ECE 540 Final Exam –Take Home

Winter Quarter, 1998

Name: Key   Date: ________________

Time picked up: ________________
Time returned: ________________

You may use any books, notes, computer, calculator, etc. Show complete solutions including your work. PLEASE do NOT consult with any person (other students, instructors, etc.) about this exam.

1. Design a single stub tuner to match an antenna with $Z_L = 25 + j25\Omega$ to a 50Ω microstripline.

Specify: Parallel or series stub ____________

Open or short circuit stub ________

Justify your choice of the type of tuner you choose.

Distance from load to stub d = ~~0.0433 λ~~ 0.0738λ

Length of stub L = ~~0.0898λ~~ 0.125λ

~~$Z_{Ln} = \frac{Z_L}{Z_0} = \frac{25+j50}{50} = \frac{1}{2}+j1$~~

~~Using TLine software~~

~~Rotate TWG 0.0433λ = d to matching circle~~

~~Read Z_{LSn} = 1 + j 1.58~~

~~Stub needs to have Z_S = −j1.58~~

~~Plot on Smith Chart~~

~~Rotate TWL 0.0898λ = L~~

parallel open
d = 0λ
or 0.5λ
l = 0.125λ

$Z_{Ln} = \frac{Z_L}{Z_0} = \frac{25+j25}{50} = \frac{1}{2} + j\frac{1}{2}$

Plot on Smith Chart (I used TLine software)

Rotate TWG $\boxed{0.0738\ \lambda = d}$ to matching circle

Read Z_n = 1 + j

Stub needs to have Z_S =

Plot on smith chart, Rotate TWL to Zopen.

$\boxed{L = 0.125\lambda}$

2. Design a double stub tuner to match the same antenna to a 50 Ω co-axial line.

Distance from load to first stub = 0.1λ
Distance between stubs = 0.3λ

Specify: Parallel or series stub ___________

Open or short circuit stub ________

Justify your choice of tuner.

Length of first stub (nearest load) _________

Length of second stub (nearest source) __________

Plot $z_{nb} = \frac{1}{2} + j\frac{1}{2}$. Convert to admittance.

Rotate 0.1λ TWG

Rotate matching circle 0.3λ TWL

Move along constant R circle to rotated matching circle

Option 1

Length of Stub 1 = ~~0.523λ~~ 0.173λ

2 = 0.0905λ

Option 2

L1 = 0.331λ

L2 = 0.30...

Series Short

L1 = No Sol^n L1 =

L2 = L2 =

3.

(a) Choose a circular waveguide (see attached table) for use transmitting a signal at 9GHZ.

WC109

WC94

$f_{c\,mn} = \frac{p'_{nm}\,(c)}{2\pi a\sqrt{\varepsilon_r}}$ TE

$TM = \frac{p_{nm}\,(c)}{2\pi a\sqrt{\varepsilon_r}}$

a = inner radius = $\frac{1.094''}{2}$

a = 0.013894m

$\varepsilon_r = 1.0$ air

$c = 2.996e8$ m/s

(b) Specify the first four modes of this waveguide and their frequencies.

$p_{01} = 2.405$

$p'_{01} = 3.832$

$p'_{11} = 1.841$

$p'_{21} = 3.054$

TE_{11} f_{c11} = ~~6.32~~ 6.32 GHz

TM_{01} f_{c01} = 8.256 GHz

TE_{21} f_{c21} = 10.48 GHz

TE_{01} f_{c01} = 16.316 GHz

(c) What range of frequencies do you recommend using this waveguide for?

Range of TE_{11} mode is 6.32 GHz − TE_{21} 10.48 GHz

Need to stay in this range. Manufactures chooses above TE_{11} and below TE_{21} ... 7.27 − 9.97 GHz

TM_{01} mode is suppressed by not exciting it (feed system)

(d) Why?

(e) How far can you propagate the 9GHZ signal on this waveguide before it is attenuated to 50% of its original magnitude?

