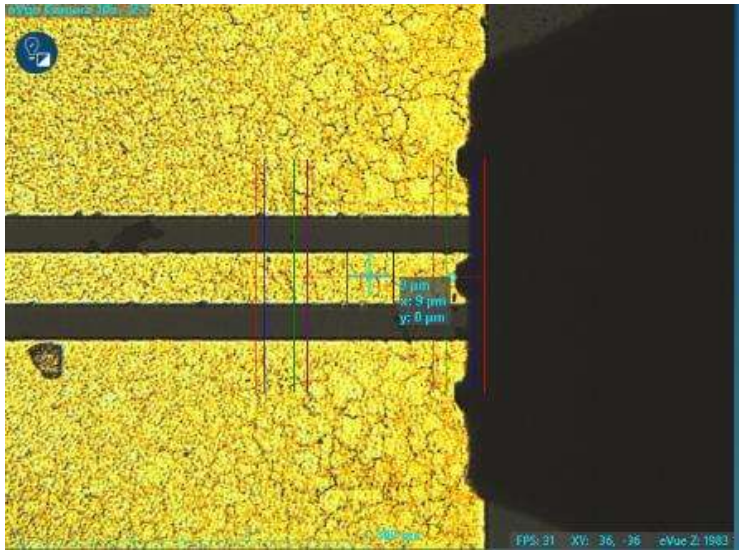
The problem – planarity of iss and positioner runout

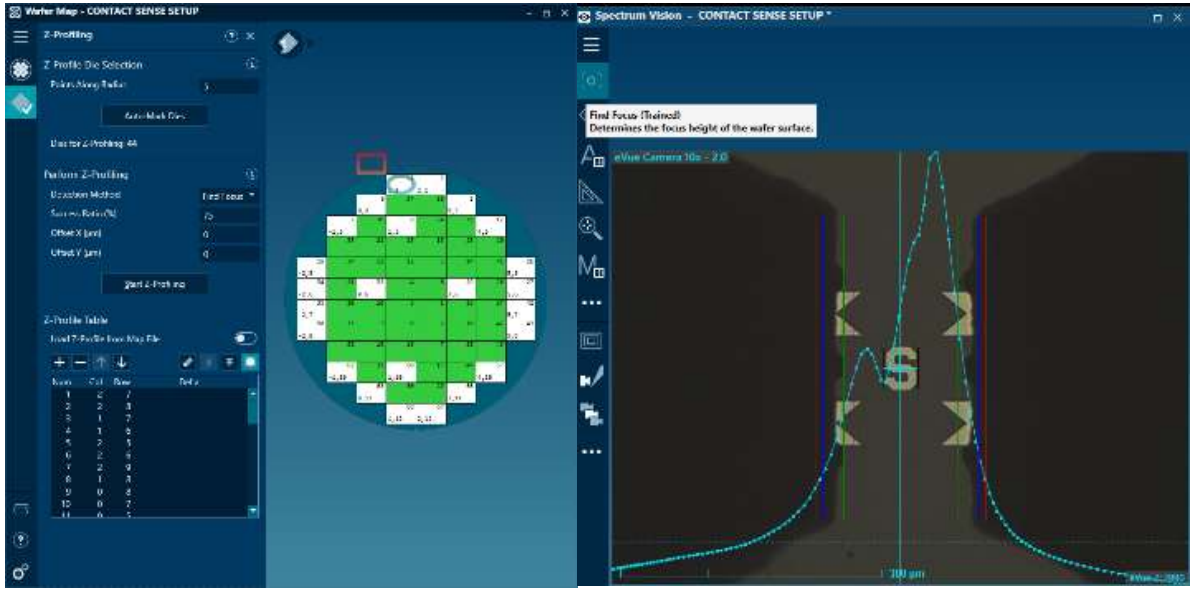




- Final placement error seen here is 10 um – A combination of small positioner planarity error and iss planarity error and small X offset
- Note height of scope Z reference was changed by 16 um to get best focus

Alternative solutions to contact sensing?

- Velox supports Z profiles to the main wafer chuck but doesn't do this at the auxiliary chucks
- Lookup table for Z that could be applied at calibration time ,breaking into the automatic calibration routine but needs calculated initially
- Dynamic height adjustment could be done using the FindFocus algorithm and height adjusted this way but there is potential for failure with contaminants on iss itself.
- Find focus wouldn't detect probe changes or tiny positioner runout.



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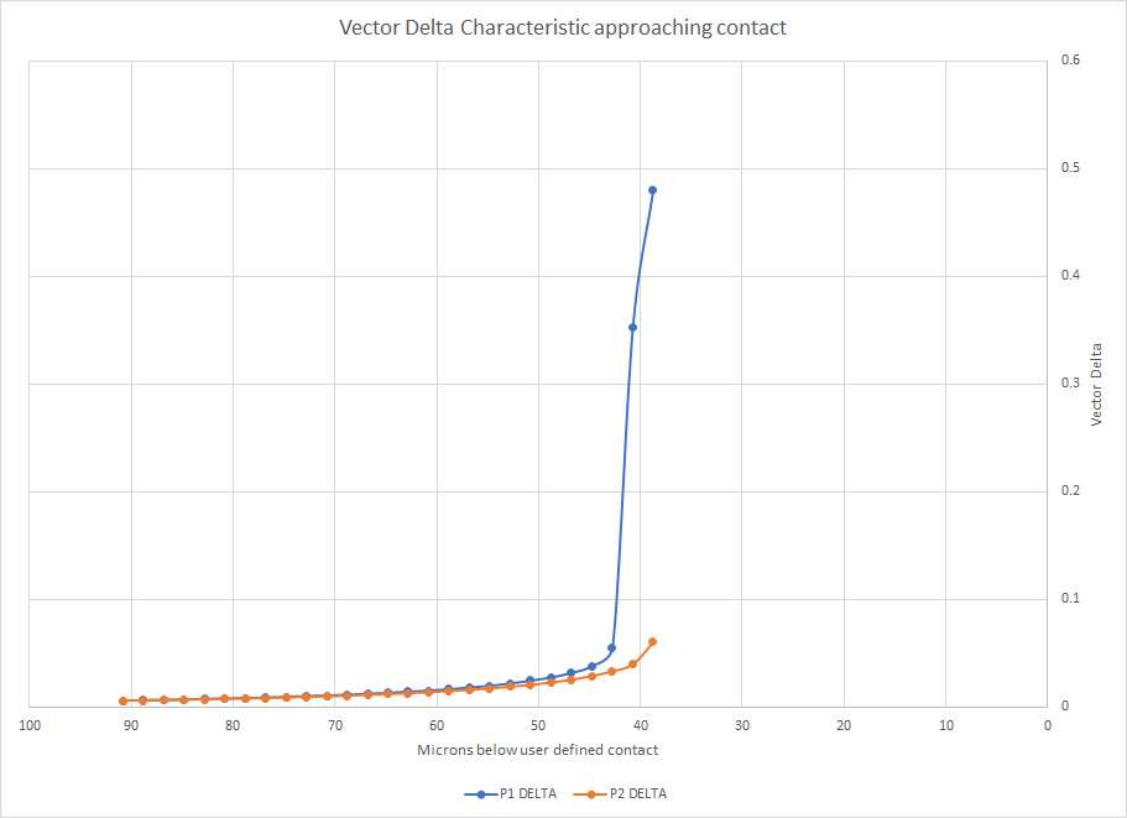
Contact sensing

