Ham Radio Fun

Determining Antenna Feedpoint Impedance

Even you can learn from this tutorial.

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How do you find the feedpoint impedance of a resonant antenna? Have you ever attempted to match a transmission line to an antenna? What method did you use for determining when the feedline impedance was matched?

Of course, measuring the feedpoint impedance and measuring the resulting VSWR will lead you toward a proper match. But what do you use when an impedance bridge and a VSWR indicator are not available? Certainly, you can guess and/or make a judgment.

A method is described here for determining the mechanical dimension that relates to an approximate impedance value and provides a judgment guide to impedance matching. Once the transmission line is attached, it is only necessary to fine-tune the adjustment to achieve a proper match.

Before continuing with determining the antenna impedance value, a short review of transmission lines must occur. Everyone is familiar with coaxial cable and TV twinlead. Both are transmission lines suitable for use in communication systems. But what do you know about these two types of transmission lines? Perhaps the first important fact is that twinlead is a balanced line and coax is unbalanced. What is the difference between balanced and unbalanced? The two words themselves describe the differences.

Let's consider the twinlead first. It is two identical wires running parallel. Being balanced, the two wires exhibit the same characteristics. The easiest way to understand the balanced concept is to consider yourself as being a bird and to sit on one of the wires while looking at the other. Then hop over to the other wire and look back at the first one. What do you see and conclude? Of course, the two wires look exactly alike, and that means that they are balanced.

What about coax? It also has two conductors that run parallel, as does twinlead. However, when you try the bird's-eye view again, what do you see? One wire completely surrounds the other and they are not alike. Therefore, coax is an unbalanced line.

The characteristic impedance of a transmission line is usually known. Therefore, a discussion is unnecessary here as to how the impedance of a line is determined.

Transformer impedance theory

With that in mind, let's continue with finding the impedance of a resonant circuit, which may be a coil and capacitor connected in parallel, or perhaps a dipole antenna. The impedance correlation between the two is identical, and transformer theory/calculation can be used to find the impedance at various turns of the coil or at mechanical points along the dipole.

For this process to work, it is necessary to make an impedance assumption for the calculations to provide useful data. If one end of the coil is grounded, then the impedance at the ground end is considered to be zero ohms, and the top end of the coil is 1000 ohms. Where does the 1000 ohm figure come from? In free space, the impedance would be infinity, but when the circuit is loaded by the surrounding environment and a realistic circuit "Q," the impedance is lower than infinity. But how low? Some believe the

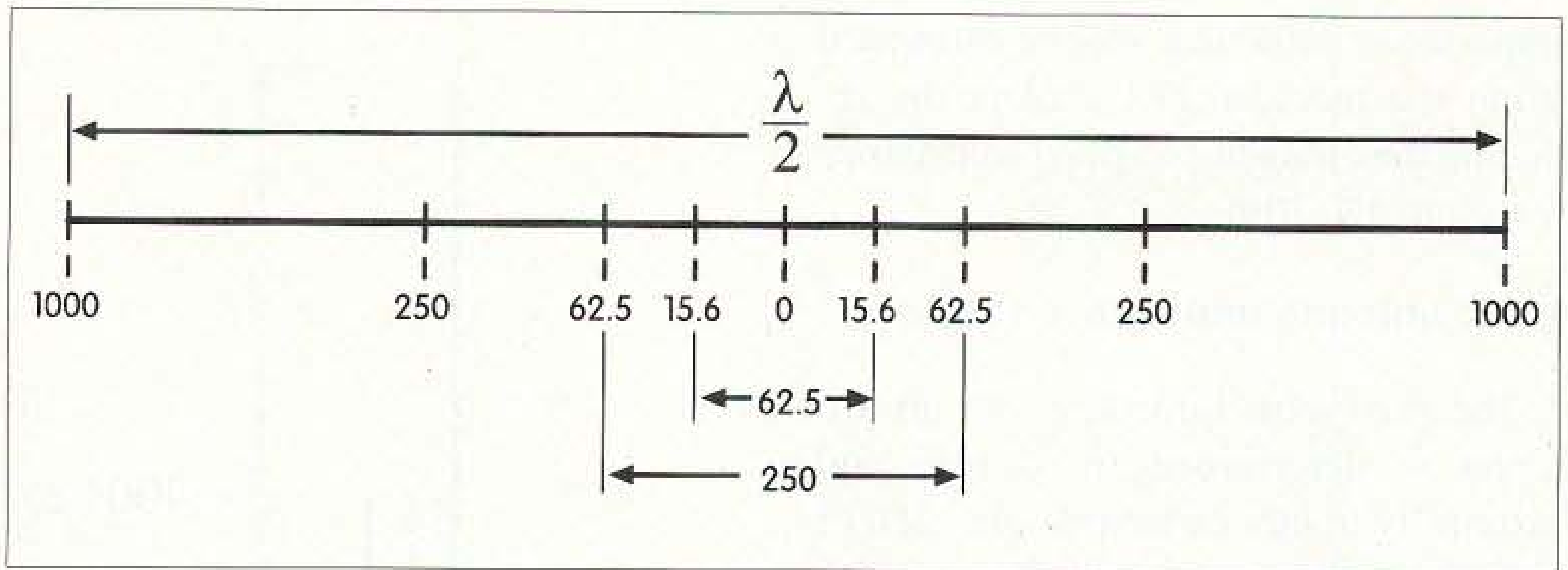

Fig 1. Impedance distribution along a solid half-wave dipole in free space, assuming the end impedance to be 1000 ohms. Balanced feedpoints shown.

