

Design of Chaotic CDSK Modulation System using Different Chaotic Maps

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Abstract— Recently, it has been studied how to reduce the probability of interception and to increase the communication security efficiently in the wireless communication systems. Among the possible approaches for the information security, the chaotic signal can be used to encode information very efficiently in many ways due to the inherent characteristic of irregularity. Also, the chaotic signal is very sensitive to the initial conditions. So, if you do not know the initial conditions. In noise and interference environment, we will evaluate performance of different chaotic maps in the CDSK chaotic modulation system. Also, we analyze BER performance depending on the selection of spreading factor. We like to propose the selection condition of spreading factor to maximize BER performance. For this analysis, we were used Tent map, logistic map, henon map, Bernoulli shift map. Through the theoretical analysis and computer simulations, it is confirmed that henon map is better than the other three chaotic maps. Also, henon map shows maximize BER performance when spreading factor is 70.

Keywords— Correlation Delay Shift Keying; Chaotic maps; Spreading factor; Henon map; Tent map;

I. INTRODUCTION

Chaos theory was widely known by E. Lorenz in 1963. He studied non-linear characteristics of weather, and then he presented a paper with the name of ‘Deterministic Non-periodic Flow’. The paper is the basis of chaos theory. And it is the beginning of the chaotic system.

Chaotic phenomena can be used to encode information efficiently in many ways due to Irregular characteristics of chaos. Random signal is unpredictable in any way, and the value of current is generated independent of the value of the past. However, in principle, chaotic signals can be predicted. And the value of the future can be derived in a certain way from value of the past.

The characteristics of chaotic signals are determined from the initial conditions of the equation in signal generator. Chaotic signal has self-correlation, low cross-correlation. So, even small changes in initial conditions can become completely different signals. From these characteristics of chaotic signal such as aperiodicity, broadband, sensitive initial conditions, the difficulty of predicting the signal, simple implementation, we can replace the random carrier signal used in the spread spectrum communication systems. Therefore,

chaos-based digital modulation system using chaotic signal instead of the spreading code for spread spectrum, so security is very good. Even contains an interference signal, it is spread. The size is reduced in the process of diffusion. So, the size of interference signal is reduced. It will have highly resistant to interference by increasing the size of own signal. Also, it is strong in fading situation because of the wide bandwidth of the transmitted signal. Therefore, it becomes strong in multipath and jamming channel. In addition, it can be improved to be a solution to the problem such as eavesdropping, privacy, security.

For application into the generated digital communication system by chaotic system, we will use the chaotic signal instead of spreading factor. If you are using a wide spreading factor, you can get the gain as much as you can get but interference is increased. On the other hand, if you are using a small spreading factor, interference is reduced, and the gain is also reduced. Thus, in order to the most efficient performance, it is necessary to select the appropriate spreading factor depending on the channel environment.

In this paper, we will evaluate performance of different chaotic map in the CDSK chaotic modulation system. Also, in noise and interference environment, we analyze BER performance depending on the selection of spreading factor.

We propose the selection condition of spreading factor to maximize BER performance of chaotic CDSK modulation system. For apply to the generated digital communication system by chaotic system, we will use the chaotic signal instead of digital carrier. And we made chaotic signal generator using four kind of chaotic maps. Four chaos equations, we were used previously proposed Tent map, Logistic map, Henon map, Bernoulli map. Through proposed chaotic map, it can be found which spreading factor is best performance. Through proposed chaotic maps, we propose the selection condition of spreading factor to maximize BER performance of chaotic CDSK modulation system.

This paper is organized as follows. In the section 2, we will show the CDSK (correlation delay shift keying) and the modulation system using different chaotic maps. In the section 3, we will evaluate the performance of different chaotic maps in the CDSK chaotic modulation system. And we propose the selection condition of spreading factor for the chaotic CDSK modulation system. Finally, we will make the conclusion.

II. SYSTEM OVERVIEW

In this paper, we propose the selection condition of spreading factor to maximize BER performance of chaotic CDSK modulation system. Each is described on the next.