$R_{s\,copper} = \sqrt{\frac{\omega\mu_0}{Z_o}} = 0.025\ \Omega$

$\sigma_{Cu} = 5.813\times10^{7}$ S/m

$\alpha = \alpha_c + \alpha_d$

↑ dielectric loss = 0 in air

$\alpha_c = \frac{R_s}{ak\eta\beta}\left(k_c^2 + \frac{k^2}{p_{01}^2 - 1}\right) = 0.00497$ Np/m

$k = \frac{2\pi}{\lambda}$ $k_c =$

$\beta = \sqrt{k^2 - k_c^2}$

$e^{-\alpha z} = 0.5$

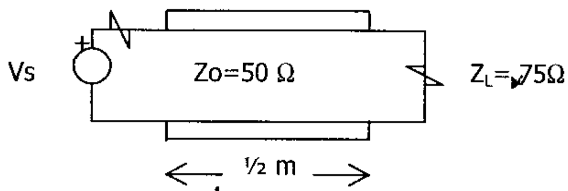
$z = 139.5$ m

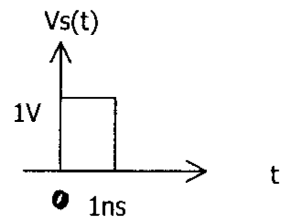
TABLE 4.3. Some standard circular waveguides.

EIA Designation	Inside Dimensions (Inches)			Recommended Frequency Range GHz
	Diameter	Tolerance + or −	Roundness Tolerance	
WC 992	9.915	.010	.010	0.803–1.10
WC 847	8.470	.008	.008	0.939–1.29
WC 724	7.235	.007	.007	1.10–1.51
WC 618	6.181	.006	.006	1.29–1.76
WC 528	5.280	.005	.005	1.51–2.07
WC 451	4.511	.005	.005	1.76–2.42
WC 385	3.853	.004	.005	2.07–2.83
WC 329	3.292	.003	.003	2.42–3.31
WC 281	2.812	.003	.003	2.83–3.88
WC 240	2.403	.0025	.002	3.31–4.54
WC 205	2.047	.002	.002	3.89–5.33
WC 175	1.750	.0015	.0015	4.54–6.23
WC 150	1.500	.0015	.0015	5.30–7.27
WC 128	1.281	.0013	.0013	6.21–8.51
WC 109	1.094	.001	.0011	7.27–9.97
WC 94	0.938	.0009	.0009	8.49–11.6
WC 80	0.797	.0008	.0008	9.97–13.7
WC 69	0.688	.0007	.0007	11.6–15.9
WC 59	0.594	.0006	.0006	13.4–18.4
WC 50	0.500	.0005	.0005	15.9–21.8
WC 44	0.438	.00045	.0004	18.2–24.9
WC 38	0.375	.00038	.0004	21.2–29.1
WC 33	0.328	.00033	.0003	24.3–33.2
WC 28	0.281	.00028	.0001	28.3–38.8
WC 25	0.250	.00025	.0001	31.8–43.6
WC 22	0.219	.00025	.0001	36.4–49.8
WC 19	0.188	.00025	.00007	42.4–58.1
WC 17	0.172	.00025	.00007	46.3–63.5
WC 14	0.141	.00025	.00005	56.6–77.5
WC 13	0.125	.00025	.00005	63.5–87.2
WC 11	0.109	.00025	.00005	72.7–99.7
WC 9	0.094	.00025	.00005	84.8–116

