Practically Speaking

Joe Carr, K4IPV

PART 1

HIGH-FREQUENCY DIPOLE ANTENNAS

An unfortunate myth arose in Amateur Radio circles some time ago. People came to believe that large antenna arrays were absolutely necessary for effective communications — especially for DX work. They tend to overlook basic, but effective, antennas that anyone can erect and make work. The simple *dipole* or *doublet* antenna is a case in point. This antenna is sometimes called the *Hertz* or *Hertzian* antenna, because radio pioneer Heinrich Hertz is said to have used it in his experiments.

The dipole is a balanced antenna with two quarter-wavelength radiators (**Figure 1**), making a total of a half wavelength. The antenna is usually installed horizontally, producing a corresponding horizontally polarized signal.

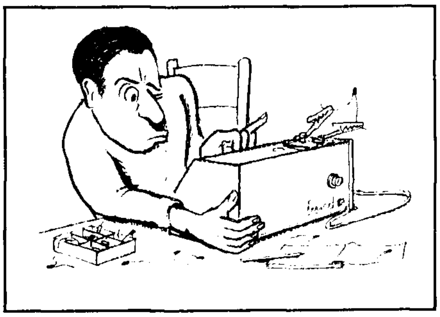
In its most common configuration (**Figure 1**), the dipole is supported at each end by rope and insulators. The rope supports are tied to trees, buildings, masts, or some combination of structures.

As I said before, the antenna length is a half wavelength. Remember that the physical length of the antenna and the theoretical electrical length often differ by about 5 percent. In free space, a half wavelength is found from:

$$L = \frac{492}{F_{MHz}} \text{ feet} \qquad \textbf{(1)}$$

Equation 1 gives you the physical length of a perfect, self-supporting antenna that's many wavelengths away from any object. But for real antennas, the length calculated using this equation is too long. The physical length is about 5 percent shorter because of the capacitive effects of the end insulators. A more nearly correct *approximation* (remember that word; it's important) of a half-wavelength antenna is:

$$L = \frac{468}{F_{MHz}} \text{ feet} \qquad \textbf{(2)}$$



Where:

L is the length of a half-wavelength radiator, in feet.

F_{MHz} is the operating frequency in megahertz.

Example 1

Calculate the approximate physical length for a half-wavelength dipole operating on a frequency of 7.25 MHz.

Solution:

$$L = \frac{468}{F_{MHz}} \text{ feet}$$

$$L = \frac{468}{7.25} \text{ feet} = 64.55 \text{ feet}$$

or, restated another way:

$L = 64$ *feet* 6.6 *inches*

Unfortunately, a lot of people accept **Equation 2** as a universal truth — perhaps because of books and articles on antennas that fail to tell it all. For example, you must consider *resonance*. An antenna acts like a complex RLC network. At some frequencies it will appear as an inductive reactance ($X_l = +jX$), and at others as a capacitive reactance ($X_C = -jX$). At a specific frequency the reactances are equal in magnitude but opposite in sign, so they cancel each other out: $X_l - X_C = 0$. At this frequency the impedance is purely resistive, and the antenna is resonant.

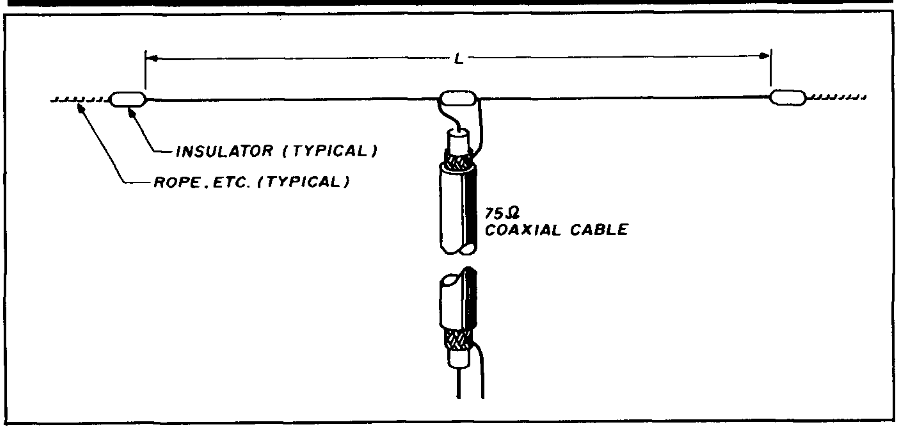
The goal in erecting a dipole is to make the antenna resonant at a frequency that's inside the band of interest — preferably the portion of the band most often used by your station. I'll discuss some of the implications of this later, but for now assume that you have to custom tailor the antenna length. Depending on several local factors (*among them nearby objects, the* antenna conductor's shape, and the conductor's length/diameter ratio), you may have to add or trim the length a bit to reach resonance.

The dipole feedpoint

The dipole is a half-wavelength, center-fed antenna. **Figure 2** shows the voltage (V), current (I), and impedance (Z) distributions along the length of the half-wavelength radiator element. The feedpoint voltage is at a minimum and the current is at a maximum, so you can assume that the feedpoint is a current "loop" or "antinode."

The impedance of the feedpoint at resonance is $R_O = V/I$. R_O is made up of two resistances. First there are ohmic losses that generate nothing but heat when the transmitter is turned on. These losses result because conduc-

FIGURE 1



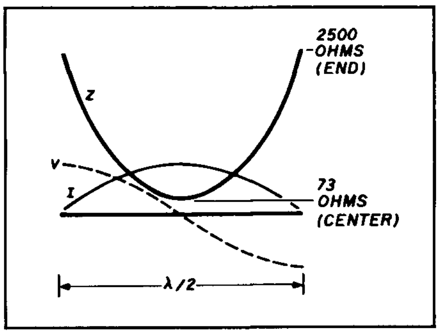
Standard coaxial cable fed half-wavelength dipole antenna.

tors have electrical resistance, and because electrical connections aren't perfect (even when properly soldered). Fortunately, in a well-made dipole these losses are almost negligible. The second contributor is the antenna's radiation resistance (R_r). This resistance is a hypothetical concept that accounts for the fact that the antenna radiates RF power. The radiation resistance is the fictional resistance that would dissipate the amount of power radiated away from the antenna.

For example, suppose you're using a large diameter conductor as an antenna, and it has negligible ohmic losses. If you apply 1,000 watts of RF power to the feedpoint, and measure a current of 3.7 A, what is the radiation resistance?

$$R_r = P/I^2$$
$$R_r = (1{,}000 \text{ watts})/(3.7)^2$$
$$R_r = 73 \text{ ohms}$$

FIGURE 2



Plot of current, voltage, and impedance distribution along half-wavelength dipole.

It's important to match the feedpoint impedance of an antenna to the transmission line impedance. Maximum power transfer always occurs when the source and load impedances (in any system) are matched. If some applied power isn't absorbed by the antenna (as happens in a mismatched system), then the unabsorbed portion is reflected back down the transmission line towards the transmitter. This results in standby waves, and the so-called standing wave ratio (SWR or VSWR).

Matching antenna feedpoint impedance may seem easy because the free space feedpoint impedance of a simple dipole is about 72 ohms. You'd think this would be a good match to 75-ohm coaxial cable. Unfortunately, the 72-ohm feedpoint impedance is almost a myth in practical situations. **Figure 3** shows a plot of approximate radiation resistance (R_r) versus height above ground (as measured in wavelengths). As before, you must deal in the approximations found in **Figure 3**; here the ambiguity is introduced by ground losses.

