EE290C High-Speed Electrical Interfaces **Spring 2004.**

HOMEWORK 1. **Due: Thursday, February 12, 2003 at 5pm in 558 Cory**

This is an individual assignment!

Problem 1: Getting to be familiar with transmission lines.

a) Using phasor notation, calculate the voltage and current waves on a transmission line by solving the phase equation. Assume that R, L, C, G are all non-zero and independent of frequency. From these solutions derive the formulas for the characteristic impedance and the phase velocity of the transmission line.

b) Using the voltage and current equations from part a), derive the formulas for the reflection and transmission coefficients at the interface of two transmission lines with characteristic impedances Z_1 and Z_2.

c) Calculate the voltage at the point *A* as a function of time, for $t = 0$ until $t = 20$ns for the combination of transmission lines from Figure 1. Assume that the source produces a step of 1V at time $t = 0$. Properties of transmission line segments are indicated in the figure.

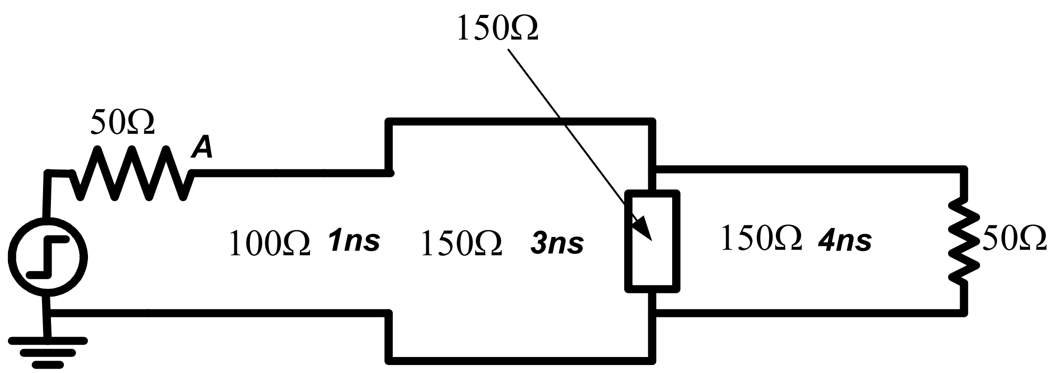

Figure 1.

d) Using the circuit parameters derive the characteristic impedance and phase velocity of a lossless transmission line that includes mutual inductance and capacitance, as shown in Figure 2, and is excited in the odd mode. Repeat for the case of the even mode.

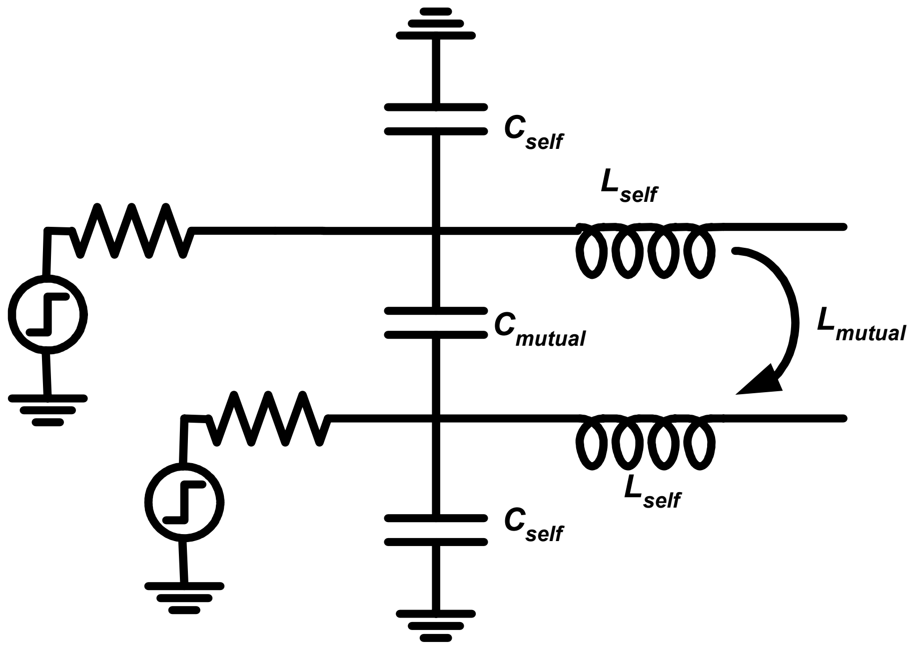

Figure 2.

Hint: Find the equivalent inductance, capacitance seen by a conductor and substitute in the formulas in (a):
Note: In the W-element models $L_{11}=L_{self}$, $L_{12}=L_{mutual}$, $C_{11}=C_{self}+C_{mutual}$, $|C_{12}|=C_{mutual}$.

