EEC 130A: Homework 2

Due: 3:30 pm, Jan. 24, 2012

1. (4 points) (FAE P2.1) 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 (and **why?**):

(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. (4 points) (FAE P2.3) Show that the transmission-line model shown in Fig. 1 yields the same telegrapher's equations given by Eqs. (2.14) and (2.16) in the textbook.

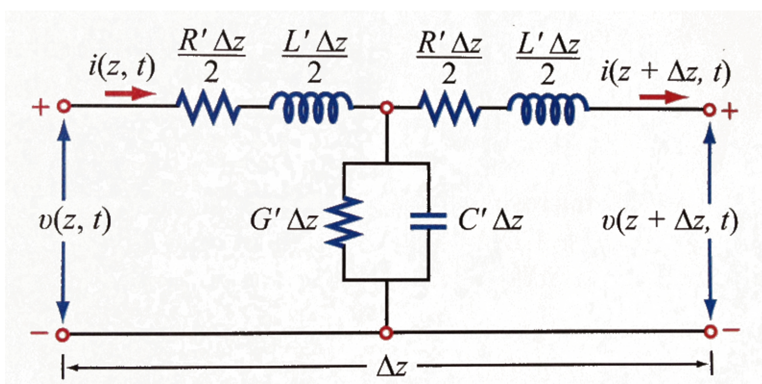

Figure 1: Transmission-line model for Problem 2.

3. (4 points) (FAE P2.4) A 1-GHz parallel-plate transmission line consists of 1.2-cm-wide copper strips separated by a 0.15-cm-thick layer of polystyrene. Appendix B gives $\mu_c = \mu_0 = 4\pi \times 10^{-7}$ (H/m) and $\sigma_c = 5.8 \times 10^7$ (S/m) for copper, and $\epsilon_r = 2.6$ for polystyrene. Use Table. 1 to determine the line parameters of the transmission line. Assume that $\mu = \mu_0$ and $\sigma \simeq 0$ for polystyrene.

The relevant part of Fig.2-4 from FAE is reprinted here for your reference.

4. (4 points) (FAE P2.13) In addition to not dissipating power, a lossless line has two important features: (1) it is dispersionless (u_p is independent of frequency); and (2) its characteristic impedance Z_0 is purely real. Sometimes, it is not possible to design a transmission

Table 1: (Table 2-1 from FAE)Transmission-line parameters R', L', G', and C' for three types of 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'	$\frac{R_s}{2\pi}\left(\frac{1}{a}+\frac{1}{b}\right)$	$\frac{2R_s}{\pi d}$	$\frac{2R_s}{w}$	Ω/m
L'	$\frac{\mu}{2\pi}\ln(b/a)$	$\frac{\mu}{\pi}\ln\left[(D/d)+\sqrt{(D/d)^2-1}\right]$	$\frac{\mu h}{w}$	H/m
G'	$\frac{2\pi\sigma}{\ln(b/a)}$	$\frac{\pi\sigma}{\ln\left[(D/d)+\sqrt{(D/d)^2-1}\right]}$	$\frac{\sigma w}{h}$	S/m
C'	$\frac{2\pi\varepsilon}{\ln(b/a)}$	$\frac{\pi\varepsilon}{\ln\left[(D/d)+\sqrt{(D/d)^2-1}\right]}$	$\frac{\varepsilon w}{h}$	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 $(D/d)^2 \gg 1$, then $\ln\left[(D/d)+\sqrt{(D/d)^2-1}\right] \simeq \ln(2D/d)$.

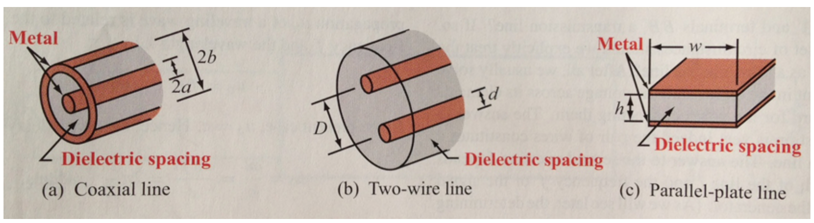

Figure 2: (Fig.2-4 from FAE) A few examples of transmission lines.

line such that $R' \ll \omega L'$ and $G' \ll \omega C'$, but it is possible to choose the dimensions of the line and its material properties so as to satisfy the condition

$$R'C' = L'G' \qquad \text{distortionless line}$$

Such a line is called a distortionless line, because despite the fact that it is not lossless, it nonetheless possesses the previously mentioned features of the lossless line. Show that for a distortionless line,

$$\alpha = R'\sqrt{\frac{C'}{L'}} = \sqrt{R'G'},$$

$$\beta = \omega\sqrt{L'C'},$$

$$Z_0 = \sqrt{\frac{L'}{C'}}.$$

5. (4 points) (FAE P.2.12) Generate a plot of Z_0 as a function of strip with w, over the range from 0.05 mm to 5 mm, for a microstrip line fabricated on a 0.7-mm-thick substrate with $\epsilon_r = 9.8$.