Despite the fact that **Figure 3** is based on approximations, you can see that radiation resistance varies from less than 10 to almost 100 ohms as a function of height. At heights of many wavelengths, this oscillation of the curve settles down to the free space impedance (72 ohms). At the higher frequencies it may be possible to install a dipole many wavelengths high. On the 2-meter band (144 to 148 MHz) one wavelength is around 6.5 feet (2 meters × 3.28 feet/meter), so it's relatively easy to achieve "many" wavelengths at reasonably attainable heights. In the 80-meter band (3.5 to 4.0 MHz), however, one wavelength is about 262 feet, so many wavelengths is a practical impossibility.

There are three tactics you can follow. The first is to ignore the problem altogether. In many installations, the height above ground will be such that the radiation resistance is close enough to present only a slight impedance mismatch to a standard coaxial cable. You'd calculate the VSWR as the ratio (among other ways):

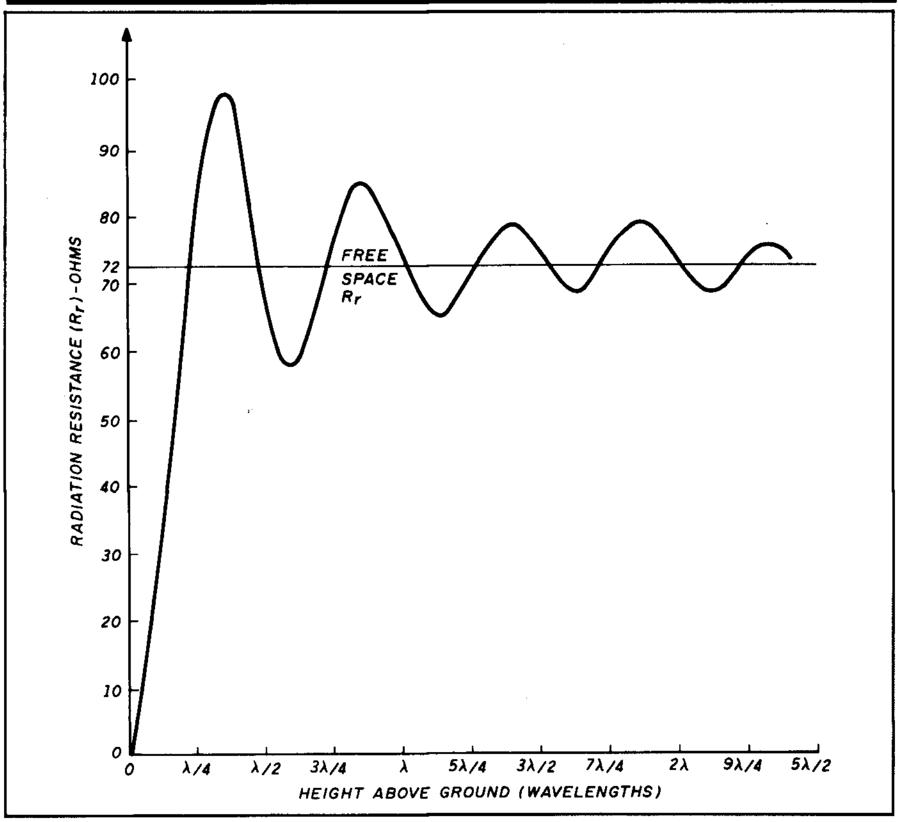
$Z_o > R_r$:
$$VSWR = Z_o/R_r \quad (3)$$
$Z_o < R_r$:
$$VSWR = R_r/Z_o \quad (4)$$

Where:
Z_0 is the coaxial cable characteristic impedance.
R_r is the radiation resistance of the antenna.

Consider an antenna mounted at a height somewhat less than a quarter wavelength, with a radiation resistance of 60 ohms. While not recommended as good engineering practice, there are many practical reasons why it's necessary to install a dipole at less than optimum height. If so, what are the implications of feeding a 60-ohm antenna with either 52 or 75-ohm standard coaxial cable? Some calculations are revealing:

For 75-ohm coaxial cable:
$$VSWR = Z_o/R_r$$
$$VSWR = 75 \text{ ohms}/60 \text{ ohms} = 1.25{:}1$$

FIGURE 3



Feedpoint impedance versus height above ground.

For 52-ohm coaxial cable:

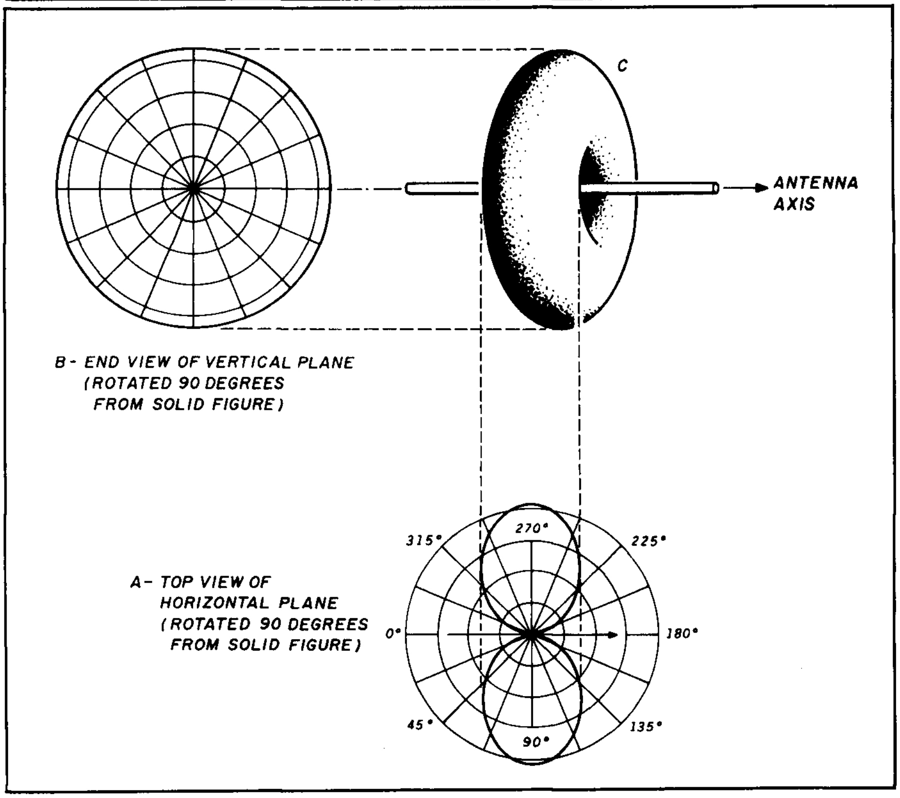
$VSWR = R_r/Z_0$
$VSWR = 60 \text{ ohms}/52 \text{ ohms} = 1.15{:}1$

In neither case is the VSWR created by the mismatch very significant.

The second approach is to mount the antenna at a convenient height and use an impedance-matching scheme to reduce the VSWR. You'll find information on suitable impedance-matching methods (including Q-sections, coaxial impedance transformers, and broadband RF transformers) in any good antenna textbook. Homebrew and commercial transformers can cover most impedance transformation tasks.

The third approach is to mount the antenna at a height (see **Figure 3**) where the expected radiation resistance crosses a standard coaxial cable characteristic impedance. The best height seems to be a half wavelength. The radiation resistance is close to the free space value of 72 ohms, and is a good match for 75-ohm coaxial cable (like RG-11/U or RG-59/U).