Problem 2:Time-Domain Reflectometry
Figure 3.

a) The setup from Figure 3 is used to obtain the odd- and even-mode TDRs for various components:

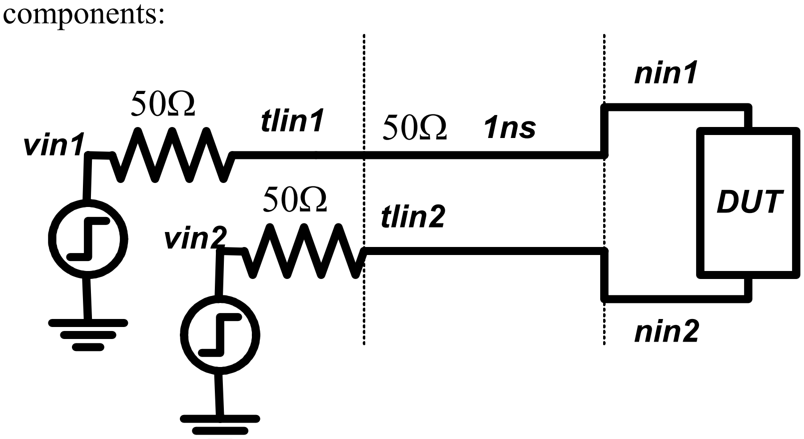

Figure 3.

The simulation results for the various cases are contained in the following files from Table 1.

Table 1.

Component	tr0 File
10’’ FR4 channel	FR4_channel_even / FR4_channel_odd
10’’ Rogers channel	Rogers_channel_even / Rogers_channel_odd
4’’ FR4 linecard trace	FR4_LC_even / FR4_LC_odd

Assuming that the components are lossless, find the W-element models.

b) The DUT in problem 2(a) is the cascade of a 3’’ FR4 linecard trace and a 6’’ FR4 channel terminated at R=50Ω. Calculate and draw the odd- and even-mode transient waveforms at the node ‘*tlin*1’ until time t=20ns.

c) The DUT in problem 2(a) is now the cascade of a FR4 linecard trace of length 5’’, a backplane via of length 10cm and a nelco channel of length 7’’. All components are assumed to be lossless. The odd and even mode TDR results are contained in the files TDR_Pr2c_odd.tr0 and TDR_Pr2c_even.tr0. Using these simulations, determine the W-element models for each of the components.

d) The following setup is used to measure the S-parameters of the DUT. The AC sources produce sinusoids of equal/opposite phases in the case of even/odd mode operation. The amplitude of the source signals is 2V. The D.U.T. is a 10’’ FR4 channel same to the one used in Problem 2(a), only now the channel has losses. The AC simulation results for the even/odd modes can be found in the files Sparam_FR4_even.ac0 and Sparam_FR4_odd.ac0, respectively. Using these, find the complete W-element model for the channel.

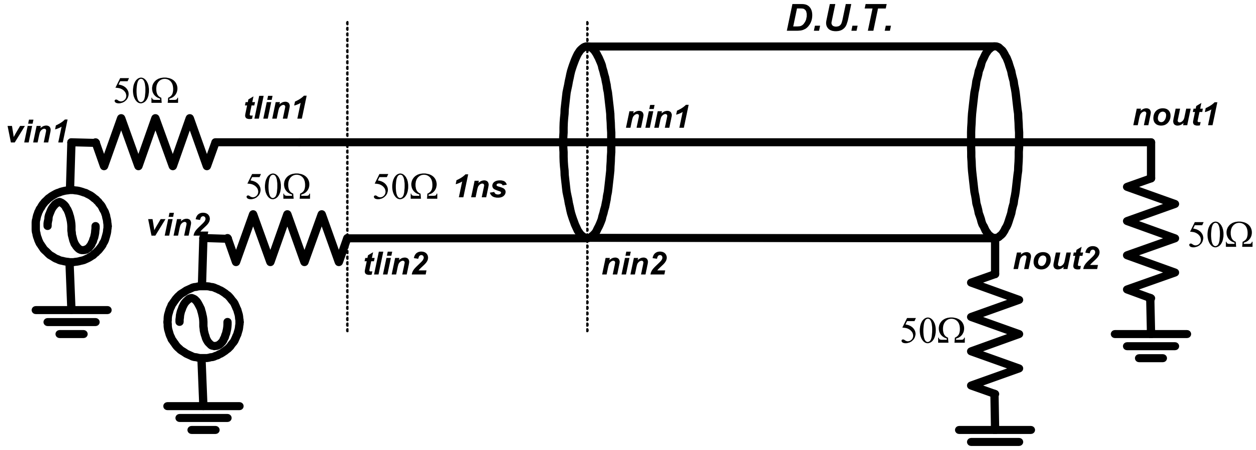

Figure 4.

Note 1: As in many practical channels, you can assume that $R_{o,12}$=0 and $G_{o,11}$=$G_{o,12}$=0. This means that you have to find the parameters $R_{o,11}$, $R_{s,11}$, $R_{s,12}$, $G_{d,11}$, $G_{d,12}$.

Note 2: The resistance per unit length at a frequency *f* is given by:

$$R_{odd/even}(f) = R_o + R_{s,odd/even} \times \sqrt{f}$$

The conductance per unit length at a frequency *f* is given by:

$$G_{odd/even}(f) = G_o + G_{s,odd/even} \times f$$

where:

$R_{s,odd} = R_{s,11} - R_{s,12}$, $R_{s,even} = R_{s,11} + R_{s,12}$,

$G_{d,odd} = G_{d,11} + |G_{d,12}|$ and $G_{d,even} = G_{d,11} - |G_{d,12}|$.