MODELING MONOPOLES ON RADIAL-WIRE GROUND SCREENS

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A special version of NEC-3 (NEC-GS) has been developed to model a monopole on a uniform radial-wire ground screen. By taking full advantage of the physical symmetry and excitation symmetry, NEC-GS can model large radial-wire screens in much less cpu time and storage than would be required by NEC-3. Little experimental data is available for comparison, however, so validation has relied on self consistency checks such as convergence and the balance of input power with radiated power. Also, a comparison with an approximation developed by Wait and Pope (1954) has helped to validate both the NEC results and the approximation.

One question in the NEC model was the treatment of the junction of the monopole and the radial wires, where many wires meet with narrow angles of separation. The current at the junction is forced to satisfy Kirchhoff's current law while the derivative of the current at the junction on the monopole above ground (I_+') and the radials below ground (I_-') is made to satisfy the condition

$$\frac{I_+'}{I_-'} = \frac{1}{\varepsilon_g}$$

where

$$\varepsilon_g = \varepsilon_- - j\,\frac{\sigma_-}{\omega\varepsilon_0} \;.$$

This condition on I' was derived for a vertical wire penetrating the interface and its application to the ground screen with a junction at the interface could be questioned.

The most difficulty, however, has been encountered in modeling ground screens floating above the ground. In this case, since all wires are in air, the derivatives of current are forced to be equal for equal wire radii. Apparently, this condition needs refinement when the radials are closely coupled to the ground while the monopole is effectively shielded from the ground. To obtain converged results for ground screens at small height ($\sim 10^{-5}\lambda_0$) above ground, it was necessary to use segment lengths at the junction on the order of the height of the screen above ground, tapering to larger segments away from the junction. This was particularly important for electrically small monopoles and screens (Logan, 1984).

Results for buried ground screens are generally found to be stable with varying segment lengths. For dense, buried ground screens the segments can often be considerably longer than recommended for a wire in the ground since, due to the shielding effect of the screen, the current behaves more like that on a wire in air.

As a check on the solution for a buried ground screen, the computed input impedance of a monopole was compared with that predicted by an approximation developed by Wait and Pope (1954). For this approximation, a current $I_0 \cos(kz)$ is assumed on the monopole. The difference in input impedance (ΔZ) between that of the monopole on the radial-wire screen on real earth and that of the monopole on an infinite perfectly conducting ground is obtained, through application of the compensation theorem, as an integral over the surface. The magnetic field over the ground screen is taken to be that on the perfect ground and the electric field is related to it by a surface impedance for the screen and ground. A derivation of this approximation and computed results are included in Wait (1969).

This approximation should be accurate for a screen radius in wavelengths (b/λ) somewhat greater than δ where

$$\delta = |\varepsilon_g|^{-1/2} \quad .$$

Also, the number of wires in the ground screen must be sufficiently large for the surface impedance approximation to be valid.

The ΔZ computed by the NEC-GS is compared with that from the approximation in Figs. 1 through 3. The input impedance computed by NEC-GS for the monopole on an infinite perfectly conducting ground was 38.6 + j22.2 ohms. Agreement in ΔZ is generally good for b/λ greater than δ. The larger discrepancies for 20 radials may be due to inaccuracy of the surface impedance approximation for a sparse screen. For the low conductivity ground of Fig. 3, the discrepancies are due to standing waves on the screen wires which are not taken into account by the approximation. This comparison seems to support the accuracy of the NEC-GS results since the agreement is best for a dense screen and highly conducting ground for which the approximation should be most accurate and the method-of-moments solution more difficult.

On screens above ground, large standing waves can exist for any range of earth conductivity. Hence the surface impedance approximation is not accurate for screens above ground.

Results obtained with NEC-GS show that it can be a useful tool for modeling radial wire ground screens. Caution is called for in applying it, however, until it is more fully validated. Screens of small radius are a particular problem since the surface impedance approximation fails as a check.

REFERENCES

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3. Wait, J. R. (1969), "Characteristics of Antennas Over Lossy Earth," Antenna Theory: Part II, ed. R. E. Collin and F. J. Zucker (New York: McGraw-Hill Book Co., Inc., 1969), Chapter 23.

