EE 481/581 Microwave Engineering (Fall 2025)
Laboratory 4 Terminated Transmission Line Measurements

Background

In this laboratory, you will be taking measurements on an unknown load connected to the lossy coaxial transmission line (TL) cable from the previous lab. Document all work in a logbook.

Experiment

1) The instructor will have the cable, Keysight E5063A vector network analyzer (VNA), Agilent 85033E 3.5mm Calibration Kit, unknown load, pliers, tape measure, and box wrenches available. Remember to include an equipment table with all relevant equipment information in logbook, i.e., description, manufacturer, and model number (as applicable).

2) Take a picture showing the unknown load with relevant dimensions (i.e., include ruler/tape measure in picture). Also, remember to include block diagram(s) of test set-up(s). Leave room for both in logbook.

3) If necessary, power on the VNA. Connect a Type N (m) - SMA (f) adapter and the cable to Port 1 of the VNA.

Wear the static wrist band whenever working with the VNA!

4) To begin, select the frequency range and settings for the VNA. The frequency should range from 4.5 GHz to 5.5 GHz in steps of 1 MHz. Calculate and record the number of data points required. Use data averaging with an averaging factor of 16.

4) Connect cable to Type N (m) - SMA (f) adapter. Press the [Format] button and use the mouse to select <Smith> and then <R +jX> to display an impedance Smith chart.

5) Per earlier labs, calibrate the VNA to the reference plane of the SMA (m) connector on the open end of the cable. I.e., we do not want the cable to be part of our measurements.

6) With nothing connected to the end of the cable after calibration, activate Marker 1 and put it at 5 GHz. Is the marker at the ∞ Ω point (or $\Gamma = 1\angle 0°$)? If not, the VNA will need to be adjusted to get to this point. Press the [Scale] button and use the mouse to select <Electrical Delay>. Then, use the keypad/wheel to adjust the electrical delay to move Marker 1 to the desired/expected point on the Smith chart. Record your specific electrical delay Δt_{delay}. [Hints: A delay of ~0.008 ns will be necessary. Look for value where the imaginary part of the impedance starts jumping between large negative and positive values.]

7) Connect the unknown load using torque wrench and pliers. Place on the bench in a location where the unknown load and cable will not be disturbed.

8) Press the [Format] button and use the mouse to select <SWR> to display the SWR of the unknown load with respect to 50 Ω. Measure the bandwidth (BW) where the load meets the specification SWR ≤ 1.25.

- Press the Scale button to bring up a softkey menu. Adjust the display so that an SWR of 1 is at the bottom of the screen and the vertical scale is set to 0.2/div. [Hint: <Reference Value> and <Reference Position>.]
- Press the MARKER button to bring up a softkey menu. By default, Marker 1 should be selected. Press the Marker Search button to bring up a softkey menu and select <Min> to move Marker 1 to the lowest SWR. Record value and frequency.
- Activate Markers 2 and 3. Move Marker 2 to an SWR = 1.25 to the left (lower frequency) of Marker 1. Move Marker 3 to an SWR = 1.25 to the right (higher frequency) of Marker 1. [Hints: Click on the appropriate marker. Use wheel/keypad to move it to SWR ≈ 1.25. Then, under the Marker Search softkey menu, use the <Target> option and enter a <Target Value> of 1.25, e.g., 1, ., 2, 5, and 1x keypad buttons.]
- Read and record value and frequency for Markers 2 and 3.
- Save a screen shot of the SWR display to a USB drive. Leave space in the logbook to insert this screen shot.

9) Press the Format button and use the mouse to select <Log Mag> to display $|S_{11}|$ in decibels. Would this display be related to the insertion loss or return loss of the unknown load? How? Measure the bandwidth where the load has a Log Mag ≤ -20 dB, a commonly accepted value for a good match.

- Press the Scale button to bring up a softkey menu. Adjust the display so that a log mag of 0 dB at the top of the screen and the vertical scale is set to 2.5 dB/div.
- Place Marker 1 at the lowest log mag value. Record value and frequency.
- Place Markers 2 and 3 to find the -20dB BW. Move Marker 2 to -20 dB to the left (lower frequency) and Marker 3 to -20 dB to the right (higher frequency) of Marker 1.
- Read and record value and frequency for Markers 2 and 3.
- Save a screen shot of the Log Mag display to a USB drive. Leave space in the logbook to insert this screen shot.
- 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.

10) Press the Format button and use the mouse to select <Lin Mag> to display $|S_{11}|$ (unitless). Measure the bandwidth where the load has $|S_{11}| \leq 0.11$.

- Press the Scale button to bring up a softkey menu. Adjust the display so that 0 is at the bottom of the screen and the vertical scale is set to 0.05/div.
- Place Marker 1 at the lowest $|S_{11}|$ value. Record value and frequency.
- Place Markers 2 and 3 to find the $|S_{11}| \leq 0.11$ BW. Move Marker 2 to 0.11 to the left (lower frequency) and Marker 3 to 0.11 to the right (higher frequency) of Marker 1.
- Read and record value and frequency for Markers 2 and 3.

- Save a screen shot of the Lin Mag display to a USB drive. Leave space in the logbook to insert this screen shot.
- If no other groups are waiting, power down the VNA, else push Preset button.

Analysis

1) What is the impedance Z_L of the unknown load where it is best matched to cable impedance?
2) For each of the **specifications** (not data), tabulate the maximum percentage of incident power reflected. Format: col. 1 quantity, col. 2 BW specification, col. 3 max % of incident power reflected.
3) Make a table to show the BW for the various specifications used. Format: col. 1 quantity measured, col. 2 lowest frequency f_L (GHz), col. 3 center frequency f_C (GHz), col. 4 highest frequency f_H (GHz), col. 5 BW or Δf (GHz), and col. 6 % BW = $\Delta f / f_C$ * 100%.

Summary and Conclusions

- Summarize and discuss results.
- Compare the various specifications. Which is the most stringent? Which is the least stringent?
- Following syllabus guidelines, compose a short report on this lab. [Your logbook will be one of your references.]

Report and logbook due Wednesday, October 15, 2025 by 4 pm.