International Journal of Engineering Research and General Science Volume 3, Issue 2, Part 2, March-April, 2015
ISSN 2091-2730

Analysis of Chaos MIMO Communication System with Fading channels

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Abstract— The security of chaos communication system is superior to other digital communication system, because it has characteristics such as non-periodic, wide-band, non- predictability, easy implementation and sensitive initial condition. Chaos sequences are non – periodic sequences which are sensitive to their initial conditions i.e. spread factor and time delay respectively. If many antennas are applied to chaos communication system, the capacity of data is proportional to the number of antenna.so it is good way applying multiple-input and multiple-output (MIMO) to the chaos communication system. This paper makes a primary contribution to evaluate the BER performance of Chaos MIMO Communication system in fading channels. The chaotic maps that have been considered are Tent map, Boss map, Henon map and logistic map. The modulation scheme that has been considered is CDSK in presence of AWGN channel and Rayleigh fading channel.

Keywords— Chaos maps, Tent map, Boss map, Henon map, Logistic map, MIMO, AWGN channel, Rayleigh channel, CDSK (correlation delay shift keying).

INTRODUCTION

Earlier use of Linear system was prominent. But with technological advancement, Non-Linear system started to be used by combining it with chaos communication system for improved performance.[1] Chaos communication aims at providing security for transmission of information performed through technologies.[2] The characteristics of Chaos communication include non-periodicity, wide-band, non-predictability and easy implementation. Chaos communication system is decided by initial conditions of equation. It has sensitive characteristic according to initial condition, because chaos signal is changed to different signal when initial condition is changed. [3-4] If the initial condition is known to the intruder, then it becomes sensitive to the outside world. As long as the initial condition concealed from the outside world, it is impossible to predict the chaos signal. The chaotic sequences make the transmitted signal look like noise; therefore, it does not attract the attention of an unfriendly receiver. These characteristics makes the security of chaos communication superior to digital communication systems. Because of this added advantage of security, chaos communication has been extensively studied.

During the last two decades or so, lots of digital communication schemes using chaos have been suggested and studied, which utilize either coherent or non-coherent detections for information extraction [5]. Because chaotic synchronization in coherent detection performs poorly, demodulation in chaos based communication schemes with coherent receivers using this synchronization technique becomes a real challenge in noisy environments. Therefore, non-coherent schemes seem more feasible and appealing in practical environments. In 1996, Kolumb´an et al. proposed the non-coherent differential chaos shift keying (DCSK) which is the most suitable scheme in wireless communications due to its good noise performance[6,7]. However, the prices that it has to pay are low attainable data rate and weakened information security. In 2000, Sushchik et al. proposed the non-coherent correlation delay shift keying (CDSK) whose bandwidth utilization ratio and information security are much better than DCSK.

Chaos communication system has many transmitted symbols, because information signal is spread according to the characteristic of chaos map. So, study of chaos system for data rate improvement is necessary. MIMO (Multi Input Multi Output) system transmit data by several paths using several antennas. And, in receiver part, it is a technique which can reduce interference by detecting received signal at each path, and provides a better data rate, link reliability and bandwidth efficiency. MIMO system increase the capacity of data communication in proportion to number of antenna, and provide the high data processing Speed[8].

This paper is organized as follows section II explains what is Chaotic system, Section III gives the Chaotic signals, section IV elaborates the system overview, Section V discuss about the performance evaluation of the system i.e., we will evaluate the performance of different chaotic maps in the CDSK chaotic modulation system and will find out which chaotic map shows superior performance. Using the superior map obtained from the analysis we proceed to the 2x2 MIMO concepts. In the later stage we compare the performance of BPSK and CDSK over MIMO AWGN channel. And a comparative analysis of the 2x2 Chaotic MIMO Concept and 4x4 chaotic MIMO concept using CDSK Modulation in AWGN channel, Then performance of 2x2 chaotic MIMO and 4x4 chaotic MIMO in Rayleigh channel was analysed. Finally in Section VI we will make the conclusion.

