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Chapter 10

# Multiband HF Antennas

For operation on a number of bands below 30 MHz, it would be impractical for most amateurs to put up a separate antenna for each band. But this is not necessary — for example, a dipole one half-wavelength long on the lowest frequency band to be used can be operated readily on higher frequencies. In fact, most common antennas can be used on multiple bands through the use of antenna tuners and other techniques. What is usually referred to as a "multiband antenna," however, is one for which a method has been devised that allows the antenna to operate on a number of bands while still offering a good match to a transmission line, usually coaxial cable.

When a single physical antenna is used on different bands, one must be aware that the changing electrical heights and lengths lead to changes in the feed point impedance and the azimuth and the elevation patterns of the antenna as described in the chapters **Antenna Fundamentals** and **Dipoles and Monopoles**. For example, a horizontal wire antenna at an electrical height of $\lambda/2$ on 20 meters is $2\lambda/3$ high on 15 meters and $\lambda/4$ on 40 meters, leading to very different elevation patterns than if the antenna were at the same electrical height on all bands. Similarly, the elevation pattern and feed point impedance of a single vertical antenna will also change dramatically on different bands.

In fact, it is usually more effective to consider the installation as a "multiband antenna system" in which the antenna, feed line, and any impedance matching devices are considered together — as a package. By thinking about the performance of the antenna on different bands you can select a combination of system elements that result in good performance on all bands and not just one.

This chapter describes a number of antennas and antenna systems that are designed to be used on two or more of the HF bands. Separate chapters cover nonresonant **Long-Wire and Traveling Wave Antennas** as well as the popular **HF Yagi and Quad Antennas**. See the **Transmission Line System Techniques** chapter for more information on using feed lines and impedance matching circuits.

### Harmonic Radiation from Multiband Antennas

Since a multiband antenna is intentionally designed for operation on a number of different frequencies, any harmonics or spurious frequencies that happen to coincide with one of the antenna resonant frequencies will be radiated with very little, if any, attenuation. Particular care should be exercised, therefore, to prevent such harmonics from reaching the antenna.

Multiband antennas using tuned feed lines have a certain inherent amount of built-in protection against such radiation, since it is nearly always necessary to use a tuned coupling circuit (antenna tuner) between the transmitter and the feed line. This adds considerable selectivity to the system and helps to discriminate against frequencies other than the desired one.

Multiple dipoles and trap antennas do not have this feature, since the objective in design is to make the antenna show as nearly as possible the same resistive impedance in all the amateur bands the antenna is intended to cover. It is advisable to conduct tests with other amateur stations to determine whether harmonics of the transmitting frequency can be heard at a distance of, say, a mile or so. If they can, more selectivity should be added to the system since a harmonic that is heard locally, even if weak, may be quite strong at a distance because of propagation conditions.

## 10.1 SIMPLE WIRE ANTENNAS

### 10.1.1 RANDOM-WIRE ANTENNAS

The simplest multiband antenna is a random length of wire, attached directly to the output of a transmitter or antenna tuner. Power can be fed to the wire on practically any frequency using one or the other of the methods shown in **Figure 10.1**. If the wire is approximately 67 or 137 feet long ($\lambda/4$ or $\lambda/2$ on 80 meters) the end impedance will be high on the bands that are harmonics of 80 meters and it can be fed through a tuned circuit, as in **Figure 10.2**. Many antenna tuners have the option to feed an end-fed random wire in this way. Use an SWR meter between the transmitter and the matching network to adjust for minimum SWR.

If you have a rotatable beam antenna, in many cases it may be possible to use the beam's coaxial feed line as an antenna on HF. Connect the shield and center conductor together at the station end and use them as a random-length wire as in Figure 10.1. The beam at the far end will serve to end-load the wire as a capacitance hat.

The primary disadvantage of all such directly-fed systems is that the antenna system is composed of the random wire plus all of the station equipment enclosures and the station ground connection. The point at which the antenna is connected can be thought of as a randomly chosen feed point in an antenna that has one end tied to ground. As such, there is a good chance that you will have "RF hot spots" in your station because of the RF current in the antenna system.

RF voltages within the station can often be minimized by choosing an antenna and ground wire length so that the low feed point impedance at a current maximum occurs at or near the transmitter. A short connection (several feet or less) with heavy wire or strap to a ground rod or metallic water pipe that runs through ground may be sufficient on the lower bands but most ground connections are not short enough to minimize RF voltage by themselves. Regardless of how you address this issue, begin by connecting all equipment enclosures together to prevent significant voltages from existing between pieces of equipment.

Using an antenna wire length close to λ/4 (65 feet at 3.6 MHz, 33 feet at 7.1 MHz), or an odd multiple of λ/4 (¾ λ is 195 feet at 3.6 MHz, 100 feet at 7.1 MHz, 50 feet at 14 MHz, etc) may be helpful. The goal is to place the antenna system's connection to the transmitter or antenna tuner at a point of low voltage. Obviously, this can be done for only one band even in the case of harmonically related bands, since the wire length that presents a current maximum at the transmitter will present a voltage maximum at two (or four) times that frequency.

Another possibility is to attach a counterpoise wire to the transmitter or antenna tuner enclosure. The counterpoise length is adjusted so that RF voltage on the station equipment is minimized. The length may or may not be λ/4 at the operating frequency since the impedance at the end of the antenna wire is unknown. Be prepared to experiment with different lengths. Different wires can be attached at different frequencies.

Another option is to use an "artificial ground" such as the MFJ-931 (**www.mfjenterprises.com**) as in **Figure 10.3** that tunes the counterpoise on different frequencies. It is also possible in many cases to use an ordinary 100-W antenna tuner to accomplish the same thing — tuning the

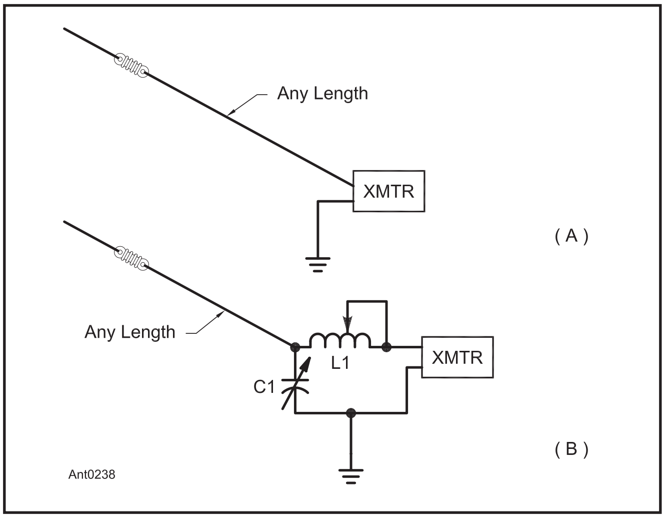



**Figure 10.1 — At A, a random-length wire can be driven directly from the pi-network output of a vacuum-tube transmitter. At B, an L network (or antenna tuner) can be used with solid state transmitters that do not have tunable output networks. C1 should have plate spacing sufficient for at least several hundred volts; a maximum capacitance of 100 pF is sufficient if L1 is 20 to 25 µH. A suitable coil would consist of 30 turns of #12 AWG wire, 2½ inches diameter, 6 turns per inch. Bare wire should be used so the tap can be placed as required for loading the transmitter.**

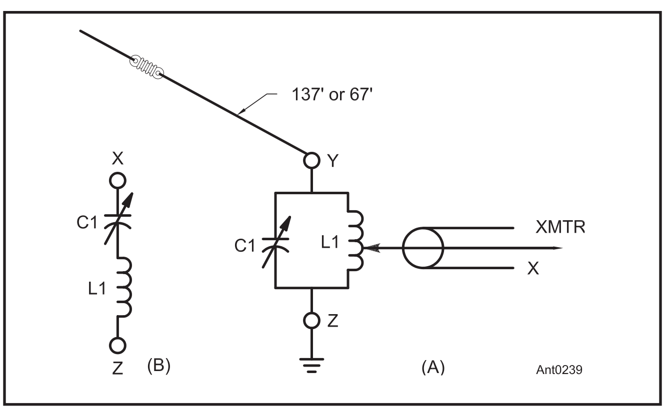



**Figure 10.2 — If the antenna length is 137 feet, a parallel-tuned coupling circuit (A) can be used on each amateur band from 3.5 through 30 MHz, with the possible exception of the 10-, 18- and 24-MHz bands. C1 should be from 500-1000 pF with plate spacing capable of withstanding several hundred volts. L1 should be chosen to resonate with 20-80% of C1's maximum value. If the wire is 67 feet long, series tuning can be used on 3.5 MHz as shown at the left; parallel tuning will be required on 7 MHz and higher frequency bands. The L network shown in Figure 10.1B is also suitable for these antenna lengths.**

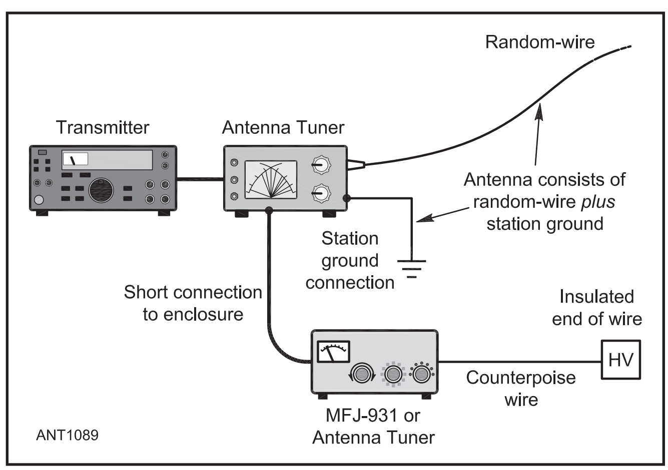



**Figure 10.3 — An "artificial ground" can be used to tune a random length of wire to minimize RF voltage on station equipment enclosures.**

random-length counterpoise to present a low impedance at the transmitter or antenna tuner enclosure.

If you do use a counterpoise, be sure to insulate the unattached end because like all unconnected ends of antennas, there will likely be enough RF voltage to cause an RF burn, particularly at 100 W or higher.

### 10.1.2 END-FED ANTENNAS

Another common antenna system for multiband operation is the *end-fed Zepp* antenna shown in **Figure 10.4**. The antenna length is λ/2 long at the lowest operating frequency. (This name came about because the first documented use of this sort of antennas was on the *Zeppelin* airships where the antenna was hung by one end and trailed below the airship.)

An antenna tuner with a balanced output can provide multiband coverage with an end-fed antenna with any length of open-wire feed line, as shown in Figure 10.4. Open-wire or window line with an impedance of 300 to 600 Ω is most often used.

The feed line length can be anything convenient, but odd multiples of λ/4 will transform the high feed point impedance to a lower value that is likely to be easier to transform to 50 Ω. (See "Tuned Feeders" below.) The asymmetrical placement of the feed line with respect to the antenna often results in common-mode current being picked up by the feed line. This results in radiation from the feed line portion of the system. (See "Feed Line Radiation" below.)

If you have room for only a 67-foot flattop and yet want to operate in the 3.5-MHz band, the two feed line wires can be tied together at the transmitter end and the entire system treated as a random-length wire fed directly, as in Figure 10.1. Steve Yates, AA5TB, has written an extensive article on the end-fed half-wave antenna at **www.aa5tb.com/efha.html**.

As explained in the section below on Feed Line Radiation, it is important to note that although the feed line is attached at one end of the horizontal wire, the radiated signal comes from current flowing on the wire and also as common-mode current on the feed line. That is, the feed line and whatever it is attached to make up part of the antenna system along with the horizontal wire. For a coaxial feed line, the current flows on the outside surface of the shield.

From the standpoint of a radiated signal, the end-fed antenna is not really "end-fed" at all! It is really an off-center fed antenna with one part of the antenna horizontal and the rest of it made up by the feed line and whatever the feed line is connected to in the shack. As you might imagine, the resulting radiation pattern is nearly omnidirectional and not very much like a classic dipole. That may be better for a portable station than an antenna with nulls along its axis.

Nevertheless, the end-fed half-wave user should be aware of where the antenna system current is flowing! The radiated signal from common-mode current flowing on a feed line can cause RFI to appliances or electronics near the feed line and the user can experience "RF in the shack" because of the RF current flowing on equipment enclosures and cables. The same precautions about bonding equipment together and using counterpoise wires for random wire antennas in the previous section should also be applied when using "end-fed" antennas.

### 10.1.3 CENTER-FED ANTENNAS

A center-fed single-wire antenna can be made to accept power and radiate it with high efficiency on any frequency higher than its fundamental resonant frequency and, with a reduction in efficiency and bandwidth, on frequencies as low as one half the fundamental.

In fact, it is not necessary for an antenna to be a full half-wavelength long at the lowest frequency. An antenna can be considerably shorter than ½ λ, even as short as ¼ λ, and still be a very efficient radiator. The use of such short antennas results in stresses, however, on other parts of the system (for example the antenna tuner and the transmission line) as discussed later on in this section.

The simplest and most flexible (and also least expensive) all-band antennas are those using parallel-wire feed lines to the center of the antenna, as in **Figure 10.5**. Because each half of the flattop is the same length, the feed line currents will be balanced at all frequencies unless, of course, imbalance is introduced by one half of the antenna being closer to ground (or a grounded object) than the other. To maintain balance of the current in each antenna leg and minimize common-mode current on the feed line, the feed line should be run at right

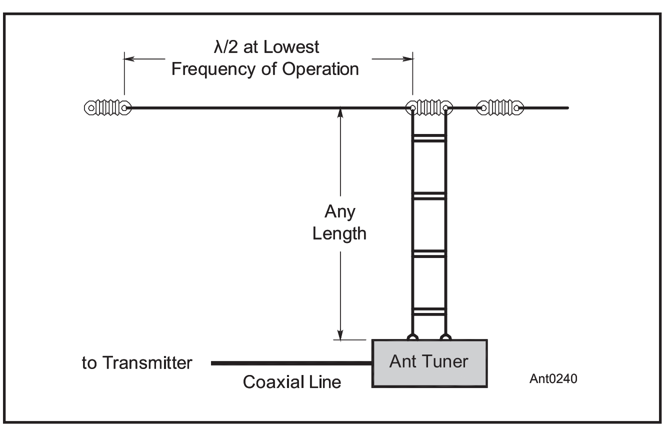



**Figure 10.4 — An end-fed Zepp antenna for multiband use.**

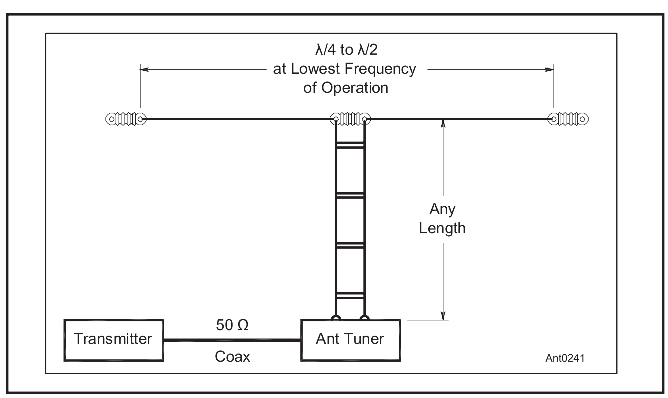



**Figure 10.5 — A center-fed antenna system for multiband use.**

angles to the antenna, preferably for a distance of at least λ/4 from the feed point.

Center feed is not only more desirable than end feed (described above) because of inherently better balance, but it generally also results in a lower standing wave ratio on the transmission line, provided a parallel-wire line having a characteristic impedance of 300 to 600 Ω is used. Ladder or window line is satisfactory for all but possibly high power installations (over 500 W), where heavier wire and wider spacing are desirable to handle the larger currents and voltages that may be present at high SWR.

The best type of antenna tuner to use in such an installation is a balanced type designed for coaxial feed line on the input and parallel-wire line on the output. An unbalanced tuner can also be used but because one wire of the output feed line is connected to the enclosure, RF current and voltages are more likely to be present in the station.

It is not recommended that coaxial feed line be used between the antenna tuner and antenna. At frequencies where the SWR is high, feed line loss in coaxial cable runs of more than 50 feet at HF can quickly become very high. (See the **Transmission Lines** chapter).

The length of the antenna is not critical, nor is the length of the line. As mentioned earlier, the length of the antenna can be considerably less than λ/2 and still be very effective. If the overall length is at least λ/4 at the lowest frequency, a quite usable system will result. Some experimentation will likely be necessary to find the length that works best at a specific location on the bands required.

Several nonresonant lengths of center-fed doublets have become popular in recent years for their consistent radiation patterns on several bands. For example, L.B. Cebik, W4RNL (SK) recommended the following lengths because the pattern remains at peak gain broadside to the antennas:

- 44 feet covers 10, 12, 15, 17, 20, 30, 40 meters
- 66 feet covers 15, 17, 20, 30, 40, 60 meters
- 88 feet covers 20, 30, 40, 60, 80 meters

The impedance of the antenna varies broadly from band to band, requiring the use of a wide-range tuner, but that is an acceptable tradeoff. Gain drops with frequency but not a great deal below that of a λ/2 dipole. Height above ground also influences the elevation pattern of the antenna as it does for a dipole, so install the antenna as high as you can for best performance at long distances.

### Feed Line Radiation

Feed line radiation results when currents in a parallel-wire feed line are not balanced so that the radiation from each wire no longer cancels. This imbalance most commonly occurs when the feed line picks up energy radiated by the antenna on both wires at the same time. This creates *common-mode* current which re-radiates a signal just as an antenna does. (The equivalent situation for coaxial feed line is for the outer surface of the shield to pick up and re-radiate energy.)

Feed lines pick up the antenna's radiated signal when they are not symmetrically oriented with respect to the antenna and its radiated field. For example, a feed line that approaches a dipole at anything other than 90° will couple more strongly to the closer leg of the antenna. The closer the feed line is to one leg, the more energy it will pick up. Feed lines to an end-fed Zepp almost always carry common-mode current because they are connected at one end and not the middle. Common-mode feed line current and techniques for minimizing it are addressed in the chapter **Transmission Line System Techniques**.

It should be emphasized that any radiation from a feed line is not "lost" energy and is not necessarily harmful. Whether or not feed line radiation is important depends entirely on the antenna system being used. For example, feed line radiation is not desirable when a directive array is being used. Such feed line radiation can distort the desired pattern of such an array, producing responses in unwanted directions. In other words, you want radiation only from the directive array, rather than from the directive array and the feed line. If the feed line passes close to appliances or home entertainment equipment, the radiated field can also cause RFI.

On the other hand, in the case of a multiband dipole where general coverage is desired, if the feed line happens to radiate, such energy could actually have a desirable effect. Antenna purists may dispute such a premise, but from a practical standpoint where you are not concerned with a directive pattern, much time and labor can be saved by ignoring possible feed line radiation.

### Tuned Feeders

References are often made to "tuned feeders" meaning sections of feed line with a specific electrical length. The lengths act to transform load (antenna feed point) impedances as described in the **Transmission Lines** chapter. The most common application of a tuned feeder is with an end-fed antenna. A feed line that is any number of odd quarter-wavelengths long transforms a high impedance into a low impedance and so can be used to connect a 50-Ω transmitter to a high-impedance end-fed antenna. This only works at frequencies for which the feed line is the required electrical length, thus the term "tuned." Most tuned feeders are constructed from parallel-wire feed line to minimize loss from the high SWR in this application.

Tuned feeders can also create problems due to their length. For example, a feed line some multiple of λ/2 long connected to grounded equipment enclosures at one end also has a low impedance at the other end. That can cause trouble for an end-fed antenna with a high feed point impedance. Resonant feed line lengths (some multiple of λ/4 long) also tend to be effective at picking up energy from the antenna where it creates common-mode currents and re-radiated signals as discussed above.

## 10.1.4 THE 135-FOOT, 80 TO 10 METER DIPOLE

As mentioned previously, one of the most versatile antennas around is a simple dipole, center-fed with open-wire transmission line and used with an antenna tuner in the shack. A 135-foot long dipole hung horizontally between two trees or towers at a height of 50 feet or higher works very well on 80 through 10 meters. Such an antenna system has significant gain at the higher frequencies. (Other lengths reported to work well are 88 and 105 feet — don't be afraid to experiment.) The antenna can also be used on 1.8 MHz as a $\lambda/4$ antenna with some reduction in efficiency.

### Flattop or Inverted V Configuration?

There is no denying that the inverted V mounting configuration is very convenient, since it requires only a single support. The flattop configuration, however, where the dipole is mounted horizontally, gives more gain at the higher frequencies. **Figure 10.6** shows the 80 meter azimuth and elevation patterns for two 135-foot long dipoles. The first is mounted as a flattop at a height of 50 feet over flat ground with a conductivity of 5 mS/m and a dielectric constant of 13, typical for average soil. The second dipole uses the same length of wire, with the center apex at 50 feet and the ends drooped down to be suspended 10 feet off the ground. This height is sufficient so that there is no danger to passersby from RF burns.

At 3.8 MHz, the flattop dipole has about 4 dB more peak gain than its drooping cousin. On the other hand, the inverted V configuration gives a pattern that is more omnidirectional than the flattop dipole, which has nulls off the ends of the wire. Omnidirectional coverage may be more important to net operators, for example, than maximum gain.

**Figure 10.7** shows the azimuth and elevation patterns

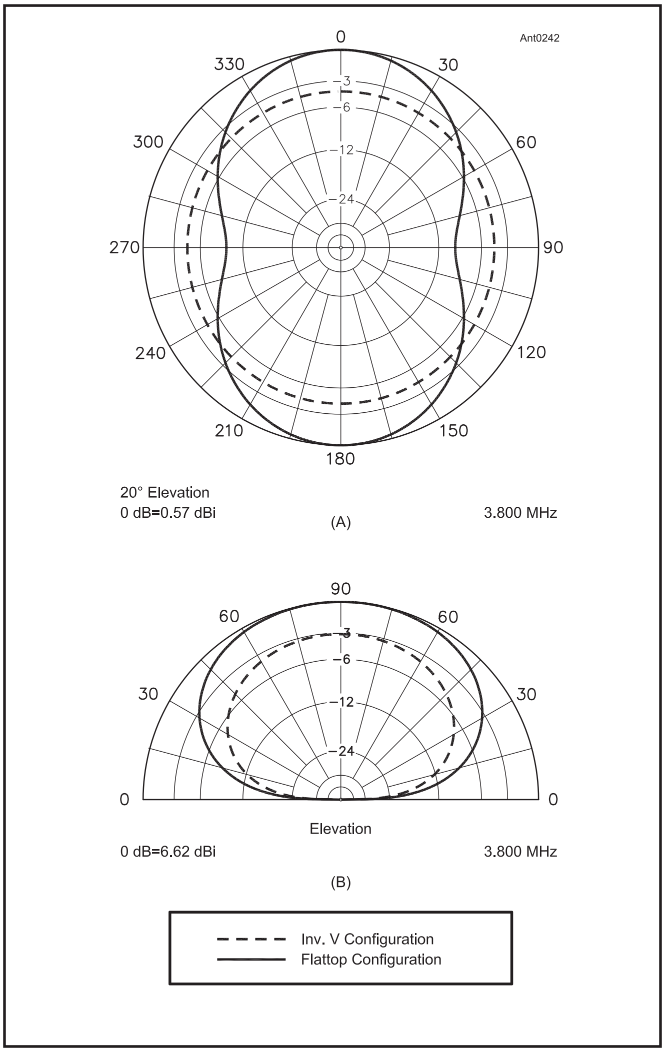



**Figure 10.6 — Patterns on 80 meters for 135-foot, center-fed dipole erected as a horizontal flattop dipole at 50 feet, compared with the same dipole installed as an inverted V with the apex at 50 feet and the ends at 10 feet. The azimuth pattern is shown at A, where the dipole wire lies in the 90° to 270° plane. At B, the elevation pattern, the dipole wire comes out of the paper at a right angle. On 80 meters, the patterns are not markedly different for either flattop or inverted V configuration.**

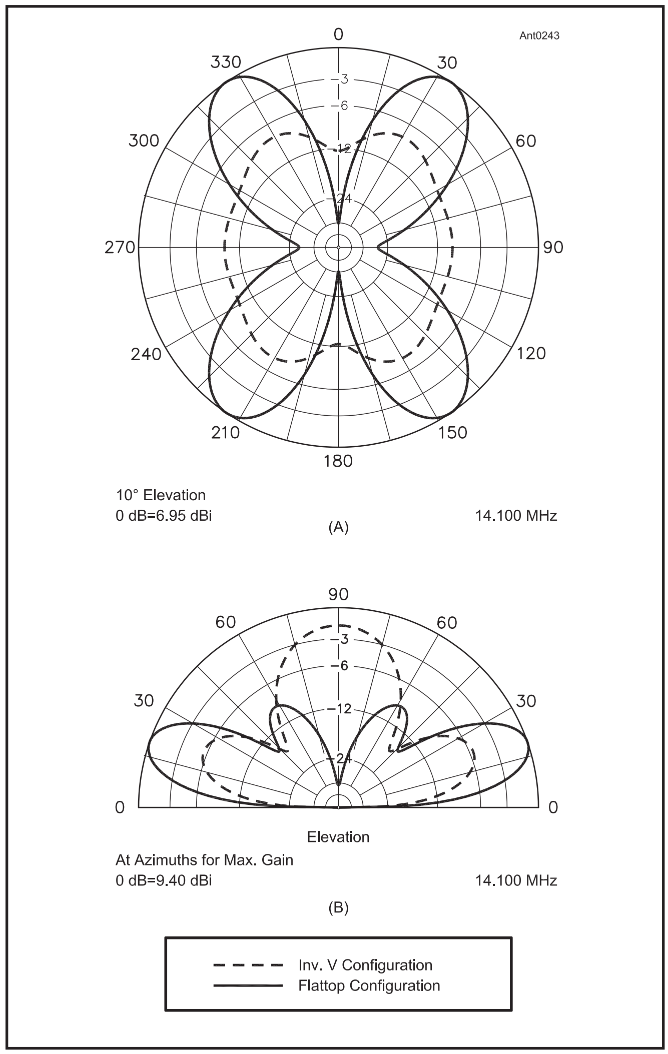



**Figure 10.7 — Patterns on 20 meters for two 135-foot dipoles. One is mounted horizontally as a flattop and the other as an inverted V with 120° included angle between the legs. The azimuth pattern is shown in A and the elevation pattern is shown in B. The inverted V has about 6 dB less gain at the peak azimuths, but has a more uniform, almost omnidirectional, azimuthal pattern. In the elevation plane, the inverted V has a large high-angle lobe, making it a somewhat better antenna for local communication, but not quite so good for DX contacts at low elevation angles.**

for the same two antenna configurations, but this time at 14.2 MHz. The flattop dipole has developed four distinct lobes at a 10° elevation angle, an angle typical for 20 meter skywave communication. The peak elevation angle gain of 9.4 dBi occurs at about 17° for a height of 50 feet above flat ground for the flattop dipole. The inverted V configuration is again nominally more omnidirectional, but the peak gain is down some 6 dB from the flattop.

