ANALYSIS AND DESIGN OF WIRE ANTENNAS NEAR A PERFECTLY CONDUCTING ELLIPTIC CONE

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ABSTRACT

Analysis and design of wire antennas near a perfectly conducting elliptic cone is presented. The field is derived as the summation of the direct and scattered field. The tip diffraction is not taken into account and a discontinuity appears in the field. Several examples giving useful results for the tip diffraction and the areas for which the scattered field is "less tip diffraction dependent" are presented. The Hybrid GTD-MoM Technique is applied to analyze arrays of wire dipoles in the vicinity of the surface of the cone. The elements of the arrays are positioned at the areas where the tip diffraction does not affect their performance. Examples for the mutual and self-impedance show the applicability of the technique.

INTRODUCTION

Scattering of the EM radiation from the surface of a perfectly conducting elliptic cone has been given in the past [1]-[6]. Most of the studies were based on the analytical solution of Maxwell equations which usually show divergence in their results.

High Frequency Techniques like GTD is another choice for the solution of the problem, [7]-[8]. In this work an attempt is made to study arrays of wire dipoles in the vicinity of the surface of an elliptic cone via the GTD-MoM Technique. The total field scattered by the cone is calculated as the summation of the incident, the reflected and the diffracted fields. The shadow regions, the reflection points and the diffraction mechanism were rigorously studied and relevant parameters such as geodesics of the cone, torsion of these geodesics and ray–fixed vectors were derived. Since the tip diffraction is omitted discontinuities appear in the fields when the tip contributes strongly to the total field. Areas characterized as "less tip diffraction dependent" were found. In these cases the drawback of the unknown tip diffraction coefficients has been overcome and it is proved that the Hybrid Technique can give reasonable results.

FORMULATION

The far field produced from an array in the vicinity of the elliptic cone is the summation of the field produced directly from the array and the field scattered from the surface of the cone. In order to define the parameters and indices of the array, like input impedance, the current distribution on the elements of the array is of great importance .

This current is contained in the integral equation, that describes the boundary condition for the electric field on the surface of the elements of the array :

$$\frac{1}{j\omega\varepsilon_0}\iiint_V \overline{J}(\overline{r'})[\nabla^2 G(\overline{r},\overline{r'}) + k^2 G(\overline{r},\overline{r'})]dV = -\overline{E}^i(\overline{r}) \tag{1}$$

To find the solution of the above equation, the Hybrid GTD-MoM Technique is applied. The classical MoM is modified by adding perturbation terms, due to the interaction of the array with the nearby elliptic cone. These terms include the diffracted $\overline{E}^d$ and the reflected fields $\overline{E}^r$ which are specified using the GTD.

The unknown current is expanded in suitable basis functions and their amplitude is found by :

$$[I]=[Z]^{-1}[V] \tag{2}$$

The matrices $[Z]$ and $[V]$ are given by:

$$Z_{mn}=\langle \overline{W}_m, \overline{E}_n^i+\overline{E}_n^r+\overline{E}_n^d\rangle \qquad V_m=\langle \overline{W}_m, \overline{E}_m^i+\overline{E}_m^r+\overline{E}_m^d\rangle \tag{3}$$

where the reflected and diffracted fields, via GTD, are presented by :

$$\overline{E}^r(r)=\overline{E}^i(Q_r)\cdot \overline{\overline{R}}\sqrt{\frac{\rho_1^r\rho_2^r}{(\rho_1^r+s)(\rho_2^r+s)}}e^{-jks} \qquad \overline{E}^d(s^d)=\overline{E}^i(Q_d)\cdot \overline{\overline{T}}\sqrt{\frac{\rho^d}{s^d(\rho^d+s^d)}}e^{-jks^d} \tag{4}$$

In above equation $\overline{\overline{R}}$ and $\overline{\overline{T}}$ are relatively the dyadic reflection and diffraction coefficients , ρ_1^r, ρ_2^r are the principal radii of curvature of the reflected wavefront, s is the distance of the observation point from Q_r , ρ^d is the position of the caustic of the diffracted field and s^d is the distance between the observation point and the point of the creeping wave geodesic path from which the ray is transmitted.

The definition of the points of reflection and diffraction on the surface of the cone is based on the Fermat principle. Finally the total field is found by summing the direct, the diffracted and the reflected fields on the surface of the cone.

RESULTS

For comparison reasons the scattering field by using the GTD and the Analytical Method (AM) is presented. The far field (Figs.1c and 1d) of a Hertzian dipole parallel to the cone axis (see Fig.1a) in the xz-plane, has been taken by the AM and GTD correspondingly. The results are in agreement except of the area from 0^o up to $\pm30^o$ about the x axis where the tip diffraction seems to be appreciable. Similar results have been taken for a λ/2 wire dipole (see Fig.1e). A Hertzian dipole normal to the cone axis (Fig. 1b) appears to have a corresponding behaviour. Finally the above dipole positioned parallel to the cone generatrix (Fig.2a) and far from the tip gives approximately similar pattern with the AM and the GTD. Figs. 2b and 2c present the field of a λ/2 dipole positioned 3λ and 10λ far from the tip. The appearance of a lobe in the shadow region comes from the diffracted rays on the surface of the cone. The hybrid GTD-MoM technique has been applied for the dipole given in the previous example. Figs. 3a and 3b present the real and imaginary part of the input impedance of the dipole versus the normal distance from the surface of the cone. As it is expected a variation around the free space impedance appears.