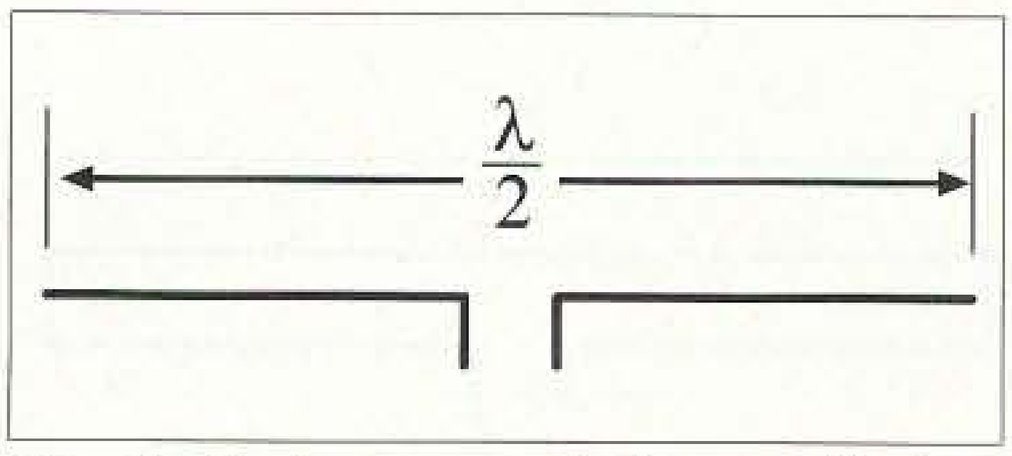

Fig. 3. Broken center half-wave dipole—feedpoint impedance is 66–72 ohms balanced.

top of the coil impedance is 2000 ohms; others believe it is around 1000 ohms. Take your choice of value, as the results of using the mechanical method of impedance determination will end up being reasonably close.

For the examples discussed here, 1000 ohms will be used. Following transformer impedance theory, the impedance varies as a function of the square root of the turns ratio, which means that one-fourth of the inductor's total impedance will be found at its center tap. Using this theory, let's find the impedance at the center of a coil whose impedance is zero ohms at the ground end and 1000 ohms at the top. The center tap on the coil will yield an impedance of 250 ohms, which is one-fourth of the total impedance. Now that was easy, wasn't it? Next, what is the impedance at one-quarter of the coil up from ground? Simple! If the impedance at the center point is 250 ohms, then at the one-quarter point, which is halfway between the center tap and ground, the impedance will be 250/4 = 62.5 ohms.

Finding element impedance mechanically

The impedance along the surface of a dipole antenna can be determined in exactly the same way as taps on the coil. **Fig. 1** shows impedance values at various mechanical points along a half-wave dipole whose center impedance is zero ohms, and whose impedance at each end is 1000 ohms. Half the distance between one end and the center of the dipole yields an impedance of one-fourth of the end impedance, or 250 ohms. Half of the remaining distance is one-fourth of 250 ohms, or 62.5 ohms. Again, half the distance between the 62.5 ohm point and zero is 15.6 ohms. Really simple, isn't it?

So what does all of this mean? It means that you can now predict with reasonable accuracy the impedance at various mechanical distances along the antenna element as long as the element is a solid conductor from end to end. When the center of the element is broken, the feedpoint impedance will be in the 66–72 ohm region. It will be balanced. The mechanical technique described for determining the impedance for a solid element does not apply to an element with a broken center.

Once the element feedpoint impedance distribution is known, it is time to select a transmission line and connect it to the antenna element. Starting with 300 ohm twinlead, as an example, where should it be connected to the half-wave dipole? Did I hear you say just beyond the two 250 ohm points? No! From zero to a distance just beyond one of the 250 ohm points? No again! Well, then, where can we connect the twinlead?

First, 300 ohm twinlead is a balanced line and must be connected at balanced feedpoints on the antenna element. Observe the mechanical length from zero to the 250 ohm point. Find the same length centered over the zero point and you will find the points to be at 62.5 ohms. Yes, we want 300 ohms; therefore, divide 300/4 = 75 ohms. Locate the 75 ohm points, one on either side of the zero, and attach the twinlead for a near-perfect match.

Coax is an unbalanced transmission line. Should we select 52 ohm coax, where would it be connected to a half-wave dipole? Using **Fig. 2**, connect the outer conductor (shield) to the zero point on the antenna, and the coax center conductor to the 52 ohm point on either side of the zero points on the element. It doesn't matter which side, as the antenna remains balanced because an unbalanced transmission line is matched to an unbalanced feedpoint on the element. Will this mechanical matching technique work with a quarter-wave dipole? Yes, as shown in **Fig. 2**, as long as the dipole is grounded at the zero point to a suitable ground plane.

