University ☺f P☺rtland
Sch☺☺l ☺f Engineering

EE 301
Spring 2013
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<u>Homework # 1</u>

(Assigned: Wednesday, January 16, 2013; <u>Due January 25, 2013, 11:25a.m.</u>)

(1) NASA robot lands on Mars. A NASA robot successfully lands on the red planet Mars and NASA Headquarters receive a post-landing radio signal from it shortly after its landing. This robot can't be maneuvered directly from Earth real time because it takes nearly 10 minutes for a radio signal to travel from Earth to Mars and about the same time for a return signal. What does this time delay translate into in terms of real distance between Mars and Earth?

(a) ~3 million km (b) ~18 million km (c) ~30 million km
(d) ~180 million km (e) ~300 million km

(2) Overhead power lines. The alternating current (ac) high-voltage overhead power lines in the United States operate at a standard frequency of 60 Hz. For overhead power lines, the phase velocity (or the travel velocity) is $v_p = c \approx 3\times10^8$ m-s^{-1}. Using the rule-of-thumb criterion which is $t_d < 0.1T$ (Inan[2] book, 1999, Section 1.1.2), find which one of the following is the minimum power-line length such that any other line length that exceeds this minimum length can't be accurately modeled using lumped parameters.

(a) ~5 km (b) ~50 km (c) ~250 km (d) ~500 km (e) ~5,000 km

(3) Lumped or distributed analysis? Consider an off-chip electrical signal path (interconnect) in a high-speed digital circuit designed to carry signals with rise times as low as 250 ps. If the dielectric substrate of the signal path is constructed from alumina (assume $\varepsilon_r \approx 9$ and $v_p \approx 0.33c$), what is the critical length of the signal path such that when the actual length of the signal path exceeds the critical length, lumped circuit approximation for this path is not appropriate to use? (Use the rule-of-thumb criterion $t_r < 2.5t_f$ discussed in Inan[2] book, 1999, Section 1.1.1, to find the correct answer for this problem.)

(a) ~1 cm (b) ~3 cm (c) ~6.2 cm (d) ~9.1 cm (e) ~13 cm

(4) Critical coax length for lumped circuit approximation. Consider a commercially used coaxial cable filled with a solid polyethylene dielectric ($\varepsilon_r \approx 2.25$). If this cable is to be used at frequencies around 900 MHz, using the criterion $l/\lambda \leq 0.1$ (where l is the cable length and λ is the dielectric wavelength), what is the critical cable length such that when the length of this coax cable does not exceed the critical value, the behavior of this cable can be approximated as a lumped circuit? Use $v_p = c/\sqrt{\varepsilon_r}$ to calculate the phase velocity of the electromagnetic signal traveling inside the coaxial cable. (See Inan[2] book, 1999, Section 1.1.3.)

(a) ~2.22 cm (b) ~22.2 cm (c) ~2.22 m (d) ~1.48 cm (e) ~1.48 m

(5) Travel time of a microstrip transmission line interconnect. What is the one-way travel time of a 4-inch long microstrip transmission line with an effective relative dielectric constant given by $\varepsilon_r \approx 3.15$? Again, use $v_p = c/\sqrt{\varepsilon_r}$.

(a) ~190 ps (b) ~237 ps (c) ~600 ps (d) ~1.08 ns (e) ~3.36 ns

(6) Rise time *versus* travel time. What is the signal rise-time condition under which the microstrip transmission line in Problem (5) can't be approximated as a lumped circuit? (Use the rule-of-thumb criterion $t_r < 2.5 t_f$ discussed in Inan[2] book, 1999, Section 1.1.1.)

(a) $t_r <$ ~475 ps (b) $t_r <$ ~593 ps (c) $t_r <$ ~1.5 ns (d) $t_r <$ ~2.7 ns (e) $t_r <$ ~8.4 ns

(7) On-chip GaAs interconnect. Consider an on-chip GaAs interconnect excited by a signal with rise time $t_r = 50$ ps. What is the critical length of this interconnect such that when its actual length exceeds this critical length, this interconnect can't be approximated as a lumped circuit? (For GaAs substrate, assume $\varepsilon_r \approx 13$.)

