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Evolution of the Stokes Wave Side-Band Instability, threshold modification of Tulin NLS Model

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Evolution of Stokes wave side-band instability along a super tank was studied experimentally and theoretically. The initial exponential growth of the resonant sidebands is followed by asymmetrical growth rates for the sidebands: lower sideband growth is much faster, and finally the main energy is concentrated in it and the primary wave. An active breaking process increases the frequency downshift during the latter stages of the wave propagation. Some type of wave stabilization takes place during the final post-breaking stages of the process and can be characterized by a sharp decreasing of wave breaking activity and stabilization of wave modulations.

The evolving wave trains experience strong modulations followed by demodulations, but the dominant component is the component at the frequency of the lower sideband of the original carrier. The amplitude of the lower side-band remains high after breaking while for cases of no-breaking the amplitude subsides significantly almost to its original state. In contrast, the upper side-band drops back from its peak towards its pre-growth value. Although the carrier wave recovers somewhat it stays lower than its initial value. Thus, two processes take place: discriminatory energy loss from the carrier and higher side-band modes, and it irreversible energy transfer to the lower side-band, that is permanent frequency down shift.

In the framework of conservative evolution of a train of Stokes waves, several authors, using either approximate equations (Dysthe equation or Zakharov equation) or the exact hydrodynamic equations, did not find permanent downshift in the two-dimensional case. This emphasizes the key role of nonconservative effects in the subharmonic transition of nonlinear 2D water waves.

The role of dissipation is still a major source of difficulty in the analysis of wave instability problems.

Our calculations show that Tulin (1996) dissipative modification of NLS model can satisfactory describe the first several stages of the wave train evolution: wave instability, the side band asymmetry and wave breaking effects. On the other hand, continuous wave breaking dissipation presumed in the model gives significantly overestimated values of wave attenuation on the latter stages of wave propagation and can not describe the wave modulation and restabilization at sufficiently long distances of propagation.

The adjusted dissipative model based on the Nonlinear SchrÖdinger Equation is suggested for adequate description the obtained experimental data. Sink/Source terms due to wave breaking processes in its right side correspond to well-known Tulin (1996) model. The wave dissipation function includes the wave steepness threshold function and applied only in the regions with active wave breaking. Permanent frequencies downshift as a result of wave breaking process and post-breaking wave modulations described by the model have the satisfactory quantitative correspondence to results of experiments conducted along a super tank.