Improving Probe-Tip S-parameters Measurements with Power Calibrations

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Agenda

- Market Trends
- Quick Recap of S-parameters Measurements
- Current Practices for Wafer-level RF Measurements & Challenges
- Proposed Probe-tip S-parameter + Power calibration
- Summary

Market Trends

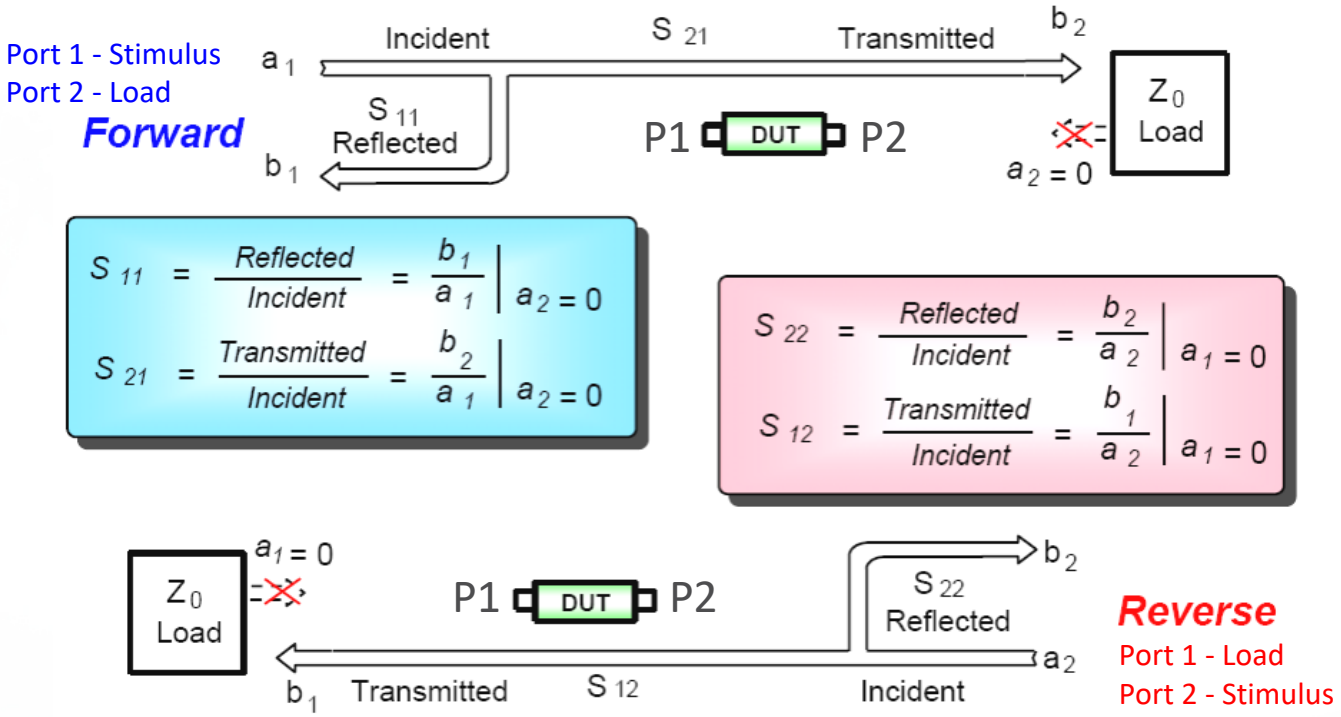
- 5G will dominate RF device growth
  - Not just for mobile comms but for
    - IoT, eHealth, Transportation, Industrial Machine Control & more
  - Higher Operating Frequencies
    - 28 to 73 GHz
    - ↑ New 110 GHz Systems around the world
  - Important & Urgent to address Challenges in testing RF devices at these frequencies.

5G 2020

Very High Data rate
Very High Capacity
Reliable & Secure
Huge no. of Devices
Long Battery Life
Very Low latency
…
Everything
Everywhere
Connected

