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RAPID

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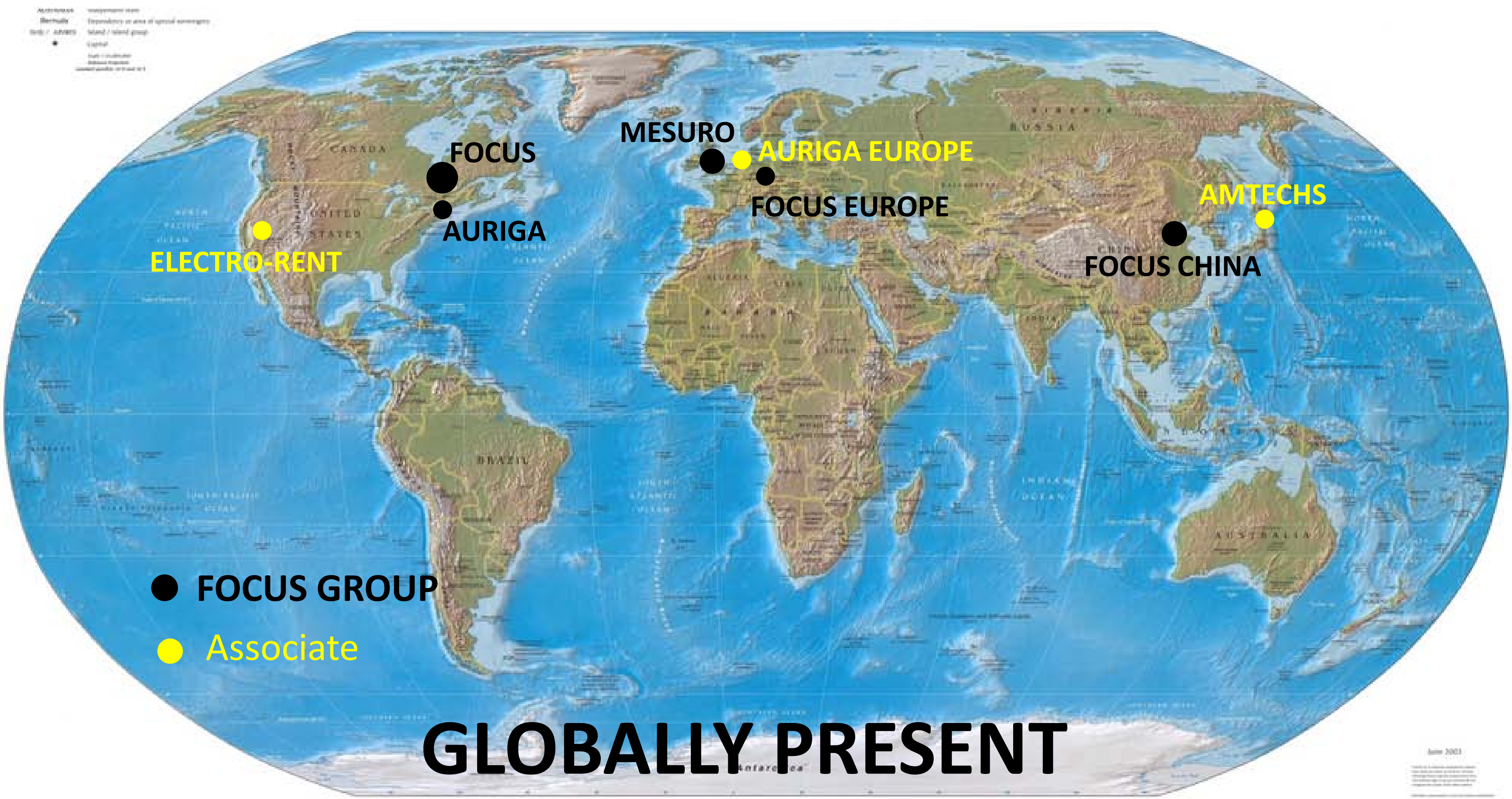

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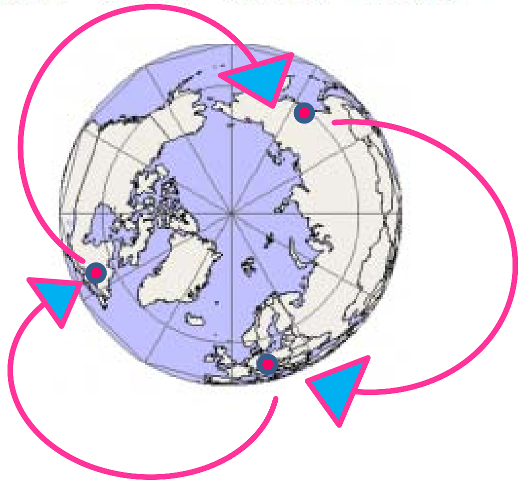

Introduction

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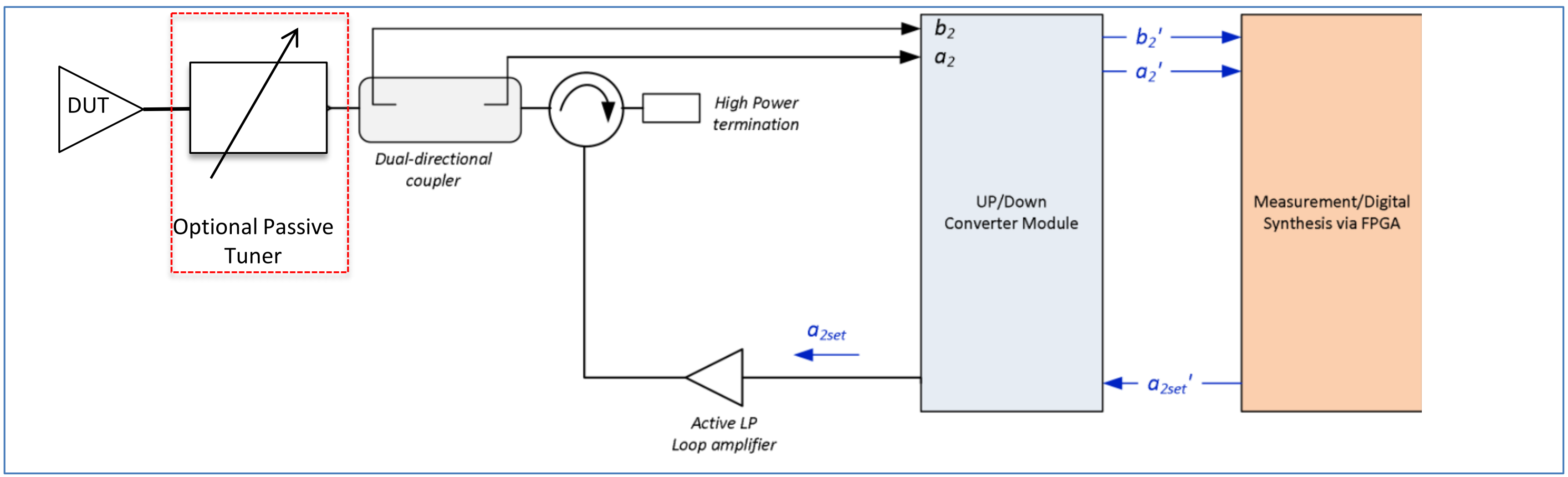
System Description

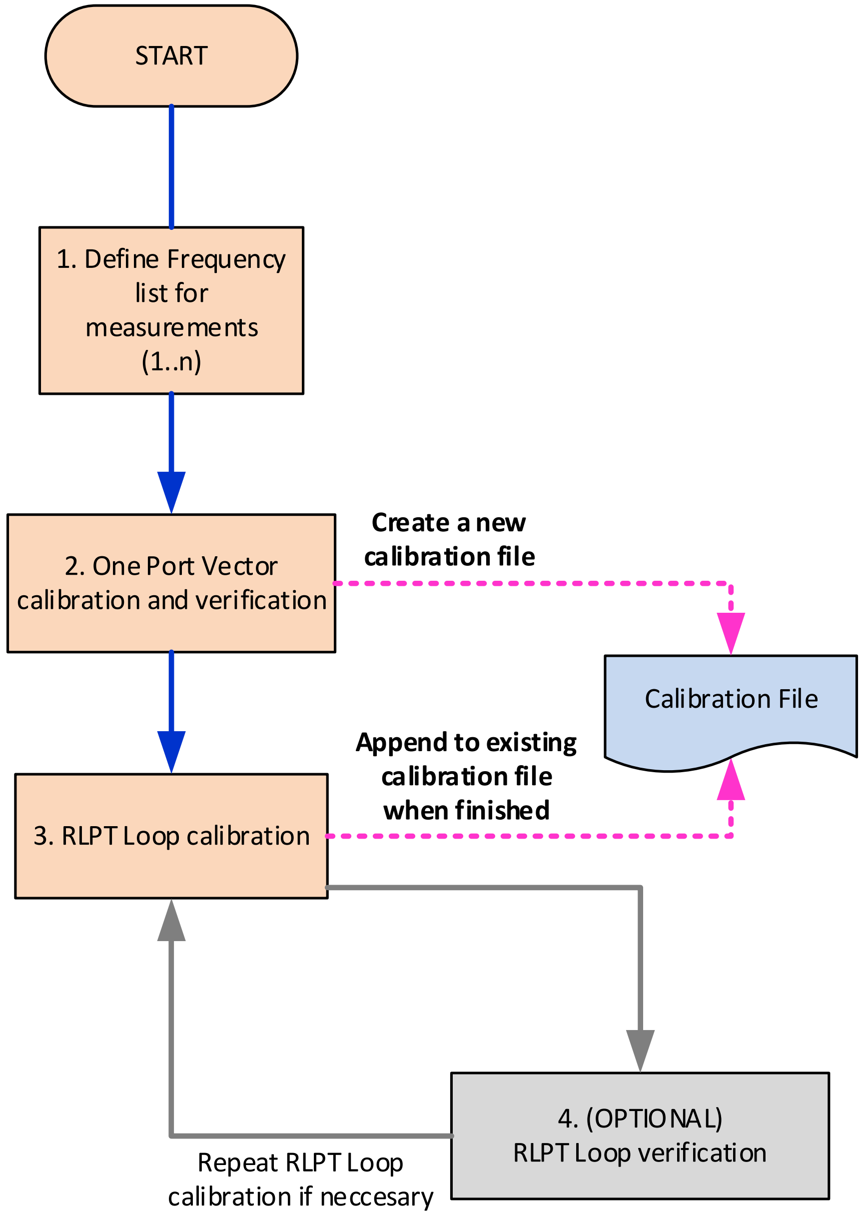
System Description

- The Rapid Load-pull Tuner (RAPID) is a programmable digital, PXI-based, feedback active load-pull tuner that maximizes throughput of a load-pull bench.
- The output port of the DUT is fed via a dual-directional coupler to a down converter module.
- The base-band data is then processed in an FPGA module and sent to the up converter to form the injected signal.



