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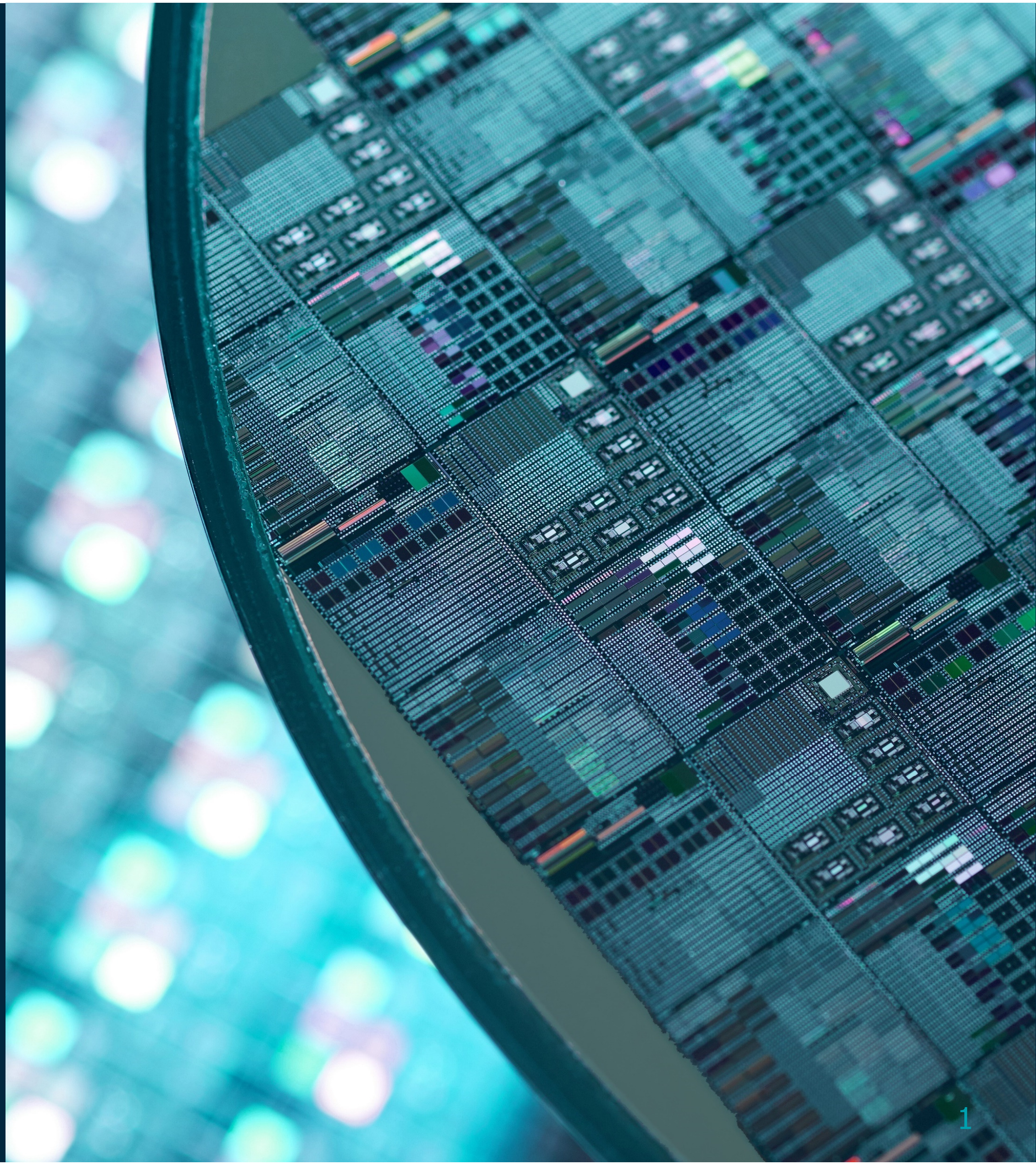
Single Sweep Broadband S-Parameter measurements to mm-wave for Semiconductor Transistor and IC Test to 220 GHz

WEMA36

Gavin Fisher

Explore the Peaks of Microwave Engineering
DENVER2022

IMS
Connecting Minds. Exchanging Ideas.



Thanks to Joint Collaboration

DMPI

KEYSIGHT TECHNOLOGIES

VDI
Virginia Diodes, Inc.

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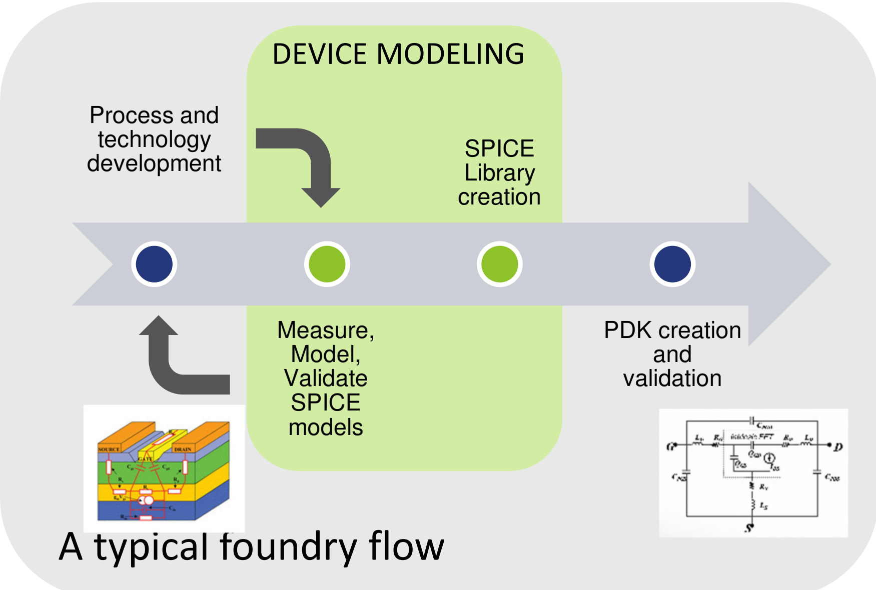
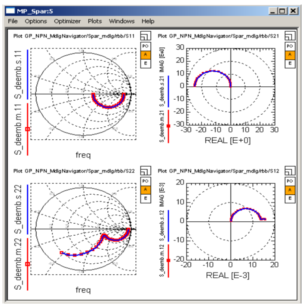
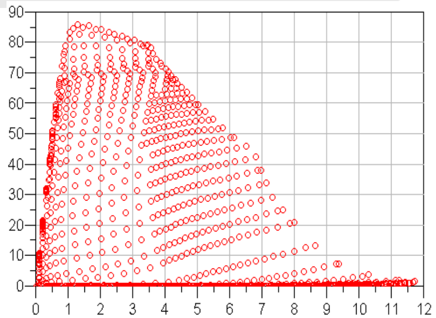
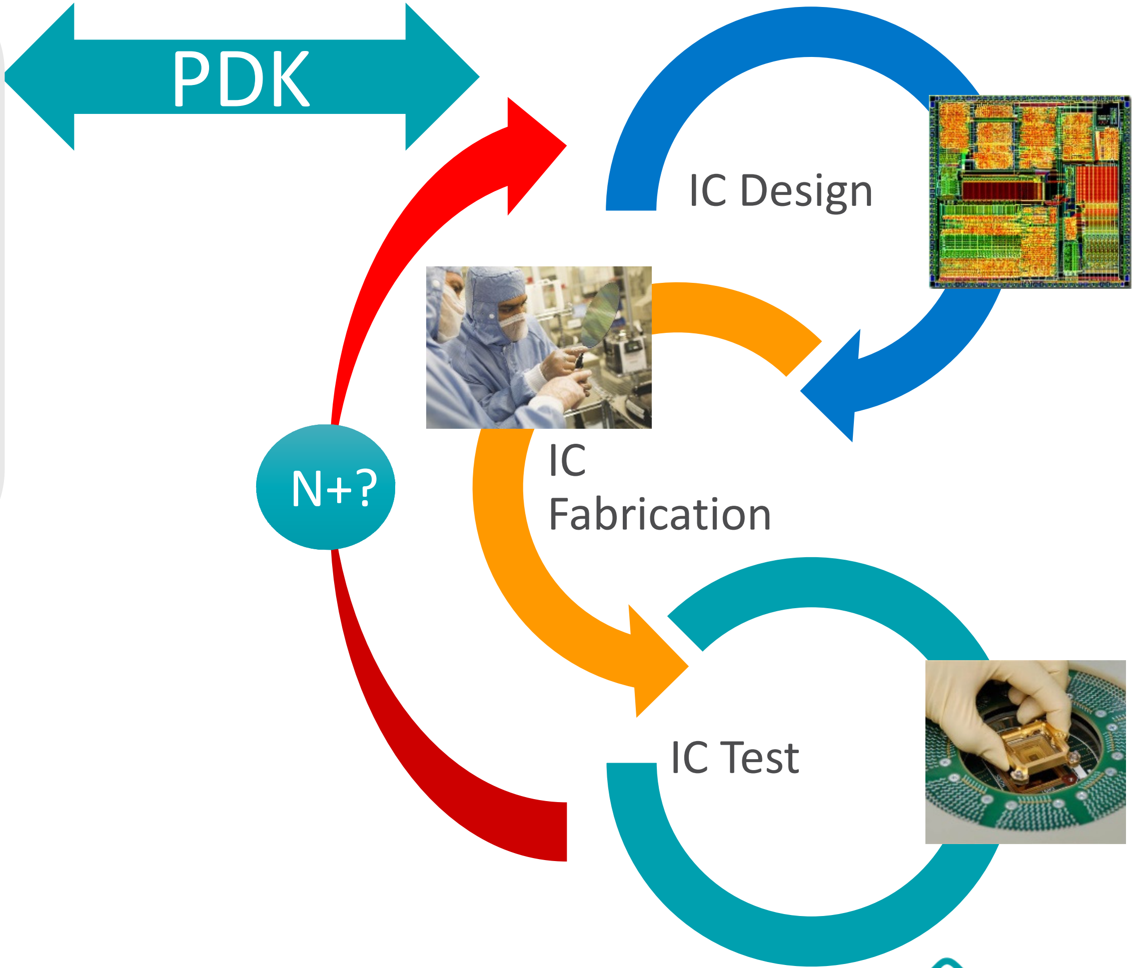
Why is Device Modeling Critical (& Process Design Kits)









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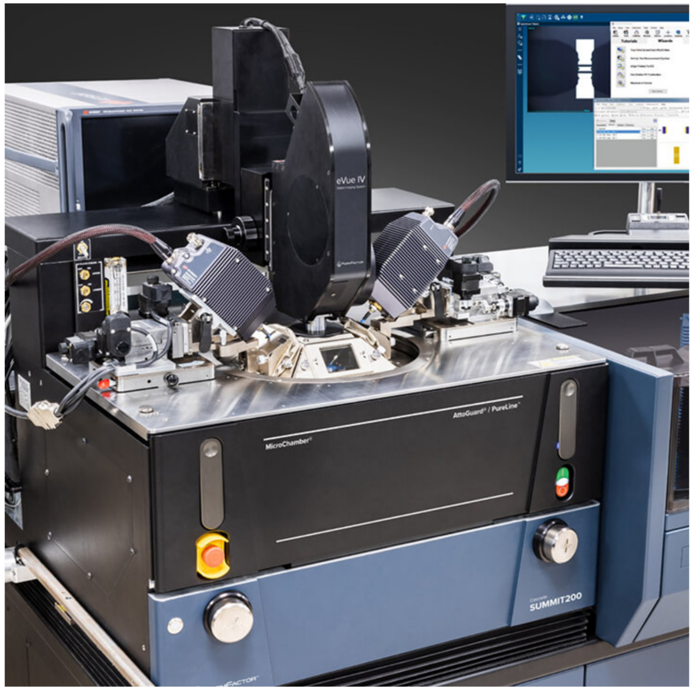
Challenges of Broadband Measurements (other than calibration)



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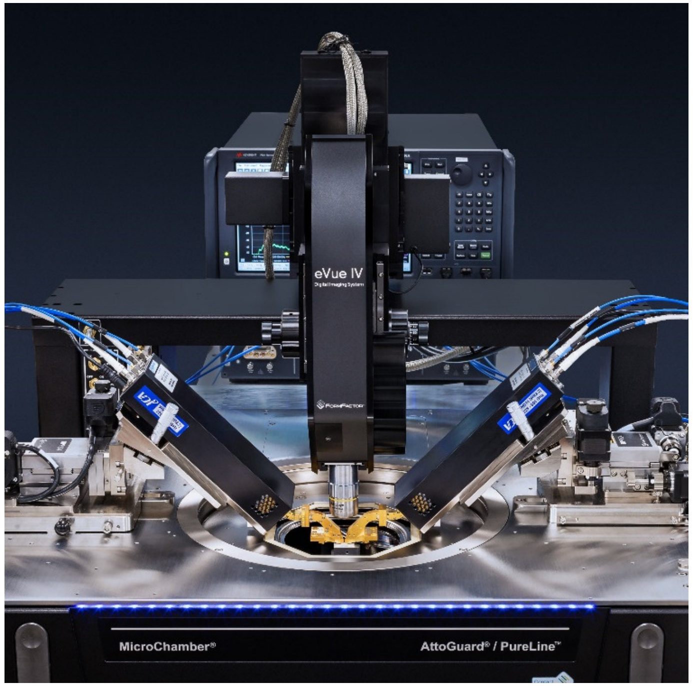
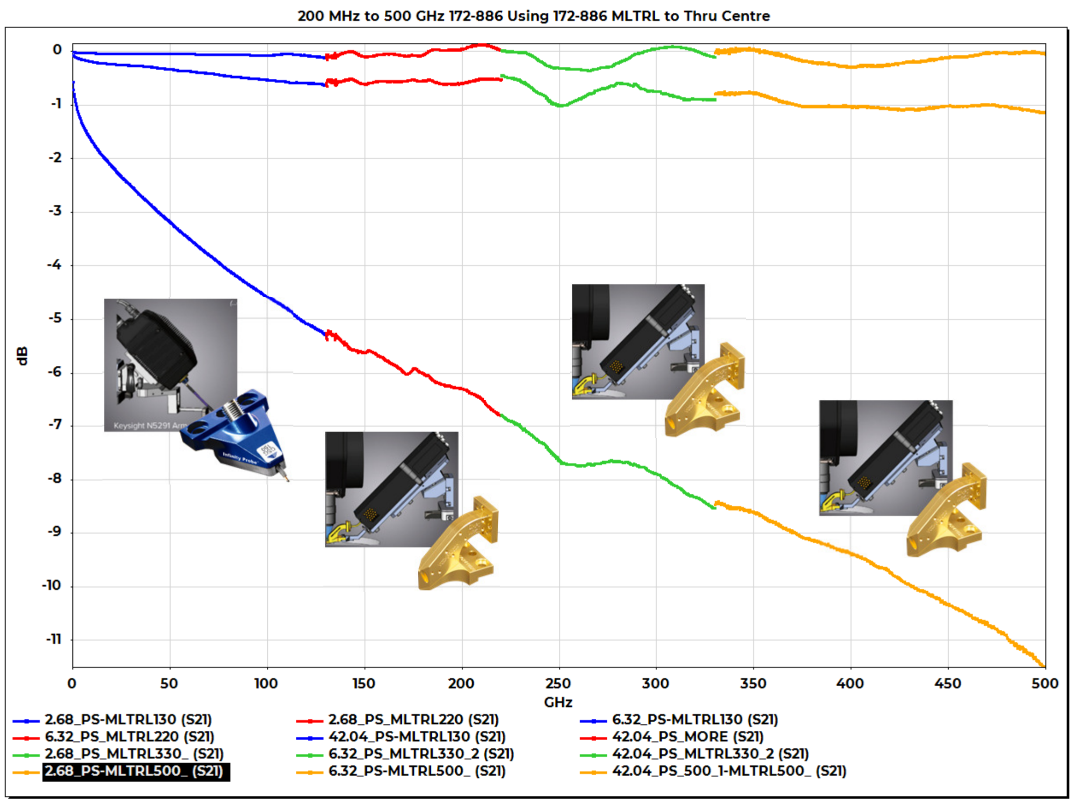


+...

