Application of the Control of Chaotic Processes in the Electronic Communications

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ABSTRACT: *We in this research have addressed the issues about the controlling of the chaotic processes in nonlinear systems with dynamic chaos. In the proposed approach is synthesized external impact on the system parameters. The issues studied can able to increase the phase trajectory from equilibrium points to achieve the chaotic regime. The approach is applied to dynamic system, described by the equations of Lorenz, as the study is done in an environment of Mathcad.*

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1. Introduction

The most important achievements of nonlinear dynamics in recent decades are the theory of the determined chaos. Chaotic processes are quite common and can occur in systems of different nature – economic, physical, and biological, etc. [3, 4, 5]. The chaotic signal is a relatively a new field in communication systems, too. Until the sixties of the last century the term "chaos" is associated with unpredictable and uncontrollable processes. The combination of the terms "control" and "chaos" is considered paradoxical. But in the last decade of the twentieth century this concept is being changed. On the limit of two studies: nonlinear dynamics and the theory of control emerged scientific direction, which explore possibilities to control the chaotic processes. Under this concept is the reforming of process by focusing a little impacts on the system in periodic, quasi-periodic, or in chaotic, but with other properties [1, 2, 3, 4, 5].

The control of the chaotic processes is associated with their sensitivity to the initial conditions [6, 7], as a requirement for performance of chaotic process is their parameters. As it is known [8, 9] small difference in the initial condition can lead to exponential decay of the trajectories, which achieve the aim of control.

Another important factor is that the systems with chaotic behavior are typical many unstable states, for example, between them can happen a little change of the system's parameters.

The main idea of the control methods of the chaotic processes in this paper is to reach needed attractor. It happens by impact on the parameters of the system.

The idea to obtaining needed chaotic attractor is applied to the chaotic generators in Chaos Shift Keying (CSK) communication system (CS) [10, 11] is proposed an approach for the synthesis of impacts of the chaotic generators parameters. Through which it is increased the amplitude of the deviation of the phase trajectory from the balance points until reaching the chaotic mode. The proposed approach is applied to the system described by the equations of Lorenz [3] and the research was done of environment of Mathcad.

2. Review of CSK Approach

A block diagram of the CS with CSK is shown in figure 1 The chaotic system with parameters μ is located in the transmitter.

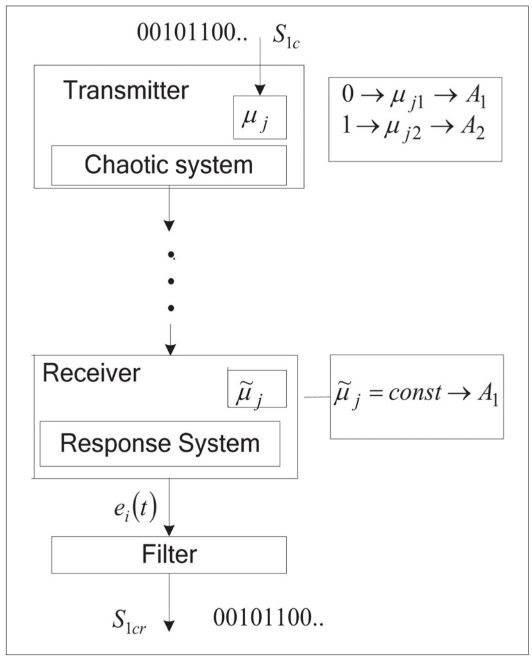


Figure 1. A principle block diagram of the CS with CSK

The transmitter dynamics are dissipative and chaotic and the transmitter state trajectory converges to a strange attractor.

A message is transmitted by changing one of the parameters μ (μ_j) which results in a change of the transmitter attractor dynamics.

If value μ_{j1} responds to symbol "0" and value μ_{j2} to symbol "1" of the binary information signal S_{1c}, the transmitter chaotic generator switches over attractors A_1 and A_2.

In the receiver is the response system. In coherent detection [5], the receiver is required to reproduce the same chaotic signals sent by the transmitter, often through a chaos synchronization process.