One caveat to this application is that the mechanical space between the zero point and 52 ohms may exceed the dimension between the coax's shield and

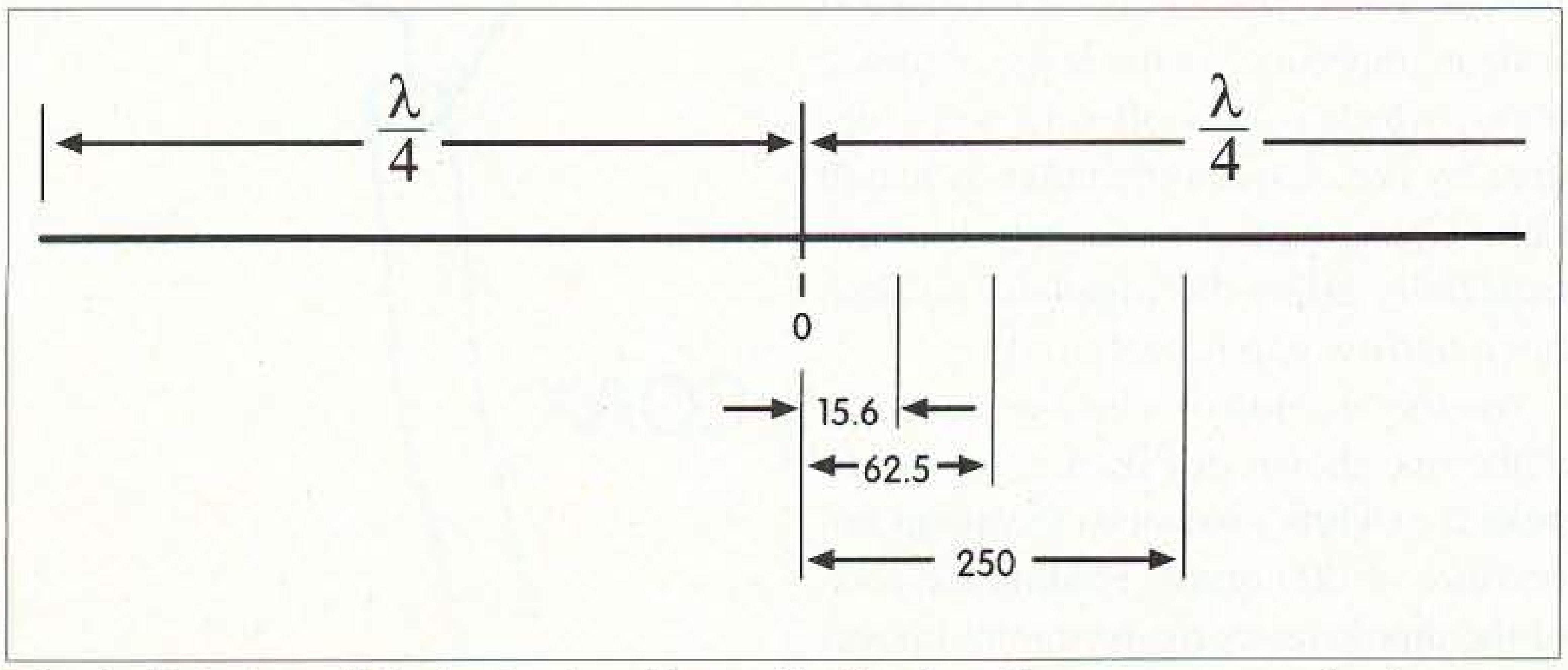

Fig. 2. Unbalanced feedpoint impedance distribution along a counterpoised quarter-wave element. Counterpoise may be a ground plane or another quarter-wave element.

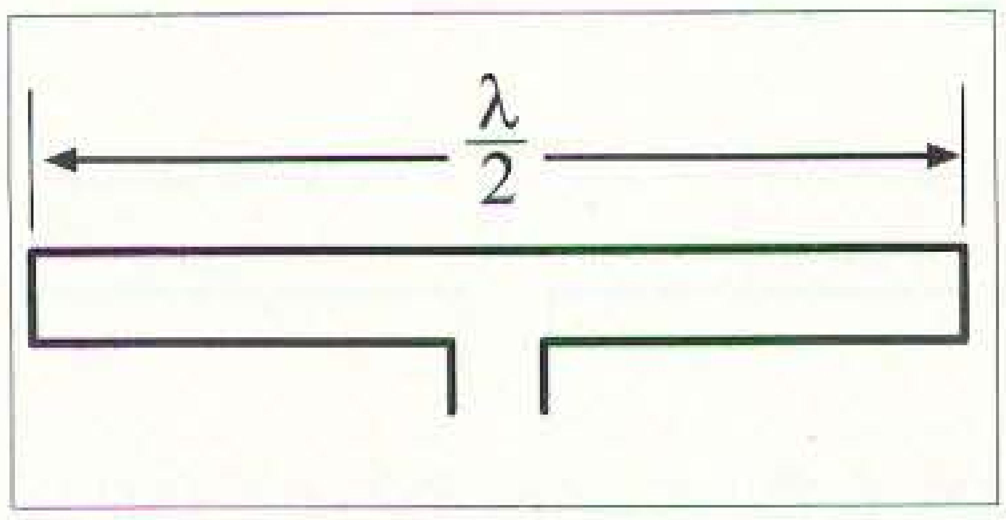

Fig. 4. Broken center folded half-wave dipole, feedpoint impedance is 300 ohms balanced.

center conductor and should not be connected directly to the element because a discontinuity would occur. To solve the problem, a gamma match is used to translate the spacing difference and still provide a proper impedance match.

Please note that many antennas currently in use have an unbalanced transmission line connected to a balanced feedpoint on an antenna. Yes, the impedance value is matched and the system may function well, but the balanced/unbalanced condition is not satisfied and a discontinuity will exist. The discontinuity results in a VSWR of about 1.5:1 which cannot be reduced simply by moving the feedpoint tap back and forth. A *balun*, which is a balanced-to-unbalanced transformer, is frequently used to solve the discontinuity problem.

