

Appendices

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Appendix A:
Connection of components

Appendix A

Connections between the components

The following connections need to be made between the various components:

1. **“RF output port”** from the front of the sweep oscillator must be connected to the **“RF input port”** at the back of the S-parameter test set.
2. The **“8410” input cable** at the back of the VNA must be connected to the **“output port”** of the frequency converter at the back of the S-parameter test set.
3. The **“Sweep Input”** port at the back of the VNA accepts the **“Sweep In/Out”** signal from the back of the sweep oscillator.
4. The **“Z-Axis”** port at the back of the VNA must be connected to the **“Pos Z-blank”** port at the back of the sweep oscillator.

Appendix B: Antenna Data

Appendix B.1:

Data for Antennas:

Antenna A:

Frequency (GHz)	Magnitude(dB)
1.4	-4
1.5	-4
1.6	-4
1.7	-4
1.8	-5
1.82	-6
1.84	-7
1.86	-8
1.88	-10
1.9	-14
1.92	-18
1.94	-22
1.96	-18
1.98	-16
2	-14
2.025	-11.5
2.05	-11
2.1	-10
2.2	-9
2.4	-8
2.6	-6
2.7	-6
2.8	-6
2.9	-6

Antenna B

Frequency (GHz)	Magnitude (dB)
1	-2
1.2	-4
1.3	-6
1.32	-10
1.334	-13
1.345	-10
1.4	-3
1.5	-2
1.6	-2
1.7	-4
1.8	-11
1.82	-18
1.825	-20
1.834	-25
1.837	-26
1.85	-20
1.873	-10
1.97	-6
2.032	-2

Appendix B.2:

Filter Data

Appendix B.2

Filter Data

Frequency(GHz)	Magnitude (dB)
1.5	-34
1.6	-32
1.7	-31
1.8	-30
1.9	-30
2	-30
2.1	-28
2.112	-24
2.12	-20
2.127	-23
2.135	-30
2.142	-35
2.151	-40
2.16	-41
2.19	-45
2.2	-45
2.317	-48
2.417	-50
3	-50

Appendix C.1:

Experiment 1

Appendix C.1:

EEE 486F *Microwave Vector Network Analyser* Experiment 1

Introduction

In this experiment you will become more familiar with the vector network analyser (VNA), s-parameter test set and the various devices used to set up the experiments.

Preparation:

- Draw a simple block diagram of the Network Analyser
- Draw a block diagram of the arrangement of the Network analyser, S-parameter test set, Sweep Oscillator (i.e. how they are connected). These can be found from
- Read through the experiments and predict the outcomes of each section (to be presented at the beginning of the practical), if you are not familiar with these experiments/concepts, do a bit of research on them so that you can gain as much as possible from the practical. This can be found at <http://www.caip.rutgers.edu/~kahrs/papers/mud2k.pdf>.
- Do a bit of research on the various types of connectors – BNC, SMA and connector care so that you are familiar with them and are able to identify the various types of connector types when you do the practical (see www.microwaves101.com for info). Draw up a table that compares the dimensions of the various connector types and compares their operating frequencies. This shouldn't be too detailed and is an exercise to become familiar with the connectors.

Please note that you will not be allowed to attempt the practical without producing your pre-lab preparations. This will be marked and depending on your effort, you may be allowed to attempt the practical.

Practical:

Set up:

Take a look at the set up and compare it to the block diagram of the set up that you prepared. If need be, make corrections to it and get a clear understanding of how the 3 machines are connected. Note that a VNA can have 2 types of display, namely rectangular (where you can view either the magnitude or the phase) or polar (where the reflection coefficient is represented as a vector). This practical will only use the rectangular display. This set-up will be explained by the demonstrator at the beginning of the practical

Safety Considerations:

- Do not exceed a power output of 6dBm
- When using the various adapters, do not turn the component that is being attached, rather turn the bullet. Do not over – tighten the SMA connectors, they should only be finger tight. If you over tighten these connectors, you could have inaccurate results.(This will be demonstrated to clarify)

The practical consists of the following sections:

1. Calibration
2. Adding a transmission line
3. Measuring the reflection coefficient of an antenna
4. Characterising an RF device.

Part 1: Calibration

In order for readings to be as accurate as possible it is necessary to calibrate the VNA. Firstly the frequency range must be set. Note that the calibration set for this frequency range is only valid for this frequency range. If you need to take measurements out of this frequency range then you will need to recalibrate the VNA within that frequency range.