5G mobile wireless - Hugh Nicklin

Quick Recap of S-parameters Measurements



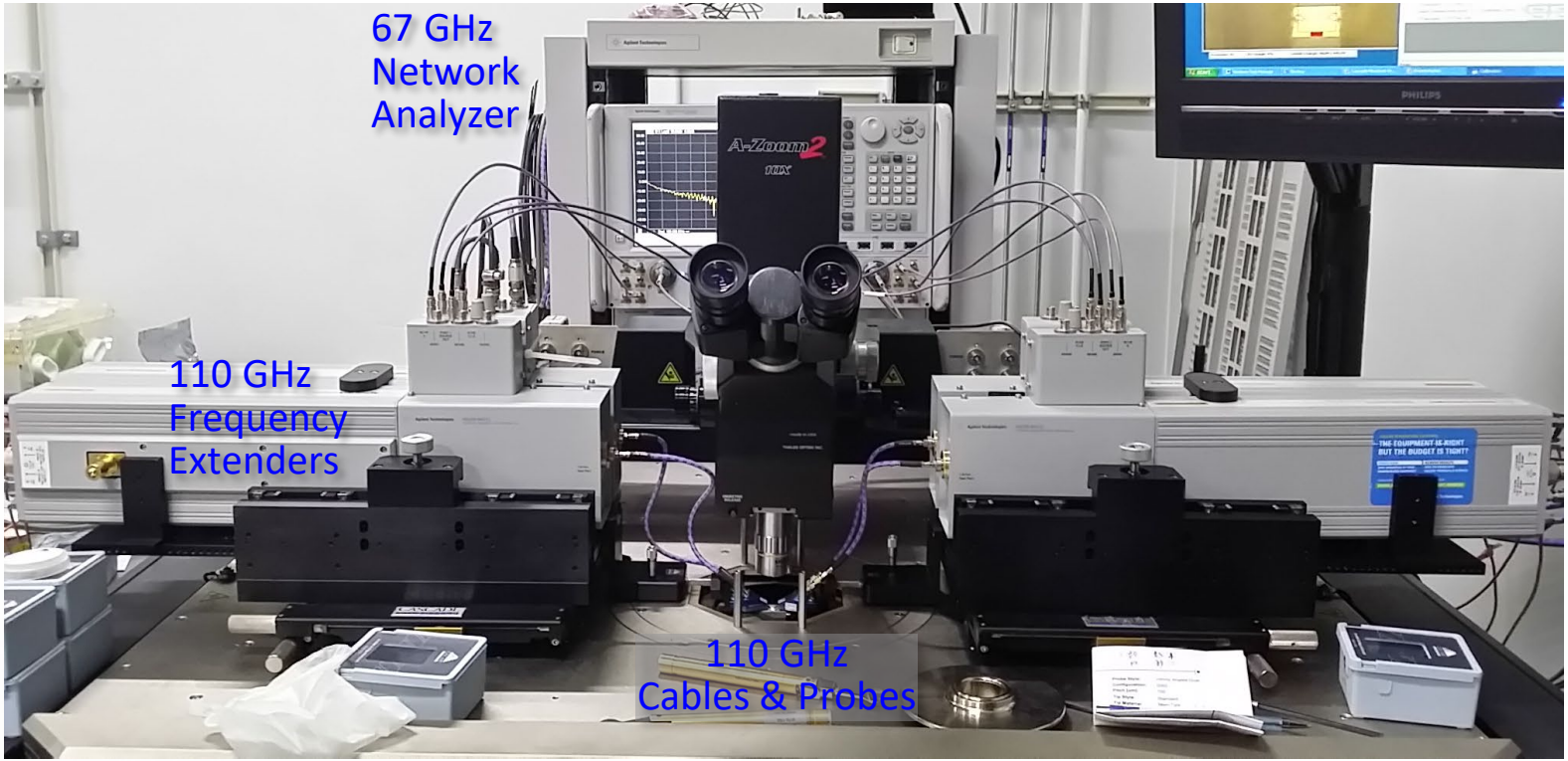
- S-parameters are relative and not absolute measurements!

Current Practices for Wafer-level RF Measurements & Challenges

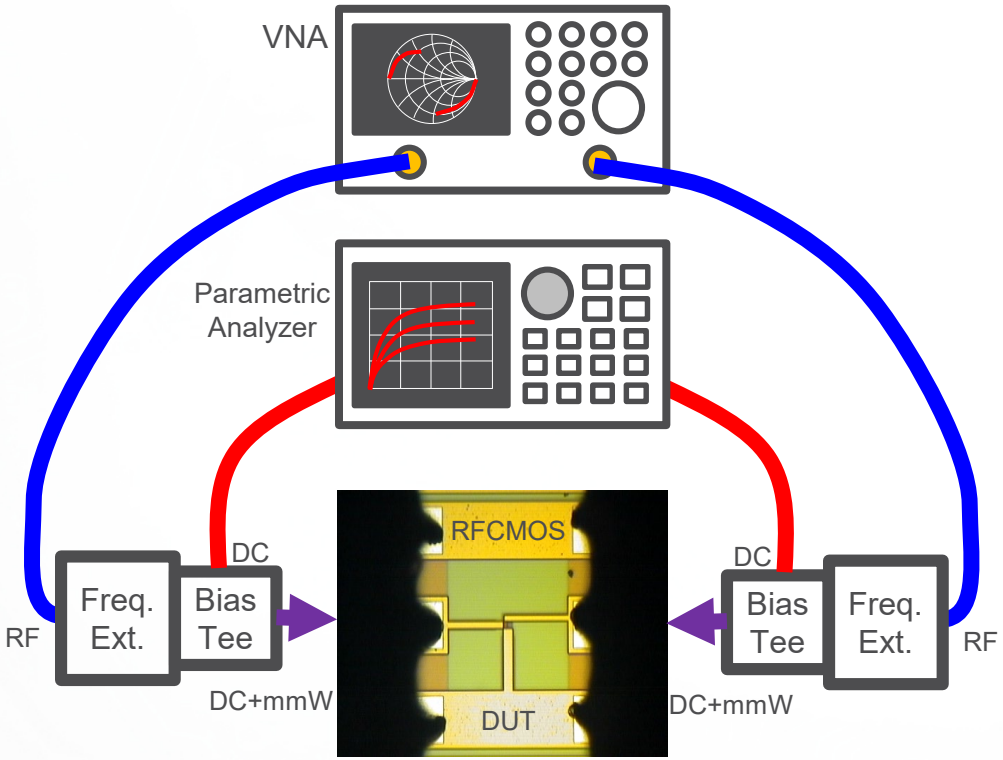
- Only Adopts S-parameter calibration
  - Since S-parameters are relative measurements, Probe-tip power calibration is redundant – or so we thought?
- Uncalibrated RF Source Power – Affects Accuracy
  - Large RF power, Stable Cal but Active Device's DC bias condition would be incorrect
  - Small RF power, Difficult to get a stable calibration

