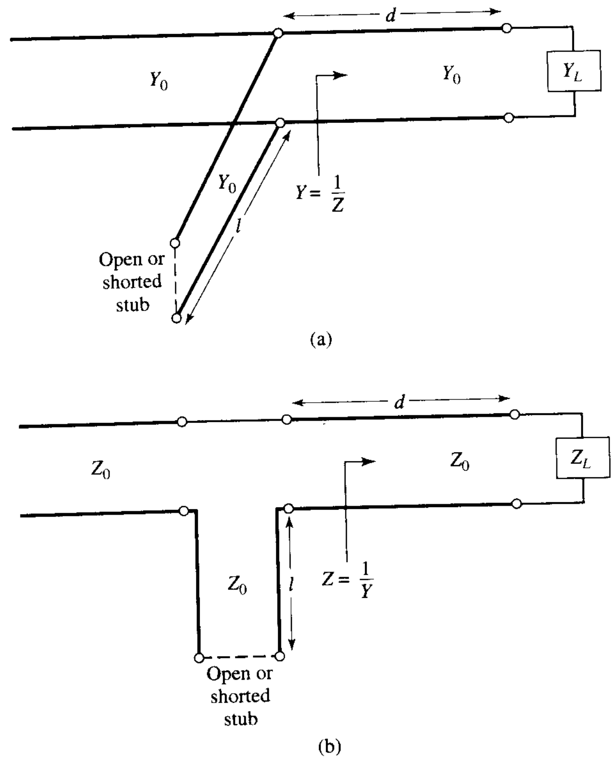
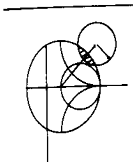


FIGURE 5.4 Single-stub tuning circuits. (a) Shunt stub. (b) Series stub.



EXAMPLE 5.2 SINGLE-STUB SHUNT TUNING

For a load impedance $Z_L = 60 - j80\ \Omega$, design two single-stub (short circuit) shunt tuning networks to match this load to a $50\ \Omega$ line. Assuming that the load is matched at 2 GHz, and that the load consists of a resistor and capacitor in series, plot the reflection coefficient magnitude from 1 GHz to 3 GHz for each solution.

Solution

The first step is to plot the normalized load impedance $z_L = 1.2 - j1.6$, construct the appropriate SWR circle, and convert to the load admittance, y_L, as shown on the Smith chart in Figure 5.5a. For the remaining steps we consider the Smith chart as an admittance chart. Now notice that the SWR circle intersects the $1 + jb$ circle at two points, denoted as y_1 and y_2 in Figure 5.5a. Thus the distance d, from the load to the stub, is given by either of these two intersections. Reading the WTG scale, we obtain

$$d_1 = 0.176 - 0.065 = 0.110\lambda,$$

$$d_2 = 0.325 - 0.065 = 0.260\lambda.$$

Actually, there is an infinite number of distances, d, on the SWR circle that intersect the $1 + jb$ circle. Usually, it is desired to keep the matching stub as close as possible to the load, to improve the bandwidth of the match and to reduce losses caused by a possibly large standing wave ratio on the line between the stub and the load.

At the two intersection points, the normalized admittances are

$$y_1 = 1.00 + j1.47,$$

$$y_2 = 1.00 - j1.47.$$

Thus, the first tuning solution requires a stub with a susceptance of $-j1.47$. The length of a short-circuited stub that gives this susceptance can be found on the Smith chart by starting at $y = \infty$ (the short circuit) and moving along the outer edge of the chart ($g = 0$) toward the generator to the $-j1.47$ point. The stub length is then