During transmission, the response system parameter $\tilde{\mu}_{j1}$ = constant. All other parameters of the chaotic system in the transmitter are identical to their corresponding parameters in the response system in the receiver.

So, synchronization will occur only during periods of submission to symbol "0", when there is a complete coincidence between the parameters of both systems.

3. Obtaining of the Parameter Value

Let the chaotic system in transmitter be defined by a system of differential equations.

$$\dot{\boldsymbol{x}} = \boldsymbol{f}(\boldsymbol{x}, \mu), \tag{1}$$

where $x = (x_1, x_2, ..., x_n)$ is the multitude of variables describe the state of the system defined in the state space R^n, μ is combination of control parameters.

For the system (1) are defined balanced states $\{\vec{x}^*\}$ with coordinates $\overset{*}{x}_1, \overset{*}{x}_2, ..., \overset{*}{x}_n$.

The stochastic process of the fluctuation, is a solution of (1), is related to the increase of the amplitude on the deviation of the phase trajectory in the surround of the balanced points.

This deviation is:

$$R = \sqrt{\left(x_1 - x_1^*\right)^2 + \left(x_2 - x_2^*\right)^2 + \ldots + \left(x_n - x_n^*\right)^2} \tag{2}$$

If we express the derivatives (3) and define them about the parameters μ, we will determine the law of change of influence $p(t)$, through which it can be achieved a chaotic mode of fluctuations.

$$\frac{d\left(x_i - x_i^*\right)^2}{dt} \tag{3}$$

Then they are synthesized external control impacts by the type (4) where K is a weight coefficient

$$P(t) = K.p(t) \tag{4}$$

They are shown into the system of differential equations (1) so that it has the type:

$$\dot{\boldsymbol{x}} = \boldsymbol{f}(\boldsymbol{x}, \mu) + \boldsymbol{P}(\boldsymbol{t}) \tag{5}$$

4. Model Construction

Let the transmitter chaotic generator be obtained by Lorenz system equation:

$$\begin{aligned} \dot{x} &= \sigma(y - x) \\ \dot{y} &= \rho x - y - xz \\ \dot{z} &= xy - \beta z \end{aligned} \tag{6}$$

where α, ρ and β are parameters, $x(t)$, $y(t)$, $z(t)$ – variables.

It is determined that at $\rho > 1$ the balanced states of (6) are points with coordinates

$$\begin{aligned} x_{1,2}^* &= \pm\sqrt{\beta(\rho - 1)} \\ y_{1,2}^* &= \pm\sqrt{\beta(\rho - 1)} \\ z_{1,2}^* &= \rho - 1 \end{aligned} \tag{7}$$

According to the equation (5) in the model of Lorentz is introduced external impact P_ρ on the second equation of the system (7):

$$\begin{aligned} \dot{x} &= \sigma(y - x) \\ \dot{y} &= \rho x - y - xz + P_\rho \\ \dot{z} &= xy - \beta z \end{aligned} \tag{8}$$

The task is to synthesize the function P_ρ so that the model (8) has a chaotic mode by the new value of parameter ρ. For this aim is expressed

$$\frac{d\left(y-y^*\right)^2}{dt} = 2\left(y-y^*\right)\frac{d\left(y-y^*\right)}{dt} = 2\left(y-y^*\right)\left(\rho x - y - xz\right) \tag{9}$$

After definition of (9) towards ρ is prepared

$$\frac{d\left[2\left(y-y^*\right)\left(\rho x - y - xz\right)\right]}{d\rho} = 2\left(y-y^*\right)x \tag{10}$$

This equation (10) gives the opportunity influence to be used on the parameter ρ. Which are determined by the sign of the current deviation of the variable y from the balanced coordinate (11), where ρ_0 is the beginning value of the parameter.

$$p_\rho = \rho_0 + sign\left(y - y^*\right)\rho_0 \tag{11}$$

On the basis of (11) is formed (12), where the weight factor K is selected depending on the desired attractor.

$$P_\rho = Kp_\rho \tag{12}$$

The described approach is simulated by Mathcad, as they are used parameters with values $\sigma = 10$, $\rho = 10$ and $\beta = 8/3$. They are shown in figure 2.

