Journal of Green Engineering (JGE)

Volume-10, Issue-12, December 2020

Implementation of a Chaotic System in Digital Satellite Transmissions in Environment

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Abstract

Chaos Shift Keying (CSK) is the main notion in this paper. CSK is the critical point of a Frequency-division multiplexing (FDM) system with a nonlinear satellite transponder. The effectiveness of the chaos in the security of satellite transmission with Quadrature Phase Shift Keying (QPSK) modulation at a symbol of 8MSymbols/second can be taken for consideration in this paper. The given information to transmit is decomposed into four combinations. We use four chaotic attractors to permute each data: quadratic map, Bernoulli's map, logistic map, tent map so the main idea of CSK system is to alternate the transmitted information between these four attractors in the goal to have a secured communication without any interception.

Keywords: Chaos, Chaotic maps, CSK, Satellite, and numerical transmission.

1 Introduction

A satellite is a radio relay in orbit, which can cover almost half of the world, offers many services to humanity like spatial imagery, radio communications, television, internet telemedicine. The ease of receiving satellite signals anywhere and on an intercontinental coverage gives a vulnerable image as to the security of the transmitted information. In the chaotic theory all the behavior given by a nonlinear dynamic system is

Journal of Green Engineering, Vol. 10_12, 13593-13605.

described and explained clearly in details, hence the butterfly effect that there is a big dependence on the initial conditions which means the evolution of the system change even if there is an negligible change in initial conditions. Chaotic systems have a random appearance; they are deterministic with an output that has an unknown parameterization [1].

The invented and tested chaos-based electrical circuits have given their efficiencies in digital transmissions and digital telecommunications networks, so the developers have the choice which chaotic system they will use especially that all this chaotic systems have the same characteristics.

A chaotic system is characterized by:

- A long-term a periodic behavior: the trajectory of any fixed point or periodic orbit when time goes to infinity. Chaotic system in the phase space does not converge towards

-Its determinism: Irregular behavior comes from intrinsic nonlinearities rather than random noises. A chaotic system does not present stochastic (probabilistic) parameters.

-High sensitivity to initial conditions: two trajectories initialized at two very close values diverge exponentially.

-globally bounded solutions

The satellite systems are among the telecommunications systems that have found all the security in the use of chaotic systems for their properties mentioned above

This paper presents a satellite system which use chaotic system in the transmission of data. In the second section we try to talk about CSK system and we describe the four chaotic attractors used in this work in Sec.3, while the fourth gives a system description of the transmission of digital signals by satellite using chaotic modulation for more security; Sec. 5 presents the results of simulation using the MATLAB software and some conclusions about the goals targeted by the work.

2 Proposed Methodology

Figure 1 shows block diagram of chaotic communication.

Figure 2 shows Four Symbols for CSK Communication System.

2.1 The Use of Chaotic Carrier

The notion of "Chaos Shift Keying" has been appeared for the first time by Parlitz [2].This modulation has the principle to code a binary message using chaotic signal[2], [3]. A CSK transmission system is schematized in figure 3. This system has a coding operation as follows: The emitter consists

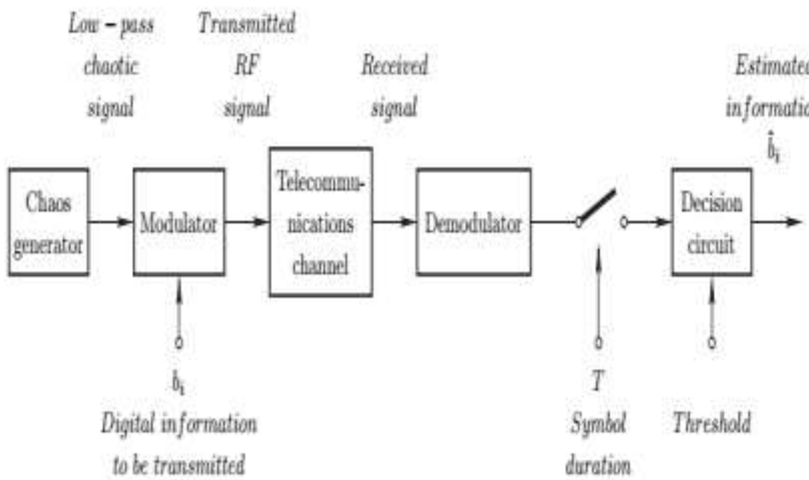

Figure 1 A chaotic communication in block diagram

of two chaotic generators f_1 and f_2 generating two chaotic signals $x_1(t)$ and $x_2(t)$ respectively. If the binary word used in the interval [(l - 1) Ts; lTs] is +1, so $x_1(t)$ is transmitted. If the binary word is -1 then $x_2(t)$ is transmitted. For Coherent CSK, two types of receivers have been proposed.