CHAOTIC SYSTEM

A chaotic dynamical system is an unpredictable, deterministic and uncorrelated system that exhibits noise-like behavior through its sensitive dependence on its initial conditions, which generates sequences similar to PN sequence. They have been successfully employed to various engineering applications such as automatic control, signals processing and watermarking Since the signals generated from chaotic dynamic systems are noise-like, super sensitive to initial conditions and have spread and flat spectrum in the frequency domain, it is advantageous to carry messages with this kind of signal that is wide band and has high communication security. Secure communication with chaos has been developed. [6]These systems tend to be more computationally complex than non-spread communication systems, yet they provide advantageous multipath mitigation and multi-user spectral re-use capabilities.

CHAOTIC SIGNALS

A chaotic sequence is non-converging and non-periodic sequence that exhibits a noise-like behavior through its sensitive dependence on its initial condition i.e., spread factor and time delay respectively. [4] A large number of uncorrelated, random-like, yet deterministic and reproducible signals can be generated by changing initial value. These sequences so generated by chaotic systems are called chaotic sequences. [7] Chaotic sequences have been proven easy to generate and store. Merely a chaotic map and an initial condition are needed for their generation, which means that there is no need for storage of long sequences. Moreover, a large number of different sequences can be generated by simply changing the initial condition. The secrecy of the transmission is important in many applications. The chaotic sequences help achieve this security from unwanted reception in several ways.

SYSTEM OVERVIEW

I. Correlation delay shift keying system

Existing modulation system consists of a switch in the transmitter, creating the problem of power wastage and eavesdropping occurs by twice transmission. Technique that has been proposed to solve these problems is CDSK system where transmitted signal does not repeat as the switch at the transmitter is being replaced with an adder circuit.

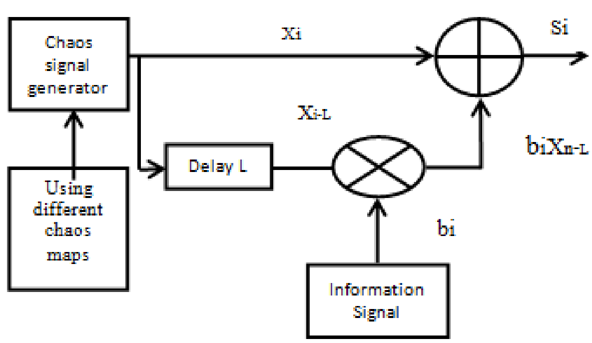

Fig .1 Transmitter of CDSK system

Fig.1 shows the transmitter of a CDSK system. The chaos signal from the generator is being delayed and is multiplied with the information signal. The resulting signal is being added with the original chaos signal generated from the generator finally producing the transmitter output.

$$s_i = x_i + b_i x_{i-l} \quad (1)$$

Equation (1) indicates transmitted signal from transmitter. Here L denotes the delay time.

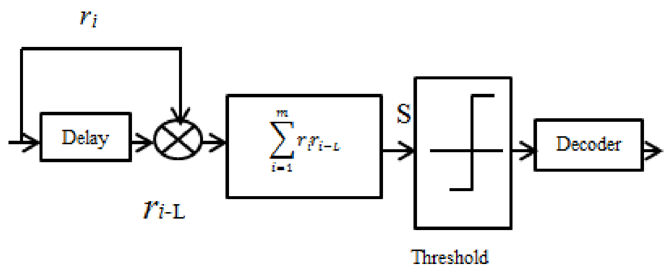

Fig.2 Receiver of CDSK system

Fig.2 shows the CDSK receiver system. CDSK receiver is correlator based receiver, and it is performed in order to recover the symbol. Received signal and delay received signal are multiplied, and this signal is added as much as the spreading factor. Afterward the signal is quantized according to an appropriate threshold and information signal is recovered through decoding.

$$s = \sum_{i=1}^{M} r_i \, r_{i-l} \qquad (2)$$

Equation (2) indicates output value of correlator of CDSK system. Information bits are possible to recover when delay time and spreading factor have to use exact value that is used in transmitted signal.

