International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 1, November-December 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

New Design Architecture of Chaotic Secure Communication System Combined with Linear Receiver

Yeong-Jeu Sun

Professor, Department of Electrical Engineering, I-Shou University, Kaohsiung, Taiwan

ABSTRACT

In this paper, the exponential synchronization of secure communication system is introduced and a novel secure communication design combined with linear receiver is constructed to ensure the global exponential stability of the resulting error signals. Besides, the guaranteed exponential convergence rate of the proposed secure communication system can be correctly calculated. Finally, some numerical simulations are offered to demonstrate the correctness and feasibility of the obtained results.

KEYWORDS: *Linear receiver, novel secure communication system, exponential synchronization, Zhao's hyperchaotic system*

How to cite this paper: Yeong-Jeu Sun "New Design Architecture of Chaotic Secure Communication System Combined with Linear Receiver" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-1, December 2020, pp.1394-1396, URL: www.ijtsrd.com/papers/ijtsrd38214.pdf

IJTSRD38214

1. INTRODUCTION

Since the chaotic system has high sensitivity to initial conditions and its output behavior is similar to random signals, several kinds of chaotic systems have been widely applied in various applications such as secure communication, system identification, image encryption, biological systems, chemical reactions, ecological systems, and master-slave chaotic systems; see, for example, [1]-[9] and the references therein.

Over the past decade, numerous secure communications have been extensively explored; see, for instance, [8] and the references therein. Generally speaking, a secure communication is composed of transmitter and receiver. In particular, linear receiver has the advantages of low price and easy implementation. Therefore, searching a lower-dimensional linear receiver for the secure chaotic communication system constitutes an important area for practical control design.

In this paper, we will firstly propose new design architecture of secure communication system with linear receiver will be constructed to ensure that the resulting error signals can converge to zero in some exponential convergence rate. In addition, the guaranteed exponential convergence rate of the proposed chaotic secure communication system can be accurately estimated. Finally, some numerical simulations are given to exhibit the capability and correctness of the main results.

This paper is organized as follows. The problem formulation and main results are presented in Section 2. Several numerical simulations are given in Section 3 to illustrate the main result. Finally, conclusions are made in Section 4. Throughout this paper, $\Re^n$ denotes the n-dimensional Euclidean space, $\|x\| := \sqrt{x^T \cdot x}$ denotes the Euclidean norm of the column vector x, and $|a|$ denotes the absolute value of a real number a.

2. PROBLEM FORMULATION AND MAIN RESULTS

In this paper, we constructed a new chaotic secure communication system with a linear receiver and its block diagram shown in Figure 1.

Transmitter:

$$\dot{x}_1(t) = a_1 x_1(t) + a_2 x_2(t), \tag{1a}$$

$$\dot{x}_2(t) = a_3 x_1(t) + a_4 x_2(t) + a_5 x_4(t) + a_6 x_1(t) x_3(t), \tag{1b}$$

$$\dot{x}_3(t) = a_7 x_3(t) + a_8 x_1^2(t), \tag{1c}$$

$$\dot{x}_4(t) = a_9 x_4(t) + a_{10} x_2(t) x_3(t), \tag{1d}$$

$$y(t) = \alpha_1 x_1(t) + \alpha_2 x_2(t), \tag{1e}$$

$$\phi_h(t) = C_T x(t) + h(t), \quad \forall\, t \ge 0. \tag{1f}$$

Receiver:

$$\dot{z}_1(t) = \left(a_1 - \frac{\alpha_1}{\alpha_2} a_2 \right) z_1(t) + \frac{a_2}{\alpha_2} y, \tag{2a}$$

