California State University, Bakersfield

ECE 3320 – Fields and Waves

Lab 7 - Lossless Transmission Lines

Introduction:

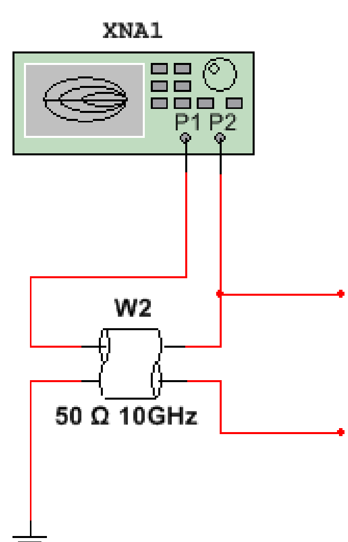
In this lab, we will simulate a lossless transmission line in Multisim and observe the effect different terminations have on the magnitude and phase of the reflection coefficient, Γ. We consider a transmission line to be a "lossless" line when the resistance and conductance is much smaller than the inductance and capacitance respectively. When this is the case, we can consider resistance and conductivity of a line to be equal to zero. Thus, the characteristic impedance of our line can be simplified to $Z_0 = \sqrt{(L'/C')}$.

The reflection coefficient is the ratio of the voltages of the reflected wave and the incident wave for a given transmission line. The incident wave is the wave that the source sends towards the load. The reflected wave is the wave that is reflected from the load back towards the source. By constructing different load terminations can view the results of the reflected wave by using a network analyzer.

Procedure:

1. Open Multisim

2. Construct the following circuit:



W2 is a lossless transmission line. In the component list search for "LOSSLESS_LINE_TYPE2" in the search bar and place it. Double click on it and set the nominal impedance to 50 Ω, frequency to 10 GHz and click "OK". XNA1 is a network analyzer, this can be found on the bar on the right. After placing your components, wire it like according to the diagram above. The two probes to the right of the transmission lines will be used to connect different loads.

3. The first load we will test we test is the open circuit. Run the simulation by pressing the green button. Open the network analyzer by double clicking on it. In order to view the reflection coefficient, set the following settings:

Param.: S-parameters, Smith
Trace: Only S11 selected
Marker: Mag/Ph(Deg)

For your calculations, use 1MHz as your frequency. You can set the frequency by using the frequency slider at the bottom. 1MHz will be to the far left. The value we are interested in is the in the upper left corner followed by the red "S11". Since it is an open circuit, you should get a magnitude of 1 and a phase of 0°.

4. Repeat step 3, but now short the terminals together. Record your correlation coefficient.

5. Remove the short and add a 50 Ω resistor. Record your correlation coefficient.

6. Change the resistor value to 100 Ω. Record your correlation coefficient.

7. Add a 10 μH inductor in series with the 100 Ω resistor. Record your correlation coefficient.

8. Replace the 10uH inductor with a 5nF capacitor. What happened to the angle of the reflection coefficient. Remove the 100 Ω resistor. Record your correlation coefficient.

9. Use the following chart to calculate the theoretical reflection coefficient magnitude and angle for each of the previous networks.

Reflection Coefficient $\Gamma = |\Gamma| e^{j\theta_r}$

Load	$\lvert\Gamma\rvert$	θ_r
Z_0 $Z_L = (r + jx)Z_0$	$\left[\frac{(r-1)^2 + x^2}{(r+1)^2 + x^2}\right]^{1/2}$	$\tan^{-1}\left(\frac{x}{r-1}\right) - \tan^{-1}\left(\frac{x}{r+1}\right)$
Z_0 Z_0	0 (no reflection)	irrelevant
Z_0 (short)	1	$\pm 180°$ (phase opposition)
Z_0 (open)	1	0 (in-phase)
Z_0 $jX = j\omega L$	1	$\pm 180° - 2\tan^{-1} x$
Z_0 $jX = \frac{-j}{\omega C}$	1	$\pm 180° + 2\tan^{-1} x$

Note: Z_0 = 50 Ω and r and x are normalized values where $r = R/Z_0$ and $x = X/Z_0$. Frequency is 100MHz.

You can also calculate the your reflection coefficient using $\Gamma = \frac{z_L - 1}{z_L + 1}$ where $z_L = Z_L/Z_0$

and Z_L is the load impedance.

10. Compare your theoretical values to the values you found using the network analyzer.

11. Discuss what effect resistive elements have on the reflection coefficient.

12. Discuss what effect reactive elements have on the reflection coefficient.

13. Discuss what happens when the load impedance is equal to the characteristic impedance. Why does this happen?