VNA COMPARISON
COPPER MOUNTAIN TR1300/1
VS
AGILENT E5061A

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Descriptions of measurements:

- ➢ There is a new VNA available in our lab, a Copper Mountain TR1300/1, and it was compared to the AGILENT E5072A, we have been using until now.
- ➢ The comparison consisted of the accuracy of the measurement of four attenuators (3dB-BW-S3W2+,6dB-BW-S6W2+,10dB-BW-S10W2+, and 15dB-BW-S15W2+), after correction using the expectations for the open, short, and match (Male,85033E). The temperature at all moments was23.5±0.5◦C
- ➢ With measurements specifications as follows:

i. Power: 0dBm
ii. bandwidth: 100 Hz
iii. Max Frequency: 200MHz
iv. Min Frequency: 40MHz
v. AVG: 10 traces
vi. Points: 641
vii. Frequency Step (MHz): 0.250
viii. Temperature: Room Temperature (23C)

- ➢ The steps in the testing at each VNA are:

i. Calibrate the VNA at its SMA port (with open, short, & match).
ii. Measure the S11 of the open, short, & match, AGAIN after calibration.
iii. Measure the S11 of the four attenuators.
iv. Repeat steps ii and iii for repeatability.

- ➢ Perform uncalibrated VNA measurements to determine uncorrected S11 parameters.

i. Measure open STD using uncorrected VNA measurement and save S1p_open
ii. Measure Short STD and save S1p_short
iii. Measure Load STD and save S1p_load
iv. Using the calibration coefficients of the OPEN, Short and load standards (found on the VNA, called C0,C1...,L0,L1...), we can compute the S parameters of a 2 port network called the "error network" (it is a hypothetical 2 port network between the VNA and DUT)
v. Measure the S11 of the DUT (attenuator) and "de-embed" the error network from the measured data, you will be left only with the S11 (complex) of the DUT.
vi. The equation you will need is this: (it is the S11 of a [S_error] network terminated with Gamma_dut)
S11_Measured = S11_error + (S21_Error * Gamma_dut*S12_error) / (1 - S22_error * Gamma_dut)
vii. Solve for the S parameters of the error network [S_error] : S11_error, S12_error,S21_error and S22_error by solving the above 4 unknown equation for:
Gamma_dut = Gamma_open_std
Gamma_dut = Gamma_short_std
Gamma_dut = Gamma_load_std
viii. Assume reciprocity: S21_error = S12_error (reasonable assumption as the error network is reciprocal, meaning that S12=S21). The results will give 3 equations to solve for the 3 unknowns.

Images of VNA connections:

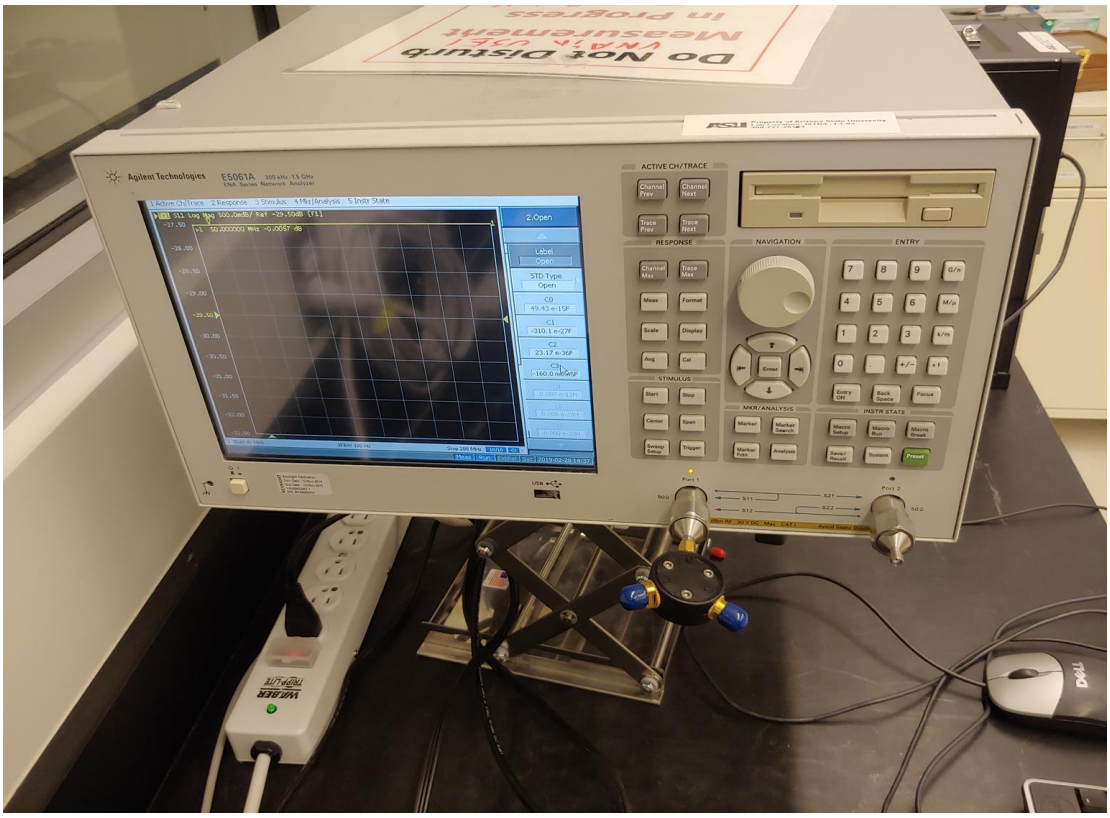

Figure1: Aligelent E5061A Calibration arrangement utilizing the male 85033E Calibration kit

Figure2: Copper Mountain TR1300/1 Calibration arrangement utilizing the male 85033E Calibration kit

Results:

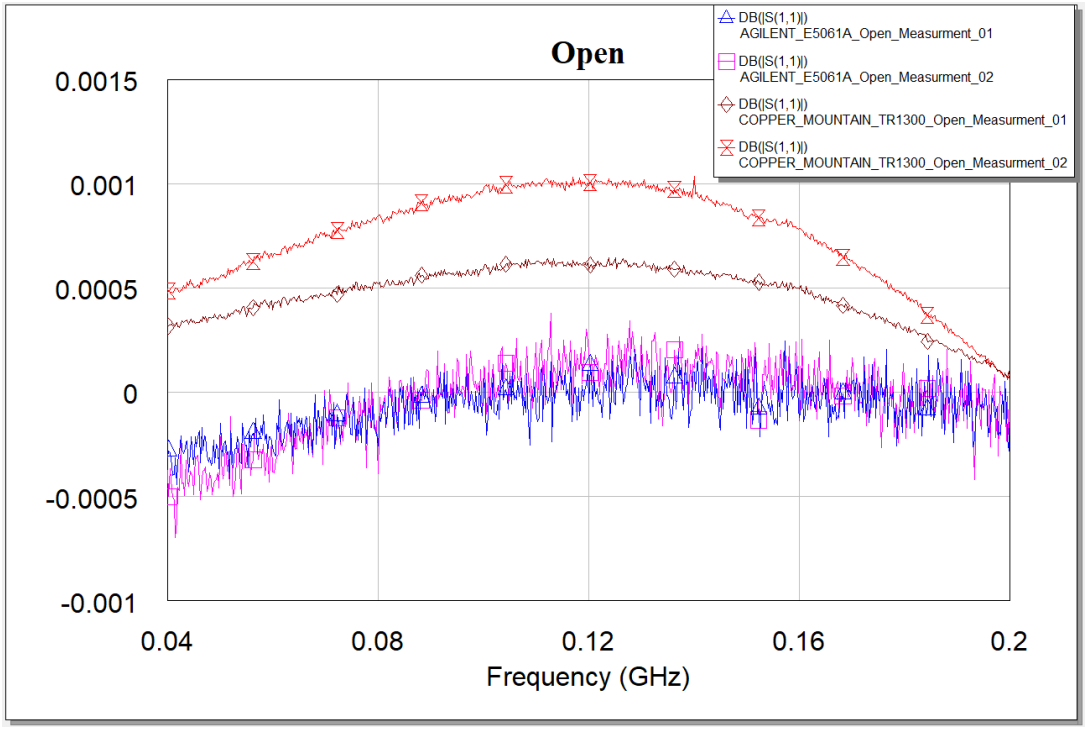

Figure3: Magnitude of the Open after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Repeatability of the Agilent E5061A is slightly better than the Copper Mountain TR1300/1 however the Agilent E5061A VNA noise level is higher.

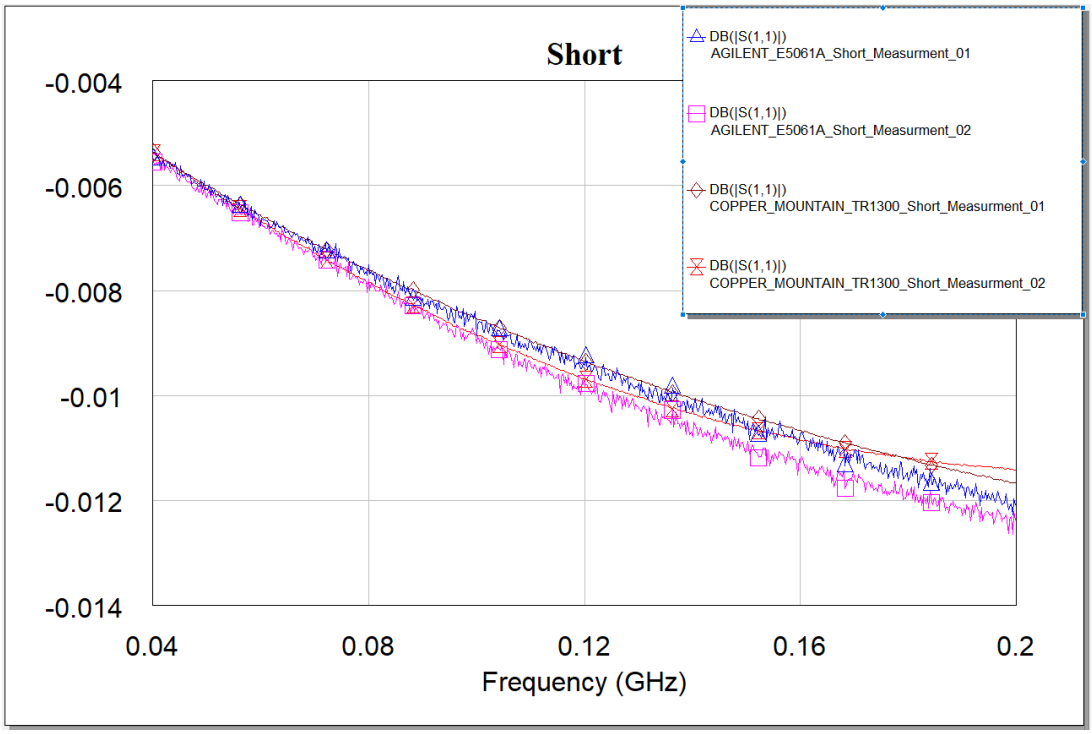

Figure4: Magnitude of the Short after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. The measurements between the two VNAs are almost identical with the Agilent E5061A having more noise.

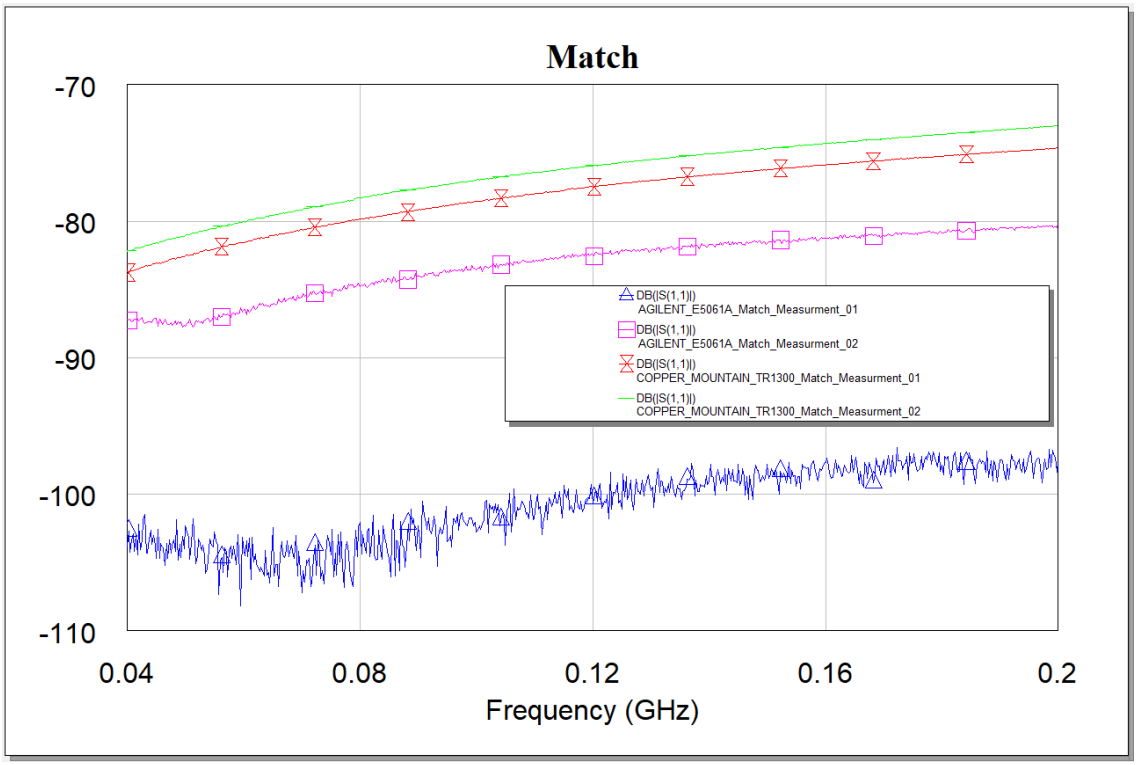

Figure5: Magnitude of the Match after calibration. Copper mountain TR1300/1 Measurement One Red trace, Copper mountain TR1300/1 Measurement Two Green trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. The Copper Mountain TR1300/1 Repeatability shows promising results with -3dB variation compared to the Agilent E5061A varying over -20dB.

