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. I

October 3, 2014

1. (25 points)

Design a coaxial line of characteristic impedance $Z_o = 60$ ohms using a dielectric filler medium $\varepsilon_r = 1.9$. For this coaxial line,

Pts		
5	a.	Calculate the ratio of the radii b/a of outer and inner conductors.
8	b.	Assuming a = 2.5 mm, calculate the loss α_c in dB/m at a frequency of 6 GHz. Assume copper as the material for the conductors of the coaxial line.
8	c.	The dielectric loss α_d in dB/m given that the loss tanget for the filler medium $\tan \delta = 0.001$.
4	d.	The length of the line needed to get a total attenuation of less than 1 dB.

Midterm I Solutions October 3, 2014

1. a. For a coaxial line, from Table 2.1 of the Text

$$Z_0 = \sqrt{\frac{L_\ell}{C_\ell}} = \frac{60}{\sqrt{\epsilon_r}} \ln\left(\frac{b}{a}\right) = 60\,\Omega$$

$$\frac{b}{a} = e^{\sqrt{\epsilon_r}} = e^{\sqrt{1.9}} = 3.97$$

Radius b of the outer Conductor $= 3.97\,a = 9.925$ mm

b. From Ex. 2.6 of the Text

$$R_s = 1.988\sqrt{\frac{f_{MHz}}{\sigma}} = 1.988\sqrt{\frac{6000}{5.813\times10^{7}}}\ 10^{4} = \boxed{0.0202\,\Omega/\square}$$

$$\alpha_c\Big|_{\text{nepers/m}} = \frac{1}{2}\left[\frac{R_s}{\eta_\epsilon \ln(b/a)}\left(\frac{1}{a}+\frac{1}{b}\right)\right]$$

$$= \frac{1}{2}\,\frac{R_s}{2\pi Z_0}\left(\frac{1}{a}+\frac{1}{b}\right)$$

$$\boxed{\eta_\epsilon \ln\left(\frac{b}{a}\right) = \frac{120\pi}{\sqrt{\epsilon_{eff}}}\ln\frac{b}{a} = 2\pi Z_0}$$

$$= \frac{0.0202}{4\pi\times60}\left(\frac{1}{2.5}+\frac{1}{9.925}\right)\times10^{3}$$

$$= \frac{20.2}{240\pi}\times0.5 = 0.0134 \text{ nepers/m} \times 8.686$$

$$= 0.1165 \text{ dB/m}$$

c. $$\alpha_d\Big|_{\text{dB/m}} = \frac{1}{2}\,\omega\epsilon''\eta_\epsilon\times8.686 = \frac{1}{\cancel{2}}\cancel{2}\pi\times6\times\cancel{10^{9}}\times\cancel{10^{-3}}\times8.85\times\cancel{10^{-12}}\,10^{6}\times\sqrt{1.9}\times\frac{377}{\cancel{\sqrt{1.9}}}\times8.686$$

$$= 6\pi\times8.85\times0.377\times10^{-3}\times8.686\sqrt{1.9}$$

$$= 0.753 \text{ dB/m}$$

d. $\alpha_c + \alpha_d = 0.8695$ dB/m

length for a total attn of 1 dB $= \frac{1}{0.8695} = \boxed{1.15\text{ m}}$

2. (25 points)

Pts

8 a. Sketch the equivalent circuit of the microstripline circuit shown in Fig. 1.

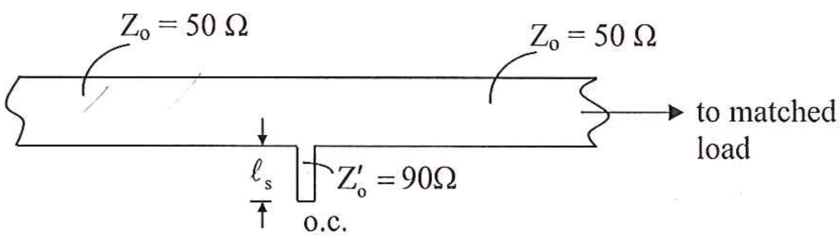


Fig. 1. Shown here is the printed microstrip with an open-circuited shunt stub.

Note that the open-circuited stubline may be represented by an admittance

$$Y_{stub} = jY_o' \tan\left(\frac{2\pi \ell_s}{\lambda_g}\right)$$

across the main microstripline of $Z_o = 50\ \Omega$.

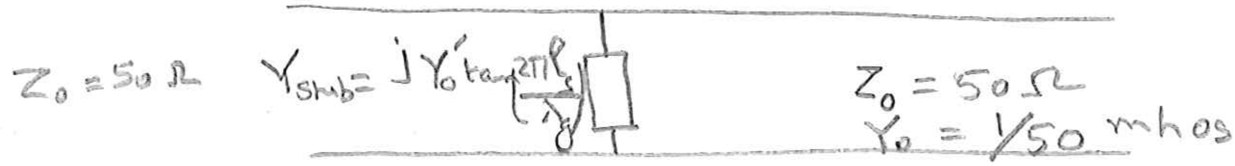
8 b. Calculate the length of the shunt stub to get $Y_{stub} = \infty$ [$Z_{stub} = 0$] at a frequency of 6000 MHz given that $\varepsilon_{eff} = 2.8$ for the shunt stubline.

Short cct.

9 c. Using this length of the shunt stub, calculate the admittance that the shunt stub presents across the microstripline at 3000 MHz where $\ell_s = \lambda_g/8$. Is this a capacitance or an inductance, and what is the value of this shunt element across the transmission line?

