Practically Speaking

Joseph J. Carr, K4IPV

VERTICALLY POLARIZED HF ANTENNAS: PART 1

Antennas are a favorite topic for technical writers because our mailbags show that they're a very popular subject with readers. This month, and for the next two months, I'll discuss vertical antennas. Although the regard with which Amateurs view verticals varies from "tremendous" down to "little better radiator than a dummy load," the vertical remains popular. My own luck with verticals has been mostly good. The vertical is the antenna of choice for people living in cramped quarters that don't allow a beam antenna.

Will the vertical antenna work as well as a Yagi beam or quad up 100 feet? The answer is a qualified "maybe." The problem is context. For the DXer the beam is the hands-down favorite if money is no object. But in a situation where an omnidirectional horizontal pattern is needed, the beam suffers. So the correct answer to such a question is, "for what application?"

Because there are so many heated opinions regarding verticals, I take on this topic with some trepidation. Let's hope that a little more light than heat is generated. Keep in mind that it's possible your buddy's bad luck with a vertical might be due to not knowing how to design, build, and use one — or expecting something totally inappropriate from the antenna.

The polarity of an antenna is the direction of the electrical (E) field. Because the transmitted signal is an orthogonal electromagnetic wave, the magnetic field radiated from the antenna is at right angles to the electrical field. The direction of the electrical field, which sets the polarity of the antenna, is a function of the geometry of the radiator element. If the element is vertical, then the antenna polarity is also vertical. The signal propagates out from the radiator in all directions of azimuth, making this antenna an "omnidirectional" radiator.

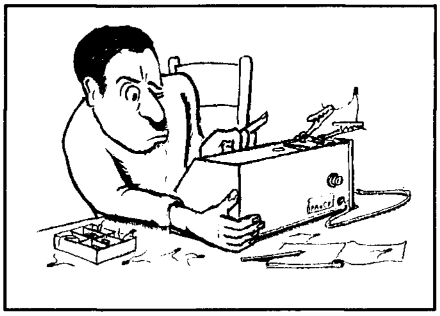
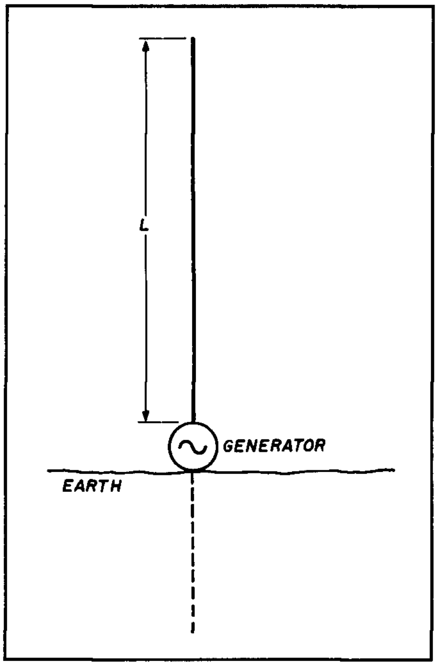


FIGURE 1A



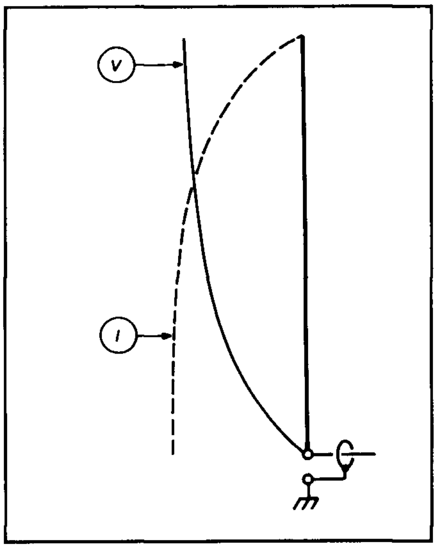
Basic concept of a vertical antenna.

Figure 1A shows the basic geometry of the vertical antenna: an RF generator (transmitter or transmission line from a transmitter) at the base of a radiator of length L. Although most commonly encountered verticals are quarter wavelength ($L = \lambda/4$), that length isn't the only permissible one. In fact, it may not even be the most desirable length. I'll talk about the standard quarter-wavelength vertical antenna here because it's so popular, and will also deal with other length verticals (both greater and less than quarter wavelength).

The quarter-wavelength vertical antenna can be modeled as half a dipole installed perpendicular to the ground, with the ground as the "other half" of the dipole. Because of this, some texts show the vertical with a dotted line "ghost radiator" in the earth beneath the main antenna element. **Figure 1B** shows the approximate current and voltage distribution for the quarter-wavelength vertical. Like the dipole, the quarter-wavelength vertical is fed at a current node, so the feedpoint impedance is at a minimum (typically 35 to 55 ohms, depending upon nearby objects). As a result, the current is maximum and the voltage is minimum at the feedpoint. As you'll see, however, not all vertical antennas are fed directly at the current node. As a result, some designs require antenna tuning units to make them match the antenna impedance to the transmitter output impedance.

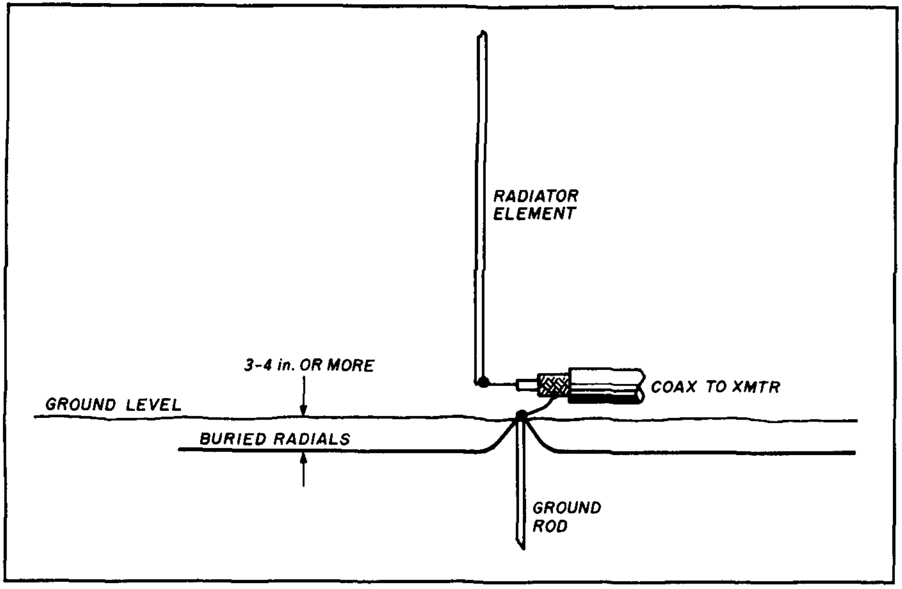
Figures 2A and **2B** show the two basic configurations for the HF vertical antenna. **Figure 2A** shows the ground-mounted vertical antenna. The radia-

FIGURE 1B



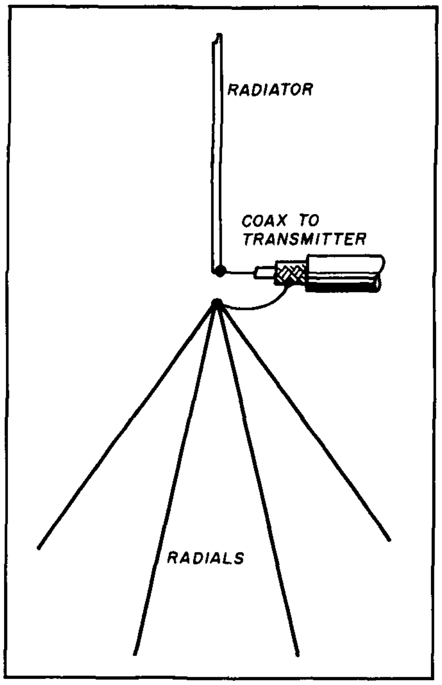
Approximate current and voltage distributions on a quarter-wave vertical.

FIGURE 2A



Basic ground-mounted HF vertical.

FIGURE 2B



A vertical with elevated radials.

tor element is mounted at ground level, but is insulated from ground. Because the antenna shown is a quarter wavelength, it's fed at a current node with 52-ohm coaxial cable. The inner conductor of the coaxial cable is connected to the radiator element, while the coaxial cable shield is connected to the ground. As you will see later, the ground system for the vertical antenna is critical to its performance. Normally, the feedpoint impedance isn't exactly 52 ohms, but somewhat lower. As a result, without some matching there will be a slight VSWR. But in most cases the VSWR is a tolerable tradeoff for simplicity. If the antenna has a feedpoint impedance of 37 ohms, the value usually quoted, then the VSWR will be 52 ohms/37 ohms, or 1.41:1.