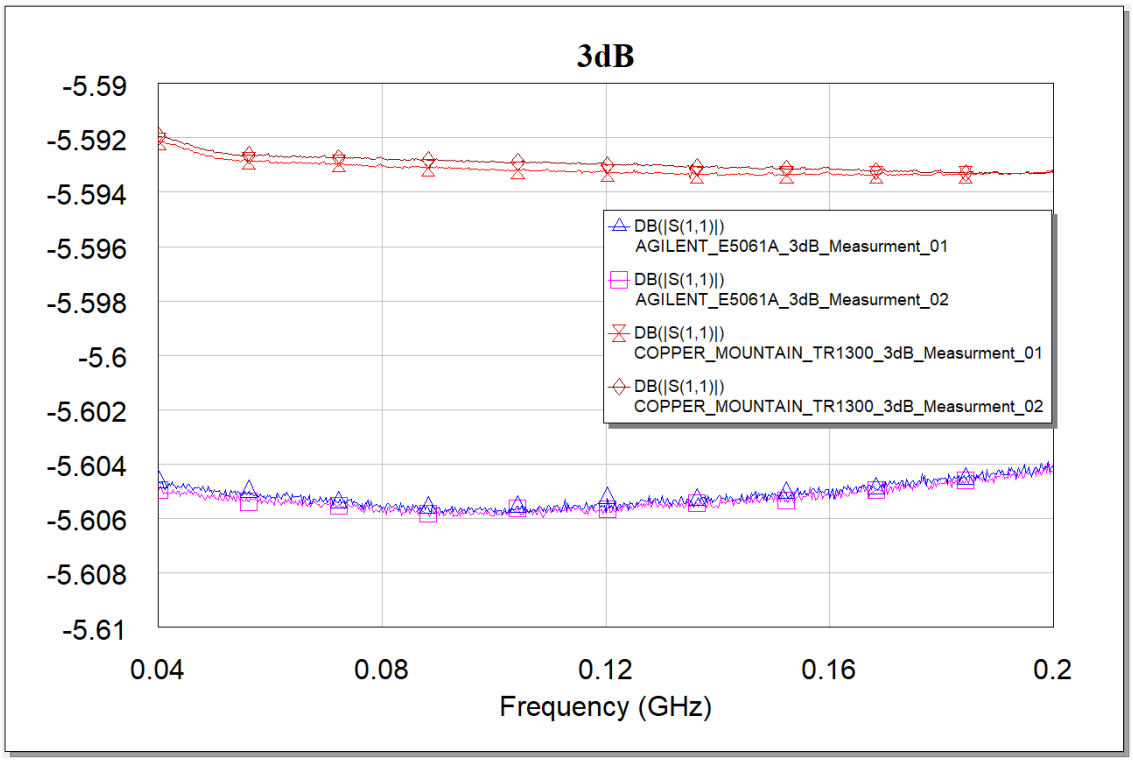

Figure6: Magnitude of the 3dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Red trace, Copper mountain TR1300/1 Measurement Two Brown trace, Agilent E5061A measurement one Blue trace, Agilent E5061A Measurement Two Pink trace. Both VNAs have similar results varying only -12dBm from one another.

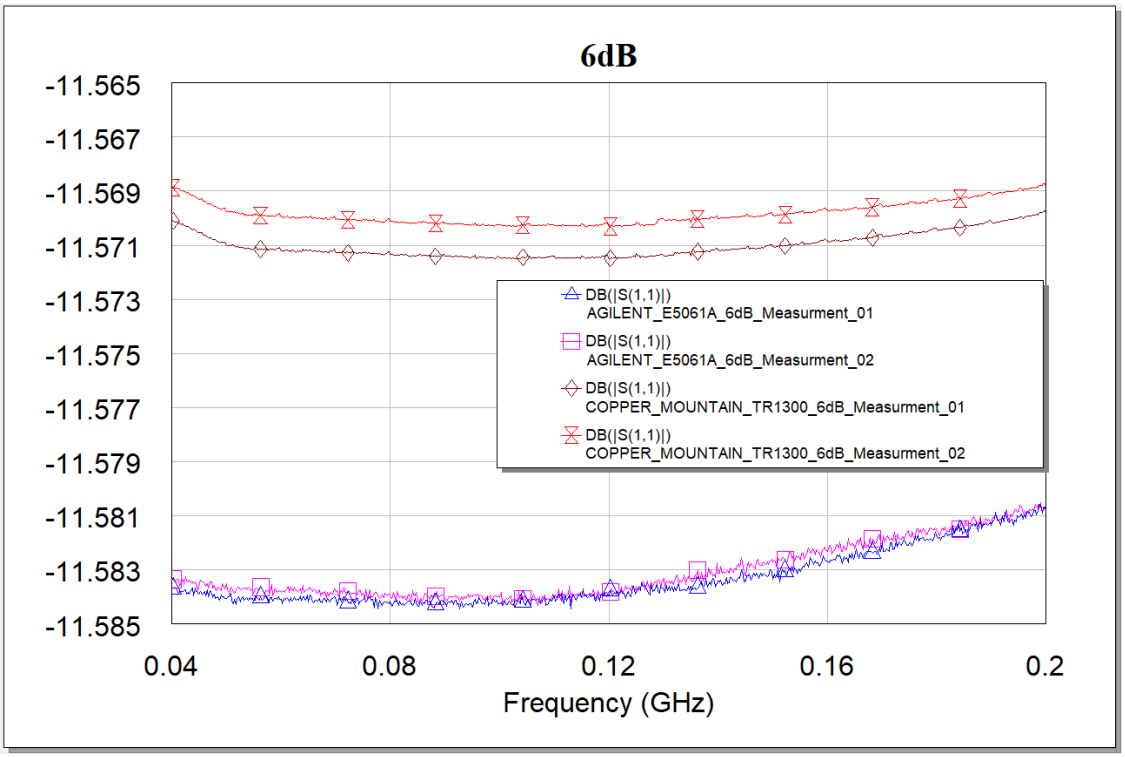

Figure7: Magnitude of the 6dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. The Agilent E5061A has closer duplications of measurements while the Copper Mountain TR1300/1 has less noise. Overall, The Results are similar varying -14dBm from one another.