As a last example the mutual impedance of two λ/2 dipoles positioned in an angular distance φ=135^o(Fig. 4a) versus their normal distance from the cone surface is given (see Figs.4b,c). As it is again expected the impedance oscillates similarly with the free space ones. According to the results taken, one can conclude that the elliptic cone scattering field and the antenna characteristics can be estimated using the hybrid GTD-MoM technique.

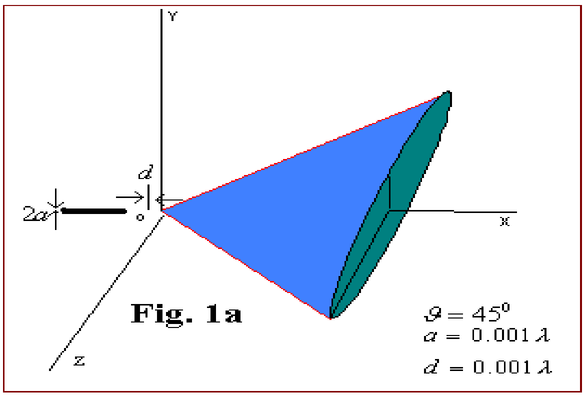

Fig. 1a

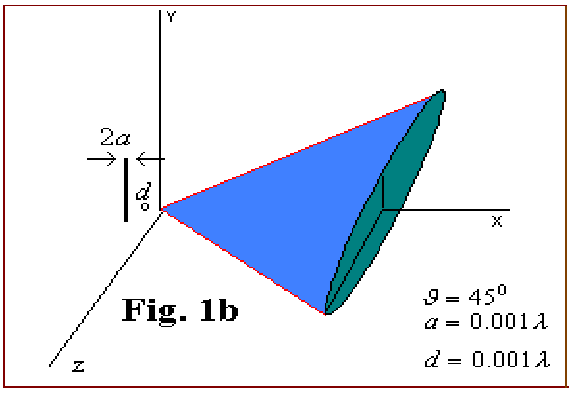

Fig. 1b

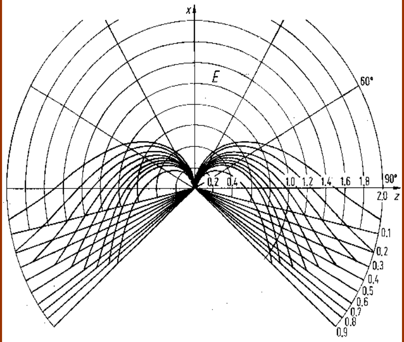

Fig. 1c Far-field pattern(xz-plane) of a small dipole, parallel to x-axis, calculated by analytical method

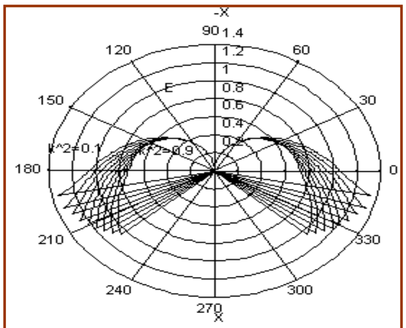

Fig. 1d Far-field pattern(xz-plane) of a small dipole, parallel to x-axis, calculated by GTD

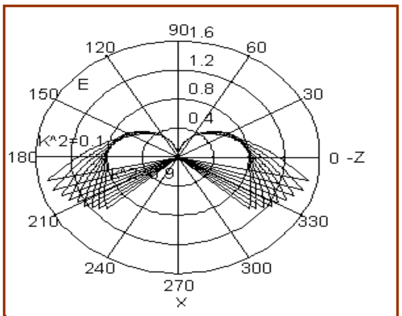

Fig. 1e Far-field pattern (xz-plane) of a half-wavelength dipole parallel to x-axis, calculated by GTD

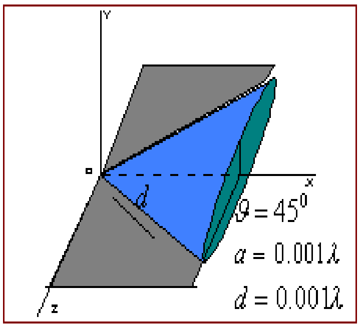

Fig. 2a

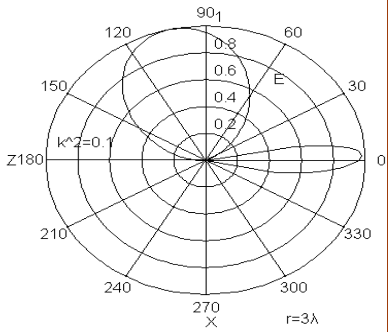

Fig. 2b Far-field pattern(xz-plane) of a half-wavelength dipole, parallel to a generatrix of the cone (distance from the tip r=3 wavelengths)

