Sample Midterm I
with Solutions

Name ______________________________
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UNIVERSITY OF UTAH

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

MICROWAVE ENGINEERING I

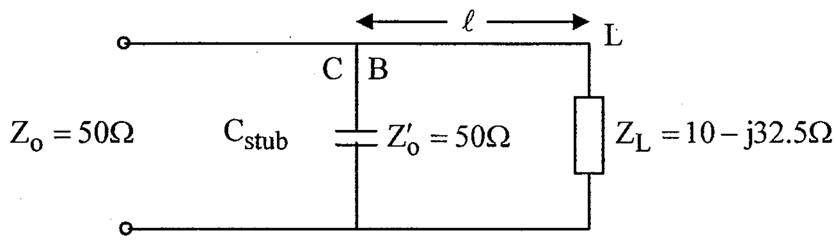
ECE 5320/6322

MIDTERM EXAMINATION NO. 1

September 28, 2009

1. (25 points)

A load of impedance $10 - j32.5\Omega$ is to be matched by using an open-circuited stub-created capacitance using a circuit of topology as follows:



Pts

12 a. Calculate the distance ℓ between Planes L and B to obtain matching using a capacitance C_{stub} created by an open-circuited stub across the transmission line. Use $\lambda_g = 5$ cm and frequency $f = 4$ GHz.

8 b. Calculate the capacitance C_{stub} needed for the matching circuit.

5 c. Calculate the length ℓ_s of the open-circuited stub given that

$$Y_{stub} = j\,Y'_o \tan(\beta \ell_s)$$

Take $Z'_o = 100\Omega$ for the open-circuited stub.

ECE 5320/6322 Midterm I – Solutions

9/28/09

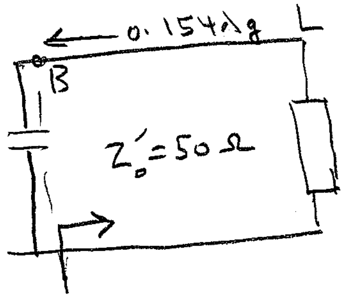
1. a. $Z_L = 10 - j\,32.5$

$z_L = \frac{10 - j\,32.5}{50} = 0.2 - j\,0.65$ (this is represented by point L on the Smith Chart)

The transmission line circle for this load is sketched as circle C on the Smith chart

From the Smith chart, the admittance point is diametrically opposite i.e. L′ on circle C

The distance ℓ from the Smith chart to a point with real part 1 is $(0.31 - 0.156)\,\lambda_g = 0.154\,\lambda_g = 0.154 \times 5 = 0.77$ cm



$Z_L = 10 - j\,32.5\,\Omega$

$z_L = \frac{Z_L}{Z_0'} = 0.2 - j\,0.65$

From Smith chart (pt. L′)

$y_L = 0.47 + j\,1.4$

$y_B = 1 - j\,2.2$

$Y_B = (1 - j\,2.2)\,Y_0' = \frac{1}{50} - j\,\frac{2.2}{50}$

Add $j\omega C_{stub} = j\,\frac{2.2}{50}$

b. $C_{stub} = \frac{2.2 \times 10^3 \text{ pF}}{50 \times 2\pi \times 4 \times 10^9} = 1.75$ pF

c. It is given that

$j\,\omega\,C_{stub} = j\,\frac{2.2}{50} = j\,\frac{1}{100}\tan(\beta \ell_s)$

$\beta \ell_s = \frac{2\pi \ell_s}{\lambda_g} = 77.2^\circ = 0.429\,\pi = 1.347$ rad

$\frac{\ell_s}{\lambda_g} = 0.2145 \rightarrow \ell_s = 0.2145 \times 5 = 1.073$ cm

