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COPPER MOUNTAIN TECHNOLOGIES PLANAR 304/1 NETWORK

ANALYZER INITIAL TESTING REPORT

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1 Introduction

This test report analyzes the Copper Mountain Technologies Planar 304/1 Network Analyzer. The analyzer has a frequency range of 0.3 MHz - 3.2 GHz. Much of this report compares test results from the Copper Mountain network analyzer to an Agilent E8364B PNA Network Analyzer that has a frequency range of 10 MHz - 50 GHz. The Agilent analyzer was calibrated in the fall of 2012 and has brand new cables that interface devices to the test ports. It is expected that the Agilent analyzer gives very accurate results and can be trusted as a reliable benchmark. It should be noted that all tests performed here were done so in an informal nature. Both analyzers were not located in the same exact location and the same cables were not used at all times. Small differences that appear in the data may be attributed to these testing differences. Any calculations or presentation of data was also done to look at estimated results. All of the testing was aimed at getting good solid estimates not high quality measurements accurate to a tenth of a dB. More rigorous analysis can be performed in the future if desired. However, for now these initial experiments gave satisfactory results.

2 Magnetic Green Box Antenna S11 Measurements

The first test performed on the Copper Mountain Planar 3041/1 Network Analyzer was to measure the S_{11} response of an antenna and compare it to the Agilent E8364B Network Analyzer. The antenna used was the green magnetic box antenna. The simple test parameters and results are discussed below.

First the analyzer was calibrated using an the Agilent 85056A 2.4 mm calibration kit. The Copper Mountain network analyzer utilizes female N type connectors on both ports. A high quality male N to male N cable manufactured by Storm was used to interface to the analyzer. A female N to male SMA adapter was used to interface to the AUT (antenna under test). Then to use the calibration kit a female SMA to female 2.4 mm adapter was used. It should be noted that the Copper Mountain software did not have this calibration kit preloaded. So a similar Agilent kit (8505D) was selected in the software and used. In the future, the parameters for the 85056A calibration kit can be manually entered into the Copper Mountain software if so desired. The calibration kit parameters are available online from Agilent. The Agilent E8364B Network Analyzer was calibrated using the Agilent N4693-60001 E Cal module.

Table 1 shows all of the settings used on both analyzers. The settings were kept consistent so that good comparisons could be made between the measured data. No smoothing or averaging was used on either piece of equipment.

Fig. 1 shows the data taken from both analyzers. The data seems to track very nicely except in the upper half of the band. At the higher frequencies the imprecise calibration of the Copper Mountain analyzer could possibly be the cause. Also, the cables and adapters used with the Copper Mountain analyzer may not be in perfect condition. For all intensive purposes, both analyzers present very similar data.

The upper portion of the band definitely does not seem to match perfectly. However, it should be noted this antenna was not designed to work much above 500 MHz. Also, at higher frequencies it is very important to be careful with anything that may be in the test

environment of the antenna. These tests were not done is the same location. Quite possibly the radiation affects and surrounding structures could have lead to these differences.

To check if the calibration was an issue at all, the Copper Mountain analyzer was calibrated using an Agilent 85033D 3.5 mm calibration kit. This kit was available to be selected in the Copper Mountain software. With this calibration, the box antenna was measured again. This data was then compared to the measured Agilent data again. It can be seen in Fig. 2 that the results are nearly the same as with the previous calibration kit. No noticeable difference is detected.

Just to be thorough, the Agilent analyzer was calibrated again using the E Cal module and the box antenna was again measured. This data was then compared to the Copper Mountain analyzer data with the 3.5 mm calibration. This data can be seen in Fig. 3. This data seems to match up better. It is not really known why in the upper portion of the band the data matches more closely this time than before.

In conclusion, it is not that important to make the higher ends of the frequency band match up perfectly on both pieces of equipment for this antenna. This antenna is not designed to work at those frequencies anyway. The differences can probably be attributed to the environments surrounding the antenna. Both pieces of equipment report the same exact data for the band of interest for this antenna.

Analyzer	Frequency Span	Number of Points	IF Bandwidth
Agilent	10 MHz - 3 GHz	201	30 kHz
Copper Mountain	10 MHz - 3 GHz	201	30 kHz

Table 1: Measurement parameters for both network analyzers when testing green magnetic box antenna.
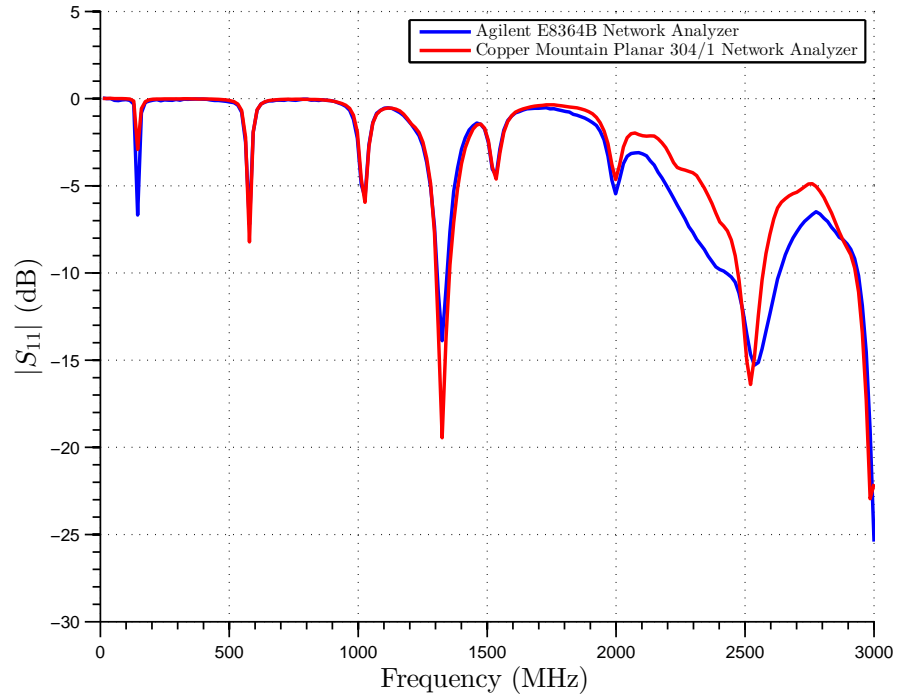
Figure 1: Comparison of data from both analyzers for green magnetic box antenna.
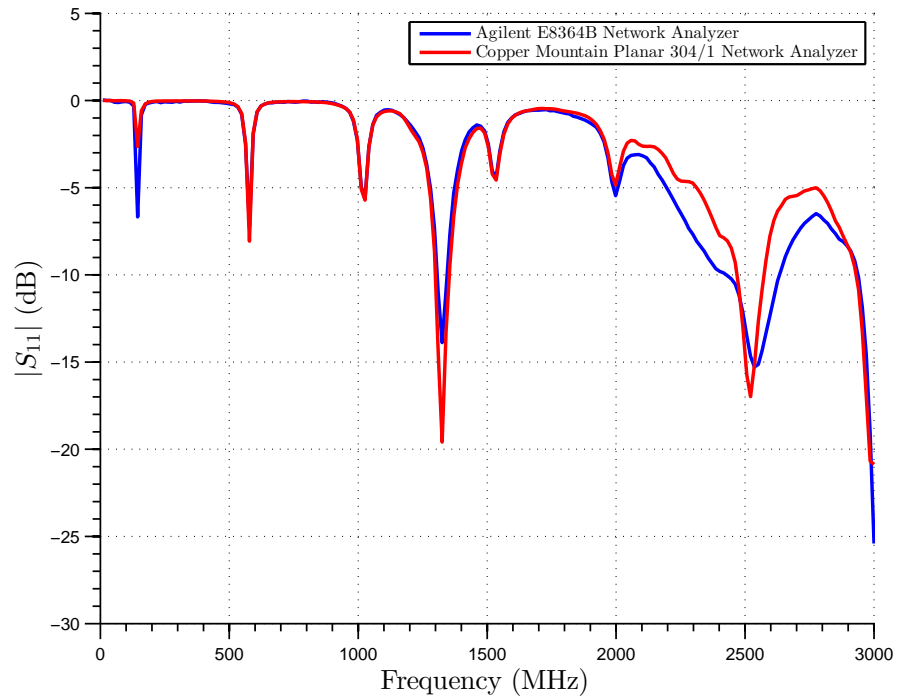