4. A 50Ω lossy microstripline has $\alpha = 0.1$ N_p/m, $V_p = 2 \times/10^8$ m/s, $\beta = 0.7$ rad/m and is ½ m long.

(a) Sketch the time domain voltage at the load for the first 30 ns.
Rg = 100Ω



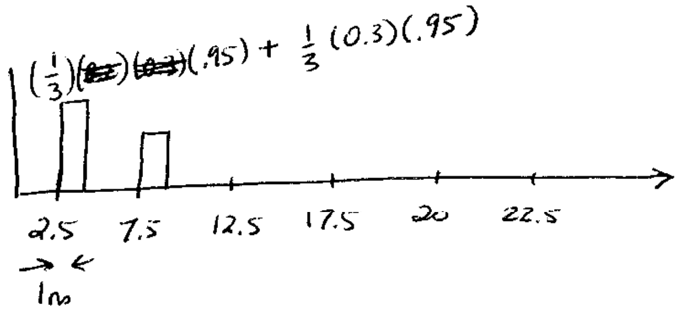


$$T = \frac{d}{v} = \frac{0.5}{2 \times 10^8} = 2.5\,ns$$

$$V_{in} = V_s \frac{Z_0}{Z_0 + R_g} = \frac{1}{3} V$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{75-50}{75+50} = 0.2$$

$$\Gamma_s = \frac{Z_g - Z_0}{Z_g + Z_0} = \frac{100-50}{100+50} = 0.3$$



(b) How long (in seconds) do you expect it to be before the pulses observed at the load are less than 0.01 V in magnitude?

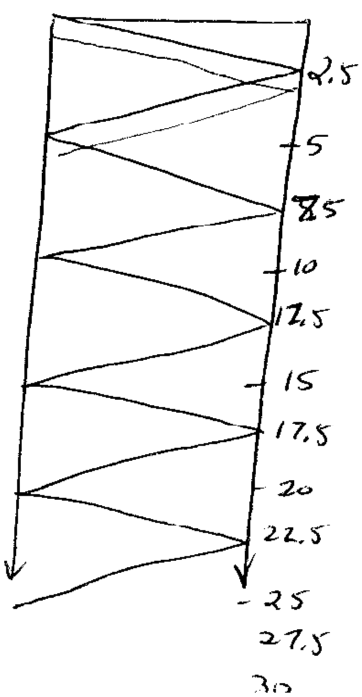
attenuation

$$e^{-\alpha z} = e^{-(0.1)(0.5)} = 0.95 \text{ each path}$$

~~[illegible]~~ $e^{-\alpha z} = 0.01 \rightarrow z = 46$ m

$\boxed{t = \frac{z}{v} = 230\,ns}$ attenuation only

(c) Sketch the voltage on the line as a function of distance at 30 ns.



pulses:
2nd pulse will already be below 0.01 V

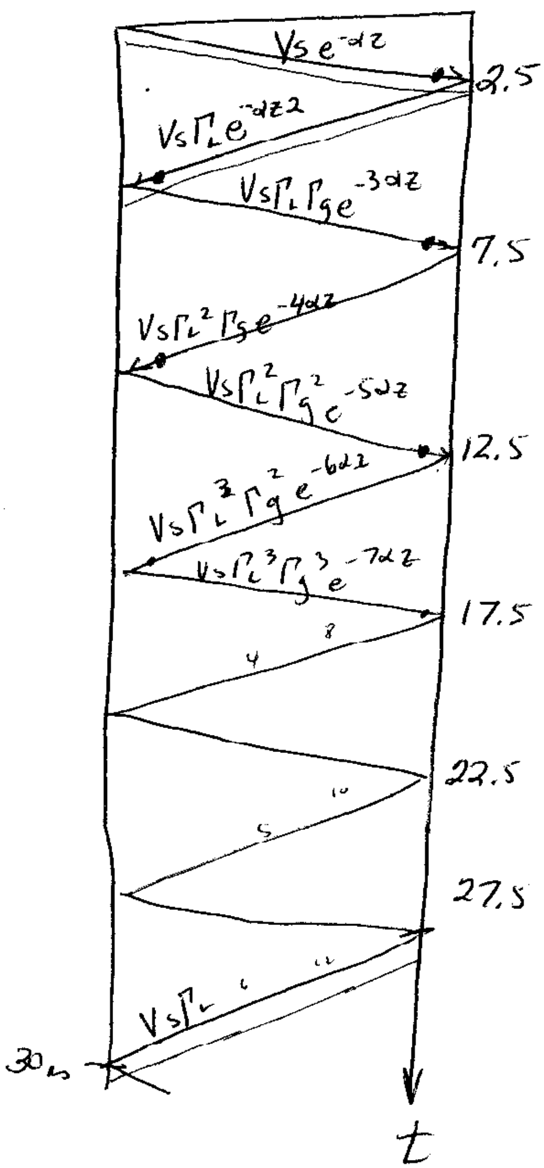
4)