The situation gets even worse in terms of peak gain at 28.4 MHz for the inverted V configuration. Here the peak gain is down about 8 dB from that produced by the flattop dipole, which exhibits eight lobes at this frequency with a maximum gain of 10.5 dBi at about 7° elevation. See the comparisons in **Figure 10.8**.

Whatever configuration you choose to mount the 135-foot dipole, you will want to feed it with some sort of low-loss open-wire feed line. For example, 450-Ω window line is popular for this application. Be sure to twist the line once or twice per foot to keep it from twisting excessively in the wind. (Do not twist it so much that the wire spacing is reduced.)

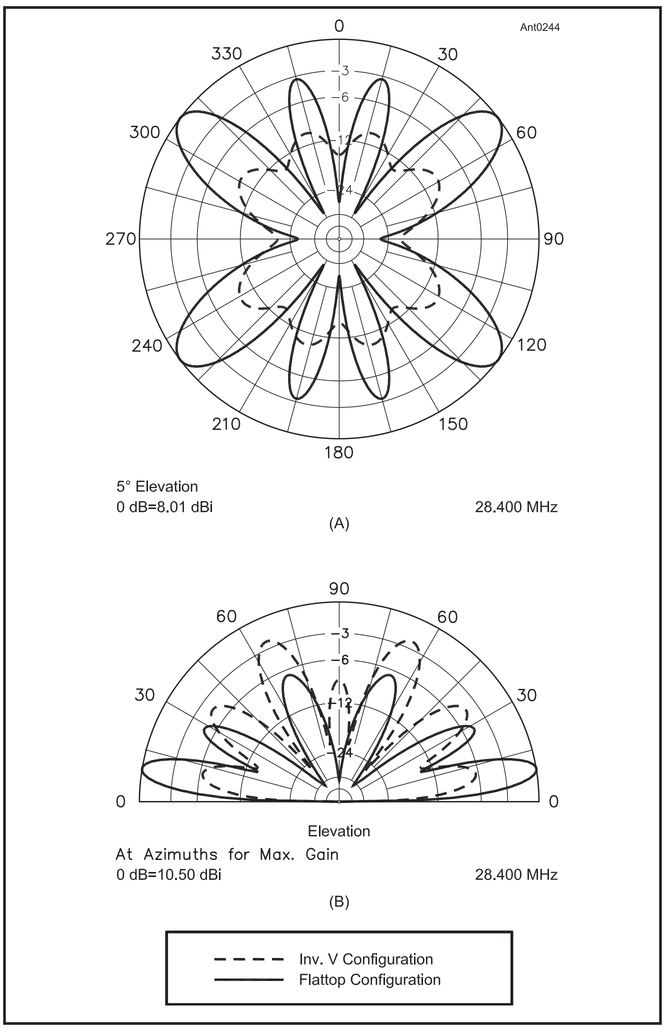



**Figure 10.8 — Patterns on 10 meters for same antenna configurations as in Figs 10.6 and 10.7. Once again, the inverted V configuration yields a more omnidirectional pattern, but at the expense of almost 8 dB less gain than the flattop configuration at its strongest lobes.**

Make sure also that you provide some mechanical support for the line at the junction with the dipole wires. This will prevent flexing of the transmission-line wire, since excessive flexing will result in breakage. (See the **Antenna Materials and Construction** chapter)

## 10.1.5 THE G5RV AND RELATED MULTIBAND ANTENNAS

A variation on the center-fed antenna that does not require a lot of space, is simple to construct and low in cost is the G5RV. Designed in England by Louis Varney, G5RV (SK), some years ago, it has become quite popular in the US. (The original article by G5RV in the *RSGB Bulletin* is included on this book's CD-ROM.) The G5RV design is shown in **Figure 10.9**. The antenna may be used from 3.5 through 30 MHz, although the use of an antenna tuner should be expected on any band except 14 MHz as Varney himself recommended. Low SWR with coax feed and no matching network on bands other than 14 MHz probably indicates excessive losses in the coax. In fact, an analysis of the G5RV feed point impedance shows there is no length of balanced line of any characteristic impedance that will transform the terminal impedance to the 50 to 75-Ω range on all bands.

Compared to a standard λ/2 20 meter dipole at 50 feet and a 132-foot long center-fed doublet at 50 feet (also discussed in the next section on Windom-style antennas), on 20 meters the G5RV is within 1 dB of peak gain of either antenna. The G5RV has a four-lobed pattern that is somewhat more omnidirectional than either dipole or doublet. This is somewhat of an advantage for a wire antenna which cannot be rotated. The G5RV patterns for other frequencies are similar to those shown for the 135-foot dipole in the previous section.

The portion of the G5RV antenna shown as horizontal in Figure 10.9 may also be installed in an inverted V dipole arrangement, subject to the same loss of peak gain mentioned above for the 135-foot dipole. Or instead, up to ⅙ of the total length of the antenna at each end may be dropped vertically or semi-vertically, or bent at a convenient angle to the main axis of the antenna, to cut down on the requirements for real estate.

A useful variation on the G5RV theme was designed

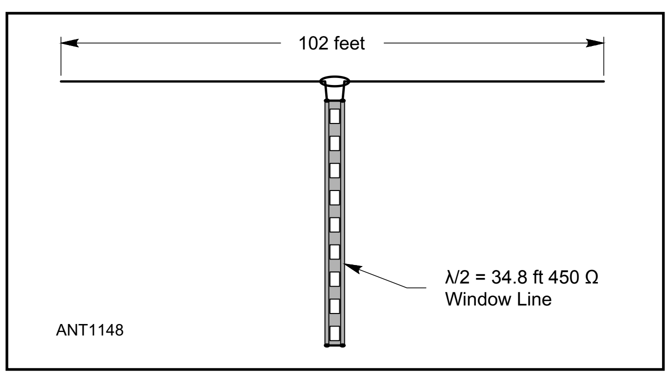



**Figure 10.9 — The G5RV multiband antenna covers 3.5 through 30 MHz. Although many amateurs claim it may be fed directly with 50-Ω coax on several amateur bands, Louis Varney, its originator, recommends the use of a matching network on bands other than 14 MHz.**

by Brian Austin, ZS6BKW (now GØGSF — see the Bibliography). It is shown in **Figure 10.10** and has a very similar radiation pattern to the G5RV. It is almost 10 feet shorter than the G5RV and uses a slightly longer length of 450-Ω window line to create the 50-Ω impedance point. The antenna is usable without a tuner in some portion of the 7, 14, 18, 24, and 28 MHz bands. The SWR is high on 3.5 MHz but within range of a tuner.

All of the G5RV/ZS6BKW and other variations that use a section of balanced transmission line to create a 50-Ω point require the use of a 1:1 current or choke balun as described in the chapter on **Transmission Line System Techniques**. Without the isolation between the balanced and unbalanced feed lines, the coaxial feed line will pick up significant common-mode RF current and allow noise picked up on the coax to enter the feed line.

The weight of the balun should be supported by sturdy construction and strain relief for the parallel conductor feed line. For this antenna, window line using stranded conductors is preferable to copper-plated steel since the repeated flexing will eventually cause the conductors to break. The window line matching section should be oriented at right angles to the top section (or symmetrically in an inverted V configuration) to avoid unbalancing the antenna system which would exacerbate common-mode current problems and distort the pattern unpredictably.

### 10.1.6 THE WINDOM AND CAROLINA WINDOM

An antenna that enjoyed popularity in the 1930s and into the 1940s was what we now call the Windom. It was known at the time as a "single-feeder Hertz" antenna, after being described in September 1929 *QST* by Loren G. Windom, W8GZ (see Bibliography).

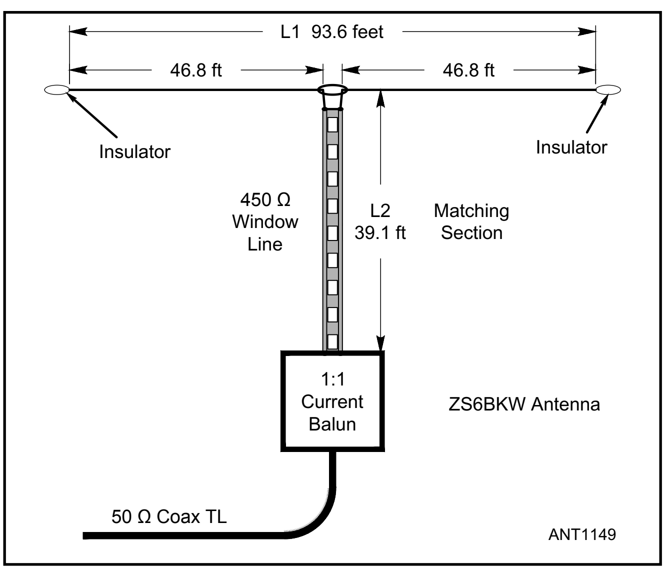



**Figure 10.10 — The ZS6BKW multiband antenna is a development of the G5RV. The length of the matching section of feed line is based on a velocity factor of 0.91 (91%). (see text)**

The Windom antenna, shown in **Figure 10.11**, is fed with a single wire, attached approximately 14% off center. In theory, this location provides a match for the single-wire transmission line, which is driven against an earth ground. Because the single-wire feed line is not inherently well balanced and because it is brought to the operating position, "RF in the shack" is a likely result of using this antenna. For that reason, the true single-feed-wire Windom antenna is rarely used although the name is often given to wires with non-centered feed points as described in the next section.

A recent variation is called the "Carolina Windom," apparently because two of the designers, Edgar Lambert, WA4LVB, and Joe Wright, W4UEB, lived in coastal North Carolina (the third, Jim Wilkie, WY4R, lived in nearby Norfolk, Virginia). One of the interesting parts about the Carolina Windom is that it turns a potential disadvantage — feed line radiation — into a potential advantage.

**Figure 10.12** is a diagram of a flattop Carolina Windom, which uses a 50-foot wire joined with an 83-foot wire at

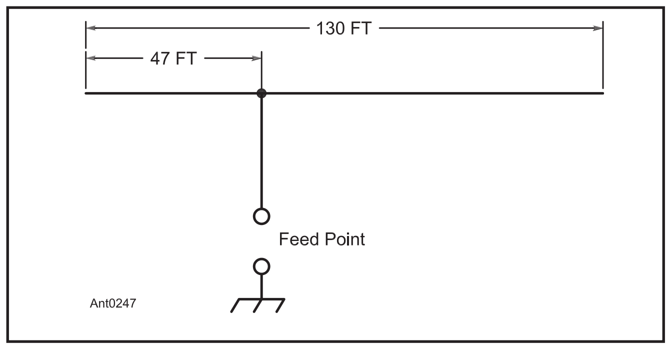



**Figure 10.11 — The Windom antenna, cut for a fundamental frequency of 3.75 MHz. The single-wire feed line, connected 14% off center, is brought into the station and the system is fed against ground. The antenna is also effective on its harmonics.**

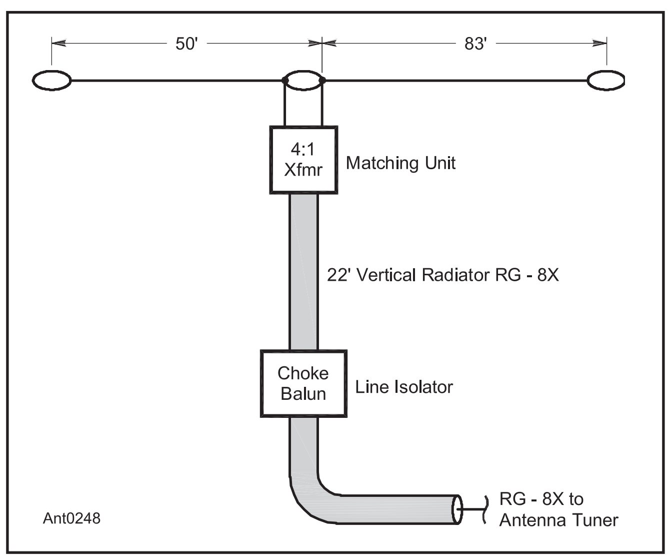



**Figure 10.12 — Layout for flattop "Carolina Windom" antenna.**

the feed point insulator. This resembles the layout shown in Figure 10.11 for the original W8GZ Windom. The "Vertical Radiator" for the Carolina Windom is a 22-foot piece of RG-8X coax, with a "line Isolator" (current-type choke balun) at the bottom end and a 4:1 "matching unit" (impedance transformer) at the top. The system takes advantage of the asymmetry of the horizontal wires to purposely induce current onto the outer shield surface of the vertical coax section. Note that the matching unit is a voltage-type balun transformer, which purposely does not act like a common-mode current choke balun. You must use an antenna tuner with this system to present a 1:1 SWR to the transmitter on the amateur bands from 80 through 10 meters.

The radiation resulting from current induced onto the 22-foot vertical coax section tends to fill in the deep nulls that would be present if the 132 feet of horizontal wire were center fed. Over saltwater, the vertical radiator can give significant gain at the low elevation angles needed for DX work. Indeed, field reports for the Carolina Windom are most impressive for stations located near or on saltwater. Over average soil the advantage of the additional vertically polarized component is not quite so evident. **Figure 10.13A** compares a 50-foot high Carolina Windom on 14 MHz over saltwater to a 50-foot high, 132-foot long, flattop center-fed dipole. The Carolina Windom has a more omnidirectional azimuthal pattern, a desirable characteristic in a 132-foot long wire antenna that is not normally rotated to favor different directions.

Another advantage of the Carolina Windom over a traditional Windom is that the coax feed line between the transmitter and common-mode choke balun does not radiate, meaning that there will be less "RF in the shack." Since the feed line is not always operating at a low SWR on various ham bands, use the minimum length of feed coax possible to hold down losses in the coax.

Figure 10.13B shows the azimuth responses for a 50-foot high flattop Carolina Windom on 28.4 MHz over saltwater and over average soil. The pattern for a 50-foot high, flattop 20 meter dipole operated on 28.4 MHz is also shown, since this 20 meter dipole can also be used as a multiband antenna, when fed with open-wire transmission line rather than with coax. Again, the Carolina Windom exhibits a more omnidirectional pattern, even if the pattern is somewhat lopsided at the bottom.

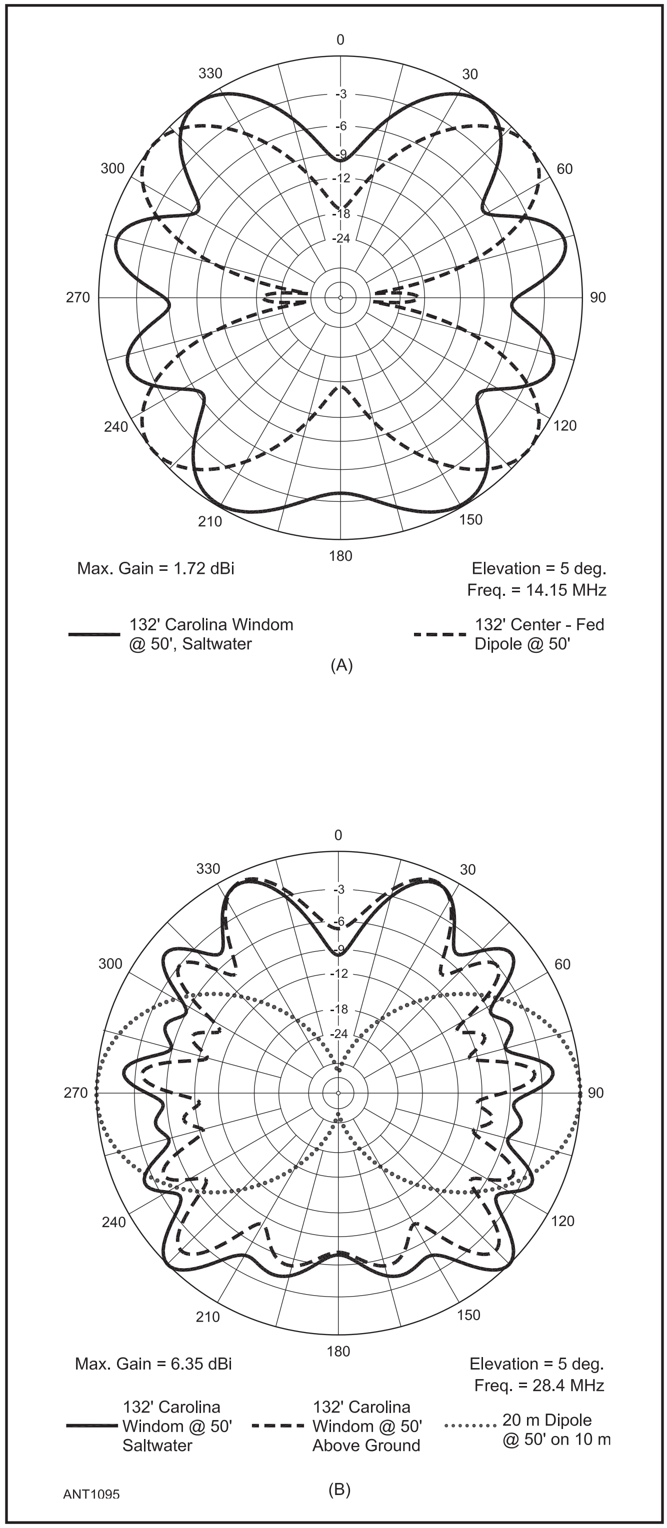



**Figure 10.13 — At A, 20 meter azimuth patterns for a 132-foot long off-center fed Carolina Windom and a 132-foot long center-fed flattop dipole on 20 meters, both at a height of 50 feet above saltwater. The response for the Carolina Windom is more omnidirectional because the vertically polarized radiation from the 22-foot long vertical RG-8X coax fills in the deep nulls. At B, 10 meter azimuthal responses for a 132-foot long, 50-foot high Carolina Windom over saltwater (solid line) and over average ground (dashed line), compared to that for a 20 meter half-wave dipole at 50 feet (dotted line).**

## 10.1.7 OFF-CENTER-FED (OCF) DIPOLES

The usual practice is to feed a $\lambda/2$ dipole in the center where the feed point impedance is low and makes a suitable match to coaxial cables. The dipole will accept energy from a feed point anywhere along its length, however, assuming that the source is matched to the higher impedance that is presented away from the center point. (As discussed in the **Dipoles and Monopoles** chapter, if the feed point is moved away from the center of the dipole, the impedance rises because current is dropping while voltage is rising.)

The *off-center-fed* dipole takes advantage of placing the feed point in a location along the dipole at which the impedance is similar on more than one band, generally in the

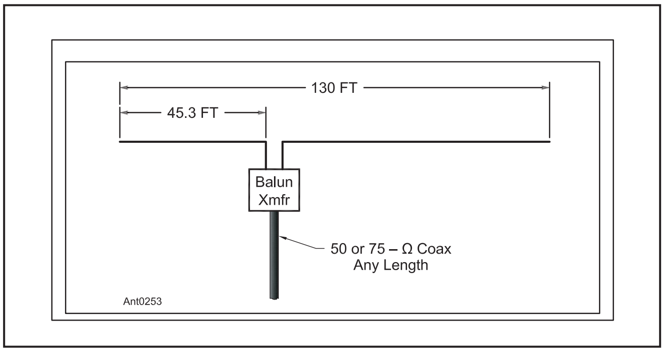



**Figure 10.14 — The off-center-fed (OCF) dipole for 3.5, 7 and 14 MHz. A 1:4 or 1:6 balun is used at the feed point.**

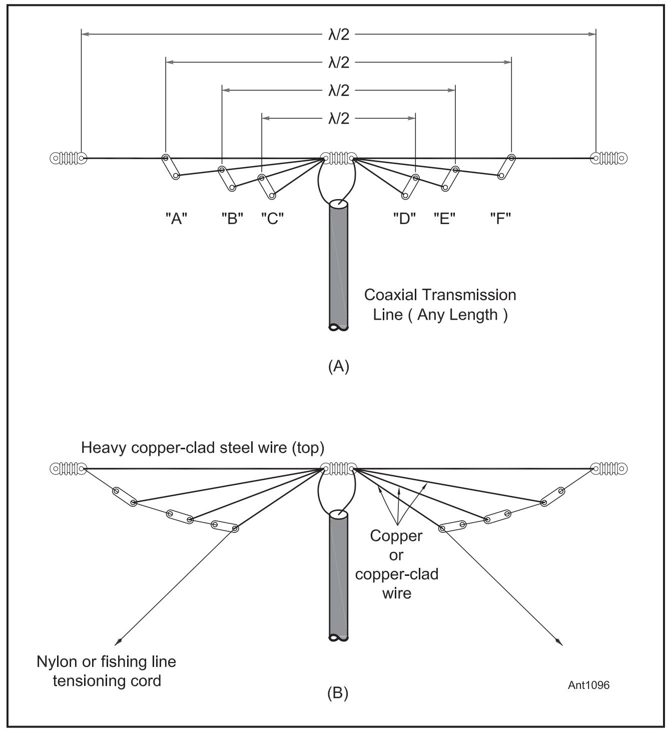



**Figure 10.15 — At A, multiband antenna using paralleled dipoles all connected to a common low-impedance transmission line. The half-wave dimensions may be either for the centers of the various bands or selected to fit favorite frequencies in each band. Because of interaction among the various dipoles, the builder should expect to adjust lengths for resonance on each band. B shows a method of constructing the dipole that offers less interaction between the dipoles, making it easier to tune.**

neighborhood of 150-300 Ω. A suitable impedance matching device such as an impedance transformer is then used to reduce the feed point impedance to something closer to 50 Ω. Note that the feed point impedance of the antenna varies with height above ground and so will SWR.

**Figure 10.14** shows an off-center-fed or *OCF* dipole. Because it is similar in appearance to the Windom of Figure 10.11, this antenna is often mistakenly called a "Windom," or sometimes a "coax-fed Windom." The two antennas are not the same, since the Windom is driven against an earth ground, while the OCF dipole is fed like a regular dipole — just not at its center. The extreme case of an OCF is the end-fed Zepp where the feed point is moved all the way to the end of the antenna.

The OCF dipole of Figure 10.14, fed ⅓ of its length from one end, may be used on its fundamental and even harmonics. Its free-space antenna-terminal impedance at 3.5, 7 and 14 MHz is on the order of 150 to 200 Ω. A 4:1 impedance transformer at the feed point should offer a reasonably good match to 50- or 75-Ω line, although some commercially made OCF dipoles use a 6:1 transformer. The usual caution is repeated here about height above ground affecting feed point impedance.

At the 6th harmonic, 21 MHz, the antenna is three wavelengths long and fed at a voltage maximum instead of a current maximum. The feed point impedance at this frequency is high, a few thousand ohms, so the antenna is unsuitable for use on this band.

### Balun Requirements

Because the OCF dipole is not fed at the center of the radiator, the feed line is not placed symmetrically with respect to the antenna's radiated field. As a result, common-mode current will flow on the feed line, usually a coaxial cable. How much current flows depends on the impedance of the coaxial cable's outer surface which, in turn, depends on the orientation of the cable, how long it is, height above ground, and so forth. (Some of the common-mode current results from the slightly unequal impedances presented by the OCF legs but most of the shield current is induced by the asymmetric location in the antenna's field.)

Regardless of how the common-mode current is caused to flow on the feed line, it is generally viewed as undesirable and a current or choke balun is used to increase the impedance of coaxial cable's outer surface. Radiation from the feed line may not be a problem in your installation and may even improve the antenna's radiation pattern by filling in nulls. (See "Feed line radiation" above.) In that case, no balun is required. (Choke baluns are discussed in the chapter **Transmission Line System Techniques**.)

## 10.1.8 MULTIPLE-DIPOLE ANTENNAS

The antenna system shown in **Figure 10.15A** consists of a group of center-fed dipoles, all connected in parallel at the point where the transmission line joins them. Each of the dipole elements is individually constructed to be an electrical λ/2 at different frequencies. This is often referred to as a "fan dipole," although that term is also applied to a dipole constructed as a bow-tie to increase operating bandwidth. (See the section "Broadband Dipoles" in the chapter **Single-Band MF and HF Antennas**.) The general idea is that the feed point impedance of the dipoles far from resonance will be high enough that nearly all of the signal power is applied to the resonant dipole which "ignores" the nonresonant dipoles.

In theory, the 4-wire antenna of Figure 10.15A can be used with a coaxial feed line on five bands. The four wires are prepared as parallel-fed dipoles for 3.5, 7, 14 and 28 MHz. The 7-MHz dipole is intended to be used on its 3rd harmonic for 21-MHz operation to cover a fifth band. However, in practice it has been found difficult to get a good match to coaxial line on all bands.

The λ/2 resonant length of any one dipole in the presence of the others is not the same as for a dipole by itself due to interaction and attempts to optimize all four lengths can become a frustrating procedure. The problem is compounded because the optimum tuning changes in a different antenna environment, so what works for one amateur may not work for another. The builder should start with a single dipole longer than resonance as discussed in the **Dipoles and Monopoles** chapter and be prepared to make repeated adjustments to the dipole lengths as more dipoles are added to the antenna.

Even if a perfect match cannot be obtained on all bands, many amateurs with limited antenna space are willing to accept the mismatch on some bands just so they can operate on those frequencies using a single coax feed line. The fewer dipoles that are used in parallel, the easier it will be to adjust them for the desired performance.

If an attempt is made to model the multi-wire dipole, take extra care to define the feed point construction carefully. As noted in the **Antenna Modeling** chapter, wires that are very close to each other or that join at small angles are hard to model so that the results reflect actual performance.

The multiple-dipole antenna can be fed with parallel-wire feed line and an antenna tuner but that negates the intended advantage of the design over a conventional single-wire nonresonant dipole — the use of a single coaxial feed line. The usual feed method is to use a coaxial feed line and a choke balun at the feed point as described in the chapter **Transmission Line System Techniques**.

The separation between the dipoles for the various frequencies does not seem to be especially critical. One set of wires can be suspended from the next larger set, using insulating spreaders (of the type used for feed line spreaders) to give a separation of a few inches. Users of this antenna often run some of the dipoles at right angles to each other to help reduce interaction. Some operators use inverted V-mounted dipoles as guy wires for the mast that supports the antenna system. The top (and longest) dipole must support the weight of the rest of the antenna plus the feed line, so use heavy wire (copper-clad steel is the strongest) for the top antenna.