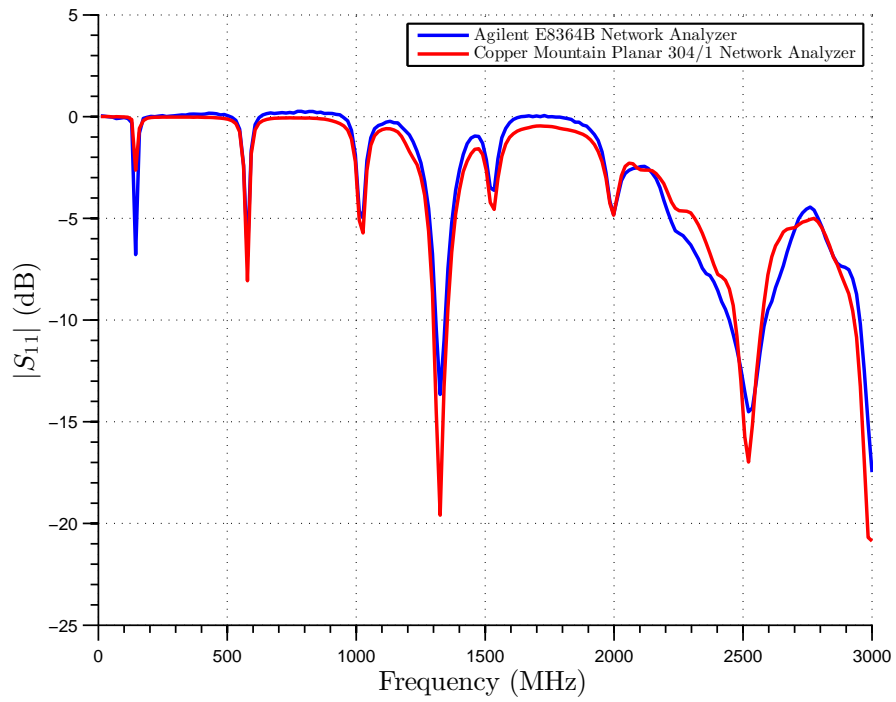Figure 2: Data collected using both analyzers after calibrating the Copper Mountain Analyzer with a 3.5 mm kit.

Figure 3: Data collected using both analyzers after calibrating the Copper Mountain Analyzer with a 3.5 mm kit and calibrating the Agilent analyzer for a second time with the E Cal module.

3 2 Piece Egg Shaped Antenna S11 Measurements

The next antenna tested was the antenna that approximated a half of an egg shape above a ground plane. The Copper Mountain analyzer was calibrated using the Agilent 85033D calibration kit while the Agilent analyzer was calibrated using the E Cal module. Table 2 shows the settings on both analyzers were the same. Fig. 4 shows the plotted data. This data seems to match up very well. This antenna was very sensitive to whatever was in its surrounding environment. Just being close enough to the system to control the mouse to save data affected the plot. Again, for all intensive purposes both analyzers show similar data.

Analyzer	Frequency Span	Number of Points	IF Bandwidth
Agilent	10 MHz - 3 GHz	201	30 kHz
Copper Mountain	10 MHz - 3 GHz	201	30 kHz

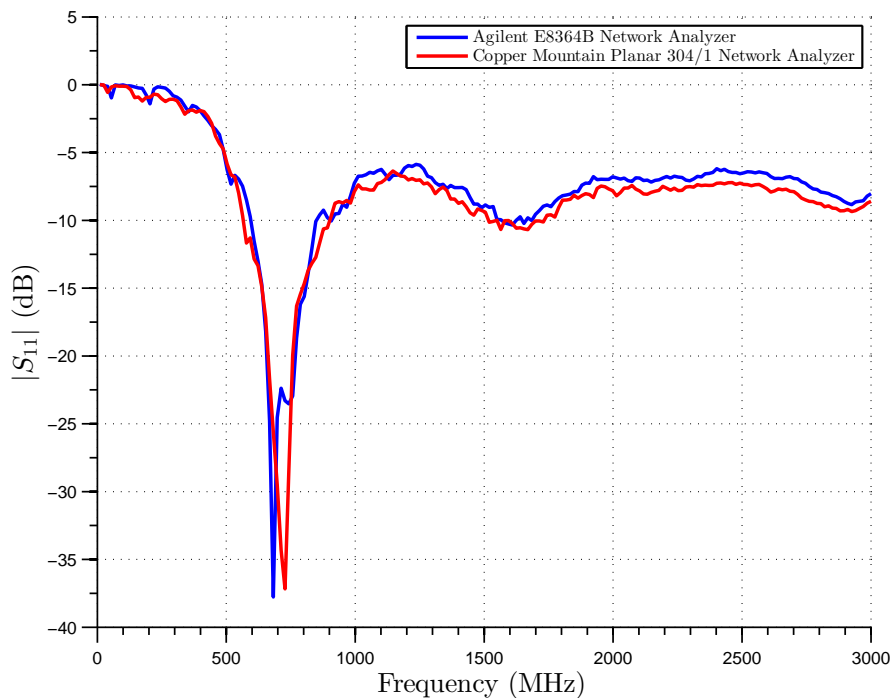Table 2: Measurement parameters for both network analyzers when testing the 2 piece egg shaped antenna.

