Tao Gao

Nonlinear wave interactions on the surface of a conducting fluid under vertical electric fields

We are concerned with capillary–gravity waves propagating on a two-dimensional conducting fluid under the effect of an electric field imposed in the direction perpendicular to the undisturbed free surface. This work aims to investigate the impact of the electric fields on the nonlinear wave interactions in this context. The full system is mathematically difficult to solve since it is a nonlinear, two-layered, free boundary problem, and the interface dynamics results from the strong coupling between the Euler equations for the lower fluid layer and an electric contribution from the upper gas layer. To investigate electrohydrodynamic wave interactions, we propose a novel numerical scheme based on a time-dependent conformal map and an interpolation technique to conduct unsteady simulations of the fully nonlinear electrified Euler equations of the two-layered problem. To gain analytical insights, we first derive weakly nonlinear envelope equations based on the method of multiple scales for the resonant triad, long-short wave interaction, and modulation of a single-mode wavetrain (a special case of resonant quartet interaction). Summative remarks are made to illustrate the transition from 3-wave interactions to 4-wave interactions and vice versa, occurring when the coefficients of the associated nonlinear Schrödinger equation become singular. The fully nonlinear results obtained by the prescribed numerical method are compared with the predictions by the weakly nonlinear theories, and good agreement is achieved.