While the separation between dipoles does not seem to be especially critical to final performance, it does affect the amount of interaction between them that makes tuning each dipole difficult. A method of construction and tuning reported by Don Butler, N4UJW (**www.hamuniverse.com/multidipole.html**) is shown is Figure 10.15B. For dipoles in the 2-18 MHz range, separating the dipoles at the feed point by at least 5½ inches vertically and at the ends by 38 inches results in a final length closer than ±2% of a single dipole.

An interesting method of construction used successfully by Louis Richard, ON4UF, is shown in **Figure 10.16**. The antenna has four dipoles (for 7, 14, 21 and 28 MHz) constructed from 300-Ω twin lead. A single length of twin lead makes two dipoles. Thus, two lengths, as shown in the sketch, serve to make dipoles for four bands. Be sure to use twin lead with copper-clad steel conductors because all of the weight, including that of the feed line, must be supported by the uppermost wire (450-Ω window line could also be used).

Two pieces of twin lead are first cut to a length suitable for the two halves of the longest dipole. Then one of the conductors in each piece is cut to proper length for the next band higher in frequency. The excess wire and insulation is stripped away. A second pair of lengths is prepared in the same manner, except that the lengths are appropriate for the next two higher frequency bands. (Note the potential for interaction between higher and lower-frequency dipoles that may alter the tuning of previously adjusted dipoles.)

A piece of thick plastic sheet (plexiglass, polycarbonate, or high-density polyethylene) drilled with holes for anchoring each wire serves as the central insulator. The shorter pair of dipoles is suspended the width of the ribbon below the longer pair by clamps also made of poly sheet. Intermediate spacers are made by sawing slots in pieces of poly sheet so they will fit the ribbon snugly.

The multiple-dipole principle can also be applied to vertical antennas. Parallel or fanned λ/4 elements of wire or tubing can be driven against ground or tuned radials from a common feed point.

### Double-L Antenna

The Double-L antenna by Don Toman, K2KQ is a variation of the multi-wire dipole. (**www.yccc.org/Articles/double_l.htm**) Shown in **Figure 10.17**, the antenna is basically a vertical dipole with its ends bent to run horizontally over ground. It can be constructed as a single antenna for one band or a second dipole can be added to use the antenna on two bands.

Construction is not critical. The bottom wires should be at least 10 feet above ground and no radial system is required. If you do construct the dual-band version, the vertical wires are connected together at the feed point and separated by

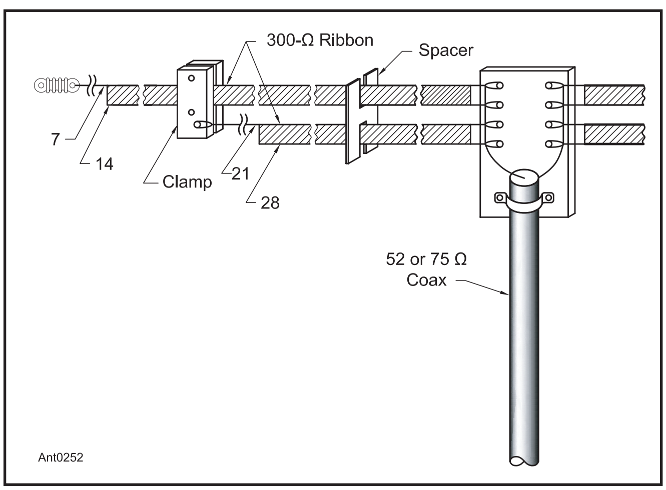



**Figure 10.16 — Sketch showing how the twin-lead multiple-dipole antenna system is assembled. The excess wire and insulation are stripped away.**

about 3 feet where they bend to become horizontal. The two horizontal sections are separated by about 30°. If the antennas are supported by a metal tower, the vertical section should be at least 3 feet from the tower.

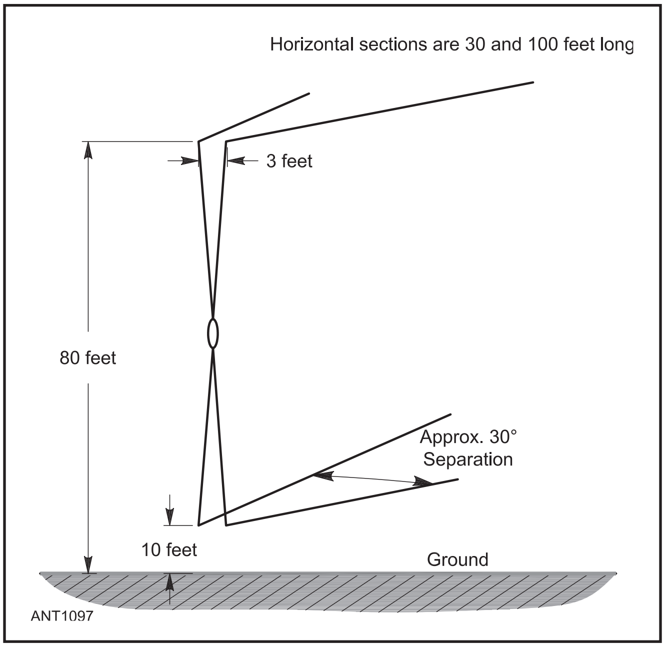



**Figure 10.17 — The Double-L antenna by K2KQ is a pair of vertical dipoles with their ends bent to be parallel to the ground. The bottom horizontal wires should be at least 10 feet above ground. For single-band operation, install only a single dipole. The antenna works well as either a single-band or dual-band antenna.**

The antenna is inherently unbalanced and may be tuned by removing or adding wire to the lower legs without dramatically affecting performance or feed point impedance. The dimensions given result in an SWR minimum near 1.83 MHz and 3.75 MHz.

### 10.1.9 HORIZONTAL LOOP "SKYWIRE"

A horizontal full-wavelength loop is a very effective omnidirectional antenna for regional communications on its fundamental frequency where its radiation is a maximum at high angles. The loop is also useful on higher bands where the pattern begins to divide into multiple lobes at lower elevation angles.

While the feed point impedance might be reasonably low on some bands, using a coax feed line will result in significant losses on others. The best way to feed this versatile antenna is with parallel-wire window or ladder line using an antenna tuner in the shack.

The Loop Skywire is shown in **Figure 10.18**. The antenna has one wavelength of wire in its perimeter at the design or fundamental frequency. If you choose to calculate $L_{total}$ in feet, the following equation should be used:

$L_{total} = 1005 / f$

where f equals the frequency in MHz.

Loop shapes other than a square are possible, but the larger the area enclosed by the loop, the better its performance will be. (A circle encloses the maximum area but this is rarely practical.) The Loop Skywire can also be operated as a vertical antenna with top-hat loading by tying both feed line conductors together at the antenna tuner. This method requires

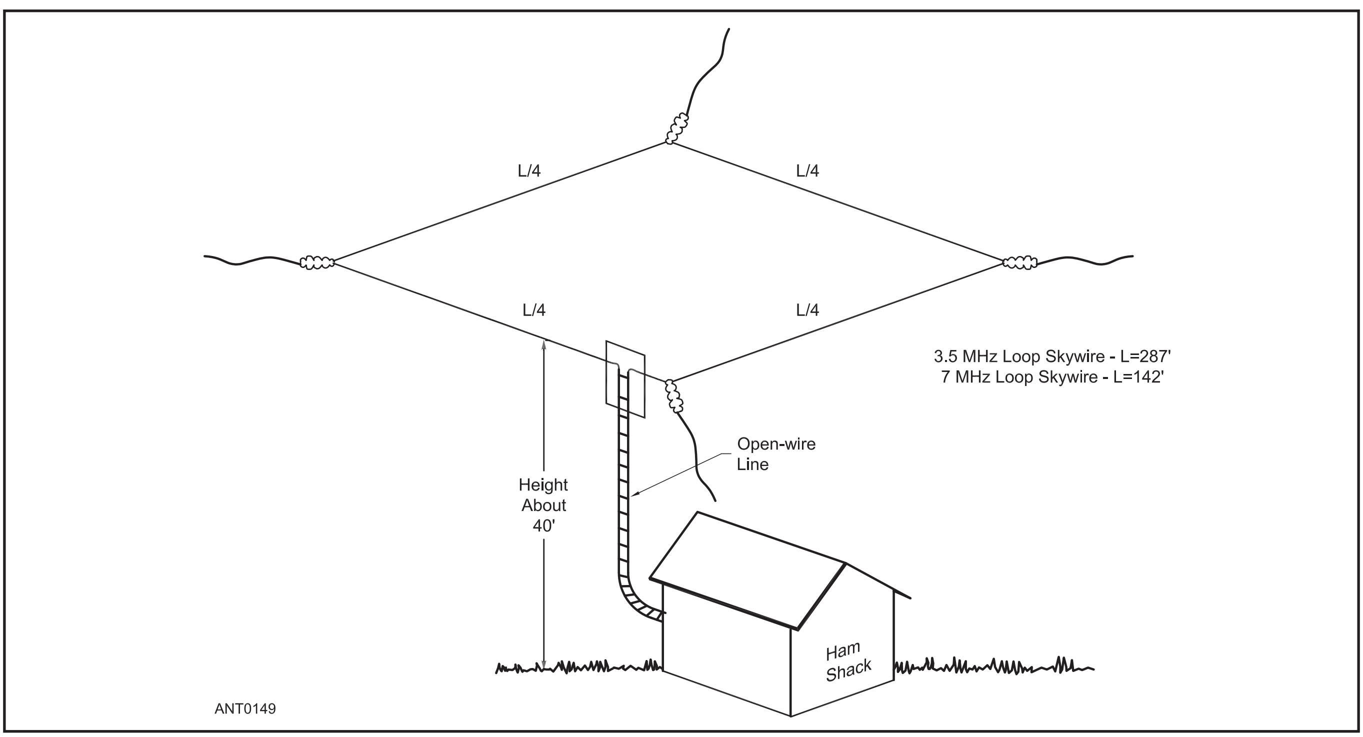



**Figure 10.18 — A complete view of the Loop Skywire. The square loop is erected horizontally.**

good station ground as described in the previous section on Random-Wire Antennas.

Although the loop can be made for any band or frequency of operation, the following two Loop Skywires are good performers. The 10-MHz band can also be used on both.

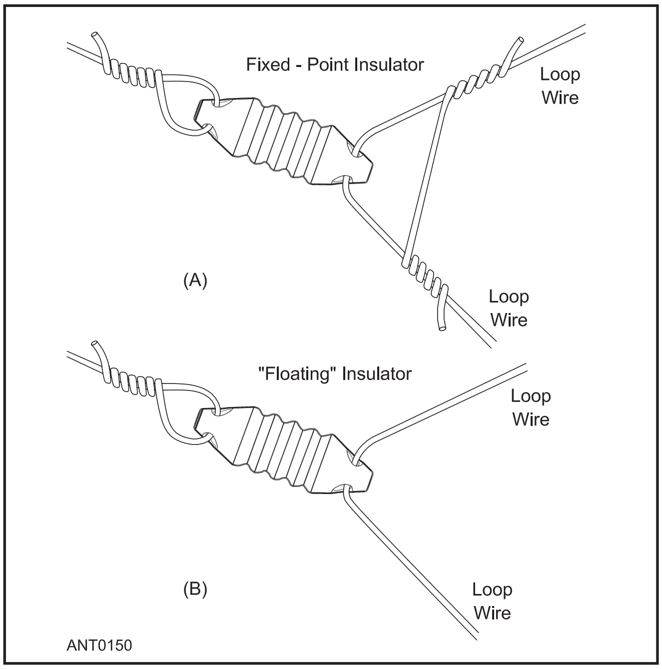



**Figure 10.19 — Two methods of installing the insulators at the loop corners.**

*3.5-MHz Loop Skywire*
(3.5-28 MHz loop and 1.8-MHz vertical)
Total loop perimeter: 272 feet
Square side length: 68 feet
*7-MHz Loop Skywire*
(7-28 MHz loop and 3.5-MHz vertical)
Total loop perimeter: 142 feet
Square side length: 35.5 feet

The actual total length can vary from the above by a few feet, as the length is not at all critical. Do not worry about tuning and pruning the loop to resonance as it will not make a significant difference in performance.

Bare #14 AWG wire is used in the loop. Copper-clad steel wire is recommended for the 3.5-MHz version. **Figure 10.19** shows the placement of the insulators at the loop corners. Two common methods are used to attach the insulators. Either lock or tie the insulator in place with a loop wire tie, as shown in Figure 10.19A, or leave the insulator free to "float" or slide along the wire, Figure 10.19B. Most loop users float at least two insulators. This allows pulling the slack out of the loop once it is in the air, and eliminates the need to have all the supports exactly placed for proper tension in each leg. Floating two opposite corners is recommended.

The feed point (**Figure 10.20**) can be positioned anywhere along the loop that you wish. However, most users feed the Skywire at a corner. The feed line can be attached as described in the **Antenna Materials and Construction** chapter. Placing the feed point a foot or so from one corner allows the feed line to exit more freely and keeps the feed line free of the loop support.

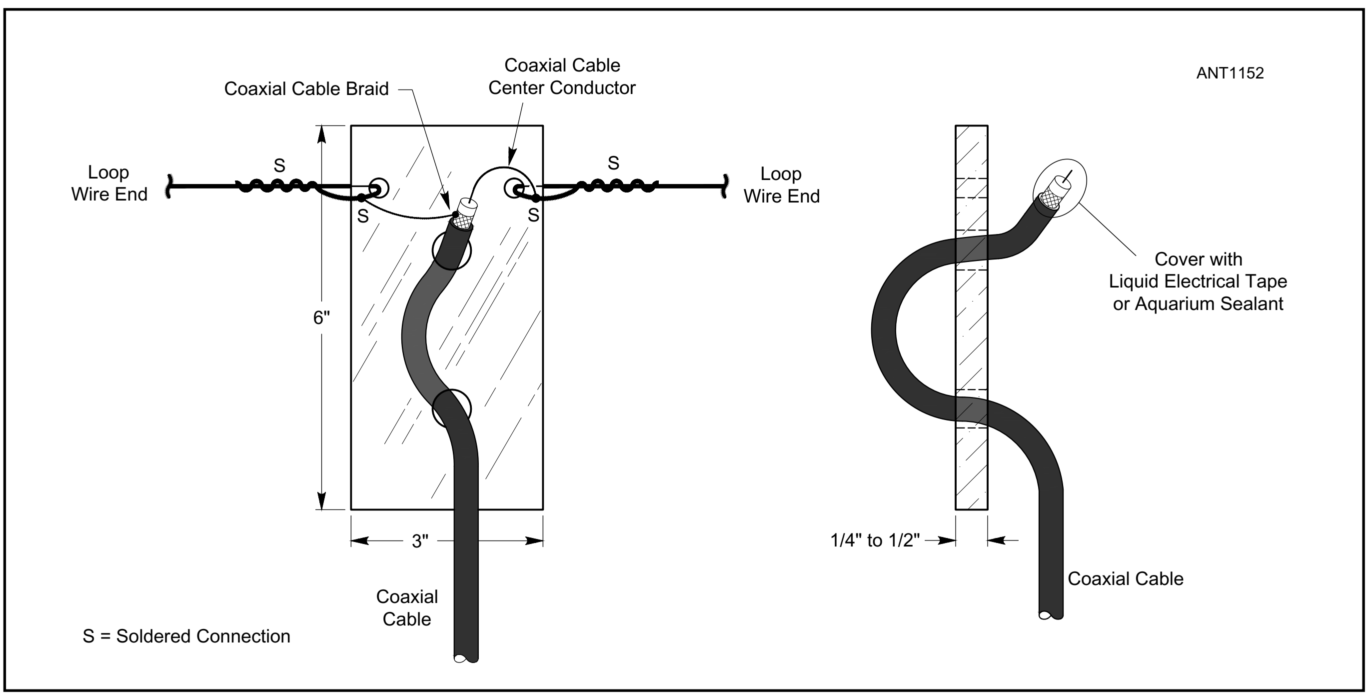



**Figure 10.20 — While most builders feed the Skywire at a corner, this feed insulator can be used anywhere on the antenna and provides some support for the coaxial cable although very long runs of RG-213-size cable are too heavy for this approach. Drill the holes for the coax at an angle to prevent the edges of the hole from biting into the coax. Use a heavy UV-resistant plastic for the insulator and waterproof the coax pigtail using liquid electrical tape or aquarium sealant.**

Generally a minimum of four supports is required. If trees are used for supports, then at least two of the ropes or guys used to support the insulators should be counterweighted and allowed to move freely. The feed line corner is almost always tied down, however. Very little tension is needed to support the loop (far less than that for a dipole). Thus, counterweights are light. Several such loops have been constructed with bungee cords tied to three of the four insulators. This eliminates the need for counterweighting.

**Figure 10.21A** shows the azimuth performance on 7.2 MHz of a 142-foot long, 7-MHz Loop Skywire, 40 feet high at an elevation angle of 10º, compared to a regular flattop ½-λ dipole at a height of 30 feet. The loop comes into its own at higher frequencies. Figure 10.21B shows the response at 14.2 MHz, compared again to a ½-λ 14.2-MHz dipole at a height of 30 feet. Now the loop has several lobes that are stronger than the dipole. Figure 10.21C shows the response at 21.2 MHz, compared to a dipole. Now the loop has superior gain compared to the ½-λ dipole at almost any azimuth. In its favored direction on 21.2 MHz, the loop is 8 dB stronger than the dipole.

Recommended height for the antenna is 40 feet or more. Higher is better, especially if you wish to use the loop in the vertical mode. However, successful local and DX operation has been reported in several cases with the antenna at 20 feet.

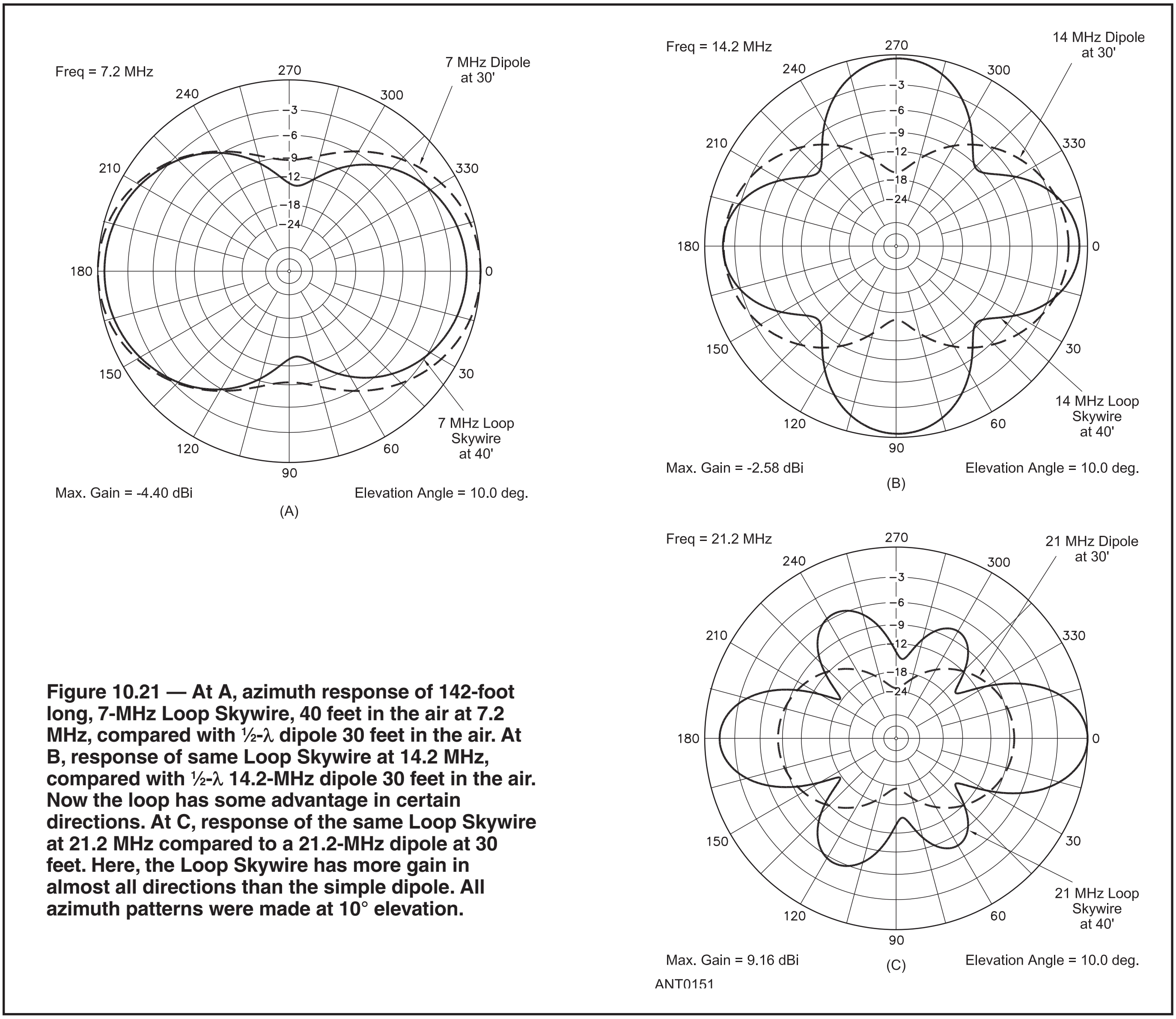



**Figure 10.21 — At A, azimuth response of 142-foot long, 7-MHz Loop Skywire, 40 feet in the air at 7.2 MHz, compared with ½-λ dipole 30 feet in the air. At B, response of same Loop Skywire at 14.2 MHz, compared with ½-λ 14.2-MHz dipole 30 feet in the air. Now the loop has some advantage in certain directions. At C, response of the same Loop Skywire at 21.2 MHz compared to a 21.2-MHz dipole at 30 feet. Here, the Loop Skywire has more gain in almost all directions than the simple dipole. All azimuth patterns were made at 10° elevation.**

# 10.2 TRAP ANTENNAS

By using tuned circuits of appropriate design strategically placed in a dipole, the antenna can be made to show what is essentially fundamental resonance at a number of different frequencies. The general principle is illustrated by **Figure 10.22**. The tuned circuits are also referred to as "traps" and so an antenna that uses tuned circuits to change its electrical configuration at different frequencies is called a "trap antenna" or a "trapped antenna."

Even though a trap antenna arrangement is a simple one, an explanation of how a trap antenna works can be elusive. For some designs, traps are resonated in our amateur bands, and for others (especially commercially made antennas) the traps are resonant far outside any amateur band.

A trap in an antenna system can perform either of two functions, depending on whether or not it is resonant at the operating frequency. A familiar case is where the trap is parallel-resonant in an amateur band. For the moment, let us assume that dimension A in Figure 10.22 is 32 feet and that each L/C combination is resonant in the 7-MHz band. Because of its parallel resonance, the trap presents a high impedance at that point in the antenna system. The electrical effect at 7 MHz is that the trap behaves as an open circuit. It serves to separate the outside ends, the B sections, from the inner sections of the antenna. The result is easy to visualize — we now have an antenna system that is resonant in the 7-MHz band. Each 33-foot section (labeled A in the drawing) represents $\lambda/4$ with the trap acting as an open circuit. We therefore have a full-size 7-MHz antenna.

The second function of a trap, obtained when the frequency of operation is *not* the resonant frequency of the trap, is one of electrical loading. If the operating frequency is below the trap's resonant frequency, the trap behaves as an inductor; if above, as a capacitor. Inductive loading will electrically lengthen the antenna, and capacitive loading will electrically shorten the antenna.

Let's carry our assumption a bit further and try using the antenna we just considered at 3.5 MHz. With the traps resonant in the 7-MHz band, they will behave as inductors when operation takes place at 3.5 MHz, electrically lengthening the antenna. This means that the total length of sections A and B (plus the length of the inductor) may be something less than a physical $\lambda/4$ for resonance at 3.5 MHz. Thus, we have a two-band antenna that is shorter than full size on the lower frequency band. But with the electrical loading provided by the traps, the overall electrical length is $\lambda/2$. The total antenna length needed for resonance in the 3.5-MHz band will depend on the L/C ratio of the trap elements.

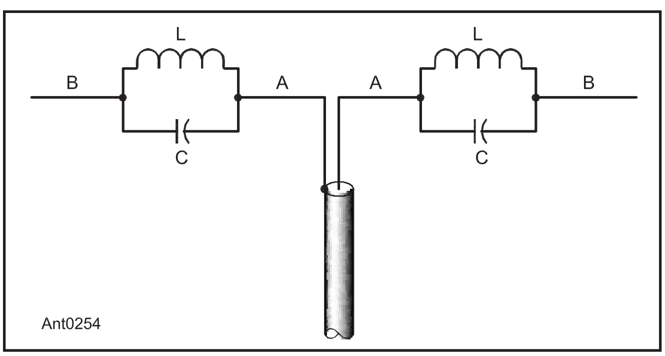



**Figure 10.22 — A trap dipole antenna. This antenna may be fed with 50-Ω coaxial line. Depending on the L/C ratio of the trap elements and the lengths chosen for dimensions A and B, the traps may be resonant either in an amateur band or at a frequency far removed from an amateur band for proper two-band antenna operation.**

The key to trap operation away from resonance is its L/C ratio, the ratio of the value of L to the value of C. At resonance, however, within practical limitations the L/C ratio is immaterial as far as electrical operation goes. For example, in the antenna we've been discussing, it would make no difference for 7-MHz operation whether the inductor were 1 µH and the capacitor were 500 pF (the reactances would be just below 45 Ω at 7.1 MHz), or whether the inductor were 5 µH and the capacitor 100 pF (reactances of approximately 224 Ω at 7.1 MHz). But the choice of these values will make a significant difference in the antenna size for resonance at 3.5 MHz. In the first case, where the L/C ratio is 2000, the necessary length of section B of the antenna for resonance at 3.75 MHz would be approximately 28.25 feet. In the second case, where the L/C ratio is 50,000, this length need be only 24.0 feet, a difference of more than 15%.

The above example concerns a two-band antenna with trap resonance at one of the two frequencies of operation. On each of the two bands, each half of the dipole operates as an electrical $\lambda/4$. However, the same band coverage can be obtained with a trap resonant at, say, 5 MHz, a frequency quite removed from either amateur band. With proper selection of the L/C ratio and the dimensions for A and B, the trap will act to shorten the antenna electrically at 7 MHz and lengthen it electrically at 3.5 MHz. Thus, an antenna that is intermediate in physical length between being full size on 3.5 MHz and full size on 7 MHz can cover both bands, even though the trap is not resonant at either frequency. Again, the antenna operates with electrical $\lambda/4$ sections. Note that such nonresonant traps have less RF current flowing in the trap components, and hence trap losses are less than for resonant traps.

Additional traps may be added in an antenna section to cover three or more bands. Or a judicious choice of dimensions and the L/C ratio may permit operation on three or more bands with just a pair of identical traps in the dipole.

