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Detection of the Chaotic Process Distorted by the White Noise Using BDS Statistics

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Abstract—A nonparametric criterion for the detection of a chaotic process observed against the background of white noise has been proposed with due regard for the dependence of the process values. BDS statistic is used for the numerical account of the degree of dependence of values of the process observed. It was shown that this criterion refined the conventional estimate of the chaotic process stealthiness that was obtained using the energy criterion for detecting deterministic signals of the unknown "waveform" and random processes. Characteristics of a nonparametric detector of chaotic processes with a different degree of the dependence of its values were obtained on the basis of computer simulation under condition of the exposure to additive white Gaussian noises of different intensity.

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The studies dealing with applications of the dynamic chaos for data transmission systems (DTS) have been actively conducted for about fifteen years (e.g., papers [1–3]). One of the motivations for these studies was a hope of DTS designers to solve the issues of system security from the unauthorized access and their operation disguised as noise for ensuring the stealthiness of operation. In this case it is implied that the efficiency of stealthiness of such systems is based on a small probability of the correct classification of the process observed as chaotic or random due to their visual similarity, the absence of indicators of periodicity or other kind of order (regularity). In addition, these processes are practically indiscriminate within the framework of the correlation and spectral analyses. At the same time the visual analysis of chaotic and random processes in the phase (pseudophase) space shows a significant difference of their evolutions ("trajectories") that is determined by a different degree of the dependence of their values. The account of the data dependence intrinsic to chaotic processes increases the probability of correct classification and leads to the reduction of potential stealthiness of the chaotic carrier to the level determined by its observation noise.

In what follows under stealthiness we shall understand [4] the capability of resisting the measures of radio intelligence: signal detection and determination of its structure based on estimating a number of the signal parameters. Value $p_{stl} = 1 - p_{int}$ can be used as a stealthiness criterion. The problem of disclosing the meaning of data often is not raised, then it can be assumed that stealthiness is determined by the intelligence probability $p_{int} = p_{det}\, p_{str}$ that is characterized by the probability of correct detection of signal p_{det} and the probability of disclosure of its structure p_{str}.

The analysis of probability p_{str} is based on the accuracy of joint estimation of parameters of the chaotic process (carrier) that include the initial values and control parameters in equations describing the operation of a transmitting dynamic system. Given the exact setting of these parameters at the receiving side, DTS will be capable of operating at a small signal-to-noise power ratio. However, in fact, at a small number of parameters and a low level of noise they are characterized by limited confidentiality, since the synchronization phenomenon intrinsic to these dynamic systems actually eliminates the estimation of the initial value of the process and enables an outside observer to separate the data message. In this case only the system control parameters are estimated. For enhancing the structure stealthiness it is proposed to use the systems with delay demonstrating the chaotic dynamics of a very high dimension resulting in the need of estimating a great number of process initial values, rather than one value, belonging to the finite time interval preceding the values of the chaotic signal transmitted. However, in this case the data message can be also separated by an outside observer after the estimation of transmitter parameters of the dynamic system by viewing the transmitted signal at an insignificant level of noise. In all cases the quality of separating a data message depends on the accuracy of estimation of unknown parameters of the transmitter. Small variations of parameters essentially reduce the efficiency of message separation [3].