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DESIGN AND SIMULATIONS OF THE ARNEODO ATTRACTOR'S CHAOTIC OSCILLATOR AND SIGNAL MASKING CIRCUITS

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Abstract

The nonlinear chaotic autonomous Arneodo system is algebraically simple but can generate complex chaotic attractors. In this paper, Arneodo Attractor's chaotic oscillator circuits were designed and simulated. Also Arneodo Attractor is addressed suitable for chaotic masking communication circuits using Matlab-Simulink and PSpice programs. We have demonstrated in simulations that chaos can be synchronized and applied to signal masking communications. We suggest that this phenomenon of chaos synchronism may serve as the basis for little known Arneodo Attractor to achieve signal masking communication applications. Simulation results are used to visualize and illustrate the effectiveness of Arneodo chaotic system in signal masking. All simulations results performed on Arneodo chaotic system are verify the applicable of secure communication.

Key words: *arneodo attractor, arneodo oscillator, chaotic oscillator, chaotic masking, chaotic synchronization, secure communication system*

1. INTRODUCTION

Chaos behavior can occur every where, even in very simple and low-dimensional nonlinear systems. The well known Poincare'-Bendixon theorem [1], requires an autonomous continuous time state space model to be at least three-dimensional in order to have bounded chaotic solutions. On the other hand, for non-autonomous systems, chaos can appear in two-dimensional models. There are many examples, such as Lorenz [2], and Rössler [3, 4] systems that have been widely studied. Electronic circuits that consist of two nonlinear elements can be used to verify theoretical predictions. As an example, nonlinear Duffing forced oscillators have been experimentally studied [5]. Another popular example is the nonlinear chua's circuit, built and experimentally examined [6]. Up to now, various chaotic systems are introduced in [7-9] Chaos and chaotic systems have many fields of applications. One of the popular practical application is secure communication. Synchronization of chaotic systems and chaos based secure communications have become an area of active research in recent years[10-22]. Different approaches are proposed and being pursued.

Chaotic signals depend very sensitively on initial conditions, have unpredictable features and noise like wideband spread spectrum. So, it can be used in various communication applications because of their features of masking and immunizing information against noise. Chaos-based secure communication systems have been alternative of the standard spread-spectrum systems, since they are able to spread the spectrum of the information signals and simultaneously encrypt the information signals with chaotic circuitry which is simple and inexpensive. Many researchers have investigated the implications of chaotic signals in communication systems. For example, Kocarev et. al., and Cuomo et al., [14,15], have used chaotic signals in communication security, and spread spectrum

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communication.

This paper focuses on design of chaotic oscillator and signal masking circuits. The brief is organized as follows. In Section II, Simulink modeling and PSpice circuit design and their simulations of the Arneodo system are obtained. In Section III, chaotic masking communication circuits and their simulations of the Arneodo system are realized also using Simulink and PSpice. Section IV contains conclusions.

2. DESIGN AND SIMULATIONS OF THE ARNEODO ATTRACTOR'S CHAOTIC OSCILLATOR

Following nonlinear autonomous ordinary differential equations are the Arneodo chaotic system.

$$\dot{x} = y \qquad (1.a)$$

$$\dot{y} = z \qquad (1.b)$$

$$\dot{z} = -b_1 \cdot x - b_2 \cdot y - b_3 \cdot z + b_4 \cdot x^3 \qquad (1.c)$$

The Lyapunov exponents of the Arneodo Attractor are 0.232, 0, and -1.232. Namely, only one positive LE is present. The Figure 1 and Figure 2 show the Simulink modeling and the simulation results of the Arneodo Attractor respectively.

