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Numerical Analysis of the Near-Field and the Surface Current Density in 3-D Scattering problems

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1. Introduction

Numerical analysis of the near-field and the surface current density on the scatterer surface is a very important task in the field of electromagnetic compatibility, scanning near-field optical microscopy, and antennas technology [1,2].

The objective of this paper is to clarify scattering properties of 3-D perfectly conducting scatterers of arbitrary shape. For such purpose, we calculate the total magnetic field in the near-field region and surface current density on the scatterer surface by using the Yasuura metofd[3,4], and examine the shape and the polarization dependence of such physical quantities. Throughout this paper we keep 3 significant figures on the numerical data.

2. Near-field and surface current density

Let consider a 3-D electromagnetic scattering from a doughnut-like perfectly conducting scatterer whose surface is described by

$$r(\theta,\phi)=a(1+\gamma\sin\theta\cos2\phi)(1+\delta\cos2\theta),\qquad |\gamma|<1,\ -1<\delta\leq 0$$

as shown in Fig.1. A plane wave whose direction of incidence denoted by $(\theta i, \phi i)$ impinges on the scatterer where an angle between the plane of incidence and the incident electric field vector is defined by α.(See Fig.1).

In order to clarify scattering properties of 3-D scatterers, we calculate the near-fields and the surface current densities. First we show the absolute value of the total magnetic field $|H|/|H^i|$ on the surface defined by $((a+D)(1+\gamma\sin\theta\cos2\phi)(1+\delta\cos2\theta),\theta,\phi)$ with respect to D in Fig.2, where ka is the normalized frequency. The direction of incidence is toward the center. Fig.2 represents the total magnetic field by the gray scale in which the deep and the light gray denote high and low intensity, respectively. We find that the field pattern for D greater than 5 λ (λ is a wavelength of the incident wave in the free space) behaves like the far-field;it shows an oscillatory behavior due to the interference between the incident wave and the scattered waves. When we change the observation point from far zone to near one, the deep gray level region gradually reduces itself. This corresponds to the fact that the shadowed side of the incident wave increases as D decreases. Circular stripes in the light gray level outside the deep gray level may show the interference among the creeping waves. Furthermore it is found that the central part of the near- field pattern significantly changes with respect to D and particularly the very near-field depends on the scatterer shape [5,6]. More precisely we can point out this feature in the behavior of surface current density shown in the latter example.

Second we calculate surface current density $|J|/|H^i|$ on the scatterer surface and examine the shape and the polarization dependence of the surface current density. To see the shape dependence of surface current densities, we calculate them for the incident angle(0.0,0.0). First we show the surface current density on the contour of the cross sectional area cut by the y-z plane with $\phi = \pi/2$ in Fig.3(a) and (d). The symmetry of the surface current density with respect to $\theta = 0$ results from the symmetry of the scatterer shape with respect to z-axis in y-z plane. By comparing the first row with the second row in Fig.3 we find the shape dependence of the surface current density such that the surface density on the doughnut-like scatterer abruptly changes across the point $\theta = 0$, while the body of revolution keeps almost the same value around $\theta = 0$. This can be interpreted by the fact that the former scatterer has a convex part around $\theta = 0$ in addition to the concave part, although the latter does not have a convex part there. The comparison of Fig. 2(e) with the first row of Fig.3 indicates the shape dependence of the very near-field. Finally we show the polarization dependence of the surface current density. To examine this we prepare three typical observation planes such as the y-z, x-z planes, and their intermediate plane. The left and right hand sides of the first and second rows correspond to the E- and H-polarization states in the 2-D scattering problem, respectively [7]. The middle column represents a mixed polarization states;they are inherent in 3-D scattering problems. To clearly recognize the polarization dependence, the physical optics surface current density is also shown.

.3. Conclusion

We have calculated near-field patterns and the surface current density of indented 3-D perfectly conducting scatterers using the Yasuura method and discussed their shape and polarization dependence. As a result we have clarified several inherent properties of 3-D scattering problems.

Acknowledgment

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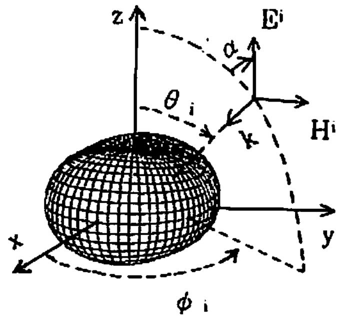

Fig.1 Geometry of doughnut-like scatterer.

