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Computer Simulations of Rough Surface Scattering

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7.1. Introduction

"Numerically exact" methods for rough surface scattering have increased in their relevance to surface scattering studies over the past quarter century. This increase in relevance follows the increase in computational power that has become readily available over the same period, along with developments in approaches for reducing the computational complexity of such methods. However, while computational power has increased by several orders of magnitude, and the range of surface scattering problems that can be studied numerically has followed directly, the overall impact of numerical studies has been decidedly less dramatic, while still of some import, as will be discussed throughout this chapter.

Several excellent review articles have been previously written on the subject of numerical algorithms for rough surface scattering\textsuperscript{1–3}, including two recent contributions\textsuperscript{4,5}; all these reviews are strongly recommended to the reader as excellent surveys of the variety of studies and approaches that have been used. Given these articles, the current chapter is written as a more specific review of the author's research in this area, with particular examples and recommendations provided from the author's experiences. The discussions provided therefore should not be taken as representative of all possible studies and techniques; again the reader is referred to the cited review articles for broader information.

The next section provides a description of a few fundamental issues involved in describing a rough surface scattering problem, while specific integral equation formulation and matrix solution methods utilized in previous studies are described in Sects. 7.3 and 7.4. Sample results are illustrated in Sect. 7.5 to demonstrate a range of problems, and Sect. 7.6 provides summary recommendations from the author's experience regarding use of numerical methods in future studies.

7.2. Fundamental Issues

Any numerical surface scattering simulation begins with a description of the problem to be solved, including properties of the surface and the background media.
involved. Here the basic problem considered involves scattering from a rough interface between two simple and homogeneous media. Typically the coordinate system is defined so that the incident field approaches from above the interface, and the resulting scattered fields are determined above the interface as well as below the interface in the case of a penetrable lower medium. Typically it is the scattered and/or transmitted fields in the far field of the surface that are of interest, although it is quite simple to compute the resulting fields in the near field of the rough surface, and a few studies have taken this route.

7.2.1. One- and Two-Dimensional Surfaces

A major factor in modeling rough surface scattering problems involves the choice of a “one-” or “two”-dimensional surface model. Here a one-dimensional surface refers to a surface with variations along one horizontal coordinate only, with the surface profile constant along the other horizontal coordinate. Two-dimensional surfaces alternatively have variations along both horizontal coordinates, as illustrated in Fig. 7.1.

The major advantage of the one-dimensional geometry is the fact that discretization for a numerical method is required only in the coordinate along which the surface varies. This results in a tremendous computational savings compared to the two-dimensional case. Typically it is found that results using one-dimensional surfaces show nearly identical physical behaviors to those from simulations with two-dimensional surfaces, and in the majority of cases, use of one-dimensional surfaces is found reasonable. The author is not aware of any cases where significantly different physical behaviors were obtained from two-dimensional versus one-dimensional surface predictions, in cases where one-dimensional simulations are relevant.

However there exists a set of physical scattering effects for which one-dimensional models are certainly inadequate. These include studies of cross-polarized scattering as well as studies of scattering outside the plane of incidence (i.e. when the scattered field propagation direction in the far field lies outside the plane formed by the incident field propagation direction and the normal to the mean surface). For scattering within the plane of incidence, one-dimensional models always predict zero cross-polarized fields, while it is well known that such fields, though small, can result from two-dimensional surfaces. Although it is possible to compute bistatically scattered fields outside the plane of incidence