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EE 529: Selected Topics in Communications
Second Exam (Spring 2018) April 10th, 2018

3.5

Question 1 (6 pts)

Design a three-port resistive divider for an equal power split and a 100 Ω system impedance.
a) If port 3 is matched, calculate the change in output power at port 3 (in dB) when port 2 is connected first to a matched load, and then to a load having a mismatch of Γ = 0.3. Assume the incident voltage from port 1 is 1 V.

$\boxed{R = \frac{100}{3} = 33.3\,\Omega}$

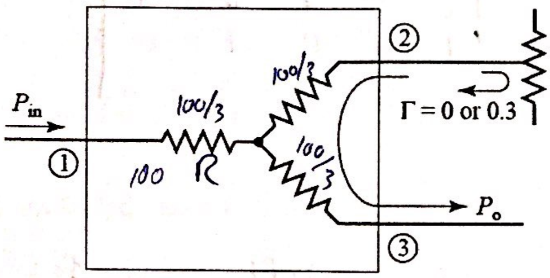
$P_3 = \frac{1}{2}\frac{|V_3|^2}{Z_3}$

$\boxed{Z_3 = R + Z_0 = 133.3\,\Omega}$

$V_3 = V_3^+ + V_3^-$

$P_2 = P_3 = \frac{1}{2}P_1 \times \frac{1}{4}$

3dB will be lossed in the resistors.



*case (1): port is matched.

so $V_2^+ = V_3^+ = 0$

$V_3 = V_3^-$, $V_2 = \cancel{V_2^+} + V_2^-$

$V_1 = 1\angle 0$ volt.

$V_2 = \frac{1}{2}V_1 = 0.5.$

$$\begin{bmatrix} V_1^- \\ V_2^- \\ V_3^- \end{bmatrix} = \begin{bmatrix} 0 & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & 0 \end{bmatrix} \begin{bmatrix} V_1^+ \\ V_2^+ \\ V_3^+ \end{bmatrix}$$

$\cancel{\frac{1}{4}P_1} =$

$V_2 = V_3 = \frac{1}{2}V_1 = 0.5$ volt.

~~$V_2 = V_2^+ + V_2^-$~~

~~$V_2 = P|V_2^+|$~~

~~$V_1^+ = 1\angle 0$~~

$V_3^- =$

so $P_3 = \frac{1}{2} \times \frac{(0.5)^2}{100 + 33.3} = 9.38 \times 10^{-4}$ W

$\boxed{P_3 = -30.3 \text{ dB}}$

* Case (2):

$V_3 = V_3^-$, $V_2 = V_2^+ + V_2^- \Rightarrow V_2 = 1.3\,V_2^+$

$V_1^- = S_{12}V_2^+$ $\boxed{V_2^- = (0.3)\,V_2^+}$

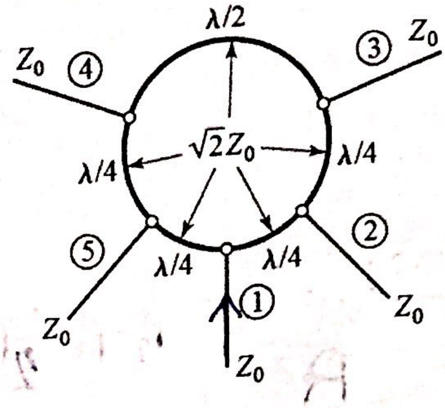
$P_3 = \frac{1}{2}\frac{|V_3^-|^2}{133.33} = \frac{|0.35|^2}{2 \times 133.33} = 4.6 \times 10^{-4}$ W.

$\boxed{P_3 = -33.4 \text{ dB}}$

5.5

Question 2 (7 pts)

For the symmetric hybrid shown below. If port 1 is fed with an incident wave of 1∠0 V. Assume that the outputs are matched.



a) Construct the scattering matrix.

$$[S] = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 \end{bmatrix}$$

2.5

b) Calculate the phase between ports 3 and 4.

$$\text{phase shift}_{(3\&4)} = \lambda/2 = 180^\circ$$

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c) What is the coupler properties?

① Matched for all ports.

② The Power is divided equally.

