EE 481/581 Microwave Engineering (Fall 2024)
Laboratory 3 Lossy Transmission Lines- Part 2

Background

In this laboratory, you will be taking measurements on the lossy coaxial transmission line (TL) cable from the previous lab with the objective of measuring some key parameters. You use this data to make comparisons with the results taken or calculated from the TL datasheet information in the previous lab. Document all work in a logbook.

Experiment

1) The instructor will have the cable, i.e., lossy coaxial TL with connectors, Keysight E5063A vector network analyzer (VNA), Agilent 85033E 3.5mm Calibration Kit, tape measure, and box wrenches available. Remember to record all relevant equipment information in logbook, i.e., description, manufacturer, and model number. Also, remember block diagrams.

2) Measure and record the physical length ℓ_{phys} (inches & cm) of the cable.

3) If necessary, power on the VNA. Ensure a Type N (m) - SMA (f) adapter is connected to Port 1 of the VNA.

Wear the static wrist band whenever working with the VNA!

4) To begin, set up the frequency settings for the VNA.
   - On the front panel of the VNA, press the Start, 1, and G/n buttons to set the start of the frequency sweep to 1 GHz.
   - To set the stop of the frequency sweep to 8 GHz, press the Stop, 8, and G/n buttons.
   - Next, set the number of points in the sweep to 71 by pressing Sweep Setup. A softkey menu will appear on the right hand side of the display. Use the mouse to click on the number under <Points> and press the 7, 1, and 1x buttons on the front of the VNA.
   - To reduce jitter in the measurements, press the Avg button, click on the <Avg Factor> softkey, and press the 1, 6, & 1x buttons to set it to 16. Then, click on <Averaging> to toggle it "ON".
   - Calculate and record the frequency step size Δf for the measurements.

5) Calibrate the VNA to the reference plane of the Type N (m) - SMA (f).
   - Press the Cal button to bring up the calibration softkey menu.
   - Ensure under <Corrections> that "OFF" is shown, <Cal Kit> that "85033E" is shown, <velocity factor> that "1" is shown, <Set Z0> that "50 Ω" is shown, <Port Extensions> that "OFF" is shown, and <Property> that "OFF" is shown.
   - Use mouse to click <Calibrate>. Then, click <1-Port Cal>.
   - Ensure under <Select Port> that "1" is shown.
   - Retrieve the 3.5mm (male) calibration standards, i.e., O (open circuit), S (short circuit), and L (matched load), from the Agilent 85033E 3.5mm Calibration Kit. Remove red plastic dust covers from the connectors and carefully set in the empty slot in kit.

- **Following the directions from previous lab regarding torque and box wrenches**, connect the O (open circuit) calibration standard to the adapter on Port 1 and use the mouse to click the <Open> softkey. You should hear a 'beep' and see a check mark next to the <Open> softkey to indicate that the measurements are completed.
- Disconnect the O (open circuit) and connect the S (short circuit) calibration standard to the adapter on Port 1 and use the mouse to click the <Short> softkey. You should hear a 'beep' and see a check mark next to the <Short> softkey.
- Disconnect the S (short circuit) and connect the L (matched load) calibration standard to the adapter on Port 1 and use the mouse to click the <Broadband> softkey. You should hear a 'beep' and see a check mark next to the <Broadband> softkey.
- Disconnect the L (matched load) calibration standard and click the <Done> softkey. You should hear a 'beep', the VNA is now calibrated.
- Replace dust covers on the 3.5 mm connectors for the calibration standards and put it back into its slot in calibration kit.

6) Connect cable to Type N (m) - SMA (f) adapter. Press the Format button and use the mouse to select <Polar> and then <Real/Imag> to display a polar plot of S_{11}.

7) Measure S_{11} with an **open circuit termination** on the cable at 1, 2, 4, 6, & 8 GHz.
   - Retrieve the 3.5 mm (female) calibration standards from the Agilent 85033E 3.5mm Calibration Kit. Remove red plastic dust covers from the connectors and carefully set in the empty slot in kit. Connect the O (open circuit) standard to end of the cable.
   - Press the MARKER button to display a frequency marker (shows value of selected format quantity at selected frequency). By default, marker 1 should be selected and be at 1 GHz, the start frequency. If not, press the 1 and G/n buttons. Read and record (table) the displayed value of $S_{11,\mathrm{OC}}$ at 1 GHz. See note below for table format.
   - Press the 2 and G/n buttons. Read and record the displayed value of $S_{11,\mathrm{OC}}$ at 2 GHz.
   - Press the 4 and G/n buttons. Read and record the displayed value of $S_{11,\mathrm{OC}}$ at 4 GHz.
   - Press the 6 and G/n buttons. Read and record the displayed value of $S_{11,\mathrm{OC}}$ at 6 GHz.
   - Press the 8 and G/n buttons. Read and record the displayed value of $S_{11,\mathrm{OC}}$ at 8 GHz.

