Development of new data carriers on the basis of non-linear system characterised by dynamic chaos

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Abstact - The pseudo-random signals generators with controlled statistical characteristics on the basis of nonlinear systems with dynamic chaos are considered. It is shown that the optimization of the time digitization parameters provides improvement of correlative characteristics and probability distributions of pseudo-random signals samples. The quasi-resonance control influences on the parameters of Lorenz's system are researched.

Keywords – chaos, nonlinear systems, quasi-resonant influences.

1. Introduction

Non-linear systems with dynamic chaos are used to describe processes in radioelectronics, quantum devices, systems of plasma stabilization and warming-up, systems of phase automatic frequency control. Provision of the needed (regular or chaotical) working regime for non-linear radioelectronics, quantum devices and for systems with chaotical dynamics is a critical task put forward by practical demands.

Development of new data carriers on the basis of non-linear system characterised by dynamic chaos is also one of the most important practical targets **[1]**. The overall concern about the chaotical signals is first of all determined by their correlating and spectral characteristics similar to the characteristics of random signals. The important feature of non-linear systems with dynamic chaos causing chaotic signals is that there appears an ability to manage statistical features of the signals by direct influencing on the system parameters and features of temporal discretisation **[2]**.

The aim of the work is to develop of new data carriers on the basis of non-linear system by researching correlation characteristics and distribution of pseudorandom signals realization probabilities, formed on the basis of non-linear systems with dynamic chaos.

At the present moment the following items have been researched: generators of chaotic signals created on the basis of the Chua schemes, of phase automatic frequency control, on the basis of the systems of related generators, systems of ring self- vibrating systems, on the basis of elements with delay elements and registers on module two, on the basis of non-linear reflections of Bernulli, Henonn, Lozi, on the basis of non-linear systems with dynamic chaos. The Lorenz system is one of the most studied systems with chaotical dynamics realized in the form of special integral microschemes **[3]**:

$$\dot{X} = \sigma(Y - X),\ \dot{Y} = rX - Y - XZ,\ \dot{Z} = -bZ + XY \tag{1}$$

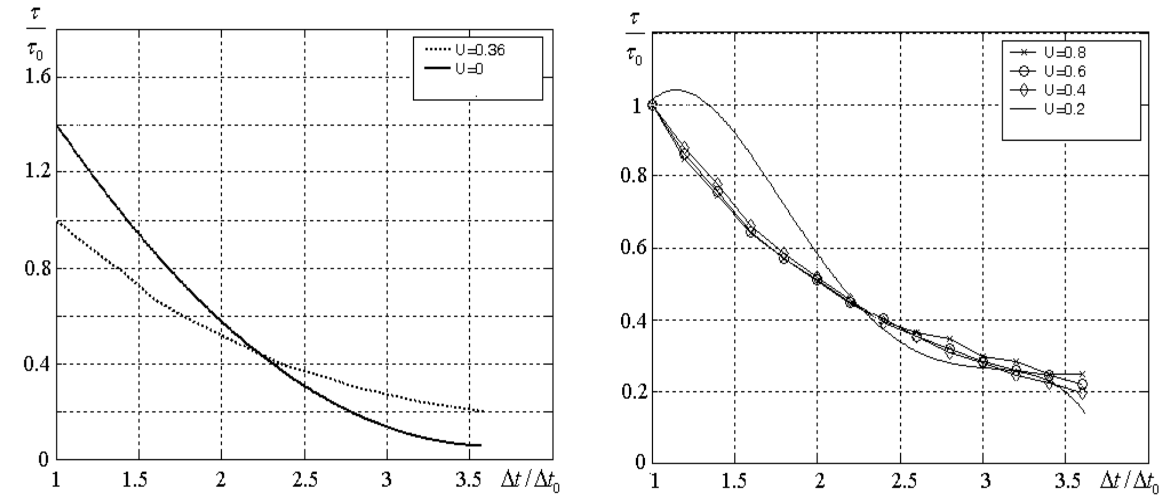
where X, Y, Z are variables of the systems, r, σ, b are parameters of the Lorenz system.

2. Suggested solution

Analogous realizations forming pseudorandom signals on the basis of non-linear systems with chaotical dynamics do not possess any reproduced statistical characteristics. Thus it makes it necessary to form pseudorandom signals on the basis of numerical integration procedures of non-linear difference equations used to describe systems with chaotic dynamics.