Challenges of Broadband Measurements to 220GHz

- Broadband solutions typically require
    - Multiple probes
    - Multiple extenders
    - Multiple calibrations
    - Multiple measurements
- Then the data needs stitching together
    - Potential Discontinuities
- Whole process is time consuming, manual and intensive



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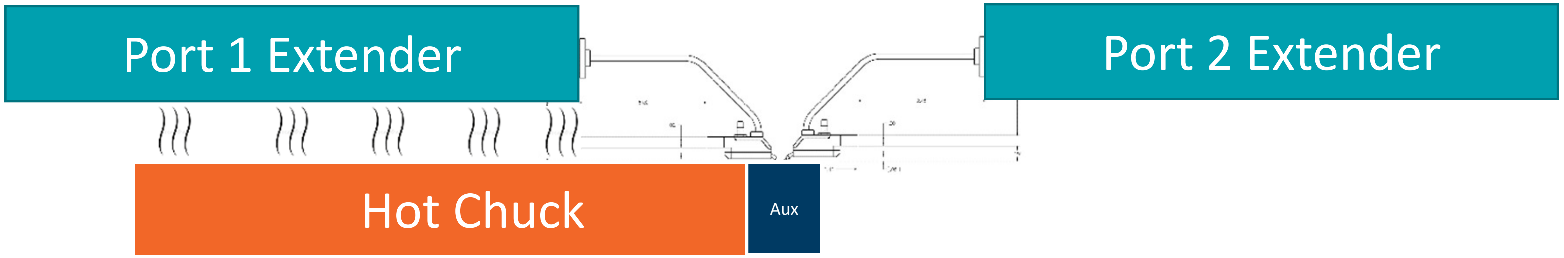
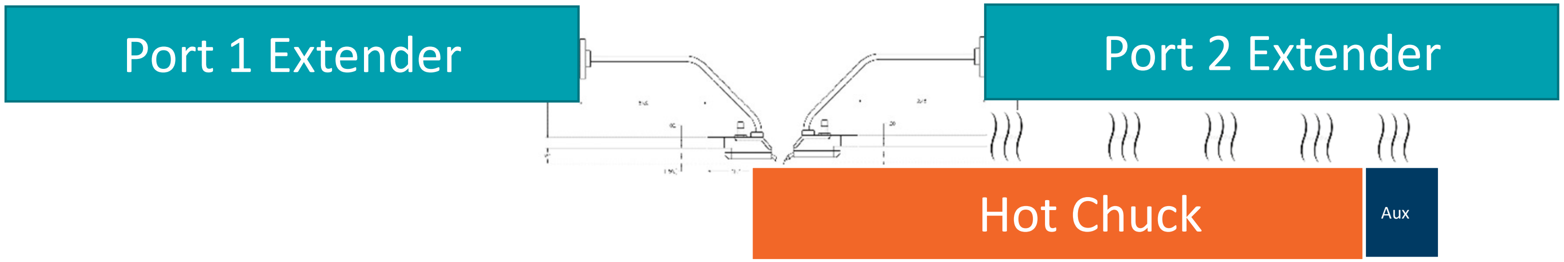
Challenges of Calibration Drift

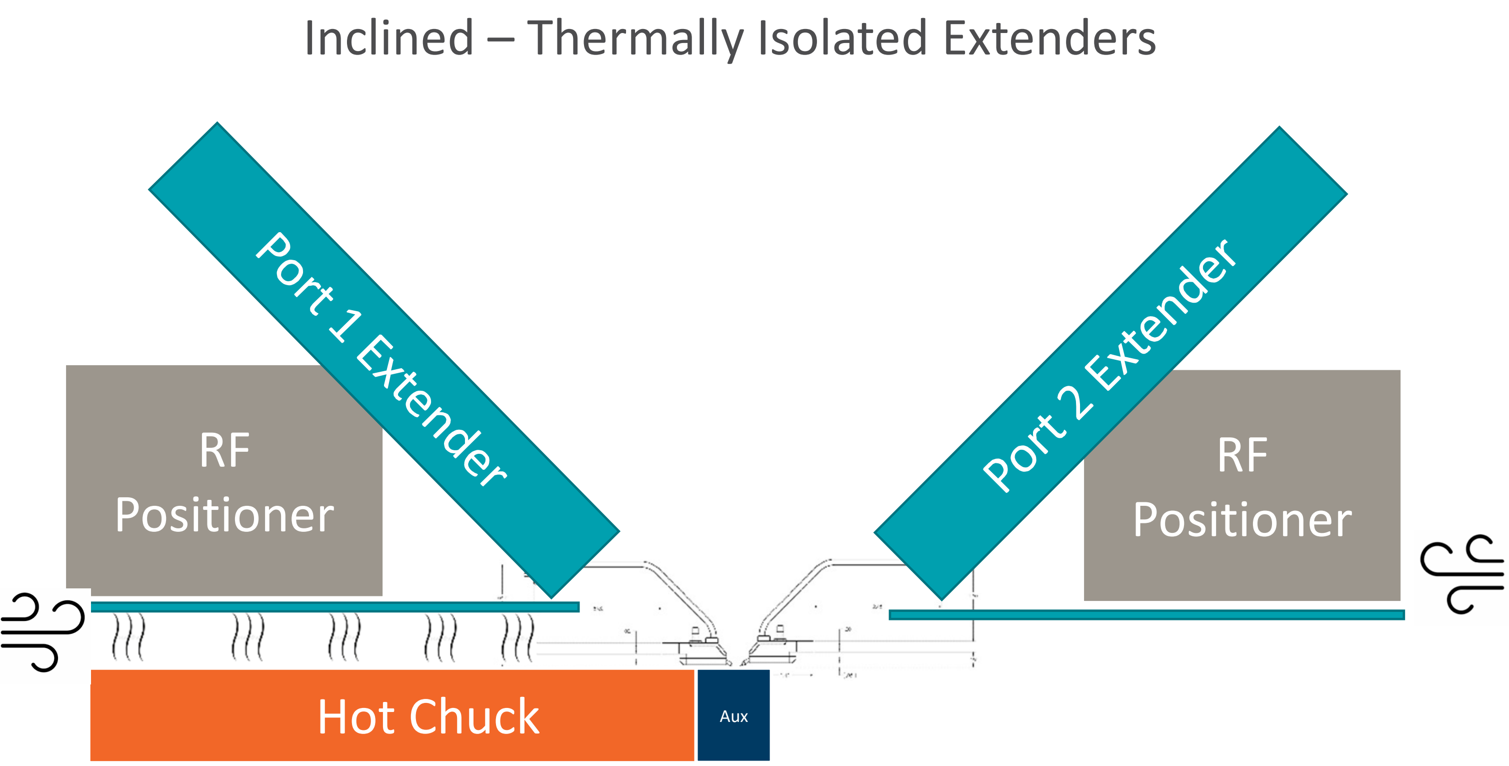
Calibrating on Aux Chuck or measuring DUT on Right side



Measuring DUT on left side

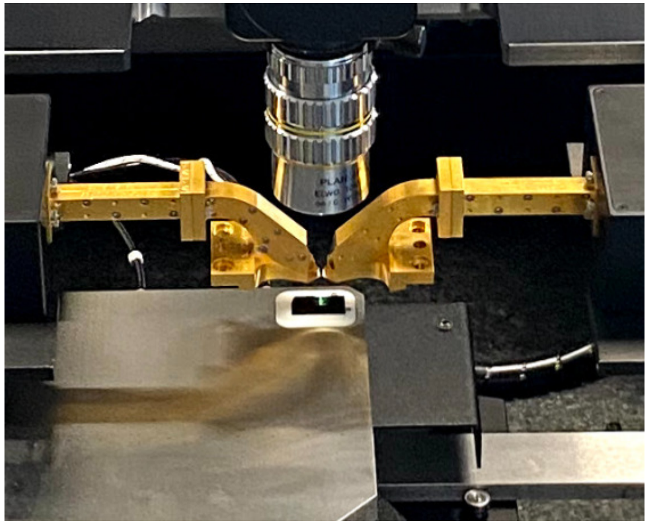


Thermally Isolated Extenders

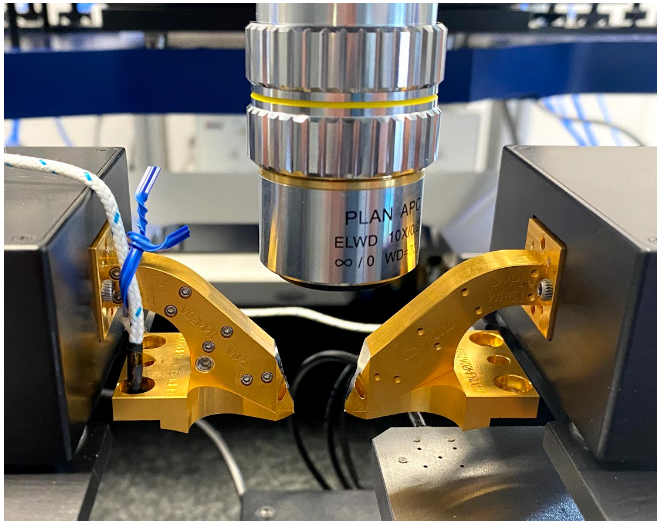


- Having the extenders inclined offers naturally improved thermal isolation
- Air jets improve cooling of platen surface
- Result is extenders stay at ambient temperature and not affected by thermal chuck
- This greatly improves drift stability regardless of chuck location

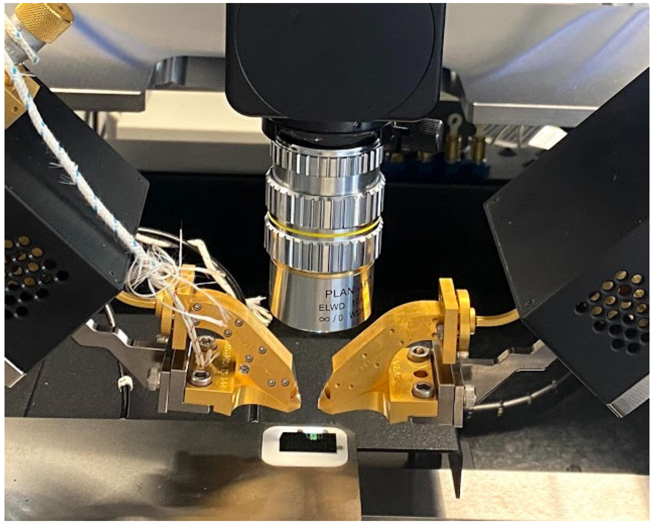
Comparison Between Extender/Probe Integration



Horizontal Extender – 50mm VDI WG - Probe



Horizontal Extender – Direct Connect - Probe



Inclined Extender – 45deg WG - Probe

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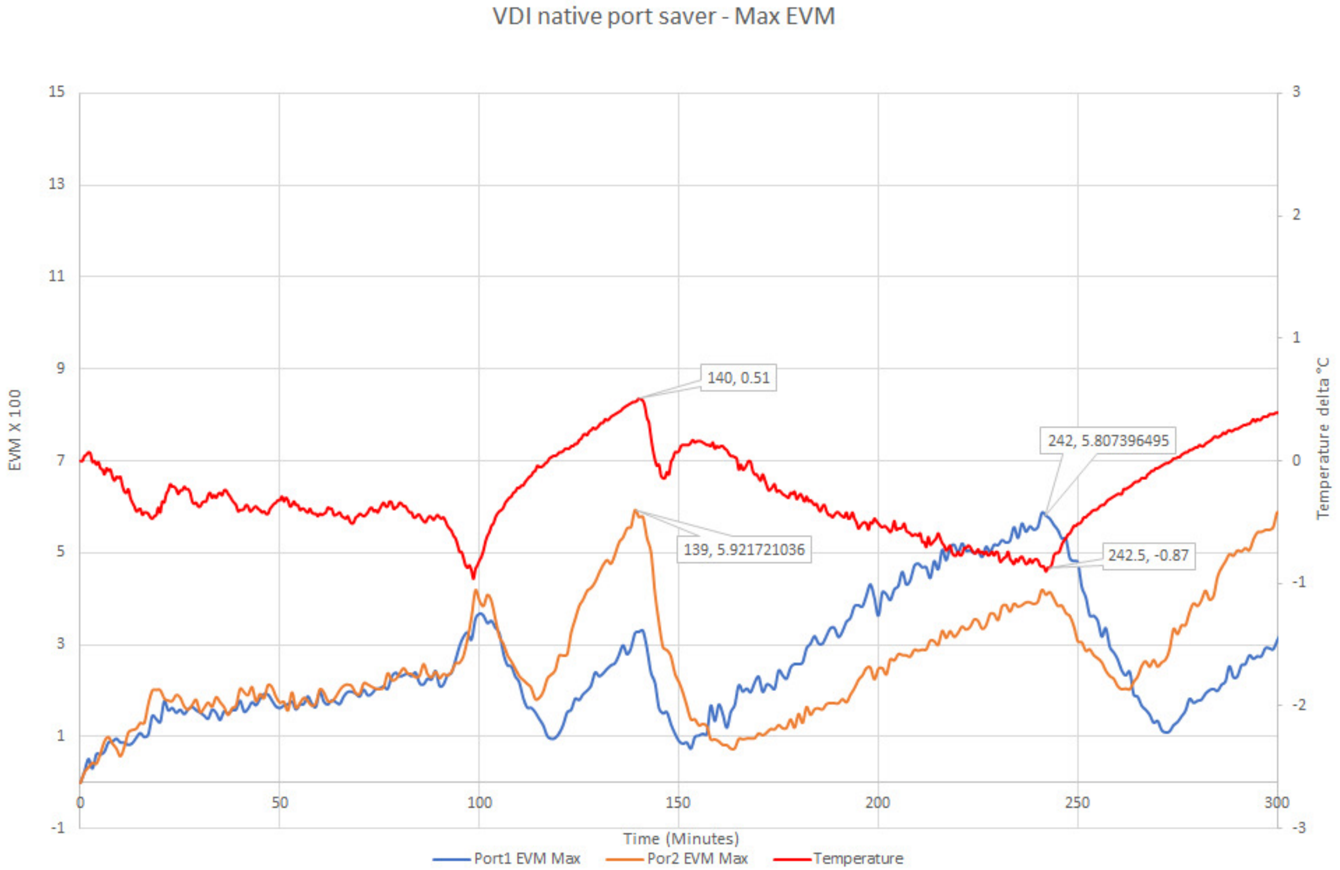
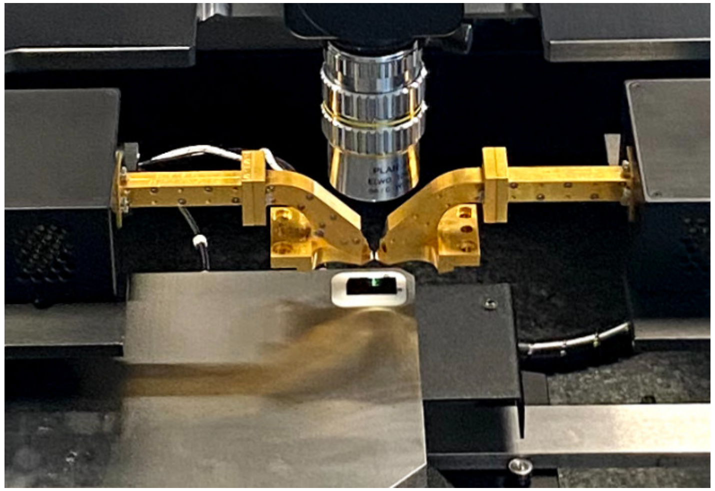
Drift comparison – Horizonal Extender – 50mm WG - Probe



