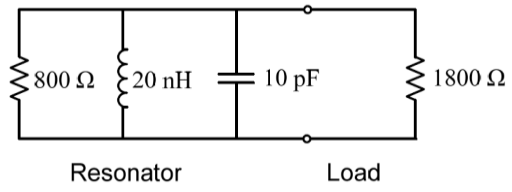
# Homework Five

## Microwave Resonators, Power Dividers, Couplers, and Filters

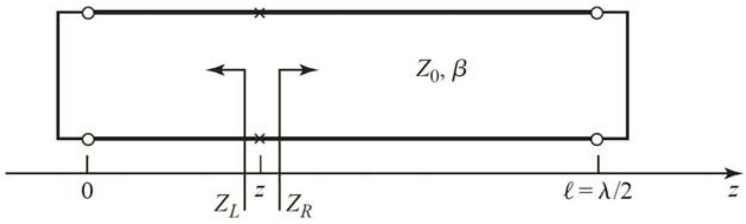
### Text: Chapter 6-8, 4th Edition, Microwave Engineering, Pozar

---

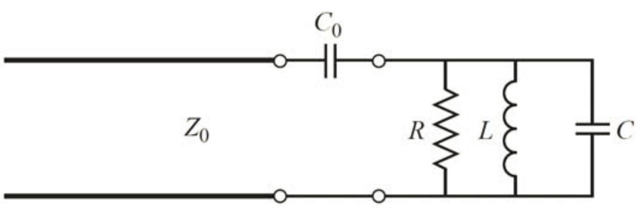
1. Consider the loaded parallel resonant RLC circuit shown below. Compute the resonant frequency, unloaded $Q$, and loaded $Q$.




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.)



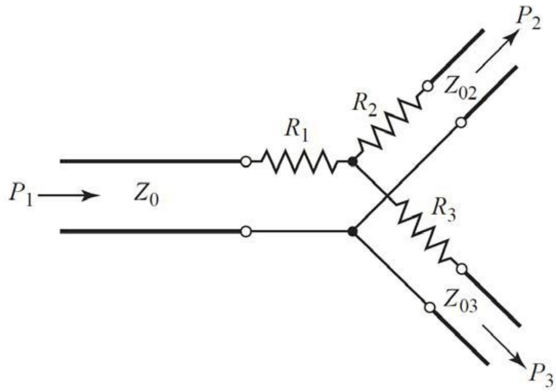

3. A parallel $RLC$ circuit, with $R = 1000\ \Omega$, $L = 1.26$ nH, $C = 0.804$ pF, is coupled with a series capacitor, $C_0$, to a 50 Ω transmission line, as shown below. Determine $C_0$ for critical coupling to the line. What is the resonant frequency?



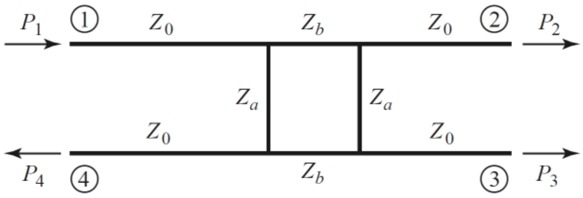

4. A 2 W power source is connected to the input of a directional coupler with C = 20 dB, D = 25 dB, and an insertion loss of 0.7 dB. Find the output powers (in dBm) at the through, coupled, and isolated ports. Assume all ports to be matched.

5. Design a single-section coupled line coupler with a coupling of 19.1 dB, a system impedance of 60Ω, and a center frequency of 8 GHz. If the coupler is to be made in stripline (edge-coupled), with $\varepsilon r = 2.2$ and $b = 0.32$ 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.

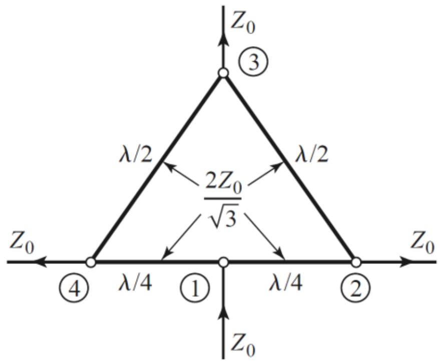
6. Consider the general resistive divider shown below. For an arbitrary power division ratio $\alpha = P_2/P_3$, derive expressions for the resistors $R_1$, $R_2$, and $R_3$, and the output characteristic impedances $Z_{o2}$ and $Z_{o3}$ so that all ports are matched, assuming the source impedance is $Z_0$.




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 $\alpha = P_2/P_3$, 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.

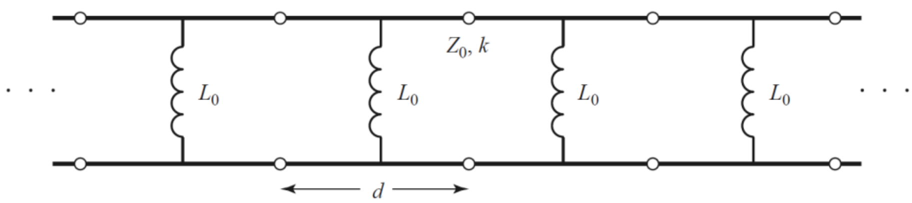



8. Find the scattering parameters for the four-port Bagley polygon power divider shown below.




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 Ω, $f_c$ = 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 Ω. 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 Ω. 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 Ω, 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 Ω and $Z_h$ = 150 Ω. 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 Ω. (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 μm 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.