As a reminder, the impedance of a dipole, whether quarter-wave or half-wave, can be determined as indicated when the antenna is operated in free space. And when enclosed in proximity with other elements as in a yagi configuration, the impedance will decrease. Yet, the approximate feedpoint impedance value can still be estimated using the mechanical technique by reducing the element end point impedance by about 10–20%.

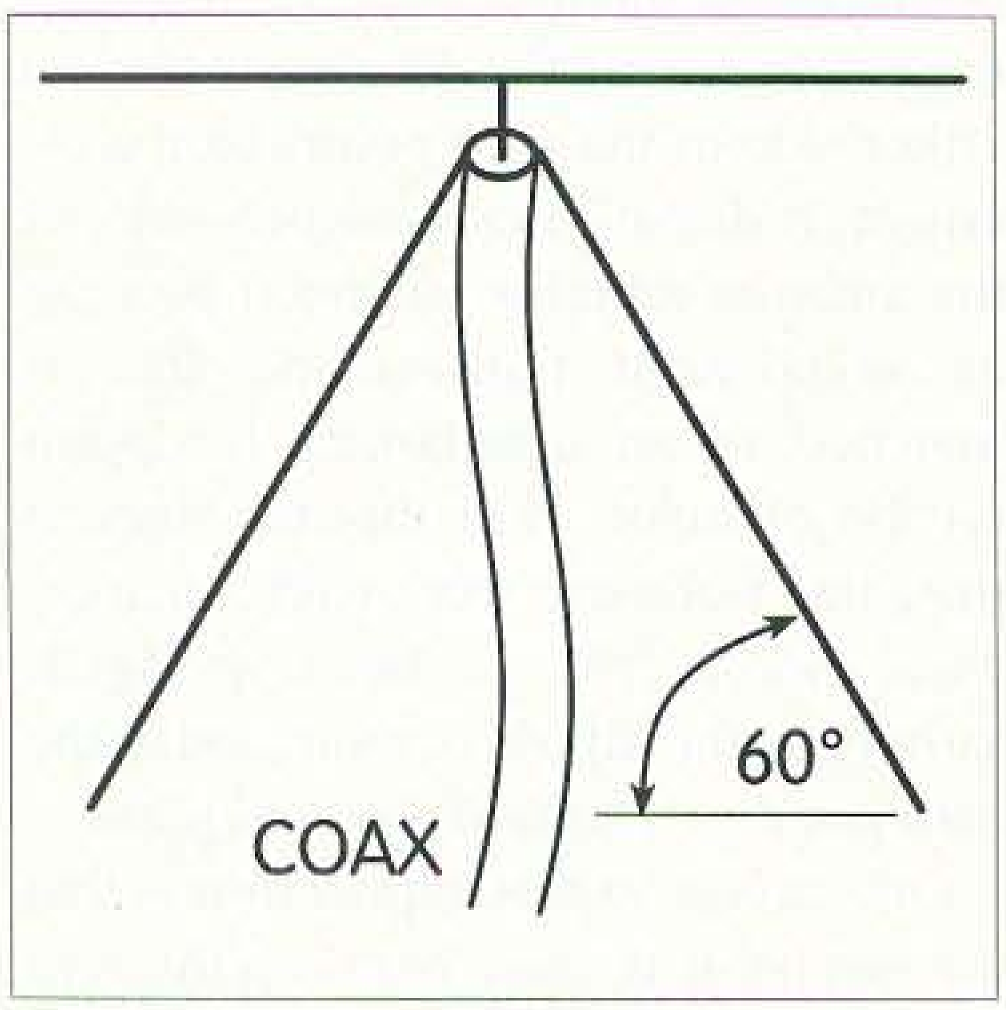

Fig. 5. Discone antenna, feedpoint is 52 ohms unbalanced.

Basic antenna impedance values

The feedpoint impedance of an antenna is determined by design and proximity to other elements. In each of the illustrations shown in **Figs. 3–10**, note the mechanical configuration of the element and whether it presents a balanced or unbalanced feedpoint to the transmission line. Some of the impedance values obtained by a design may not match the standard impedance value of transmission lines. Therefore, the closest transmission line impedance is usually selected for use and the resulting VSWR is either tolerated or some impedance adjustments are performed. When there is a known impedance difference the resulting VSWR can be estimated by dividing the higher impedance value by the lower. VSWR values below 2:1 rarely interfere with the ability to communicate via radio, but it is desirable to reduce the VSWR value as much as possible. The VSWR detector in most solid state transmitters have a threshold set for about 1.5:1, making it mandatory to have a VSWR value lower than 1.5:1.

Basic antenna types

Each of the antenna types shown in **Figs. 3–10** represents a basic antenna type with the figure providing an indication of the feedpoint impedance for each. The dipole antenna shown in **Fig. 3** is a half-wave element with a broken center. The feedpoint is balanced with an impedance in the range of 66–72 ohms, which is controlled to some degree by the element diameter-to-length ratio. Changing the center gap does not materially affect the impedance value, but a narrow gap is preferred.

Another version of a half-wave dipole is the one shown in **Fig. 4**, a folded dipole. It exhibits a balanced feedpoint impedance of 300 ohms. Folding the ends of the dipole raises the feedpoint impedance as compared with **Fig. 3**. A small change in the feedpoint impedance may be accomplished by changing the diameter ratio between the two parallel elements.