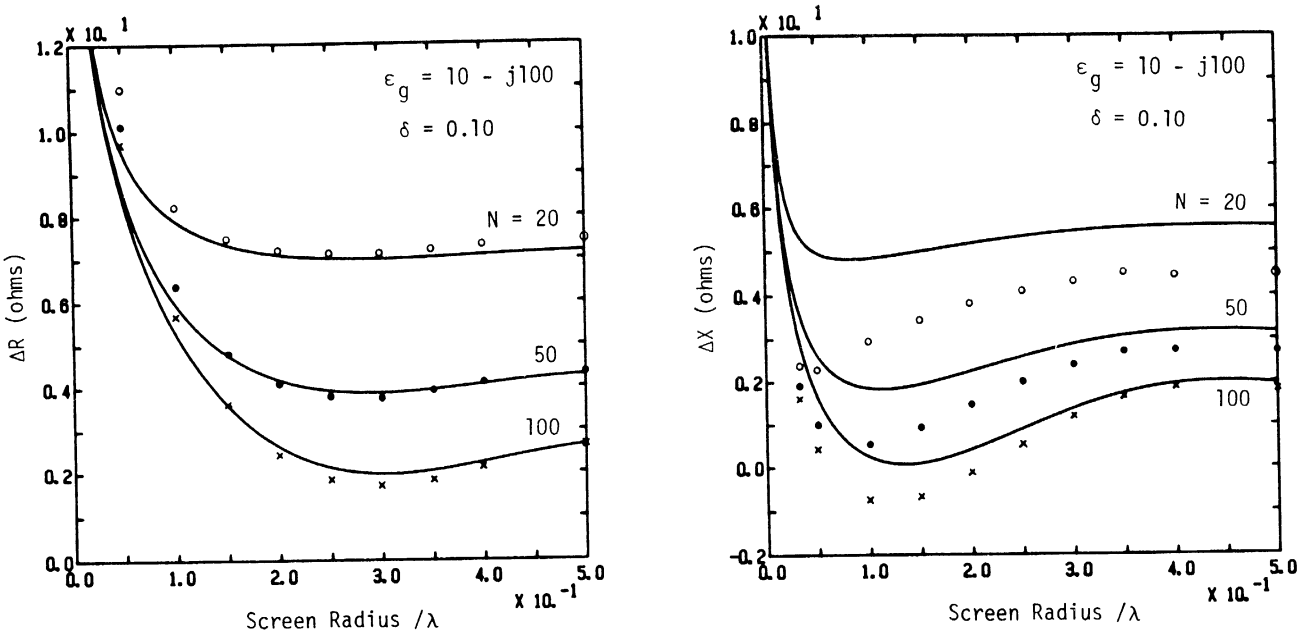

Figure 1. Impedance change ($\Delta R + j\Delta X$) for a 0.25 λ monopole on a ground screen of N radial wires with $\varepsilon_g = 10 - j100$. Symbols (o • x) represent the NEC solution for 20, 50, and 100 radials, respectively. Solid lines are from the approximation of Wait and Pope (1954).

