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RANDOM SIGNALS DETECTOR BASED ON SYNCHRONOUS CHAOTIC OSCILLATORS

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The article considered the functional transducer based on chaotic oscillators designed for the detection of weak random signals in noise, presents a numerical analysis of the noise immunity of the system.

Keywords: measuring transducer, detection of weak signals, non-autonomous chaotic oscillator, generalized chaotic synchronization.

At the moment, due to the introduction of industry-standard IEEE 802.15.4a-2007 again increased interest in the study of synchronization of chaotic oscillations [1]. This standard provides a method for wireless data transmission based on the chaotic carrier. With the advantages of ultra-wideband communications, this approach is characterized by direct modulation of the information signal in broadband. Furthermore, this method can improve secrecy of information transmission. Besides the possibility of transmission of information, chaotic oscillators can be used to obtain it in the various control devices which requires to detecting the useful signal at the prevailing background noise. The problem of detection of random signals in noise in the devices control remains relevant and occurs in cases when received at the input of the device the desired signal is weak in comparison with the internal noise in the instrument or exposed to strong external interference. The most affordable way to detect periodic signals using chaotic oscillators - bifurcation. However, for the detection of random signals must use the synchronization of chaotic oscillators.

There are various approaches to the implementation of the synchronization of chaotic oscillators, for example, direct sync, lag-synchronization, generalized synchronization, phase synchronization, noise - induced synchronization and others.

With regard to the question of detecting a signal in noise, the most promising is now considered approach using generalized synchronization.

To apply the method of generalized synchronization requires the following components: a master chaotic oscillator (MCO), two slave chaotic oscillators (SCO) and a comparator (CMP). Figure 1 shows a simplified scheme of generalized synchronized chaotic oscillators.

Master oscillator signal in the communication channel is exposed to interference $D \cdot \xi(t)$, where $\xi(t)$ - Gaussian stochastic process with zero mean and unit variance, D - the degree of interference. The receiving system consists of two identical, unrelated slave oscillators SCO1 and SCO2.

This scheme is well studied on the example of autonomous Rössler chaotic oscillators [2]. In this paper, a study using non-autonomous Duffing-Holmes oscillators, and obtained similar results.

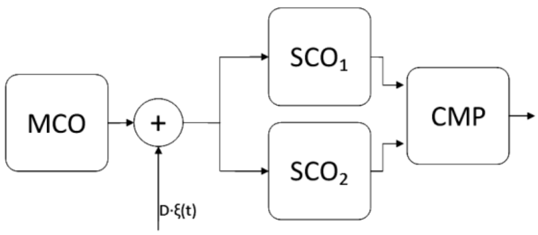

Figure 1 - Simplified diagram of a generalized synchronization of chaotic oscillators. MCO-master chaotic oscillator, SCO1, SCO2 – slave chaotic oscillators, CMP - comparing unit In dimensionless form Duffing - Holmes oscillator is described by the following equation:

$$\ddot{x} + \delta \cdot \dot{x} - x + x^3 = f \cdot \cos(\omega t), \qquad (1)$$

where δ - dissipation parameter in the system; f - the amplitude of the reference oscillator; ω - frequency of the reference oscillator.

Chaos in this system is observed in a rather narrow range of parameters, so it was obtained a two-parameter bifurcation diagram of the oscillations modes (Figure 2).

To observe the generalized chaotic synchronization should take the following theses:

– master system is set to the operating mode with chaotic dynamics;

– two identical slave systems are deployed close to the master, but in the mode of periodic oscillations;

– when there is no input signal, the slave system, while in periodic mode, set the synchronous mode together. This will happen regardless of the initial conditions, since both the slave oscillator, use one reference harmonic oscillator. Synchronization is detected by the minimum difference signal at the output of comparator;

– when entering the input signal is only the noise, the slave systems exhibit chaotic oscillations randomly drawn out input process, wherein stability of the periodic modes results in that the difference signal is also in this case be minimized;

– when applied to the input signal master system, the slave systems are beginning to show true chaotic dynamics, namely a random process with a high sensitivity to initial conditions. Since the internal implementation of the slave oscillatory systems cannot be absolutely identical, their vibrations will vary significantly and the output of comparator is significant in scale random signal. If the parameters of the master oscillator to differ materially from the slave systems, such as the frequency ω, it will not cause such a chaotic response. And hence, the present method also allows to distinguish between several chaotic oscillator signals.

