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Computer Modelling of the Information Properties of Hyper Chaotic Lorenz System and Its Application in Secure Communication System

Volodymyr Rusyn1 , Mujiarto2, Mustafa Mamat3 , Firmansyah Azharul4 and W. S. Mada Sanjaya5 , Aceng Sambas2 , Estiyan Dwipriyoko6 and Akhmad Sutoni7*

1Yuriy Fedkovych Chernivtsi National University, Kotsybynsky str., 2, Chernivtsi, 58012, Ukraine.
2Department of Mechanical Engineering, Universitas Muhammadiyah Tasikmalaya, Indonesia
3Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia
4Department of Mechanical Engineering, Sekolah Tinggi Teknologi Cileungsi, Indonesia
5Department of Physics, Universitas Islam Negeri Sunan Gunung Djati, Bandung, Indonesia
6Informatics Study Program, Universitas Langlangbuana, Bandung, Indonesia
7Department of Industrial Engineering, Universitas Suryakancana, Cianjur, Indonesia
&#61482-mujiarto@umtas.ac.id

Abstract

This paper presents computer modeling, analysis and research of the hyper-chaotic Lorenz system based on programming interface that has been developed in LabView software environment. This study allows for generating and research of the main information properties of hyper-chaotic Lorenz system, focusing on time distribution of the four chaotic coordinates, phase portraits and Lyapunov exponents. The programming interface demonstrates the algorithm of masking and decrypt of the information carrier. **(Approx. 69 words)**

Keywords: Nonlinear, hyper-chaotic, Lorenz, LabView

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Letter of Acceptance for Abstract

Dear Authors: Volodymyr Rusyn1 , Mujiarto2*, Mustafa Mamat3 , Firmansyah Azharul4 and W. S. Mada Sanjaya5 , Aceng Sambas2 , Estiyan Dwipriyoko6 and Akhmad Sutoni7

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[1]Yuriy Fedkovych Chernivtsi National University, Kotsybynsky str., 2, Chernivtsi, 58012, Ukraine.
[2]Department of Management, Sekolah Tinggi Ilmu Ekonomi IBBI, Medan, Indonesia
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[4]Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia
[5]Department of Physics, Universitas Islam Negeri Sunan Gunung Djati, Bandung, Indonesia

[*]Email: fajrillahhasballah@gmail.com

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1. Introduction

The generation and application of chaotic attractors have been studied with increasing interest and have become a central topic in research due to its great potential in chaos communication technology [1]-[5]. Chaos theory has been established since the 1970's due to its applications in many different research areas, such as electronic circuits [6]-[7], secure communication systems [8]-[9], robotics [10]-[11], optics [12]-[13], economy [14]-[15], biology [16]-[17], etc.

In order to obtain hyper-chaos, two important requisites are as follows:

- The minimal dimension of the phase space that embeds a hyper-chaotic attractor should be at least four, which requires the minimum number of coupled first-order autonomous ordinary differential equations to be four.

- The number of terms in the coupled equations giving rise to instability should be at least two, of which at least one should have a nonlinear function.

A great interest is the simulation that using different software environments allows to demonstration different information properties of chaotic oscillations. For modelling of information properties of the hyper-chaotic Lorenz system and demonstrate results was selected software LabView (LabView-2015 (32-bit version for Windows).

2. Modelling of a hyper-chaotic Lorenz system

Hyper-chaotic Lorenz system is described by equations:

$$\begin{cases} \dot{x} = a(y - x), \\ \dot{y} = bx + y - xz - w, \\ \dot{z} = xy - cz, \\ \dot{w} = kyz, \end{cases} \tag{1}$$

where a, b, c – system parameters, x, y, z – initial conditions, k – constant that determines the attractor, which in some senses can be chaotic, and in particular – controlled.

Fig. 1 shows the block scheme that implements of hyper-chaotic Lorenz system. The main functional part is a formula node, in which would include the equation (1). In the input formula node fed values of system parameters (a, b, c) and the value of the initial conditions (x, y, z). At the output assigned equations (1). Also, the output is an opportunity to demonstrate the solution of equations in three dimensions.

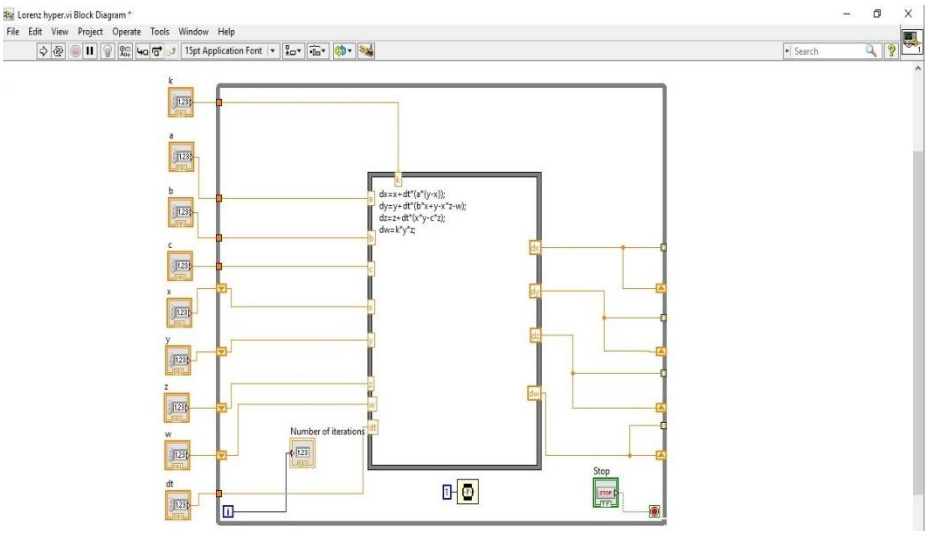

Fig. 1. Block scheme of hyper-chaotic Lorenz system

When changing the system parameters and initial conditions we can be analysed in detail and investigate the behaviour of a hyper-chaotic Lorenz system, which in many cases is a basic element of the functional blocks of chaotic secure communication systems.

Fig. 2 shows the software interface, which shows these information modelling properties as temporal distributions of the values of the coordinates X, Y, Z, W, when:

- the number of iterations $N = 5000$;
- the system parameters $a = 10$, $b = 28$, $c = 8/3$, $k = 0{,}1$;
- initial conditions $x = y = z = 1$.