A vertical mounted above the ground level is shown in **Figure 2B**. This antenna is as popular as the ground mounted. Amateurs find it easy to construct this form of antenna because the lightweight vertical can be mounted at reasonable heights (15 to 50 feet) using fairly inexpensive television antenna slip-up telescoping masts. A problem with the nonground level vertical antenna is that there's no easy way to connect it to ground. The solution to the problem is to create an artificial counterpoise ground with a system of quarter-wavelength radials.

In general, at least two radials are required for each band — and even that number is marginal. The standard wisdom holds that the greater the number of radials, the better the performance. While that statement is true,

FIGURE 2C

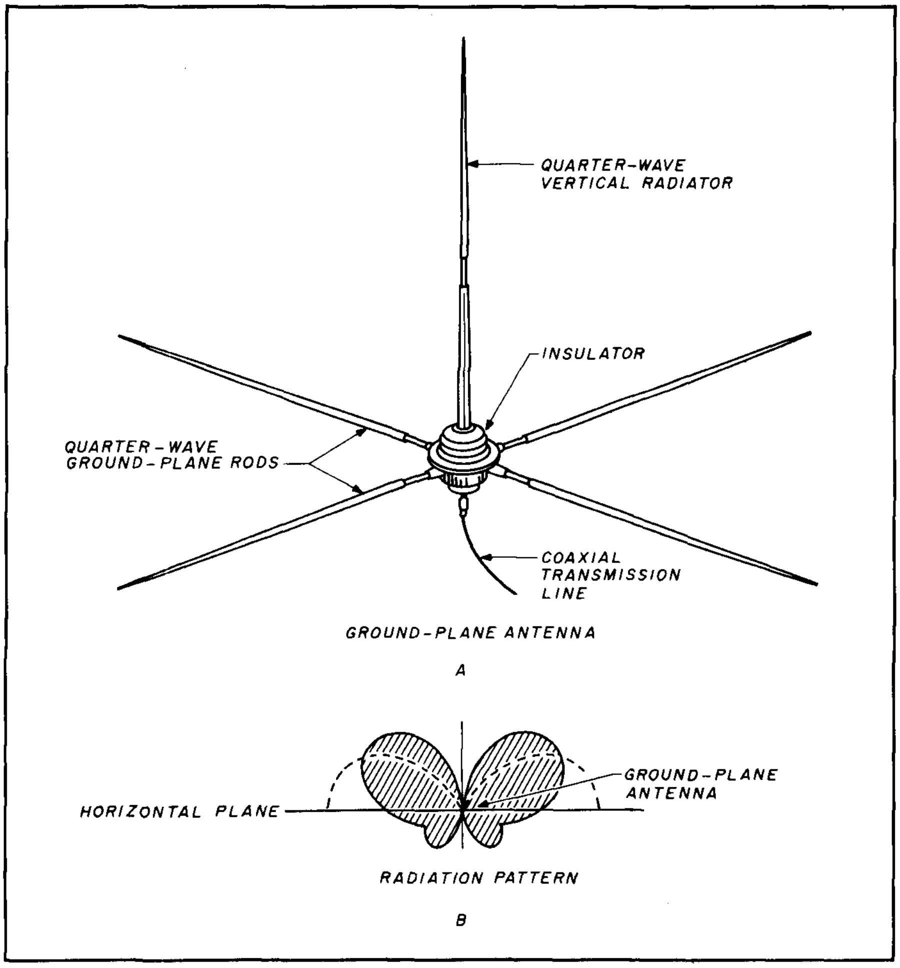


Diagram of a commercial ground plane with four radials mounted 90° apart.

there are both theoretical and practical limits to the number of radials. The theoretical limit is derived from the fact that more than 120 radials return practically no increase in operational effectiveness, and at more than 16 radials the returned added effectiveness per new radial is less than the case for fewer radials. That is, going from 16 to 32 radials (doubling the number) creates less of an increase in received field strength at a distant point than going from 8 to 16 radials (both represent doubling the density of the radial system).

The radials of the above-ground vertical antenna can be at any angle. In **Figure 2B** they are "drooping radials;" i.e., the angle is greater than 90 degrees relative to the vertical radiator element. Similarly, **Figure 2C** shows a vertical antenna equipped with radials at exactly 90 degrees. (No common antenna has radials of less than 90 degrees.) Both of these antennas are called ground-plane vertical antennas.

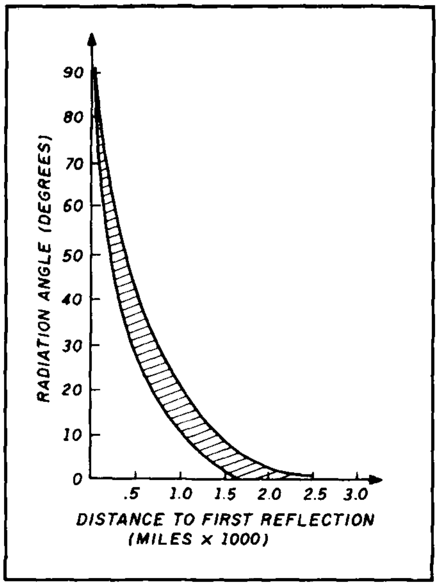
The angle of the radials is said to affect the feedpoint impedance and the angle of radiation of the vertical antenna. While those statements are undoubtedly true in some sense, there are other factors that also affect those parameters and are probably more important in most practical installations. Before digging further into the subject of vertical antennas, let's take a look at the subjects of angle of radiation and gain in vertical antennas.

Angle of radiation

Long distance propagation in the HF region depends upon the ionospheric phenomena called "skip." In this type of propagation, the signal leaves the transmitting antenna at angle a, called the angle of radiation, and enters the ionosphere where it is refracted back to earth at a distance from the transmitting station. The signal in the zone between the outer edge of the antenna's ground wave region and the distant skip point is weak or nonexistent.

The distance covered by the signal on each skip is a function of the angle of radiation. **Figure 3** shows a plot of the angle of radiation of the antenna, and the distance to the first skip zone. The angle referred to along the vertical axis is the angle of radiation away from the antenna relative to the horizon. For example, an angle of 10 degrees is elevated above the horizon 10 degrees. Shorter distances are found when the angle of radiation is increased. At an angle of about 30 degrees, for example, the distance per skip is only a few hundred miles.

FIGURE 3



Graph of skip zone versus angle of radiation.

Although you might expect to see a single line on the graph, there's actually a zone shown (shaded). This phenomenon exists because the ionosphere is found at different altitudes at different times of the day and different seasons of the year. Generally, however, in the absence of special event phenomena in the ionosphere, expect from 1500 to 2500 miles per bounce in the HF bands for low angles of radiation. Note, for example, that for a signal that's only a degree or two above the horizon, the skip distance is maximum.

At distances greater than those shown in **Figure 3**, the signal will make multiple hops. Given a situation where the skip distance is 2500 miles, covering a distance of 7500 miles requires three hops. Unfortunately, there's a signal strength loss of 3 to 6 dB on each hop, so you can expect the distant signal to be attenuated from making multiple hops between the earth's surface and the ionosphere. For maximizing distance, the angle of radiation needs to be minimized.

So what's the ideal angle of radiation? It's standard — but actually erroneous — wisdom among Amateur Radio operators (and even commercial operators, it turns out) that the lower the angle of radiation the better the antenna. This statement is only true if you're looking for long distance, so it reflects a strong bias toward the DX community. The correct answer to the question is: "It depends on where you want the signal to go." For example, I live in Virginia. If I want to work stations in the Carolinas or New England, it would behoove me to select a high angle of radiation for radio conditions represented in **Figure 3**, so that the signal will land in those regions. But if I want to work stations in Europe, Africa or South America, then a lower angle of radiation is required. Because of the difference between performance of high and low angles of radiation, some stations have two antennas for each band — one each for high and low angles of radiation.

Figure 4 shows a signal from a hypothetical antenna located at point O to show what angle is meant by angle of radiation. The beam from the antenna is elevated above the horizon (represented by the horizontal "tangent to horizon" line). The angle of radiation, a, is the angle between the tangent line and the center of the beam. This angle is not to be confused with the beamwidth, which is also an angle. In the case of beamwidth, I'm talking about the thickness of the main lobe of the signal between points where the field strength is 3 dB down from the maximum signal (which occurs at point P); these points are represented by points x and y in **Figure 4**. Thus, angle b is the beamwidth, while angle a is the angle of radiation.

FIGURE 4

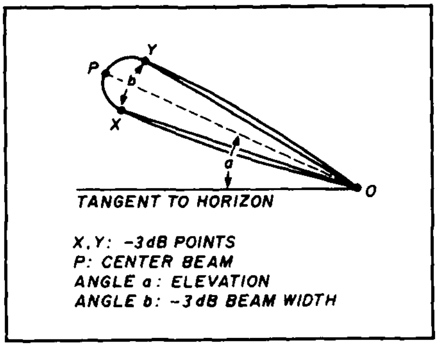


Diagram illustrating angle of radiation.