As the system contains two RF receivers it can accurately measure power and impedance removing the need for power meter and/or VNA in the load-pull test bench.

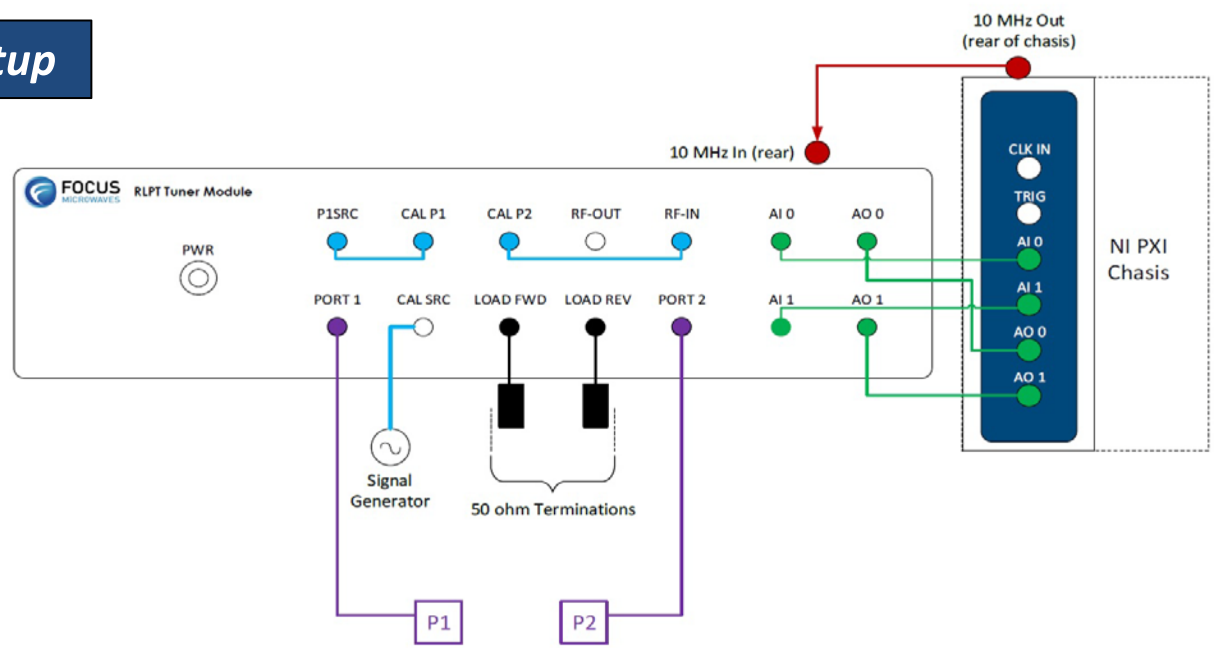
Calibration of the RAPID



S-Parameter & Power Calibration

- The system can measure the forward and reverse travelling waves, so unlike a passive tuner calibration, there is **no requirement for an external VNA**.
- The first step is therefore to perform a one or two port VNA calibration, this is performed as a standard **SOL, SOLT, or TRL** cal at the desired reference plane.
- A power meter can then be used to calibrate for accurate power measurements, by attaching a **power meter to the reference plane**.

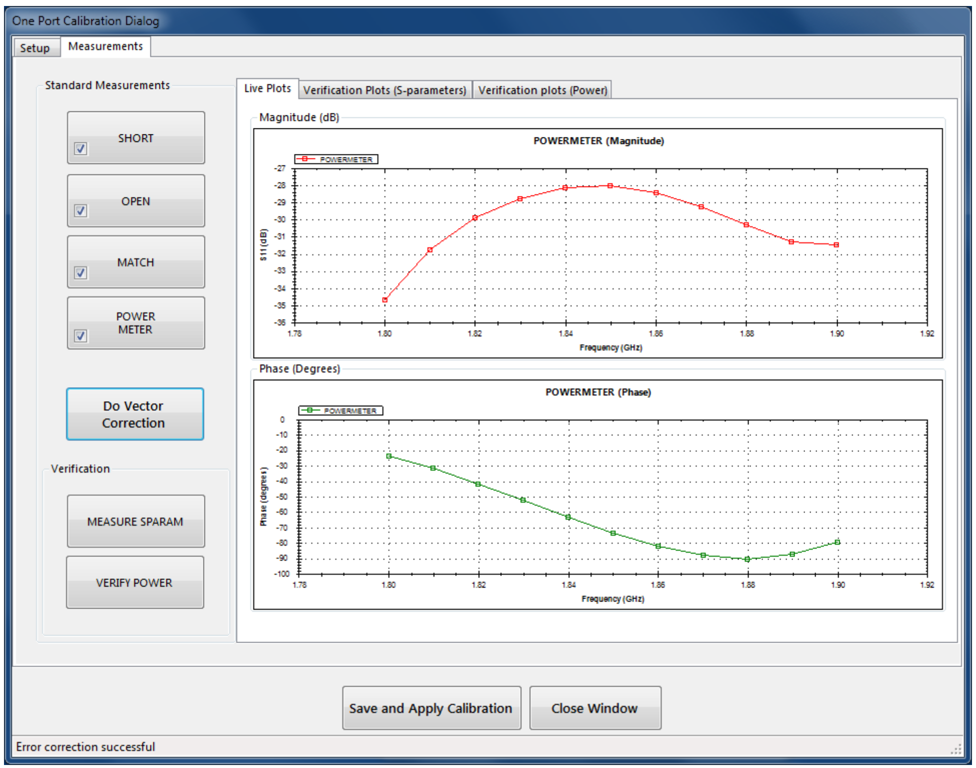
Hardware setup

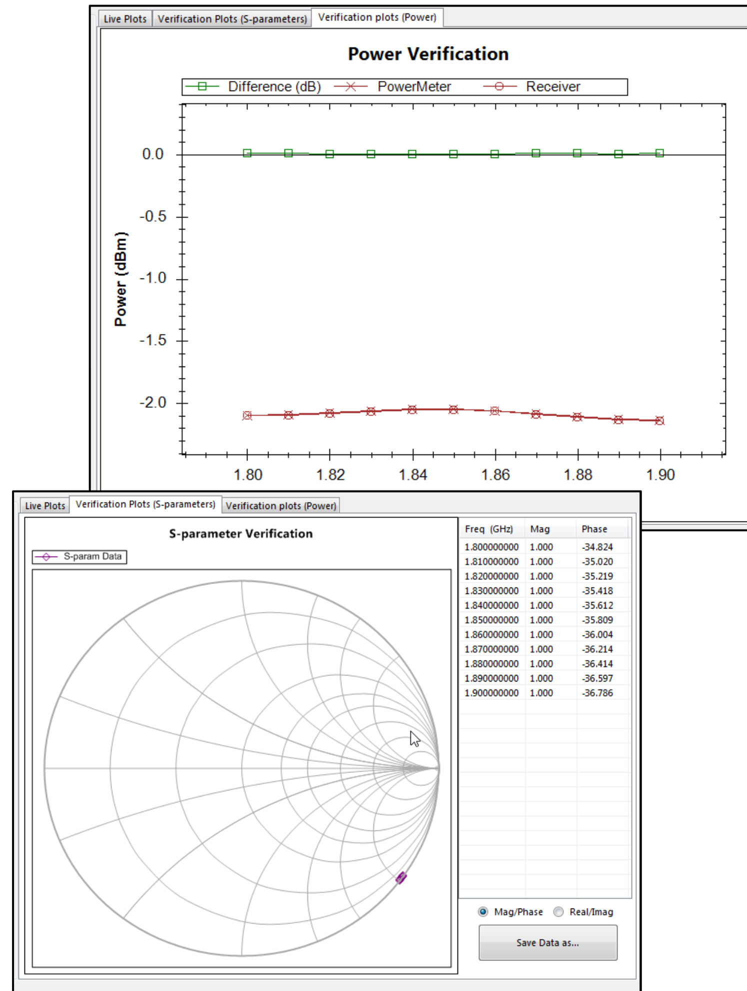


S-Parameter/Power Calibration

- The RAPID calibration utility offers a guided one-port calibration with built-in verification tools for power and s-parameter measurements.