- Very repeatable and uses the measurement system itself
- Is dynamic and reflects the height of the probe at the actual time of calibration (as probes cool the height can change)
- Can be very quick when communicating directly with the vna via tcp (as we did)
- Drawback of direct approach is a driver is needed per instrument type additional to Wincal's own
- Can be compatible with Autonomous RF setups
- Is simple – probes need setup for the iss anyway….
- Delta Magnitude = ((Real_current – Real_Open)^2+(Imag_current – Imag_Open)^2)^0.5

Contact detection Threshold



- Steps are in 2 um here
- It takes off typically at 0.05 delta
- Here the stopping point is 0.05 – probes barely kissing pad

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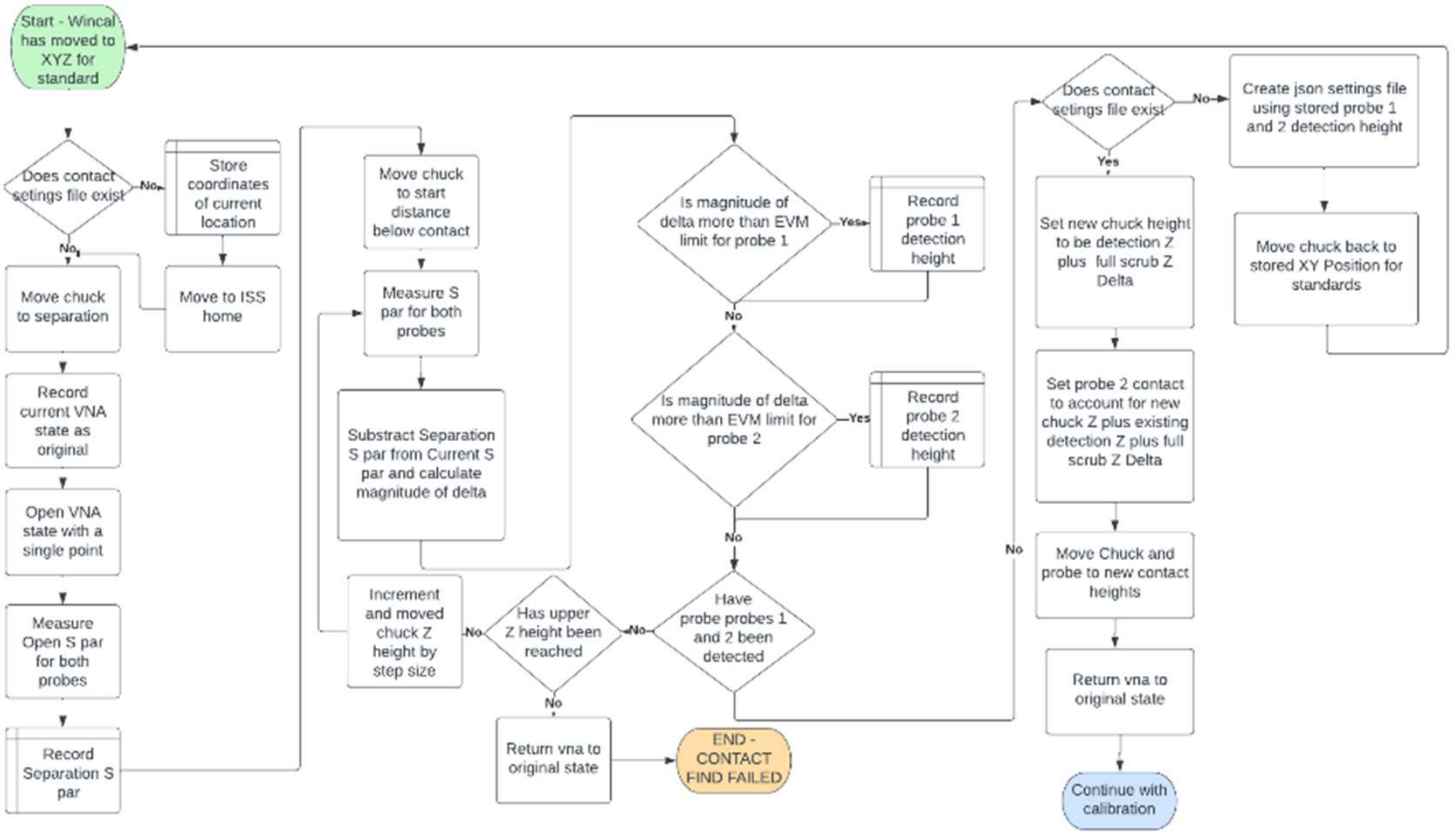
How does it work in general inside Python script?



This is a flowchart of the general contact sense python script logic

This script is run during the calibration process

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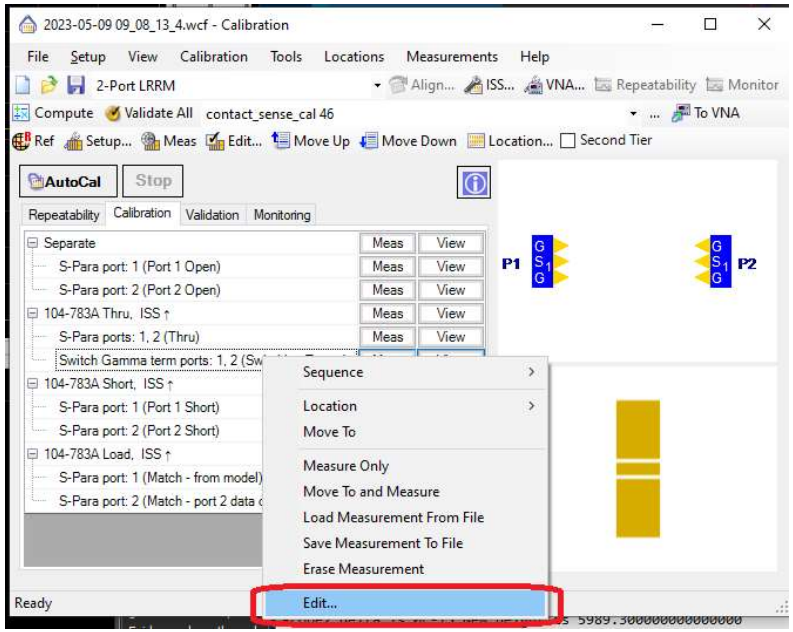
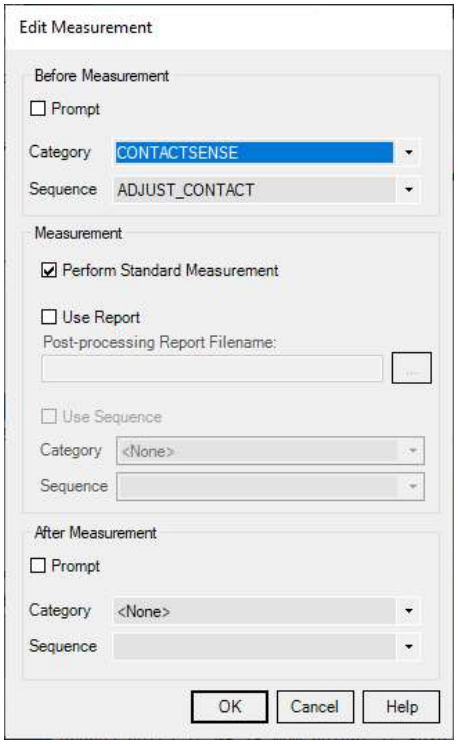
How to make python scripts work within Wincal