2.2 Coherent CSK based on Error Calculation

The first CSK receivers integrate two chaotic synchronization units per coupling. In figure 4, the received signal drives the two synchronization units.

At the moment when the signal x1(t) is transmitted, the generator $\tilde{f}1$ generates a signal $\tilde{x}(t)1$ synchronous with the signal received and the generator $\tilde{f}2$ him, not synchronous with the received signal, the binary message can be estimated by measuring the difference (error) between the reception and emission of signal.

2.3 Coherent CSK based on Correlation

Kolumb'an and al [4] have developed another type of CSK system receiver. This receiver is based on the coherent detection of CSK signals using a correlation on each channel as shown in Figure 5. In this structure, the two synchronization circuits can generate two chaotic signals$\tilde{x}(t)1$and $\tilde{x}(t)2$ synchronous with the chaotic signals emitted.

A time T_a is necessary so that the two synchronization blocks can converge towards the signals x1 (t) and x2 (t). The signals thus generated are correlated with the signal received over a symbol period, and then the operations of sampling and comparison are made for the outputs of the correlation.

The signal received at the entrance of the CSK receiver is

$$r(t) = u(t) + n(t) \qquad (1)$$

Where u (t) is the signal emitted, and n (t) is an additive, white, and Gaussian noise. For a symbol l, the received signal can take two values according to the value of the symbol l.

$$(r) = \begin{cases} x_1(t) + n(t) & if\ l = +1 \\ x_2(t) + n(t) & if\ l = -1 \end{cases} \qquad (2)$$

For the symbol received l, the output of the correlation at the end of the symbol period is given by

$$D_{1,l} = \int_{(l-1)T_s+T_a}^{lT_a} r(t)x_1(t)dt \qquad (3)$$

$$D_{2,l} = \int_{(l-1)T_s+T_a}^{lT_a} r(t)x_2(t)dt \qquad (4)$$

If the difference between $\boldsymbol{D_{1,l}}$ **and** $\boldsymbol{D_{2,l}}(d = \boldsymbol{D_{1,l}} - \boldsymbol{D_{2,l}})$ is positive, then +1 is decoded for the $\boldsymbol{l^{th}}$ symbol, otherwise -1 is decoded.Modern communication systems are essentially digital and analog systems based on chaos such as chaotic masking and parameterized chaotic modulation are being abandoned in favor of chaotic systems based on Shift Keying methods. One of the first chaotic communication systems is the CSK which is a digital modulation based on the synchronization at the receiver level [5].A CSK transmitter switches between two chaos generators representing bits 0 and 1 [6]. Only binary signals can be encrypted by this method [7]. The receiver decides, through the correlation between the received signal and a synchronous reference signal, which generator has been used and thus the message transmitted. Chaotic shift keying is robust against noise and variation of transmit / receive system parameters. Classical theory we can use about four attractors for more robustness in CSK system like what we make in our work and we have four symbols for four attractors Figure 2 Four Symbols for CSK Communication System.

