EE 163A Fall 2020

Final Exam

Total Points: 140

Due: 12/18/2020 1PM

Policy: Open Book, PDF version of the book and slides are ok to use. You should not use internet and computer simulators. Calculator and Smith chart are ok to use.

Problem 1 (25 points)

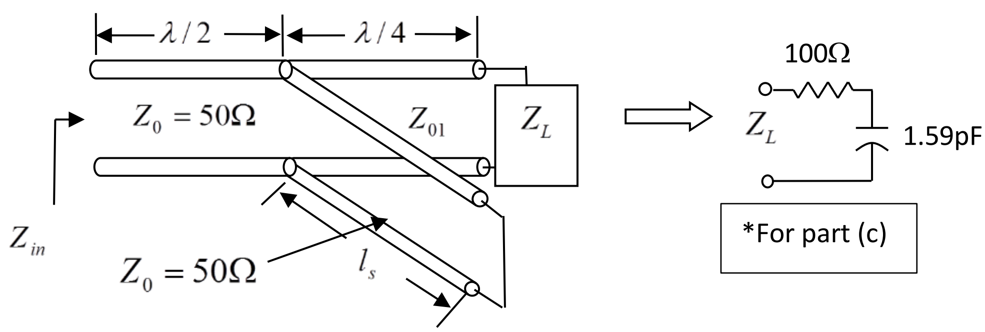
Consider the impedance matching circuit shown in the figure below. It is a combination of a short circuit stub and a quarter wavelength transformer.

(a) If the length of the short stub $l_s = \lambda/4$, characteristic impedance of the transformer $Z_{01} = 80\Omega$, load impedance $Z_L = 100\Omega$, find the input impedance Zin

(b) How should you change the characteristic impedance of the quarter wavelength transformer Z_{01} to realize an impedance match?

(c) If the load impedance is given by the series RC circuit shown on the right side of the figure, how should you change both Z_{01} and l_s to realize impedance match at 1GHz?

* Note: Do not use Smith chart in this problem.



Problem 2 (20 points)

A 50 Ω transmission line is terminated by Z_L consisting of a series combination of 100 Ω resister and 0.995 pF capacitor. For impedance matching at 2 GHz, we will use a single shunt stub tuner made of an open-ended transmission line with its characteristic impedance of 100 Ω.

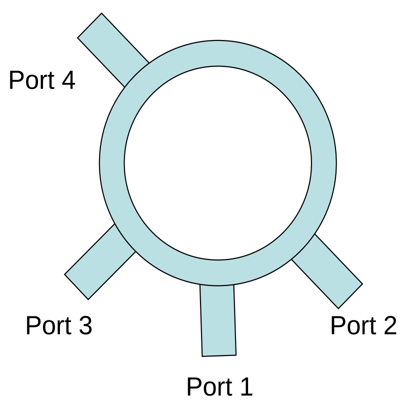
(a) Find out the minimum distance away from the load where the shunt stub can be placed.

(b) Find out the length of the open shunt stub. Would this length be smaller or larger if a short circuit shunt stub is used?

Problem 3 (35 points)

Consider the following ring hybrid with the S-parameter matrix shown below. Answer the following questions. (Assume that all ports have a characteristic impedance of 50 Ω):

a. Check the circuit is lossless, matched, and reciprocal from the S-matrix.
b. Assuming all the ports are matched with impedance 50 Ω, if we inject 1 W power in port 1, and 2 Watt in port 4, how much output powers we will obtain from port 2 and port 3, if these inputs are in phase?
c. Repeat (b) if the input powers are 180 degree out-of-phase.
d. For parts (b) and (c), check for power conservation.
e. If we let port 4 grounded, what are the S parameters of the resultant 3-port network consisting of port 1, 2, 3?
f. Find out with reasons if the S matrix of this three-port device is reciprocal, matched and unitary.



$$[S] = \frac{j}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

Problem 4 (20 points)

Two infinitely long microstrip lines are placed very close to each other. Electromagnetic wave is propagating along z direction. When only Line 1 is excited with 1 volt at $z = 0$, the power is completely transferred to Line 2 at $z = L = 60$ cm at the shortest distance. At this location, the accumulated phase delay of the wave with respect to $z = 0$ is 35π. Find the guide wavelengths of the even and odd modes, λ_e and λ_o.

Problem 5 (25 points)

Design a low-pass third order maximally flat filter that has a series inductor as the first element.

(a) Derive the prototype of the low pass filter and scale it for 3 GHz cutoff frequency and 50 Ω impedance.

(b) Realize this filter with an open shunt stub for the capacitor and stepped impedance for the inductors. The maximum and minimum available characteristic impedance of the transmission line for the stepped impedance section are 200 Ω and 10 Ω respectively.

Problem 6 (15 points)

It is desired to design a circuit that rejects the interference caused by power lines at 60 Hz. With reference to the circuit below, answer the following:

a) Derive an expression for the impedance seen by the source, voltage drop across the load resistor R_L and the current through the load resistor R_L as a function of ω.
b) What would be the resonant frequency of the circuit in terms of L and C? Also find the impedance seen by the source at the resonant frequency.
c) Assuming an inductance of 47 mH, what would be the value of capacitance to completely reject a frequency of 60 Hz?
d) What should be the value of R_L so that the bandwidth of this circuit is 5 Hz? The bandwidth is defined as the difference between frequencies corresponding to which $\left|\frac{V_{R_L}}{V_s}\right| = \frac{1}{\sqrt{2}}$ where V_{R_L} represents the voltage across the resistor R_L.