Inverse Problem in the Theory of Wave Scattering from Rough Surfaces

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In the theory of wave scattering from rough surfaces direct problems draw much more attention than the inverse ones. This is, probably, due to the reasonable assumption that solution of the inverse problems should be preceded by an ability to solve reliably a direct problem, which is still not the case in many instances. Nevertheless, practical necessity to approach this problem does exist. There are two basic paradigms here: reconstruction of the roughness through near and far field measurements. Remote sensing applications, in particular, often require retrieval of the properties of scattering surfaces based on measurements of the scattering in the far field. This talk will be devoted to the review of the existing approaches to this problem.

Inversion techniques that allow analytical treatment are immediately related to the approximate methods of solution of the direct problem. One of such techniques is based on small-perturbation method, or Bragg scattering. Scattering cross-section in this case is proportional to the spectrum of surface roughness at a wave-vector equal to the difference of horizontal projections of scattered- and incident wave-vectors, and measurements of scattering cross-section at all scattering angles allow to reconstruct surface roughness for all spectral components in the range corresponding to propagating waves. This approach is used, in particular, for estimation and tuning sea-wave spectrum in the range of centimeter waves.

Another inversion method is based on the Kirchhoff approximation. In the geometric-optics limit scattering cross-section is proportional to the probability density of slopes, which can thus be directly measured by using near-nadir measurements. In the directions far from nadir, this allows to infer probability distribution of steep waves.

There is an interesting possibility to use full-wave Kirchhoff diffraction integral for solution of the inverse problem. This integral generally depends on two parameters, one of which coincides with the Bragg wave-vector, and the other equals to the appropriate sum of the vertical projections of the incident- and scattered wave-vectors. If measurements of scattering cross-sections are made at a sufficiently rich set of the incident/scattering angles, or if backscattering cross-section is measured at different angels and frequencies, one can infer exponential of correlation function by making Fourier transform over a special subset of scattering data. The same approach works in the case of small-slope approximation as well, since to the lowest order scattering cross-section in this case is also proportional to the same Kirchhoff-type diffraction integral. In a deterministic setting solutions based on the small-perturbation and the Kirchhoff approximations were suggested and investigated by R. Wombell and J.A. DeSanto.

If backscattering cross-section is known as a function of incidence angle at a fixed frequency, the inversion problem becomes strongly non-linear even in the case of small slopes. Analytical approach to this problem is not known yet. In this case one can try to treat it numerically using the approach based on different iteration schemes, or on invariant embedding.