Lab Report

ON

REFLECTION COEFFICIENT MEASUREMENTS USING GENERATOR AND SPECTRUM ANALYZER AND VNA

MEASUREMENTS

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1 Device characteristics Measurement

1.1 Equipment used in this measurement work

In this laboratory work we are using following equipment:

- Spectrum analyzers
  - Tektronix RSA 6114A
  - Rohde & Schwarz FSEA 50 Hz - 3.5 GHz
  - Rohde & Schwarz FSV 10 Hz - 13.5 GHz
  - Siglent SSA 3075 YR
- Vector signal generators
  - Rohde & Schwarz SMBV100A signal generator
  - Rohde & Schwarz SMW 200A signal generator
- Circulator.
- Kit containing short and matched load.

We need also 6dB attenuator, suitable cables and adapters to connect the equipment together.

1.2 Objective

The objective of the measurements is to understand the characteristics of circulator. We measure **the insertion loss and isolation between ports**, while varying the setup by varying the impedance(open, short & load) at ports.

We start with a brief description of the set up, followed by port numbering of the device concerned and schematics of the set up. Finally, the recorded measurements are shown through a suitable table containing all required fields.

1.3 Commonly used abbreviations

In order to maintain comprehensibility of the measurement tables, we use abbreviations of the commonly used words in them:-

Original Word	Abbreviated Word
Signal Generator	SG
Spectrum Analyzer	SA
Short Circuit	SC
Open Circuit	OC
Frequency	Freq.
Connection	@
Port X	PX
Insertion Loss(After Cable loss)	IL
Isolation(After Cable loss)	Iso

Few commonly used set up description examples would be

• SG@P1→ It means the signal generator is connected to Port 1.
• OC@P4 → It means Open circuit load is connected to Port 4.
• IL@P12 → It means insertion loss between port 1 and port 2 is measured and noted.

2 Circulator Measurements

2.1 Cable loss

- In initial state (before any other measurements), measure the cable loss between the generator and spectrum analyzer. For that connect generator directly to the input of the spectrum analyzer. The measurement set up is in figure 1.
- Generate signal at 3 GHz with amplitude -10 dBm. The cable passes the signal to spectrum analyzer.
- The cable loss has to be counted in every future measurement involving signal generator and spectrum analyzer.

Figure 1: Measure Cable losses

(1) Record the measurements in the table as shown below.

Freq	SG(dBm)	SA(dBm)	Loss(dB)

2.2 First step: Measure Insertion loss(IL) at port 2, Matched Load(ML) at Port 3

- For the measurement, connect:
  - the signal generator to the port 1,
  - spectrum analyzer to port 2,
  - terminate port 3 by 50 Ω.
- The set up is shown in the figure below.Here it is important to remember that, we are measuring the losses at port 2.

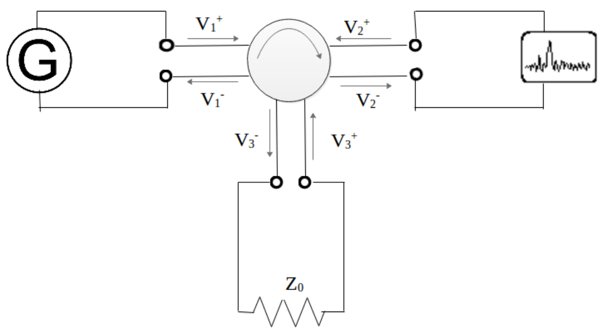

Figure 2: Set up for Insertion loss measurement for port@12

(2) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

Freq	SG@P1(dBm)	SA@P2(dBm)	LOAD@P3(Ohm)	IL@12(in dB)

(3) Repeat the step five times and note the insertion loss values.

(4) Calculate the confidence interval for 99 % & 90 % confidence levels.

(5) Fill up the following table.

