Added Gain Using Vertical Antennas

H. W. Kasper, K2GAL*
NAS, Lakehurst, N. J.

Did you know that a single vertical antenna has 3 db gain? Better yet, you can get 6 or 9 db gain by stacking them!

It is a well known fact that the radiation pattern of a quarter wave vertical operating against ground can be calculated by assuming the existence of an image antenna. The resulting structure as shown in fig. 1A is identical to a dipole antenna. Theoretically the radiation patterns are identical, but in practise the lower half of the figure eight pattern does not exist. Likewise, the field along the ground is not maximum, but drops considerably in magnitude depending on the extent and composition of the ground plane. (see figure 1B.)

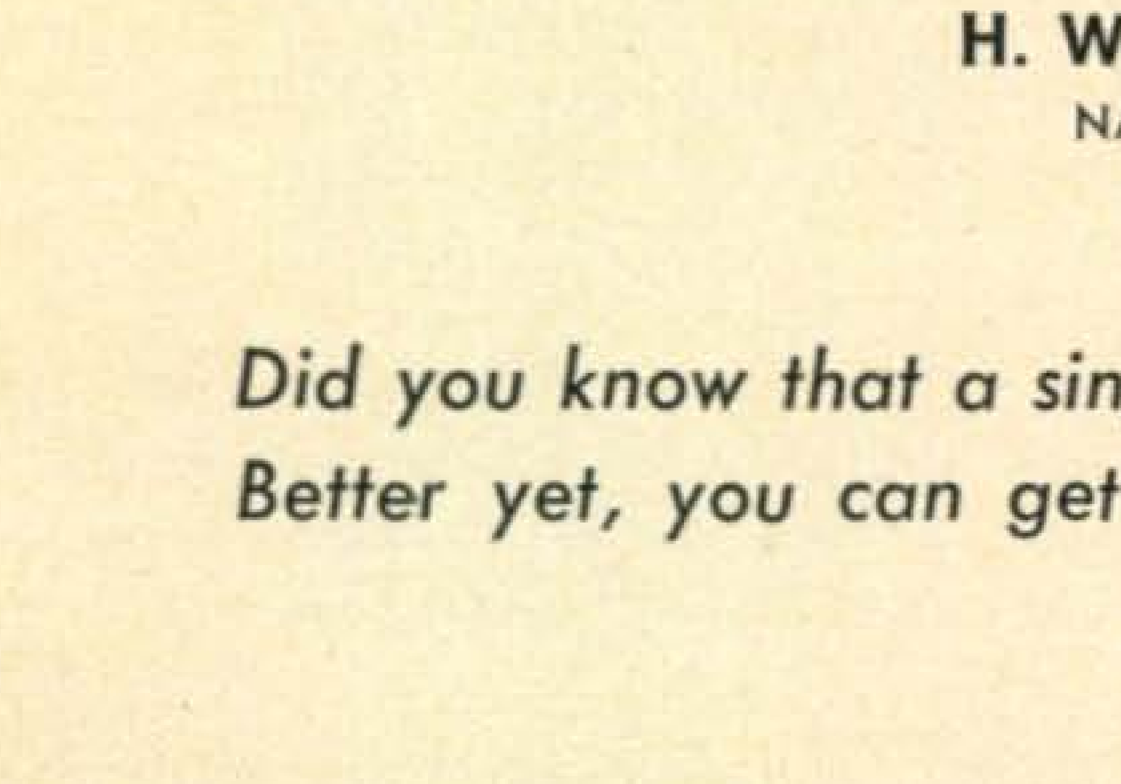

Fig. 1A—Theoretical field pattern for a ¼ wave vertical. Note that the addition of the image results in a dipole structure and pattern. Arrows show current flow.