FIGURE 4



Radiation pattern of dipole in free space as seen from two planes (A and B), and three dimensionally (C).

The dipole radiation pattern

When discussing antennas I keep returning to the concepts of *directivity* and *gain*, which are actually different expressions of the same fundamental concept. Antenna theory recognizes a point of reference called the *isotropic radiator*. This device is a theoretical construct consisting of a spherical point source of omnidirectional RF radiation. It creates an ever-expanding sphere as the RF wave front propagates outward. Antenna gain is a measure of how the antenna focuses available power away from a spherical wave front in a limited number of directions (two, for a dipole). This is how the concepts of directivity and gain are related.

Always remember that *directivity and gain are specified in three dimensions*. Many times authors (including me) simplify the topic too much by publishing only part of the radiation pattern (i.e., azimuth aspect as seen from above). You, in turn, wind up with a pattern viewed from above that shows the directivity in the horizontal plane. A signal doesn't propagate away from an antenna in an infinitely thin sheet, as such presentations seem to imply, but has an elevation extent in addition to the azimuth extent. Proper antenna evaluation takes both horizontal and vertical plane patterns into consideration.

Figure 4 shows the radiation pattern of a dipole antenna in free space "in the round." When the horizontal plane is viewed from above (**Figure 4A**), the pattern is a "figure eight" that exhibits bidirectional radiation. Two main "lobes" contain the RF power from the transmitter, with sharp nulls of little or no power off the ends of the antenna axis. This is the classic dipole pattern published in most antenna books.

I've also shown the vertical plane pattern for a dipole antenna in free space. Note that the radiation pattern is circular when sliced in this aspect (**Figure 4B**). When the two patterns are combined, you see a three-dimensional doughnut-shaped pattern (**Figure 4C**) that most nearly approximates the true pattern of an unobstructed dipole in free space.

When a dipole antenna is installed close to the ground and not in free space, as is the case at most stations, the pattern is distorted from that of **Figure 4**. You must take two effects into consideration. First and most important is that the signal from the antenna is reflected from the surface and bounces back into space. This signal will be phase shifted by both the reflection and the time required for the transit to occur. At points where the reflected wave combines in phase with the radiated signal, the signal is reinforced; in places where it combines out of phase, the signal is attenuated. Thus the reflection of the signal from the ground alters the pattern from the antenna. The second factor to consider is that the ground is lossy, so not all of the signal is reflected; some of it heats the ground underneath the antenna. Consequently, the signal is attenuated at greater than inverse square law, further altering the expected pattern.

Figure 5 shows patterns typical of dipole antennas installed close to ground. The views in this illustration correspond to **Figure 4B** in that they are looking at the vertical plane from a line along the antenna axis. The antenna is represented by "R" in each case shown. **Figure 5A** shows the pattern for a dipole installed at one-eighth wavelength above ground. For this antenna, most of the RF energy is radiated almost straight up (now very useful). This type of antenna is basically limited to groundwave and very short skip (when available). The second case (**Figure 5B**) shows the pattern when the antenna is a quarter wavelength above the ground. Here the pattern is flattened, but still shows considerable vertically reflected energy (where it is useless). Now look at the pattern obtained when the antenna is installed a half wavelength above the surface. In **Figure 5C**, the pattern is best for long distance work because energy is redirected away from the vertical into lobes at relatively shallow angles.

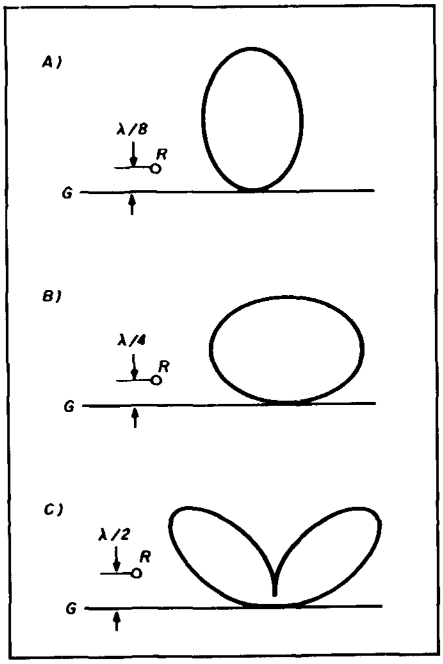
Dipole construction and installation techniques

According to "conventional wisdom," the ideal dipole antenna should be installed at a very high altitude where its performance resembles the free space model. Unfortunately, complying with conventional wisdom is impossible — even for antennas in the higher end of the HF spectrum. Given that the dipole feedpoint impedance is a good match for 75-ohm coaxial cable, and that the pattern is ideal for long distance work when the antenna is installed at a height of a half wavelength above the surface, it's a good idea to try installing the antenna at that height.

Building and installing simple dipoles isn't terribly difficult. **Figure 6** shows the method for building the antenna. First, cut the wire radiator elements to the approximate length indicated by **Equation 2** plus an additional 12 to 24 inches; each element will finally be a quarter wavelength long. The wire can be either hard-drawn copper wire or Copperweld®. The latter is a special tough-service steel core antenna wire coated with copper. The RF resistance of this wire at frequencies above 1 MHz is the same as that of solid copper wire because of the "skin effect" (alternating currents like RF flow on the outer surface of the conductor only). At 160 meters the skin effect depth is only 50 microns (2 mils), while at 10 meters it's only 12 microns (0.5 mils). This means you have the advantage of copper conductivity along with the strength of steel wire.