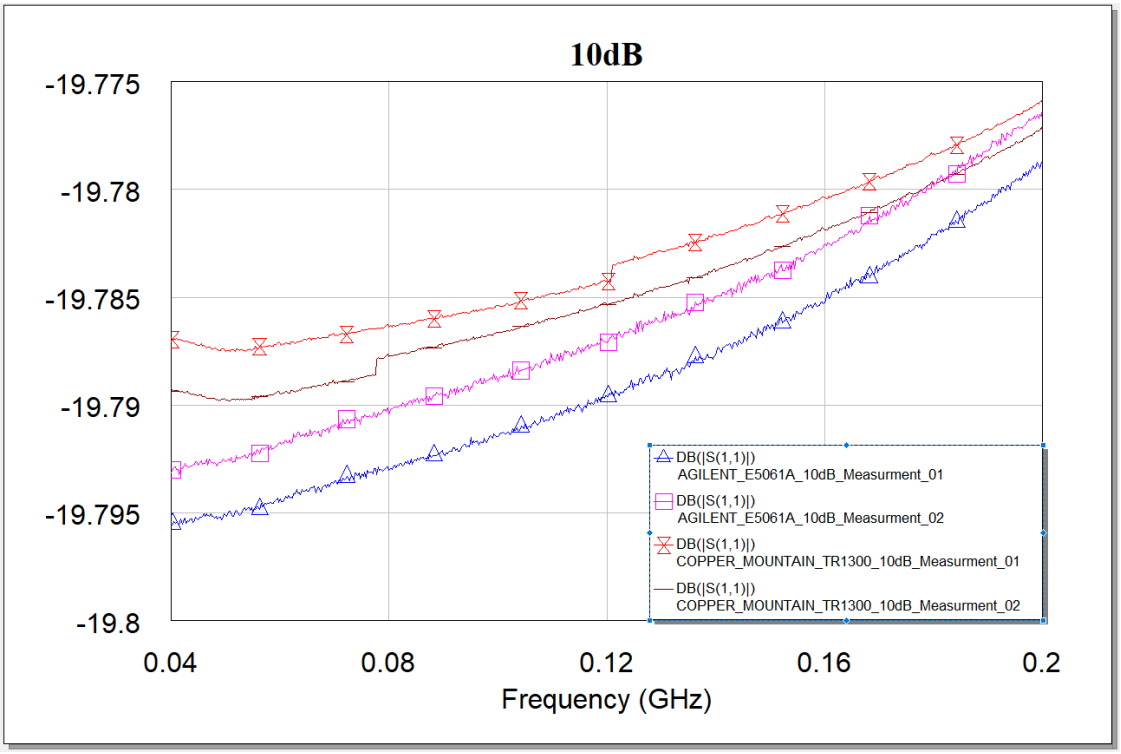

Figure8: Magnitude of the 10dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Red trace, Copper mountain TR1300/1 Measurement Two Brown trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Due to extreme sensitivity of heat the Copper Mountain TR1300/1 has a slightly small step (See Discussion #2). Results are suitable to one another with similar linear curvature.

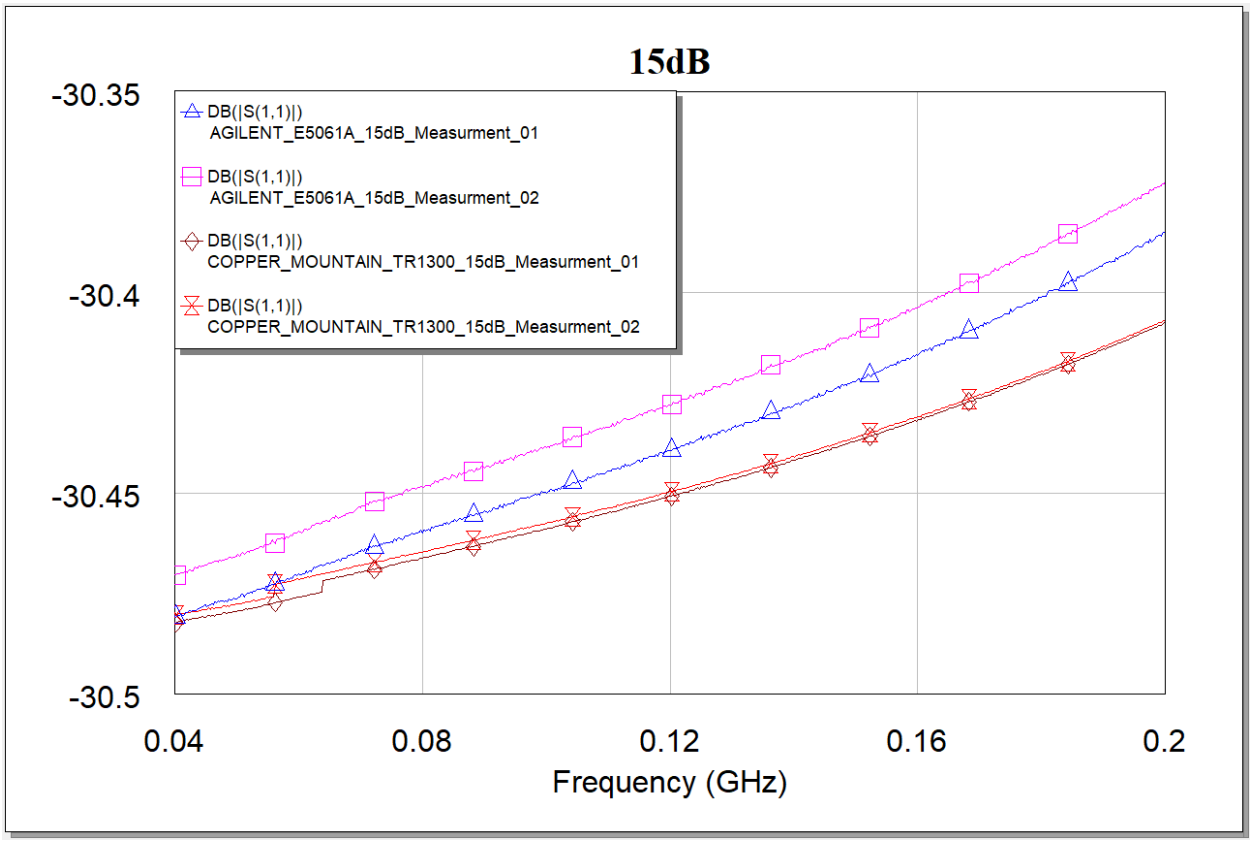

Figure9: Magnitude of the 15dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Due to extreme sensitivity of heat the Copper Mountain TR1300/1 has a slightly small step (See Discussion #2). The Copper Mountain TR1300/1 repeatability is tighter compared to the Agilent E5061A.