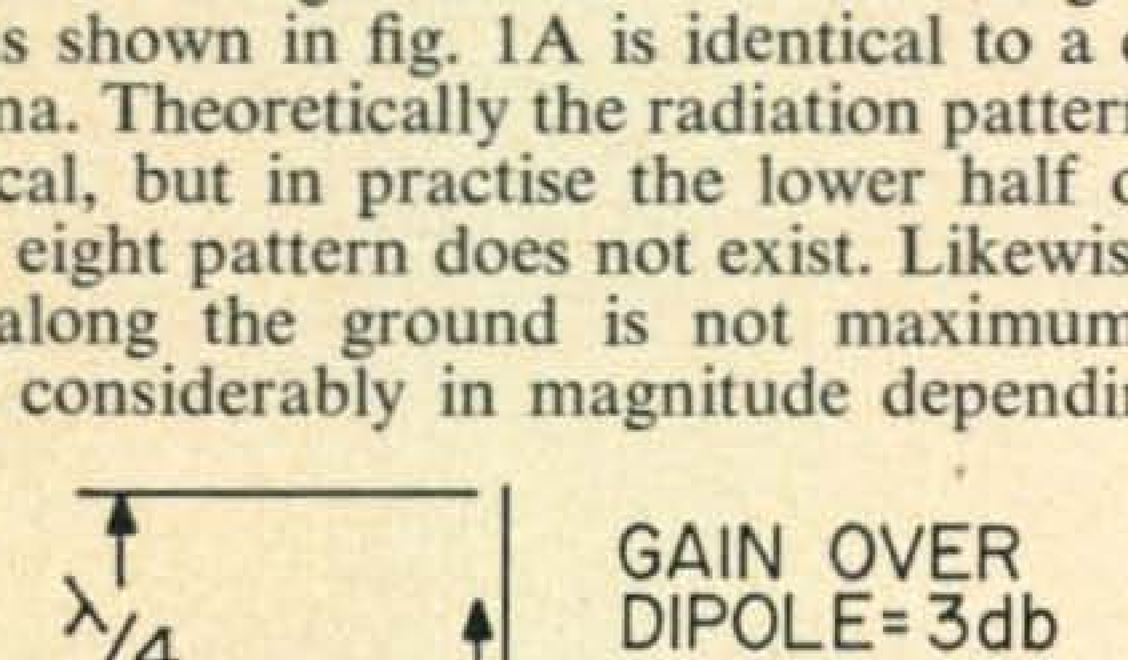

Fig. 1B—Effect of imperfect ground on the radiation pattern.

Less well known is the fact that the quarter wave vertical exhibits 3 *db* more gain than the dipole. The gain of an antenna is a function of its radiation pattern and in general the sharper the pattern (smaller the beamwidth), the higher the gain. For the quarter wave vertical it can be shown mathematically[1] that since the lower half of the radiation pattern (as shown in fig. 1), does not exist,[2] the gain must increase over that of a dipole by 3 *db*.

Why Vertical?

The 3 *db* increase in gain over that of a dipole is only one of the reasons why properly adjusted verticals perform so well, and in some cases outperform even a three element yagi. There are two other factors that play an important part in gaining this advantage; angle of maximum radiation, and polarization. For horizontal polarization at h.f., the angle of maximum radiation is a function of antenna height over ground. This effect is not as severe for vertical polarization except as noted in fig. 1B. The choice of polarization when selecting an antenna is an important point. Experiments have shown[3] that around 16 *mc*, the dominant polarization of downcoming waves is vertical and most of the waves have an angle of arrival centered about 8° and 15°.

The preceding paragraphs offer convincing reasons why a vertical antenna should be used. Mechanical ease and low cost considerations (or other considerations, if you are planning to build a beer can vertical) are further reasons for choosing a vertical. The purpose of this article is not to sell you on verticals however, but to show how more gain can be had if you are leaning in the vertical direction. (how else?")

*Home address, 96 Maplewood Dr.
Birchwood Pk., Bricktown, N. J.

[1]Kraus, "Antennas", *1950* Edition, p. 16.

[2]Followers of Larson E. Rapp, ("A Compact All Band Antenna", *QST*, April, 1957.) disagree on this point, however they have not unearthed any factual evidence to support their theories as yet.

[3]"Arrival Angle of H. F. Waves", *Wireless Eng.*, Feb., 1956.

Added Gain

As we saw in fig. 1A, good old mother earth helps the vertical form its pattern. Now consider the arrangement shown in fig. 2. Here we have a dipole operating above ground. If the dipole height above ground is such that the center to center spacing between it and its image is about ¾ wavelengths, maximum gain occurs, and the result is an antenna having 6 *db* gain over a reference dipole. Going one step further, an additional 3 *db* of gain can be obtained by adding an additional dipole as shown in fig. 3. Note the resulting low angle of radiation. A pattern pull-in such as shown in fig. 1B can be expected due to imperfect ground. Such an arrangement would be quite attractive for ten meter operation.