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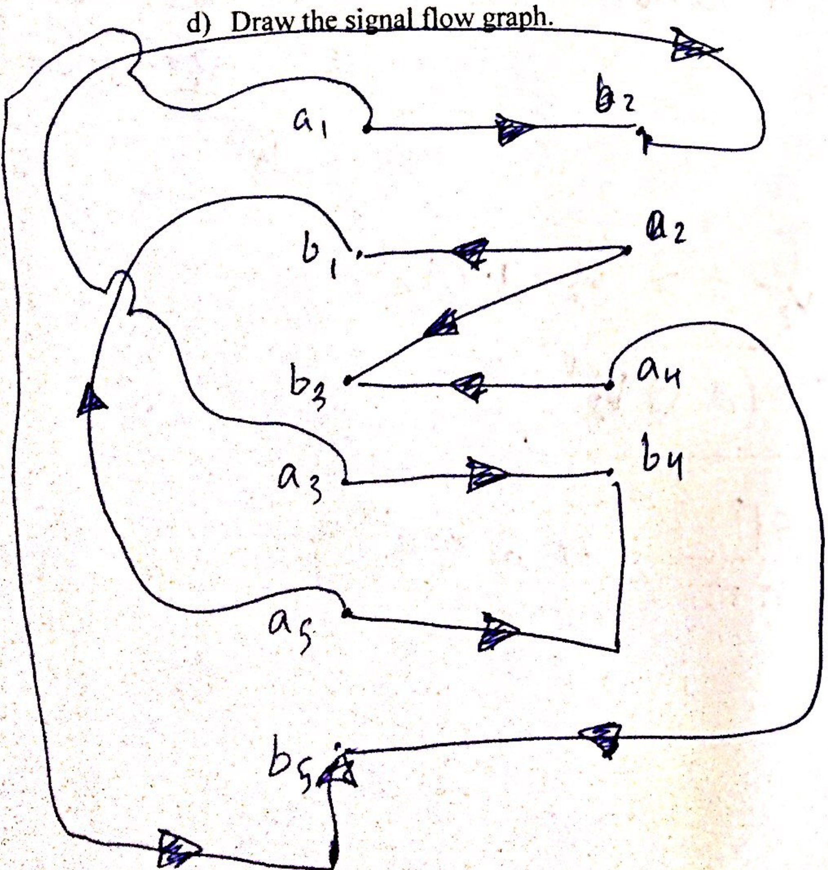
d) Draw the signal flow graph.



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Question 3 (7 pts) 2.5

$\frac{2G - 1.9G}{2} = 0.05\,GHZ = f_c$

To suppress noise in a 50 Ω (R_o) digital communication system a bandpass RF filter is required with a passband from 1.9 GHz to 2 GHz. The minimum attenuation of the filter at 6 GHz and 0.475 GHz should be 25 dB. Assuming that a 0.5 dB ripple in the passband can be tolerated.

a) Design a filter that will use a minimum number of components.
b) Draw the circuit and label all the components.
c) Plot the attenuation as a function of frequency.
d) Determine the frequency in which the attenuation equal to 10 dB.

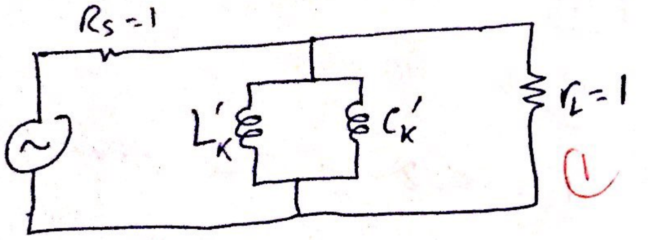
(a) $\left|\frac{\omega}{\omega_c}\right| - 1 = \left|\frac{0.475G}{0.05G}\right| - 1 = 8.5$ so $\boxed{N = 1}$

