ECE 6130/5930 Final Exam
May 2, 2000

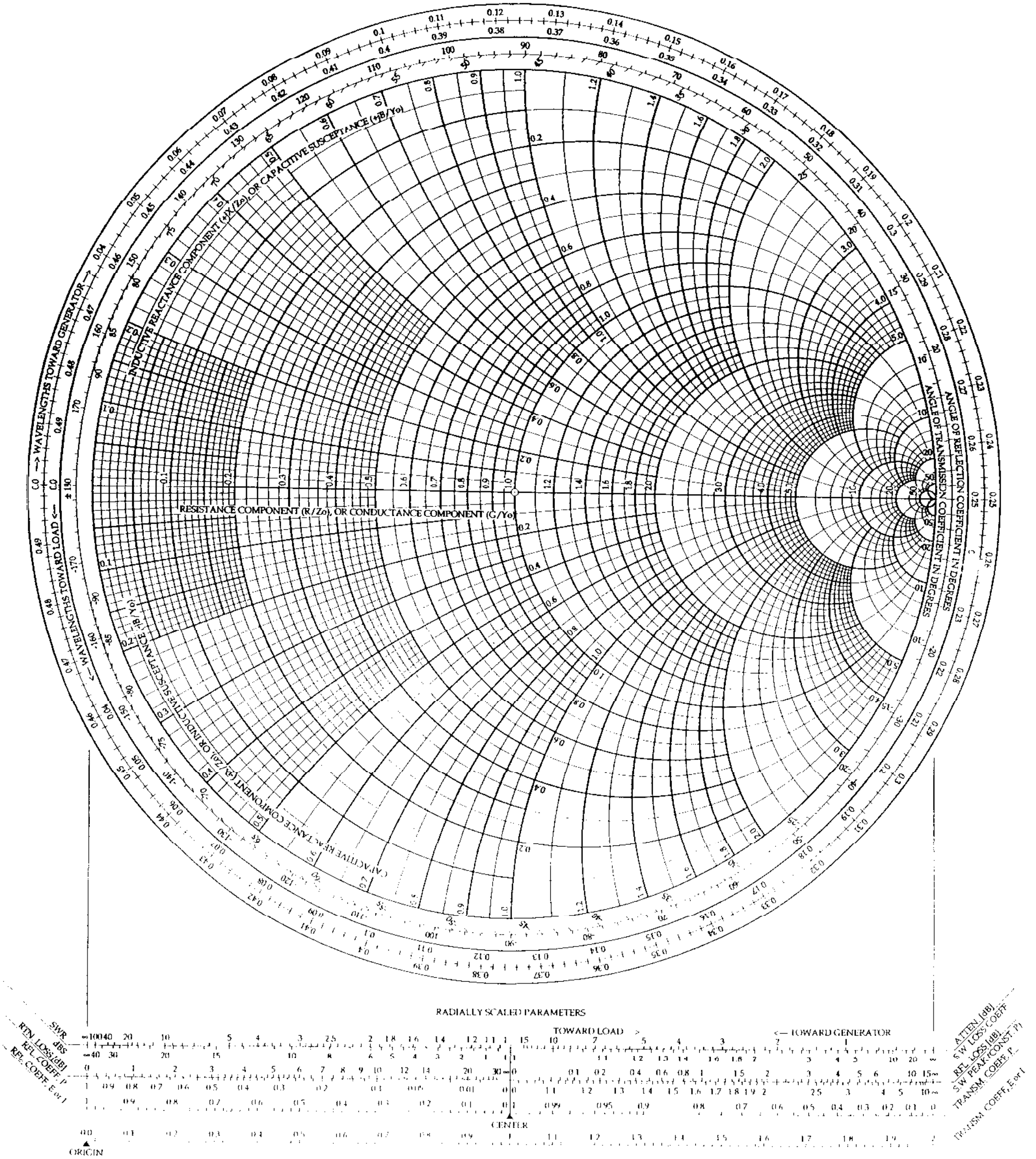
Name Key

You may use your portfolio and a calculator. Good luck! Do well.

1. (33 points) Design a microstripline double stub matching network to match an antenna with an impedance of 80 + j 20 ohms to a 50 ohm line. Sketch the stub matching network, and clearly label all lengths.

The Complete Smith Chart

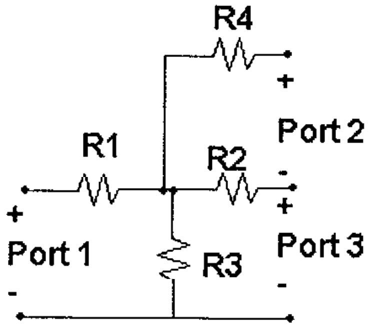
Black Magic Design



2. (33 points) Design a π-junction lumped element matching network to match an antenna with an impedance of 80 ohms to a 50 ohm line. The frequency is 1 GHz. Sketch the matching network, and clearly label the optimal values of the lumped elements.