Another important thing to note is that you should calibrate from the point that you are going to be connecting your device under test. For example, if you need to attach a transmission line from one of the ports to your device under test, then you must calibrate at the end of the transmission line and not at the port. This calibration will compensate for losses and phase delays in the transmission line. If you do not calibrate at this point then your readings will be inaccurate and you will be measuring the characteristics of your device as well as the transmission line.

Calibration can be done as follows:

Set the frequency range to the range of your measurements:

Frequency: Start: 1GHz
Stop: 2.5GHz

Set the following parameters:

Display the Magnitude
Magnitude/Division to 10dB/division

Procedure:

Short Circuit test:

Amplitude:

Attach a short circuit to port 1. Port 1 is female, so you need a male to female adapter connected between Port 1 and the short circuit. Set the S-parameter test set to S_{11} .

You should then see a straight line across the display. What does this line represent?
(Hint: what is the reflection coefficient (Γ) of a short circuit? This line represents $20 \log |\Gamma|$)

Adjust the **amplitude vernier** so that this line is directly above one of the division lines, then adjust the **amplitude test channel gain** so that the line is as far on top of the screen as possible. This can be illustrated in Fig 1.

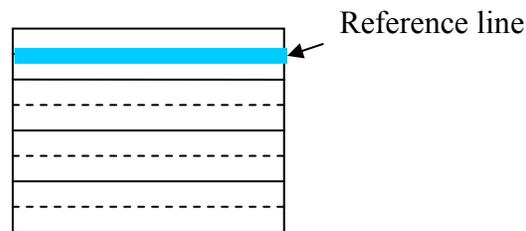


Figure 1. Magnitude Display

Phase:

Follow the same procedure but set the display to channel to phase.

Open Circuit Test:

As in the case of a short circuit test, attach the open circuit test standard to port 1 of the S-parameter test set. Measure S_{11} . What does this line represent?
Observe both the phase and the magnitude display and explain what you see.

Do the same for the load test and thru test (in the case of the thru test, attach a transmission line from port 1 of the S-parameter test set to port 2 of the test set and observe S_{21} .

Part 2: Effect of adding a transmission line

Attach a transmission line to port 1. Observe S_{11} . Observe the phase. What effect would you predict? How can you calculate this change?

Connect a transmission line from port 1 to port 2. Measure the various S parameters. What do you predict?

Do this for 3 different types and lengths of transmission lines and observe the various losses and phase changes for each transmission line.

Part 3: Measuring the reflection coefficient of various antennas

Set the frequency to 1GHz to 2.5GHz

Attach a BNC male/SMA Female connector to port 1. Attach a BNC transmission line to the connector and then attach antenna A to the transmission line. Observe S_{11} . What can you tell by looking at S_{11} ? What does this tell you about the characteristics of an antenna? Make sure that you acquire enough readings to plot these graphs for your report. Do the same for antenna B

Characterising an unknown RF device

You will be given an unknown 2 port device and have to figure out what this device is by looking at the reflection and transmission characteristics of this device. Towards the end of this practical you will be required to make suggestions of what this device could be. The demonstrator will then tell you whether you are wrong or right. Record the serial number of this device. You will be required to look up its specifications and compare them to your results.

Report:

Write a report that summarises the fundamental concepts of the network analyser, describes the procedure of the lab and explains your results. You need to give a description for each experiment, explaining what actually happens, this can be aided by means of illustrations.

Appendix C.1: Experiment 1

Appendix C.2:

Model Solutions to Experiment 1

Preparations:

Block diagram of Vector Network Analyser:

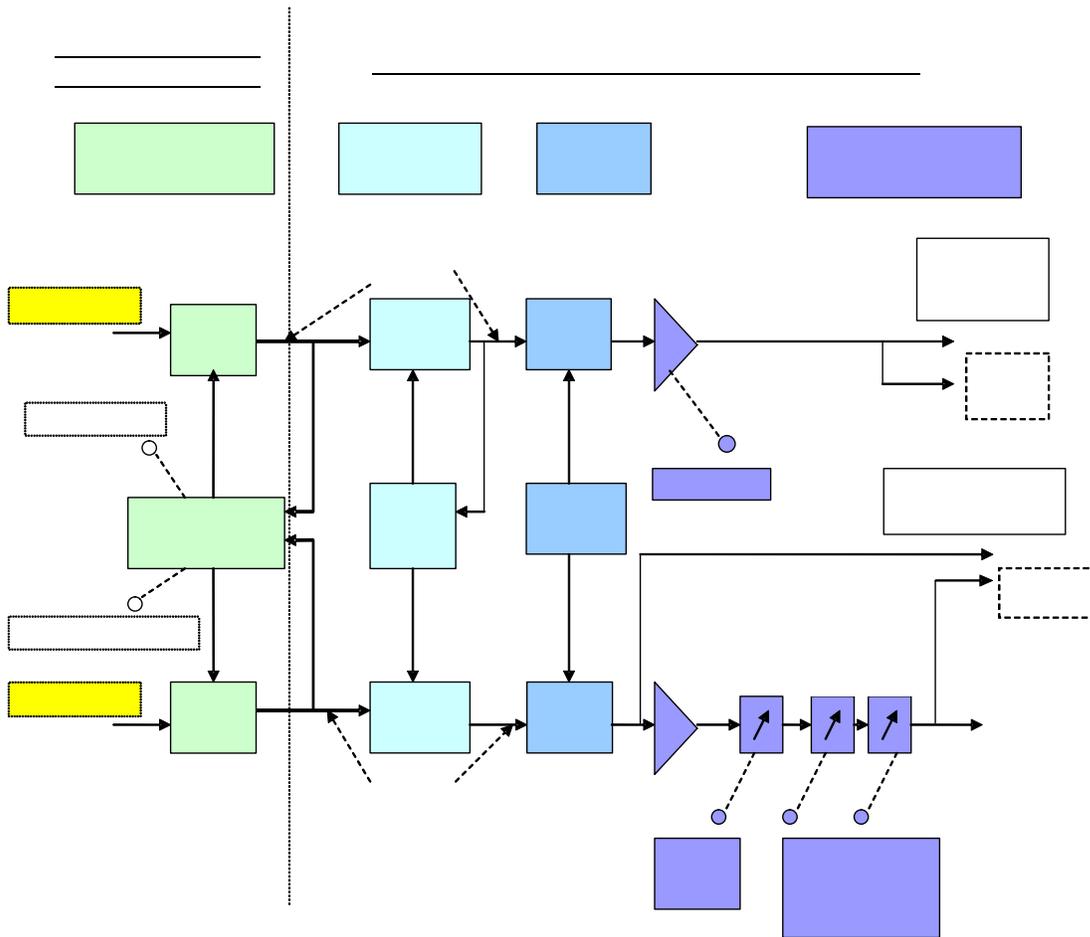


Figure 2: Block diagram of Vector Network Analyser [i]

FREQUENCY
CONVERTER

Simplified block diagram of Vector Network Analyser:

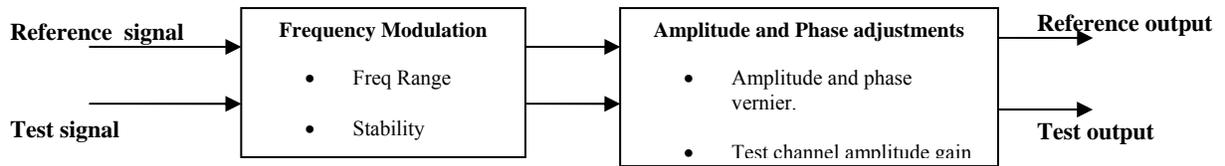


Figure 3: Simplified block diagram of Vector Network Analyser

Block diagram illustrating interconnection of VNA, Sweep Oscillator and S-parameter test set:

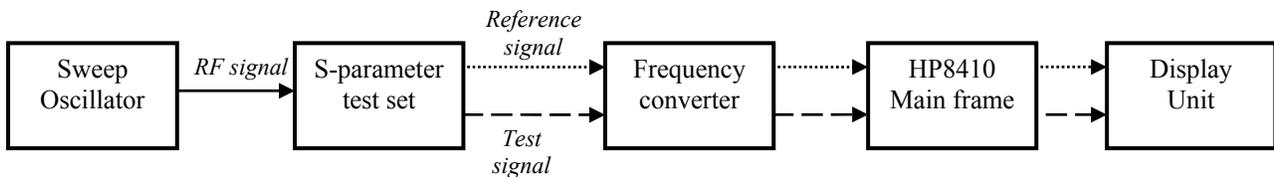


Figure 4: Block diagram illustrating interconnection of VNA, Sweep Oscillator and S-parameter test set [ii]

Part 1: Calibration

Outcomes predicted:

Short circuit test:

When a transmission line is terminated in a short circuit, a reflected wave is sent back to the source. The reflected wave is exactly equal to the sent wave in magnitude but 180° out of phase. [iii]

S₁₁:

Magnitude:

Reflection coefficient (Γ) of short circuit test is -1 therefore the magnitude of the display is $20 \log |\Gamma| = 0\text{dB}$. The line across the screen represents the reference (0dB) line. This should be true for all frequency values. If there is an oscillatory reading (which usually occurs at high frequencies) then this oscillatory reference needs to be recorded carefully and measurements at different frequencies must be relative to the reference of that particular frequency (do not assume a straight line).

