Monostatic Scattering from an Object Near an Ocean-Like Surface from an Efficient Fast Numerical Method

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***Abstract*— The rigorous computation of the monostatic scattering from an object near a one-dimensional sea surface (2D case) needs to solve a problem involving a high number of unknowns. By using a recently developed fast numerical method, called E-PILE+FBSA (Extended Propagation-Inside-Layer Expansion combined with Forward-Backward Spectral Acceleration), the monostatic scattering of such a complex scene can be investigated. Two canonical objects are considered in this paper: the cross and the cylinder. Results allow us to understand the physical mechanisms involved in the coupling between the object and the sea surface.**

I. Introduction

Electromagnetic scattering from an object near a rough surface has attracted much interest during recent years. In order to solve this issue, some asymptotic and exact numerical models have been developed [1], [2], [3], [4]. But when the rough surface is numerically generated, its length must be long to avoid edge effects. Thus, it is interesting and necessary to investigate exact fast numerical methods to treat a large problem. Moreover, for the monostatic configuration, a longer surface (due to the incident beam) and a high computing time are required. This is why, to our knowledge, there is no result of such a complex problem for monostatic configuration from a rigorous approach.

It is the purpose of this paper. To solve this issue, a recently developed method is used: the E-PILE (Extended Propagation-Inside-Layer Expansion) method combined with Forward-Backward Spectral Acceleration (FBSA) for the computation of the local interactions on the rough surface [5]. Thus, by using the E-PILE+FBSA method, monostatic results can be obtained for realistic maritime scenes made up of an object (cylinder and cross are considered) above an ocean-like surface obeying the Elfouhaily et al. height spectrum [6]. Moreover, the Impedance Boundary Condition (IBC) is used since the sea surface is assumed to be highly conducting at radar microwave frequencies [7]. The results obtained from the rigorous E-PILE+FBSA method permits us to confirm some intuitively known conclusions and, also, to establish some behaviors of the monostatic NRCS (Normalized Radar Cross Section).

II. The Efficient Numerical Method

Let us consider two scatterers (with homogeneous media) embedded in an homogeneous medium as depicted in Figure 1.

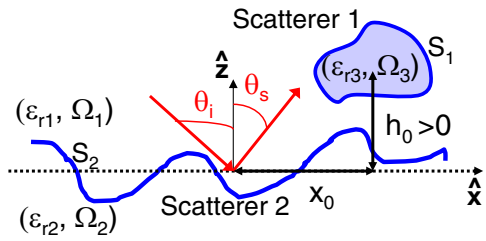

Fig. 1. Description of the scattering from an object above a rough surface. The media $\{\Omega_1, \Omega_2, \Omega_3\}$ of permittivities $\{\epsilon_{r1}, \epsilon_{r2}, \epsilon_{r3}\}$ are assumed to be homogeneous, and the scatterers are invariant along the direction normal to the figure.

The use of the integral equations discretized by the MoM leads to the linear system $\bar{\mathbf{Z}}\mathbf{X} = \mathbf{b}$, in which $\bar{\mathbf{Z}}$ is the impedance matrix of the scene made up of the two scatterers, $\mathbf{b}$ the incident field, and $\mathbf{X}$ the current on both the scatterers (the field and its normal derivative on the surfaces). If the scene is made up of an object above a very long surface, the direct inversion of $\bar{\mathbf{Z}}$ cannot be done. One way to solve this difficult task is to apply the recently developed E-PILE method which is a rigorous numerical method for the scattering from two arbitrary scatterers [5], [8] based on a Taylor expansion of the Schur complement. Indeed, one can show that the unknowns on the object surface $\mathbf{X}_1$ are obtained from

$$\mathbf{X}_1 = \sum_{p=0}^{p=P_{\text{PILE}}} \mathbf{Y}_1^{(p)}, \tag{1}$$