II. Chaos maps

In this paper, the types of chaos map that has been considered are Tent map, Boss map, Logistic map and Hénon's map.

a. Tent map

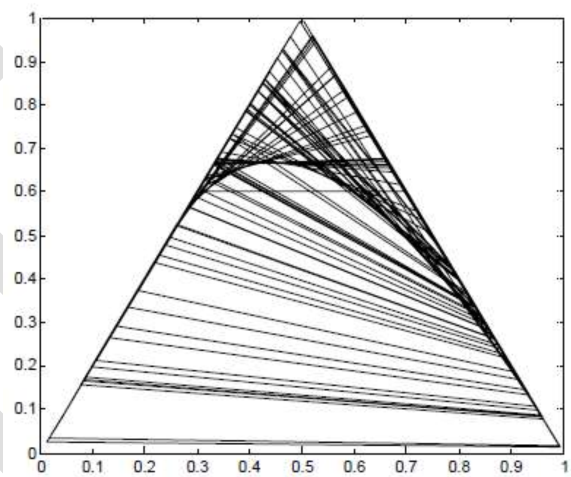

Fig.3 Trajectory of tent map

Fig.3 shows trajectory of Tent map. The x-axis and the y-axis of fig.3 mean x_n and x_n+1, and Tent map has trajectory of triangular shape.

$$x_{n+1} = \begin{cases} \alpha x_n & for\ x_n < 0.5 \\ \alpha(1 - x_n) & for\ 0.5 \leq x_n \end{cases} \qquad (3)$$

Equation (3) is the representation of tent map. Equation of Tent map uses existing output value as current input value, and it is indicated as figure when initial value is 0.1 and parameter alpha is 1.9999.

b. Boss map

Boss map is similar to Tent map because of the fact that Boss map was obtained by transforming the Tent map. Equation (3) is the representation of Boss map. The initial value as 0.1 and parameter alpha as 2.5 are used in the equation

$$x_{n+1} = \propto |0.45 - |0.503 - x_n|| \quad (4)$$

$$y_{n+1} = x_n - 0.3$$

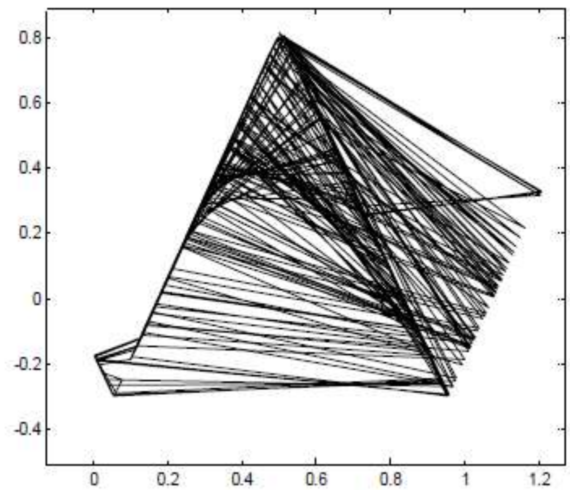

Fig. 4 Trajectory of boss map

Fig.4 shows trajectory of Boss map. The x-axis and the y-axis of Boss map mean x_n and y_n unlike the Tent map, it draws trajectory in a pyramid shape. The equation below defines the Boss map.

c. Logistic map

The logistic map is a polynomial mapping (equivalently, recurrence relation) of degree 2, often cited as an archetypal example of how complex, chaotic behavior can arise from very simple non-linear dynamical equation.

$$x_{n+1} = rx_n(1 - x_n) \quad (5)$$

Equation (5) is the representation of Logistic map. Here x_n is a number between zero and one it represents the ratio of existing population to the maximum possible population.

The bifurcation diagram is a self-similar if you zoom in on the above-mentioned value $r = 3.82843$ and focus on one arm of the three, the situation nearby looks like a shrunk and slightly distorted version of the whole diagram. The same is true for all other non-chaotic points. This is an example of the deep and ubiquitous connection between chaos and fractals.

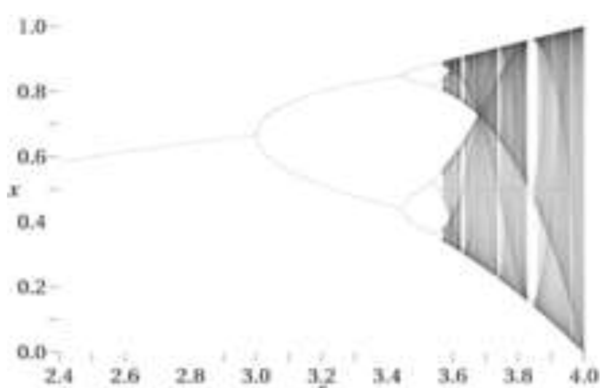

Fig. 5 Representation logistic map

d. Hénon's map

The Hénon's map is a discrete-time dynamical system. It is one of the most studied examples of dynamical systems that exhibit chaotic behavior.

$$x_{n+1} = 1 - ax_n^2 + y_n$$
$$y_{n+1} = bx_n \quad (6)$$

The Hénon's map takes a point (x_n, y_n) in the plane and maps it to a new point. Equation (6) is used to specify Hénon's map.

