HIGH FREQUENCY SCATTERING FROM A SHIP AT SEA

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I. INTRODUCTION

There have been a lot of papers discussing scattering from a target alone. There have been also many researches on scattering from rough surface. However, there have been very few literatures dealing with the scattering of a target in the presence of a rough surface. To the authors' knowledge, only Huang's report [1] was focused on a similar problem [1]. In his work, Huang utilized the UTD technique to obtain the radar signature from a ship model at a slightly rough sea. Through UTD, however, the determination of the multiple-reflection and/or diffraction points is very tricky and difficult. With the recently developed PTD/SBR technique [2], on the other hand, we are able to deal with the multiple reflection and single diffraction from complex target easily. Thus, in this paper, we will apply the PTD/SBR technique to compute the high frequency scattering from a ship model on a rough sea surface. This technique, of course, can be also used to analyze other similar problems.

II. STATEMENT OF THE PROBLEM

For simplicity, assume that both the rough sea surface and the ship model are made of PEC triangular facets. Suppose that the transmitting is so far away that we can treat the incident wave $\overline{E}^i$ as a uniform plane wave. The distant receiving antenna then will receive the total scattered field as $\overline{E}^C + \overline{E}^S$. Here $\overline{E}^C$ denotes the sea clutter, the scattered field due to the background sea surface when the ship is absent. The other component $\overline{E}^S$ is the scattered field that can be attributed to the existence of the ship. Provided that we can get rid of $\overline{E}^C$ from the received field, the RCS due to the ship, then, is defined as

$$\sigma_s = \lim 4\pi R^2 \frac{|\overline{E}^s|^2}{|\overline{E}^i|^2} \qquad (1)$$

where R is the distance from the origin to the receiver, and approaches to infinity. Note that $\bar{E}^S$ includes the scattering directly from the ship and the interaction between the ship and the sea surface.

III. PTD/SBR TECHNIQUE

The PTD/SBR technique used here is basically the same as that introduced in [2]. We just summarize the algorithm here: First, we compute the PO (Physical Optics) contribution from the ship, with local and global shadowing taken into consideration. Next, the wedge contribution is included by PTD equivalent current sources [3]. These are the first-bounce field. To consider the multiple-bounce effect, we shoot many ray tubes along the direction of incidence. Each ray is then traced by Snell's law and an efficient ray-tracing technique developed in computer graphics [4]. If a ray tube experiences two or more bounces and hits the ship at least once, its contribution is evaluated by the method in [2], and is added to $\bar{E}^S$. Finally, we compute the RCS from $\bar{E}^S$ by Eq. (1).

IV. NUMERICAL RESULTS

To verify our approach, we first compute σ_s of an elliptic cylinder standing on a PEC ground plane. This case can be also solved by the Rayleigh image method [5] along with PTD. The comparison of the results by the image method and our PTD/SBR technique is shown in Fig. 1. Both results agree reasonably. Note that the rather flat response for the incident θ between 30^o and 60^o is due to the double reflection similar to that occurs in dihedral RCS [6].

Next, we tried a ship model shown in Fig. 2, which is constructed and divided into triangular facets by a CAD package called Pro/Engineer. The sea surface is modeled by

$$z = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} C_{mn} \cos\left(\frac{2m\pi x}{L_x} + \frac{2n\pi y}{L_y} + \phi_{mn} \right) \tag{2}$$

which is extended from [7] by Marzougui [8]. Here we assume that the considered sea surface is in the area defined by $-Lx/2 < x < Lx/2$ and $-Ly/2 < y < Ly/2$. The coefficients C_{mn} are related to the power spectrum of the sea surface, while ϕ_{mn} are random phases uniformly distributed between $-\pi$ and π. In this study we assume that the power spectrum of the sea surface is Gaussian. Note also C_{00} must be zero to keep a zero average height. The RCS due to the ship model at such a sea surface is given in Fig. 3.