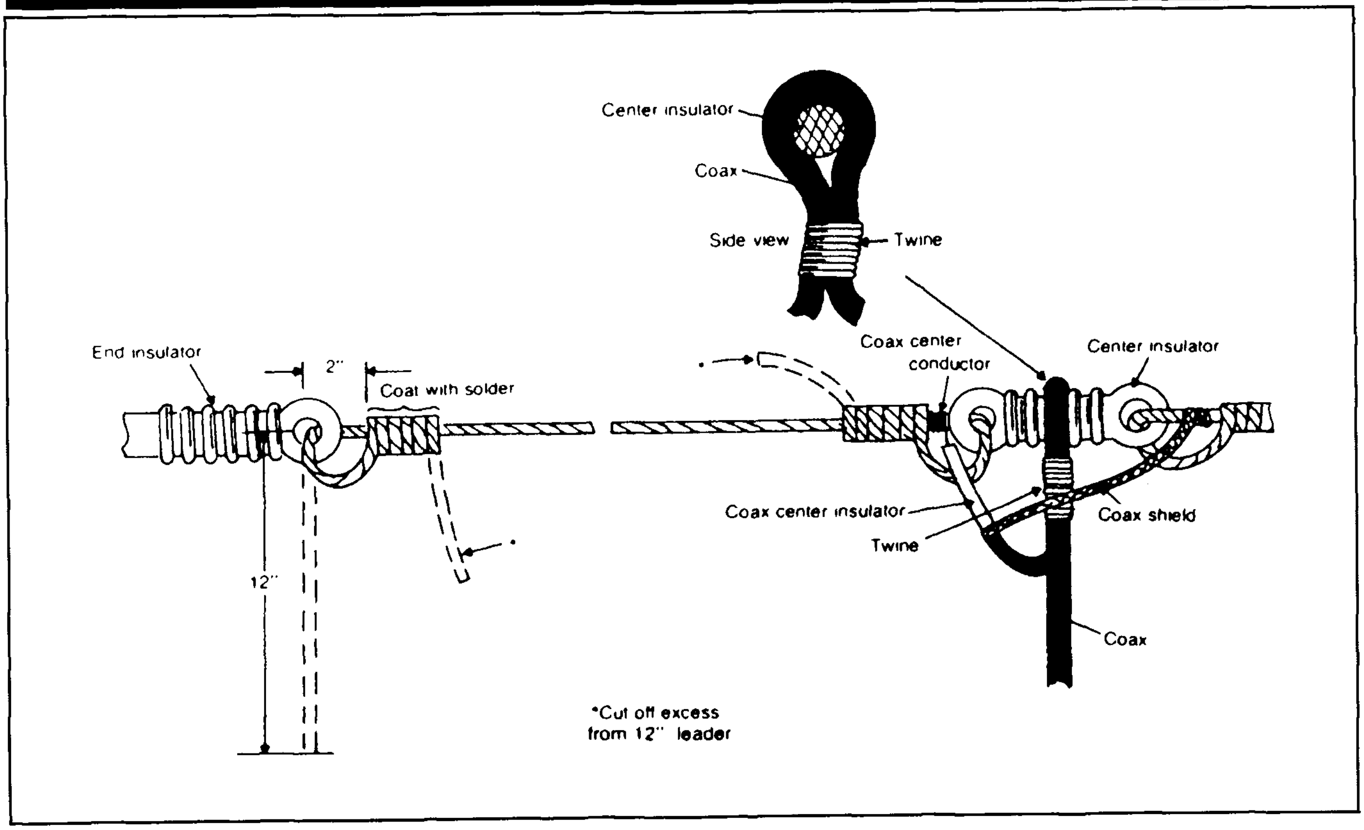
You'll need two end insulators, and both are assembled in the same way. Pass the wire through the hole in the insulator (see **Figure 6**) to a length of about 12 inches. Wrap the wire back on itself and wind it around the portion of the wire that's left on the other side of the insulator. Make this a permanent

FIGURE 5



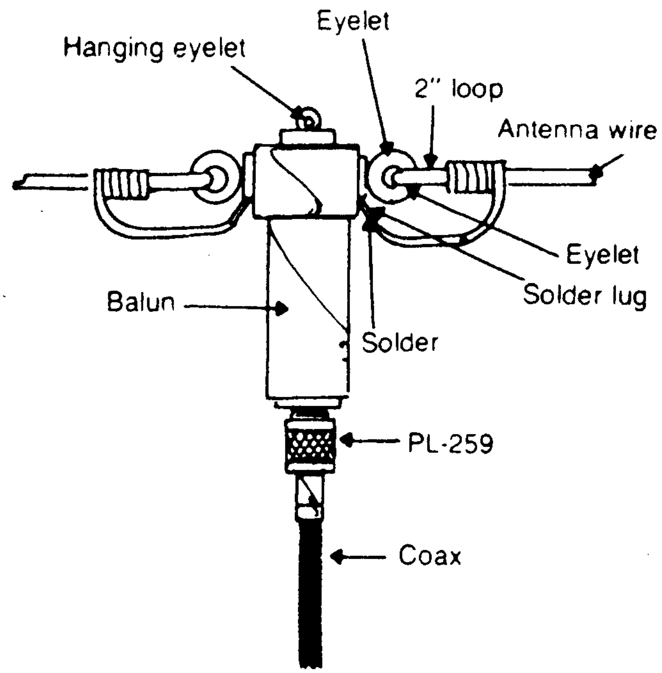
Vertical aspect radiation pattern of dipole close to earth's surface: (A) 1/8-wavelength, (B) 1/4-wavelength, and (C) 12/2-wavelength.

FIGURE 6



Construction details of dipole antenna (from ***TAB Handbook of Radio Communications*** **by J.J. Carr).**

FIGURE 7



Use of a 1:1 balun transformer at the feedpoint (from *TAB Handbook of Radio Communications* by *J.J. Carr*).

connection by soldering it and clipping off the excess wire. The solder *won't* provide mechanical strength. Its purpose is to make a good electrical connection in the presence of corrosion.

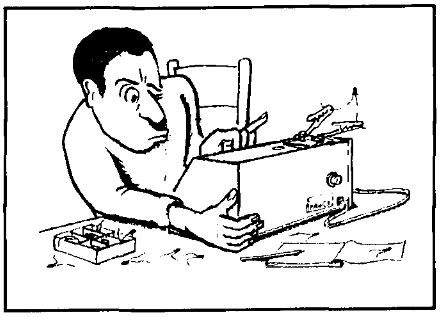
Fix the antenna wires to the center insulator in the same way, unless you plan to use one of the special center insulators now on the market. Make these connections temporary until after you've tuned and tested the antenna. You may have to either lengthen or shorten the radiators when tuning your dipole.

Connect the transmission line (usually coaxial cable) to the antenna wire at the center insulator as shown. Attach the center conductor to one radiator element and the shield of the coax to the other. You need to provide strain relief for the coaxial cable; if you don't the cable will break after only a short period of service. The easiest strain relief method is shown in **Figure 6**. Simply wrap the cable once around the insulator and tie it off with twine. Some commercial center insulators offer a strain relief hole or other mechanism. Many people prefer to use a 1:1 balun transformer at the dipole's feedpoint (see **Figure 7**). The transformer has a 1:1 impedance ratio, so it doesn't provide any matching. Instead, it's said to balance the currents flowing in the two radiators, and prevent radiation from reaching the feedline. While this claim has been controversial for some time, and the issue is still not resolved, the best evidence suggests that the pattern of a dipole close to ground is most nearly like the ideal pattern if a 1:1 balun transformer is used at the feedpoint. In **Figure 7** the balun transformer also acts as the center insulator, so no other arrangement is needed.

Next month...

This month I looked at the basic resonant dipole. In part 2, I'll discuss tuning methods for the standard dipole, and some additional variations on the dipole theme. hr

Practically Speaking



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PART 1

HIGH-FREQUENCY DIPOLE ANTENNAS

Last month I discussed the basic ingredients of the dipole antenna. This antenna has acquired an undeservedly poor reputation in an era of multiband beams and other costly antennas. When installed correctly (which is easy to do), the dipole turns in a credible performance. In fact, some poorly constructed (or designed) commercial three-element beam antennas perform only as well as a dipole at the same height. The dipole antenna performs well for the money, time, and brainpower invested. This month I'll take a second look at this antenna and discuss how you might go about tuning one. I'll also describe dipole variants like the broadbanded and loaded dipoles.

Tuning the dipole antenna

There are two issues to address when tuning an antenna (any antenna, not just the dipole): *resonance* and *impedance matching*. Although they are frequently treated in the literature as the same issue, they are not. In this article I'll deal primarily with the process of tuning the antenna to resonance. Not all antennas are resonant, but the dipole is.

There's a lot of misinformation on antenna tuning. Perhaps much of what is believed is a result of using VSWR as the indicator of both resonance and impedance matching. Many people honestly (but erroneously) believe that the VSWR can be "tuned out" by adjusting the feedline length. That myth probably derives from the fact that voltage or current-sensing instruments are used for VSWR measurement, and these are affected by transmission line length. But the problem lies in the instruments; it's not a fact of radio physics. Another factor which leads to confusion is that varying the line length may provide an impedance transformation that matches the antenna to the transmitter, but doesn't address the point that the antenna is off resonance and therefore less efficient.

