8. From the Smith chart

$$y_g = \frac{1}{z_g} = -j4.35$$

9. Add y_2 and y_g

$$y_{in} = y_2 + y_g = 1.6 - j2.75$$

which is located on the Smith chart.

10. Inverting y_{in} on the Smith chart to z_{in} gives

$$z_{in} = 0.16 + j0.28$$

11. Unnormalizing z_{in} by $Z_0 = 315$, reduces it to

$$Z_{in} = 50.4 + j88.2$$

12. The capacitance should be

$$C = \frac{1}{2\pi f_0(88.2)} = \frac{1}{2\pi(15\times10^6)(88.2)}$$
$$= 120.3\times10^{-12} \simeq 120 \text{ pF}$$

Since $R_{in} = 50.4$ ohms is not exactly equal to $Z_0 = 50$ ohms, one of the physical dimensions (usually the length of the rod) can be changed slightly and then the process can be repeated. However in this case they are so close that for practical purposes this is not required.

A MATLAB computer program, entitled ***Gamma***, has been developed to perform the design of a folded dipole. The description of the program is found in the corresponding READ ME file included in the CD attached to the book.

9.7.5 Omega Match

A slightly modified version of the gamma match is the omega match shown in Figure 9.24. The only difference between the two is that in addition to the series capacitor C_1 there is one in shunt C_2 which can aid in achieving the match. Usually the presence of C_2 makes it possible to use a shorter rod or makes it easier to match a resonant driven element. The primary function of C_2 is to change y_{in} in step 9 of the design procedure so that when it is inverted its unnormalized real part is equal to the characteristic impedance of the input transmission line. This will possibly eliminate the need of changing the dimensions of the matching elements, if a match is not achieved.

9.7.6 Baluns and Transformers

A twin-lead transmission line (two parallel-conductor line) is a symmetrical line whereas a coaxial cable is inherently unbalanced. Because the inner and outer (inside

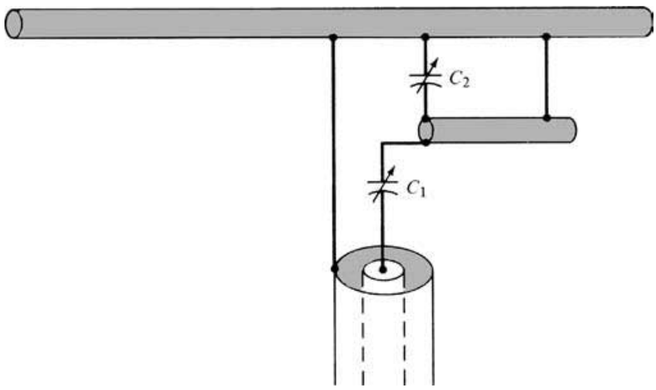

Figure 9.24 Omega match arrangement.

and outside parts of it) conductors of the coax are not coupled to the antenna in the same way, they provide the unbalance. The result is a net current flow to ground on the outside part of the outer conductor. This is shown in Figure 9.25(a) where an electrical equivalent is also indicated. The amount of current flow I_3 on the outside surface of the outer conductor is determined by the impedance Z_g from the outer shield to ground. If Z_g can be made very large, I_3 can be reduced significantly. Devices that can be used to balance inherently unbalanced systems, by canceling or choking the outside current, are known as *baluns* (*bal*ance to *un*balance).

One type of a balun is that shown in Figure 9.25(b), referred to usually as a *bazooka* balun. Mechanically it requires that a $\lambda/4$ in length metal sleeve, and shorted at its one end, encapsulates the coaxial line. Electrically the input impedance at the open end of this $\lambda/4$ shorted transmission line, which is equivalent to Z_g, will be very large (ideally infinity). Thus the current I_3 will be choked, if not completely eliminated, and the system will be nearly balanced.

Another type of a balun is that shown in Figure 9.25(c). It requires that one end of a $\lambda/4$ section of a transmission line be connected to the outside shield of the main coaxial line while the other is connected to the side of the dipole which is attached to the center conductor. This balun is used to cancel the flow of I_3. The operation of it can be explained as follows: In Figure 9.25(a) the voltages between each side of the dipole and the ground are equal in magnitude but 180° out of phase, thus producing a current flow on the outside of the coaxial line. If the two currents I_1 and I_2 are equal in magnitude, I_3 would be zero. Since arm #2 of the dipole is connected directly to the shield of the coax while arm #1 is weakly coupled to it, it produces a much larger current I_2. Thus there is relatively little cancellation in the two currents.

The two currents, I_1 and I_2, can be made equal in magnitude if the center conductor of the coax is connected directly to the outer shield. If this connection is made directly at the antenna terminals, the transmission line and the antenna would be short-circuited, thus eliminating any radiation. However, the indirect parallel-conductor connection of Figure 9.25(c) provides the desired current cancellation without eliminating the radiation. The current flow on the outer shield of the main line is canceled at the bottom end of the $\lambda/4$ section (where the two join together) by the equal in magnitude, but opposite in phase, current in the $\lambda/4$ section of the auxiliary line. Ideally then there is no current flow in the outer surface of the outer shield of the remaining part of the

