INTRODUCTION

The scattered field from a conducting cylinder with impedance load has been studied by several authors. Short and Chen [1] have derived the exact solution of the TE-scattering from an impedance loaded slotted circular cylinder. Lee [2] and Aas [3] have investigated the scattering from two-dimensional wing profiles loaded by impedance strips by using a combination of the half-plane solution and the method of moments (MoM) for TE and TM polarization, respectively. Alexopoulos and Tadler [4] have investigated the scattering from an elliptic cylinder loaded by surface impedances by using Galerkin's method. Mautz, Yuan and Harrington [5] have calculated the scattering from a slotted TM cylindrical conductor by using the pseudo-image method. In this paper, the problem of electromagnetic scattering from a large convex conducting cylinder with arbitrary cross section loaded by multiple surface impedances is considered. The problem is based on a reaction integral equation formulation, and solved by a hybrid method combining the Fock theory and MoM in conjunction with the Leontovich impedance boundary condition. As an example, some numerical results for an infinitely long circular cylinder loaded by multiple surface impedances illuminated by a circular polarized plane wave are presented, and the reduction of backscattering over wide angles is performed.

MODELLING AND FORMULATION

The geometry of a large convex conducting cylinder with arbitrary cross section loaded by multiple surface impedances is shown in Fig.1(a). Consider two most important cases, i.e. plane wave incidences of TM and TE linear polarizations, since the scattered field for the arbitrarily polarized incidence may be represented as the resultant of these two incidences. The normalized incident field for a left or right circular polarized plane wave at an arbitrary angle \( \phi \) is represented as

\[
\hat{E}^i = (\hat{z} + j \hat{\phi}) \exp[jk(x \cos \phi + y \sin \phi)]/\sqrt{2},
\]

where \( k \) is wave number in free space. A time dependence of \( \exp(j \omega t) \) is omitted.

In the manner of Ref. [3], we can derive the reaction integral equation formulation of the problem from the equivalence principle, the reciprocity theorem, and the Leontovich impedance boundary condition:

\[
\frac{1}{4} k n \int_{\Sigma} J_{sz}(\vec{\beta}') [H_0^{(2)}(k|\vec{\beta}' - \vec{\beta}_t|) + jZ_s(\vec{\beta}') \cos(n,\vec{\beta}' - \vec{\beta}_t)] \hat{E}_z(\vec{\beta}_t) \, d\Sigma = E^i_z(\vec{\beta}_t) \quad \text{for TM incidence}
\]

or

\[
\frac{1}{4} k n \int_{\Sigma} J_{sz}(\vec{\beta}') [H_0^{(2)}(k|\vec{\beta}' - \vec{\beta}_t|) + jZ_s(\vec{\beta}') \cos(n,\vec{\beta}' - \vec{\beta}_t)] \hat{H}_z(\vec{\beta}_t) \, d\Sigma = H^i_z(\vec{\beta}_t) \quad \text{for TE incidence}
\]
c for TE incidence (lb)

where $p_t$ and $p_i$ are the redial-vectors from the origin to the test source (an electric or magnetic line source here) inside and to the equivalent source point on the contour of the cross section, respectively; $n$ is outward normal vector of the surface; $\eta$ is wave impedance in free space; $H_0^{(2)}$ and $H_1^{(2)}$ are the 0-th and the 1-st order Hankel functions of the second kind, respectively; $Z_s(\hat{\rho}^t)$ is surface impedance normalized to $n$ at point $\hat{\rho}^t$.