$$z_2(t)=\frac{-\alpha_1}{\alpha_2}z_1(t)+\frac{1}{\alpha_2}y(t), \qquad (2b)$$

$$h_1(t)=\phi_h(t)-C_R z(t), \quad \forall\, t\geq 0, \qquad (2c)$$

where $x(t):=[x_1(t) \quad x_2(t) \quad x_3(t) \quad x_4(t)]^T\in\Re^{4\times 1}$ is the state vector of transmitter, $y(t)\in\Re$ is the output of transmitter, $z(t):=[z_1(t) \quad z_2(t)]^T\in\Re^{2\times 1}$ is the state vector of receiver, $C_T=[\alpha_3 \quad \alpha_4 \quad 0 \quad 0]\in\Re^{1\times 4}$, $C_R=[\alpha_3 \quad \alpha_4]\in\Re^{1\times 2}$, $a_i, i\in\{1,2,\cdots,10\}$ are system's parameters with $a_2\neq 0$, $\alpha_i, i\in\{1,2,3,4\}$ are custom parameters of communication system with $\frac{\alpha_1}{\alpha_2}a_2>a_1$, $h(t)$ is the information vector, and $h_1(t)$ is the signal recovered from $h(t)$. It is worth mentioning that the Zhao's chaotic system is the special case of the system (1) with

$$a_1=-a_2=-20,\ a_3=14,\ a_4=-11.9, \qquad (3a)$$

$$a_5=1,\quad a_6=-1,\ \ a_7=-2.5,\ a_8=1\,. \qquad (3b)$$

$$a_8=1,\ a_9=0.19,\ a_{10}=-0.1\,. \qquad (3b)$$

Besides, it has been verified in [9] that the Lyapunov exponent of Zhao's hyperchaotic system is higher than that of other well-known chaotic systems. Undoubtedly, a good secure communication system means that we can recover the message $h(t)$ in the receiver system; i.e., the error vector $e(t):=h_1(t)-h(t)$ can converge to zero in some sense.

Before presenting the main result, let us introduce a definition which will be used in the main theorem.

Definition 1: The system (1) with (2) is called secure communication system with exponential convergence type if there are positive numbers k and α such that

$$\|e(t)\|:=\|h_1(t)-h(t)\|\leq k\exp(-\alpha t), \quad \forall\, t\geq 0.$$

In this case, the positive number α is called the exponential convergence rate.

Now we present the main results for secure communication system of (1) with (2).

Theorem 1: The system (1) with (2) is a secure communication system with exponential convergence type. Besides, the guaranted exponential convergence rate is given by

$$\alpha=\frac{\alpha_1}{\alpha_2}a_2-a_1\,.$$

Proof. Define

$$\begin{aligned}\psi(t)&=[\psi_1(t) \quad \psi_2(t)]^T\\ &=[x_1(t)-z_1(t) \quad x_2(t)-z_2(t)]^T\in\Re^2.\end{aligned} \qquad (4)$$

Thus, from (1), (2), and (4), one has

$$\dot{\psi}_1=\dot{x}_1-\dot{z}_1=-\left(a_1-\frac{\alpha_1}{\alpha_2}a_2\right)(x_1-z_1)=-\alpha\psi_1$$

and $\psi_2=x_2-z_2=\frac{-\alpha_1}{\alpha_2}(x_1-z_1)=\frac{-\alpha_1}{\alpha_2}\psi_1.$

It yields that

$$\begin{cases}\psi_1(t)=e^{-\alpha t}\psi_1(0),\\ \psi_2(t)=\dfrac{-\alpha_1}{\alpha_2}e^{-\alpha t}\psi_1(0), \quad \forall\, t\geq 0.\end{cases} \qquad (5)$$

It can be readily obtained that

$$\begin{aligned}\|e(t)\|&=\|h_1(t)-h(t)\|\\ &=\|\phi_h(t)-\alpha_3 z_1(t)-\alpha_4 z_2(t)-\phi_h(t)\\ &\quad+\alpha_3 x_1(t)+\alpha_4 x_2(t)\|\\ &=\|\alpha_3\psi_1(t)+\alpha_4\psi_2(t)\|\\ &\leq\|\alpha_3\psi_1(t)\|+\|\alpha_4\psi_2(t)\|\\ &\leq\left(|\alpha_3\psi_1(0)|+\left|\frac{\alpha_1\alpha_4}{\alpha_2}\psi_1(0)\right|\right)e^{-\alpha t}, \forall\, t\geq 0,\end{aligned}$$

in view of (1), (2), and (5). This completes the proof.