Gain in vertical antennas

Vertical antennas are known as omnidirectional because they radiate equally well in all directions. Gain in an

FIGURE 5

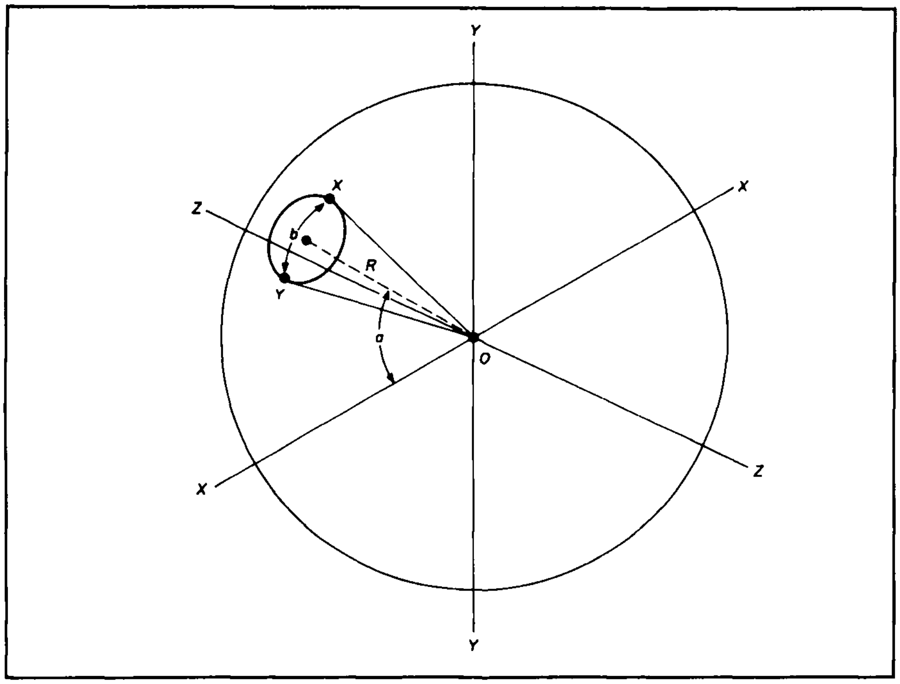
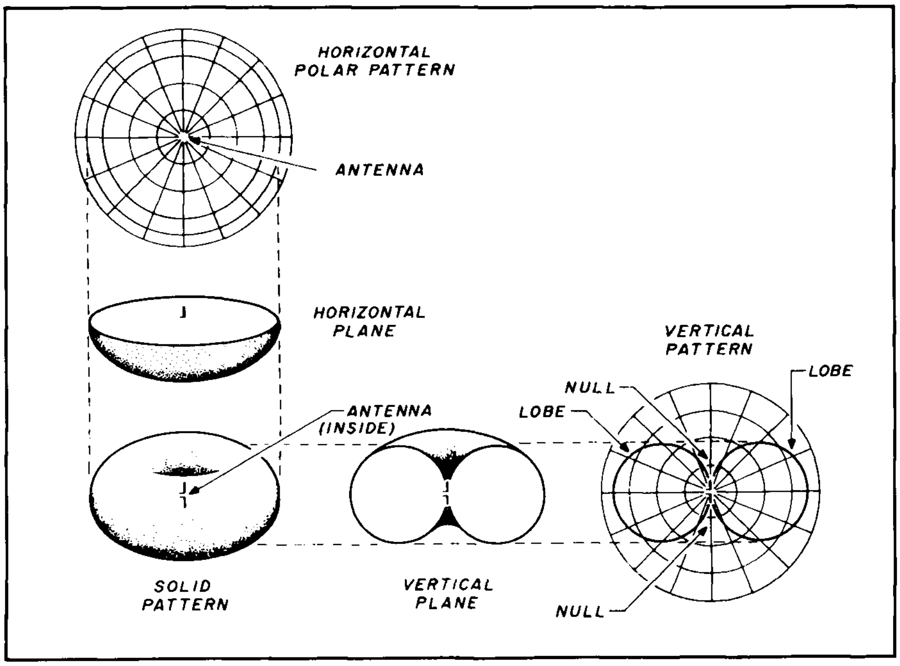


Diagram of a theoretical isotropic radiator.

FIGURE 6



E and H plane patterns of a typical vertical.

antenna is not the creation of power, but rather a simple refocusing of energy from all directions to a specific one. Therefore, gain implies directivity. According to the convention, then, the vertical antenna can't have any gain because it radiates in all directions equally, and gain implies directivity. Right? No, not really. Let's develop the theme more carefully.

Again consider the idea of an isotropic radiator (the word "isotropic" means equal power in all directions). Consider a spherical point source radiator located at point O in **Figure 5**. Whatever the level of power available from the transmitter, it will be spread equally well over the entire surface of the sphere as it radiates out into space away from point O. If you measure the power distributed over some area, A, at a distance, R, from the source, then the power available will be a fraction of the total power:

$$P_{avail} = \frac{\textit{Total Available Power} \times \textit{Area "A"}}{\textit{Total Surface Area of Sphere}} \quad \textbf{(1)}$$

or, in math symbols, we can write the expression:

$$P_a = \frac{P_s}{4\pi r^2} \quad \textbf{(2)}$$

Where:

P_a is the power available per solid degree

P_s is the total radiated power in watts

R is the radius of the sphere, i.e., the distance from O to P.

A practical rule of thumb for this problem is to calculate from the surface area of the sphere. If you perform the right calculations, you'll find that there are approximately 41,253 square degrees on the surface of a sphere. By calculating the surface area of the beam front (also in square degrees), you can find the power within that region.

Now for the matter of gain in a vertical antenna. The vertical isn't gainless because it doesn't radiate equally well in all directions. In fact, the vertical is quite directional except in the horizontal (azimuth) plane. **Figure 6** shows the radiation pattern of the typical vertical radiator. The pattern looks like a giant doughnut in free space (see solid pattern in **Figure 6**). When sliced like a bagel, the pattern is the familiar circular omnidirectional pattern. When examined in the vertical plane, however, the plane looks like a sliced figure eight. The gain comes from the fact that energy isn't spread over an entire sphere, but concentrated to the toroidal doughnut-shaped region shown. Therefore, the power per unit area is greater than for the isotropic (truly omnidirectional) case.

Non quarter-wavelength verticals

The angle of radiation for a vertical antenna, hence the shape of the hypothetical doughnut radiation pat-

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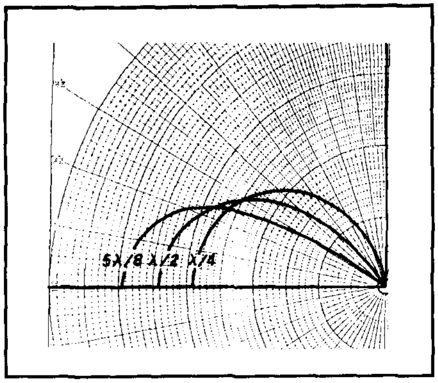
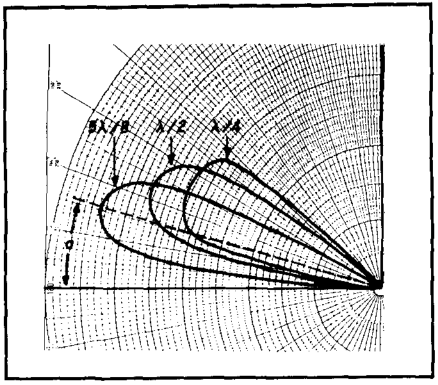
FIGURE 7A



Approximate patterns for three different length verticals. Relative power gains are also visible.

FIGURE 7B



Effects of ground losses on the patterns of the same three antennas.

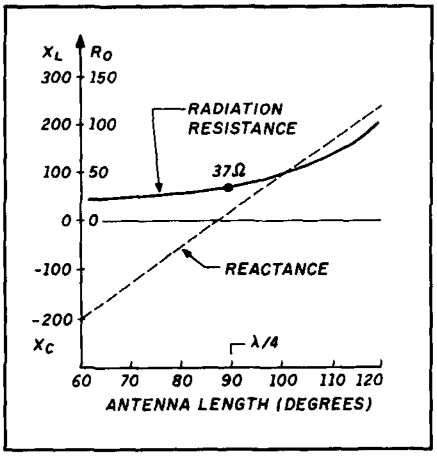
tern, is a function of the antenna length. (Note: "length" in terms of vertical antennas is the same as "height," and is sometimes expressed in degrees or wavelength, as well as feet and/or meters). **Figure 7A** shows the approximate patterns for three different length vertical antennas: quarter wavelength, half wavelength, and 5/8 wavelength. Note that the quarter-wavelength antenna has the highest angle of radiation, as well as the lowest gain of the three cases. The 5/8-wavelength antenna has both the lowest angle of radiation and the highest gain (compared with isotropic).