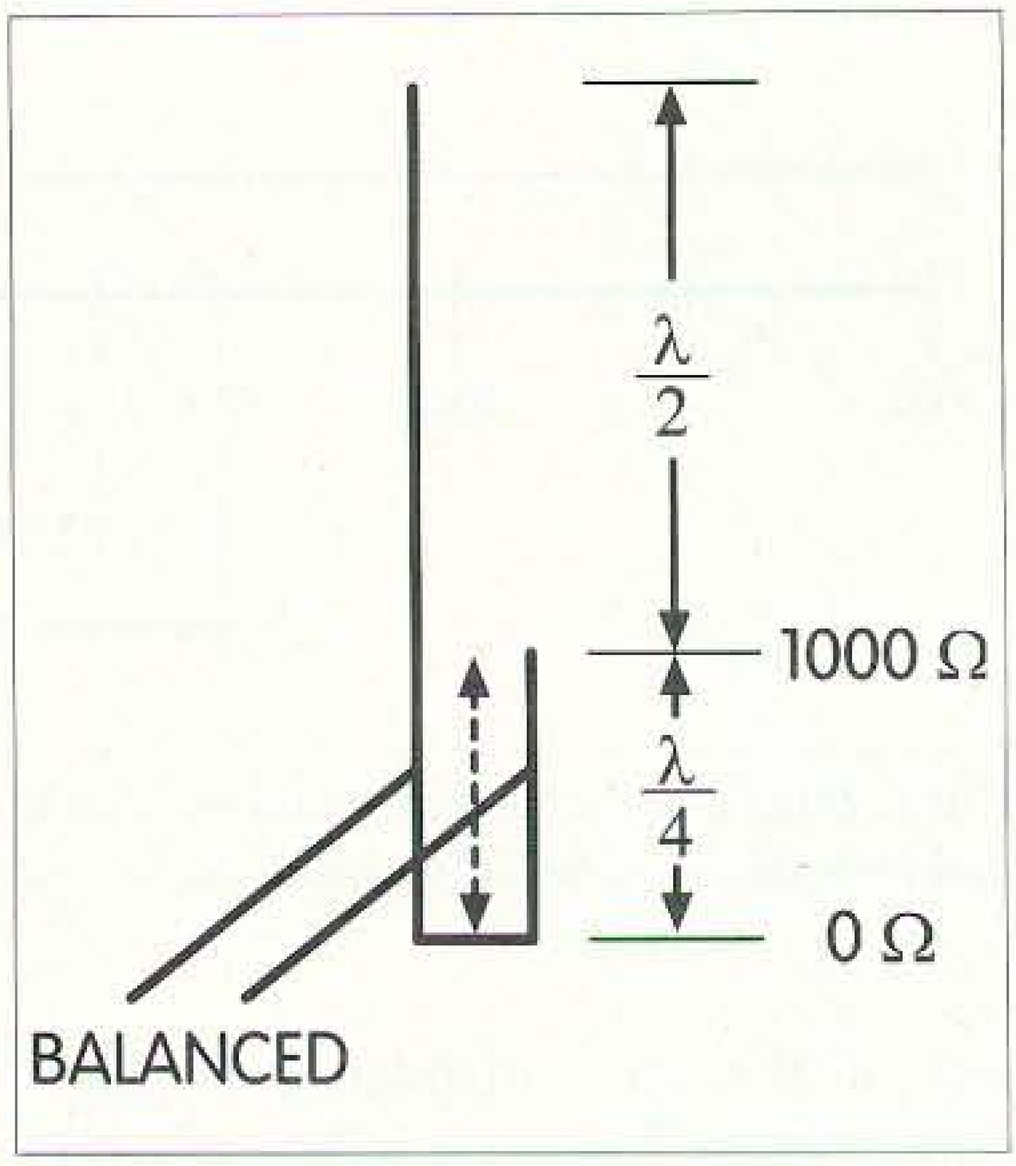

Fig. 6. "J" antenna showing a balanced feedpoint that is variable from 0–1000 ohms.

The antenna shown in **Fig. 5** is a discone which covers a wide frequency range while maintaining a constant unbalanced feedpoint impedance of 52 ohms. The gap between the disk and the top of the cone must be kept small.

