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Influence of Double Interaction in Multipath Propagation at Small Grazing Angles

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Abstract—In the case of low wind-induced waves the surface irregularities of troughs between sea waves ridges are located outside of the deep shadowing region with respect to the corresponding points and it is necessary to estimate their role in the field forming at the receiving point. The analysis has demonstrated that under these conditions there may occur a multiple interaction of the irradiating field with the irregularities of underlying surface. The analysis is limited by the account of double interaction due to the significant magnitude reduction for each reradiation of the secondary wave with respect to the original one. It this paper we propose to estimate its influence using the technique of comparison of the received signal characteristics, which have been obtained by taking into account the double interaction and without it.

The characteristics are obtained by the simulation of the electromagnetic field propagation in the case of low wind-induced waves in the context of Kirchhoff approximation using the secondary Huygens sources principle.

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In the theoretical works on the radiowaves propagation over a roughened surface, for which the horizontal dimensions of the irregularities are much greater than the wavelength of the radiowave, one utilizes the assumption of a single interaction of each beam of the incident wave with the surface [1–3]. It is also assumed that this interaction occurs in the vicinity of the point of graze of the beam and the surface.

It has been demonstrated in [4–12] that such an assumption under certain conditions is applicable to the case of grazing propagation of millimeter and centimeter radiowaves over the sea surface with wind waves. This is caused by the fact that at speeds of the wind above the sea surface greater than a certain critical value at small grazing angles (of order of several milliradians) only the peaks of the waves remain irradiated, but the troughs between are located in the region of deep shadow with respect to the radiator and the receiver.

Assuming that the trough surface is irradiated by the field, which represents the result of diffraction of the primary plane electromagnetic wave by a half-plane, whose boundary coincides with the ridge of the wave, that produces the shadow, the following condition has been obtained in [4]

$$U_{10} > \frac{37.5\sqrt{\lambda}}{1 - 75\psi_{gr}}, \tag{1}$$

in case of whose satisfaction the field at the bottom of the trough is 10 dB attenuated in comparison with the one occurring above the shadow boundary. Here U_{10} denotes the wind speed at 10 m height above the sea surface [m/s]; λ stands for the wavelength [m]; ψ_{gr} designates the grazing angle relative to the imaginary central plane of the surface [rad].

For typical parameters of the considered paths ($\lambda = 10^{-2}$ m and $\psi_{gr} = 10^{-3}$ rad) according to (1) we obtain $U_{10} > 4.05$ m/s. This wind speed corresponds to the mean square value of wave height of about 10 cm. Therefore, at the height of 10 m above the sea surface and wind speeds exceeding 5 m/s for accepted heights of corresponding points of several meters and path ranges of several kilometers in the case of radiowave propagation it is possible to be limited by the account of single interaction of the irradiating electromagnetic field with the roughnesses of the sea surface. This interaction occurs in the vicinity of wave peaks [4, 6, 7]. In