the half-wave vertical

A 40-meter DX antenna without a radial-wire ground system

A current-fed vertical antenna, such as a quarter- or five-eighths-wavelength monopole, must have a radial-wire ground system for maximum efficiency.[1-3] This is known as a groundplane.

the groundplane

What is the purpose of this groundplane? Will it provide the low-angle radiation necessary for working distant stations? The radial-wire ground system under the antenna must provide a low resistance to reduce ohmic losses in the system. The ground-loss resistance, referred to the base of the antenna can, by a groundplane, be made low with respect to the system radiation resistance. For a quarter-wave vertical the radiation resistance is approximately 36 ohms. The radiation efficiency is therefore high. The radial-wire groundplane system is therefore important, since the length and number of radials, as well as the conductivity of the ground, determine this terminal loss resistance.

The parameters of the antenna, however, to launch sky waves at low angles above the horizon extend to distances well beyond the antenna and its ground system. *In fact,* the conductivity of the ground, fifty or more wavelengths from the antenna, is important in that it influences the vertical radiation pattern of the antenna. And this effect is significant, especially for launch angles of less than 10 degrees above the horizon.

Fig. 1A shows the theoretical vertical radiation pattern for a 6-MHz quarter-wave antenna over poor, good, and very good ground (sea water). The pattern for an antenna over very poor ground, but with an extensive ground system,[4] is shown in **fig. 1B**. It is clear that, while the radiation efficiency of the antenna is improved by using a ground screen, the power gains for elevation angles less than 10 degrees becomes vanishing small.

the half-wave antenna

An alternative approach is to use a half-wave radi-

By John S. Belrose, VE2CV, 3 Tadhoussac Drive, Aylmer (Lucerne), Quebec, J9J 1G1, Canada

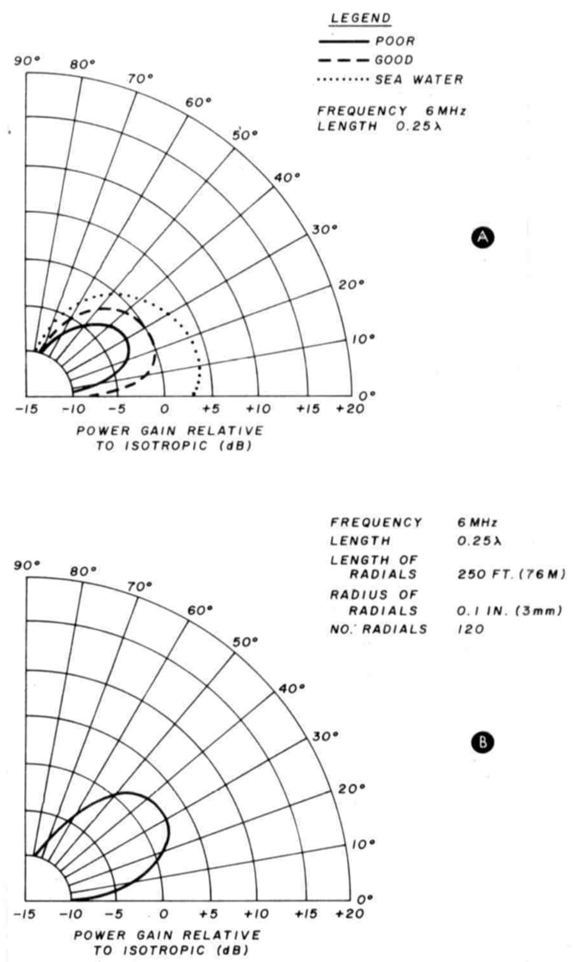
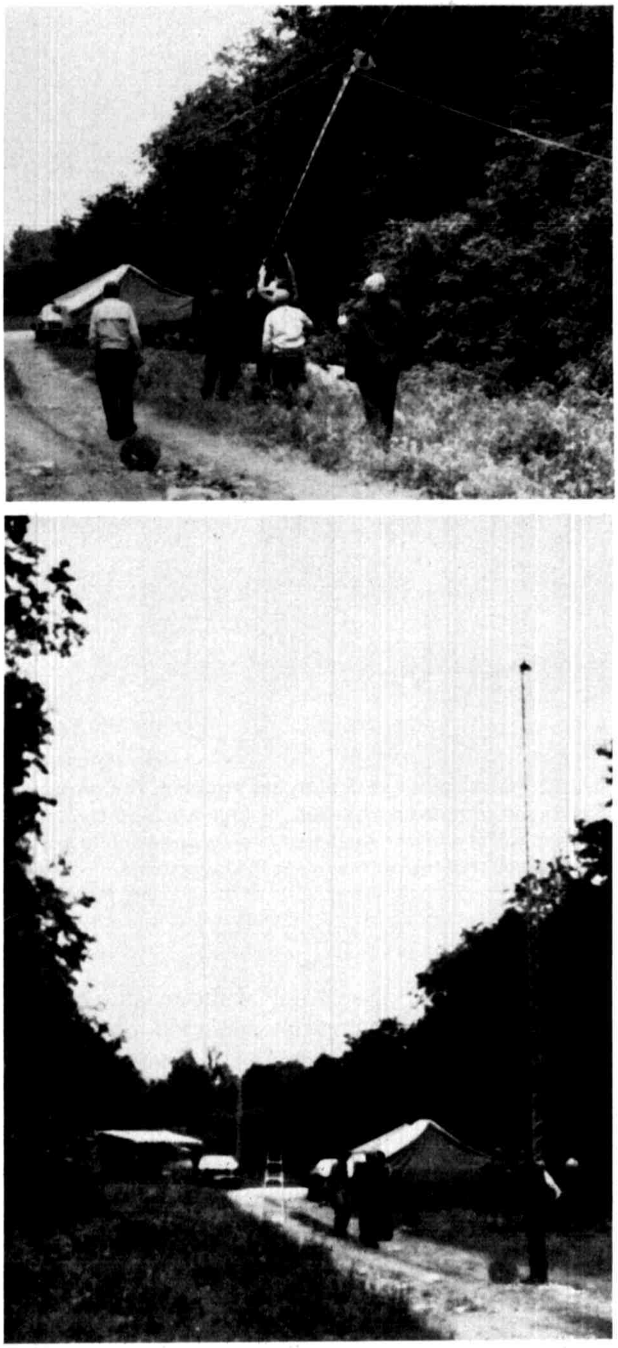