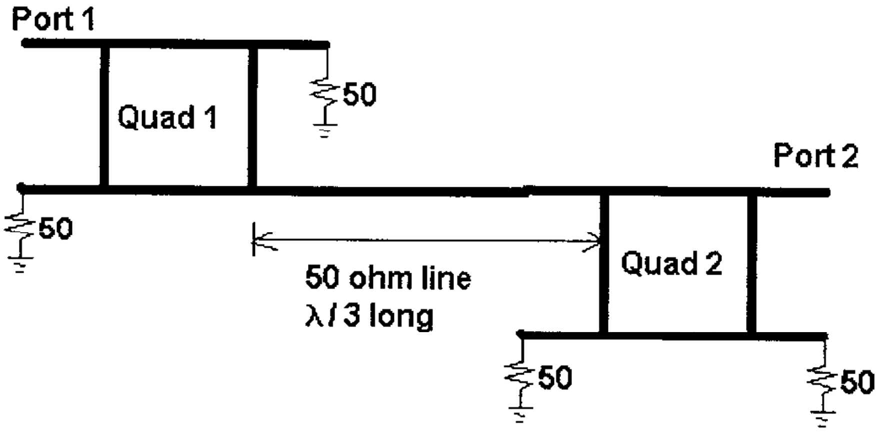
3. (33 points) Compute the S12 parameter for the following circuit where R1=R2=R3=100 ohms, R4 = 50 ohms. Assume the circuit is to be connected to 50-ohm lines.

Graduate Students Only: If we intended to use this network in a twin-lead (300 ohm) system for TV reception, would the S-parameters be any different? Explain.



4. (33 points) Two 50-ohm quadrature couplers are connected by a 50-ohm line as shown below. What is the S-parameter matrix between ports 1 and 2 as shown? Lengths of line connected to the 50-ohm terminations can be neglected. (You can just write the equations if needed to save time.)

Graduate Students Only: Suppose you change the length of line between the couplers. Does it change the VSWR at port 1? The reflection coefficient at port 1? Explain why or why not.



5. (33 points) Design a microstrip low pass stepped impedance filter that passes 1 GHz and is down at least 30 dB at 2 GHz. The filter must be matched to 50 ohm lines at both the input and output. Sketch the filter and specify all lengths and impedances of lines.

6. (33 points)

   a. Explain and sketch the electric and magnetic field distributions in a microstripline.
   b. Is it a TEM, TE, or TM wave?
   c. Give integral equations for calculating the R and G components for the lumped element (RLGC) model of the microstripline. Clearly sketch or explain *what* is being integrated and the *limits* of integration for each term. You do NOT need to compute these integrals.

   Graduate Students only: Also give the integral equations for L and C.

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Name ______________________________

Problem 1 ________ / 33 Points

Problem 2 ________ / 33 Points

Problem 3________ / 33 Points

Problem 4 ________ / 33 Points

Problem 5 ________ / 33 Points

Problem 6 ________ / 33 Points

+2

Total ________/100 Points

ECE 6130 Final - Key

1. Design a double stub matching network to match an antenna of $Z = 80 + j20\,\Omega$ to a $50\,\Omega$ line.

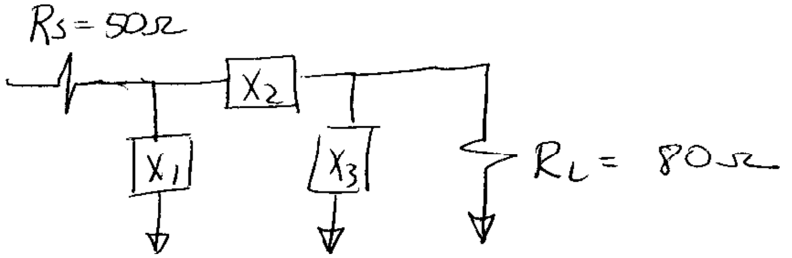
$Z_L = 80 + j20\,\Omega$

normalize

$Z_{in} = \dfrac{80 + j20}{50} =$

2. Design a Π junction lumped element network to match $Z_L = 80\,\Omega$ to a $50\,\Omega$ line.
Use a Q of 15. Allow high frequencies to pass.
Block DC