The patterns shown in **Figure 7A** assume a perfectly conducting ground underneath the antenna. However, that's not a possible situation for practical antennas — all real grounds are lossy. The effect of ground loss pulls the pattern in close to the ground (**Figure 7B**). Although all of the patterns are elevated from those of **Figure 7A**, the relationships still remain. The 5/8-wavelength radiator has the lowest angle of radiation and highest gain.

The feedpoint impedance of a vertical antenna is a function of the radiator length. For the standard quarter-wavelength antenna, the feedpoint radiation resistance is approximately 37 ohms, with only a very small reactance component. **Figures 8A** and **B** show the approximate feedpoint impedances for antennas from nearly zero effective length to 120 degrees of length.

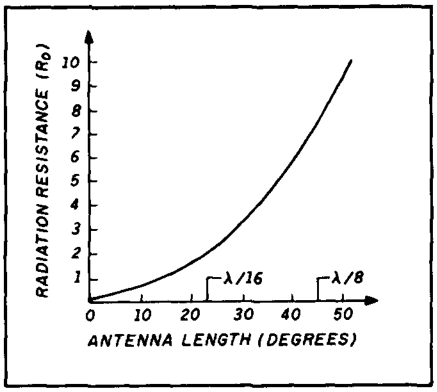
Antenna length as it is expressed in degrees derives from the fact that one wavelength equals 360 degrees. Thus, a quarter-wavelength antenna has a length of 360 degrees/4 = 90 degrees. To convert any specific length from degrees to wavelengths, divide the length in degrees by 360. Thus, for a 90-degree antenna: 90 degrees/360 degrees = 1/4 wavelength. The graph in **Figure 8A** shows the antenna feed-

FIGURE 8A



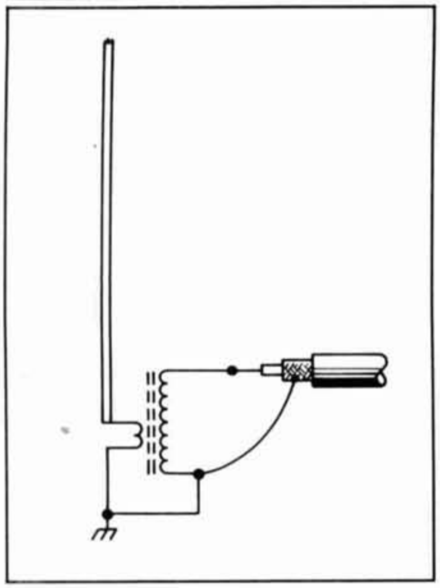
Approximate feedpoint impedances of antennas from 0° to 120° in electrical length.

FIGURE 8B



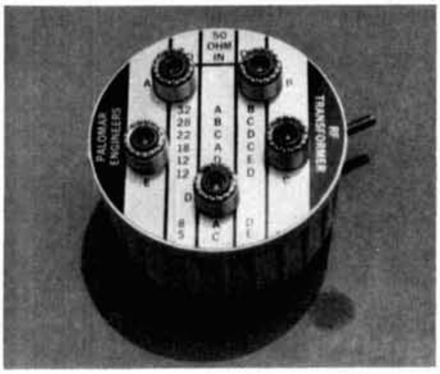
Radiation resistance of antennas from 0° to 60° in electrical length.

FIGURE 9



Basic connection of a toriodal transformer to a vertical antenna.

PHOTO A



Commercial impedance matching transformer.

point impedance, both reactance and radiation resistance, for antennas from 60 to 120 degrees; **Figure 8B** shows the radiation resistance for antennas from near zero to 60 degrees. Note that the radiation resistance for such short antennas is extremely small. For example, an antenna that is 30 degrees long (30/360 = 0.083 wavelength) has a resistance of approximately 3 ohms.

It's generally the practice on vertical antennas with an impedance-matching problem to use a broadband impedance-matching transformer to raise the impedance of these antennas to a higher value. **Figure 9** shows the basic connection of the toroidal transformer to the vertical antenna. You can wind a homebrew transformer following instructions given in *The ARRL Handbook*, other publications, or a past issue of this column. You can also use a manufactured impedance transformer like the Palomar Engineers' model shown in **Photo A**. This transformer is designed specifically for HF vertical antennas.

Next month...

In the second installment of this three-part series I'll look at two topics: the installation of vertical antennas, and vertical antenna construction and mounting techniques.

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Practically Speaking

Joseph J. Carr, K4IPV

VERTICALLY POLARIZED HF ANTENNAS: PART 2

Last month I introduced a series on vertical antennas. I discussed the basic theory and configuration of the "standard" quarter-wavelength vertical antenna. This month I'll take a look at some practical issues involving the much-needed ground system for the vertical, and vertical antenna construction details.

Vertical antenna ground systems

The vertical antenna works well only when placed over a good ground system. The usual way to provide a good ground for a vertical is to use a system of radials like that shown in **Figure 1**. A view from above shows 16 quarter-wavelength radials arranged to cover a full circle around the antenna. Each radial is a quarter wavelength, so each will have a length (in feet) of $246/F_{MHz}$. All the radials are connected together at the base of the antenna, and the ground side of the transmission line is connected to this system. The radials may be placed on the surface or underground. A friend of mine placed an extensive radial system on the bare dirt when his house was being built. When the sod was laid down, he had a very high quality underground radial system.

If you decide to use an above-ground radial system, be sure to make provisions to prevent people from tripping over it. You may be liable if people trip over your radials and injure themselves — even if the person is an intruder or trespasser!

Some experts prefer to place a copper wire screen at the center of the radial system. The minimum screen size is about 2 meters (6 feet) square. Use solder to connect it to the radials at the points shown in **Figure 1**. Other experts drive ground stakes into the ground at these points. Still another method is shown in **Figure 2**. Here you see a "spider web" of conductors shorting the radials at points a meter or two from the antenna. Again, some authorities recommend that ground rods be driven into the earth at the points indicated.

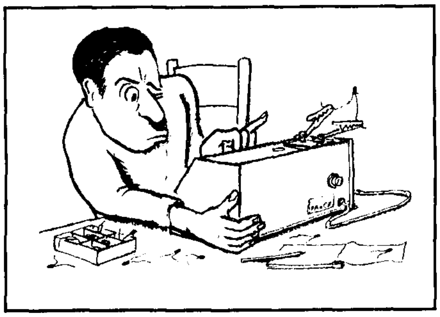
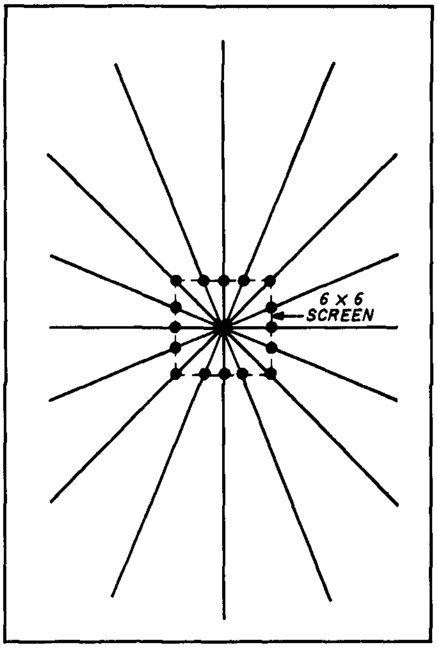


FIGURE 1

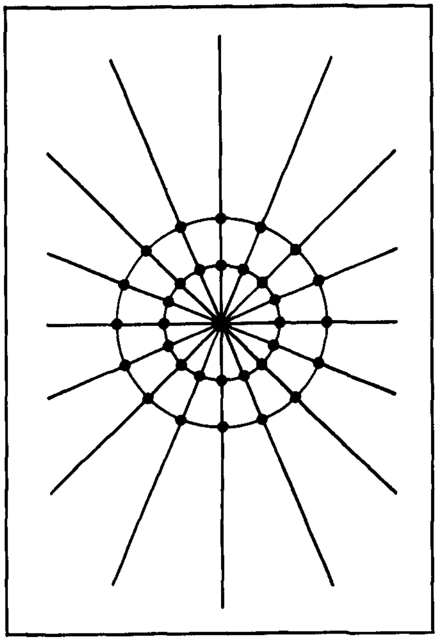


Basic ground radial system.

The exact number of radials you use depends in part on practical matters — like how much money you have to spend, or how many you can physically install. Use at least two radials per band; four per band is preferred for simple, low cost systems. However, be aware that even four radials is considered a compromise. The general rule is: the more radials, the better. But there's also a law of diminishing returns as the number of radials increases. **Figure 3** shows the approximate field intensity (mV/meter) as a function of the number of radials. Notice that the field intensity doesn't increase as rapidly per extra radial when the total number of radials is above 20 or so. The Federal Communications Commission requires AM band (550 to 1620 KHz) stations to use 120 radials, but that number isn't necessary for Amateur stations. A practical upper limit of 16 radials is usually accepted for Amateur radio work, and your antenna can work well with fewer.

