EEC 130A Introductory Electromagnetics I Midterm 1

Winter 2012

Instructor: Xiaoguang "Leo" Liu

Closed Text and Notes

1) Make sure you have 6 problems. Each problem is worth 20 points. Problem 6 is for extra credits.

2) Write only on the question sheets. Show all your work. If you need more space, please use the reverse side.

3) Write neatly. If your writing is illegible then please print.

4) A formula sheet will be provided separately from the problem sheets.

5) Smith charts are provided for Problem 1, 3, 5, and 6. You may not need any or all of them.

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Print your name below after reading and verifying the above notes.

Name: ______________________________

1. (20 points) A lossless 100-Ω transmission line 0.3λ in length is terminated in an unknown impedance Z_L. The input impedance is measured to be Z_{in} = 40-j20 Ω,

(a) Use the Smith chart to find Z_L.
(b) Use the Smith chart to find VSWR.
(c) If a shunt resistor R is placed on the transmission line at a strategic distance d from the load, then it is possible to make Z_{in}=100 Ω. Find out R and d.

2. (20 points)

(a) **Derive** an expression for the input impedance of a transmission line (with length l) terminated in an open circuit.

(b) Show that the characteristic impedance Z_0 and the propagation constant β of a transmission line (with length l) can be determined by its input impedance $Z_{in,SC}$ when the line is terminated in short circuit and its input impedance $Z_{in,OC}$ when the line is terminated in open circuit.

3. (20 points) As shown in Fig. 1, a capacitor C=1 pF is connected to a 50-Ω air filled transmission line of length l=6 mm.

(a) Calculate the load reflection Γ_L **without** using the Smith chart.
(b) Calculate the input impedance Z_{in} at 1 GHz.
(c) Calculate the frequency at which the transmission line is a quarter wavelength.

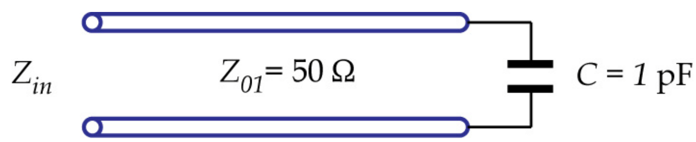

Figure 1 Circuit for Problem 1

4. (20 points) In the lectures we talked about microstrip lines, which is a type of transmission line often used in high frequency circuits. Another popular type of transmission line is the coplanar waveguide (CPW), which is shown in Fig. 2. A CPW line consists of a center conductor and a pair of ground planes, all on top of a substrate. Like microstrip lines, CPW lines are quasi-TEM transmission lines. An advantage of CPW lines is that it is a lot easier to add both series and shunt lumped circuit components because the signal trace and grounds are all on the same plane.

A CPW line is measured to have characteristic impedance of Z_L=50 Ω, attenuation constant α=18.8 Np/m and β=46 rad/m at 1 GHz[1]. Find the line parameters R′, L′, G′, and C′.

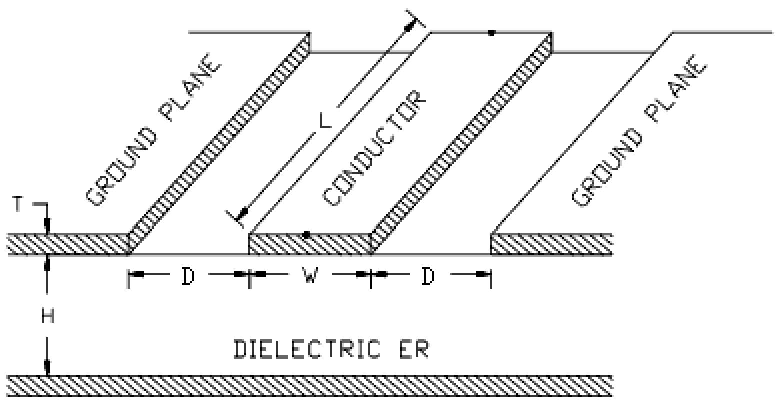

Figure 2 Coplanar waveguide (CPW)[2]

[1] Williams, D.F.; Marks, R.B., "Accurate transmission line characterization," Microwave and Guided Wave Letters, vol.3, no.8, pp.247-249, Aug 1993.

[2] http://cp.literature.agilent.com/litweb/pdf/ads2008/ccdist/ads2008/CPWG_(Coplanar_Waveguide_with_Lower_Ground_Plane).html

5. (20 points) An amplifier designer comes to you for help with matching his amplifier to an antenna, both working at 2.4 GHz. The output impedance of the amplifier and the antenna are 12.5 Ω and 75-j25 Ω. Please use the single stub matching method to do the matching. Find out *d* and *l*. You will work with 12.5-Ω microstrip lines with an effective relative permittivity of ε_{eff}=4. Assume that the via is an ideal short. You may use the Smith chart to help you.