- Python direct approach could use Wincal as a slave but preference is to sense in the normal cal approach
- Wincal can invoke a "sequence" during the calibration sequence
- Calibration sequence can in turn invoke a python script using DoScript command
- Each measurement can have a sequence run before and after and even use a specified report for process work

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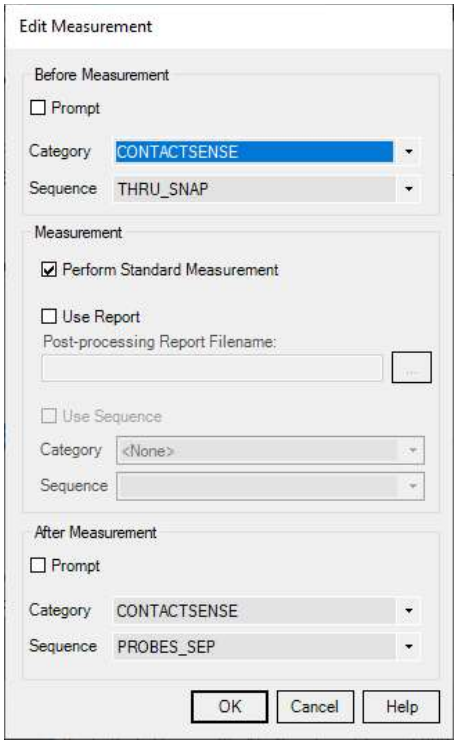
A few tricks regarding implementation



- By default Wincal will do all the movement activities prior to reaching the standard including movement to contact
- However it will not bring positioners to contact if they were previously at separation
- Multiple touchdowns avoided to reduce pad wear
- For this reason the ProbeSeperation sequence is done after the standard measurements
- In this case this is the second standard in the pair of reflect standards

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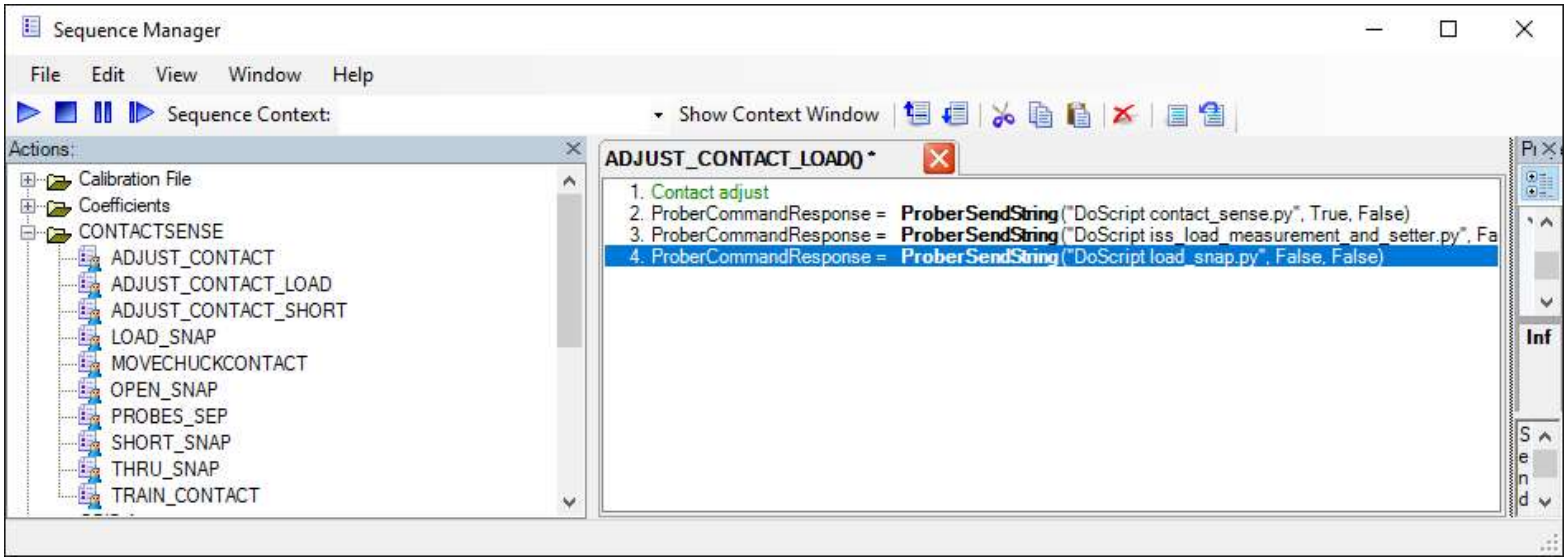
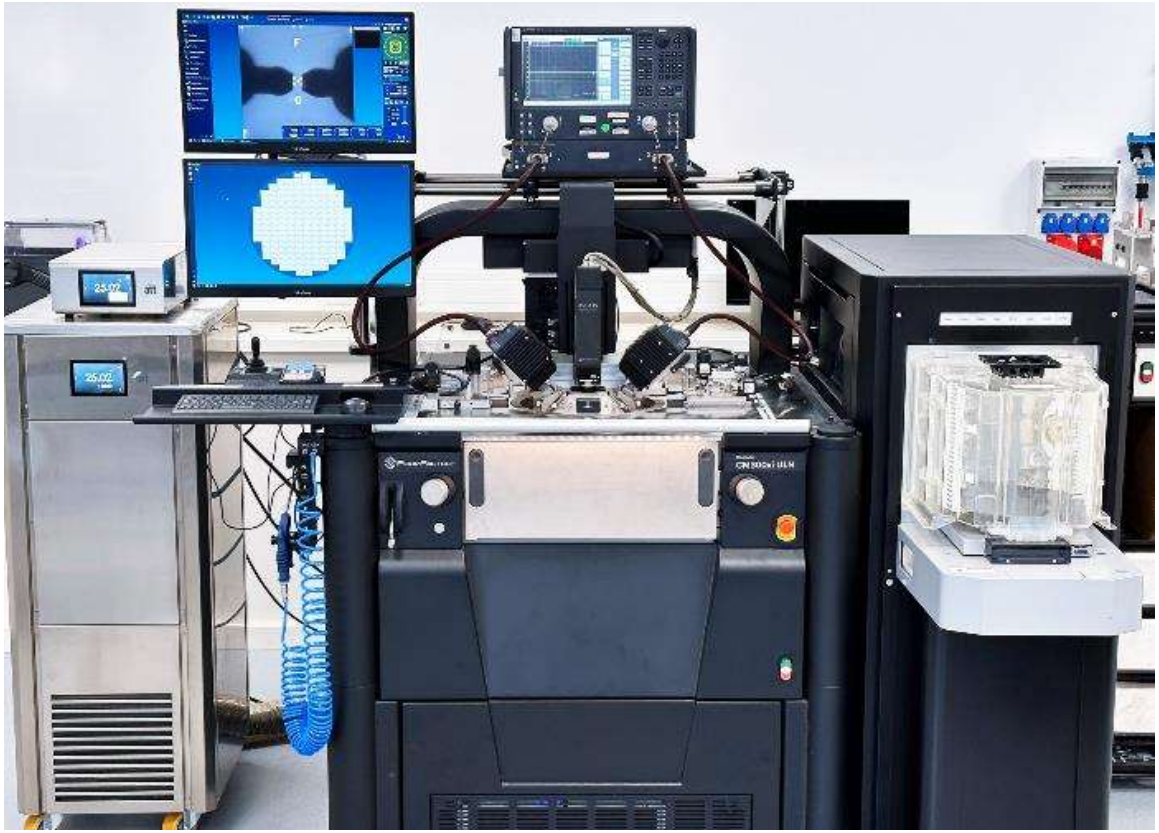
Sequence manager being used to call Python scripts



