THE UNIVERSITY OF TEXAS AT DALLAS

Electromagnetic Engineering I

EE 4301

Spring 2008
Assignment 11

Due Date and Time:

April 7, 2008, at the beginning of class

Reading:

N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Chapter 10

Problems:

Please write your answers to the following problems on engineering paper. No credit will be given for work handed in on other types of paper.

1. A parallel-plate transmission line has the following parameters: Material of plates is copper (conductivity $\sigma = 5.8\times10^7$ S/m), plate thickness is $h = 10\ \mu$m, length $l = 10$ cm, width $w = 7.5$ mm, plate separation $d = 1$ mm, permittivity of the dielectric between the plates $\epsilon = 4.0\,\epsilon_0$, permeability of the dielectric between the plates $\mu = \mu_0$.

   (a) Find the inductance per unit length of the transmission line, L'.

   (b) Find the capacitance per unit length, C'.

   (c) Find the characteristic impedance of the transmission line, Z_0.

   (d) Find the DC resistance of one of the plates, R. The relevant formula is

   $$R = \frac{l}{\sigma w h}.$$

   (Be sure to convert units correctly!)

   (e) At what frequency is the skin depth equal to 10 μm in copper?

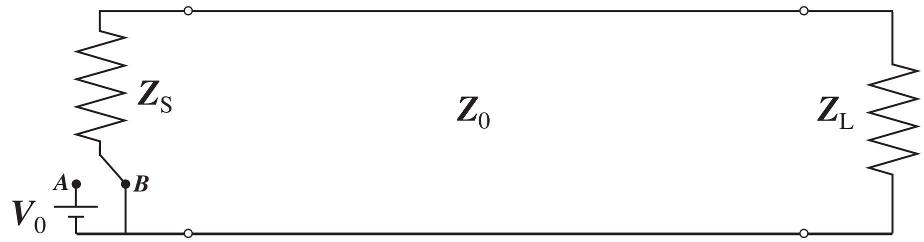

Figure 1: Transmission line for problem 2.

2. A pulse generator produces a rectangular voltage pulse $V_0(0,t)$ of duration 15 ns and amplitude 10 V, starting at time $t = 0$. The velocity of electromagnetic waves on the transmission line is 2×10^8 m/s = 0.2 m/ns, and the length of the transmission line is 2 m. The impedances of the source and load are Z_S and Z_L, respectively. The characteristic impedance of the transmission line is $Z_0 = 50\ \Omega$. Find the input acceptance function, the reflection and transmission coefficients at the source and load (ρ_S, $\tau_S = 1+\rho_S$, and ρ_L, $\tau_L = 1+\rho_L$, respectively), construct a bounce diagram, and calculate $V(z = 1.5\ \text{m}, t)$ (the time waveform at $z = 1.5$ m) and $V(z, t = 30\ \text{ns})$ (the snapshot of the voltage all along the line at time $t = 30$ ns), for each of the following cases:
   (a) $Z_S = 0\ \Omega$, $Z_L = 100\ \Omega$.
   (b) $Z_S = 0\ \Omega$, $Z_L = 10\ \Omega$.
   (c) $Z_S = 50\ \Omega$, $Z_L = 10^6\ \Omega$.
3. Answer the same questions as in Problem 2 if the voltage pulse is turned on at time $t = 0$ and left on.
4. Consider a two-conductor transmission line 10 m long, with a characteristic impedance of 60 Ω and a phase velocity equal to 2/3 the vacuum velocity of electromagnetic waves, a source impedance equal to 60 Ω, and a 120-Ω resistor connected between the conductors at a distance of 4 m from the source end. A voltage pulse of amplitude 12 V is turned on at $t = 0$ and left on. The load end of the line ($z = 10$ m) is an open circuit. Construct a bounce diagram from $t = 0$ to $t = 160$ ns.
5. Consider a two-conductor transmission line of length l, with a voltage source V_0 in series with a resistor R_S at the source end, a switch at the source end, and a resistor R_L at the load end. The time for electromagnetic waves to go from the source end to the load end is T. The switch is open until time $t = 0$, when it is closed. You are given the additional information that the voltage at the SOURCE end of the transmission line is constant in time, with an amplitude of 100 V, from time $t = 0$ to time $t = 4\ \mu$s, and an amplitude of 90 V for times from 4 to 5 μs. At the LOAD end of the transmission line, the voltage is 0 V until time $t = 2\ \mu$s, and is 75 V from time $t = 2\ \mu$s to time $t = 5\ \mu$s. The characteristic impedance of the line is $Z_0 = 60\ \Omega$.
   (a) Construct a bounce diagram from $t = 0$ to $t = 5\ \mu$s from the voltage data given above.
   (b) Find the transit time T.
   (c) Show algebraically that if
   $$\alpha = \frac{Z_0}{Z_0 + R_S}$$
   is the input acceptance function, then
   $$\rho_S = 1 - 2\alpha. \qquad (1)$$
   (d) From Eq. (1) and the data given above, find V_0, R_S, and R_L.

6. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.1.
7. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.2. [Hint: The transmission line is coming out of the paper.]
8. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.6.
9. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.7.
10. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.8.
11. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.10.
12. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.11.
13. N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Exercise P6.13.