fig. 1. Theoretical radiation pattern for a quarter-wave antenna over poor, good, and very good ground (A) and over very poor ground but with an extensive ground system (B).

ator. Since its radiation resistance is high compared with the ground-loss resistance, the radiation efficiency can be high, even without wire ground radials. The base resistance of a half-wave antenna depends on its height-to-diameter ratio. For a tower antenna, the base radiation resistance is about 500 ohms; for thin wire antennas this resistance is several thousand ohms. Furthermore, if the antenna feedpoint is elevated from the ground, the influence of the finite conductivity of the ground on the input impedance of the antenna is even further reduced. The antenna will therefore radiate with good efficiency, even with no ground screen at all. Of course, the far-field vertical radiation pattern, especially at low elevation angles, is affected by the conductivity of the ground as discussed above; but we have little control over this except to erect the antenna over a salt marsh or over alkaline flats in the prairies.



Erecting the home-built coaxial sleeve antenna at a field-day site (top). Lower photo shows the antenna in operating position.

The coaxial vertical, or sleeve antenna, (**fig. 2**), is a half-wave radiator. This antenna is used extensively at VHF. It can also be used effectively at high frequency, at least for frequencies greater than 7 MHz. The coaxial sleeve is composed of a cage of four wires connected to the top of a tower, insulated from ground and the tower but connected by a skirt wire at the lower ends. The antenna is fed by a coaxial

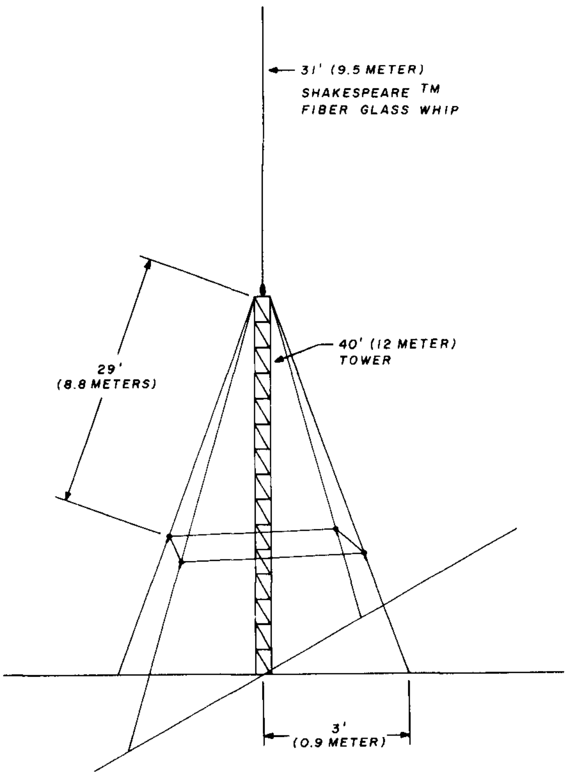


fig. 2. The 40-meter coaxial-sleeve antenna. The coaxial sleeve is composed of a cage of four wires connected to the top of a tower, insulated from ground and tower, but connected by a skirt wire at the lower ends.