The current density $J_{sz}$ or $J_{sc}$ is the unknown under solving. The contour of cross section can be divided into three parts, i.e. the illuminated, transited and shadowed regions $L_i$, $L_t$ and $L_s$, respectively. Loads are assumed to be placed within the $L_i$ region. For both the $L_i$ and $L_t$ regions denoted as MoM region, the current function is difficult to be predicted, thus the subdomain basis functions are used for expanding the unknown. For the $L_s$ region denoted as Fock region, the current function can be predicted from the Fock theory, i.e. be expanded by the Fock-type entire domain basis functions available in Ref.[6]. Since a given point $\vec{Q}$ in the $L_s$ region is at the confluence of two different geodesic paths emanating from the shadowed boundary $\vec{Q}'$ and $\vec{Q}''$ (see Fig.1(b)), a linear combination of the Fock-type basis functions from two diffraction points $\vec{Q}'$ and $\vec{Q}''$ is adopted to make a good approximation. Finally, Eq.(1a) or (1b) can be applied to the same number of test source positions (usually, it is preferable to choose the test sources at the surface) as the number of unknown expansion coefficients. This procedure leads to a matrix equation which can be solved to determine those unknown coefficients, so the unknown surface current $J_{sz}$ or $J_{sc}$ is found. The scattered field at far-field point $\hat{\rho}(\rho,\phi)$ may be calculated for TM or TE incidence by

$$E_z^s(\hat{\rho}) = -k_\eta \frac{e^{-j(k\rho-n\phi/4)}}{\sqrt{8\pi k\rho}} \left[ J_{sz}(\hat{\rho}^t)[1-Z_s(\hat{\rho}^t)\cos(\hat{n},\hat{\rho}^t)]e^{jk(x\cos\phi+y\sin\phi)} \right] dl \quad (2a)$$

or

$$H_z^s(\hat{\rho}) = -jk \frac{e^{-j(k\rho-n\phi/4)}}{\sqrt{8\pi k\rho}} \left[ J_{sc}(\hat{\rho}^t)[\cos(\hat{n},\hat{\rho}^t)-Z_s(\hat{\rho}^t)]e^{jk(x\cos\phi+y\sin\phi)} \right] dl \quad (2b)$$

and the radar scattering width [7] can be calculated by

$$\sigma = \lim_{\rho \to \infty} 2\pi \rho \left[ \frac{|E_z^s|^2}{|E_z^t|^2} \right]. \quad (3)$$

**NUMERICAL EXAMPLES**

As an example, the above hybrid analysis is applied to a circular cylinder with circumference $ka = 10$. For the MoM region, the pulse bases with
colocation technique are employed. In all the subsequent calculations, the width of MoM pulse basis is 0.1λ, and D_t and D_m in Fig.1(b) are chosen to be 0.6λ and 0.05λ so that the satisfactory results are obtained.

To check the accuracy of the results and the validity of the method, the results of hybrid method are compared with those of complete MoM for a loaded conducting circular cylinder, as shown in Fig.2. The agreement between them is good.

Fig.3 represents the ratio of amplitude between TM- and TE-scattering fields for a conducting cylinder loaded by a surface impedance placed at -3.6 ~ 3.6 deg. within the illuminated region. It can be suggested that, the polarization of scattering wave for a circular polarized incidence is not circular but elliptical.

Fig.4 shows the backscattering width of a conducting cylinder with one or more surface impedance loads placed at different regions for a left circular polarized incidence. The reduction of backscattering is achieved over more wide angles for multiple impedance loadings than that for one impedance loading. Since more loading parameters can be selected and adjusted, we possess the considerable freedom in controlling the backscattering of a conducting cylinder.

In order to estimate the effect of different loading parameters on the backscattering width, Fig.5 gives such an example as a cylinder with one fixed and one position varied impedance load illuminated by a left circular polarized plane wave. It is easy to find that, the loading parameter strongly influences the backscattering for different incident angles.

REFERENCES

Fig. 2 Comparison of backscattering widths of a loaded conducting cylinder.

Fig. 3 Ratio of amplitude between TM- and TE-scattering fields for a loaded conducting cylinder.

Fig. 4 Backscattering widths of a conducting cylinder with one or more surface impedance loads (left circular polarized incidence).

Fig. 5 Backscattering widths of a conducting cylinder with two surface impedance loads placed at different positions (left circular polarized incidence).