C = 0.59 pF

2. a. EQVT cct. is as shown below



b. To get $Y_{stub} = \infty$ or $Z_{stub} = 0$ we need a length $l_s = \lambda_g/4$ at 6000 MHz

$$l_s = \frac{\lambda_0}{4}\frac{1}{\sqrt{\epsilon_{eff}}} = \frac{5}{4}\frac{1}{\sqrt{2.8}} = 0.747 \text{ or } 7.47 \text{ mm}$$

c. once this length l_s has been calculated

$$Y_{stub} = j\,Y_0' \tan 45^\circ \quad \text{at } 3000\,\text{MHz}$$

$$= j\frac{1}{90}$$

This is a capacitance which can be calculated from

$$j\omega C_{eq}\Big| = j\frac{1}{90}$$

$$C_{eq}\Big|_{3000\,MHz} = \frac{1}{90 \times 2\pi \times 3 \times 10^9} = \boxed{0.589 \text{ pF}}$$

3. (25 points)

Pts

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

$$[S] = \begin{bmatrix} 0.4\angle -45° & 0.4 \\ 3.5 & 0.4\angle 45° \end{bmatrix}$$

8 b. Calculate the power delivered to a fully matched load with $\Gamma_\ell = 0$. It is given that $a_1 a_1^* = 0.05\text{W}$.

8 c. Calculate the power delivered to a conjugate matched load with $\Gamma_\ell = S_{22}^* = 0.4\angle -45°$.

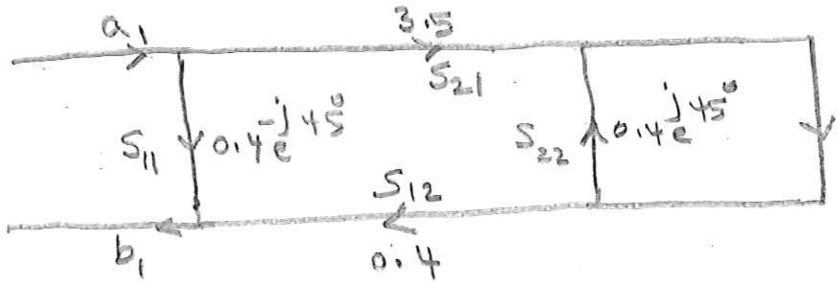
4 d. How much higher is the power delivered for condition c as compared to the power for the fully matched load of condition b in this problem?

For 10 extra points:

6 e. Calculate the power input to the amplifier $a_1 a_1^* - b_1 b_1^*$ for conditions b and c, and

4 f. the power gains of the amplifier for conditions b and c above.

3.a. The flow graph for the transistor amplifier is sketched below



b. For a fully matched load $\Gamma_\ell = 0$

$$\frac{b_2}{a_1} = S_{21}$$

Power delivered to this fully matched load $= b_2 b_2^* = |S_{21}|^2 a_1 a_1^*$

$$= (3.5)^2 a_1 a_1^* = (3.5)^2 \times 0.05 = \boxed{0.6125\ \mathrm{W}}$$

c. Power delivered to a conjugate matched load $\Gamma_\ell = S_{22}^* = 0.4e^{-j45°}$

$$= b_2 b_2^* (1-|\Gamma_L|^2) = \left| S_{21} + \frac{S_{22} S_{21} \Gamma_\ell}{1 - S_{22}\Gamma_\ell} \right|^2 a_1 a_1^* \left[1-|\Gamma_L|^2\right]$$

$$= \left| 3.5 + \frac{3.5\,|\Gamma_\ell|^2}{1-|S_{22}|^2} \right|^2 a_1 a_1^* \times 0.84$$

$$= \left| 3.5 + \frac{3.5 \times 0.16}{0.84} \right|^2 a_1 a_1^* \times 0.84$$

$$= (4.167)^2 \underbrace{a_1 a_1^*}_{0.05} = 0.729\ \mathrm{W}$$

The power delivered to the conjugate matched load is 19.1 % higher than that for the fully matched load.

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e. $P_{in}\Big|_{\substack{\text{Condition b} \\ \Gamma_L = 0}} = a_1 a_1^*\left[1-|S_{11}|^2\right] = 0.05 \times 0.84 = 0.042\,\mathrm{W}$

$P_{in}\Big|_{\text{Cond. c}} = a_1 a_1^* \left[1 - |\Gamma_{in}|^2\right] = \boxed{0.039}\,\mathrm{W}$

$$\Gamma_{in} = \frac{S_{11}(1-|S_{22}|^2) + S_{21}\Gamma_\ell S_{12}}{1-|S_{22}|^2}$$

$$= S_{11} + \frac{3.5 \times 0.4 \times 0.4e^{-j45°}}{1-0.16}$$

$$= 0.4e^{-j45°}\left[1 + \frac{1.4}{0.84}\right] = 1.067\,e^{-j45°}$$

f. $\text{Power gain}\Big|_{\text{Cond. b}} = \frac{0.6125}{0.042} = \boxed{14.58}$

See next page for condition c which can be turned into an oscillator.

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Solution of Prob. 3 — Continued

e. It is interesting that the reflected power $b_1 b_1^*$ is more than $a_1 a_1^*$. This is because of amplification of S_{21} in the forward path.

Such an amplifier is potentially unstable unless the reflected power $b_1 b_1^*$ is terminated into an absorbing load. Such an amplifier is also capable of being turned into an <u>oscillator</u>.

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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