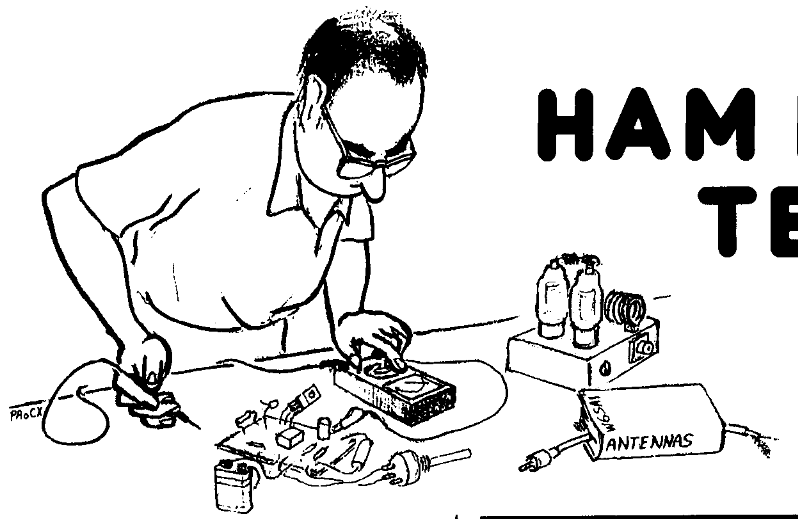


HAM RADIO TECHNIQUES

Bill Orr, W6SAI

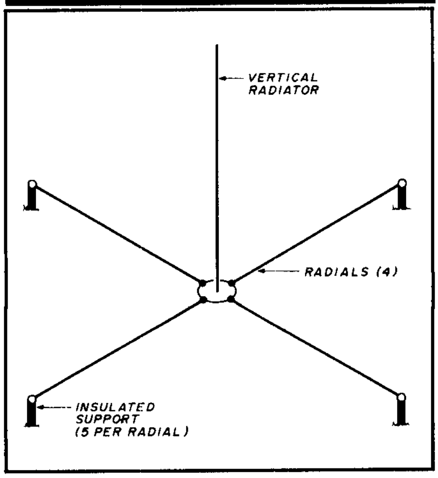
A look at the ground-plane antenna

In April I discussed "Vertical Monopoles With Elevated Radials" by Christman, Radcliff, Adler, Breakall, and Resnick.[1] Their work summarized computer studies indicating that a vertical monopole antenna with four elevated horizontal radials produces more groundwave (low angle) field strength than a conventional ground-mounted monopole with 120 buried radials. The monopole and radials were all a quarter wavelength long and the frequency of operation was 1.0 MHz. Base heights between 5 and 20 meters were investigated. Three different ground constants were used simulating average, very good, and very bad soil conductivity. For average soil, a radial height of 6 meters provided superior performance; for poor soil, a height of 8 meters was required.

The study concluded that "the use of elevated radials would provide superior performance, allowing the collection of electromagnetic energy in the form of displacement currents rather than forcing it to flow through lossy earth in the form of conduction currents."

Figure 1 shows the physical configuration of this antenna design. My remarks on the subject brought letters from readers asking for more information. There seems to be a great deal of interest in 160-meter vertical antennas.

FIGURE 1

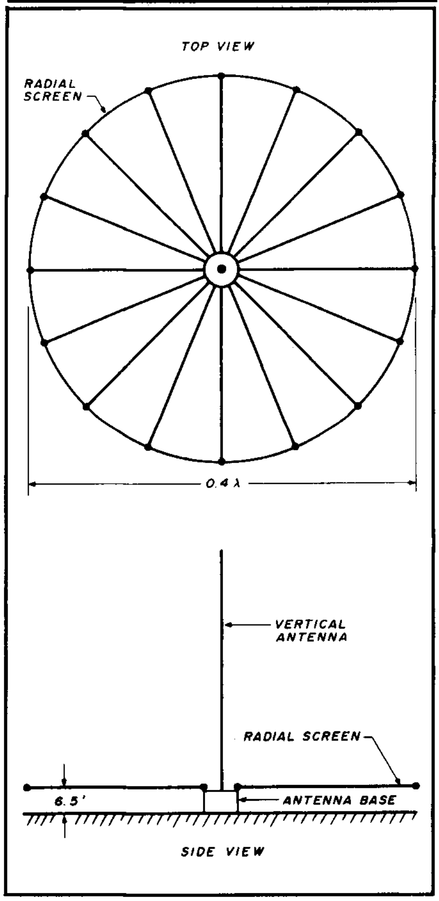


Layout of elevated radial system. Radial height is 6-8 meters at operating frequency of 1 MHz.

The concept of above-ground radial wires has been around for a long time. Experiments conducted by Doty, Frey, and Mills[2,3] and outlined in the 1982 bulletin of the Radio Club of America (later written up in the February 1983 issue of *QST* and also in my column), determined that the traditional ground radial system composed of a number of buried or surface wires can be equaled or bettered by using an elevated ground screen about 6.5 feet off the ground. This is shown in **fig. 2**. Note that this height is much less than that indicated in the layout of **fig. 1**.

