CMPE 330 **Spring 2015** **Problem Set #2**

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

1. A transmission line of length l connects a load to a sinusoidal voltage source with an oscillation frequency f. Assuming that the velocity of wave propagation on the line is c, for which of the following situations is it reasonable to ignore the presence of the transmission line in the solution of the circuit. Use both the Ulaby, et al. criterion after Eq. 2.4 on p. 49 and the Schmitt criterion on slide 1.2. Why are the criteria different? [modified from Ulaby, et al. 2.1, p. 121].

   a. $l = 20$ cm, $f = 20$ kHz

   b. $l = 50$ km, $f = 60$ Hz

   c. $l = 20$ cm, $f = 600$ MHz

   d. $l = 1$ mm, $f = 100$ GHz

2. A 500-MHz parallel-plate transmission line consists of 1.5-cm-wide copper strips separated by an 0.15-cm-thick layer of polystyrene. Appendix B in Ulaby's book gives $\mu_\mathrm{c} = \mu_0 = 4\pi \times 10^{-7}$ (H/m) for copper and $\sigma_\mathrm{c} = 5.8 \times 10^7$ (S/m) for copper, and $\epsilon_r = 2.6$ for polystyrene. Use Table 2-1 in Ulaby's book (reproduced in my notes) to determine the line parameters of the transmission line. Assume that $\mu = \mu_0$ and $\sigma \simeq 0$ for polystyrene. Find α, β, u_p, and Z_0 [modified from Ulaby, et al. 2.4 and 2.5, p. 122]. Note: Ulaby's solutions do not keep the same number of places consistently and are not correct to the number of places reported. Please keep two significant figures in the solution that you report.

3. Consider a lossless coaxial cable with an inner diameter of 1 mm and a relative dielectric constant $\epsilon_\mathrm{r} = 2.25$. Find the outer diameter that corresponds to choosing $Z_0 = 50\ \Omega$. Determine the corresponding L' and C'. Calculate all quantities to three significant figures. Verify the result using the Ulaby, et al. module 2.2 and show a screen printout. These specifications correspond to RG-8X coaxial cable.

4. A lossless microstrip line uses a 1-mm-wide conducting strip over a 1-cm-thick substrate with $\epsilon_\mathrm{r} = 2.5$. Determine the line parameters, ϵ_eff, Z_0, and β at 10 GHz. Compare your results with those obtained by using the Ulaby, et al. CD module 2.3. Include a printout of the screen display. Note that you must provide both a hand calculation with details AND the calculation using the CD manual; you are being asked to solve the same problem in two different ways, which allows you to check your results and the results in the book. [Ulaby, et al. 2.9]. Calculate all quantities to three significant figures. Note: You have to change the range of the substrate thickness from its original value of 2 mm on the CD in order to calculate the result using the module.

5. In the following, you want to 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. So, for example, $\lfloor 3.2 \rfloor = \lfloor 3.9 \rfloor = 3$. (Both are part of the syllabus for CMSC 203 and can be found in the textbooks for that subject.) We are using the notation of Ulaby's section 2-12. In this section, he sets $z = 0$ at the *beginning* of the 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 $V_{\mathrm{g}}(t) = 0$ when $t < 0$ and equals a constant V_{g} when $t \geq 0$, then

$$
\begin{aligned}
V(0,t) &= \frac{Z_0 V_{\mathrm{g}}}{R_{\mathrm{g}} + Z_0} \left[\frac{1 - (\Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}})^{m_{\mathrm{g}}+1} + \Gamma_{\mathrm{L}}\big[1 - (\Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}})^{m_{\mathrm{g}}}\big]}{1 - \Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}}} \right], \\
I(0,t) &= \frac{V_{\mathrm{g}}}{R_{\mathrm{g}} + Z_0} \left[\frac{1 - (\Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}})^{m_{\mathrm{g}}+1} - \Gamma_{\mathrm{L}}\big[1 - (\Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}})^{m_{\mathrm{g}}}\big]}{1 - \Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}}} \right], \\
V(l,t) &= \frac{Z_0 V_{\mathrm{g}}}{R_{\mathrm{g}} + Z_0} \left[\frac{(1 + \Gamma_{\mathrm{L}})\big[1 - (\Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}})^{m_{\mathrm{L}}}\big]}{1 - \Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}}} \right], \\
I(l,t) &= \frac{V_{\mathrm{g}}}{R_{\mathrm{g}} + Z_0} \left[\frac{(1 - \Gamma_{\mathrm{L}})\big[1 - (\Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}})^{m_{\mathrm{L}}}\big]}{1 - \Gamma_{\mathrm{g}}\Gamma_{\mathrm{L}}} \right],
\end{aligned}
$$

where the delay time is T and

$$m_{\mathrm{g}} = \lfloor t/2T \rfloor \quad \text{and} \quad m_{\mathrm{L}} = \lfloor (t+T)/2T \rfloor.$$

b. Use these results to reproduce the results in slide 3.29 (Paul's Example 6.1) and to determine the final asymptotic values.

6. A 100-V battery is switched onto a line of length 400 m. The line characteristics are: $R_{\mathrm{g}} = 25\ \Omega$, $R_{\mathrm{L}} = 100\ \Omega$, $Z_0 = 50\ \Omega$, and $u_p = 2.00 \times 10^8$ m/s.

   a. Find R', G', L', and C'.

   b. Calculate $V(0,t)$, $I(0,t)$, $V(l,t)$, and $I(l,t)$ for times up to $12T$. Calculate the final values for $V(l,t)$ and $I(l,t)$ as $t \to \infty$. Hint: Use the formulae on slides 3.25 and 3.26.

   c. Modify the MATLAB code `Transmission_Line_1` (located on the Blackboard WEB site) to plot these quantities. Provide the modified code and the output plots. Verify that the results from (b) and (c) are consistent.