One of the parameters influencing statistical characteristics of the signals formed is the temporal discretisation step. Temporal discretisation step estimation Δt to T_1 of quasi-resonant vibrations at the conditions of the balance of dynamic systems $C_{1,2} = \pm X_{01}, \pm Y_{01}, Z_{01}\left(X_{01} = Y_{01} = \sqrt{b(r-1)}, Z_{01} = r - 1\right)$ is made in accord with the parameter $K = T_1 / \Delta t$. The existence of the variations of the parameter of the temporal discretisation K when forming pseudorandom signals on the basis of the system (1) is the reason the level of discretisation noises changes and consequently the changes also happen to the statistical characteristics of the formed signals. In that case it is necessary to define the influence of the parameter of the temporal discretisation on the correlating characteristics and on the distribution of the possible realizations of the formed pseudorandom signals when the variation is $K \in [K_{\min}, K_{\max}]$ where $K_{\min}$ is defined on the basis of system equations solutions' analysis linearized in the neighbourhood of the dots stable and unstable balance [2], and where $K_{\max}$ is defined in accord with **[5]**.

One of the main characteristics of the chaotic signals is their autocorrelating function (ACF) defined in accord with signals' realizations of the system (1) and under variations of the temporal discretisation of K parameter. In this paper changes of the ACF signals formed by the system (1) have been valued with respect to standardized intervals $\tau(\theta)/\tau_0(\theta)$ until the first crosscuts with the correlating functions of the levels θ=0.8, 0.6, 0.4, 0.2; $\tau(\theta)$. The value $\theta = 1/e$ corresponds to the correlation interval at the end of which the fall of correlation function in e times happens in comparison with maximum value. Value $\theta = 0$ corresponds to the interval of correlation function of the zero level (fig. 1); $\tau_0(\theta)$ are correlation intervals while K=200 chosen within analytically defined range of values K **[2]**.



a б

Fig. 1 Defence of $\tau(\theta)/\tau_0(\theta)$ on the K

In the fig. 1 we can see that when the parameter K of temporal discretisation is decreased so decrease the correlation intervals of signals formed on the basis the Lorenz system of chaotical dynamics.

3. Quasi-resonant influences

Quasi-resonant influences on the parameters of the non-linear systems with dynamic chaos are referred to as one of the most perspective ways of functioning effectiveness increasing of signals forming on the basis of non-linear systems with chaotic dynamics.

The influence of quasi-resonant on the parameters of the non-linear systems with dynamic chaos is studied in **[6]**. When forming signals on the basis of the proceedings of numerical system integration (1) the parameter of temporal discretisation K can be used as the controlling. That makes dynamic changes definition of the parameter K actual **[2]**.

In the given paper quasi-resonant influences on the parameters of temporal discretisation of the kind **[4]** have been used

$$t_i = \Delta t\left(1 + M f_{i-1}\right), \tag{2}$$

$$f_{i-1} = \mathrm{sgn}\left(\frac{|X_i|}{X_{01}} \pm a\right).$$

The research results of the quasi-resonant parameters' influence under variation a on the correlation signal characteristic produced by the Lorenz system are in the table.

Table. Dependence of relative intervals correlation on the depth of modulation for M and threshold a .

a	M	$\frac{\tau(0.8)}{\tau_0(0.8)}$	$\frac{\tau(0.6)}{\tau_0(0.6)}$	$\frac{\tau(0.4)}{\tau_0(0.4)}$	$\frac{\tau(0.2)}{\tau_0(0.2)}$	$\frac{\tau(e)}{\tau_0(e)}$	$\frac{\tau(0)}{\tau_0(0)}$
0.1	0.5	0.82...0.9	0.83...0.9	0.79...0.92	0.82...1.15	0.85…1	0.28...2.02
	0.8	0.73...0.75	0.72...0.75	0.72...0.74	0.58...0.73	0.81…0.9	0.2...1.8
	0.9	0.57...0.61	0.58...0.61	0.55...0.62	0.43...0.57	0.37…0.8	0.18...0.5
0.5	0.5	0.64...0.75	0.64...0.72	0.63...0.69	0.56...0.77	0.6…0.75	0.21...0.87
	0.8	0.43...0.46	0.43...0.47	0.4...0.45	0.33...0.43	0.38…1.9	0.12...0.43
	0.9	0.28...0.33	0.32...0.34	0.3...0.33	0.27...0.31	1.05…4	0.08...0.28
0.8	0.5	0.53...0.58	0.52...0.57	0.48...0.57	0.41...0.58	0.48…0.61	0.18...0.6
	0.8	0.28...0.31	0.28...0.29	0.25...0.3	0.21...0.28	0.25…0.3	0.08...0.25
	0.9	0.13...0.15	0.15...0.16	0.14...0.15	0.15...0.17	0.15…0.17	0.05...0.18

From the table we see that when the values of relative departure are small and it is true that $a = 0.1$ not only the reduction till $\tau(u)/\tau_0 \approx 0.2$ but also increase of intervals of formed signals correlation may occur. That is why it is necessary to choose the values a>0.1. When $a = 0.5$ it is possible to extract the area of values of depth modulation $0.33...0.5 \le M \le 0.75...0.78$ where reduction of intervals of correlation in accord to both criteria $\tau(e), \tau(0)$ happen regardless of the chosen initial conditions of the system (1).

