Secure communication with Chaos

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Abstract- One of the most exciting recent developments in nonlinear dynamics is the realization that chaos can be useful. One application involves “secure Communication”. The phenomena of chaos synchronization and secure communication have been investigated both numerically and experimentally. A piecewise linear system with switching nonlinearity has been taken as chaos generator.

Keywords- Chaos, Communication, Buck converter.

I. INTRODUCTION

CHAOS is aperiodic long-term behavior in a deterministic system. It exhibits a sensitive dependence of a system’s dynamical variable on the initial conditions meaning that no two chaotic systems will evolve in the same way. Trajectories of two perfectly identical chaotic systems starting with nearby initial conditions diverge from each other exponentially. Synchronization means that the trajectories of two chaotic systems be locked to each other. Hence synchronization seems unlikely for two chaotic systems if trajectories start from initial conditions that differ slightly. Moreover, in practical applications the existence of noise (both internal and external) and system imperfect identification makes the hope of synchronizing two chaotic systems even more remote. Nonetheless, it has been established that [1,2,3] synchronization of chaotic dynamical systems is not only possible but it is believed to have potential applications in communication. The strategy is that when we transmit the message to a friend, we mask it with louder chaos. An outside listener only hears the chaos, which sounds like meaningless noise. But if the friend has a magic receiver that perfectly reproduces the chaos, then he can subtract off the chaotic mask and listen to the message. This synchronization is possible only when a similar chaotic circuit as that of sending end is fabricated. If the configuration of chaotic circuit is secret, it is impossible to extract information from the transmitted message.

Hence there has been growing interest in the possibility of synchronizing chaotic signals. This idea has been tested theoretically as well as experimentally in a variety of linear dynamical systems, including Chua’s circuit and Driven Chua circuit [4]. Ying Chang Lai etal [5] demonstrated that applying small temporal parameter perturbation to one of them could synchronize two identical chaotic systems. But in all those methods, synchronization is possible without any message signal. K. Murali and M. Lakshmanan [6] investigated the method of transmitting signal using chaos synchronization in Vander Pol-Duffing oscillator. But they transmitted very weak signal with chaotic masking. The synchronization failed with high strength of message signal. Moreover the system is to be broken into a number of subsystems. These shortcomings have been eliminated in the present work. The synchronization and faithful recovery of message at the receiving end is independent of message signal strength. The system needs not to be broken into subsystems. Here we have chosen power electronic converter called buck converter [7] as chaos generator. They are piecewise linear system with switching nonlinearity.

II. THE BUCK CONVERTER CIRCUIT

The Buck converter [7], well known in power electronic, is a circuit used to convert a dc voltage to a lower dc voltage. Here we consider the current controlled buck converter, whose circuit is shown in figure 1. The input voltage is connected in series with an inductor and the load resistance. There are two switches- S is a controlled switch (realized by a transistor) and D is uncontrolled (realized by a diode). The controlled switch is in series with the input voltage and the uncontrolled switch is in parallel with the combination of inductor and load resistor. Sometimes a capacitor is connected (shown by a dashed line) to smoothen the load voltage waveform. This is optional, and is not considered in the following analysis for the sake of simplicity.

When S is in the “on” state, the diode is off, and the current builds up through the inductor and the load. When the transistor is off, the current freewheels through the diode and decays. By properly choosing the switching frequency and inductor value, one achieves continuous current operation and the average output voltage is then given by

\[ V_{out} = V_{in} \frac{T_{on}}{T_{on} + T_{off}} \]

Where \( V_{in} \) = input voltage, \( V_{out} \) = output voltage, \( T_{on} \) & \( T_{off} \) = on and off times of the controlled switch.

To control the switching through current feedback, the load current is sensed as the voltage across 1-ohm resistor.
connected in series with the load. The signal is integrated by passing it through a low pass filter. The output of the integrator is compared with a triangular wave voltage. The output of the comparator that compares the triangular wave and error integrator voltage is used to control the on and off periods of the switch. When error integrator voltage is less than triangular wave voltage, the controlled switch is turned on, and current flows through the inductor and the load. The controlled switch is turned off when error integrator voltage is greater than triangular wave voltage. At this instant, the voltage across the inductor reverses its polarity, and the current path completes through the diode and the load. Consequently the stored energy in the inductor decreases and the output voltage falls. When the integrator output voltage drops below the triangular wave voltage, the switch is turned on and the process continues. The choke is designed for linear inductance and diode with negligible storage is employed.

The system is governed by two sets of linear differential equations pertaining to the on and off states of the controlled switch. The error integrator voltage and load current are taken as state variables.

During the on period, the equations are:

\[
\frac{di}{dt} = \frac{V_{in}}{L} - \frac{R_i i}{L} \\
\frac{dv_{io}}{dt} = \left( R_i + R_2 \right) - \frac{R_i}{R_i C} v_{io} + \frac{V_{in}}{L}
\]

And the state equations during off period are:

\[
\frac{di}{dt} = -\frac{R_i i}{L} \\
\frac{dv_{io}}{dt} = \left( \frac{R_i + R_2}{R_i C} \right) - \frac{R_i}{R_i C} v_{io}
\]

Though the equations are linear, bifurcation and chaos appears in this circuit because of the switching nonlinearity.

III. SECURE COMMUNICATION

The scheme is shown in figure 1. The signal s(t) to be transmitted is added with error integrator voltage. The resulting signal x(2) + s(t) is used to compare with triangular wave at the transmitter end. The same signal is transmitted through the communication channel.

Fig. 1 Scheme for secure communication

At the receiving end the transmitted signal x(2) + s(t) is fed to the inverting input of the comparator of the buck converter. The circuit parameters and configuration of the receiver buck converter circuit are same as that of the transmitter. Due to synchronization, the receiver buck converter also generates the same x(2) as that of transmitter. We can extract the message transmitted by subtracting the x(2) from the transmitted signal.

IV. RESULT

The proposed scheme is verified experimentally. The results are the photograph of the screen of the oscilloscope.

Fig. 2(a) shows the masked sinusoidal signal in channel
V. CONCLUSION

A new scheme of synchronization and secure communication has been investigated experimentally. This method of synchronization uses same signal $x(t) + s(t)$ to be compared with triangular wave and switching in the chaos generators in the receiving and sending end take place at the same instant of the triangular wave. As the switching in the chaos generators takes place at the same instant, chaotic trajectories of all the generators will be the same. As a result of this, synchronization of chaos can be achieved very easily independent of the strength of the message signal. As the chaos generator is a piecewise linear system with switching nonlinearity, chaotic trajectory of many of such chaos generators may be combined to make a complex chaotic trajectory to achieve higher degree of security. Work in this direction is in progress.

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REFERENCES
