Analysis of Numerically Simulated Wide-Band Low-Grazing HF Backscatter from Time-Varying Ocean-Like Surfaces

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Vertically polarized high-frequency (HF) radiowaves are known for their long propagation distances over ocean surface. The electromagnetic wave lengths within the HF band (3-30 MHz) vary from 10 to 100 m, and should interact in a rather simple, easily interpreted Bragg-resonant manner with large gravity waves that constitute the energy-bearing part of ocean spectrum. As a result, HF radars have been a useful tool in the remote sensing of sea waves and currents. Lately, there has been an interest in wide-band (WB) and ultra-wide band (UWB) HF applications. The range resolution, when using the entire HF band, can be as small as 15 meters. This study is the first to investigate the properties of such WB and UWB surface echoes using direct numerical scattering simulations.

Surface backscatter is calculated using the accelerated Method of Ordered Multiple Interactions (MOMI) – a first-principles technique that solves a discretized boundary integral equation for the surface current. Sea water dielectric properties are accounted for using the impedance boundary condition. A surface profile is generated as a realization of a Gaussian random process with the Pierson-Moskowitz spectrum. Its evolution in time is achieved by adjusting the phases of surface harmonics according to the free-wave dispersion relation. While still limited to the 2-D space, these simulations can provide insight in many surface scattering phenomena, and are especially useful in scattering problems that involve challenging low-grazing geometry. With receiver and transmitter located close to the surface, most of backscatter in this problem indeed occurs in the low or very low grazing regime.

Coherent, UWB backscatter was calculated for two evolving surface realizations corresponding to 5 m/s and 20 m/s wind speeds, respectively. These data are then Fourier-transformed in both range and time coordinates. As expected for the Bragg scattering mechanism, the ω-K spectra of the complex-valued echoes bear strong resemblance to their counterparts for the surface realizations. Similar analysis of the backscatter magnitude (or power) shows that it too carries surface-wave signature. The latter becomes especially evident for the higher sea state. These observations are checked against predictions of approximate scattering theories such as the Small Perturbation Method (SPM). The impact of the signal bandwidth is also investigated.