Figure 4: Comparison of data collected from both analyzers for 2 piece egg shaped antenna

4 Time Domain Measurements

4.1 ETS Lindgren Horn Antennas

Two horn antennas were used in this testing. First, two horn antennas were connected to port 1 and port 2. All parameters used for both analyzers are listed in Table 3. The Copper Mountain analyzer was calibrated using the Agilent 85033D calibration kit and the Agilent analyzer was calibrated using the E Cal module. Fig. 5, Fig. 6, and Fig. 7 show response data and comparisons for the antennas. The data is very similar as expected from both analyzers. The difference can most likely be attributed to different surrounding environments as both analyzers are not in the same exact location.

With the responses of the antennas checked, time domain experiments were performed. The parameters used for the time domain experiments are shown in Table 4. A large metal plate was positioned roughly 1.22 m (4 ft) from both antennas connected to the Copper Mountain analyzer. The time domain analysis converts the frequency domain information of S parameters into a time series to show at what time signals are received back at the analyzer. Peaks in the time series correspond to large impedance differences. Using this round trip travel time and the speed of light, the distance to the metal plate can be estimated.

S_{11} and S_{22} measurements were investigated in the time domain. These measurements are similar to a monostatic radar setup. A signal is sent out of the antenna on a port then received after reflection on the same port. Using this information a range profile plot was generated for each antenna on each port using Matlab. This can be seen in Fig. 8. Notice on the plot the first two peaks to the right of 0 m. These peaks are due to the antenna itself. The next large peak at roughly 1.5 m is the large metal plate. Both ports report nearly the same distance to the metal plate. Again, none of these measurements or experiments were performed rigorously. They are a ballpark distance to the large piece of metal.

Next an S_{21} measurement was used to approximate a bistatic radar setup. A signal was sent on the port 1 horn antenna and then received on the port 2 antenna. Again, using

this information a range profile plot could be generated using Matlab. This plot is shown in Fig. 9. The first peak to the right of 0 m is again the antenna itself. The next large peak around 1.5 m is the large metal plate. This result agrees with the S_{11} and S_{22} measurements.

The next logical experiment was to use the time gating feature on the Copper Mountain analyzer to remove the reflections present from the large metal plate. This feature was used with the parameters shown in Table 5. The gating was performed on the S_{11}, S_{22}, and S_{21} time domain data. The results can be seen in Fig. 10 and Fig. 11. The time gating nicely reduces the reflection from the large metal plate in all sets of data by roughly 15 dBm.

Analyzer	Frequency Span	Number of Points	IF Bandwidth	Output Power
Agilent	2 - 3.2 GHz	201	10 kHz	0 dBm
Copper Mountain	2 - 3.2 GHz	201	10 kHz	0 dBm

Table 3: Measurement parameters for both network analyzers for measuring the horn antenna responses.

Type	Span	Window	Impulse Width	Kiser Beta
Bandpass	-10 - 30 ns	Maximum	2.309 ns	13

Table 4: Time domain parameters for Copper Mountain analyzer.

Type	Span	Shape
Notch	8 - 11 ns	Normal

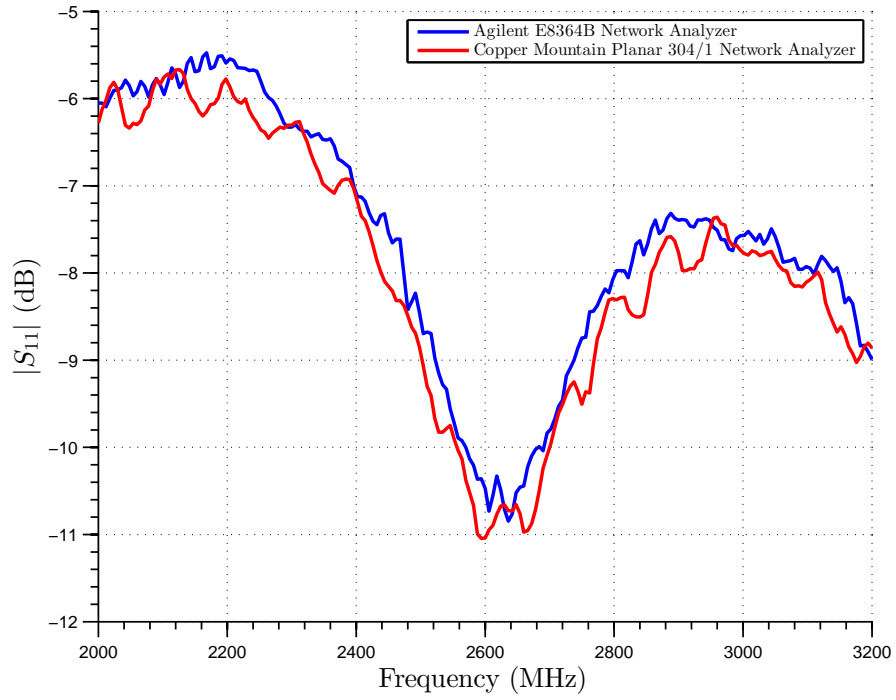Table 5: Time gating parameters for Copper Mountain analyzer.

