Chapter 15

Secure Transmission of Analog Information Using Chaos

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ABSTRACT

In this work the authors present a thorough experimental study of a practical realization of a complex analog signal transmission system using dynamic chaos. It is demonstrated that the chaotic synchronous response could be used as a basis for the design of secure communication channels. The results presented in this work confirm the possibility of secure wireless communications in RF band, while they allow the authors to analyze in detail the restrictions and problems connected with the quality of synchronization of the transmitter and the receiver of the wireless communication systems. The effect of the perturbing factors on the transmission quality is investigated theoretically. It is shown that the main reason of the transmission's quality degradation is the chaotic response desynchronization associated with the phenomenon of “on-off” intermittency. It is found that under the effect of the perturbing factors, the level of information signal fed to the transmitter must be increased in order to obtain qualitative information transmission. However, in order to provide secure communication, one must decrease the information signal level. A compromise on these contradictory requirements provides an improvement of the quality of the synchronous chaotic response in the receiver.

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1. INTRODUCTION

A number of approaches to the design of communication systems with chaos was proposed at the beginning of 1990s (Kocarev et al., 1992; Belsky & Dmitriev, 1993; Cuomo et al., 1993; Dedieu et al., 1993; Halle et al., 1993; Volkovskii & Rul’kov, 1993, Bohme et al., 1994). Some of them were designed for transmission of analog signals. There was also experimental data that dealt mainly with transmission of simple analog signals, such as sinusoidal signals (Kocarev et al., 1992, Halle et al., 1993, Volkovskii & Rul’kov, 1993).

The main element of the above reported systems is a chaotic module devoted to generate chaotic signal and to introduce information into the transmitting signal, and at the same time, to retrieve the information in the receiver. One of the most important operation requirements to the majority of the known systems is the identity of the chaotic module parameters in the transmitter and receiver (Belsky & Dmitriev, 1995). This is associated with the necessity to obtain in the receiver an exact copy of the signal formed in the transmitter (synchronous response) (Pecora & Carroll, 1990). A question arises then: can the synchronous response, hence, information retrieval, be achieved in real conditions, i.e., using chaotic modules in RF communication systems? The problem is that in such systems the signal undergoes a number of additional manipulations (modulation, frequency conversion, detection, amplification, etc.) which can lead to distortions, regarding the complex structure of the formed signal and essentially to nonlinear characteristics of the system’s functional elements.

This chapter describes an experimental study of a practical realization of a complex analog signal transmission system using dynamic chaos (Dmitriev et al., 1997, 2000).

The structure of the chapter is as follows; First, the system and its operating principles are described, then the fundamental information on the system’s hardware implementation is provided, a summary of experimental results on transmission of music and speech signals in low frequency range is presented. Thereafter, the structure of a communication system in RF band employing dynamic chaos is described. The mathematical model of the communications system is presented in the next section and computer modeling results are analyzed. The last section is devoted to experiments on communications in RF band.

2. BASE BAND EXPERIMENTS ON SPEECH AND MUSIC SIGNAL TRANSMISSION USING CHAOS

The block diagram of the communication system is shown in Figure 1a. It includes a transmitter, a receiver and a communication channel. This system is based on the idea of nonlinear signal mixing and subsequent restoration of the synchronous chaotic response as suggested in (Volkovskii & Rul’kov, 1993).

Both the transmitter and the receiver are based on the decomposition of Chua’s circuit (Madan, 1993) into two subsystems (RLC and RCNR) (Figures 1b and 1c) which are connected in a closed loop (Figure 1d). Subsystem RLC is a band pass filter and subsystem RCNR is a low-frequency first-order filter loaded at a nonlinear resistance NR with three-segment of piecewise-linear voltage-current characteristics (Madan, 1993):

\[ I_N(V_{C1}) = G_b V_{C1} + 1/2(G_b - G_a)[|V_{C1} + E| - |V_{C1} - E|], \]  

(1)