An important point to remember about traps is this. If the operating frequency is below that of trap resonance, the trap behaves as an inductor; if above, as a capacitor. The above discussion is based on dipoles that operate electrically as $\lambda/2$ antennas. This is not a requirement, however. Elements may be operated as electrical $\frac{3}{2}\lambda$, or even $\frac{5}{2}\lambda$, and still present a reasonable impedance to a coaxial feed line. In trap antennas covering several HF bands, using electrical lengths that are odd multiples of $\lambda/2$ is often done at the higher frequencies.

To further aid in understanding trap operation, let's now choose trap L and C components that each have a reactance of 20 Ω at 7 MHz. Inductive reactance is directly proportional to frequency, and capacitive reactance is inversely proportional. When we shift operation to the 3.5-MHz band, the inductive reactance becomes 10 Ω, and the capacitive reactance becomes 40 Ω. At first thought, it may seem that the trap would become capacitive at 3.5 MHz with a higher capacitive reactance, and that the extra capacitive reactance would make the antenna electrically shorter yet. Fortunately, this is not the case. The inductor and the capacitor are connected in parallel with each other.

$$Z = j\frac{X_L X_C}{X_L + X_C} \qquad \text{(Eq 1)}$$

where *j* indicates a reactive impedance component, rather than resistive. A positive result indicates inductive reactance, and a negative result indicates capacitive. In this 3.5-MHz case, with 40 Ω of capacitive reactance and 10 Ω of inductive, the equivalent series reactance is 13.3 Ω inductive. This inductive loading lengthens the antenna to an electrical λ/2 overall at 3.5 MHz, assuming the B end sections in Figure 10.22 are of the proper length.

With the above reactance values providing resonance at 7 MHz, $X_L$ equals $X_C$, and the theoretical series equivalent is infinity. This provides the open-switch effect, disconnecting the antenna ends.

At 14 MHz, where $X_L$ = 40 Ω and $X_C$ = 10 Ω, the resultant series equivalent trap reactance is 13.3 Ω capacitive. If the total physical antenna length is slightly longer than 3/2 λ at 14 MHz, this trap reactance at 14 MHz can be used to shorten the antenna to an electrical 3/2 λ. In this way, three-band operation is obtained for 3.5, 7 and 14 MHz with just one pair of identical traps. The design of such a system is not straightforward, however, because any chosen L/C ratio for a given total length affects the resonant frequency of the antenna on both the 3.5 and 14-MHz bands.

### 10.2.1 TRAP LOSSES

Since the tuned circuits have some inherent losses, the efficiency of a trap system depends on the unloaded Q values of the tuned circuits. Low-loss (high-Q) coils should be used, and the capacitor losses likewise should be kept as low as possible. With tuned circuits that are good in this respect — comparable with the low-loss components used in transmitter tank circuits, for example — the reduction in efficiency compared with the efficiency of a simple dipole is small, but tuned circuits of low unloaded Q can lose an appreciable portion of the power supplied to the antenna.

The commentary above applies to traps assembled from conventional components. The important function of a trap that is resonant in an amateur band is to provide a high isolating impedance, and this impedance is directly proportional to Q. Unfortunately, high Q restricts the antenna bandwidth, because the traps provide maximum isolation only at trap resonance.

### 10.2.2 FIVE-BAND W3DZZ TRAP ANTENNA

C. L. Buchanan, W3DZZ, created one of the first trap antennas for the five pre-1979 WARC amateur bands from 3.5 to 30 MHz. Dimensions are given in **Figure 10.23**. Only one set of traps is used, resonant at 7 MHz to isolate the inner (7-MHz) dipole from the outer sections. This causes the overall system to be resonant in the 3.5-MHz band. On 14, 21 and 28 MHz the antenna works on the capacitive-reactance principle just outlined. With a 75-Ω feed line, the SWR with this antenna is under 2:1 throughout the three highest frequency bands, and the SWR is comparable with that obtained with similarly fed simple dipoles on 3.5 and 7 MHz. (The complete article is available on this book's CD-ROM.)

#### Trap Construction

Traps frequently are built with coaxial aluminum tubes (usually with plastic tubing in-between them for insulation) for the capacitor, with the coil either self-supporting or wound on a form of larger diameter than the tubular capacitor. The coil is then mounted coaxially with the capacitor to form a unit assembly that can be supported at each end by the antenna wires. In another type of trap devised by William J. Lattin, W4JRW (see Bibliography at the end of this chapter), the coil is supported inside an aluminum tube and the trap capacitor is obtained in the form of capacitance between the coil and the outer tube. This type of trap is inherently weatherproof.

A simpler type of trap can be easily assembled from readily available components. A small transmitting-type ceramic "doorknob" capacitor is used, together with a length of commercially available coil material, these being supported by an ordinary ceramic or plastic antenna strain insulator 4¼ inches long. The circuit constants and antenna dimensions differ slightly from those of Figure 10.23, in order to bring the antenna resonance points closer to the centers of the various phone bands. Construction data are given in **Figure 10.24**.

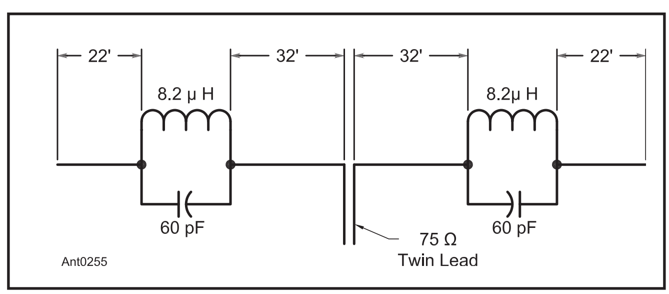



**Figure 10.23 — Five-band (3.5, 7, 14, 21 and 28 MHz) trap dipole for operation with 75-Ω feed line at low SWR (C. L. Buchanan, W3DZZ). The balanced (parallel-conductor) line indicated is desirable, but 75-Ω coax can be substituted with a choke balun at the feed point to maintain symmetry. Dimensions given are for resonance (lowest SWR) at 3.75, 7.2, 14.15 and 29.5 MHz. Resonance is very broad on the 21-MHz band, with SWR less than 2:1 throughout the band.**

If a 10-turn length of inductor is used, a half turn from each end may be used to slip through the anchor holes in the insulator to act as leads.

The components used in these traps are sufficiently weatherproof in themselves so that no additional weatherproofing has been found necessary. However, if it is desired to protect them from the accumulation of snow or ice, a plastic cover can be made by cutting two discs of plastic slightly larger in diameter than the coil, drilling at the center to pass the antenna wires, and cementing a plastic cylinder on the edges of the discs. The cylinder can be made by wrapping two turns or so of 0.02-inch plastic sheet around the discs, if no suitable ready-made tubing is available. Plastic drinking glasses and 2-liter soft-drink plastic bottles are easily adaptable for use as impromptu trap covers.

### 10.2.3 W8NX MULTIBAND, COAX-TRAP DIPOLES

Over the last 60 or 70 years, amateurs have used many kinds of multiband antennas to cover the traditional HF bands. The availability of the 30, 17 and 12 meter bands has expanded our need for multiband antenna coverage. This section is based on the August 1994 *QST* article "Two New Multiband Trap Dipoles" by Al Buxton, W8NX. This article and two others by the same author are included on this book's CD-ROM, providing designs for trap dipoles operating on all of the amateur bands below 30 MHz.

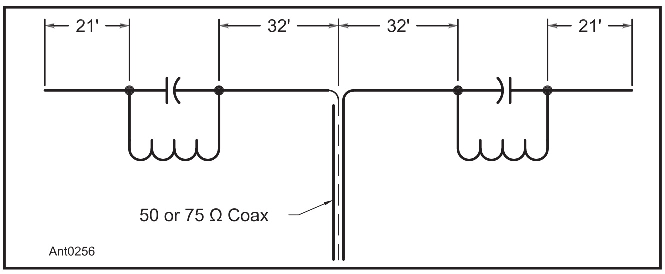



**Figure 10.24 — Layout of multiband antenna using traps constructed as shown in Figure 10.25. The capacitors are 100 pF each, transmitting type, 5000-V dc rating (Centralab 850SL-100N). Coils are 9 turns of #12 AWG wire, 2½ inches diameter, 6 turns per inch (B&W 3029) with end turns spread as necessary to resonate the traps to 7.2 MHz. These traps, with the wire dimensions shown, resonate the antenna at approximately the following frequencies on each band: 3.9, 7.25, 14.1, 21.5 and 29.9 MHz (based on measurements by W9YJH).**

Two different antennas are described here. The first covers the traditional 80, 40, 20, 15 and 10 meter bands, and the second covers 80, 40, 17 and 12 meters. Each uses the same type of W8NX trap — connected for different modes of operation — and a pair of short capacitive stubs to enhance coverage. The W8NX coaxial-cable traps have two different modes: a high- and a low-impedance mode. The inner-conductor windings and shield windings of the traps are connected in series for both modes. However, either the low- or high-impedance point can be used as the trap's output terminal. For low-impedance trap operation, only the center conductor turns of the trap windings are used. For high-impedance operation, all turns are used, in the conventional manner for a trap. The short stubs on each antenna are strategically sized and located to permit more flexibility in adjusting the resonant frequencies of the antenna.

#### 80, 40, 20, 15 and 10 meter Dipole

**Figure 10.25** shows the configuration of the 80, 40, 20, 15 and 10 meter antenna. The radiating elements are made of #14 AWG stranded copper wire. The element lengths are the wire span lengths in feet. These lengths do not include the lengths of the pigtails at the balun, traps and insulators. The 32.3-foot-long inner 40 meter segments are measured from the eyelet of the input balun to the tension-relief hole in the trap coil form. The 4.9-foot segment length is measured from the tension-relief hole in the trap to the 6-foot stub. The 16.1-foot outer-segment span is measured from the stub to the eyelet of the end insulator.

The coaxial-cable traps are wound on PVC pipe coil forms and use the low-impedance output connection. The stubs are 6-foot lengths of ⅛-inch stiffened aluminum or copper rod hanging perpendicular to the radiating elements. The first inch of their length is bent 90° to permit attachment to the radiating elements by large-diameter copper crimp connectors. Ordinary #14 AWG wire may be used for the stubs, but it has a tendency to curl up and may tangle unless

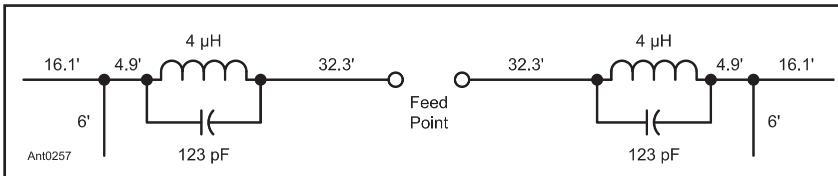



**Figure 10.25 — A W8NX multiband dipole for 80, 40, 20, 15 and 10 meters. The values shown (123 pF and 4 μH) for the coaxial-cable traps are for parallel resonance at 7.15 MHz. The low-impedance output of each trap is used for this antenna.**

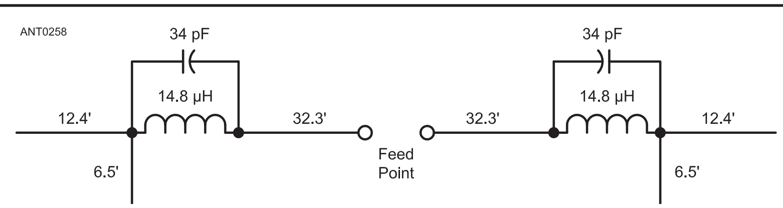



**Figure 10.26 — A W8NX multiband dipole for 80, 40, 17 and 12 meters. For this antenna, the high-impedance output is used on each trap. The resonant frequency of the traps is 7.15 MHz.**

weighed down at the end. You should feed the antenna with 75-Ω coaxial cable using a choke balun.

This antenna may be thought of as a modified W3DZZ antenna due to the addition of the capacitive stubs. The length and location of the stub give the antenna designer two extra degrees of freedom to place the resonant frequencies within the amateur bands. This additional flexibility is particularly helpful to bring the 15 and 10 meter resonant frequencies to more desirable locations in these bands. The actual 10 meter resonant frequency of the original W3DZZ antenna is somewhat above 30 MHz, pretty remote from the more desirable low frequency end of 10 meters.

### 80, 40, 17 and 12 meter Dipole

**Figure 10.26** shows the configuration of the 80, 40, 17 and 12 meter antenna. Notice that the capacitive stubs are attached immediately outboard after the traps and are 6.5 feet long, ½ foot longer than those used in the other antenna. The traps are the same as those of the other antenna, but are connected for the high-impedance parallel-resonant output mode. Since only four bands are covered by this antenna, it is easier to fine tune it to precisely the desired frequency on all bands. The 12.4-foot tips can be pruned to a particular 17 meter frequency with little effect on the 12 meter frequency. The stub lengths can be pruned to a particular 12 meter frequency with little effect on the 17 meter frequency. Both such pruning adjustments slightly alter the 80 meter resonant frequency. However, the bandwidths of the antennas are so broad on 17 and 12 meters that little need for such pruning exists. The 40 meter frequency is nearly independent of adjustments to the capacitive stubs and outer radiating tip elements. Like the first antennas, this dipole is fed with a balun and 75-Ω feed line.

**Figure 10.27** shows the schematic diagram of the traps. It explains the difference between the low and high-impedance modes of the traps. Notice that the high-impedance terminal is the output configuration used in most conventional trap applications. The low-impedance connection is made across only the inner conductor turns, corresponding to one-half of the total turns of the trap. This mode steps the trap's impedance down to approximately one-fourth of that of the high-impedance level. This is what allows a single trap design to be used for two different multiband antennas.

**Figure 10.28** is a drawing of a cross-section of the coax trap shown through the long axis of the trap. Notice that the traps are conventional coaxial-cable traps, except for the added low-impedance output terminal. The traps are 8¾ close-spaced turns of RG-59 (Belden 8241) on a 2⅜-inch-OD PVC pipe (schedule 40 pipe with a 2-inch ID) coil form. The forms are 4⅛ inches long. Trap resonant frequency is very sensitive to the outer diameter of the coil form, so check it carefully. Unfortunately, not all PVC pipe is made with the same wall thickness. The trap frequencies should be checked with a dip meter and general-coverage receiver and adjusted to within 50 kHz of the 7150 kHz resonant frequency before installation. One inch is left over at each end of the coil forms to allow for the coax feed-through holes and holes for tension-relief attachment of the antenna radiating elements to the traps. Be sure to seal the ends of the trap coax cable to prevent moisture from entering the coaxial cable. (See the discussion on waterproofing in the **Building Antenna Systems and Towers** chapter.)

Also, be sure that you connect the 32.3-foot wire element at the start of the inner conductor winding of the trap. This avoids detuning the antenna by the stray capacitance of the coaxial-cable shield. The trap output terminal (which has the shield stray capacitance) should be at the outboard side of the trap. Reversing the input and output terminals of the trap will lower the 40 meter frequency by approximately 50 kHz, but there will be negligible effect on the other bands.

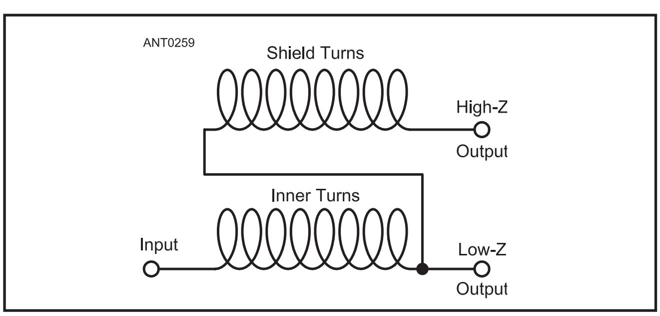



**Figure 10.27 — Schematic for the W8NX coaxial-cable trap. RG-59 is wound on a 2-⅜-inch OD PVC pipe.**

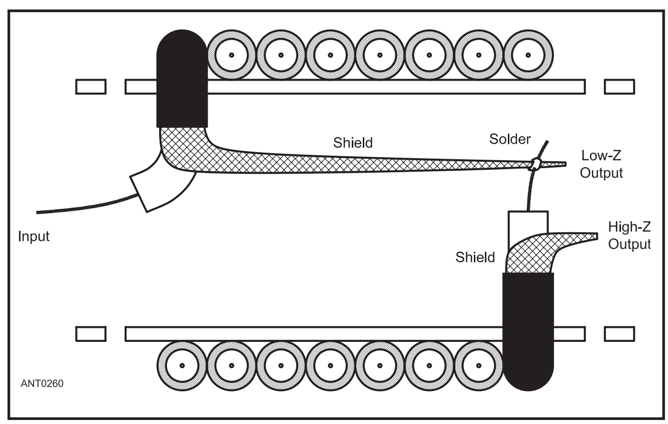



**Figure 10.28 — Construction details of the W8NX coaxial-cable trap.**

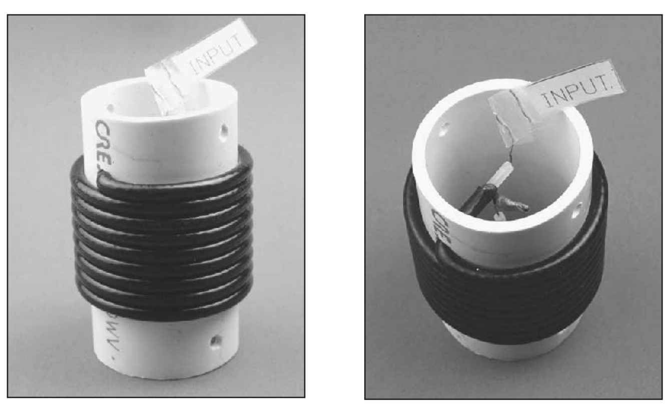



**Figure 10.29 — Other views of a W8NX coax-cable trap.**

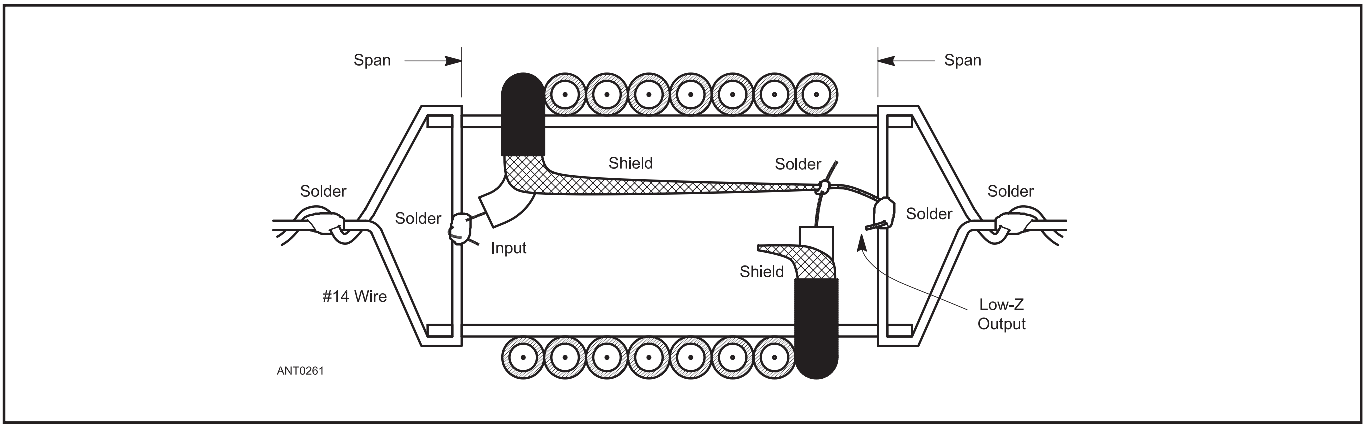



**Figure 10.30 — Additional construction details for the W8NX coaxial-cable trap.**

**Figure 10.29** shows a coaxial-cable trap. Further details of the trap installation are shown in **Figure 10.30**. This drawing applies specifically to the 80, 40, 20, 15 and l0 meter antenna, which uses the low-impedance trap connections. Notice the lengths of the trap pigtails: 3 to 4 inches at each terminal of the trap. If you use a different arrangement, you must modify the span lengths accordingly. All connections can be made using crimp connectors rather than by soldering. Access to the trap's interior is attained more easily with a crimping tool than with a soldering iron.

## Performance

The performance of both antennas has been very satisfactory. W8NX uses the 80, 40, 17 and 12 meter version because it covers 17 and 12 meters. (He has a tribander for 20, 15 and 10 meters.) The radiation pattern on 17 meters is that of a 3/2-wave dipole. On 12 meters, the pattern is that of a 5/2-wave dipole. At his location in Akron, Ohio, the antenna runs essentially east and west. It is installed as an inverted V, 40 feet high at the center, with a 120° included angle between the legs. Since the stubs are very short, they radiate little power and make only minor contributions to the radiation patterns. In theory, the pattern has four major lobes on 17 meters, with maxima to the northeast, southeast, southwest and northwest. These provide low-angle radiation into Europe, Africa, South Pacific, Japan and Alaska. A narrow pair of minor broadside lobes provides north and south coverage into Central America, South America and the polar regions.

There are four major lobes on 12 meters, giving nearly end-fire radiation and good low-angle east and west coverage. There are also three pairs of very narrow, nearly broadside, minor lobes on 12 meters, down about 6 dB from the major end-fire lobes. On 80 and 40 meters, the antenna has the usual figure-8 patterns of a half-wave-length dipole.

Both antennas function as electrical half-wave dipoles on 80 and 40 meters with a low SWR. They both function as odd-harmonic current-fed dipoles on their other operating frequencies, with higher, but still acceptable, SWR. The presence of the stubs can either raise or lower the input impedance of the antenna from those of the usual third and fifth harmonic dipoles. Again W8NX recommends that 75-Ω, rather than 50-Ω, feed line be used because of the generally higher input impedances at the harmonic operating frequencies of the antennas.

The SWR curves of both antennas were carefully measured using a 75 to 50-Ω transformer from Palomar Engineers inserted at the junction of the 75-Ω coax feed line and a 50-Ω SWR bridge. The transformer is required for accurate SWR measurement if a 50-Ω SWR bridge is used with a 75-Ω line. Most 50-Ω rigs operate satisfactorily with a 75-Ω line, although this requires different tuning and load settings in the final output stage of a vacuum tube amplifier or antenna tuner. The author uses the 75 to 50-Ω transformer only when making SWR measurements and at low power levels. The transformer is rated for 100 W, and when he runs his 1-kW PEP linear amplifier the transformer is taken out of the line.

**Figure 10.31** gives the SWR curves of the 80, 40, 20, 15 and 10 meter antenna. Minimum SWR is nearly 1:1 on

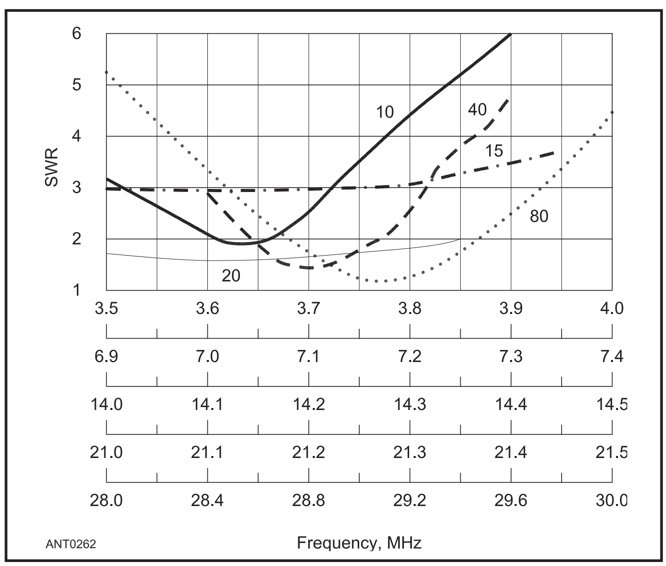



**Figure 10.31 — Measured SWR curves for an 80, 40, 20, 15 and 10 meter antenna, installed as an inverted V with 40-ft apex and 120° included angle between legs.**

80 meters, 1.5:1 on 40 meters, 1.6:1 on 20 meters, and 1.5:1 on 10 meters. The minimum SWR is slightly below 3:1 on 15 meters. On 15 meters, the stub capacitive reactance combines with the inductive reactance of the outer segment of the antenna to produce a resonant rise that raises the antenna input resistance to about 220 Ω, higher than that of the usual ½-wavelength dipole. An antenna tuner may be required on this band to keep a solid-state final output stage happy under these load conditions.

**Figure 10.32** shows the SWR curves of the 80, 40, 17 and 12 meter antenna. Notice the excellent 80 meter performance with a nearly unity minimum SWR in the middle of the band. The performance approaches that of a full-size 80 meter wire dipole. The short stubs and the low-inductance traps shorten the antenna somewhat on 80 meters. Also observe the good 17 meter performance, with the SWR being only a little above 2:1 across the band.

But notice the 12 meter SWR curve of this antenna, which shows 4:1 SWR across the band. The antenna input resistance approaches 300 Ω on this band because the capacitive reactance of the stubs combines with the inductive reactance of the outer antenna segments to give resonant rises in impedance. These are reflected back to the input terminals. These stub-induced resonant impedance rises are similar to those on the other antenna on 15 meters, but are even more pronounced.

High SWR in coaxial cables longer than about 100 feet can lead to high feed line losses as shown in the **Transmission Lines** chapter. If you plan on operating this antenna with an SWR of greater than 3:1, make sure the amount of feed line loss is acceptable.

High voltages in the feed line should not cause too much concern. Even if the SWR is as high as 9:1 *no destructively high voltages will exist on the transmission line*. Recall that transmission-line voltages increase as the square root of the SWR in the line. Thus, 1 kW of RF power in 75-Ω line corresponds to 274 V line voltage for a 1:1 SWR. Raising the SWR to 9:1 merely triples the maximum voltage that the line must withstand to 822 V. This voltage is well below the 3700-V rating of RG-11, or the 1700-V rating of RG-59, the two most popular 75-Ω coax lines. Voltage breakdown in the traps is also very unlikely. As will be pointed out later, the operating power levels of these antennas are limited by RF power dissipation in the traps, not trap voltage breakdown or feed line SWR.

### Trap Losses and Power Rating

**Table 10.1** presents the results of trap Q measurements and extrapolation by a two-frequency method to higher frequencies above resonance. W8NX employed a Boonton Q meter for the measurements. Extrapolation to higher-frequency bands assumes that trap resistance losses rise with skin effect according to the square root of frequency, and that trap dielectric loses rise directly with frequency. Systematic measurement errors are not increased by frequency extrapolation. However, random measurement errors increase in magnitude with upward frequency extrapolation. Results are believed to be accurate within 4% on 80 and 40 meters, but only within l0 to 15% at 10 meters. Trap Q is shown at both the high- and low-impedance trap termi-nals. The Q at the low-impedance output terminals is 15 to 20% lower than the Q at the high-impedance output terminals.

