Electromagnetic Compatibility
Problem Set 2

1. Consider a lossless two-conductor line that has R_s=300 Ω, R_L=60 Ω, Z_c=100 Ω, v=200 m/μs, L=200 m and $V_s(t)=400\varepsilon(t)$ V, where ε(t) is the unit-step function. Sketch V(0,t) and V(L,t) for 0<t<6 μs. Use the Bergeron's diagram to verify the results.

2. A time-domain reflectometer (TDR) is an instrument used to determine properties of transmission lines. In particular, it can be used to detect the locations of imperfections such as breaks in the line. The instrument launches a pulse down the line then records the transit time for that pulse to be reflected at some discontinuity and to return to the line input. Suppose a TDR having a source impedance of 50 Ω is attached to a 50 Ω coaxial cable having some unknown length and load resistance. The dielectric of the cable is Teflon (relative permittivity 2.1). The open-circuit voltage of the TDR is a pulse of duration 10 μs. If the recorded voltage at the input of the TDR is as shown in Fig. 1, determine the length of the cable and the unknown load resistance.

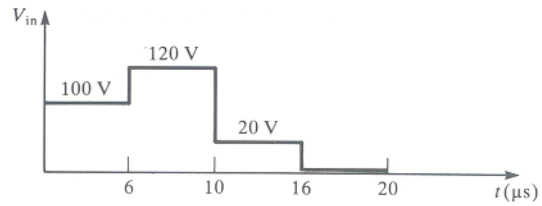

Fig. 1

3. A 12 V battery (R_s=0) is attached to an unknown length of transmission line that is terminated in a resistance. If the current to that line for 6 μs is as shown in Fig. 2, determine the line characteristic resistance and the unknown load resistance.

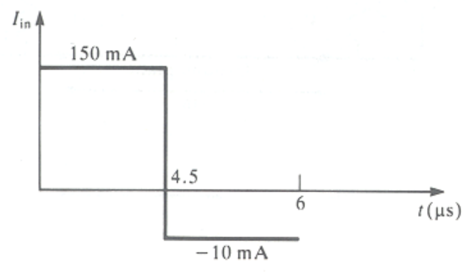

Fig. 2

4. With reference to Fig. 3, draw the voltage waveshape at the central node, for a number of nanoseconds enough to 'see' the first reflection coming from the load resistance of 20 Ω.

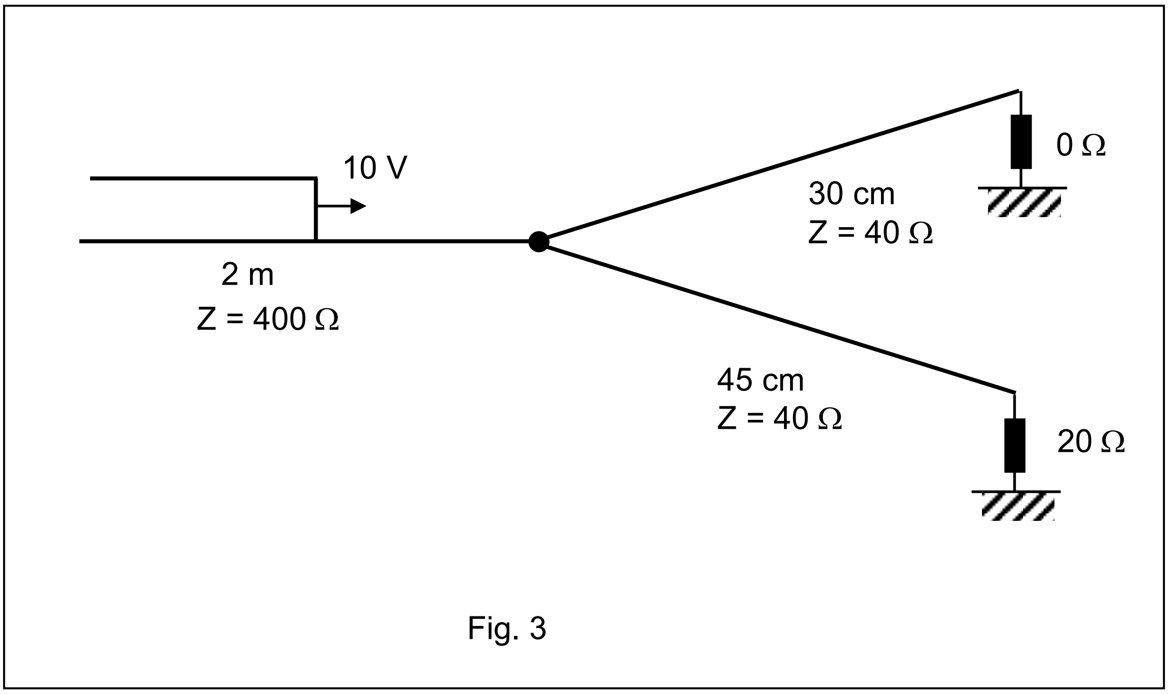

Fig. 3

5. Delays introduced by capacitive and inductive discontinuities in digital circuits. Discontinuities in the form of bends are primarily capacitive whereas vias are essentially inductive (see Fig. 4 below).