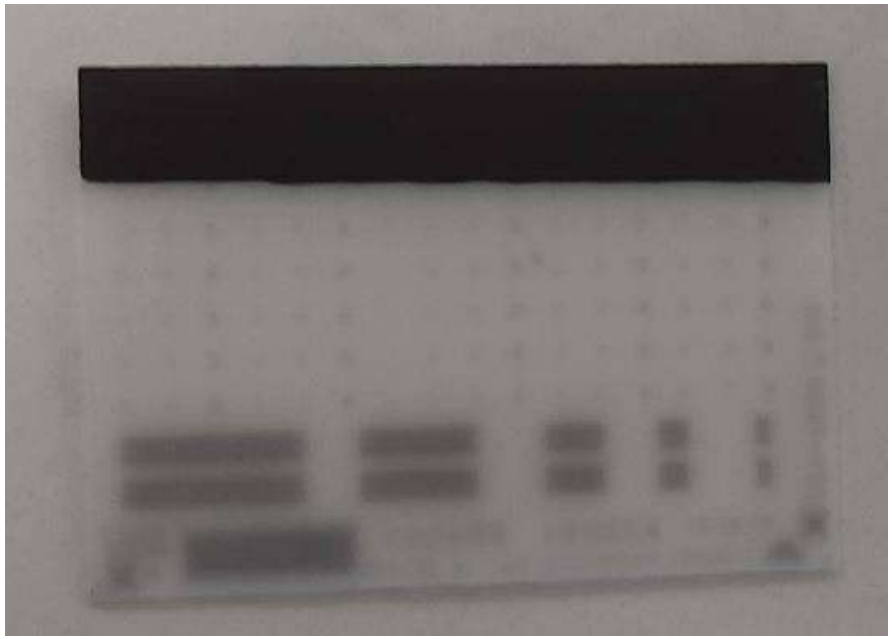
- The set of sequences is seen in the list

System used for evaluation



- WinCalXE™ 4.9
- Velox™ 3.4
- CM300xi ULN
- Keysight N5291A VNA
- I110-AM-GSG-100
- 104-783 ISS (deliberately contaminated or rear)
- RPP504 Motorised positioners
- Remote Author was in UK machine in Germany

Iss deliberate contamination

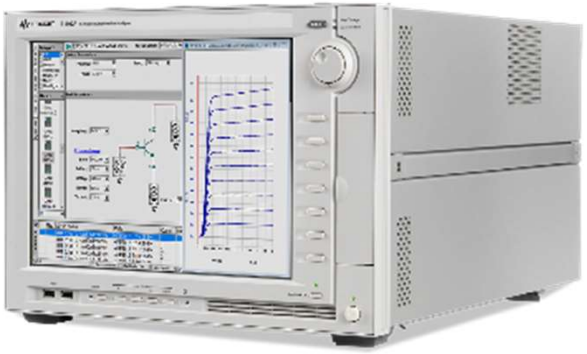


- Permanent Sharpie™ marker layered over a few coats ON ISS rear face
- This created a delta of approximately 18 um from the upper edge of the iss to the lower edge
- We have have added more but this is likely to be in the level of typical “annoyance” levels of contamination which doesn’t necessarily warrant remedial action

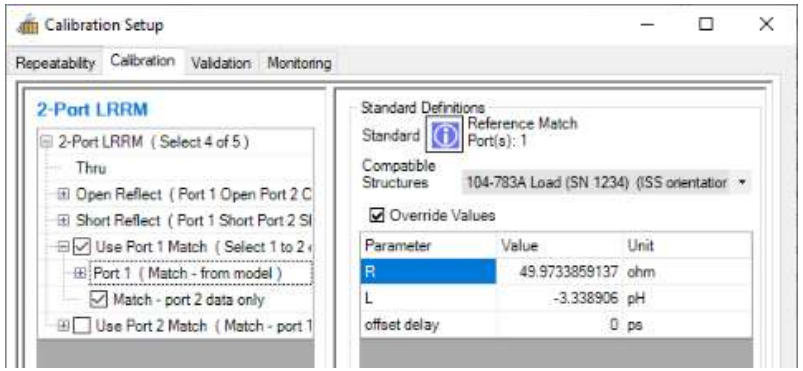
Testing methodology

- Use a script to perform calibrations at 25 locations on 104-783 – upper set of loads are totally untrimmed and so excluded
- Perform calibration set with load compensation and contact correction
- Record error sets for all locations tested and photos of probe contact.
- Measure Open in air and same thru as used for the test
- Carry out calibrations on same iss and setup but only use load compensation and no contact correction
- Compare spread of error sets
- 20 um skate used to maintain standard but also to improve contact sense – with 25 skate the probe doesn't quite touch standard initially

Load resistance measurement and adjustment



- ISS Map was not readily available so we needed to measure the load resistance – we used B1500 via instrument bias tees
- The ability to add sequences to calibration made direct measurement and compensation appealing
- Short was measured at .1 volts and used as offset reference
- Load was measured a 1 volt and resistance of short subtracted
- Corrected load value is automatically applied during calibration process
- WinCalExecuteCommand("CalSetCoefficient, 1, Match - from model, Reference Match, R, {}".format(rload1_corrected))



