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Estimation of the Initial Phase of Narrowband Radio Signal with Unknown Amplitude and Duration[1]

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Abstract—The quasi-likelihood and maximum likelihood algorithms for estimating the initial phase of radio signal with arbitrary shaped envelope and unknown duration and amplitude have been synthesized. Schematic block diagrams of initial phase meters are proposed. Characteristics of the synthesized algorithms were determined, and errors of the initial phase estimates were compared. The structure of quasi-likelihood estimate of the initial phase is shown to be invariant with respect to the lack of knowledge of radio signal amplitude. However, a mismatch between the expected value of signal duration and its true value can lead to a marked increase of dispersion of the initial phase quasi-likelihood estimate. The loss in accuracy of the initial phase estimate due to a priori lack of knowledge of signal duration has been determined. Analytical expressions for statistical characteristics of maximum likelihood estimate of initial phase at large signal-to-noise ratios are shown to coincide asymptotically with the characteristics of maximum likelihood estimate of the initial phase of radio signal with a priori known amplitude and duration. Therefore, a priori unknown signal duration (asymptotically with an increase of signal-to-noise ratio) does not affect the accuracy of the maximum likelihood estimate of initial phase. The computer methods of statistical simulation were used to determine the applicability limits of asymptotic expressions for characteristics of the maximum likelihood estimate in respect of signals with linear and exponential envelopes.

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The problem of estimating the initial phase of radio signal observed against the background of noise is relevant for many practical applications of radio electronics that was the subject of many publications [1–10]. Hence, for example, the initial phase estimate must be formed for detecting the PSK (phase-shift keyed) signals used in modern telecommunication systems. The maximum likelihood (ML) estimate of the initial phase of narrowband radio signal is considered in papers [1, 2] on condition that the remaining signal parameters are a priori known, and the estimate characteristics of estimate are also found. The techniques for building coherent demodulators of PSK signals based on the phase-locked-loop frequency control of reference carrier oscillator and on the phase shift of demodulated signal were studied in [3]. The estimation of initial phase in the presence of fast fadings was studied in [5].

However, practical applications of statistical communication theory often require to estimate the initial phase of radio signal with a nonrectangular shape of envelope and unknown duration and amplitude. Below we consider the algorithms for estimating the initial phase of narrowband radio signal with unknown duration and amplitude.

Let us assume that realization

$$\xi(t) = s(t, a_0, \tau_0, \varphi_0) + n(t) \tag{1}$$

of additive mixture of useful narrowband radio signal

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