	PORT1	PORT2
Max EVM	5.8	5.9
Δ°C at Max EVM	-0.87	+0.51
Max EVM per Δ°C	6.66	11.5



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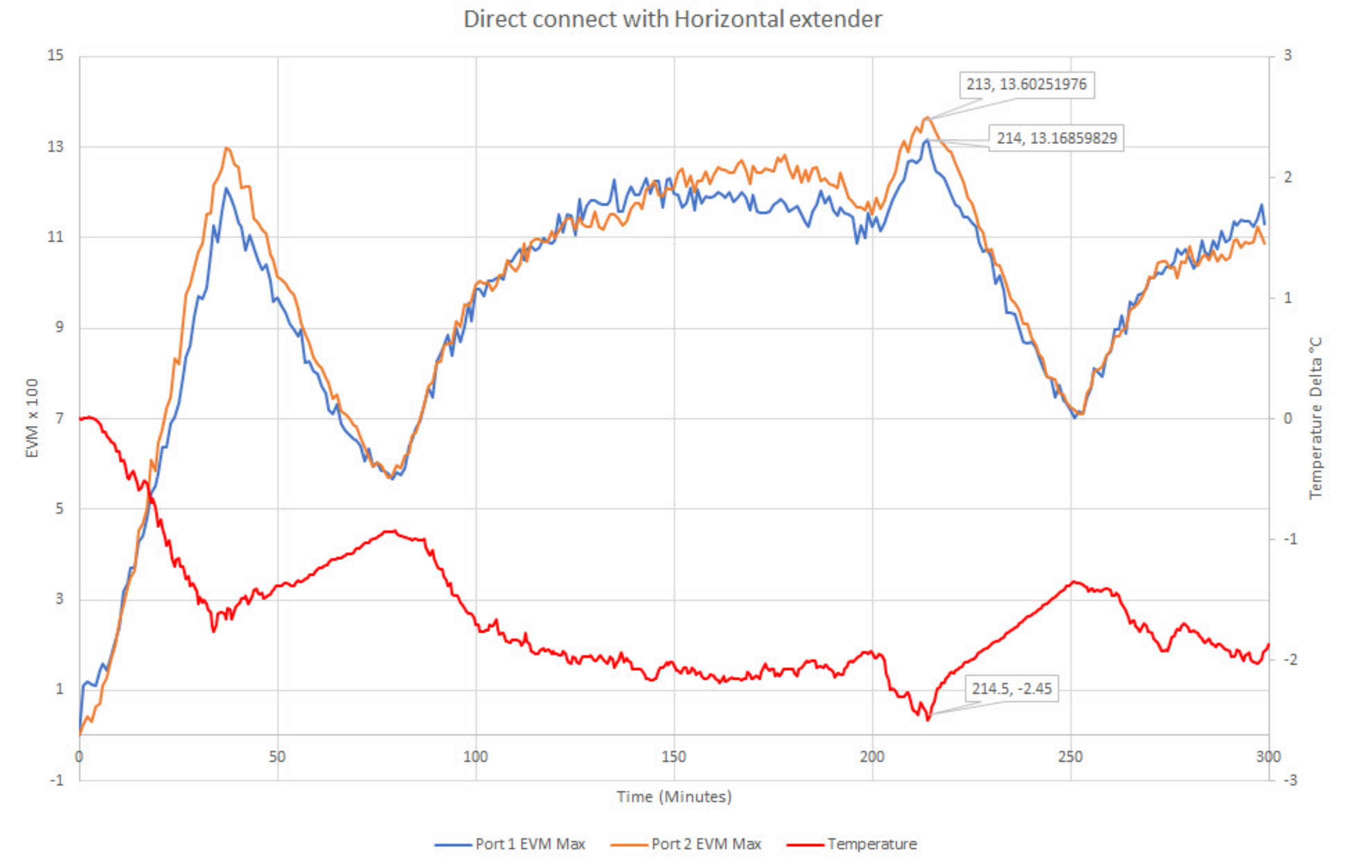
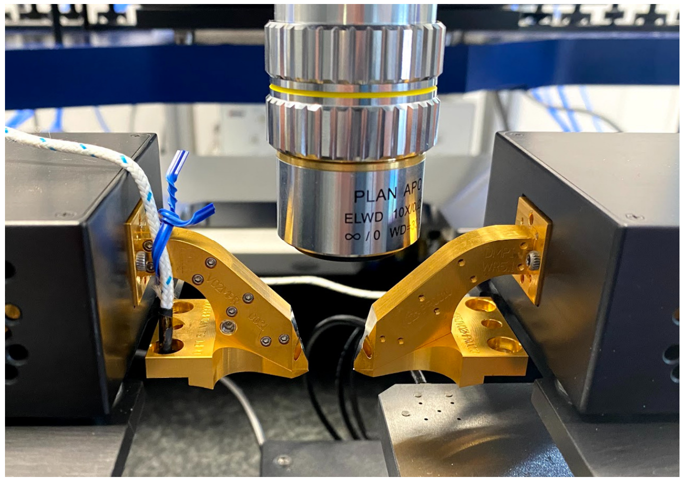
Drift comparison – Horizonal Extender – Direct Connect - Probe



	PORT1	PORT2
Max EVM	13.16	13.6
Δ°C at Max EVM	-2.45	-2.45
Max EVM per Δ°C	5.37	5.55



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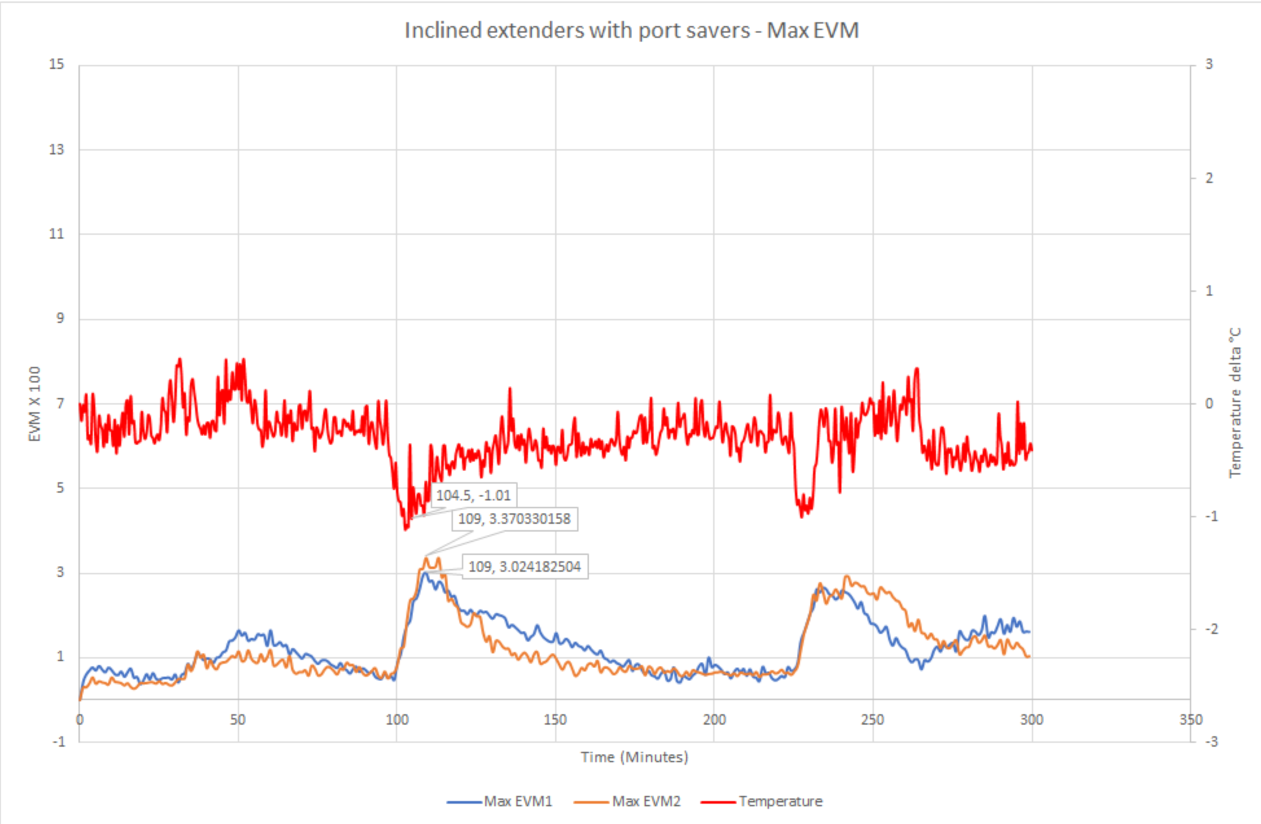
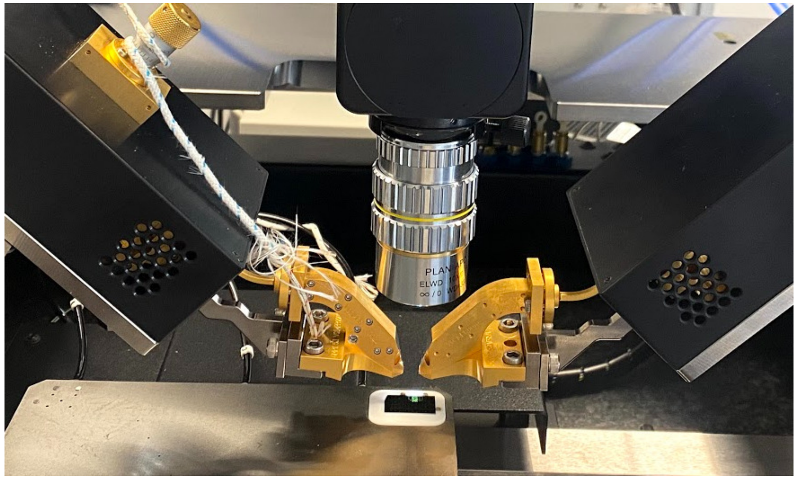
Drift comparison – Inclined Extender – 45deg WG - Probe



	PORT1	PORT2
Max EVM	3.02	3.37
Δ°C at Max EVM	-1.01	-1.01
Max EVM per Δ°C	2.99	3.33



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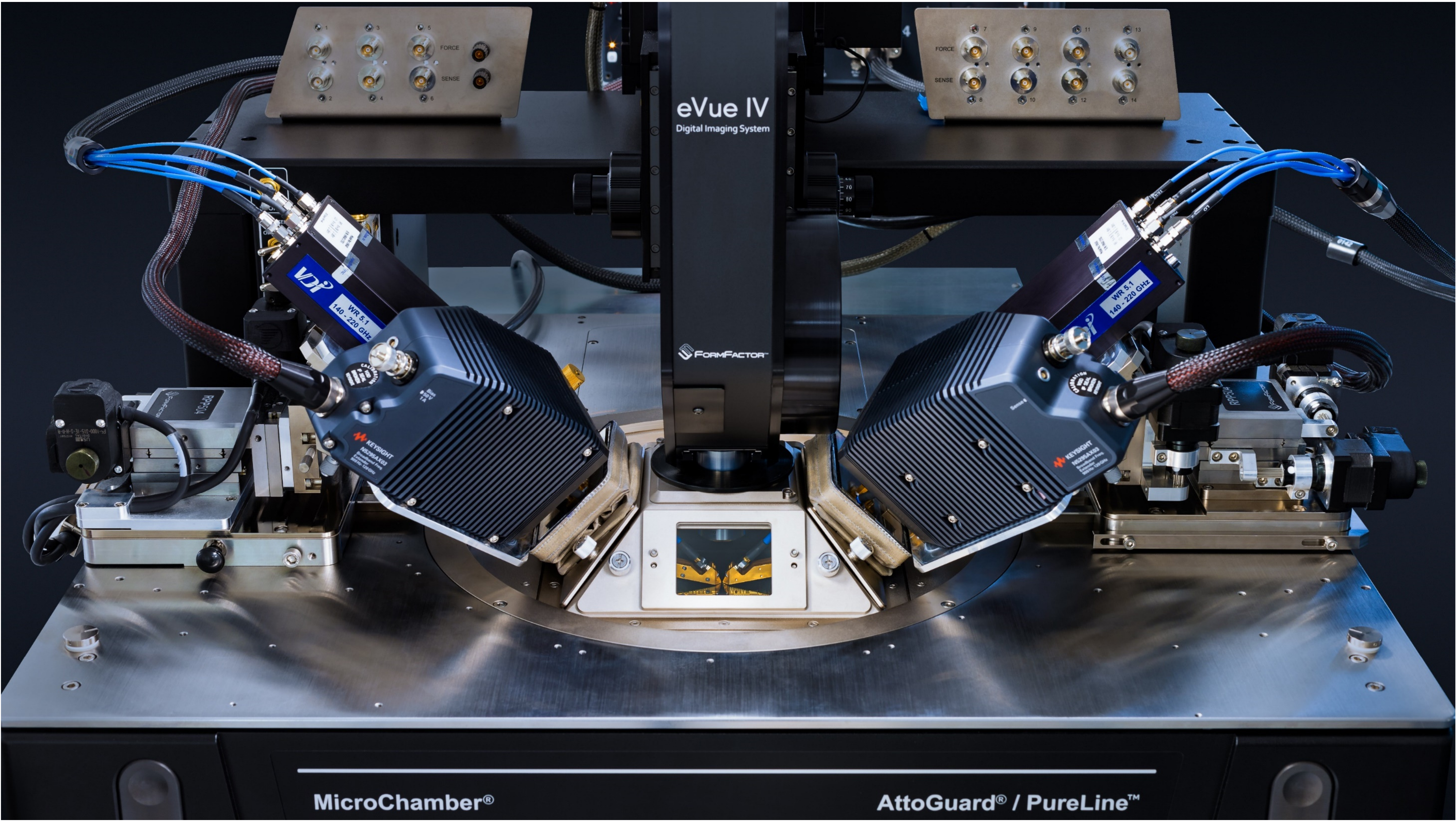