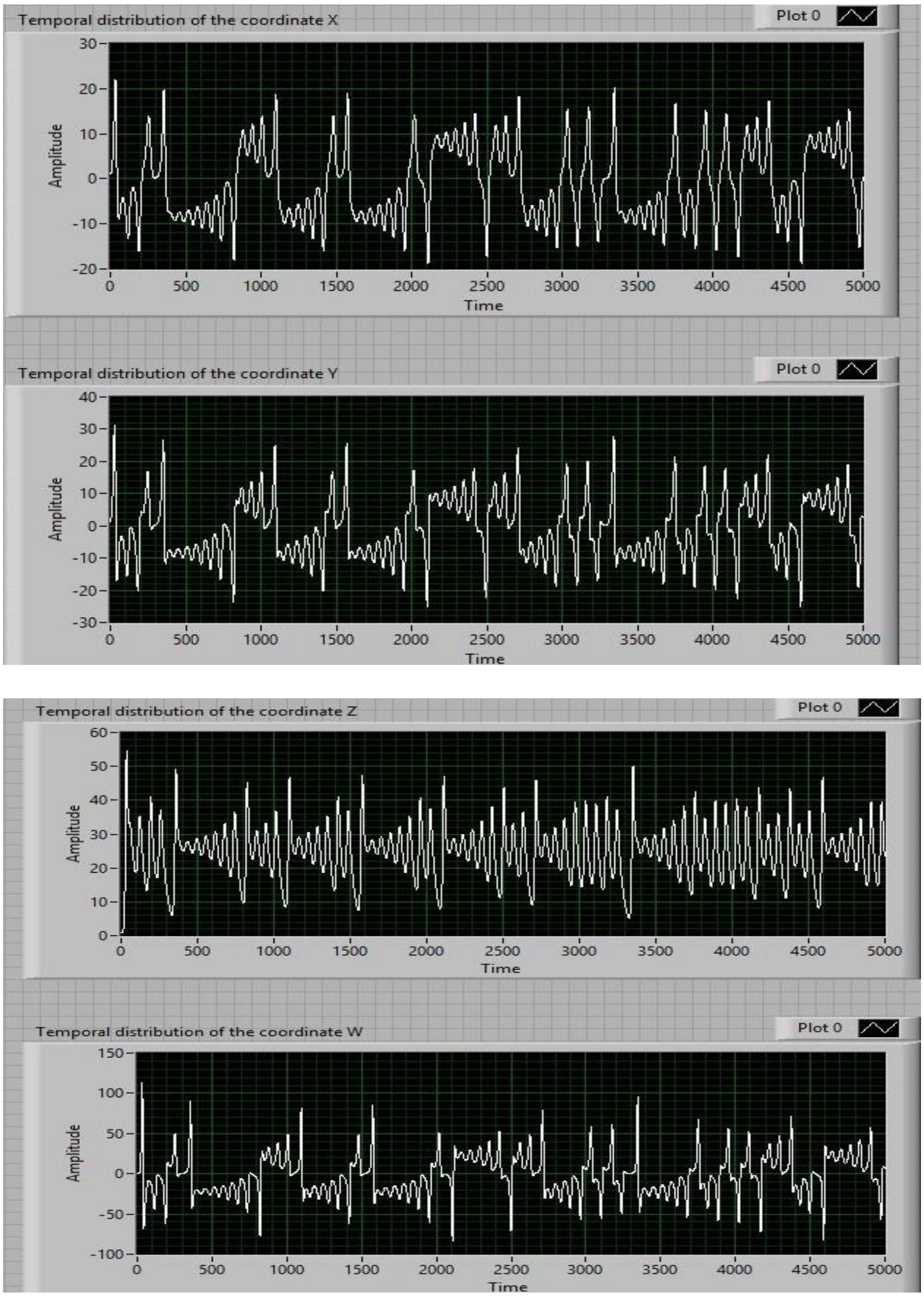

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Figure 3 shows the software interface, which shows these information modelling properties as phase portraits in the planes XY, XZ, XW, YZ, YW, and ZW, when:

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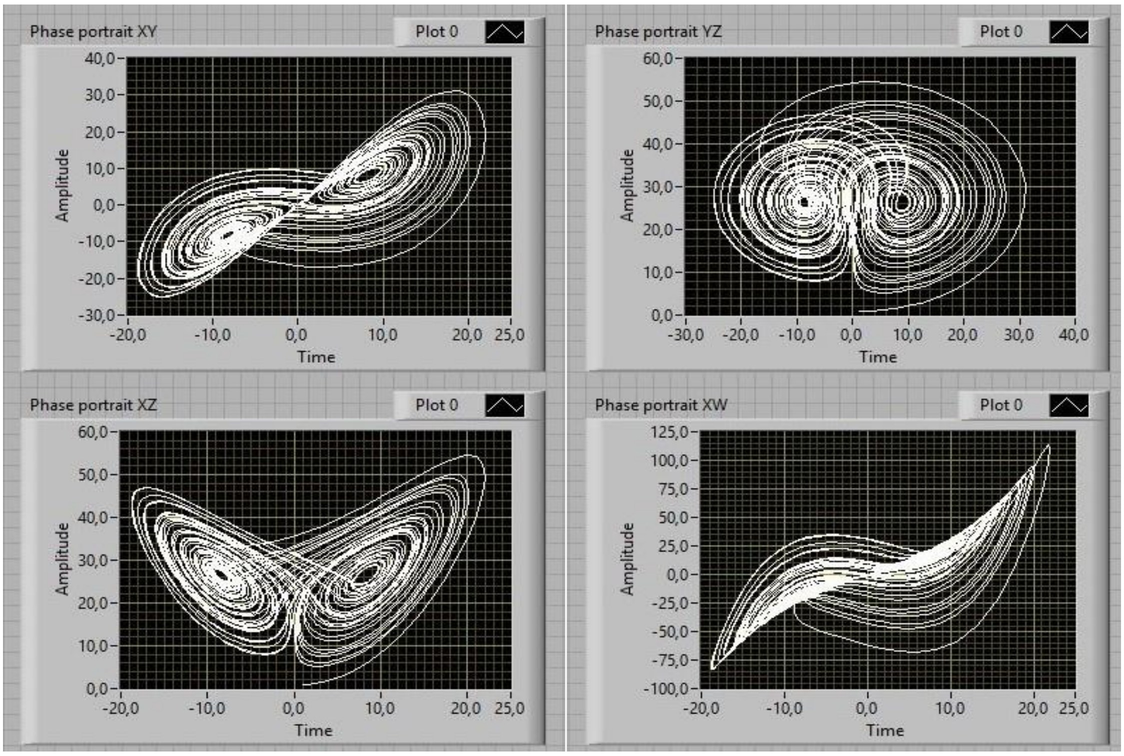

Fig. 3. Phase portraits in the planes XY, YZ, XZ and XW

The Jacobian matrix of (1) is

$$J = \begin{pmatrix} -10 & 10 & 0 & 0 \\ 28-z & 1 & -x & -1 \\ y & x & -8/3 & 0 \\ 0 & kz & ky & 0 \end{pmatrix} \qquad (2)$$

The chaotic system (1) is a four-dimensional dynamical system, which has four Lyapunov exponents. This may lead to a hyper-chaotic system.

