2018 SCIENCELINE
Journal of World's Electrical Engineering and Technology
J. World. Elect. Eng. Tech. 7(2): 09-16, December 15, 2018
ISSN: 2322-5114

Masking Communication Using Sprott94 Case A Chaotic System in AWGN Channel

Majid Mobini* and Mohammad Reza Zahabi

Department of Electrical and Computer Engineering, Babol University of Technology, Babol, Iran

*Corresponding's Email: mmobini@stu.nit.ac.ir

ORIGINAL ARTICLE
PII: S232251141800002-7
Received February 13, 2018
Revised November 15, 2018

Abstract *– Chaos masking is one of the most important methods in the Chaos based secure communication. Synchronization between transmitter and receiver play an important role in chaos masking systems. When the communication channel is imperfect due to the noise of the channel, the degraded signal at the receiver cause synchronization mismatch and decrease the performance of the system. In this study, we investigate two masking communication scheme based on Sprott94 Case A based masking system. We compare performance of the two different implementations of Sprott94 Case A based masking system in the noisy channel conditions using Mean Squared Error (MSE) Criterion. The Results show that the basic design of the system has better performance in AWGN channel.*

Keywords*: Chaos Masking, Sprott94 Case A, Synchronization*

INTRODUCTION

Chaos has been used in many engineering applications such as spacecraft targeting, analog to digital converters, radar imaging, signal detection, encryption, and wireless communication [1]. A large number of the applications of the chaotic signals in communication systems are reported up to now such as, chaos based coding [2] to [4], chaotic-based modulation [5-6] and multiple access systems [7-8].

Chaos found in different electrical circuits [9-10]. Chaotic signals can potentially be used as carriers in the communication systems. One of the important concepts for chaotic systems is high sensitivity to initial conditions. The simplicity of chaotic signal generators is another attractive feature of chaos that have caused a widely interest in utilization of the chaotic signals in the signal transmitting.

The self-synchronization property of the chaotic systems is a key feature of the chaotic based communication systems. One of the most popular chaotic synchronization methods is the cascade technique [11]. In this method, drive subsystem and response subsystem are coupled together and the receiver circuit constructs a version of the transmitted signal. Many chaos based circuits is presented up to now, in which produce the chaotic signals for communication applications. A popular example is the Lorenz based chaotic system [12]. In this study, we focus on Sprott94 Case A chaotic generators in which are based on a three dimensional equations [13].

Security is an important challenge in wireless communication systems, because all of the communication systems have special requirements due to physical layer conditions. Wireless communication systems use the air as a transmission medium and use of this medium, result in easy access to data. Chaotic masking is a common technique in the chaos based secure wireless communication systems [14-15]. In the chaotic masking communication, the transmitted signal contains the original message is added to a chaotic signal. At the receiver side, the chaotic signal is subtracted from the received signal to retrieve the original data [16].

When the communication channel is imperfect due to the noise of the channel or circuitry noise, the degraded signal at the receiver cause synchronization mismatch [17]. In some papers the channel noise is considered in evaluating the performance of the synchronization system. For example, in [18], the performance of the synchronization system with two Colpitts oscillators is evaluated in the different noisy conditions.

So, in this study, we consider the basic Sprott94 Case A based masking system in [19] and modified Sprott94 Case A based masking system (M- Sprott94 Case A based masking system) in [20] and compare these systems from the viewpoint of the effect of the channel noise on the performance of these masking communication systems, because in both the two papers the effect of noise is neglected. The advantage of modified system is able to work in the higher amplitude and lower frequency with low synchronization error. We aim to investigate the performance of these two systems in the noisy condition.

SPROTT94 CASE A BASED MASKING SYSTEM

We start with basic Sprott94 Case A masking system is presented in [19].

