AN IMPROVED TWO-SCALE MODEL FOR THE OCEAN SURFACE BISTATIC SCATTERING

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1. INTRODUCTION

The scattering of waves by random rough surfaces at low grazing angles has important applications in remote sensing of ocean and land and require developing accurate models to predict radar bistatic scattering from these surfaces. Over the years considerable effort has been devoted to the development of such models. Among them, we can cite the Small-Perturbation Method, the Kirchhoff Approximation, the Phase Perturbation Technique, the Small Slope Approximation, Integral Equation Model and the Two Scale Model.

For electromagnetic scattering from ocean surface the Two Scale Model (TSM) can be used by splitting the surface in to two scales: a large and small one related to the incident wave. The classical bistatic TSM use the Kirchhoff Approximation (KA) for the large scale and Small-Perturbation Method of first-order (SPM1) for the small scale [1]. It has broader range of validity but is inaccurate for grazing angles and there is a gap in regions of validity of SPM1 and KA. Several attempts have been made to improve this model, e.g., in [2] another formulation was obtained by replacing the SPM1 with SSA1,while in [3] , SSA2 and statistical integral equation model (SIEM) was used.

In this paper, we study the second-order Small Perturbation Method (SPM2) which yield greater accuracy on low grazing angles and give larger domain of frequency. We develop an improved TSM by replacing the SPM1 by SPM2. To capture the features exhibited by sea scattering, we use a roughness spectrum obtained from the Elfouhaily et al which takes into account several physical parameters. Moreover, we examine the accuracy of the improved TSM by comparing the numerical results with SSA in bistatic configuration and with the published experimental data in backscattering case.This paper containes three parts. The first part deals with the review and developement of diffusion models. In second part ocean surface spectrum is explained briefly and at the end we discuss the numerical results.

2. MODELS OF DIFFUSION

2.1. Second-order small perturbation Method

For SPM2 we use the formulation given by Tsang [5]. The extended boundary condition method was used to solve the surface field parameters. The bistatic scattering coefficients for horizontal and vertical polarizations are given by

$$\begin{aligned}\sigma_{hh} &= 4\pi k^2\cos^2\theta_s\left(\int_{-\infty}^{\infty} d\overline{k}'_\perp W\left(\overline{k}_\perp-\overline{k}'_\perp\right)W\left(\overline{k}'_\perp-\overline{k}_{i\perp}\right)\widetilde{\widetilde{f}}_{ee}\left(\overline{k}_\perp,\overline{k}'_\perp,\overline{k}_{i\perp}\right)\right.\\ &\qquad\left.\left[\widetilde{\widetilde{f}}^{*}_{ee}\left(\overline{k}_\perp,\overline{k}'_\perp,\overline{k}_{i\perp}\right)+\widetilde{\widetilde{f}}^{*}_{ee}\left(\overline{k}_\perp,\overline{k}_\perp-\overline{k}'_\perp+\overline{k}_{i\perp},\overline{k}_{i\perp}\right)\right]\right) \qquad (1)\\ \sigma_{vv} &= 4\pi k^2\cos^2\theta_s\left(\int_{-\infty}^{\infty} d\overline{k}'_\perp W\left(\overline{k}_\perp-\overline{k}'_\perp\right)W\left(\overline{k}'_\perp-\overline{k}_{i\perp}\right)\widetilde{\widetilde{f}}_{hh}\left(\overline{k}_\perp,\overline{k}'_\perp,\overline{k}_{i\perp}\right)\right.\\ &\qquad\left.\left[\widetilde{\widetilde{f}}^{*}_{hh}\left(\overline{k}_\perp,\overline{k}'_\perp,\overline{k}_{i\perp}\right)+\widetilde{\widetilde{f}}^{*}_{hh}\left(\overline{k}_\perp,\overline{k}_\perp-\overline{k}'_\perp+\overline{k}_{i\perp},\overline{k}_{i\perp}\right)\right]\right) \qquad (2)\end{aligned}$$

the expressions for cross polarizations and all the parameters and functions used in above expressions are defined in [5].

2.2. Two-scale model

In reasonable way, ocean surfaces roughness can be split into two scales: a large and small with the incident electromagnetic wavelength (see figure-2).

The key idea of this method is to take advantages of the classic approaches (SPM1 and KA) and enlarge the application domain [1]. Then scattering coefficients are estimated in two steps. Firstly, the classical TSM uses SPM1 on small scale waves and then determine the diffuse component in the global reference by a tilting process. The specular component is evaluated using the KA.

3. SEA SPECTRUM

Among the several sea spectrum models published in the literature, Elfouhaily et al [4] proposed a unified directional spectrum for long and short wind-driven waves. Its agreement with the slope model proposed by Cox and Munk and with actual remote sensing data make it a credible model.

The Elfouhaily directional wave spectrum $W\left(K\right) = W\left(K, \psi\right)$ is defined as the product of the non-directional spectrum $W\left(K\right)$ with a directional function $f\left(K\right)$:

$$W\left(K, \psi\right) = W\left(K\right) \times f\left(K, \psi\right) \tag{3}$$

where

$$f\left(K, \psi\right) = \left[1 + \Delta\left(K\right)\cos\left(2\psi\right)\right]/2\pi \tag{4}$$

$\Delta(K)$ is recognized as the coefficient of the second harmonic when truncating the Fourier series expansion of $f(K, \psi)$. We use this definition of sea spectrum while estimating the electromagnetic matrix coefficients.

4. NUMERICALS RESULTS

We replace the SM1 by SPM2 and get an improved TSM. To validate this model we compare the numerical results, in backscattering configration, with SPM1, SPM2, SSA1 [6] and published numerical data [7] for different frequency bands. Then in bistatic configration we give the predictions by improved TSM and compare them with SSA1.

5. REFERENCES

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