Remark 1: It should be pointed out that the proposed receiver of (2) is linear and has dual advantages of low price and easy implementation by electronic circuit.

Remark 2: It has been verified in [9] that the Lyapunov exponent of Zhao's chaotic system is higher than that of other well-known hyperchaotic systems. The higher the Lyapunov exponent, the greater the sensitivity of the trajectory of the time-domain signal to the initial value; in other words, the higher the Lyapunov exponent of a dynamic system, the more difficult it is to predict its trajectory.

3. NUMERICAL SIMULATIONS

Consider the novel secure communication system of (1)-(3) with $\alpha_1=\alpha_2=1, \alpha_3=3, \alpha_4=4$. By Theorem 1, the synchronization of signals $h(t)$ and $h_1(t)$ for the proposed secure communication (1)-(3) can be achieved with guaranteed exponential converence rate $\alpha=40$. The real message $h(t)$, the recoverd message $h_1(t)$, and the error signal are depicted in Figure 2-Figure 4, respectively, which clearly indicateds that the real message $h(t)$ is recoved after 0.5 seconds.

4. CONCLUSION

In this paper, the exponential synchronization of secure communication system has been introduced and a new secure communication design combined with linear receiver has been developed to guarantee the global exponential stability of the resulting error signals. Meanwhile, the guaranteed exponential convergence rate of the proposed secure communication system can be correctly estimated. Finally, some numerical simulations have been proposed to show the effectiveness and feasibility of the obtained results.

ACKNOWLEDGEMENT

The author thanks the Ministry of Science and Technology of Republic of China for supporting this work under grant MOST 109-2221-E-214-014. Besides, the author is grateful to Chair Professor Jer-Guang Hsieh for the useful comments.

REFERENCES

[1] Raymond S. T. Lee, "Chaotic type-2 transient-fuzzy deep neuro-oscillatory network (CT2TFDNN) for worldwide financial prediction," IEEE Transactions on Fuzzy Systems, vol. 28, pp. 731-745, 2020.

[2] W. Luo, H. Jin, H. Li, X. Fang, and R. Zhou, "Optimal performance and application for firework algorithm using a novel chaotic approach," IEEE Access, vol. 8, pp. 120798-120817, 2020.

[3] L. Zhou, F. Tan, and F. Yu, "A robust synchronization-based chaotic secure communication scheme with double-layered and multiple hybrid networks," IEEE Systems Journal, vol. 14, pp. 2508-2519, 2020.

[4] Y. Wang, Z. Li, and J. Sun, "Three-variable chaotic oscillatory system based on DNA strand displacement and its coupling combination synchronization," IEEE Transactions on NanoBioscience, vol. 19, pp. 434-445, 2020.

[5] Z. Hua, Y. Zhang, and Y. Zhou, "Two-dimensional modular chaotification system for improving chaos complexity," IEEE Transactions on Signal Processing, vol. 68, pp. 1937-1949, 2020.

[6] Y. Huang, L. Huang, Y. Wang, Y. Peng, and F. Yu, "Shape synchronization in driver-response of 4-D chaotic system and its application in image encryption," IEEE Access, vol. 8, pp. 135308-135319, 2020.

[7] L. Zhang, Z. Chen, W. Rao, and Z. Wu, "Efficient and secure non-coherent OFDM-based overlapped chaotic chip position shift keying system: design and performance analysis," IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 67, pp. 309-321, 2020.

[8] S. Liu, N. Jiang, A. Zhao, Y. Zhang, and K. Qiu, "Secure optical communication based on cluster chaos synchronization in semiconductor lasers network," IEEE Access, vol. 8, pp. 11872-11879, 2020.

[9] Y. Zhao, C. Gao, J. Liu, and S. Dong, "A self-perturbed pseudo-random sequence generator based on hyperchaos," Chaos, Solitons & Fractals, vol. 4, pp. 1-8, 2019.

