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ON THE PHYSICAL OPTICS FOR CALCULATING THE SCATTERING MATRIX OF COATED TARGET

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1. Introdution

In recent year, the physical optics (PO) approximation theory has proposed to solve the high-frequency RCS problems. In this paper, the scattering matrix of coated target is studied. A PO formulation with the impedance boundary condition is presented. It is shown that the scattering matrix of such target is symmetric for the monostatic case.

2. Impedance Parameter and Reflection Coefficient

Consider that a plane wave is incident on the surface of target at an angle of incidance θ. It is known that the following impedance condition

$$\mathbf{E}-(\mathbf{n}\cdot\mathbf{E})\mathbf{n}=\eta\,\mathbf{n}\times\mathbf{H} \tag{1}$$

will be held under some conditions. The material coating and the dimension of the convex surface must satisfy certain criteris [1]. The magnitude of the index of refraction, N, is very large and has a large imaginary part. The thickness, d, is less than the principal radii of curvature of the outer surface, and $kd \ll |N|$. The radii of curvature of the surface are large compared to the wavelength. For these conditions, the impedance parameter is given by [2]

$$\eta=-j(\mu/N)\tan(Nkd) \tag{2}$$

If the external medium to be characterized by the constants, $\varepsilon_0=\mu_0=1$, then the surface impedance Z is given by Eq. (2), i. e. , $Z=\eta$. The reflection coeffieient has the following polarization dependence [2]

$$R_{11}=\frac{Z-\cos\theta}{Z+\cos\theta} \tag{3}$$

$$R_{\perp}=\frac{Z-\sec\theta}{Z+\sec\theta} \tag{4}$$

3. Formula for Calculating the Scattering Field

Assume that the polarizations of transmitter and receiver are denoted by e_i and e_r, respectively, and $|e_i|=|e_r|=1$. The incident field and far scattering field are denoted by E^i and E^s. Assume that E^i is given by

$$E^i=|E^i|[(e_i \cdot u_{11})u_{11}+(e_i \cdot u_{\perp})u_{\perp}]\exp[-jk_i \cdot \rho] \tag{5}$$

Then, according to the OP approximation theory, we obtain

$$\begin{aligned} E^s \cdot e_r = & -\frac{j\omega}{4\pi R}|E^i|\exp[-jkR] \\ & \times \int_s \{(1-R_{\perp})(e_i \cdot u_{\perp})[(n\times u_{11}) \cdot e_r \\ & +Z(u_{11} \cdot e_r')-Z(n \cdot u_{11})(n \cdot e_r')] \\ & -(1-R_{11})(e_i \cdot u_{11})[(n\times u_{\perp}) \cdot e_r \\ & +Z(n_{\perp} \cdot e_r')-Z(n \cdot u_{\perp})(n \cdot e_r')]\} \\ & \exp[-jk_i \cdot \rho+jk\rho \cdot R_0]ds \end{aligned} \tag{6}$$

where

$u_{11}\times u_{\perp}=-s$, $\quad u_{11} \cdot u_{\perp}=0$, $\quad |u_{11}|=|u_{\perp}|=1$

$e_r'=R_0\times e_r$, $\quad e_r \cdot R_0=0$

s = unit vector along the incident direction of plane wave

n = unit outward normal to the surface

R_0 = unit vector directed from the target toward the point of observation

4. Scatlering Matrix for the Monostatic Case

Let

$$s=z, \qquad R_0=-z \tag{7}$$

The scattering matrix is denoted as follows:

$$S=\begin{pmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{pmatrix} \tag{8}$$

From Eq. (6), we obtain the following results:

(i) $e_i = y, e_r = y$

$$s_{11} = -A \int_s \{(1-R_\perp)\left(\frac{n \cdot y}{\sin\theta}\right)^2 (\cos\theta - Z) + (1-R_{11})\left(\frac{n \cdot x}{\sin\theta}\right)^2 (\cos\theta - Z\cos^2\theta)\}\Phi ds \tag{9}$$

