ECR 5320 / 6322 Midterm I

October 11, 2006

Name

Are you taking ECE 5320 or ECE 6322 (circle only one :)

Random Student Number

You may use your portfolio and a calculator but no textbook. Read each problem carefully. Good luck, and do well!

NOTE that the point distribution is:

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<td>+10 points (extra part of the problem)</td>
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1. (30 points) Write an expression for $S_{12}$ of the following network. Your equation can be as complicated as you want to leave it (ie. no need to compute or simplify). Write it in such a way that you could later use Matlab to find a numerical value. SPECIFY THE VALUE OF ALL VARIABLES. Hint. There are many ways to do this problem, so give some thought as to which might be the easiest.

$L = 1\text{nH}$
$F = 1\text{MHz}$

\[ 0.2 \xrightarrow{Z_o = 50\Omega} 0.375 \xrightarrow{Z_o = 1\text{M}\Omega} \text{Short Circuit} \]

Additional question for ECE6322 Students (10 points): BRIEFLY describe at least one other method of finding the S parameters that is significantly different than what you did above.
Problem 1: Find ABCD

\[ F = 1 \text{MHz} \]
\[ L = 1 \text{nH} \]
\[ d = 0.2 \lambda \]
\[ Z_0 = 50 \Omega \]
\[ L = 1.375 \lambda \]
\[ Z_0 = 100 \Omega \]

Find \( Z \) of inductor:
\[ Z = j \omega L = j Z \pi (1 \times 10^{-6} \text{ Hz})(1 \times 10^{-9} \text{ H}) \]
\[ Z = j 2\pi \times 10^{-3} \Omega \]

Find \( Y \) of stub:
\[ Y = (j 10)(\frac{1}{100 \Omega}) \]
\[ Y = 0.01j \Omega \]

Find ABCD of \( Z \):
(1) \[ [AB]_z = \begin{bmatrix} 1 & j 2\pi \times 10^{-3} \\ 0 & 1 \end{bmatrix} \]

Find ABCD of \( Y \):
(2) \[ [AB]_y = \begin{bmatrix} 0 & 1 \\ 0.01j & 1 \end{bmatrix} \]

Find ABCD of line:
(3) \[ [AB]_{\text{line}} = \begin{bmatrix} \cos(\frac{2\pi}{\lambda} 0.2\lambda) & j 50 \sin(\frac{2\pi}{\lambda} 0.2\lambda) \\ -j 50 \sin(\frac{2\pi}{\lambda} 0.2\lambda) & \cos(\frac{2\pi}{\lambda} 0.2\lambda) \end{bmatrix} \]
2. (30 points) Design a double stub matching network to match a load of $Z_L = 5-j17 \, \Omega$ to a 50 $\Omega$ line. Use parallel short circuited stubs. Use a distance of 0.1 wavelengths between the load and the first stub, and a distance of 0.375 wavelengths between the two stubs. Although there are two possible configurations, you only need to calculate one. Sketch and clearly label your system and your Smith Chart.

Additional question for ECE6322 Students (10 points): Tell how the length of the first stub would change if the impedance of that stub (only) is 100 ohms instead of 50 ohms.
Problem 2

\[ Z_0 = 50 \Omega \]

1. Normalize & Plot \( Z \)
   Convert to \( Y \)

2. Rotate 0.15 TwA to \( Y_L' = 1 - j3 \)
   \( Y_{L2A} = Y_m - Y_A' \)

3. Rotate circle 0.375 x 1 iW

4. Choose point A or B on circle
   Following real parts (10)

5. \( Y_A = 1 + j0 \) \( Y_B = 1 - j2.05 \)
   \( Y_{SA} = Y_A - Y_L' = (1+j0) - (1-j3) = j3 \)

6. \( Y_{SB} = Y_B - Y_L' = (1-j2.05) - (1-j3) = j0.95 \)

7. \( Y_m = 1 + j0 \) (matched)

\( Y_m = Y_A' + Y_{L2A} = 1 + j0 + j3 = 1 + j3 \)

\( Y_{L2} = (5 - j172) / 50 \Omega = (0.1 - j0.34) \) Plot

\[ L_{1A} = 0.5 - (0.25 - 0.198) = 0.448 \lambda \]
\[ L_{1B} = 0.5 - (0.25 - 0.12) = 0.37 \lambda \]

\[ L_{2A} = 0 \]
\[ L_{2B} = 0.308 \]

\[ L_{2A} = 0.058 \]

\[ Y_A' = 1 + j0 \]
\[ Y_B' = 1 + j2.05 \]
The Complete Smith Chart
Black Magic Design

Problem 2

The Smith chart is a graphical representation used in electrical engineering, particularly in the field of microwave and RF engineering. It is a complex plane that plots impedance or admittance values. The chart is useful for visualizing the behavior of circuits and systems.