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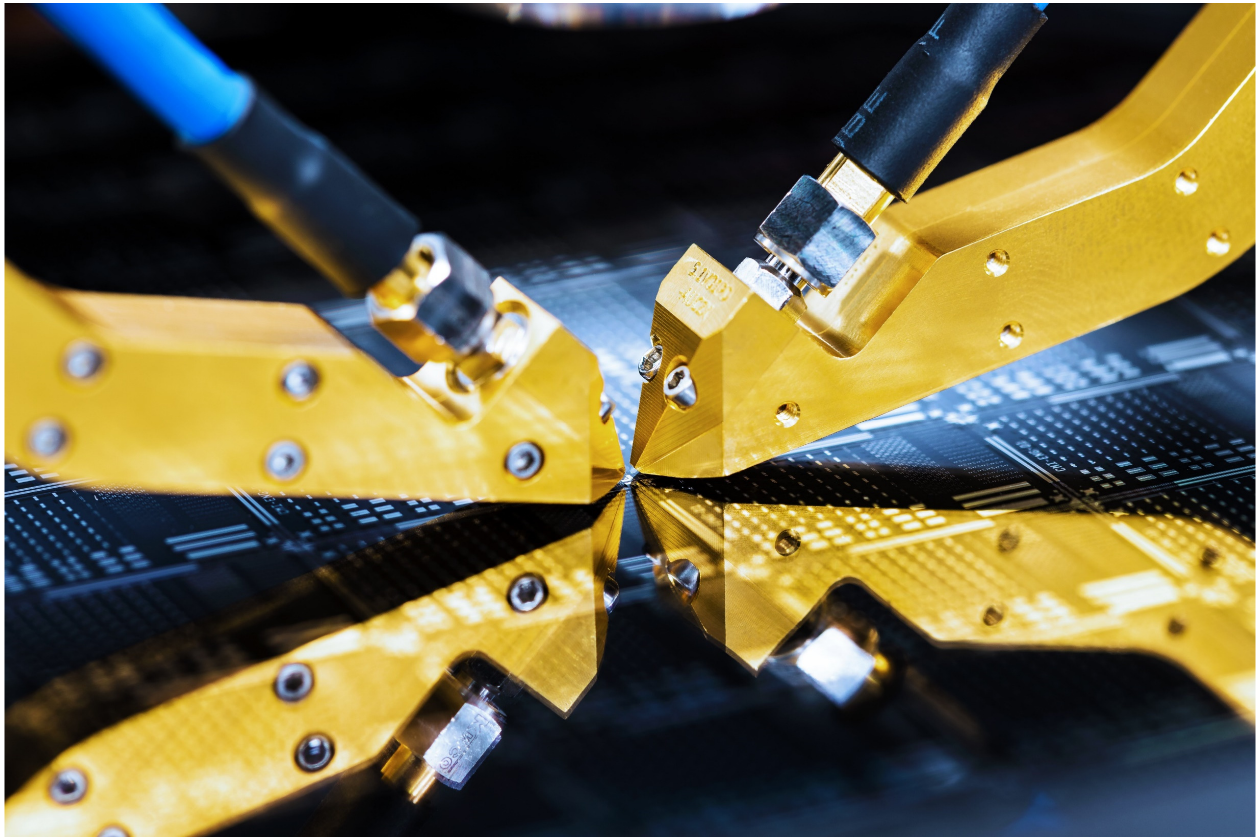
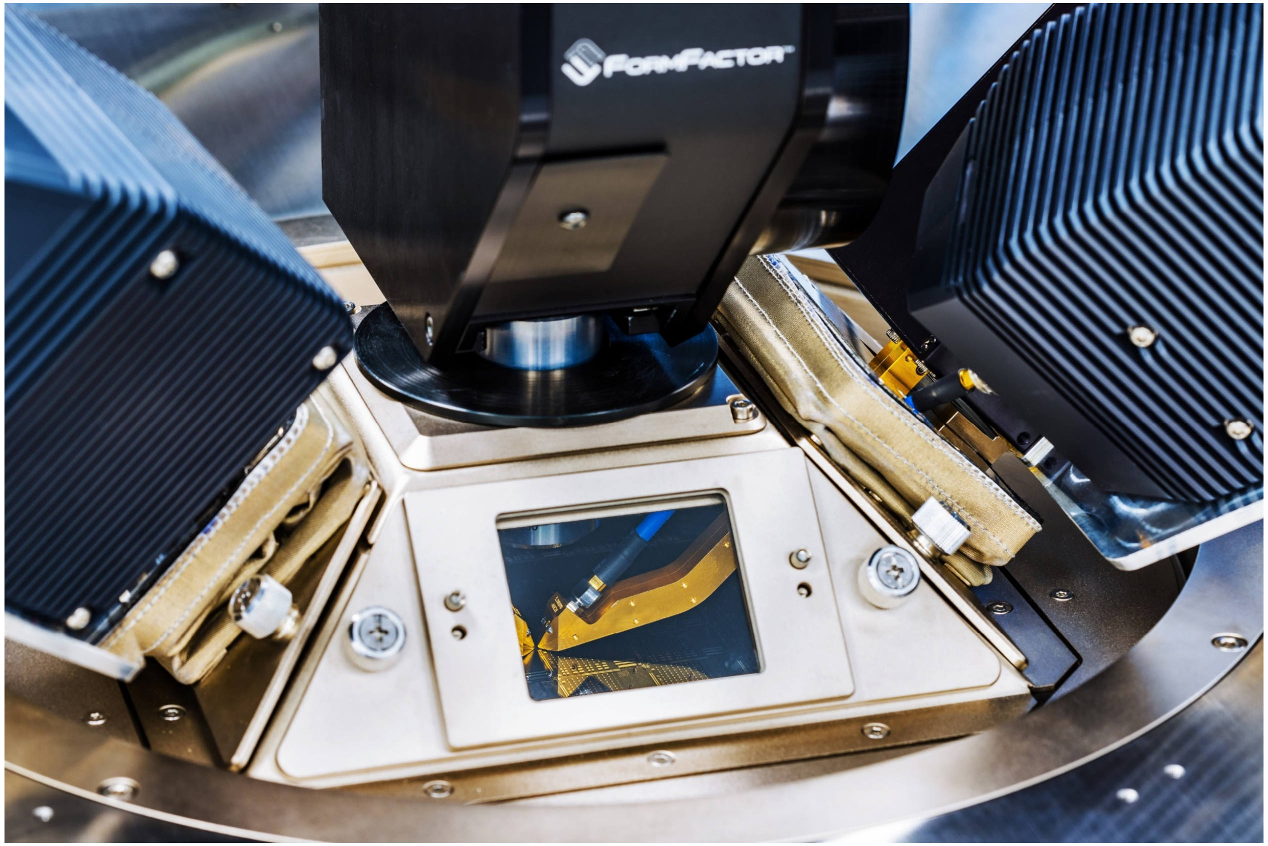
New Dual Band 220GHz Integration



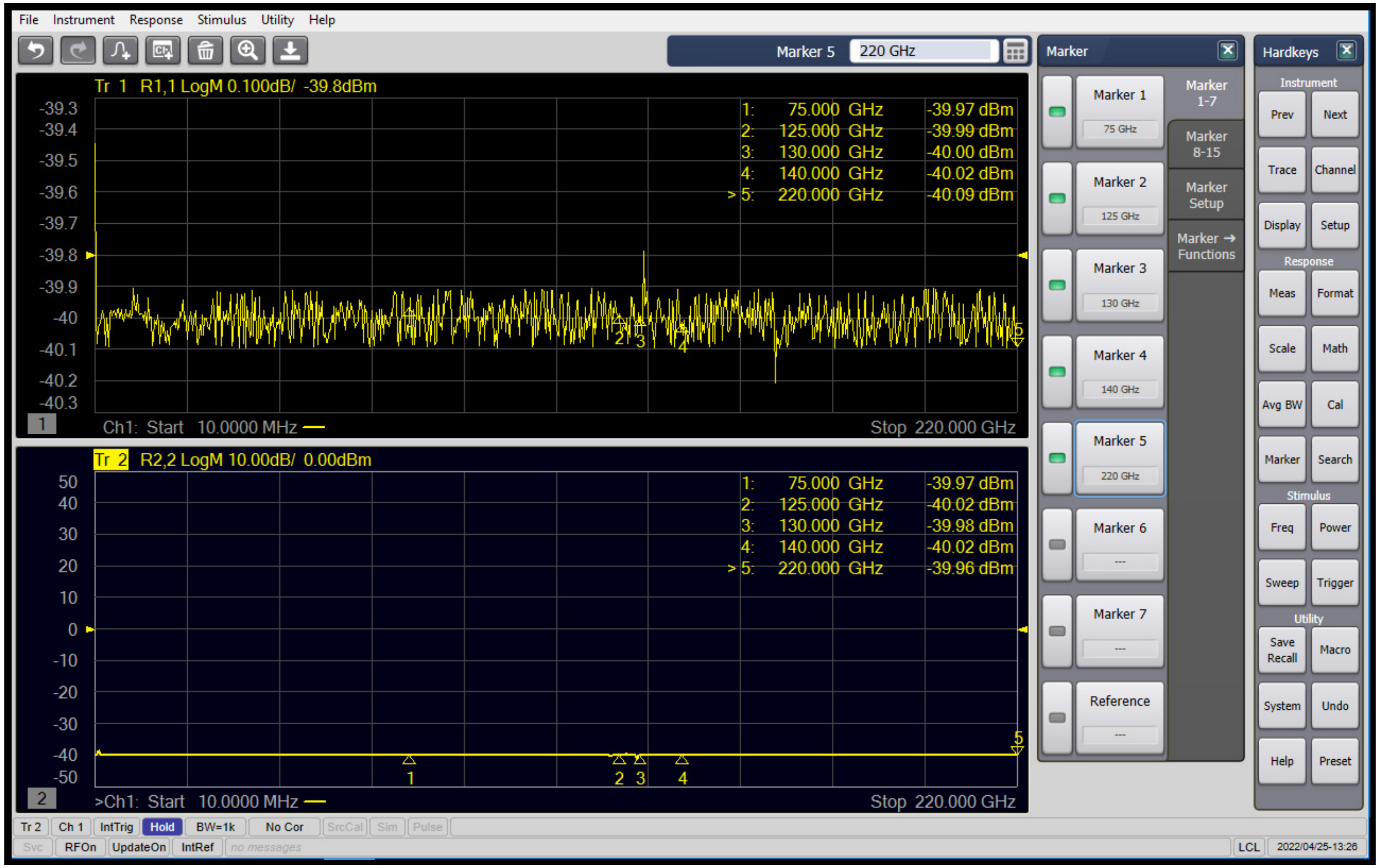
- Combines coax and waveguide bands via diplexer integral to the probe
- Single sweep measurements
  - One set of probes
  - One Calibration
  - One Measurement

Features & Benefits of Dual Band

- Re-use existing tools
  - Probe station, extenders, positioners and tophat enclosure
- Manual, semi-auto or fully-auto systems
- Full thermal capability
- Dark, EMI Shielded and dry measurements
- Allows an existing N5291A to be extended to 220 GHz



Minimum settable power accurate to the probe tip



- After correction of the install Cal files (@ the Probe Tip) settable to -40 dbm
- Correction applied using supplied values for probes, 130 GHz Rf cables and power table for VDI extenders
- Alternatively - data can be obtained from 2 tier probe calibration if cal kit available

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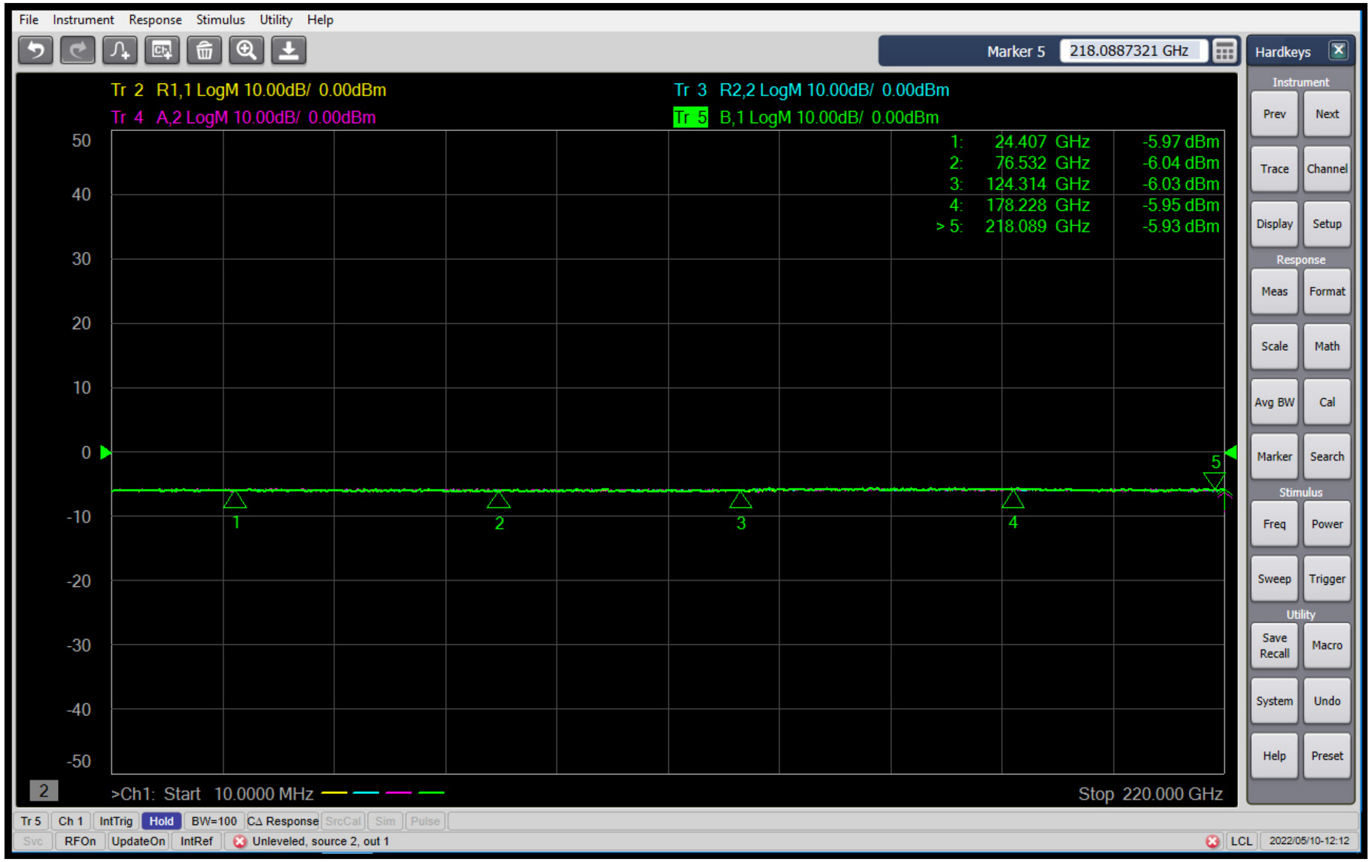
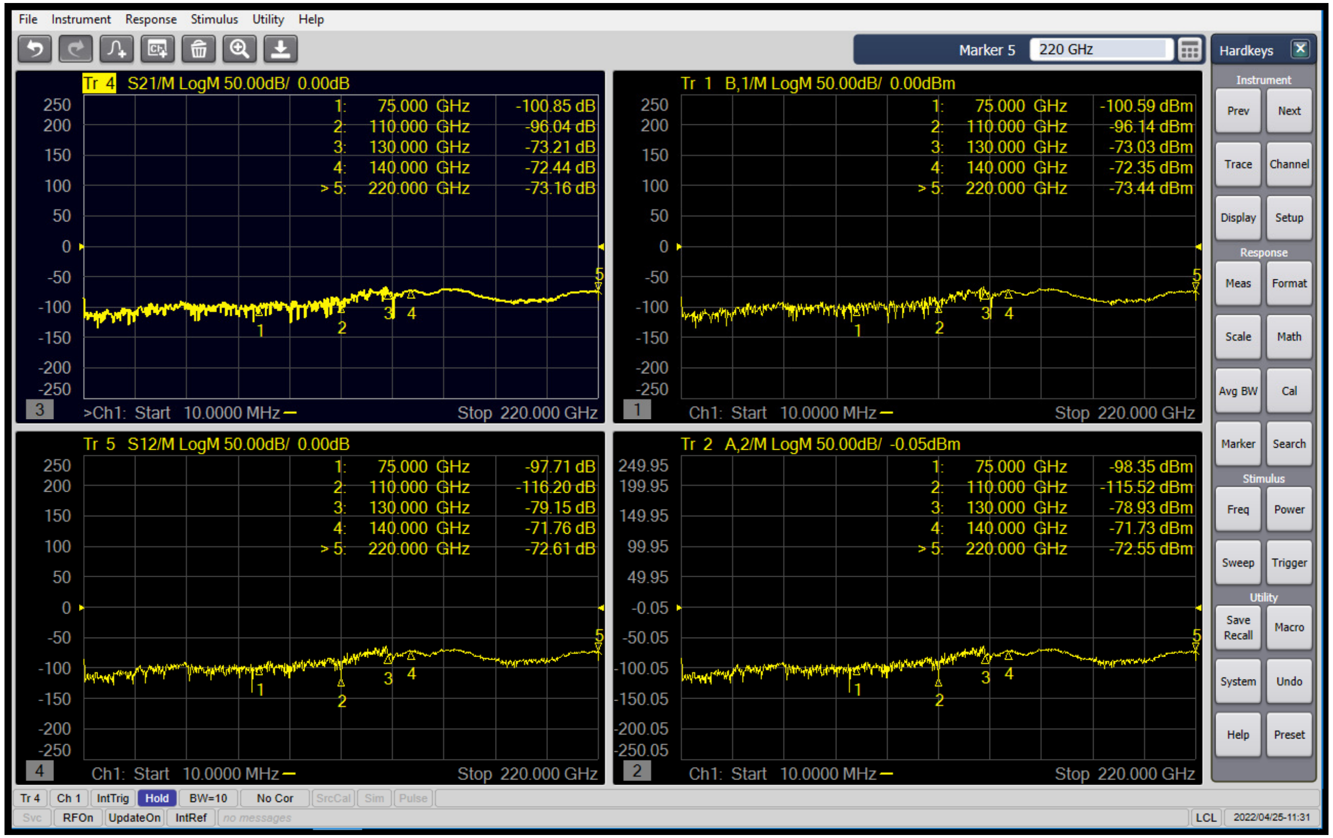
Maximum settable levelled power of –6 dbm throughout the band