There's only one proper way to tune a dipole antenna — *adjust the length of the antenna elements*. You don't adjust the transmission line. As I mentioned when discussing construction methods last month, you leave the electrical connections at the center insulator unsoldered so you can make these adjustments.

The minimum point in the VSWR curve is the resonance indicator. **Figure 1** shows a graph of VSWR versus frequency for several different cases. Curve A represents a disaster — a high VSWR across the band. The actual VSWR value may be anything from about 3.5:1 to 10:1 (or thereabouts), but the cause is the same. The antenna is either open or shorted, or is so far off resonance that it appears open or shorted to the VSWR meter.

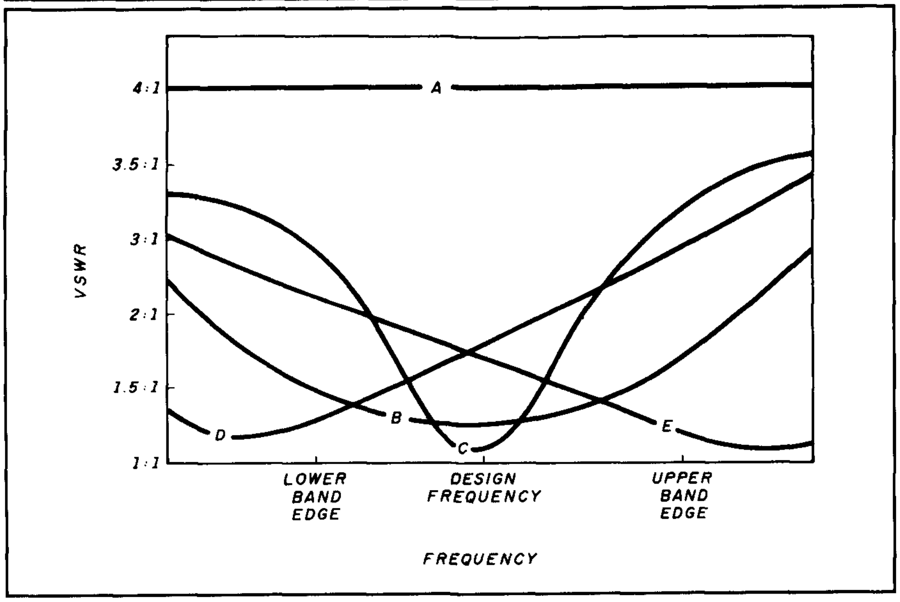
Curves B and C represent antennas that are resonant within the band of interest. Curve B represents a broadbanded antenna that's relatively flat across the band, and doesn't exhibit excessive VSWR until the frequency is outside the band. Curve C is also resonant within the band, but this antenna has a lot higher Q than curve B. In the simplest sense the broadbanded antenna is best, but that statement is true only if broadness is not purchased at the expense of efficiency. Resistive losses tend to broaden the antenna frequency response but also reduce its effectiveness. The antenna is effectively "broadbanded," as seen by the transmitter, by the addition of the equivalent of a power-absorbing resistor at the feedpoint. Again, it's undesirable if this broadbandedness is purchased at the cost of increased loss.

Curves D and E in **Figure 1** are resonant outside the band of interest. The D curve is resonant at a frequency on the low side of the band, making that dipole too long. In this case you need to shorten the antenna to raise the resonant point inside the band. Curve E represents an antenna that's resonant outside the upper limit of the band; this antenna is too short and must be lengthened. Because the antenna is frequently too short, cut the elements longer than necessary at first.

How much you cut depends on two factors: how far the resonant point is from the desired frequency, and which band you're working on. The second requirement results from the fact that the "frequency per unit" length varies from one band to another. Let's look at an example of how to calculate this figure. The procedure is simple:

- Calculate the length required for the upper end of of the band.
- Calculate the length required for the lower end of the band.
- Calculate the difference in lengths for upper and lower ends of the band.
- Calculate the width of the band in kilohertz by subtracting the difference between the upper frequency limit and the lower frequency limit.

FIGURE 1



VSWR versus frequency for several cases.

- Divide the length difference by the frequency difference; the result is in kilohertz per unit length.

Example

Calculate the frequency change per unit of length for 80 and 15 meters.

Solution:

For 80 meters (3.5 to 4.0 MHz):

$L_{ft} = 468/4\ MHz = 117\ feet$

$L_{ft} = 468/3.5\ MHz = 133.7\ feet$

Difference in length: $133.7\ feet - 117\ feet = 16.7\ feet$.

Frequency difference: $4000\ kHz - 3500\ kHz = 500\ kHz$.

Calculate frequency/unit length: $500\ kHz/16.7\ feet = 30\ kHz/foot$.

For 15 meters (21.0 to 21.45 MHz):

$L_{ft} = 468/21.45 = 21.82\ feet$

$L_{ft} = 468/21 = 22.29\ feet$

Difference in length: $22.29 feet - 21.82\ feet = 0.47\ feet$.

Convert to inches: $0.47\ feet \times 12\ inches/foot = 5.64\ inches$.

Frequency difference: $21{,}450\ kHz - 21{,}000\ kHz = 450\ kHz$.

Calculate frequency/unit length: $450\ kHz/5.64\ inches = 80\ kHz/inch$.

The frequency change per foot at 80 meters is small, but even small changes can result in very large frequency shifts at 15 meters. You can calculate approximately how much to add or subtract from an antenna under construction using this kind of calculation. If, for example, you design an antenna for the so-called "international net frequency" on 15 meters (21,390 kHz), but find the actual resonant point is 21,150 kHz, then the frequency shift required is 21,390 − 21,150, or 240 kHz. To determine how much to add or subtract (as a first guess):

The factor for 15 meters is 80 kHz/inch, which is the same as saying 1 inch/80 kHz.

The required frequency shift is 240 kHz.

Therefore:

$$Length\ change = 240\ kHz\ \frac{1\ inch}{80\ kHz}$$

$$Length\ change = 3\ inches$$

Each side of the antenna must be adjusted by half the length calculated above, or 1.5 inches. Because the first resonant frequency is less than the desired one, you should shorten the length by 1.5 inches. Once the length is correct (as proven by the VSWR curve), solder the connections at the center insulator to make them permanent, and hoist the antenna back to operating level.

You can see the difference between resonance and impedance matching in the value of the VSWR minimum. While the minimum indicates the resonant point, the value of that minimum is a measure of the relationship between the feedpoint impedance of the antenna and the characteristic impedance of the transmission line. Last month you learned that:

$Z_o > R_r$:

$$VSWR = Z_o/R_r \qquad (1)$$

$Z_o < R_r$:

$$VSWR = R_r/Z_o \qquad (2)$$

Where:

Z_0 is the coaxial cable characteristic impedance.

R_r is the radiation resistance of the antenna.

Although knowing the VSWR won't tell you which situation is true, you'll know that there's a high probability that one of them is. Experiment to find which is the case. Of course, if the VSWR is less than about 1.5:1 or 2:1 then forget about it; the improvement isn't generally worth the expense and cost. When the transmission line is coupled to a transmitter that's equipped with a tunable output network (most tube-type transmitters or final amplifiers), it can accommodate a relatively wide range of reflected antenna impedances. But modern solid-state final amplifiers tend to be a little more picky about the load impedance. For these transmitters a coax-to-coax antenna-tuning unit (ATU) is needed.