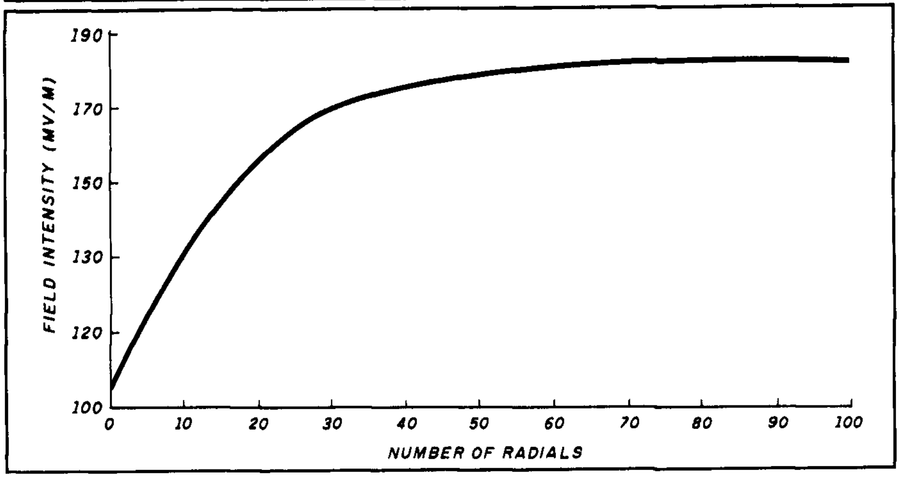
For vertical antennas *mounted* above ground, there's an optimum height for the base of the antenna. This height is a quarter wavelength above the actual ground plane. Unfortunately, that distance may or may not be the actual physical height above the surface. Depending upon ground conductivity and ground water content, the height may be exactly a quarter wavelength above the surface or

FIGURE 2



Spiderweb ground radial system.

FIGURE 3



Effect of the number of radials on the effective radiation of the antenna.

slightly lower. Find the optimum height by experimenting; remember that it will vary over the course of the year if climatic changes are the norm in your location.

Vertical antenna variants

So far, the vertical antennas I've considered have been standard quarter-wavelength models. Let's take a look at several variations. **Figure 4** shows the vertical half-wavelength dipole. The vertical dipole is constructed in exactly the same manner as the horizontal dipole, but is mounted in the vertical plane. In general, the section of the radiator closest to the ground should be connected to the shield end of the coaxial cable transmission line.

Like the horizontal dipole, the approximate length of the vertical dipole is calculated from:

$$L_{ft} = \frac{468}{F_{MHz}} \tag{1}$$

Where:

L_{ft} is the length in feet, and

F_{MHz} is the operating frequency in megahertz.

Of course, each leg of the vertical dipole is one-half the calculated length.

The vertical dipole antenna is used in many locations where it's impossible to mount a horizontal dipole properly, or where a roof or mast-mounted antenna is impossible to install because of logistics or a hostile landlord and/or homeowners' association. Some row and townhouse dwellers, for example, have been successful with the vertical dipole. In the 1950s and 1960s, the vertical dipole was popular among European Amateurs because of space restrictions in many locations.

Vertical dipole construction is relatively straightforward. First, find or build a vertical support structure. In the system shown in **Figure 4**, the support is a wooden or heavy wall PVC mast. Thin wall PVC pipe whips around too much in the wind and requires more guy line support than is reasonable; so avoid it for this application. Ropes and insulators at either end support the wire elements from the ends and keep the antenna taut. If neighbors are a problem, try to find some white thick wall PVC pipe that you can use to build a fine flagpole (be patriotic), and simply hide a vertical dipole inside it. If your home doesn't have metal siding and is tall enough, a support from the roof structure (or soffits) will make a proper support.

One problem we liability-conscious people need to consider when using a vertical dipole is the high impedance voltage at the ends of a half-wavelength dipole. Anyone touching the antenna is likely to receive a nasty RF burn or shock.

Coaxial vertical construction is similar to that of the vertical dipole in that it uses a pair of vertical radiator elements. It can even be argued that it's a form of vertical dipole. However, with the coaxial vertical antenna, the radiator that's closest to the ground is coaxial with the transmission line and the main radiator element (see the example in **Figure 5A**). An insulator at the feedpoint separates the two halves of the radiator. In most cases, the top radiator is smaller in diameter than the coaxial sleeve (also called the "shield pipe" in some publications). For the most part, the reasons for this arrangement are mechanical rather than electrical. The coaxial cable transmission line passes through the sleeve and is itself coaxial to the sleeve.

The overall length of the coaxial vertical antenna is one-half wavelength, consisting of two quarter-wavelength sections. Both the radiator and the sleeve are a quarter wavelength long. The starting length of each is found (approximately) from:

$$L_{ft} = \frac{246}{F_{MHz}} \tag{2}$$

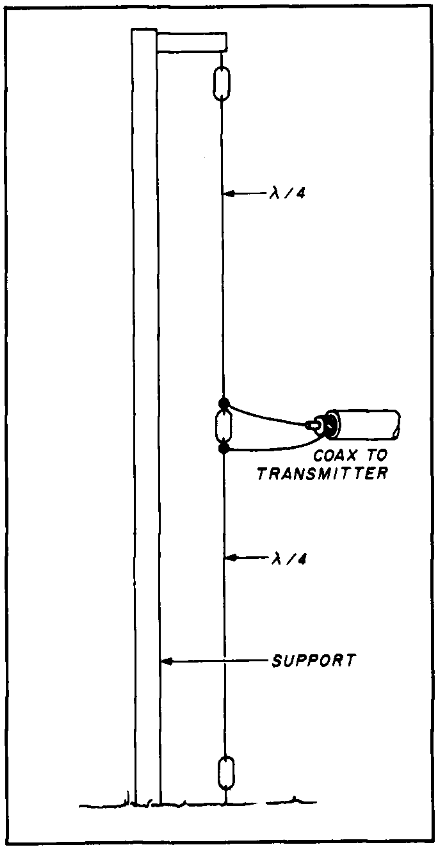
or,

$$L_{meters} = \frac{72}{F_{MHz}} \tag{3}$$

These equations are similar to the one used to calculate half-wavelength antennas, but they are reduced by a factor of 2.

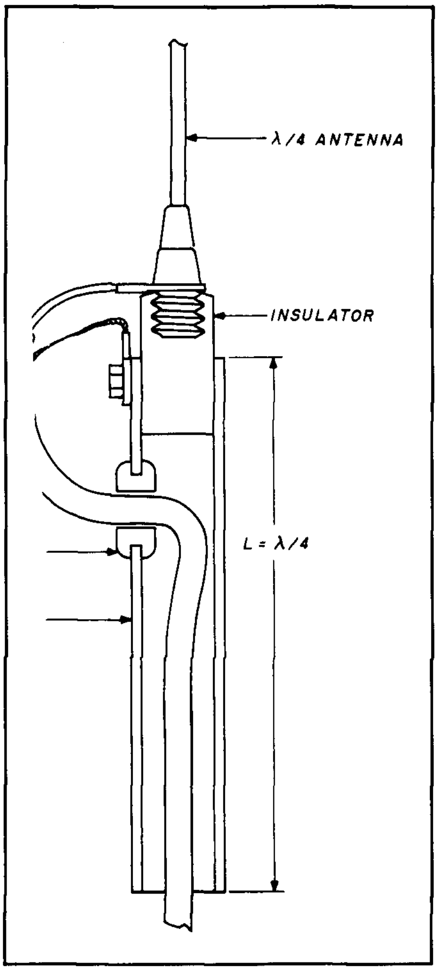
The coaxial vertical antenna was once popular with CB operators and was called the "colinear antenna." You can sometimes find hardware from these antennas at hamfests or surplus

FIGURE 4



Simple half-wave vertical dipole.

FIGURE 5A



Commercially used system for feeding a coaxial half-wave antenna.

markets and modify the pieces for Amateur Radio use. If you're building a 10-meter band antenna, it's a simple matter to cut the 11-meter CB antenna for operation on a slightly higher frequency. But it's a little more difficult for the lower frequency bands, and it's likely that only the insulator and mounting assembly are salvageable. Keep in mind, however, that adjacent sizes of aluminum tubing are designed so that the inner diameter (ID) of the larger piece is a slip fit for the outer diameter (OD) of the smaller piece. This lets you connect adjacent sizes of aluminum tubing together without special couplers. I find that salvaged insulator assemblies with just 6 to 10 inches of the former radiator and sleeve can be cut off, and new radiators from "adjacent size" tubing can be installed.

The configuration in **Figure 5A** is the construction technique used by commercial antenna manufacturers for VHF and CB colinear vertical dipoles. This method is a little difficult for those who don't have access to a machine shop for making the center insulator. You'll need to find another construction method to make this antenna practical.