Figure 5: This shows a comparison of the S11 data taken for the horn antenna connected to port 1 of both analyzers.
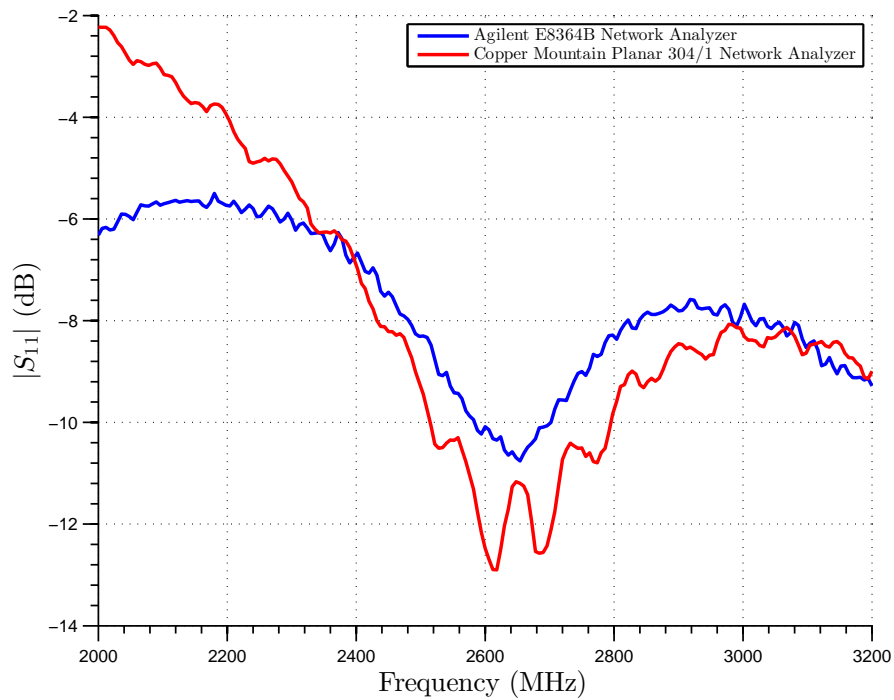
Figure 6: This shows a comparison of the S22 data taken for the horn antenna connected to port 2 of both analyzers.
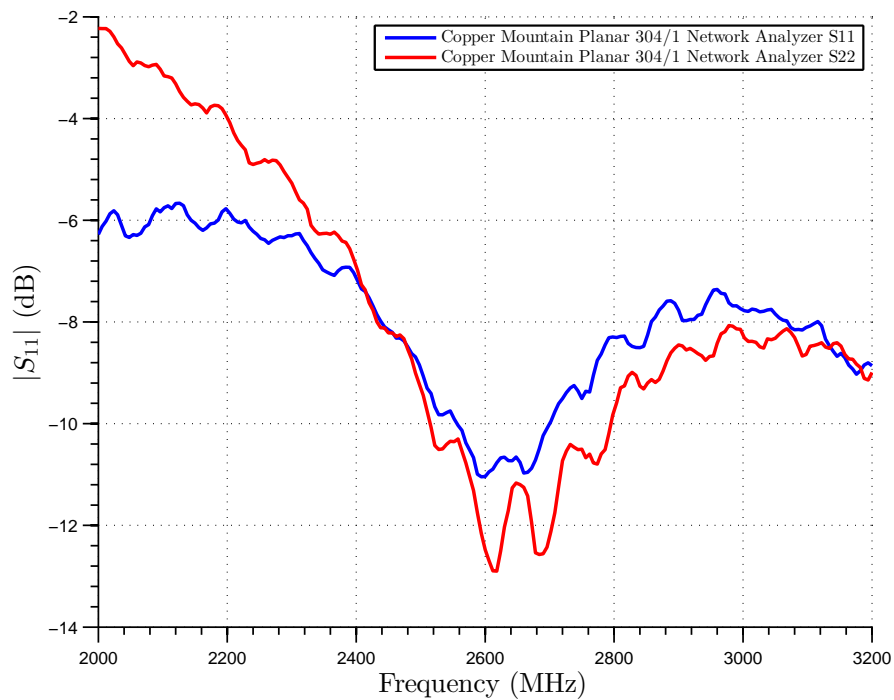

Figure 7: This shows a comparison of the S11 and S22 data taken for identical horn antennas connected on port 1 and port 2 of the Copper Mountain Analyzer.
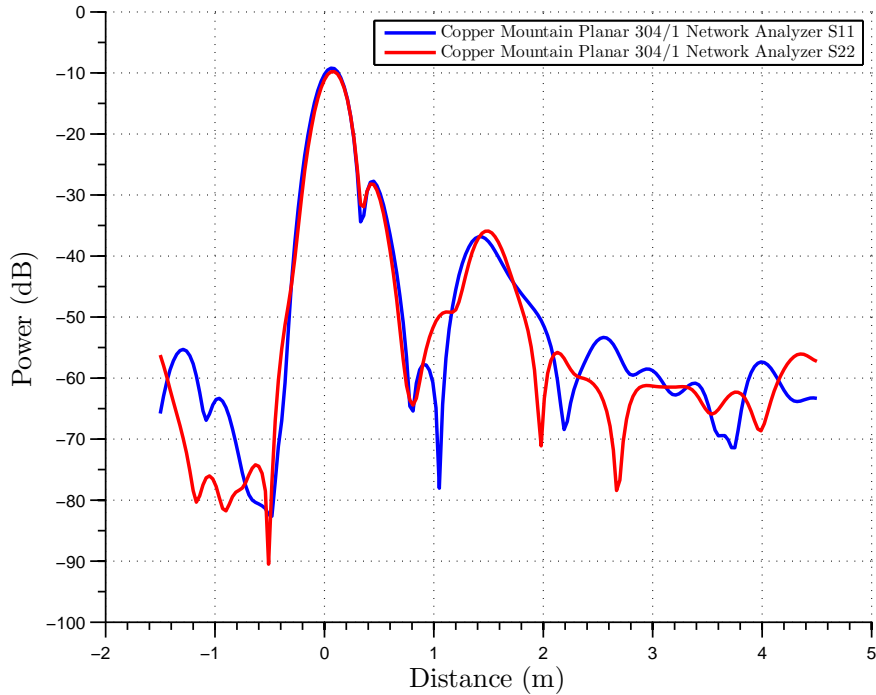
Figure 8: This shows a comparison of the S11 and S22 data taken for identical horn antennas connected on port 1 and port 2 of the Copper Mountain Analyzer in the time domain. Note the large reflection at roughly 1.5 m.
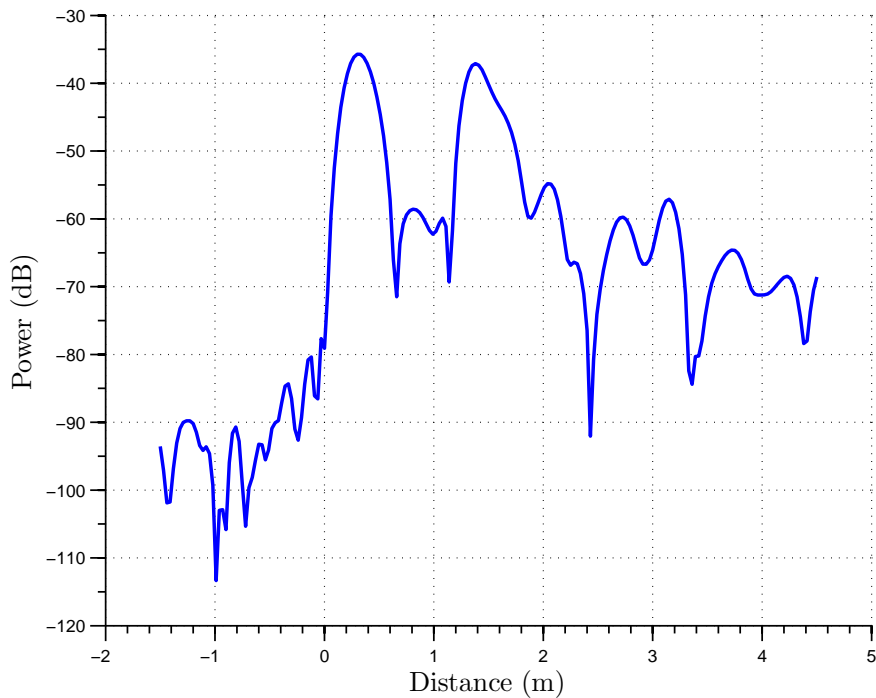

