Constructor University Bremen

CO-527-A
PCB Design and Measurement Automation

Spring 2024

Lab Report – Measurement Automation

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The Date of Submission:
14 April 2024

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Introduction

This Measurement Automation Laboratory came with three core objectives along with tasks that included the assessment of some very important devices and tools for measurement, the imperative use of MATLAB and Labview to conduct thorough and informative examinations of these devices and then the comprehension and exploration of the properties of a Nano Vector Network Analyser or a Nano VNA. And this was done practically with the aid of hands-on practice.

Firstly, the investigation was conducted for the critical and relevant measurements instruments: the function generator, digital oscilloscope, spectrum analyser, and the vector network analyser. Such an investigation was carried through with the aid of provided university computers that were connected to LAN in lieu of the purpose to control and use these devices (that were also connected to the LAN).

Furthermore, the relevant complementary MATLAB programs were run on the computers to acquire the required output and facilitate an intrinsic understanding of the subject. To elaborate on this process (that will be detailed upon later), the requisite files were acquired from the matlab_begin folder to generate an inception to control these devices. These files were incomplete at the start, notwithstanding, provided some hints on how to accomplish the requirements. The experimenters then completed these programs with their understanding and through understanding the necessities of the program with the aid of the manuals provided for the devices and the programs. After the completion of this program, the executed MATLAB scripts and their program outputs were contrasted with those obtained on the displays of the VNA, spectrum analyser, and, finally, the scope.

In the case of the second objective, Labview was used. Labview is a system-design platform and development environment that aids with several important functionalities: data acquisition, instrument control, and, critically, industrial automation. Here, it pertains to the objective of modelling device blocks; this is similar to Simulink, where this was then controlled with the aid of MATLAB-like functionality. As done previously, a folder entitled labview_begin was provided as a means to begin. After the completion of the missing sections (with consultation and readings from the manual) to accomplish the functionality as before using MATLAB scripts, these were executed and compared to the device outputs.

Our final fundamental objective for this lab featured some important properties of the cables and balun and its investigation with the equipment of the NanoVNA supplied. Now, the characteristics here are: the s-parameters, characteristic impedance, and ABCD parameters. The NanoVNA was calibrated with the aim of acquiring accurate and precise results. After the completion of the calibration, for the balun's measurements: the open, brief, and results, with the remainder of the requisite parameters were conducted. On the cable, then, the open and brief measurements were conducted. Next on the list: MATLAB and Python were enabled to control the NanoVNA whilst it was connected to the computer with the aid of the USB for the same responsibilities as was in the first task. After this, MATLAB was used one more time to obtain the parameters of the NanoVNA for the provided data series using the .txt files for the open, short, and termination measurements of cables and balun. Ultimately, the respective graphs for the Characteristic Impedance's amplitude, phase, attenuation (Alpha), and beta were generated. And the derived parameters from the data provided and the ones derived from the results generated earlier were compared to ascertain if the tasks had been completed effectively.

Execution

Part 1:
Direct Setting

1.1.
Spectrum Analyzer – GSP-9300B

In the first part of the experiment, the function generator was used to create a sweep function for the spectrum analyzer by inserting a 2 MHz sine wave directly in the device. Then in the spectrum analyzer, the RBW was set to 100 kHz, start frequency at 9 KHz, and stop frequency at 20MHz with no offset. A single spike was observed in the function generator as expected.

Note: While the TA was showing us what to do, we could not take a picture and did not have ample time to do it ourselves as we switched to another measurement device for the proceeding data collection.

Then, the function generator was set to a square wave with the same settings as the previous one. The results are shown in figure 2 (see below). We can see there are some small spikes (cursor at the 1st odd peak) in the odd harmonics as the square wave is not precisely square.

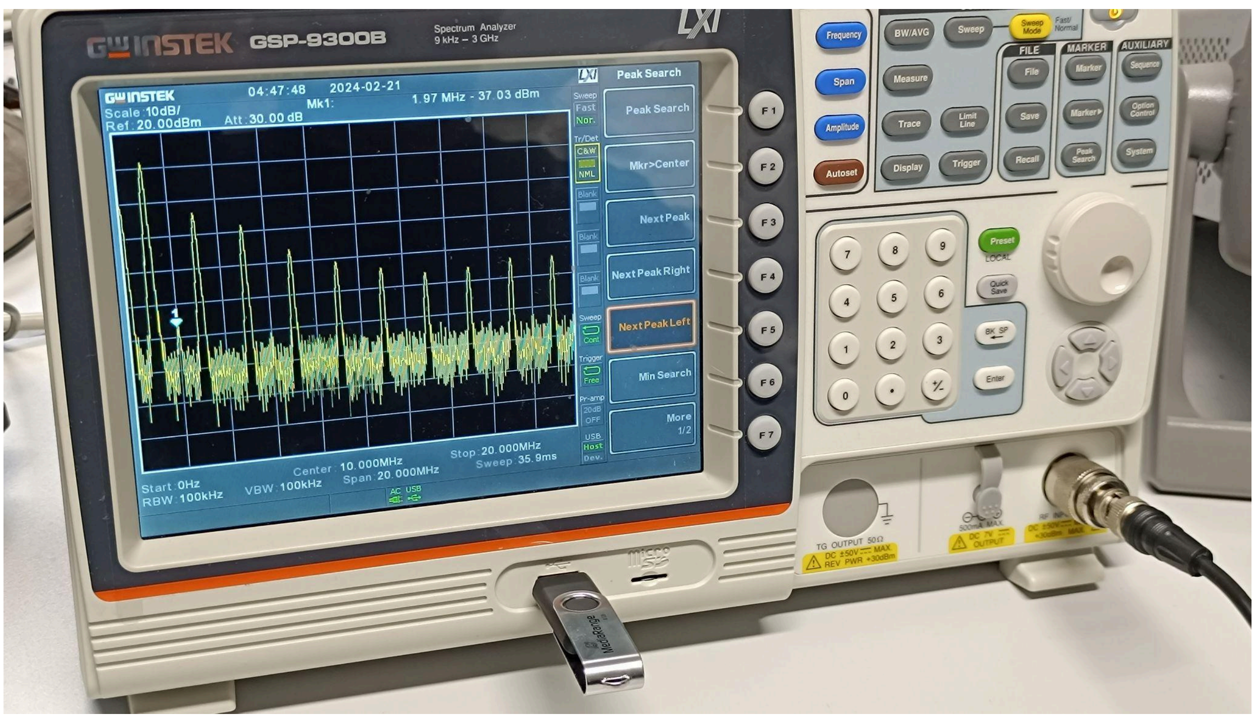

Figure 2:
The Signal Generated with the 2MHz Square Wave

The ramp function was utilised to observe the behaviour of the function with a frequency of 200 kHz. Unfortunately, a picture was not taken for this part as the TA said it was not required for the lab report.

1.2.
Digital Oscilloscope

This part of the experiment is to be directly observed and utilised from the Oscilloscope, which was to be used to observe the electrical noise from a drill running near the coil of wire.

After setting up and adjusting the Oscilloscope, the drill was triggered the immediate response was observed, the trigger level had to be set correctly, but after some changes and experimentation, the measurements details are shown below:

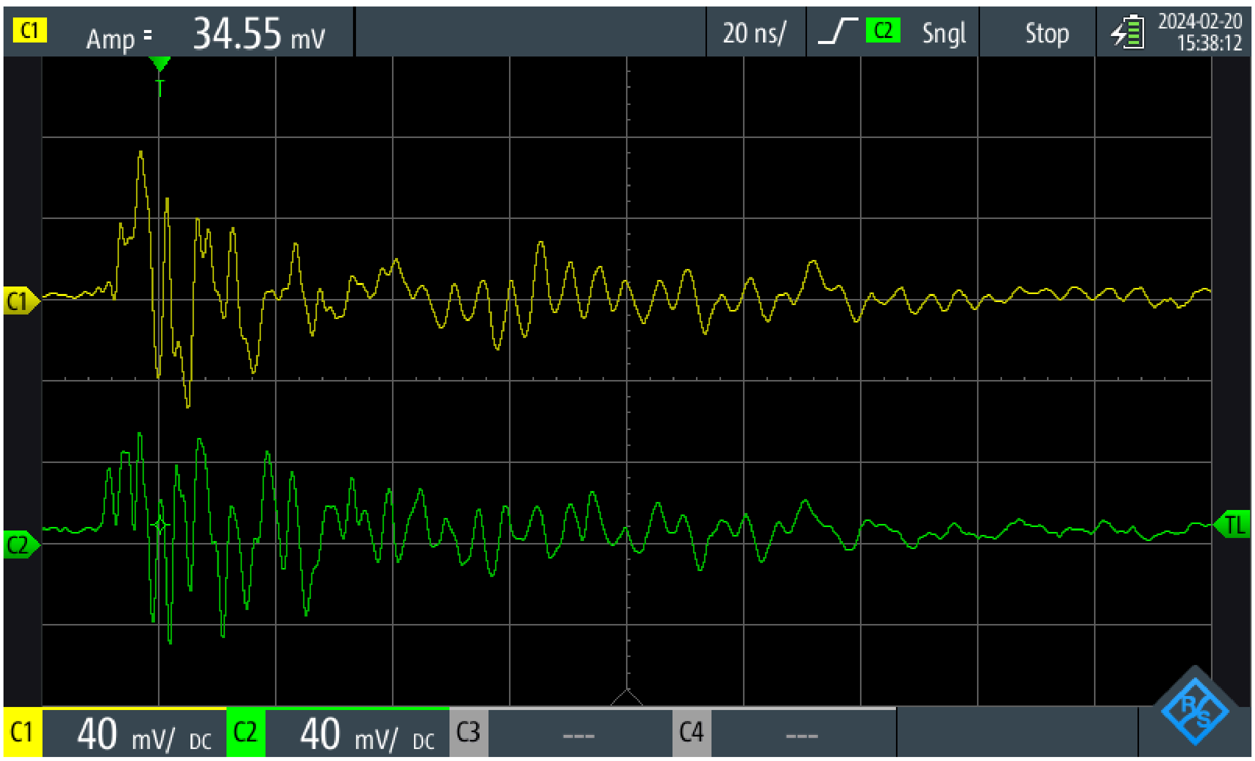

Figure 3:
Results for Digital Oscilloscope

1.3.
Vector Network Analyzer

In this part, the vector network analyzer was used to observe an open, shorted and terminated balun. First, the VNA was calibrated and the 100m wire presented in the lab was used to carry out the measurements for open, short, and terminated connections (with a 47Ω resistor).

The results were observed on a monitor connected to the VNA and data was taken from the VNA using a floppy disk as .csv files.

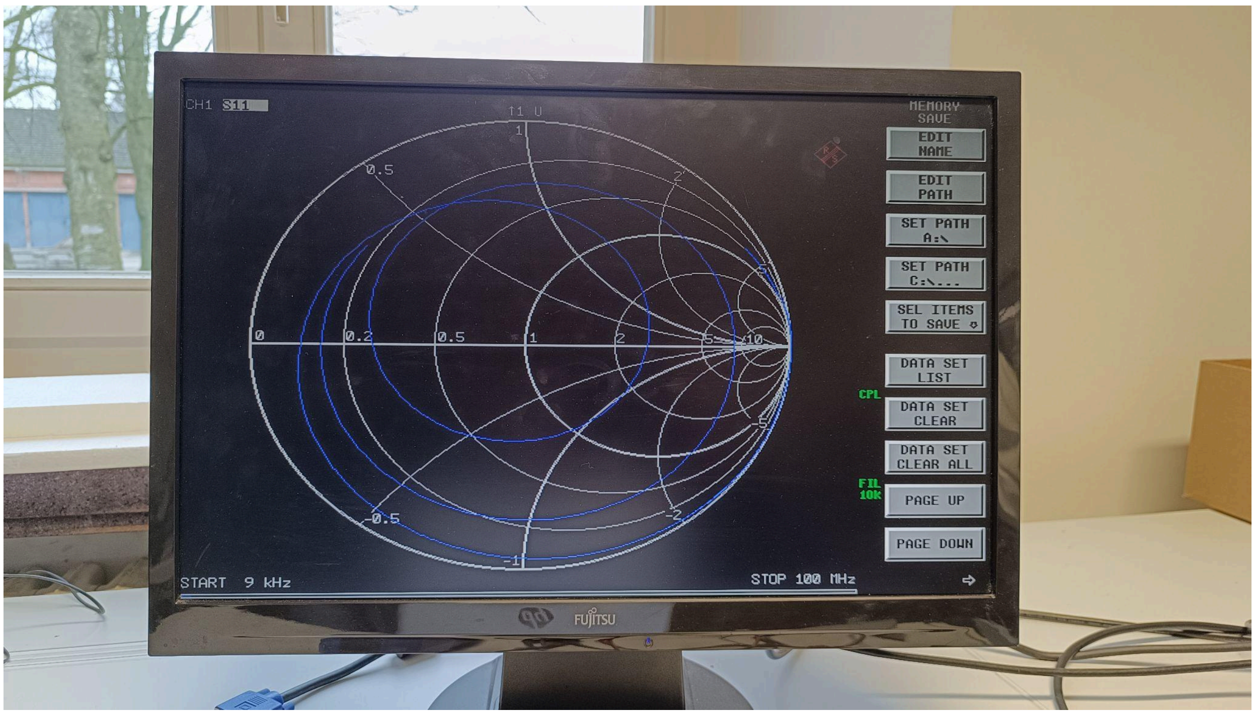

Figure 4:
Results for the Vector Network Analyzer

1.4.
Matlab Code and Results for Characteristic Impedance and Propagation Constant

```
% Closing all windows and clearing variables for ease of use
close all;
clear all;

% Reading and storing the data from the files
f = dlmread('BAL_46_7.ASC',';','A15..A2015');

bal_O = dlmread('BAL_46_7.ASC',';','B15..B2015') + ...
     1i*dlmread('BAL_46_7.ASC',';','C15..C2015');

bal_S = dlmread('BAL_O.ASC',';','B15..B2015') + ...
     1i*dlmread('BAL_O.ASC',';','C15..C2015');

bal_T = dlmread('BAL_S.ASC',';','B15..B2015') + ...
     1i*dlmread('BAL_S.ASC',';','C15..C2015');

cab_S = dlmread('CABLE_S.ASC',';','B15..B2015') + ...
     1i*dlmread('CABLE_S.ASC',';','C15..C2015');

cab_O = dlmread('CABLE_O.ASC',';','B15..B2015') + ...
     1i*dlmread('CABLE_O.ASC',';','C15..C2015');

% Computing BALUN impedances for 47 ohm termination
ZBO = 47*(1+bal_O)./(1-bal_O);
ZBS = 47*(1+bal_S)./(1-bal_S);
ZBT = 47*(1+bal_T)./(1-bal_T);

% Computing ABCD parameters
A = ZBO.*sqrt((ZBS-ZBT)./(47*(ZBT-ZBO).*(ZBO-ZBS)));
B = ZBS.*sqrt(47*(ZBT-ZBO)./((ZBS-ZBT).*(ZBO-ZBS)));
C = sqrt((ZBS-ZBT)./(47*(ZBT-ZBO).*(ZBO-ZBS)));
D = sqrt(47*(ZBT-ZBO)./((ZBS-ZBT).*(ZBO-ZBS)));

% Computing CABLE impedances
Z1CO = 47*(1+cab_O)./(1-cab_O);
Z1CS = 47*(1+cab_S)./(1-cab_S);
Z2CO = (B-D.*Z1CO)./(C.*Z1CO-A);
Z2CS = (B-(D.*Z1CS))./((C.*Z1CS)-A);

% Computing characteristic impedance and propagation constant
ZW = sqrt(Z2CS.*Z2CO);
gamma = atanh(sqrt(Z2CS./Z2CO));
ReG = real(gamma);
ImG = imag(gamma);

% Plotting
figure(1);
plot(f,abs(ZW));
title('Amplitude of Characteristic Impedance');
xlabel('Frequency [Hz]');
ylabel('Magnitude of ZW)');

figure(2);
plot(f,angle(ZW)*(180/pi));
title('Phase of Characteristic Impedance');
xlabel('Frequency [Hz]');
ylabel('Phase of ZW');

figure(3);
ReGnp = ReG*(20/log(10));
plot(f,ReGnp);
title('Attenuation');
xlabel('Frequency [Hz]');
ylabel('Re(Gamma)');

figure(4);
plot(f,ImG);
title('Phase Constant');
xlabel('Frequency [Hz]');
ylabel('Im(Gamma) [rad/m]');
```