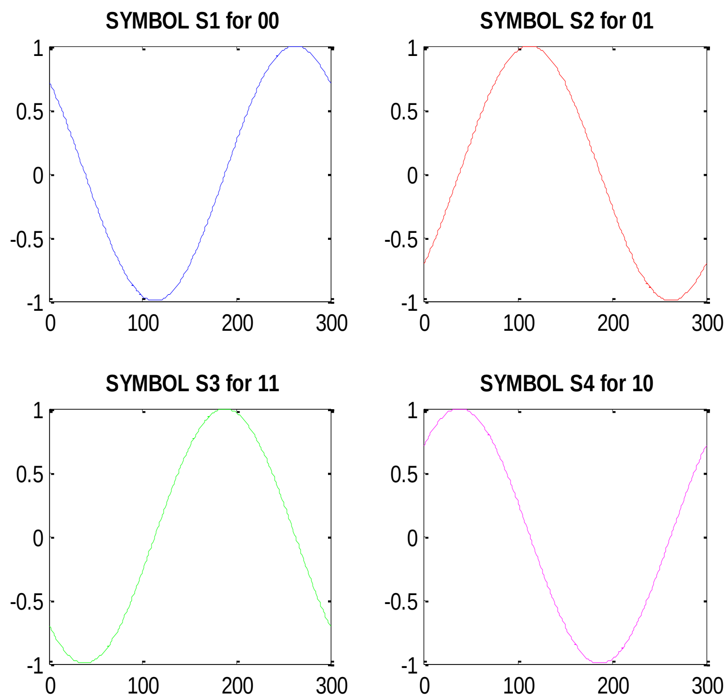

Figure 2 Four Symbols for CSK Communication System

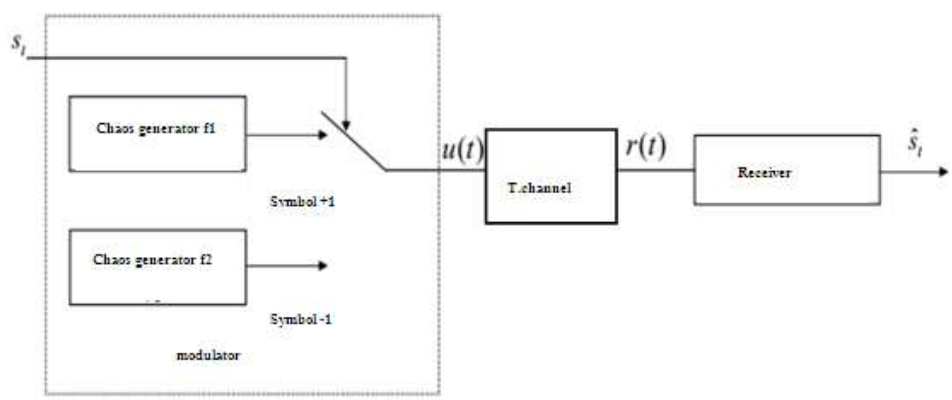

Figure 3 CSK communication systems

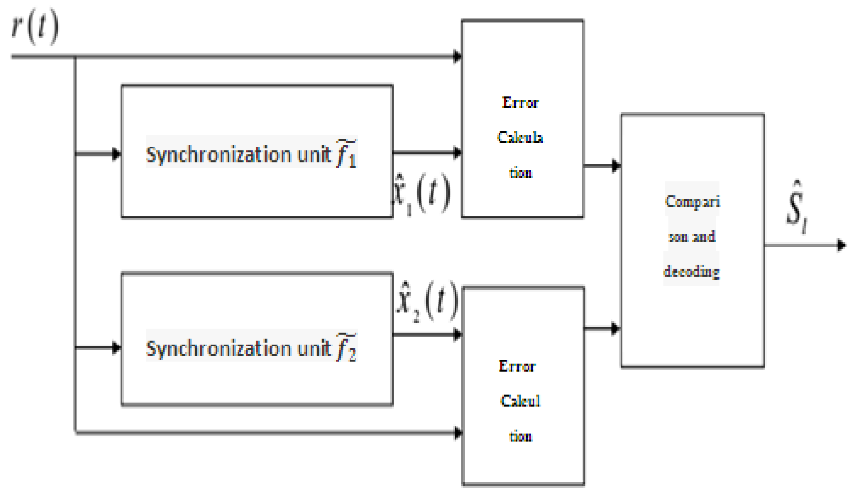

Figure 4 CSK receiver based on synchronization

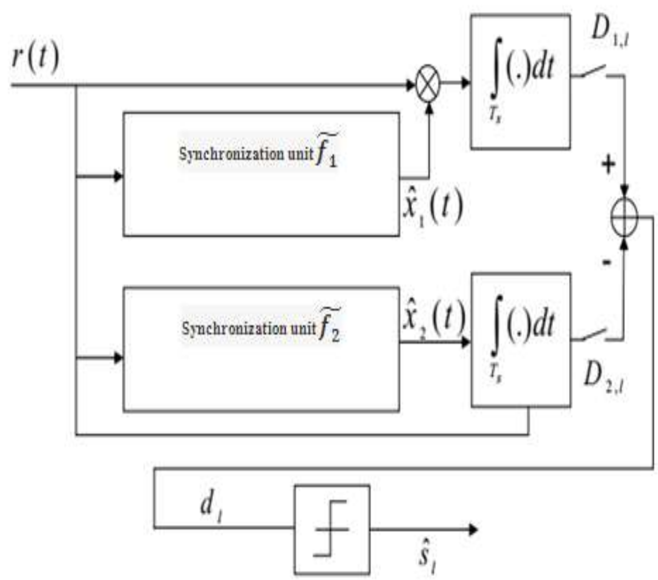

Figure 5 CSK Receiver Based on Coherent Correlation

2.4 Chaotic Maps

2.4.1 Logistic map

The equation of the logistic map is:

$$x_{n+1} = f\mu x_n = \mu x_n(1 - x_n) \qquad (5)$$

Where μ is a parameter wich the map depends on $0 \leq x_n \leq 1$

Figure 6 shows the logistic map graph

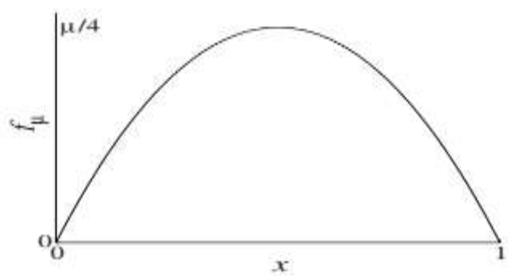

Figure 6 logistic map graph

2.4.2 Tent Map

The tent map, T: [0, 1] → [0, 1], defined by

$$T(x) = \begin{cases} \mu x & 0 \leq x \leq 1/2 \\ \mu(1 - x) & 1/2 \leq x \leq 1 \end{cases} \qquad (6)$$

Where $0 \leq \mu \leq 2$.

Figure 7 shows tent map graph.

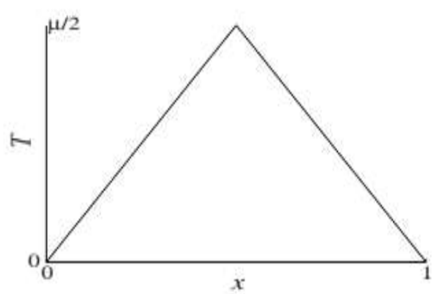

Figure 7 Tent map graph

2.4.3 Quadratic Map

Quadratic map is a simple discrete system exhibiting chaos and defined by
$x_{n+1} = f_c(x_n) = x_n^2 + c$ (7)

Where $0 \leq C \leq 2$ is called control parameter and $x_n \in$ (- 2, 2) is the state variable of the system Quadratic map can show rich dynamic behaviors from a stationary system to a chaotic state. The Quadratic map is capable of very complicated behavior which means that the output of the map is a periodic, non-convergent and very sensitive to initial conditions.

2.4.4 Bernouli Map

The map is defined by:

$$f(x) = \begin{cases} 2x & 0 \leq x < 0.5 \\ 2x - 1 & 0.5 \leq x < 1 \end{cases} \quad (8)$$

Figure 8 shows a graph of the Bernoulli map

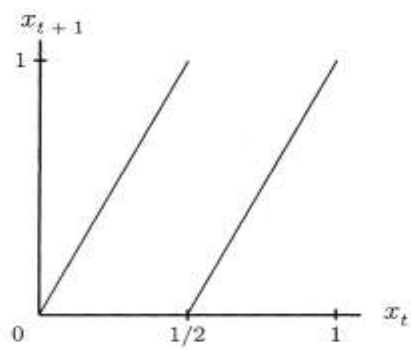

Figure 8 Bernoulli map

Figure 9 shows Generator of Bernoulli map

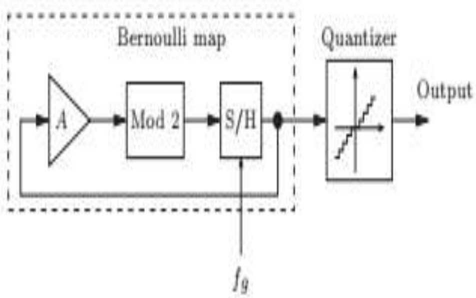

Figure 9 Generator of Bernoulli map

3 System Description and Simulation Objectives

The system to be simulated is a transmission of data of a network composed of 48 ground stations; for simplifying this communications there is a hierarchy that the ground stations send their data to eight regional center witch send in their turn to a satellite in his orbit the information; this information in six channels of data, which called an FDM group transmitted in the uplink to the satellite using an FDMA scheme;. The frequency spectrum for the 48-channel transponder is illustrated in Figure10. A single uplink antenna receive the 48 uplink signals
The received signal at the satellite is:

$$x(t) = \sum_{i=1}^{48} a_i(t-\tau_i)cos[2\pi f_i(t-\tau_i) + \emptyset_i(t\ -\tau_i)] \quad (9)$$