W8NX computer-analyzed trap losses for both antennas in free space. Antenna-input resistances at resonance were first calculated, assuming lossless, infinite-Q traps. They were again calculated using the Q values in Table 10.1. The radiation efficiencies were also converted into equivalent trap losses in decibels. **Table 10.2** summarizes the trap-loss analysis for the 80, 40, 20, 15 and 10 meter antenna and **Table 10.3** for the 80, 40, 17 and 12 meter antenna.

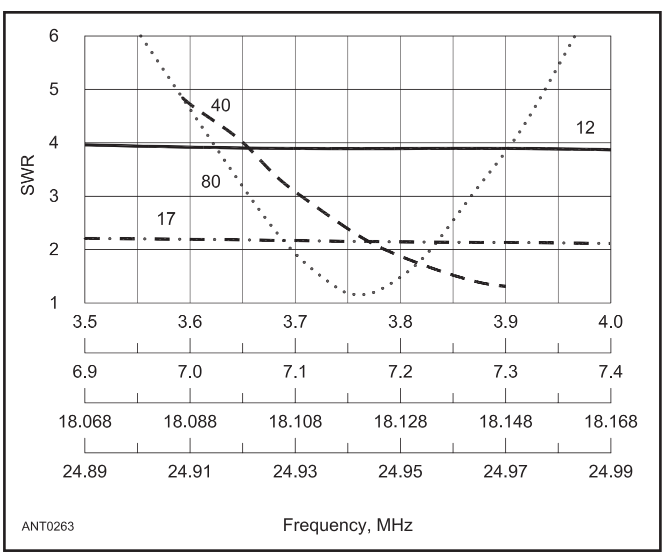



**Figure 10.32 — Measured SWR curves for an 80, 40, 17 and 12 meter antenna, installed as an inverted V with 40-ft apex and 120° included angle between legs.**

**Table 10.1**
**Trap Q**

| Frequency (MHz) | 3.8 | 7.15 | 14.18 | 18.1 | 21.3 | 24.9 | 28.6 |
|---|---|---|---|---|---|---|---|
| High Z out (Ω) | 101 | 124 | 139 | 165 | 73 | 179 | 186 |
| Low Z out (Ω) | 83 | 103 | 125 | 137 | 44 | 149 | 155 |

**Table 10.2**
**Trap Loss Analysis: 80, 40, 20, 15, 10 meter Antenna**

| Frequency (MHz) | 3.8 | 7.15 | 14.18 | 21.3 | 28.6 |
|---|---|---|---|---|---|
| Radiation Efficiency (%) | 96.4 | 70.8 | 99.4 | 99.9 | 100.0 |
| Trap Losses (dB) | 0.16 | 1.5 | 0.02 | 0.01 | 0.003 |

**Table 10.3**
**Trap Loss Analysis: 80, 40, 17, 12 meter Antenna**

| Frequency (MHz) | 3.8 | 7.15 | 18.1 | 24.9 |
|---|---|---|---|---|
| Radiation Efficiency (%) | 89.5 | 90.5 | 99.3 | 99.8 |
| Trap Losses (dB) | 0.5 | 0.4 | 0.03 | 0.006 |

The loss analysis shows radiation efficiencies of 90% or more for both antennas on all bands except for the 80, 40, 20, 15 and 10 meter antenna when used on 40 meters. Here, the radiation efficiency falls to 70.8%. A 1-kW power level at 90% radiation efficiency corresponds to 50-W dissipation per trap. In W8NX's experience, this is the trap's survival limit for extended key-down operation. SSB power levels of 1 kW PEP would dissipate 25 W or less in each trap. This is well within the dissipation capability of the traps.

When the 80, 40, 20, 15 and 10 meter antenna is operated on 40 meters, the radiation efficiency of 70.8% corresponds to a dissipation of 146 W in each trap when 1 kW is delivered to the antenna. This is sure to burn out the traps — even if sustained for only a short time. Thus, the power should be limited to less than 300 W when this antenna is operated on 40 meters under prolonged key-down conditions such as RTTY. A 50% CW duty cycle would correspond to a 600-W power limit for normal 40 meter CW operation. Likewise, a 50% duty cycle for 40 meter SSB corresponds to a 600-W PEP power limit for the antenna.

The author knows of no analysis where the burnout wattage rating of traps has been rigorously determined. Operating experience seems to be the best way to determine trap burn-out ratings. In his own experience with these antennas, he's had no traps burn out, even though he operated the 80, 40, 20, 15 and 10 meter antenna on the critical 40 meter band using his AL-80A linear amplifier at the 600-W PEP output level. He did not make a continuous, key-down, CW operating test at full power purposely trying to destroy the traps!

Some hams may suggest using a different type of coaxial cable for the traps. The dc resistance of 40.7 Ω per 1000 feet of RG-59 coax seems rather high. However, W8NX has found no coax other than RG-59 that has the necessary inductance-to-capacitance ratio to create the trap characteristic reactance required for the 80, 40, 20, 15 and 10 meter antenna. Conventional traps with wide-spaced, open-air inductors and appropriate fixed-value capacitors could be substituted for the coax traps, but the convenience, weatherproof configuration and ease of fabrication of coaxial-cable traps is hard to beat.

## 10.3 THE TERMINATED FOLDED DIPOLE

Originally described in June 1949 *QST* by G. L. Countryman, W3HH, the terminated folded dipole (TFD) is often used by amateurs as a wide-band antenna that operates over the HF range without a tuner. (A tilted version is abbreviated as the T2FD. The original article is available on this book's CD-ROM.) The antenna, shown in **Figure 10.33** looks like a folded dipole but acts as a traveling wave antenna. It is generally useful over a 5:1 or 6:1 range with its lower frequency, $f_L$, used to calculate dimensions.

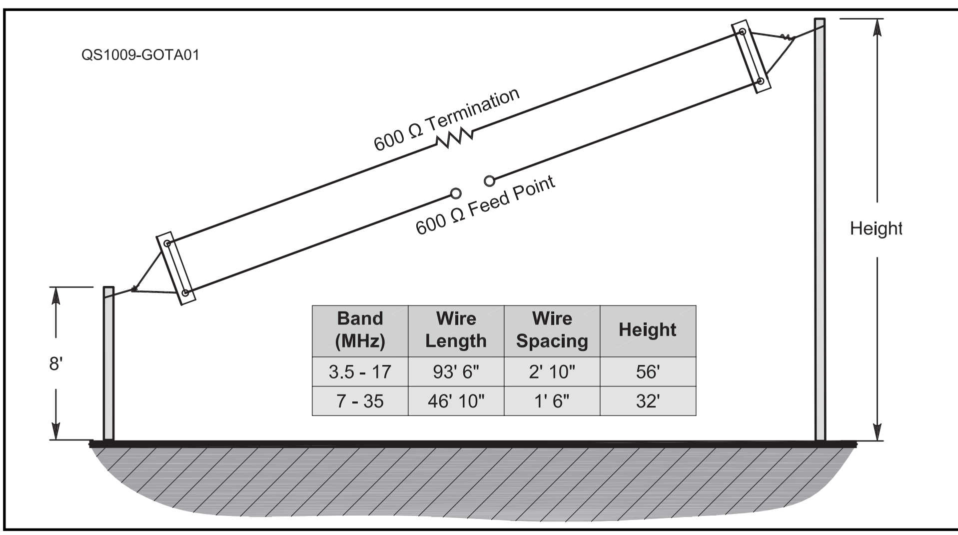
Two common approximations of the antenna dimensions are used:

Wide-Long:
Length (feet) = $300/f_L$ (MHz)
Separation (feet) = $10/f_L$ (MHz) (Eq 2)

And Narrow-Short:
Length (feet) = $200/f_L$ (MHz)
Separation (feet) = $0.5/f_L$ (MHz) (Eq 3)

The Narrow-Short configuration is closest to commercial models sold today. Figure 10.33 also provides two sets of dimensions for different HF frequency ranges.

The termination resistor directly opposite the feed point acts as a *swamping load* to dampen swings in feed point impedance, particularly toward the lower end of the antenna's range. A value of around 600 Ω is required and must be non-inductive. (The resistance value can vary ±10% and still obtain good results.) The resistor can dissipate an appreciable fraction of the applied power and is usually rated at ⅓ of the




| Band (MHz) | Wire Length | Wire Spacing | Height |
|---|---|---|---|
| 3.5 - 17 | 93' 6" | 2' 10" | 56' |
| 7 - 35 | 46' 10" | 1' 6" | 32' |

**Figure 10.33 — The terminated folded dipole adds a 600-Ω terminating resistor to smooth out the feed point impedance variations over a wide range. The terminating resistor dissipates some of the input power in order to provide a consistent match.**

transmitter output power. If a single resistor is not available, strings of resistors in series-parallel combinations will work.

The feed point resistance of the antenna requires a 12:1 matching transformer to provide a match to 50-Ω coaxial cable. Designs using an 800-Ω terminating resistor and 16:1 transformer also work well.

The antenna wire chosen must be capable of supporting the antenna's weight, which with the balun and terminating resistor, plus any spacers used to keep the antenna wires separated, can be significantly higher than for a single-wire dipole. A common choice is #12 AWG hard-drawn copper. An analysis by L.B. Cebik, W4RNL (SK), of models of the antennas provides an alternate set of guidelines for the terminating resistor. (See Bibliography.)

As the operating frequency approaches the lower end of the antenna's range, efficiency and gain will begin to fall off rapidly. An analysis of the TFD by Belrose (see Bibliography) shows that the antenna's gain is approximately 0 dBi over most of its range (see **Figure 10.34**) and is significantly less effective than a dipole with a tuner by as much as 10 dB (see **Figure 10.35**).

However, at heights of 50 feet or less, the antenna will provide a relatively high-angle, nearly omnidirectional pattern useful for NVIS-like coverage. Tilting the antenna, as described in the original article by W3HH, enhances high-angle radiation even further. This is the TFD's most common application, as a regional coverage antenna over a wide range of HF when only a single, fixed antenna without tuners can be installed, such as for an EOC, a MARS station, or portable disaster relief.

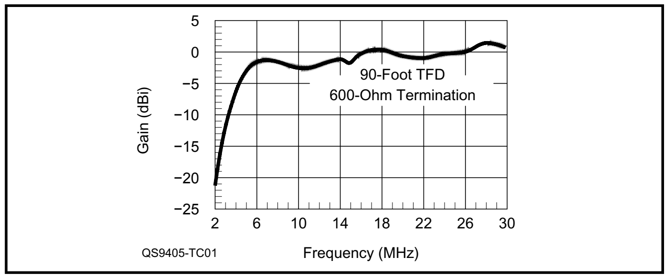



**Figure 10.34 — Theoretical gain (in dBi) versus frequency for a 90-foot terminated folded dipole (600-Ω termination) in free space.**

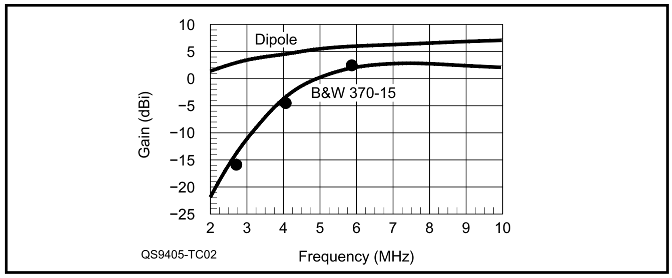



**Figure 10.35 — Theoretical gain of a dipole and a 90-foot TFD antenna over poor ground (conductivity of 1 mS/m), and measured NVIS gain (the solid circles) for the B&W 370-15 antenna. All antennas were installed horizontally at 30 feet.**

## 10.4 MULTIBAND VERTICAL ANTENNAS

There are two basic types of vertical antennas; either type can be used in multiband configurations. The first is the ground-mounted vertical and the second, the ground plane. These antennas are described in detail in the chapter **Dipoles and Monopoles**.

The efficiency of any ground-mounted vertical depends a great deal on near-field earth losses. As pointed out in the chapter **Effects of Ground**, these near-field losses can be reduced or eliminated with an adequate radial system. Considerable experimentation has been conducted on this subject by Jerry Sevick, W2FMI (SK), and several important results were obtained. It was determined that a radial system consisting of 40 to 50 radials, 0.2 λ long, would reduce the earth losses to about 2 Ω when a λ/4 radiator was being used. These radials should be on the earth's surface, or if buried, placed not more than an inch or so below ground. Otherwise, the RF current would have to travel through the lossy earth before reaching the radials. In a multiband vertical system, the radials should be 0.2 λ long for the lowest band, that is, 55 feet long for 3.5-MHz operation. Any wire size may be used for the radials. The radials should fan out in a circle, radiating from the base of the antenna. A metal plate, such as a piece of sheet copper, can be used at the center connection.

The other common type of vertical is the ground-plane antenna. Normally, this antenna is mounted above ground with the radials fanning out from the base of the antenna. The vertical portion of the antenna is usually an electrical λ/4, as is each of the radials. In this type of antenna, the system of radials acts somewhat like an RF choke, to prevent RF currents from flowing in the supporting structure, so the number of radials is not as important a factor as it is with a ground- mounted vertical system. From a practical standpoint, the customary number of radials is four or five. In a multiband configuration, λ/4 radials are required for each band of operation with the ground-plane antenna.

This is not so with the ground-mounted vertical antenna, where the ground plane is relied upon to provide an image of the radiating section. Note that even quarter-wave-long radials are greatly detuned by their proximity to ground — radial resonance is not necessary or even possible. In the ground-mounted case, so long as the ground-screen radials are approximately 0.2 λ long at the lowest frequency, the length will be more than adequate for the higher frequency bands.

## 10.4.1 FULL-SIZE VERTICAL ANTENNAS

A vertical antenna should not be longer than about ¾ λ at the highest frequency to be used, however, if low-angle radiation is wanted. You can see why from reviewing the radiation patterns for dipoles in the chapter **Dipoles and Monopoles**. As the antenna lengthens, the pattern breaks up into lobes that are at high elevation angles for a vertical antenna. Nevertheless, an antenna that is λ/4 on the lower frequency of operation can still be useful over a 3:1 frequency range or even more if the high-angle radiation can be tolerated. For example, an 80 meter λ/4 vertical around 66 feet high is useful through the 30 meter band and a 25-foot vertical would be useful from about 10 MHz through the 28 MHz band.

In recent years, the 43-foot ground-mounted vertical antenna with an automatic antenna tuner mounted at the base of the antenna has become very popular as an all-band HF vertical, including 160 meters with the appropriate tuner. See **Figure 10.36**. While the elevation angle of maximum radiation begins to increase significantly above the 20 meter band, the combination of simplicity and clean appearance make up for the compromise. (A variation on this idea is the "flagpole" antenna discussed in the **Stealth and Limited Space Antennas** chapter.) If the lower bands are not required, a 22-foot vertical is quite effective at and above 40 meters. The antennas can be constructed from aluminum tubing or as a fiberglass mast with wires inside or taped along the outside of the mast.

In lieu of using an automatic antenna tuner at the base of the vertical, several *QST* articles listed in the Bibliography serve as examples of how a single vertical antenna can be put to work on several bands. The referenced articles by Phil Salas, AD5X discuss matching the antenna's impedance on 160 and 80 meters.

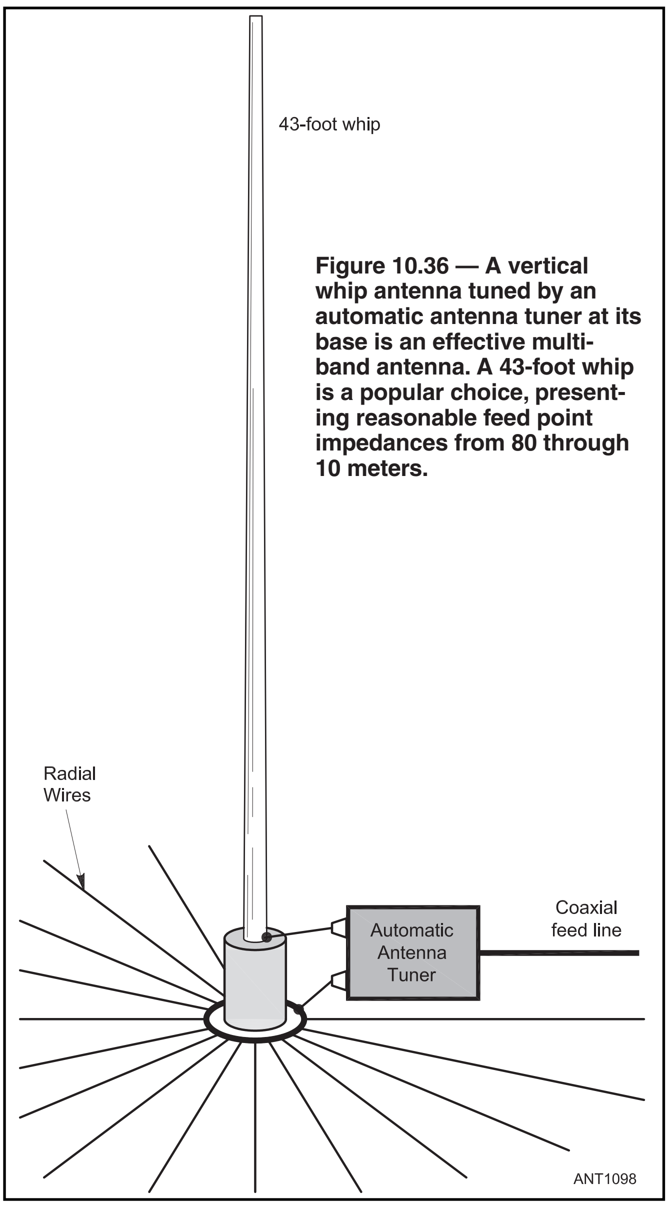



**Figure 10.36 — A vertical whip antenna tuned by an automatic antenna tuner at its base is an effective multi-band antenna. A 43-foot whip is a popular choice, presenting reasonable feed point impedances from 80 through 10 meters.**

## 10.4.2 SHORT VERTICAL ANTENNAS

A short vertical antenna (one less than λ/4 at the operating frequency) can be operated on several bands by loading it at the base, the general arrangement being similar to Figures 10.1 and 10.2. That is, for multiband operation the vertical can be handled by the same methods that are used for random-length wires.

Another method of feeding is shown in **Figure 10.37**. L1 is a loading coil, tapped to resonate the antenna on the desired band. A second tap permits using the coil as a transformer for matching a coax line to the transmitter. C1 is not strictly necessary, but may be helpful on the lower frequencies, 3.5 and 7 MHz, if the antenna is quite short. In that case C1 makes it possible to tune the system to resonance with a coil of

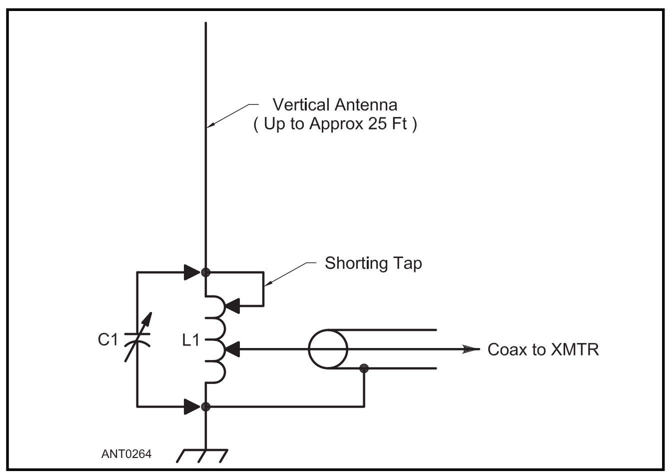



**Figure 10.37 — Multiband vertical antenna system using base loading for resonating on 3.5 to 28 MHz. L1 should be wound with bare wire so it can be tapped at every turn, using #12 AWG wire. A convenient size is 2½ inches in diameter, 6 turns per inch (such as B&W 3029). Number of turns required depends on antenna and ground lead length, more turns being required as the antenna and ground lead are made shorter. For a 25-foot antenna and a ground lead of the order of 5 feet, L1 should have about 30 turns. The use of C1 is explained in the text. The smallest capacitance that will permit matching the coax cable should be used; a maximum capacitance of 100 to 150 pF will be sufficient in any case.**

reasonable dimensions at L1. C1 may also be useful on other bands as well, if the system cannot be matched to the feed line with a coil alone. (This is similar to the techniques described in the chapter **Mobile and Maritime HF Antennas**.)

The coil and capacitor should preferably be installed at the base of the antenna, but if this cannot be done a wire can be run from the antenna base to the nearest convenient location for mounting L1 and C1. The extra wire will of course be a part of the antenna, and since it may have to run through unfavorable surroundings it is best to avoid using it if at all possible. (Use the shortest possible ground connection both for efficiency and to avoid creating an unintended radiating element of the antenna system.)

This system is best adjusted with the help of an SWR indicator. Connect the coax line across a few turns of L1 and take trial positions of the shorting tap until the SWR reaches its lowest value. Then vary the feed line tap similarly; this should bring the SWR down to a low value. Small adjustments of both taps then should reduce the SWR to close to 1:1. If not, try adding C1 and go through the same procedure, varying C1 each time a tap position is changed.

### 10.4.3 TRAP VERTICALS

The trap principle described in Figure 10.22 for center-fed dipoles also can be used for vertical antennas. There are two principal differences. Only one half of the dipole is used, the ground connection taking the place of the missing half, and the feed point impedance is one half the feed point impedance of a dipole. Thus it is in the vicinity of 30 Ω (plus the ground-connection resistance), so 52-Ω cable should be used since it is the commonly available type that comes closest to matching.

Commercial multiband trap verticals such as the Hustler 4/5/6BTV series and the Hy-Gain AVQ series have been widely used for many years and provide effective performance as ground-mounted antennas when used with a good radial system.

Verticals advertised as "ground-independent" are intended to be mounted above ground. Models such as the Cushcraft R8 and R6000 and the Hy-Gain Patriot are end-fed systems that are electrically longer than λ/4 at the frequency of operation. They have a high feed point impedance that is reduced to 50 Ω with a matching network at the base of the antenna. These are particularly useful antennas for temporary stations and when restrictions prevent the installation of ground systems.

Most amateurs prefer to purchase multiband trap verticals because of the mechanical complexities and requirements to be self-supporting.

### 10.4.4 A FIVE-BAND VERTICAL DIPOLE

This antenna, shown in **Figure 10.38**, is a short version of the 135-foot described earlier, except that it is oriented vertically. The antenna gives good performance on the HF bands from 20 through 10 meters and can be used at a fixed station or for portable or temporary operation. Like the longer horizontal "flat-top," it is fed with 450-Ω window line and a balanced tuner. The antenna can be installed at an angle as long as the feed line is oriented symmetrically at right angles to the antenna. Feed line lengths of more than 33 feet are recommended to help minimize RF common-mode current on the feed line from coupling to the tuner enclosure.

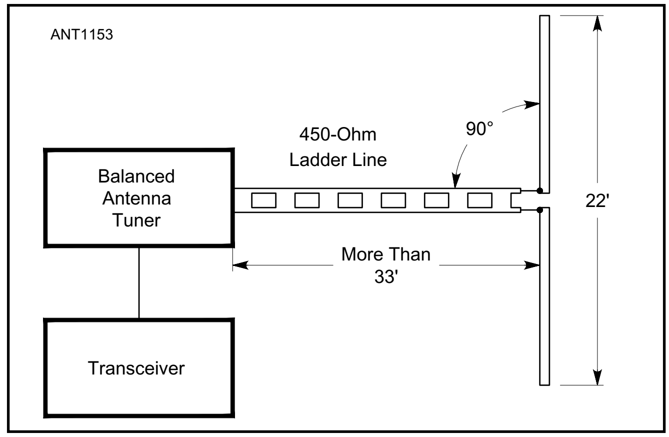



**Figure 10.38 — A five-band vertical dipole that covers 20, 17, 15, 12, and 10 meters. The antenna is fed with 450-Ω window line and requires a balanced antenna tuner.**

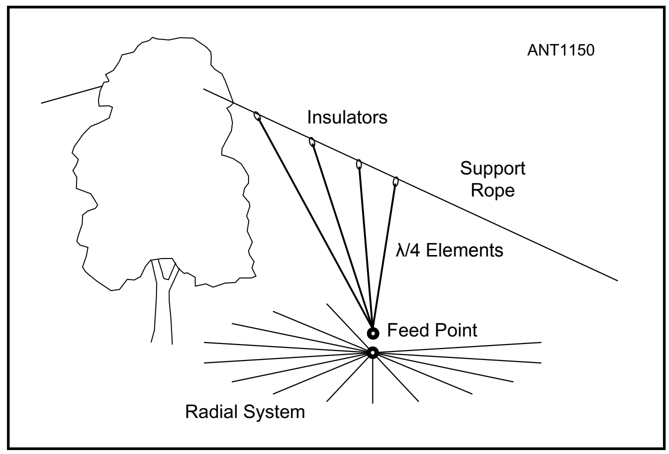



**Figure 10.39 — A set of fan dipoles. The support must be high enough to clear λ/4 on the lowest frequency band used. At higher frequencies, the shorter elements can be held up with ropes to the support rope as necessary. Radials are required to provide a ground plane.**

### 10.4.5 A FAN VERTICAL

Just like the fan dipole described earlier, the fan vertical shown in **Figure 10.39** connects multiple elements to a single feed point. In the case of the fan vertical, each element is λ/4 long instead of λ/2 and a set of radials is used to provide a ground plane. The same cautions apply regarding interaction between the verticals as for the fan dipoles. Getting a full set tuned on each band can be frustrating! Nevertheless, whether used for a fixed station or for portable operation, being able to use multiple bands with a single feed line is very convenient.

### 10.4.6 A DUAL-BAND VERTICAL FOR 80 AND 160

When stationed on Guam, Dave Mueller, N2NL, needed a temporary vertical antenna for contesting on 80 and 160 meters but had only one tall tree to act as a vertical support. Based on the idea of a fan vertical, he used 450-Ω window line as his pair of radiators as shown in **Figure 10.40**.

One of the window line conductors is tuned as an inverted L on 80 meters. Extra wire is then attached to the end of one of the window line conductors and to the point at which the inverted L makes the right-angle bend at the top. These form top loading wires for a 160 meter T or "flat-top" vertical. Thus, one conductor of the window line is made into the inverted L and the other conductor is the top-loaded vertical.

At the feed point, both of the window line conductors are shorted together and connected to the coax center conductor. A set of ground radials is required and connected to the shield of the coax. Tune the 80 meter L first, then adjust the length of the 160 meter top loading wire connected at the bend of the window line — this results in the least interaction during tuning. You will probably have to adjust each of the conductor lengths to get the resonant point of the system to the desired frequencies.