Phase:

The phase should be $+180^\circ$ or -180° [iv].

Open Circuit Test

S₁₁:

Magnitude:

As in the case of the short circuit test, the reflection coefficient is -1.
The magnitude should be 0dB

Phase:

The phase should be 0 degrees.

Thru Test

S₂₁:

Magnitude:

Reflection coefficient is 1 therefore $S_{21} = 0\text{dB}$

Phase:

The phase should be 0 degrees

50Ω Load Test

S₁₁:

Magnitude:

The $50\ \Omega$ load should absorb all the power therefore there shouldn't be any reflected power. S_{11} should be much less than 0dB (Around -40dB)

Part 2: Adding a transmission line:

When adding a transmission line, students must observe the phase change. Adding a transmission line increases the phase delay. There is a 2π radian phase shift per wavelength (λ).

Part 3: Characterising antennas

The students should measure S_{11} for each antenna. There are 2 antennas available for this practical. Their S_{11} characteristics are as follows:

Antenna A:

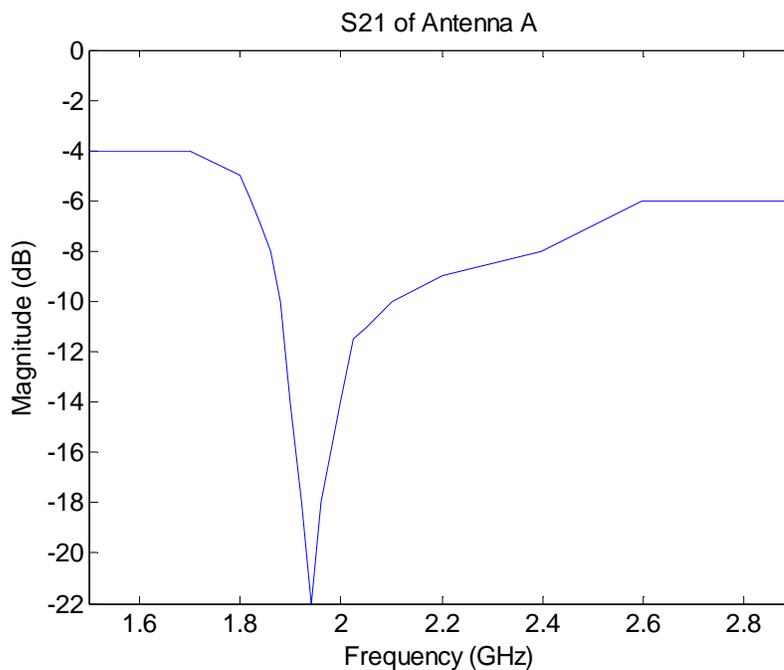


Figure 5: S_{21} transmission characteristic of Antenna A

By looking at this graph students should be able to gather that the resonant frequency of antenna A is 1.94 GHz

Antenna B:

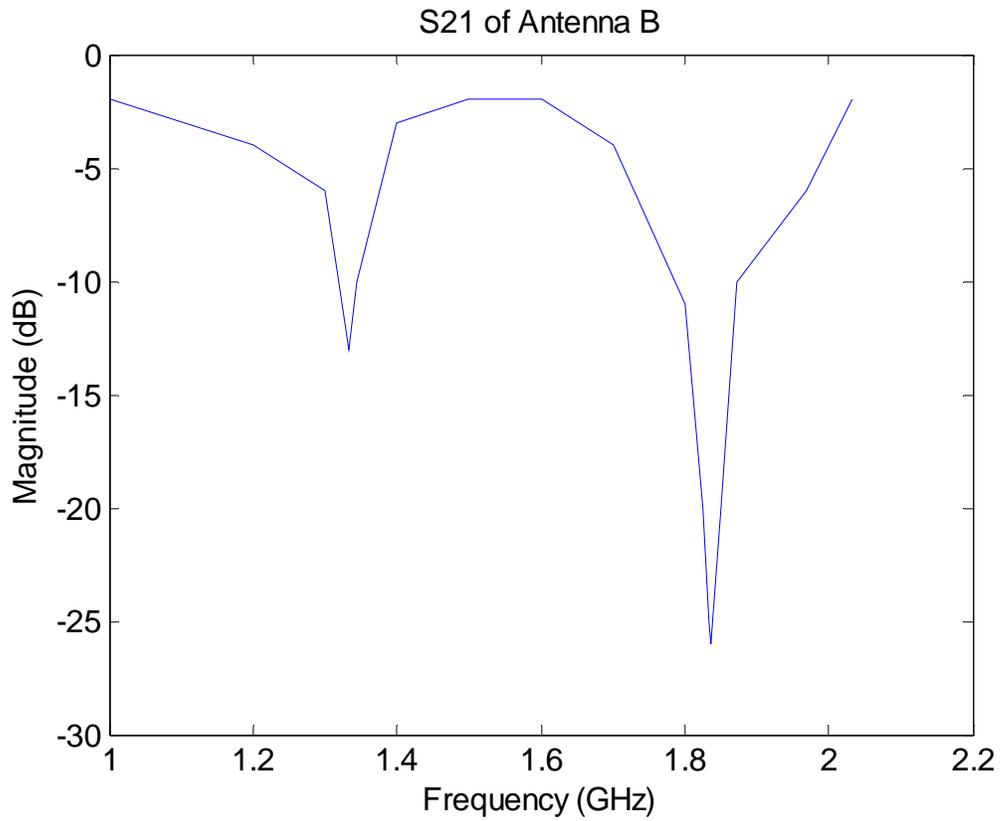


Figure 6: S₂₁ transmission characteristic of Antenna B

The resonant frequency of antenna B is 1.84 GHz

Part 4: Characterising an unknown device

The device is attached between port 1 and port 2 of the S-parameter test set and then S₂₁ is plotted as follows:

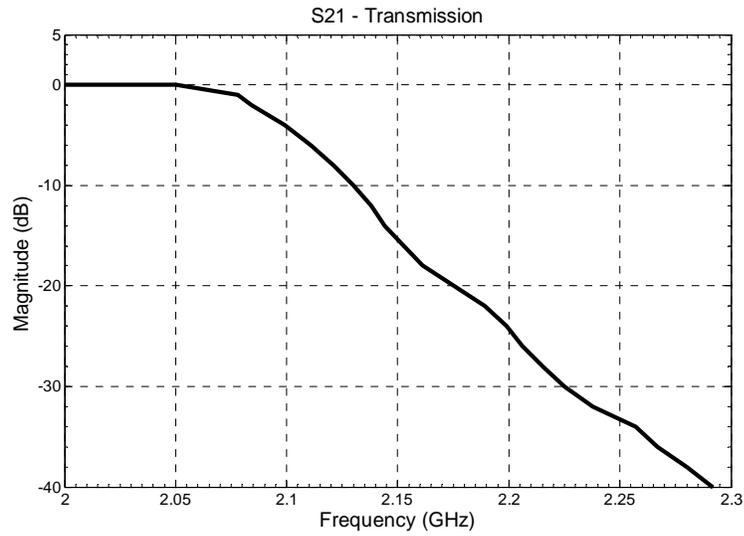


Figure 7: S₂₁ of an unknown device

By looking at

Figure 7, the students should be able to tell that the device is a low pass filter with a cut-off frequency of 2.05 GHz, as it allows signals lower than 2.05 GHz to pass through, but rejects signals of higher frequencies. This particular filter has the following specifications:

Manufacturer	Lark Engineering
Serial Number	LSF2050-9AA-0960-0085
Type	Low Pass Filter
Cut-off Frequency	2.05 GHz
Insertion Loss	1.4dB

References

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- [i] Unknown Author, *Operating Information – 8410B Network Analyzer. 8411A Harmonic Frequency Converter includes Opt.018* (HP 8410 Network Analyser Product Manual), June 1979
- [ii] Mark Kahrs, *Owning and Operating the HP8410 Network Analyzer* [Online]. Available: <http://www.caip.rutgers.edu/~kahrs/papers/mud2k.pdf> September 8, 2000
- [iii] Unknown Author, *Agilent AN 1287-1 Understanding the Fundamental Principles of Vector Network Analysis –Application Note*. [Online]. Available: <http://cp.literature.agilent.com/litweb/pdf/5965-7707E.pdf>
- [iv] Elec 453/6391 Microwave Engineering, *Experiment #4: Network Analyser Measurements*.