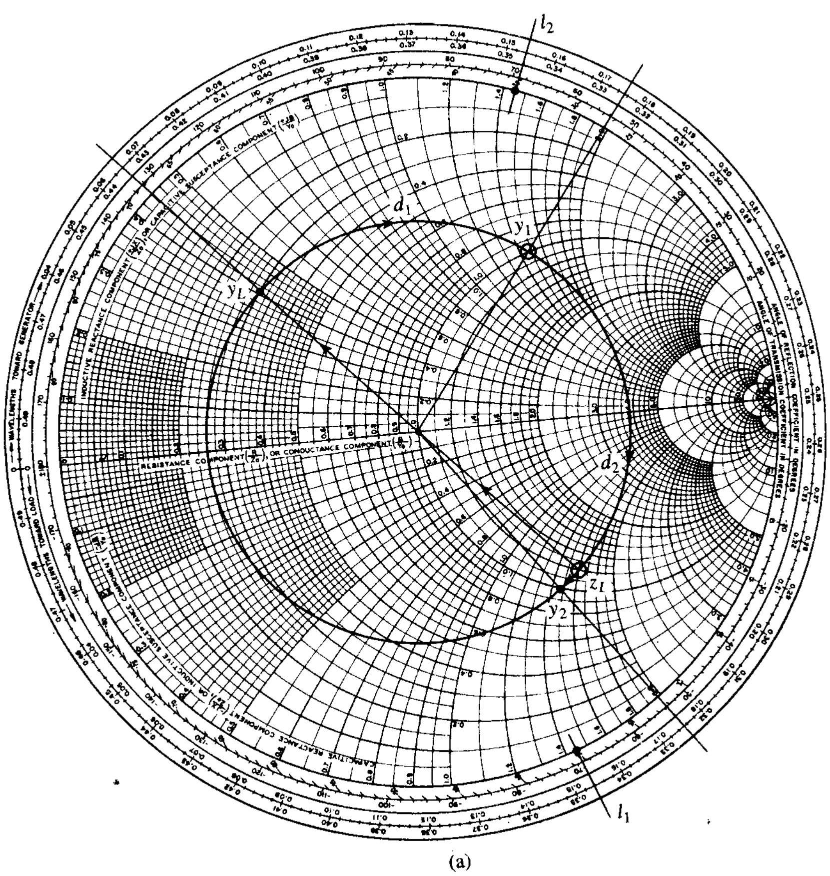
$$\ell_1 = 0.095\lambda.$$

Similarly, the required open-circuit stub length for the second solution is

$$\ell_2 = 0.405\lambda.$$

This completes the tuner designs.

To analyze the frequency dependence of these two designs, we need to know the load impedance as a function of frequency. The series-RL load impedance is $Z_L = 60 - j80\ \Omega$ at 2 GHz, so $R = 60\ \Omega$ and $C = 0.995$ pF. The two tuning



(a)

FIGURE 5.5 Solution to Example 5.2. (a) Smith chart for the shunt-stub tuners.

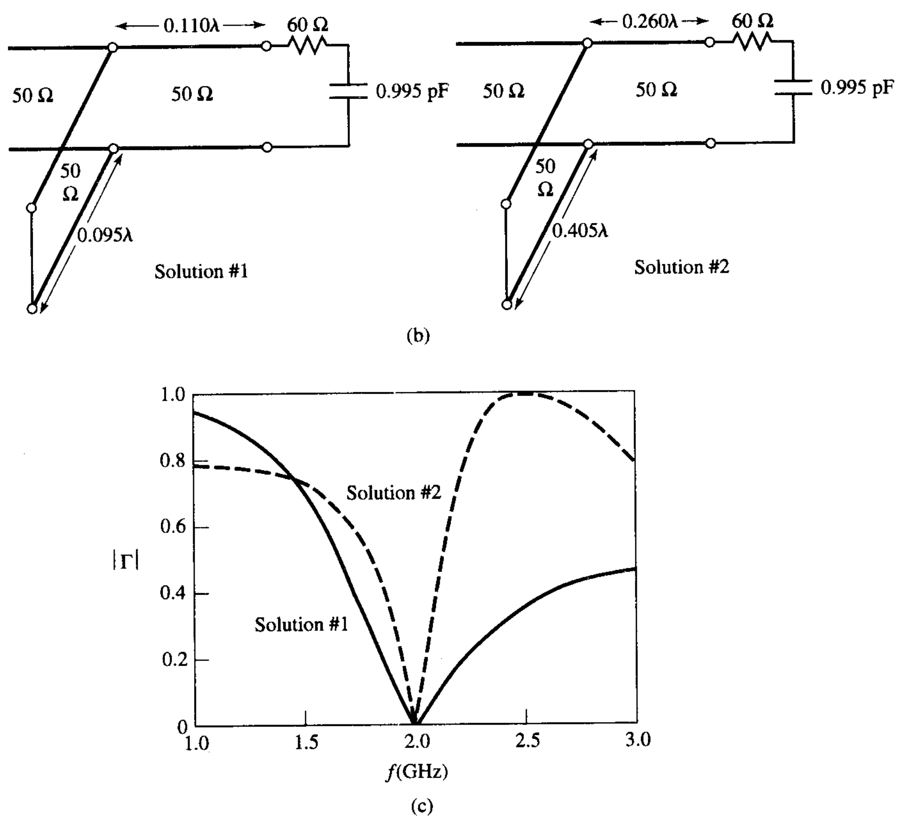


FIGURE 5.5 Continued. (b) The two shunt-stub tuning solutions. (c) Reflection coefficient magnitudes versus frequency for the tuning circuits of (b).

circuits are shown in Figure 5.5b. Figure 5.5c shows the calculated reflection coefficient magnitudes for these two solutions. Observe that solution 1 has a significantly better bandwidth than solution 2; this is because both d and ℓ are shorter for solution 1, which reduces the frequency variation of the match. ■

To derive formulas for d and ℓ, let the load impedance be written as $Z_L = 1/Y_L = R_L + jX_L$. Then the impedance Z down a length, d, of line from the load is

$$Z = Z_0 \frac{(R_L + jX_L) + jZ_0 t}{Z_0 + j(R_L + jX_L)t}, \tag{5.7}$$

where $t = \tan \beta d$. The admittance at this point is

$$Y = G + jB = \frac{1}{Z},$$

where

$$G = \frac{R_L(1+t^2)}{R_L^2 + (X_L + Z_0 t)^2}, \tag{5.8a}$$

$$B = \frac{R_L^2 t - (Z_0 - X_L t)(X_L + Z_0 t)}{Z_0\left[R_L^2 + (X_L + Z_0 t)^2\right]}. \tag{5.8b}$$