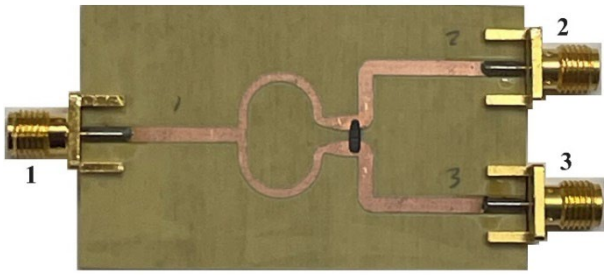
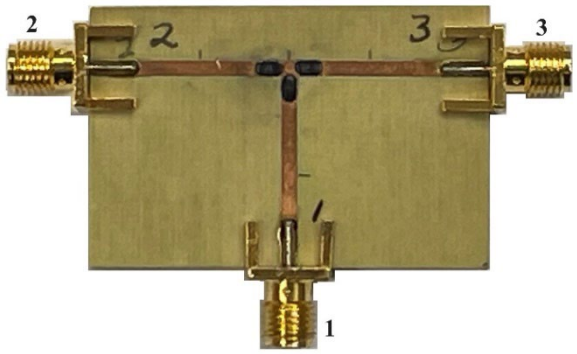
EE 481/581 Microwave Engineering (Fall 2024)
Laboratory 7 Multiport Device Analysis- Part 2

Preliminary

To follow-up the initial investigation, you will now conduct forensic tests on the devices to confirm, dispel, and/or refine your initial theories. You will have access to the devices (see below), a digital multimeter, ruler, tape measure, caliper, Keysight E5063A vector network analyzer (VNA), Agilent 85033E 3.5mm Calibration Kit, 50 Ω SMA (m) loads, SMA (m) - SMA (m) coaxial cables, calibrated torque wrenches, pliers, box wrenches, and whatever personal equipment you or your team might possess. Under interrogation, the informant revealed that Device 1 was intended for use at 2.4 GHz.



Device 1



Device 2

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.

Device 1

1) Power on the VNA. Connect Type N (m) - SMA (f) adapters and cables to Ports 1 & 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 and record 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 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 6-9 ps/0.006-0.009 ns.]

6) Use torque wrench and pliers (on device) to attach 50 Ω SMA (m) loads to ports 2 & 3 and then attach the cable from Port 1 of the VNA to port 1 of Device 1. Place Device 1 on the bench 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 a log mag of 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 the lowest frequency where the log mag is -20 dB. Place Marker 2 at 2.4 GHz. Place Marker 3 at the lowest log mag value. Place Marker 4 at the highest frequency where the log mag is -20 dB.
   - Save a screen shot of the Log Mag display for $|S_{11}|$ to a USB drive. Leave space in the logbook to insert this screen shot.
   - Without moving the markers, change to an impedance Smith chart format, and save a screen shot to a USB drive. Leave space in the 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 and the cable to port 2 of Device 1. Place Device 1 on the bench where it will not be disturbed. Then, repeat step 7 for $|S_{22}|$.

9) Use torque wrench and pliers (support SMA connectors on Device 1) to attach 50 Ω SMA (m) loads to ports 1 & 2 and the cable to port 3 of Device 1. Place Device 1 on the bench where it will not be disturbed. Then, repeat step 7 for $|S_{33}|$. Disconnect Device 1 from cable.

10) In the absence of a compatible 2-port eCal unit (☹), we will *estimate* the magnitude of some through parameters by filling out the **Device 1 Through Parameter Table** (below). Connect the open ends of the 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 a log mag of 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.
   - Activate Marker 1 and go to each of the frequencies listed in the **Device 1 Through Parameter Table** and record the value in the '$|S_{21}|$' (dB) (SMA bullet) column.

11) Use torque wrench and pliers (on device) to attach a 50 Ω SMA (m) load to port 3, attach the 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 on the bench where it will not be disturbed. Fill out in the '$|S_{21}|$' (dB) (Device 1) column.

12) 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 on the bench where it will not be disturbed. [Note: $|S_{21}|$ on the VNA is now $|S_{23}| = |S_{32}|$ on Device 1.] Change vertical scale to 5 dB/div. Fill out in the '$|S_{32}|$' (dB) (Device 1) column. Disconnect Device 1 from cables and remove 50 Ω SMA (m) load.

Device 1 Through Parameter Table

f (GHz)	'$\|S_{21}\|$' (dB) (SMA bullet)	'$\|S_{21}\|$' (dB) (Device 1)	'$\|S_{32}\|$' (dB) (Device 1)	$\|S_{21}\|_{est}$ (dB)	$\|S_{32}\|_{est}$ (dB)
1					
1.5					
2					
2.2					
2.4					
2.5					
2.6					
2.8					
3					
3.5					
4					

- $|S_{21}|_{est}$ (dB) = '$|S_{21}|$' (dB) (Device 1) - '$|S_{21}|$' (dB) (SMA bullet)
- $|S_{32}|_{est}$ (dB) = '$|S_{32}|$' (dB) (Device 1) - '$|S_{21}|$' (dB) (SMA bullet)

