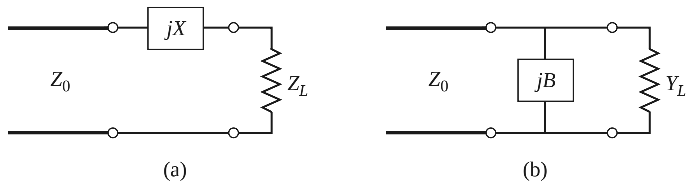
PROBLEMS

5.1 Design two lossless L-section matching circuits to match each of the following loads to a 100 Ω generator at 3 GHz. (a) $Z_L = 150 - j200\ \Omega$ and (b) $Z_L = 20 - j90\ \Omega$.

5.2 We have seen that the matching of an arbitrary load impedance requires a network with at least two degrees of freedom. Determine the types of load impedances/admittances that can be matched with the two single-element networks shown below.



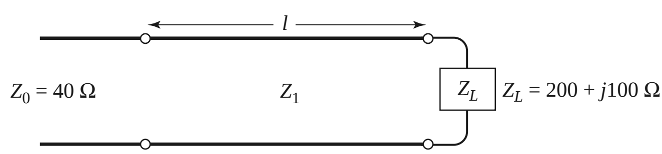
5.3 A load impedance $Z_L = 100 + j80\ \Omega$ is to be matched to a 75 Ω line using a single shunt-stub tuner. Find two designs using open-circuited stubs.

5.4 Repeat Problem 5.3 using short-circuited stubs.

5.5 A load impedance $Z_L = 90 + j60\ \Omega$ is to be matched to a 75 Ω line using a single series-stub tuner. Find two designs using open-circuited stubs.

5.6 Repeat Problem 5.5 using short-circuited stubs.

5.7 In the circuit shown below a load $Z_L = 200 + j100\ \Omega$ is to be matched to a 40 Ω line, using a length ℓ of lossless transmission line of characteristic impedance Z_1. Find ℓ and Z_1. Determine, in general, what type of load impedances can be matched using such a circuit.



5.8 An open-circuit tuning stub is to be made from a lossy transmission line with an attenuation constant α. What is the maximum value of normalized reactance that can be obtained with this stub? What is the maximum value of normalized reactance that can be obtained with a shorted stub of the same type of transmission line? Assume $\alpha\ell$ is small.

5.9 Design a double-stub tuner using open-circuited stubs with a $\lambda/8$ spacing to match a load admittance $Y_L = (0.4 + j1.2)Y_0$.

5.10 Repeat Problem 5.9 using a double-stub tuner with short-circuited stubs and a $3\lambda/8$ spacing.

5.11 Derive the design equations for a double-stub tuner using two series stubs spaced a distance d apart. Assume the load impedance is $Z_L = R_L + jX_L$.

5.12 Consider matching a load $Z_L = 200\ \Omega$ to a 100 Ω line, using single shunt-stub, single series stub, and double shunt-stub tuners, with short-circuited stubs. Which tuner will give the best bandwidth? Justify your answer by calculating the reflection coefficient for all six solutions at $1.1 f_0$, where f_0 is the match frequency, or use CAD to plot the reflection coefficient versus frequency.

5.13 Design a single-section quarter-wave matching transformer to match a 350 Ω load to a 100 Ω line. What is the percent bandwidth of this transformer, for SWR ≤ 2? If the design frequency is 4 GHz, sketch the layout of a microstrip circuit, including dimensions, to implement this matching transformer. Assume the substrate is 0.159 cm thick, with a relative permittivity of 2.2.

5.14 Consider the quarter-wave transformer of Figure 5.13 with $Z_1 = 100\ \Omega$, $Z_2 = 150\ \Omega$, and $Z_L = 225\ \Omega$. Evaluate the worst-case percent error in computing $|\Gamma|$ from the approximate expression (5.42), compared to the exact result.

5.15 A waveguide load with an equivalent TE_{10} wave impedance of 377 Ω must be matched to an air-filled X-band rectangular guide at 10 GHz. A quarter-wave matching transformer is to be used, and is to consist of a section of guide filled with dielectric. Find the required dielectric constant and physical length of the matching section. What restrictions on the load impedance apply to this technique?

5.16 A four-section binomial matching transformer is to be used to match a 12.5 Ω load to a 50 Ω line at a center frequency of 1 GHz. (a) Design the matching transformer, and compute the bandwidth for $\Gamma_m = 0.05$. Use CAD to plot the input reflection coefficient versus frequency. (b) Lay out the microstrip implementation of this circuit on an FR4 substrate having $\epsilon_r = 4.2$, $d = 0.158$ cm, and $\tan\delta = 0.02$, with copper conductors 0.5 mil thick. Use CAD to plot the insertion loss versus frequency.

5.17 Derive the exact characteristic impedance for a two-section binomial matching transformer for a normalized load impedance $Z_L/Z_0 = 1.5$. Check your results with Table 5.1.

5.18 Calculate and plot the percent bandwidth for an $N = 1$-, 2-, and 4-section binomial matching transformer versus $Z_L/Z_0 = 1.5$ to 6 for $\Gamma_m = 0.2$.

5.19 Design a four-section Chebyshev matching transformer to match a 50 Ω line to a 30 Ω load. The maximum permissible SWR over the passband is 1.25. What is the resulting bandwidth? Use the approximate theory developed in the text, as opposed to the tables. Use CAD to plot the input SWR versus frequency.

5.20 Derive the exact characteristic impedances for a two-section Chebyshev matching transformer for a normalized load impedance $Z_L/Z_0 = 1.5$. Check your results with Table 5.2 for $\Gamma_m = 0.05$.

5.21 A load of $Z_L/Z_0 = 1.5$ is to be matched to a feed line using a multisection transformer, and it is desired to have a passband response with $|\Gamma(\theta)| = A(0.1 + \cos^2\theta)$ for $0 \le \theta \le \pi$. Use the approximate theory for multisection transformers to design a two-section transformer.

5.22 A tapered matching section has $d\ln(Z/Z_0)/dz = A\sin\pi z/L$. Find the constant A so that $Z(0) = Z_0$ and $Z(L) = Z_L$. Compute Γ, and plot $|\Gamma|$ versus βL.

5.23 Design an exponentially tapered matching transformer to match a 100 Ω load to a 50 Ω line. Plot $|\Gamma|$ versus βL, and find the length of the matching section (at the center frequency) required to obtain $|\Gamma| \le 0.05$ over a 100% bandwidth. How many sections would be required if a Chebyshev matching transformer were used to achieve the same specifications?

5.24 An ultra wideband (UWB) radio transmitter, operating from 3.1 to 10.6 GHz, drives a parallel *RC* load with $R = 75$ Ω and $C = 0.6$ pF. What is the best return loss that can be obtained with an optimum matching network?

5.25 Consider a series RL load with $R = 80$ Ω and $L = 5$ nH. Design a lumped-element L-section matching network to match this load to a 50 Ω line at 2 GHz. Plot $|\Gamma|$ versus frequency for this network to determine the bandwidth for which $|\Gamma| \le \Gamma_m = 0.1$. Compare this with the maximum possible bandwidth for this load, as given by the Bode–Fano criterion. (Assume a square reflection coefficient response like that of Figure 5.23a.)