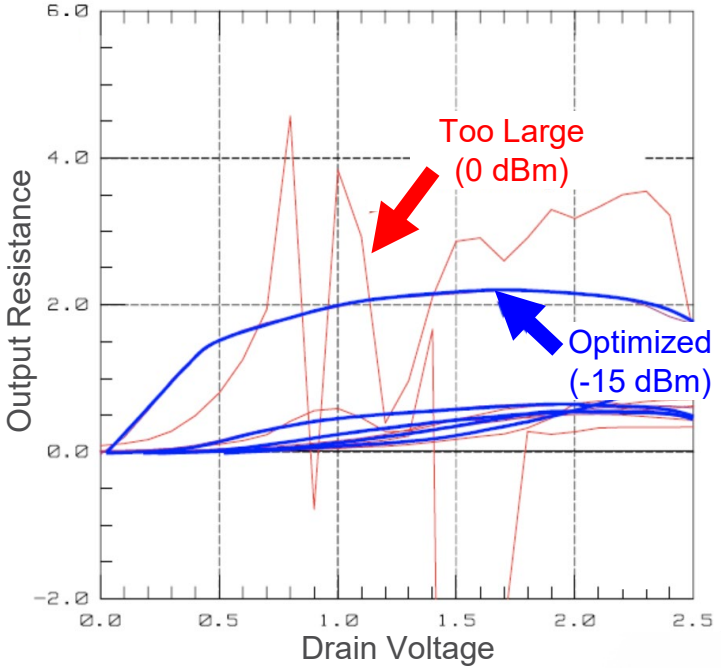
  ⇒ Need to Optimize RF power & make it Constant w.r.t. Frequency
- Post-Calibration Stability – How long a calibration state can lasts?
  - Affects Accuracy & Measurement Throughput
  - Environment & Cable lengths are often assumed to be primary root cause
    - Control Lab temperature/Humidity
    - Use Shortest cable possible
  - Optimizing VNA instrument settings eg Low IFBW of 5 Hz

