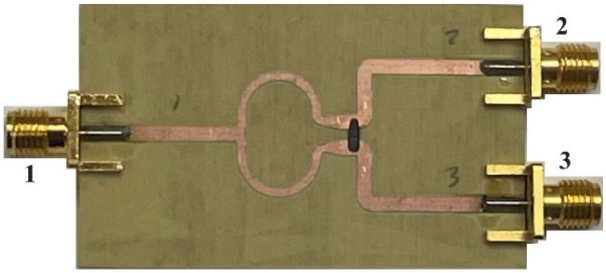
EE 481/581 Microwave Engineering (Fall 2024)
Laboratory 7 Multiport Device Analysis- Part 2

Preliminary

To follow-up the initial investigation, you will now conduct forensic tests on Device 1 (see below) to confirm, dispel, and/or refine your initial theories. You will have access to Device 1, a digital multimeter, ruler, tape measure, caliper, Keysight E5063A vector network analyzer (VNA), Agilent 85033E 3.5mm Calibration Kit, adapters, coaxial cables, calibrated torque wrenches, pliers, box wrenches, and whatever personal equipment you or your team might possess. Under 'good cop - bad cop' interrogation, the informant revealed that Device 1 was *intended* for use at 2.4 GHz.



Device 1

Experiment

Remember to include an equipment table with all relevant equipment information in logbook, i.e., description, manufacturer, and model number (as applicable). Also, draw a block diagram(s) of the test set-up(s) as needed.

Procedure (Device 1)

1) Power on the VNA. Connect Type N (m) - SMA (f) adapters as well as coaxial cables to both ports 1 and 2 of VNA.

Wear static wrist band whenever working with the VNA!

2) To begin, select the frequency range and settings for the VNA. The frequency should range from 5 MHz to 5 GHz in steps of 5 MHz. Calculate, record, and set the number of data points N required. Press Avg, then use mouse to toggle **Averaging** ON and set the **Avg Factor** to 8.

3) Display an impedance Smith chart, i.e., press Format and use mouse to select Smith and R +jX.

4) Per earlier labs, perform a 1-port calibration of the VNA to the reference plane of the SMA (m) connector on the open end of the coaxial cable connected to port 1 of the VNA.

5) With nothing connected to the open end of the cable, activate Marker 1 and put it at 2.5 GHz. Is the marker at the $\infty\ \Omega$ point (or $\Gamma = 1\angle 0°$)? If not, the VNA will need to be adjusted to get as close as possible to this point. Press the Scale button and use the mouse to select Electrical Delay. Adjust the electrical delay to move Marker 1 roughly to the desired point on the Smith chart. Then, switch to a Phase format (i.e., $\angle S_{11}$) display. Set scale to 0.5°/div. Refine the electrical delay so that the phase is as close as possible to 0° at 2.5 GHz. Record your specific electrical delay Δt_{delay}. [Hint: Expect 0.006-0.009 ns/6-9 ps).]

6) Use torque wrench and pliers (on device SMA connectors) to attach 50 Ω SMA (m) loads to ports 2 and 3. Then, attach the cable from port 1 of the VNA to port 1 of Device 1. Place Device 1 where it will not be disturbed.

7) Press the Format button and use the mouse to select Log Mag to display $|S_{11}|$ in decibels.
   - Press the Scale button to bring up a softkey menu. Adjust the display so that 0 dB is at the top of the screen and the vertical scale is set to 5 dB/div with 10 divisions (default).
   - Place Marker 1 at lowest frequency where $|S_{11}|$ is -20 dB. Place Marker 2 at 2.4 GHz. Place Marker 3 at lowest $|S_{11}|$ value. Place Marker 4 at highest frequency where $|S_{11}|$ is -20 dB.
   - Save a screen shot of the Log Mag display for $|S_{11}|$ to a USB drive (e.g., s11logmag_dev1.bmp). Leave space in logbook to insert this screen shot.
   - Without moving the markers, change to impedance Smith chart format, and save a screen shot to a USB drive (e.g., s11smith_dev1.bmp). Leave space in logbook to insert this screen shot.

8) Use torque wrench and pliers (on device) to attach 50 Ω SMA (m) loads to ports 1 & 3. Connect the coaxial cable from port 1 of the VNA to port 2 of Device 1. Place Device 1 where it will not be disturbed. Then, repeat step 7 for $|S_{22}|$. Disconnect Device 1 from coaxial cable.