(ii) $e_i = y, e_r = x$

$$s_{12} = -A \int_s \{(1-R_\perp)\left(\frac{n \cdot x}{\sin\theta}\right)\left(\frac{n \cdot y}{\sin\theta}\right)(\cos\theta - Z) - (1-R_{11})\left(\frac{n \cdot x}{\sin\theta}\right)\left(\frac{n \cdot y}{\sin\theta}\right)(\cos\theta - Z\cos^2\theta)\}\Phi ds \tag{10}$$

(iii) $e_i = x, e_r = y$

$$s_{21} = -A \int_s \{(1-R_\perp)\left(\frac{n \cdot x}{\sin\theta}\right)\left(\frac{n \cdot y}{\sin\theta}\right)(\cos\theta - Z) - (1-R_{11})\left(\frac{n \cdot x}{\sin\theta}\right)\left(\frac{n \cdot y}{\sin\theta}\right)(\cos\theta - Z\cos^2\theta)\}\Phi ds \tag{11}$$

(iv) $e_i = x, e_r = x$

$$s_{22} = -A \int_s \{(1-R_\perp)\left(\frac{n \cdot x}{\sin\theta}\right)^2 (\cos\theta - Z) - (1-R_{11})\left(\frac{n \cdot y}{\sin\theta}\right)^2 (\cos\theta - Z\cos^2\theta)\}\Phi ds \tag{12}$$

where

$$A = \frac{j\omega}{4\pi R} |E^i| \exp[-jkR]$$

From Eqs. (10) and (11), it can be seen that

$$s_{12} = s_{21} \tag{13}$$

Therefore, the scatlering matrix of such target is symmetric for the monostatic case.

5. Example

An numerical example is presented as follows. Assume that the target is an ellipsold of revolution without right crown. The height of crown is 24.6λ. The suface of ellipsold is given by

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{(z-a)^2}{a^2} = 1$$

where $a=24.3\lambda$ and $b=300\lambda$. Let $d=\lambda/8$, $\varepsilon_r=10-j$ and $\mu_r=1$. For the monostatic case, the scattering matrix can be obtained as

$$S=C\begin{pmatrix} 0.2551+0.04523j & 0 \\ 0 & -1.73100-0.24214j \end{pmatrix}$$

where C is a complex number. Note that it is of no importance in the study of polarization characteristics of target.

References

[1] Weston, V. H., Theory of absorbers in scattering, IEEE Trans. on AP, Vol. 11, 1963, p. 578.

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[3] Hill, D. W. and C. C. Cha, Physical optics approximation of the RCS of an impedance surface, IEEE APS, Vol. 1, 1988, pp. 416-419.

[4] Baldauf, J., et al., On physical optics for calculating scattering from coated bodies, J. of EM Waves and Applications, Vol. 5, No. 8, 1989, pp. 725-748.

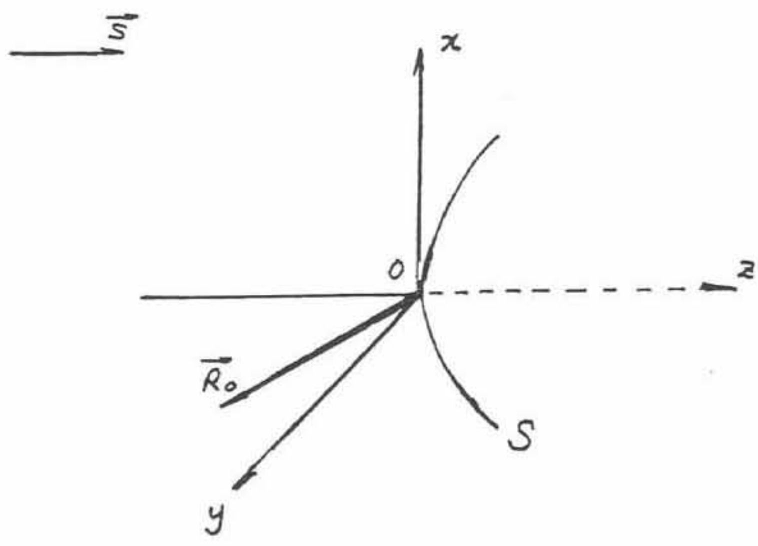

Fig. 1