The Lyapunov exponents for hyper-chaotic Lorenz system:

$$\lambda_1 = -2.667, \quad \lambda_2 = 13.11, \quad \lambda_3 = -22.11, \quad \lambda_4 = 0$$

Figure 4 shows Lyapunov exponents graphically.

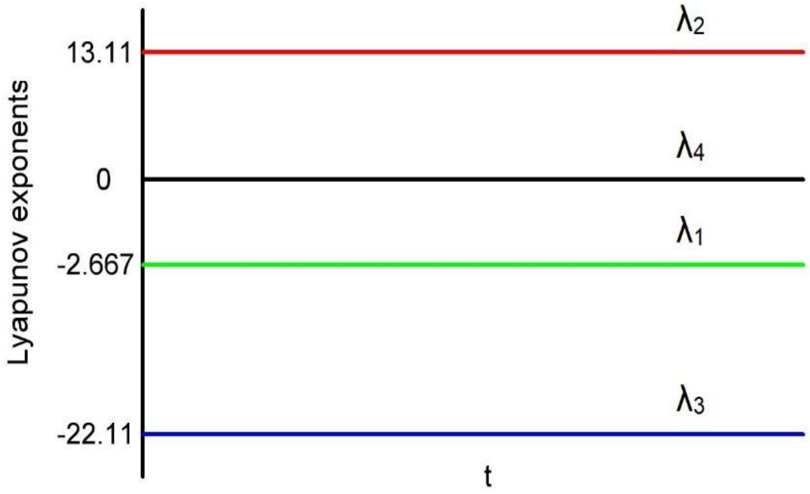

Fig. 4. Graphical presentation of Lyapunov exponents for hyper-chaotic Lorenz system

3. Chaotic masking and decryption of the information carrier

The coherent receivers usually are dynamical systems that resemble the chaos producing transmitters. They achieve synchronization with the transmitter, enabling the synchronization to extract the information signal from the received chaotic signal. In order to achieve synchronization, the parameters of the transmitter have to be known. They can be considered as the encryption key of the message; thus, coherent receptions allows for some privacy of the information transmission.

Fig. 5 demonstrates the presence of the chaotic signal between the transmitter and receiver. In this case, the use of chaos in secure communication systems has been proposed. The design of these systems depends on the self-synchronization property of the hyper-chaotic attractor. As shown in Fig. 5, the transmitter and the receiver systems are identical

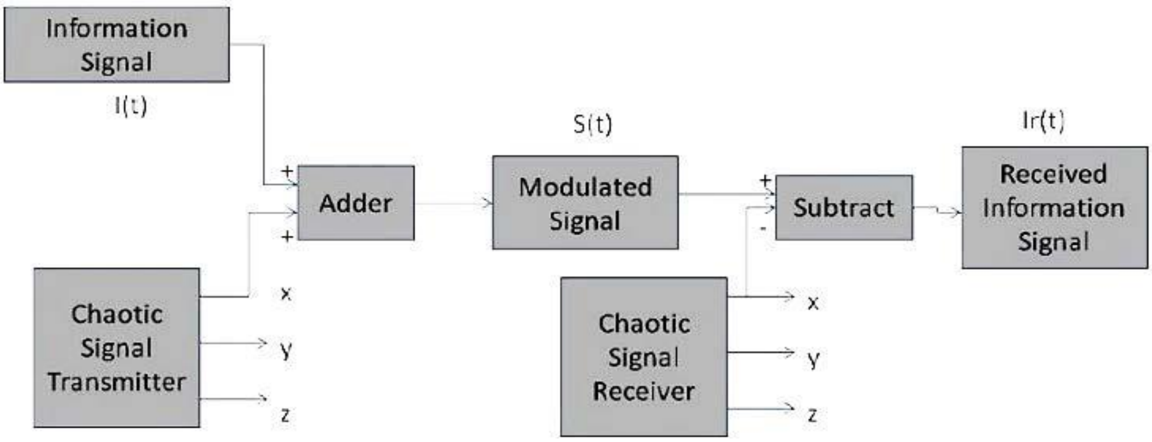

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Figure 6 presents the program interface, which demonstrates the masking of the carrier of information based on a hyper-chaotic Lorenz system (1).

The masking of the carrier of information based on chaos is provided by blending information with the chaotic signal. A sinusoidal signal (useful signal) was used as information (input) with amplitude of *5 V* and system parameters $a = 10$, $b = 28$, $c = 2.67$, $k = 0.1$, dynamic variables $x = y = z = 1$. System parameters and dynamic variables are the keys for the masking information. Algorithm for the decryption has opposite effect.

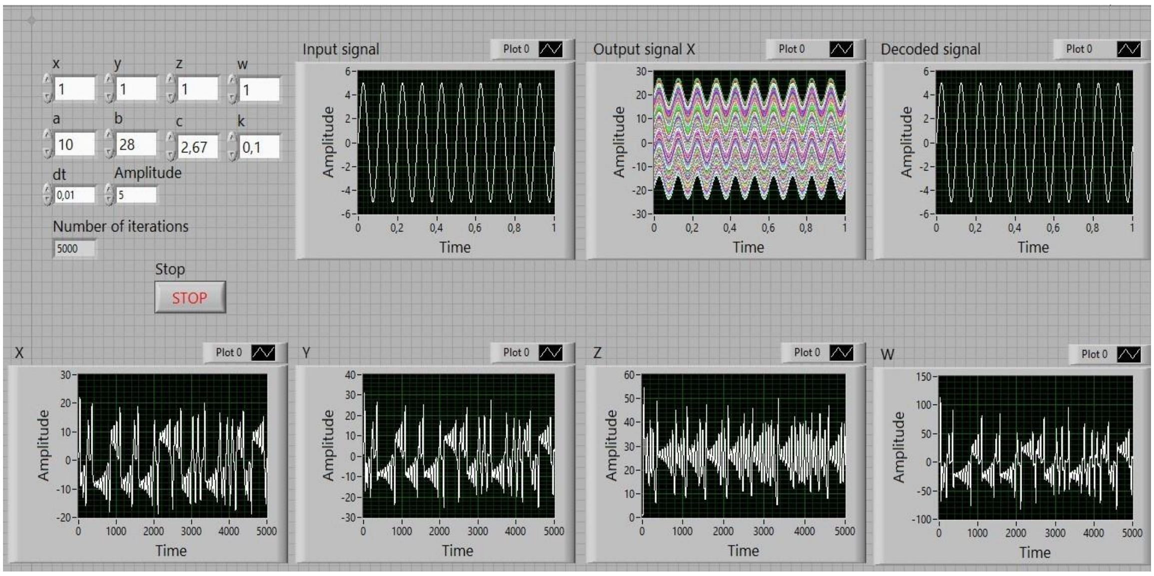

Fig. 6. Software interface show's masking and decryption of the information carrier

4. Conclusions

For modelling of information properties of the hyper-chaotic Lorenz system and demonstrate computer modelling results was selected software LabView (LabView-2015 (32-bit version for Windows). The main information properties of hyper-chaotic Lorenz system such as a time distribution of the four chaotic coordinates, phase portraits and Lyapunov exponents are presented. The programming interface demonstrates the algorithm of masking and decrypt of the information carrier.

