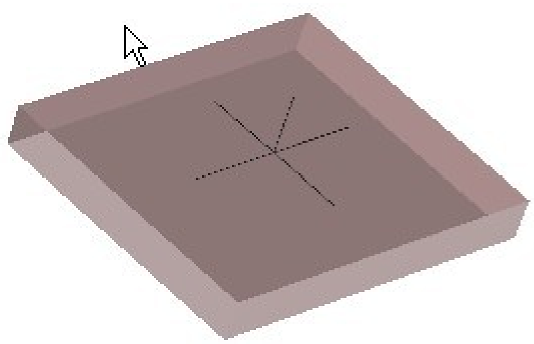
Comparison of FDTD Maxwell Equation Simulations for Ground Losses for λ/4 Vertical Antenna with Different Numbers of λ/4 Radials (< = 4) plus a Ground Plane, Different Radial Heights and Different Ground Parameters.

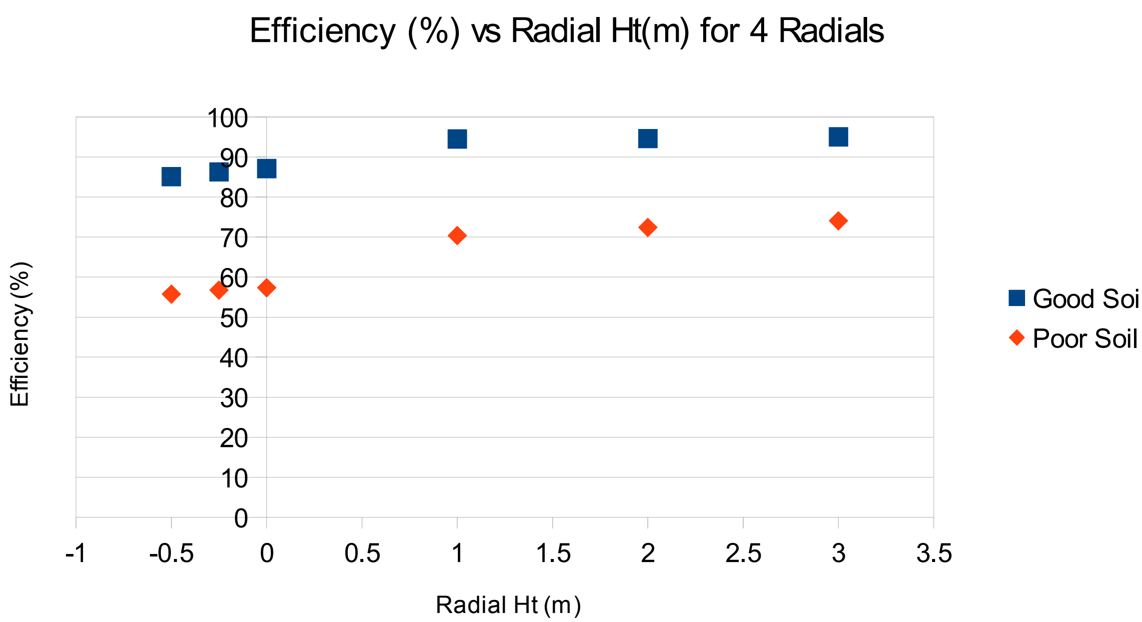
The MAGIC [Orbital ATK] code solves Maxwell's equations using a finite difference time domain method over a gridded region. Aside from (sometimes important) limitations in grid size and resolution, there are no approximations including for the ground effects. Here I have used this high end commercial code to look at ground losses for various conditions to get a measure of the antenna efficiency. This ignores questions of antenna impedance (which can always be matched, somehow) and radiation pattern details (which depend on ground properties beyond the region being simulated).

All cases are at 3.5 MHz (wavelength, λ, of ~ 86 meters), although everything scales to other frequencies, provided the conductivity and dielectric constant are independent of frequency. The antenna and radials are all λ/4 long, the one ground plane case is λ/4 X λ/4 in area and the antenna and radials "wires" are 1/4 m square. (Smaller is not possible due to limit on number of cells.) The gridded volume has ground 15 meters deep, air (really vacuum) 50 meters above ground and with full lateral dimensions of 78 meters. The basic case is 4 radials on the ground as pictured below. More than 4 radials is not practical for the Cartesian geometry used. The boundary conditions on all six sides have been artfully set up to provide minimal reflections.



The results will be expressed as efficiency (Power Input-Power Loss)/(Power Input), where the Power Loss is the sum of ohmic losses in the ground and the power transmitted through the five ground boundaries. Note that this power transmitted through the ground boundaries would result in distant ohmic losses if we were able to use a larger grid. We expect that the efficiency values will be upper bounds but the trends should be reasonable.