A. CDSK(correlation delay shift keying)

Correlation Delay Shift Keying modulation was proposed by Sushchik for continues to transmit information and to increase the efficiency of bandwidth. Figure 1 shows a block diagram of the CDSK system. (A) is the transmitter; (b) is the receiver.

The transmitted signal is the sum of the generated chaotic signals in the generator and delayed chaotic signals by the transmitted symbol. Thus, the transmitted signal will have the information signal and reference chaotic signal. Therefore, the transmitted signal is the same as equation (1).

$$S_i = x_i + b_i x_{i-L} . \quad (1)$$

In Eq. (1), x_i is the chaotic signal, L is the delayed time. M is the spreading factor of each signal is a bit chaotic.

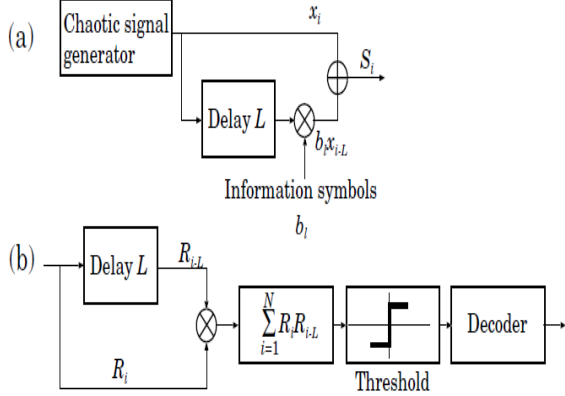


Figure 1. CDSK operation (a)transmitter, (b)receiver.

Figure 2 shows the CDSK transmitter using Simulink. Digital input block generates to transmit binary information.

The receiver based on the CDSK is performed to restore the symbol. Thus, the received signal, we can find the information by multiply the received signal and delayed signal such as equation (2).

Where M is the spreading factor, R_i is the received signal passed through the channel.

$$Y_1 = \sum_{i=0}^M R_i R_{i-L} \quad (2)$$

Figure 3 shows the CDSK receiver using Simulink. The decode symbol is decided as "+1" or "-1" depending on output being larger or smaller than 0.

Also, CDSK system does not require a switch to generate the transmitted signal. Transmitted signal does not repeat. We can overcome this problem.

The switch on the transmitter that problem of DCSK system is replaced by the adder. Figure 4 shows the simulation of CDSK operation.

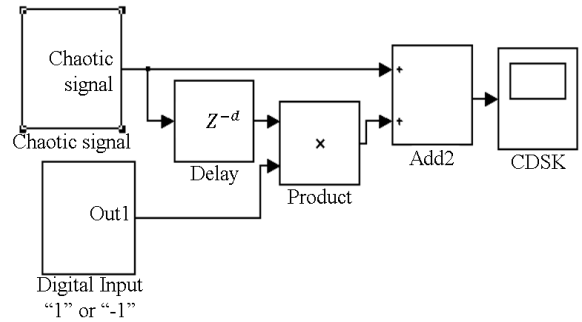


Figure 2. Block diagram of transmitter.

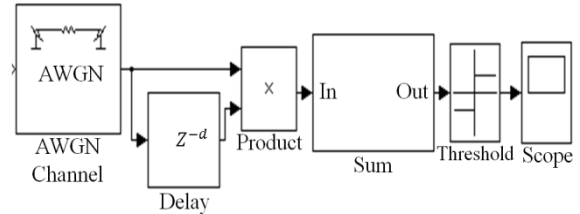


Figure 3. Block diagram of receiver.

SF was set to a value of 10. Delay was set to a value of 5. Modulation is multiplied with information signal and delayed chaotic spreading factor.