Figure 5:
The Preceding MATLAB Code

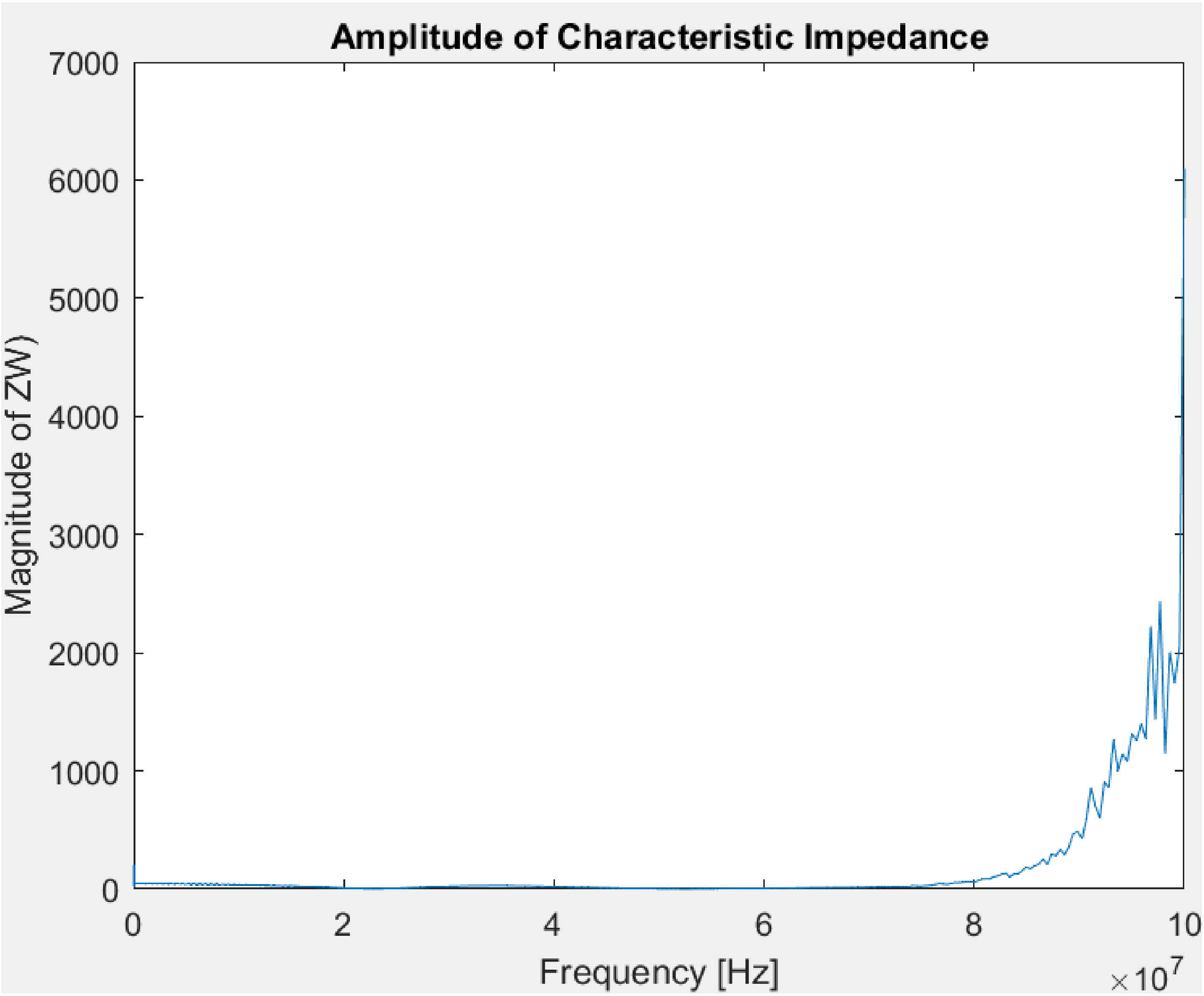

Figure 6:
Amplitude of the Characteristic Impedance

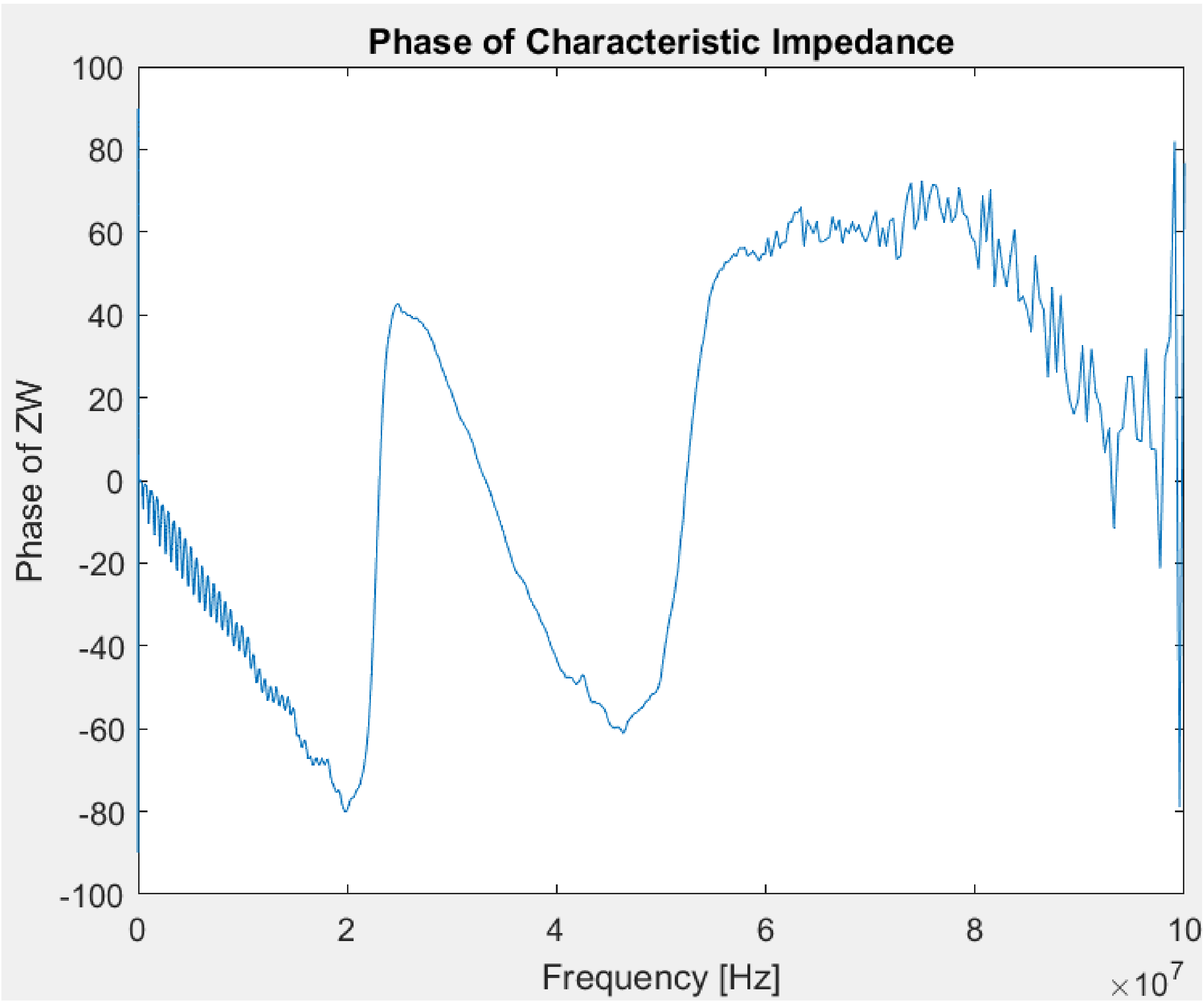

Figure 7:
Phase of the Characteristic Impedance

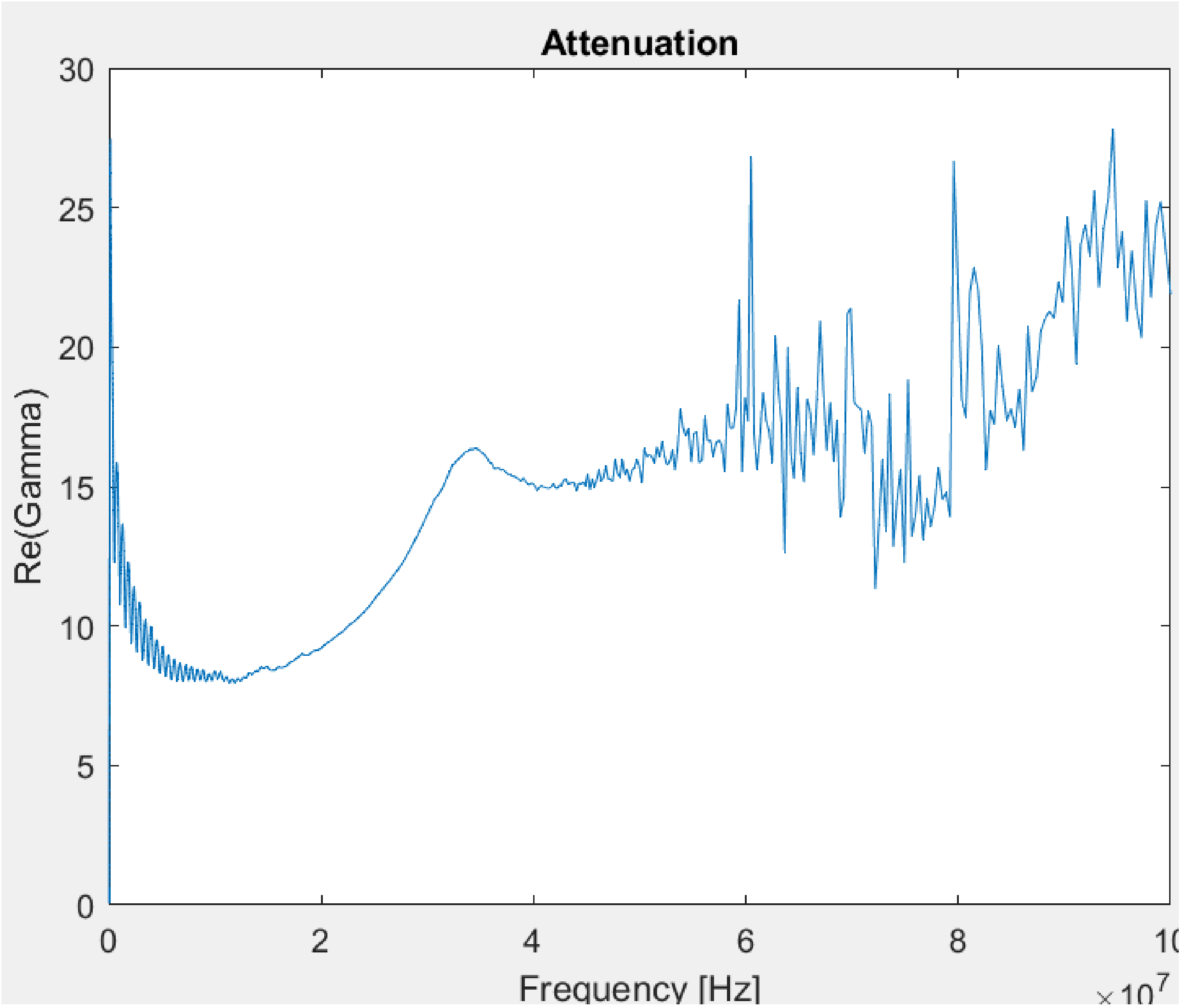

Figure 8:
The Attenuation Constant

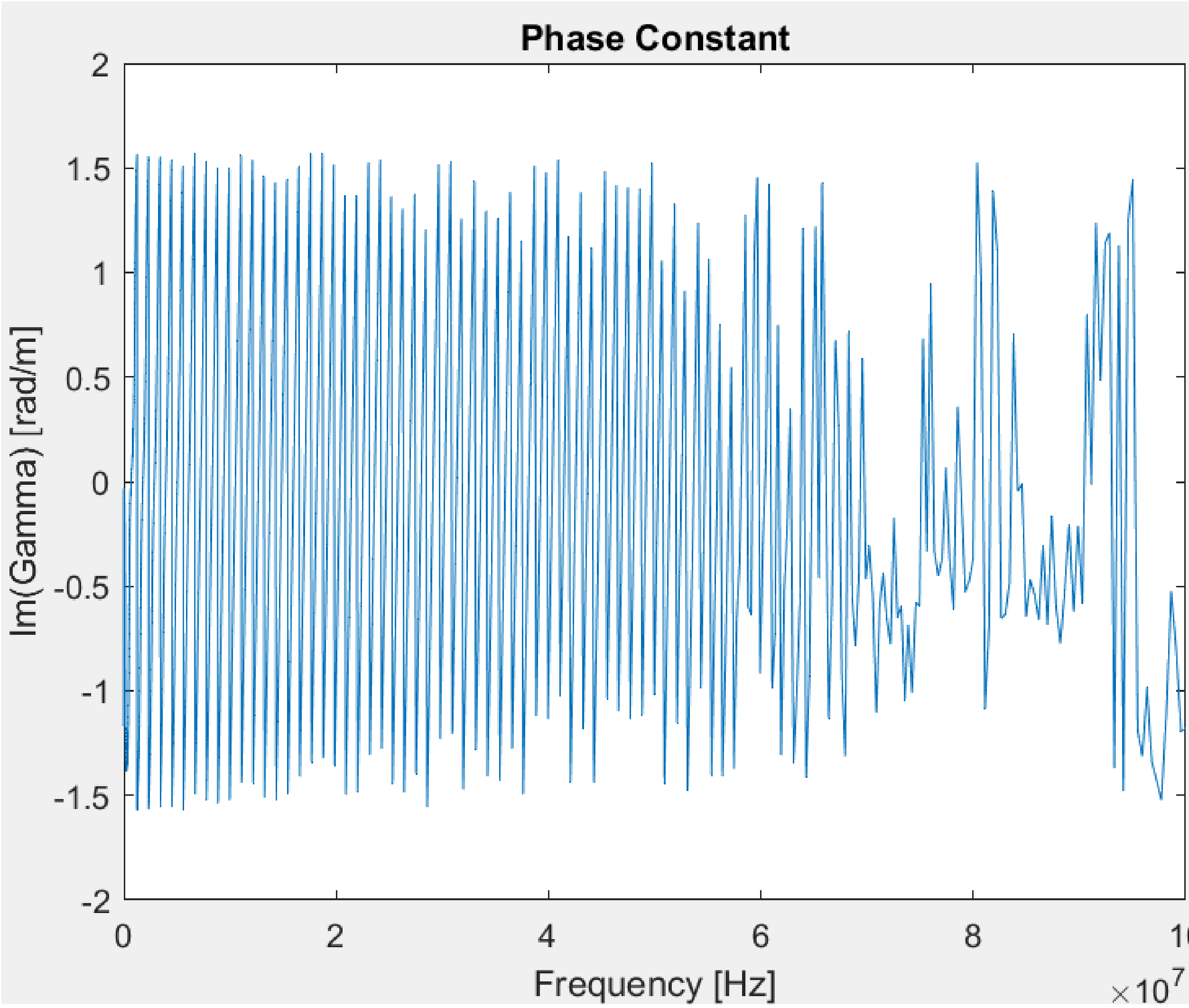

Figure 9:
The Phase Constant

Part 2:
Controlling Using MATLAB

2.1.
Spectrum Analyzer – GSP-9300B

A function generator was used in this section and the Spectrum Analyser was then equipped. The MATLAB code for the same is provided below:

```
clc; close all; clear all;
h = visa('ni','TCPIP::10.50.251.117::INSTR');  % check IP address!!!
h.inputbuffersize = 1000000;
fopen(h);
    fprintf(h,':FREQ:STAR 9khz');
    fprintf(h,':FREQ:STOP 20Mhz');
    fprintf(h,':BAND:VID 1kHz');
    fprintf(h,':BAND 100kHz');
    fprintf(h,'SWE:POIN 10001');
%fprintf(h,'FORM ASCII');
pause(10);
fprintf(h,'TRAC? TRACE1');
tr = fscanf(h);
fclose(h);
trace = str2num(tr);
freq = ((20e6) - (9e3))/(600);   % produce frequency axis
freq1 = 9e3:freq:20e6;
plot(freq1, trace);
xlabel('Frequency [Hz]');
ylabel('Magnitude [dB]');
title('Video BW= 1kHz, Res BW=100kHz');
```