Figure 9: This shows the S21 data from the large metal plate reflection on the Copper Mountain Network Analyzer.
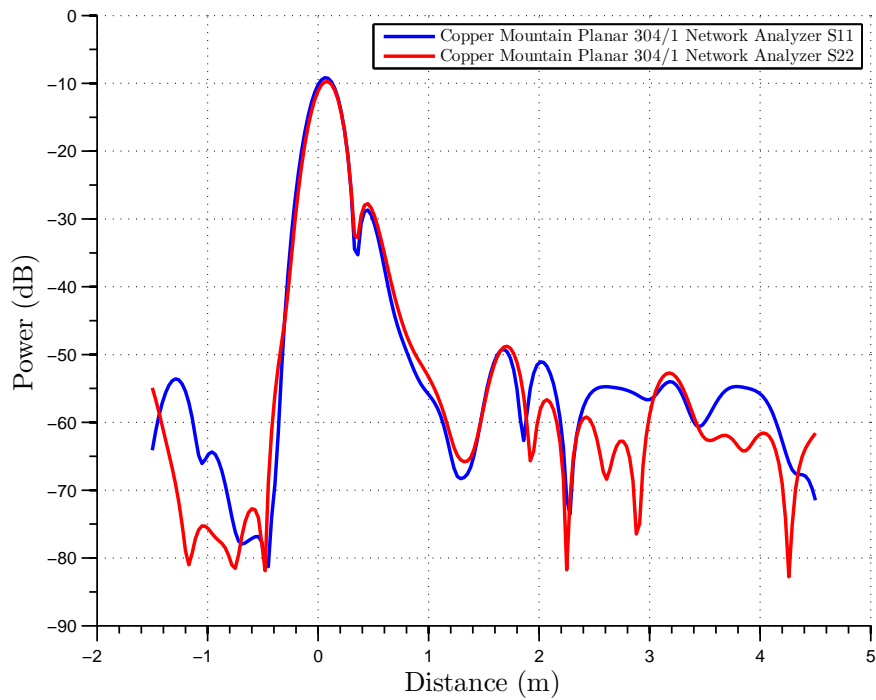
Figure 10: This shows the S11 and S22 time domain data with the large metal plate reflection notched out using time gating.
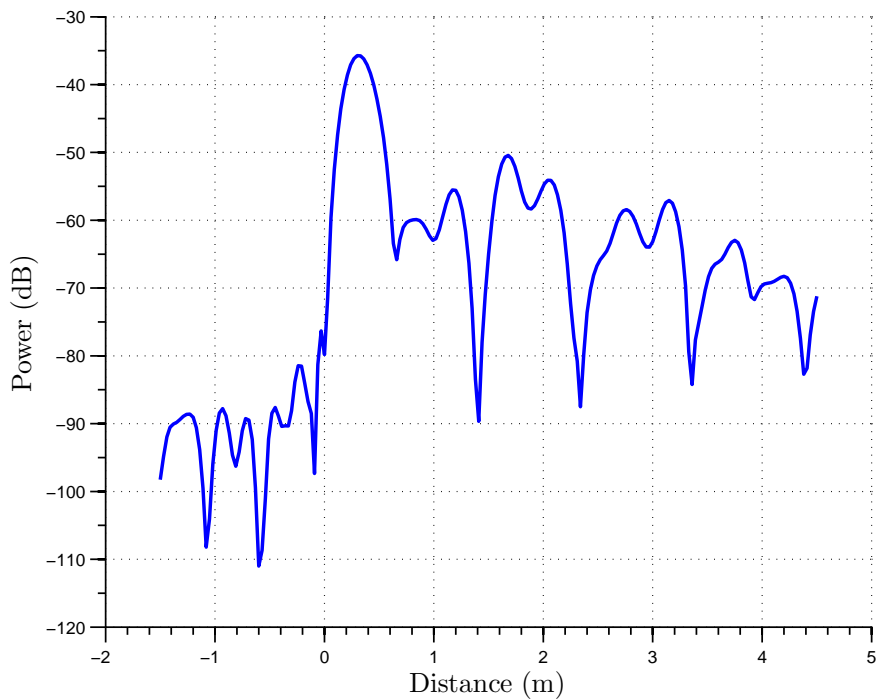

Figure 11: This shows the S21 time domain data with the large metal plate reflection notched out using time gating.

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4.2   3 Cables of Different Length

The time domain function was then tested on 3 SMA cables of length roughly 0.6 m (2 ft), 0.15 m (6 inches), and 0.10 m (4 inches). The analyzer settings can be seen in Table 6 and the time domain settings can be seen in Table 7. The Copper Mountain analyzer was calibrated using the Agilent 85033D calibration kit. Using the same conversion process the time domain information was manipulated in Matlab to produce output plots showing the approximate length of the cables. These can be seen in Fig. 12, Fig. 13, and Fig. 14. Again, these results and calculations are estimates. The speed of light for free space was used in these calculations not the true propagation velocity in the cables being tested. These results could be more accurate if the appropriate propagation velocities were obtained for the cables tested. However, for now these experiments show that the length of the cables under test are approximated very well by this process.

Analyzer	Frequency Span	Number of Points	IF Bandwidth	Output Power
Copper Mountain	2 - 3.2 GHz	201	10 kHz	0 dBm

Table 6: Measurement parameters for Copper Mountain analyzer when measuring cables.

Type	Span	Window	Impulse Width	Kiser Beta
Bandpass	-10 - 30 ns	Maximum	2.309 ns	13

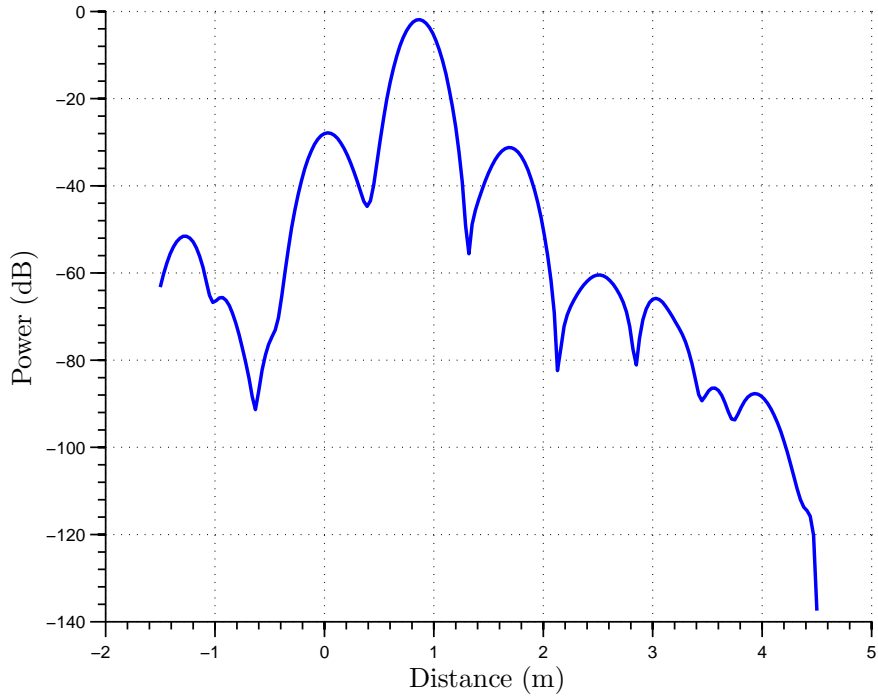Table 7: Time domain parameters for Copper Mountain analyzer.