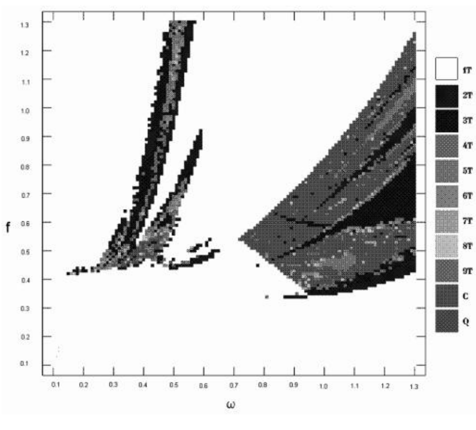

Figure 2 - Two-parameter bifurcation diagram of the oscillations modes of Duffing-Holmes oscillator in the parameter space ω - f, with δ = 0.5. Numerals indicate the periodic modes of different periods; C -chaotic mode

To verify the above theses on the example of Duffing-Holmes oscillator following parameters were chosen: for master system δ = 0.5; ω = 1; f_1 = 0.81, for the slave systems δ=0.5; ω = 1; f_2 = 0.83. According to the bifurcation diagram (Figure 2), these points are separated by bifurcation intermittency. One-way communication was performed by a dynamic variable $\dot{x}$. Thus, the slave dynamic systems described by the following equations:

$$\ddot{y}_{1,2} + \delta \cdot \dot{y}_{1,2} + \varepsilon \cdot \dot{x} + D \cdot \xi(t) - y_{1,2} + y_{1,2}^{3} = \\ = f_2 \cdot \cos(\omega t), \quad (2)$$

where ε - the coefficient of dissipative coupling.

A numerical experiment was carried out in Matlab / Simulink. Synchronization slave systems monitored visually by the difference signal.

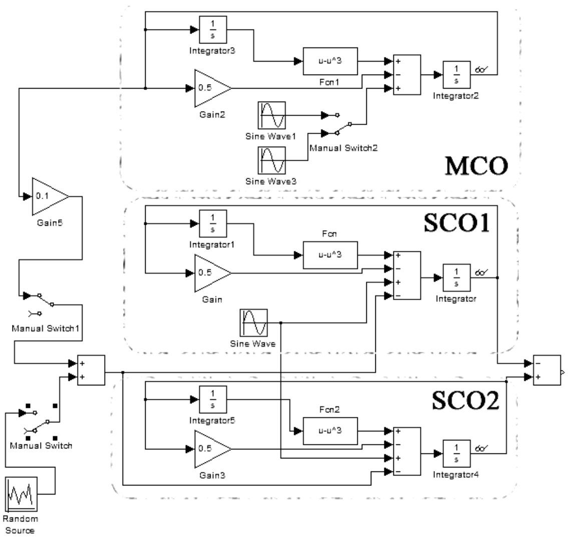

Figure 3 - The estimated model in Matlab / Simulink

Figures 4 and 5 show the time dependences of the master and slave oscillators in different modes of generalized synchronization.

The observed effect can be explained by the following considerations. Slave oscillators in the absence of external influences being carried out in a periodic mode synchronous periodic oscillations as periodic mode for their is stable and even for different initial conditions, hold a single stable trajectory in the phase space - a limit cycle. In the case of an input random noise signal and the chaotic oscillator, a noticeable shift from the slaves, for example, the frequency of the reference oscillator ω, outwardly noticeable complexity motion trajectory, but at the same time, driven by oscillators, trying to simplify the trajectory of the system, will inevitably come to the generation of similar oscillations. Finally, the impact of the chaotic oscillator signal, with similar parameters, gives rise to a truly chaotic dynamics. While even under identical signals, slave oscillator, nevertheless, exhibit different oscillation processes, since even slight differences in their initial conditions lead to a rapid divergence of the trajectories. Different time realizations are easily detectable by comparator. Furthermore, the possibility of discriminating signals is maintained even under the influence of the prevailing interferences. Excluding time for detection and frequency band occupied by the stable operation was achieved at SNR = -24dB.

