STATISTICS OF TRAVEL TIMES AND INTENSITIES OF THE EARLIEST ARRIVED SHORT PULSES BACKSCATTERED BY A ROUGH SURFACE

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Precise measurements of the travel times of backscattered waves, and especially the travel times of the first (i.e., earliest) arrivals, underlie a number of geophysical remote sensing techniques. In this paper, statistical properties of the travel time and intensity of pulses backscattered by a two-dimensional rough surface are investigated within the geometric optics approximation by adopting a method originally developed in the theory of excursions of a stochastic process.

Two specific cases are investigated: a sufficiently wide collimated incident beam with plane wave front, and a spherical wave front. Signals from the rough surface return to the source location earlier than from the mean plane by $O(2\sigma/c)$, where c is the velocity of wave propagation, and σ is an r.m.s. of surface roughness. We assume a wave source located sufficiently far from a rough surface with a Gaussian statistics, and show that the probability distribution functions of the deviation of the travel time of the first and second backscattered pulses from the travel time in the absence of roughness, normalized by $2\sigma/c$, are functions of a single dimensionless parameter, $T = \gamma_0^2 H/(2\pi\sigma)$, where γ_0^2 is the variance of the rough surface slope, and H is the source altitude. On average, the travel times of the first and second arrivals decrease as parameter T increases, with the travel time shift being proportional to $\sqrt{\ln T}$. The time delay between the first and the second arrivals is inversely proportional to $\sqrt{\ln T}$.

The joint probability density functions (PDF) of the travel times and the intensities of the first two backscattered pulses are derived. This allows us to obtain the travel time PDF for signals exceeding the given intensity threshold. It is shown that travel time and the intensity are strongly correlated: on average, earlier arrivals have smaller amplitudes.

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