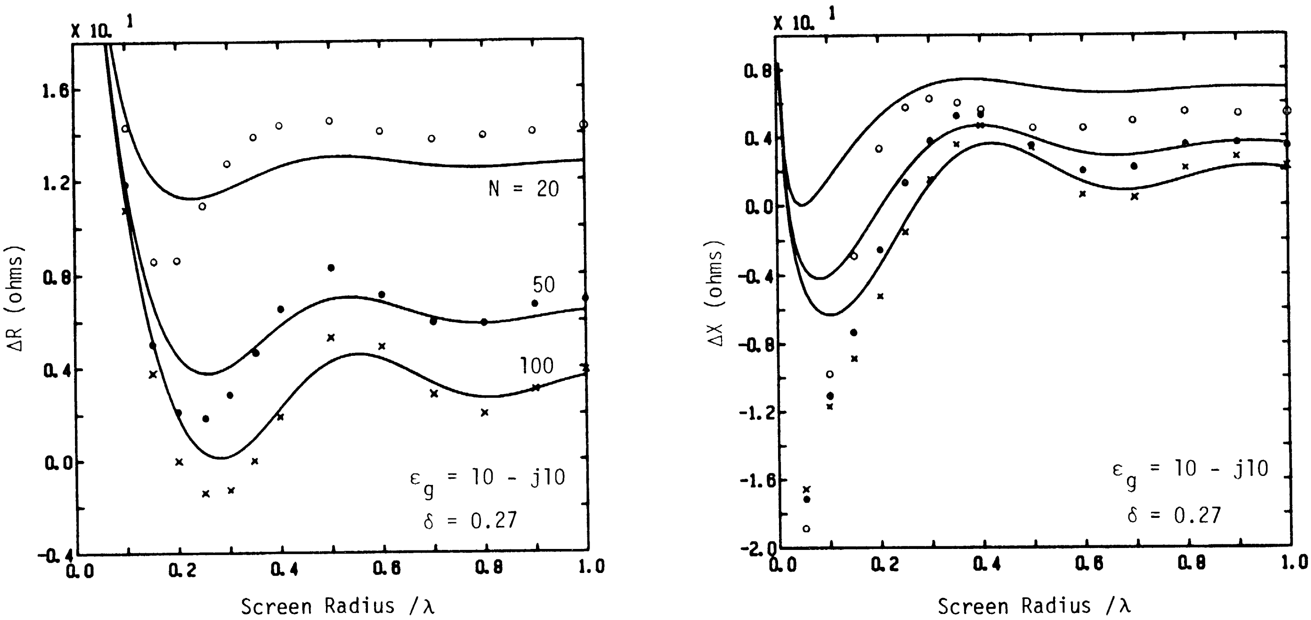

Figure 2. Impedance change ($\Delta R + j\Delta X$) for a 0.25 λ monopole on a ground screen of N radial wires with $\varepsilon_g = 10 - j10$.

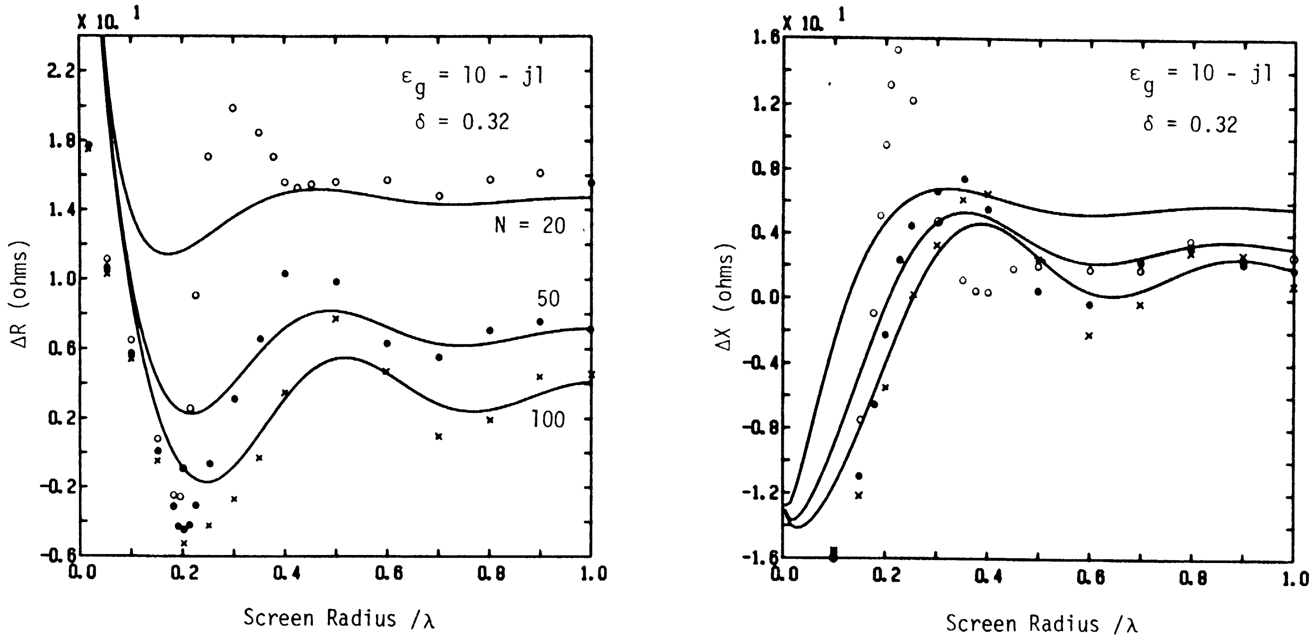

Figure 3. Impedance change ($\Delta R + j\Delta X$) for a 0.25 λ monopole on a ground screen of N radial wires with $\varepsilon_g = 10 - j1$. With low ground conductivity,[8] a large standing wave can exist on the radials that is included in the NEC solution but not in the surface impedance approximation.

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