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# Asynchronous anti-noise hyper chaotic secure communication system based on dynamic delay and state variables switching

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ABSTRACT

This Letter designs an asynchronous hyper chaotic secure communication system, which possesses high stability against noise, using dynamic delay and state variables switching to ensure the high security. The relationship between the bit error ratio (BER) and the signal-to-noise ratio (SNR) is analyzed by simulation tests, the results show that the BER can be ensured to reach zero by proportionally adjusting the amplitudes of the state variables and the noise figure. The modules of the transmitter and receiver are implemented, and numerical simulations demonstrate the effectiveness of the system.



## 1. Introduction

In recent years, the use of chaotic signals for information transmission attracts great attention of modern scientists, the methods of secure communication such as chaotic masking [1], chaotic modulation [2], chaos shift keying [3] and chaotic digital code-division multiple access (CDMA) [4] have been widely used. Based on these methods, scholars advance a lot of chaos-based secure communication schemes [5,6]. Further researches show that the security of chaotic masking is dissatisfactory [7], which requires the signal energy should be much lower than the chaotic signal energy, so it's weak to resist noise jamming. Compares with the chaotic masking method, the chaos shift keying method performs better over noise jamming and parameter mismatch capacity, but poor in privacy and security [8], so it's easily to be deciphered. Short [7,9] deciphered the chaotic communication systems and pointed out that the security of existing chaotic communication systems is almost as same as that of spread spectrum communication system.

Recently, the scholars proposed many new chaos-based secure communication schemes. Chang designed a secure communication system to modulate each of delivered bit information to be a carrier signal in the continuous form, which is taken as a parameter of the unified chaotic system, and this guarantees the communication security more [10]. Li et al. designed a secure communication scheme based on chaotic maps and strong tracking filter (STF). The message is modulated by chaotic mapping and is output through a nonlinear function, and message is recovered dynamically by the STF with estimation of message. Simulation results demonstrate that STF can effectively recover the codes of the message from the noisy chaotic signals [11]. Wu et al. designed two different hyper chaotic secure communication schemes by using generalized function projective synchronization (GFPS), and the information signal can be recovered accurately by the receiver [12].

Channel noise is ubiquitous in the transmission of the masked signal, many experimental and numerical results show that noises play an important role in chaos synchronization in different ways [13], so the effect of noise should be taken into account when to evaluate the performance of a chaos communication scheme. Minai et al. proposed a method for the secure transmission of encrypted message using chaos and noises [14]. Wang et al. considered the robust demodulation problem when there are disturbances and noises in the channel [15]. Murali numerically investigated the secure communication based on the heterogeneous chaotic systems with channel noises and nonidentity of parameters [16]. Moskalenko et al. reported a secure communication based on the generalized synchronization, they

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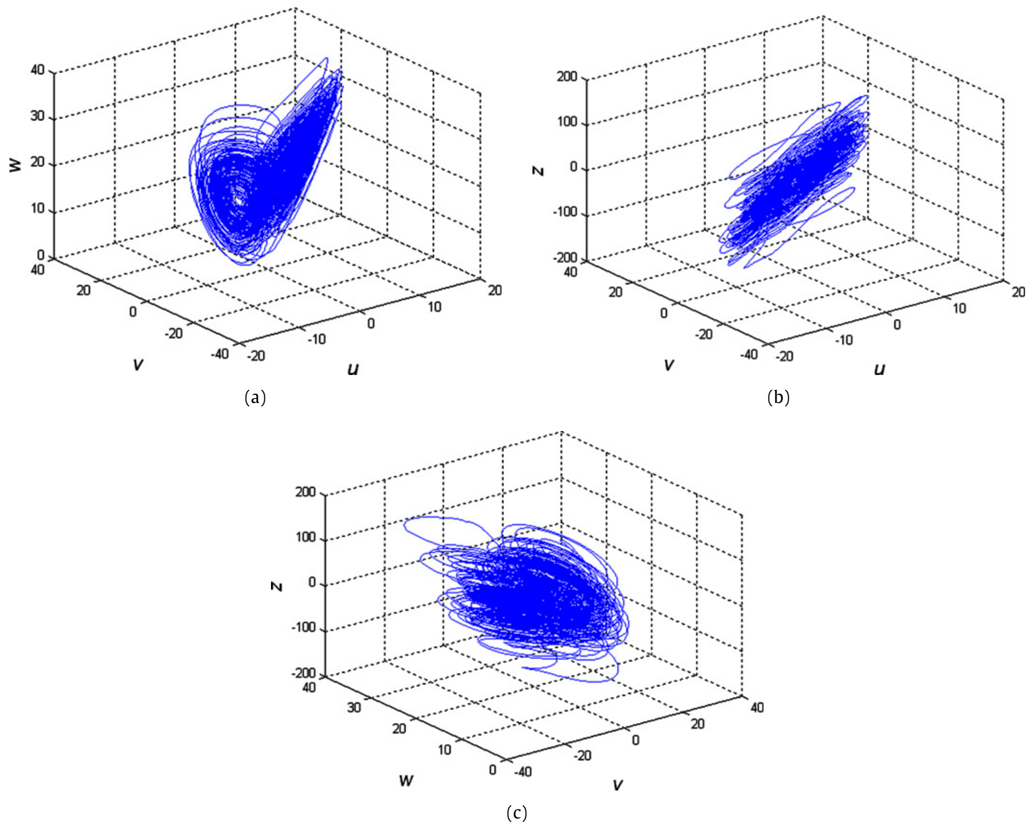