$$V_{in} = V_s \frac{Z_0}{Z_0 + R_g} = \frac{1}{3} V$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{75-50}{75+50} = 0.2$$

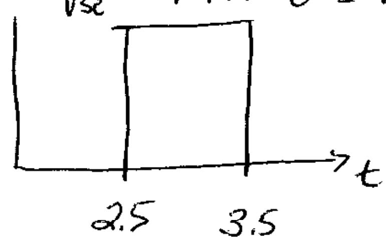
$$\Gamma_g = \frac{Z_g - Z_0}{Z_g + Z_0} = \frac{100-50}{100+50} = 0.3$$

attenuation per trip $e^{-\alpha z} = e^{-(0.1)(0.5)} = 0.95$

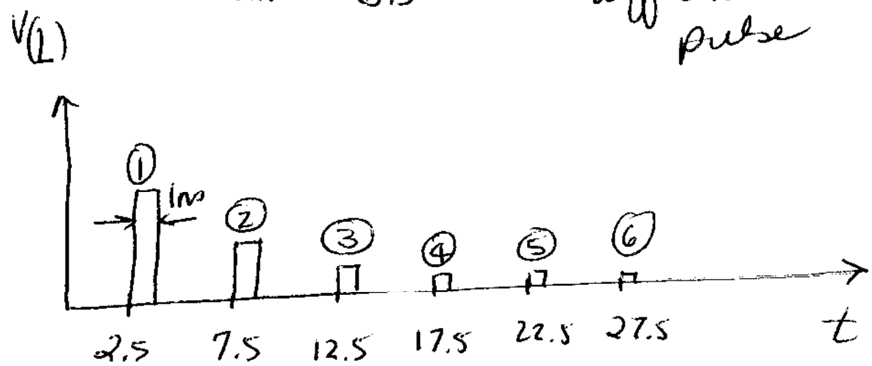


Examine first pulse at load

$V_s e^{-\alpha z} + V_s \Gamma_L e^{-\alpha z} = V_s (e^{-\alpha z} + \Gamma_L e^{-\alpha z})$



Neglecting attenuation difference over pulse



① $V_1 = V_s e^{-\alpha z} + V_s e^{-\alpha z} \Gamma_L = V_s e^{-\alpha z} (1 + \Gamma_L)$

② $V_2 = V_s \Gamma_L \Gamma_g e^{-3\alpha z} (1 + \Gamma_L)$

③ $V_3 = V_s \Gamma_L^2 \Gamma_g^2 e^{-5\alpha z} (1 + \Gamma_L)$

④ $V_4 = V_s \Gamma_L^3 \Gamma_g^3 e^{-7\alpha z} (1 + \Gamma_L)$

⑤ $V_5 = V_s \Gamma_L^4 \Gamma_g^4 e^{-9\alpha z} (1 + \Gamma_L)$

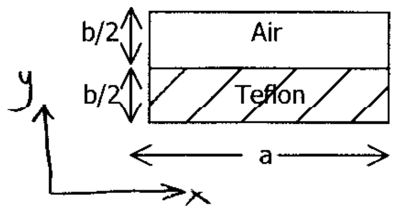
⑥ $V_6 = V_s \Gamma_L^5 \Gamma_g^5 e^{-11\alpha z} (1 + \Gamma_L)$

$z = 0.5m$

$V_0 = V_s \Gamma_L^6 \Gamma_g^5 e^{-12\alpha z} + V_s \Gamma_L^6 \Gamma_g^6 e^{-12\alpha z}$