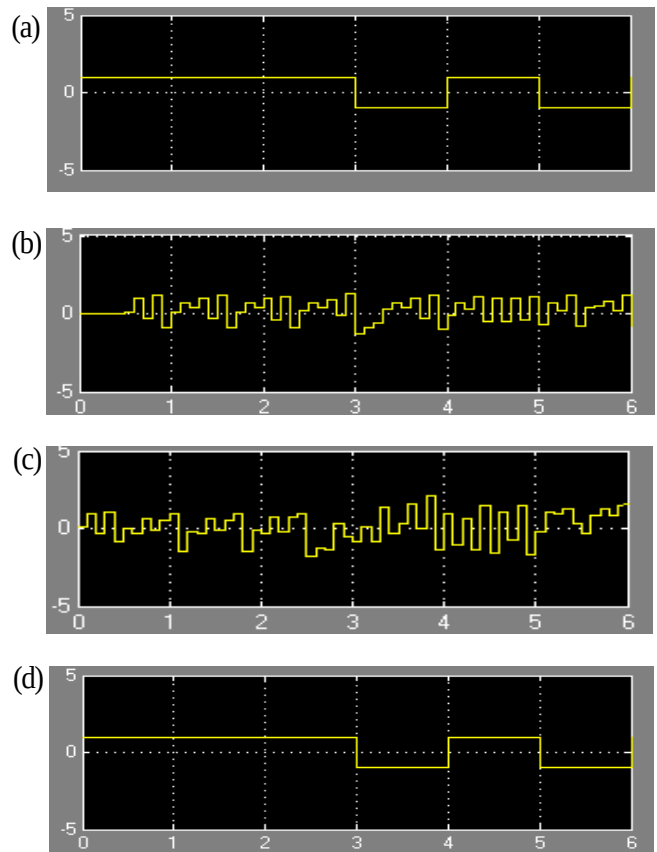


Figure 4. Block diagram of receiver (a)data input, (b)delayed chaotic signal, (c)transmitted signal, (d)data output.

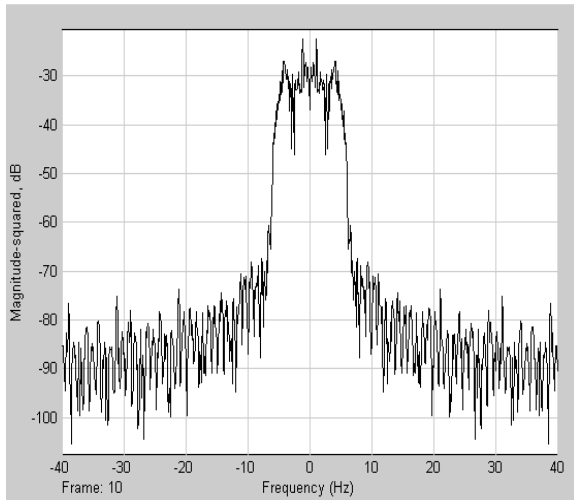


Figure 5. Spectrum of transmitted signal

The transmitted signal passes through the channel, and then it demodulated at the receiver. When the sample time is 1, SF value is 10. So, the spectrum characteristics are same as figures 5 and 7.

Figure 6 shows evaluation performance of Tent map in the CDSK chaotic modulation system. The result of probability of error according to the change of the SNR in AWGN channel, it shows when BER is 10^{-3} , experimental value is loss of approximately 0.4dB than the theoretical value. However, it shows Experimental curves of the overall BER performance closed to the theoretical value.

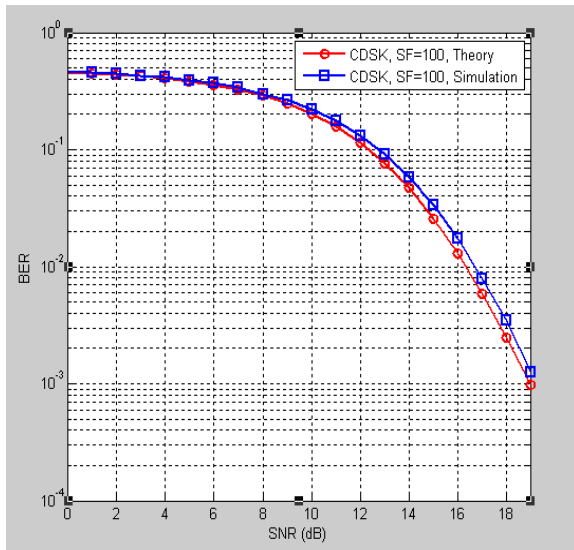


Figure 6. Ber performances of CDSK system using tent map.

B. CDSK(correlation delay shift keying)

As explained in the introduction, it shows the effect of chaotic systems that changes the length of spreading factor depending on the initial value. In addition, from this results, we can be expected the system performance of chaotic map.