Although the execution of this ground system is slightly different from

FIGURE 2



The ground radial system of Doty, et al. uses 50 radials, at least 0.2-wavelength long and 6.5 feet above ground.

the design shown in **fig. 1**, the concept seems to be the same. According to Edward Laport, former vice president of RCA and author of *Radio Antenna Engineering*, "All earth currents should enter the ground wires as displacement currents rather than conduction currents."

Enter the ground-plane antenna

The antennas shown in **figs. 1** and **2** are similar to the conventional ground-plane antenna. Then why all the fuss? A closer look at the ground-plane concept may clear the air. An excellent discussion of the ground-plane antenna was given in the "Technical Topics" column by Pat Hawker, G3VA, in the July 1981 issue of *Radio Communication*.

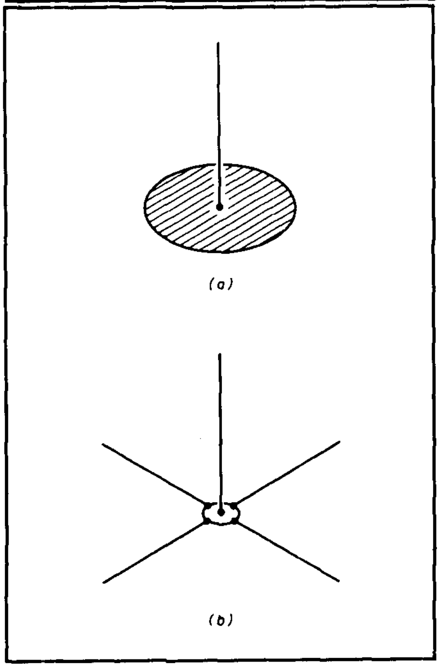
Pat points out that conventional wisdom (the *ARRL Antenna Handbook*, for example) claims that in order to obtain an omnidirectional pattern, the ground plane requires a metal ground disc with a quarter-wavelength radius (**fig. 3A**). The disc can be simulated with at least four straight radials equally spaced around a circle (**fig. 3B**). This implies that, as with buried radials, the more above-ground radials the better. It also suggests that such an antenna cannot be expected to function efficiently with an omnidirectional pattern with only one or two radials.

Pat refers to R.C. Hills, G3HRH, who asserts that the radial system of the normal elevated ground plane has little to do with the angle of radiation, but only provides a convenient low potential connection for the shield of the coax line. Hills states that the radials are electrically very transparent and the ground below the radials is well illuminated by the vertical antenna, so the presence of a good ground system is just as important as if the antenna were fed against ground.

G3VA comments on Hills saying, "Here the casual reader would assume that the use of four or more radials plus an extensive earth system buried in ground of good electrical conductivity was advisable to obtain optimum results."

In summary, G3VA points out that the effectiveness of any vertical antenna in providing low-angle radiation depends to a very marked extent upon earth conductivity. But an earth system that really meets this requirement can't use a normal buried earth system because it should extend many wavelengths around the antenna, in all directions.

FIGURE 3



Solid ground plane having 1/4-wavelength radius (A) can be simulated by four radials, each 1/4-wavelength long (B).

Getting down to basics

The conclusion is that ground conductivity is very important, but this does not answer the puzzle of the number of radials required. As G3HRH pointed out, their prime job is to provide an rf ground point for the coax line and to bring the antenna system to resonance. So why four radials? Why not five? Or three? Or perhaps one?

Pat, G3VA, had the enviable opportunity to meet Dr. George Brown of RCA, the man responsible for the development of the ground-plane antenna. On Dr. Brown's visit to England, Pat put the question to him. Here's what Pat had to say about this conversation:

"He (Brown) told me that the elevated ground-plane antenna was first devised in the thirties to meet an early requirement for police communications around 30 to 45 MHz. Its success was immediately evident when, at the first demonstration, the transmissions reached well beyond the anticipated service area. Now the important point was that the original design had only two radials; however, when it came to marketing the design the sales engineers reported that they could not persuade potential users that a two-radial antenna, with the two radials looking like a half-wave dipole, could possibly have an omnidirectional radiation pattern. On the classic principle that the customer is always right, George Brown and his colleagues simply added two more radials — and everybody was satisfied."

Pat's conclusion is that all that's required for the ground-plane antenna to function effectively is that the bulk of the horizontal radiation from the radials is cancelled out — and this happens with only two radials. This doesn't prove that four may not be better, but it is an indication that a two-radial ground plane certainly serves the purpose the inventor had in mind!

Separating the two problems

The experiments outlined in **fig. 1** indicate that a radial system is required for a vertical antenna in the vicinity of the earth. They show that a low, but elevated, system of radials is more efficient than a buried system. The data of **fig. 2** point to the same conclusion but indicate that a maximum of only four radials need be used, as opposed to a multiple radial design.

Looking at Dr. Brown's comments with reference to his original design, it is safe to assume that his ground-plane concept envisioned the antenna mounted several wavelengths in the air. The frequency of operation and the need for coverage to the horizon dictated that as great a height as possible be used. Two radials did the job in this special case. Since the antenna was high above the earth, the return currents entered the radials as displacement currents, and the conduction currents in the earth were quite low because of physical separation of earth and antenna.

