ECE 3300 LAB 2 – Pre Lab

Transmission Lines and Time-domain Reflectometry

Overview: This document is a preparation for lab 2. It is due at the beginning of the lab session.

Equipment: Matlab® software is needed to complete this pre-lab.

For more information: Contact the teacher assistants or class instructor. See website for details: www.ece.utah.edu/~ece3300

Objectives:

- Learn about different types of transmission lines including coaxial cable, two wire lines, and microstrip.
- Measure the effect of external materials on capacitance and therefore impedance of a line.
- Understand the meaning of characteristic impedance Z_0 and how it differs from impedance Z(z).
- Understand step function voltage transients on transmission lines.

Background:

Students should understand before the lab:

- Lumped element (RLGC) model for transmission lines (TL) and how to calculate the RLGC parameters for a variety of transmission lines.
- How to make bounce diagrams and calculate the voltage at a point on the line as a function of time.

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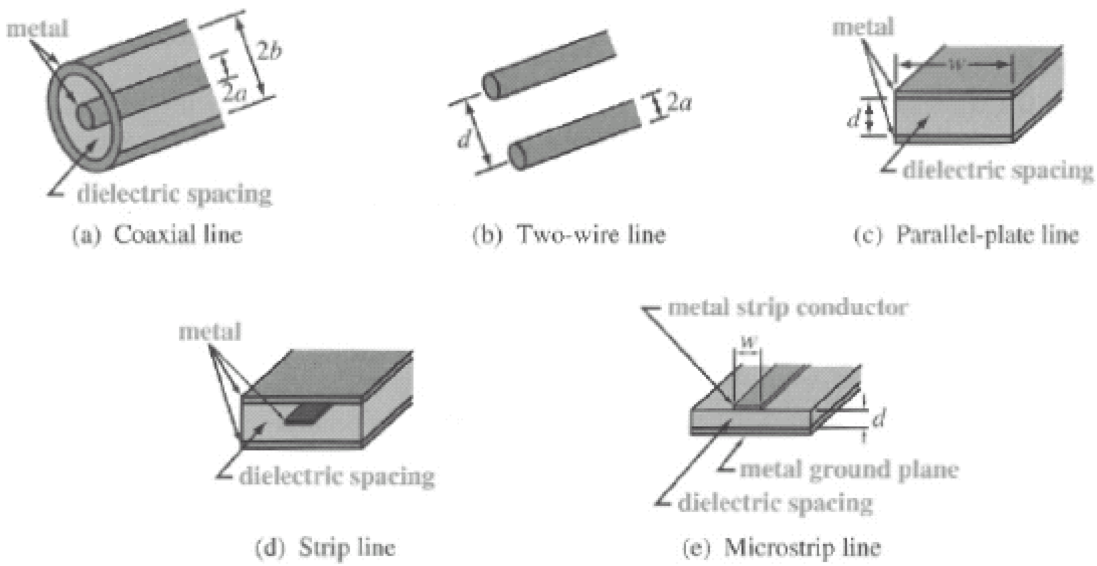
Pre-lab :

1. RLGC Model of Transmission Lines:

Write a Matlab[TM] code that will calculate the values of R, L, G, C, α, β , velocity of propagation, and Zo for a coaxial transmission line, two wire line, and parallel plate transmission line. The following information is from [1].



TEM Transmission Lines

Table 2-1: Transmission-line parameters R', L', G', and C' for three types of lines.

Parameter	Coaxial	Two Wire	Parallel Plate	Unit
R'	$\frac{R_s}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$	$\frac{R_s}{\pi a}$	$\frac{2R_s}{w}$	Ω/m
L'	$\frac{\mu}{2\pi}\ln(b/a)$	$\frac{\mu}{\pi}\ln\left[(d/2a)+\sqrt{(d/2a)^2-1}\right]$	$\frac{\mu d}{w}$	H/m
G'	$\frac{2\pi\sigma}{\ln(b/a)}$	$\frac{\pi\sigma}{\ln\left[(d/2a)+\sqrt{(d/2a)^2-1}\right]}$	$\frac{\sigma w}{d}$	S/m
C'	$\frac{2\pi\varepsilon}{\ln(b/a)}$	$\frac{\pi\varepsilon}{\ln\left[(d/2a)+\sqrt{(d/2a)^2-1}\right]}$	$\frac{\varepsilon w}{d}$	F/m

Notes: (1) Refer to Fig. 2-4 for definitions of dimensions. (2) μ, ε, and σ pertain to the insulating material between the conductors. (3) $R_s = \sqrt{\pi f \mu_c / \sigma_c}$. (4) μ_c and σ_c pertain to the conductors. (5) If $(d/2a)^2 \gg 1$, then $\ln\left[(d/2a)+\sqrt{(d/2a)^2-1}\right] \simeq \ln(d/a)$.