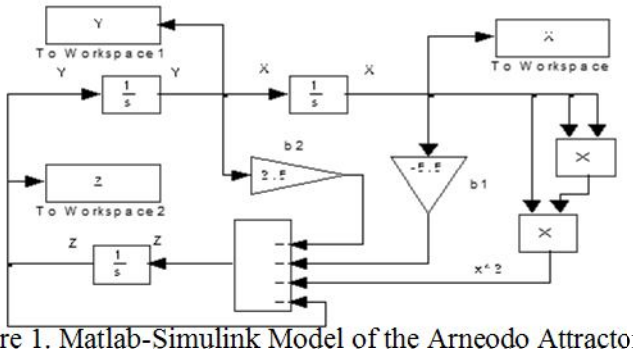
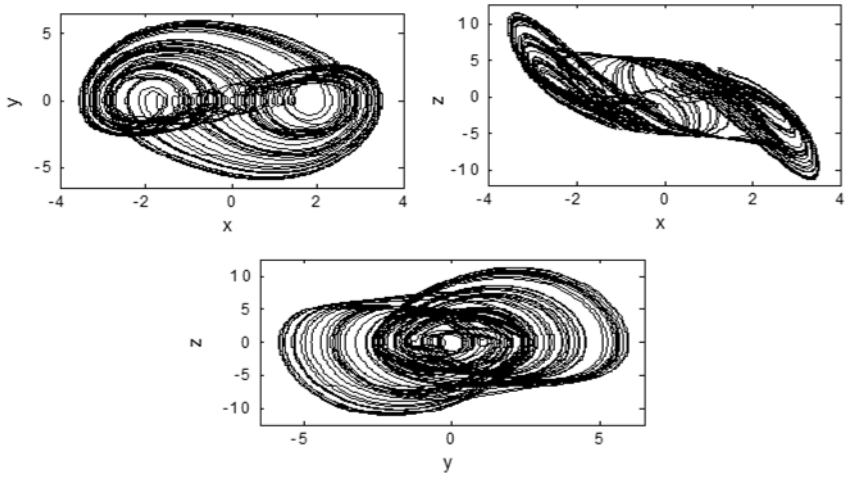


Figure 1. Matlab-Simulink Model of the Arneodo Attractor

(a)



(b)

(c)

Figure 2. Phase portraits ((a) x-y, (b) x-z , (c) y-z) of the Arneodo Attractor when $b_1 = -5.5$, $b_2 = 3.5$, $b_3 = 1$, $b_4 = -1$, and $x_O = 0.5$, $y_O = -1$, $z_O = 0.5$

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Figure 3 shows the circuit schematic for implementing the Arneodo Attractor. We use TL081 opamps, the Analog Devices AD633JN multipliers, appropriate valued resistors and capacitors for PSpice simulations. The circuit is supplied ±15 V power supplies. Acceptable inputs to the AD633 multiplier IC are –10 to +10 V. The resistors R1-R12, are all shown with nominal values in Figure 3. Figure 4 also shows PSpice simulation results of this circuit. Electronic circuit PSpice simulations of this circuit are implemented for $b_1 = -5.5,\ b_2 = 3.5,\ b_3 = 1,\ b_4 = -1$ parameters and initial conditions $x_O = 0.5,\ y_O = -1,\ z_O = 0.5$. Matlab-Simulink and PSpice simulation results of Arneodo Attractor (Fig.1-2) give the same conclusions.