RAPID Calibration Utility

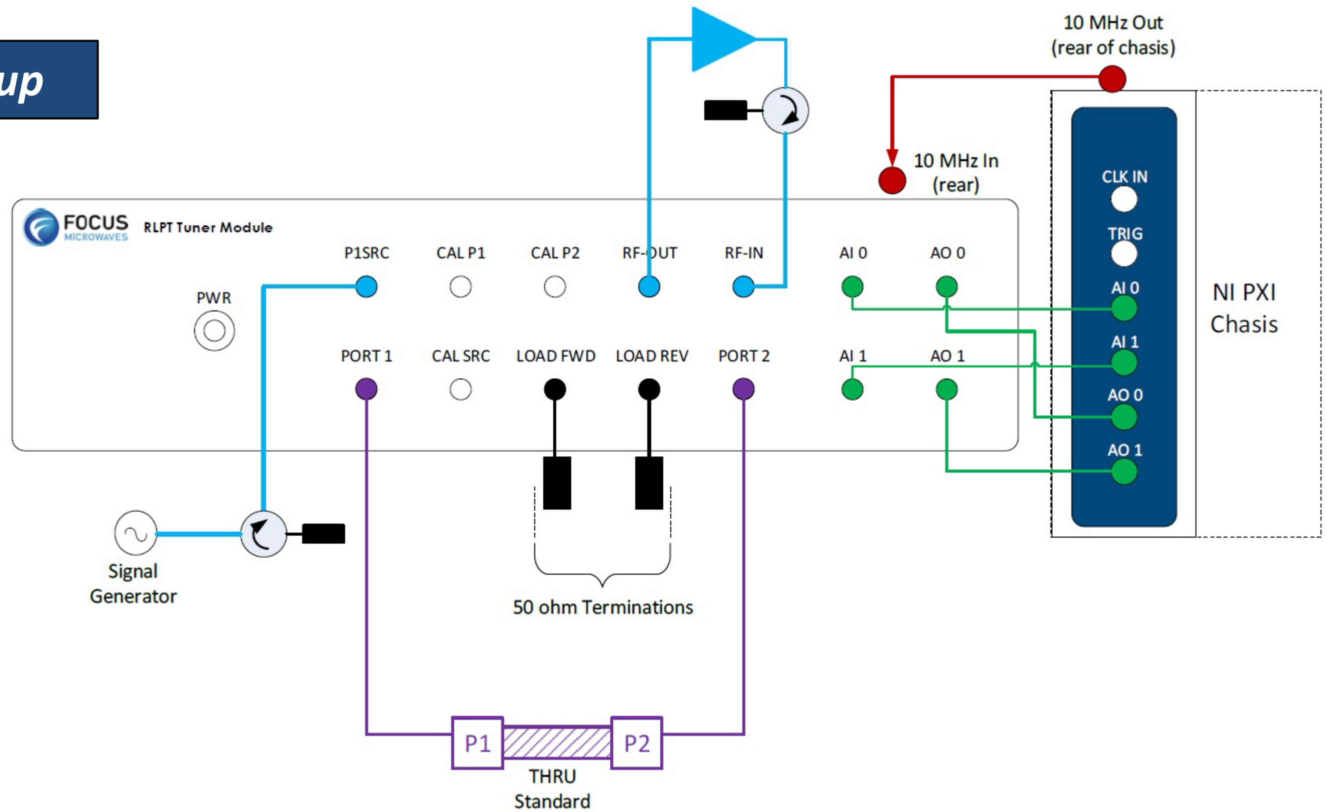




RAPID Loop Calibration

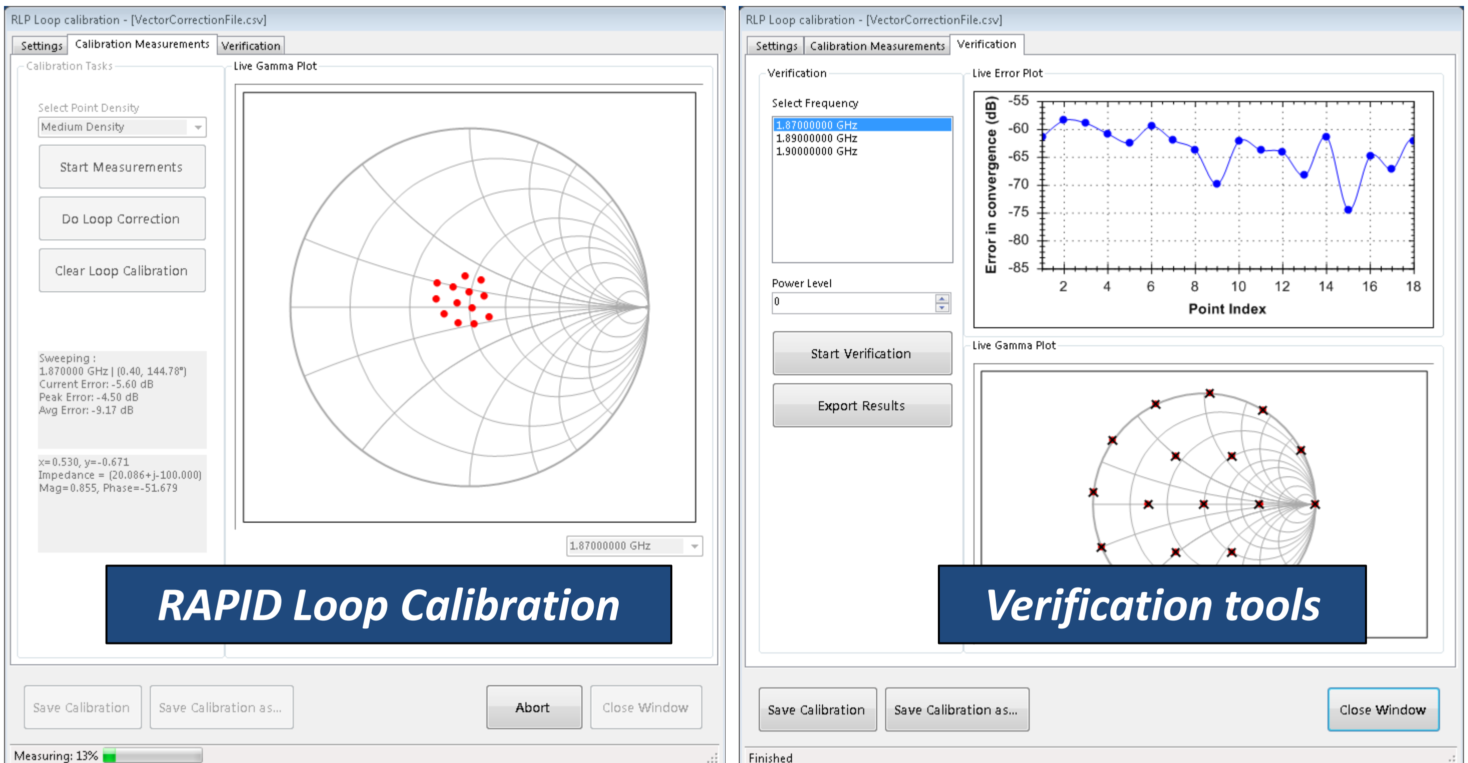
- The loop calibration must be performed before attaching the device.
- It is used to calculate the error coefficients associated with the feedback loop.
- Once these error coefficients have been found the user can accurately set any impedance on the smith chart **without the need for interpolation**.

Hardware setup



RAPID Loop Calibration

- The loop calibration is **an automated process** and the calibration coefficients are calculated and saved within the RAPID loop calibration module of the RAPID Automation suite software.
- The software also includes a **verification step** to test the accuracy of the loop calibration.

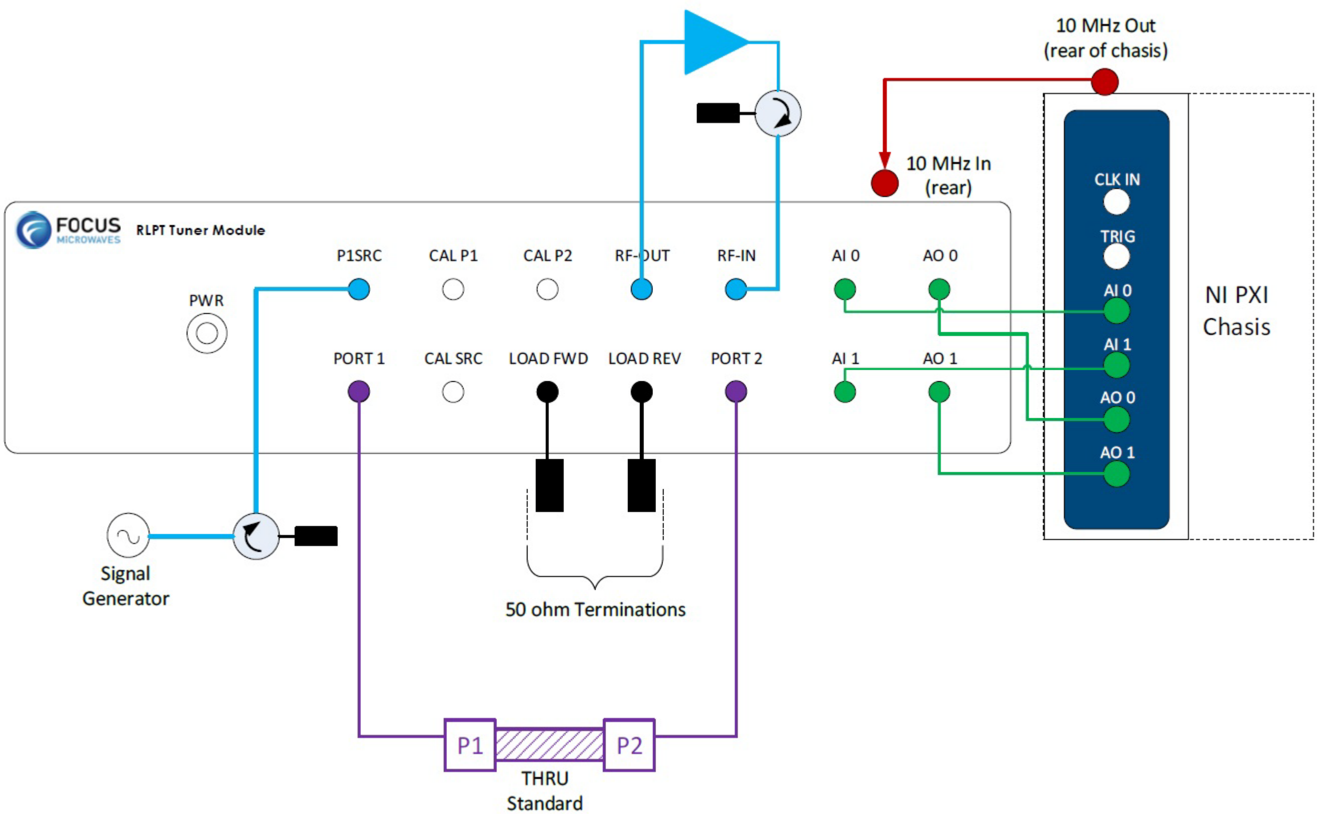


Tuning Accuracy

Active Load-Pull Measurements

Ability to Control Gamma Load

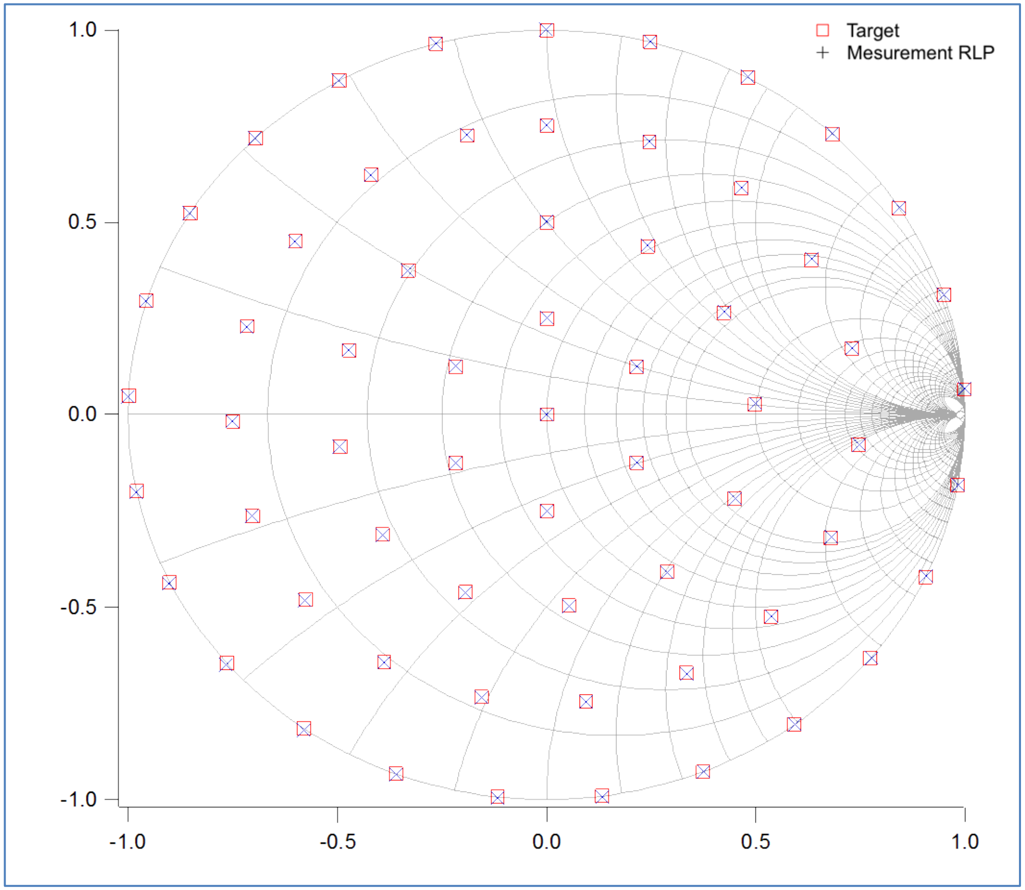
- After running the loop calibration, verification measurements are carried out with impedance measured by the rapid hardware.
- A power amplifier is included as part of the loop.