To see the results of these expectations, we will evaluate performance by using simulation.

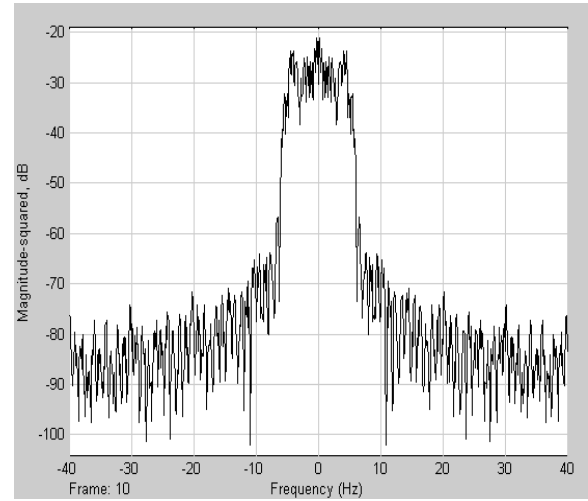


Figure 7. Spectrum of received signal.

Before performance evaluation, we will define about chaotic maps in the modulation process. Chaotic maps are shown in Figure 8.

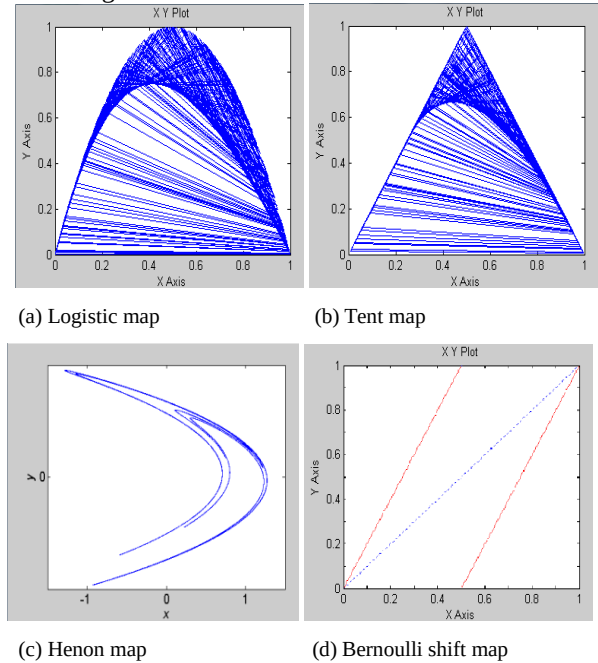


Figure 8. Spectrum of received signal.

Logistic map was proposed by Robert may. An object of this equation can't grow independently by environmental factors. Because it is saturated or rash, does not have only a linear characteristic. Logistic map equation is described on the next.

$$x_{n+1} = Rx_n(1 - x_n) \quad (3)$$

Tent map equation is non-linear system by using the previous output from current input. If the value of the gain alpha is less than 1.01, it has a linear characteristic. And increasing the value of the gain alpha, the trajectory of output

will change more dramatically. Tent map equation is described on the next.

$$x_{n+1} = \alpha |0.5 - |0.5 - x_n|| \quad (4)$$

Henon map equation is a dynamic system in discrete-time. Equation of the chaotic phenomena is progressed most actively studied. Henon map depends on two parameters and b. Standard Henon map equation has a value a = 1.4 and b = 0.3. The equation is described on the next.

$$\begin{aligned} x_{n+1} &= 1 + y_n - a(x_n)^2 \\ y_{n+1} &= bx_n \end{aligned} \quad (5)$$

Bernoulli shift map equation is defined same as (6).

$$D(x) = \begin{cases} 2x & \text{if } 0 \leq x < 1/2 \\ 2x-1 & \text{if } 1/2 \leq x < 1 \end{cases} \quad \text{or} \quad (6)$$

$$D(x) = 2x \bmod(1)$$

III. PERFORMANCE EVALUATION

In this section, we will evaluate performance of the CDSK chaotic modulation system by using computer simulation. The performance of CDSK chaotic modulation system will depend on the channel environment, spreading factor, and chaotic map in the modulation process. In this paper, we analyze BER performance depending on the selection of spreading factor. And we propose the selection condition of spreading factor to maximize BER performance of chaotic CDSK modulation system. By this experiment, bit error rate is given as equation (7).