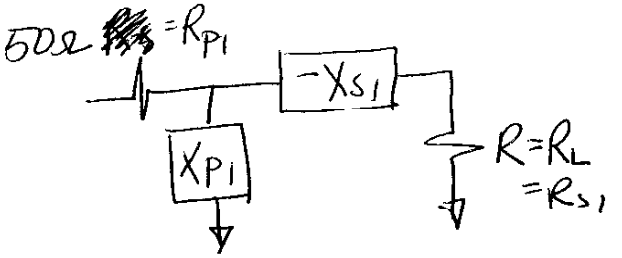
Begin by matching $Z_L = 80\,\Omega$

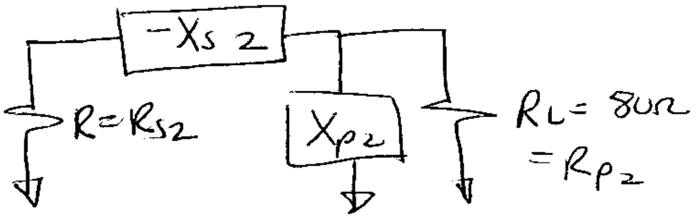


$R_H = \max(R_L, R_S) = 80\,\Omega$

$Q^2 = \frac{R_H}{R} - 1$ $\Big] \longrightarrow$ $R = \frac{R_H}{Q^2+1} = \frac{80\,\Omega}{(15)^2+1} = .354\,\Omega$

$\frac{R_H}{R} = Q^2 + 1$





$Q_1 = \sqrt{\frac{R_{p1}}{R_{S1}} - 1} = \sqrt{\frac{50}{R} - 1} =$

$X_{S1} = Q_1 R_S = Q_1 R = 4.192\,\Omega$

$X_{p1} = R_p/Q_1 = \frac{50}{Q_1} = 4.222\,\Omega$

L_{p1} $Z_{p1} = j\underbrace{\omega L_{p1}}_{X_{p1}}$ $C_{S1} = \frac{1}{\omega X_{S1}}$
$=$

$L_{p1} = \frac{X_{p1}}{\omega} =$

$Q_2 = \sqrt{\frac{R_{p2}}{R_{S2}} - 1} = \sqrt{\frac{80}{R} - 1} =$

$X_{S2} = Q_2 R_{S2} = Q_2 R = 5.31\,\Omega$

$X_{p2} = R_{p2}/Q_2 = 80/Q_2 = 5.335\,\Omega$

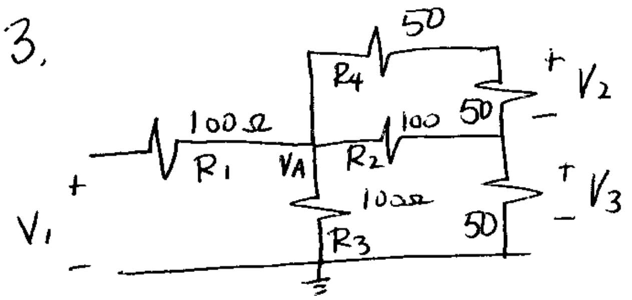
$L_{p2} = X_{p2}/\omega =$

C_{S2} $Z_{S2} = \frac{1}{j\omega C} = \frac{-j}{\omega C}$

$-X_{S2} = -\left(\frac{-1}{\omega C_{S2}}\right)$

$C_{S2} = \frac{1}{\omega X_{S2}} =$

3.



$$Z_A = (((R_4 + 50) \parallel R_2) + 50) \parallel R_3$$

$$= ((100 \parallel 100) + 50) \parallel 100$$

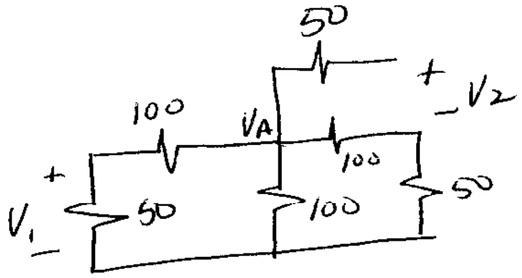
$$= (50 + 50) \parallel 100$$

$$= 50\Omega$$

$$V_A = V_1 \frac{Z_A}{R_1 + Z_A} = V_1 \frac{50}{150} = \frac{V_1}{3}$$

$$V_2 = V_A \frac{50}{50+50} = \frac{V_A}{2} = \frac{V_1}{6}$$

$$S_{21} = \frac{V_2}{V_1} = \frac{1}{6}$$



$$Z_A = 150 \parallel 150 \parallel 100$$

$$= 75 \parallel 100 = \frac{(75)(100)}{175}$$

$$=$$

$$V_A = V_2 \frac{Z_A}{Z_A + 50}$$

$$= V_2 \left(\qquad \right)$$

$$V_1 = V_A \frac{50}{150}$$

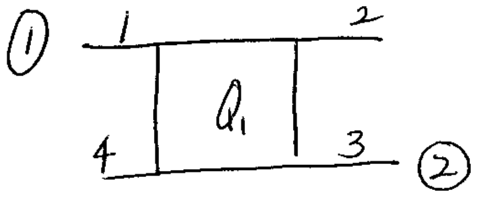
$$= V_2 \left(\qquad \right) \frac{1}{3}$$