Typical Single Sweep 110 GHz Probe System Setup



Implications of Inaccurate RF Source Power

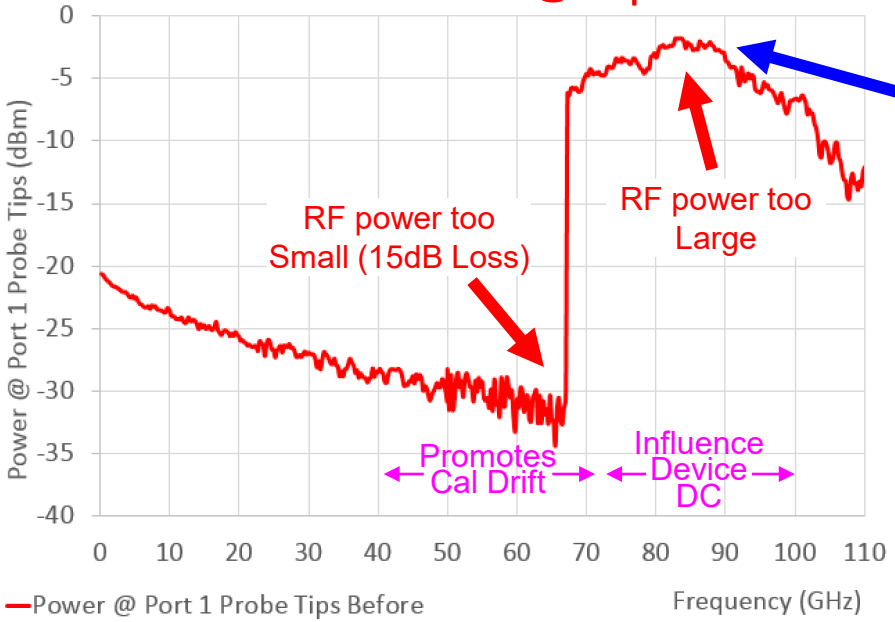




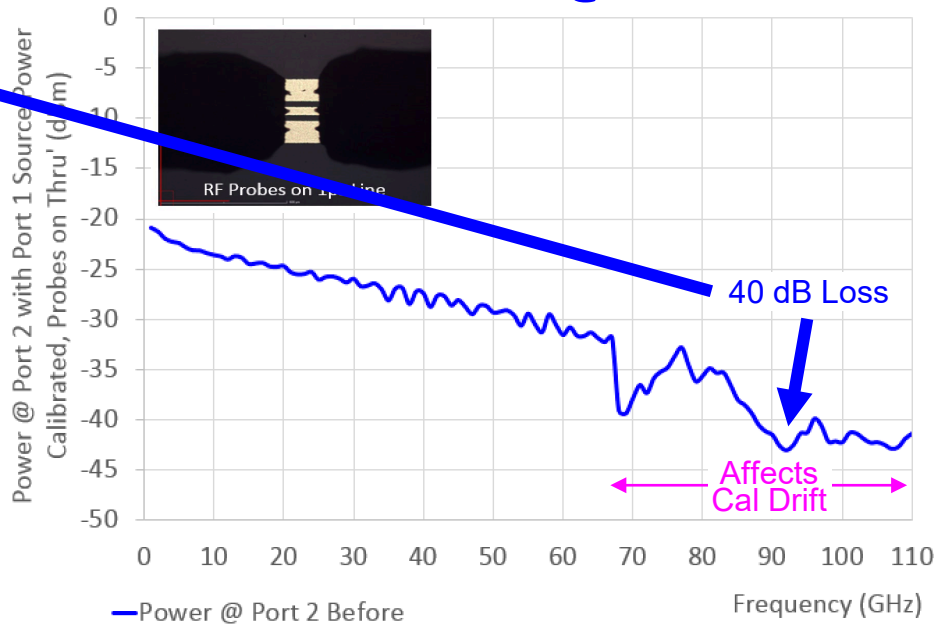
- With device scaling, $L_G \downarrow$, $V_T \downarrow$
  $\Rightarrow$ Optimal RF power $\downarrow$

Uncalibrated Probe Tip RF Source Power

Source Power @ Tips



Measured Power @ P2 Receiver

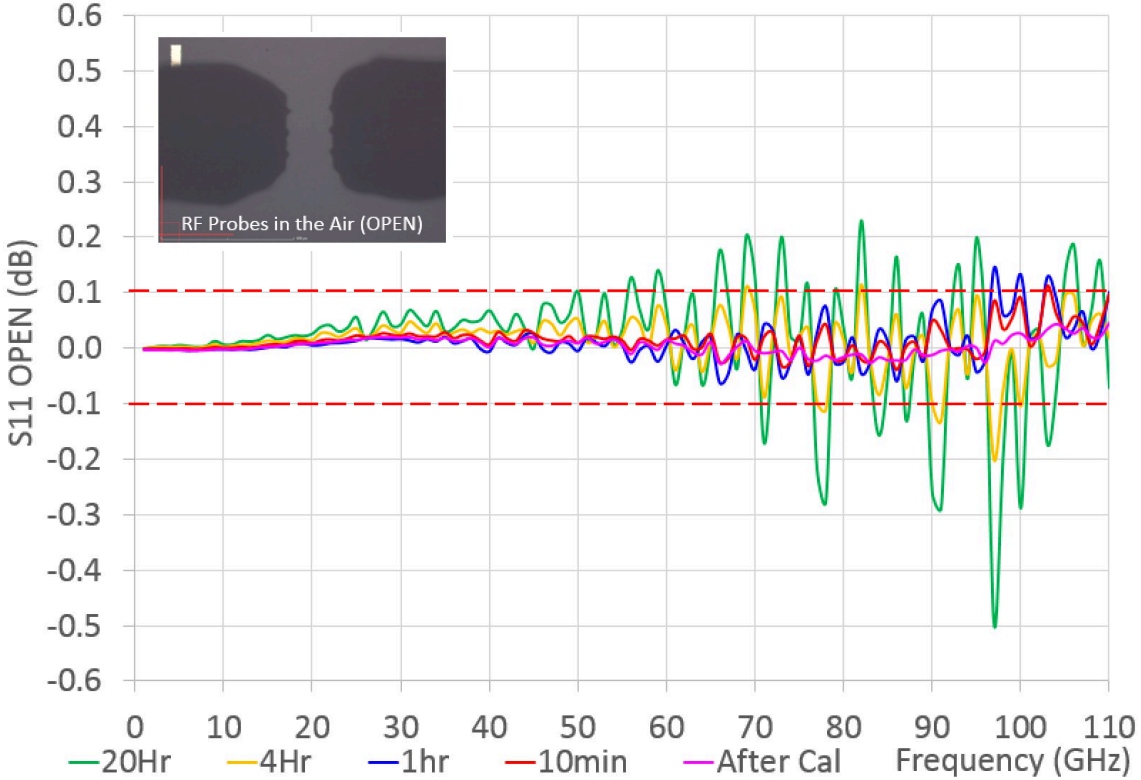


- Source Power = -20 dBm setting
- Power should be constant w.r.t freq.

