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Estimation of the Number of Orthogonal Signals with Unknown Non-Energy Parameters[1]

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Abstract—The synthesis and analysis of an algorithm for estimation of the number of orthogonal signals with unknown non-energy parameters have been performed by using the maximum likelihood method.

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The need of estimating the number of received signals arises in case of the unknown number of signal sources and in case of the unknown channel structure through which the signal is transmitted. For example, in the case of using a multipath radio communication channel in MIMO systems [1, 2], the number of beams is often a priori unknown and it should be determined. In case of radar and acousto-detection-and-ranging (active or passive) observation, it is quite a common situation when the number of signals arriving at the antenna array is unknown [3–9].

However, today the problem of estimating the number of signals has been solved only partially. The difficulties arise in determining the structure of estimation algorithm. In practice the results of theoretical analysis of the performance quality of algorithms for estimating the number of signals are not available. Moreover, the generally accepted and well-defined quantitative characteristic of such algorithms is also lacking. Without the introduction of quantitative characteristics of algorithms for estimating the number of signals, difficulaties arise in comparing the specified algorithms and choosing the most effective one.

The problem of estimating the number of signals with unknown amplitudes was investigated in [10] where it was assumed that the received signals could be nonorthoonal. The signal amplitude is an energy parameter [11] because the signal energy depends on it. At the same time, there is often a need of estimating the number of signals, which contain unknown non-energy parameters. They include the time of signal arrival, signal frequency, initial phase, etc.

Below we consider the problem of synthesis and analysis of the algorithm for estimation of the number of orthogonal signals with unknown non-energy parameters that are received against the background of the Gaussian white noise. The synthesis of estimation algorithm is performed on the basis of the maximum likelihood method [11]. The algorithm efficiency is characterized by the error probability in estimating the number of signals. The analysis of the obtained algorithm involved the use of the signal detection theory [12] and the notion of the truncated error probability [10].

Following [10] we shall consider the maximum likelihood estimate of the number of orthogonal deterministic signals. Let us assume that a sum of ν signals $s_i(t)$ is observed, so that the signal received will have the form:

$$s(t,\nu)=\sum_{i=1}^{\nu} s_i(t), \tag{1}$$

where $\nu=\overline{1,\nu_{\max}}$, $\forall i\ \ s_i(t)\in L_2(0,T)$.

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