To raise the base impedance of the vertical, a shunt inductor can be used across the feed point. If you have the equipment, measure the feed point impedance to determine the resistive component. The instructions for hairpin matching in the chapter on **Transmission Line System Techniques** provide a chart of required inductive reactances. Another effective technique is to wind a coil with about 100 Ω of reactance (about 9 μH at 1.8 MHz) and adjust a tap on the coil until a match is obtained. A relay or manual switch can be used to change the tap for different bands or switch the coil in and out of circuit.

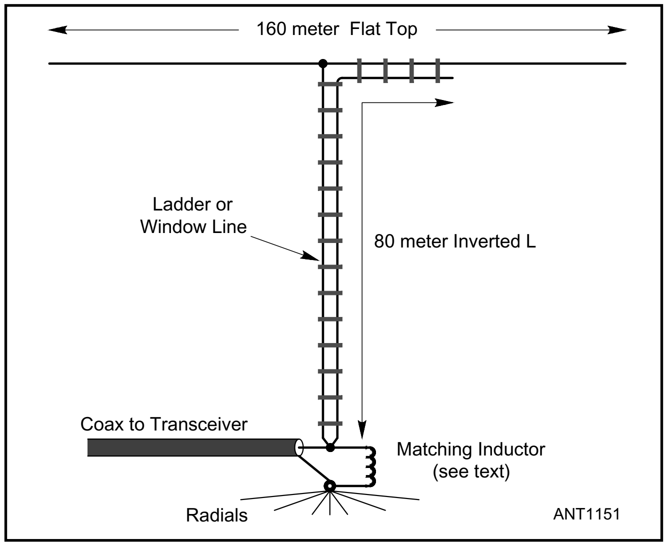



**Figure 10.40 — A dual-band vertical for 80 and 160 meters constructed by N2NL/KH2. 450-Ω window line is used to construct an 80 meter inverted L and top loading wires added to create a 160 meter T vertical. A shunt inductor across the base is used to raise the feed point impedance to 50 Ω as described in the text.**

## 10.5 THE OPEN-SLEEVE ANTENNA

Although only recently adapted for the HF and VHF amateur bands, the open-sleeve antenna has been around since 1946. The antenna was invented by Dr J. T. Bolljahn, of Stanford Research Institute. This section on sleeve antennas summarizes material by Roger A. Cox, WBØDGF in previous editions. The complete article is available on this book's CD-ROM.

The basic form of the open-sleeve monopole is shown in **Figure 10.41**. The open-sleeve monopole consists of a base-fed central monopole with two parallel closely spaced parasitics, one on each side of the central element, and grounded at each base. The lengths of the parasitics are roughly one half that of the central monopole.

### 10.5.1 IMPEDANCE

The operation of the open sleeve can be divided into two modes, an antenna-mode and a transmission-line mode. This is shown in **Figure 10.42**.

The antenna-mode impedance, $Z_A$, is determined by the length and diameter of the central monopole. For sleeve lengths less than that of the monopole, this impedance is essentially independent of the sleeve dimensions.

The transmission-line mode impedance, $Z_T$, is determined by the characteristic impedance, end impedance, and length of

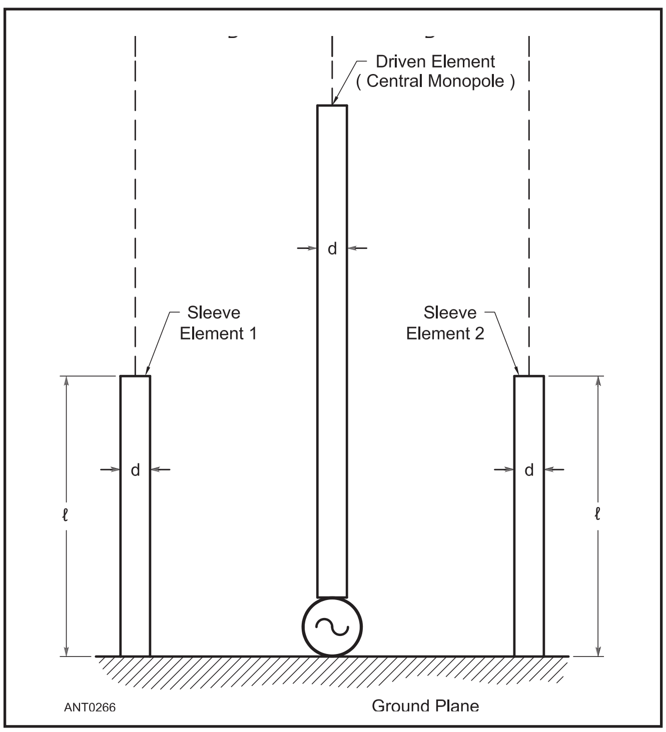



**Figure 10.41 — Diagram of an open-sleeve monopole.**

the 3- wire transmission line formed by the central monopole and the two sleeve elements. The characteristic impedance, $Z_c$, can be determined by the element diameters and spacing if all element diameters are equal, and is found from

$$Z_c = 207 \log 1.59 (D/d) \qquad \text{(Eq 4)}$$

where

D = spacing between the center of each sleeve element and the center of the driven element

d = diameter of each element

This is shown graphically in **Figure 10.43**. However, since the end impedance is usually unknown, there is little need to know the characteristic impedance. The transmission-line mode impedance, $Z_T$, is usually determined by an educated guess and experimentation.

As an example, let us consider the case where the central monopole is λ/4 at 14 MHz. It would have an antenna mode impedance, $Z_A$, of approximately 52 Ω, depending upon the ground conductivity and number of radials. If two sleeve elements were added on either side of the central monopole, with each approximately half the height of the monopole and at a distance equal to their height, there would be very little effect on the antenna mode impedance, $Z_A$, at 14 MHz.

Also, $Z_T$ at 14 MHz would be the end impedance transformed through a λ/8 section of a very high characteristic impedance transmission line. Therefore, $Z_T$ would be on the order of 500-2000 Ω resistive plus a large capacitive reactance component. This high impedance in parallel with 52 Ω would still give a resulting impedance close to 52 Ω.

At a frequency of 28 MHz, however, $Z_A$ is that of an end-fed half-wave antenna, and is on the order of 1000-5000 Ω resistive. Also, $Z_T$ at 28 MHz would be on the order of 1000 to 5000 Ω resistive, since it is the end impedance of the sleeve elements transformed through a quarter-wave section of a very high characteristic impedance three-wire transmission line. Therefore, the parallel combination of $Z_A$ and $Z_T$ would still be on the order of 500 to 2500 Ω resistive.

The actual impedance plots of a 14/28-MHz open-sleeve monopole appear in **Figures 10.44** and **10.45**. The length of the central monopole is 195.5 inches, and of the sleeve elements 89.5 inches. The element diameters range from 1.25 inches at the bases to 0.875 inch at each tip. The measured impedance of the 14-MHz monopole alone, curve A of Figure 10.44, is quite high. This is probably because of a very poor ground plane under the antenna. The addition of the sleeve elements raises this impedance slightly, curves B, C and D.

As curves A and B in Figure 10.45 show, an 8-inch sleeve spacing gives a resonance near 27.8 MHz at 70 Ω, while a 6-inch spacing gives a resonance near 28.5 MHz at 42 Ω. Closer spacings give lower impedances and higher resonances. The optimum spacing for this particular antenna

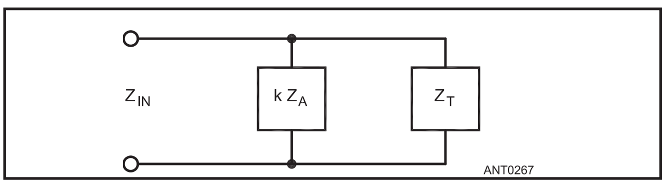



**Figure 10.42 — Equivalent circuit of an open-sleeve antenna.**

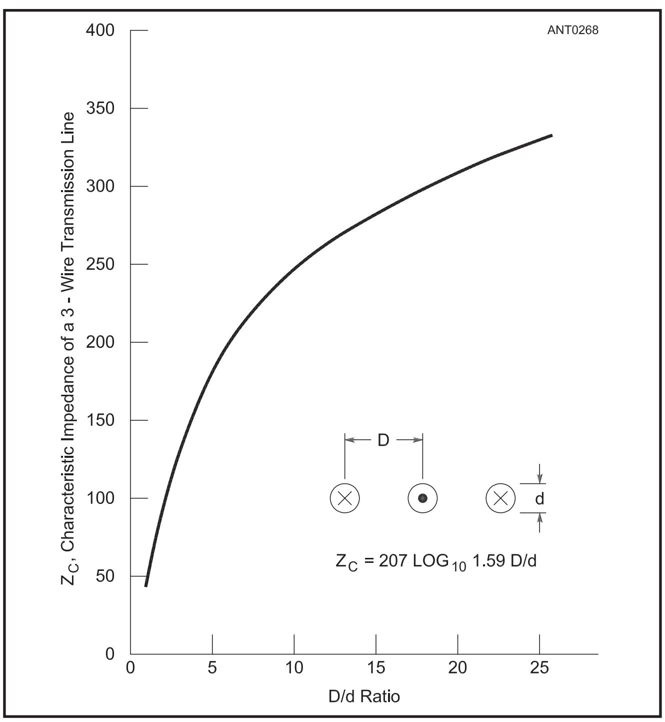



**Figure 10.43 — Characteristic impedance of transmission-line mode in an open-sleeve antenna.**

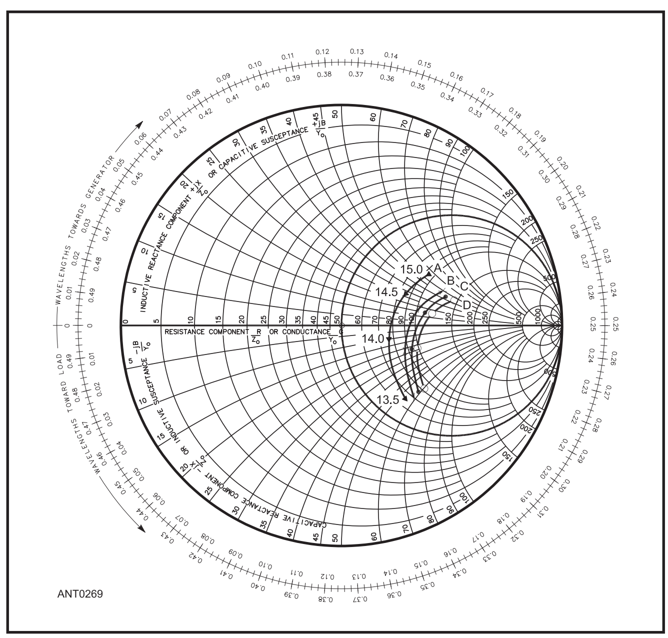



**Figure 10.44 — Impedance of an open-sleeve monopole for the frequency range 13.5-15 MHz. Curve A is for a 14 MHz monopole alone. For curves B, C and D, the respective spacings from the central monopole to the sleeve elements are 8, 6 and 4 inches. See text for other dimensions.**

would be somewhere between 6 and 8 inches. Once the spacing is found, the lengths of the sleeve elements can be tweaked slightly for a choice of resonant frequency.

In other frequency combinations such as 10/21, 10/24, 14/21 and 14/24-MHz, spacings in the 6 to 10-inch range work very well with element diameters in the 0.5 to 1.25-inch range.

### 10.5.2 BANDWIDTH

The open-sleeve antenna, when used as a multiband antenna, does not exhibit broad SWR bandwidths unless the two bands are very close together. For example, **Figure 10.46** shows the return loss and SWR of a single 10-MHz vertical antenna. Its 2:1 SWR bandwidth is 1.5 MHz, from 9.8 to 11.3 MHz. Return loss and SWR are related as given by the following equation.

$$SWR = \frac{1+k}{1-k} \qquad \text{(Eq 5)}$$

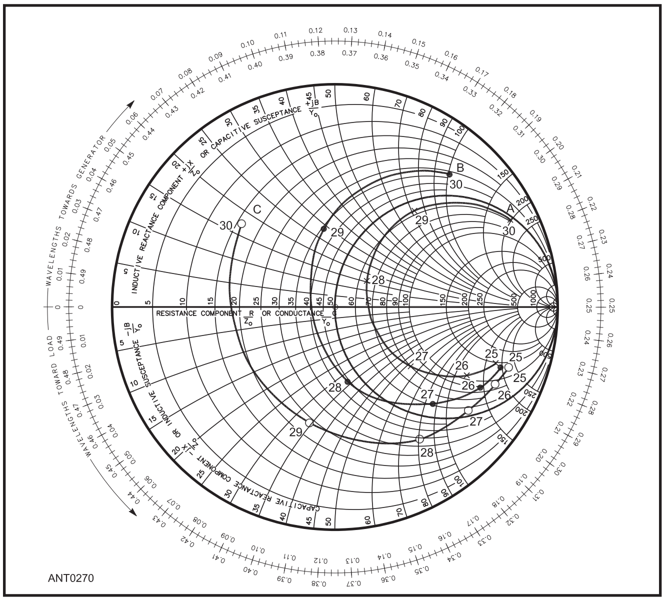



**Figure 10.45 — Impedance of the open-sleeve monopole for the range 25-30 MHz. For curves A, B and C the spacings from the central monopole to the sleeve elements are 8, 6 and 4 inches, respectively.**

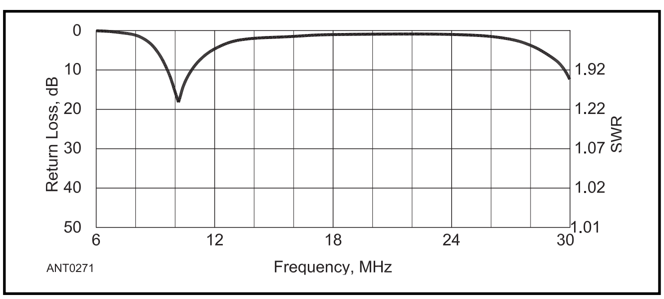



**Figure 10.46 — Return loss and SWR of a 10 MHz vertical antenna. A return loss of 0 dB represents an SWR of infinity. The text contains an equation for converting return loss to an SWR value.**

where

$k = 10^{RL/20}$

RL = return loss, dB

### 10.5.3 RADIATION PATTERN AND GAIN

The current distribution of the open-sleeve antenna where all three elements are nearly equal in length is nearly that of a single monopole antenna. If, at a particular frequency, the elements are approximately λ/4 long, the current distribution is sinusoidal.

If, for this and other length ratios, the chosen diameters and spacings are such that the two sleeve elements approach an interelement spacing of λ/8, the azimuthal pattern will show directivity typical of two in-phase vertical radiators, approximately λ/8 apart. If a bidirectional pattern is needed, then this is one way to achieve it.

Spacings closer than this will produce nearly circular azimuthal radiation patterns. Practical designs in the 10 to 30 MHz range using 0.5 to 1.5-inch diameter elements will produce azimuthal patterns that vary less than ±1 dB.

If the ratio of the length of the central monopole to the length of the sleeves approaches 2:1, then the elevation pattern of the open-sleeve vertical antenna at the resonant frequency of the sleeves becomes slightly compressed. This is because of the in-phase contribution of radiation from the λ/2 central monopole.

The third, fifth, and seventh-order resonances of the sleeve elements and the central monopole element can be used, but their radiation patterns normally consist of high-elevation lobes, and the gain on the horizon is less than that of a λ/4 vertical.

### 10.5.4 CONSTRUCTION AND EVALUATION

The open-sleeve antenna lends itself very easily to home construction. For the open-sleeve vertical antenna, only a feed point insulator and a good supply of aluminum tubing are needed. No special traps or matching networks are required. The open-sleeve vertical can produce up to 3 dB more gain than a conventional λ/4 vertical. Further, there is no reduction in bandwidth, because there are no loading coils.

The open-sleeve design can also be adapted to horizontal dipole and beam antennas for HF, VHF and UHF. A good example of this is Hy-Gain's Explorer 14 triband beam which utilizes an open sleeve for the 10/15 meter driven element. The open-sleeve antenna is also very easy to model in computer programs such as *NEC* and *MININEC*, because of the open tubular construction and lack of traps or other intricate structures.

In conclusion, the open-sleeve antenna is an antenna experimenter's delight. It is not difficult to match or construct, and it makes an ideal broadband or multiband antenna.

## 10.6 THE COUPLED-RESONATOR DIPOLE

A variation of the open-sleeve system above is the coupled-resonator system described by Gary Breed, K9AY, in an article in *The ARRL Antenna Compendium*, *Vol 5*, entitled "The Coupled-Resonator Principle: A Flexible Method for Multiband Antennas." The following is condensed from that article.

In 1995, *QST* published two antenna designs that use an interesting technique to get multiband coverage in one antenna. Rudy Severns, N6LF, described a wideband 80 and 75 meter dipole using this technique (see the **Single Band MF and HF Antennas** chapter), and Robert Wilson, AL7KK, showed us how to make a three-band vertical. Both of these antennas achieve multi-frequency operation by placing resonant conductors very close to a driven dipole or vertical — with no physical connection.

### 10.6.1 THE COUPLED-RESONATOR PRINCIPLE

As we all know, nearby conductors can interact with an antenna. Our dipoles, verticals and beams can be affected by nearby power lines, rain gutters, guy wires and other metallic materials. The antennas designed by Severns and Wilson use this interaction intentionally, to combine the resonances of several conductors at a single feed point. While other names have been used, I call the behavior that makes these antennas work the coupled-resonator (C-R) principle.

Take a look at **Figure 10.47**, which illustrates the general idea. Each figure shows the SWR at the feed point of a dipole, over a range of frequencies. When this dipole is all alone, it will have a very low SWR at its half-wave resonant frequency (Figure 10.47A). Next, if we take another wire or tubing conductor and start bringing it close to the dipole, we will see a "bump" in the dipole's SWR at the resonant frequency of this new wire. See Figure 10.47B. We are beginning to the see the effects of interaction between the two conductors. As we bring this new conductor closer, we reach a point where the SWR "bump" has grown to a very deep dip — a low SWR. We now have a good match at both the original dipole's resonant frequency and the frequency of the new conductor, as illustrated in Figure 10.47C.

We can repeat this process for several more conductors at other frequencies to get a dipole with three, four, five, six, or more resonant frequencies. The principle also applies to verticals, so any reference to a dipole can be considered to be valid for a vertical, as well.

We can write a definition of the C-R principle this way: *Given a dipole (or vertical) at one frequency and an additional conductor resonant at another frequency, there is an optimum distance between them that results in the resonance of the additional conductor being imposed upon the original dipole, resulting in a low SWR at both resonant frequencies.*

### Some History

In the late 1940s, the coaxial sleeve antenna was developed (**Figure 10.48**), covering two frequencies by surrounding a dipole or monopole with a cylindrical tube resonant at the

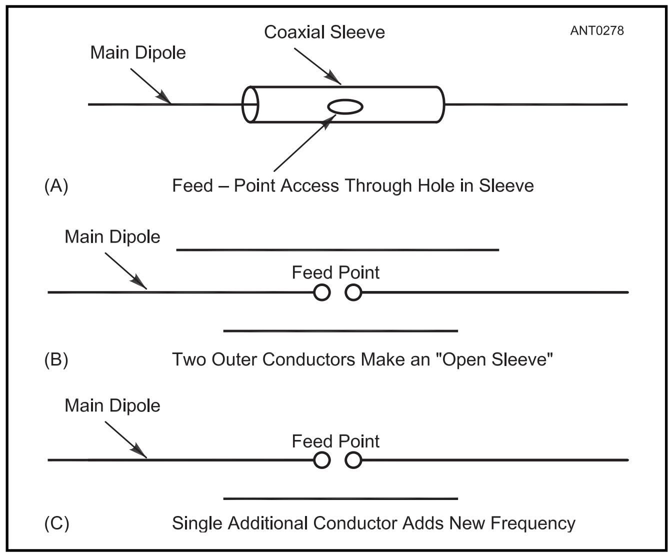



**Figure 10.48 — Evolution of coupled-resonator antennas: At A, the *coaxial-sleeve* dipole; at B, the *open-sleeve* dipole; and at C, a *coupled-resonator* dipole, the most universal configuration.**

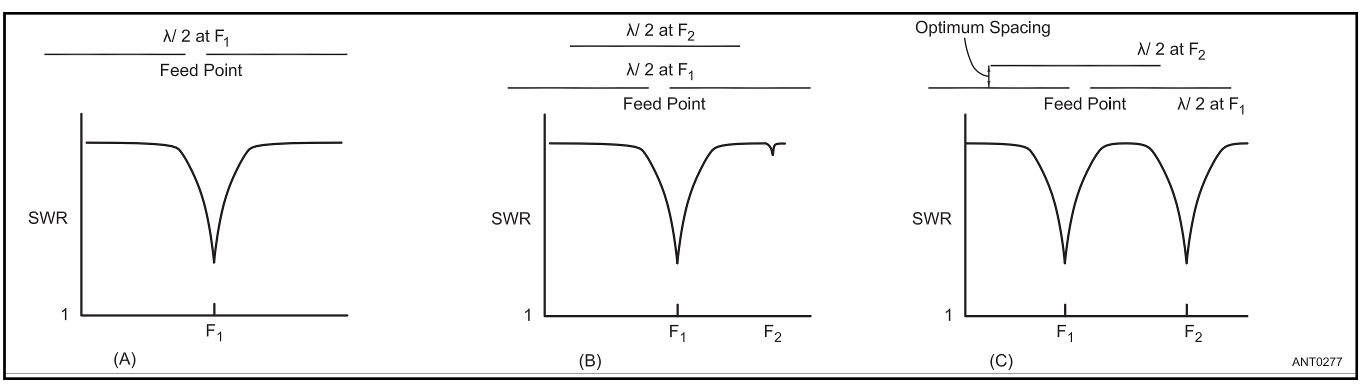



**Figure 10.47 — At A, the SWR of a dipole over a wide frequency range. At B, a nearby conductor is just close enough to interact with the dipole. At C, when the second conductor is at the optimum spacing, the combination is matched at both frequencies.**

higher of the desired frequencies. In the 1950s, Gonset briefly marketed a two-band antenna based on this design. Other experimenters soon determined that two conductors at the second frequency, placed on either side of the main dipole or monopole, would make a skeleton representation of a cylinder (Figure 10.48B). This is called the *open-sleeve antenna*. The Hy-Gain Explorer tribander uses this method in its driven element to obtain resonance in the 10 meter band. Later on, a few antenna developers finally figured out that these extra conductors did not need to be added in pairs, and that a single conductor at each frequency could add the extra resonances (Figure 10.48C). This is the method used by Force 12 in some of their multiband antennas.

This is a perfect example of how science works. A specific idea is discovered, with later developments leading to an underlying general principle. The original coaxial-sleeve configuration is the most specific, being limited to two frequencies and requiring a particular construction method. The open-sleeve antenna is an intermediate step, showing that the sleeve idea is not limited to one configuration.

Finally, we have the coupled-resonator concept, which is the general principle, applicable in many different antenna configurations, for many different frequency combinations. Severns's antenna uses it with a folded dipole, and Wilson uses it with a main vertical that is off-center fed. The author, K9AY used it with conventional dipoles and quarter-wave verticals. Other designers have used the principle more subtly, like putting the first director in a Yagi very close to the driven element, broadening the SWR bandwidth the same way Severns's design does with a dipole.

In the past, most open-sleeve or multiple-open-sleeve antennas built with this technique have also been called *open-sleeve* (or *multiple-open-sleeve*) antennas, a term taken from the history of their development. However, the term *sleeve* implies that one conductor must surround another. This is not really a physical or electrical description of the antenna's operation, therefore, K9AY suggests using the term *coupled-resonator*, which is the most accurate description of the general principle.

### A Little Math

The interaction that makes the C-R principle work is not random. It behaves in a predictable, regular manner. K9AY derived an equation that shows the relationship between the driven element and the additional resonators for ordinary dipoles and verticals:

$$\frac{\log_{10} d}{\log_{10}(D/4)} = 0.54 \qquad \text{(Eq 6)}$$

## C-R Element Spacing

K9AY's Eq 7 presented in the text does indeed yield a good "first-cut" value for the spacing between coupled-resonator elements. **Figure 10.A** shows the spacing, in inches, plotted against the ratio of frequencies, for two coupled resonator elements with different diameters, again expressed in inches. This is for an upper frequency of 28.4 MHz. Beyond a frequency ratio of about 1.5:1 (28.4:18.1 MHz), the spacing flattens out to a fixed distance between elements for each element diameter. For example, if ½-inch elements are used at 28.4 and 18.1 MHz, the spacing between the elements is about 3.75 inches.

*EZNEC* verifies Eq 7's computations. Note that a large number of segments are necessary for each element when they are closely spaced from each other, and the segments on the elements must be closely aligned with each other. Be sure to run the Average Gain test, as well as Segmentation tests. The modeler should also be aware that if mutually coupled resonators are placed along a horizontal boom (as they would be on multiband Yagis using coupled resonators), the higher-frequency elements will act like retrograde directors, producing some gain (or lack of gain, depending on the azimuth being investigated).

For example, in the *EZNEC* file **K9AY C-R 28-21-14 MHz 1 In.EZ**, using 1-inch diameter elements spaced 6 inches apart, if the 28-MHz element is placed 6 inches behind the 14-MHz driven element (with the 21-MHz element placed 6 inches ahead), on 28 MHz the system will have a F/B of 2.6 dB, favoring the rearward direction. On 21 MHz, the system will exhibit a F/B of 1.6 dB, favoring the forward direction. Of course, there are systems where gain and F/B due to the C-R configuration may be put to good use, such as the multiband Yagis mentioned above. However, if the elements are spaced above/below the 14-MHz driven element there is no distortion of the dipole patterns.

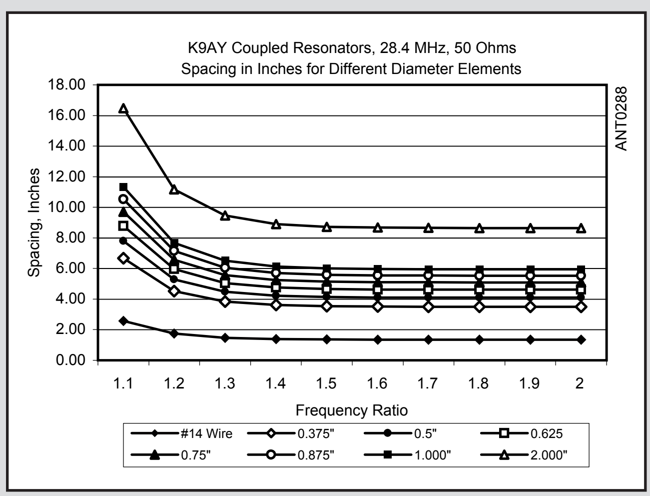



**Figure 10.A — Graph of the spacing versus frequency ratio for two Coupled-Resonator elements at 28.4 MHz, for 50-Ω feed point impedance.**

where

d = distance between conductors, measured in wavelengths at the frequency of the chosen additional resonator

D = the diameter of the conductors, also in wavelengths at the frequency of the additional resonator.

