Ground Systems as a Factor in Antenna Efficiency

Brown, Lewis & Epstein — IRE proceedings June 1937

Abstracted by Walter Maxwell, W2DU (SK)

The renowned Brown, Lewis and Epstein paper, reporting the voluminous and enlightening experimental data concerning the length and number of ground radials required in approaching the condition of perfect ground underneath a vertical radiator. This paper has long been well known and highly respected in the communications engineering community, and since 1938 has become the standard for engineering the radial systems for AM BC stations Worldwide. The FCC requirement for radials in US BC stations is based on data in the BLE paper.

The tragedy here is that BLE paper has gone practically unknown in the amateur community, as witnessed by so many continual questions and incorrect answers concerning the length and number of radials required to achieve the desired performance of our vertical radiators.

So let me present a short, but definitive abstract of the pertinent numbers taken from the paper, that answer some of the pertinent questions correctly.

As a reference on which to base the radiated field strength, the industry standard has traditionally used millivolts per meter to describe field strength. Specifically, the field strength of 194.5 millivolts per meter at one mile, radiated from a quarter-wavelength radiator over perfect ground with 1000 watts input, is the industry standard. In other words, this field strength is the maximum attainable under ideal conditions. The data below, obtained directly from measurements made at 3 MHz by Brown, Lewis and Epstein in 1937, provide definitive answers to those who ask how many radials of what length are necessary to provide a suitable ground plane. When comparing the fields strengths below, remember that 194.5 mv/meter is the field strength obtained with perfect lossless ground.

Number of Radials	Field Strength in mv/meter			Loss in dB Relative to Perfect Ground		
	0.4λ	1/4λ	1/8λ	0.4λ	1/4λ	1/8λ
113	192	180	152	0.112	0.673	2.14
60	185	176	150	0.435	0.868	2.26
30	174	162	150	0.967	1.59	2.26
15	158	153	*	1.81	2.08	*
2	126	120	118	3.77	4.19	4.39

** Values not discernible on charts (Figures 30 & 32) of BL&E's study.*

When reviewing these data, please keep in mind that as the field strength approaches 194.5 mv/meter the effective ground is approaching perfect ground, which means that the conductivity of the ground in which the radials are planted is irrelevant, only the ground external to the radial system is relevant with respect to conductivity.

It should also be kept in mind that the energy in the EM fields surrounding the vertical radiator diminishes with distance from the radiator. Thus the displacement currents entering the ground diminish proportionately with distance. Consequently, there is a distance from the radiator after which the currents become too small to be significant to the conservation of power radiated. This fact determines the maximum length of the radials necessary to reach the point where the law of diminishing returns prevails. The measurements reported in the BLE paper show this distance to be between 0.4 and 0.5 wavelengths. As noted above, this distance is relative to the amount of energy in the displacement currents at this distance from the radiator, and is in no way relevant to any resonant length of the radial. It is well known that radials buried in the ground lose all sense of resonance.

Walt, W2DU