Accurate Closed-Form Solution of Vertical Dipoles above a Semi-Infinite Ground

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Using the induced EMF method, the input impedance of a vertical antenna in *homogeneous free-space* can be obtained in closed-form in terms of Sine and Cosine integrals. In doing this, the induced EMF method assumes a sinusoidal current distribution along the vertical dipole and uses the free-space potential Green's function expressed as a spherical wave.

This paper extends the use of the induced EMF method for vertical antennas *above a Semi-infinite ground*. To do this, we must first obtain a spherical-wave representation of the half-space potential Green's function. This is done using the simulated complex image technique which was introduced to model microstrip and multilayered structures (R. M. Shubair, *Proc. IEEE AP-S*, 838-841, 2001). Using this technique here allows us to model the effect of the lower dielectric half-space by introducing a finite set of simulated image antennas. The result is an equivalent problem in which the lower dielectric half-space has been replaced with free-space so that the simulated image antennas form a simulated image array located in homogeneous free-space. The derivation of this simulated image array allows for the use of induced EMF method to calculate the input impedance of the original vertical antenna. This results in a *closed-form expression* which represents the superposition of the antenna's self-impedance, and the mutual impedances due to the presence of image antennas within the derived simulated image array. It should pointed out that as one simulated image array is found for a given height above the dielectric half-space, then for a different antenna height, say upwards, the image array remains unchanged except that it is bodily translated downwards by the same distance. This means that as the induced EMF method is applied *only once*, then at other heights the convergence is even faster since the simulated image antennas need not to be recalculated.

To verify the accuracy and convergence of method, numerical results are obtained showing the complex coefficients of the simulated image antennas, as well as, the input impedance as a function of height above the dielectric half-space, with or without loss.