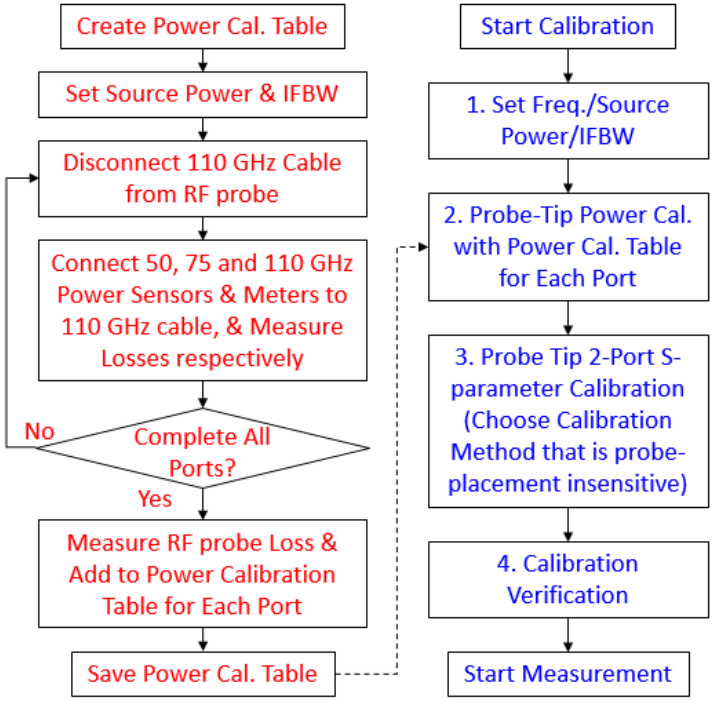
- P1 & P2 connected by low-loss thru'
- P2 should detect -20 dBm

Post-Calibration Stability (No Tip Power Cal)

- Probes in Air as OPEN, Source power = -20dBm, IFBW = 10 Hz, LRRM cal.
- ±0.1dB as criteria, Cal. only last 10 mins
- Test engineers need to recalibrate every 10 mins
  - Passive devices take 1 min
  - RFCMOS device requires about 30 mins to measure

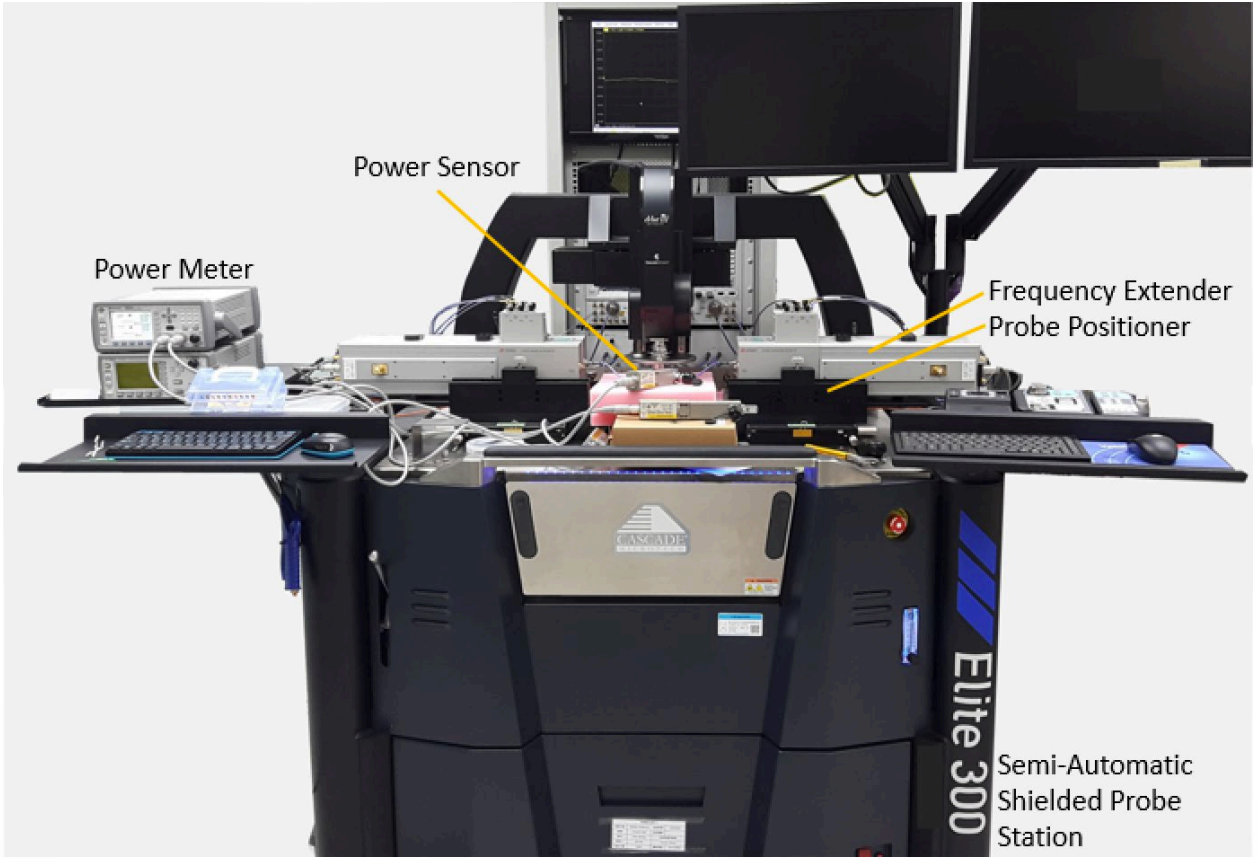


Probe-Tip Power+S-parameter Cal.