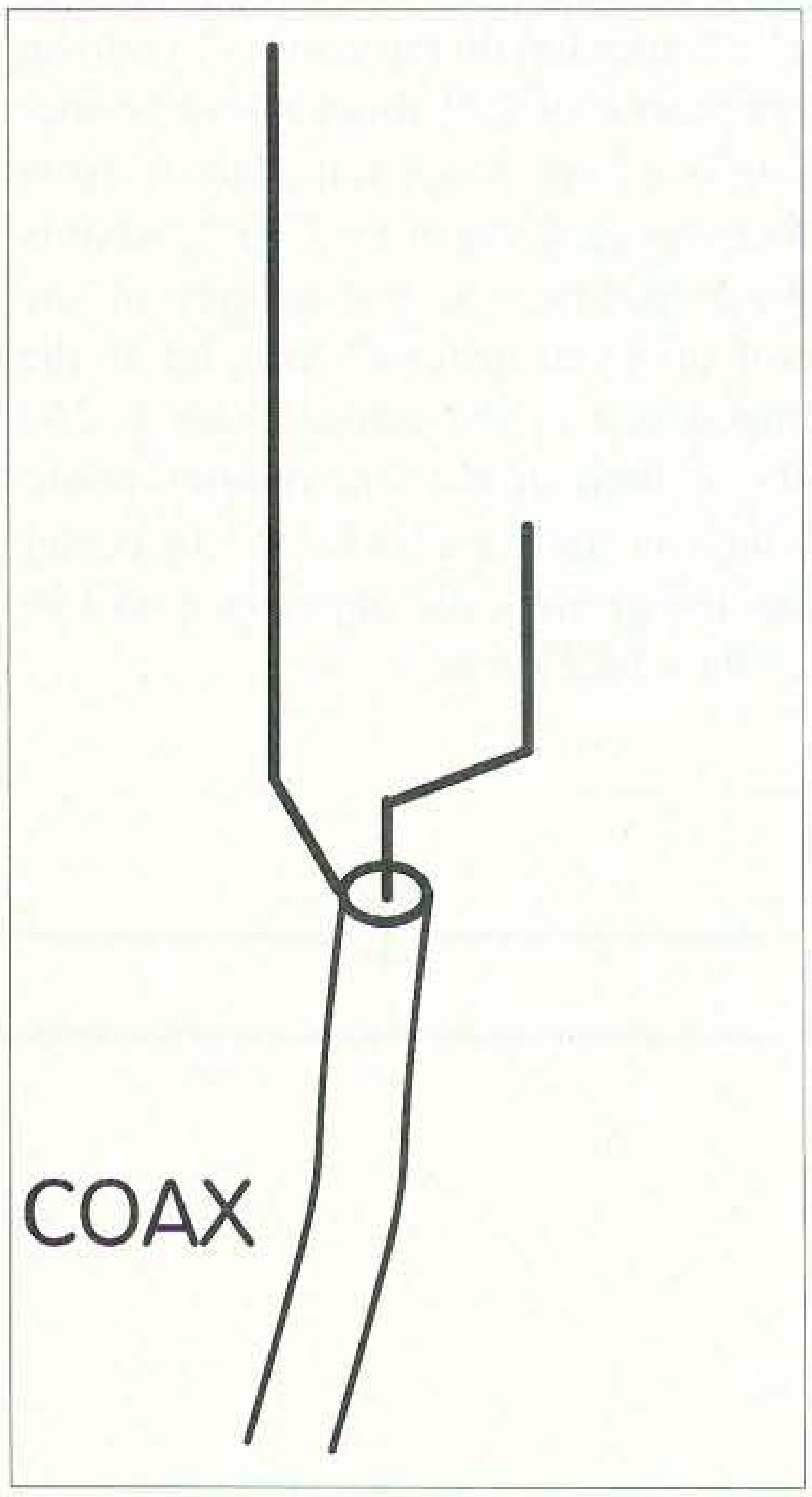

Fig. 7. "J" antenna showing an unbalanced feedpoint of 52 ohms.