Other dipoles

So far I've discussed classic dipoles with half-wavelength single conductor radiator elements connected to a coaxial transmission line. This type of antenna is most often installed horizontally a half wavelength above the ground (or wherever convenient if that's impossible). Next I'll take a look at other forms of dipoles. Some of these are equal in every way to the horizontal dipole; others are basically compensation antennas used when a proper dipole isn't practical.

Inverted-V dipole

The inverted-V dipole is a half-wavelength antenna fed in the center like a dipole. By definition, the inverted-V is merely a variation on the dipole theme. In this antenna (**Figure 2**) the center is elevated as high as possible above ground, but the ends droop very close to the surface. Angle "a" can be almost any convenient angle greater than 90 degrees. Most inverted-V antennas use an angle of about 120 degrees. This antenna provides a compromise when a dipole can't be used. Many operators believe it's a better performer on 40 and 80 meters in cases where the dipole can't be mounted at a half wavelength (64 feet or so).

Sloping the antenna elements down from the horizontal to an angle (**Figure 2**) effectively lowers the resonant frequency. This means the antenna will need to be shorter than a dipole for any given frequency. There's no absolutely rigid equation for calculating the overall length of the antenna elements. Although the concept of "absolute" length doesn't hold for regular dipoles close to the ground, it's even less viable for the inverted-V. There is, however, a rule of thumb you can use for a starting point — make the antenna about 5 percent shorter than a dipole for the same frequency. Try cutting the antenna to the length required for a regular dipole on the same frequency and trim from there, using the tuning procedure.

$$L = \frac{468}{F_{MHz}} \text{ feet} \qquad \textbf{(3)}$$

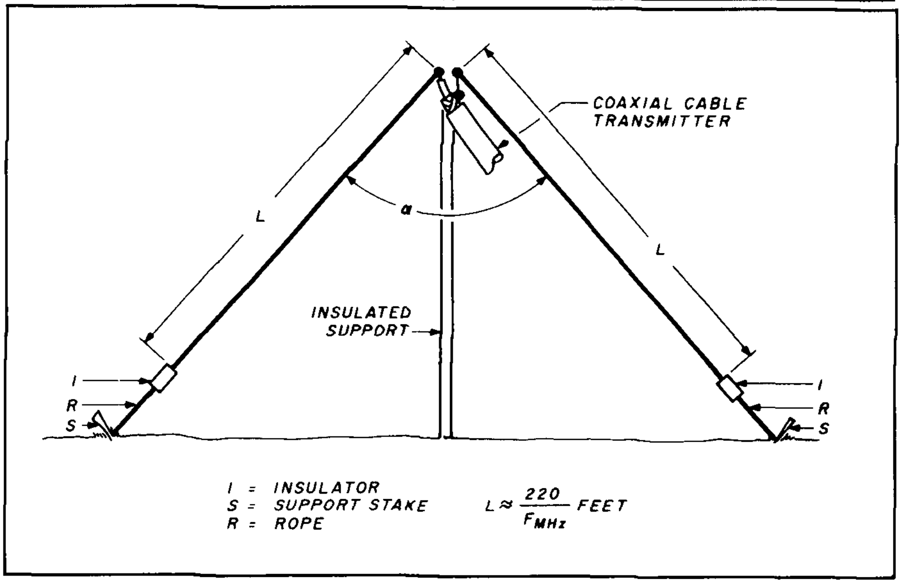
After determining the approximate length, find the actual length with the same cut-and-try method used to tune the dipole in the previous section.

Sloping the elements changes the feedpoint impedance of the antenna and narrows its bandwidth. You'll need to make some adjustments as a result. You might want to use an impedance-matching scheme at the feedpoint, or an antenna tuner at the transmitter.

Sloping dipole ("sloper" or "slipole")

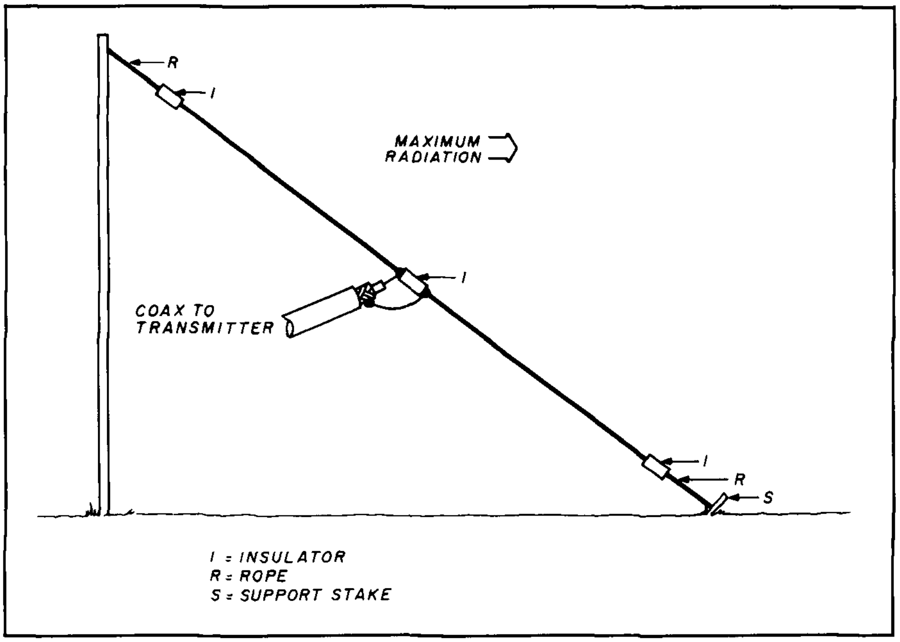
The sloping dipole in **Figure 3** is popular with operators who need a low angle of radiation but don't have a large area for their antenna installation. Various texts call this antenna the sloper or the slipole. I use the term slipole to distinguish this antenna from a sloping vertical. But whatever you call it, it's a half-wavelength dipole with one end at the top of a support and the other end close to ground, fed in the center by coaxial cable.

FIGURE 2



Inverted-V dipole antenna.

FIGURE 3



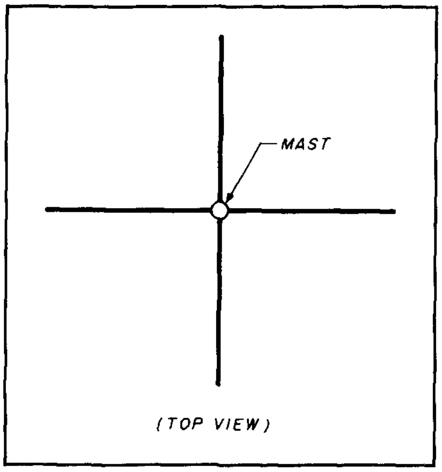
Sloper dipole (also called "slipole").

Some operators like to hang four sloping dipoles from the same mast pointing in different directions (**Figure 4**). A single four-position coaxial cable switch lets you switch a directional beam on different headings that favor various locations.