[10] Yeong-Jeu Sun, "A Novel Design of Secure Communication System with Linear Receiver," Journal of Multidisciplinary Engineering Science and Technology, vol. 4, pp. 8541-8543, 2017.

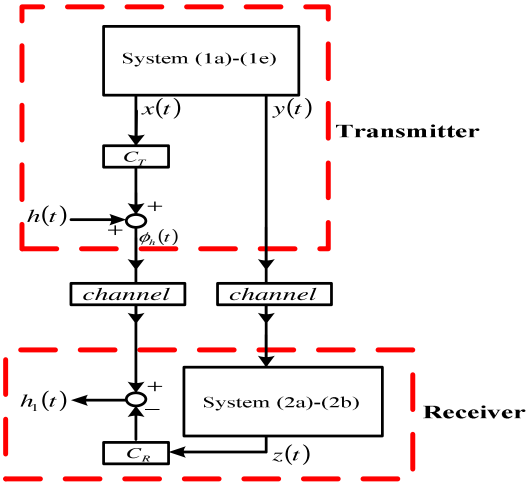

Figure 1: Secure-communication scheme ($h(t)$ is the information vector and $h_1(t)$ is the recovered vector).

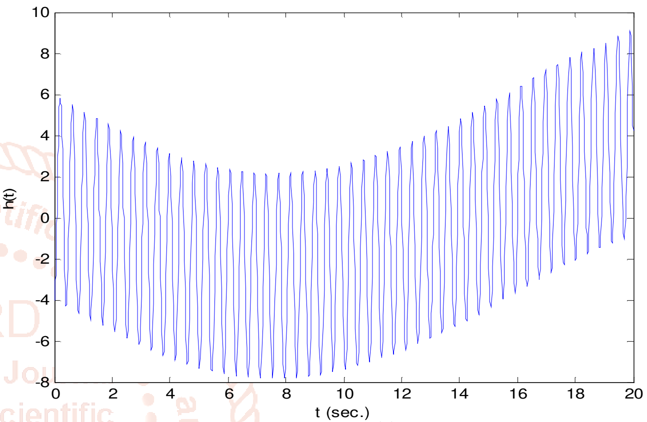

Figure 2: Real message of $h(t)$ described in the transmitter of (1).

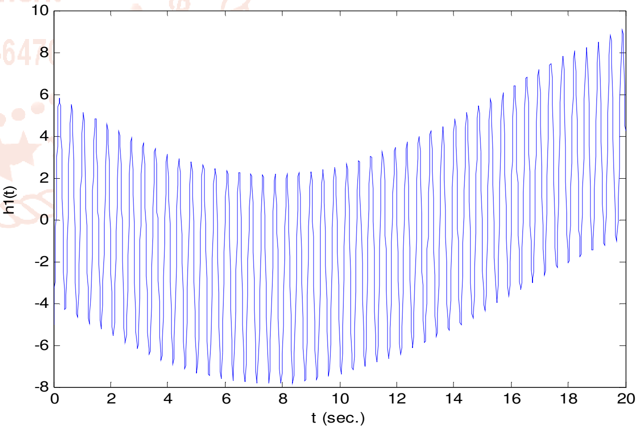

Figure 3: Recoverd message of $h_1(t)$ described in the receiver of (2).

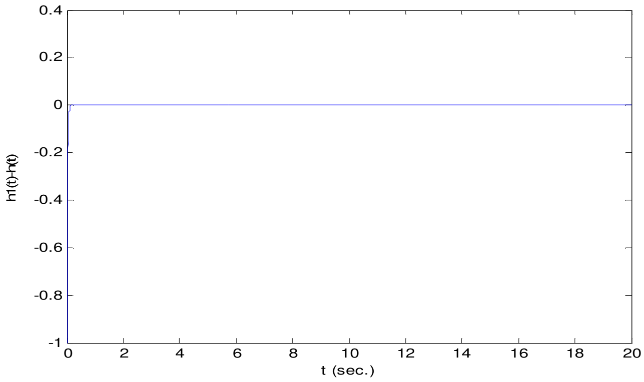

Figure 4: Error signal of $h_1(t)-h(t)$.