Figure 10 shows frequency spectrum for our system

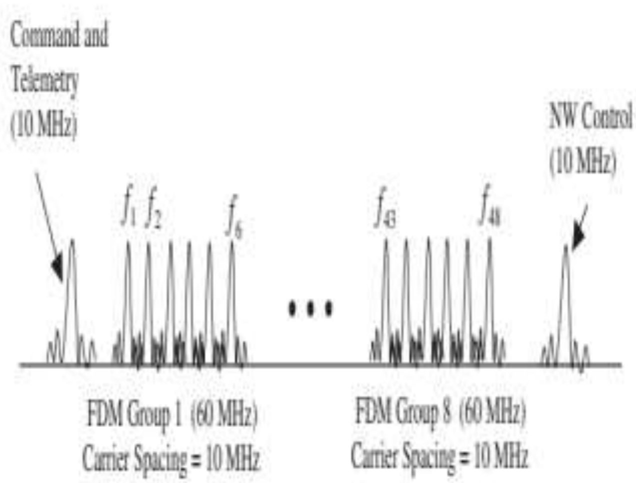

Figure 10 fréquence spectrum

The equation (9) can be written as

$$x(t) = \text{Re}\left\{\begin{matrix}\sum_{i=1}^{48} a_i(t-\tau_i)\exp[j\emptyset(t-\tau_i)]\exp(-j2\pi f_i\tau_i) \\ * \exp[j2\pi(f_i - f_0)t]\exp(j2\pi f_0 t)\end{matrix}\right\} \quad (10)$$

Where f_0 is the frequency of reference; τi represents the propagation delays of the ith uplink channel. The low pass complex envelope of x (t) is

$$\tilde{x}(t) = \sum_{i=1}^{48} a_i(-\tau_i)\exp[j\emptyset(-\tau_i)]\exp(j2\pi f_i\tau_i)\exp[j2\pi(f_i - f_0)t] \quad (11)$$

In this system we focus our work on the modulation of the signal, so we introduce the chaotic behavior in the carrier of transmission in which all transmitted data will be covered by chaotic signal for more security because of the large band signal and its sensitivity.

4 Results and Conclusions

By the use of MATLAB we can simulate the satellite transmission; Figure (11) shows the system considered. For constructing the FDM signal six arbitrary binary bit streams are mapped into chaotic QPSK symbols and modulated at the equivalent carrier frequencies. Figure 11 shows Satellite communications system by use of CSK.

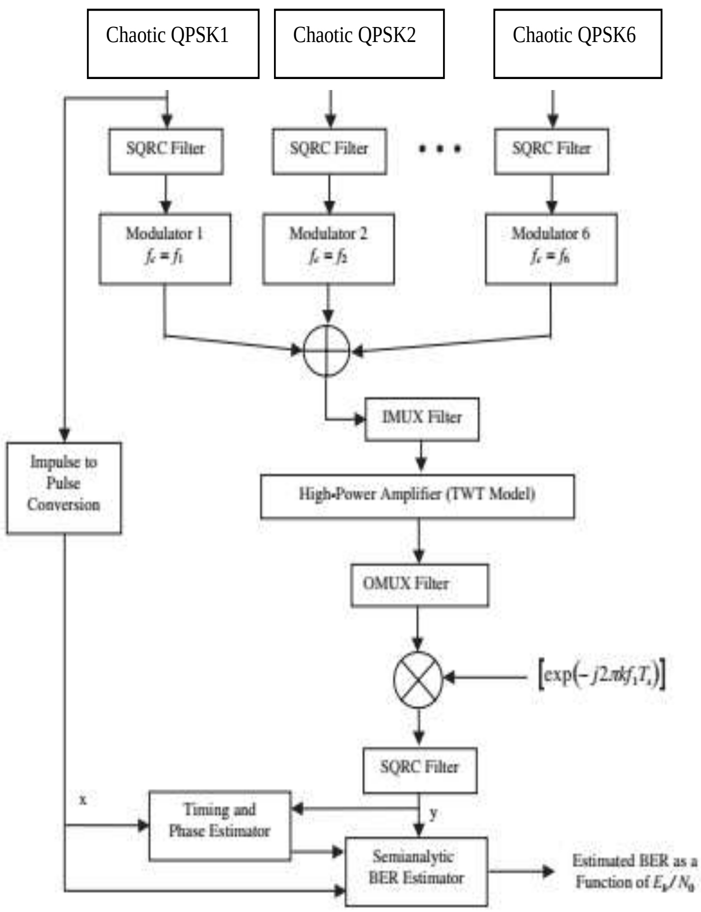

Figure 11 Satellite communications system by use of CSK.