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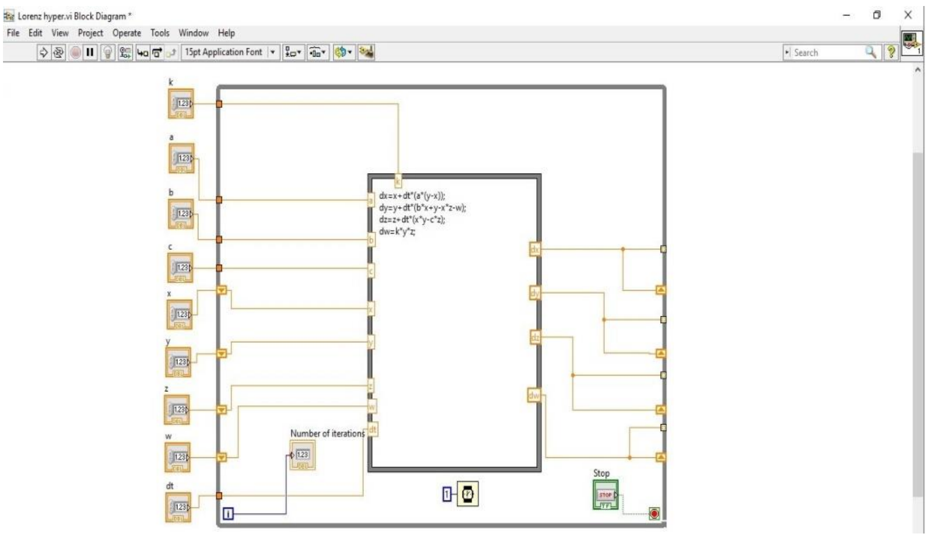

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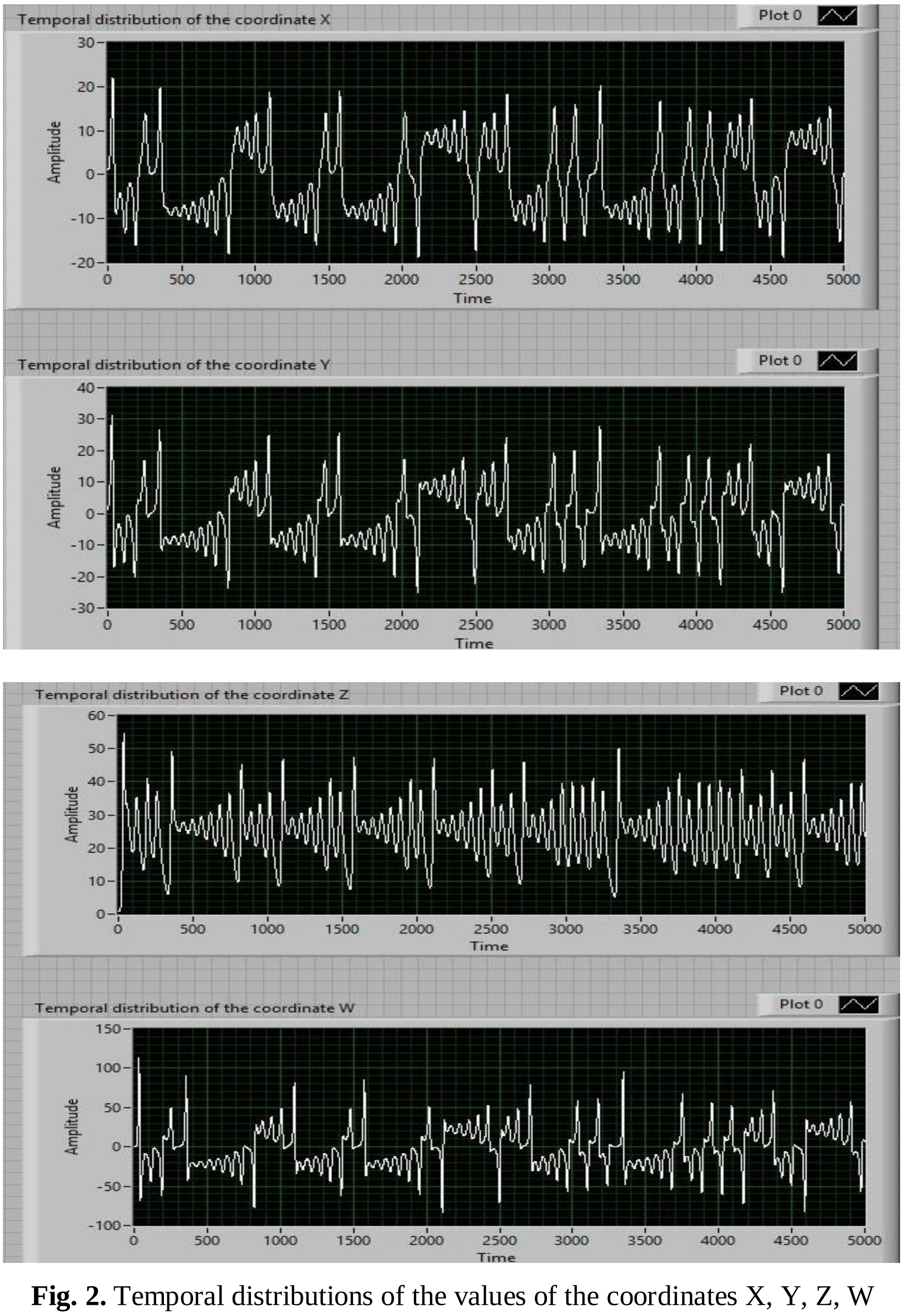