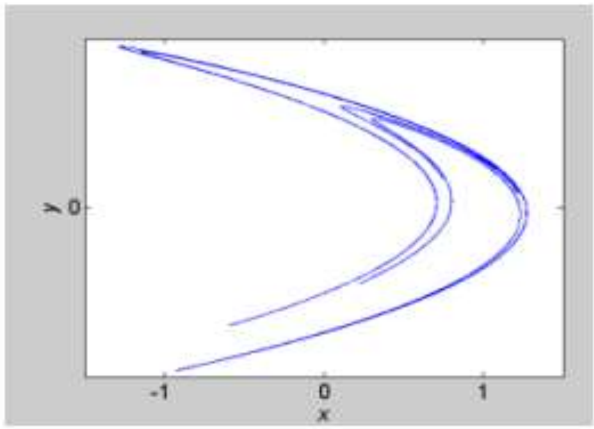

Fig.6 representation of Hénon's map

Fig.6 shows the representation of Hénon's map. The map depends on two parameters, *a* and *b*, which for the classical Hénon map have values of *a* = 1.4 and *b* = 0.3. For the classical values the Hénon map is chaotic. For other values of *a* and *b* the map may be chaotic, intermittent, or converge to a periodic orbit. An overview of the type of behaviour of the map at different parameter values may be obtained from its orbit diagram.

III. MIMO communication channel

The use of multiple antennas at the transmitter and the receiver in communication systems are generally known as MIMO (multiple-input-multiple-output). This technology has rapidly gained over the past decade due to its powerful performance-enhancing capabilities. Communication in wireless channels is impaired predominantly by multi-path fading. Multi-path is the arrival of the transmitted signals at an intended receiver through differing angles or differing time delays or differing frequency (i.e., Doppler) shifts due to the scattering of electromagnetic waves in the environment. Consequently, the received signal power fluctuates in space (due to angle spread) or frequency (due to delay spread) or time (due to Doppler spread) through the random superposition of the impinging multi-path components.

The random fluctuation in signal level, known as fading, can severely affect the quality and reliability of wireless communication. Additionally, the constraints posed by limited power and scarce frequency bandwidth make the task of designing high data rate, high reliability wireless communication systems extremely challenging.

MIMO technology constitutes a breakthrough in wireless communication system design. The technology offers a number of that helps meet the challenges posed by both the impairments in the wireless channel as well as resource constraints. In addition to time and frequency dimensions that are exploited in conventional single-antenna (single-input single-output) wireless systems, the leverages of MIMO are realized by exploiting the spatial dimension (provided by the multiple antennas at the transmitter and the receiver).

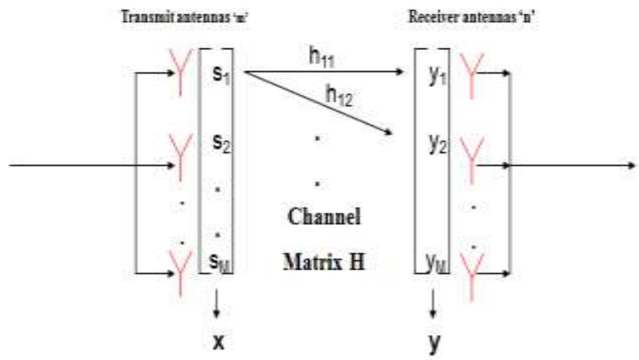

Fig. 7 General outline of MIMO

$$where, H = \begin{bmatrix} h_{11} & h_{21} & \cdots & h_{m1} \\ h_{12} & h_{22} & \cdots & h_{m2} \\ \cdot & \cdot & \cdots & \cdot \\ h_{1m} & h_{2m} & \cdots & h_{mm} \end{bmatrix} \quad (7)$$

The two main formats for MIMO are given below:

(1)Spatial diversity: Spatial diversity used in this narrower sense often refers to transmit and receive diversity. These two methodologies are used to provide improvements in the signal to noise ratio and they are characterised by improving the reliability of the system with respect to the various forms of fading.