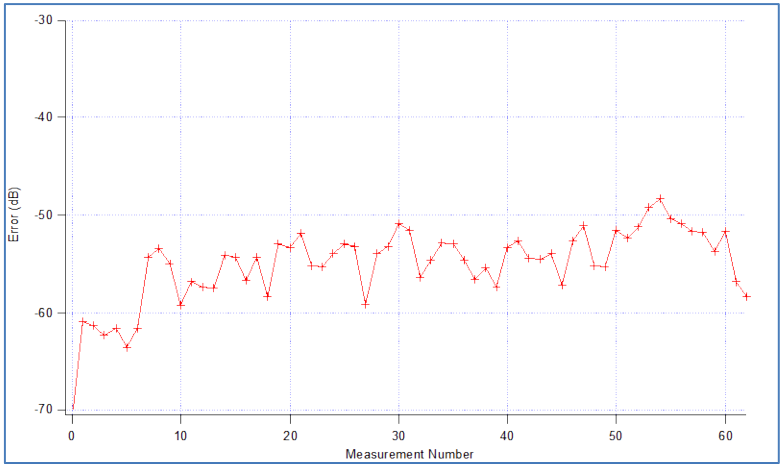


Active Load-Pull Measurements

Ability to Control Gamma Load

- The following plots show the error between target and achieved impedance.



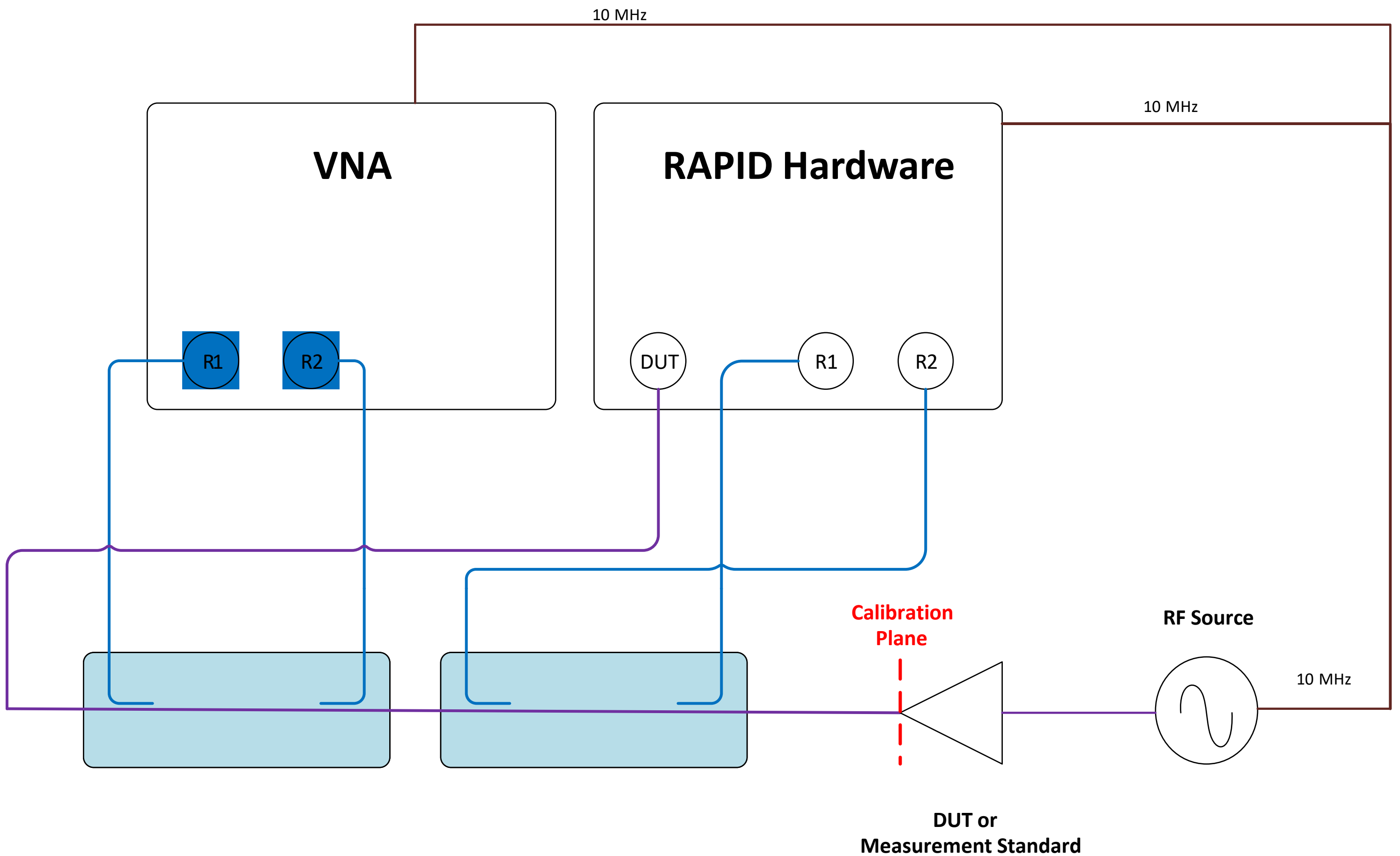


Excellent agreement between set and measured impedance

****Note Passive tuners are generally specified to >40dB repeatability***

Comparison to Commercial VNA

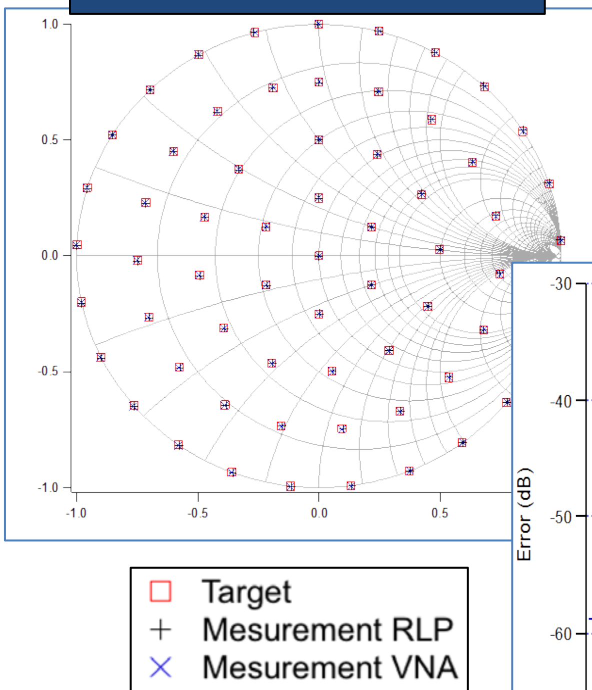
- Measurement Configuration is shown below.
- VNA and RAPID are calibrated at the same reference plane for direct comparison of measured s-parameters



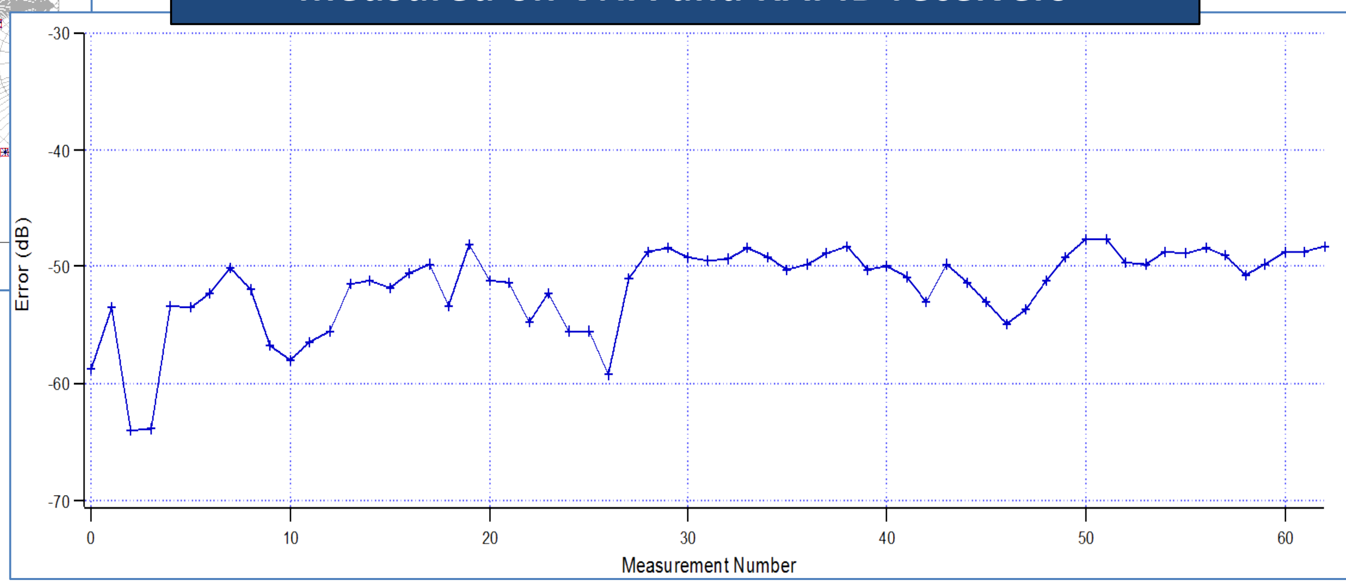
Comparison to Commercial VNA

- Here we show the difference between ZVA and RAPID measurements both on the Smith chart and expressed as error in dB-scale format.