Parameter	Sample Size	Mean	Standard Deviation	Confidence Level	Confidence Interval

2.3 Second step: Insertion loss at port 3, Matched load(ML) at Port 1

- Create a connection where
  - Port 1 is terminated by a matched load.
  - Port 2 is connected to signal generator.
  - Port 3 is connected to the spectrum analyzer.
- The set up would like figure 3.

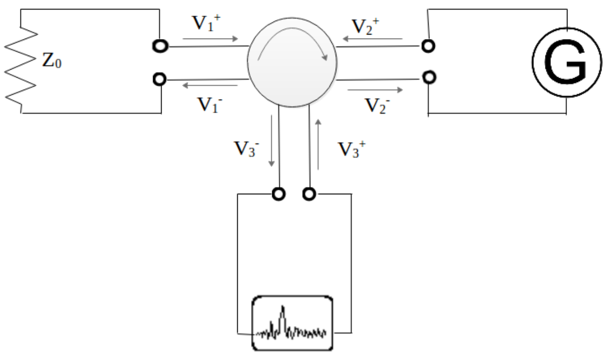

Figure 3: Set up for Insertion loss measurement at port 3

(6) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

Freq	LOAD@P1(Ohm)	SG@P2	SA@P3	IL(dB)

2.4 Third Step: Isolation at port 3, Matched Load at port 2

- Create a connection where
  - Port 1 is connected to signal generator.
  - Port 2 is terminated by a matched load (there will be no incident waves from this port).
  - Port 3 is connected to the spectrum analyzer.
- The set up would like figure 4.

(7) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

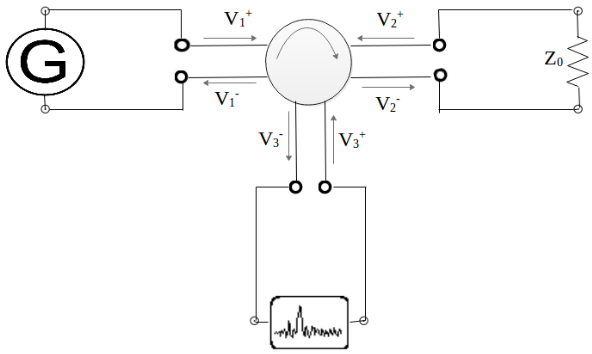

Figure 4: Measure Isolation at port3 ,Matched Load at Port2

Freq	SG@P1(dBm)	LOAD@P2(Ohm)	SA@P3(dBm)	Iso@P13(dB)

2.5 Fourth Step: Measure Isolation at port 3, Open circuit(OC) at port 2

- Create a connection where
  - Port 1 is connected to signal generator.
  - Port 2 is open (there will be incident waves from this port).
  - Port 3 is connected to the spectrum analyzer.
- The set up would like figure 5.

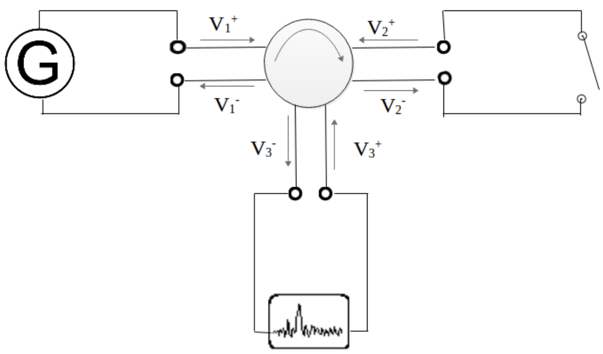

Figure 5: Measure Isolation at port3 ,open circuit at Port2

(8) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

Freq	SG@P1(dBm)	OC@P2	SA@P3(dBm)	Iso@P13(dB)

2.6 Fifth Step: Measure Isolation at port 3, Short circuit(SC) at port 2

- Create a connection where
  - Port 1 is connected to signal generator.

- Port 2 is short circuited, i.e. connect a shorted connector to this port (there will be incident waves from this port).
- Port 3 is connected to the spectrum analyzer.

- The set up would like figure 6.