Broadbanded dipoles

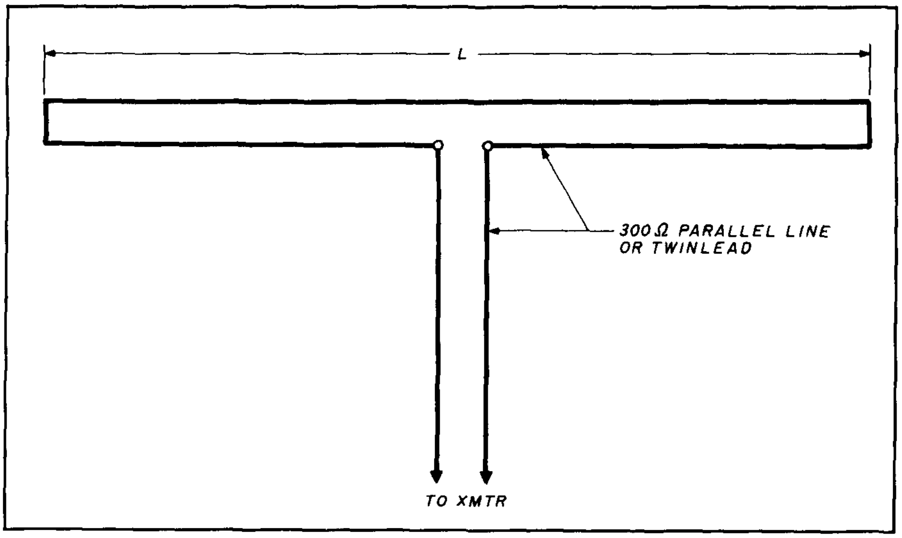
It is rarely discussed that the length/diameter ratio of the conductor used for the antenna element is a factor in determining antenna bandwidth. In general, a large cross-sectional area makes the antenna more broadbanded. In some cases, using aluminum tubing instead of copper wire for the antenna radiator is advisable. Tubing is a viable solution on the higher frequency bands. Aluminum tubing is inexpensive, lightweight, and easily worked with common tools. You can make a rotatable directional dipole with ordinary aluminum tubing. But as

FIGURE 4



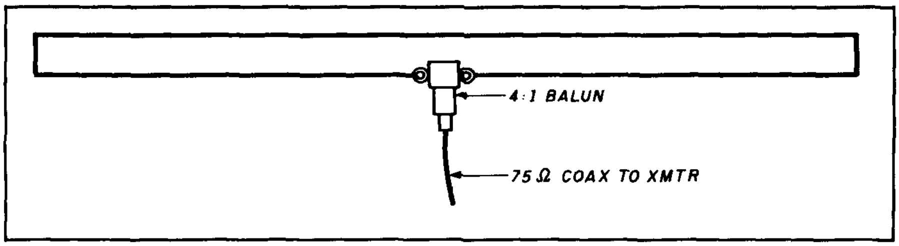
Several slopers supported from a common mast give directional characteristics.

FIGURE 5A



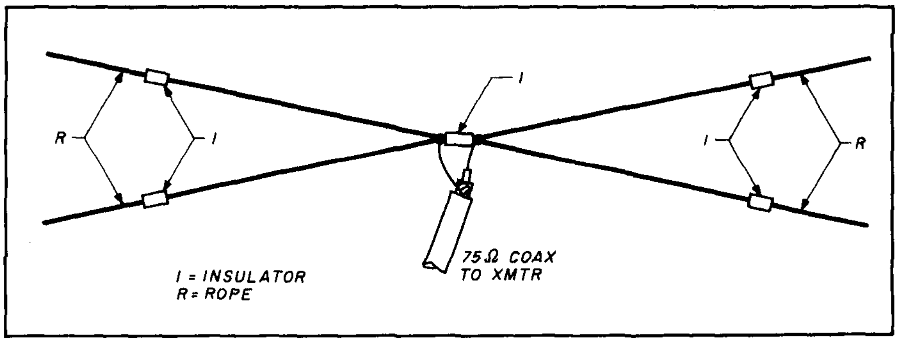
Folded dipole fed with twin lead.

FIGURE 5B



Folded dipole fed with coax and a 4:1 BALUN.

FIGURE 6



Broadbanded "bowtie" dipole.

the frequency decreases, the weight becomes greater. This is because the tubing is longer and must be of greater diameter for structural strength.

Aluminum tubing is impractical on 80 meters and nearly impractical on 40. Yet it's at 80 meters that you find a significant problem (especially with certain older transmitters). The band is 500 kHz wide, and older transmitters often lack the tuning range for the entire band. Three basic solutions to the problem of wide bandwidth dipole antennas are: the *folded dipole*, the *bowtie dipole*, and the *cage dipole*.

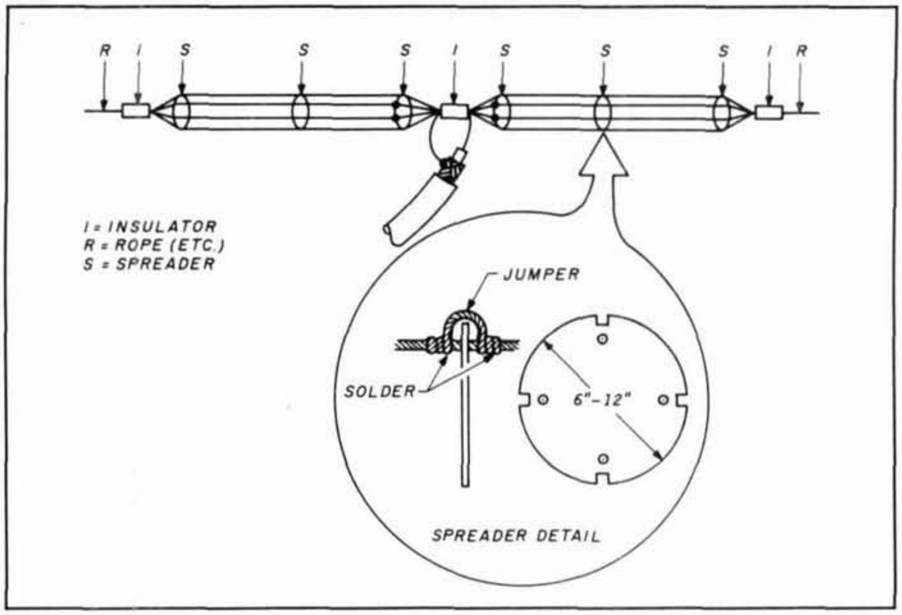
Figure 5A shows the folded dipole antenna. It's basically two half-wavelength conductors shorted together at the ends and fed in the middle of one of them. The folded dipole is usually constructed from 300-ohm television antenna twin-lead transmission line. Because the feedpoint impedance is nearly 300 ohms, you can use the same type of twin lead for the transmission line. The folded dipole exhibits excellent wide bandwidth properties, especially on the lower bands.

For a folded dipole the transmitter has to match the 300-ohm balanced transmission line, which is a disadvantage. Unfortunately, most modern radio transmitters are designed to feed coaxial cable transmission line. Although you can place an antenna tuner at the transmitter end of the feedline, it's also possible to use a 4:1 balun transformer at the feedpoint (**Figure 5B**). This arrangement makes the folded dipole a reasonable match to 52 or 75-ohm coaxial cable transmission line.

Another method for broadbanding the dipole is to use two identical dipoles fed from the same transmission line arranged to form a "bowtie," as shown in **Figure 6**. Using two identical dipole elements on each side of the transmission line increases the conductor cross-sectional area, so the antenna has a slightly improved length/diameter ratio.

The bowtie dipole was popular in the 1930s and '40s; it was the basis for the earliest television receiver antennas. (TV signals are 3 to 5 MHz wide and require a broadbanded antenna.) This antenna was also popular during the 1950s as the so-called "Wonder Bar" antenna for 10 meters. Some are still in use, but the antenna's

FIGURE 7



Cage dipole.

popularity has faded. The ends are spread to approximately 11 percent of the total length.