	1-P1	1-P2	2-P1	2-P2	3-P1	3-P2	4-P1	4-P2	5-P1	5-P2
D	50.16738	49.97174	50.108	49.94734	50.07572	49.92857	50.05479	49.96162	50.07692	49.96095
E	50.06263	50.02269	50.09324	49.99304	50.26224	50.25585	50.04498	49.96696	50.1972	49.96872
F	50.0823	49.92257	50.04715	49.96062	50.02146	49.92824	49.97339	49.99766	50.02857	49.93536
G	50.05876	49.96696	50.00833	49.95592	49.99709	49.92257	50.10094	49.92424	50.13753	49.93255
H	50.08611	49.96229	50.02901	49.893	50.10251	49.92391	50.0209	49.9485	50.07824	49.93803

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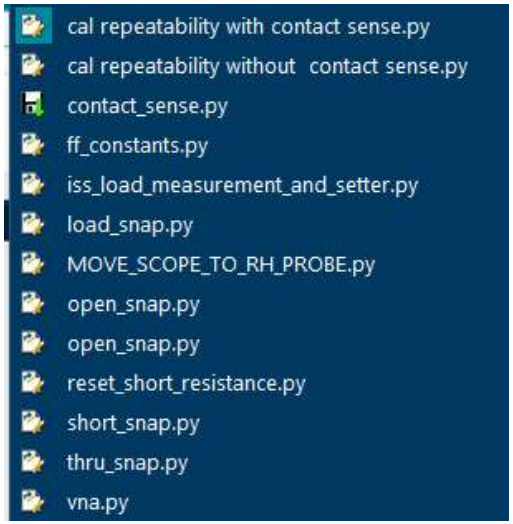
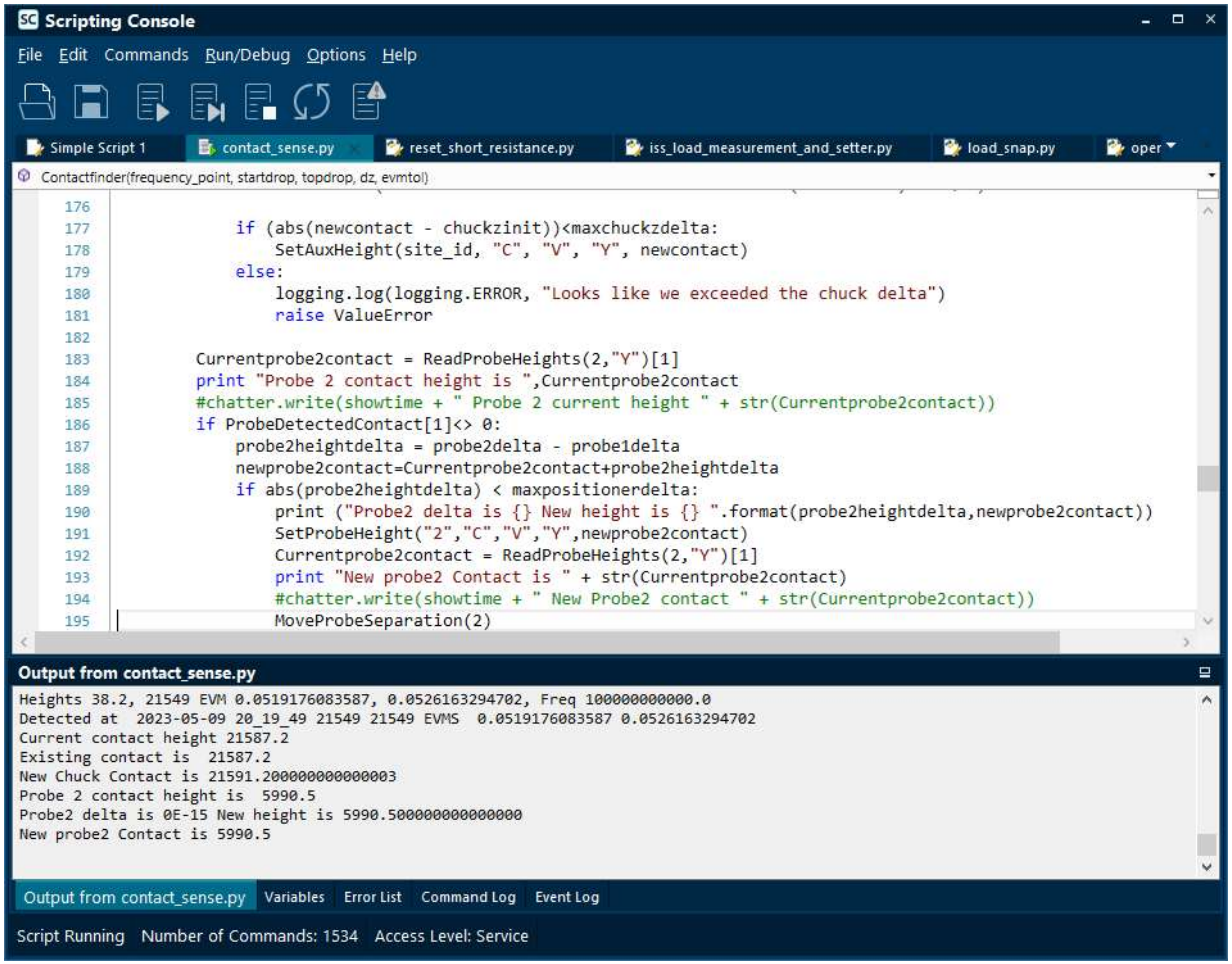
Scripts used



- Main script is contact_sense which either determines the required overdrive per probe set by the user from sensing or corrects the chuck and probe2 contact based on contact sensing of current standard
- VNA is crucial to communicate to the vna directly over socket
- Ff_constants are the primary control variables
- Iss Load measurement and setter measure the short resistance and if on a load measures and compensates the load and sends to WinCal XE
- Cal repeatability scripts are used to run the tests
- Reset_Short_Resistance removes the short data file to force measurement of a short rather than a load

Scripting console



- The python scripts used were run via the scripting console but other approaches could also have been used
- Console is advantageous that the command choose and Intellisense for all the Velox commands makes coding fairly straightforward