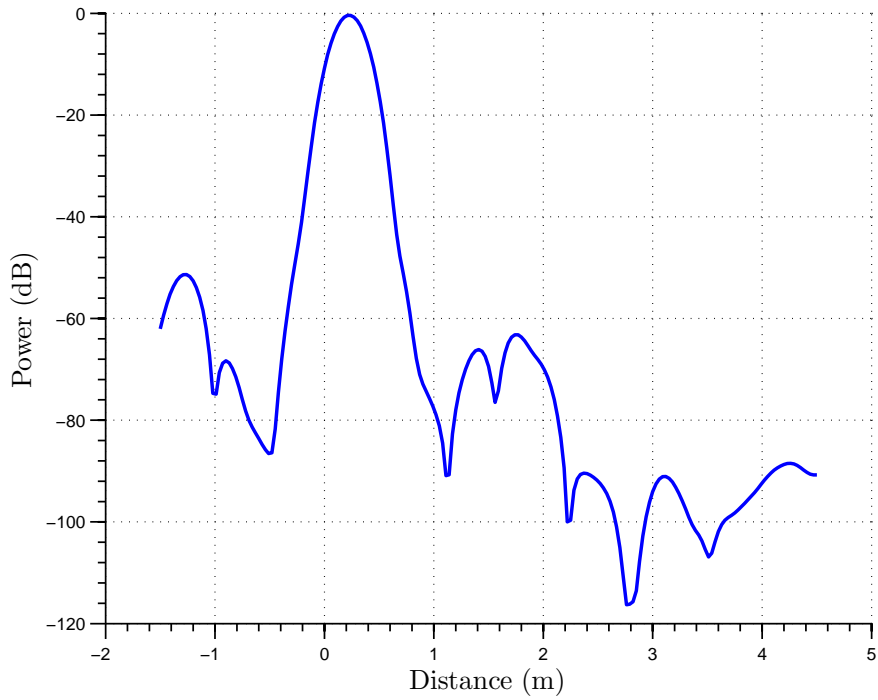Figure 12: Time domain data for the 0.6 m SMA cable.

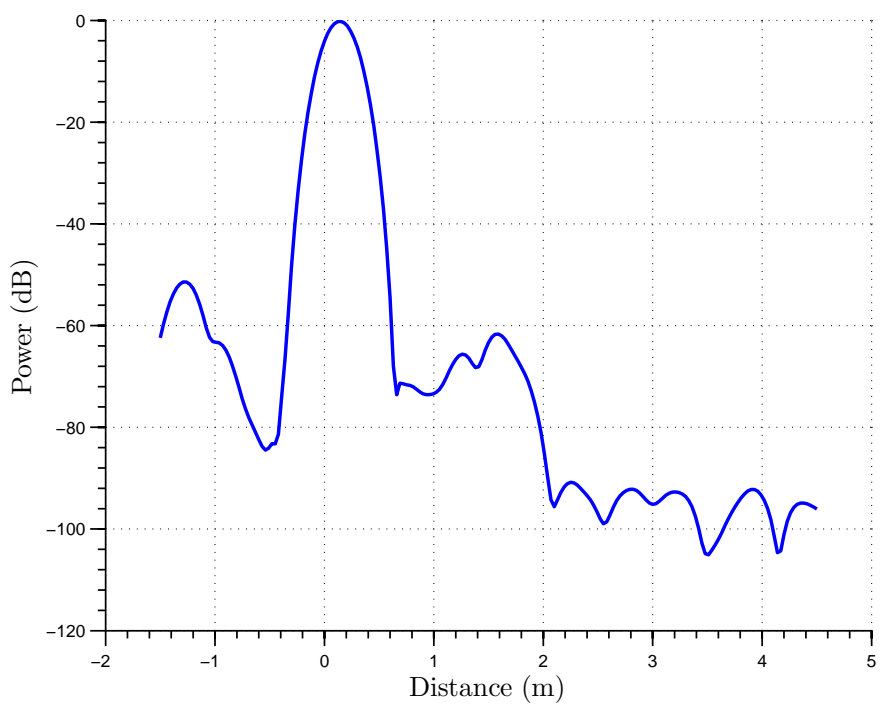Figure 13: Time domain data for the 0.15 m SMA cable.

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Figure 14: Time domain data for the 0.10 m SMA cable.

5 Filter Measurements

From this point on it must be noted that a slight inaccuracy was discovered on the Agilent analyzer. The cable connected to port 1 showed some sign of not operating perfectly. When the cable was moved to a new position the response of an S_{11} measurement would change and then require time to settle back to the proper values. This is not of great concern because all of these measurements are just ballpark comparisons.

All filter measurements utilized the parameters shown in Table 8. The Copper Mountain analyzer was calibrated using the Agilent 85033D calibration kit while the Agilent analyzer was calibrated using the E Cal module. The Agilent analyzer could not go below 10 MHz. The lower calibration on the Copper Mountain analyzer was just done to show that the Copper Mountain Analyzer could go lower than the Agilent analyzer.

Analyzer	Frequency Span	Number of Points	IF Bandwidth	Output Power
Agilent	10 MHz - 3 GHz	201	10 kHz	0 dBm
Copper Mountain	1 MHz - 3 GHz	201	10 kHz	0 dBm

Table 8: Measurement parameters for both network analyzers for measuring the filter responses.

5.1 Bandpass Filter 1

The first filter measured on both analyzers was a bandpass filter which passed frequencies of roughly 385 MHz to 675 MHz. The results of this S_{21} measurement can be seen in Fig. 15. The data from both analyzers matches up nearly perfectly.