Smith Chart view



Error values (in dB) when comparing Gamma measured on VNA and RAPID receivers

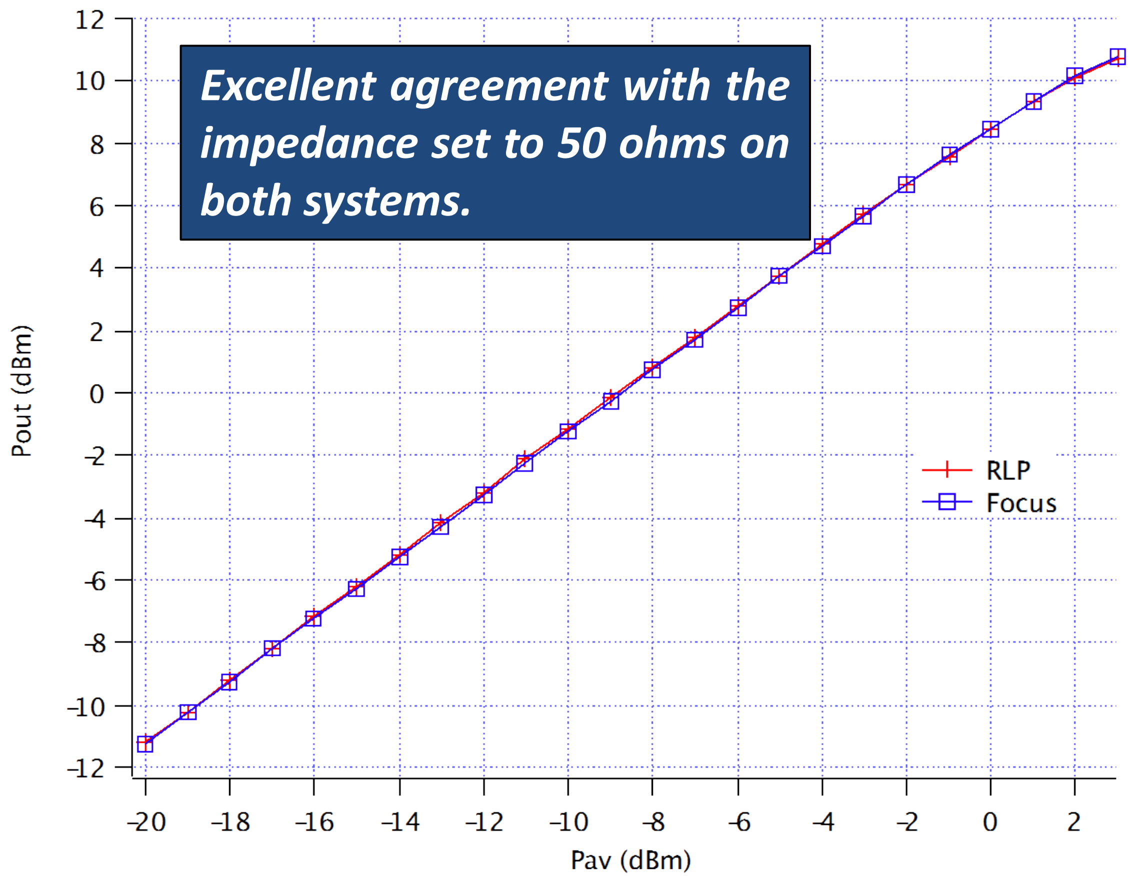


Device Testing

* Note No Source tuning has been performed during testing. The device is a 50 ohm matched part.

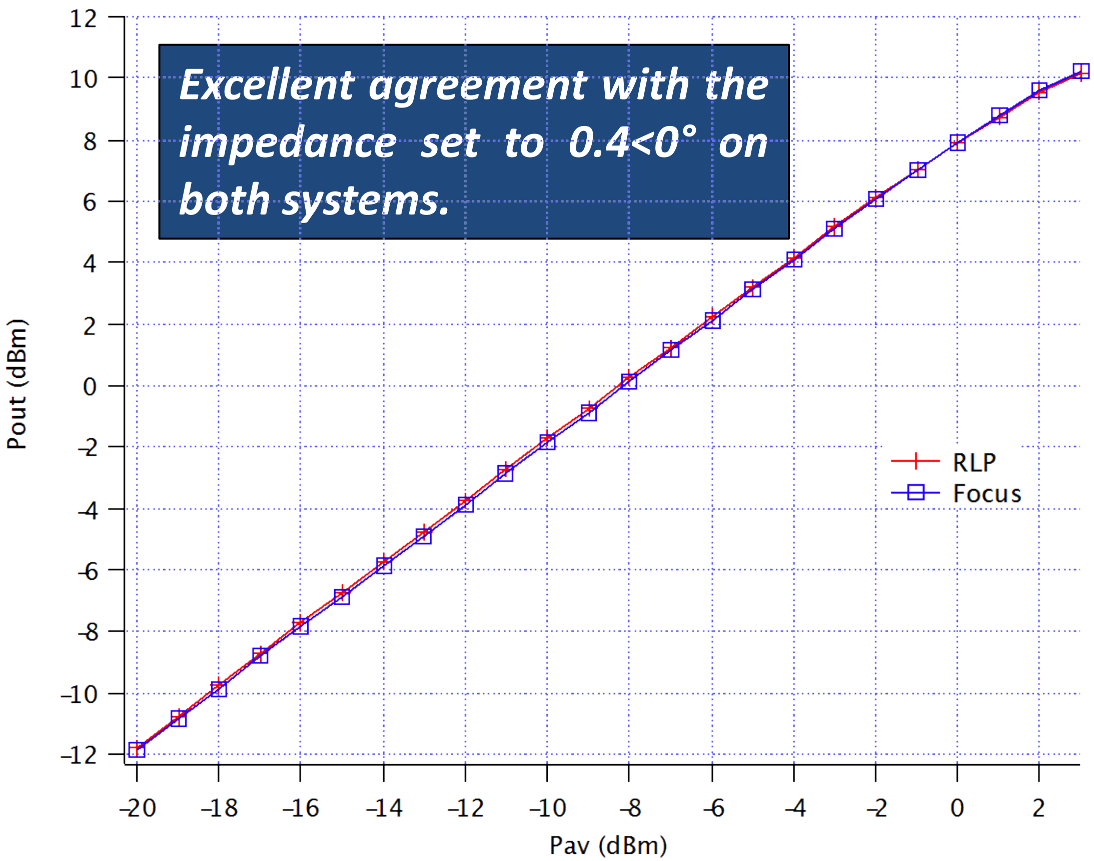
50 Ohm power-Sweep: *Focus Passive to RAPID*

- This comparison measurement shows results of a 50 ohm power sweep conducted with a Focus passive load-pull system with integrated power meter behind the tuner and the RAPID unit with the power measurement performed within the calibrated unit.



Power-Sweep at 0.4<0°: *Focus Passive to RAPID*

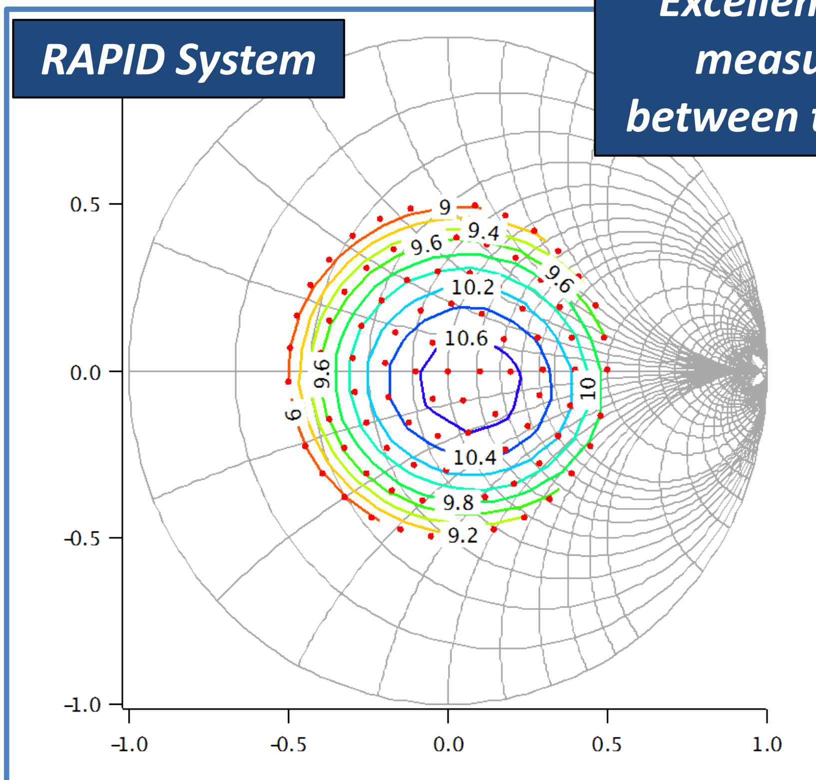
- This comparison measurement shows results of a power sweep at a non-50 ohm load-pull position conducted with a Focus passive load-pull system with integrated power meter behind the tuner and the RAPID unit with the power measurement performed within the calibrated unit.

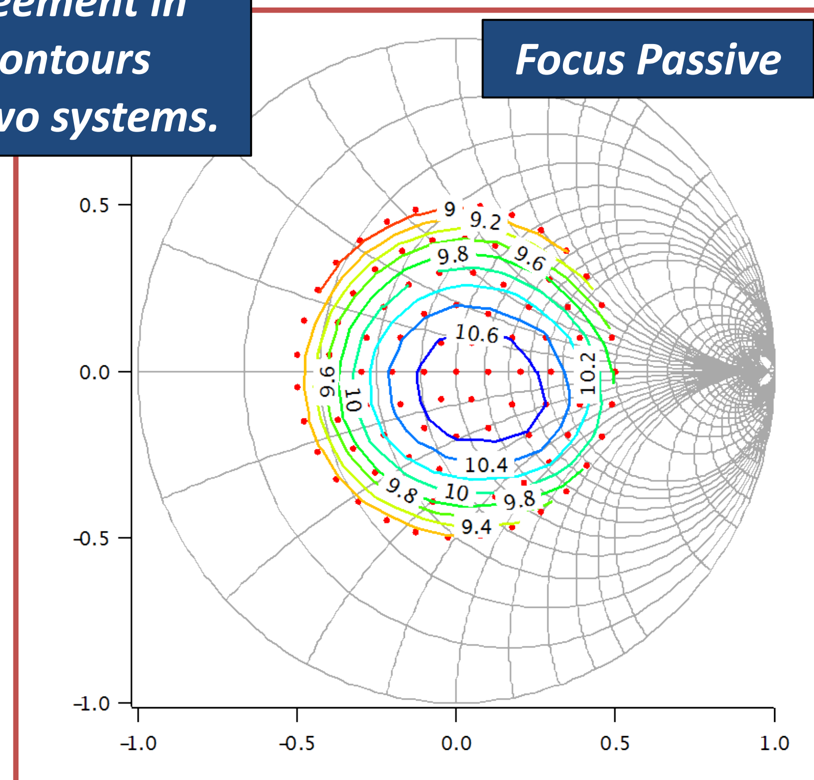


Measured Contours: *Focus Passive to RAPID*

- Next a power contour is plotted from the data from each of the systems.
- Measurement was performed for a constant available power of 3dBm.

Excellent agreement in measured contours between the two systems.