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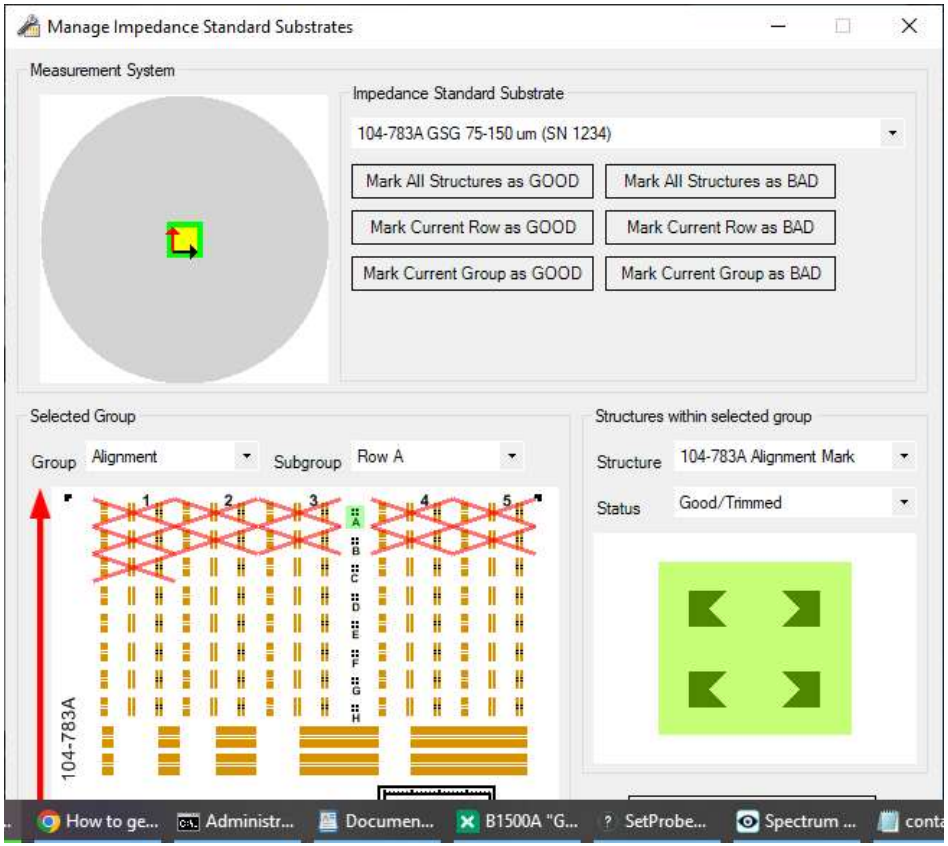
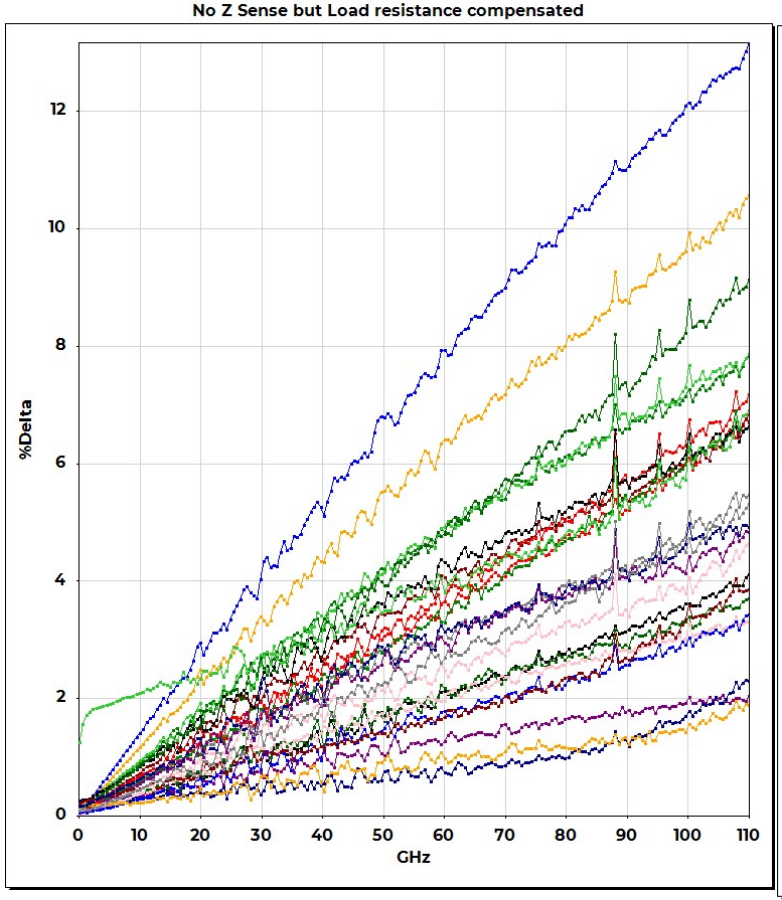
Adjusting the Cal group for measurement

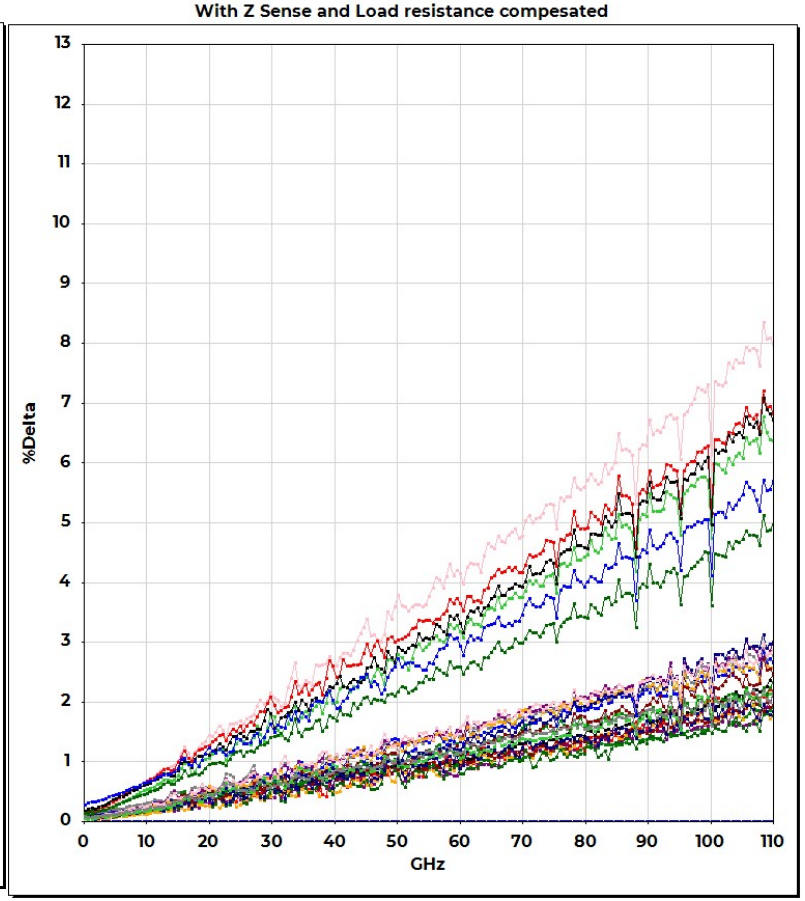


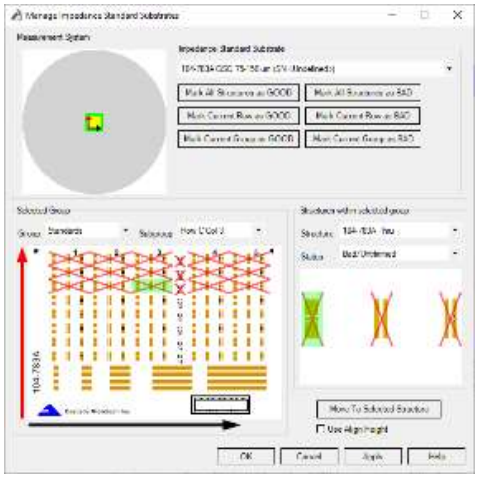
- This is often done manually but there is a command to progress to next cal group

  w.CalUseNextGoodGroupOnIss()