Figure 10:
The MATLAB Source Code for Spectrum Analyzer

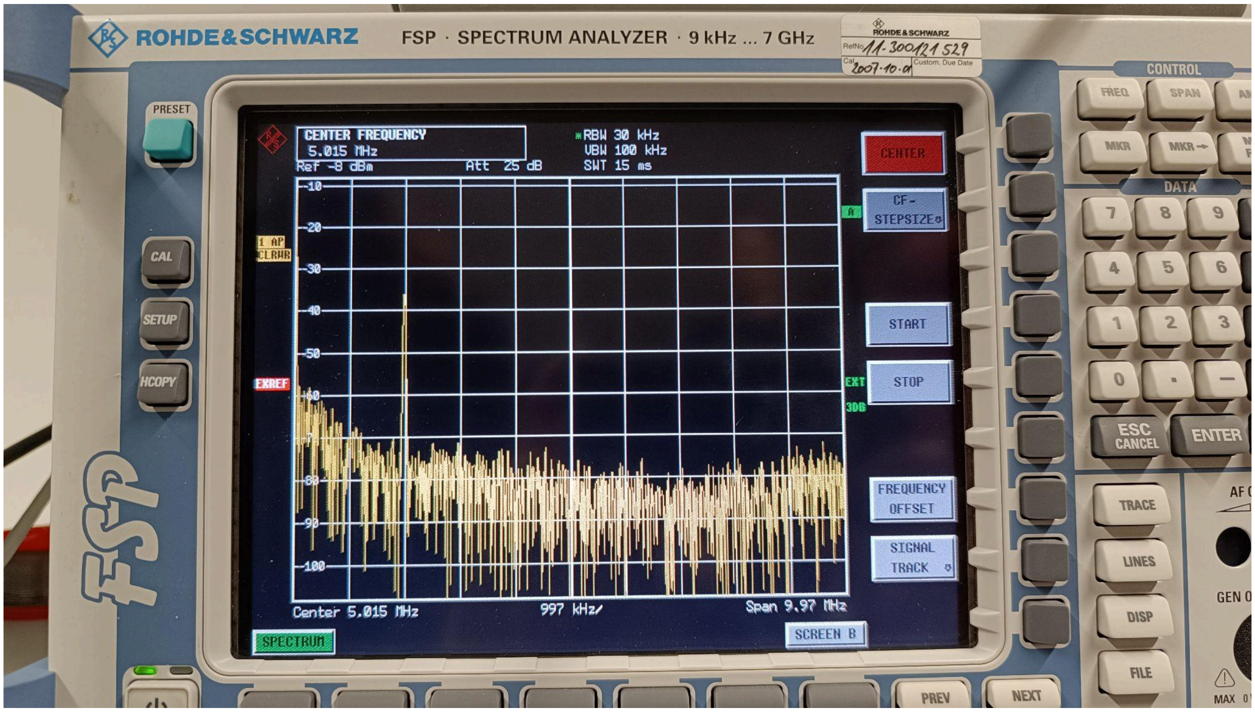

Figure 11:
The MATLAB Results for the 9kHz to 20MHz Sweep

As the result should be, there is an individual thin peak that is moving from low to high frequencies in the MATLAB result above.

2.2.
Rohde and Schwarz – Digital Oscilloscope

With the aid of the code, both the channels are activated. Then, the scales are set between 100mV and 200mV, and the time base is configured. After this, the trigger mode is set to single, the trigger edge slope to positive, and the trigger level is set to 0.005. The RS Scope demonstrates that the measurements remain consistent until the operation of the drill.

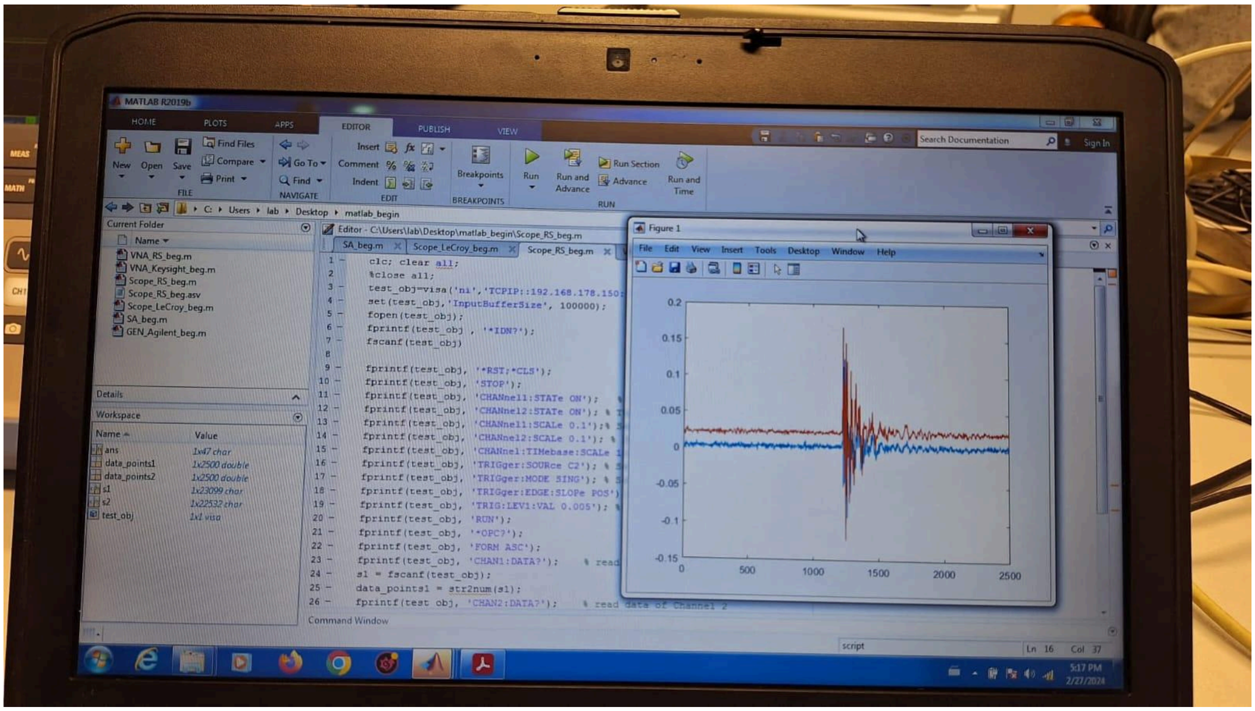

Figure 12:
The MATLAB Code & Plot Generated from the Code Run for RS Scope

2.3.
Keysight – Vector Network Analyzer

The MATLAB code is equipped now with the requirement to communicate with the Keysight VNA that is listed below. The codework is explained thoroughly with the aid of the comments provided per line of code, detailing its purpose, and contribution in the generation of the end result. The procedure detailed is consistent with the instrument's application.

```
clc; clear all; close all;
test_obj=visa('agilent','TCPIP0::10.50.243.19::INSTR'); % enter correct IP address
set(test_obj,'InputBufferSize',100000);
fopen(test_obj);
fprintf(test_obj, '*IDN?') ;
fscanf(test_obj);
fprintf(test_obj, 'INST:SEL "NA"') ; % select network analyzer function
fprintf(test_obj, 'SENS:FREQ:START ');  % set start frequency
fprintf(test_obj, 'SENS:FREQ:STOP  ');  % set stop frequency
fprintf(test_obj, 'SENS:SWE:POIN 1001');    % set number of points <= 10001
fprintf(test_obj, 'CALCulate:FORMat SMITh');    % Smith chart
fprintf(test_obj, 'SENS:INIT:CONT OFF');    % turn off continuous mode
fprintf(test_obj, 'INIT:IMM; *WAI') ;           % wait command
fprintf(test_obj, 'FORM:DATA ASCii,0') ;        % define the data format as ASCii
fprintf(test_obj, 'CALC:DATA:SDATA?') ;         % read data in Re/Im format
s = fscanf(test_obj);
data_points = str2num(s) ;
fclose(test_obj) ;
re = data_points(1:2:2002);
im = data_points(2:2:2002);
plot(re,im);
fid = fopen('cableshort.txt','w');
fprintf(fid,'%f',data_points);
fclose(fid);
```

Figure 13:
The MATLAB Code for Keysight VNA

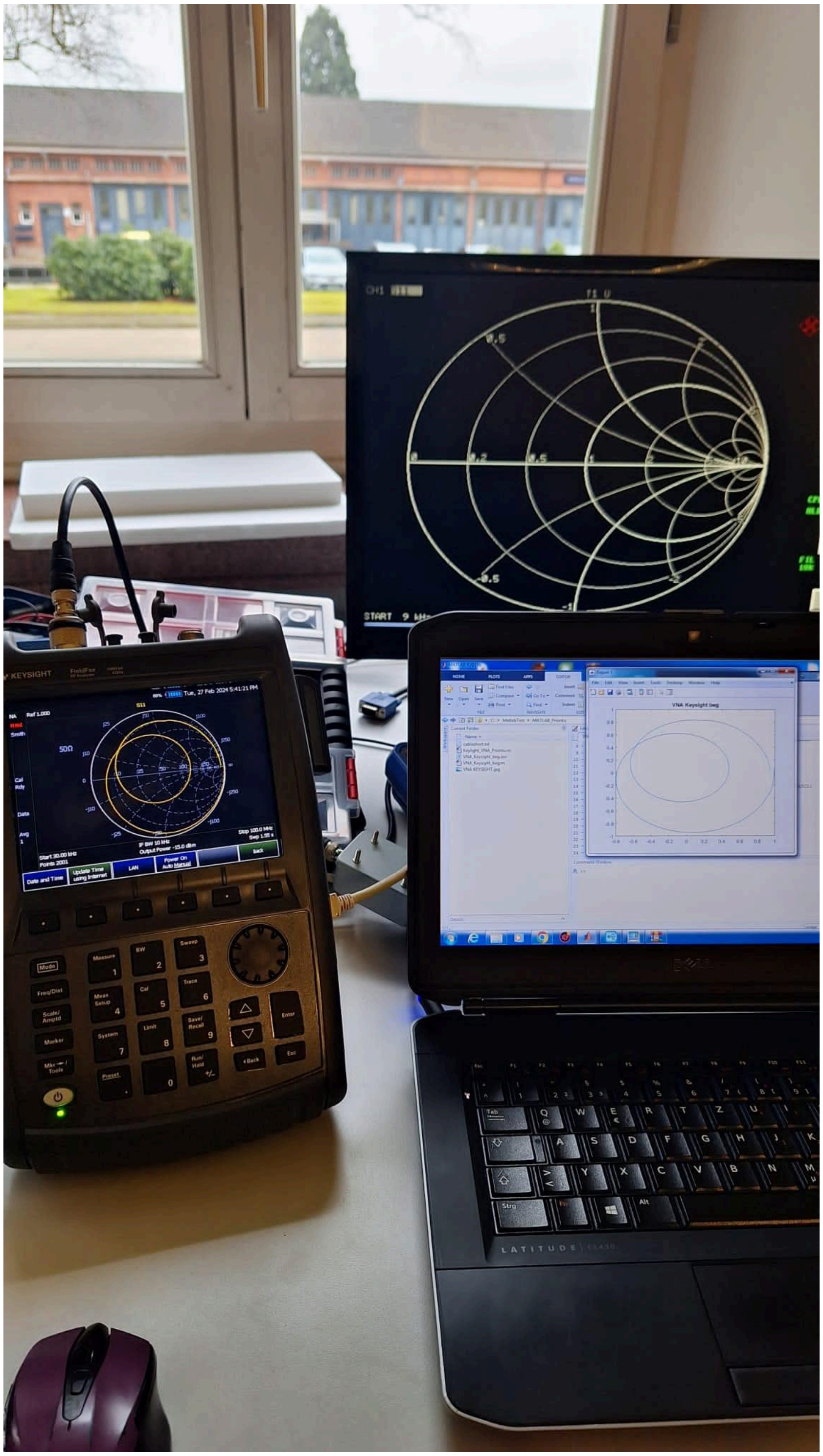

Figure 14:
The MATLAB Results for the Keysight VNA

The MATLAB results for the Keysight VNA are important in this case because it is clear from this demonstration that they are similar to the measurements that were acquired directly from the instrument.

Part 3:
Controlling Using LabView

In the lab report on Measurement Automation for PCB Design, LabView was introduced, which is a graphical programming language commonly used in commercial settings. Instructions were given as to how to replicate the MATLAB parts in LabView. Each MATLAB code was translated into LabView, and the outcomes of the LabView implementation were documented. This transition from MATLAB to LabView allowed the exploration of a different programming environment and experience in utilising LabView for measurement automation tasks.

3.1.
Spectrum Analyzer GSP-9300B

The LabView code is provided below:

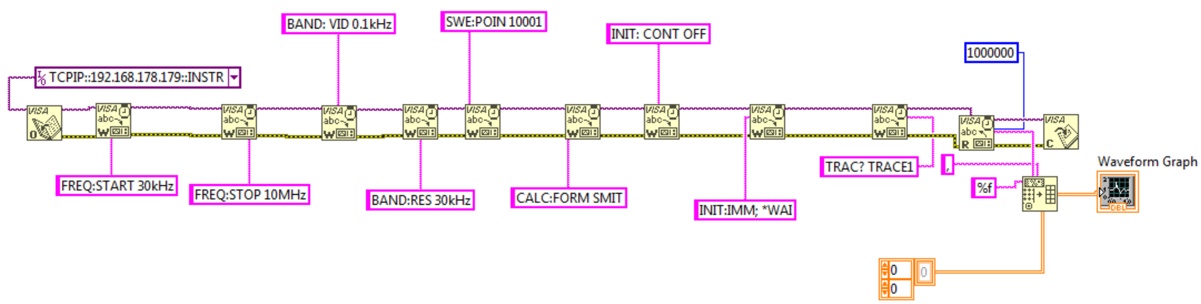

Figure 15:
The Block Diagram (LabVIEW code) for the Spectrum Analyzer

In the lab report, it was noted that the plot generated using LabView showed the same result as when the device was manually operated. This indicates that the LabView implementation successfully replicated the manual operation of the device, demonstrating the effectiveness of using LabView for measurement automation tasks.

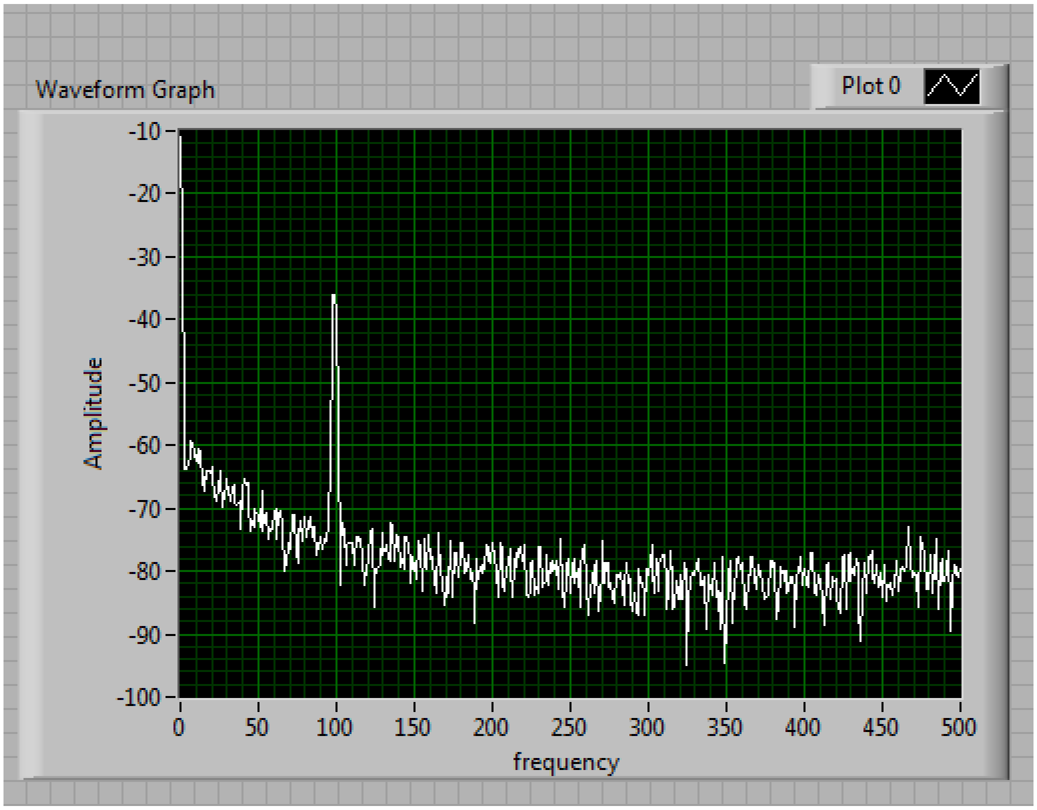

Figure 16:
The Plot Generated by LabVIEW During the Code Run

Further analysing the output plots produced, it can be observed that the plot was not discrete spectral lines for the sinusoidal input as could be expected, due to each particular sinusoid having its own distinct frequency. This can be explained by taking the function principle of the spectrum analyzer into account. According to this principle, when the spectrum analyzer sweeps the sinusoid across its set frequency range, a shift in frequency occurs due to the filter applied. This shift in frequency depends on the resolution bandwidth that is used for the sweep.

