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Millimeter-wave radar scattering from the water surface : a wind-wave tank study

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Abstract:

We report on a recent experiment conducted in the large wind-wave tank of Marseille-Luminy aimed at characterizing the small-scale statistics of ocean- and river-like surfaces as well as their radar return at millimeter waves (Ka-band).
Simultaneous measurements of waves elevations and slopes from gravity to capillarity-gravity scale as well as the corresponding Ka-band Normalised Radar Cross Section (NRCS) have been performed for various wind speeds and scattering configurations. For each wind speed, the incidence angle of the radar beam has been varied between 0 and 15 degrees away from nadir and several azimuthal directions with respect to wind have been investigated by step of 45 degrees.
Based on this data set we have developed an original technique to estimate the directional wave number spectrum of the water surface from decimeter to millimeter scales. We show that the inclusion of surface current is crucial in the correct derivation of the omnidirectional spectrum and that a non-trivial angular spreading function can be obtained from the measurements of the up-wind and down-wind slope spectra, providing some additional reasonable assumptions. The resulting spectrum is compared with the high-frequency part of the classical oceanic models such as Elfouhaily unified spectrum and Kudryavtsev et al. spectrum. Some consistency tests are proposed to validate the surface model, which is then incorporated in classical analytical scattering models.

The main qualitative features of the observed NRCS are a minimum of sensibility to wind speed around 7-8 degrees incidence, non-monotonic variations with incidence at small wind speeds and a marked up/cross wind asymetry. We show that the Physical Optics approximation provides a very satisfactory estimation of the NRCS as compared the experimental values at all wind speeds and azimuths, contrarily to the Geometrical Optics model which is found inaccurate even at the larger wind speeds. The unconventional behavior of the NRCS at small wind is well explained and predicted by a Bragg mechanism. Non-Gaussian corrections are included in the scattering model and their effect evaluated.