Chapter 8
Chaos Synchronization

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ABSTRACT

Chaos synchronization is the central core of various message encryption methods which are developed based on the properties of chaotic systems. This chapter introduces the concept of chaos synchronization and its application in secure communication. Some standard approaches such as complete, lag, phase and generalized synchronization are defined first. Then application of control theory for synchronization of different chaotic systems is discussed. Some synchronization algorithms based on different control techniques are presented. It is shown that how the controlling methods can be modified in a synchronization framework to cope with parameter uncertainties and measurement noise. Several chaotic systems are simulated and synchronized to show the performance of the reported methods.

INTRODUCTION

Chaotic signals produced by nonlinear systems can be used for encrypting the transmitting messages in secure communications. Synchronization of chaotic systems has an important role in this field of science. Figure 1 shows how chaotic signals and chaos synchronization are utilized for secure communication. The message is a signal that should be transferred in a secure encrypted form. Using two chaotic systems, one in the transmitter side and the other in the receiver side, one can produce a secure link for communication. Indeed the system in the receiver side is synchronized to the one in the transmitter side for signal transmission. The message signal is usually modulated by a high amplitude chaotic signal to provide an encrypted signal for transmission. In the receiver side the other chaotic system which is called response or slave system is synchronized to the chaotic system of transmitter side which is usu-

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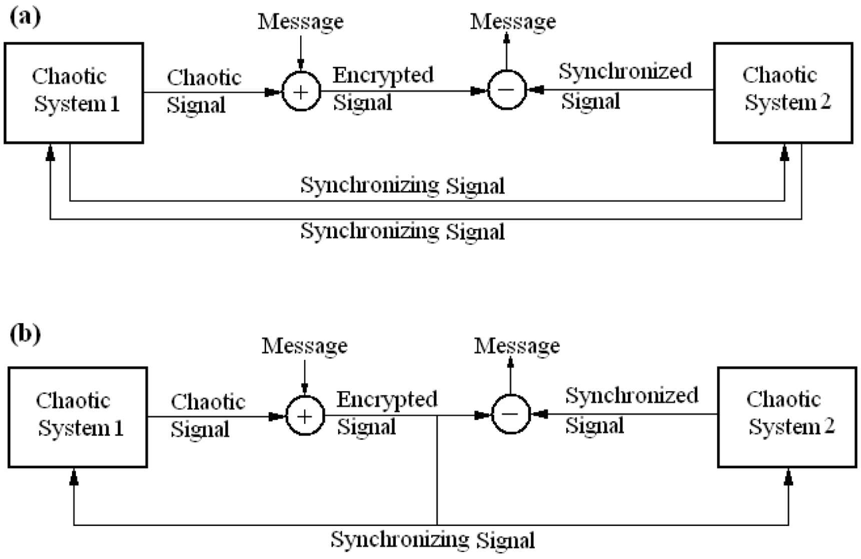
ally called drive or master system. Synchronization goal is achieved by coupling two chaotic systems through synchronizing signals which are transferred between two systems. The synchronized chaotic signal is subtracted from modulated signal (demodulation) to extract the message.

There are many techniques for chaotic modulation and synchronization. Synchronization generally occurs when the error between the states or phases of two dynamical systems becomes zero as time approaches to infinity. Synchronization may be achieved normally when a coupling is taken place between two systems. The coupling may be set naturally or intentionally by an error feedback from the modulating system to the demodulating system and vice-versa.

There are two ways for encoding and decoding a data signal, i.e. message, using chaotic systems. The first approach is called *chaos masking* in which the message signal is directly modulated by a chaotic signal (Scholl, and Schuster, 2008). Figure 1a shows a chaos masking scheme. The second approach is to modulate the chaotic system in transmitter side by the message signal and then transmitting the encrypted signal to the receiver. The encrypted signal is used for coupling two chaotic systems and synchronizing them. This method is called the *chaos modulation* or *chaos shift keying* (Scholl, and Schuster, 2008).

Many scientists and engineers have studied the conditions that result in synchronization. Winful and Rahamn (1990) showed that in an array of coupled lasers, identical chaotic signals are produced, and beyond a critical coupling strength, synchronization is substituted by spatiotemporal chaos. Pecora and Carroll (1990) described the conditions necessary for synchronizing a subsystem of a chaotic system with another chaotic system by sending a signal from the chaotic system to the subsystem. Carroll and Pecora (1991) built a simple circuit based on chaotic circuits described by Newcomb et al. (1983, 1986) and showed that a system, consisting of two Lorenz oscillators exhibiting chaos, could achieve synchronization if a portion of the second oscillator is driven by the first one. He and Vaidya (1992) introduced the necessary and sufficient condition for synchronization. Based on obtained results, they designed a high-dimensional chaotic system with nonlinear synchronized subsystems. The possibility of

Figure 1. Schematic diagram of secure data transfer using chaotic systems, (a) chaos masking technique, (b) chaos modulation technique


(a)
Message
Message
Chaotic System 1
Chaotic Signal
+
Encrypted Signal
−
Synchronized Signal
Chaotic System 2
Synchronizing Signal
Synchronizing Signal
(b)
Message
Message
Chaotic System 1
Chaotic Signal
+
Encrypted Signal
−
Synchronized Signal
Chaotic System 2
Synchronizing Signal