8) Measure S_{11} with a **short circuit termination** on the cable at 1, 2, 4, 6, & 8 GHz.
   - Disconnect the O (open circuit) standard and connect the S (short circuit) standard to end of the cable.
   - Read and record (table) the displayed values of $S_{11,\mathrm{SC}}$ at 1, 2, 4, 6, and 8 GHz.
   - Disconnect the S (short circuit) standard. Replace the dust covers on 3.5 mm connectors of standard and put it back into slot in calibration kit.
   - If no other groups are waiting, power down the VNA and get instructor to put away equipment.

Note: Format for S_{11} data tables: col. 1 frequency (GHz), col. 2 $\mathrm{Re}(S_{11,\mathrm{xx}})$, col. 3 $\mathrm{Im}(S_{11,\mathrm{xx}})$, col. 4 $|S_{11,\mathrm{xx}}|$, and col. 5 $\angle S_{11,\mathrm{xx}}$.

Analysis

For all work, give citations, show all work, and detail any assumptions, approximations ...

1) Use the open circuit S_{11} data at 1, 2, 4, 6, & 8 GHz, ℓ_{phys}, and lossy TL theory to compute the measured attenuation constant $\alpha_{meas,OC}$ at each frequency (Np/m and dB/m). In a table, compare $\alpha_{meas,OC}$ results with attenuation constants α_{data} found in the previous lab. Format: col. 1 frequency (GHz), col. 2 $\alpha_{meas,OC}$ (Np/m), col. 3 α_{data} (Np/m), col. 4 $\alpha_{meas,OC}$ (dB/m), col. 5 α_{data} (dB/m), and col. 6 % difference where % difference = 100%*(α_{meas} - α_{data})/α_{data}.

   EE 581 only- Plot $\alpha_{meas,OC}$ & α_{data} (Np/m) versus frequency in linear and semilog formats. Plot $\alpha_{meas,OC}$ & α_{data} (dB/m) versus frequency in linear and semilog formats.

2) Use the short circuit S_{11} data at 1, 2, 4, 6, & 8 GHz, ℓ_{phys}, and lossy TL theory to compute the measured attenuation constant $\alpha_{meas,SC}$ at each frequency (Np/m and dB/m). In a table, compare $\alpha_{meas,SC}$ results with attenuation constants α_{data} found in the previous lab. Format: col. 1 frequency (GHz), col. 2 $\alpha_{meas,SC}$ (Np/m), col. 3 α_{data} (Np/m), col. 4 $\alpha_{meas,SC}$ (dB/m), col. 5 α_{data} (dB/m), and col. 6 % difference where the % difference = 100%*(α_{meas} - α_{data})/α_{data}.

   EE 581 only- Plot $\alpha_{meas,SC}$ & α_{data} (Np/m) versus frequency in linear and semilog formats. Plot $\alpha_{meas,SC}$ & α_{data} (dB/m) versus frequency in linear and semilog formats.

3) Use the open circuit S_{11} data at 1, 2, 4, 6, & 8 GHz, phase constant & velocity data from previous lab, ℓ_{phys}, and lossy TL theory to compute the measured length $\ell_{meas,OC}$ at each frequency (cm). In a table, compare $\ell_{meas,OC}$ results with the measured length ℓ_{phys}. Format: col. 1 frequency (GHz), col. 2 $\ell_{meas,OC}$ (cm), col. 3 ℓ_{phys} (cm), and col. 4 % difference where the % difference = 100% * ($\ell_{meas,OC}$ - ℓ_{phys})/ ℓ_{phys}.

4) Use the short circuit S_{11} data at 1, 2, 4, 6, & 8 GHz, phase constant & velocity data from previous lab, ℓ_{phys}, and lossy TL theory to compute the measured length $\ell_{meas,SC}$ at each frequency (cm). In a table, compare $\ell_{meas,SC}$ results with the measured length ℓ_{phys}. Format: col. 1 frequency (GHz), col. 2 $\ell_{meas,SC}$ (cm), col. 3 ℓ_{phys} (cm), and col. 4 % difference where the % difference = 100% * ($\ell_{meas,SC}$ - ℓ_{phys})/ ℓ_{phys}.

Hints: Consider that each value of S_{11} &/or Γ contains two pieces of information, magnitude and phase. Compute length of transmission line in wavelengths.

Summary and Conclusions

- Summarize and discuss results. At each frequency, which attenuation constant α do you believe to be the most accurate? Which TL length ℓ do you believe to be the most accurate? Explain/justify answers. If there were any consistent discrepancies and/or trends between the measured, calculated, and/or datasheet results, theorize on possible reasons.
- Following syllabus guidelines, compose a report on this and the previous lab. [Your logbook will definitely be one of your references.]

Report and logbook due Monday, September 30, 2024 by 4 pm.