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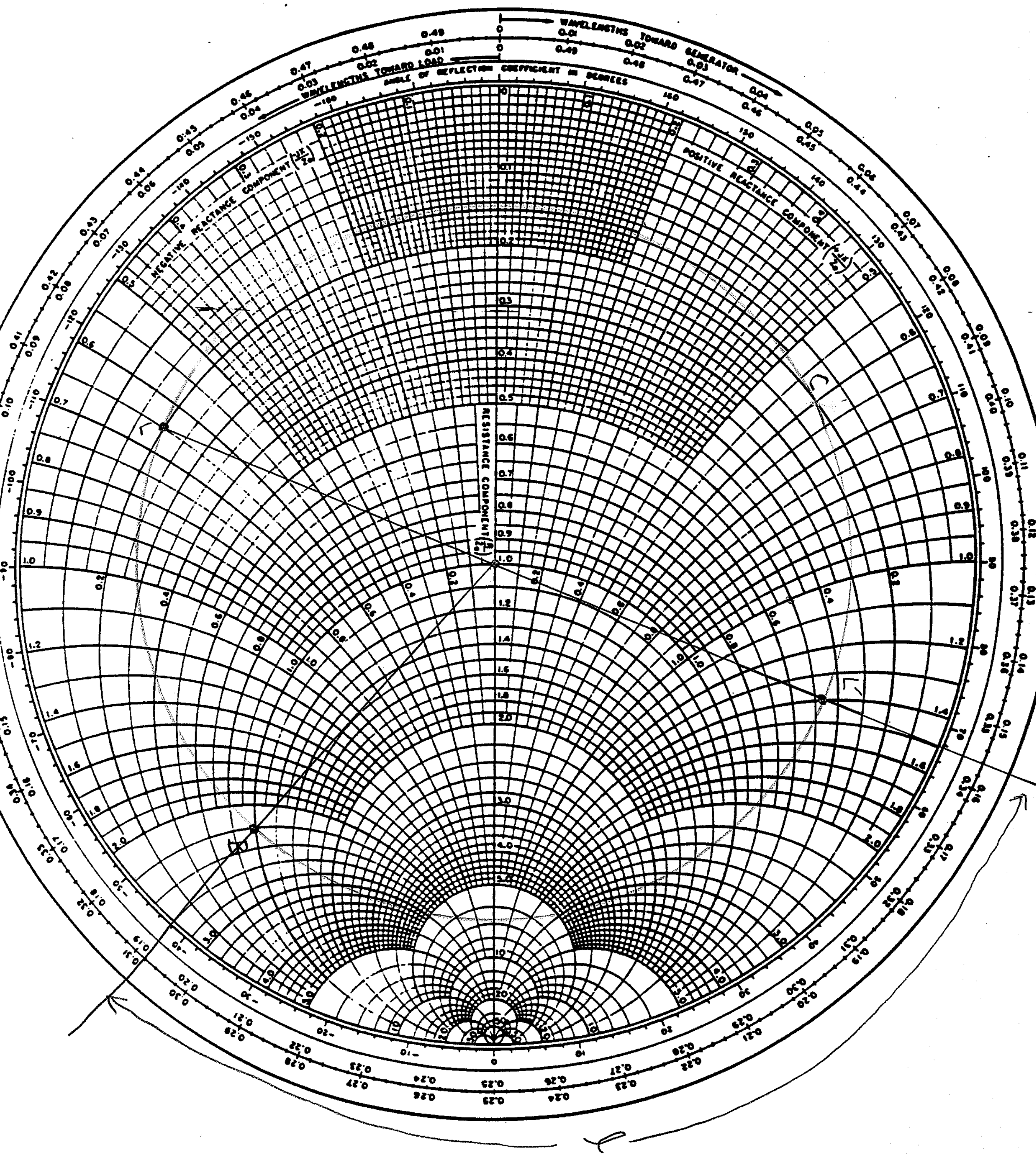


Ref. Phillip H. Smith "Transmission Line Calculator" Electronics Jan 1939 and Jan 1944

Printed in U.S.A.

2. (25 points)

A microstripline with microstrip width w to substrate thickness d ratio w/d = 2.3 is printed on a quartz substrate ($\varepsilon_r = 3.78$). For this microstripline, calculate:

Pts	
5	a. the characteristic impedance.
3	b. effective dielectric constant.
5	c. the RMS value of the RF voltage between the microstrip and the ground plane for an input power of 1 W.
6	d. attenuation α_d in dB/m due to **dielectric** losses for a signal frequency of 20 GHz. The loss tangent for quartz from p. 667 of the Text is given to be 10^{-4}.
6	e. for a substrate thickness d = 0.1", the maximum frequency to which the microstripline may be used without exciting any of the higher-order modes.

