Geometric Optics and Diffraction Effects in Forward- and Backscattering From Steep and Breaking Waves

Alexander G. Voronovich* and Valery U. Zavorotny
NOAA/ESRL/PSD, Boulder, CO 80305, USA
http://www.esrl.noaa.gov/psd/

Process of surface gravity wave breaking and following modeling of the full-wave electromagnetic (EM) scattering from them pose an ultimate challenge for analytical methods. On the other hand, recent successes in the fast numerical modeling show that this problem can be handled efficiently and conveniently, giving useful insight into relationship between various parts of this complex problem. Using such an approach for 2-D case we successfully reproduced main features of the observable temporal and polarization behavior of the scattering cross section from breaking waves (e.g., sea spikes) and related Doppler spectra.

This approach can be used to answer the question what specific physical mechanism is responsible for a particular feature of the back- or forward scattered signal. Also, there were suggestions that multiple scattering effects could significantly contribute to radar scattering on steep and breaking waves. To shed some light on these issues, we have undertaken a numerical modeling by applying both a full-wave and a ray-tracing approach to the problem. The latter one would exclude diffraction from the consideration leaving only geometric optics (GO) effects that cover also multiple reflections, (e.g., "whispering gallery" phenomenon), and interference of different rays.

In order to calculate the amplitude associated with each ray, the ray tracing was accompanied by the algorithm that collects all the rays arriving to a given receiving point. After that, the code computes a change in a ray pencil cross section leading to an amplitude change, total phase along the ray including phase shift due to caustics, and sums up the complex amplitudes for all rays arriving to the receiving point providing the value of the field in the GO approximation.

Finally, angular dependences of the scattering cross section based on the ray approach were calculated and compared with results from the full-wave approach. The comparisons demonstrate a better agreement between two approaches for smoother surfaces and a steeper wave incidence. Good agreement between GO and full-wave solution is obtained for the forward scattering directions. However, in the backscattering direction GO does not reproduce the HH/VV ratio with spikes observed in the full-wave solution. This indicates that diffraction effects are critical for backscattering from breaking waves. The role of multiple reflections from the breaking wave profile in creating spikes with anomalous HH/VV ratio is proved to be negligible.