Another feature explored was the bandwidth search option. This option searched for the max and 3 dB down points in the bandpass response to display some characteristics of the filter. This feature is very convenient. The Agilent analyzer had a similar function. A screen shot of the display provided by this function can be seen in Fig. 16. The Copper Mountain analyzer provided other functions that the Agilent analyzer did not provide. These other functions gave RF filter statistics and even a flatness value in the pass band.
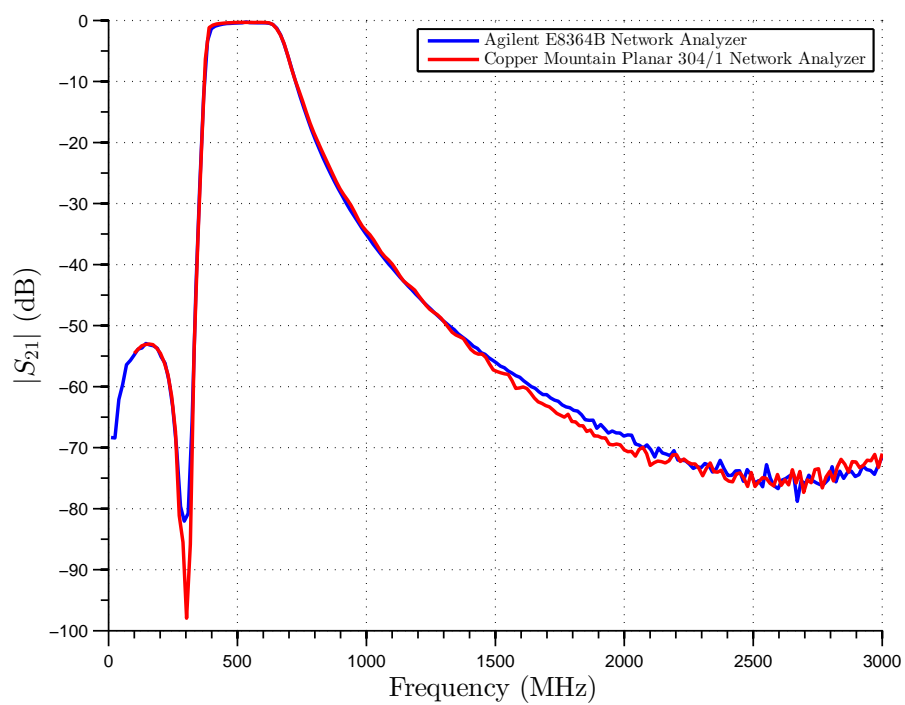
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Figure 15: Comparison of the first bandpass filter data taken on both analyzers.
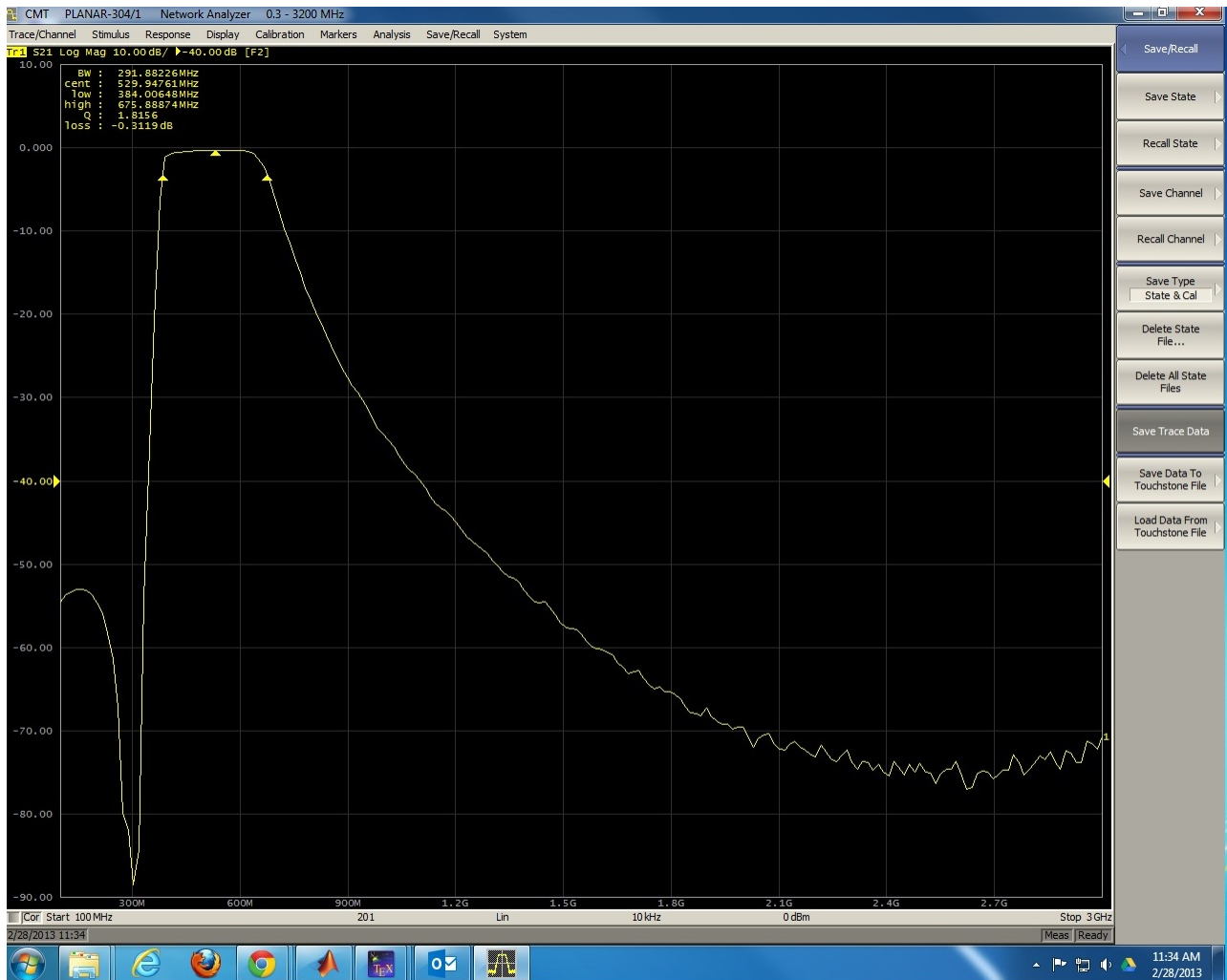
Figure 16: Screen shot showing the bandwidth search function of the Copper Mountain analyzer.

5.2   Bandpass Filter 2

The next filter measured was also a bandpass filter. It passed frequencies from roughly 58 MHz to 80 MHz. The data for this S_{21} measurement can be seen in Fig. 17. Again, the data matches up nearly perfectly for the two analyzers.
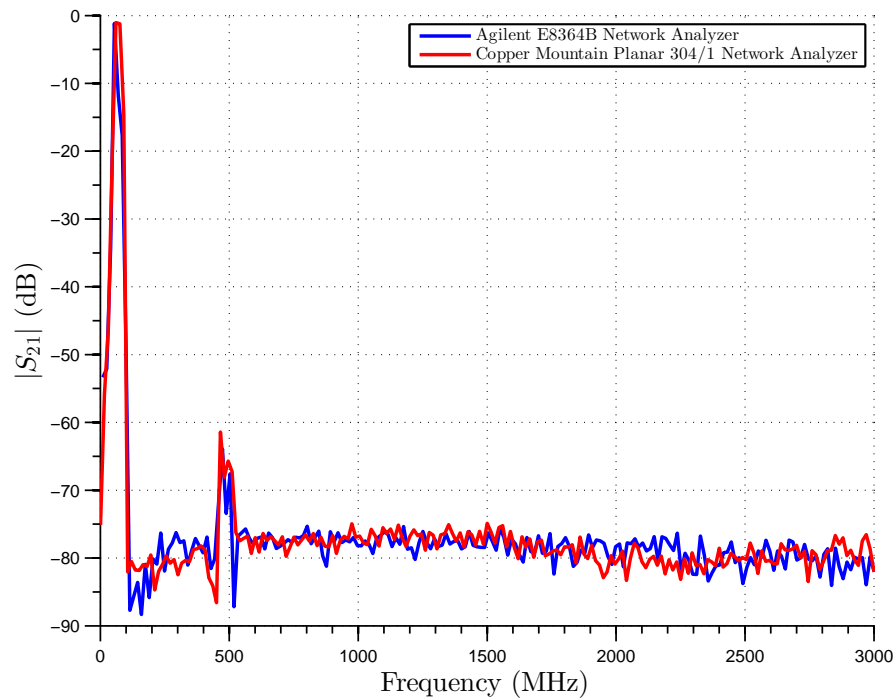