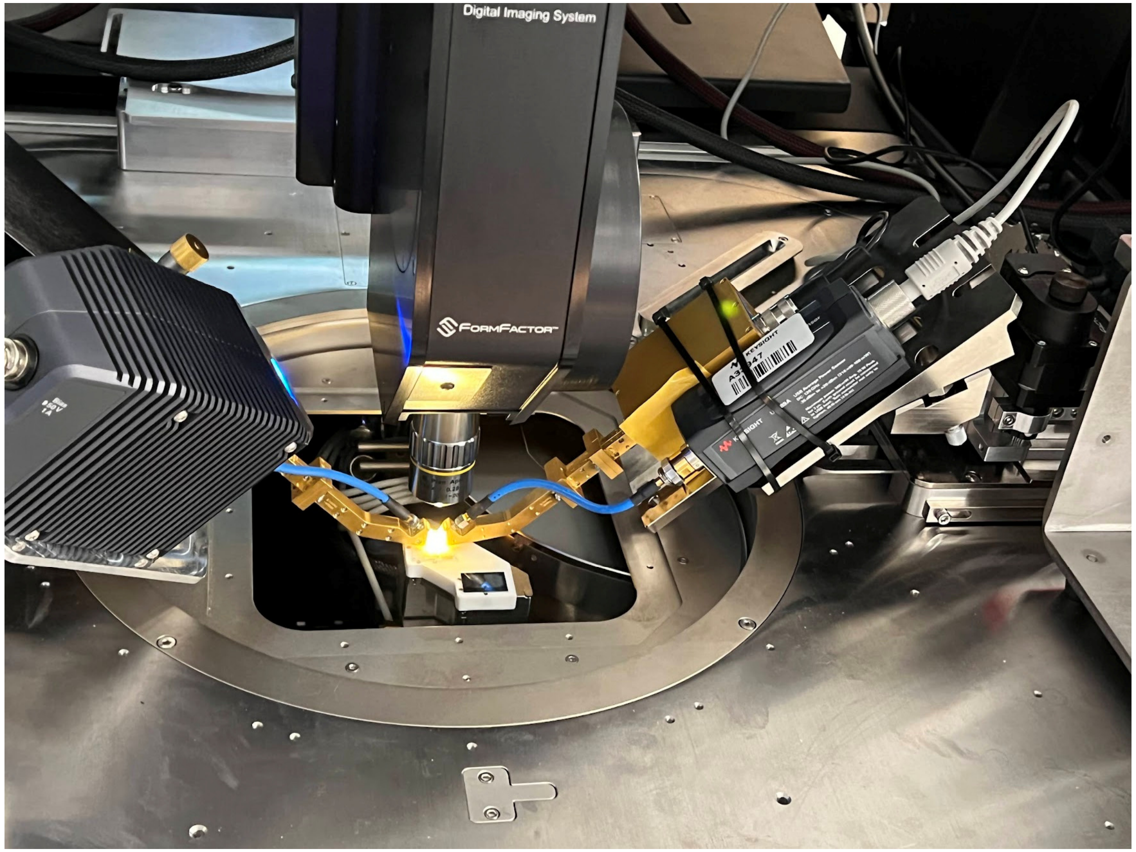
- Higher power levels are possible but this is the maximum that can be levelled for the band

Dynamic Range



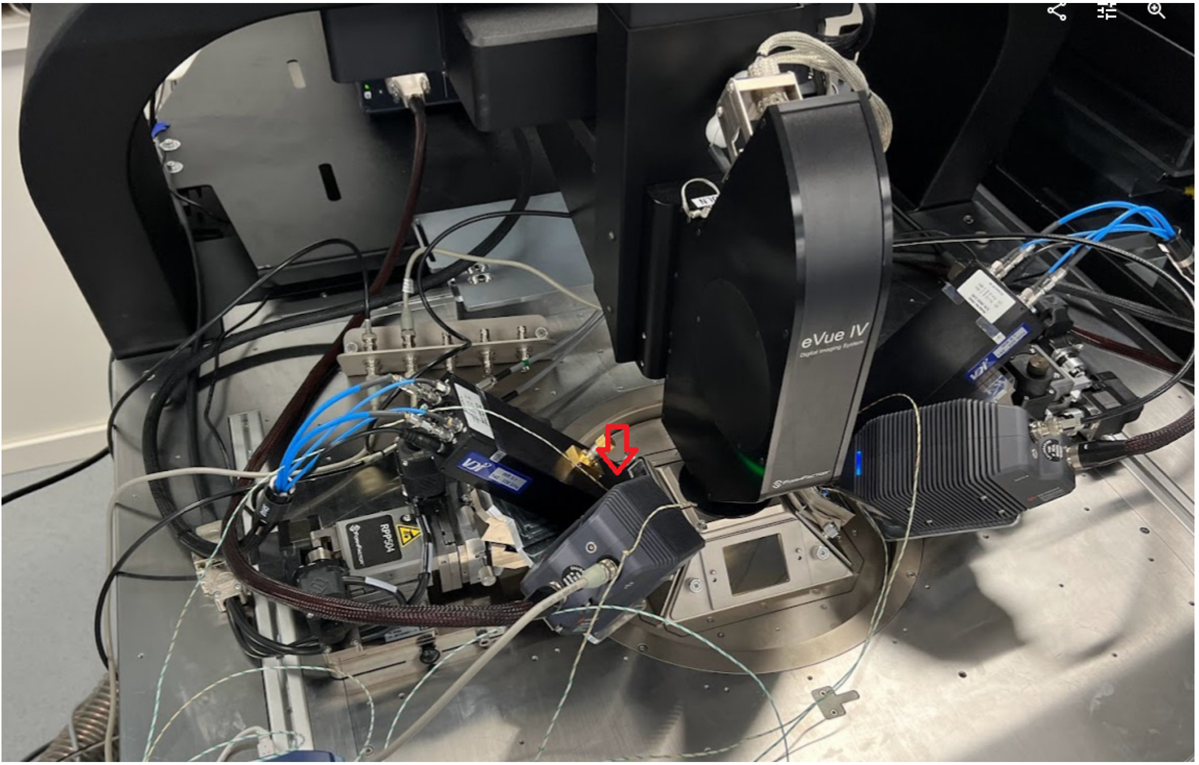
- 10 Hz with probe in Air and chuck down

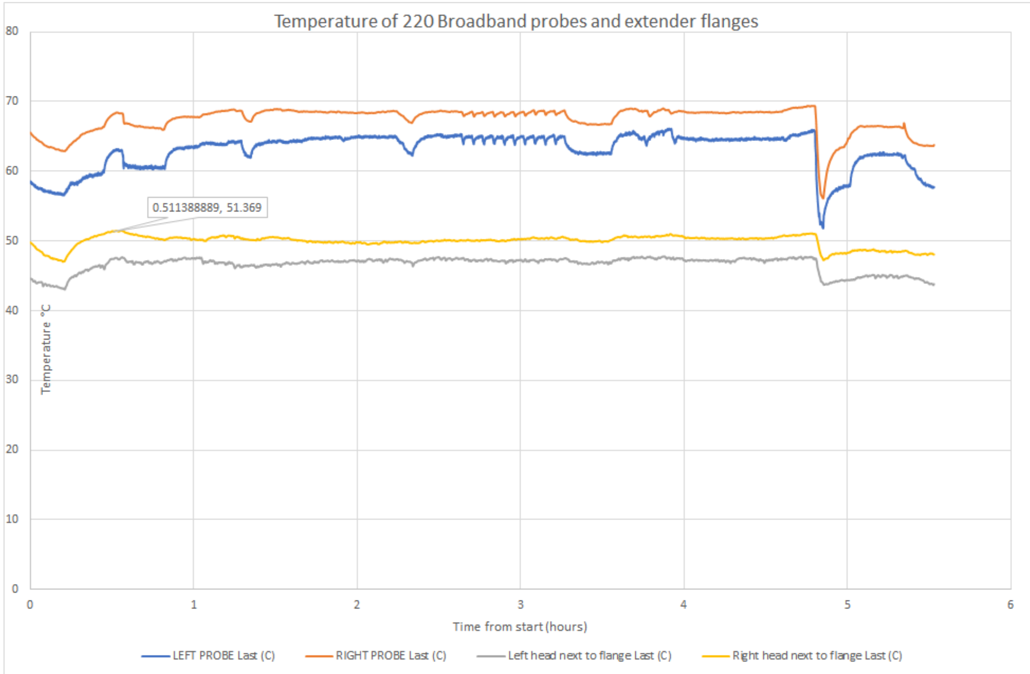
Verification of power at the probe tip..



- Power evaluated using 1mm also PM5 VDI power meter

Thermally tested to 150 °c





- Probe tip at 150 °c but flange limited to 52 °c worst case and the rest of the extender is in ambient air with platen jet cooling

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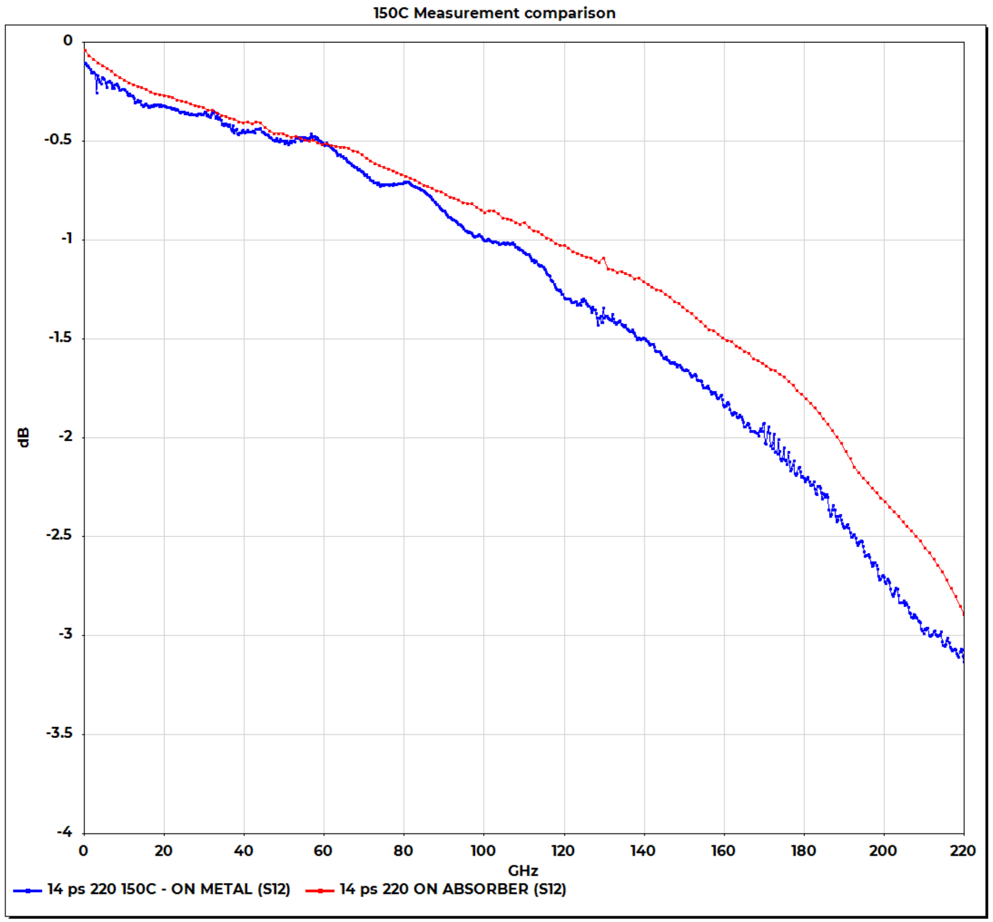
Thermally tested to 150 °c



- Comparison is of a Cal on metal and measurement on metal as compared to cal on absorber with measurement on absorber
- Increased loss is expected

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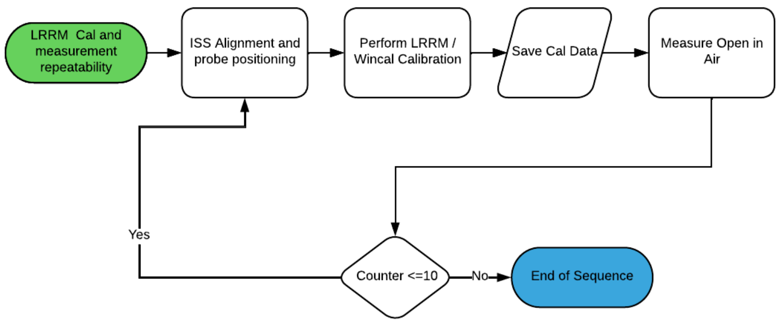
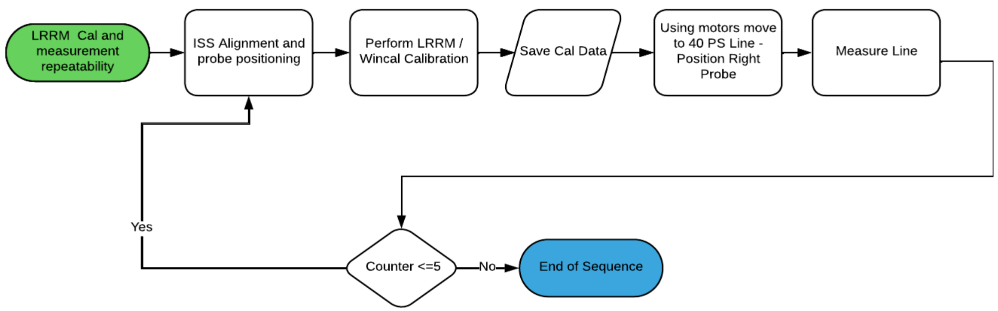
System evaluation

- Approaches were taken similar to those used for our Wafer level measurement solutions namely
  - Measurements of multiple transmission lines
  - Repetitive calibrations without moving the probes and evaluating for variation of post LRRM open and Cal to cal worst case Sij variation
  - Repetitive calibrations with measurement of ISS line standards
  - Measurement drift as a function of time and temperature
  - Measurements of active devices
  - Python scripting was used for all the testing with Wincal and for analysis purposes





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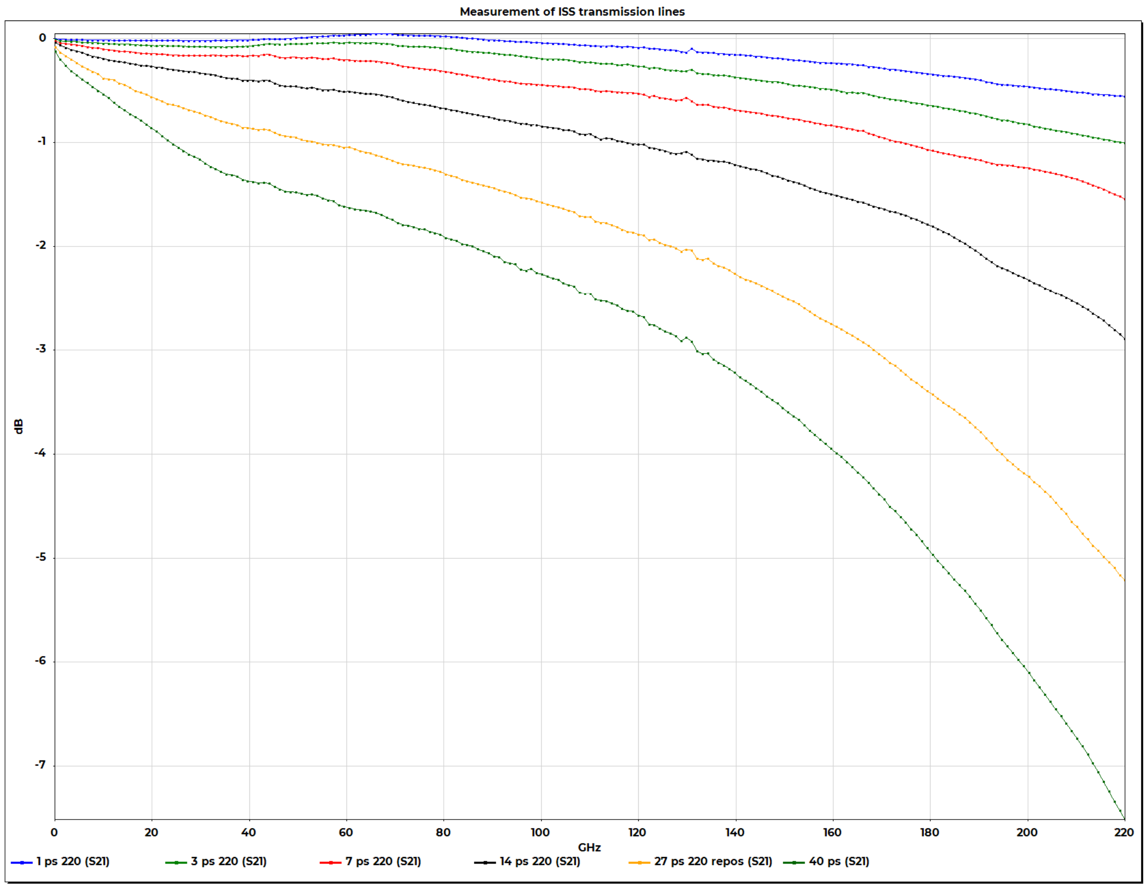
Measurement of transmission lines T220