(2) Spatial multiplexing: This form of MIMO is used to provide additional data capacity by utilising the different paths to carry additional traffic, i.e. increasing the data throughput capability.

As a result of the use multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. This makes MIMO wireless technology one of the most important wireless techniques to be employed in recent years.

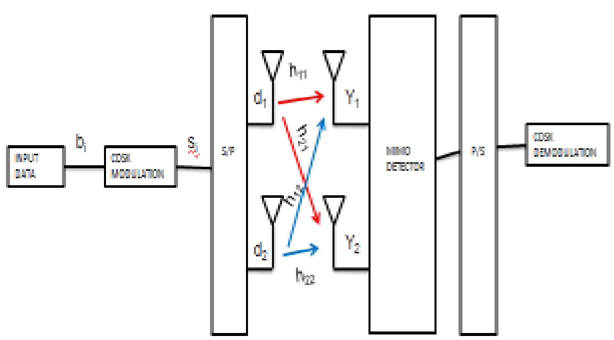

Fig.8 Block diagram of CDSK system with 2x2 MIMO.

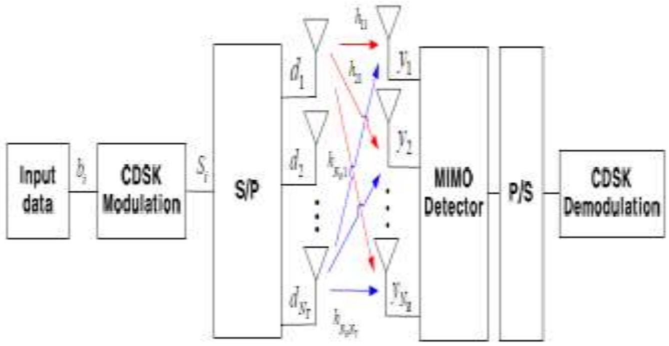

Fig.9 Block diagram of CDSK system with 4x4 MIMO.

PERFORMANCE EVALUATION

In this paper, the BER performance of chaos MIMO system in AWGN (Additive White Gaussian noise) channel and Rayleigh channel. A comparative analysis of chaotic maps is evaluated. And the outperform map is considered for fading channels. The figure (9) shows BER performance of chaotic CDSK system in AWGN channel over all the above stated maps.

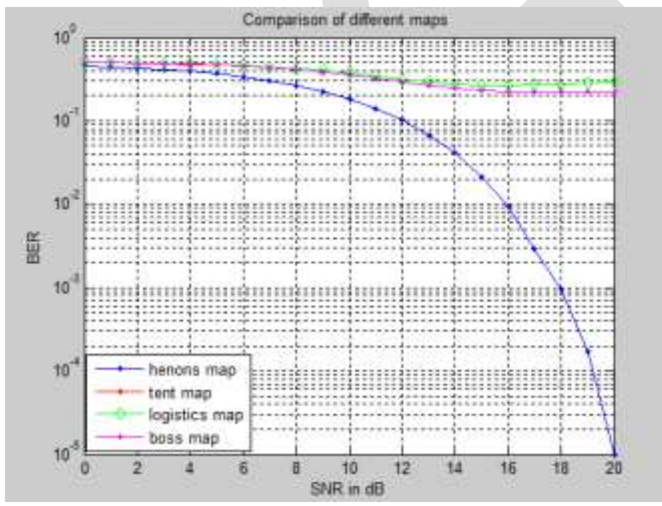

Fig.10 BER performance of chaotic CDSK system

Fig.10 shows the comparative analysis of all the maps. Here, we observe that the BER Performance of Hénon's map is better than other maps i.e., at different values of SNR we observe that the Hénon's map shows better performance than other three maps. At low SNR the performance of all maps are more or less similar but for high SNR Hénon's map performs well.