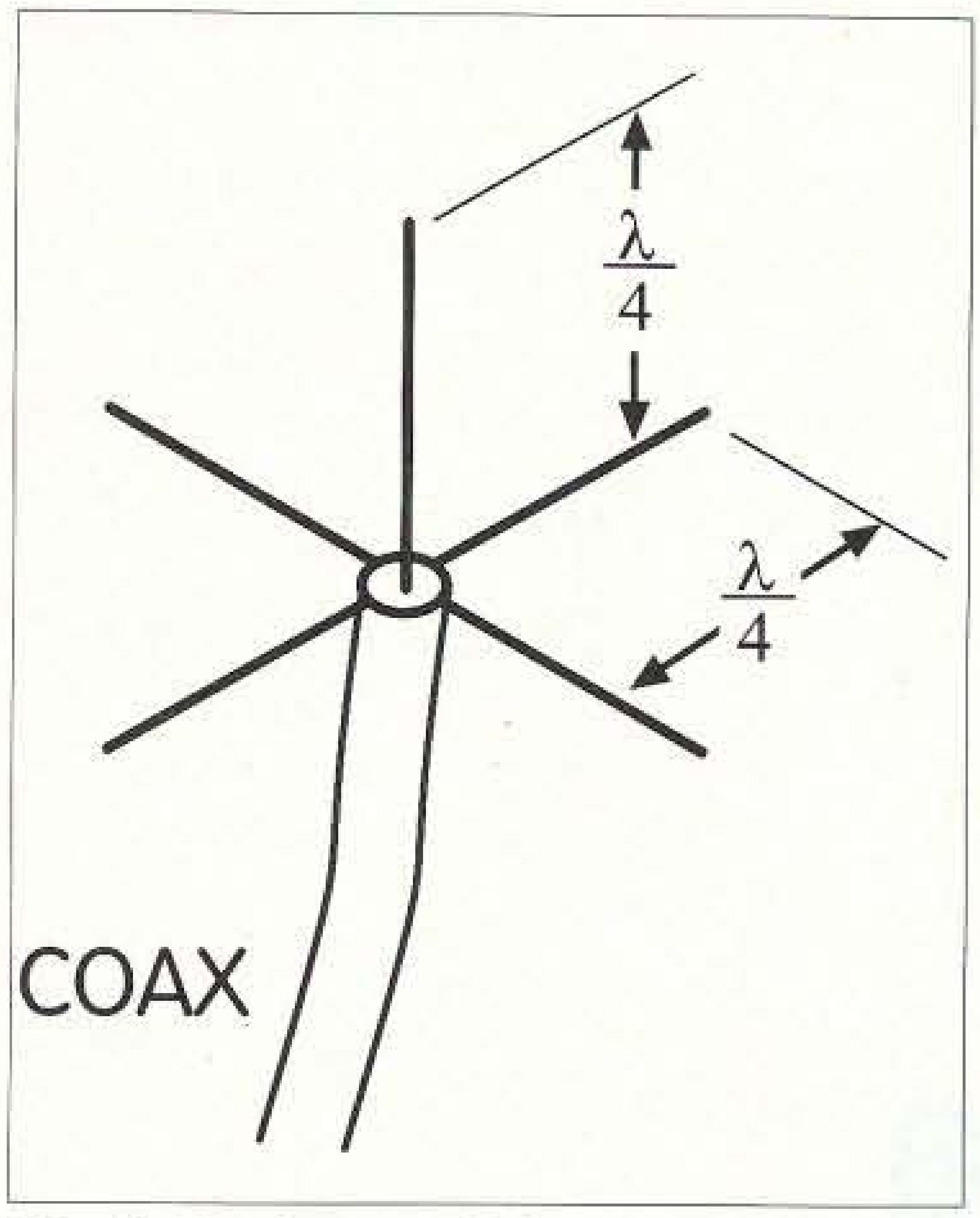

Fig. 8. Simple ground plane antenna. Feedpoint impedance is 23 ohms unbalanced.

A "J" antenna is shown in **Figs. 6** and **7**, with each having a different feedpoint. A "J" antenna utilizes a quarter-wave matching transformer mounted on one end of a one-half-wave element. The half-wave element is endfed at a high impedance from the transformer section. The transformer section operates as a resonant matching stub, permitting a balanced variable matching impedance for a transmission line from zero to approximately 1000 ohms. The impedance distribution along the transformer section may be determined by using the mechanical technique described previously. As shown in **Fig. 7**, the bottom of the transformer section has been broken, creating an unbalanced feedpoint exhibiting an impedance of 52 ohms.

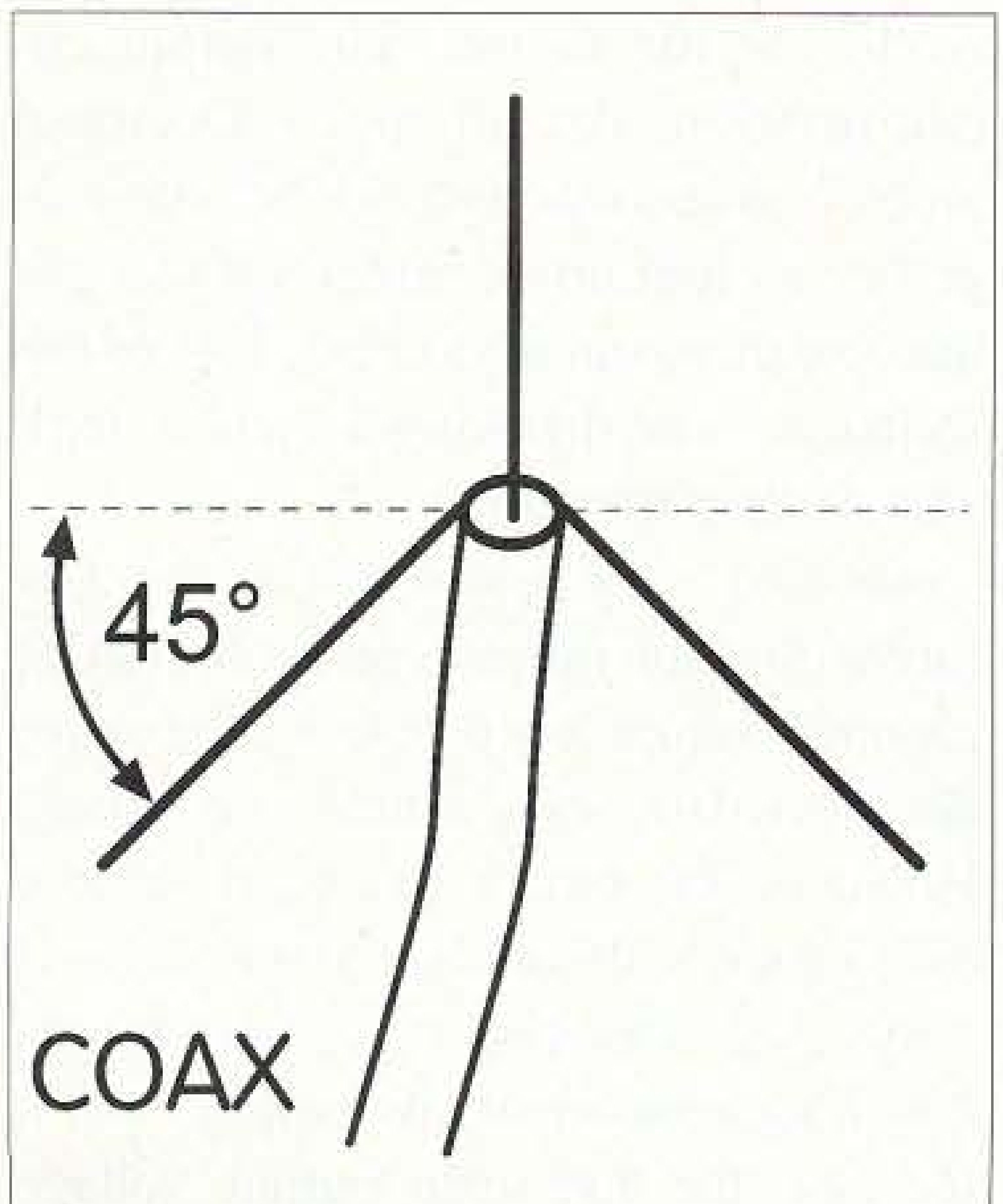

Fig. 9. Modified ground plane antenna with ground elements bent down 45 degrees below horizontal. Feedpoint impedance is 52 ohms unbalanced.