Results #2 (*5min thermal stability*):

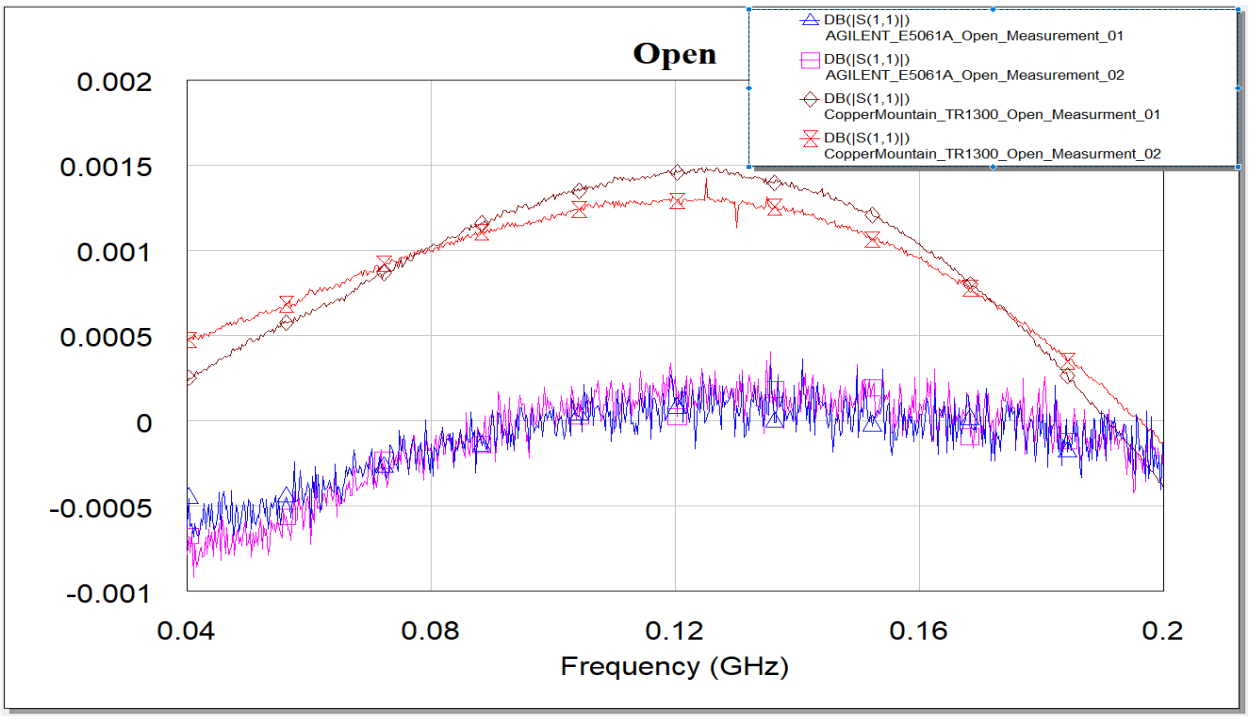

Figure10: Magnitude of the Open after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Repeatability of the Agilent E5061A is slightly better than the Copper Mountain TR1300/1 however the Agilent E5061A VNA noise level is higher.

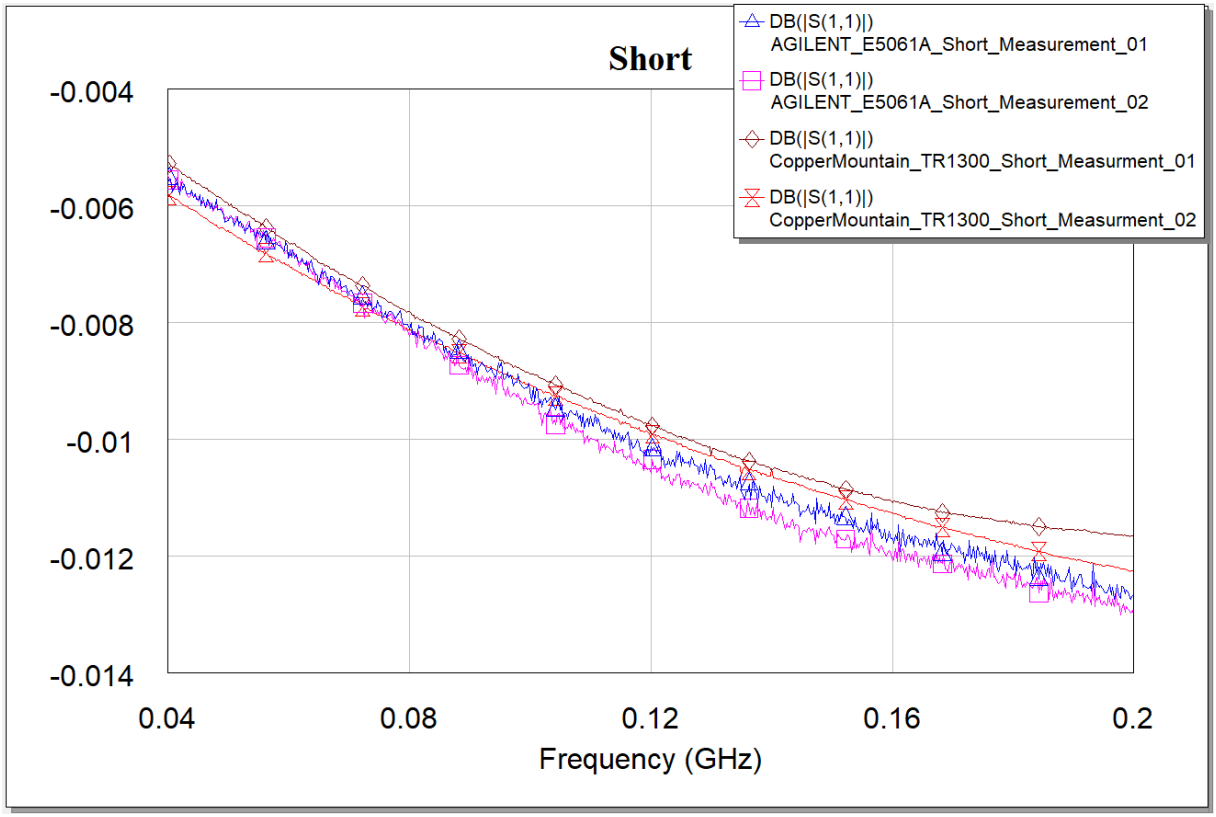

Figure11: Magnitude of the Short after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. The measurements between the two VNAs are almost identical with the Agilent E5061A having more noise.