A. Synchronization system model

The key for chaos based communication is the synchronization among two or more oscillators. Recovering the transmitted signal means that the state trajectory on the receiver's chaotic attractor must reproduce drive signal which is transmitted through the channel. This technique has proven to be effective when some noise is added to the signal. This approach is shown in Figure 1. We can achieve secure communication using chaotic synchronization between two coupled Sprott94 Case A oscillators.

The general Block diagram of a masking communication system is shown in figure 2. As shown in this figure, the chaotic generator at the receiver produce the drive signal *x(t)* and data signal *m* is added to the drive signal. The masking signal *s(t)* is sent to the receiver due to communication channel. At the receiver side, the chaotic generator produces a copy of the drive signal $\acute{x}(t)$ using the master-slave synchronization method. This signal is subtracted from the received signal to retrieve the original transmitted data.

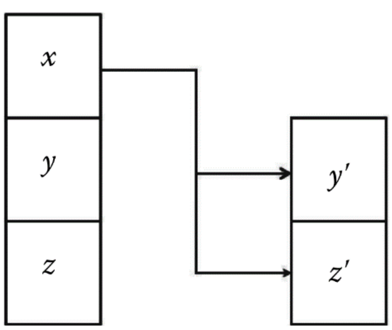

Fig.1 master Slave Synchronization Scheme

B. System Implementation

The Sprott94 Case A chaotic equation is simple but can produce a complex attractor. The basic Sprott94 Case A is expressed by the set of differential equations as follow:

$$\dot{x} = y$$
$$\dot{y} = -x + yz$$
$$\dot{z} = 1 - y^2 \qquad (1)$$

Consider sinusoidal data signal *d(t)* is added to the drive signal *x(t)* and masking signal *s(t)* is sent to the receiver through the AWGN channel. Thus, the received signal at the input of the receiver is given by:

$$r(t) = x(t) + d(t) + n(t) \qquad (2)$$

Where, $n(t)$ is the effect of additive noise and *r(t)* is the representative of the received signal. The MATLAB-SIMULINK Implementation of the Sprott94 Case A based masking system in the noisy condition is shown in figure 3. As shown in figure 3, at the receiver side, the chaotic generator produces a copy of the drive signal and this signal is subtracted from the received signal to retrieve the original data.

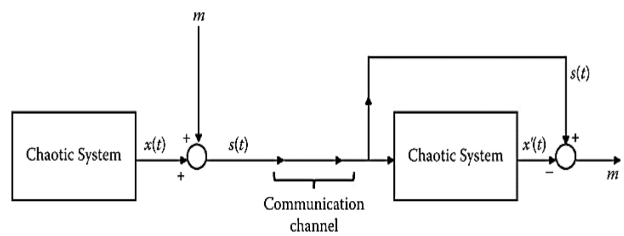

Fig. 2. Block Diagram of the chaotic masking scheme [1]

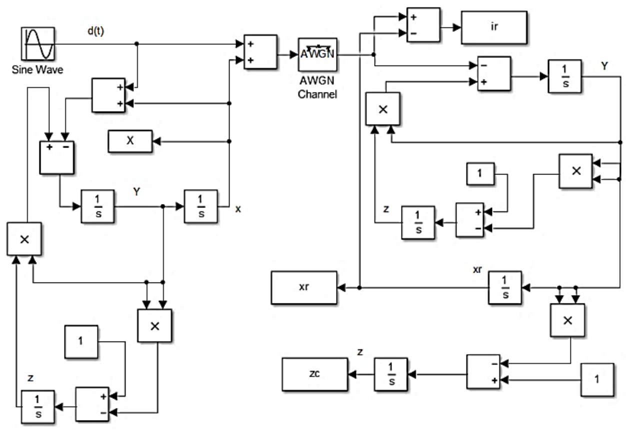

Fig. 3. Simulink model of the Sprott94 Case A based chaotic masking scheme

M- SPROTT94 CASE A BASED MASKING SYSTEM

In [20], the authors proposed the modified Sprott94 Case A based chaotic masking system (M- Sprott94 Case A Based Masking System) to transmit a data signal with higher amplitude and lower frequency and improve the performance of the synchronization system.