5. Derive the electric and magnetic fields in the partially-filled WR98 waveguide shown below:

TE_{0n} modes only



For TE modes $E_z = 0$

For on modes $\partial/\partial x = 0$

$$\left(\frac{\partial^2}{\partial y^2} + K_1^2\right) H_{z_1} = 0 \quad \text{for teflon} \quad 0 \le y \le b/2$$

$$\left(\frac{\partial^2}{\partial y^2} + K_2^2\right) H_{z_2} = 0 \quad \text{for air} \quad \frac{b}{2} \le y \le b$$

Guess $H_{z_1} = (A_1 \cos k_1 y + B_1 \sin k_1 y)\cancel{(C_1 \cos k_1 x + D_1 \sin k_1 x)}$ on

$H_{z_2} = (A_2 \cos k_2 (b-y) + B_2 \sin k_2 (b-y))\cancel{(C_2 \cos k_2 x + D_2 \sin k_2 x)}$ on

Need E_x for boundary conditions (remember $\partial/\partial x = 0$)

$$\begin{cases} E_{x_1} = \dfrac{-j\omega\mu_0}{k_1^2}\dfrac{\partial H_{z_1}}{\partial y} = \dfrac{-j\omega\mu_0}{k_1^2}\left(-A_1 k_1 \sin k_1 y + B_1 k_1 \cos k_1 y\right) \cancel{(C_1 \cos k_1 x + D_1 \sin k_1 x)} \text{ on} \\ E_{x_2} = \dfrac{-j\omega\mu_0}{k_2^2}\left(-A_2 k_2 \sin k_2 (b-y) + B_2 k_2 \cos k_2 (b-y)\right) \cancel{(C_1 \cos k_1 x + D_1 \sin k_1 x)} \text{ on} \end{cases}$$

Boundary conditions on E_x

$E_{x_1}(y=0) = 0 \longrightarrow B_1 = 0 \qquad 0 = \frac{j\omega\mu_0}{k_1}(A_1 \cancel{\sin 0}^{0} + B_1 \cos 0)$

$E_{x_2}(y=b) = 0 \qquad 0 = \frac{j\omega\mu_0}{k_2}(A_2 \sin k_2 0 - B_2 \cos k_2 0)$

$E_{x_1}(y=b/2) = E_{x_2}(y=b/2) \longrightarrow B_2 = 0$

$$\frac{\cancel{j\omega\mu_0}}{k_1} A_1 \sin k_1 b/2 = \frac{\cancel{j\omega\mu_0}}{k_2}\left(A_2 \sin k_2 b/2 + \cancel{B_2}^{0} \cos k_2 b/2\right)$$

$$\left.\frac{A_1}{k_1}\sin\frac{k_1 b}{2} = \frac{A_2}{k_2}\sin\frac{k_2 b}{2}\right]$$ Knowing k_1 and k_2 we could find A_1/A_2

~~Need E_y for boundary conditions~~

$$\cancel{E_{y_1} = \frac{j\omega\mu}{k_1^2}\frac{\partial H_{z1}}{\partial y} = \frac{j\omega\mu}{k_1^2} A_1 k_1 \sin k_1 y}$$

Apply center BC on Hz also

$$H_{z_1}(b/2) = H_{z_2}(b/2)$$

$$\underline{A_1} \cos k_1 b/2 = A_2 \cos k_2 b/2$$

Combine these equations

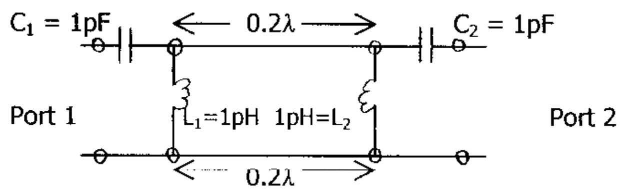
$$\frac{\cancel{A_1} \cos b/2k_1 = \cancel{A_2} \cos k_2 b/2}{\frac{\cancel{A_1}}{k_1} \sin k_1 b/2 = \frac{\cancel{A_2}}{k_2} \sin k_2 b/2}$$

$$k_1 \tan k_1 b/2 = k_2 \tan k_2 b/2$$

Solve numerically for k_1 & k_2

6.