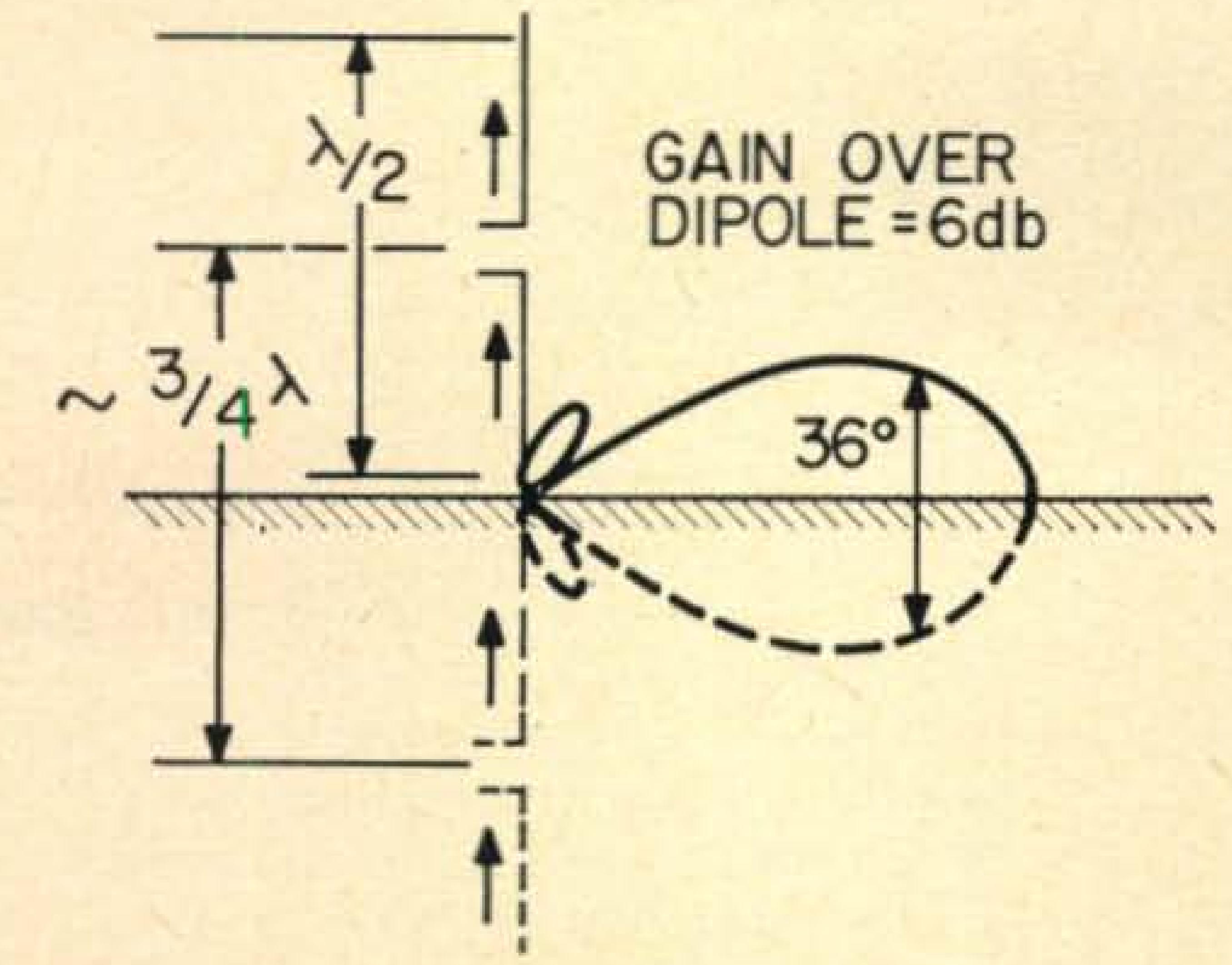

Fig. 2—Radiation pattern for a vertical dipole (half shown).