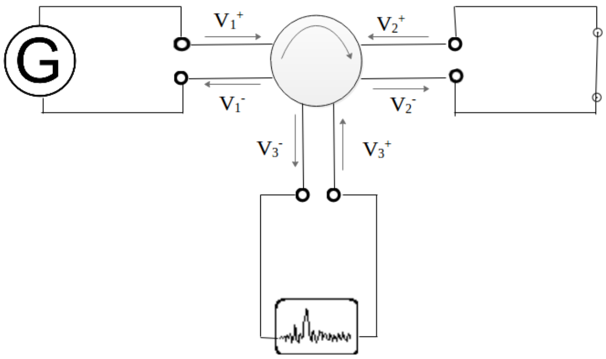

Figure 6: Measure transmission loss @ port3 ,short circuit @Port2

(9) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

Freq	SG@P1(dBm)	SC@P2(Ohm)	SA@P3(dBm)	Iso@P13(dB)

2.7 Sixth Step: Measure Isolation at port 3, 6 dB attenuation at port 2

- Create a connection where
  - Port 1 is connected to signal generator.
  - Port 2 is connected a 6 dB attenuator, i.e. it is not terminated with matched load.
  - Port 3 is connected to the spectrum analyzer.
- The set up would like figure 7.

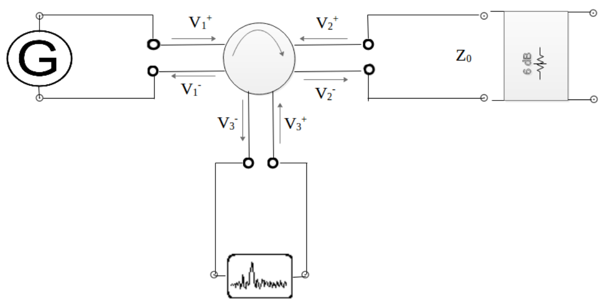

Figure 7: Measure transmission loss @ port3 ,6dB @Port2

(10) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

Freq	SG@P1(dBm)	6dB(Inf)@P2	SA@P3(dBm)	Iso@P13(dB)

(11) Repeat the step five times and note the insertion loss values.

(12) Calculate the confidence interval for 99 % & 90 % confidence levels.

(13) Fill up the following table.

Parameter	Sample Size	Mean	Standard Deviation	Confidence Level	Confidence Interval

2.8 Seventh Step: Measure Isolation loss at port 3, 6 dB attenuation and matched circuit at port 2

- Create a connection where
  - Port 1 is connected to signal generator.
  - Port 2 is connect a 6 dB attenuator that is followed by 50 Ω matched circuit.
  - Port 3 is connected to the spectrum analyzer.
- The set up would like figure 8.

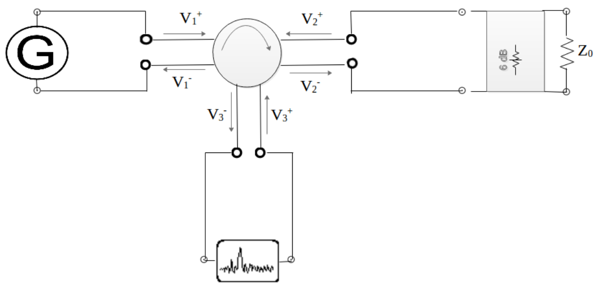

Figure 8: Measure transmission loss @ port3 , Matched Load+ 6dB @Port2

(14) Measure the loss at the spectrum analyzer. Record the measured values as in the table below.

Freq	SG@P1(dBm)	LOAD@P2 + 6 dB	SA@P3(dBm)	Iso@P13(dB)

(15) Repeat the step five times and note the insertion loss values.

(16) Calculate the confidence interval for 99 % & 90 % confidence levels.

(17) Fill up the following table.

Parameter	Sample Size	Mean	Standard Deviation	Confidence Level	Confidence Interval

2.9 Summarize the Measurements

(18) Collect measurement results into table (like shown below).