If the resolution bandwidth is high, the spectrum will be broad and if the resolution bandwidth is low, the spectrum will be narrow and look more like the expected single-frequency line. However, decreasing the resolution bandwidth also means that the sweep rate would be lower. In this case, a resolution bandwidth of 30kHz was used, and a broader spectrum is seen as expected. Another parameter that could be used to control the sweep time was the video bandwidth which was set to 100Hz.

3.2.
Rohde and Schwarz – Digital Oscilloscope

The LabView code is provided below:

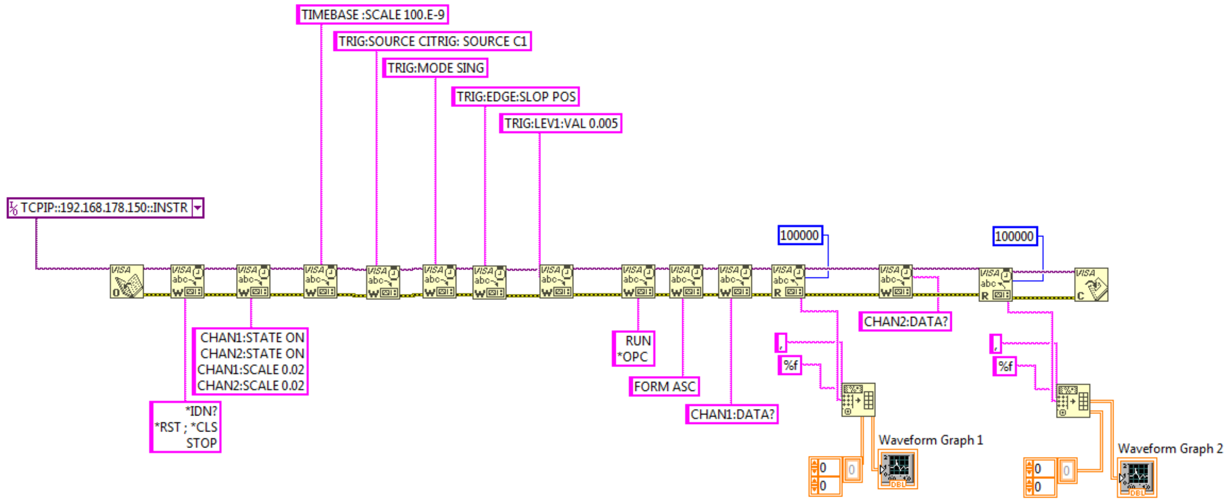

Figure 17:
The Block Diagram (LabVIEW Code) for the Oscilloscope

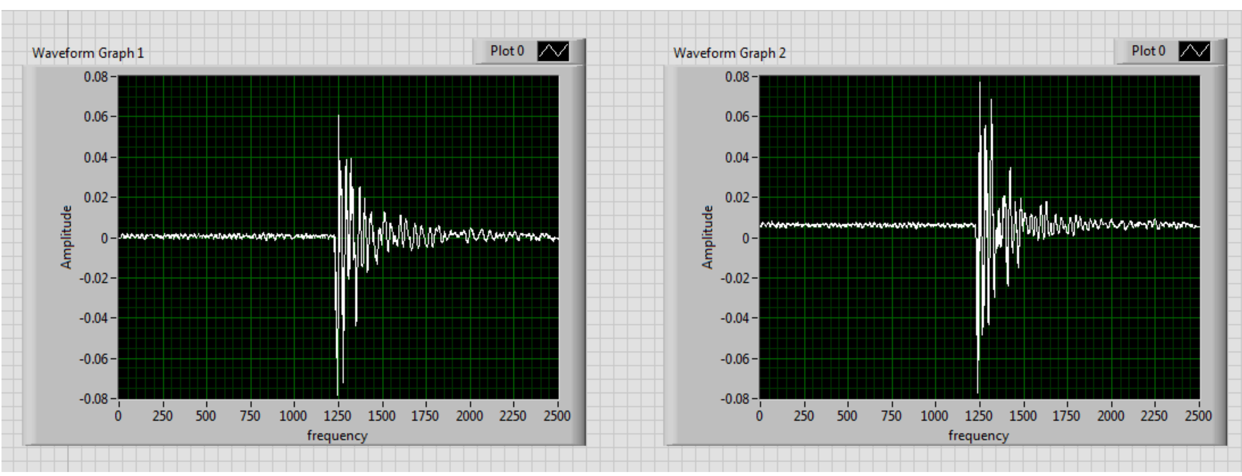

Figure 18:
The Plot Generated by LabVIEW During the Code Run

Figure 19:
Screenshot at the Scope

The results obtained from the digital oscilloscope using LabView were noted to be similar to those from earlier sections, as expected. This consistency in results indicates that the LabView implementation produced outcomes in line with previous manual operations or MATLAB implementations, showcasing the reliability and accuracy of the measurement automation process.

3.3.
Keysight – Vector Network Analyzer

The LabView code is provided below:

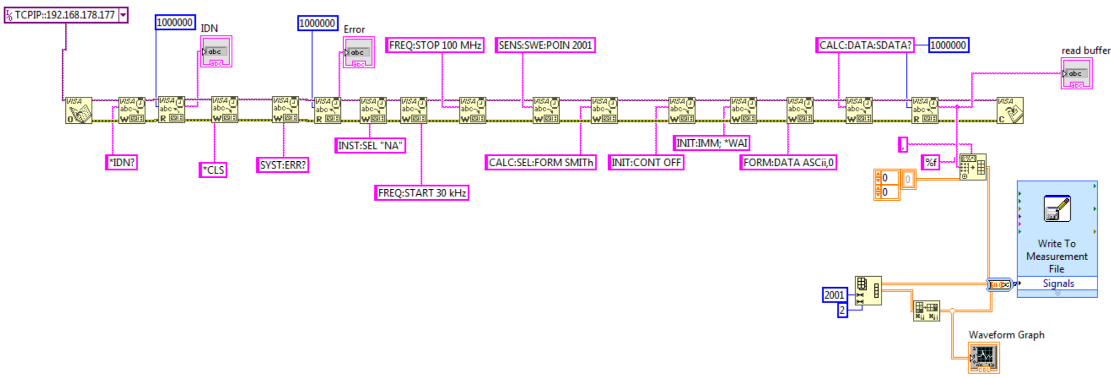

Figure 20:
The Block Diagram (LabVIEW Code) for Vector Network Analyzer

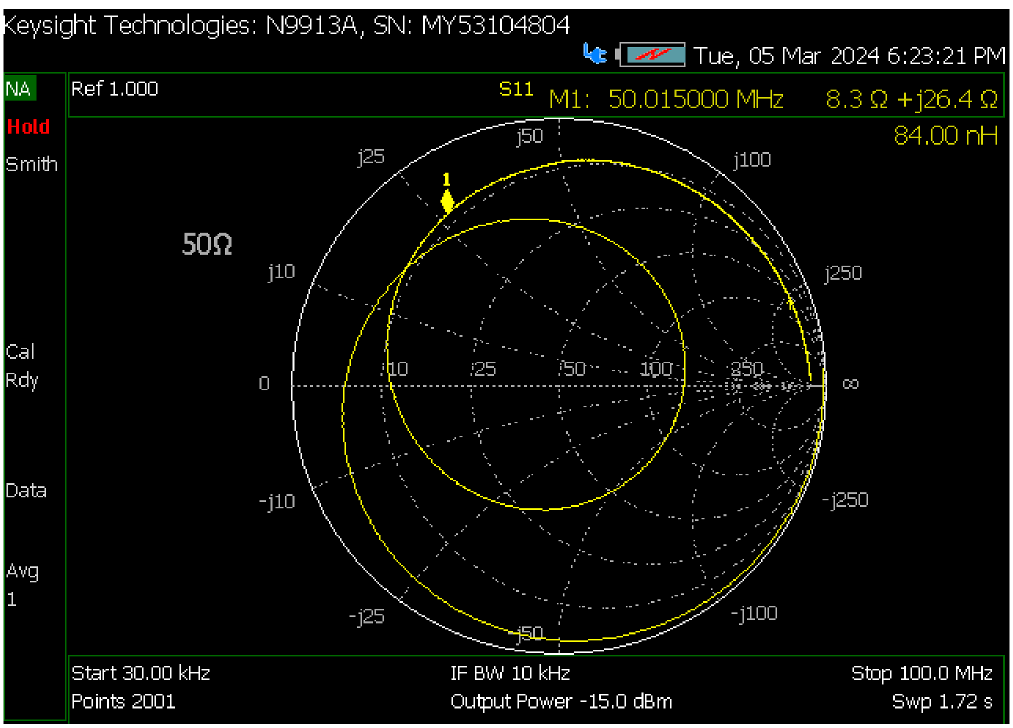

Figure 21:
The Plot Generated in the VNA During the Code Run

Once more, the plot closely resembles those from previous trials, as anticipated.

Part 4:
Measurements Using the NANO VNA

4.1.
Introduction and Background

A physical NanoVNA (Nano Vector Network Analyzer) with a coaxial cable, a balun, an ethernet cable, and other measurement parts (for opening, shorting, and terminating the NanoVNA, balun, and ethernet cable) were equipped. All these measurements and calibrations were conducted with the provided and requisite parts, and all the necessary impedances and parameters were recorded. **Note** that all measurements of termination were conducted with an impedance of 75 Ω. Preceding this section, it was important to pursue the ordeal correctly, so we learnt from the Professor how to correctly calibrate the NanoVNA and collect the requisite data. This will be showcased with two sets of plots: one for data series 1 and the other for data series 2, which is then detailed thoroughly.

4.2.
The Calibration of NANO VNA - S11 Port

For the first step: the NanoVNA was calibrated with the aid of the S11 port for the open, short, and termination measurements. Here, the NanoVNA was set onto sweep mode from the values of 50kHz to 900MHz. After this, it was calibrated with the open, short, load, isolation and through settings.