In the new scheme *x(t)* is replaced by *x(t)+d(t)* in the transmitter side. The equations of modified system at the transmitter are given by:

$$\dot{x} = y$$
$$\dot{y} = -\big(x + d(t)\big) + yz$$
$$\dot{z} = 1 - y^2 \quad (3)$$

When we pass the masking signal through the AWGN channel, at the receiver we have:

$$\dot{x_r} = y_r$$
$$\dot{y_r} = -(S + n(t)) + y_r z_r$$
$$\dot{z_r} = 1 - y_r^2 \quad (4)$$

Where, signal S is masking signal equal to x(t)+d(t).

The Figure 4 Shows the MATLAB-SIMULINK implementation of the M- Sprott94 Case A Based Masking system under the noisy conditions. We consider a sinusoidal wave generator as the data source and an AWGN channel in this model.

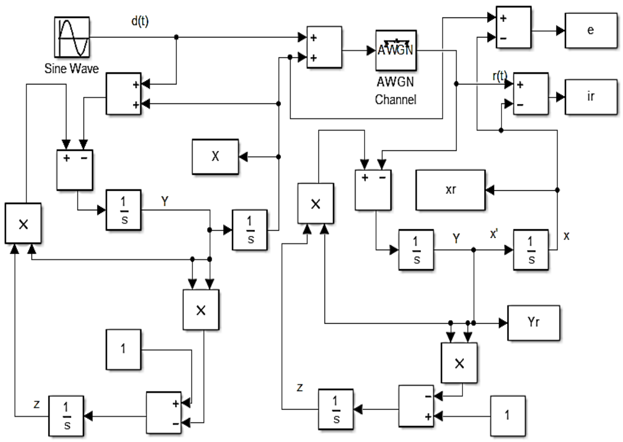

Fig. 4. Simulink model of the M- Sprott94 Case A based chaotic masking scheme

RESULTS AND DISCUSSION

In this section we investigate the effect of channel noise on the basic Sprott94 Case A based chaotic masking scheme and M- Sprott94 Case A based chaotic masking scheme. Simulation is performed in the MATLAB-SIMULINK environment for the two above mentioned systems using the sinusoidal data signal with amplitude 0.2V and frequency 1 kHz. For the both two systems we consider equal values for amplitude and frequency to accurate measurement of the performance of the systems under the AWGN channel.

We start with basic Sprott94 Case A based masking system. All of the parameters in transmitter and receiver systems are equal except for their initial values. The initial values at the transmitter side considered as (0, 5, 0), and for the receiver subsystem1 equal to (5, 0) and for the receiver subsystem 2 as (1, 0).

In figure 5, we can see that in ideal condition with noise neglecting, data signal can recover perfectly and basic Sprott94 Case A is proper for use in the masking communication system.

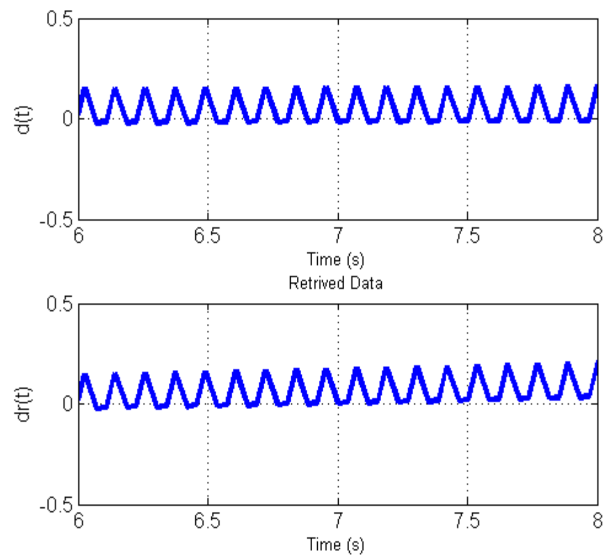

Fig. 5. Transmitted Data vs recovered signal in the Basic Sprott94 Case A based Masking Scheme

The comparison between the drive signal at the transmitter and receiver in ideal condition and free noise channel is shown in figure 6.