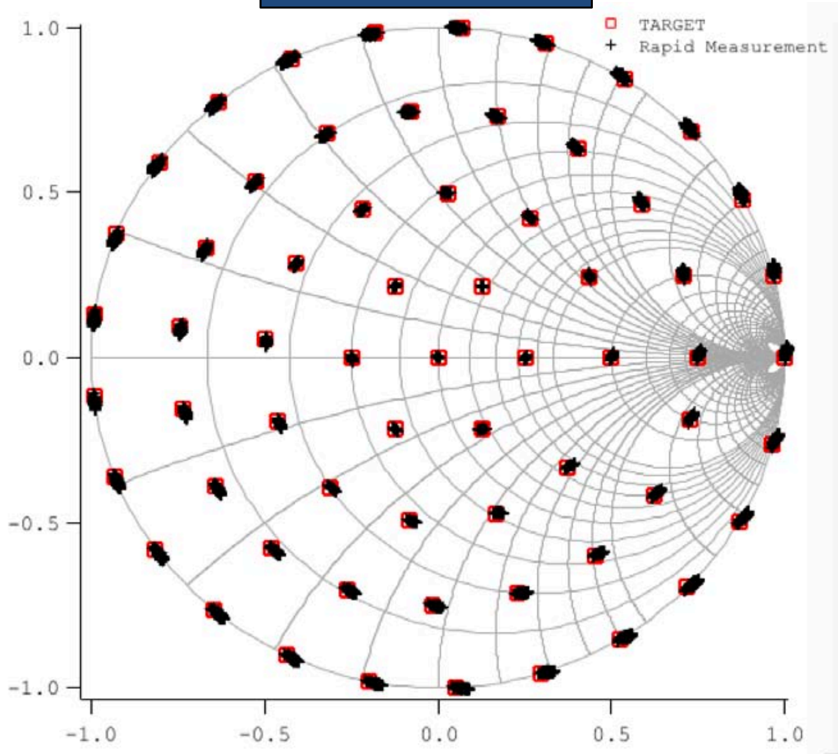
Long Term Testing

(Raw Performance)

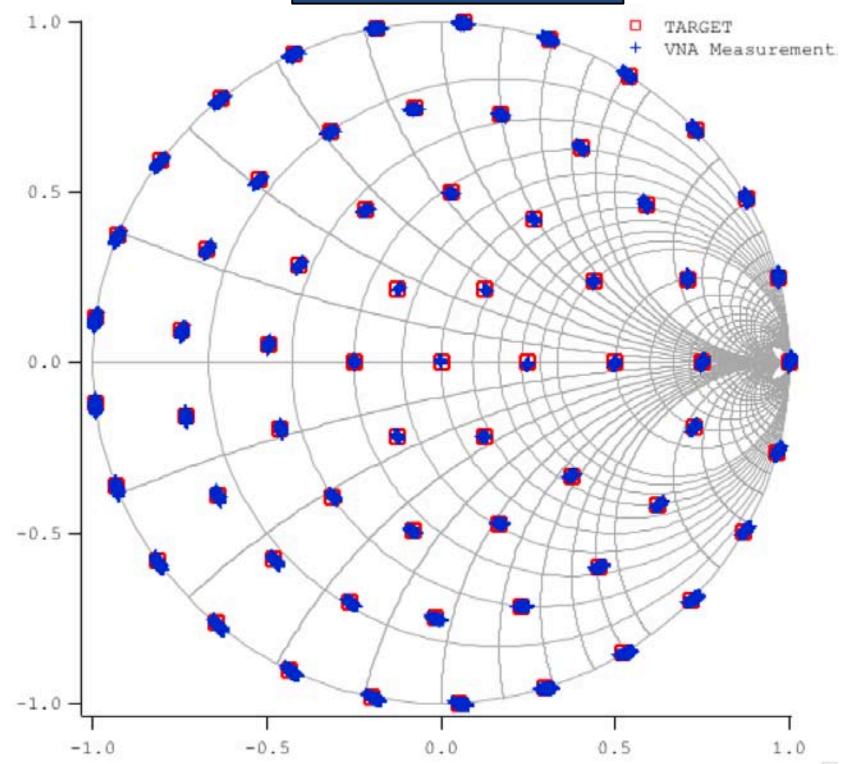
Active Load-Pull: *Long Term Test (1)*

- Long term test plan was to run a grid of 62 impedances covering the smith chart, over a power range of 30dB in 1 dB steps every 30 minutes for a period of 48 Hours.
- The results shown on a Smith chart for the entire sweep of **130,000 measurements** with a ZVA-8 VNA and the rapid system are shown below. No live correction is employed.

RAPID System

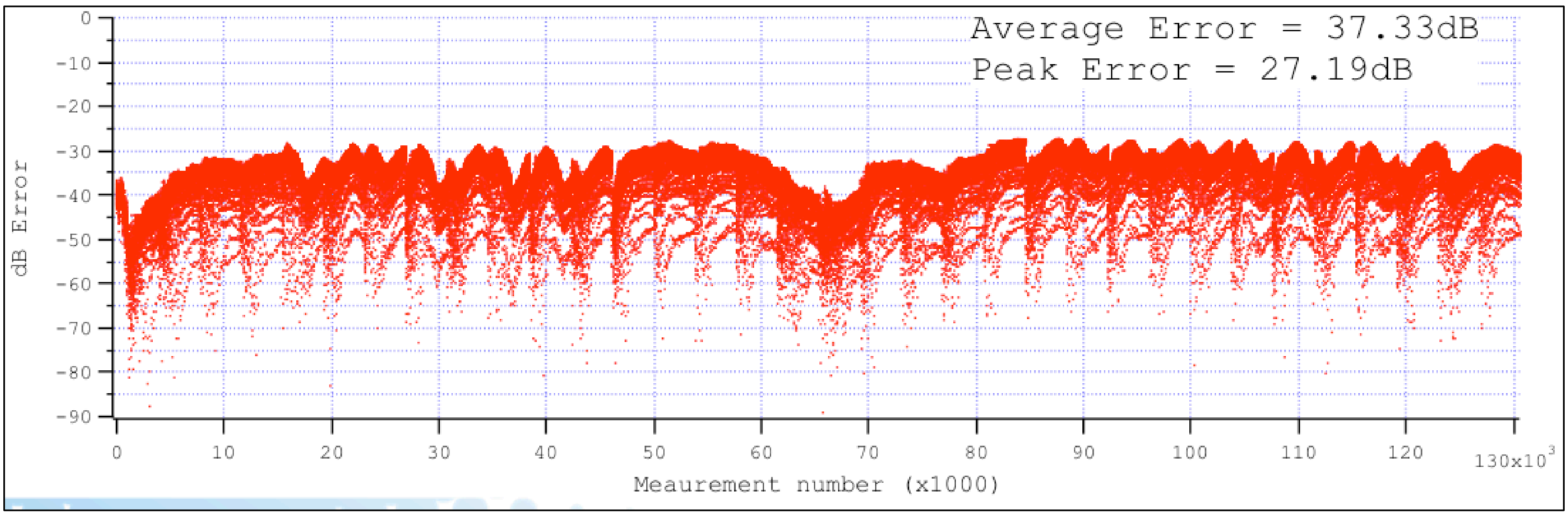


VNA



Active Load-Pull: *Long Term Test (2)*

- Plot below shows the difference in dBs between the target and measured impedance using the RAPID hardware.