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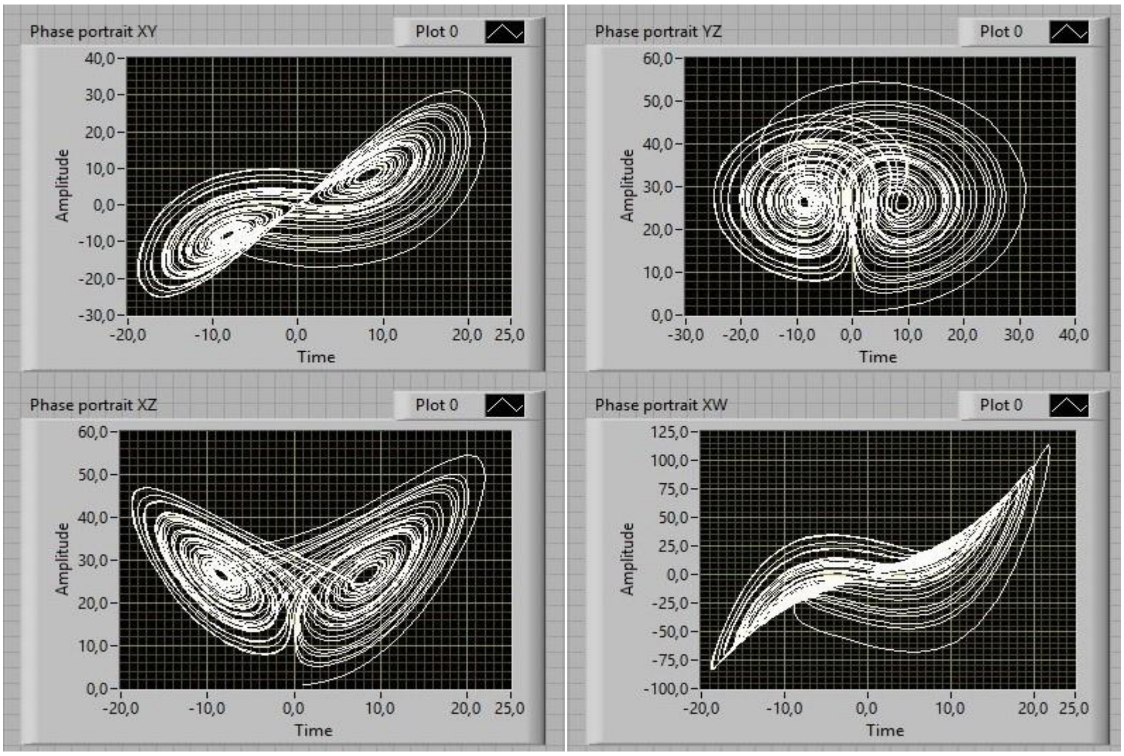

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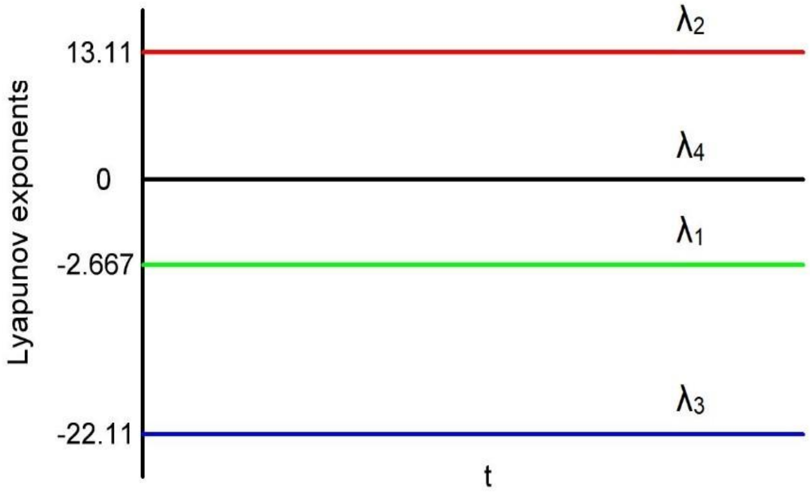

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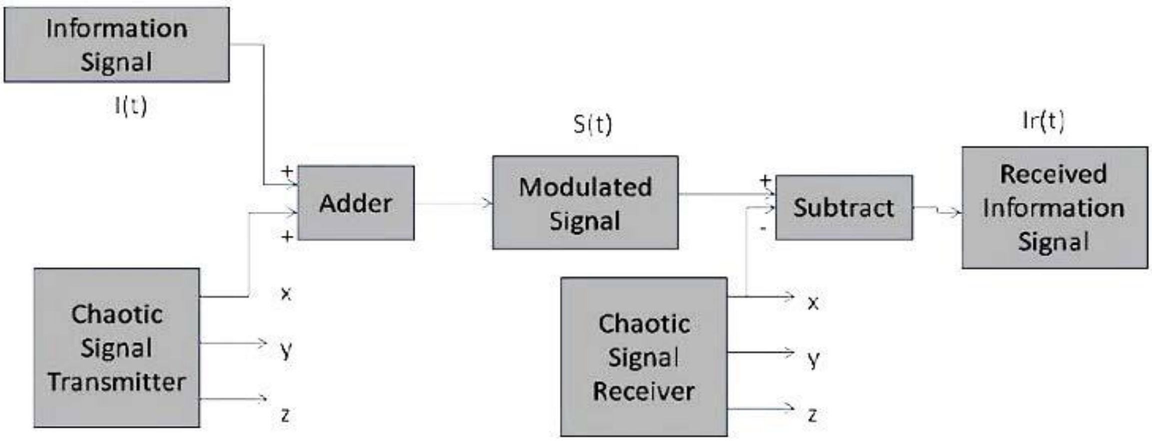

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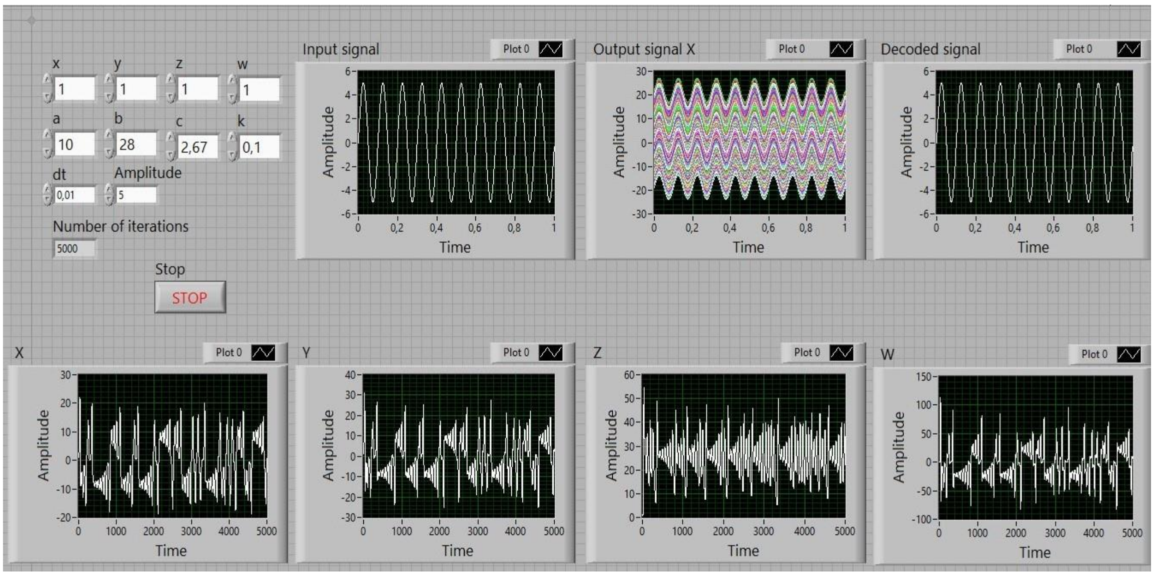

Fig. 6. Software interface show's masking and decryption of the information carrier

4. Conclusions

For modelling of information properties of the hyper-chaotic Lorenz system and demonstrate computer modelling results was selected software LabView (LabView-2015 (32-bit version for Windows). The main information properties of hyper-chaotic Lorenz system such as a time distribution of the four chaotic coordinates, phase portraits and Lyapunov exponents are presented. The programming interface demonstrates the algorithm of masking and decrypt of the information carrier.