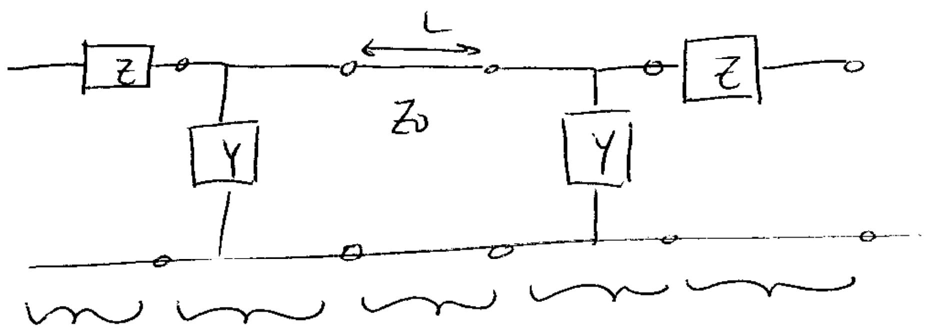
(a) Derive the S-parameters for the circuit below. Line lengths not shown are assumed to be zero length.



F = 1GHZ

(b) If a 75Ω load is connected to port 2 and a 1V source is input to port 1 (V^+ = 1V) how much power is delivered to the load?

(a)



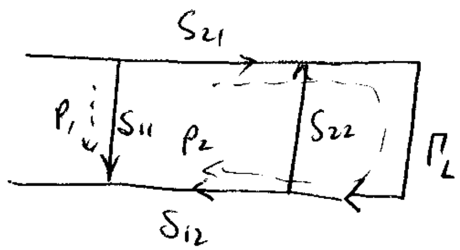
ABCD matrices

$$\begin{bmatrix} 1 & 1/j\omega C \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & \cancel{1/j\omega L}\ 0 \\ 1/j\omega L & 1 \end{bmatrix}\begin{bmatrix} 0.3 & j47.5 \\ j0.019 & 0.3 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 1/j\omega L & 1 \end{bmatrix}\begin{bmatrix} 1 & 1/j\omega C \\ 0 & 1 \end{bmatrix}$$ Using Matlab.

$$= \begin{bmatrix} -0.19 & j\,3.05 \\ -j\,.0001 & -.0192 \end{bmatrix} \times 10^{10}$$ ← ABCD

Convert to S $= \begin{bmatrix} .8 - j.57 & \sim 0 \\ \sim 0 & .8 - j.57 \end{bmatrix}$

(b)



Using Mason Loop Rules

$$S_{11}' = \frac{S_{11}\,(1 - S_{22}\Gamma_L) + S_{21}\Gamma_L S_{12}\,(1-0)}{1 - S_{22}\Gamma_L} \cong .82 - j.57$$

$$S_{12}' = \frac{S_{12}\,(1-0)}{1 - S_{22}\Gamma_L} \cong 0$$

$$S_{21}' = \frac{S_{21}\,(1-0)}{1 - S_{22}\Gamma_L} \sim 0$$

$$S_{22}' = \frac{S_{22}\,(1-0)}{1 - S_{22}\Gamma_L} \cong .86 - j\,.80$$

$V_2^+ = 0 \qquad V_2 = V_2^- = S_{21}' V_1^+ \cong 0$

$$P = \frac{V_2^2}{Z_L} \sim 0$$

Grading/Points Possible

Name ______________________

Problem 1 ____________ / 30 points

Problem 2 ____________ / 35 points

Problem 3 ____________ / 35 points

Problem 4 ____________ / 30 points

Problem 5 ____________ / 40 points

Problem 6 ____________ / 30 points

Total ______________________ / 200 points