Figure 17: Comparison of the second bandpass filter data taken on both analyzers.

5.3   Notch Filter

Next a notch filter was measured. The data for this S_{21} measurement can be seen in Fig. 18. Again nearly perfect agreement is seen from both of the analyzers measurements.
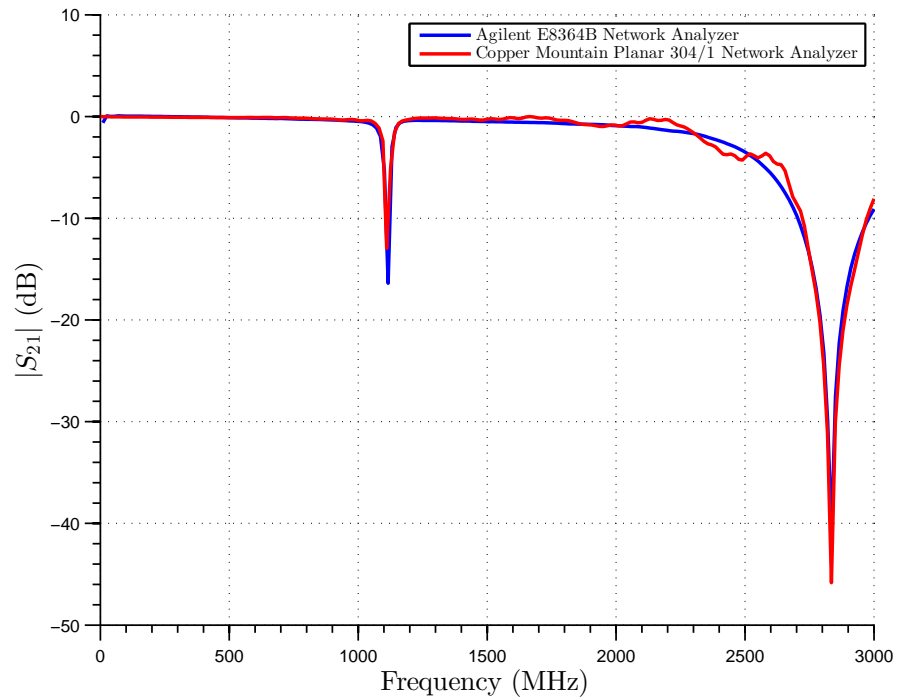

Figure 18: Comparison of the notch filter data taken on both analyzers.

6 Amplifier Measurements

The final measurements were made on a 10 dB amplifier. The Copper Mountain analyzer was calibrated using the Agilent 85033D calibration kit while the Agilent analyzer was calibrated using the E Cal module. Table 9 shows the settings used on both analyzers. The results of this S_{21} measurement can be seen in Fig. 19. A slight difference can be seen in the data. The data are off by roughly 1 dB in the lower portion of the band. This may be attributed to the touchy cable being used on port 1 of the Agilent analyzer. Overall, the analyzers show the same general measurement.

Analyzer	Frequency Span	Number of Points	IF Bandwidth	Output Power
Agilent	10 MHz - 3 GHz	201	10 kHz	0 dBm
Copper Mountain	1 MHz - 3 GHz	201	10 kHz	0 dBm

Table 9: Measurement parameters for both network analyzers for measuring the amplifier response.
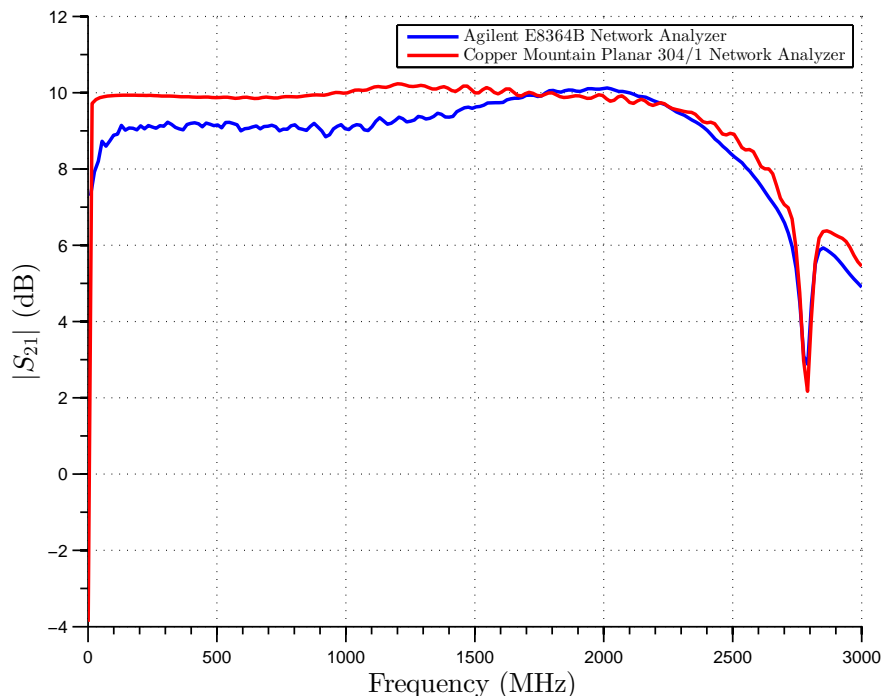

Figure 19: Comparison of the amplifier data taken on both analyzers.

7 Conclusions

From all of the measurements taken, it can safely be concluded that the Copper Mountain Planar 304/1 Network Analyzer is just as accurate as the current Agilent E8364B PNA Network Analyzer used in the lab. The Copper Mountain analyzer provides a simple, intuitive, and smooth interface to look at measured data. The Copper Mountain analyzer even provides some other built in functionality that the Agilent analyzer does not have such as the additional RF filter statistics and the time domain analysis. Overall, the Copper Mountain analyzer seems like a great piece of test equipment.