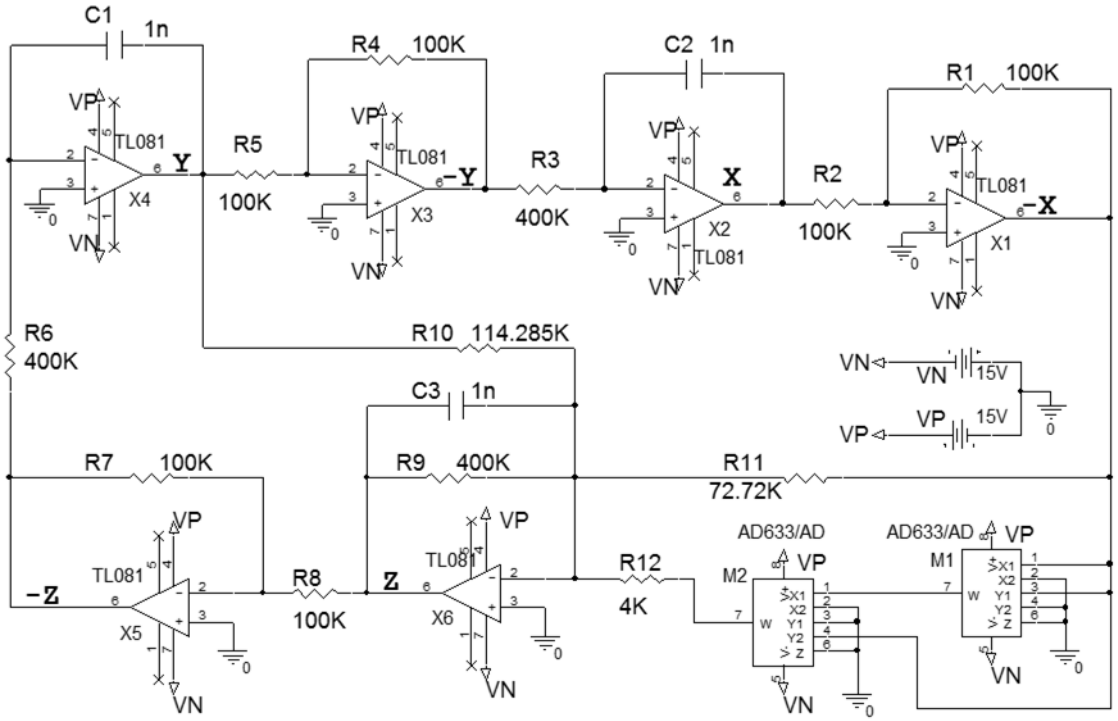


Figure 3. Designed Circuit Schematic of the Arneodo Attractor

(a)

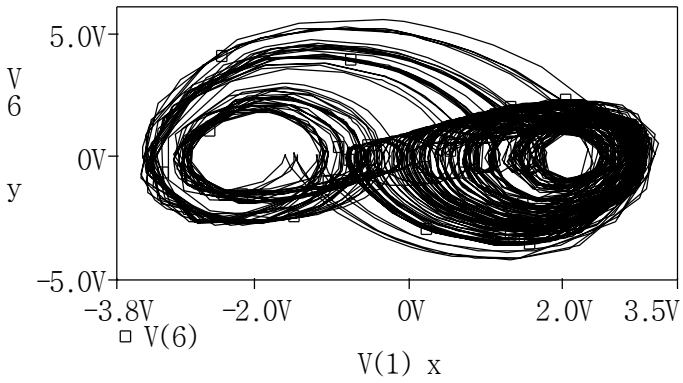
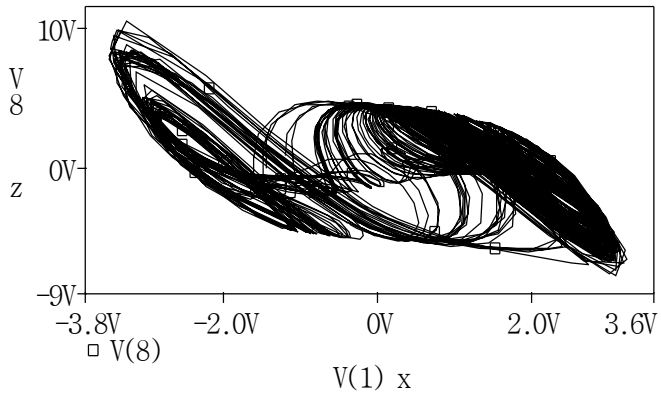


Figure 4. PSpice simulation results of the Arneodo Attractor, (a) x, y phase portrait

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(b)



(c)

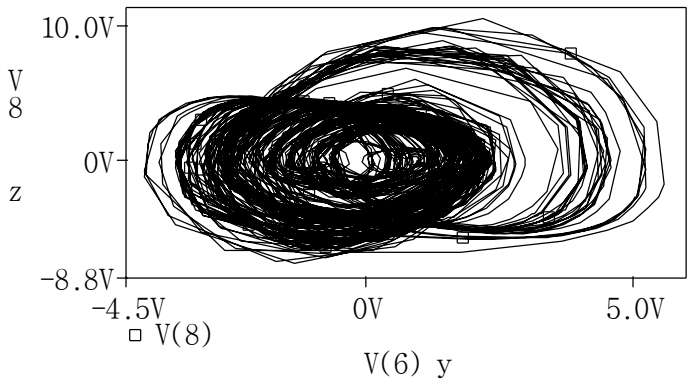


Figure 4. PSpice simulation results of the Arneodo Attractor, (b) x, z, (c) y, z phase portraits

3. CHAOTIC SIGNAL MASKING CIRCUITS OF THE ARNEODO SYSTEM

Due to the fact that output signal can recover input signal, it indicates that it is possible to implement secure communication for a chaotic system. Figure 5 shows the principle scheme of a general secure communication system that employs the masking technique. Figure 6 shows simulink modeling of chaotic masking communication circuit of the Arneodo Attractor.