(b) consider the element is Capacitor

$g_1 = 0.6986$

$L_K' = \frac{\Delta R_o}{\omega_o C_K}$

$\boxed{\Delta = 0.1}$

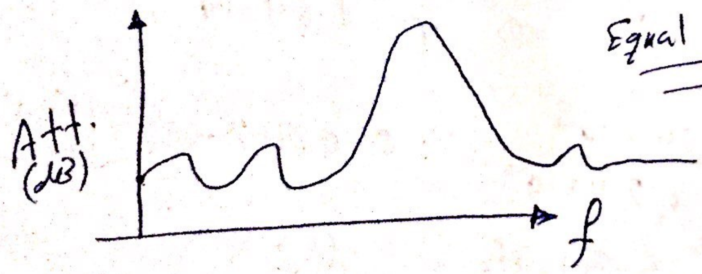


1

$L_K' = \frac{0.1 \times 50}{2\pi \times 50 \times 10^6 \times 0.6986} = 22.78\,nH$

$C_K' = \frac{C_K}{\Delta \omega_o R_o} = \frac{0.6986}{0.1 \times 2\pi \times 50 \times 10^6 \times 50} = 0.445\,nF.$

(c) Equal ripple 0.5 dB.



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(d) @ 10 dB $\Rightarrow \left|\frac{\omega}{\omega_c}\right| - 1 \simeq 7.2$

$\left|\frac{\omega}{\omega_c}\right| = 8.2 \Rightarrow \omega = 8.2\,\omega_c = 8.2 \times 2\pi \times 50 \times 10^6$

$\Rightarrow \omega = 2\pi \times 410 \times 10^6$ rad/s

so $\boxed{f = 410\,MHZ}$

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4.5

Question 4 (5 pts)

Consider a microstrip resonator constructed from a $\lambda/2$ length of 50 Ω open-circuited microstrip line. The substrate is FR-4 ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$), with a thickness of 0.78 mm, and the conductors are copper ($\sigma = 5.813*10^7$ S/m).

a) Compute the required length of the line for resonance at 2.4 GHz, and the unloaded Q of the resonator. Ignore fringing fields at the end of the line.

b) Sketch its equivalent RLC lumped circuit and determine their values.

(a) $Q_o = \frac{\beta}{2\alpha}$ --- (1)

for μstrip: $A = \frac{Z_o}{60}\sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1}\left(0.23 + \frac{0.11}{\epsilon_r}\right)$

$= 1.53$

$B = \frac{377\pi}{2Z_o\sqrt{\epsilon_r}} = 5.65$

Assume $\frac{W}{d} < 2$: $\frac{W}{d} = 1.9 < 2$. True Assumption.

so $W = 0.78\text{mm} \times 1.9 \Rightarrow \boxed{W = 1.482\text{mm}}$

$\epsilon_e = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} * \frac{1}{\sqrt{1+\frac{12}{W/d}}} = 3.329$

so $V_p = \frac{c}{\sqrt{\epsilon_e}} = \frac{3\times10^8}{\sqrt{3.329}} \Rightarrow V_p = 1.64\times10^8$

$\ell = \frac{\lambda}{2} = \frac{V_p}{2f} = \frac{1.64\times10^8}{2\times2.4\times10^9} = 0.0342\text{m} = 3.42\text{cm}$

$\beta = \frac{2\pi f}{V_p} = \frac{2\pi\times2.4\times10^9}{1.64\times10^8} = 91.95$ --- (2)

$\alpha_c = \frac{R_s}{Z_o W} \Rightarrow R_s = \sqrt{\frac{\omega\mu_o}{2\sigma}} = \sqrt{\frac{2\pi\times2.4\times10^9\times4\pi\times10^{-7}}{2\times5.813\times10^7}} = 0.0128\,\text{Np/m}$

$\alpha_d = \frac{K_o\epsilon_r(\epsilon_e-1)\tan\delta}{2\sqrt{\epsilon_e}(\epsilon_r-1)} = \frac{50.3\times4.4(3.329-1)(0.02)}{2\sqrt{3.329}(4.4-1)} = 0.8309\,\text{Np/m}$

$K_o = 50.3$

so $\alpha_{Total} = \alpha_c + \alpha_d = 0.8309 + 0.0128 = 0.8437\,\text{Np/m}$ (3)

Substitute (3) & (2) into (1)

$\Rightarrow \boxed{Q_o = 108.98}$ #

(b) Eqn. cct:

$R = \frac{Z_o}{\alpha\ell} = 1732.83\,\Omega$

$C = \frac{\pi}{2\omega_o Z_o} = 2.083\text{pF}$

$L = \frac{1}{\omega_o^2 C} = 2.111\text{ nH}$