Eq 6 assumes they are both the same diameter and that the feed point impedance at both frequencies is the same as a dipole in free space (72 Ω) or a quarter-wave monopole over perfect ground (36 Ω).

The equation only describes the impedance due to the additional resonator. The main dipole element is always part of the antenna, and it may have a fairly low impedance at the additional frequency. This is the case when the frequencies are close together, or when the main element is operating at its third harmonic. At these frequencies, the spacing distance must be adjusted so that the parallel combination of dipole and resonator results in the desired feed point impedance.

K9AY worked out two correction factors, one to cover a range of impedances and another for frequencies close together. These can be included in the basic equation, which is rearranged below to solve for the distance between the conductors:

$$d = 10^{0.54 \log_{10}(D/4)} \times \frac{Z_0 + 35.5}{109} \times \left[1 + e^{-[((((F_2/F_1)-1.1)\times 11.3)+0.1)]}\right] \quad \text{(Eq 7)}$$

where

d and D are the same as in Eq 6 above.

$Z_0$ = the desired feed point impedance at the frequency of the additional resonator (between 20 and 120 Ω). For a vertical, multiply the desired impedance by two to get $Z_0$. If you want a 50-Ω feed, use 100 Ω for $Z_0$.

$F_1$ = the resonant frequency of the main dipole or vertical.

$F_2$ = the resonant frequency of the additional conductor. The ratio $F_2/F_1$ is more than 1.1.

e = 2.7183, the base of natural logarithms.

Eq 7 does not directly allow for conductors of unequal diameters, but it can be used as a starting point if you use the diameter of the driven dipole or vertical element for D in the equation.

### 10.6.2 CHARACTERISTICS OF COUPLED-RESONATOR (C-R) ANTENNAS

Here's the important stuff — what's different about C-R antennas, what are they good for and what are their drawbacks? The key points are:

- Multiband operation without traps, stubs or tuners
- Flexible impedance matching at each frequency
- Independent fine-tuning at each frequency (little interaction)
- Easily modeled using *MININEC* or *NEC*-based programs
- Pruning process same as a simple dipole
- Can accommodate many frequencies (seven or more)
- Virtually lossless coupling (high efficiency)
- Requires a separate wire or tubing conductor at each frequency
- Mechanical assembly requires a number of insulated supports
- Narrower bandwidth than equivalent dipole
- Capacitance requires slight lengthening of conductors

To begin with, the most obvious characteristic is that this principle can be used to add multiple resonant frequencies to an ordinary dipole or vertical, using additional conductors that are not physically connected. This gives us three variable factors: (1) the diameter of the conductor, (2) its length, and (3) its position relative to the main element.

Having the freedom to control these factors gives us the advantage of *flexibility*; we have a wide range of control over the impedance at each added frequency. Another advantage is that the behavior at each frequency is quite *independent*, once the basic design is in place. In other words, making fine-tuning adjustments at one frequency doesn't change the resonance or impedance at the other frequencies. A final advantage is *efficiency*. With conductors close together, and with a resonant target conductor, coupling is very efficient. Traps, stubs, and compensating networks found on other multiband antennas all introduce lossy reactive components.

There are two main disadvantages of C-R antennas. The first is the relative *complexity* of construction. Several conductors are needed, installed with some type of insulating spacers. Other multiband antennas have their complexities as well (such as traps that need to be mounted and tuned), but C-R antennas will usually be bulkier. The larger size generally means greater windload, which is a disadvantage to some hams.

The other significant disadvantage is *narrower bandwidth*, particularly at the highest of the operating frequencies. We can partially overcome this problem with large conductors that are naturally broad in bandwidth, and in some cases we might even use an extra conductor to put two resonances in one band. It is interesting to note that the pattern is opposite that of trap antennas. The C-R antenna gets narrower at the highest frequencies of operation, while trap antennas generally have narrowest bandwidth at their lowest frequencies.

There are two special situations that should be noted. First, when the antenna has a resonance near the frequency where the driven dipole is 3⁄2 λ long (3⁄4 λ for a vertical), the dipole has a fairly low impedance. The spacing of the C-R element needs to be increased to raise its impedance so that the parallel combination of the main element and C-R element equals the desired impedance (usually 50 Ω). There is also significant antenna current in the part of the main dipole extending beyond the C-R section, contributing to the total radiation pattern. As a result, this particular arrangement radiates as three λ/2 sections in phase, and has about 3 dB gain and a narrower directional pattern compared to a dipole (**Figure 10.49**). This might be an advantage for antennas covering bands with a frequency ratio of about three, such as 3.5 and 10.1 MHz, 7 and 21 MHz, or 144 and 430 MHz.

The other special situation is when we want to add a new

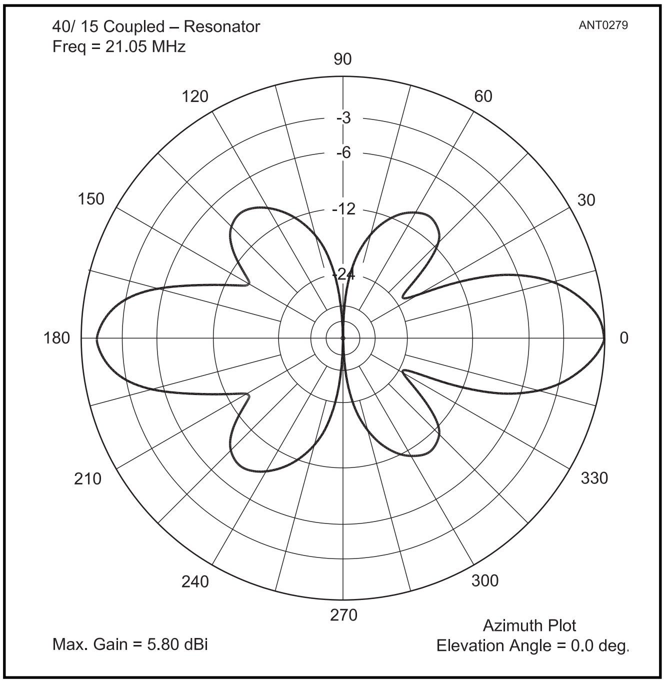



**Figure 10.49 — Radiation pattern for the special case of a C-R antenna with the additional resonance at the third harmonic of the main dipole resonant frequency.**

frequency very close to the resonant frequency of the main dipole. An antenna for 80 and 75 meters would be an example of this. Again, the driven dipole has a fairly low impedance at the new frequency. Add the fact that coupling is very strong between these similar conductors and we find that a wide spacing is required to make the antenna work. A dipole resonant at 3.5 MHz and another wire resonant at 3.8 MHz will need to be 3 or 4 feet apart, while a 3.5 MHz and 7 MHz combination might only need to be spaced 4 or 5 inches.

Another useful characteristic of C-R antennas is that they are easily and accurately modeled by computer programs based on either *MININEC* or *NEC*, as long as you stay within each program's limitations. For example, Severns points out that *MININEC* does not handle folded dipoles very well, and *NEC* modeling is required. With ease of computer modeling, a precise answer isn't needed for the design equation given above. An approximate solution will provide a starting point that can quickly be adjusted for optimum dimensions.

The added resonators have an effect on the lengths of all conductors, due to the capacitance between the conductors. Capacitance causes antennas to look electrically shorter, so each element needs to be about 1% or 2% longer than a simple dipole at the same frequency. As a rule of thumb, use 477/f (in feet) instead of the usual 468/f when calculating dipole length, and 239/f instead of 234/f for a $\lambda/4$ vertical.

## Summary

The coupled-resonator principle is one more weapon in the antenna designer's arsenal. It's not the perfect method for all multiband antennas, but what the C-R principle offers is an alternative to traps and tuners, in exchange for using more wire or aluminum. Although a C-R antenna requires more complicated construction, its main attraction is in making a multiband antenna that can be built with no compromise in matching or efficiency.

### 10.6.3 A C-R DIPOLE FOR 30/17/12 METERS

To show how a C-R antenna is designed, let's build a dipole to cover 30, 17 and 12 meters. We'll use #12 AWG wire, which has a diameter of 0.08 inches, and the main dipole will be cut for the 10.1 MHz band. From the equation above, the spacing between the main dipole and the 18-MHz resonator should be 2.4 inches for 72 Ω, or 1.875 inches for 50 Ω. At 24.9 MHz, the spacing to the resonator for that band should be 2.0 inches for 72 Ω, or 1.62 inches for 50 Ω. Of course, this antenna will be installed over real ground, not in free space, so these spacing distances may not be exact. Plugging these numbers into your favorite antenna-modeling program will let you optimize the dimensions for installation at the height you choose.

For those of you who like to work with real antennas, not computer-generated ones, the predicted spacing is accurate enough to build an antenna with minimum trial-and-error. You should use a nice round number just larger than the calculated spacing for 50 Ω. For this antenna, K9AY decided that the right spacing for the desired height would be 2 inches for the 18 MHz resonator and 1.8 inches for the 24.9 MHz resonator. For simplicity of construction, he just used 2 inches for both, figuring that the worst he would get is a 1.2:1 SWR if the numbers were a little bit off. Like all dipoles, the impedance varies with height above ground, but the 2-inch spacing results in an excellent match on the two additional bands, at heights of more than 25 feet.

The final dimensions of the dipole for 10.1, 18.068 and 24.89 MHz are shown in **Figure 10.50**. These are the final pruned lengths for a straight dipole installed at a height of about 40 feet. If you put up the antenna as an inverted V, you will need each wire to be a bit longer. Pruning this type of antenna is just like a dipole — if it's resonant too low in frequency, it's too long and the appropriate wire needs to be shortened. So, you can cut the wires just a little long to start with and easily prune them to resonance.

A final note: if you want to duplicate this antenna design, remember that the 2-inch spacing is just for #12 AWG wire! The required spacing for a C-R antenna is related to the conductor diameter. This same antenna built with #14 AWG wire needs under 1½-inch spacing, while a 1-inch aluminum-tubing version requires about 7-inch spacing.

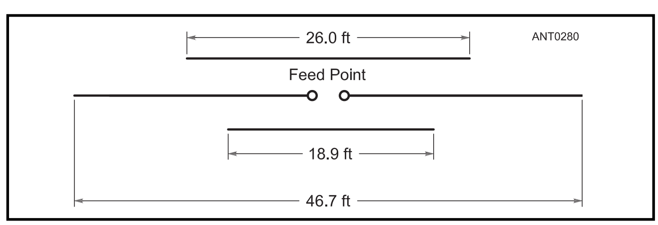



**Figure 10.50 — Dimensions of a C-R dipole for the 30, 17 and 12 meter bands.**

# 10.7 HF LOG PERIODIC DIPOLE ARRAYS

The log periodic antenna whose theory is presented in the chapter **Log-Periodic Dipole Arrays** is intended to be used across a wide frequency range. Designs that cover two or more amateur bands are fairly common and rotatable LPDAs (Log Periodic Dipole Arrays) are popular antennas for 20 meters through the UHF bands.

This section presents a pair of LPDA designs — a fixed array of wire dipoles for the 3.5 and 7 MHz bands and a rotatable array for the five amateur bands from 14 through 30 MHz. In addition, the *QST* article "Practical High Performance HF Log Periodic Antennas" by Bill Jones, K8CU is provided on this book's CD-ROM for additional design information.

## 10.7.1 LPDAS FOR 3.5 OR 7 MHZ

These wire log-periodic dipole arrays for the lower HF bands are simple in design and easy to build. They are designed to have reasonable gain, be inexpensive and lightweight, and may be assembled with stock items found in large hardware stores. They are also strong — they can withstand a hurricane! These antennas were first described by John J. Uhl, KV5E, in *QST* for August 1986. **Figure 10.51** shows one method of installation. You can use the information here as a guide and point of reference for building similar LPDAs.

If space is available, the antennas can be rotated or repositioned in azimuth after they are completed. A 75-foot tower and a clear turning radius of 120 feet around the base of the tower are needed. The task is simplified if you use only three anchor points, instead of the five shown in Figure 10.51. Omit the two anchor points on the forward element, and extend the two nylon strings used for element stays all the way to the forward stay line.

### Design of the Log-Periodic Dipole Arrays

Design constants for the two arrays are listed in **Tables 10.4** and **10.5**. The **Log-Periodic Dipole Arrays** chapter has more information about the design procedure for arriving at the dimensions and other parameters of these arrays. The primary differences between these designs and one-octave upper HF arrays are the narrower frequency ranges and the use of wire, rather than tubing, for the elements. As design examples for the LPDA, you may wish to work through the step-by-step procedure and check your results against the values in Tables 10.4 and 10.5. You may also wish to compare these results with the output of an LPDA design software package such as *LPCAD*.

From the design procedure, the feeder wire spacings for the two arrays are slightly different, 0.58 inch for the 3.5-MHz array and 0.66 inch for the 7-MHz version. As a compromise toward the use of common spacers for both bands, a spacing of ⅝ inch is quite satisfactory. Surprisingly, the feeder spacing is not at all critical here from a matching

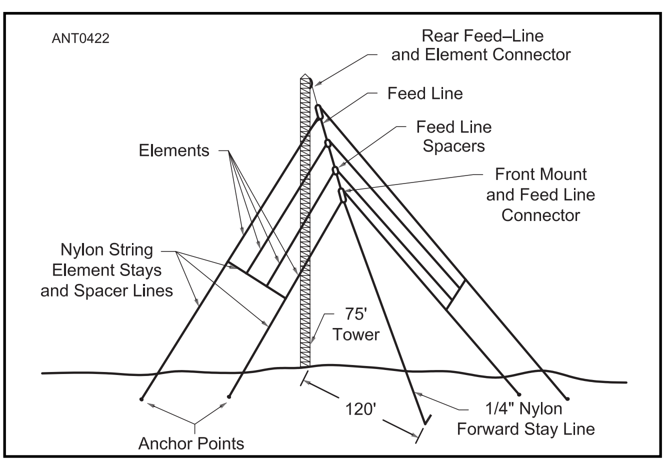



**Figure 10.51 — Typical lower-HF wire 4-element log periodic dipole aray erected on a tower.**

**Table 10.4**
**Design Parameters for the 3.5-MHz Single-Band LPDA**

| | |
|---|---|
| f1 = 3.3 MHz | Element lengths: |
| $f_n$ = 4.1 MHz | $\ell$1 = 149.091 feet |
| B = 1.2424 | $\ell$2 = 125.982 feet |
| $\tau$ = 0.845 | $\ell$3 = 106.455 feet |
| $\sigma$ = 0.06 | $\ell$4 = 89.954 feet |
| Gain = 5.9 dBi = 3.8 dBd | Element spacings: |
| cot $\alpha$ = 1.5484 | $d_{12}$=17.891 feet |
| $B_{ar}$ = 1.3864 | $d_{23}$ = 15.118 feet |
| $B_s$ = 1.7225 | $d_{34}$ = 12.775 feet |
| L = 48.42 feet | Element diameters |
| N = 4.23 elements (decrease to 4) | All = 0.0641 inches |
| $Z_t$ = 6-inch short jumper | $\ell$/diameter ratios: |
| $R_0$ = 208 Ω | $\ell/diam_4$ = 16840 |
| $Z_{AV}$ = 897.8 Ω | $\ell/diam_3$ = 19929 |
| σ' = 0.06527 | $\ell/diam_2$ = 23585 |
| $Z_0$ = 319.8 Ω | $\ell/diam_1$ = 27911 |
| Antenna feeder: #12 AWG wire spaced 0.58 inches | |
| Balun: 4:1 | |
| Feed line: 52-Ω coax | |

**Table 10.5**
**Design Parameters for the 7-MHz Single-Band LPDA**

| | |
|---|---|
| f1 = 6.9 MHz | Element lengths: |
| $f_n$ = 7.5 MHz | $\ell$1 = 71.304 feet |
| B = 1.0870 | $\ell$2 = 60.252 feet |
| $\tau$ = 0.845 | $\ell$3 = 50.913 feet |
| $\sigma$ = 0.06 | $\ell$4 = 43.022 feet |
| Gain = 5.9 dBi = 3.8 dBd | Element spacings: |
| cot $\alpha$ = 1.5484 | $d_{12}$ = 8.557 feet |
| $B_{ar}$ = 1.3864 | $d_{23}$ = 7.230 feet |
| $B_s$ = 1.5070 | $d_{34}$ = 6.110 feet |
| L = 18.57 feet | Element diameters: |
| N = 3.44 elements (increase to 4) | All = 0.0641 inches |
| $Z_t$ = 6-inch short jumper | $\ell$/diameter ratios: |
| $R_0$ = 208 Ω | $\ell4/diam_4$ = 8054 |
| $Z_{AV}$ = 809.3 Ω | $\ell3/diam_3$ = 9531 |
| σ' = 0.06527 | $\ell2/diam_2$ = 11280 |
| $Z_0$ = 334.2 Ω | $\ell1/diam_1$ = 13349 |
| Antenna feeder: #12 AWG wire spaced 0.66 inches | |
| Balun: 4:1 | |
| Feed line: 52-Ω coax | |

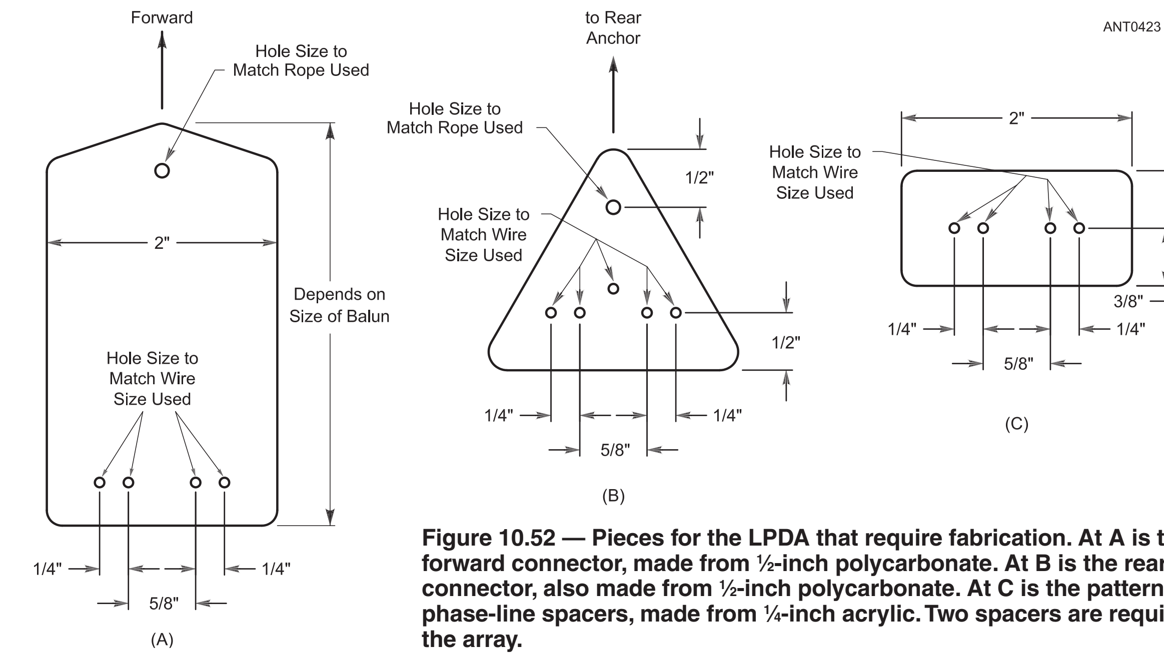



**Figure 10.52 — Pieces for the LPDA that require fabrication. At A is the forward connector, made from ½-inch polycarbonate. At B is the rear connector, also made from ½-inch polycarbonate. At C is the pattern for the phase-line spacers, made from ¼-inch acrylic. Two spacers are required for the array.**

standpoint, as may be verified from the equations in the **Log-Periodic Dipole Arrays** chapter. Increasing the spacing to as much as 3/4 inch results in an $R_0$ SWR of less than 1.1:1 on both bands.

## Constructing the Arrays

Construction techniques are the same for both the 3.5 and the 7-MHz versions of the array. Once the designs are completed, the next step is to fabricate the fittings; see **Figure 10.52** for details. Cut the wire elements and feed lines to the proper sizes and mark them for identification. After the wires are cut and placed aside, it will be difficult to remember which is which unless they are marked. When you have finished fabricating the connectors and cutting all of the wires, the antenna can be assembled. Use your ingenuity when building one of these antennas; it isn't necessary to duplicate these LPDAs precisely.

The elements are made of standard #14 AWG stranded copper wire. The two parallel-wire feed lines are made of #12 AWG solid copper-clad steel wire, such as Copperweld. Copperweld will not stretch when placed under tension. The front and rear connectors are cut from ½-inch thick polycarbonate sheeting, and the feed line spacers from ¼-inch acrylic sheeting.

Study the drawings carefully and be familiar with the way the wire elements are connected to the two feed lines, through the front, rear and spacer connectors. Details are sketched in **Figures 10.53** and **10.54**. Connections made in the way shown in the drawings prevent the wire from breaking. All of the rope, string, and connectors must be made of materials that can withstand the effects of tension and weathering. Use nylon rope and strings, the type that yachtsmen use. Figure 10.51 shows the front stay rope coming down to ground level at a point 120 feet from the base of a 75-foot tower. Space

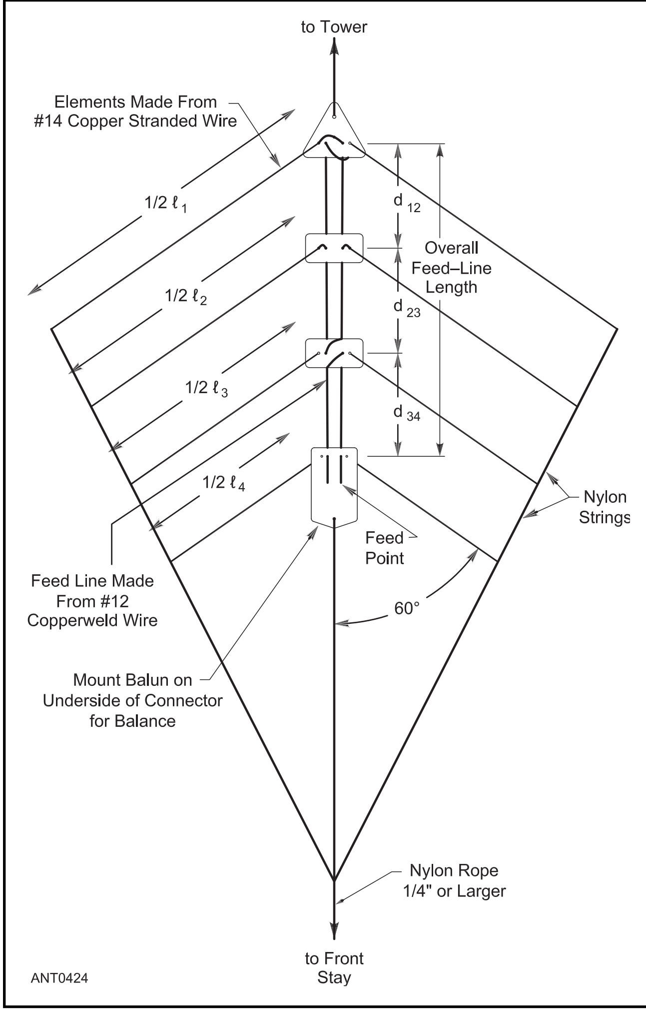



**Figure 10.53 — The generic layout for the lower HF wire LPDA. Use a 4:1 balun on the forward connector. See Tables 10.4 and 10.5 for dimensions.**

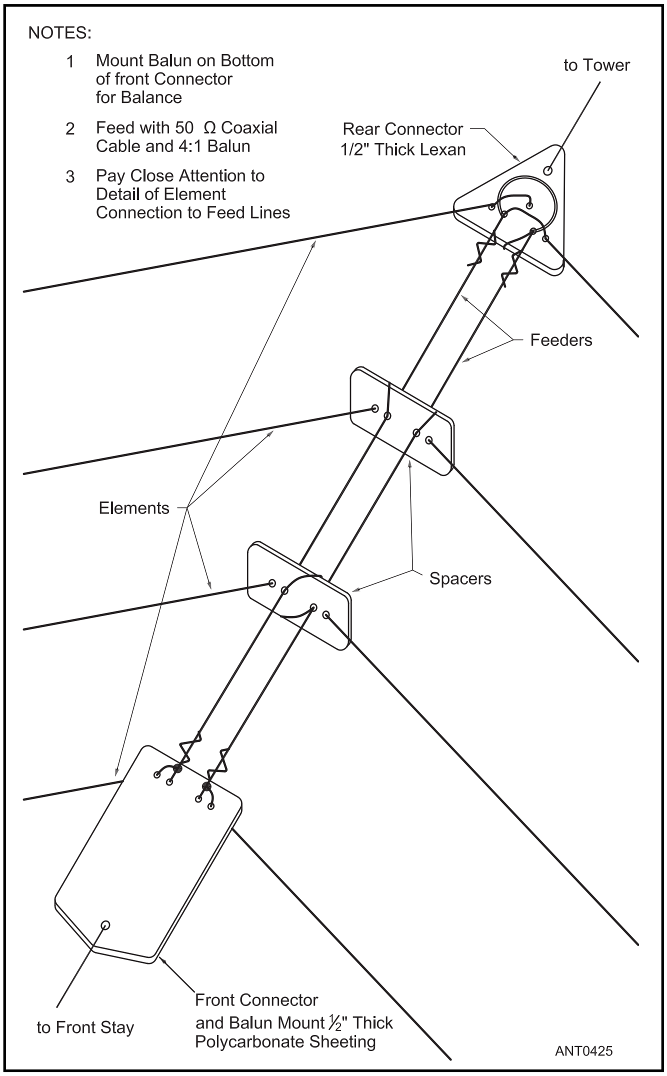



**Figure 10.54 — Details of the electrical and mechanical connections of the elements to the phase-line. Knots in the nylon rope stay line are not shown.**

may not be available for this arrangement in all cases. An alternative installation technique is to put a pulley 40 feet up in a tree and run the front stay rope through the pulley and down to ground level at the base of the tree. The front stay rope will have to be tightened with a block and tackle at ground level.

