Time-Domain Simulation of Scattering by Two-Dimensional Random Rough Surfaces

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The numerical analysis of electromagnetic scattering by rough surfaces is a subject of continued interest within the research community. Our work is particularly motivated by evaluating clutter levels in the context of using low-frequency, ultra-wideband ground penetrating radar for detection of objects placed at or under a rough air-ground interface.

Whereas many numerical tools for rough surface analysis are based on integral-equation solvers, we approach the problem in the time-domain, based on the multi-resolution time-domain (MRTD) method. The advantages of this technique include the possibility of handling arbitrary media and obtaining results over a wide band of frequencies in one time-marching run. The application of MRTD to modeling large two-dimensional rough surfaces (three-dimensional simulations) comes at a significant computational cost. Therefore, we implemented a parallel MPI version of our MRTD code that enables us to handle surfaces of tens of wavelengths on each side. The emphasis in this paper is on dielectric (penetrable) interfaces with Gaussian statistics, although the techniques can be applied to any other configuration.

The results are presented as radar cross-section (RCS) per unit surface area as a function of frequency, for different angles of incidence, polarizations and surface parameters. In order to make the results statistically meaningful, we perform a Monte Carlo analysis, by averaging the clutter levels over a large number of independent rough surface realizations. We address implementation issues such as the effects of the finite surface size and the staircase approximation of the interface. Also, we perform a comparison of our numerical results with theoretical rough surface analysis techniques.