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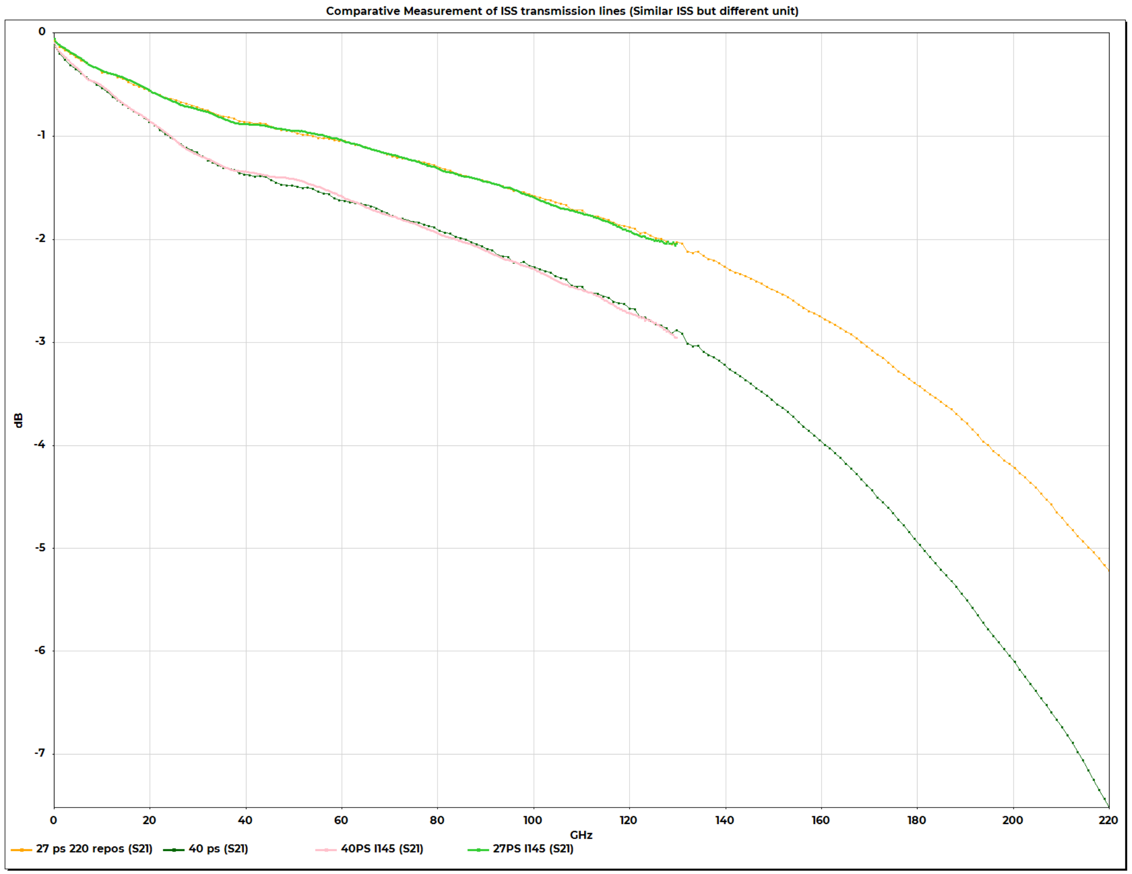
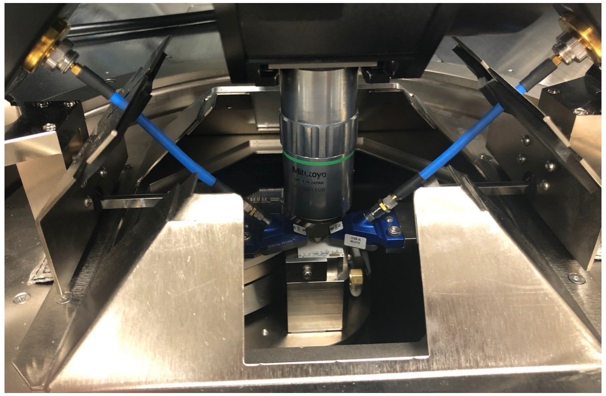
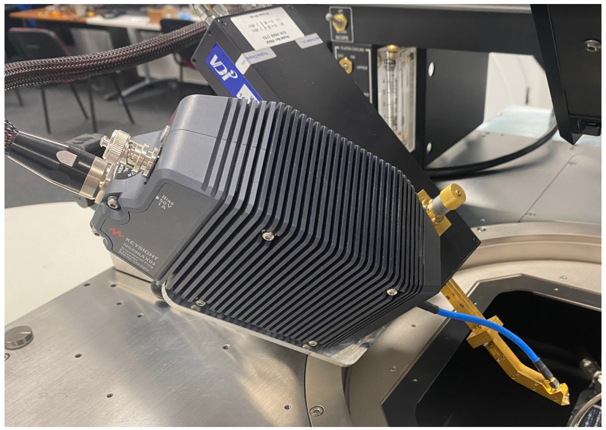
Comparative measurements with I145 and T220 Broadband

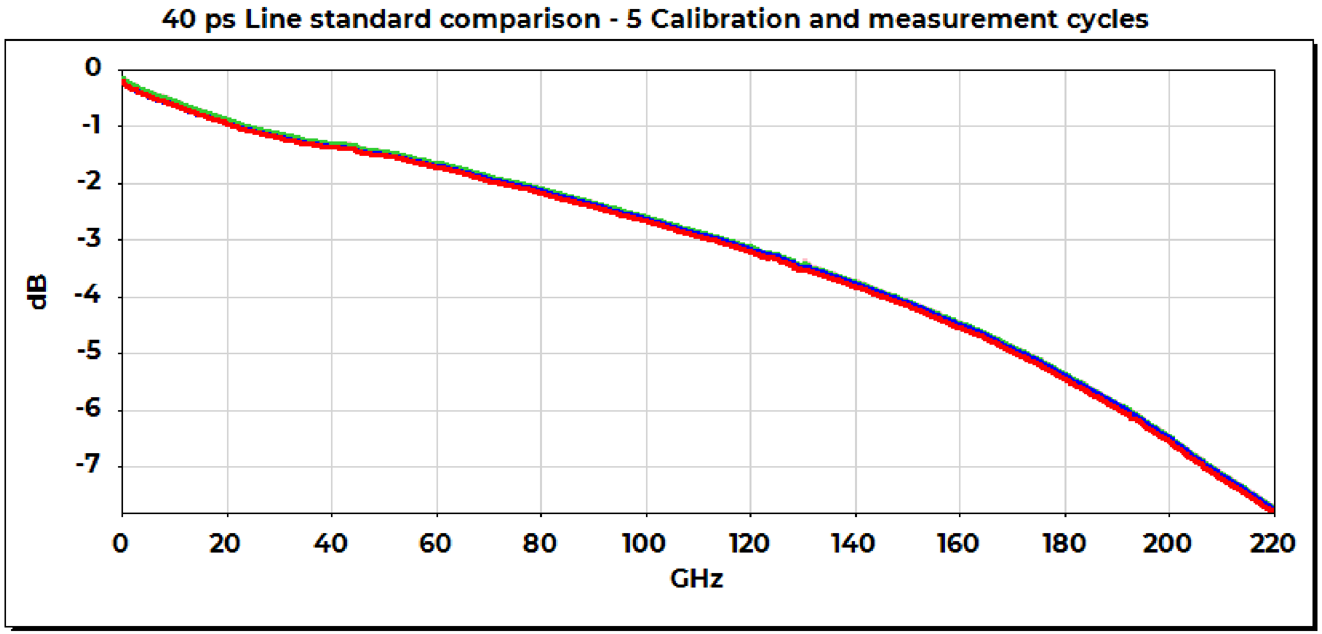


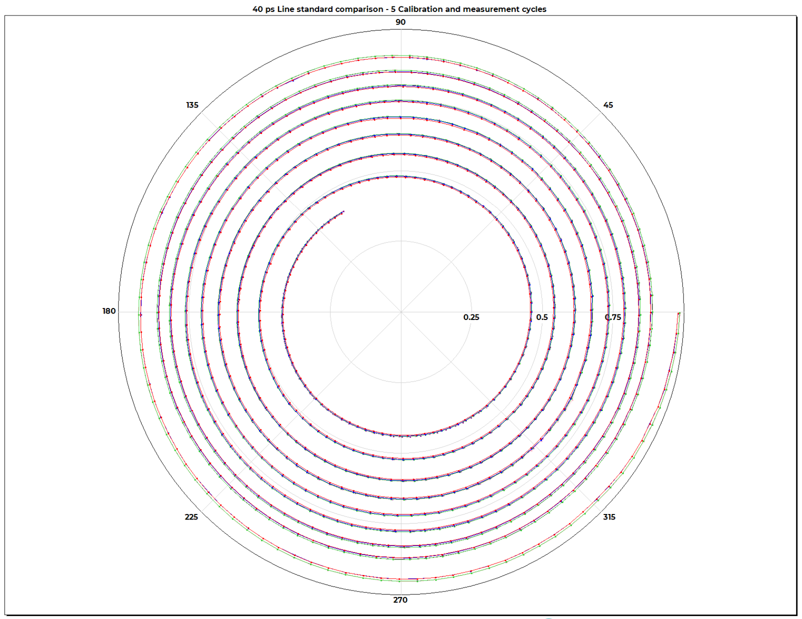




Calibration / Measurement repeatability

- 100 Hz IF
- 10 MHz to 220 GHz
- 40 ps with 5 cycles on 185-400 50 um specific iss with LRRM





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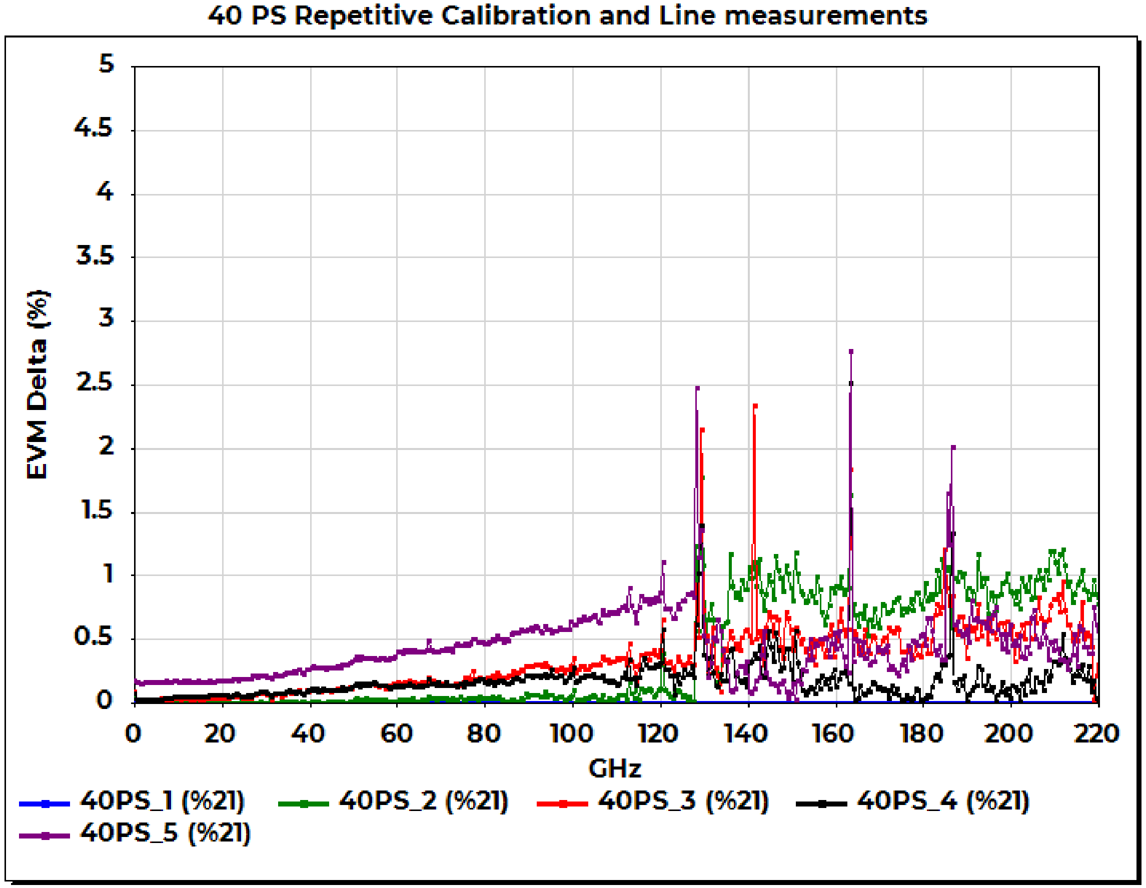
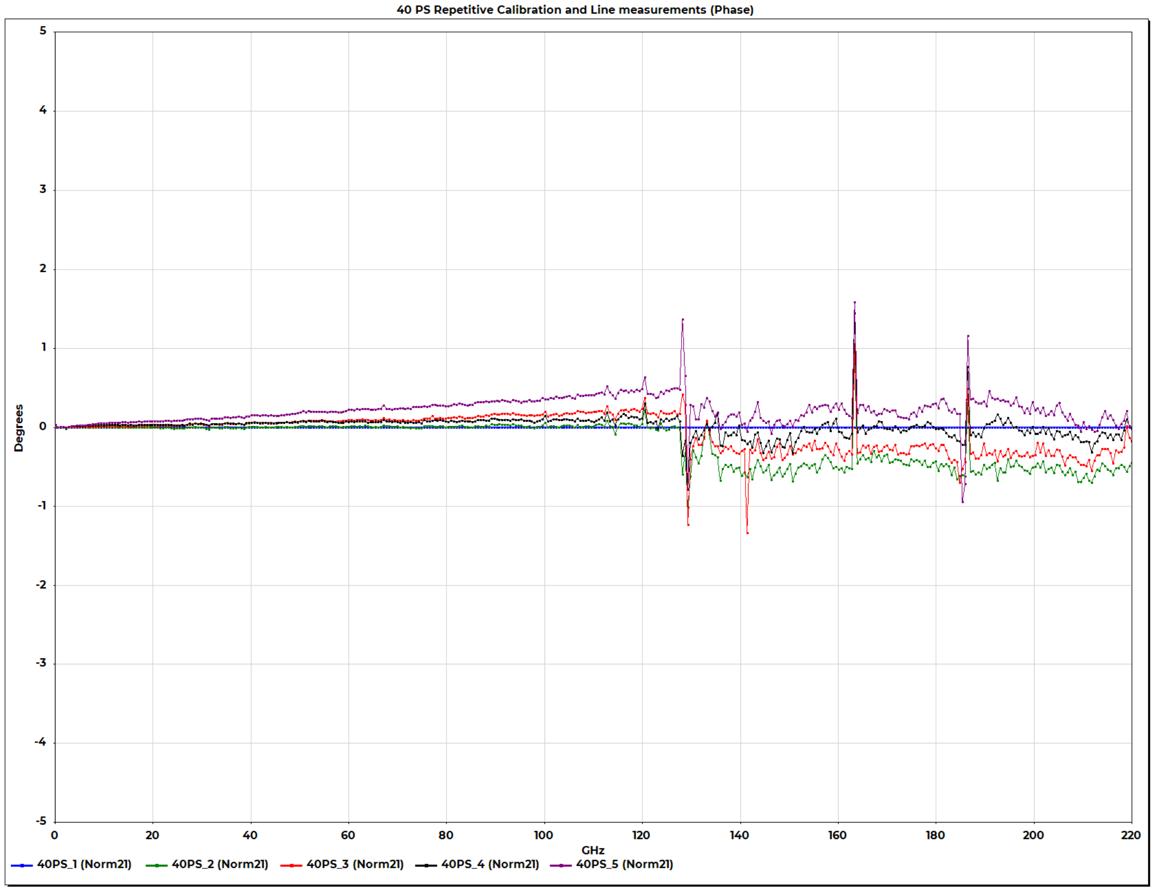
Calibration / Measurement repeatability