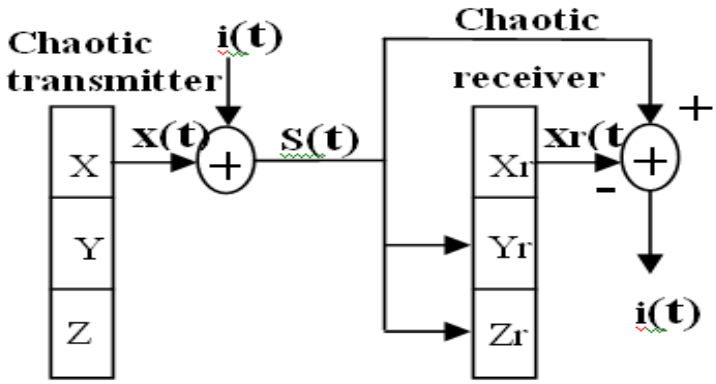


Figure 5. Principle scheme of a general secure communication system with masking technique

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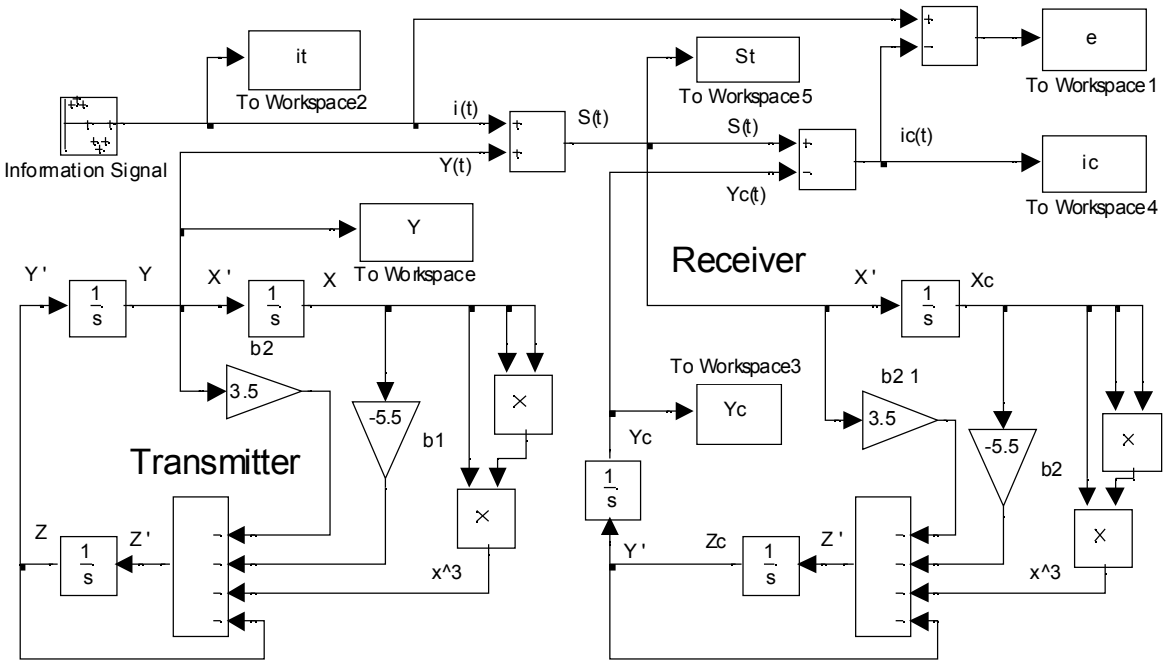
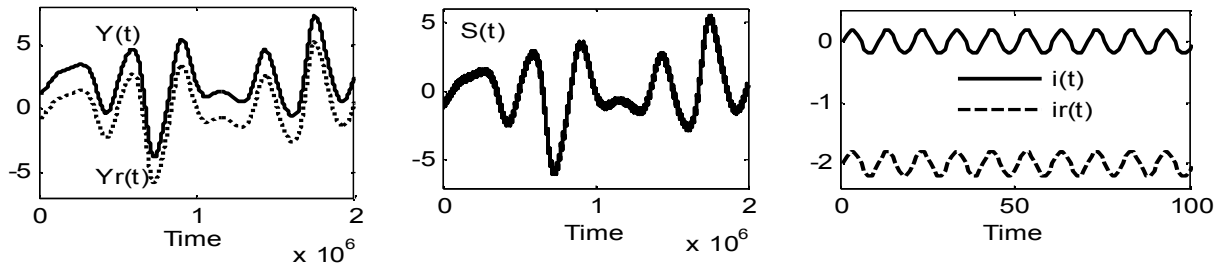


Figure 6. Simulink modeling of chaotic masking communication circuit of the Arneodo Attractor.

