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Characteristics of the Quasi-Probable Detection of Finite Signal with the Unknown Time of Arrival[1]

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Abstract—An algorithm synthesized for certain predictable signal waveform has been used to detect signals having a priori unknown waveform. Asymptotically exact, as the signal-to-noise ratio increases, expressions for the signal detection characteristics were derived under conditions of interferences in the form of white Gaussian noise. The synthesized algorithm was simulated on a computer.

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The problem of optimal reception of the most common model of finite signal representing the elementary rectangular pulse with the unknown time of arrival against the background of Gaussian white noise was the subject of investigations in papers [1–3], etc. It was shown that legitimate signal is discontinuous in terms of the unknown parameter. The synthesis of the maximum likelihood algorithm was performed and detection characteristics of the signal with unknown time of arrival were also found. However, the actual conditions of signal generation and propagation result in its waveform being different from rectangular. Under conditions of a priori unknown waveform of the finite signal received, quasi-probable (QP) receiver synthesized for a certain predictable (supposed) signal of the same duration can be used for detecting such finite signal [3]. For that matter it may be of interest to synthesize and analyze the QP algorithm designed for detection of the discontinuous signal of finite duration and arbitrary waveform with the unknown time of arrival.

Let us consider the problem of detecting a finite signal of arbitrary waveform with the unknown time of arrival

$$s(t-\lambda_0) = f(t-\lambda_0) I\left[\frac{(t-\lambda_0)}{\tau}\right], \tag{1}$$

observed during time interval $[0,T]$ against the background of additive Gaussian white noise $n(t)$ with one-sided spectral density N_0. Here $I(x)=1$ at $|x| \le 1/2$, $I(x) = 0$ at $|x| > 1/2$, $\lambda_0 \in [\Lambda_1, \Lambda_2]$ is the unknown time of arrival, τ is the signal duration, $f(t)$ is the unknown differentiable function describing the waveform of the input signal. The value $\Lambda = \Lambda_2 - \Lambda_1$ determines the duration of a priori interval of possible values of the time of arrival. The realization of data observed at the receiver input has the form:

$$x(t) = \gamma_0 s(t-\lambda_0) + n(t), \quad t \in [0,T]. \tag{2}$$

Here and elsewhere zero index means the true value of appropriate parameter. Parameter $\gamma_0 \in 0, 1$ where $\gamma_0 =$ 0 corresponds to the case of the absence of signal in observed data, while $\gamma_0 = 1$ corresponds to the presence of signal. Given the observed realization $x(t)$ (2), a decision must be made as to the value taken on by parameter γ.

If the waveform $f(t)$ of signal (1) is known, one can find the logarithm of likelihood ratio functional (LRF) and implement the maximum likelihood (ML) detector. We assume that function $f(t)$ is unknown

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