THE UNIVERSITY OF TEXAS AT DALLAS

Electromagnetic Engineering I

EE 4301

Spring 2008
Assignment 10

Due Date and Time:

At 9:30 AM, March 31, 2008

Reading:

N. N. Rao, *Elements of Engineering Electromagnetics*, **Sixth Edition**, Chapter 6

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 aluminum (conductivity $\sigma = 3.54 \times 10^7$ S/m), plate thickness is $h = 0.1\ \mu$m, length $l = 100\ \mu$m, width $w = 1.0\ \mu$m, plate separation $d = 0.1\ \mu$m, 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, L'.
   (b) Find the capacitance per unit length, C'.
   (c) Find the characteristic impedance, Z_0.
   (d) Find the one-way transit time for this transmission line.
2. Design a parallel-plate transmission line such that $\epsilon_r = 4$, $\mu_r = 1$, $w = 0.5$ mm, and $Z_0 = 75\ \Omega$. (Your design must specify the spacing, d.)
3. You are given the information that a certain transmission line has a characteristic impedance of 225 Ω, and that the load is an antenna. What is the reflection coefficient at the load if the antenna's impedance is 75 Ω?

Exercises 4–8 concern a transmission line with the following parameters: Source impedance = 100 Ω, load impedance = 25 Ω, characteristic impedance = 50 Ω, velocity of electromagnetic waves = 2×10^8 m/s, length = 6 m.

4. What is the transit time T from one end of the line to the other?

5. Draw a bounce diagram from time $t = 0$ to time $t = 3T$ showing V_+ and V_- as functions of z and t, assuming that a short pulse with amplitude 5 V, traveling towards $+Z$, is injected instantaneously at $z = 0$ and at time $t = 0$.

6. Repeat Problem 5 when the source is a 5-volt battery that is connected to the source end of the transmission line at $t = 0$ and is left connected indefinitely.

7. Plot the total voltage at the load end ($z = 6$ m) as a function of time from $t = 0$ to $t = 3T$.

8. Plot the total voltage at $z = 4$ m as a function of time from $t = 0$ to $t = 3T$.

9. Consider an ideal parallel-plate transmission line with the following parameters: Length = 9 cm, relative permittivity of the dielectric medium between the plates = 4, characteristic impedance = 30 Ω, internal impedance of source = 20 Ω, load impedance = 60 Ω, source voltage = 5 V. Find the velocity of electromagnetic waves on the transmission line, and the one-way transit time, T.

10. For the transmission line in Problem 9, find the reflection coefficients at the source and load ends.

11. For the transmission line in Problem 9, draw a bounce diagram from time $t = 0$ to time $t = 3T$ showing V_+ and V_- as functions of z and t, assuming that a source voltage of 5 V is turned on instantaneously at time $t = 0$.

12. For the transmission line in Problem 9, plot the total voltage at the load end ($z = 9$ cm) as a function of time from $t = 0$ to $t = 3T$.

13. A transmission line formed by an aluminum trace, an SiO_2 insulating layer and a Si substrate has the following parameters:

    Length $l = 10^{-3}$ m = 1000 μm

    Phase velocity $v = 2 \times 10^8$ m/s = 200 μm/ps

    Characteristic impedance $Z_0 = 50\ \Omega$

    This transmission line is unterminated at the load end, and is driven by a very-low-impedance source. The resulting reflection coefficients are

    $$\rho_S = -0.8, \qquad \rho_L = 1.0.$$

    The signal risetime is $T_{\rm rise} = 20$ ps.

    (a) Would you expect to see significant overshoot or ringing after a time duration of two risetimes, given this signal and transmission line? [Hint: Compare the round-trip transit time,

    $$2T = 2\frac{l}{v},$$

    with twice the signal risetime, $2T_{\rm rise}$.]

    (b) According to the criterion[1] that a transmission line is *not* short if

    $$l > \frac{1}{6} v T_{\rm rise},$$

    is the transmission line described in this problem short? Justify your answer.

    (c) Using the formula[2]

    $$t_{\rm settle} \approx 2T \frac{\ln \epsilon}{\ln |\rho_S \rho_L|}$$

    for the time for the signal to settle to within a fraction $\epsilon < 1$ of its final value, evaluate the settling time $t_{\rm settle}$ for the transmission line and signal considered in this problem. Is $t_{\rm settle}$ greater, or less, than the signal risetime $T_{\rm rise}$?

[1] Howard W. Johnson and Martin Graham, *High-Speed Digital Design* (Prentice-Hall, 1993), p. 166

[2] Howard W. Johnson and Martin Graham, *High-Speed Digital Design* (Prentice-Hall, 1993), p. 167