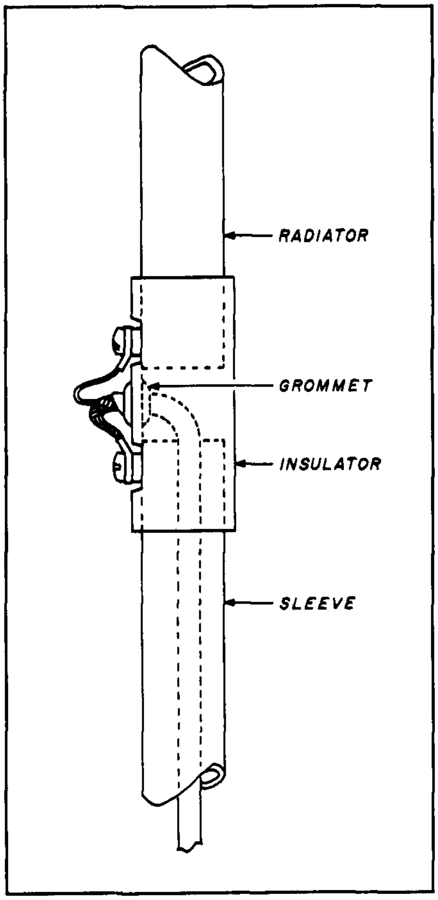
Figure 5B shows a construction method that has been used by Amateurs with good results. The radiator and shield pipe (sleeve) are joined together in an insulating piece of thick wall PVC plumbing pipe, Lucite™, or Plexiglas™ tubing; 6 to 10 inches of tubing are needed.

Leave a gap of about 2 inches between the bottom end of the radiator pipe and the top end of the shield pipe to keep them electrically insulated from each other, and to allow the coaxial cable to be passed through to the outside world. Drill a hole in the insulator pipe for this purpose.

Fasten the aluminum tubing pieces for the radiator and the sleeve to the insulator using at least two heavy machine screws for each. You can use one of the machine screws on each piece as the electrical connection between the coaxial cable and the pipes, as long as you cut a larger hole in the insulator at that point to admit the washer that provides the electrical pathway between the screw head and the aluminum pipe. If you omit the washer, and depend on the contact between the machine screw and the pipe, your connection will probably be intermittent and cause you quite a bit of aggravation.

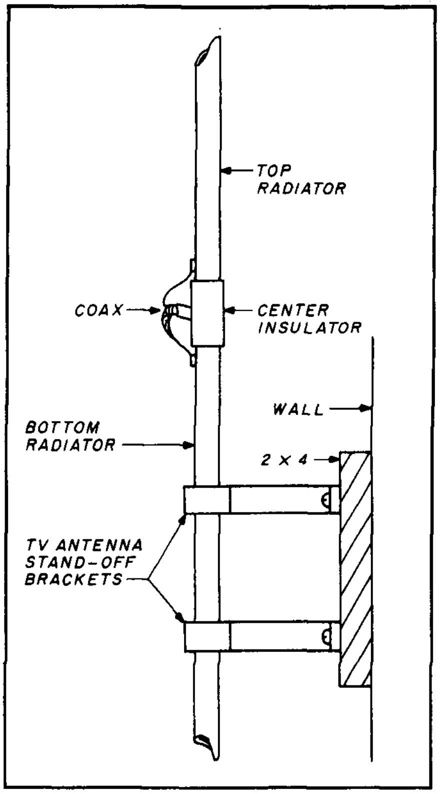
Mounting the homebrew coaxial vertical antenna can be a "pain in the neck." Normally this antenna is mounted high in the air, so some form of support is needed. Fortunately, you can use small area metal supports connected to the sleeve. **Figure 5C** shows one popular mounting method that uses a pair of television antenna standoff mounting brackets to support the sleeve. You can buy these brackets in sizes from 6 to 24 inches. Note that a 2 × 4 piece of lumber is used between the building wall and the brackets. This wood serves as an insulator, so it should be varnished or painted. Attach it to the wall with lag bolts, wing bolts, or some other secure anchoring method. Keep in mind that the forces on the brackets increase tremendously during windstorms.

FIGURE 5B



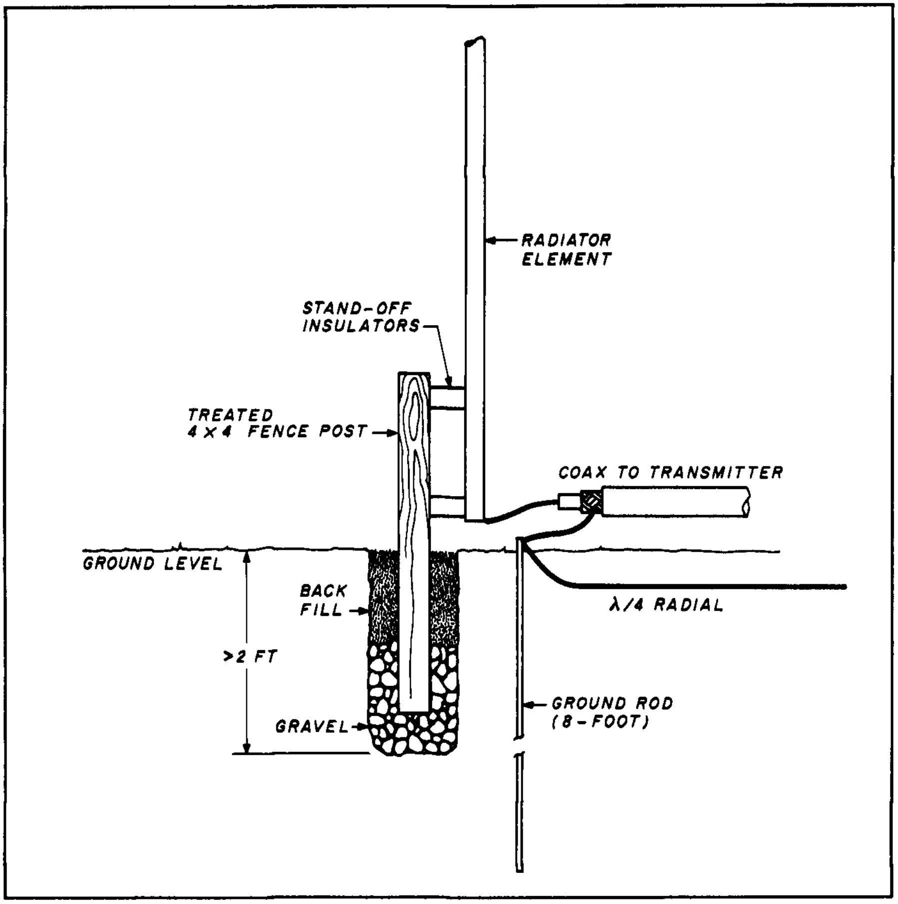
Homebrew method for feeding a coaxial half-wave vertical.

FIGURE 5C



Antenna mounting scheme.

FIGURE 6



Basic ground installation of a quarter-wave vertical.

The two vertical antennas shown here can present a shock hazard to anyone who touches them. Both of those antennas are half-wavelength radiators and of the dipole form of construction. The center point is used for feeding the antenna, so it forms the low impedance point in the antenna. As a result, the ends of the antenna, one of which is close to the ground, are the high impedance points. This means the voltages at those points can be high, and also within reach of prying hands playing in the yard. It's wise to either mount the antennas so far above ground that they can't be reached, or build a small nonconductive fence around the ends of the antenna.

Vertical antenna construction

Vertical antenna installations are generally ground level or nonground mounted. In this section I'll take a brief look at both forms of mounting, concentrating on the installation of homebrew verticals rather than commercial ones. I assume that the vendors of these antennas will provide their own instructions.

The ground-level mounted vertical is shown in **Figure 6**. The typical vertical antenna is 8 to 40 feet high. Thus, although the actual weight of the antenna is small, *the forces applied to the mounting structure can be quite high, especially during windstorms.* Don't be fooled by the apparent light weight of the antenna in this respect.

The mounting structure for the vertical antenna can be a metal or wooden fence post buried in the ground. Make sure at least 2 feet of the fence post are above ground. In **Figure 6**, a 4 × 4 wooden fence post is used as the mounting, but the principles are similar for all forms of post. Try to make sure you have a fence post hole at least 2 feet deep. In some cases, it may be possible to use 1 foot of gravel fill topped with back-filled dirt. In other cases, especially where a steel fence post is used, place a concrete plug at the bottom of the hole over a 4-inch layer of gravel.

Install the antenna radiator element to the fence post with standoff insulators. You may have to omit these insulators, as they are difficult to find. Given that varnished or painted wood isn't a very good conductor, it's not unreasonable to bolt the radiator directly to the 4 × 4 fence post. Use 5/16-inch (or larger) bolts; make sure they're long enough to fit through both the antenna element and the 4 × 4 post. Bolts 5/16 inch in diameter and 6 or 8 inches long will probably work best. Use at least two bolts, one at the bottom of the antenna radiator element and one near the top of the fence post. A third bolt, halfway between the other two, wouldn't be out of order.