Port 1	Port 2	Port3	Measurement	Loss(dB)
Generator	Spectrum analyzer	Matched Load	Insertion@P12	
Matched Load	Signal Generator	Spectrum analyzer	Insertion@P23	
Generator	Matched Load	Spectrum analyzer	Isolation@P13	
Generator	Open circuit Load	Spectrum analyzer	Isolation@P13	
Generator	Short circuit Load	Spectrum analyzer	Isolation@P13	
Generator	6 dB attenuator	Spectrum analyzer	Isolation@P13	
Generator	6 dB +Matched Load	Spectrum analyzer	Isolation@P13	

3 Circulator measurements with VNA

3.1 Equipment

In this part of the laboratory work, we will measure the circulator performance with vector network analyzer (VNA) called LibreVNA. You will be tasked to take screenshots of the VNA's graphical user interface (GUI) and record measured values. Recommended way to take screenshots is to use `Print Screen`-button, sometimes `Prt Scrn` or equivalent, on the keyboard, after which the screenshots will be saved to `Pictures/Screenshots` inside `Home` directory. Save them your own USB-stick or upload them to external storage in order to be used in your report, as these pictures will be deleted after each laboratory session.

The equipment used is:

- LibreVNA.
- Circulator.
- Kit containing short and matched load.

3.2 VNA setup

The VNA has been calibrated with the cables connected to it. During your measurements: **DO NOT DISCONNECT THE TWO BLUE SMA CABLES FROM THE VNA!** You can (and should) disconnect from the other end, **NOT FROM VNA'S PORTS!** If you disconnect these cables, the VNA has to be re-calibrated.

- Before any measurements can be done, you are required to start and setup the VNA. On the computer to which the VNA is connected by USB, navigate to following directory from `Desktop`: "`E7250/L2`".
- In the directory, you should see an executable named "`LibreVNA-GUI`". Double click it (or execute from terminal). You should see GUI like in figure **??**.
- By default, the VNA measures S11, S12, S21 and S22 from its two ports: Port1 and Port2. The GUI by default displays two Smith charts and two XY-plots.
- We will now change the Smith charts to XY-plots. Right click on the Smith chart labeled S11 (top-left corner) and select "`Close`". From the new menu, select "`XY-plot`" and click "`Ok`". Finally, right click the new figure and select `S11` from `Primary Traces`. This will add measured magnitude values, and adding `S11` from `Secondary Traces` would add phase values.
- Now do the same for S22, bottom-right figure in the GUI.
- You should see GUI like in figure **??**.
- Next, change the starting frequency of sweep by typing `1.5G` to `Start`.
- Then, change the stop frequency of sweep by typing `5.5G` to `Stop`.
- After that, change the data points of the sweep by typing `1001` to `Points` and then pressing `Enter`.
- From GUI tab on the top, select `Calibration` and then `Load`. Select file named `SOLT_12_1M-5_5G_1001pt.cal` and then select `Open`. The calibration is okay if top-right corner does **not** have a red bar over "`Calibration`" (like figure **??** has).
- Once again, during your measurements: **DO NOT DISCONNECT THE TWO BLUE SMA CABLES FROM THE VNA!**

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3.3 First step: Measuring S-parameters with open circuit at port 2

DO NOT DISCONNECT CABLES FROM THE VNA.

- For this measurement, we connect VNA's Port1 SMA-cable to circulator's port 1, VNA's Port2 SMA-cable to circulator's port 3 and leave circulator's port 2 open. The set up would look like figure 11.
- Once the connections have been done, you should be able to observe the outcome on VNA. The VNA sweeps over specified frequency and outputs magnitude (and phase, if secondary trace is enabled) for different S-parameters.
- To help analysis, you will have to add markers to the GUI followingly: right click on the figure in question and select ”`Add marker here`”. An marker should appear with its values recorded on the right side of the figure's screen and on the bottom right corner `Marker`-window. To remove a marker, select it from the `Marker`-window and click red minus ”`Delete marker`” symbol, or right click on the marker and select `Delete`.