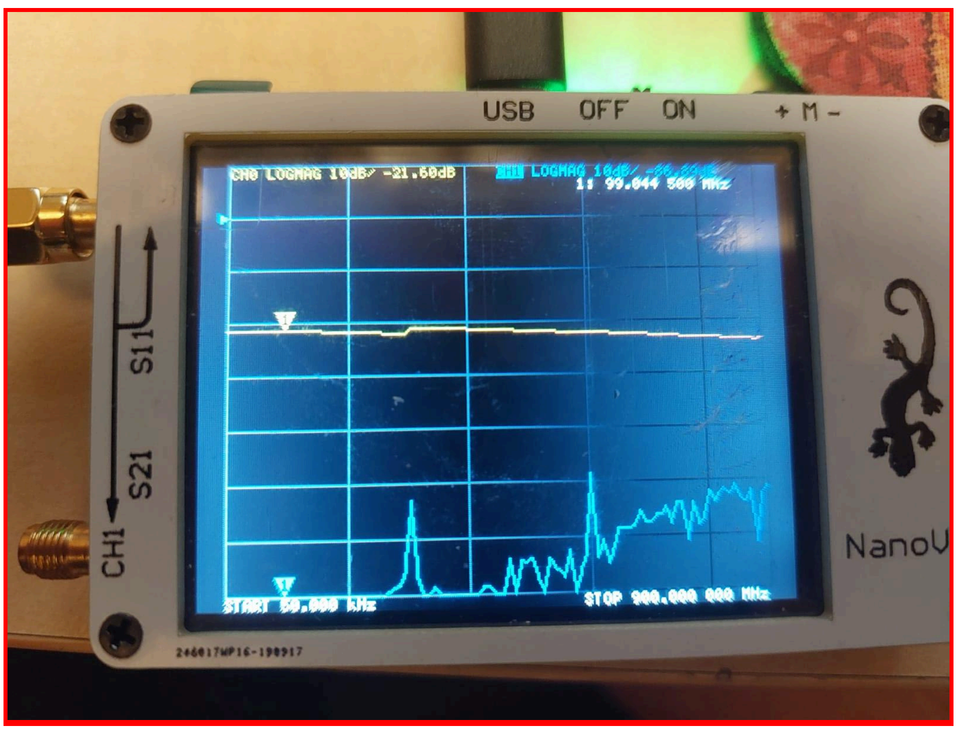

Figure 22:
The NanoVNA Display Output for the Open Measurement

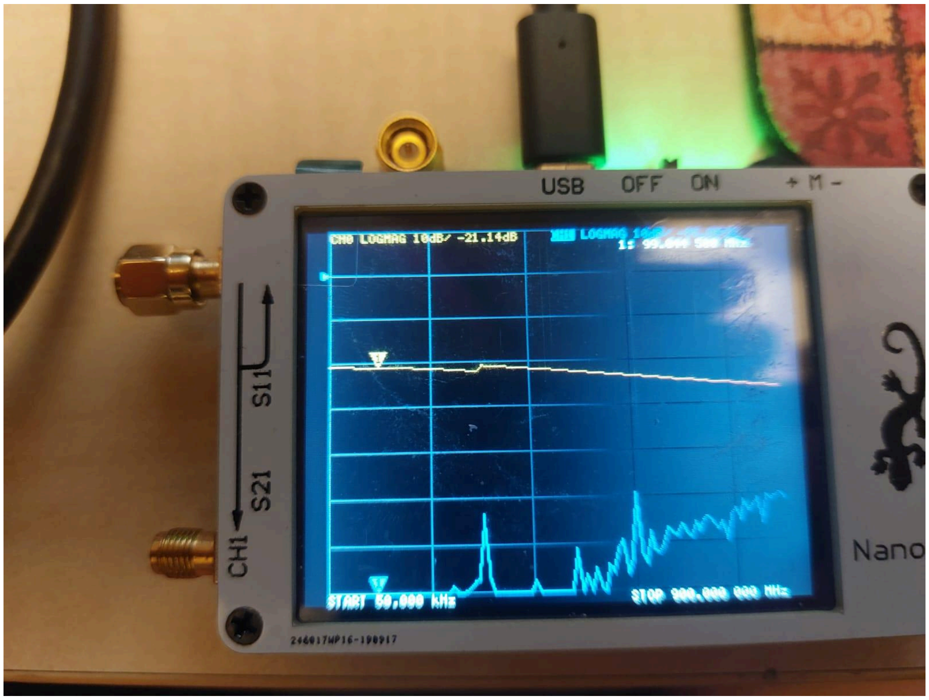

Figure 23:
The NanoVNA Display Output for the Short Measurement

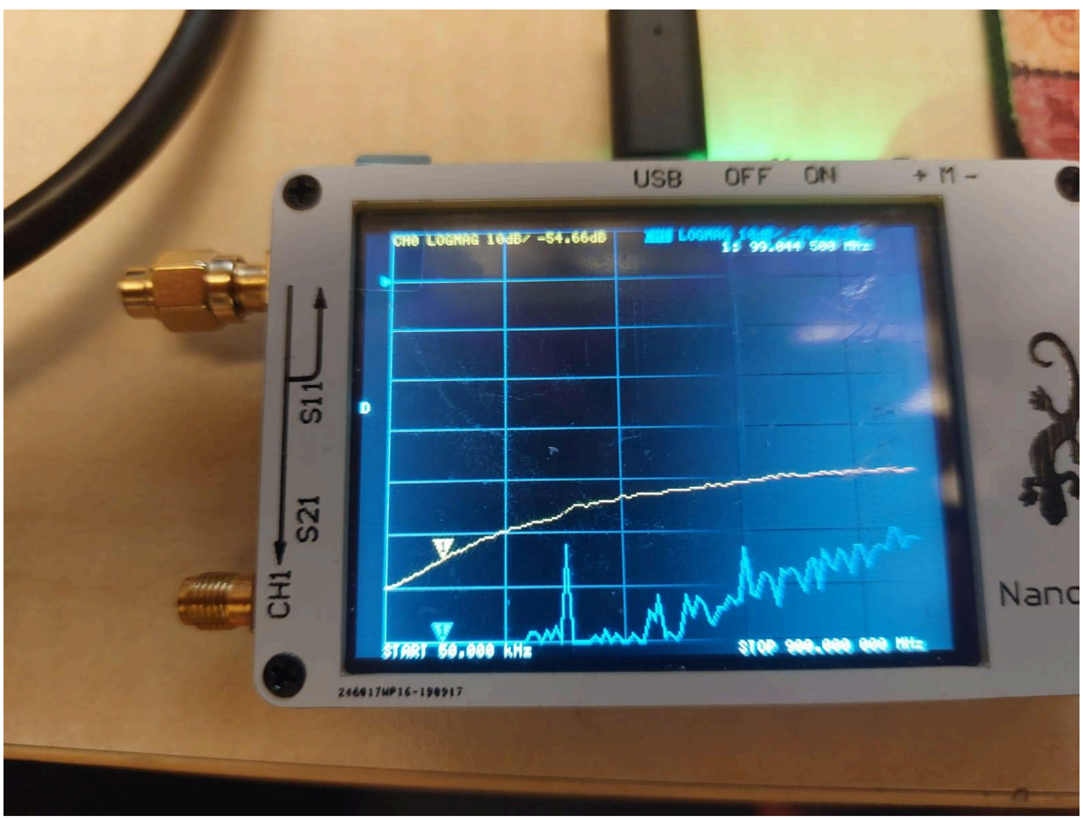

Figure 24:
The NanoVNA Display Output for the Load Measurement

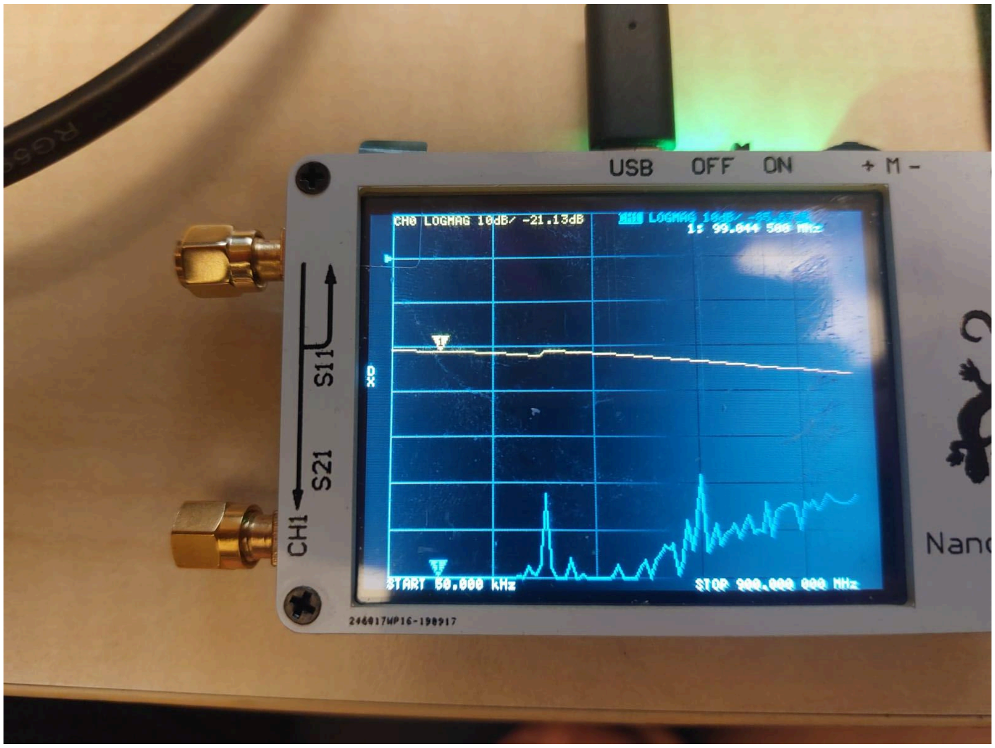

Figure 25:
The NanoVNA Display Output for the Isolation Measurement

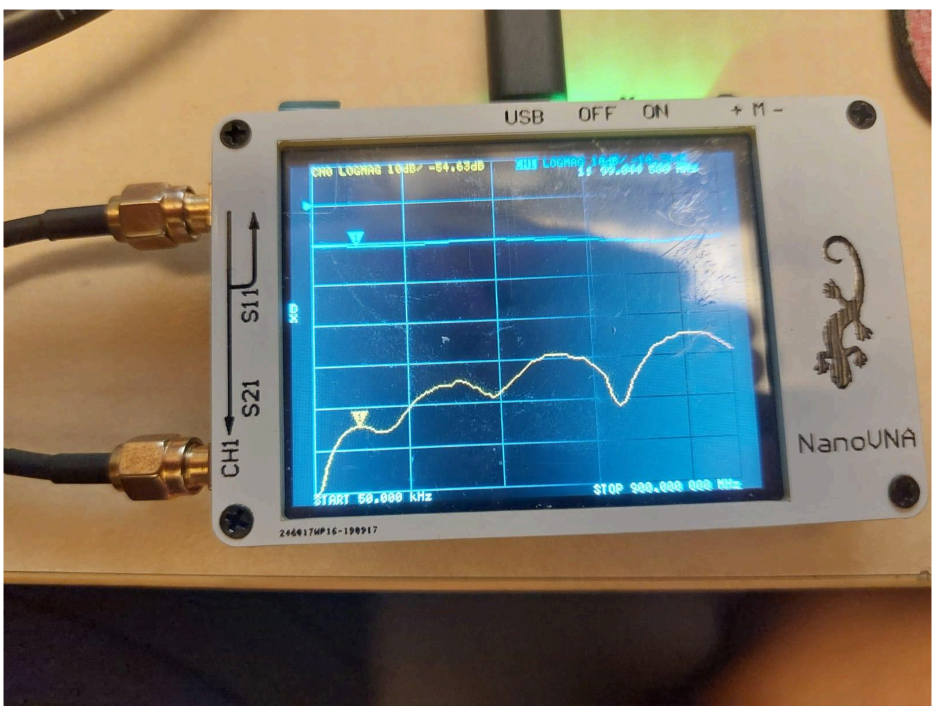

Figure 26:
The NanoVNA Display Output for the Through Measurement

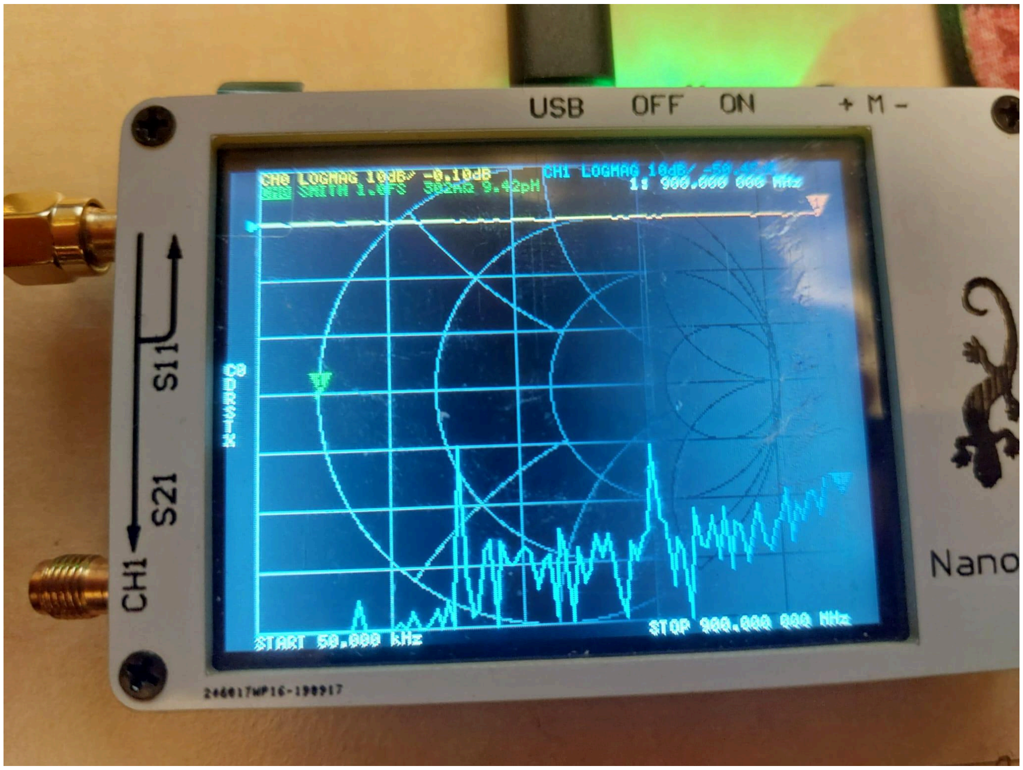

Figure 27:
The NanoVNA Display Output for the Checking Calibration - Short Measurement

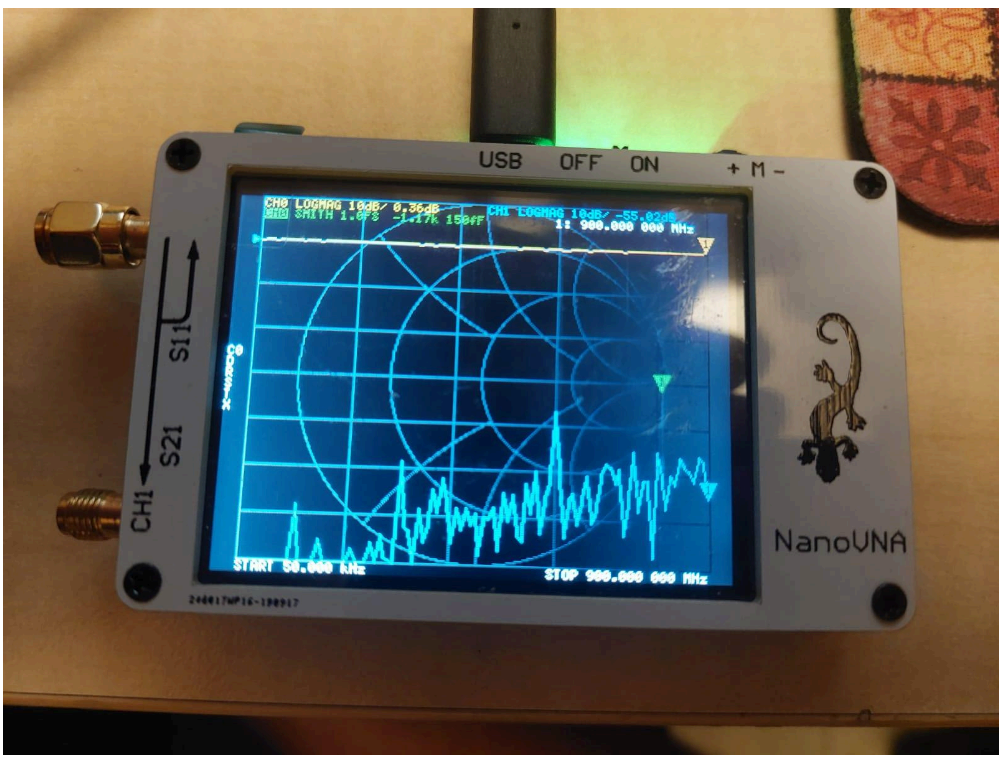

Figure 28:
The NanoVNA Display Output for the Checking Calibration - Open Measurement

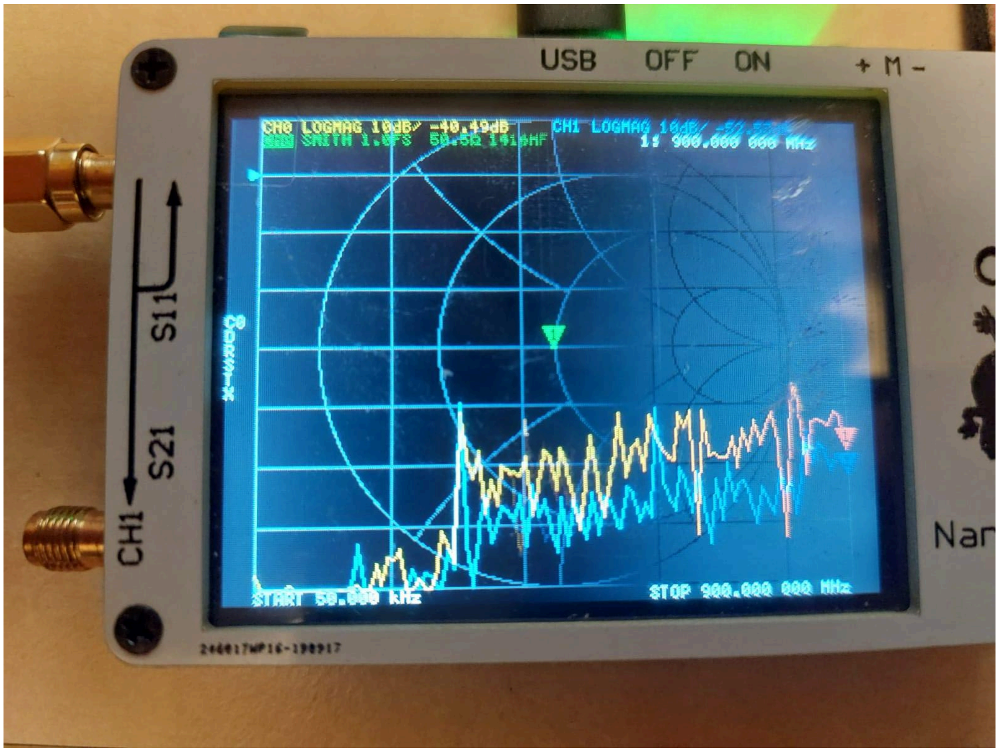

Figure 29:
The NanoVNA Display Output for the Checking Calibration - Load Measurement

Henceforth, the channel 0 of Smith trace was then turned on to test if or if not the NanoVNA was properly calibrated. As showcased in the upcoming figures, the indexes of the Channel 0 Smith chart traces (green) are in the foreseen positions of the Smith Chart:

On the extreme right for open measurements, on the extreme left for short measurements, and in the intermediate region for termination measurements.

4.3.
Using the NanoVNA for Parameter Measurements using Balun

After connecting the coaxial cable and balun, we measured on the NanoVNA using the S11 port for open, short, and termination measurements.