The cage dipole (**Figure 7**) is similar to the bowtie in concept, if not construction. Again, the idea is to connect several parallel dipoles extending from the same transmission line in an effort to increase the apparent cross-sectional area. But with the cage dipole, spreader disk insulators keep the wires separated. The insulators can be built from Plexiglas™, lucite, or ceramic. They may also be made of materials like wood that's properly treated with varnish, polyurethene, or any other material that prevents water-logging. The spreader disks are held in place with wire jumpers (see inset to **Figure 7**) soldered to the main element wires.

Some bowtie and cage dipole builders make the elements slightly different lengths. This "stagger tuning" method forces one dipole to favor the upper end of the band and the other to favor the lower end. The overall result is a slightly flatter frequency response characteristic across the entire band. On the cage dipole, with four half-wavelength elements, it should be possible to overlap even narrower sections of the band in order to create an even flatter characteristic.

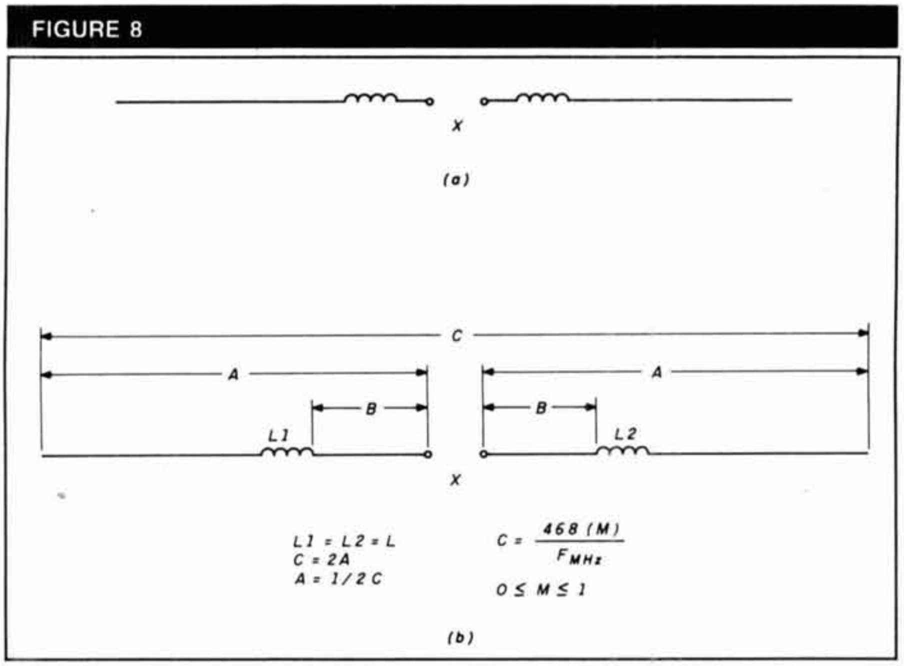
Shortened dipoles

The half-wavelength dipole is too long for some applications — espe-

TABLE 1

Approximate inductance reactances as a function of the percentage of half wavelength represented by the shortened radiator.

Percent of half wavelength	Coils at feedpoint (ohms)	Coils at middle of radiators (ohms)
20	1800	2800
30	950	1800
40	700	1300
50	500	950
60	360	700
70	260	500
80	160	320
90	75	160
95	38	80
98	15	30



Coil-loaded dipole: a) coils at feedpoint; b) coils at 50-percent point.

cially where real estate is at a premium. Many operators solve this problem by using a coil-loaded shortened dipole like the one shown in **Figure 8**. A shortened dipole (one which is less than half a wavelength) is capacitive, so it must have an in-line inductance to compensate for the inherent capacitive reactance. There's no reason why the loading coil can't be put at any point along the radiator, but in **Figures 8A** and **8B** they are placed at 0 and 50 percent of the element length, respectively. This makes coil inductance calculations easier, and also represents the most common practice.

Table 1 shows approximate inductive reactances as a function of the percentage of half wavelength represented by the shortened radiator. It's likely that the percentage figure will be imposed on you by the situation, but the general rule is to pick the largest figure consistent with the available space. For example, suppose you have about 40 feet available for a 40-meter antenna that normally needs about 65 feet for a half wavelength. Because 39 feet is 60 percent of 65 feet, you can use this value as the design point for your antenna. In **Table 1** you'll see that a 60-percent antenna with the loading coils at the midpoint of each radiator element wants to see an inductive reactance of 700 ohms. Rearrange the standard inductive reactance equation (X_L = 6.28 FL) to the form:

$$L_{\mu H} = \frac{X_L \times 10^6}{6.28\ F}$$

Where:

$L_{\mu H}$ is the required inductance in microhenries.
F is the frequency in hertz (Hz).
X_L is the inductive reactance calculated from **Table 1**.

Example

Calculate the inductance required for a 60-percent antenna operating on 7.25 MHz. The table requires a reactance of 700 ohms for a loaded dipole with the coils in the center of each element (**Figure 8B**).

Solution:

$L\mu H = X_L \times 10^6/6.28\ F$

$L\mu H = (700)(10^6)/(6.28)(7,250,000)$

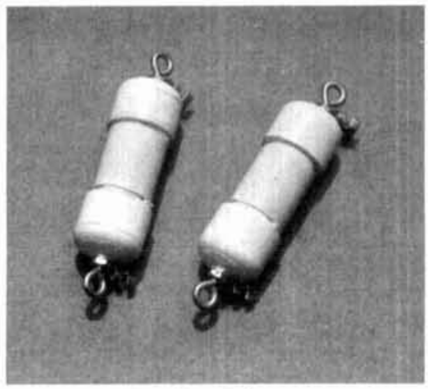
$L\mu H = 7\times10^8/4.6\times10^7 = 15.4\ \mu H$

The calculated inductance is approximate and may have to be altered by cut-and-try methods.

The loaded dipole antenna is very sharply tuned. Because of this, you must either confine operation to one segment of the band or provide an antenna tuner to compensate for the sharpness of the bandwidth characteristic. However, efficiency drops markedly far from resonance, even with a transmission line tuner. The tuner overcomes the bad effects on the transmitter, but doesn't alter the basic problem. Only a variable inductor in the antenna will do that. (At least one commercial loaded dipole once used a motor-driven inductor at the center feedpoint.)

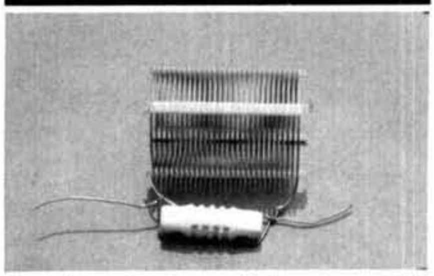
Photos A and **B** show two methods for making a coil-loaded dipole antenna. **Photo A** shows a pair of commercially available loading coils designed for this purpose. These coils are for 40 meters, but other models are also available. The inductor in **Photo B** is a section of B&W Miniductor connected to a standard end or center insulator. No structural stress is assumed by the coil; all forces are applied to the insulator.

PHOTO A



Commercial loading coils.

PHOTO B



Homebrew loading coil based on B&W Miniductor.

Conclusion

The dipole antenna is easy to design, easy to build, and well behaved enough that even novice builders can make it work successfully, and well. *Go for it!*