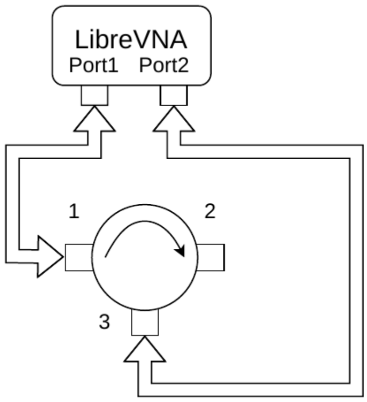

Figure 11: VNA connection with open port 2.

Into you report,

(19) Take a screenshot of the measurement

(20) Using markers, record the S-parameter values for various frequencies into the table below:

Frequency	S11 (dB)	S12 (dB)	S21 (dB)	S22 (dB)
2.0 GHz				
2.5 GHz				
3.0 GHz				
3.4 GHz				
3.8 GHz				
4.5 GHz				
5.0 GHz				

3.4 Second step: Measuring S-parameters with short circuit at port 2

DO NOT DISCONNECT CABLES FROM THE VNA.

- For this measurement, we connect VNA's Port1 SMA-cable to circulator's port 1, VNA's Port2 SMA-cable to circulator's port 3 and connect short circuit to circulator's port 2. The set up would look like figure 12.

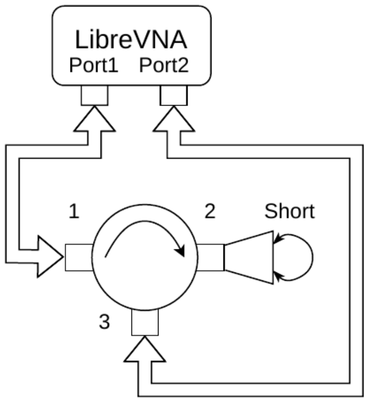

Figure 12: VNA connection with shorted port 2.

Into you report,

(21) Take a screenshot of the measurement

(22) Using markers, record the S-parameter values for various frequencies into the table below:

Frequency	S11 (dB)	S12 (dB)	S21 (dB)	S22 (dB)
2.0 GHz				
2.5 GHz				
3.0 GHz				
3.4 GHz				
3.8 GHz				
4.5 GHz				
5.0 GHz				

3.5 Third step: Measuring S-parameters with matched load at port 2

DO NOT DISCONNECT CABLES FROM THE VNA.

- For this measurement, we connect VNA's Port1 SMA-cable to circulator's port 1, VNA's Port2 SMA-cable to circulator's port 3 and connect matched load to circulator's port 2. The set up would look like figure 13.

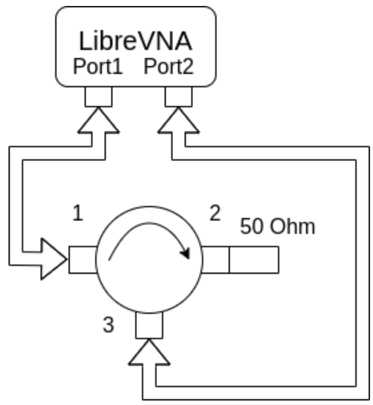

Figure 13: VNA connection with matched port 2.

Into you report,

(23) Take a screenshot of the measurement

(24) Using markers, record the S-parameter values for various frequencies into the table below:

Frequency	S11 (dB)	S12 (dB)	S21 (dB)	S22 (dB)
2.0 GHz				
2.5 GHz				
3.0 GHz				
3.4 GHz				
3.8 GHz				
4.5 GHz				
5.0 GHz				

3.6 Fourth step: Effects of the calibration

DO NOT DISCONNECT CABLES FROM THE VNA.

- Keep the connections same as in "`Third step`": VNA's Port1 SMA-cable to circulator's port 1, VNA's Port2 SMA-cable to circulator's port 3 and connect matched load to circulator's port 2.
- From the GUI interface, on top-right corner you will see a "`Calibration`"-drop down menu (`>>`-symbol). Click it.
- A small menu should appear. From the menu, untick the calibration. The text "`Calibration`" should be highlighted with red.
- Observe how the values for S-parameters have changed. You can enable and disable the calibration as you please to better observe the effects.