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Computer Modelling of the Information Properties of Hyper Chaotic Lorenz System and Its Application in Secure Communication System

Computer Modelling of the Information Properties of Hyper Chaotic Lorenz System and Its Application in Secure Communication System

Volodymyr Rusyn[1], Mujiarto[2*], Mustafa Mamat[3], Firmansyah Azharul[4] and W. S. Mada Sanjaya[5], Aceng Sambas[2], Estiyan Dwipriyoko[6] and Akhmad Sutoni[7]

[1]Yuriy Fedkovych Chernivtsi National University, Kotsybynsky str., 2, Chernivtsi, 58012, Ukraine.
[2]Department of Mechanical Engineering, Universitas Muhammadiyah Tasikmalaya, Indonesia
[3]Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia
[4]Department of Mechanical Engineering, Sekolah Tinggi Teknologi Cileungsi, Indonesia
[5]Department of Physics, Universitas Islam Negeri Sunan Gunung Djati, Bandung, Indonesia
[6]Informatics Study Program, Universitas Langlangbuana, Bandung, Indonesia
[7]Department of Industrial Engineering, Universitas Suryakancana, Cianjur, Indonesia

[*]mujiarto@umtas.ac.id

Abstract. This paper presents computer modeling, analysis and research of the hyper-chaotic Lorenz system based on programming interface that has been developed in LabView software environment. This study allows for generating and research of the main information properties of hyper-chaotic Lorenz system, focusing on time distribution of the four chaotic coordinates, phase portraits and Lyapunov exponents. The programming interface demonstrates the algorithm of masking and decrypt of the information carrier.

Keywords: Nonlinear, hyper-chaotic, Lorenz, LabView

1. Introduction

The generation and application of chaotic attractors have been studied with increasing interest and have become a central topic in research due to its great potential in chaos communication technology [1]-[5]. Chaos theory has been established since the 1970's due to its applications in many different research areas, such as electronic circuits [6]-[7], secure communication systems [8]-[9], robotics [10]-[11], optics [12]-[13], economy [14]-[15], biology [16]-[17], etc.

In order to obtain hyper-chaos, two important requisites are as follows:

- The minimal dimension of the phase space that embeds a hyper-chaotic attractor should be at least four, which requires the minimum number of coupled first-order autonomous ordinary differential equations to be four.
- The number of terms in the coupled equations giving rise to instability should be at least two, of which at least one should have a nonlinear function.

A great interest is the simulation that using different software environments allows to demonstration different information properties of chaotic oscillations. For modelling of information properties of the hyper-chaotic Lorenz system and demonstrate results was selected software LabView (LabView-2015 (32-bit version for Windows).

2. Modelling of a hyper-chaotic Lorenz system

Hyper-chaotic Lorenz system is described by equations:

$$\begin{cases} \dot{x} = a(y - x), \\ \dot{y} = bx + y - xz - w, \\ \dot{z} = xy - cz, \\ \dot{w} = kyz, \end{cases} \tag{1}$$

where a, b, c – system parameters, x, y, z – initial conditions, k – constant that determines the attractor, which in some senses can be chaotic, and in particular – controlled.

Fig. 1 shows the block scheme that implements of hyper-chaotic Lorenz system. The main functional part is a formula node, in which would include the equation (1). In the input formula node fed values of system parameters (a, b, c) and the value of the initial conditions (x, y, z). At the output assigned equations (1). Also, the output is an opportunity to demonstrate the solution of equations in three dimensions.

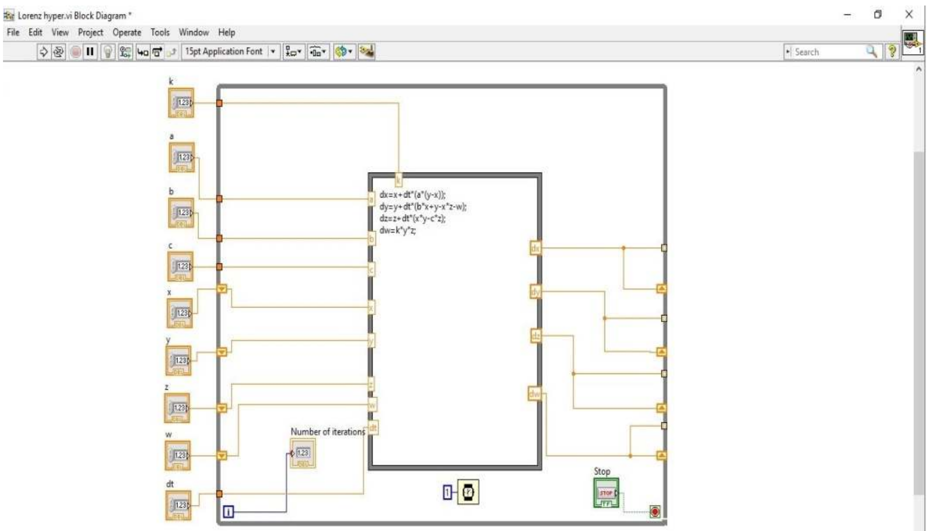

Fig. 1. Block scheme of hyper-chaotic Lorenz system

When changing the system parameters and initial conditions we can be analysed in detail and investigate the behaviour of a hyper-chaotic Lorenz system, which in many cases is a basic element of the functional blocks of chaotic secure communication systems.

Fig. 2 shows the software interface, which shows these information modelling properties as temporal distributions of the values of the coordinates X, Y, Z, W, when:

- the number of iterations $N = 5000$;
- the system parameters $a = 10$, $b = 28$, $c = 8/3$, $k = 0{,}1$;
- initial conditions $x = y = z = 1$.