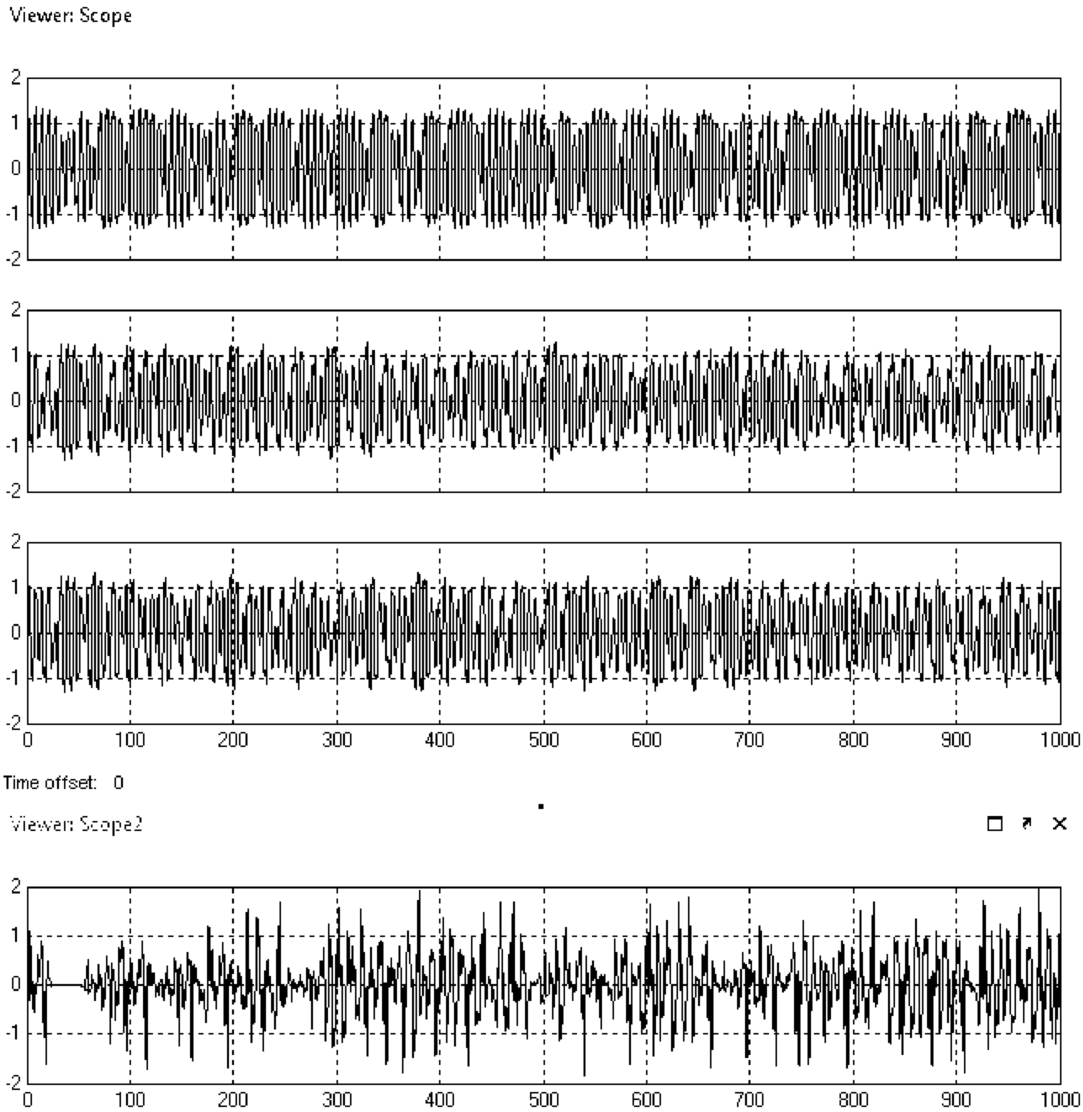

Figure 4 - Output signals in time domain. From top to bottom: master oscillator, first slave oscillator, second slave oscillator, the difference signal. Shows the case where the slave oscillators exhibit truly chaotic behavior, generating different signals

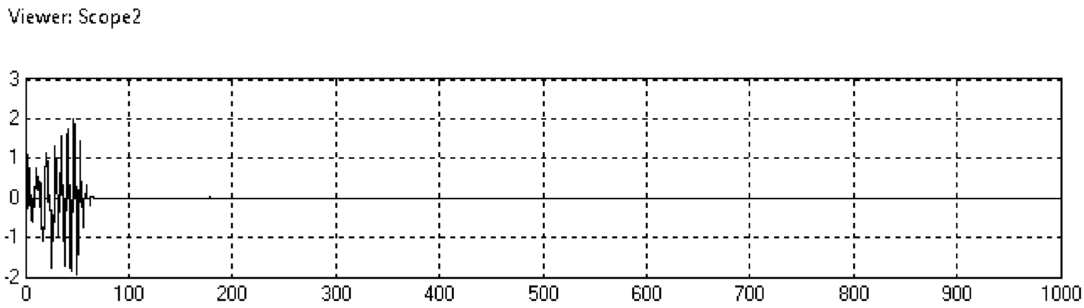

Figure 5 - The difference signal slave oscillators in the suppression of their own chaotic dynamics

The results indicate the possibility of using the chaotic random signals detector not only in the transmission of information, but also to get it to measuring control devices using broadband signals for radiation-reception.

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