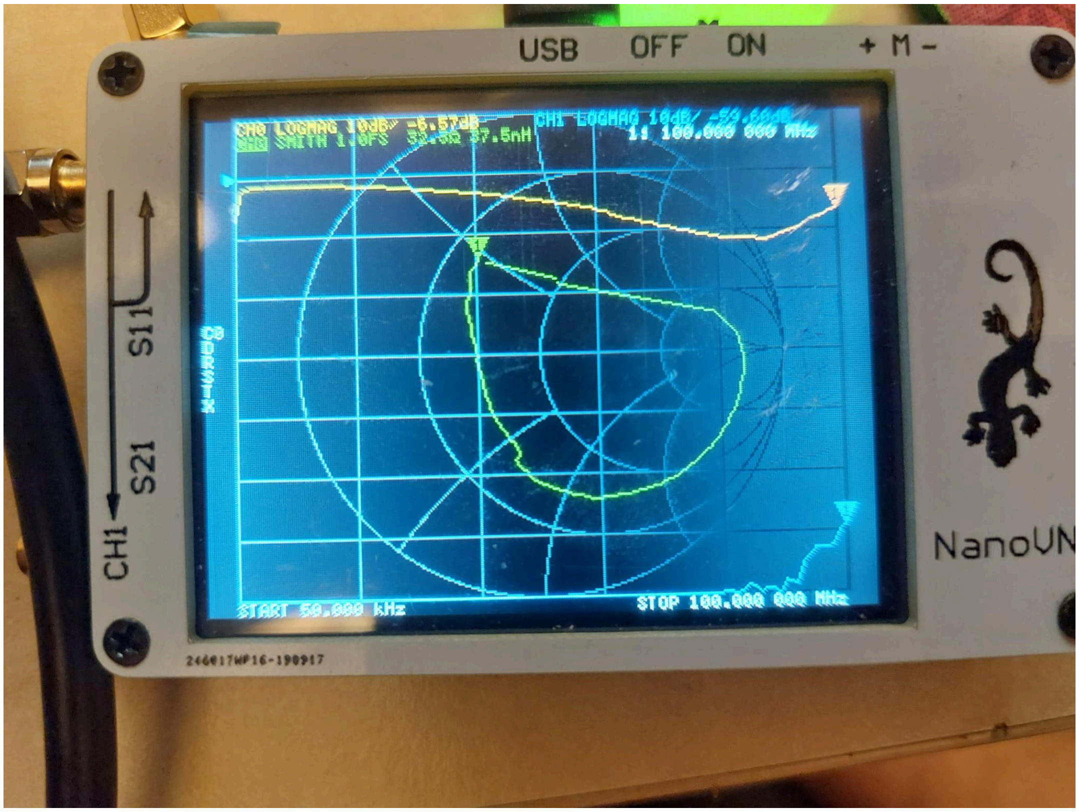

Figure 30:
The NanoVNA Display Output for the Open Measurement

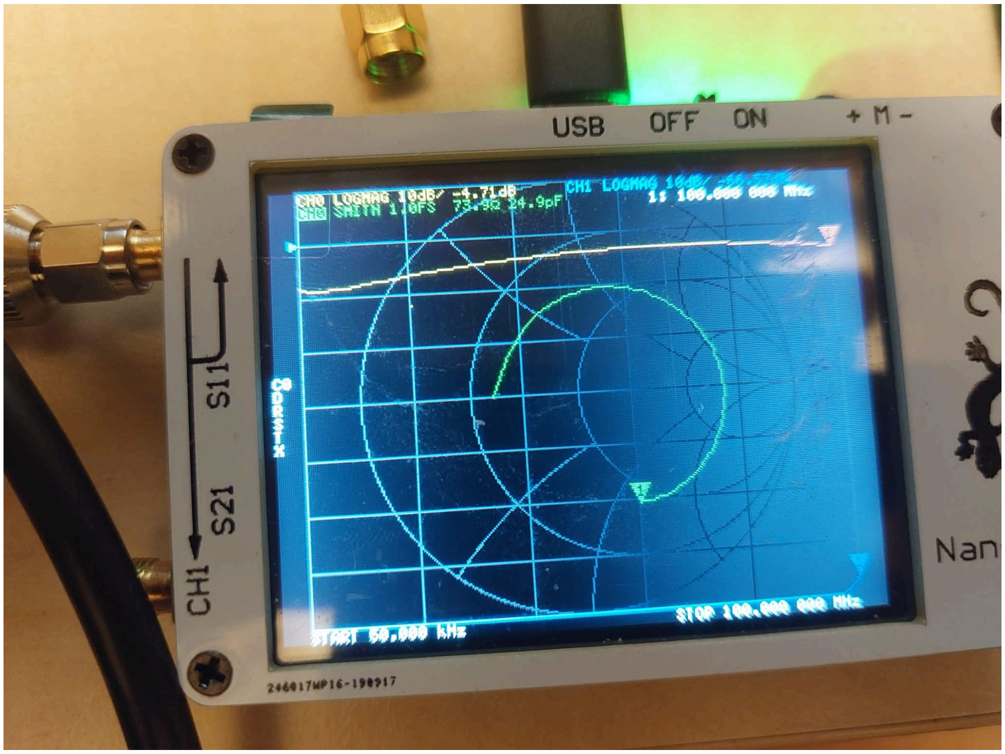

Figure 31:
The NanoVNA Display Output for the Short Measurement

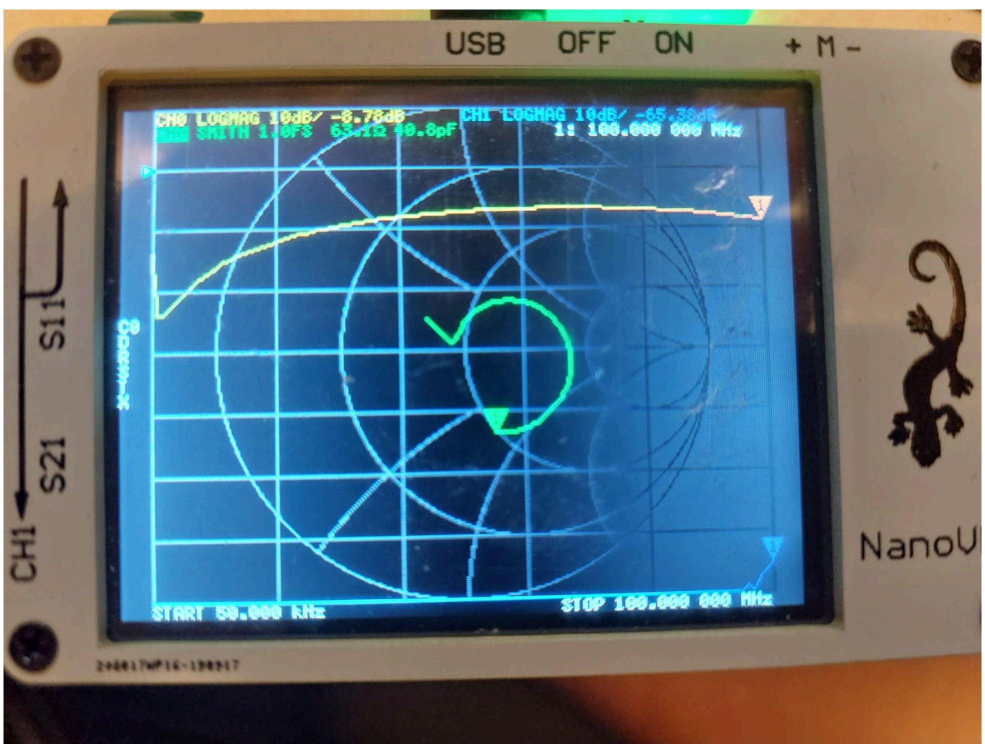

Figure 32:
The NanoVNA Display Output for the Termination Measurement

4.4.
Using the NanoVNA for Parameter Measurements of the Ethernet Cable

Finally, we connected the ethernet cable to the balun and recorded the parameters for the open and short measurements.

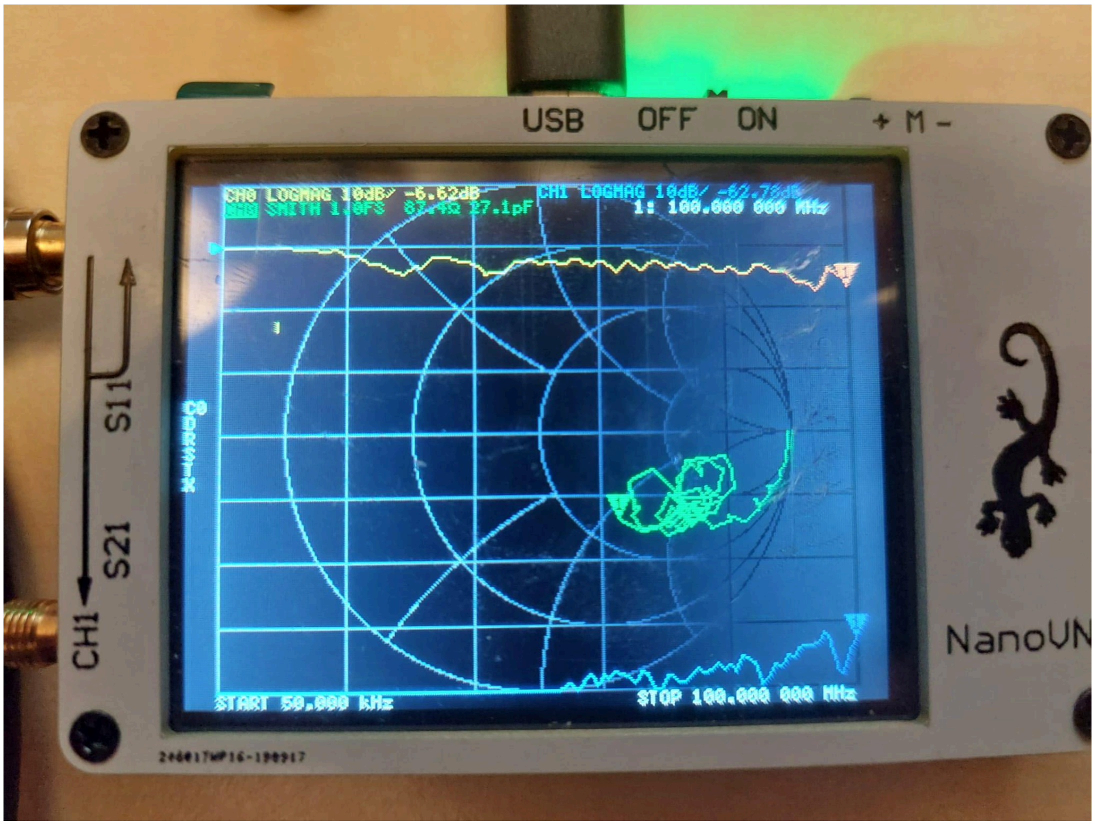

Figure 33:
The NanoVNA Display Output for the Open Measurement

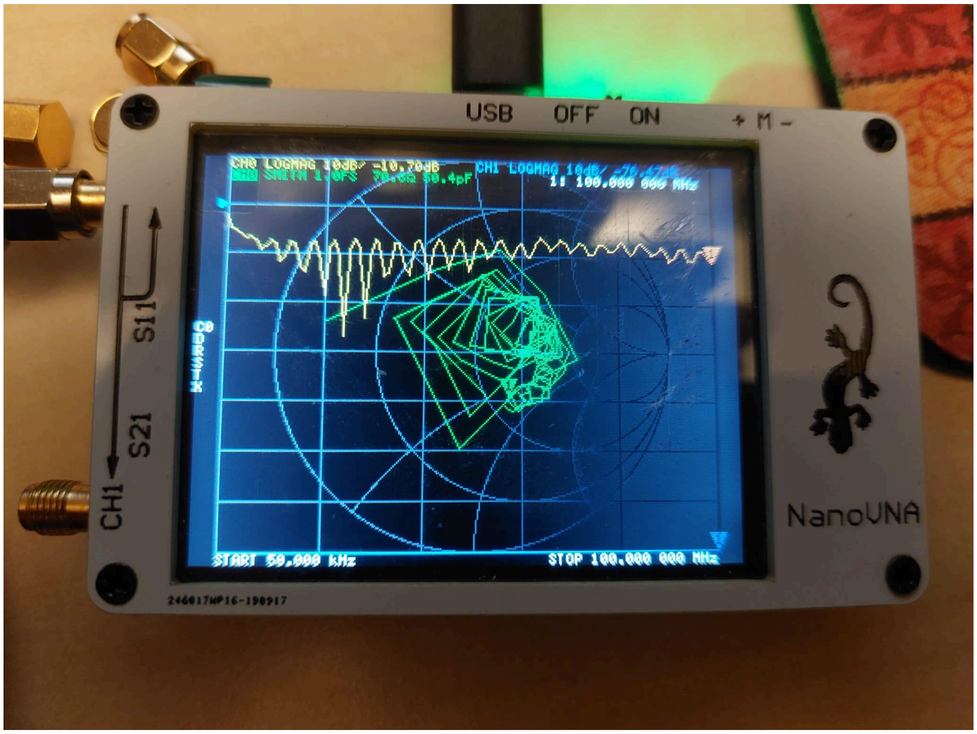

Figure 34:
The NanoVNA Display Output for the Short Measurement

4.5.
Getting Estimated Parameters Using Single Physical Measurements

Observing the plots above, the following parameters are measured:

Parameters	**Impedance(Ω)**
Balun Open (B_o)	32.3
Balun Short (B_s)	73.9
Balun Termination (B_t)	63.1
Cable Open (C_{open})	87.4
Cable Short (C_{short})	70.8

Table 1:
The Measurements of Relevant Impedances

Characteristic Impedance (Z_0)

Using the cable impedance measurements listed in the table above, the characteristic impedance can be calculated as follows:

$$Z_n = \sqrt{C_{open} \cdot C_{short}} \cdot e^{jne\pi}$$

Therefore,

$$|Z_0| = 78.64$$

$$\angle Z_0 = 0°$$

ABCD Parameters for Balun

Using the three impedance measurements obtained for the balun (B_o, B_s, and B_t as shown in the table above), the following ABCD parameters can be determined:

For the value of A,

$$A = B_o \cdot \sqrt{\frac{B_s - B_t}{75 \cdot (B_t - B_o) \cdot (B_o - B_s)}} = \Omega$$

$$A = 0.3433\ \Omega$$

For the value of B,

$$B = B_s \cdot \sqrt{\frac{75 \cdot (B_t - B_o)}{(B_s - B_t) \cdot (B_o - B_s)}} = \Omega$$

$$B = 167.5\ \Omega$$

For the value of C,

$$C = \sqrt{\frac{B_s - B_t}{75 \cdot (B_t - B_o) \cdot (B_o - B_s)}} = \Omega^{-1}$$

$$C = 0.0106\ \Omega^{-1}$$

For the value of D,

$$D = \sqrt{\frac{75 \cdot (B_t - B_o)}{(B_s - B_t) \cdot (B_o - B_s)}} = \Omega^{-1}$$

$$D = 2.269\ \Omega^{-1}$$

Therefore, the ABCD matrix would be:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.3433 & 167.5 \\ 0.0106 & 2.269 \end{bmatrix}$$

Secondary Parameters

For these parameters, we first calculate gamma (γ), followed by alpha (α) and beta (β) using the measurements from the above table as follows:

$$\gamma^{l} = atanh\left(\sqrt{\frac{Z_s}{Z_o} \cdot e^{jn\pi}}\right) + jm\pi$$

Assuming that $l = 1, n = 0$, and $m = 1$, the formula above reduces to:

$$\gamma = atanh\left(\sqrt{\frac{C_{short}}{C_{open}}}\right) + j\pi$$

$$\gamma = atanh\left(\sqrt{\frac{70.8}{87.4}}\right) + j\pi$$

Therefore,

$\gamma = 1.07358 + j\pi = 1.074 + 3.1416j$

Getting the value of α and β:

$\alpha(alpha) = Re\{\gamma\} = 1.074$

$\beta(beta) = Im\{\gamma\} = 3.1416$

4.6.
Plotting Data for Balun and Cable using MATLAB

For this section, the data obtained by the NanoVNA was recorded in files in order to obtain plots for Characteristic Impedance, ABCD Parameters, and Secondary Parameters. Measurements were required for Open, Short, and Balun Termination, as well as Open and Short measurements for the cable. All of the relevant sweeps were performed for all the relevant configurations (measurements for Open, Short, and Termination of Balun, as well as Open and Short measurements for the cable), and the files were saved in *.s1p* format. Note that since the range goes up to $100MHz$, the NanoVNA may perform some extrapolation, but since this is minimal, this was done to create a more aesthetically pleasing plot.
The MATLAB code is shown below:

```
% Closing all windows and clearing variables for ease of use
close all;
clear all;

% Reading and storing the data from the files
f = dlmread('bal_O.s1p','','A1..A100');

bal_O = dlmread('bal_O.s1p','','B1..B100') + ...
     1i*dlmread('bal_O.s1p','','C1..C100');

bal_S = dlmread('bal_S.s1p','','B1..B100') + ...
     1i*dlmread('bal_S.s1p','','C1..C100');

bal_T = dlmread('bal_T.s1p','','B1..B100') + ...
     1i*dlmread('bal_T.s1p','','C1..C100');

cab_S = dlmread('cab_S.s1p','','B1..B100') + ...
     1i*dlmread('cab_S.s1p','','C1..C100');

cab_O = dlmread('cab_O.s1p','','B1..B100') + ...
     1i*dlmread('cab_O.s1p','','C1..C100');

% Impedance of the BALUN for 47 ohm termination
ZBO = 47*(1+bal_O)./(1-bal_O);
ZBS = 47*(1+bal_S)./(1-bal_S);
ZBT = 47*(1+bal_T)./(1-bal_T);
```

```
% Computing ABCD parameters
A = ZBO.*sqrt((ZBS-ZBT)./(47*(ZBT-ZBO).*(ZBO-ZBS)));
B = ZBS.*sqrt(47*(ZBT-ZBO)./((ZBS-ZBT).*(ZBO-ZBS)));
C = sqrt((ZBS-ZBT)./(47*(ZBT-ZBO).*(ZBO-ZBS)));
D = sqrt(47*(ZBT-ZBO)./((ZBS-ZBT).*(ZBO-ZBS)));

% Computing CABLE impedances
Z1CO = 47*(1+cab_O)./(1-cab_O);
Z1CS = 47*(1+cab_S)./(1-cab_S);
Z2CO = (B-D.*Z1CO)./(C.*Z1CO-A);
Z2CS = (B-(D.*Z1CS))./((C.*Z1CS)-A);

% Computing characteristic impedance and propagation constant
ZW = sqrt(Z2CS.*Z2CO);
gamma = atanh(sqrt(Z2CS./Z2CO));
ReG = real(gamma);
ImG = imag(gamma);

% Plotting
figure(1);
plot(f,abs(ZW));
title('Amplitude of Characteristic Impedance');
xlabel('Frequency [Hz]');
ylabel('Magnitude of ZW)');
```

```
% Plotting
figure(1);
plot(f,abs(ZW));
title('Amplitude of Characteristic Impedance');
xlabel('Frequency [Hz]');
ylabel('Magnitude of ZW)');

figure(2);
plot(f,angle(ZW)*(180/pi));
title('Phase of Characteristic Impedance');
xlabel('Frequency [Hz]');
ylabel('Phase of ZW');

figure(3);
plot(f,ReG);
title('Attenuation');
xlabel('Frequency [Hz]');
ylabel('Re(Gamma)');

figure(4);
plot(f,ImG);
title('Phase Constant');
xlabel('Frequency [Hz]');
ylabel('Im(Gamma) [rad/m]');
```

Figure 34:
The MATLAB Code Used to Plot Data

Plot Collection 1: Using Data Series 1

The plot is shown below:

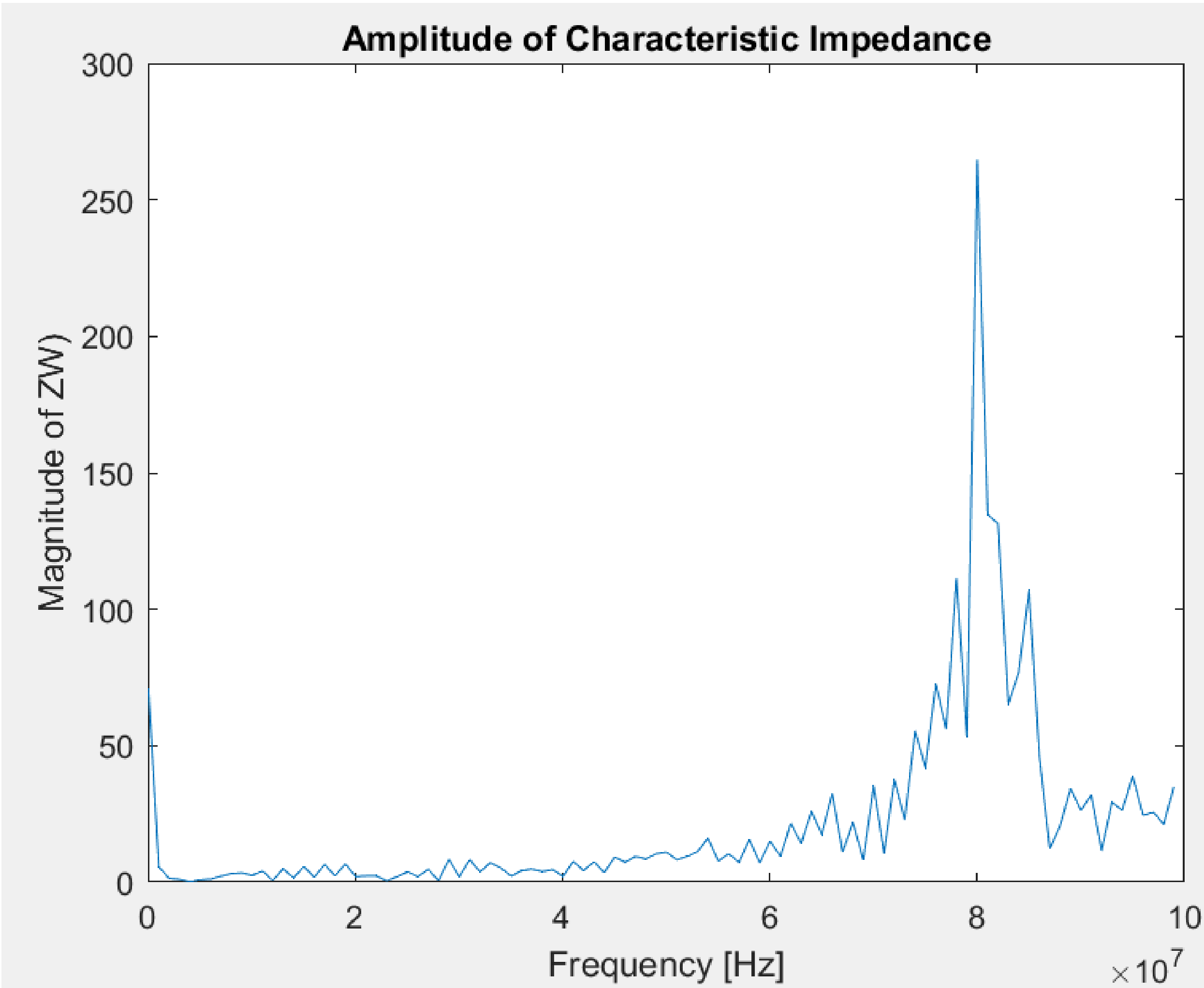

Figure 35:
Amplitude of the Characteristic Impedance for Ethernet Cable

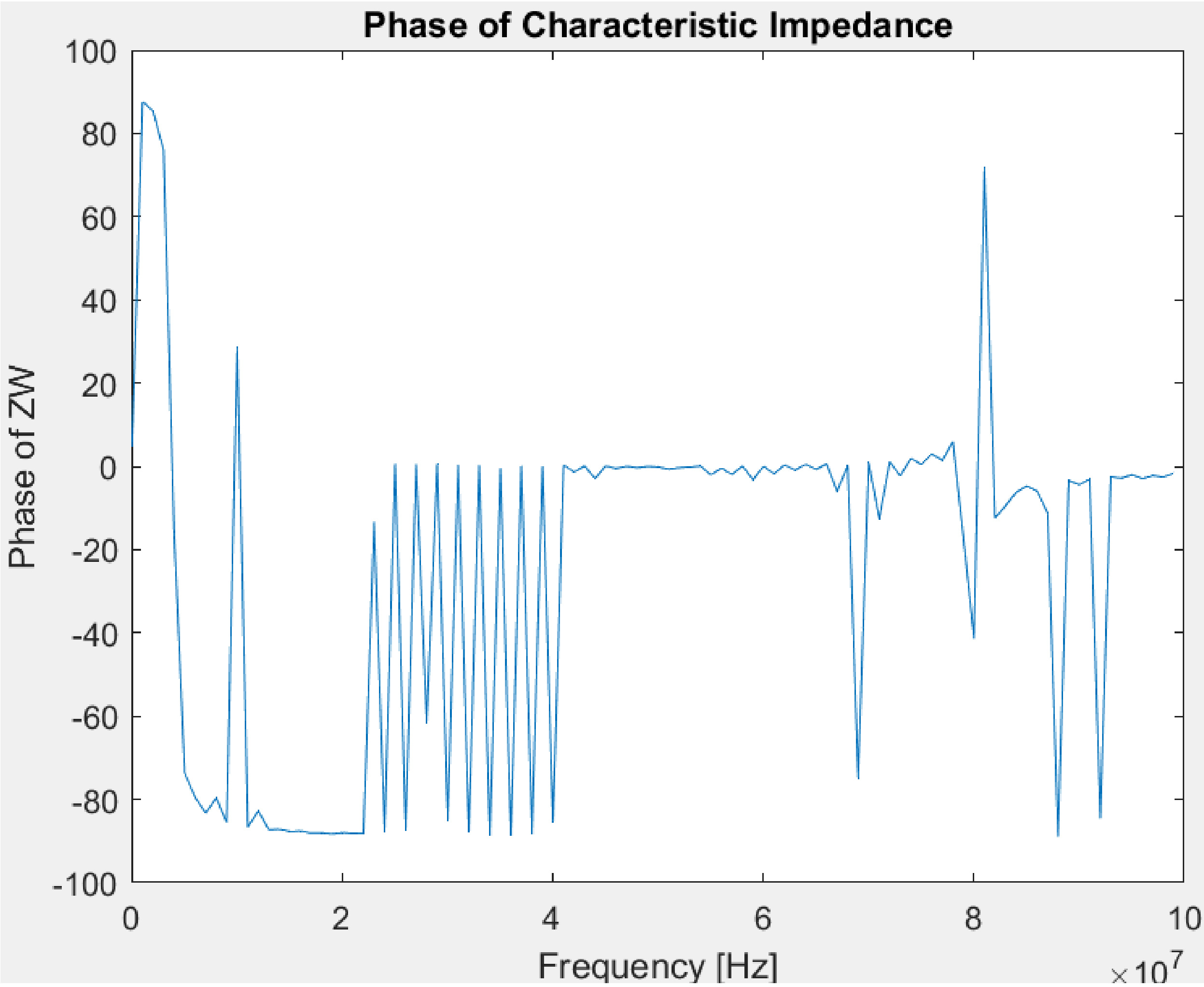

Figure 36:
Phase of the Characteristic Impedance for Ethernet Cable

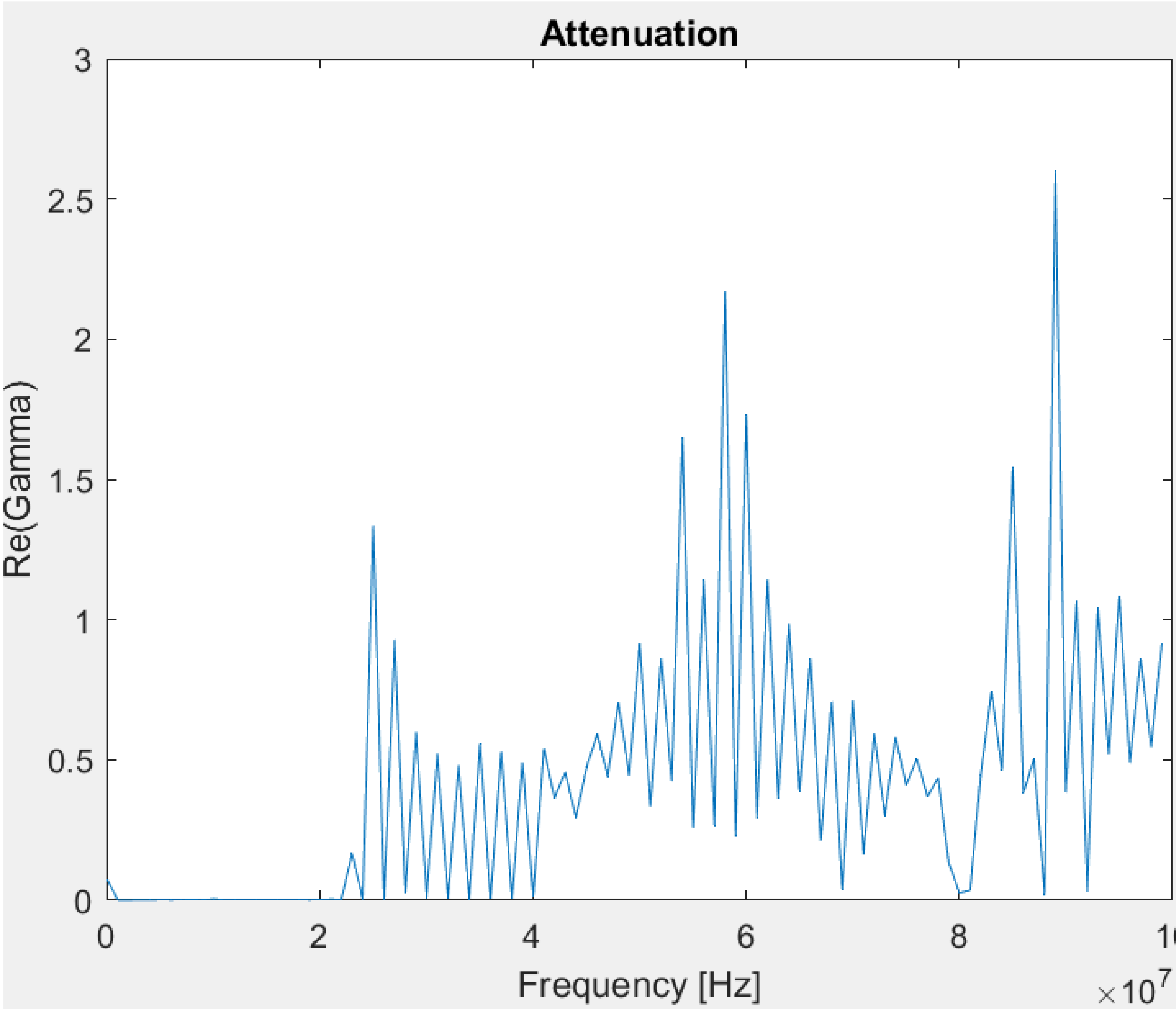

Figure 37:
The Attenuation Constant for the Ethernet Cable

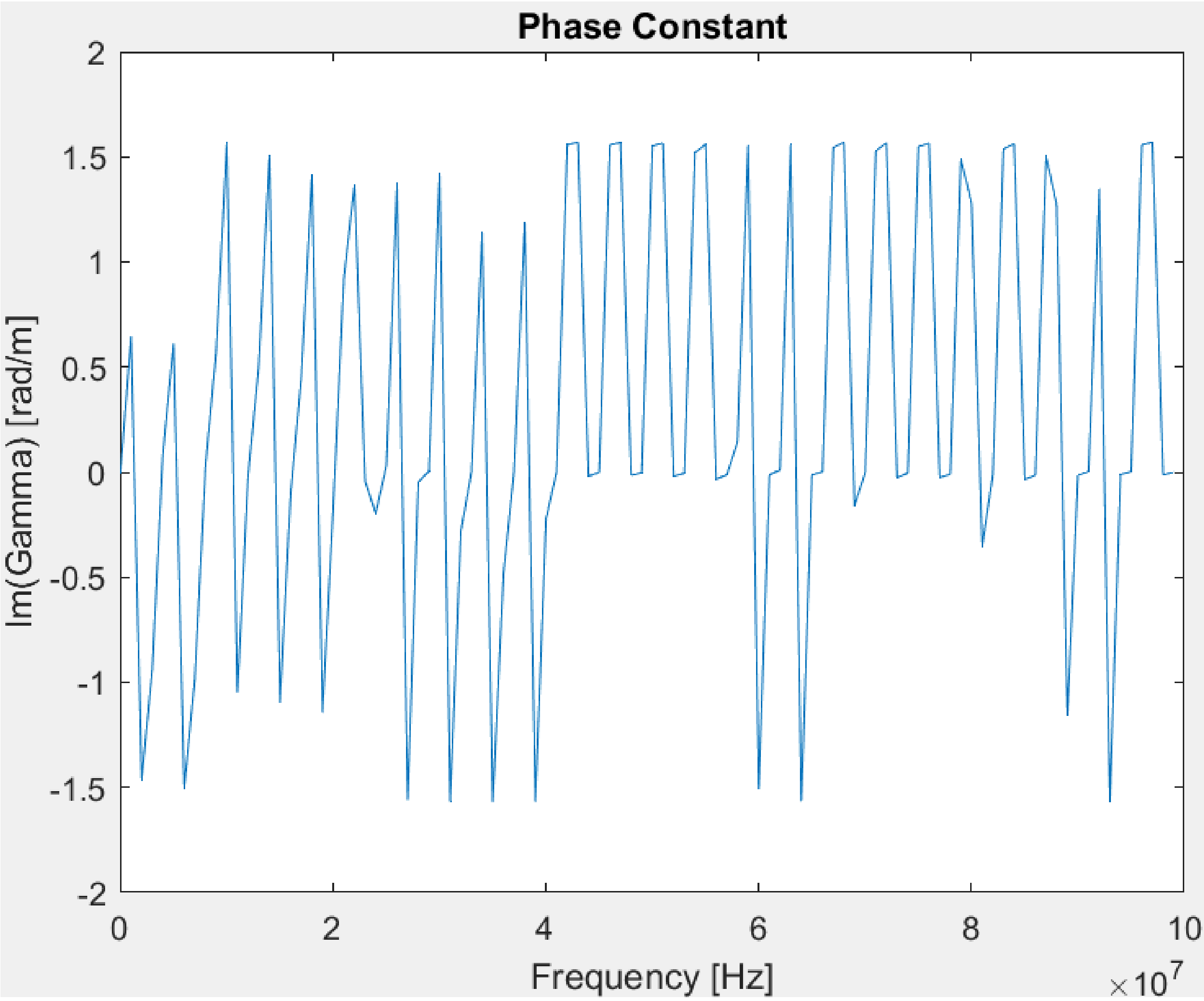

Figure 38:
The Phase Constant for the Ethernet Cable

Plot Collection 2: Using Data Series 2 (Self-Collected Data)

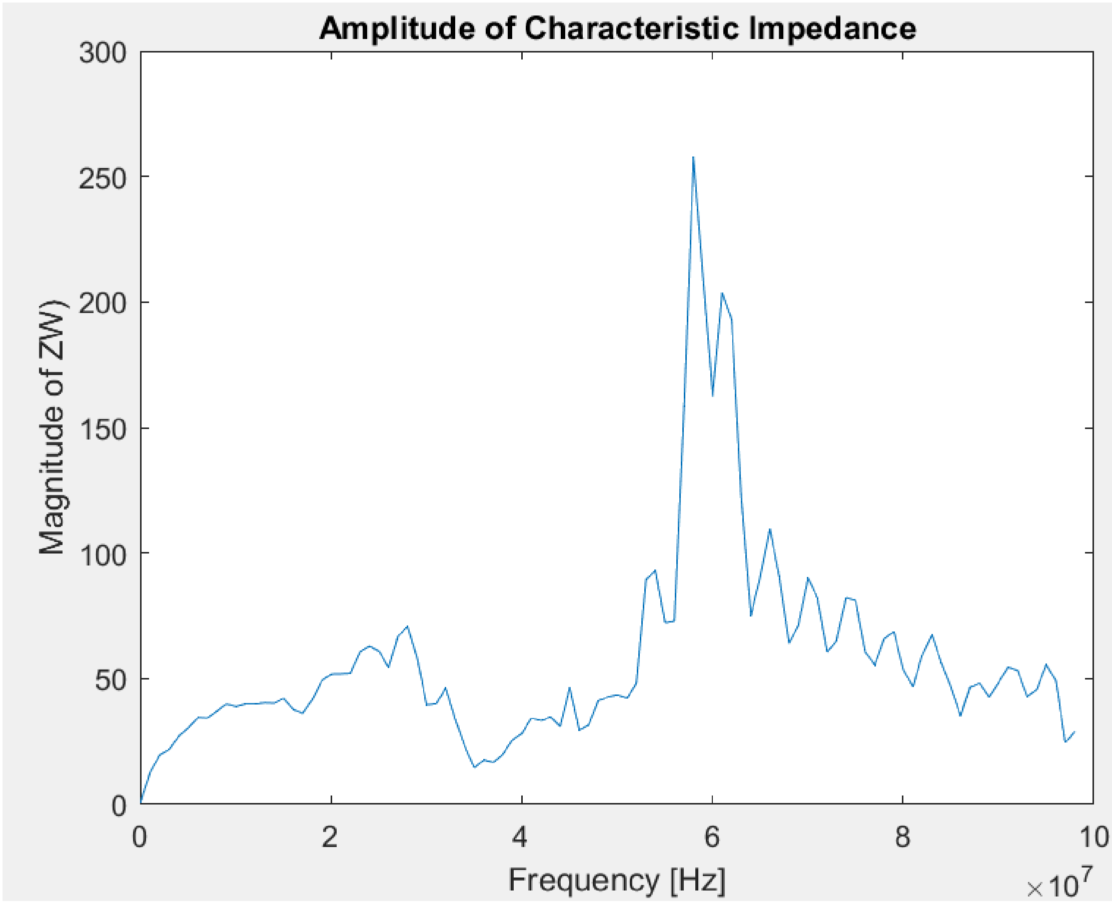

Figure 39:
Amplitude of the Characteristic Impedance for Ethernet Cable

The average of the graph seems to be around 70 if it were to be averaged, which is in line with what the expectation was.