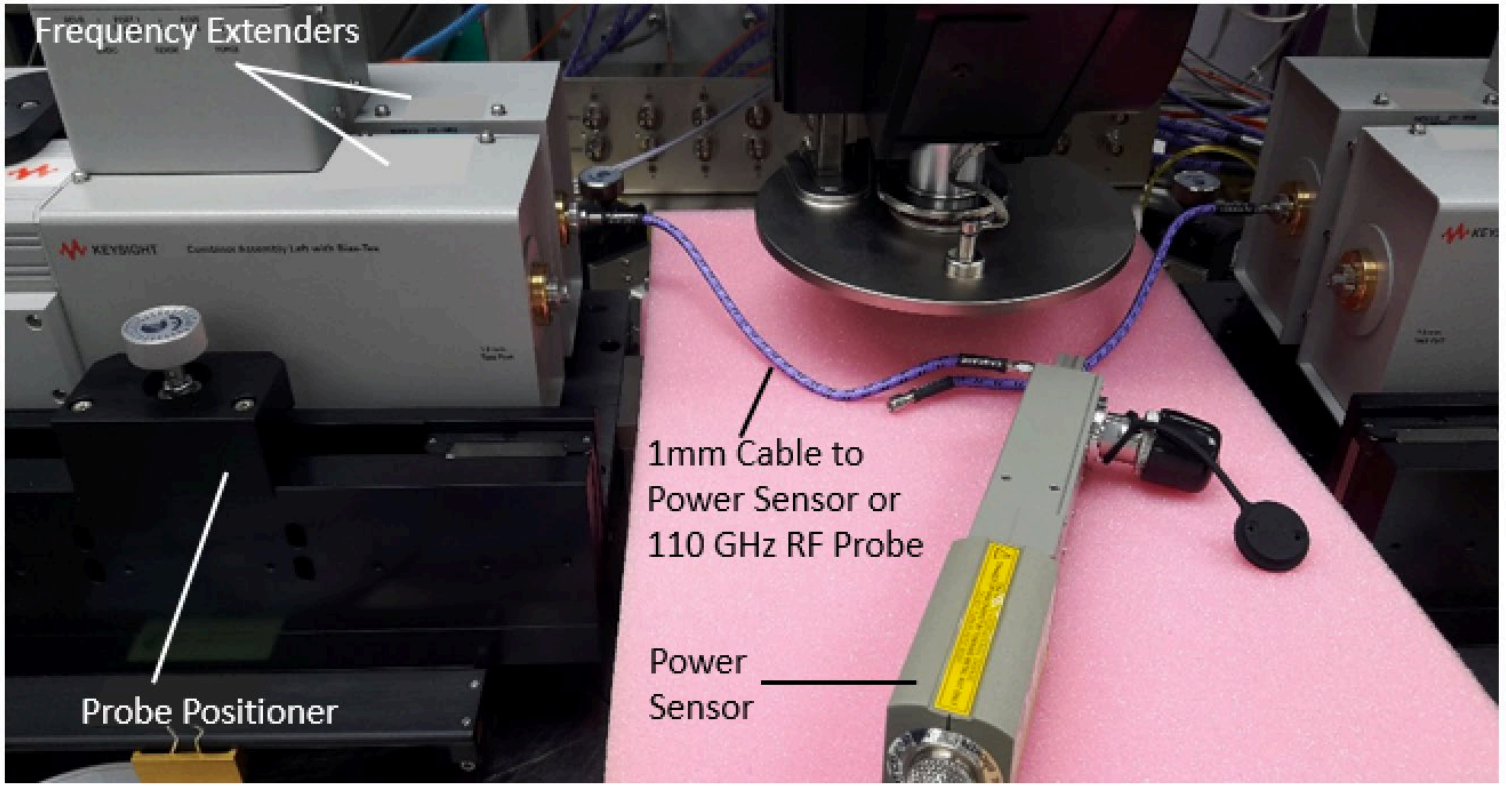


- Create Power Table (one time pain)
  - Characterize losses to the cables
  - Extend losses to the RF probe tips
  - Table is reusable unless setup modifications
- Wafer-Level Power+S-parameter Calibration
  - Perform Power cal. with power table
  - Perform standard S-parameters cal.
- No removal/installation of RF cables/probes during calibration
- Simple & Convenient
- Takes about 10% more time to complete Cal.