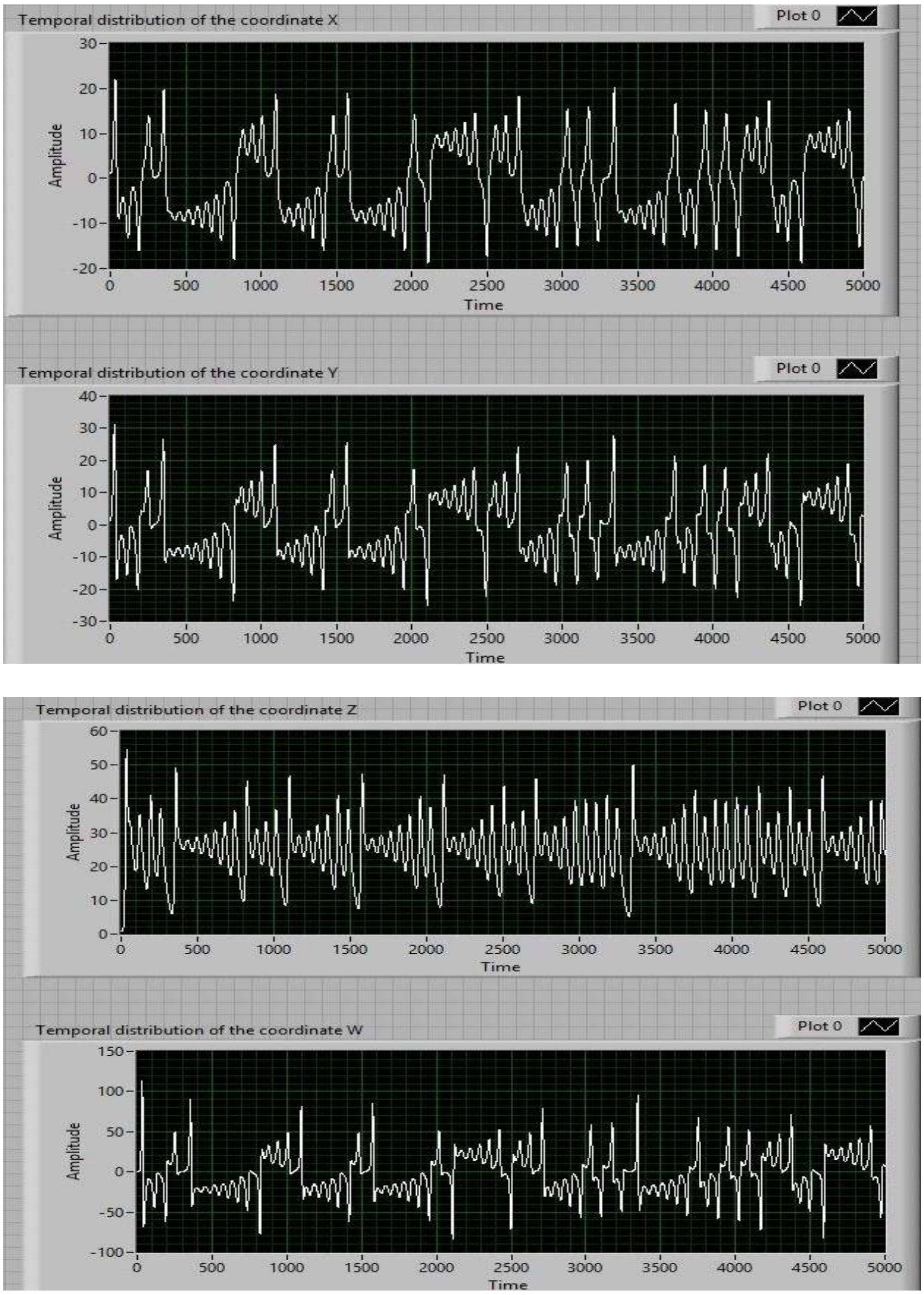

Fig. 2. Temporal distributions of the values of the coordinates X, Y, Z, W

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Figure 3 shows the software interface, which shows these information modelling properties as phase portraits in the planes XY, XZ, XW, YZ, YW, and ZW, when:

- the number of iterations $N = 5000$;
- the system parameters $a = 10$, $b = 28$, $c = 8/3$, $k = 0{,}1$;
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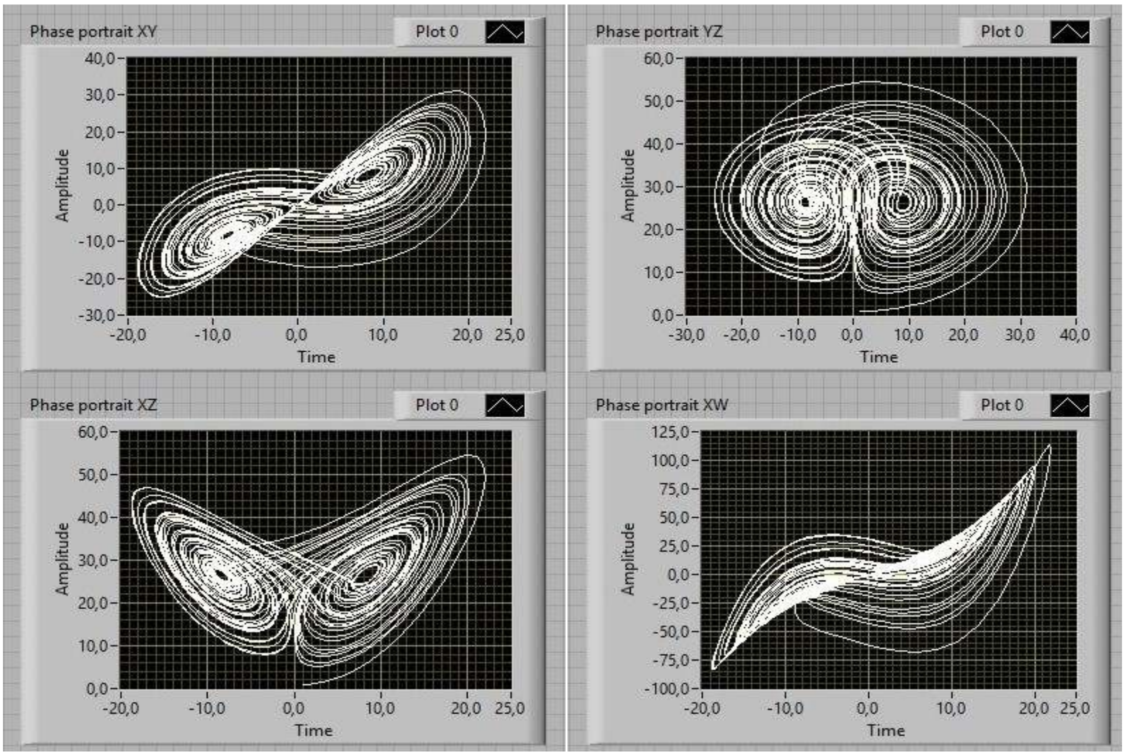


Fig. 3. Phase portraits in the planes XY, YZ, XZ and XW

The Jacobian matrix of (1) is

$$J = \begin{pmatrix} -10 & 10 & 0 & 0 \\ 28 - z & 1 & -x & -1 \\ y & x & -8/3 & 0 \\ 0 & kz & ky & 0 \end{pmatrix} \tag{2}$$

The chaotic system (1) is a four-dimensional dynamical system, which has four Lyapunov exponents. This may lead to a hyper-chaotic system.
The Lyapunov exponents for hyper-chaotic Lorenz system:

$$\lambda_1 = -2.667, \quad \lambda_2 = 13.11, \quad \lambda_3 = -22.11, \quad \lambda_4 = 0$$

Figure 4 shows Lyapunov exponents graphically.