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Test your code on the following transmission lines, and bring the code to lab with you:

RG58 Coaxial Line (cable type is printed on the side of the cable)

- The frequency is 1 GHz.
- The inner radius a = 0.445 mm, and the outer radius b = 1.765 mm.
- The conductor is copper ($\sigma_c = 5.8 \times 10^7$ S/m, $\mu_r = 1.0$).
- The insulation between the coaxial lines is polyethylene (PE) ($\varepsilon_r = 2.25$, $\sigma = 0.0001$ S/m). Unless a material is clearly magnetic (ferrite materials), assume $\mu_r = 1.0$.

  Answers for coax:
  R = 3.6947 ohms/m
  L = 2.7557e-007 H/m
  G = 4.5602e-004 mohs/m
  C = 9.1164e-011 F/m
  alpha = 0.0461 Np/m
  beta = 31.4923 rad/m
  vp = 1.9951e+008 m/s
  Zo = 54.9796 - 0.0368i ohms

Parallel Plate Line

- The frequency is 1 GHz.
- The polyethylene substrate has a thickness of 1mm.
- The top and bottom are made of copper.
- The width of the line is 6mm.

Twin Lead

- The frequency is 1 GHz.
- The radius of the wires is 2mm, and the distance between the wires is 6mm.
- Assume they are seperated by polyethylene.

  Answers for twin lead line:
  R = 1.3131 ohms/m
  L = 3.8497e-007 H/m
  G = 3.2643e-004 mohs/m
  C = 6.5256e-011 F/m
  alpha = 0.0211 Np/m
  beta = 31.4923 rad/m
  vp = 1.9951e+008 m/s
  Zo = 76.8071+ 0.0097i ohms

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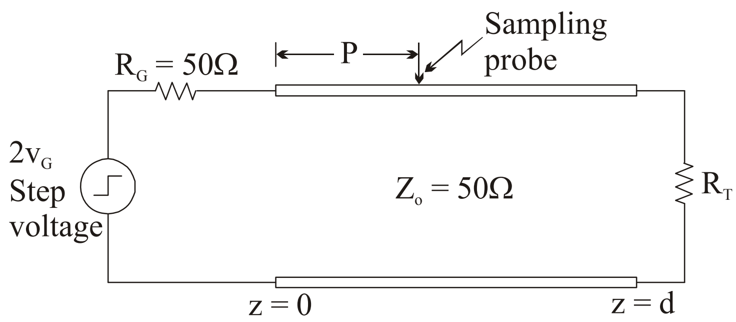
2. Voltage Step Function Response:



Sketch Voltage Reflection Diagrams (Bounce Diagrams) for a 50 Ω RG58 coaxial line connected to the following terminations. Assume P = 1m and d = 2m. Use the velocity of propagation calculated in the previous section for polyethylene-filled coaxial line. Sketch the voltage at the sampling probe P as a function of time. Also calculate and show on your plot the steady state voltage (from Ulaby equation 2.159).

a) Matched Load (50 Ω)
b) Open Circuit
c) Short Circuit
d) Resistor = 100 Ω
e) Resistor = 25 Ω
f) 75 Ω transmission line that is 0.8 meters long and open at the end (connected to the 50 Ω line where R_T is shown). This creates tandem transmission lines, which are discussed in Agilent Application Note 1304-2.
g) Inductor (qualitative drawing is sufficient), also discussed in the application note.
h) Capacitor (qualitative drawing is sufficient), also discussed in the application note.

Questions:
2.1) Explain the concept of "step function response" of a system. See your circuits book if you do not remember.
2.2) Explain how the bounce diagrams and their related voltage vs. time plots relate to the step function response.

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References

[1] F. Ulaby, *Fundamentals of Applied Electromagnetics*, 6th ed., 2010, ch. 2.

[2] Agilent Application Note 1304-2 on TDR Theory (available on the Lab website).

[3] Step function response – see your basic circuits book.

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