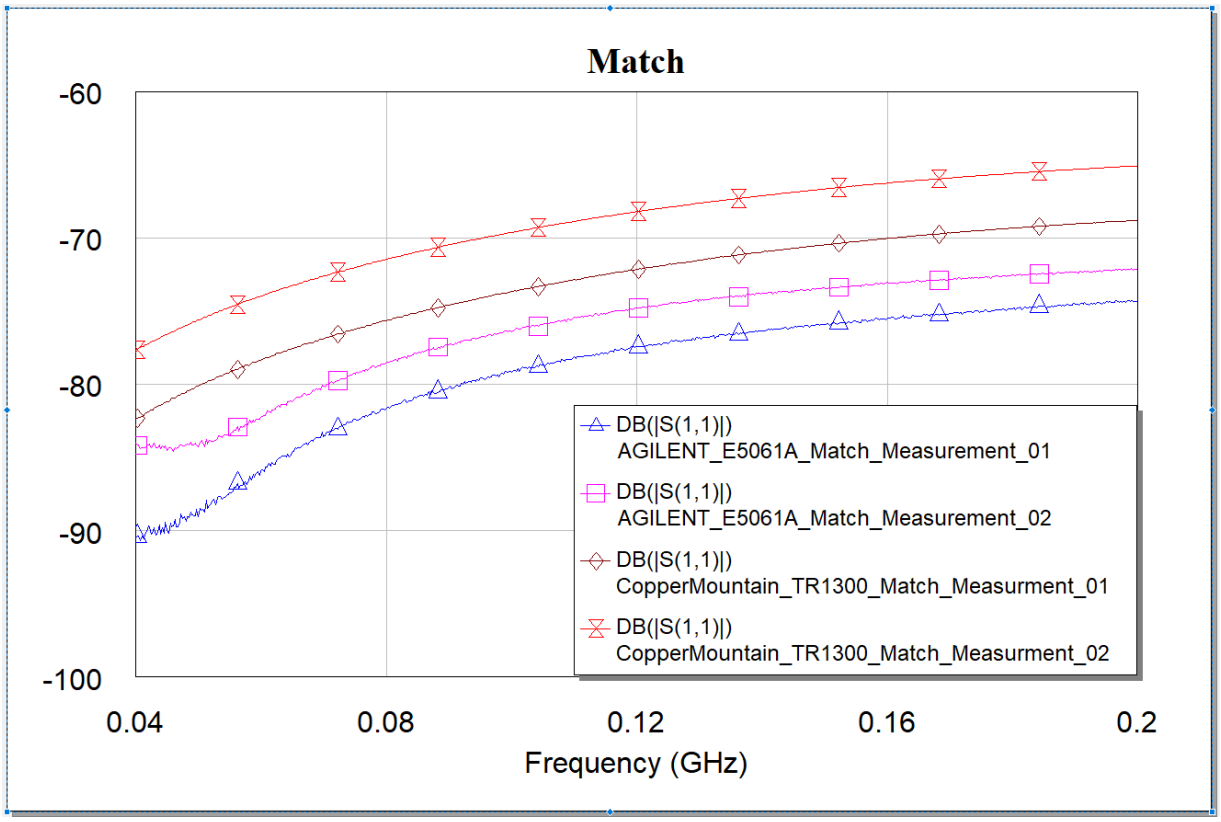

Figure12: Magnitude of the Match after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Traces are similar in comparison. While the Copper Mountain TR1300/1 linear curvature is consistent compared to the Agilent E5061A.

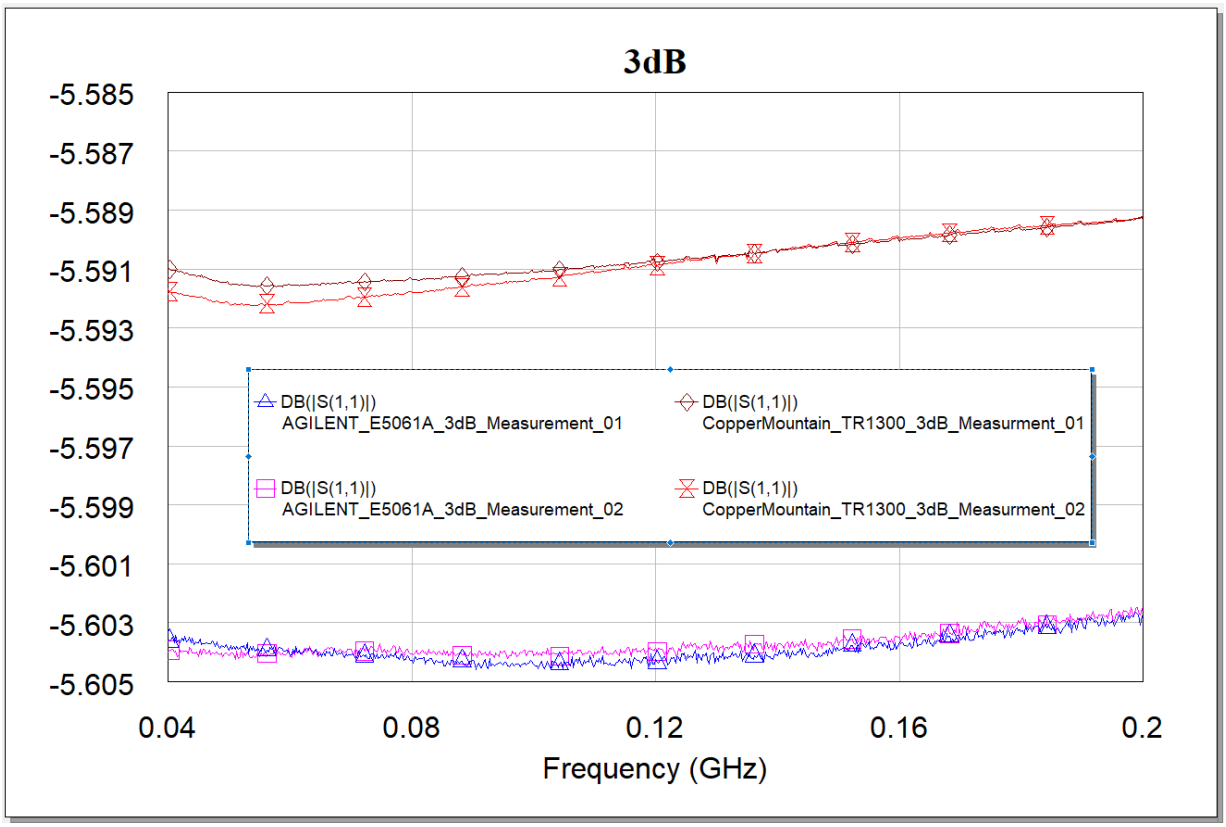

Figure13: Magnitude of the 3dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A measurement one Blue trace, Agilent E5061A Measurement Two Pink trace. Both VNAs have similar results varying only -0.012dBm from one another.