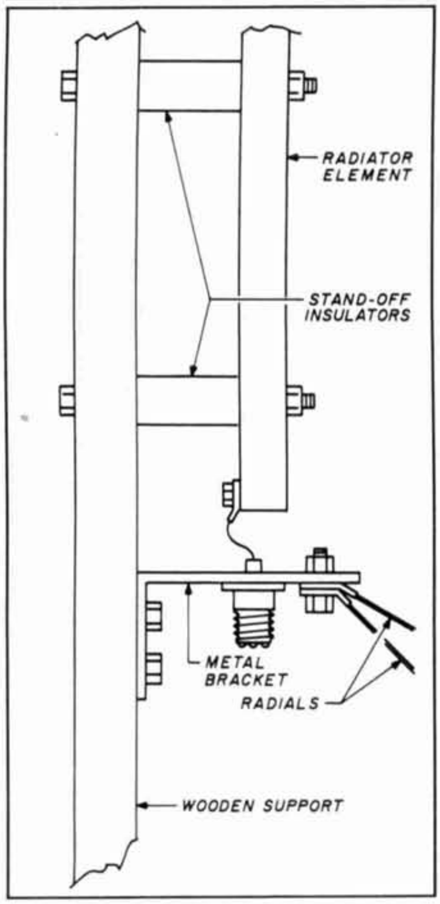
Generally, no matching is necessary if the antenna is a quarter wavelength. Although the feedpoint impedance isn't exactly 52 ohms, it's close enough (37 ohms) to form a reasonable match for 52-ohm coaxial cable (with VSWR ≃ 1.4:1). The center conductor of the coaxial cable is connected to the radiator element, while the shield is connected to the ground system. Two ground methods are used in the example shown in **Figure 6**. The first is an 8-foot ground rod driven into the earth at the base of the antenna; the second is a system of quarter-wavelength radials. Remember that the ground system is absolutely essential.

Figure 7 shows a method for installing a vertical antenna above ground. A wooden support (2 × 4 or 4 × 4) is put up in a manner similar to the one in **Figure 6**, but a deeper hole is used to counter the longer length. The support can also be affixed to the side of a building wall, shed, or other preexisting structure. Once you've decided on your support, attach the radiator element using the method described for the previous antenna.

Electrical connections to the antenna are also shown in **Figure 7**. Because the antenna is above ground level, an electrical counterpoise ground consisting of a system of radials is absolutely essential; provide at least two radials per band. Use a small L bracket to support the radials and provide an SO-239 coaxial connector for the coax. This connector is a chassis-mounted type with its center conductor connected to the radiator element. Fasten the connector shield to the bracket; this connects it to the radial system.

In some installations the antenna support structure will require guy wires

FIGURE 7



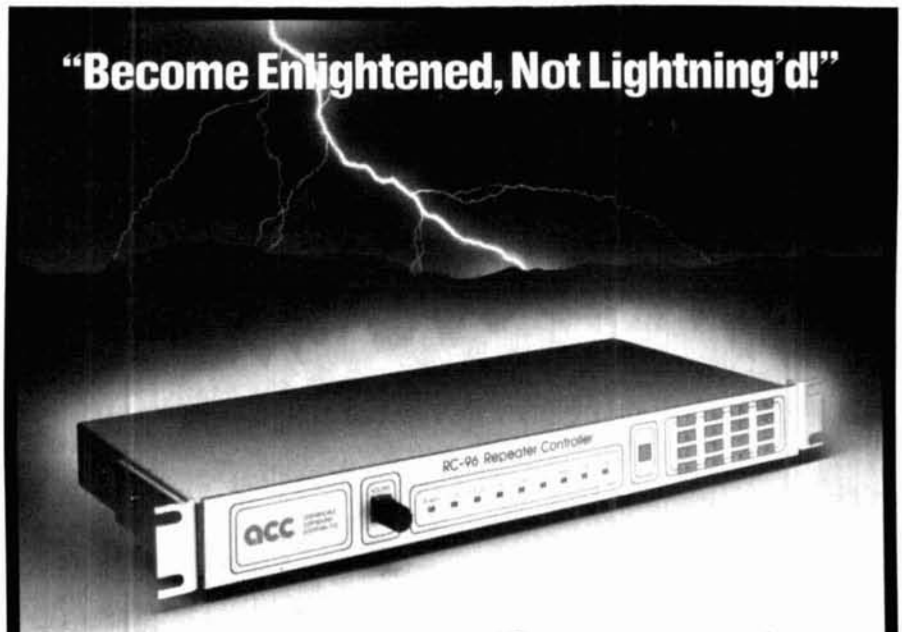
Scheme for mounting an elevated vertical with an elevated radial system.

to keep the structure stable. Don't use the radials as guy wires. The type of wire that usually works well for radials is too soft and too easily stretched for guy wire service. Use regular steel guy line, available where TV antenna supplies are sold, for this antenna. Make the lengths nonresonant and break the guy lines up with egg insulators, if necessary, to achieve nonresonance.

Next month...

I'll look at two topics in the final installment of this three-part series. One is the 5/8-wavelength vertical antenna. These verticals have a generally lower angle of radiation than quarter-wavelength antennas, and may offer many Amateurs a superior "DX solution" over the quarter-wavelength model. The second issue that I'll address is safety.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column. hr



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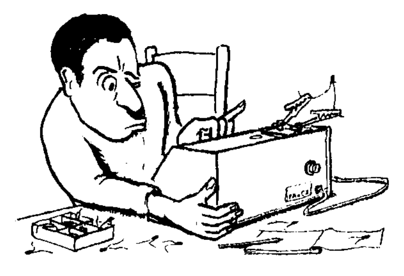
By Joe Carr, K4IPV



VERTICALLY POLARIZED HF ANTENNAS: PART 3

In the first part of this three-part series, I examined the basic theory of vertical antennas. In part 2, I developed the theme further by looking at the construction, mounting, and grounding of verticals. In this third and final part, I'll look at the 5/8-wavelength vertical (including shunt-feed alternatives to the series feed normally used on vertical antennas) and a safety issue.

Five-eighth wavelength verticals

Figure 1 shows the configuration for the 5/8-wavelength vertical antenna. Such an antenna generally gives a lower angle of radiation than the more common 1/4-wavelength radiator, so, presumedly, it's better for long distance work.

The radiator of this antenna is made from 1/2 to 2-inch aluminum tubing. (Remember that adjacent sizes fit together snugly to form longer sections.) The physical length of the 5/8-wavelength radiator is found from:

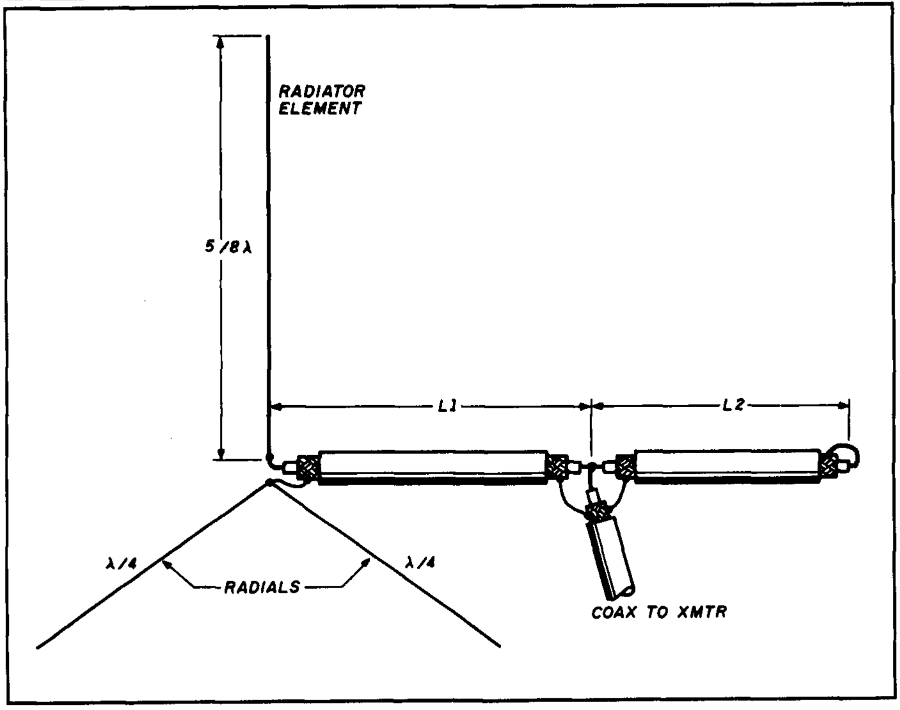
$$L(ft) = \frac{585}{F(in\ MHz)} \qquad \textbf{(1)}$$

The radials are the usual quarter wavelength, made of no. 12 or no. 14 copper wire. This length is found from:

$$L(ft) = \frac{246}{F(in\ MHz)} \qquad \textbf{(2)}$$

The feedpoint impedance of the 5/8-wavelength antenna isn't a good match for the ordinary coaxial cables routinely available on the Amateur market. You'll need some form of impedance matching.

