Bound Waves and Radar Backscattering from the Sea Surface

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Abstract: New effects recently revealed in field experiments conducted in IAP RAS on radar probing of the sea surface and associated with strong nonlinearity of short gravity-capillary waves and generation of high-order harmonics and "parasitic" capillary ripples (bound waves) are discussed. The effects are: "abnormal" radar Doppler shifts and strong (cascade) modulation of radar backscatter due to internalor long surface waves in organic slicks. It is shown that the Doppler shifts ofKa-band radar signals are changed in slicks being larger or smaller compared tosurrounding clean water, and the effect depends on the film elasticity parameter. A physical explanation of the effect is proposed based on the idea that the spectrum of Bragg wind waves contains both linear capillary waves, obeying their dispersion relationship and bound waves propagating with the phase velocities of carrying short gravity waves. Therefore, the resulting phase velocity of Bragg ripples is a combination of the phase velocities of linear and bound waves weighted with their relative intensities. Depression of the carrying waves due to a surface film depends strongly on the film elasticity, this leads to changing of the relative intensities of linear and bound waves and as a result to changing of the resulting phase velocity of Bragg waves and the corresponding Doppler shift. Wave tank experiments on radar probing of short wind waves in the presence/absence of films are also described and relative intensities of linear and bound waves are estimated. The second effect - strong modulation of bound capillary waves- is due to a nonlinear dependence of the intensity of bound waves on the steepness of carrying gravity waves. The modulation of the carrying waves by long surface or internal waves even being small can lead to strong (cascade) modulation of bound waves. The effect is demonstrated by results of wave tank experiments with internal waves, and it is shown that the modulation coefficient for bound waves exceeds the modulation of carrying waves up to an order of magnitude. Modulation of Bragg capillary wind ripples contains both the modulation (usually weak) of the linear waves and the cascade modulation of bound waves. One, therefore, can expect that depression of the linear components due to films will lead to enhanced residual modulation of Bragg bound waves. Field and wave tank experiments has confirmed the expected intensification of modulation of Bragg ripples due to long surface waves, the modulation coefficient has been shown to be several times the modulation on a clean water surface.