This figure shows that the drive signal at the receiver varies according to the drive signal of the transmitter. In the other word, this figure verify the results in figure 5 and denote that the basic Sprott94 Case A based masking system has the proper performance in ideal condition.

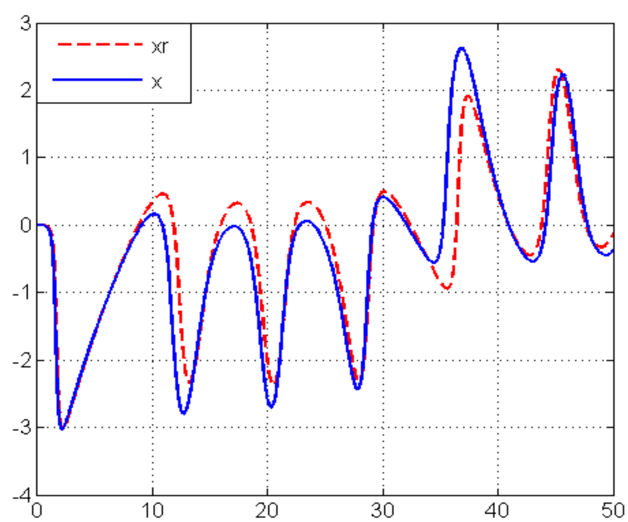

Fig. 6. Carrier recovery in the ideal condition in the Basic Sprott94 Case A based Masking

The error in data signal retrieval process under the ideal condition is shown in figure 7. In the next step, we consider an AWGN channel between the transmitter and receiver. Recall that when the amount of the noise is large, this noise has a destructive effect on the performance of the synchronization system.

The error in data signal recovery for the SNR= 10dB in the AWGN channel is shown in figure 8. As shown in this figure, the channel noise has a considerable destructive effect on the performance of the basic Sprott94 Case A based chaotic masking system.

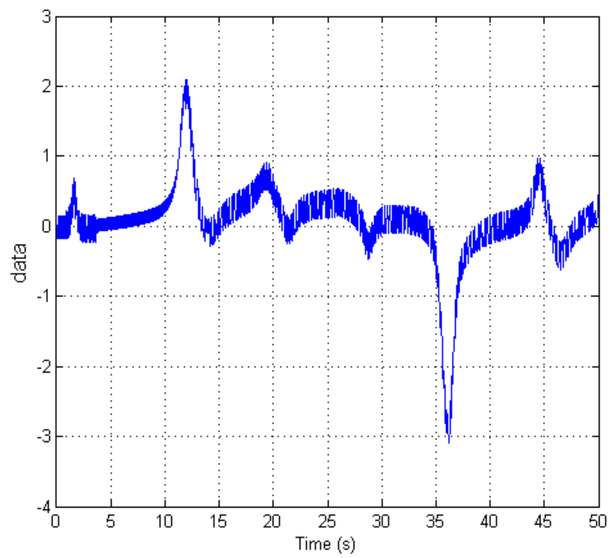

Fig. 7. Data Recovery Error in the ideal condition the Basic Sprott94 Case A based Masking