Creating Power Table for Power Calibration



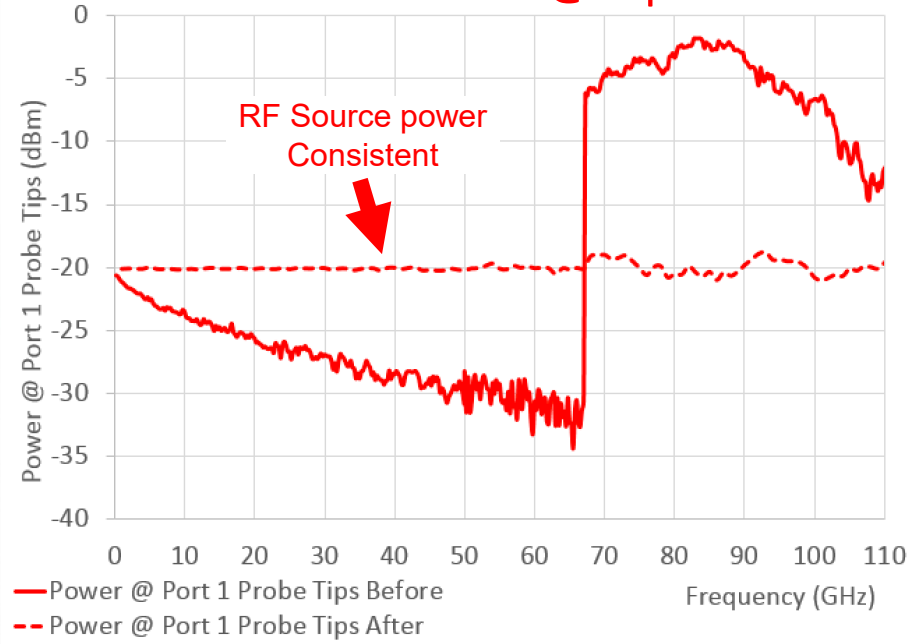
Creating Power Table for Power Calibration



Measuring Actual Power at the 1mm cable

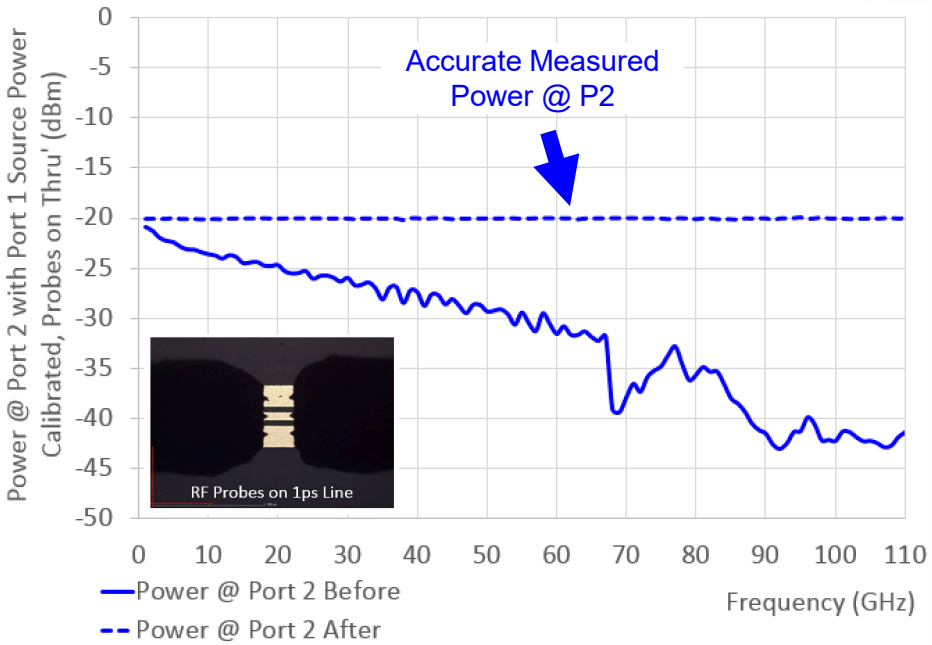
RF Power @ Probe Tips after Power Calibration

Source Power @ Tips



- Consistent Source Power

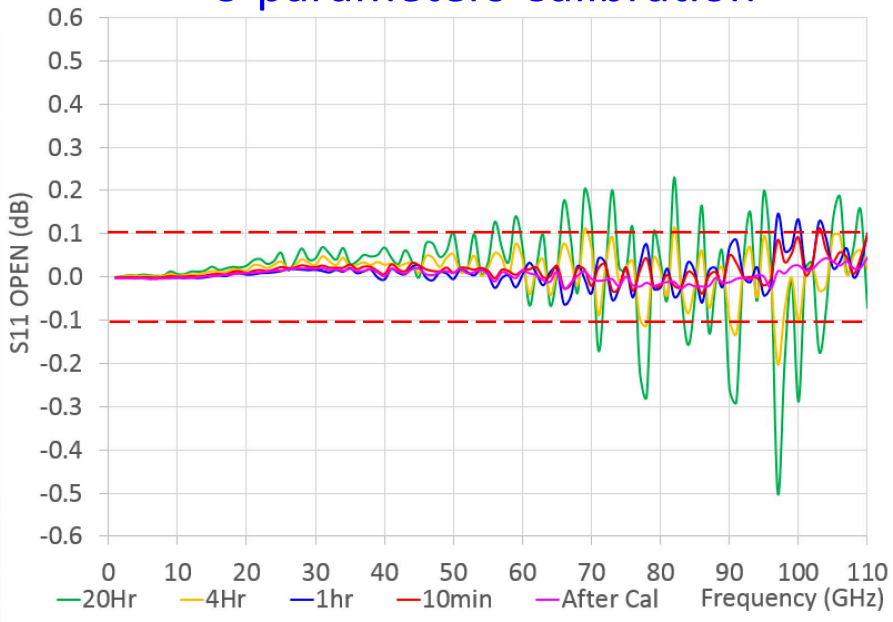
Measured Power @ P2 Receiver



- P2 detects -20 dBm regardless of freq.