The presence of the chaotic signal between the transmitter and receiver has proposed the use of chaos in secure communication systems. The design of these systems depends on the self-synchronization property of the Arneodo Attractor. Transmitter and receiver systems are identical except for their initial values, in which the transmitter system are 0.5, -1, 0.5 and the receiver system are 0.5, 1, and 0.5 as shown in Fig.6. It is necessary to make sure the parameters of transmitter and receiver are identical for implementing the chaotic masking communication. In this masking scheme, a low-level message signal is added to the synchronizing driving chaotic signal in order to regenerate a clean driving signal at the receiver. Thus, the message has been perfectly recovered by using the signal masking approach through cascading synchronization in the Arneodo Attractor. Computer simulation results have shown that the performance of Arneodo Attractor in chaotic masking and message recovery. One disadvantage of using one-way coupling method is that compared to this cascading method, it takes longer to synchronize the coupled systems, especially when the coupling parameter is small. This may cause problems in practical applications such as secure communications since information may be delayed or lost during the first period of matching time. The transmitted signal is a sinus wave of amplitude 0.2 volts and of 10 KHz frequency. The sinus wave signal is added to the generated chaotic x signal, and the S(t)= y + i(t) is feed into the receiver. The chaotic y signal is regenerated allowing a single subtraction to retrieve the transmitted signal, [y+i(t)]-y r = i(t), If y = yr. This is a result of synchronization as in Fig.7.(a). Figure 7 (c) shows the information signal-sinus wave and the retrieved signal output of scope. Figure 8 shows the circuit schematic for implementing the Arneodo Attractor's Chaotic Masking Communication. Figure 9 shows PSpice simulation results of this Chaotic Masking Circuit. The transmitted signal is a sinus wave of amplitude 0.2V and frequency 10 KHz.

Transmitter and receiver circuits are identical except for their initial values, in which the transmitter circuit are 0.5, -1, 0.01 and the receiver circuit are 0.5, 0, 0.5 as shown in Fig. 8. Simulink and PSpice simulations (Fig. 7, 9) of Chaotic Masking circuit give the same conclusions.

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(a) (b) (c)

Figure 7. Simulink outputs of Masking Communication Scheme of Arneodo Attractor
(a) Drive (y) and response (yr) system chaotic signals vs. time (b) Transmitted signal S(t) = y(t) + i(t)
(c) Information i(t) and retrieved ir(t) signals (sinus signal) has 0.2V amplitude and frequency 10 KHz,

