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Application of the Orthogonal Representation Method for Determining the Probability Densities of Typical Models of Fluctuation Signals

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Abstract—The theoretical and experimental probability densities of fluctuation signals have been determined for typical models of elementary pulses based on their orthogonal representations and using mathematical simulation. The obtained results showed the validity of such representation.

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STATEMENT OF THE PROBLEM

Fluctuation signals are information carriers in various radio engineering and radiophysical passive systems [1]. These signals are formed by objects under investigation in the process of their natural functioning. Fluctuation signals generally represent a random sequence of elementary pulses. The examples of fluctuation signals are noises of electronic devices and systems, various radiophysical phenomena, the acoustic and biomedical noise signals, etc. [1, 2].

The Bunimovich–Rice processes represent the most widespread model of fluctuation signals that is based on their consideration as a result of pile-up of a large (random) number of elementary pulses with random parameters. The specified processes are determined by the following expression [1–4]:

$$\xi(t) = \sum_{k=1}^{N(t)} \eta_k h(t - t_k), \tag{1}$$

where t_k are the random instants of time of pulse appearance representing a uniform Poisson flow of events with intensity $\Lambda > 0$; $h(t)$ is the determinate function describing the waveform of elementary pulses; η_k are the amplitudes of elementary pulses that are interchangeable, identically distributed random quantities independent of t_k; $N(t)$ is the homogeneous Poisson process.

Model (1) was first thoroughly investigated in fundamental papers of Bunimovich V. I. [3] and Rice S. [4]. This model is extensively used in radiophysics [1], statistical radio engineering [5], electronics [6], in researches of ferromagnetism [7], acoustic emission [8], cavitation noise [9], etc.

For processes (1) that are stationary in the narrow sense the formulas [1, 3–5, 10] are known for determining the one-dimensional and multidimensional characteristic functions, one-dimensional and multidimensional cumulant functions, etc.

It is usually assumed [1, 3–5, 10] that condition $\Lambda\tau_0 >> 1$ is fulfilled, where τ_0 is the effective duration of elementary pulse, which allows the distribution of processes (1) to be approximately considered as Gaussian. In the general case processes (1) are non-Gaussian [11] and have the infinitely divisible distribution law, hence the direct determination of probability density in closed form is possible only in individual cases [2].

That is why in the majority of cases the determination of probability density of fluctuation signals involves the need of applying the approximate methods, among which the method of orthogonal representations is the most universal [5, 10, 12].

In spite of the recommendations [1, 5, 10] to use the orthogonal representations for finding the probability densities of fluctuation signals and for the analysis of their functional transformations, nowadays the specific results of solving such problems are practically not present in the known literature.