$$BER = \frac{1}{2} \operatorname{erfc} \left(\sqrt{\frac{E_b}{8N_o} \left(1 + \frac{19}{20M} \frac{E_b}{N_o} + \frac{M}{4} \frac{N_o}{E_b} \right)^{-1}} \right) \quad (7)$$

M is spreading factor. Figure 9, it is compared gain variation of CDSK(correlation delay shift keying) system by using Tent map according to the change of spreading factor. As Spreading factor increases, we can see that both interference and energy errors is reduced. Depending on the choice of spreading factor in interference environment, the effect of interference is different. Spread-spectrum communication systems are modulated relatively narrowband information signal.

As a result, the information signals are cumulative, channel noise and interference will become average. Thus, increasing the spreading factor in the same chaotic map and channel environment, we can see that improving performance in Figure 9. At the same conditions of the channel environment and Spreading factor, the performance of CDSK will depend on chaotic maps. In the signal modulation process, the process

order of chaotic map is follow like Logistic map, Tent map, Henon map and Bernoulli shift map.

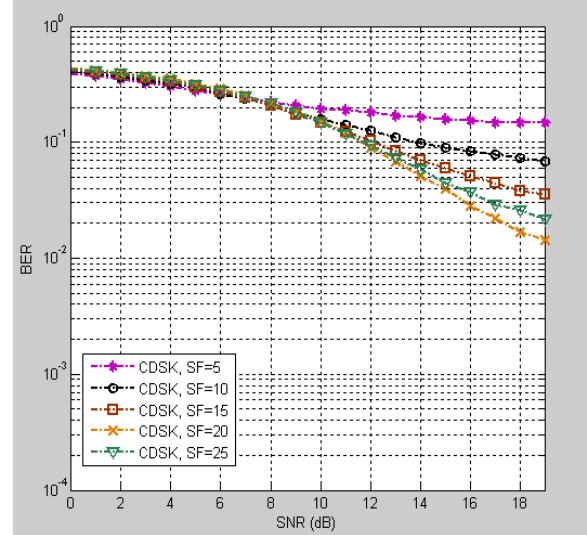


Figure 9. BER curves of CDSK system when Tent map is used.

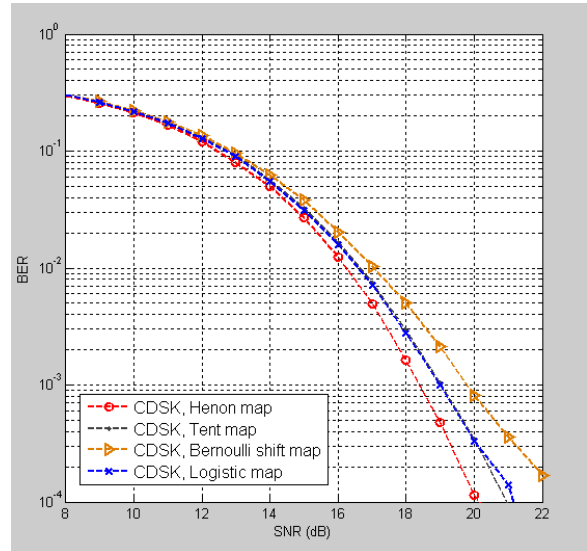


Figure 10. BER curves of CDSK system with different chaotic maps.

Also, Figure 10 shown the performance of each chaotic map can be found.

SF is set to a value of 100. As a result, we can see that the BER performance using Henon map is better than the other three systems. When comparing the performance of Logistic map and Tent map, Bernoulli shift map, Tent map and Logistic map are about 1dB better than Bernoulli shift map. However, the case of Henon map, at BER of 10⁻³, it shows much better performance about 0.7dB than Tent map and Logistic map.

If you are using a wide spreading factor, you can get the gain as much as you can get but interference is increased. On the other hand, if you are using a small spreading factor, interference is reduced, and the gain is also reduced. In noise and interference environment, Effect of interference is different depending on the selection of spreading factor.