2. From Eq. 3.195 p. 144

b. $$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12 \frac{d}{W}}}\quad \frac{1}{2.3} = 2.947$$

a. $$\frac{W}{d} = 2.3 \quad > 1$$

from Eq. 3.196 p. 145

$$Z_o = \frac{120\pi}{\sqrt{2.947}\left[\underbrace{2.3 + 1.393 + \underset{0.8805}{\cancel{0.667 \ln(2.3 + 1.444)}}}_{4.57}\right]} = 48.02\ \Omega$$

c. $$\frac{|V|^2_{peak}}{2Z_o} = 1\text{ W} \; ; \quad |V|_{rms} = \sqrt{Z_o} = 6.93 \text{ Volts}$$

$$\frac{|V_{rms}|^2}{Z_o} = 1 \text{ W}$$

e. $$f_c\Big|_{TE} = \frac{c}{4d\sqrt{\epsilon_r - 1}} = \frac{30 \times 10^9}{4 \times 0.254 \sqrt{2.78}} = 17.71 \text{ GHz}$$

d. From Eq. 3.198

$$\alpha_d = \frac{2\pi}{\underset{0.10}{\cancel{0.20}}} \times \frac{\overset{1.89}{\cancel{3.78}} \times 1.947 \times 10^{-4}}{\cancel{2}\sqrt{2.947}\,(2.78)} \times 8.686 = 2210 \times 10^{-4} \text{ dB/m}$$

$$= 0.021 \text{ dB/m}$$

3. (25 points)

Pts

8 a. Draw a flow graph for a transistor amplifier with S-parameters given in the following:

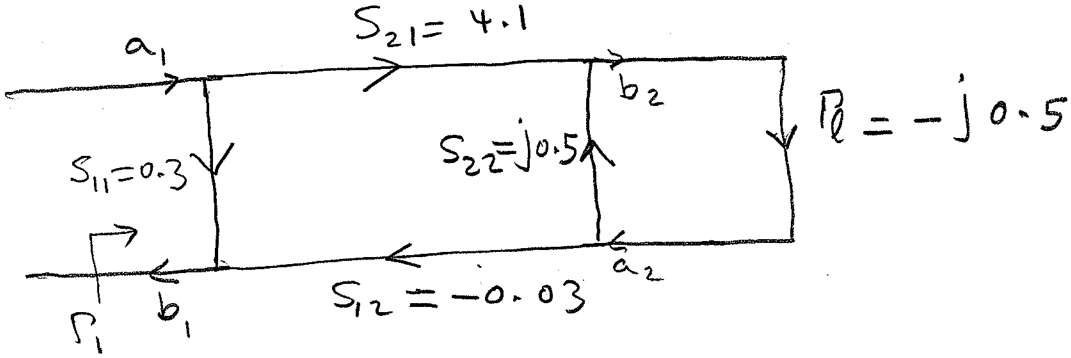
$$[S] = \begin{bmatrix} 0.3 & -0.03 \\ 4.1 & 0.5\angle 90^\circ \end{bmatrix}$$

8 b. Calculate the reflection coefficient at port ① if port ② is connected to a load of reflection coefficient

$$\Gamma_\ell = S_{22}^* = 0.5\angle -90^\circ \qquad \text{or} \qquad \text{-j0.5}$$

9 b. Calculate the power coupled to the "conjugate-matched" load given in part b if the input power $a_1 a_1^* = 0.08\text{W}$.

3.



$$\Gamma_1 = \frac{b_1}{a_1} = S_{11} + \frac{S_{21}\Gamma_L S_{12}}{1 - S_{22}\Gamma_L} = 0.3 + \frac{(-0.03)(-j0.5)(4.1)}{1-(j0.5)(-j0.5)}$$

$$= 0.3 + \frac{0.0615j}{~~1-0.25~~\ 0.75} = 0.3 + j0.082$$

$$= 0.311 \angle 15.29^\circ$$

$$\frac{b_2}{a_1} = \frac{S_{21}}{1 - S_{22}\Gamma_\ell} ~~a_1~~ = \frac{4.1}{0.75} = 5.467$$

Power coupled to the load $b_2 b_2^* - a_2 a_2^* = (5.467)^2 a_1 a_1^* \left[1 - |\Gamma_\ell|^2\right] = (5.467)^2 \left[1 - 0.25\right] a_1 a_1^*$

$$= 1.793 \text{ W}$$

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Score:

Problem 1	________	of a possible	25	points
Problem 2	________	of a possible	25	points
Problem 3	________	of a possible	25	points
Total	________	of a possible	75	points