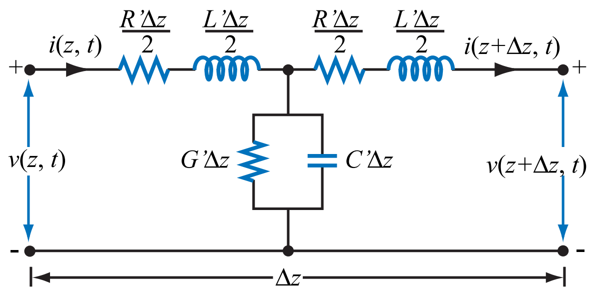
CMPE 330 **Spring 2017** **Problem Set #2**

NOTE: You must show complete work for full credit. When nothing else is stated, report two significant figures.

1. Use Kirchoff's laws to show that the transmission line model shown below [Ulaby and Ravaioli, Fig. P2.3] yields the same telegrapher's equation that we derived in class and is given by Ulaby's equations (2.14) and (2.16) [Ulaby and Ravaioli, 2.3, p. 124.]



2. A two-wire copper transmission line is embedded in a dielectric material with $\epsilon_r = 2.6$ and $\sigma = 2 \times 10^{-6}$ S/m. Its wires are separated by 3 cm and their radii are 1 mm each. [modified from Ulaby and Ravaioli, 2.2 and 2.7, p. 124.]

   a. Calculate the line parameters R', L', G', and C' at 2 GHz. Find γ, α, β, u_p and Z_0. Report two significant figures for both the real and imaginary parts of γ and Z_0.

   b. Verify the results using the Ulaby and Ravaioli module 2.1 and show a screen printout.

3. A coaxial line with inner and outer conductor diameters of 0.5 cm and 1 cm, respectively, is filled with an insulating material with $\epsilon_r = 4.5$ and $\sigma = 10^{-3}$ S/m. The conductors are made of copper. [modified from Ulaby and Ravaioli 2.6 and 2.8, p. 124.]

   a. Calculate the line parameters R', L', G', and C' at 1 GHz, as well as γ, α, β, Z_0, and u_p. Report two significant figures for both the real and imaginary parts of γ and Z_0.

   b. Verify the results using the Ulaby and Ravaioli module 2.2 and show a screen printout.

4. Design a 100-Ω microstrip transmission line using the expressions in Ulaby, et al., Sec. 2.5. The substrate thickness is 1.8 mm and its $\epsilon_r = 2.3$ Select the strip width w and determine the guide wavelength λ at $f = 5$ GHz. (Hint: Use Example 2-2 as a guide.) Verify your results using the Ulaby and Ravaioli module 2.3 and show a screen printout. [modified from Ulaby and Ravaioli 2.10, p. 124.]

5. In the following, you should make use of the relation for a geometric series,

$$1 + x + \cdots + x^m = \frac{1 - x^{m+1}}{1 - x}$$

and the definition of the floor operator $\lfloor x \rfloor =$ the integer part of any real number. We are using the notation of Ulaby et al.'s Sec. 2-12. In this section, he sets $z = 0$ at the *beginning* of the transmission line, and he uses $z = l$ for the load. Note that l corresponds to $\mathcal{L}$ in my slides. The subscript "g" corresponds to the subscript "S" and Z_0 corresponds to Z_C.

a. Consider a transmission line and show that if $V_g(t) = 0$ when $t < 0$ and $t > t_\mathrm{D}$ and equals a constant V_g when $0 \le t \le t_\mathrm{D}$, derive the expressions on slide 3.33, which in the notation of Ulaby, et al. become

$$V(0,t) = \frac{Z_0 V_\mathrm{g}}{R_\mathrm{g} + Z_0} \left[\frac{1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}1}+1} + \Gamma_\mathrm{L}\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}1}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} \right. \\ \left. - \frac{1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}2}+1} + \Gamma_\mathrm{L}\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}2}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} \right],$$

$$I(0,t) = \frac{V_\mathrm{g}}{R_\mathrm{g} + Z_0} \left[\frac{1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}1}+1} - \Gamma_\mathrm{L}\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}1}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} \right. \\ \left. - \frac{1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}2}+1} - \Gamma_\mathrm{L}\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{g}2}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} \right],$$

$$V(l,t) = \frac{Z_0 V_\mathrm{g}}{R_\mathrm{g} + Z_0} \left[\frac{(1 + \Gamma_L)\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{L}1}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} - \frac{(1 + \Gamma_L)\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{L}2}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} \right],$$

$$I(l,t) = \frac{V_\mathrm{g}}{R_\mathrm{g} + Z_0} \left[\frac{(1 - \Gamma_L)\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{L}1}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} - \frac{(1 - \Gamma_L)\left[1 - (\Gamma_\mathrm{g}\Gamma_\mathrm{L})^{m_{\mathrm{L}2}}\right]}{1 - \Gamma_\mathrm{g}\Gamma_\mathrm{L}} \right],$$

where the delay time is T,

$$m_{\mathrm{g}1} = \lfloor t/2T \rfloor, \quad m_{\mathrm{L}1} = \lfloor (t+T)/2T \rfloor,$$

$$m_{\mathrm{g}2} = \lfloor (t - t_\mathrm{D})/2T \rfloor, \quad m_{\mathrm{L}2} = \lfloor (t + T - \tau_D)/2T \rfloor,$$

and we recall that we only subtract the second half of each expression for $t > t_\mathrm{D}$.

b. Use these expressions to reproduce the results on slide 3.34 (Paul's Example 6.2). Keep all digits in your solution. What is required for all digits to be meaningful?

6. Consider a transmission line of length 400 m. The generator voltage is a pulse of 100 V amplitude and 6 μs duration. The line has a characteristic impedance of 50 Ω and a velocity of propagation of 2×10^8 m/s. The source resistance is 100 Ω, and the load is short circuited (the load resistance is 0 Ω). [Based on Paul, example 6.3; note the different source resistance.]

a. Write a MATLAB program to plot both the input voltage and current and the load voltage and current for a time up to 20 μs. Provide both the MATLAB code (M-file) and the plot output. [Hint: The MATLAB code will be almost the same as `Transmission_Line_2`, which is available on Blackboard.]

b. Use the expressions on slide 3.33, which you just derived, to give an expression for the input voltage at all times. What are the values of the voltage up to 20 μs? The input voltage tends to zero as $t \to \infty$. Why?