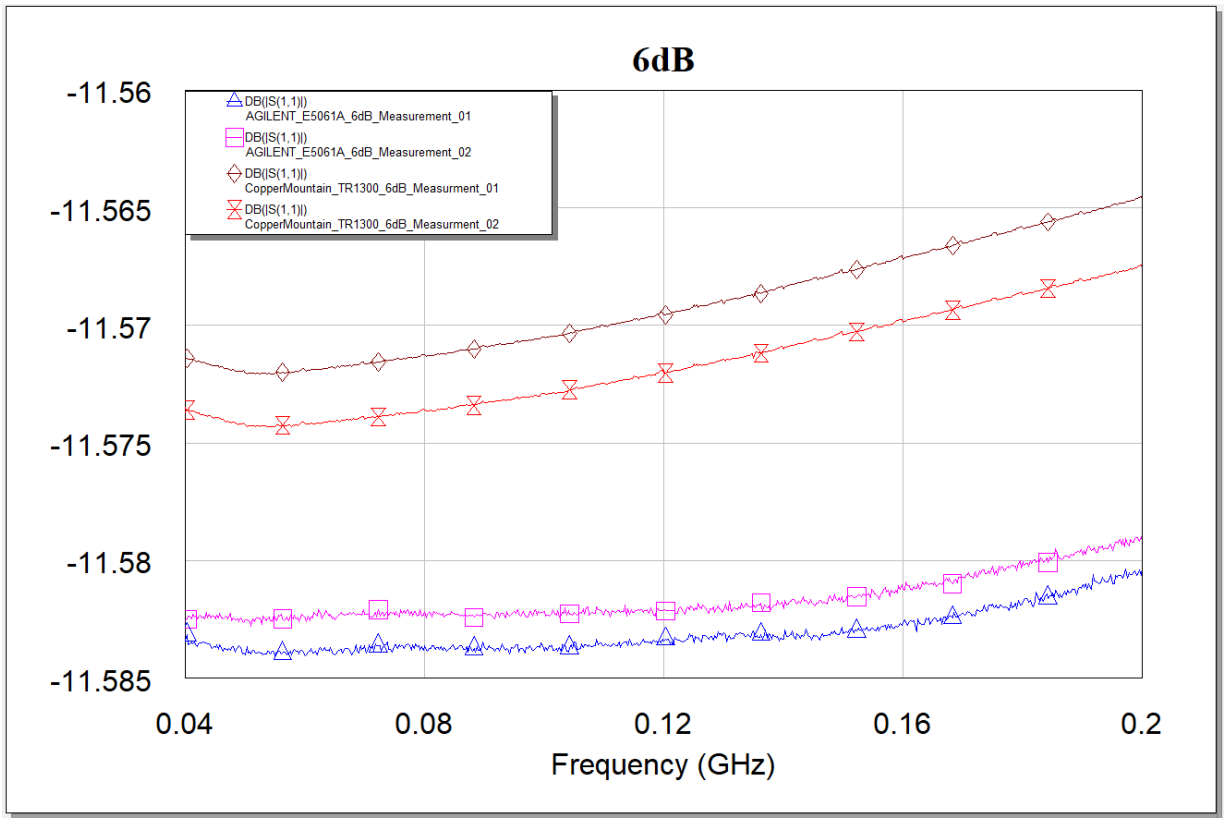

Figure14: Magnitude of the 6dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. The Agilent E5061A has closer duplications of measurements while the Copper Mountain TR1300/1 has less noise. Overall, The Results are similar varying -9dBm from one another.

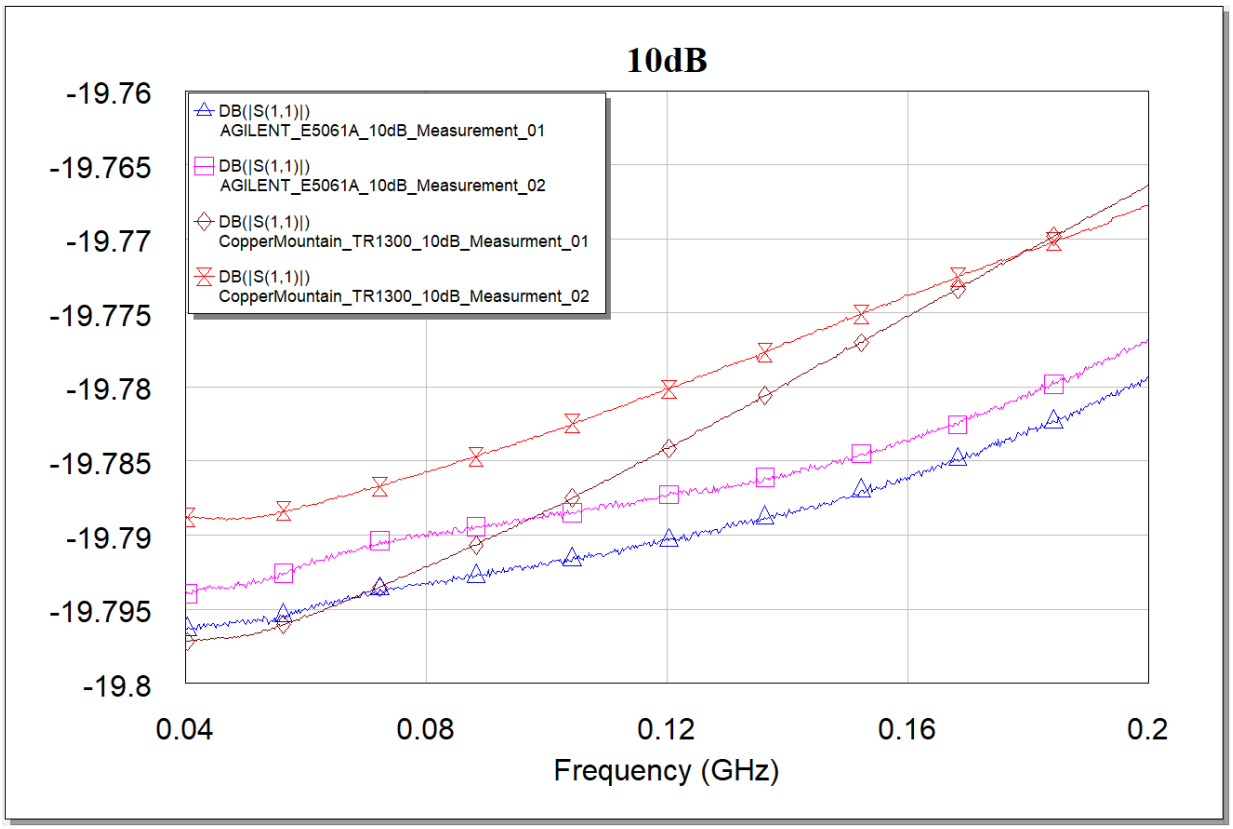

Figure15: Magnitude of the 10dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Repeatability with the Agilent E5061A is closer from one measurement to another compared to the Copper Mountain TR1300/1.