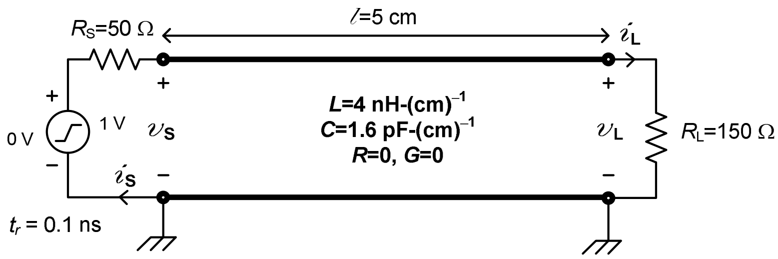
(a) ~0.46 mm (b) ~1.66 mm (c) ~1.04 cm (d) ~1.66 cm (e) ~2.16 cm

(8) A coaxial cable-lumped or distributed analysis? A 50 Ω coaxial cable of length 10 m and velocity factor 0.75 ($v_p \approx 0.75c$) is used to connect the antenna and the receiver of a microwave receiver system. Assuming sinusoidal steady state, what is the lowest sinusoidal-signal frequency above which the behavior of the coaxial cable can't be approximated as a lumped circuit? (To solve this problem, use the rule-of-thumb criteria $t_d < 0.1T$ provided in Inan[2] book, 1999, Section 1.1.2.)

(a) ~2.25 MHz (b) ~3 MHz (c) ~22.5 MHz (d) ~30 MHz (e) ~225 MHz

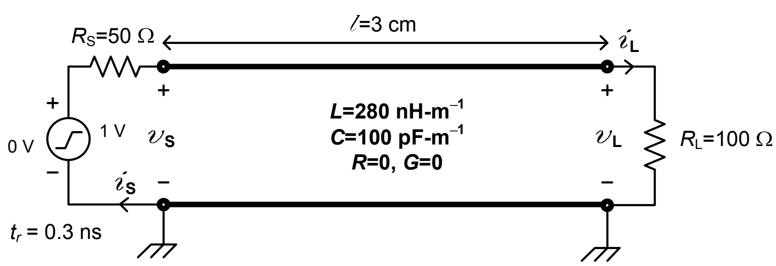
(9) Lumped or distributed circuit element? A uniform lossless transmission line with the L and C parameters and the length ℓ given as shown in the figure below is excited by a unit step source with rise-time equals $t_r = 0.1$ ns. Determine the following:

(a) The characteristic impedance Z_0 and the one-way time delay t_d of the transmission line.
(b) Whether it is appropriate or not to model the transmission line in this circuit as a lumped element. (Hint: Use the criteria $t_r/t_d < 2.5$ to justify your answer.)



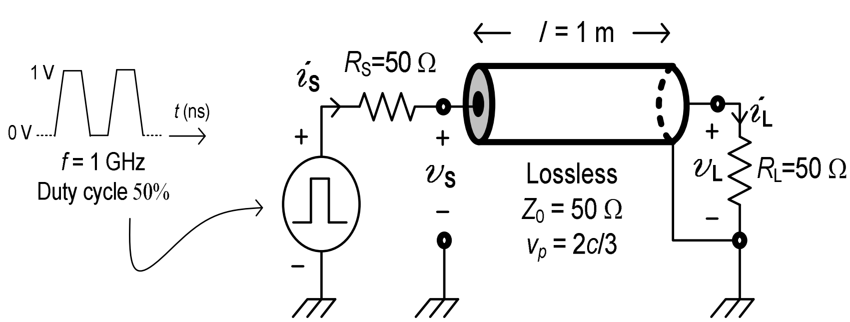
(10) Lumped or distributed circuit element? A uniform lossless transmission line with the L and C parameters and the length ℓ given as shown in the figure below is excited by a unit step source with rise-time equals t_r = 0.3 ns. Do the following:

a. Write the *telegrapher's equations* for this transmission line. (Hint: See Inan[2] text, p. 26, Eqs. [2.3] and [2.4].)
b. Write the *wave equations* for this transmission line. (Hint: Eqs. [2.5] and [2.6].)
c. Write the general solution of the wave equations for both voltage and current waves traveling on this transmission line. (Hint: Eqs. [2.8] and [2.9].)
d. Find the one-way time delay t_d of the transmission line.
e. Determine whether it is appropriate or not to model the transmission line in this circuit as a lumped element. (Hint: Use the criteria t_r/t_d < 2.5 to justify your answer.)



(11) Lumped or distributed circuit element? A uniform lossless transmission line is used to connect a periodic pulse waveform to a load as shown. Using the data provided on the figure, determine the following:

f. The per-unit-length parameters L and C of the transmission line.
g. The one-way propagation time delay t_d of the transmission line.
h. Whether this transmission line can be treated as a lumped element or not.



Please use the following guidelines for your homework solutions:

1) On the first sheet, at the top center, write: Homework #1-Solutions.
2) Provide your full name on the upper right corner of the first sheet.
3) Also write: EE 301/Spring 2013 on the upper left corner of the first sheet.
4) Solve each problem on a separate sheet unless your solution is very short.
5) Box all of your answers.
6) Staple your solutions in the above order before you turn them in.

Please turn in your homework on time.