Into your report,

(25) Take screenshot of S-parameters when the calibration is on.

(26) Take screenshot of S-parameters when the calibration is off.

Answer to the following questions:

(27) Why does the vector network analyzer's (VNA) measured values for S-parameters change, when the calibration is turned off?

(28) Why is the calibration needed?

4 Antenna measurements with a VNA

4.1 Equipment

In this section, using the same VNA as in the earlier section, we will measure a whip antenna's S-parameters, specifically the forward reflection coefficient. You will also have to take screenshots of the VNA's GUI and record values.

The equipment used are:

- LibreVNA.
- Whip antenna.

4.2 VNA setup

DO NOT DISCONNECT CABLES FROM THE VNA.

- Before measuring, we will need to setup the VNA from its GUI.
- From the GUI, type "`1M`" to "`Start`".
- Type "`2G`" to "`Stop`".
- Ensure that the amount of data points in the sweep is `1001` by typing the value to `Points`.
- From "`IF BW`" drop-down menu, set "`Averaging`" to 3. Now, the VNA will average its measurements over three sweeps, thus the final stable result will take few sweeps. You can notice this effect when making changes to the measurement system.
- Remove all other figures, but S11 XY-plot. In all other figures, right click the figure, select "`Close`" and then select "`Close tile`". Your output should resemble figure 14 (if an antenna is connected).
- Also ensure that the calibration has been enabled from top-right corner.

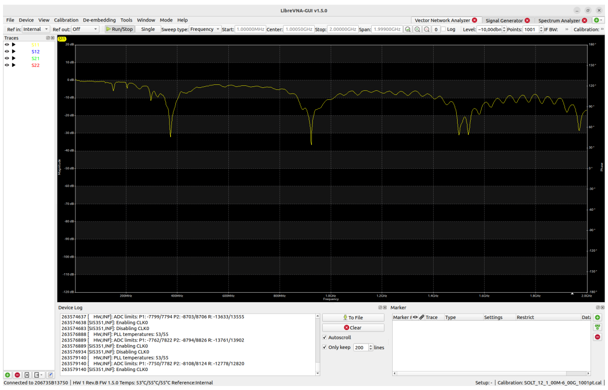

Figure 14: VNA GUI interface after setting up for antenna measurement.

4.3 Measurement: Whip antenna, short

DO NOT DISCONNECT CABLES FROM THE VNA.

- Attach antenna to the VNA's Port1 SMA-cable for S11 measurements. Your setup should resemble figure 15.
- Make the whip antenna as short as possible.
- Locate the first notch generated by the antenna, after 400 MHz, and set a marker to it.

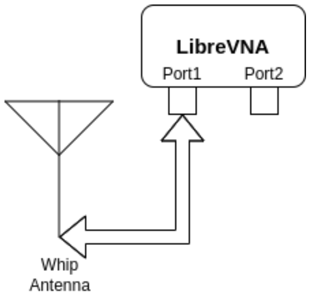

Figure 15: VNA connection with antenna.

Into you report,

(29) Take screenshot of the S11 plot with the marker.

(30) What is the resonance frequency of the antenna?

(31) How much energy the antenna reflects back? (i.e. S11 value at the resonance frequency.)

4.4 Measurement Whip antenna, long

DO NOT DISCONNECT CABLES FROM THE VNA.

- Use same connection and the same antenna as in the previous measurement.
- However, now extend the whip antenna to be as long as possible.
- Locate the first notch generated by the antenna, after 400 MHz, and set a marker to it.

Into you report,

(32) Take screenshot of the S11 plot with the marker.

(33) What is the resonance frequency of the antenna?

(34) How much energy the antenna reflects back? (i.e. S11 value at the resonance frequency.)

(35) Why there are other notches on S11 plot?