Penetration of sound into rough marine sediments: numerical analysis and statistics

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The problem of acoustical scattering by rough (rippled) sediments is important for many applications, such as buried objects detection, seafloor characterization, AUV navigation, etc. The presented numerical analysis concerns a general case of an arbitrary grazing angle that can be as low as 5°-10° and a realistic ratio between the height and the quasi-period of roughness. We use the Boundary Element Method (BEM) in 2D geometry to obtain the scattered pressure field in water and in sediment and compare these results to the well-known Helmholtz-Kirchhoff (HK) approximation. Further development of the BEM (accelerated BEM) has been realized by means of numerical implementation of an exact analytical solution to the Helmholtz equation in the discretized matrix form; an acceleration factor of 10 is easily obtained. Using a Monte-Carlo technique, we evaluate the distribution of the pressure field together with its essential characteristics, such as average and standard deviation. A regime in which a Gaussian distribution for the real and imaginary parts of the penetrated field is found which means that the penetrated field is a result of interference of many statistically independent components scattered from the surface. Another observation is depth independence of the averaged penetrated field that appears below some minimum depth in lossless sediment, whereas this phenomenon is not observed for a single roughness realization. Interpretation of these results could help building up a theoretical description for penetration at low grazing angles and high frequency.