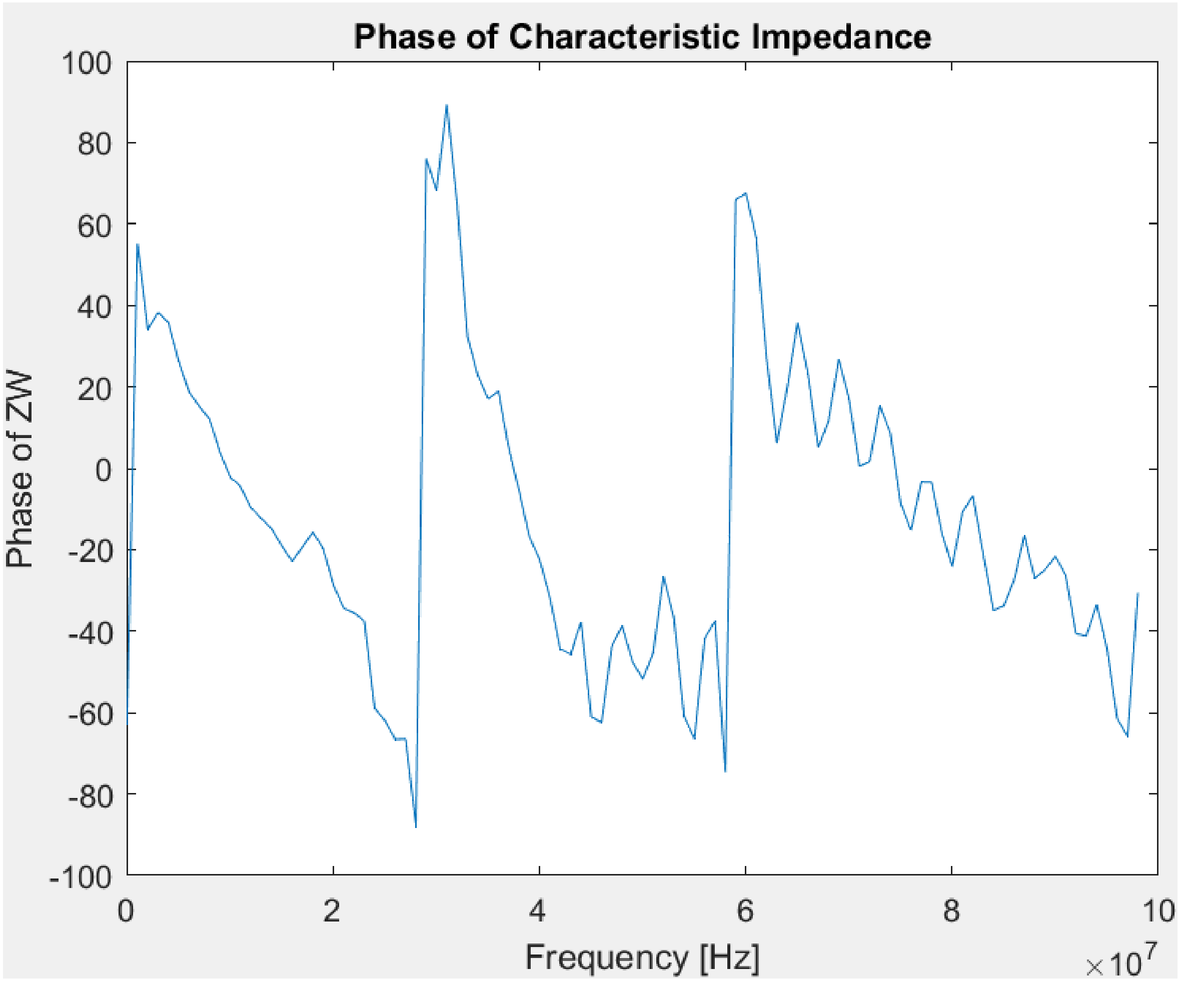

Figure 40:
Phase of the Characteristic Impedance for Ethernet Cable

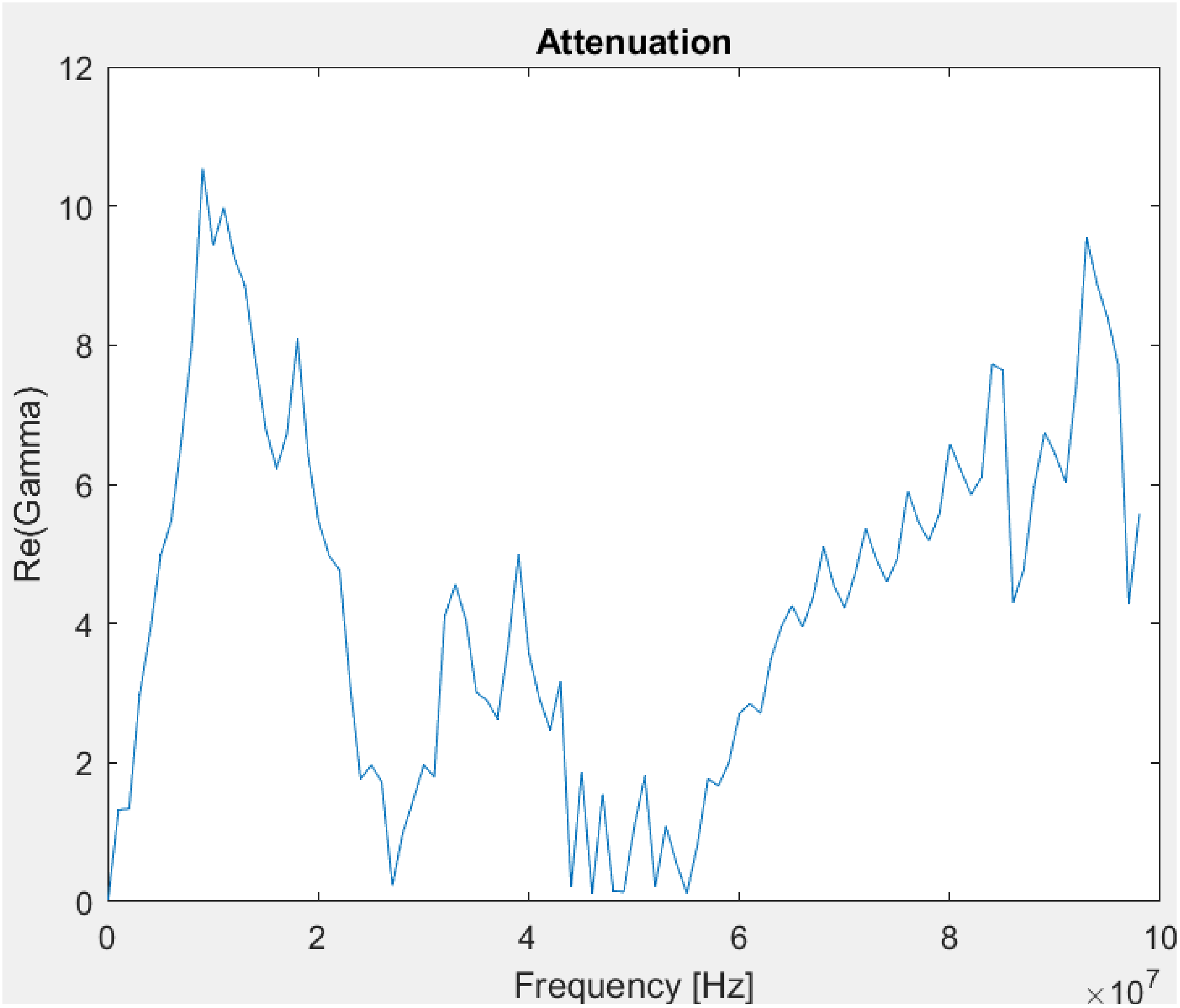

Figure 41:
The Attenuation Constant for the Ethernet Cable

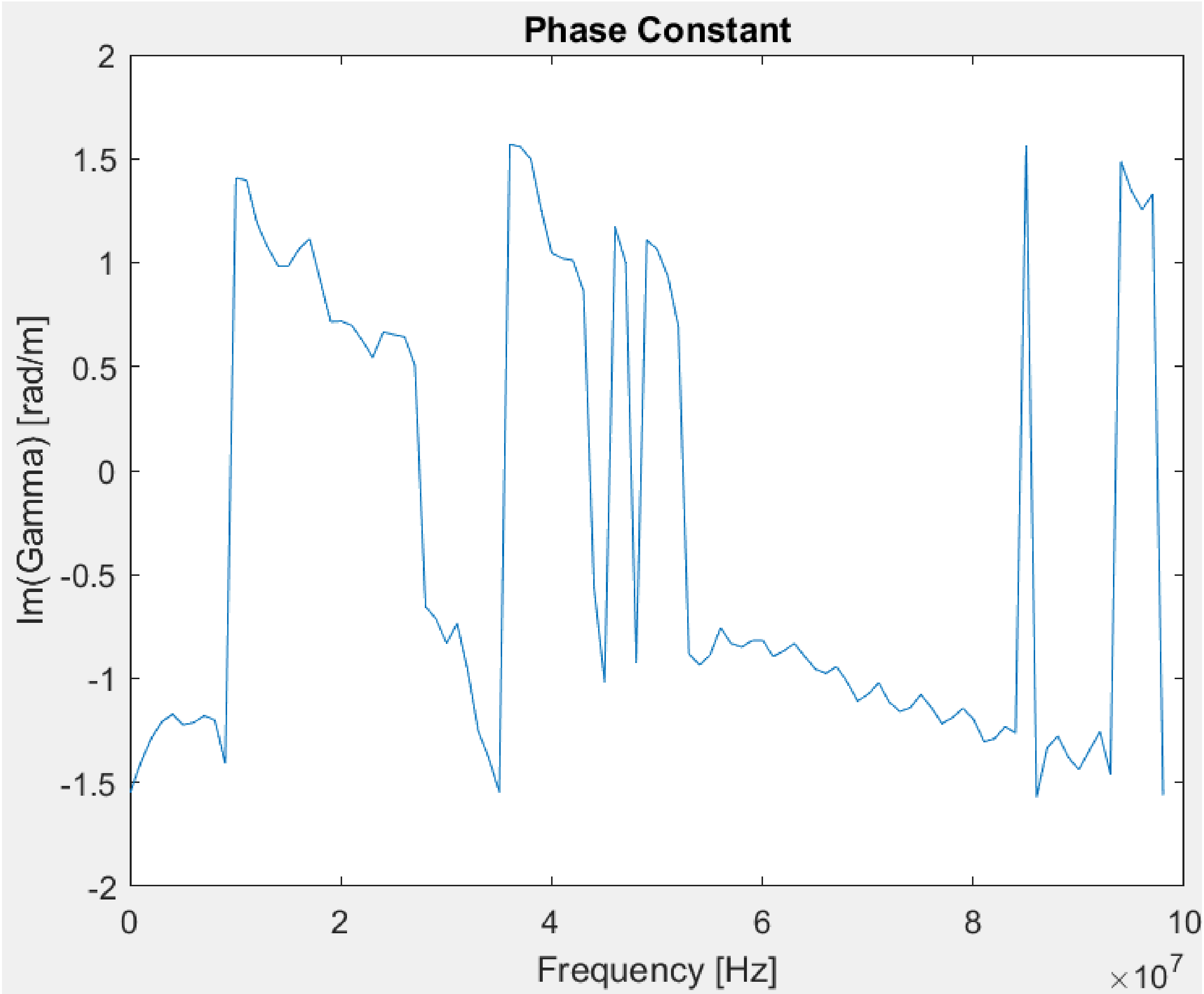

Figure 42:
The Phase Constant (the Beta Value) for the Ethernet Cable

The measurements do not look alike as expected.

This could likely be due to instrumental error and related attributes. Firstly, there were issues with the connections of the resistors, some were loose or improper. Secondly, the ends of the cable were rusty, which may also have contributed to the wary final results. Although: the steps were conducted routinely with all requisites for the successful calibration of the device.

Conclusion and Analysis

In this lab, we commenced with the objective to understand some very important measurement instruments: Spectrum Analyzer, RS Scope, and different VNAs. For the purposes of application, MATLAB and Labview methodologies were also employed for remote control of the aforementioned instruments, and these consequent objectives were demonstrated.

The lab began with the comprehension and application of the Spectrum Analyzer and Function Generator, and, here, a sinusoidal signal was generated on the Function Generator and implemented a sweep on the Spectrum Analyzer. And this is where we found the expected solitary peak. After this, this experiment was repeated with multiple sweep ranges.

Next, the investigation of the RS Scope was proceeded with. This was then configured to measure the drill's electrical noise. After the obtainment of these results, it was found that these results derived from the RS Scope was a damped oscillating signal that was triggered at the activation of the drill, and this was actually otherwise constant.

Hereafter, the examination of the measurements with the equipment of the RS VNA was conducted. This frequency ranges from 9kHz to 20MHz in the sweep mode. These results (derived from the aforementioned parameters) were then projected on the Smith Chart.

The most significant part of our data collection and experimentation series was, perhaps, the NanoVNA: the final instrument used in relation to this lab. In this portion, the required gadgets were a coaxial cable, a balun, an Ethernet cable, and other necessary components that contributed to the diligent collection of the readings. All the measurements and calibrations were performed, hence, with the aid of the materials supplied. Henceforth, accordingly, all the necessary impedances and parameters were carefully recorded and stored. The measurements for the termination value were conducted with 75 impedance.

The ultimate gain from this laboratory was the comprehensive understanding and applications conducted of the various measurement instruments provided and furtherances on how to correctly equip them in varied scenarios. Other significant facets include: studying how to control these instruments remotely, and this taught a very beneficial mode of equipping these measurement instruments. This becomes incredibly instrumental when it comes to investigations that necessitate collecting these results when one is absent from the very room itself. This is an important distinction to make because, as discussed during the laboratory sessions, even an individual's presence in the room of experimentation can lead to significantly enough alterations due to one's movements. This is a difficult situation because it is always better to isolate the measurement instruments and to control it remotely to not generate results with high error margins.

Whilst experimenting, there were some difficulties: there were broken devices at times or when we had peers alter the correct calibration records of particular devices. But these setbacks proved to be useful in their own ways as this prompted the experimenters to seek out and ask ample questions to really understand and become familiarised with the operation of these critical instruments.

References

- Lab Manual - Wireline Communications Book Project
http://trsys.jacobs-university.de/login/spec_lab/book_lab.pdf
- Measurement Automation Course Website
http://trsys.jacobs-university.de/login/spec_lab.htm