Direct Numerical Simulations of Pulse Scattering from Evolving Ocean-Like Surfaces: Range-Doppler Analysis

Jakov V. Toporkov and Mark A. Sletten*
Naval Research Laboratory, Code 7255, Washington DC. 20375-5320

Over the past several years, a significant progress has been made in developing numerical methods that allow exact evaluation of electromagnetic field scattered from a surface with an arbitrary profile. While techniques for truly three-dimensional (3-D) large-scale geometries are still under development, the 2-D methods have achieved considerable maturity. They offer highly efficient solution of the scattering problem for electrically large surfaces at all incidence angles including the challenging low grazing angle (LGA) regime. With modern high-performance computers, these techniques can be applied to practical problems of interest to radar and remote sensing community.

The presentation reviews the integral equation-based numerical scattering technique and the hydrodynamic surface model that form the basis for this study. The numerical scattering method (originally formulated for monochromatic incident wave and motionless surfaces) is extended to produce a time-varying range-resolved response from evolving ocean surfaces. Processing times are addressed, as the range-Doppler simulations, even confined to a 2-D space, prove to be computationally intensive and require high performance computing (HPC) resources.

To illustrate capabilities of direct numerical simulation technique, scattering of a 5-ns X-band pulse from an evolving 60 m-long realization of non-linear Pierson-Moskowitz surface is calculated. Accounting for non-linear hydrodynamic interactions of surface harmonics was shown to be essential in simulating LGA Doppler spectra (J. V. Toporkov and G. S. Brown, *IEEE Trans. Geosci. Remote Sensing*, **38**, 1616-1625, 2000), and it has significant effect on the range-resolved LGA backscattering signature as well, particularly for HH polarization. The data is calculated at both VV and HH polarizations and the incidence angles of 60^o and 85^o (5^o grazing). The differences in scattering signatures for these polarizations are clearly observed, especially at LGA. Range-resolved Doppler spectra for different incidence angles and polarizations are also compared.

Range-Doppler description of the sea clutter is most detailed, and the ability to benchmark it through direct simulations will benefit the development of Navy radars, as well as remote sensing studies of the surface hydrodynamic processes.