Putting an LPDA together is not difficult if it is assembled in an orderly manner. It is easier to connect the elements to the feeder lines when the feed line assembly is stretched between two points. Use the tower and a block and tackle. Attaching the rear connector to the tower and assembling the LPDA at the base of the tower makes raising the antenna into place a much simpler task. Tie the rear connector securely to the base of the tower and attach the two feeder lines to it. Then thread the two feed line spacers onto the feed line. The spacers will be loose at this time, but will be positioned properly when the elements are connected. Now connect the front connector to the feed lines. A word of caution: Measure accurately and carefully! Double-check all measurements before you make permanent connections.

Connect the elements to the feeder lines through their respective plastic connectors, beginning with element 1, then element 2, and so on. Keep all of the element wires securely coiled. If they unravel, you will have a tangled mess of kinked wire. Recheck the element-to-feeder connections to ensure proper and secure junctions. (See Figures 10.53 and 10.54.) Once you have completed all of the element connections, attach the 4:1 balun to the underside of the front connector. Connect the feeder lines and the coaxial cable to the balun.

You will need a separate piece of rope and a pulley to raise the completed LPDA into position. First secure the eight element ends with nylon string, referring to Figures 10.51 and 10.53. The string must be long enough to reach the tie-down points. Connect the front stay rope to the front connector, and the completed LPDA is now ready to be raised into position. While raising the antenna, uncoil the element wires to prevent their getting away and tangling up into a mess. Use care! Raise the rear connector to the proper height and attach it securely to the tower, then pull the front stay rope tight and secure it. Move the elements so they form a 60° angle with the feed lines, in the direction of the front, and space them properly relative to one another. By adjusting the end positions of the elements as you walk back and forth, you will be able to align all the elements properly. Now it is time to hook your rig to the system and make some contacts.

### Performance

The reports received from these LPDAs were compared with an inverted-V dipole. All of the antennas are fixed; the LPDAs radiate to the northeast, and the dipole to the northeast and southwest. The apex of the dipole is at 70 feet, and the 40- and 80-meter LPDAs are at 60 and 50 feet, respectively. Basic array gain was apparent from many of the reports received. During pileups, it was possible to break in with a few tries on the LPDAs, yet it was impossible to break the same pileups using the dipole. The gain of the LPDAs is several dB over the dipole. For additional gain, experimenters may wish to try a parasitic director about ⅛ λ ahead of the array. Director length and spacing from the forward LPDA element should be field-adjusted for maximum performance while maintaining the impedance match across each of the bands.

Wire LPDA systems offer many possibilities. They are easy to design and to construct: real advantages in countries where commercially built antennas and parts are not available at reasonable cost. The wire needed can be obtained in all parts of the world, and cost of construction is low. If damaged, the LPDAs can be repaired easily with pliers and solder. For those who travel on DXpeditions where space and weight are large considerations, LPDAs are lightweight but sturdy, and they perform well.

### 10.7.2 5-BAND LOG PERIODIC DIPOLE ARRAY

A rotatable log periodic array designed to cover the frequency range from 13 to 30 MHz is pictured in **Figure 10.55**. This is a large array having a free-space gain that varies from 6.6 to over 6.9 dBi, depending upon the operating portion of the design spectrum. This antenna system was originally described by Peter D. Rhodes, K4EWG, in November 1973 *QST*. A measured radiation pattern for the array appears in **Figure 10.56**.

The characteristics of this array are:

1) Half-power beamwidth, 43° (14 MHz)
2) Design parameter $\tau = 0.9$
3) Relative element spacing constant $\sigma = 0.05$
4) Boom length, L = 26 feet
5) Longest element $\lambda 1$ = 37 feet 10 inches.
6) Total weight, 116 pounds
7) Wind-load area, 10.7 square feet
8) Required input impedance (mean resistance), $R_0 = 72\ \Omega$, $Z_t$ = 6-inch jumper #18 AWG wire
9) Average characteristic dipole impedance, $Z_{AV}$: 337.8 Ω
10) Impedance of the feeder, $Z_0$: 117.1 Ω
11) Feeder: #12 AWG wire, close spaced
12) With a 1:1 toroid balun at the input terminals and a 72-Ω coax feed line, the maximum SWR is 1.4:1.

The mechanical assembly uses materials readily available from most local hardware stores or aluminum supply houses. A complete set of tables and assembly drawings are included in the original article included on this book's CD-ROM.

Experimenters may wish to improve the performance of the array at both the upper and lower frequency ends of the design spectrum so that it more closely approaches the performance in the middle of the design frequency range. The most apt general technique for raising both the gain and the front-to-back ratio at the frequency extremes would be to circularize $\tau$ as described in the chapter **Log-Periodic Dipole Arrays**. However, other techniques may also be applied.

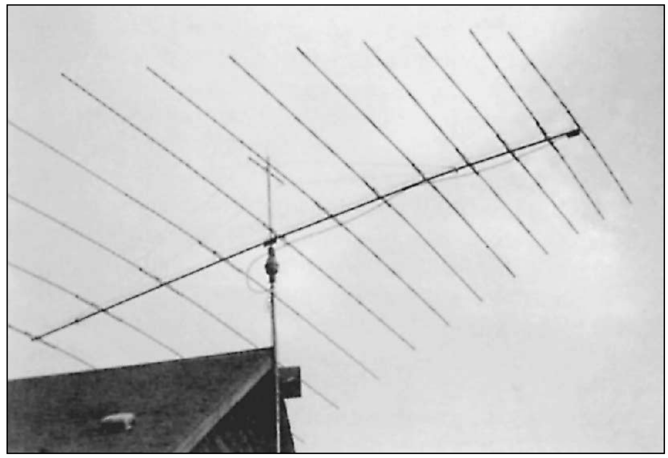


**Figure 10.55 — The 13-30 MHz log periodic dipole array.**

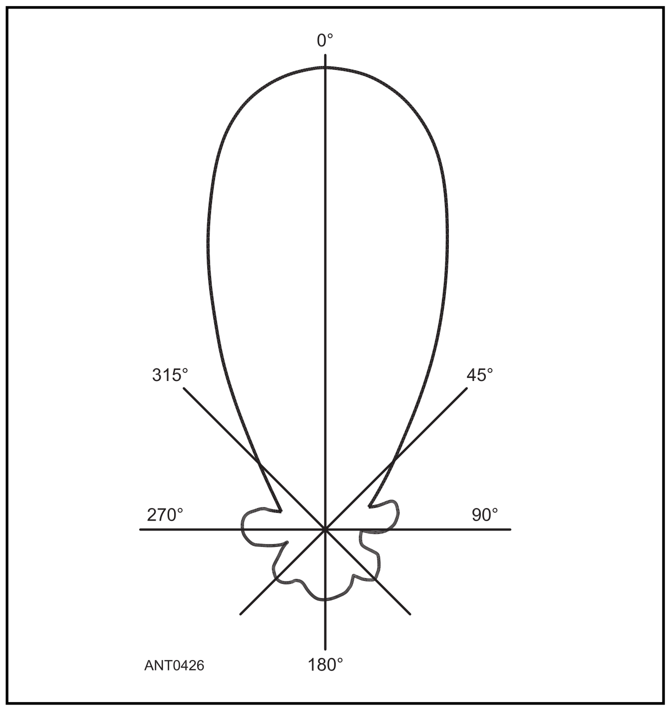



**Figure 10.56 — Measured radiation pattern of the 13-30 MHz LPDA. The front-to-back ratio is about 14 dB at 14 MHz and increases to 21 dB at 28 MHz.**

# 10.8 HF DISCONE ANTENNAS

The material in this section is adapted from an article by Daniel A. Krupp, W8NWF, in *The ARRL Antenna Compendium, Vol 5*. (Additional articles on discone antennas are referenced in the Bibliography or included on this book's CD-ROM.) The name "discone" is a contraction of the words "disc" and "cone." Although people often describe a discone by its design-center frequency (for example, a "20 meter discone"), discones work very well over a wide frequency range, as much as several octaves. **Figure 10.57** shows a typical discone, constructed of sheet metal for UHF use. On lower frequencies, the sheet metal may be replaced with closely spaced wires and/or aluminum tubing.

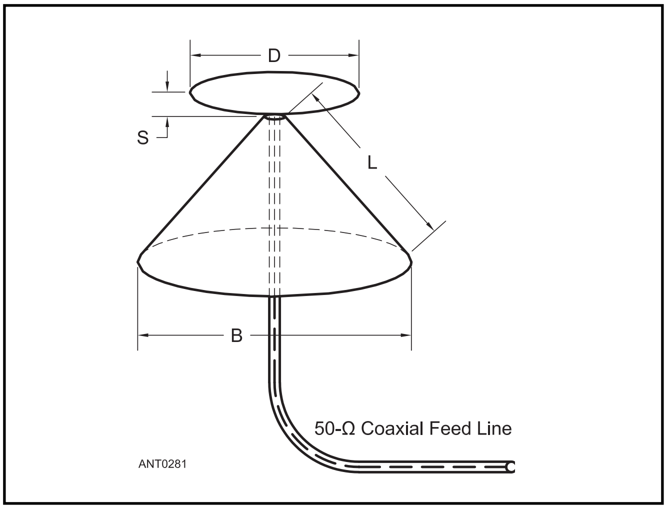



**Figure 10.57 — Diagram of VHF/UHF discone, using a sheet-metal disc and cone. It is fed directly with 50-Ω coax line. The dimensions L and D, together with the spacing S between the disc and cone, determine the frequency characteristics of the antenna. L = 246 / $f_{MHz}$ for the lowest frequency to be used. Diameter D should be from 0.67 to 0.70 of dimension L. The diameter at the bottom of the cone B is equal to L. The space S between disc and cone can be 2 to 12 inches, with the wider spacing appropriate for larger antennas.**

## 10.8.1 DISCONE BASICS

The dimensions of a discone are determined by the lowest frequency of use. The antenna produces a vertically polarized signal at a low-elevation angle and it presents a good match for 50-Ω coax over its operating range. One advantage of the discone is that its maximum current area is near the top of the antenna, where it can radiate away from ground clutter, reducing losses. The cone-like skirt of the discone radiates the signal — radiation from the disc on top is minimal. This is because the currents flowing in the skirt wires essentially all go in the same direction, while the currents in the disc elements oppose each other and cancel out. The discone's omnidirectional characteristics make it ideal for roundtable QSOs or for a net control station.

Electrical operation of this antenna is very stable, with no changes due to rain or accumulated ice. It is a self-contained antenna — unlike a traditional ground-mounted vertical radiator, the discone does not rely on a ground-radial system for efficient operation. However, just like any other vertical antenna, the quality of the ground in the Fresnel area will affect the discone's far-field pattern.

Both the disc and cone are inherently balanced for wind loading, so torque caused by the wind is minimal. The entire cone and metal mast or tower can be connected directly to ground for lightning protection.

Unlike a trap vertical or a triband beam, discone antennas are not adjusted to resonate at a particular frequency in a ham band or a group of ham bands. Instead, a discone functions as a sort of high-pass filter, efficiently radiating RF all the way from the low-frequency design cutoff to the high-frequency limits imposed by the physical design.

### History of the Discone

The July 1949 and July 1950 issues of *CQ* magazine both contained excellent articles on discones. The first article, by Joseph M. Boyer, W6UYH, said that the discone was developed and used by the military during World War II. (See Bibliography.) The exact configuration of the top disc and cone was the brainchild of Armig G. Kandonian. Boyer described three VHF models, plus information on how to build them, radiation patterns, and most importantly, a detailed description of how they work. He referred to the discone as a type of "coaxial taper transformer."

The July 1950 article was by Mack Seybold, W2RYI. He described an 11-MHz version he built on his garage roof. The mast actually fit through the roof to allow lowering the antenna for service. Seybold stated that his 11-MHz discone would load up on 2 meters but that performance was down 10 dB compared to his 100-MHz Birdcage discone. He commented that this was caused by the relatively large spacing between the disc and cone. Actually, the performance degradation he found was caused by the wave angle lifting upward at high frequencies. The cone wires were electrically long, causing them to act like long wire antennas.

## 10.8.2 A-FRAME 20-10 METER DISCONE

W8NWF's first discone was designed to cover 20 through 10 meters without requiring an antenna tuner. The cone assembly uses 18-foot long wires, with a 60° included apex angle and a 12-foot diameter disc assembly. See **Figure 10.58**. The antenna was assembled on the ground, with the feed coax and all guys attached. Then with the aid of some friends, it was pulled up into position.

The author used a 40-foot tall wooden "A-frame" mast, made of three 22-foot-long 2×4s. He primed the mast with sealer and then gave it two coats of red barn paint to make it look nice and last a long time. The disc hub was a 12-inch length of 3-inch schedule-40 PVC plumbing pipe. The PVC is very tough, slightly ductile, and easy to drill and cut. PVC is well suited for RF power at the feed point of the antenna.

Three 12-foot by 0.375-inch OD pieces of 6061

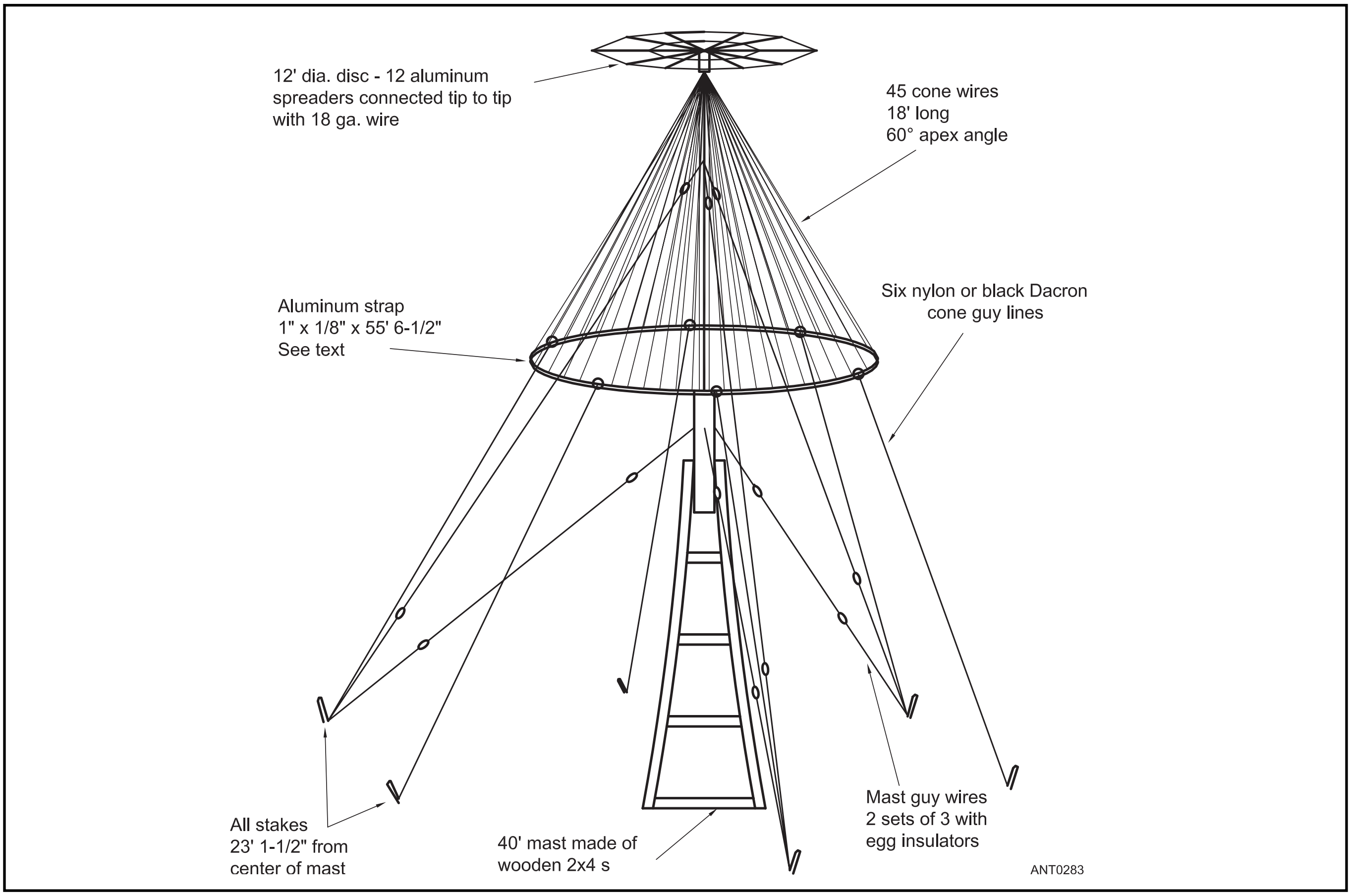



**Figure 10.58 — Detailed drawing of the A-frame discone for 14 to 30 MHz. The disc assembly at the top of the A-frame is 12 feet in diameter. There are 45 cone wires, each 18 feet long, making a 60° included angle of the cone.**

aluminum, with 0.058-inch wall thickness, were used for the 12-foot diameter top disc. These were cut in half to make the center portions of the six telescoping spreaders. Four twelve foot by 0.250-inch OD (0.035-inch wall thickness) tubes were cut into 12 pieces, each 40 inches long. This gave extension tips for each end of the six spreaders.

### 10.8.3 40-10 METER DISCONE

When an opportunity arose to buy a 64-foot self-supporting TV tower, W8NWF jumped at the chance to implement a full 7 to 30-MHz discone. His new tower had eight sections, each eight feet long. Counting the overlap between sections, the cone wires would come off the tower at about the 61.5-foot mark. See **Figure 10.59**.

W8NWF took some liberties with the design of this larger discone compared to the first one, which he had done strictly "by the book." The first change was to make the cone wires 70 feet long, even though the formula said they should be 38 feet long. Further, the cone wires would not be connected together at the bottom. With the longer cone wires, he felt that 75 and 80-meter operation might be a possibility.

The second major change was to widen the apex angle out from 60° to about 78°. Modeling said this should produce a flatter SWR over the frequency spectrum and would also give a better guy system for the tower.

The topside disc assembly would be 27 feet in diameter and have 16 radial spreaders, using telescoping aluminum tubing tapering from ⅝ to ½ to ⅜ inches OD. All spreaders were made from 0.058-inch wall thickness 6063-T832 aluminum tubing, available from Texas Towers and other suppliers. A section of 10-inch PVC plumbing pipe would be used as the hub for construction of the disc assembly.

On the air tests proved to be very satisfying. Loading up on 40 meters was easy — the SWR was 1:1 across the entire band. W8NWF can work all directions very well and receives excellent signal reports from DX stations. When he switches to his long (333 foot) center-fed dipole for comparison, he finds the dipole is much noisier and that received signals are weaker. During the daytime, nearby stations (less than about 300 to 500 miles) can be louder with the dipole, but the discone can work them just fine also.

The author happily reports that this antenna even works well on 75 meters. As you might expect, it doesn't present a 1:1 match. However, the SWR is between 3.5:1 and 5.5:1 across the band. W8NWF uses an antenna tuner to operate the discone on 75. It seems to get out as well on 75 as it does on 40 meters.

The SWR on 30 meters is about 1.1:1. On 20 meters the

SWR runs from 1.05:1 at 14.0 MHz to 1.4:1 at 14.3 MHz. The SWR on the 17, 15, 12 and 10-meter bands varies, going up to a high of 3.5:1 on 12 meters.

From modeling using *NEC/Wires* by K6STI, W8NWF verified that the low-angle performance for the bigger antenna is worse than that for the smaller discone on the upper frequencies. See **Figure 10.60** for an elevation-pattern comparison on 10 meters for both antennas, with average ground constants. The azimuth patterns are simply circles. Radiation patterns produced by antenna modeling programs are very helpful to determine what to expect from an antenna.

The smaller discone, which was built by the book, displays good, low-angle lobes on 20 through 10 meters. The frequency range of 14 through 28 MHz is an octave's worth of coverage. It met his expectations in every way by covering this frequency span with low SWR and a low angle of radiation.

The bigger discone, with a modified cone suitable for use on 75 meters, presents a little different story. The low-angle lobe on 40 meters works well, and 75-meter performance also

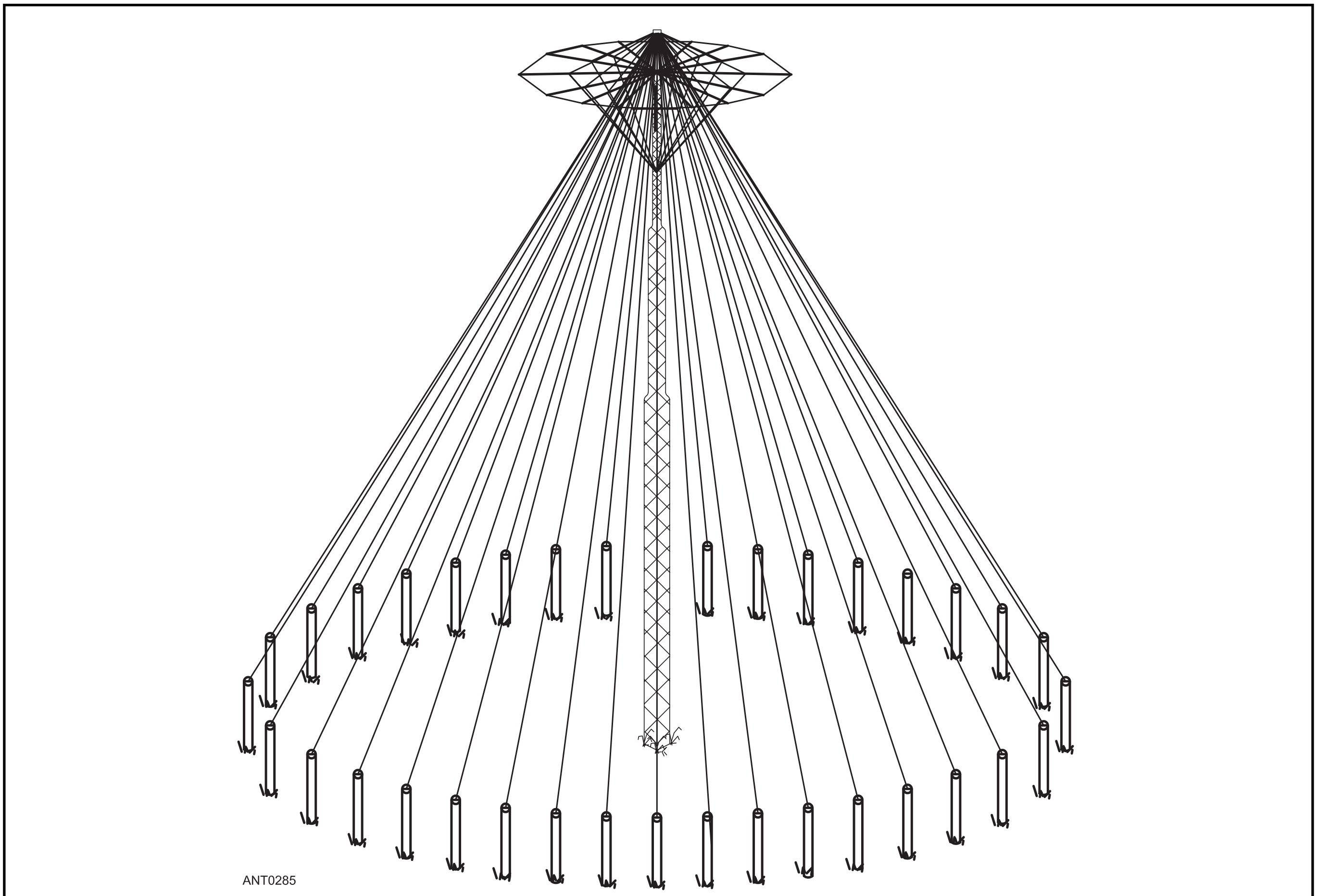



**Figure 10.59 — The large W8NWF discone, designed for operation from 7 to 14 MHz, but useable with a tuning network in the shack for 3.8 MHz.**

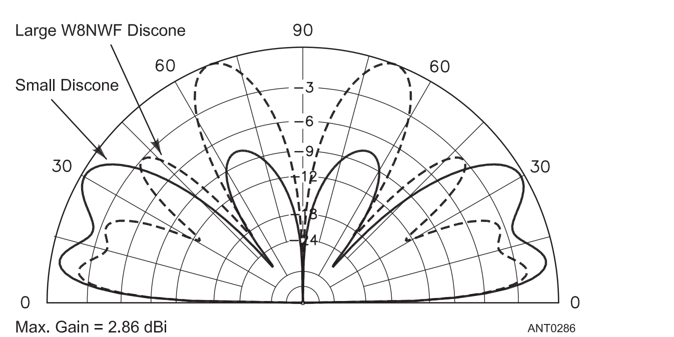



**Figure 10.60 — Computed patterns showing elevation response of small discone at 28.5 MHz compared to that of the larger discone at 28.5 MHz. The cone wires are clearly too long for efficient operation on 10 meters, producing unwanted high-angle lobes that rob power from the desirable low-elevation angles.**

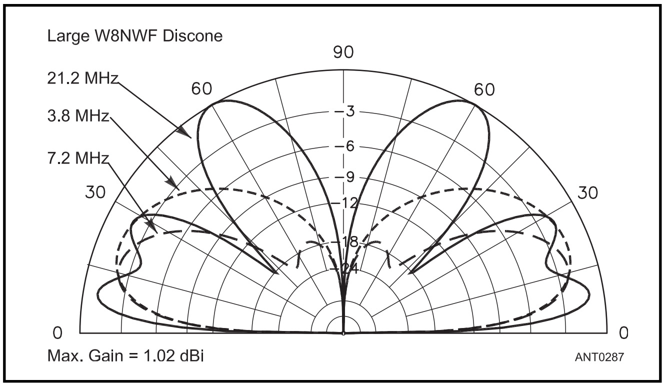



**Figure 10.61 — Computed elevation-response patterns for the larger W8NWF discone for 3.8, 7.2 and 21.2 MHz operation. Again, as in Figure 10.60, the pattern degrades at 21.2 MHz, although it is still reasonably efficient, if not optimal.**

is good, although an antenna tuner is necessary on this band. The 30-meter band has a good low-angle lobe but secondary high-angle lobes are starting to hurt performance. Note that 30 meters is roughly three times the design frequency of the cone. On 20 and 17 meters there still are good low-angle lobes but more and more power is wasted in high-angle lobes.

The operation on 15, 12, and 10 meters continues to worsen for the larger discone. The message here is that although a discone may have a decent SWR as high as 10 times the design frequency, its radiation pattern is not necessarily good for low-angle communications. See **Figure 10.61** for a comparison of elevation patterns for 3.8, 7.2 and 21.2 MHz on the larger discone.

A discone antenna built according to formula will work predictably and without any adjustments. One can modify the antenna's cone length and apex angle without fear of rendering it useless. The broadband feature of the discone makes it attractive to use on the HF bands. The low angle of radiation makes DX a real possibility and the discone is also much less noisy on receive than a dipole.

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