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Secure communication via parameter modulation in a class of chaotic systems

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Abstract

The problem of secure communication via parameter modulation in a class of chaotic systems is studied. Information signal is used to modulate one parameter of a chaotic system. The resulting chaotic signal is later demodulated and the information signal is recovered using an adaptive demodulator. The convergence of the demodulator is established. We show that the proposed scheme is robust with respect to noise and parameter mismatch. Computer simulation on the Chua circuit is given to validate the theoretical prediction.

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Keywords: Chaotic systems; Observer; Adaptive synchronization; Secure communication

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1. Introduction

After the seminal works of Pecora and Carroll [1,2], the idea of synchronization and control chaotic systems has received a great deal of interest among researchers from various fields. Along this line of research, it should be noted that an even broader problem of synchronization of non-linear oscillations has already had a long history with a great variety of applications. For more information on this subject and for more references, see [3,4]. Most of the synchronization schemes consist of two parts: a generator of chaotic signals, which is called the drive system, and a receiver, which is also called a response system. A signal generated by the drive system may be used as an input to the receiver to achieve synchronization. While the synchronization of two chaotic systems is an interesting subject on its own, an important aspect of chaos synchronization is the possibility of using chaotic signals for secure communication [5–9]. Use of chaos may also increase the performance of communication systems [9]. An extensive list of references for various aspects of chaotic systems may be found in [3].

Chaotic systems may be used in message transmission in various ways, see e.g., [7–13]. Actually, three main message encoding schemes were developed: chaotic masking [5,8], chaotic shift keying [9] and chaos modulation [5,8,11–13]. In chaotic masking, the message to be transmitted is added to a much stronger chaotic signal in order to hide the information, the overall signal is then transmitted to the receiver. Under certain conditions the message may be recovered at the receiver, see [5–14]. In chaos shift keying, the transmitted signal is obtained by switching between N chaotic generators according to the information level of an N-ary message (usually binary messages are used with two chaotic generators). In chaotic modulation, the message modifies the states or the parameters of the chaotic generator through an invertible procedure, thus the generated chaotic signal inherently contains the information of the transmitted message. As in chaotic masking scheme, the message may be recovered in the receiver under certain conditions [10–13]. Even though these approaches have been successful demonstrated in simulations, theoretically, performance of the communication schemes were usually quantified by assuming an identical chaos synchronization. This may impose some limitations to the applicability of these techniques. Of particular interest is the problem of synchronizing two or more systems when the designer of the receiver does not know not only the initial states but also some or all parameters. This is a more complicated problem referred to as adaptive synchronization [10–16]. Its solution is important in communications when the parameter modulation is used for message transmission (see, e.g., [10,11] and references therein), where a solution based on adaptive observers in an idealized setting with neglected noise and parameter mismatch was proposed. This effect should be taken into account when we want to evaluate the performance of a practical chaos communication scheme. As a consequence, secure communication via parameter modulation in chaotic systems in the presence of unknown parameters is an important issue.

In this paper, we consider continuous-time chaotic systems. For the synchronization of such systems various methods are available, and we choose the method based on adaptive observers [17–19]. For the message transmission, we propose one scheme based on chaotic modulation. We show that it is possible to design a secure communication system using adaptive synchronization techniques of two uncertain chaotic systems based on modern non-linear control theory. We take an information signal and use it to modulate one parameter of a chaotic system. The resulting transmitted signal consists of the information hidden in the signal from the chaotic system.