Device 2

1) Use torque wrench and pliers (on device) to attach 50 Ω SMA (m) loads to ports 2 & 3 and then attach the cable from Port 1 of the VNA to port 1 of Device 2. Place Device 2 on the bench where it will not be disturbed.
2) Press the Meas button and use the mouse to select S11. 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 a log mag of 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 the lowest frequency where the log mag is -20 dB (or highest value). Place Marker 2 at 2.5 GHz. Place Marker 3 at the lowest log mag value.
   - Save a screen shot of the Log Mag display for $|S_{11}|$ to a USB drive. Leave space in the logbook to insert this screen shot.
   - Without moving the markers, change to an impedance Smith chart format, and save a screen shot to a USB drive. Leave space in the logbook to insert this screen shot.
3) Use torque wrench and pliers (on device) to swap connections on ports 1 & 2 on Device 2. Place Device 2 on the bench where it will not be disturbed. Then, repeat step 2 for $|S_{22}|$.
4) Use torque wrench and pliers (on device) to swap connections on ports 2 & 3 on Device 2. Place Device 2 on the bench where it will not be disturbed. Then, repeat step 2 for $|S_{33}|$. Disconnect Device 2 from cable and remove 50 Ω SMA (m) load.

5) We will *estimate* the magnitude of some through parameters by filling out the **Device 2 Through Parameter Table** (below). Connect the open ends of the 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 a log mag of 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.
   - Activate Marker 1 and go to each of the frequencies listed in the **Device 2 Through Parameter Table** and record the value in the '$|S_{21}|$' (dB) (SMA bullet) column.

6) Use torque wrench and pliers (on device) to attach a 50 Ω SMA (m) load to port 3, attach the cable from Port 1 of the VNA to port 1 of Device 2, and attach the cable from Port 2 of the VNA to port 2 of Device 2. Place Device 2 on the bench where it will not be disturbed. If necessary, make -2 dB the Reference Value. Fill out in the '$|S_{21}|$' (dB) (Device 2) column.

7) Use torque wrench and pliers (on device) to attach the cable from Port 1 of the VNA to port 3 of Device 2. Attach 50 Ω SMA (m) load to port 1 of Device 2. Place Device 2 on the bench where it will not be disturbed. [Note: $|S_{21}|$ on the VNA is now $|S_{23}| = |S_{32}|$ on Device 2.] Fill out in the '$|S_{32}|$' (dB) (Device 2) column. Disconnect Device 2 from cables and remove 50 Ω SMA (m) load.

8) Ask instructor if you should power down the VNA.

Device 2 Through Parameter Table

f (GHz)	'$\|S_{21}\|$' (dB) (SMA bullet)	'$\|S_{21}\|$' (dB) (Device 2)	'$\|S_{32}\|$' (dB) (Device 2)	$\|S_{21}\|_{est}$ (dB)	$\|S_{32}\|_{est}$ (dB)
1					
1.5					
2					
2.5					
3					
3.5					
4					
4.5					
5					

- $|S_{21}|_{est}$ (dB) = '$|S_{21}|$' (dB) (Device 2) - '$|S_{21}|$' (dB) (SMA bullet)
- $|S_{32}|_{est}$ (dB) = '$|S_{32}|$' (dB) (Device 2) - '$|S_{21}|$' (dB) (SMA bullet)

Analysis

Device 1

1) Complete 'Device 1 Through Parameter Table'.
2) Use data in 'Device 1 Through Parameter Table' to plot $|S_{21}|_{est}$ (dB) versus f (GHz) with a vertical scale ranging from -2 to -4 dB. Add a labeled dashed horizontal line at -3.26 dB and estimate frequency range over which $|S_{21}|_{est} > -3.26$ 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 'Device 1 Through Parameter Table' to plot $|S_{32}|_{est}$ (dB) versus f (GHz) with a vertical scale ranging from 0 to -35 dB. Add dashed horizontal line at -20 dB and estimate frequency range over which $|S_{32}|_{est} < -20$ 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 $|S_{11}| < -20$ dB. What percent 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) Using screen shot of $|S_{33}|$ (dB), estimate frequency range over which $|S_{33}| < -20$ dB.
7) Based on the above forensic results, what is Device 1?
8) 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? Why?
9) Comment on any deficiencies/virtues of Device 1.

Device 2

1) Complete 'Device 2 Through Parameter Table'.
2) Use data in 'Device 2 Through Parameter Table' to plot $|S_{21}|_{est}$ & $|S_{32}|_{est}$ (dB) versus f (GHz) with a vertical scale ranging from -5 to -7 dB. Add a labeled dashed horizontal line at -6.02 dB. What percent of the power is making it to port 2 from port 1 when $|S_{21}|_{est} = -6.02$ dB?
3) Using screen shot of $|S_{11}|$ (dB), estimate frequency range over which $|S_{11}| < -20$ dB.
4) Using screen shot of $|S_{22}|$ (dB), estimate frequency range over which $|S_{22}| < -20$ dB.
5) Using screen shot of $|S_{33}|$ (dB), estimate frequency range over which $|S_{33}| < -20$ dB.
6) Based on the above forensic results, what is Device 2?
7) What would you consider to be the usable frequency range (i.e., f_{low} to f_{high}) of Device 2? Why?
8) What factors might limit the usable frequency range of this device?
9) Comment on any deficiencies/virtues of Device 2.

Summary and Conclusions

- Summarize and discuss results.
- Following syllabus guidelines, compose a report on the results of Labs 6 & 7. [Your logbook will be one of your references.]

Report and logbook due Tuesday, December 10, 2024 by 4 pm.