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ANALYSIS OF THE SECOND-ORDER STATISTICAL CHARACTERISTICS OF A RAPIDLY FADING RADIO SIGNAL*

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The average number of intersections with a given level of the envelope of a rapidly fading signal and the mean duration of a fading are determined for different propagation paths.

Information transmission in the information channels using free propagation of radio waves always occurs with fluctuations of the signal amplitude. The random fluctuations of signal level at the receiver input are called fading. Usually, the amplitude fluctuations may be categorized as rapid and slow fading [1–3]. The reason for the rapid fading lies in the multi-beam structure of the signal and beams' interference, while the reason for the slow one lies in shadowing the first Fresnel half-zone of the radio signal along the path because of the land relief. Since the nature of the fast and slow fading is different, their impacts are often considered separately. In what follows, we shall speak of the rapid fading.

In order to describe the fading quantitatively, the second-order statistical characteristics are often used, such as *the average number of intersections* with a given level per time unit, and *average duration of a fading*. Let us investigate these characteristics as applied to the following situation. For the model of a received signal we shall take the sum of a harmonic signal $s(t)=A_m\cos(\omega_0 t)$ and a quasiharmonic Gaussian noise $n(t)=N(t)\cos(\omega_0 t+\varphi_N(t))=N_c(t)\cos(\omega_0 t)-N_s(t)\sin(\omega_0 t)$, which represents a Gaussian centered random process with the correlation function $K_n(\tau)=\sigma^2\rho(\tau)\cos(\omega_0\tau)$. Here the envelope $N(t)$ is distributed in accordance with Rayleigh's law [3], the phase $\varphi_N(t)$ is uniformly distributed on the interval [–π; π], and the quadrature functions $N_c(t)$ and $N_s(t)$ are uncorrelated Gaussian random processes with identical correlation functions $\sigma^2\rho(\tau)$. Hence, the observed data can be represented in the form

$$x(t)=s(t)+n(t)=U(t)\cos[\omega_0 t+\psi(t)],$$

where $U(t)=\sqrt{(N_c(t)+A_m)^2+N_s(t)^2}$ and tan $(\varphi_n(t))=N_s(t)/(N_c(t)+A_m)$. It is known [3] that the envelope $U(t)$ in this case is described by the Rayleigh-Rice distribution $W(U|A_m)=(U/\sigma^2)I_0(A_m U/\sigma^2)\exp(-(U^2+A_m^2)/2\sigma^2)$, where $I_0(\cdot)$ is the zero-order modified Bessel function [4]. Obviously, in the absence of the determinate component, i.e., at $A_m=0$, we arrive at the Rayleigh distribution [3].

Consider the characteristics of outbursts of the envelope $U(t)$. The average number of intersections with a given level C per time unit refers to the mean value of the number of "negative" outbursts of the envelope [5–7] with respect to the level C. The mean duration of fading corresponds to the average time, during which the envelope does not exceed the level C. At first, consider the determination of the average number of intersections $N^-(C)$. Provided the process $U(t)$ is stationary,

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