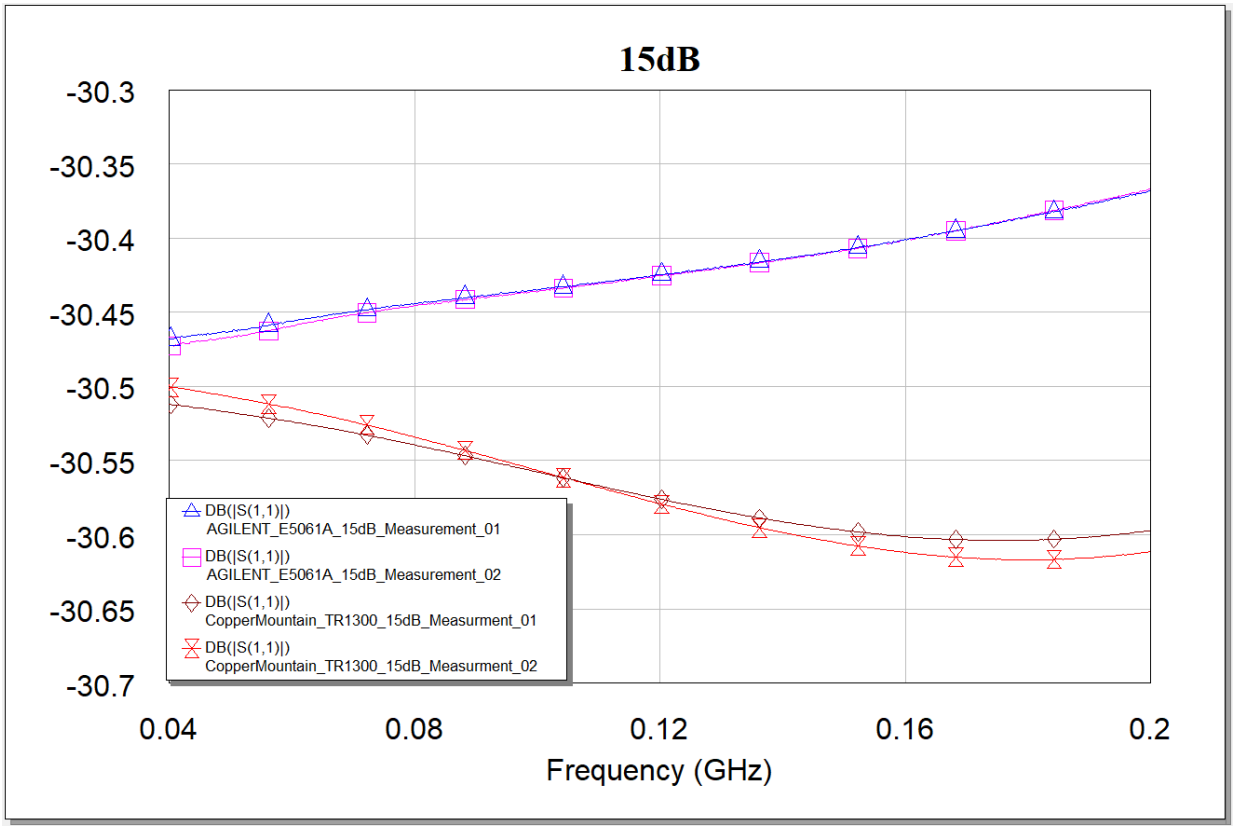

Figure16: Magnitude of the 15dB Attenuator after calibration. Copper mountain TR1300/1 Measurement One Brown trace, Copper mountain TR1300/1 Measurement Two Red trace, Agilent E5061A Measurement One Blue trace, Agilent E5061A Measurement Two Pink trace. Results are suitable to one another with similar linear curvature.

Manually-applied OSL calibration:

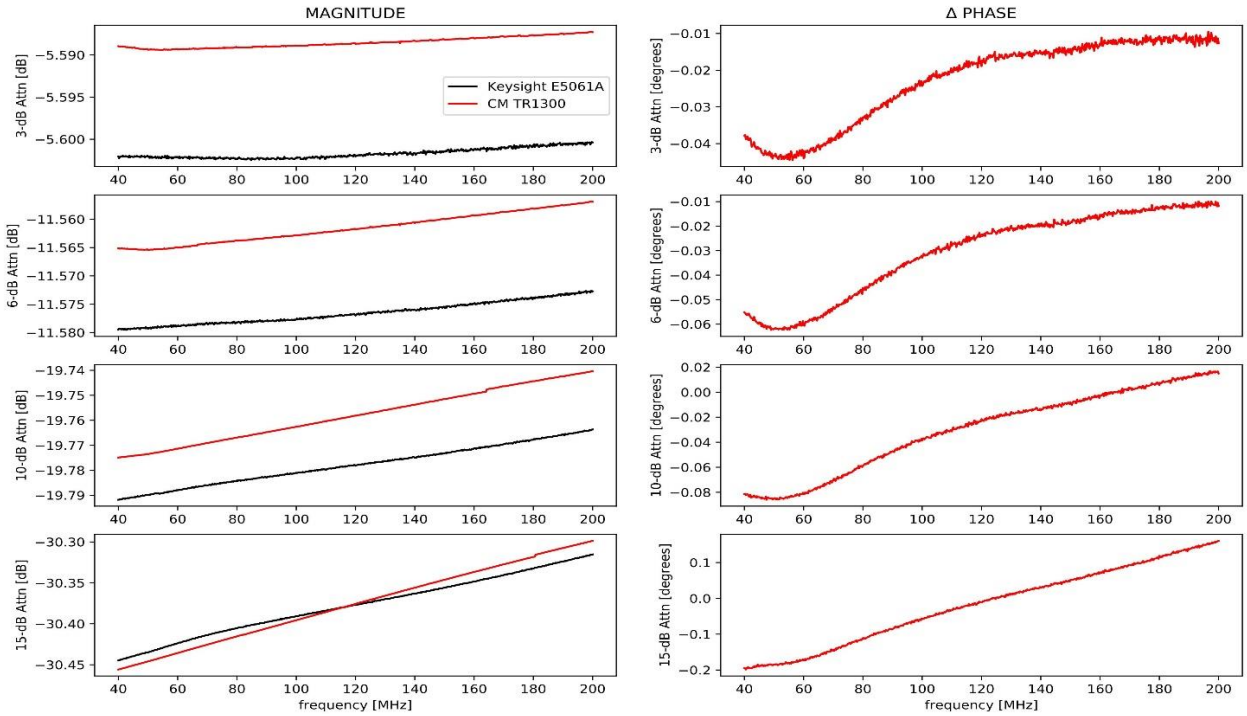

Figure17: Magnitude and Phase comparison between Agilent E5061A (Black) and Copper Mountain TR1300/1 (Red). Both VNAs have similar linearity with minimal variation in amplitude.

Discussion:

1. Implicitly we assume that the devices measured, including the calibration standards, are the same in all cases. The Copper Mountain TR1300 VNA is one of the best VNAs tested. In my opinion, it is second to the Agilent E5061A VNA. The measurements are very smooth and have low noise.
   The first order differences between the measurements with the Agilent E5061A and the TR1300 could be produced by the 50-ohm calibration load having different resistance during the measurements with the two VNAs, which I am not accounting for here.
   A couple of measurements with the TR1300 show some low-level glitches (in magnitude), close to the noise level. These glitches might not be produced necessarily by the VNA, but by some aspect related with the connection and disconnection of devices, and the trace average performed
2. The Copper Mountain TR1300/1 VNA is extremely sensitive to heat with increased scaling, therefore an average of 30 traces is recommended to sustain stable thermal equilibrium.