cable that runs up the center of the mast. The outside conductor of the coax is connected to the top of the tower; the center conductor is connected to the base of a free-standing, base-insulated whip at the top of the tower. (For base-station use, the tower should be grounded for lightning protection.)

The optimum height, measured from the center of the antenna above the ground, is one-half wavelength, since the antenna and its image are then separated by one wavelength. This is the height for maximum gain, which for a perfectly conducting ground, would be 6.27 dB over a dipole in free space. However, this height can be decreased to about 0.35 wavelength before ground losses appreciably affect the input impedance.[5]

antenna fundamentals

A vertical antenna of physical length or height, H, is related to its electrical length, G, by a factor k:

$$H = kG \tag{1}$$

where H is height
k is a factor (less than 1)
G is electrical length (degrees)

That is, the physical height, H, is *less* than the electrical height, G, due to a) end effects and b) the velocity of propagation of the wave along the radiator, which is less than its velocity in free space. Usually G will be one-quarter, one-half, or five-eighths wavelength (90, 180, or 225 electrical degrees). If G is measured in meters rather than in degrees, (as for example, we express wavelength in meters), then the physical height, H, or in this case, h, will also be in meters.

The factor k depends on the length-to-diameter ratio (H/D) of the radiator and on its electrical length. **Fig. 3** shows the experimentally determined relationship between these parameters. In **fig. 3** the percent increase of G over H is plotted versus the electrical diameter, D, (degrees), for a very wide range of values of D. Thus for thin antennas, this factor is approximately 5 percent, and for fat antennas, the percent increase is considerable. The experimental values were obtained from various sources. I measured those labeled 2 in **fig. 3** for first and second resonance. Previous investigators, for example Brown and Woodward,[6] got into difficulty for the larger values of D because of the capacitance of the base plate since the disk they used, which closed the bottom of the cylindrical radiator, formed a shunt capacitance across the terminals of the radiator. In my measurements I used rods rather than tubes, and the radiators were tapered to a point at their bottom end (but the taper was over a distance small with respect to the length of the radiator) to minimize this effect. I have used the curves in **fig. 3** for antenna design. The curve for $G = 225$ *degrees* probably lies midway between those for $G = 90$ *degrees* and *180 degrees*.

Towers are not usually of circular cross section. For triangular towers $d = 0.48b$ **(2)**

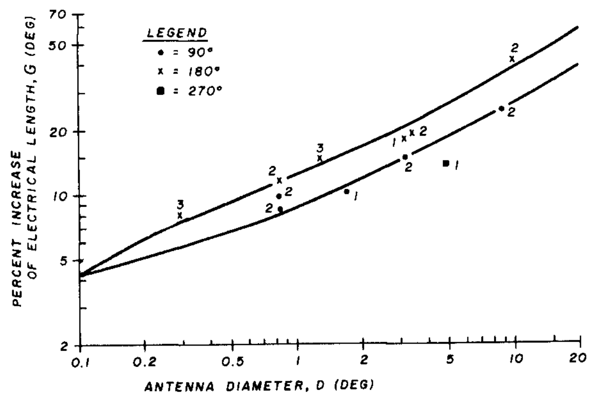


fig. 3. Percent increase of electrical length, G, over the physical length of a monopole antenna at height H. Points labeled 2 were measured by the author for one-quarter and one-half wavelength resonance. Other points were taken from various sources.

and for square towers

$$d = 1.18b \qquad \textbf{(3)}$$

where b = face width of tower
d = effective diameter of the tower

design of the coaxial-sleeve antenna

Suppose we design a coaxial-sleeve antenna for a frequency of 7.15 MHz ($\lambda = 984/fMHz = 137.6$ *feet or 42 meters*, and *a quarter wavelength* $= 34.4$ *feet*, or *10.5 meters*). The antenna arrangement is sketched in **fig. 2**.