FIGURE 1



Basic configuration for a 5/8-wavelength vertical antenna.

One option is to use a broadbanded RF transformer like the Palomar Engineers, Inc. models shown in part 1. These transformers will work throughout the HF spectrum, and match a wide variety of impedances to the 50-ohm standard system impedance.

Another option, especially for a single band antenna, is to use a coaxial cable impedance transformer like the one shown in **Figure 1**. The transformer consists of two sections of coaxial cable joined together. These sections appear as L1 and L2 in **Figure 1**. The length is found from:

$$L1 = \frac{122}{F(in\ MHz)} feet \qquad \textbf{(3)}$$

and,

$$L2 = \frac{30}{F(in\ MHz)} feet \qquad \textbf{(4)}$$

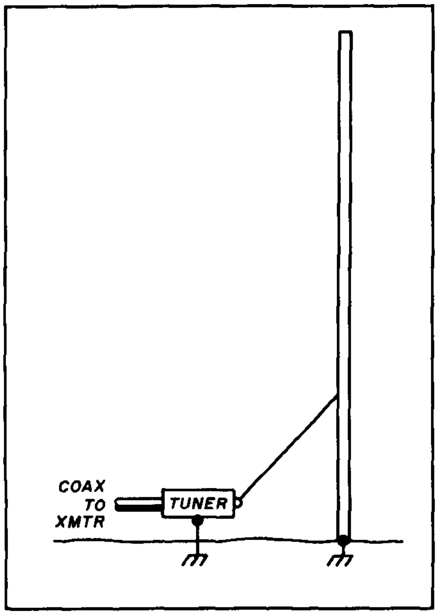
Grounded vertical antennas

The vertical antennas I've presented in this series so far are called *series-fed verticals* because the generator is esentially in series with the radiator element. Such antennas must be insulated from ground. The other class of vertical is the *shunt-fed vertical*, which is grounded at one end (see **Figure 2**). There are three methods of shunt feeding a grounded vertical antenna: *delta*, *gamma*, and *omega*. All three matching systems have exactly the same function. They form an impedance transformation between the antenna radiation resistance at the feedpoint and the coaxial cable characteristic impedance, and cancel any reactance in the system.

The delta feed system is shown in

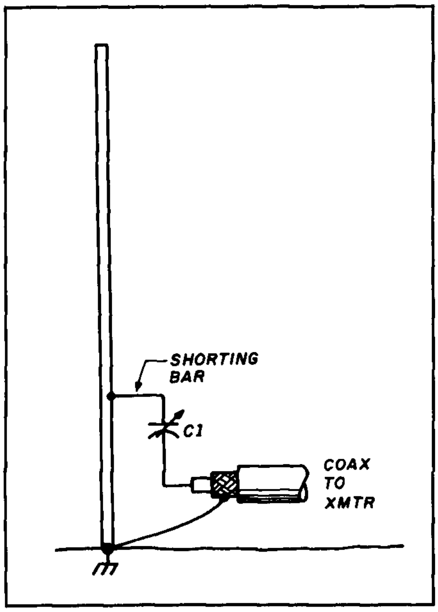
Figure 2. A taut feed wire is connected between a point on the antenna, which represents a specific impedance, and an antenna tuner. This feed method is common on AM broadcast antennas (usually, or perhaps always, verticals). Although you'd think that the sloping feed wire would distort the pattern, that's not the case. The distortion of the pattern, if any, is very minimal and negligible.

FIGURE 2



Shunt-fed vertical using the Delta match.

FIGURE 3



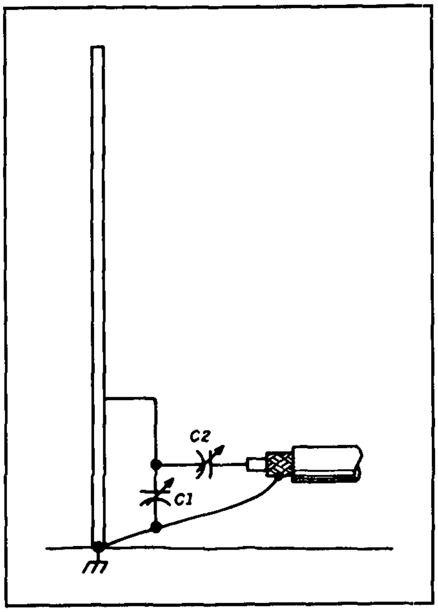
Shunt-fed vertical using the Gamma match.

The gamma feed system is shown in **Figure 3**. Since Amateurs commonly use this method to feed Yagi beam antennas, it's a familiar one to most of us. The feed system consists of a variable capacitor to tune the system, and a matching rod that parallels the antenna radiator element. It's important that the rod not be anywhere near a quarter wavelength, or it will become a vertical antenna in its own right. In fact, it would resemble the so-called J-pole antenna. The omega feed shown in **Figure 4** is similar to the gamma match, except that you use a series-shunt capacitor network.

Safety first!

Rarely does a year go by that we don't hear of an Amateur killed by ill-advised antenna installations. There are always stories (fortunately, not always regarding fatalities) about how inept antenna installations cause property damage or, worse yet, serious injury. There are several issues involved. A standard HF vertical is 18 to 27 feet high. When installed on a mast, the total antenna height may be 50 to 60 feet. Having antennas this tall can lead to serious problems. *Before erecting your antenna, be sure that it won't fall onto power lines if it gets away from you.* Also, be aware of windows and other objects the antenna may damage if it falls, and make plans to avoid that problem.

FIGURE 4



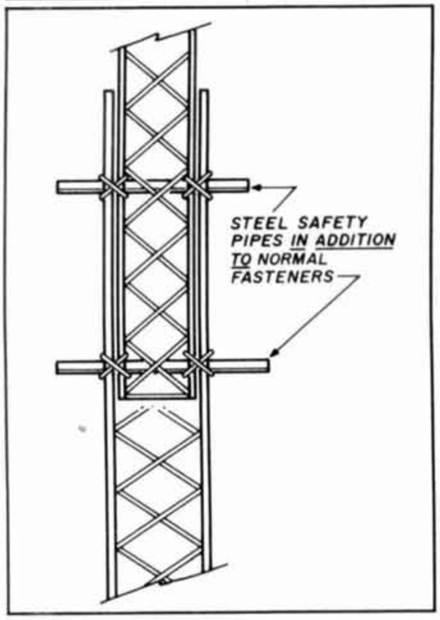
Shunt-fed vertical using the Omega match.

There's a no-nonsense, common sense, two-person rule that you should follow when erecting antennas: *Aways use two or more physically fit people when installing a vertical antenna.* These antennas aren't terribly heavy on the ground, so you might get the false impression that handling one is going to be easy. But try holding onto the lower end of a 20-foot high aluminum "wind sail" while standing on a ladder; even the slightest breeze can become terribly dangerous! You'll also find that normal antenna motions ("wiggle") become serious when amplified by a 20-foot lever arm. I made that foolish mistake one Thanksgiving day, and I'm thankful that my father-in-law showed up in the nick of time to help steady a 37-foot high vertical, plus mast.

Another safety issue is illustrated in **Figure 5**. Although it doesn't pertain to vertical antennas exactly, it's nonetheless an antenna safety issue. My friend from Novice days, Doug (now EI2CN), has a slip-up tower from his beam. He told me about something called the "guillotine effect." I didn't think much about this problem until, on one of my business trips, I read about a professional tower rigger for a two-way radio company who'd had an arm amputated after it was crushed while he was climbing a slip-up tower. Apparently he failed to use the safety stops provided on the tower, and it collapsed while he was on it. The center section came slicing down, crushing his arm so badly that the surgeons couldn't save it.

A slip-up tower lets you do your maintenance closer to the ground. So why would you be at risk of being crushed? There are two reasons. First, even if your tower is collapsed completely, it's possible for the antenna to shift downward a couple of inches — especially if a physical failure is present. Second, it's easier to do some types of work on the tower while it's in an upright position. For example, repairing a coaxial line or damaged gamma match is easier with the tower in place. Sometimes, it simply seems like too much trouble to release the guys and crank down the tower. Some Amateurs also ignore the manufacturer's directions and climb the tower. Those who insist on tackling this type of job by climbing the tower are better off double rigging it for safety. But you'll need more than the mechanisms provided by the manufacturer.

FIGURE 5



A means of providing additional safety precautions when working with a slip-up tower.

Figure 5 shows a tower that's safety rigged to protect against failures. A pair of heavy wall steel pipes are inserted across the tower, impeding the center section. These pipes can be bolted or tied securely in place, and should be used *in addition to any fasteners or safety features provided by the tower manufacturer.* Do not defeat the builder's safety features.

Wear two leather safety belts, not one. Always make sure one of the belts is connected; don't depend on your own physical strength to stay on the tower.

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