Homework Five

Microwave Resonators, Power Dividers, Couplers, and Filters

Text: Chapter 6-8, 4th Edition, Microwave Engineering, Pozar

1. Consider the loaded parallel resonant RLC circuit shown below. Compute the resonant frequency, unloaded $Q$, and loaded $Q$.

![RLC Circuit Diagram]

2. Consider the resonator shown below, consisting of a $\lambda/2$ length of lossless transmission line shorted at both ends. At an arbitrary point, $z$, on the line, compute the impedances $Z_L$ and $Z_R$ seen looking to the left and to the right, respectively, and show that $Z_L = Z_R^*$. (This condition holds true for any lossless transmission line resonator and is the basis for the transverse resonance technique discussed in Section 3.9.)

![Resonator Diagram]

3. A parallel $RLC$ circuit, with $R = 1000 \, \Omega$, $L = 1.26 \, \text{nH}$, $C = 0.804 \, \text{pF}$, is coupled with a series capacitor, $C_0$, to a 50 $\Omega$ transmission line, as shown below. Determine $C_0$ for critical coupling to the line. What is the resonant frequency?

![Parallel RLC Circuit]

4. A 2 W power source is connected to the input of a directional coupler with $C = 20 \, \text{dB}$, $D = 25 \, \text{dB}$, and an insertion loss of 0.7 dB. Find the output powers (in dBm) at the through, coupled, and isolated ports. Assume all ports to be matched.

5. Design a single-section coupled line coupler with a coupling of 19.1 dB, a system impedance of 60$\Omega$, and a center frequency of 8 GHz. If the coupler is to be made in stripline (edge-coupled), with $\varepsilon_r = 2.2$ and $b = 0.32 \, \text{cm}$ and tan$\delta = 0.01$, find the necessary strip widths and separation. Use ADS to plot the S parameters (both amplitude [dB] and phase [deg]) versus frequency in the range of 6-10 GHz.
6. Consider the general resistive divider shown below. For an arbitrary power division ratio \( \alpha = \frac{P_2}{P_3} \), derive expressions for the resistors \( R_1, R_2, \) and \( R_3 \), and the output characteristic impedances \( Z_{o2} \) and \( Z_{o3} \) so that all ports are matched, assuming the source impedance is \( Z_0 \).

![Resistive Divider Diagram]

7. Consider the general branch-line coupler shown below, with shunt arm characteristic impedances \( Z_a \) and series arm characteristic impedances \( Z_b \). Using an even-odd mode analysis, derive design equations for a quadrature hybrid coupler with an arbitrary power division ratio of \( \alpha = \frac{P_2}{P_3} \), and with the input port (port 1) matched. Assume all arms are \( \lambda/4 \) long. Is port 4 isolated, in general? Validate your design using ADS.

![Branch-Line Coupler Diagram]

8. Find the scattering parameters for the four-port Bagley polygon power divider shown below.

![Bagley Polygon Power Divider Diagram]

9. An input signal \( V_1 \) is applied to the sum port of a 180° hybrid, and another signal \( V_4 \) is applied to the difference port. What are the output signals?

10. Sketch the \( k-\beta \) diagram for the infinite periodic structure shown below. Assume \( Z_0 = 75 \ \Omega \), \( d = 1.0 \) cm, \( k = k_0 \), and \( L_0 = 1.25 \) nH.
11. Design a composite low-pass filter by the image parameter method with the following specifications: \( R_0 = 50 \, \Omega \), \( f_c = 50 \, MHz \), and \( f_{\infty} = 52 \, MHz \). Use ADS to plot the insertion loss versus frequency.

12. Design a low-pass, maximally flat lumped-element filter having a passband of 0–3 GHz, and an attenuation of at least 20 dB at 5 GHz. The characteristic impedance is 75 \( \Omega \). Use ADS to plot the insertion loss versus frequency.

13. Design a low-pass, fourth-order, maximally flat filter using only shunt stubs. The cutoff frequency is 8 GHz and the impedance is 50 \( \Omega \). Use ADS to plot the insertion loss versus frequency.

14. Design a stepped-impedance low-pass filter with \( f_c = 2.0 \, GHz \) and \( R_0 = 50 \, \Omega \), using the exact transmission line equivalent circuit of Figure 8.39a. Assume a maximally flat \( N = 5 \) response, and solve for the necessary line lengths and impedances if \( Z_l = 10 \, \Omega \) and \( Z_h = 150 \, \Omega \). Use the software to plot the insertion loss versus frequency.

15. Design a bandpass filter using three quarter-wave short-circuited stub resonators. The filter should have a 0.5 dB equal-ripple response, a center frequency of 3 GHz, a 20\% bandwidth, and an impedance of 100 \( \Omega \). (a) Find the required characteristic impedances of the resonators, and use ADS (Schematic simulation) to plot the insertion loss from 1 to 5 GHz. (b) Lay out the microstrip implementation of the filter on a Rogers RO4003 substrate having \( \varepsilon_r = 3.55 \), \( d = 0.5 \, mm \), and \( \tan \delta = 0.027 \), and with copper conductors 17 \( \mu \)m thick (Use ADS LinCalc tool to find the microstrip line physical length and width). Use ADS Momentum simulation to plot the insertion loss versus frequency in the passband of the filter, and compare with the lossless case.