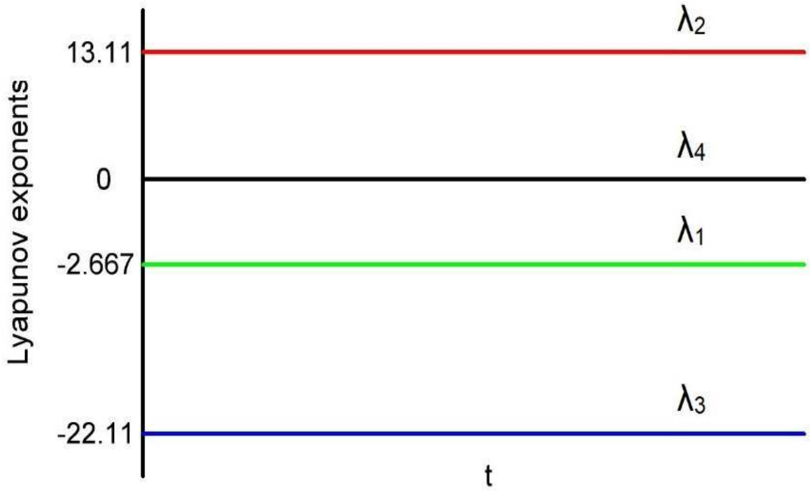


Fig. 4. Graphical presentation of Lyapunov exponents for hyper-chaotic Lorenz system

3. Chaotic masking and decryption of the information carrier

The coherent receivers usually are dynamical systems that resemble the chaos producing transmitters. They achieve synchronization with the transmitter, enabling the synchronization to extract the information signal from the received chaotic signal. In order to achieve synchronization, the parameters of the transmitter have to be known. They can be considered as the encryption key of the message; thus, coherent receptions allows for some privacy of the information transmission.

Fig. 5 demonstrates the presence of the chaotic signal between the transmitter and receiver. In this case, the use of chaos in secure communication systems has been proposed. The design of these systems depends on the self-synchronization property of the hyper-chaotic attractor. As shown in Fig. 5, the transmitter and the receiver systems are identical

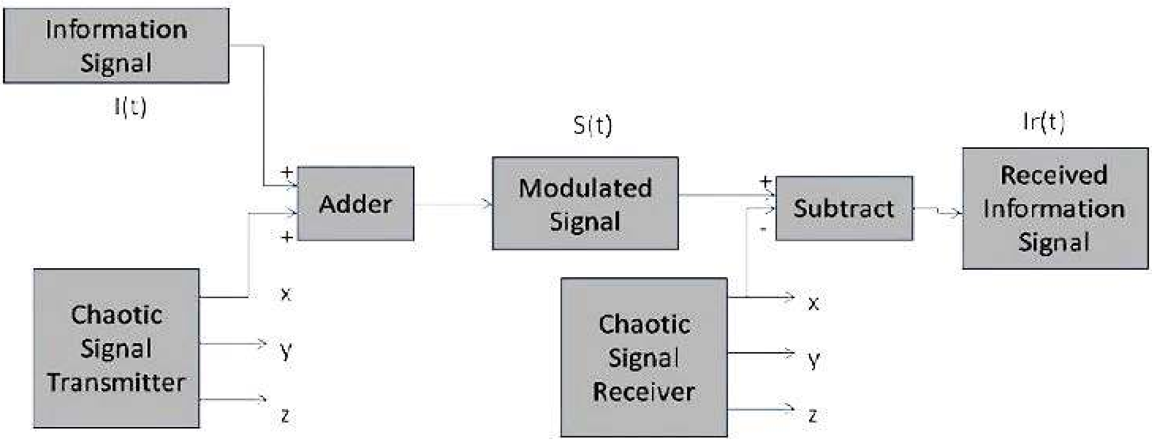
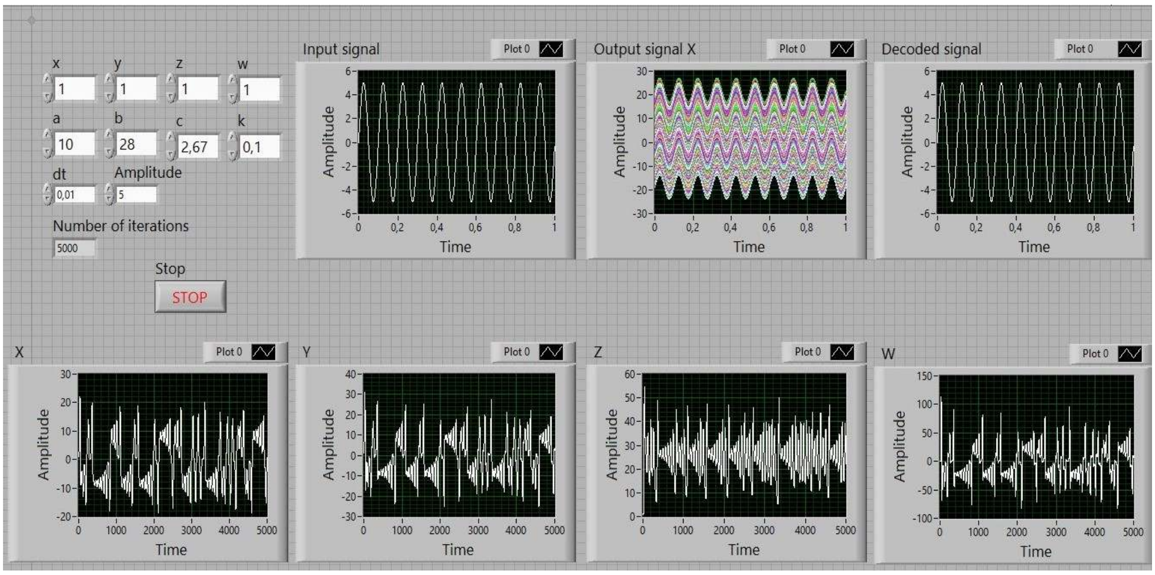


Fig. 5. Transmitter and receiver systems

Figure 6 presents the program interface, which demonstrates the masking of the carrier of information based on a hyper-chaotic Lorenz system (1).

The masking of the carrier of information based on chaos is provided by blending information with the chaotic signal. A sinusoidal signal (useful signal) was used as information (input) with amplitude of *5 V* and system parameters $a = 10$, $b = 28$, $c = 2.67$, $k = 0.1$, dynamic variables $x = y = z = 1$. System parameters and dynamic variables are the keys for the masking information. Algorithm for the decryption has opposite effect.



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