Signal Masking Applications Using Chaotic Circuits

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Abstract—In this paper, different signal masking applications were introduced. Firstly, chaotic oscillator circuit of the P chaotic system were designed and realized. Then chaotic signal masking circuits of the P system were designed and simulated using PSpice program. Lastly experimental chaotic signal masking circuits of the P system were realized. We have demonstrated in simulations and real electronic applications that the P chaotic system can be synchronized and applied to signal masking communications.

Keywords—Chaotic system, P system, chaotic circuit, chaotic oscillator, chaotic synchronization, chaotic masking

I. INTRODUCTION

The Lorenz system displays very complex dynamical behaviors, especially the well-known two scroll butterfly chaotic attractor[1]. Chen constructed another chaotic system², which nevertheless is not topologically equivalent to the Lorenz's[2,3]. This system is the dual to the Lorenz system and similarly has a simple structure[3]. Li and Chen found the critical new chaotic system[4] which represents the transition between the Lorenz and Chen attractors.

For the investigation on generic 3D smooth quadratic autonomous systems, Sprott[5,7] found by exhaustive computer searching about 19 simple chaotic systems with no more than three equilibria. It is very important to note that some 3D autonomous chaotic systems have three particular fixed points: one saddle and two unstable saddle-foci (for example, Lorenz system[1], Chen system[2], Lu system[4]). The other 3D chaotic systems, such as the original Rossler system[8], DLS[9] and Burke-Shaw system[10], have two unstable saddle-foci. Yang and Chen found another 3D chaotic system with three fixed points: one saddle and two stable fixed points[11].

Recently, Yang et al.[12] and Pehlivan et al. [13] introduced and analyzed the new 3D chaotic systems with six terms including only two quadratic terms in a form very similar to the Lorenz, Chen, Lu and Yang–Chen systems, but they have two very different fixed points: two stable node-foci. There has been increasing interest in exploiting chaotic dynamics in engineering applications, where some attention

has been focused on effectively creating chaos via simple physical systems, such as electronic circuits[14-19]. Lately, the pursuit of designing circuits to produce chaotic attractors has become a focal point for electronics engineers, not only because of their the theoretical interest, but also due to their potential real world applications in various chaos-based technologies and information systems[20-27].

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.

II. THE CHAOTIC CIRCUIT DESIGN AND REALIZATION

Following new chaotic system¹³ was used for realizing the chaotic circuit. We will call it as P chaotic system.

\[ \dot{x} = y \cdot x \]
\[ \dot{y} = a \cdot y - x \cdot z \]
\[ \dot{z} = x \cdot y - b \] (1)

Typical parameters of the system are a=0.5 and b=0.5. Experimental electronic circuit of the P chaotic system is implemented for parameter a=0.5, b=0.5, and initial conditions \( \dot{x}_0=0, \dot{y}_0=0, \dot{z}_0=0 \). Chaotic differential equations (2) of the P chaotic circuit are given below.

\[ \dot{x} = \frac{1}{R_1 C_1} \cdot y - \frac{1}{R_2 C_1} \cdot x \]
\[ \dot{y} = \frac{1}{R_4 C_2} \cdot y - \frac{1}{R_3 C_2} \cdot x \cdot z \] (2)
\[ \dot{z} = \frac{1}{R_5 C_3} \cdot x \cdot y - \frac{V_p}{R_6 C_3} \]
III. SIGNAL MASKING APPLICATIONS OF THE P CHAOTIC SYSTEM

That an output signal can recover an input signal indicates that it is possible to create secure communication for a chaotic system. Fig. 3 shows the chaotic masking communication circuits of the P system. The presence of the chaotic signal between the transmitter and receiver led to the use of chaos in secure communication systems. The design of these systems depend on the self-synchronization property of the P system. Transmitter and receiver systems are identical as shown in Fig. 3. It is necessary to make sure that transmitter and receiver parameters are identical in order to implement chaotic masking communication. In this masking scheme, a low-level message signal is added to the synchronization driving chaotic signal in order to regenerate a clean driving signal at the receiver. Thus, the message has been perfectly recovered using the signal masking approach by identical synchronization in the P system. Computer simulation results have shown the performance of P system in chaotic masking and message recovery is strong. Two different signal masking applications were designed and realized. The first transmitted signal is sine wave of amplitude 0.5 V and frequency 1 kHz. The second transmitted signal is square wave of amplitude 0.5 V and frequency 1 kHz.

The sinus and square wave signals are added to the generated chaotic X signal. The chaotic x signal is regenerated allowing a single subtraction to retrieve the transmitted signal.

\[ X+i(t) - X2 = i(t), \text{ If } X = X2. \]

Figure 3 shows the circuit schematic for implementing the chaotic masking communication of the P system. Figure 4 shows PSpice simulation results of this chaotic masking circuit. The transmitted signal are sinus wave of amplitude 0.5V and frequency 1KHz and sinus wave of amplitude 0.5V and frequency 1KHz. Transmitter and receiver circuits are identical except for their initial values, in which the transmitter circuit are 0, 0, 0 and the receiver circuit are 1, 0, 0. Figure 4 (c) shows the information signal-sinus wave and the retrieved signal output of PSpice. Figure 4 (d) shows the information signal-square wave and the retrieved signal output of PSpice.

Figure 5 shows the real oscilloscope outputs of the P chaotic system masking communication circuit. Figure 5(c) shows the information signal-sinus wave and the retrieved signal output. Figure 5(d) shows the information signal-square wave and the retrieved signal output.
Figure 3: Chaotic masking communication circuits of the P system, a) Transmitter circuit, b) Receiver circuit, c) Adder & Inverter, d) Subtractor
Figure 4: ORCAD-PSpice simulation outputs of the P chaotic system masking communication circuit,
a) Chaotic X and X2 signals of Transmitter and Receiver circuits respectively, b) Synchronization between X and X2,
c) Information signal and Retrieved signal as sinus wave forms, d) Information signal and Retrieved signal as square wave forms

Figure 5: Real oscilloscope outputs of the P chaotic system masking communication circuit,
a) Chaotic X and X2 signals of Transmitter and Receiver circuits respectively, b) Synchronization between X and X2,
c) Information signal and Retrieved signal as sinus wave forms, d) Information signal and Retrieved signal as square wave forms
IV. CONCLUSION

This paper focuses on the P chaotic oscillator circuit and its applications in signal masking communications. Chaotic oscillator circuit and chaotic signal masking circuits of the P system were designed and simulated using PSpice program. Electronical experimental chaotic signal masking circuits of the P system were also realized. Related figures in Fig.(4,5) point out that PSpice simulation results and real oscilloscope outputs prove the same conclusions. The all results are used to visualize and illustrate the effectiveness and the applicability of the P system in signal masking communication.

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