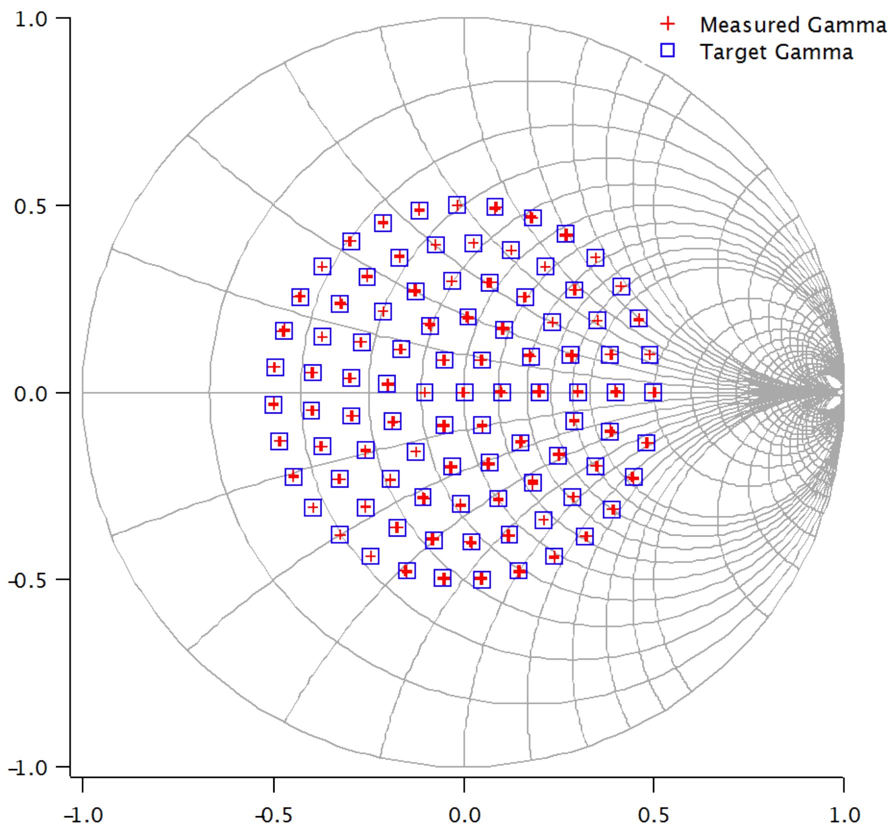
Long Term Device Testing

With Live correction

Long Term Stability

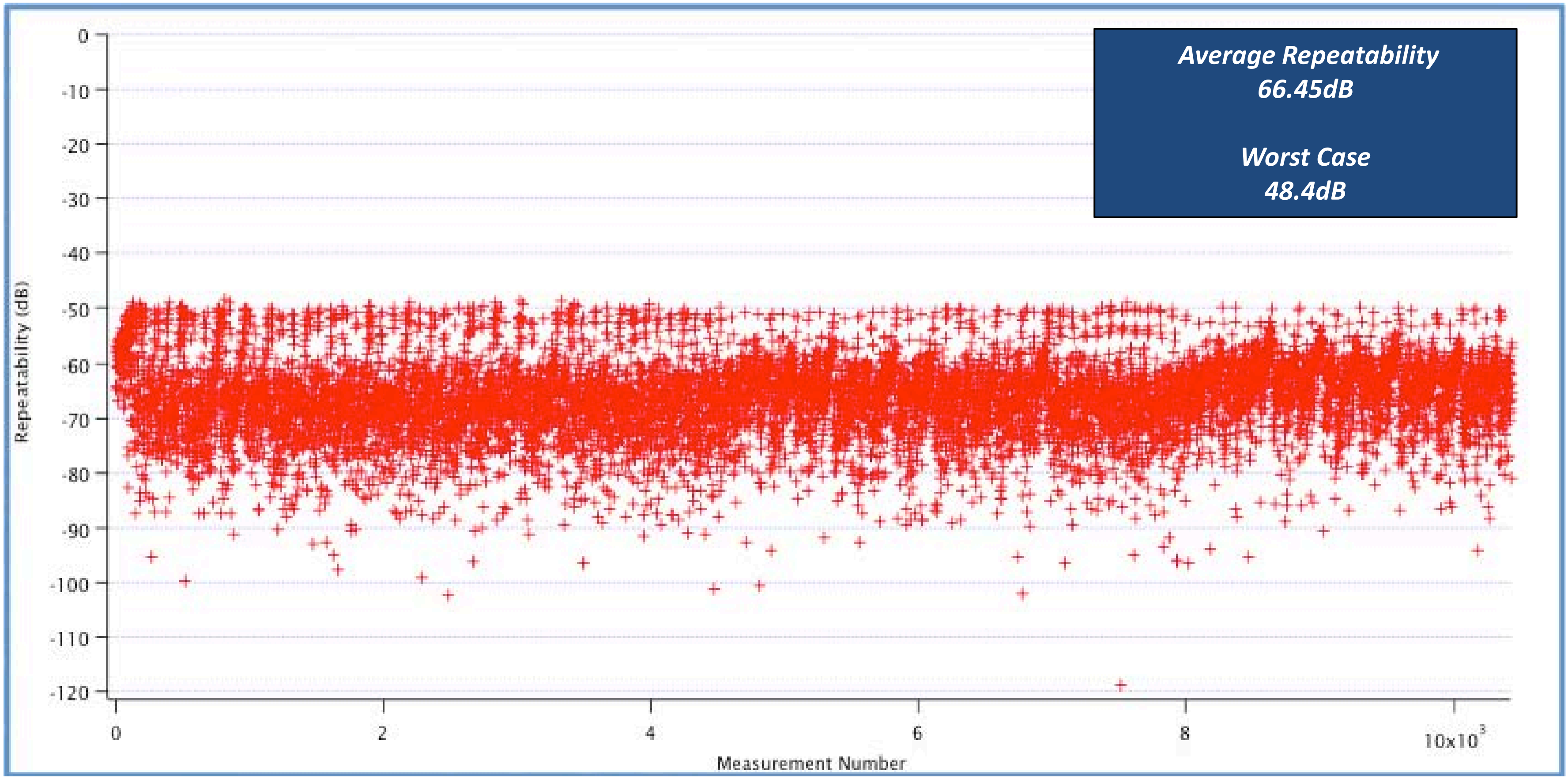
65 Hour Test (with live correction)

- The test is now repeated, this time with a DUT present
- Power and impedance were swept for a 65 hour period, this time we employ the live correction.
- Desired tolerance is set to 50dB.



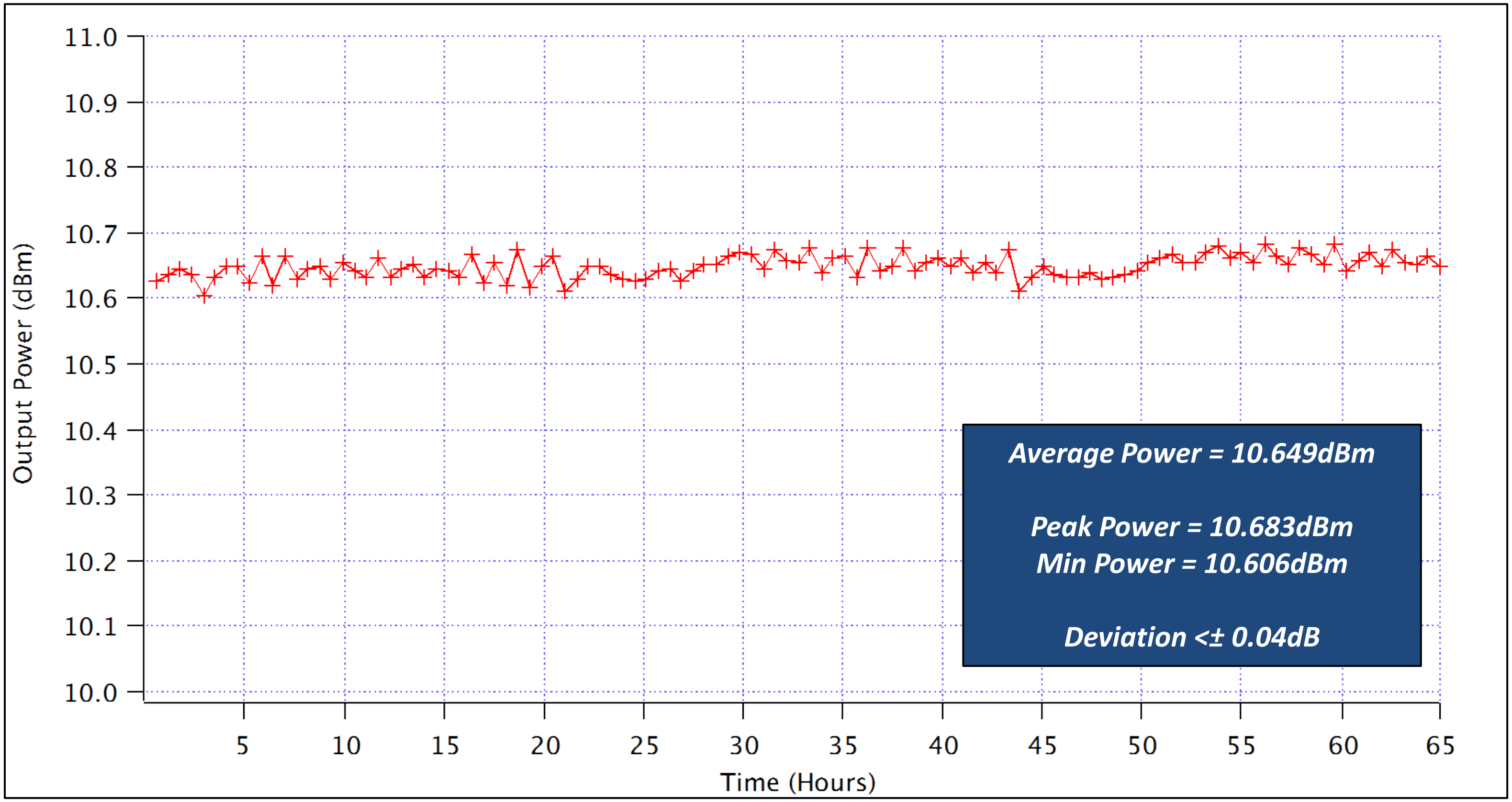
Long Term Load Stability: *65 Hour Test*

- With live correction employed it is clear that a much more accurate impedance can be obtained under long term tests..



Stability of Power Measurement – 65 Hour Test

- During the same test this looks at stability of Power measurement.
- Plot below shows power measured at the optimum impedance with a measurement every 30 minutes for a period of 65 hours.



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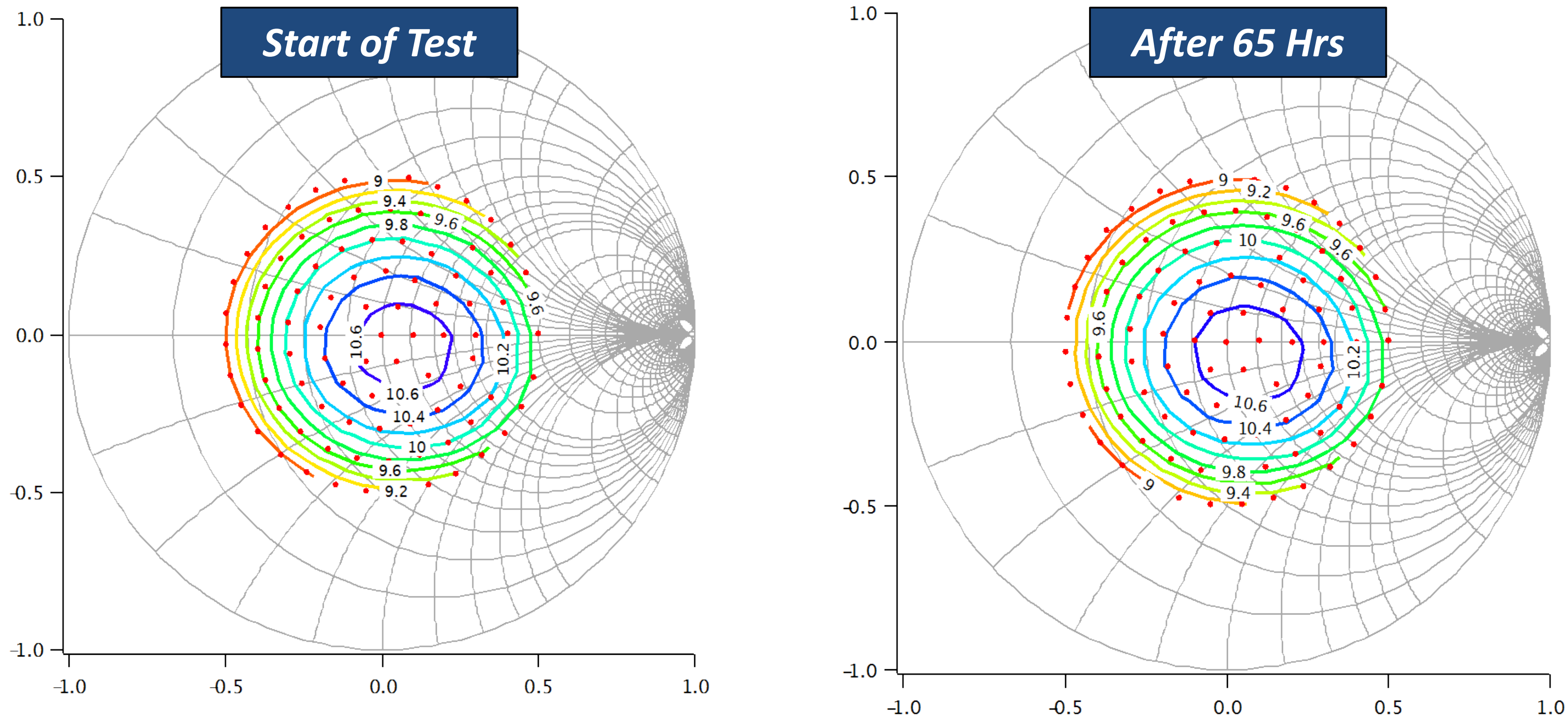
Contour plots, Before and After 65 Hour Test

- Another way to look at drift in the measurement is to look at measured power contours at the start and at the end of testing, as shown below no drift is seen.



Measurement Speed

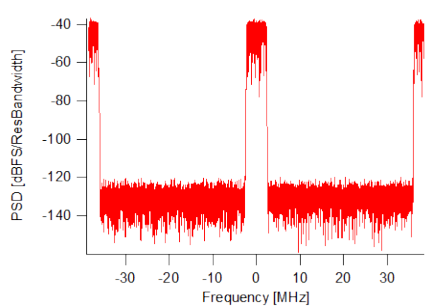
Measurement Speed

- The speed of a CW load pull is approximately: 5 ms per load synthesized at 1k IFBW (200 points/second). This includes impedance synthesis and output power measurement.
- The above time increases to approximately 15 ms per point when using full vector correction load pull (input and output DUT measurements: a1, b1, a2, b2). From these measurements power gain, gammaIn, gammaLoad, output power, delivered input power, and AM/PM can all be calculated.
- Using full NI-PXI based instrumentation (including source and DC measurement), and full vector correction load pull power measurements, the DUT efficiency can also be determined. This increases the total time per load pull point to approximately 19-20 ms (50 points/second).