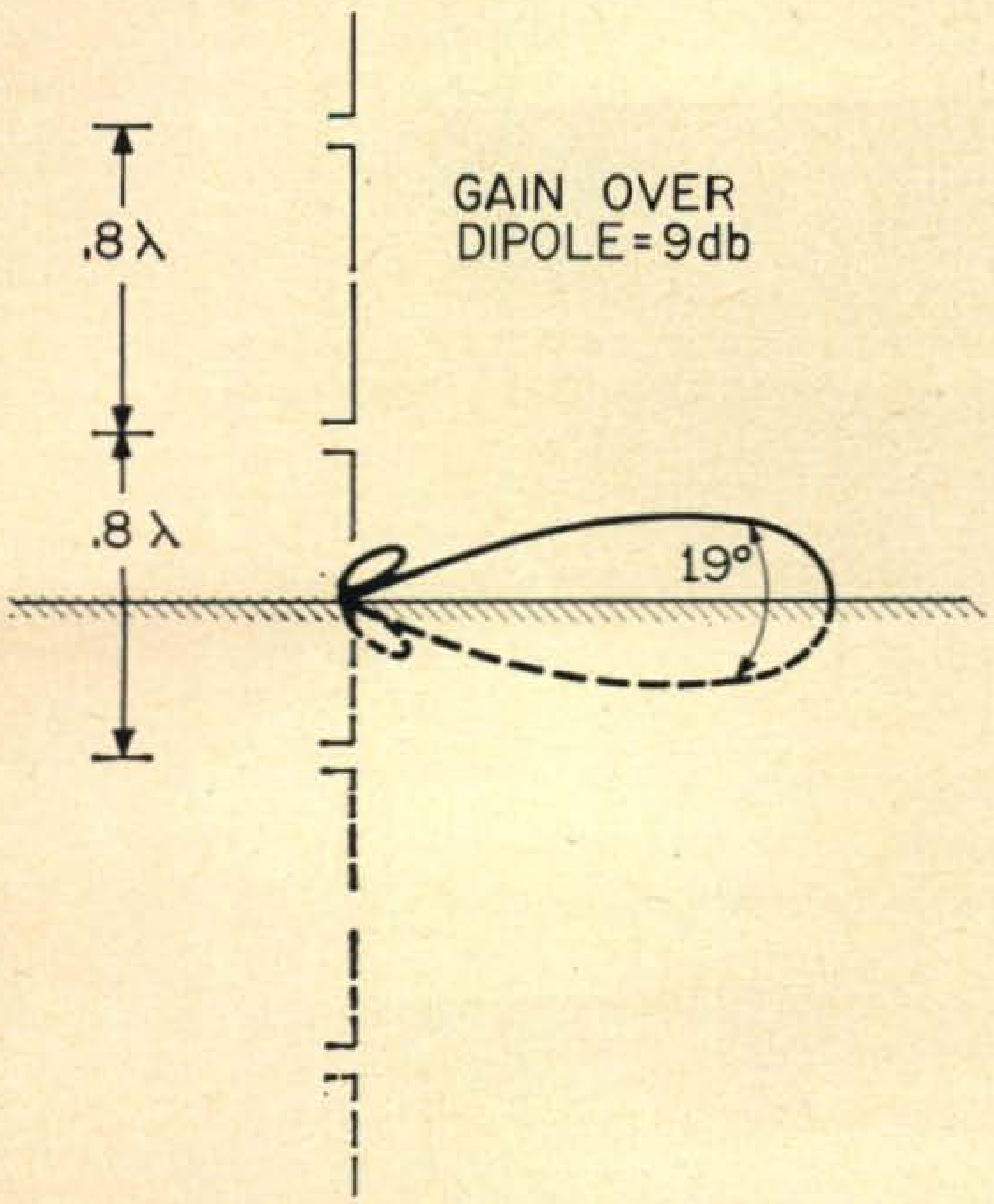

Fig. 3—Radiation pattern for 2 stacked vertical dipoles (half shown).

Impedance Matching

Most of us are familiar with the input resistance curve as a function of height over ground of a horizontal dipole. The resistance increases from zero to 98 ohms, and then follows an oscillatory form tending to the 72 ohm value. Figure 4 shows the input resistance variation of a vertical dipole as a function of height over ground.[4] Note that above a height of ⅜ wavelength, the radiation resistance of a half wave vertical antenna remains quite constant, and darn close to the 72 ohm free space value. This indicates that all the dipoles shown in figs. 2 and 3 should exhibit a radiation resistance close to 72 ohms. The simplest method of feeding the arrays would be to tie two 72 ohm feed lines (any length) in parallel, and connect the tie point to a 52 ohm line. If the resistance of one of the antennas departs considerably from the other, the two should be equalized before tieing to a common feed line, otherwise the antenna having the lower value will receive more power and the over all array gain will be lowered (Since the aperture illumination of the array becomes tapered). Bear in mind that the ground shown in the accompanying figures is perfect ground. Imperfect ground having low conductivity will alter the pattern and gain. The radiation resistance should remain relatively unaffected. Table I illustrates various soil conductivities, and leads one to suspect that living on a houseboat can be fun. ■