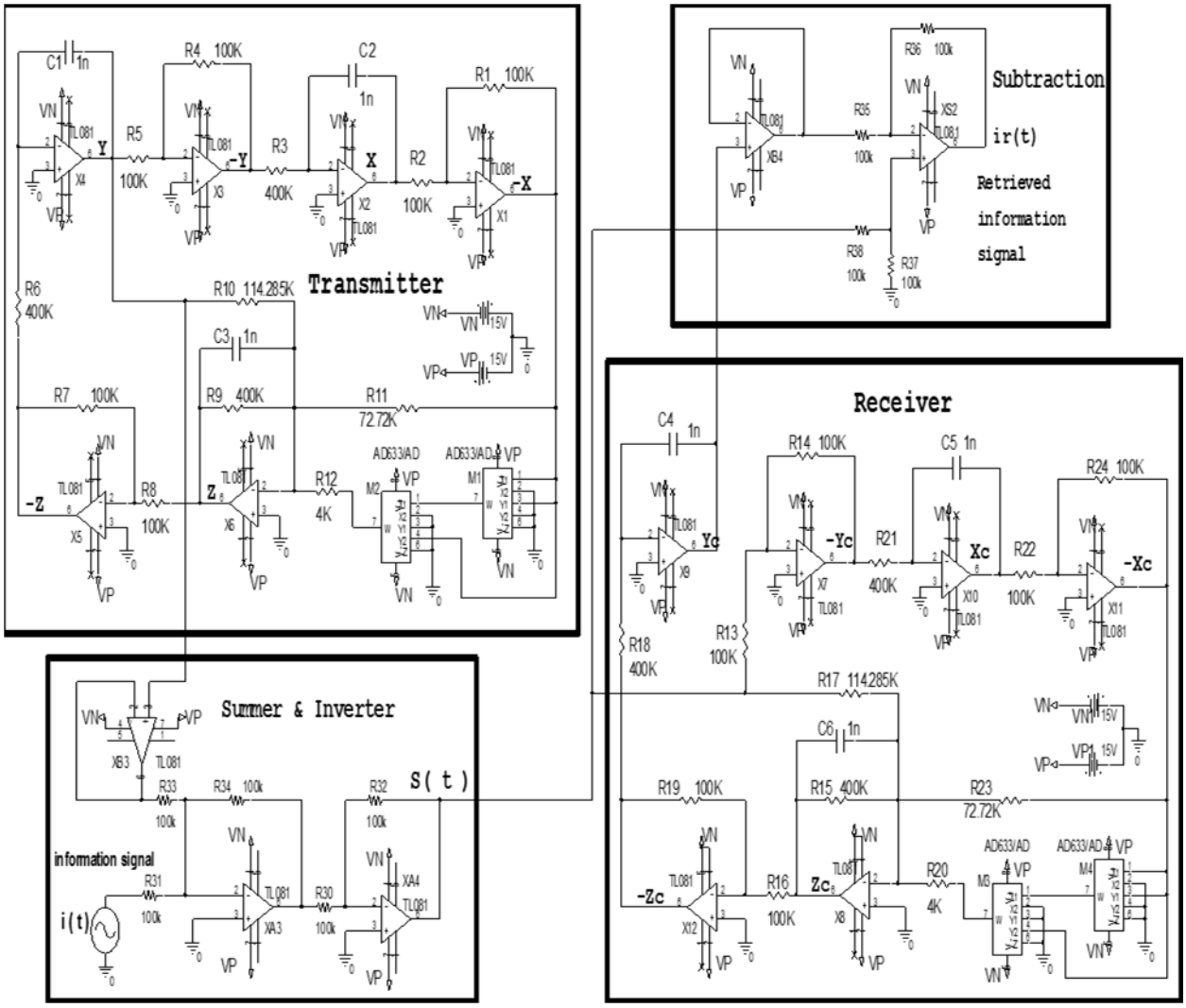


Figure 8. Arneodo Attractor Chaotic Masking Communication Circuit

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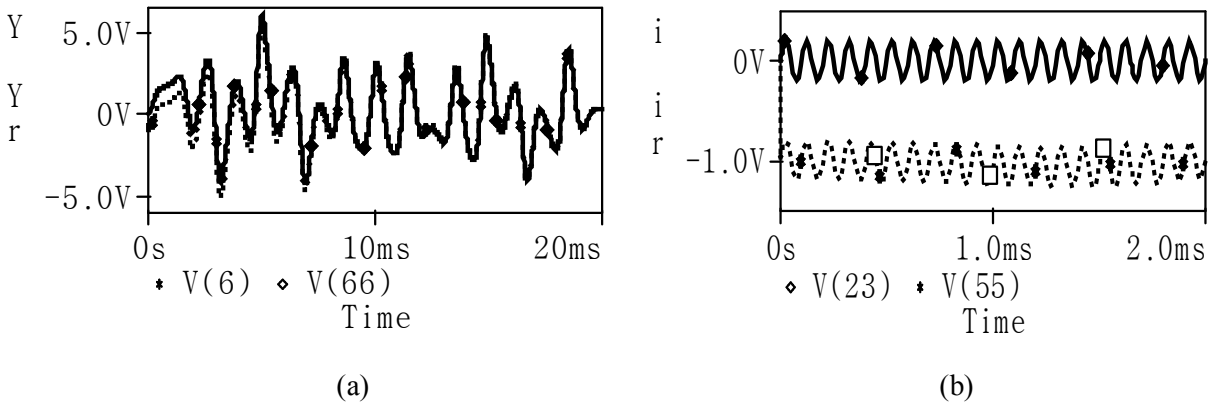


Figure 9. PSpice outputs of Arneodo Attractor Masking Communication Circuit (a) Drive system y signal and response system yr signal vs. time (b) Information and retrieved signal (0.2 V, 10 KHz)

4. CONCLUSIONS

This paper focuses on the Arneodo Attractor's chaotic oscillator circuits and their applications in signal masking communications. Arneodo Attractor's chaotic oscillator circuits were designed and simulated. Chaotic signal masking circuits were realized using Matlab-Simulink and PSpice programmes. Related figures in Fig.(7, 9) point out that Matlab-Simulink and PSpice outputs prove the same conclusions. We have demonstrated in simulations that chaos can be synchronized and applied to secure communications. We suggest that this phenomenon of chaos synchronism may serve as the basis for little known Arneodo Attractor to achieve secure communication. Simulation results are used to visualize and illustrate the effectiveness of Arneodo chaotic system in signal masking. All simulations results performed on Arneodo chaotic system are verify the applicable of secure communication.

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