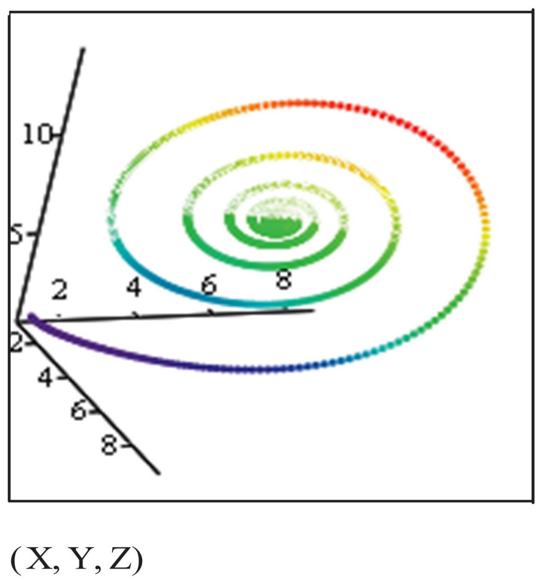
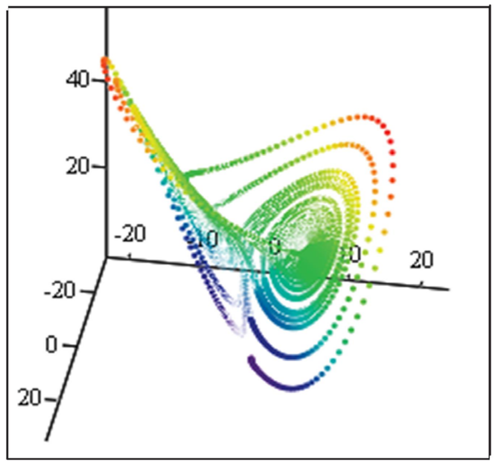


Figure 2. Periodical mode

After realization of an effect of the type (12) we received a chaotic mode. When $K = 0.1$ the attractor look like in figure 3. This is a realization of parameter $\mu_{j1} = \rho_1$.

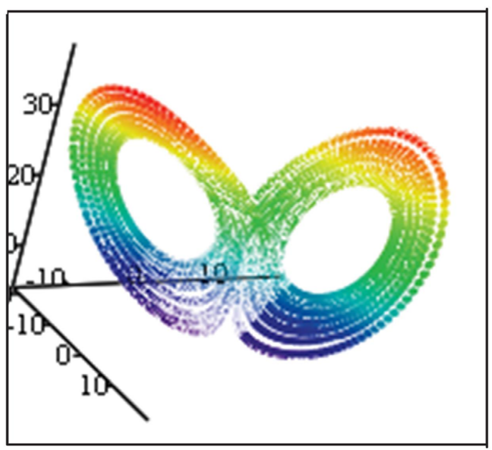
When $K = 0.2$ is given the classical attracter of Lorentz looks like in the figure 4. This is a realization of parameter $\mu_{j2} = \rho_2$.

From the given three-dimensional phase trajectories shown in figure 3 and figure 4 can be seen how through the influence P_ρ (12) is realized the needful value of the parameter ρ.



(X1, Y1, Z1)

Figure 3. Chaotic mode at K = 0,1



(X2, Y2, Z2)

Figure 4. Chaotic mode at K = 0.2

5. Conclusion

The studies, made in the paper, show that chaotic system can realize chaotic mode through external influence of its parameters, which are formed of the basis of the deviation of the phase trajectories of the balanced states. Through the changing on the strength of the impact on the parameter, which is expressed by introduce weighting factor, can achieve the wanted chaotic attractor.

The given approach for the control of the chaotic process can be applied to different chaotic system which aim is to achieve the wanted mode of work.

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