The Shakespeare™ whip had a diameter of 1-1/4 inches (31.8 mm) at its base, and 1/4 inch (6.4 mm) at the top of the radiator. The effective diameter is therefore $\frac{1.25+0.25}{2} = 0.75$ *inch, or 19 mm (0.0625 foot, or 0.02 meter).*

Thus $D = \frac{0.0625\,(360)}{137.6} = 0.16$ *degrees.* In metric terms, $D = \frac{0.02\,(360)}{42}$.

The percent lengthening is therefore approximately 5 degrees, or $k = \frac{1}{1.05} = 0.95$. However, for fiberglass whips, the conducting wires are embedded in fiberglass. The velocity of propagation is therefore further reduced by the velocity of propagation in fiberglass, which is about 0.95 times the velocity in free space. Hence

$$\begin{aligned} k_{eff} &= 0.95k \\ &= 0.95\,(0.95) = 0.9 \end{aligned}$$

The length of the whip is therefore: $0.9\,(34.4) = 31$ *feet (9.5 meters).*

The effective diameter of the coaxial sleeve is estimated as follows. The top of the sleeve is the diameter of the supporting tower, which for a triangular tower 8 inches on side is $0.84\left(\frac{8}{12}\right) = 0.56$ *foot (0.17 meter).*

The four wires of the cage that form the sleeve are tied to stakes forming a 3-foot (0.9-meter) radius about the base of the tower (see **fig. 2**).

Visualize these tie points to form the corners of a square, which at ground level has a side length of $2\sqrt{2} = 4.24$ *feet (1.3 meters).* Thus the effective diameter is $1.18\,(4.24) = 5$ *feet (1.52 meters).* The effective diameter at the end of the sleeve is approximately $\frac{30}{40}\,(5) = 3.75$ *feet (1.14 meters).* The average effective diameter of the sleeve is therefore $\frac{3.75+0.56}{2} = 2.15$ *feet or 6.57 meters.* (that is, 5.6 degrees). Hence (see **fig. 3**), the percent lengthening for $D = 5.6$ *degrees,* $G = 90$ *degrees is 19 percent.* The antenna factor $k = \frac{1}{1.19} = 0.84$. The length of the sleeve is therefore 0.84 times the length of a free-space quarter wavelength, or $0.84\,(34.4) = 29$ *feet (8.8 meters).*

The antenna* was built according to these dimensions, and indeed it was resonant in the middle of the 40-meter band. Since the input impedance of the antenna (which was not measured) is expected to be closer to 72 ohms than to 50 ohms, the feed cable should be RG-11/U. If 50-ohm cable is preferred (RG-8/U), the feeder cable should be cut so that it is an integral multiple of one-half wavelength (a cable one wavelength long would be 90.83 feet, or 27.7 meters). This is because such a transmission line, regardless of its impedance, transfers to the feedpoint the terminal impedance without introducing reactance.

a practical antenna

The antenna that we constructed for use at a field-day site is shown in the photos. A full-wave delta loop (apex down, apex fed) was also used. This antenna has quite a different vertical radiation pattern (dominantly high angle). Switching from one antenna to the other provided reception from quite a different zone — a very desirable feature for field day.

acknowledgments

I would like to thank Harry, VE2RO, and Arn, VE2SD, for help in constructing the antenna. Thanks are also due to the field-day crew who raised the antenna, and to Geof, VE3KID, who took the photographs.

---

*The 40-foot (12.2-meter) tower employed is just marginally high enough, since the height of the antenna measured from its center is approximately 0.3 wavelength. Ideally, a 70-foot (21.4-meter) tower should be employed.

references

1. J.G. Coulombe, "Don't Starve a Vertical," *TCA*, October, 1979.
2. J. Sevick, "The W2FMI Ground-Mounted Short Vertical," *QST*, March, 1973, pages 13-18.
3. G.H. Brown, *et al.*, "Ground Systems as a Factor in Antenna Efficiency," *Proc. I.R.E.* No. 25, 753-787, 1937.
4. J.L. Thomas and E.D. DuCharme, *HF Antenna Handbook — Calculated Radiation Patterns*, Department of Communications, CRC Report No. 1255, 1974.
5. E.K. Miller, *et al.*, *Analysis of Wire Antennas in the Presence of a Conducting Half-Space*, Park 1, "The Vertical Antenna in Free Space," Canadian Journal of Physics, *50*, 879-888, 1972.
6. H. Brown and O.M. Woodward, "Experimentally Determined Impedance Characteristics of Cylindrical Antennas," *Proc. I.E.E.*, No. 33, pages 257-262, 1945.

ham radio