V. CONCLUSIONS

In this paper we have successfully applied the PTD/SBR technique to compute the scattering of a plane wave from a ship at sea. The possible improvement includes treating the sea surface as a lossy dielectric surface instead of a PEC one, using more realistic sea surface power spectrum [9] instead of a Gaussian one, and assuming near transmitting/receiving antennas rather than plane wave incidence and receiver at infinity. Application of this technique to similar problems such as scattering from a tank at rough terrain is also possible.

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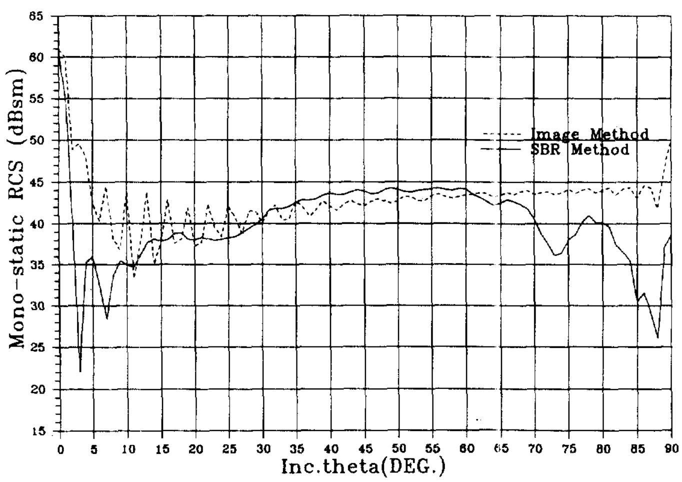

Fig. 1. Monostatic RCS of an elliptical cylinder standing on a ground plane.

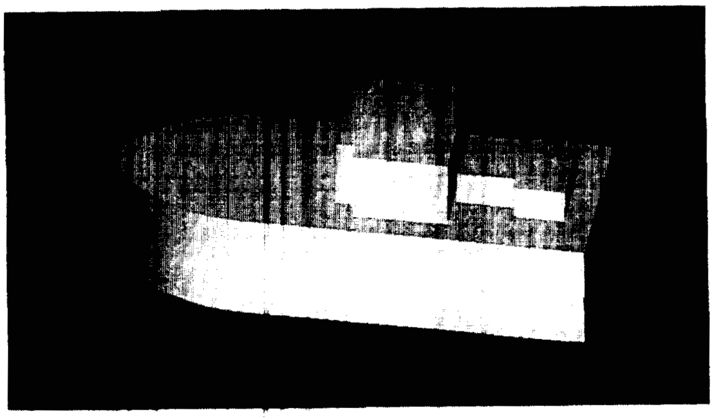

Fig. 2. A ship model.

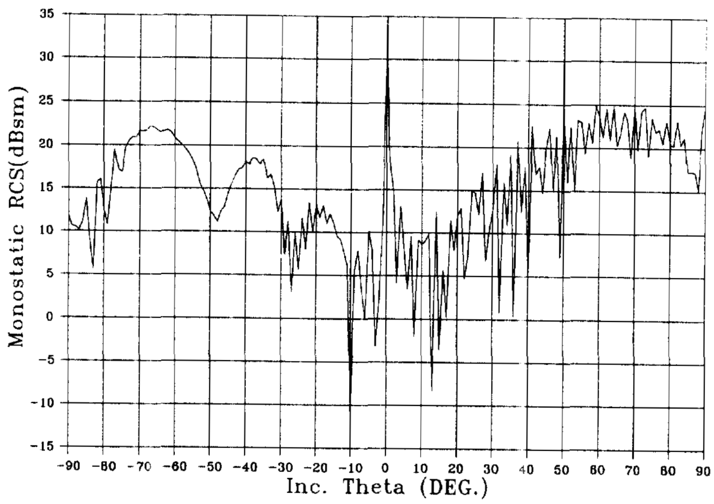

Fig. 3. Monostatic RCS of the ship model at a slightly-rough sea.