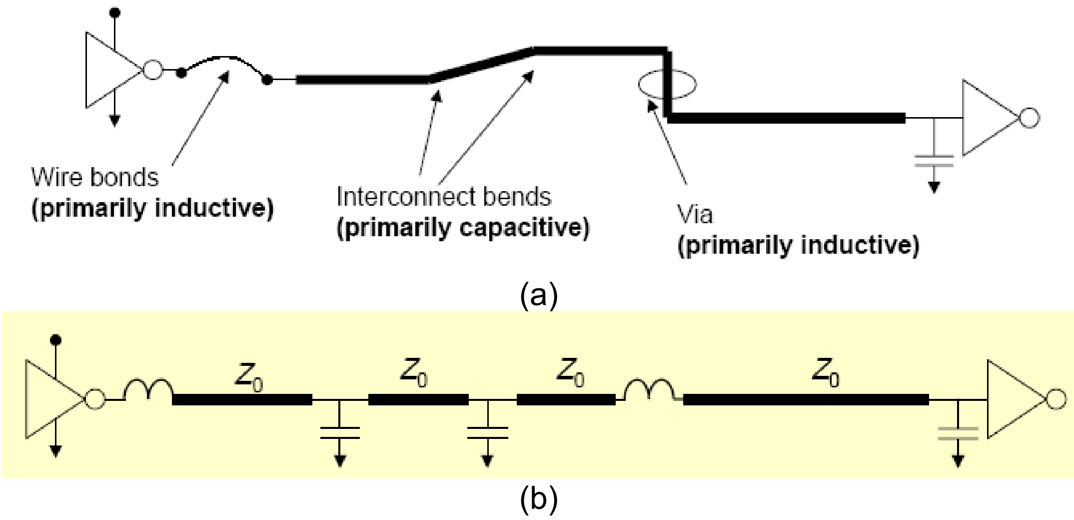

Fig. 4 – (a) Discontinuities in digital circuits. (b) Equivalent circuit.

These discontinuities introduce additional delays.

Considering a unit-step pulse of amplitude V^+, calculate the transmitted pulse V^{++} and evaluate the additional delay (to reach a value of 0.9 V^+) for

a. a capacitive discontinuity (Fig. 5a)

b. An inductive discontinuity (Fig. 5.b).

Numerical application: C= 1 pF, L=2.5 nH, Z_c=50 Ω.

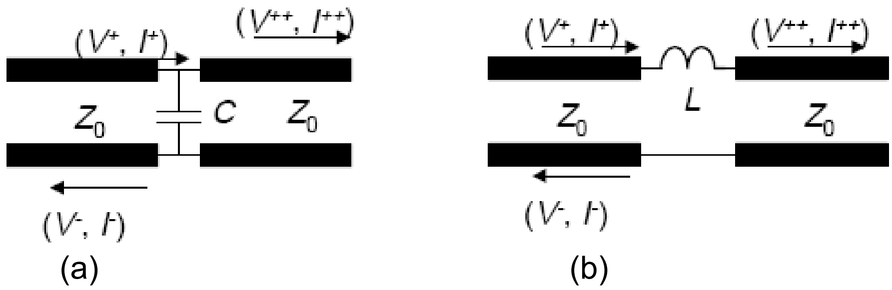

Fig. 5 – Capacitive (a) and inductive (b) discontinuities.

6. OPTIONAL

   (To be done using BMTL or SPICE) Digital data pulses should ideally consist of rectangular pulses. Actual data, however, have a trapezoidal shape with certain rise/fall times. Matching the data transmission line eliminated reflections and potential logic errors arising from these reflections. However, matching cannot always be accomplished. In order to investigate this problem, consider a line having R_s=0 Ω and $R_L=\infty$. Assume that the source voltage $V_s(t)$ is a ramp waveform given by

$$V_S(t) = \begin{cases} 0 & for \quad t \le 0 \\ \dfrac{t}{\tau_r} & for \quad t \le \tau_r \\ 1 & for \quad t > \tau_r \end{cases}$$

   where τ_r is the risetime of the pulse. Sketch the load voltage for line lengths having one-way transit times T such that

   a. $\tau_r = T/10$
   b. $\tau_r = 2T$
   c. $\tau_r = 3T$
   d. $\tau_r = 4T$

   This example shows that in order to avoid problems resulting from mismatch, one should choose line lengths short enough for τ_r to be >>T for the desired data.