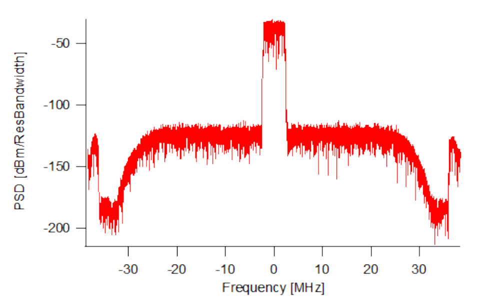
Modulated Capability

Modulated Measurements

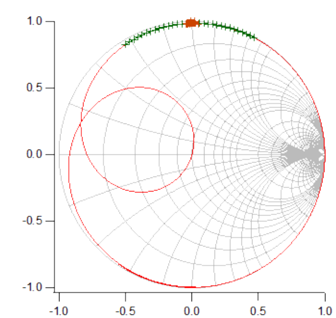
- As the active loop has 100MHz of instantaneous bandwidth it is also possible to perform real time modulated measurements.
- There are two main applications for this outlined below:
  1. **Full Active Solution**
     - Ability to present a constant static wide-band load over a full modulated bandwidth.
     - Ability to emulate a real matching circuit over a wide bandwidth.
  2. **Hybrid Solution**
     - Ability to De-skew impedance over the full modulated band.
     - Ability to emulate a real matching circuit over a wide bandwidth.



Measured Signal



Injected Signal



Circuit Emulation

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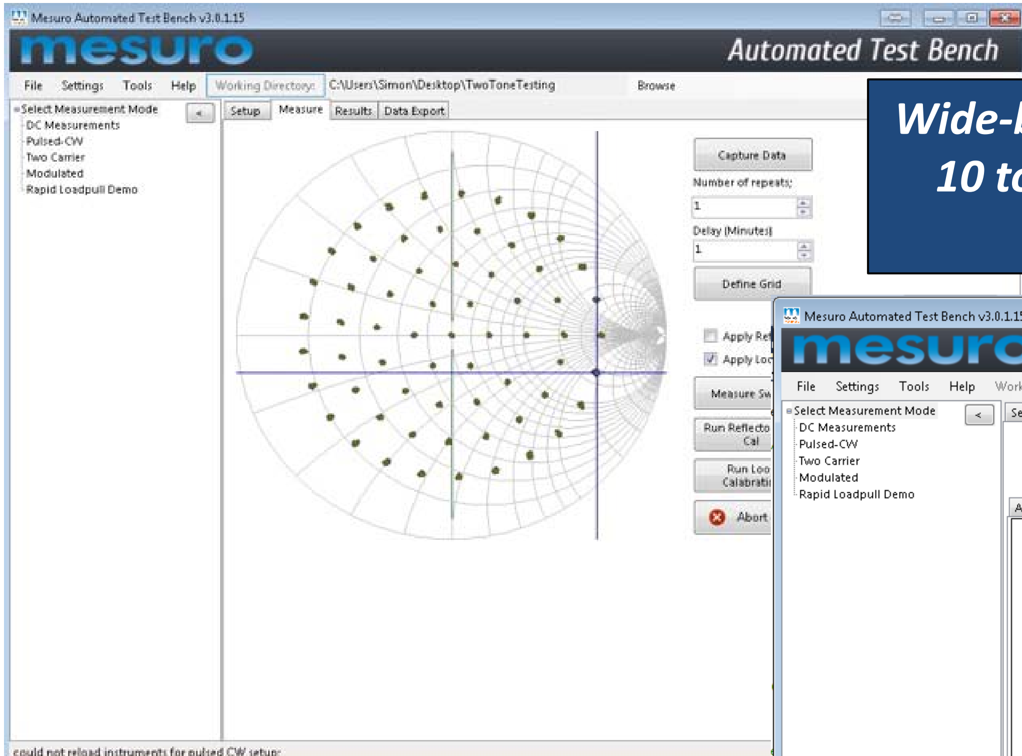
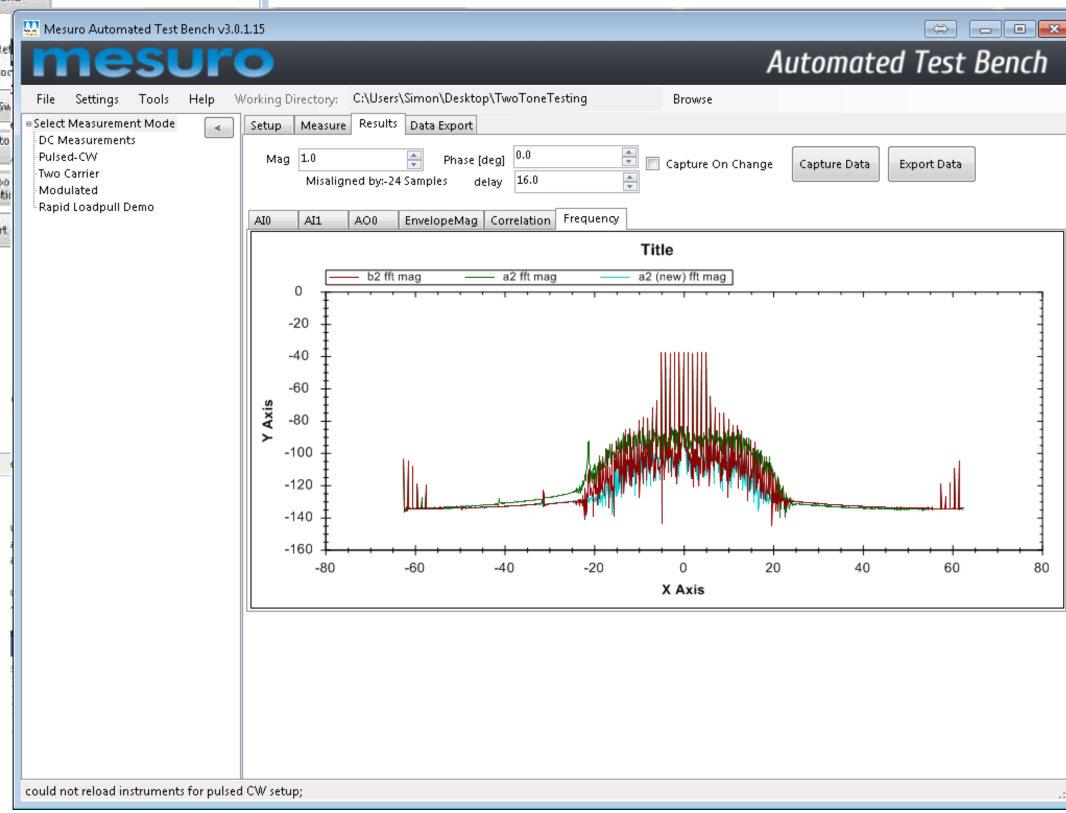
Modulated Measurements

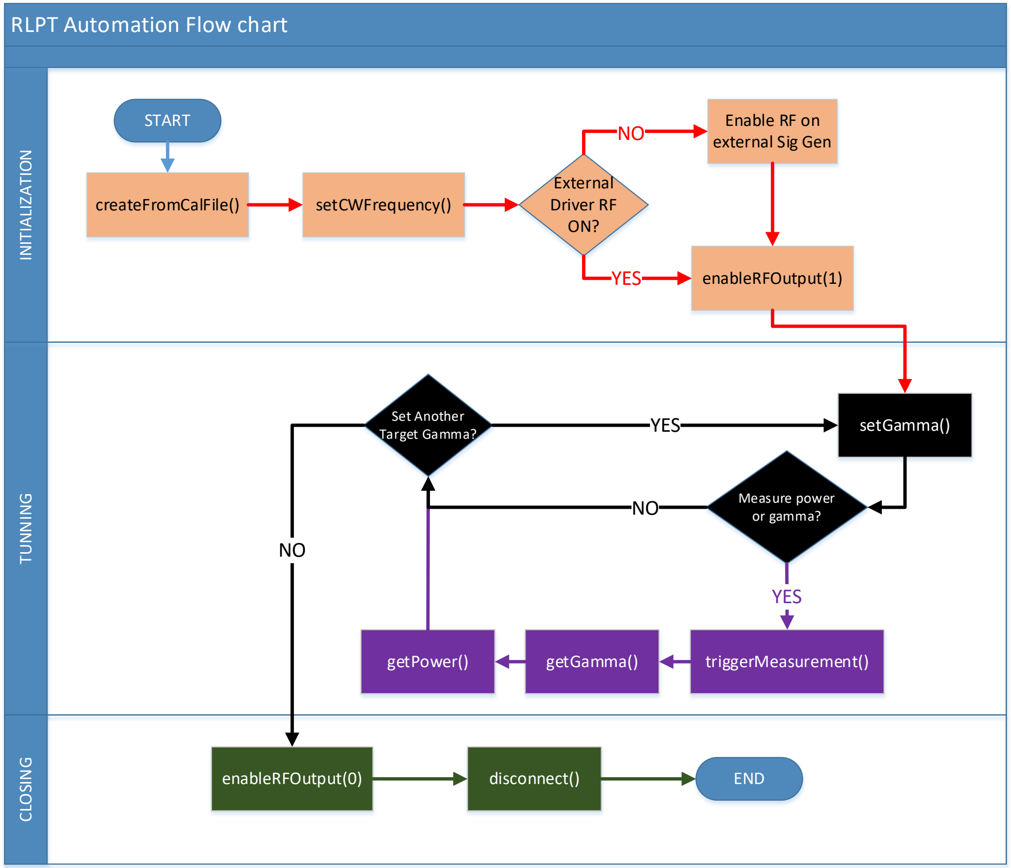
Wide-band impedance over swept impedance, 10 tones 1MHz steps. Constant impedance held over 10MHz Bandwidth.





API and Programmability

- The Focus RAPID Automation Suite software contains a fully documented impedance control library available to use on the client PC using ActiveX and Microsoft .NET framework DLLs.
- The library is thus compatible with most modern programming platforms e.g.
    - NI Lab View
    - Microsoft Visual Studio: C#, C++, Visual Basic
    - MATLAB
    - etc
- This allows the user to programmatically move the tuner to any impedance and de-embed to the DUT reference plane.



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Conclusion

- The RAPID system is an advanced load-pull tuner that can replace the passive tuner and some measurement equipment in your load-pull bench.
- We have shown the ability to accurately measure impedance and power, even over long periods of time (tested up to 65 hours).
- CW measurement speed (50-200 pts/second depending on measurement complexity), is orders of magnitude faster than existing load-pull techniques.
- System is also suitable for modulated measurements with 100MHz of instantaneous bandwidth offering the ability to de-skew passive measurements, present wide-band active loads and/or emulate circuits over modulated bandwidth.
- A full programming library (API), compatible with most modern programming environments is available for tuner automation.

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