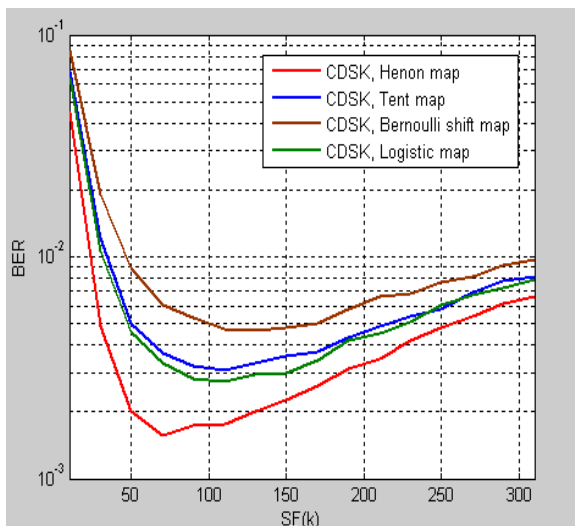


Figure 11. BER curves of CDSK system with different chaotic maps.

At the same conditions of the channel environment, the performance of CDSK will depend on the spreading factor. This simulation will proceed with changing the value of SF. Figure 11 shown the performance of each chaotic map.

When comparing the performance of Logistic map and Tent map, Bernoulli shift map, the case of Henon map, it is the best performance when SF is 70. But the case of other three chaotic signals, they are the best performance when SF is about 100.

As a result, when Henon map's SF is 70, we get maximum gain and minimum interference. So, it shows much better performance than other three chaotic signals.

IV. CONCLUSIONS

In this paper, we evaluated performance of different chaotic maps in the CDSK chaotic modulation system. To evaluate the performance, we made chaotic signal generator using four kind of chaotic maps which has non-linear characteristics and Random characteristics. We were used the chaotic signal to random carrier signal for a digital communication system. We defined about CDSK(correlation delay shift keying) and system that applies to the chaotic map. Also, we evaluate performance by using MATLAB simulation. In performance evaluation based on chaotic maps, spreading factor was defined as the length of the 100. Constant bit error rate. According to these conditions, it shown that our experimental were the same conditions.

As a result, you can see the system by using Henon map is better than the other three systems. Also, when SF is 70 in the Henon map, we get the maximum gain and minimum interference.

Therefore, we can see which spreading factor shows an effective performance improvement. Also, we can make efficient choice.

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REFERENCES

- [1] Shintaro Arai, Yoshifumi Nishio, "Noncoherent Correlation-Based Communication Systems Choosing Different Chaotic Maps," ISCAS 2007, New Orleans, LA, pp. 1433-1436, 27-30 May 2007.
- [2] Hua Yang; Guo-Ping Jiang, "High-Efficiency Differential-Chaos-Shift-Keying Scheme for Chaos-Based Noncoherent Communication," IEEE Transactions on, vol. 59, pp. 312-316, 11 May 2012.
- [3] Wren, T.J.; Yang, T.C, "Orthogonal chaotic vector shift keying in digital communications," Communications, IET, vol. 4, pp. 739-753, 16 April 2010.
- [4] Sushchik, M, Tsimring, L.S, Volkovskii, A.R, "Performance analysis of correlation-based communication schemes utilizing chaos," IEEE Transactions on. Circuits and Systems Part 1, vol. 47, pp. 1684-1691, Dec 2000.
- [5] F. C. M. Lau and C. K. Tse, Chaos-Based Digital Communication Systems, Springer, 2003.
- [6] Wai M. Tam, Francis C. M. Lau, "Generalized correlation-delay-shift-keying scheme for noncoherent chaos-based communication systems," IEEE Transactions on. Circuits and Systems Part 1, vol. 53, pp. 712-721, March 2006
- [7] Shintaro Arai, Yoshifumi Nishio, "Variable Sequence Length Transmitter for Noncoherent Chaos Shift Keying," 2006 RISP International Workshop on Nonlinear Circuits and Signal Processing (NCSP'06), Waikiki Beach Marriott, Honolulu, Hawaii, USA, March 3-5, 2006.



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