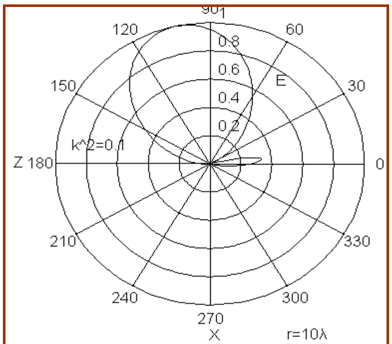

Fig. 2c Far-field pattern (xz-plane) of a half-wavelength dipole, parallel to a generatrix of the cone (disatnce from the tip r=10 wavelengths)

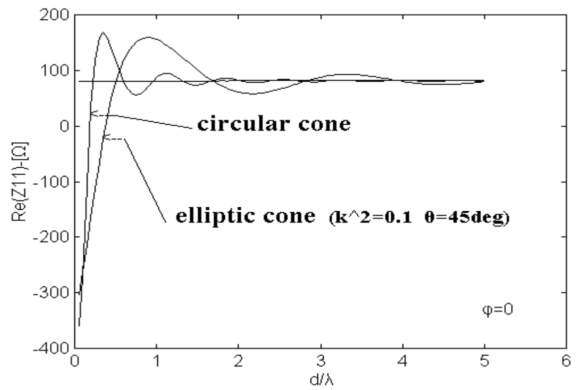

Fig. 3a Variation of the real part of the input impedance of a dipole, parallel to a generatrix of the cone, as a function of its distance from the cone surface.

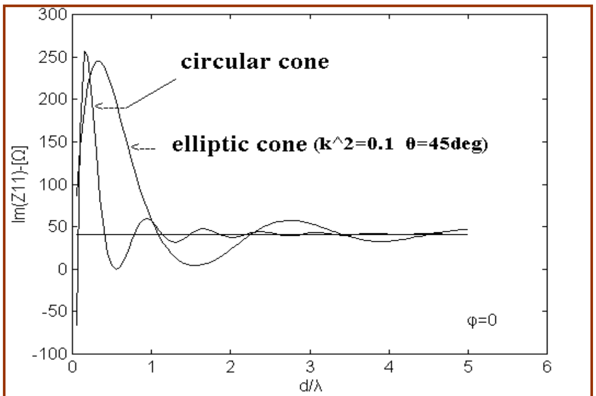

Fig. 3b Variation of the image part of the input impedance of a dipole, parallel to a generatrix of the cone, as a function of its distance from the cone surface.

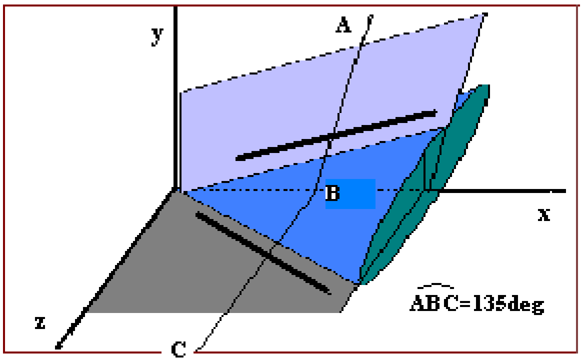

Fig. 4a

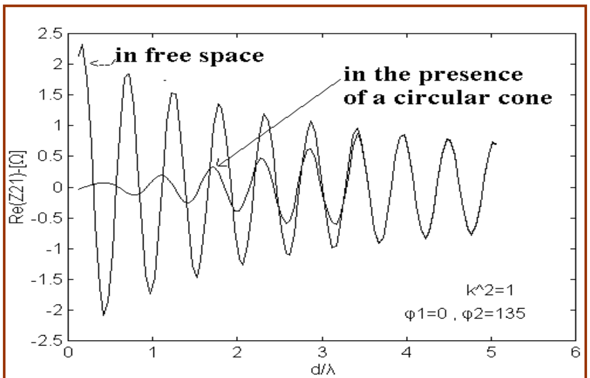

Fig. 4b Variation of the real part of the mutual impedance of two dipoles, parallel to generatrices of the cone, as a function of their distance from the cone surface

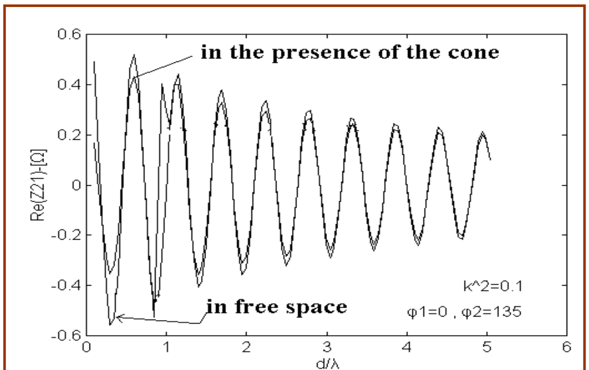

Fig. 4c Variation of the real part of the mutual impedance of two dipoles, parallel to generatrices of the cone, as a function of their distance from the cone surface.

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