After simulation we obtain first the design of PSD power spectral density at the input and the output of the TWT model; figure12, secondly the constellation signal of the non-linear effects and the BER due to the noise with nonlinear distortion figure13 .From figures we can observe that .our system results are like the ideal one which means that we have good simulation with chaotic system. Figure12 shows PSD representation of the TWT model. Figure 13 shows Non-linear effects signal constellation, and BER representation.

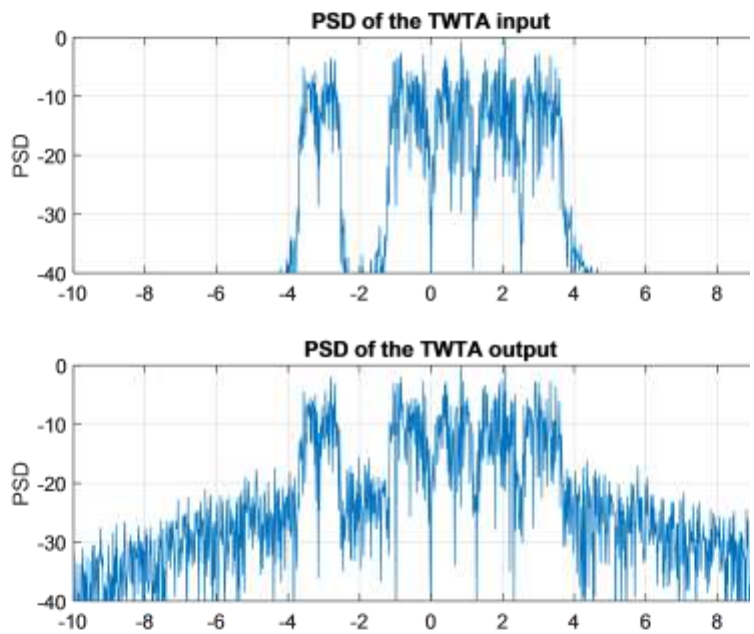

Figure12 shows PSD representation of the TWT model

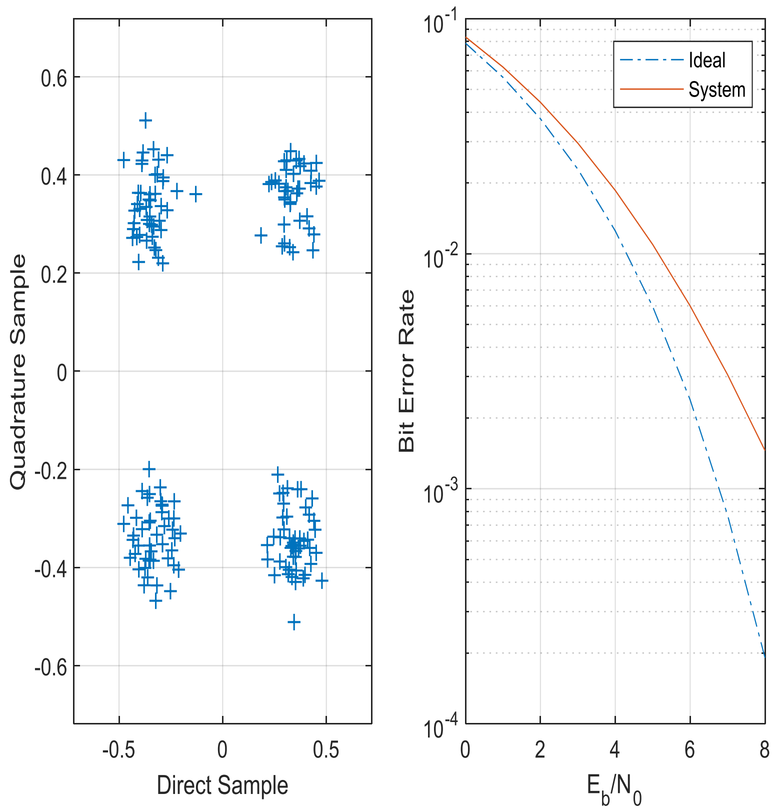

Figure 13 Non-linear effects signal constellation, and BER représentation.

5 Conclusion

This work finds desired order in the disorder of chaotic dynamical systems. After studies of each system importance of this chaotic behavior is discovered because of their sensitivity to initial conditions, unpredictability and large band Chaos gives more and more security to the information transmitted against interceptors. It presents today the best solution to best communication

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