In this chart:
- YSA is a point on the chart.
- Ysc is another point.
- Y0 is a reference point.
- 0.375 TWL is a distance marked on the chart.
- 0.298 is another distance.

The chart is used to analyze and design networks, especially in the context of reflection and transmission coefficients, which are crucial for understanding the performance of antennas and other microwave devices.

The chart's radial and angular scales are used to represent impedance values, with the center representing 0 ohms and the outer edge representing infinity. The chart's polar and rectangular coordinates allow for the visualization of complex impedances and admittances.
3. (20 points) Design an L matching network to match a load of $Z_L = 100$ ohms to a 25 ohm line. Specify the value of all capacitors and inductors to make this a low pass configuration.

\( \text{(Assume } f = 1 \text{MHz}) \)

\text{Solution}

1) Compare $Z_L$ & $Z_g$

\[ Z_L > Z_g \]

\[ R_p = 100 \Omega \]

\[ R_s = 25 \Omega \]

2) Choose the ckt

\[ \text{[LPF configuration]} \]

3) Calculate $Q$

\[ Q_s = Q_p = Q = \sqrt{\frac{R_p}{R_s}} - 1 = \sqrt{\frac{100}{25}} - 1 = \sqrt{3} \]

4) Calculate $X_s$ & $X_p$

\[ X_s = Q_s R_s \times \sqrt{3} \times 25 = 48.3 \Omega \]

\[ X_p = \frac{R_p}{Q_p} = \frac{100}{\sqrt{3}} = 57.7 \Omega \]
5) \[ X_L = \omega L \]

\[ L = \frac{X_L}{\omega} = \frac{43.3}{2\pi \times 1 \times 10^6} \]

\[ L = 6.89 \text{ mH} \]

\[ X_P = \frac{1}{\omega C} \]

\[ C = \frac{1}{\omega X_P} \]

\[ C = \frac{1}{2\pi \times 1 \times 10^6 \times 57.736} \]

\[ C = 2.756 \text{nF} \]

6) Draw final circuit

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6.89\text{ mH} \hspace{1cm} \text{Line} \hspace{1cm} 2.756\text{nF}
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4. (20 points) Absorption and Resonance:

**ECE 5320 Students:** Suppose you design a T matching network. Your value for $X_{g2} = 4$, and the load has an $X_L = 6$. **DESCRIBE THE STEPS** in detail to absorb as much of the load as possible and resonate the rest. Demonstrate each step by calculating the appropriate values for this Pi system. Sketch the final system that should be built, and give values to your components. Put a box around the load to clearly show what is the load, and what parts are external components.

**ECE 6322 Students:** Suppose you design a Pi matching network. Your value for $X_{p2} = 1/4$, and the load has an $X_L = 1/6$. **DESCRIBE THE STEPS** in detail to absorb as much of the load as possible and resonate the rest. Demonstrate each step by calculating the appropriate values for this Pi system. Sketch the final system that should be built, and give values to your components. Put a box around the load to clearly show what is the load, and what parts are external components.

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For absorption

$X_{s2} = 4$ & $X_L = 6$

we can absorb 4

So modify circuit is

This we can be absorbed by using a series reactance of -2
If we consider the Y matrix:

\[ X_{p2} = 6 \quad \text{and} \quad X_L = 6 \]

So we can absorb the load by using following chart:

\[ X_p'' = \frac{X_p \cdot X_L'}{X_L' - X_p'} \]

\[ X_p'' = \frac{1}{2} \]

Since we have to absorb:

\[ X_p'' = -\frac{1}{2} \]
ECE 6320

Problem 1 _________ / 30 points + _________ / 10 points
Problem 2 _________ / 30 points + _________ / 10 points
Problem 3 _________ / 20 points
Problem 4 _________ / 20 points

Total Score (ECE5320) _________ / 100 points

(ECE 6322) _________ / 120 points

Never fear, the final exam can replace all midterm scores. ☺