It seems to me that a ground-plane antenna for VHF and hf use, mounted well above the ground, requires but two radials for good omnidirectional performance. On the other hand, when the base of the antenna is mounted close to the ground, the probability of return currents entering the ground as displacement currents is very high.

Dr. Brown's original work on buried ground radials was done in 1936-37. As Arch Doty, K8FCU, says in his article[2] "Dr. Brown's paper on buried radial wires used with vertical antennas is a true 'classic' work, the excellence of which has established practices in the field ever since. Unfortunately, its very completeness discouraged further research in the area, and the fact that it considered only one of the several possible methods of making artificial ground systems was overlooked."

The Doty, Frey and Mills group and the Christman, Radcliff, Adler, Breakall, and Resnick group have attacked the problem of above-ground radial systems using different methods. The former made physical experiments and conducted ground current measurements using relatively low radials. The latter group employed computer-modeling techniques and investigated field strength using radials at a greater height above ground. Unfortunately, neither group worked with the same radial configuration. Generally speaking, the broad result of both investigative groups was that elevated radials were superior to buried ones.

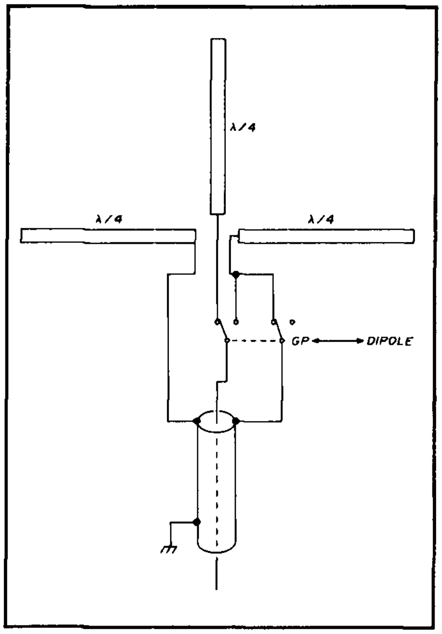
The first group indicated that 50 elevated radials, at least 0.2 wavelength long and about 6.5 feet above ground, are as effective as 120 buried uninsulated wires. The second group indicated that four radials, about 6 to 8 meters above ground and 0.25 wavelength long, "produce more groundwave field strength" than 120 buried radials. The first group measured the distribution of ground return currents. The second group examined the radiated field strength by computer. That study indicated that there was very little improvement going from four to 120 above-ground radials.

It remains for future experimenters to study the elevated radial situation. Perhaps a compromise can be found that produces good results with a minimum number of low radials.

A ground-plane dipole combination

The concept of using only two radials for a ground-plane antenna leads to the idea of a remote switching scheme like that shown in **fig. 4**. This will permit the operator to switch from the elevated ground plane (vertical polarization) to a dipole (horizontal polarization) from the operating position. It might provide an answer to the ongoing question: which performs best, a dipole or a ground-plane antenna?

FIGURE 4



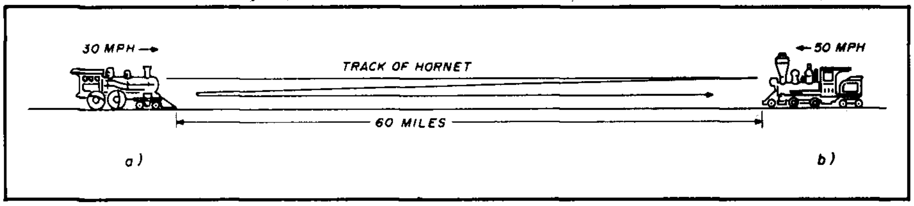
Remote double-pole double-throw relay switches from ground plane to dipole antenna.

The "Dead Band" Quiz

Here's an age-old problem for the mathematics buff (see **fig. 5**). Engine A and engine B are on the same track on a collision course. They are 60 miles apart. Engine A is going 30 miles per hour and engine B is going 50 miles per hour.

A fast hornet starts on engine A and flies to engine B, back to engine A, back to engine B, and so on. Eventually the hornet is killed when the two engines collide. The hornet flies at 400 miles per hour. Neglecting the turn-around time of the hornet, wind, and other minor delays, how many miles does the hornet fly before it's killed in the collision?

FIGURE 5



Engine and hornet problem is this month's quiz.

Send me your answer to this problem. My address is Box 7508, Menlo Park, California 94025. The calls of the math buffs who provide the most persuasive solution to this puzzle will be given in this column.

References

1. Christman, et al, "Vertical Monopoles With Elevated Ground Systems," Proceedings of the Third Annual Review of Progress in Applied Computational Electromagnetics, Naval Postgraduate School, Monterey, California, March 1987.

2. Arch Doty, "Antenna Efficiency. Is a Ground the Best Ground?" Bulletin, Radio Club of America, November 1982.

3. Doty, Frey, and Mills, "Efficient Ground Systems for Vertical Antennas," *QST*, February 1983, page 20-25.

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