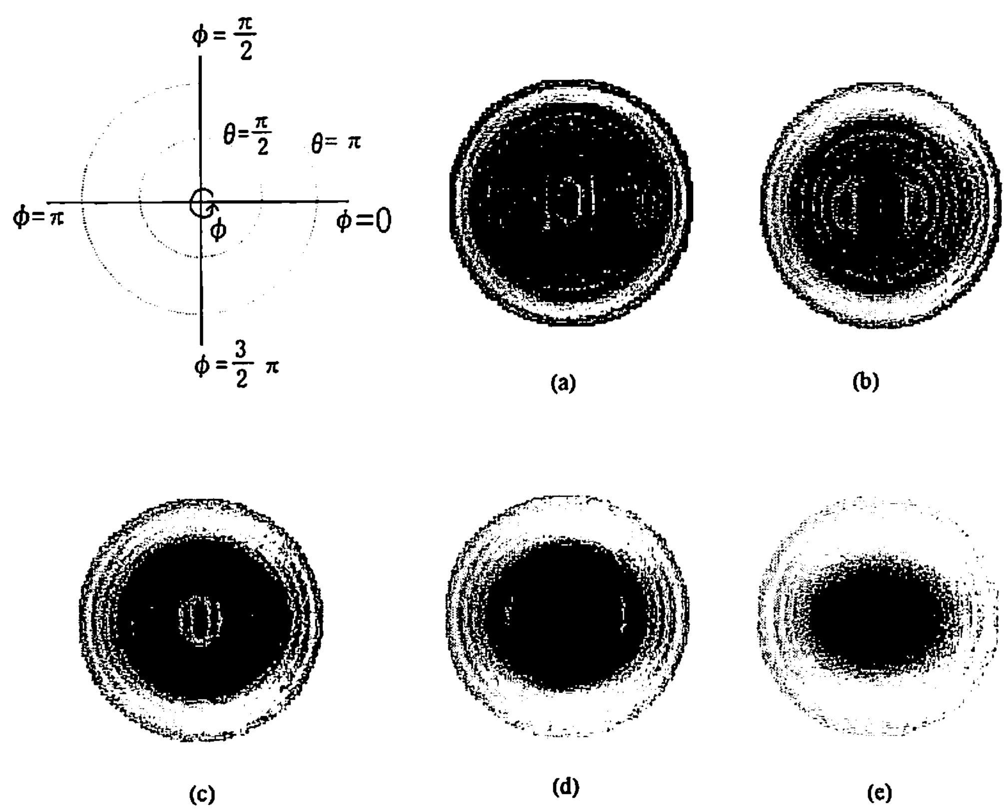

Fig.2 Near-Filed pattern of total magnetic field from doughnut-like scatterer.
($ka=10$, $\theta_i=0$, $\phi_i=0$, $\alpha=0$, $\gamma=0.1$, $\delta=-0.3$)
(a) $D=5\lambda$, (b)$D=2\lambda$, (c)$D=1\lambda$, (d)$D=0.5\lambda$, (e)$D=0.1\lambda$

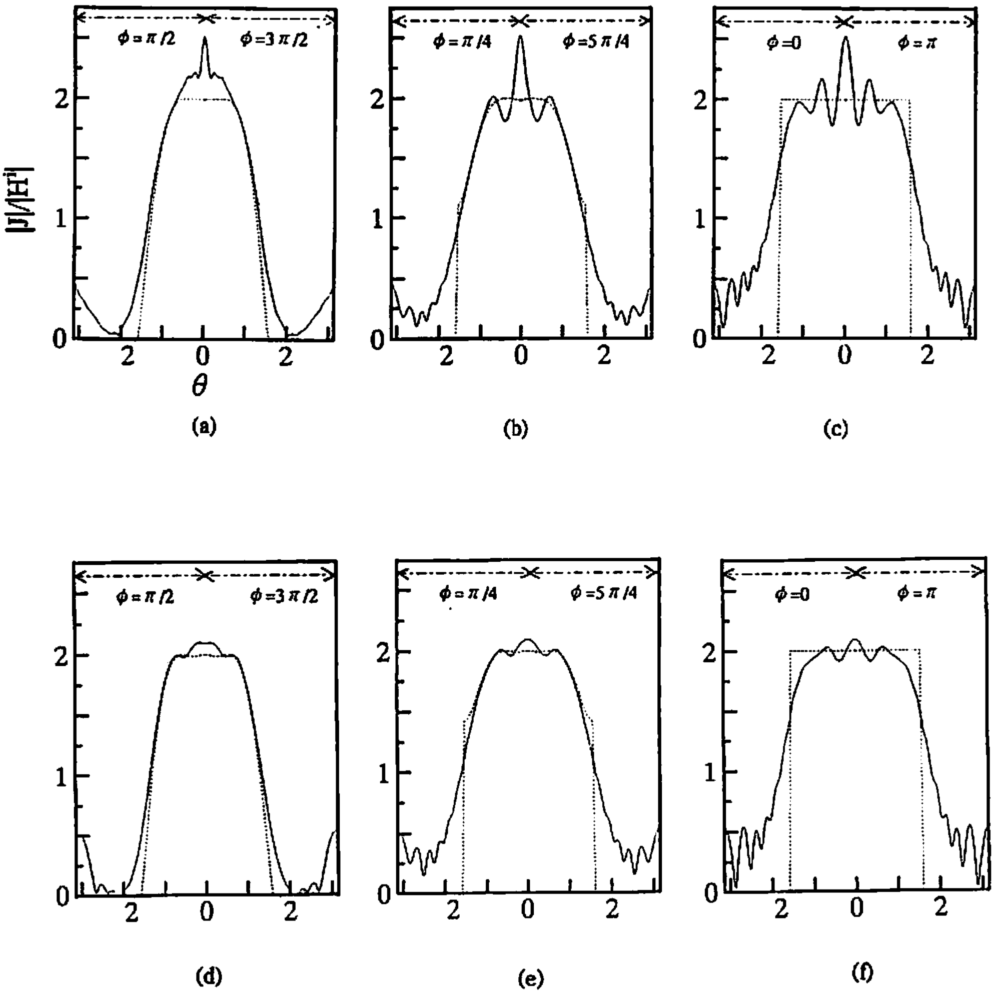

Fig.3 Surface current density. (ka=10, θ_i =0, ϕ_i =0, α =0)
(a),(b),(c) Doughnut–like scatterer (γ =0.1, δ =−0.3)
(d),(e),(f) Doughnut–like body of revolution (γ =0, δ =−0.3)
-----:Physical optics surface current density