**Fig. 1.** When $r = 0.6$, the projections of attractor of hyper chaotic Chen system.

use the subsidiary source of noise in the proposed scheme to provide the additional masking of the signal, and the results show high stability to noise [17].

For many communication systems based on chaotic maps, the time delay is usually fixed, and once one of the state variables is selected, it remains unchanged throughout the whole communication process [18,19], so it's difficult to guarantee the high security.

Coulon et al. designed multi-user receivers for a multiple-access system based on chaotic sequences on unknown asynchronous frequency-selective channels, they use a Differential Chaos Shift Keying (DCSK) modulation, the transmission channels are frequency-selective, and the channel characteristics (gains and delays) are unknown at the receiver side [20]. Kaddoum et al. proposed two systems for achieving synchronization in asynchronous multi-user chaos-based direct-sequence-CDMA (DS-CDMA), these synchronization processes are evaluated under the assumption of an additive white Gaussian noise channel together with multi-user interferences [21]. Kaddoum et al. further studied the BER performance of chaos-based DS-CDMA system over an m-distributed fading channel, the BER computation approach is generalized for asynchronous multi-user case [22].

Our Letter designs an asynchronous hyper chaotic secure communication system, which can possess high stability against noise, using dynamic delay and state variables switching to ensure the high security. We analyze the relationship between the BER and the SNR by many simulation tests, by proportionally adjusting the amplitudes of the state variables and the noise figure, the results show that the BER can be ensured to reach zero. The modules of the transmitter and receiver are implemented, and numerical simulations demonstrate the effectiveness of the system.

## 2. System description

### 2.1. The hyper chaotic Chen system

The hyper chaotic Chen system can be described as follows [23].

$$\begin{cases} \dot{x}_1 = a(x_2 - x_1) + x_4, \\ \dot{x}_2 = dx_1 - x_1x_3 + cx_2, \\ \dot{x}_3 = x_1x_2 - bx_3, \\ \dot{x}_4 = x_2x_3 + rx_4. \end{cases} \tag{1}$$

Here $\boldsymbol{X} = [x_1 \quad x_2 \quad x_3 \quad x_4]^{\mathrm{T}}$ are state variables, $a, b, c, d$ and $r$ are control parameters. When $a = 35$, $b = 3$, $c = 12$, $d = 7$ and $0.085 < r \leqslant 0.798$, the system evolves into hyper chaotic state [23].

According to the method presented by Ramasubramanian et al. [24], when $r = 0.6$ we obtain the Lyapunov exponents: $\lambda_1 = 0.567$, $\lambda_2 = 0.126$. It is obvious that the system exhibits a hyper chaotic behavior, the projections of the attractor are shown in Fig. 1. The state variables generated by the hyper chaotic Chen system will be used to mask the useful signal.