TWO-DIMENSIONAL TARGET PROFILING BY ELECTROMAGNETIC BACKSCATTERING

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1. INTRODUCTION
This paper discusses two-dimensional iterative profiling method for an arbitrary convex conducting target using the electromagnetic backscattering. The profiling method is based on the modified Extended Physical Optics (EPO) method. The EPO method assumes the physical optics current over the entire surface of conducting scatterer [1], [2]. First, we modify the EPO by using the modified wavenumber to get an improved result. We refer to this method as the modified EPO method or simply the MEPO. The validity and the limitation of the MEPO are numerically tested for the backscattering cross section of conducting spheroid at an arbitrary incident angle.

In the second part of this paper, the inverse problem based on the MEPO is studied. First, the cross sectional area along a line of sight is reconstructed by Fourier transforming the backscattering field in frequency domain. Next, the two-dimensional profile of target is reconstructed by synthesizing the above one-dimensional results for several incident angles. The validity of these methods is numerically tested using the spheroid and the cone-spheroid.

2. MODIFIED EPO METHOD
Originally, the EPO method has been applied to obtain the backscattering cross sections at nose-on incidence of axially symmetric thin targets having sharp apices [1], [2]. The validity of the EPO was confirmed for the axially symmetric target and the nose-on incidence. Furthermore, we modified the EPO to get the improved result [3]. With the use of the similar but different wavenumber, we formulate here the MEPO for the arbitrary convex scatterer as follows.

The geometry of the problem is shown in Fig. 1. The backscattered electric field based on the MEPO for an incident wave \( E_i = E_0 e^{-jk_0 \xi} \), is given by

\[
E_\theta = \frac{e^{-jk_0 R}}{R} \frac{\rho(p)}{2\sqrt{\pi}} E_0 ,
\]

where \( k_0 \) is a free space wavenumber, \( p = 2k_0 \) and

\[
\rho(p) = \frac{jp}{2\sqrt{\pi}} \int_{\xi_1}^{\xi_2} \frac{dA(\xi)}{d\xi} e^{-jsp(\xi)} d\xi .
\]

The backscattering cross section is given by \( \sigma = |\rho(p)|^2 \). In Eq. (2), \( A(\xi) \) is the cross sectional area of the scatterer as a function of the coordinate \( \xi \) which coincides with the incident direction and \( s(\xi) \) is given by

\[
s(\xi) = \begin{cases} 
\xi & ; \xi \leq 0, \\
\frac{1}{2} \left( E\xi + \tau(\xi) \right) & ; \xi > 0.
\end{cases}
\]
The parameters \( \tau(\xi) \) and \( E \) are calculated by

\[
\tau(\xi) = \int_0^\xi \sqrt{1 + \left( \frac{d\epsilon(\xi)}{d\xi} \right)^2} \, d\xi, \quad E = \tau(\xi_2)/|\xi_2|,
\]

where \( \epsilon(\xi) = \sqrt{A(\xi)/\pi} \) is an effective radius along the axis \( \xi \). The origin of \( \xi \)-coordinate is chosen at the boundary between the illuminated portion and the shadowed portion of the deformed scatterer.

The backscattering cross sections of the prolate spheroid whose major and minor axes are \( a \) and \( b \) respectively are calculated by using the EPO, the MEPO and the method of moments [4], respectively. Fig. 2 shows the results for TE-wave and TM-wave incidences. It is indicated that the MEPO can give considerably accurate results for TE-wave incidence, and can improve fairly well the EPO. However, the approximation error is not small for TM-wave incidence. Therefore, we will utilize the TE-wave as the incident wave for the target profiling in next section.

3. TWO-DIMENSIONAL TARGET PROFILE RECONSTRUCTION

In this section, we study the one and two dimensional inverse scattering problems in which the target profiles are reconstructed from the backscattering field, i.e., Eq. (2). It is noted here that the distance \( R \) in Eq. (1) between the target and the observation point is assumed to be known a priori or can be measured beforehand.

Eq. (2) can be Fourier transformed by the similar way discussed in [3] as follows.

\[
A(\xi) = \frac{2}{\sqrt{\pi}} \, \text{Re} \left\{ \int_0^\infty \frac{\rho(p)}{p^2} \, e^{jps(\xi)} \, dp \right\}.
\]

Thus, the cross sectional area \( A(\xi) \) can be reconstructed by the Fourier transform of \( \rho(p)/p^2 \), where \( \rho(p) \) is the scattered electric field defined by eq. (1). However, the phase factor \( s(\xi) \) in (5) is unknown. Therefore, we assume \( s(\xi) = 1 \) for all \( \xi \) values at first. Next, \( s(\xi) \) in (5) is determined iteratively from the reconstructed shadow profile in the previous stage of iteration. The iteration is stopped when the profile converges appropriately. Fig. 3 illustrates the iteration results obtained for the prolate spheroids. The solutions of the method of moments have been used for \( \rho(p) \) as the input. It is shown that the one-dimensional profile of target can be reconstructed with considerable degree of accuracy.

The two-dimensional profile can be reconstructed by synthesizing the above results. In order to synthesize the profile from the sparse data, the algorithm proposed by Gilbert [5] is adopted in this paper. The reconstructed results are shown in Figs. 4 and 5. The arrows in these figures indicate the directions of incident waves. The interval of the allows is 30°. It is shown that the profiles can be adequately reconstructed.

4. CONCLUSIONS

This paper has first discussed the MEPO for the backscattering calculation of arbitrary conducting targets. It is shown that the MEMO is very useful for TE-wave incidence but the approximation error is not so small for the case that the TM-wave is incident on the thin target. Next, the one-dimensional iterative radar target imaging algorithm based on the MEPO which takes into account iteratively the wave diffraction over the shadowed portion of the target has been illustrated and implemented through numerical simulations. It has been shown that the profile of not only the illuminated portion but also the shadowed portion of targets can...
be reconstructed adequately. Using this one-dimensional profiling results, the two dimensional profile of target is reconstructed. The effectiveness of this method has been demonstrated numerically.

REFERENCES

Fig.1 Geometry of the problem

Fig.2 Backscattering cross sections of the spheroid at TE- and TM-wave incidences
Fig. 3 Reconstructed cross sectional areas along the $\xi$-axis

Fig. 4 Two-dimensionally reconstructed profiles of the spheroid

Fig. 5 Two-dimensionally reconstructed profiles of the cone-spheroid