9) In the absence of a compatible 2-port eCal unit (☹), we will *estimate* the magnitude of some through parameters. Connect the open ends of the coaxial cables coming from ports 1 & 2 of the VNA together using an SMA (f) – SMA (f) adapter (AKA: SMA bullet). Press the Meas button and use the mouse to select S21. Then, press the Format button and use the mouse to select <Log Mag> to display $|S_{21}|$ (dB).
   - Press the Scale button and adjust the display so that 0 dB is at the top of the screen and the vertical scale is set to 1 dB/div with 10 divisions (default).
   - Clear all markers.
   - Successively activate Markers 1-9 and place at each of the frequencies listed in **Table 1 Device 1 Through Parameters** and record the value in the '$|S_{21}|$' (dB) (SMA bullet) column.
   - Save a screen shot to a USB drive (e.g., s21logmag_bullet.bmp). Leave space in logbook to insert this screen shot. Disconnect SMA bullet from coaxial cables.

11) Leaving markers in place, use torque wrench and pliers (on device) to attach a 50 Ω SMA (m) load to port 3, attach the coaxial cable from port 1 of the VNA to port 1 of Device 1, and attach the cable from port 2 of the VNA to port 2 of Device 1. Place Device 1 where it will not be disturbed. Save a screen shot to a USB drive (e.g., s21logmag_dev1.bmp). Leave space in logbook to insert this screen shot.

12) Leaving markers in place, use torque wrench and pliers (on device) to attach the cable from port 1 of the VNA to port 3 of Device 1. Attach 50 Ω SMA (m) load to port 1 of Device 1. Place Device 1 where it will not be disturbed. [Note: $|S_{21}|$ on the VNA is now $|S_{23}|$ on Device 1.] Change vertical scale to 5 dB/div. Save a screen shot to a USB drive (e.g., s23logmag_dev1.bmp). Leave space in logbook to insert this screen shot. Disconnect Device 1 from coaxial cables and remove 50 Ω SMA (m) load.

13) If no other groups are waiting, power down the VNA; else, push Preset button.

Analysis (Device 1)

1) Using data from screen shots, complete Table 1.

Table 1 Device 1 Through Parameters

Marker	f (GHz)	'$\|S_{21}\|$' (dB) (SMA bullet)	'$\|S_{21}\|$' (dB) (Device 1)	'$\|S_{23}\|$' (dB) (Device 1)	$\|S_{21}\|_{est}$ (dB)	$\|S_{23}\|_{est}$ (dB)
1	0.5					
2	1.0					
3	1.5					
4	2.0					
5	2.25					
6	2.5					
7	2.75					
8	3.0					
9	3.5					

- $|S_{21}|_{est}$ (dB) = '$|S_{21}|$' (dB) (Device 1) - '$|S_{21}|$' (dB) (SMA bullet)
- $|S_{23}|_{est}$ (dB) = '$|S_{23}|$' (dB) (Device 1) - '$|S_{21}|$' (dB) (SMA bullet)

2) Use data in Table 1 to plot $|S_{21}|_{est}$ (dB) versus f (GHz). For the plot, make the horizontal scale range from 0 to 4 GHz and the vertical scale range from -2 to -4 dB. Also, add a labeled dashed horizontal line at -3.01 - 0.25 = -3.26 dB. Estimate frequency range where $|S_{21}|_{est} \geq$ -3.26 dB. What percent of the power is making it to port 2 from port 1 when $|S_{21}|_{est}$ = -3.26 dB?
3) Use data in Table 1 to plot $|S_{23}|_{est}$ (dB) versus f (GHz). For the plot, make the horizontal scale range from 0 to 4 GHz and the vertical scale range from 0 to -35 dB. Also, add a labeled dashed horizontal line at -20 dB. Estimate frequency range where $|S_{23}|_{est} \leq$ -20 dB. What percent of the power is making it to port 3 from port 2 when $|S_{32}|_{est}$ = -20 dB?
4) Using screen shot of $|S_{11}|$ (dB), estimate frequency range over which $|S_{11}| \leq$ -20 dB. What percentage of the power incident on port 1 is reflected when $|S_{11}|$ = -20 dB?
5) Using screen shot of $|S_{22}|$ (dB), estimate frequency range over which $|S_{22}| <$ -20 dB.
6) What is the usable frequency range (i.e., f_{low} to f_{high}), approximate center frequency f_c, and %BW = 100 $(f_{high} - f_{low})$ / f_c of Device 1? Justify each answer.
7) Based on the above forensic results, what is Device 1? Comment on performance of Device 1.

Summary and Conclusions

- Summarize and discuss results.
- Using information in logbook, compose a report on the Device 1 results of Labs 6 & 7 following syllabus guidelines.

Report and logbook due Tuesday, December 9, 2025 by 4 pm at office or EECS mailbox.