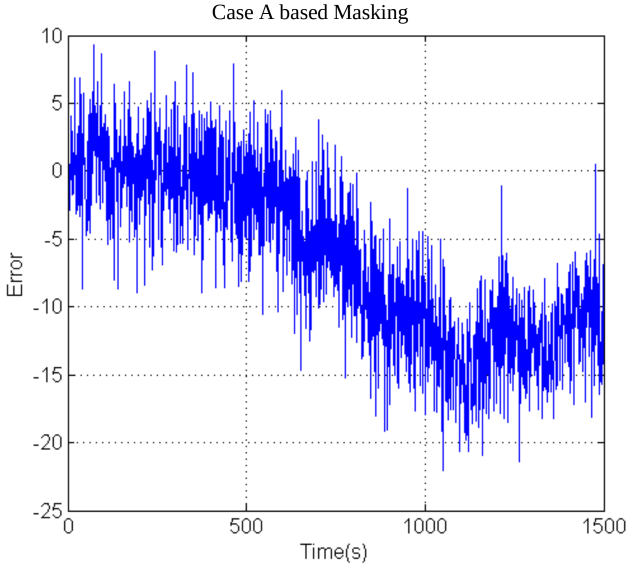

Fig. 8. Data Recovery Error in the noisy condition for the Basic Sprott94 Case A based Masking with SNR=10 dB

In this step, we want to compare the performance of the two systems, Sprott94 Case A based chaotic masking system and M- Sprott94 Case A based chaotic masking system, when we send masking signal through the AWGN channel. The general performance can now compare by estimating the mean square error (MSE) of the two systems. The general definition of the MSE is given by:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(\hat{d_i} - d_i)^2 \qquad (5)$$

The MSE plot for different SNR values in AWGN transmission is shown in figure 9.

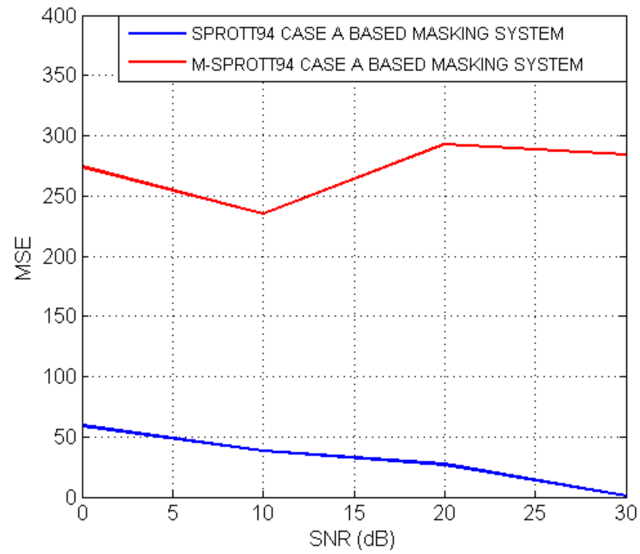

Fig. 9. MSE values of the two systems for different values of the SNR

Although, the M- Sprott94 Case A based chaotic masking system modified the basic scheme from the view point of the sensitivity to the amplitude and frequency of the data signal, the sensitivity to the noise in this system is more than the basic Sprott94 Case A based chaotic masking scheme.

CONCLUSION

In this study we investigate two masking communication scheme based on Sprott94 Case A based masking system. We compare the performance of the basic Sprott94 Case A based masking system and modified Sprott94 Case A based masking system in the noisy channel conditions using Mean Squared Error (MSE) Criterion. In the other word, we use the MSE as a measure for data recovery power comparing. Although, the advantage of modified system is able to work in the higher amplitude and lower frequency, the Results show that the basic design of the system has better performance in AWGN channel.

REFERENCES

[1] M. Eisencraft, R. Attux, R. Suyama, “Chaotic signals in Digital Communications,” *Boca Raton: Taylor & Francis Group*, 2014, pp. 15-64.

[2] IP. Marino, L. Lopez, J. Miguez, MAF. Sanjuan. “A novel channel coding scheme based on continuous-time chaotic dynamics*,” 14th Int.l Conf. on Dig. Sig. Proc*., 2002, pp. 1321-1324.

[3] D. Frey, “Chaotic digital encoding: an approach to secure communication,” *IEEE Trans Circuits Sys. II: Analog Dig. Sig. Proc.*, vol. 40, 1993, pp. 660-666.

[4] W.G. Chambers, D. Frey, “Comments on Chaotic digital encoding: an approach to secure communication and reply,” *IEEE Trans Circuits Systems II: Analog Digital Signal Proc*., vol. 46, 1999, pp. 1445–1448.