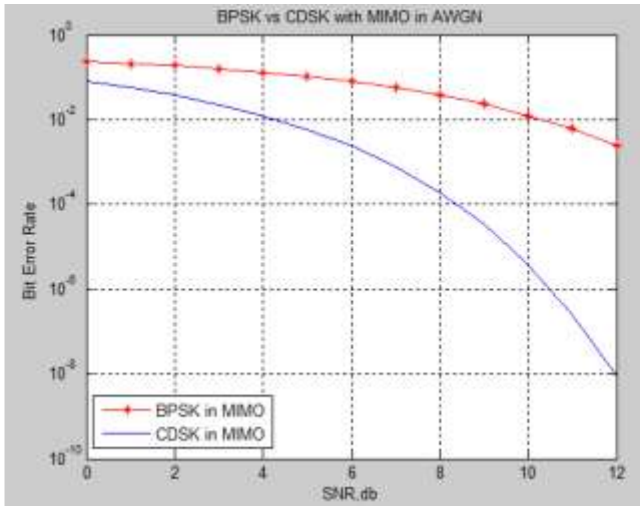

Fig.11 Performance analysis of BPSK and CDSK with2x2 MIMO in AWGN

Fig.11 shows the BER performance of BPSK and CDSK modulation over AWGN with Hénon's map in 2x2 MIMO communication channel. From the figure it is clear that CDSK performance is much better compared to BPSK.

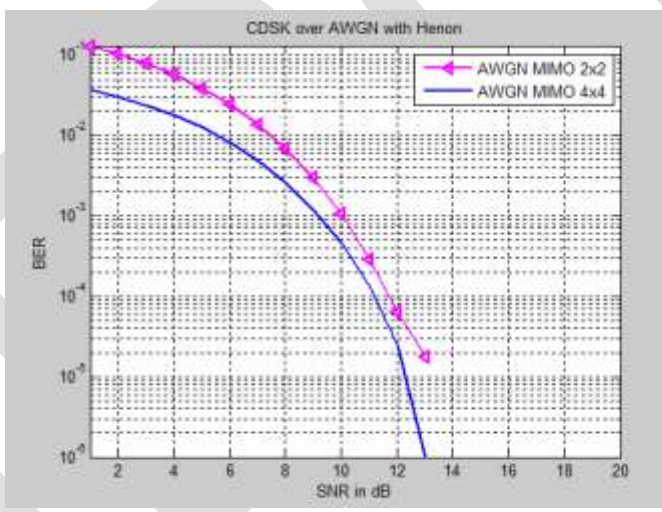

Fig.12 Performance analysis of CDSK with MIMO 2x2 and 4x4 in AWGN

Fig.12 shows the BER performance of CDSK modulation with Hénon's map over AWGN channel in 2x2 and 4x4 MIMO communication channel was analysed. From the simulation 4x4 MIMO communication channel shows a better performance.

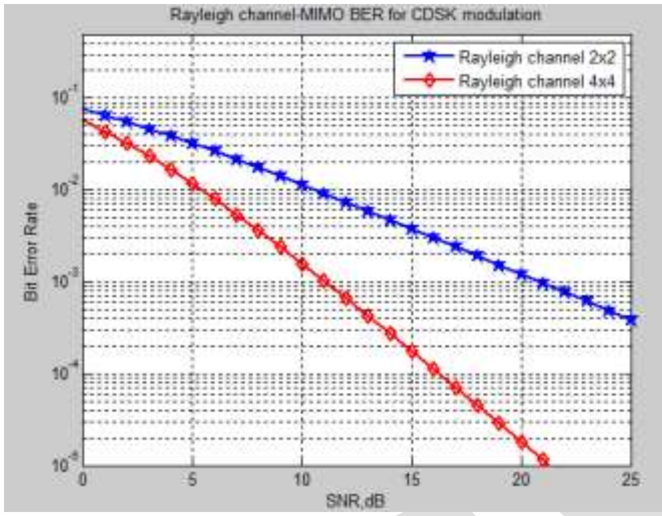

Fig.13 Analysis of Chaos MIMO 2x2 and 4x4 in Rayleigh channel

Fig.13 shows the performance of chaos MIMO communication in Rayleigh channel.

CONCLUSION

In this paper, the BER performance of Chaos communication system was evaluated using various chaotic maps i.e., Tent map, Boss map, logistic map, Hénon's map and Hénon's map was found to outperform all other maps. Further, we used Hénon's map for CDSK 2X2 and 4x4 MIMO system in AWGN and Rayleigh channels. We found an extensive improvement in system performance. This work can be carried on further by considering other channel models and evaluating the system performance.

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