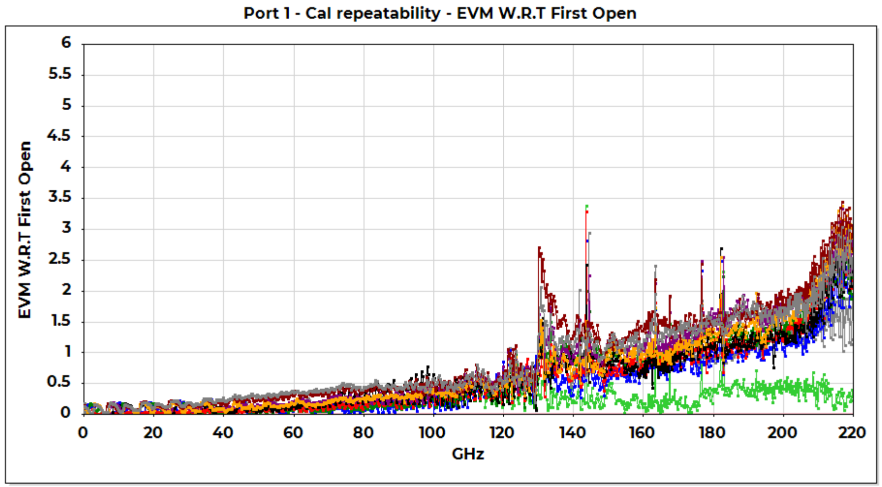
- A new calibration precedes each device measurement
- EVM = Error vector magnitude
- ((Re1-ReN)^2+(Im1-ImN)^2)^-1

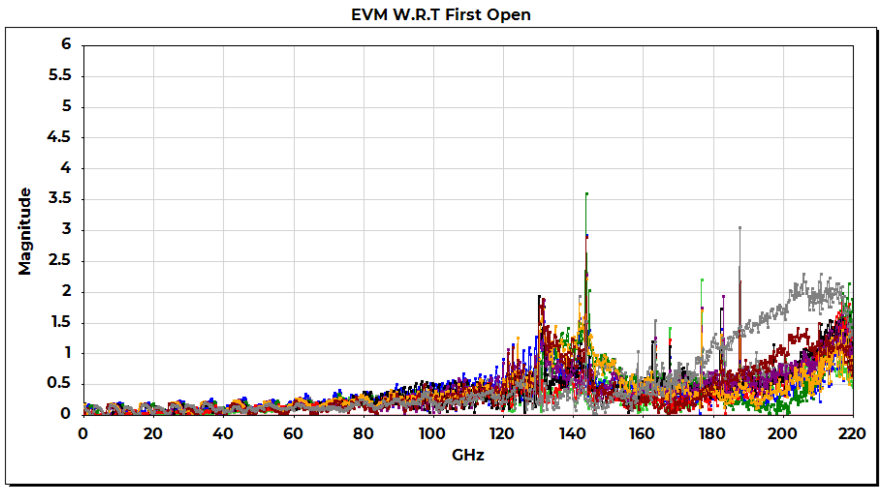
Calibration / Measurement repeatability - Phase



- Aside from outliers Phase for a 40 ps line is repeatable within +/- 1 degree

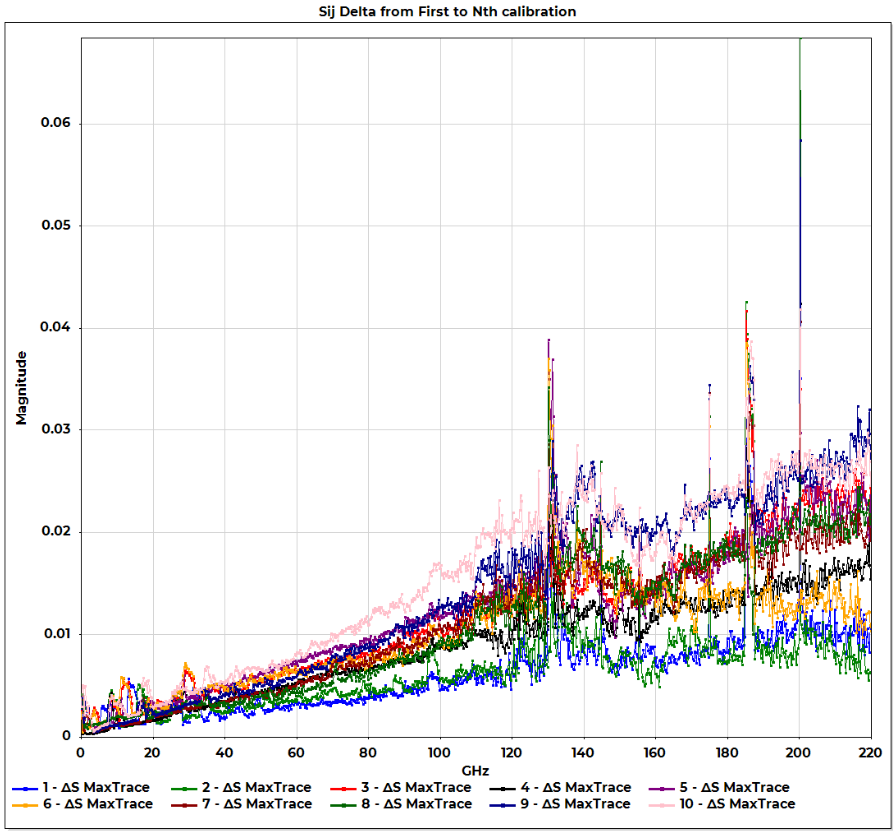
Calibration repeatability – Open in air variation

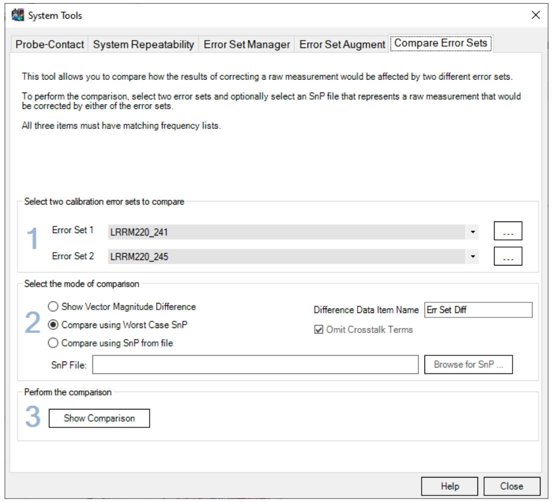




- 10 calibration cycles with eLRRM
- -6dbm 100 Hz 801 points
- Air vents for the air conditioning system were directed away from the system

Calibration Repeatability – Error set Sij comparison





- Compared using WinCalXE Error set comparison tool – Looks at the worst case S parameter change on a set of unity data
- This was automated using a combination of sequence and Wincal math scratchpad
- Uses same error set as Open comparison

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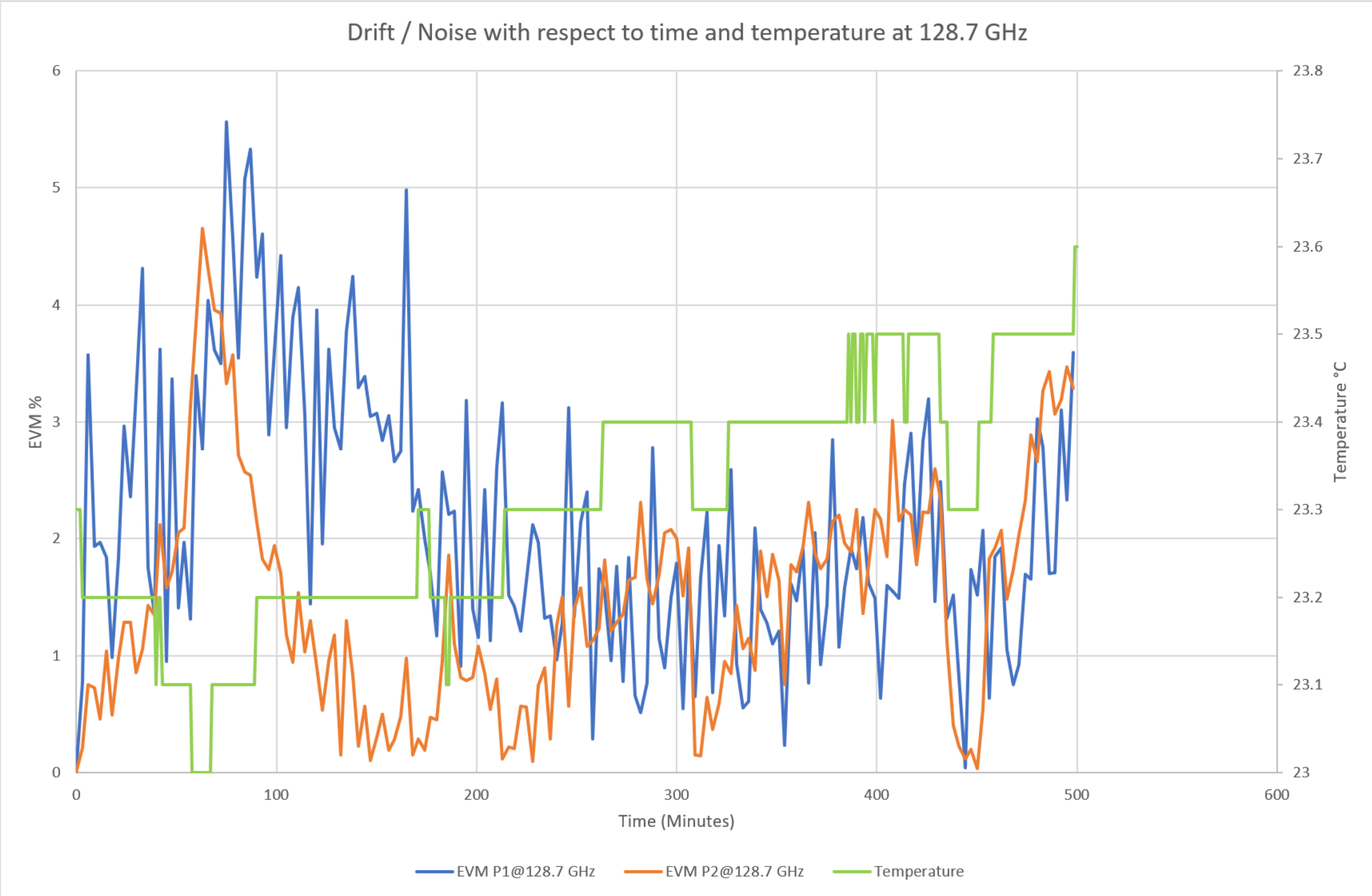
Drift at ambient temperature



- System was calibrated and left to drift with measurements every 3 minutes at -6 dbm 100 Hz
- S par sweep taken but fixed frequency point used that was next to the crossover point
- Air temperature measured with logger
- Data was processed using Wincal with a Python script using Wincal marker functions

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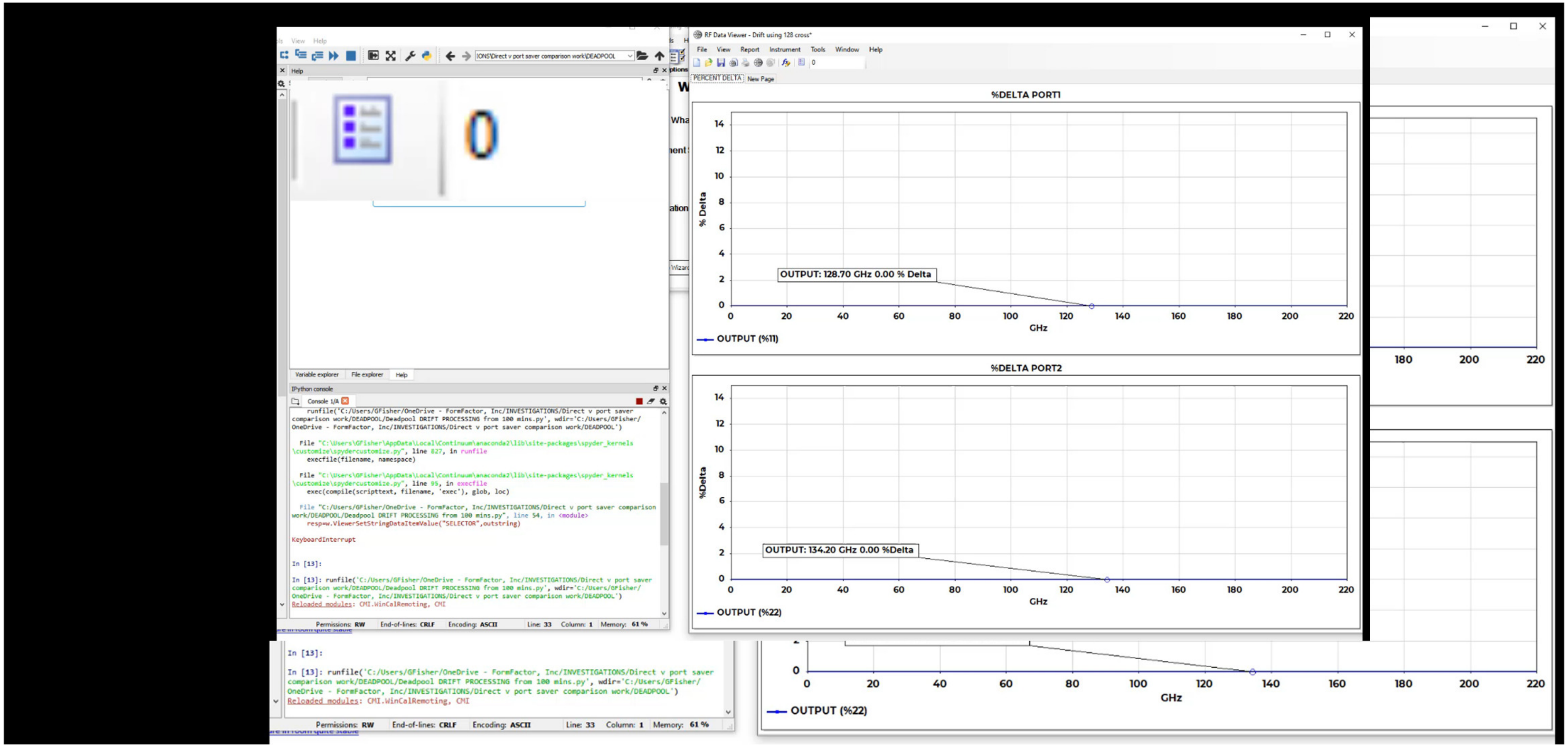
Video of drift evaluation with Wincal remoting and Python