[5] H. Dedieu, M.P. Kennedy, M. Hasler, “Chaos shift keying: modulation and demodulation of a chaotic carrier using self-synchronizing Chua’s circuits,” *IEEE Trans Circuits Systems II: Analog Digital Signal Proc.*, Vol. 40, 1993, pp. 634-642.

[6] H. Yang, G.P. Jiang, “High-efficiency differential-chaos-shift keying scheme for chaos-based non-coherent communication,” *IEEE Trans. Circuits and Sys. II: Express Briefs*, Vol. 59, no. 5, 2012, pp. 312-316.

[7] V. Mahalinga, K.N. Mandi, H. Bhat, et al. “Performance Evaluation of DS-CDMA Systems Using Chaotic Binary Sequences,” Comp. App.: Int. Jour. (CAIJ), Vol. 2, no.1, , 2015, pp. 37-52.

[8] S.M Berber, “Probability of Error Derivatives for Binary and Chaos-Based CDMA Systems in Wide-Band Channels” IEEE Trans. on Wire. Comm., 2014. pp. 5596-5606.

[9] L. Xuanchao, et al., “Weak Signal Detection Study Based on Duffing Chaos Circuit Used for Downhole Communication,” *2nd Int. Symp. (IEEC)*, Ternopil, July 2004.

[10] N. Jiteurtragool, et al., “Low-Power Discrete-Time CMOS Chaotic Oscillator Based on Approximated Non-linear Characteristic,” *IEEE Region10. Conf.*, Bangkok, October 2014, pp. 1-4

[11] L.M. Pecora, T.L. Carroll, ”Synchronization in Chaotic Systems,” *Physics Review Letters*, vol. 64,1990, pp. 821–824.

[12] K. M. Cuomo, A.V. Oppenheim S. H. Strogatz,”Synchronization of Lorenz-based chaotic circuits with application to communications. *IEEE Trans. on Circuits and Systems II*, vol. 40,1993, pp. 626-633.

[13] JC. Sprott, “Some simple chaotic flows,” *Physics Review E*, vol. 50, no. 2, 1994, p. 647-50.

[14] J.M.H. Elmirghani, et al., “Communication using chaotic masking”. *IEEE Colloquium on Exploiting Chaos in Signal Processing*, 1994.

[15] K. Murali, H. Leung , Yu, H., “Design of non-coherent receiver for analog spread-spectrum communication based on chaotic masking,” *IEEE Trans. on Circuits and Systems I: Fund*. *Theory and App.*, Vol. 50, no. 3, 2003, pp. 432-441.

[16] K. M. Cuomo, A.V. Oppenheim, “Circuit implementation of synchronized chaos with applications to communications,” *Physics Review. Letters*, Vol. 71, 1993, pp. 65-68.

[17] A.N. Miliou, I.P. Antoniades, S.G. Stavrinides, et al.,”Secure communication by chaotic synchronization: Robustness under noisy conditions,” *Nonlin. Analys.: Real World App*., vol. 8, 2007, pp. 1003-1012.

[18] R.C Bonetti, S.L.T. De Souza, A.M Batista, et al “Super persistent transient in a master – slave configuration with Colpitts oscillators,” *J. Phys. A: Math. Theory*., Vol. 47, no. 40, 2014, pp.40-51.

[19] Y., Uyaroglu, I. Pehlivan, ”Nonlinear Sprott94 Case A chaotic equation: Synchronization and masking communication applications,” *Comp. and Elec. Eng.*, Vol. 36, 2010, pp. 1093-1100.

[20] A. Pandey, S. Dahate, “Secure Communication Using A Modified Chaotic Masking Scheme Employing Sprott94 Case A Chaotic Attractor,” *Emergency Tech. Trends in Elec., Comm. and Net. (ET2ECN) 2nd Int. Conf. on*, surat, 2014, pp. 1-6.