If $M < 0.33$ it is possible that intervals $\tau(0)/\tau_0(0)$ will increase. In case $M > 0.78$ intervals $\tau(0)/\tau_0(0)$ reduce and intervals $\tau(e)/\tau_0(e)$ increase. Further increase until $a = 0.8$ leads to reduction of correlation intervals of the formed signals until $\tau(0)/\tau_0(0) = 0.08$, $\tau(e)/\tau_0(e) = 0.25$ at the values of modulation depth $0.33...0.5 \le M \le 0.75...0.78$. As well as if $a = 0.5$ there exists one more interval $0.89 \le M \le 0.9...0.91$ of correlation reduction in accord to both criteria. Hence when using influences (2) the formed on the basis of system (1) correlation intervals reduce up to 20 times.

The analysis of impact of quasi-resonant influences on the distribution of realization probabilities of signals is carried out on the basis of signals *X, Y, Z* of the system (1) realization histogram.

Distribution approximations of pseudorandom realization probabilities which are produced by non-linear systems and mixture distribution of Gauss were received (fig. 2)

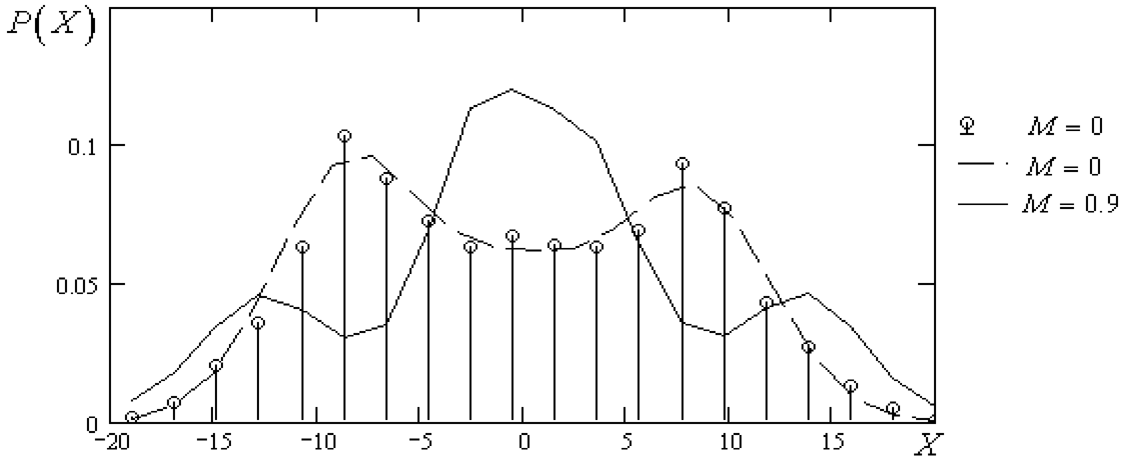


Fig. 2. Evaluation of signal *X* realization probability of system (1) distribution and its approximation by probabilistic mixture.

In the fig. 2 we see that in case *M*=0 distribution of realization probabilities of *X* has biomodal character. The distribution of realization probabilities of *X* signals of the system (1) with no controlling influences may be approximated by probabilistic influences of three Gaussian allocations with mathematical expectations $m_0 = 0, m_{1,2} = \pm\sqrt{b(r-1)}$ and least square deviations $\sigma_{0,1,2} = 3.4...3.9$ with measure of inaccuracy of approximation no more than 7% (shown by the dotted line). In the fig. 2 we can also see that using influences (2) leads to the decrease in the probability of *X* existence in the surroundings of balance conditions $C_{1,2}$ (shown by solid line).

The number of mutual transmissions of phase trajectory between the balance states $C_{1,2}$ increases. Consequently the probability of trajectory being near the dot (0,0,r-1) increases either. That is why quasi-resonant influences make it possible to control probability distributions of the formed signals and to transform biomodal *X* realizations into three mode distributions.

4. Conclusions

1. Temporal discretisation parameters' variation and quasi-resonant controlling influences on the parameters of the temporal discretisation are effective ways of correlation characteristics controlling and distributing of possible realizations of pseudorandom signals formed on the basis of Lorenz systems.

2. Quasi-resonant influences on the parameters of temporal discretisation of the Lorenz system make it possible to reduce correlation intervals of the formed *X,Y* signals no less than 20 times and also to transform biomodal distribution probabilities of the formed *X,Y* signals into the three-modal one.

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