Error set comparison – Left graph without Z compensation







- Data shown compares location 16 thru 40 from topleft
- Much tighter grouping in the 2.5% range

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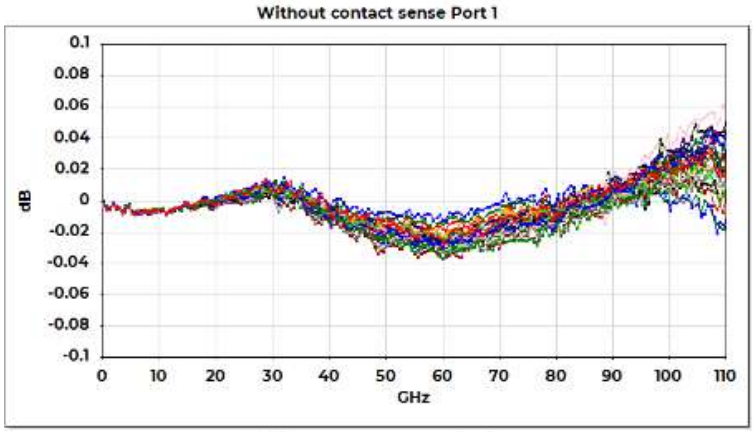
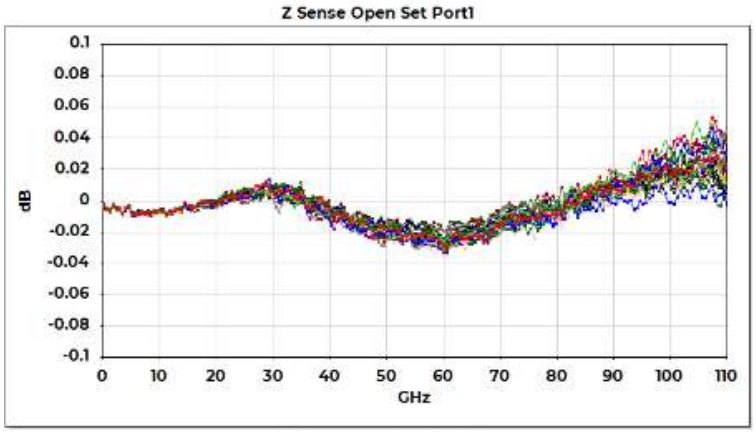
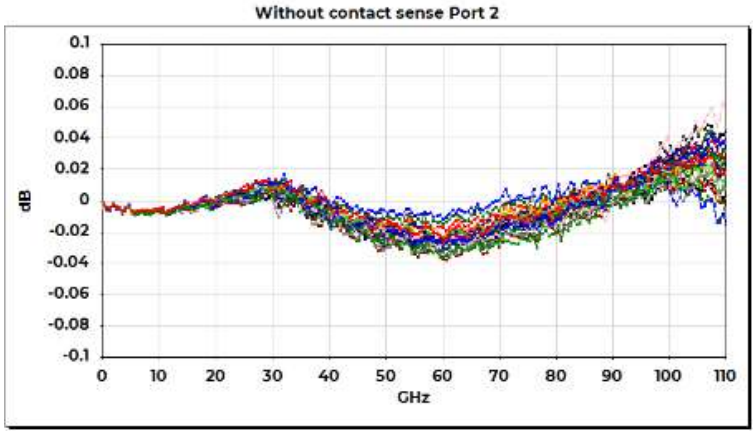
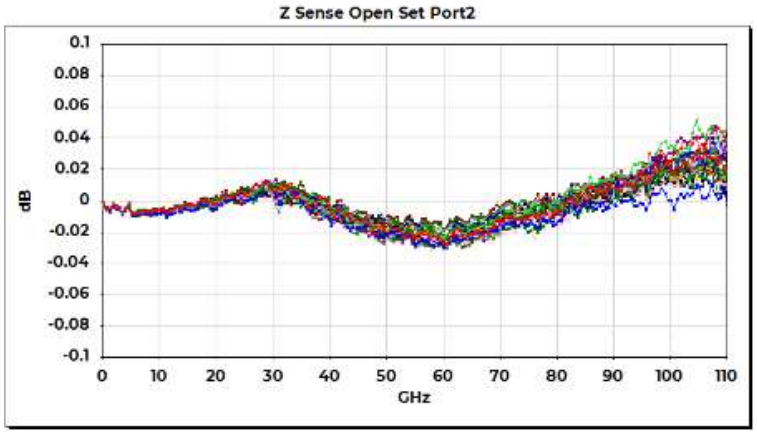
Post calibration Open Magnitude Variation