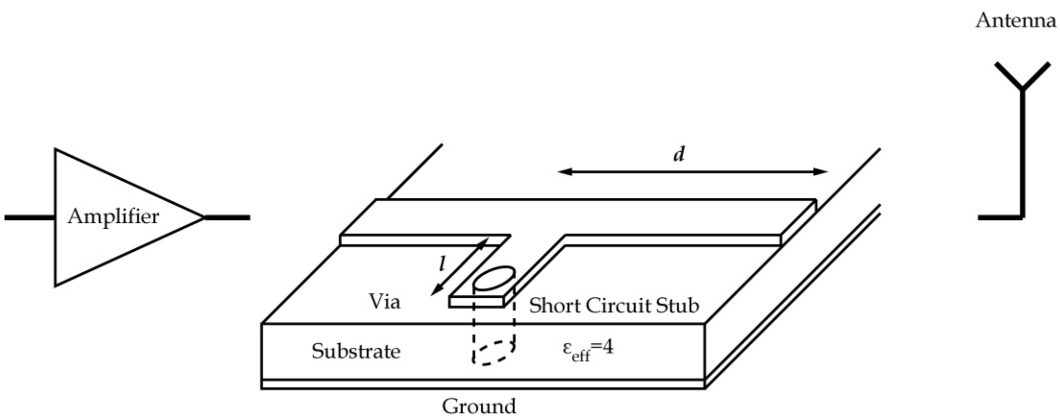

Figure 3 Circuit for Problem 5

6. **(Extra Credit: 20 points)** In modern high frequency integrated circuit designs, impedance matching is often done using all lumped elements to save space. Fig. 4 shows two matching circuits using series and shunt reactive elements only. Fig. 5 illustrates how the matching network in circuit #1 works with the help of a constant-g circle (dashed).

(a) Illustrate on the Smith chart how matching is achieved in circuit #2. You may arbitrarily choose your z_L (except for z_L=1 of course) to best illustrate the matching process.

(b) Given a normalized load impedance of z_L=0.2+j, find the right x and b values to achieve matching.

(c) It is known that circuit #2 can never achieve matching for some values of z_L. Either give a general expression or point out on the Smith chart what z_L values can not be matched.

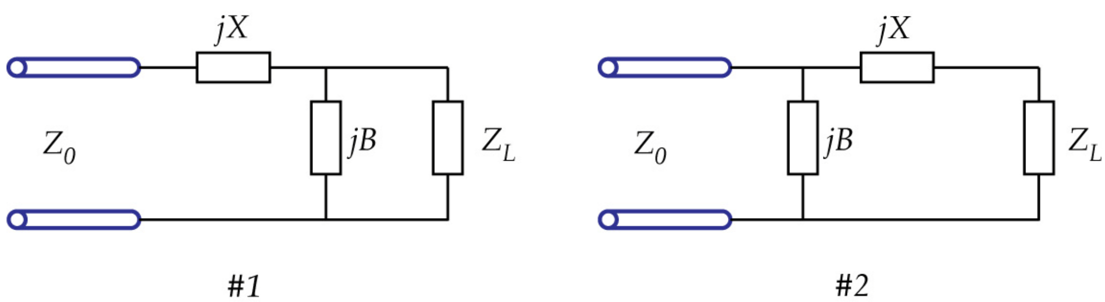

Figure 4 Lumped element matching circuits for Problem 6

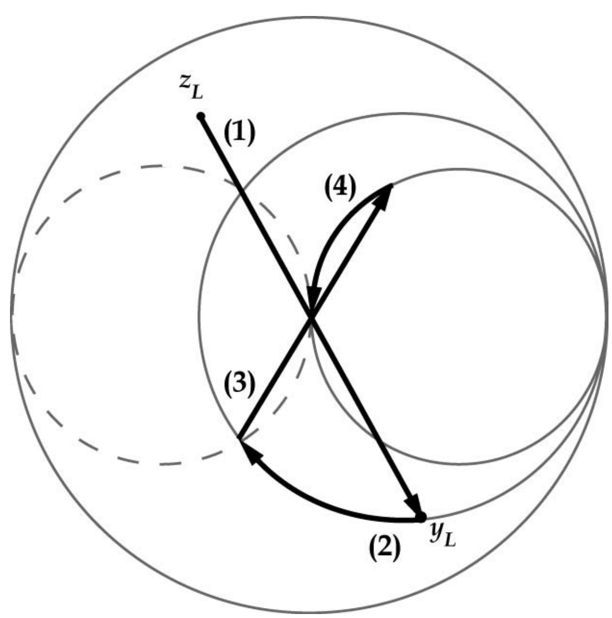

Figure 5 Smith chart illustration for impedance matching using Circuit #1