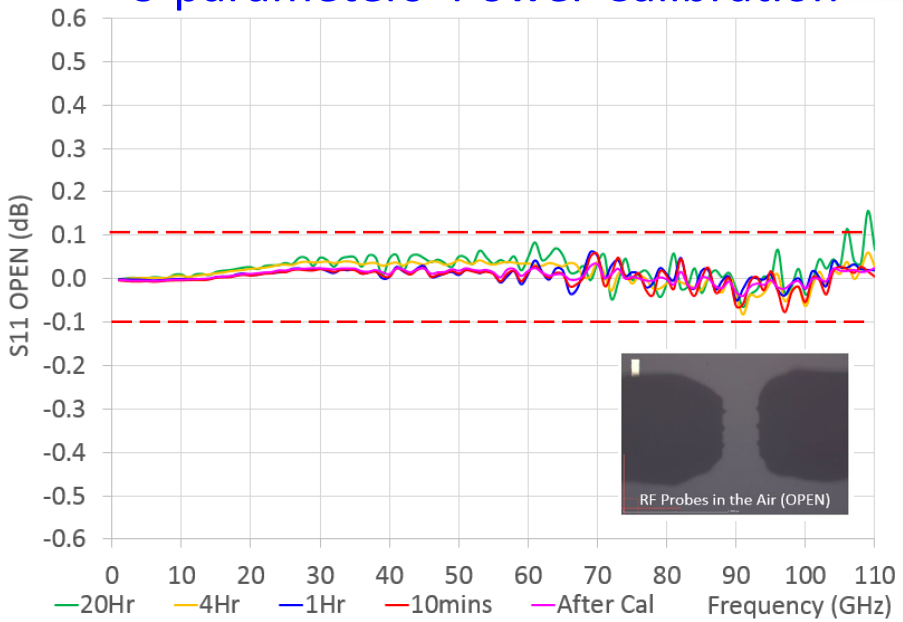
Probes in Air - Calibration Drift over 20 Hours

S-parameters Calibration



- Cal. Valid for only 10 mins

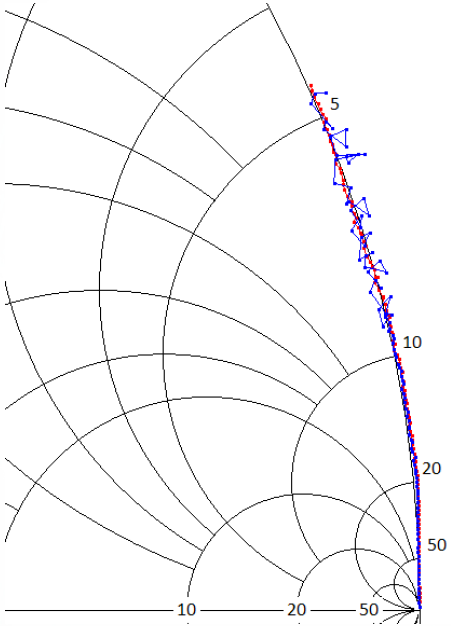
S-parameters+Power Calibration



- Cal. Valid for 4 hours!

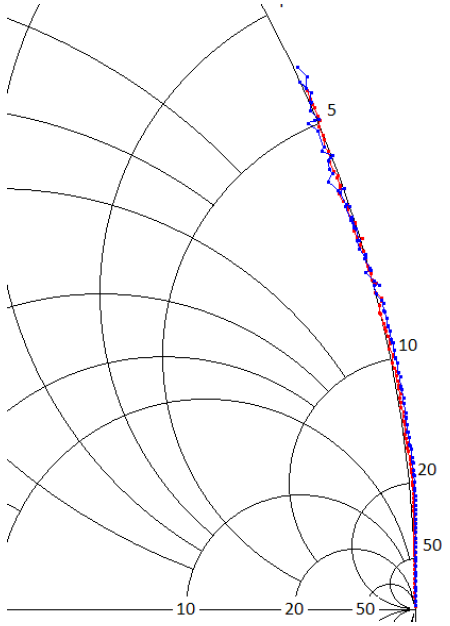
Probes in Air - Calibration Drift over 20 Hours

S-parameters Calibration



- Cal. Valid for only 10 mins

S-parameters+Power Calibration



- Cal. Valid for 4 hours!

Summary

- Power Calibration is Critical even though S-parameters is a relative and not absolute measurement!
- Adopting Power+S-parameters Probe Tip Calibration takes 10% more time but will…
  - Ensure Accurate RF source power is applied to Active Devices
  - Improve Calibration Stability to more than 4 Hours
  - Maximize Test Throughput