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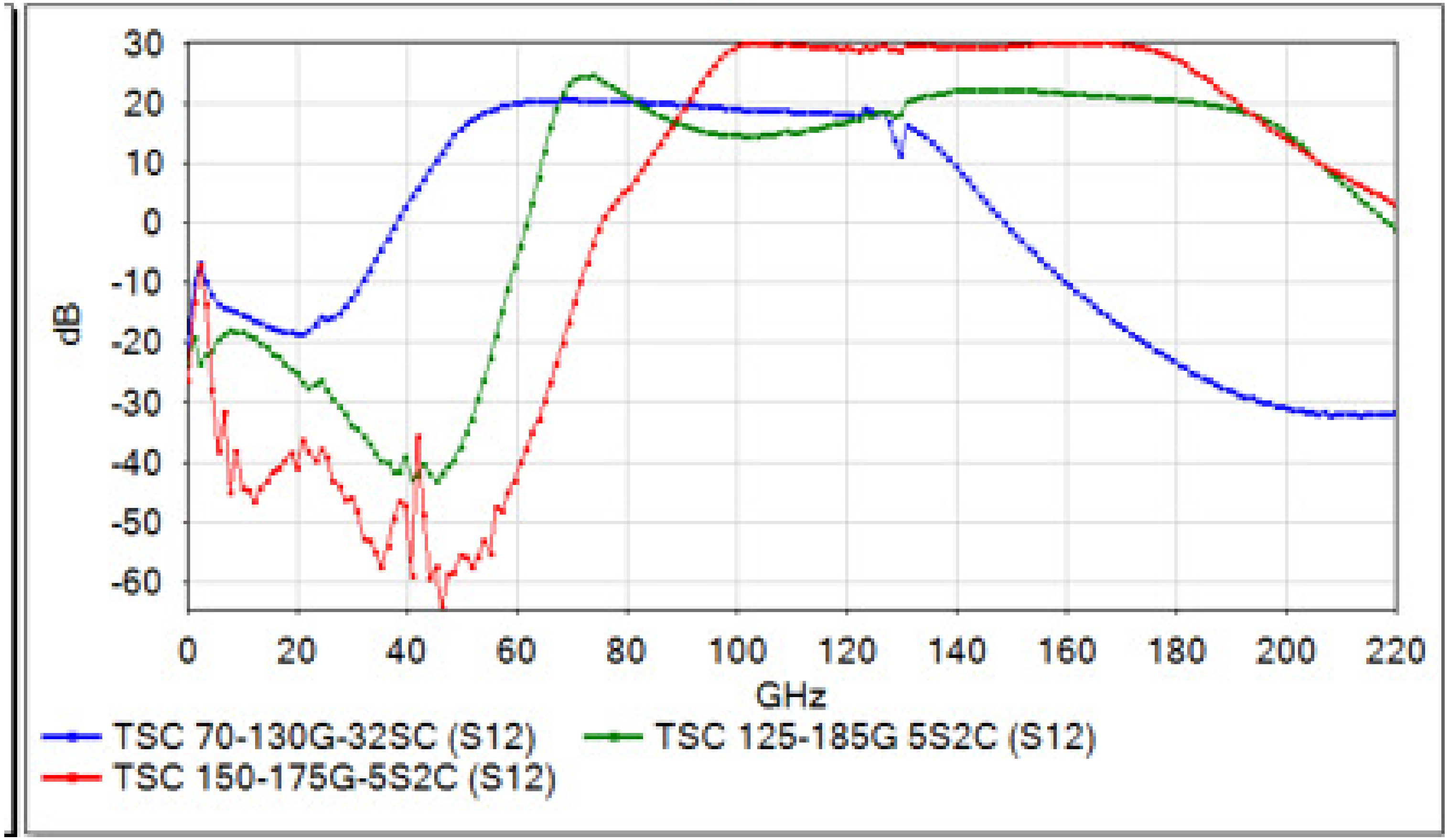
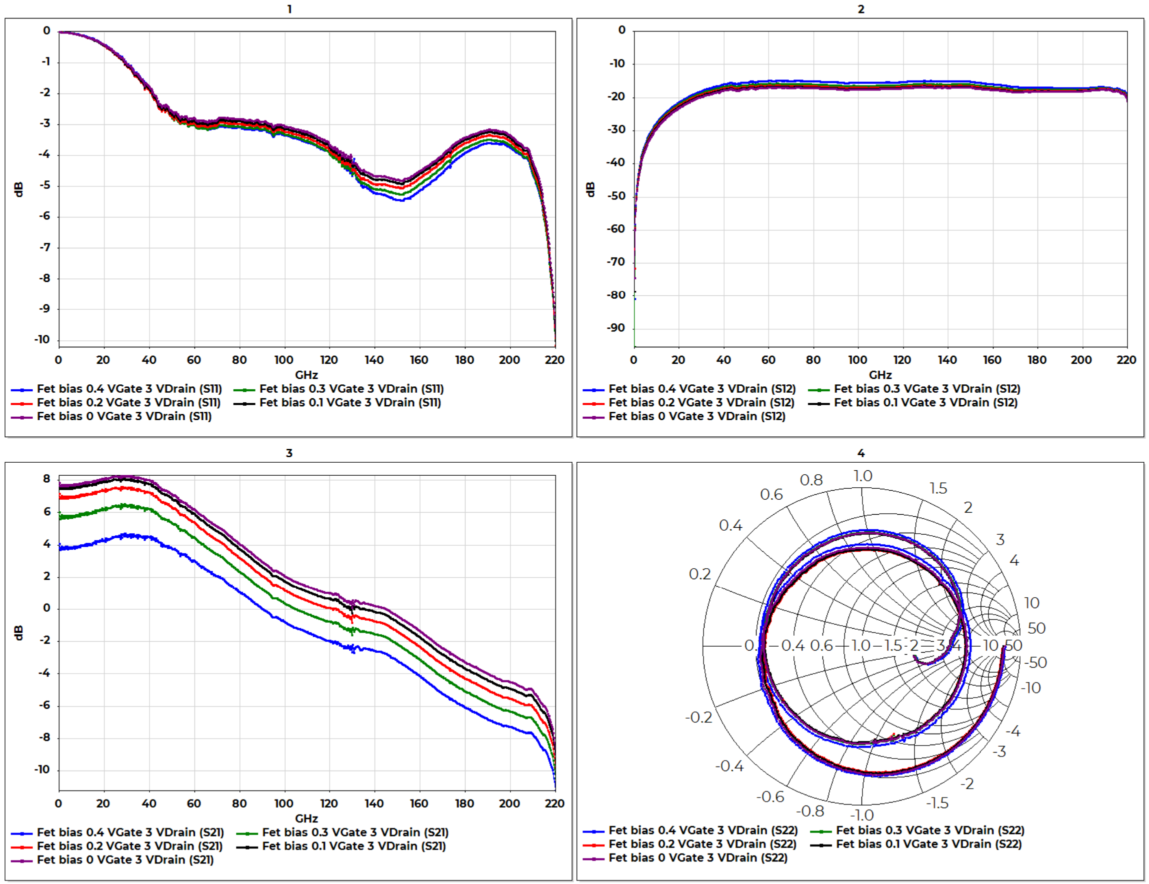
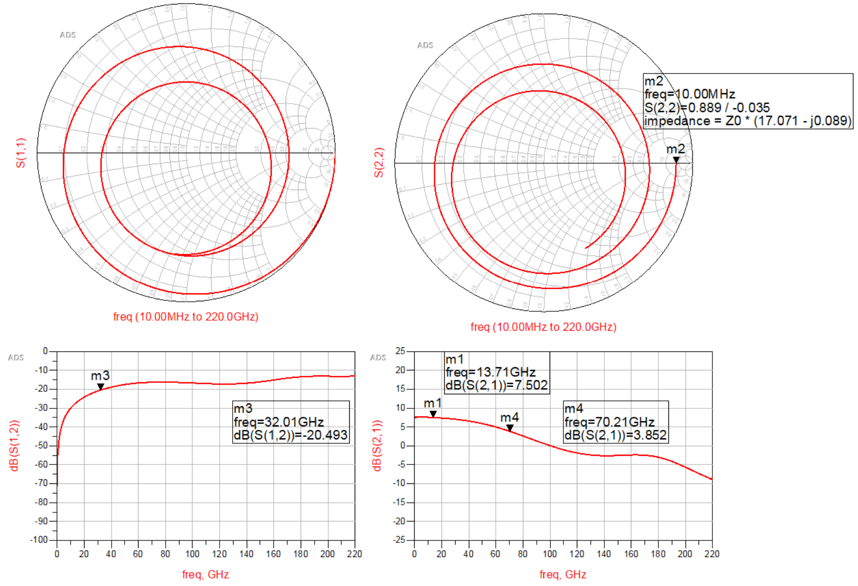
Real life active device data (Teledyne device)



Active demo device measured at -30 dbm





- Thanks to Rob Sloan for designing and providing the demo device…

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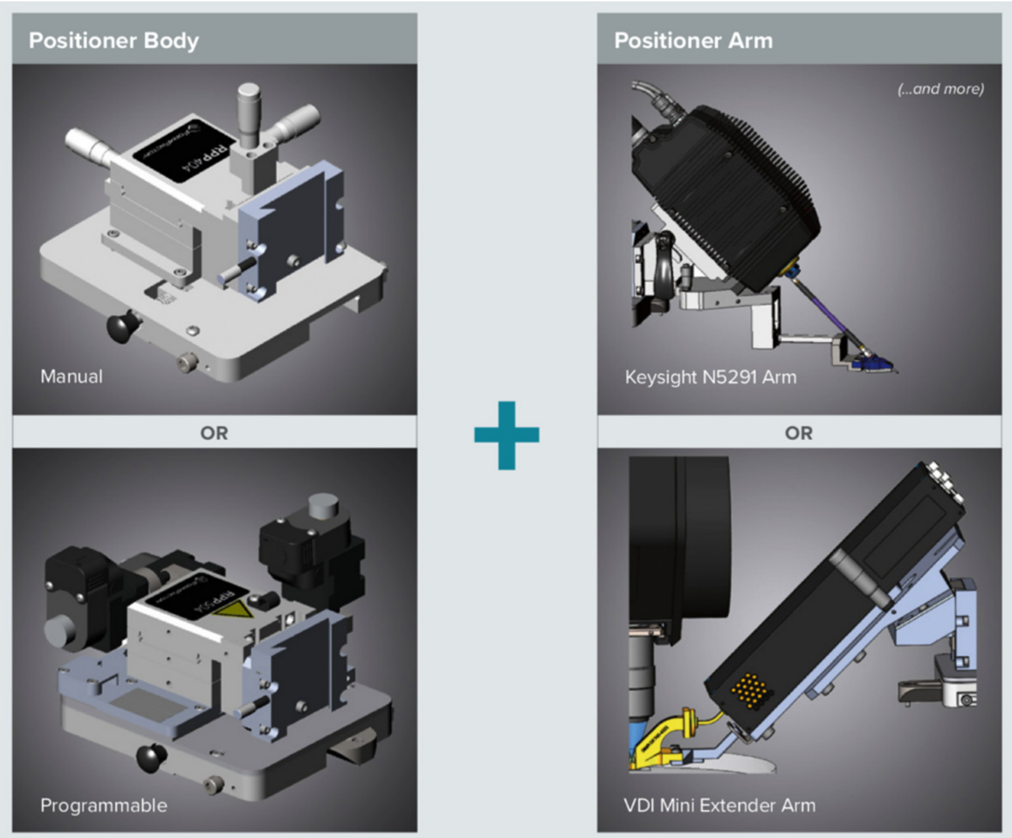
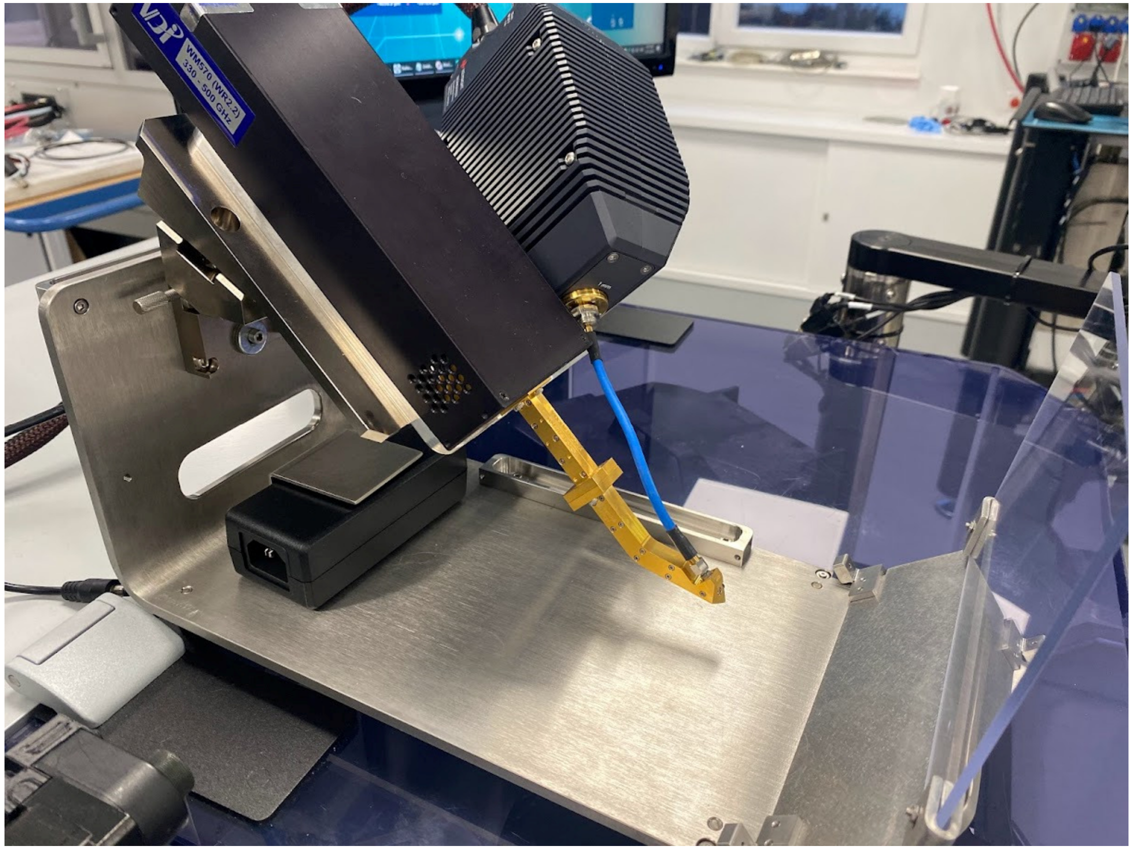
New Modular Positioners

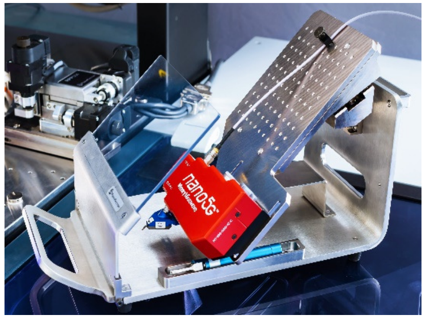


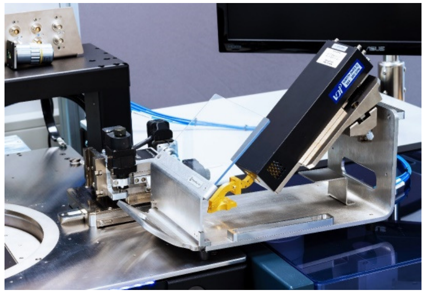
- Choose manual or programmable body
- Multiple arms for each application
- Fast-swap dovetail mounting – Easy & safe
- Upgradable
- RF TopHat/IceShield compatible

Allows optimized measurements, lower cost of ownership and ease of use

Storage Pod for easy and safe swapping







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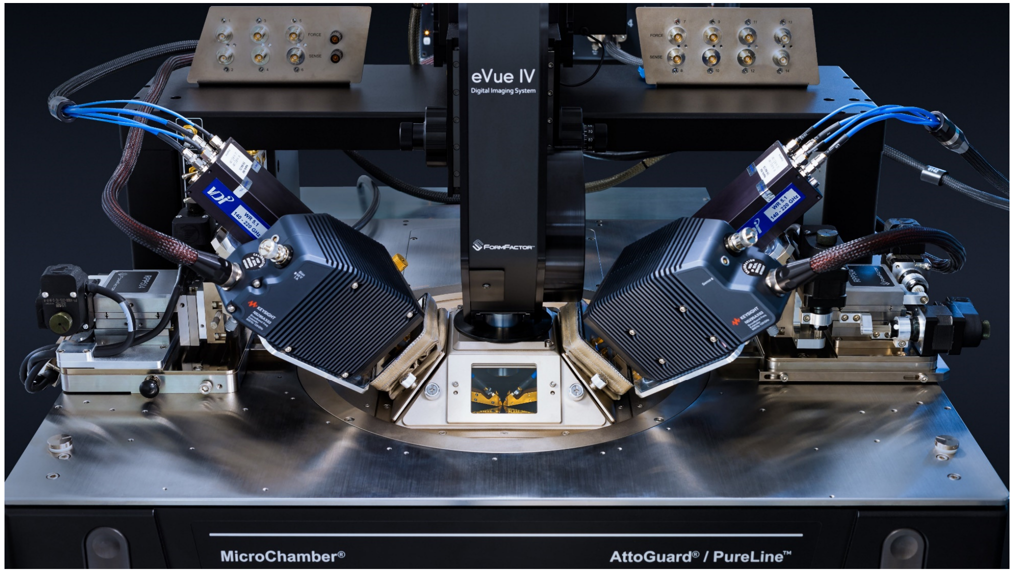
Values of Inclined Waveguide Connection

- Calibration Stability
  - Frequency extender is isolated from effects of thermal chuck
  - Reduces drift due to varying heat from chuck as you measure across the wafer
- Measurements over temperature
  - The only solution for full range hot and cold measurements without condensation
  - Full TopHat for frost-free, dark and EMI-shielded
- 45 deg port saver to avoid extender damage
  - When swapping probes, reduce risk of damage to extender test port
  - Improves crosstalk between ports



Values of single sweep broadband solution

- No time taken to swap bands
- Less effort combining results
- Less potential for mismatch between bands
- Full over temperature solution 10 MHz to 220 GHZ
- Full power levellings -40 dBm to -6dBm
- Power calibrated to the probe tip