Figs. 8 and **9** show a ground plane antenna in two configurations. **Fig. 8** is the basic form in which the ground elements are 90 degrees to the antenna element. In this configuration, the feedpoint impedance is approximately 23 ohms. Because of the low value, the impedance must be raised in order to match the 52 ohm impedance of available coax. The impedance at the feedpoint may be raised as shown in **Fig. 9** by lowering the ground elements. At a down angle of approximately 45 degrees, the feedpoint impedance will be raised to 52 ohms.

The antenna shown in **Fig. 10** is a coaxial antenna and near cousin to the ground plane shown in **Fig. 9** where the ground elements are lowered to become parallel with the plane of the vertical element. Even though the elements are one-half-wave in overall length, the lower element is usually a tube that surrounds the coaxial feedline, which makes the two element sections electrically similar but mechanically different. As a result, the feedpoint becomes unbalanced and exhibits an impedance of 66–72 ohms, similar to a broken half-wave dipole.

Conclusion

The impedance distribution along a resonant antenna element may be determined mechanically. The usefulness of knowing the distribution aids in the construction of the antenna and selection of a suitable feedline. The *caveat* to the mechanical-impedance determination is that the actual element impedance is directly affected by the proximity of other elements surrounding the antenna, requiring some mechanical compensation in the measurement, but understanding the approximate location of various impedance values along an antenna element helps the builder make construction decisions. 73

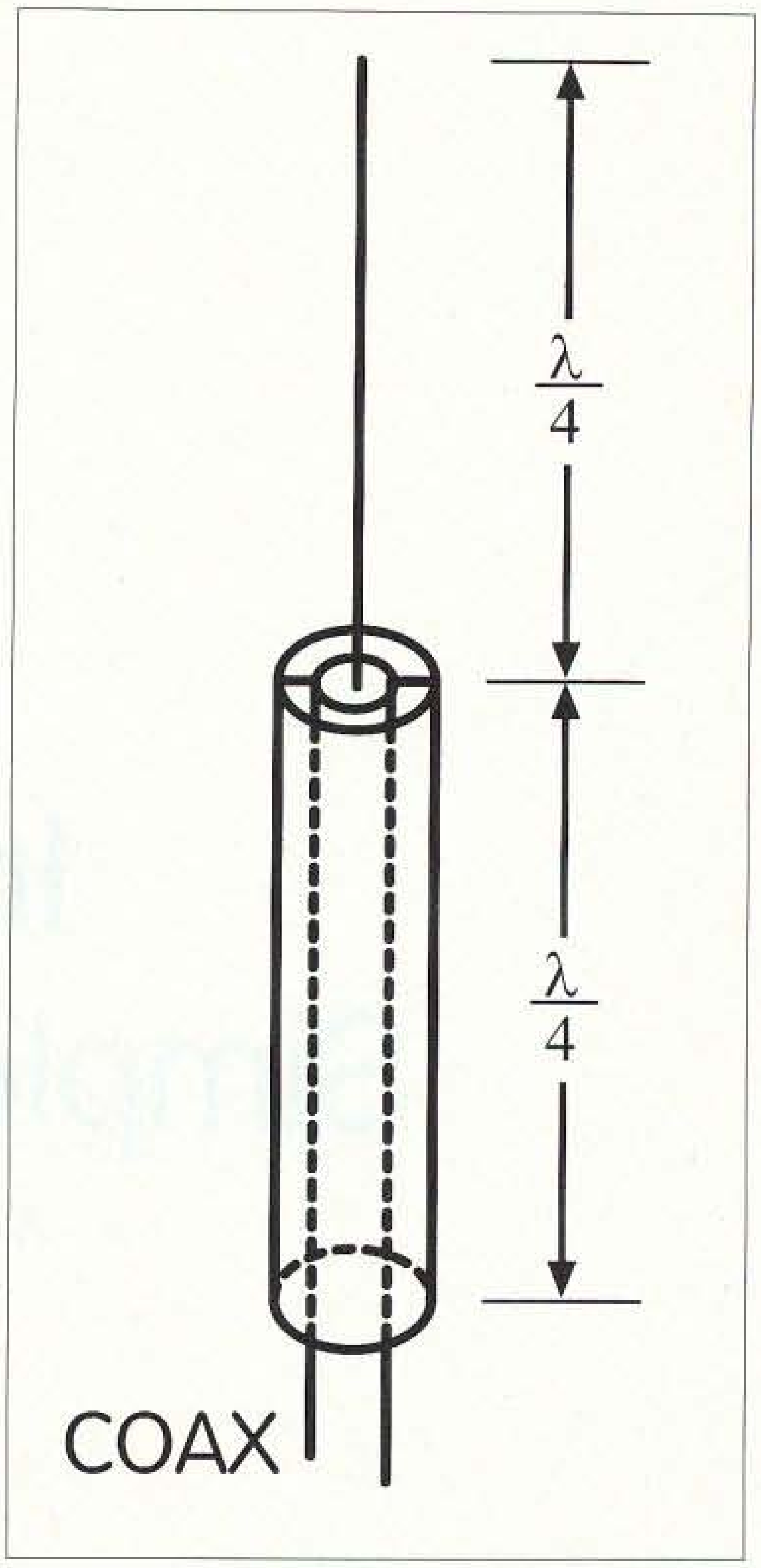

Fig. 10. Coaxial antenna. The lower quarter-wave element surrounds the feedline. The feedpoint impedance is 66–72 ohms unbalanced.