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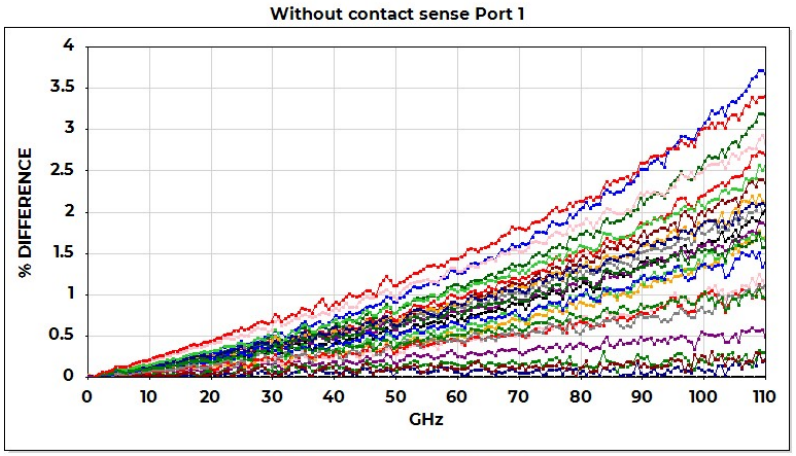
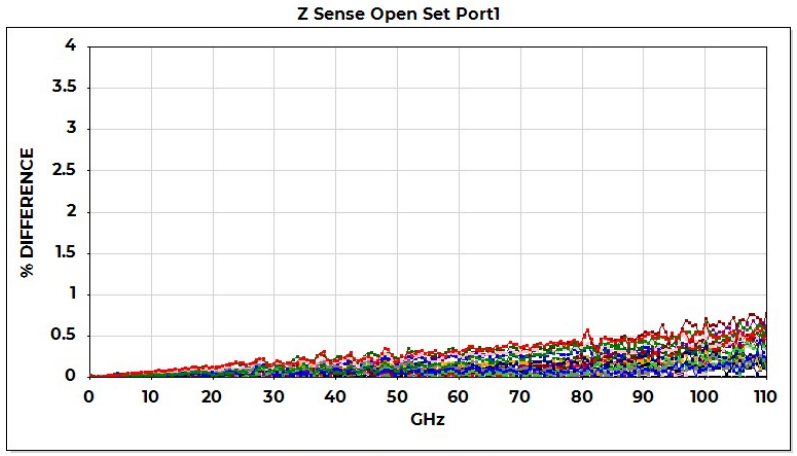
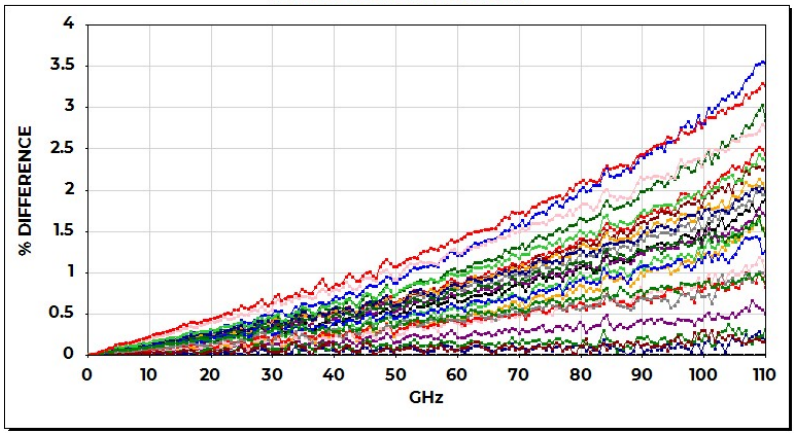
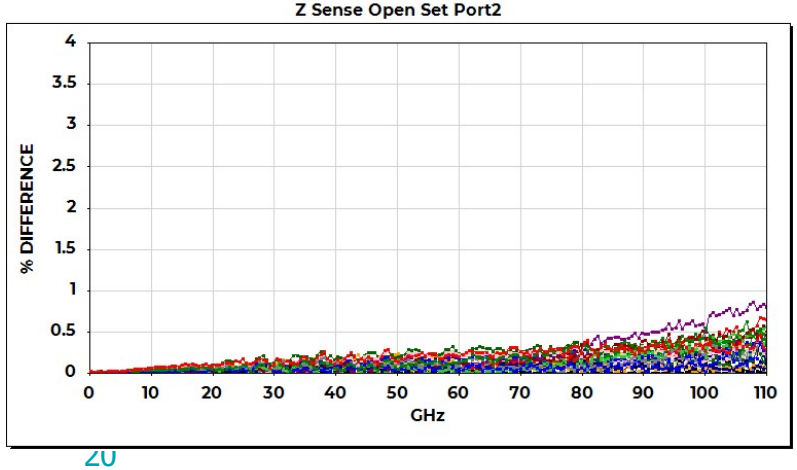
Post calibration Open EVM Delta (x100)



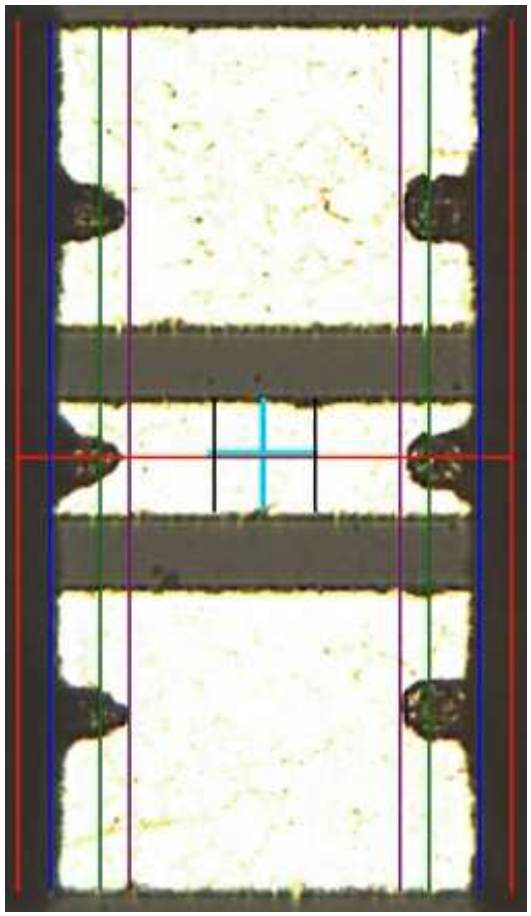




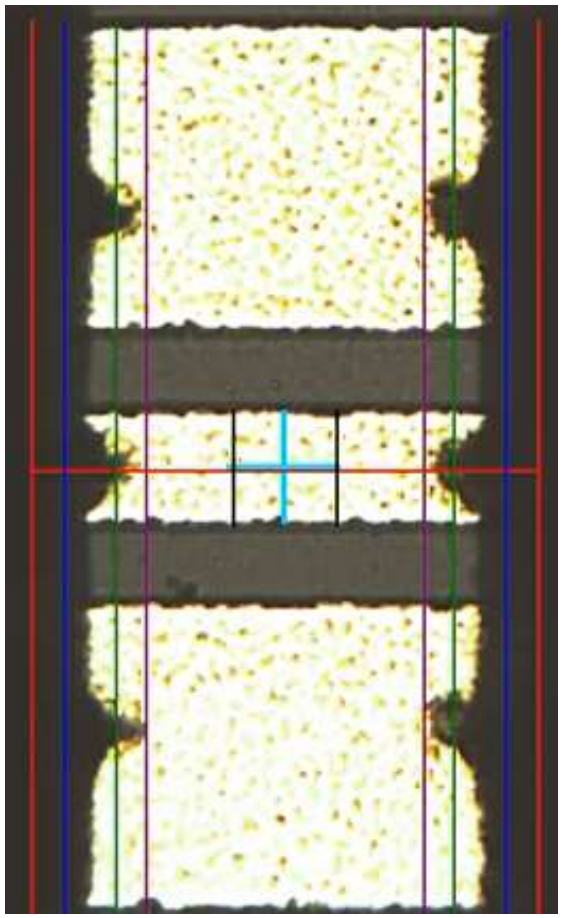


Comparing standard in the same location with and without sensing

WITHOUT SENSE



USING SENSE



- Note relationship of dark leading edge of probe wrt blue lines (170 um apart)
- Tips clearly retracted from the green 130 um lines

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Video of operation – video removed to fit inside 25 MB

Conclusion

- Contact Z adjustment via RF electrical sensing is a readily achievable enhancement to FormFactor probers equipped with WinCal XE 4.9 using existing software with the addition of some scripting
- Using a Z sensing approach, we can improve upon the spread of error sets for a given iss and for a given environmental instrument drift
- Dynamic measurement of load resistance and on the fly compensation can be performed for customers who also have a B1500 parametric instrument.