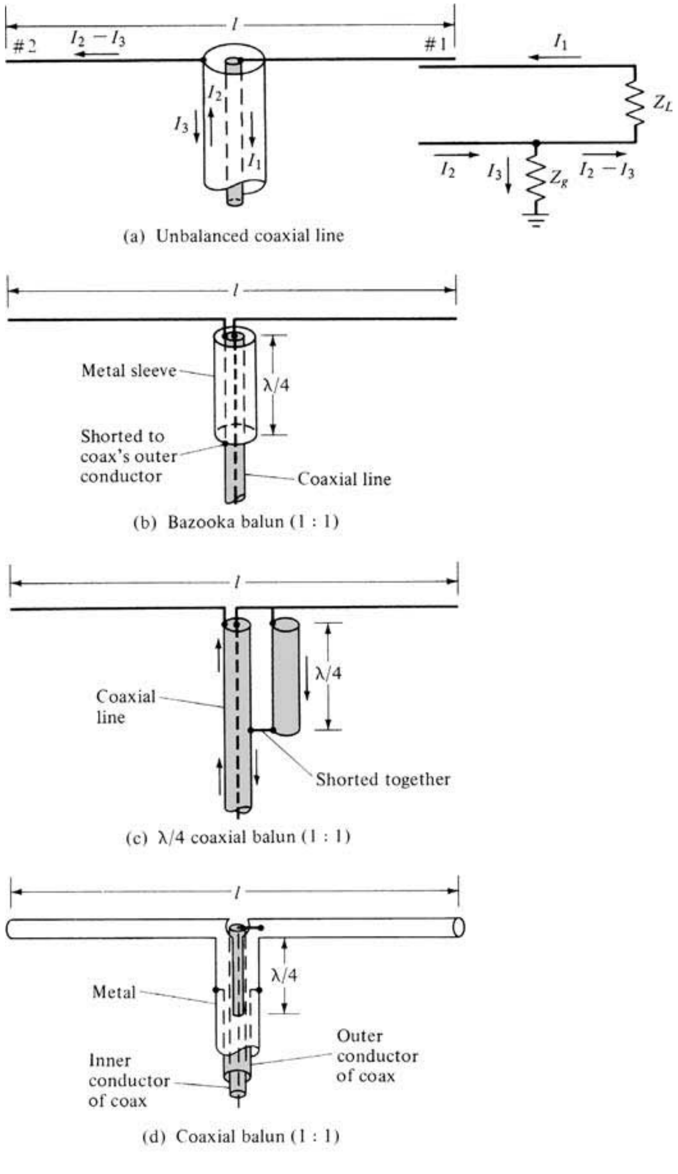

Figure 9.25 Balun configurations.

main coaxial line. It should be stated that the parallel auxiliary line need not be made $\lambda/4$ in length to achieve the balance. It is made $\lambda/4$ to prevent the upsetting of the normal operation of the antenna.

A compact construction of the balun in Figure 9.25(c) is that in Figure 9.25(d). The outside metal sleeve is split and a portion of it is removed on opposite sides. The remaining opposite parts of the outer sleeve represent electrically the two shorted $\lambda/4$ parallel transmission lines of Figure 9.25(c). All of the baluns shown in Figure 9.25 are narrowband devices.

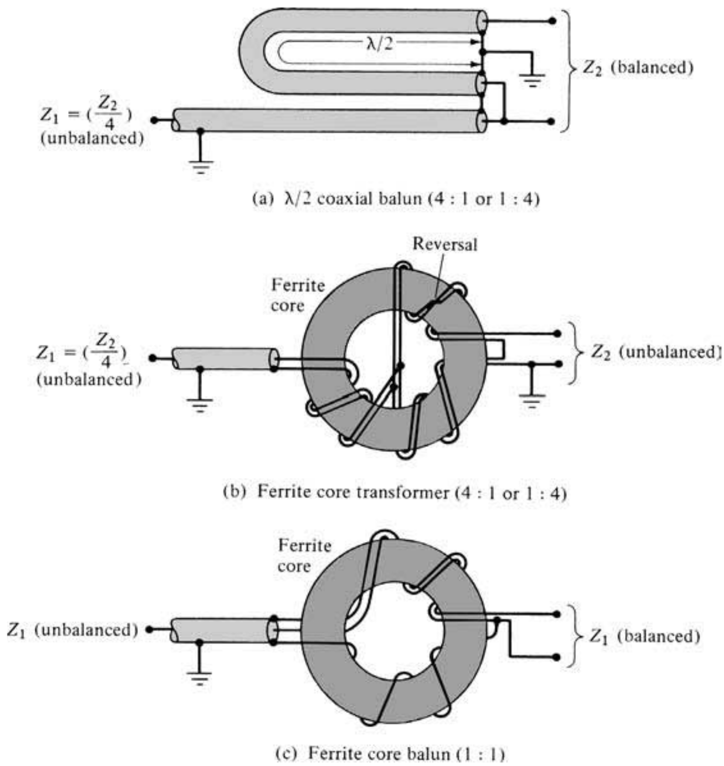

Figure 9.26 Balun and ferrite core transformers.

Devices can be constructed which provide not only balancing but also step-up impedance transformations. One such device is the $\lambda/4$ coaxial balun, with a 4:1 impedance transformation, of Figure 9.26(a). The U-shaped section of the coaxial line must be $\lambda/2$ long [21].

Because all the baluns-impedance transformers that were discussed so far are narrowband devices, the bandwidth can be increased by employing ferrite cores in their construction [22]. Two such designs, one a 4:1 or 1:4 transformer and the other a 1:1 balun, are shown in Figures 9.26(b) and (c). The ferrite core has a tendency to maintain high impedance levels over a wide frequency range [23]. A good design and construction can provide bandwidths of 8 or even 10 to 1. Coil coaxial baluns, constructed by coiling the coaxial line itself to form a balun [23], can provide bandwidths of 2 or 3 to 1.

9.8 MULTIMEDIA

In the CD that is part of the book the following multimedia resources are included for the review, understanding, and visualization of the material of this chapter:

a. **Java**-based **interactive questionnaire**, with answers.
b. **Matlab** computer program, designated ***Quarterwave***, for computing and displaying the characteristics of binomial and Tschebyscheff quarter-wavelength impedance matching designs.