$$=$$

$$S_{12} = \frac{V_1}{V_2} = \left(\qquad \right) \frac{1}{3}$$

$$=$$

7.



$$S_{Q_1} = \frac{-1}{\sqrt{2}} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix} \end{array} \qquad S_{2port} = \frac{-1}{\sqrt{2}} \begin{array}{c} \begin{array}{cc} 1 & 3 \end{array} \\ \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \end{array}$$

w/ other ports matched

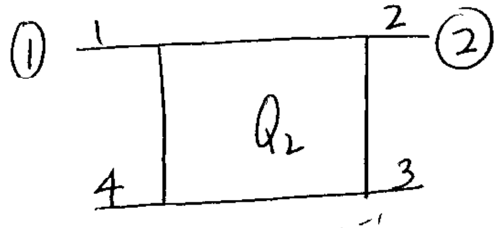
$$A_1 = \frac{(1)(1) + \frac{(1)}{\sqrt{2}}\frac{(1)}{\sqrt{2}}}{2(1)} = 3/4$$

$$B_1 = Z_0 \frac{(1)(1) - (1)(1)/2}{2(1)} = \frac{Z_0}{4}$$

$$C_1 = \frac{1}{Z_0} \frac{(1)(1) - (1)(1)/2}{2(1)} = \frac{1}{4Z_0}$$

$$D_1 = \frac{(1)(1) + (1)(1)/2}{2(1)} = 3/4$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{Q_1} = \begin{bmatrix} 3/4 & \frac{50}{4} \\ \frac{1}{200} & 3/4 \end{bmatrix}$$



$$S_{2port} = \frac{-1}{\sqrt{2}} \begin{array}{c} \begin{array}{cc} 1 & 2 \end{array} \\ \begin{bmatrix} 0 & j \\ j & 0 \end{bmatrix} \end{array}$$

$$A_2 = \frac{(1)(1) + \overset{-1}{\cancel{j^2}}\,\frac{1}{2}}{2j\left(\frac{-1}{\sqrt{2}}\right)} = j\,\frac{\sqrt{2}}{4}$$

$$B_2 = 50\,\frac{(1)(1) - \overset{-1}{\cancel{j^2}}\,\frac{1}{2}}{2j\left(\frac{-1}{\sqrt{2}}\right)} = 50\,j\,\frac{3/2}{2/\sqrt{2}} = j\,\frac{150\sqrt{2}}{4}$$

$$C_2 = \frac{1}{50}\,\frac{(1)(1) - \cancel{j^2}\,\frac{1}{2}}{2j(-1/\sqrt{2})} = \frac{1}{50}\,j\,\frac{3/2}{2/\sqrt{2}} = j\left(\frac{3}{200\sqrt{2}}\right)$$

$$D_2 = \frac{(1)(1) + j^2\,\frac{1}{2}}{2j(-1/\sqrt{2}} = \frac{j\,1/2}{2/\sqrt{2}} = j/4\sqrt{2}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{Q_2} = j \begin{bmatrix} \sqrt{2}/4 & \frac{150\sqrt{2}}{4} \\ \frac{3}{200\sqrt{2}} & \frac{1}{4\sqrt{2}} \end{bmatrix}$$

$\longrightarrow$

Over

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{Line} = \begin{bmatrix} \cos \frac{2\pi}{\cancel{\lambda}} \frac{\cancel{\lambda}}{3} & j50 \sin \frac{2\pi}{\cancel{\lambda}} \frac{\cancel{\lambda}}{3} \\ \frac{j}{50} \sin \frac{2\pi}{\cancel{\lambda}} \frac{\cancel{\lambda}}{3} & \cos \frac{2\pi}{\cancel{\lambda}} \frac{\cancel{\lambda}}{3} \end{bmatrix}$$

From Table 4.1

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{total} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{Q_1} \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{Line} \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{Q_2}$$

Find Sparameters by
converting using table 4.2 page 211

Length of line changes ∡ of Γ but not $|\Gamma|$.
VSWR stays the same.