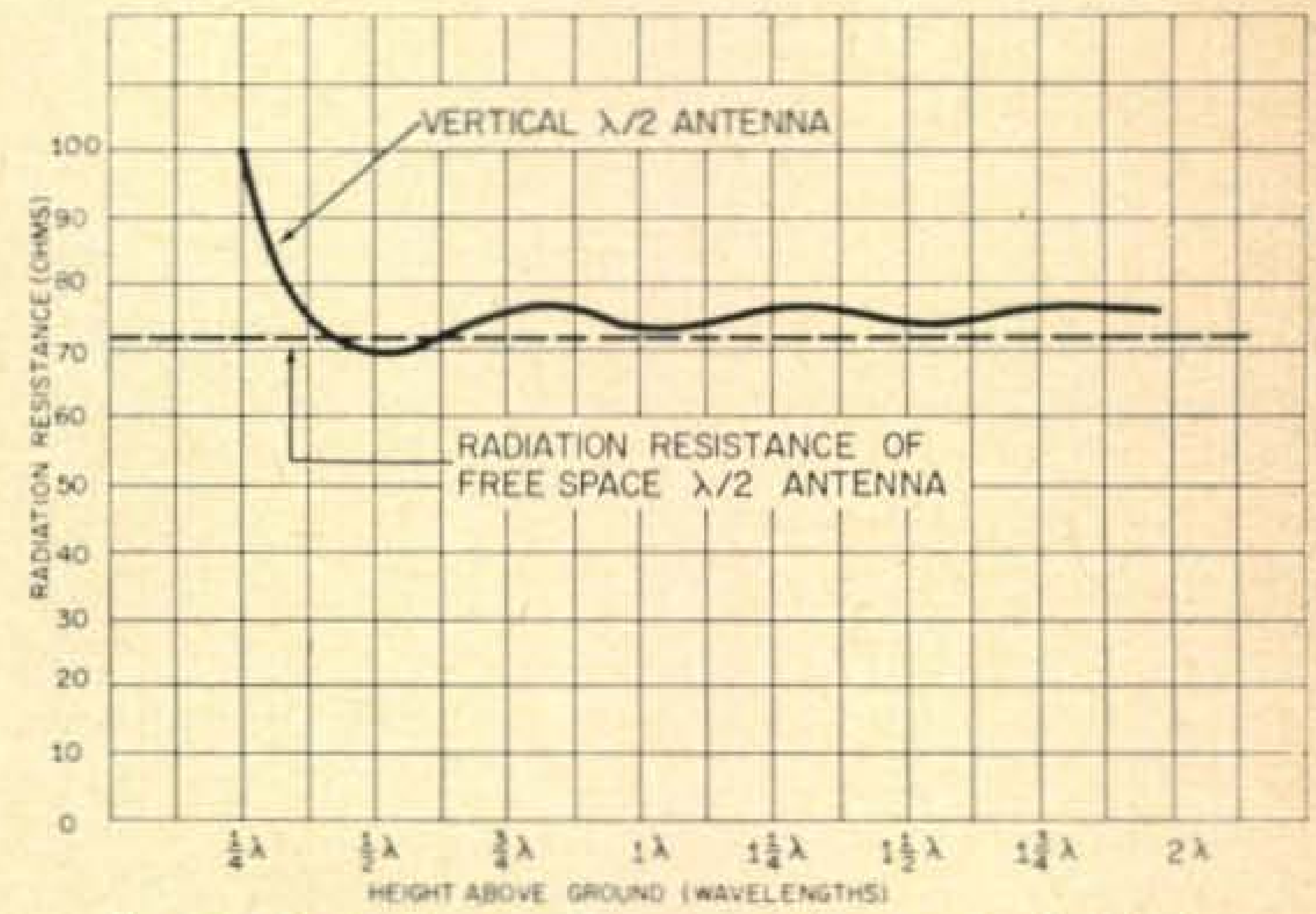

Fig. 4—Radiation resistance of a vertical dipole.

Table I

Ground Material	Relative Conductivity
Sea Water	4,500
Flat rich soil	15
Average flat soil	7
Fresh water lakes	6
Rocky hills	2
Dry, sandy flat soil	2
City, residential area	2
City, industrial area	1
My back yard	0

[4] "Antennas and Radio Propagation", *Dept. of the Army Technical Manual TM 11—666* p. 105.