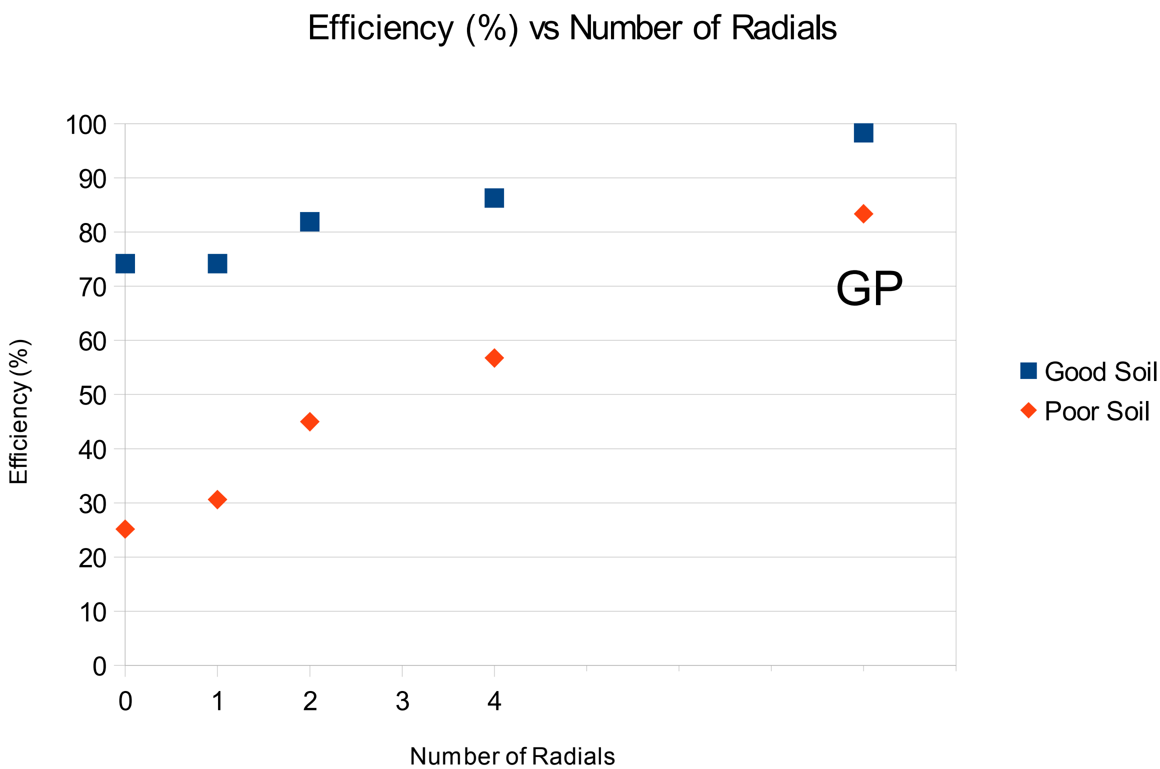
First, and most important, we look at variation with height of radials for two different sets of ground parameters. The radial heights relative to the ground surface at the bottom of (1/4 m square) radials are -1/2, -1/4, 0, 1, 2 and 3 meters. The radials at -1/2 are fully buried, the radials at -1/4 have an upper surface exactly at round level. The ground parameters used are Poor-ish soil "Dry Sandy" with σ=.002 S/m and ε = 10, and "Very Good-ish" with σ=.03 and ε = 10. One of these are slightly different from conventional choices for historical reasons not worthy of discussion.



The results are evident and not too surprising: Good ground is rather better than Poor ground. Elevated radials are rather better than on/in ground radials, especially for poor ground.

Next we look at variation with the number of radials for the two sets of ground parameters. A ground plane is included only for the high conductivity case but it should not be much different for the low conductivity case. For the case of no radials, a 2 meter conducting post was used just under the ground to feed against the antenna. Based on discussions for the final example later, this post may not be playing a significant role.

The plot below includes the same points for 4 radials as before. The ground plane case (GP) would, of course, be off scale to the right equivalent to infinite radials but is plotted at eight for clarity. As expected, the efficiency decreases for fewer radials but with good ground conductivity, the performance remains respectable. Note that the ground plane used here does not cover all the ground so there remains some ground loss that is not trivial for the low conductivity case.



Finally, we consider the case of a vertical over salt water (σ=5 and ε = 80) for 4 radials, no radials but with a 2 meter post under the antenna and finally for no radials with no post. (Of course, in reality some sort of connection would be needed for the coax braid.)

The result is not interesting to plot because in all three cases there are no significant ground (i.e., salt water) losses. This certainly suggests the use of a vertical over salt water as a very good antenna, in spite of the fact that salt water is far from a perfect conductor. However, there are very practical considerations of this use due to the little matter of tides, not to mention the need to keep the vertical vertical.