

## Optical communication using chaos based signal transmission scheme

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Optical communication system using a chaos based signal transmission scheme has been proposed to transmit digital information signal by using the conventional synchronization of chaos and digital transmission approaches. In this scheme either a chaotic or hyper chaotic system is used to generate a chaotic signal. This signal along with the information digital signal is used to generate the transmitted signal. The transmitted signal is then masked by one of the chaotic signal of the transmitter and is transmitted through the channel to the receiver as well as used to drive the transmitter chaotic system using the concept of self-modulation. At the receiver end, suitable subtractor circuit is constructed for unmasking and the reception rule is used to recover the information signal. The effect of typical perturbing factors like channel noise and parameter mismatch are also included and their corresponding performance analysis has been done. By considering appropriate circuit configuration, the results of experiment are also presented.

**Keywords:** Optical communication, Chaotic modulation, Signal transmission, Performance analysis

### 1 Introduction

The proliferation of modern communication products<sup>1</sup> in the home and office environments over the past few years has increased the need for privacy and security in optical communication<sup>2</sup>. This has led to the need for developing cheap and effective transmission schemes that are not only flexible to be used in various media applications but are also robust from a security standpoint. Transmission schemes designed for use in consumer electronics need to be implemented using simple analog circuits and at the same time maintaining the flexibility to accommodate more features. Recently the possibility of synchronizing chaotic systems and its potential usefulness in secure optical communication has attracted considerable interest<sup>3</sup>. Increasing efforts have been made to use chaotic systems for enhancing certain features of optical communication and transmission systems. However, the idea of using chaos for data and signal transmission is certainly not new and the highly unpredictable and random-look nature of chaotic signal is the most attractive feature of deterministic chaotic system that may be useful for novel engineering applications.

Based on the available chaos synchronization schemes in typical optical communication systems the information to be transmitted is carried from the transmitter to the receiver by a chaotic signal through

an analog channel. The reception of the information signal in the receiver can be carried out by means of either synchronization or without synchronization reception schemes<sup>4-10</sup>. Following these approaches, different methods have been developed in order to mask the contents of a message using chaotic signal<sup>6-13</sup>. However, it has been shown that most of these methods are not secure or have low level of security because one can extract the transmit message signal from transmitted chaotic signal by using different unmasking techniques<sup>11</sup>. So to overcome the problem of unmasking the information message from the chaotic carrier, different approaches for designing optical systems based on chaos have been recently introduced<sup>8</sup>. In these schemes both conventional optical method and synchronization of chaotic system are combined so that the level of security of the transmitted chaotic signal is enhanced. Achieving secure transmitting of the digital information signal by considering the fact of masking the chaotic transmitting signal is as important as masking the information signal.

In this paper, the modulo-two addition (op-amp arithmetic operation) is performed between the digital information signal and the threshold chaotic digital transmitted signal. A small amplitude version of the transmitted signal is further masked by one of the chaotic signal of the transmitter and is transmitted

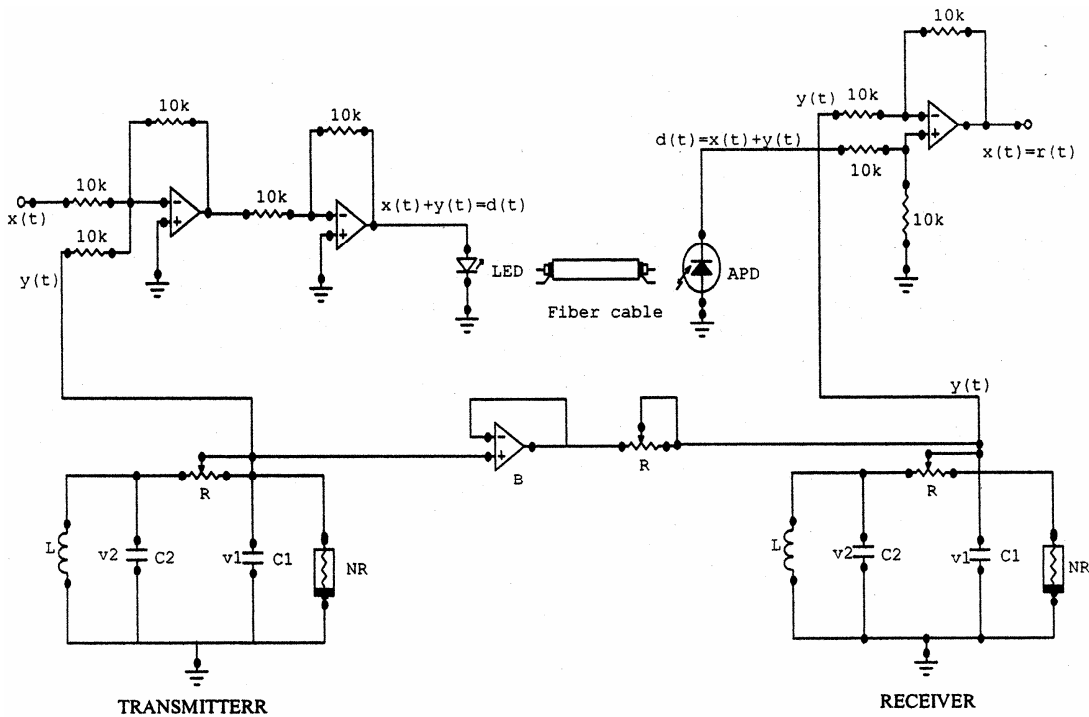


Fig. 1 — Circuit realization of the chaos based digital signal transmission scheme; NR denotes a cubic non-linear resistor described by  $f(v_1) = av_1 + bv_1^3$  ( $a < 0, b > 0$ )

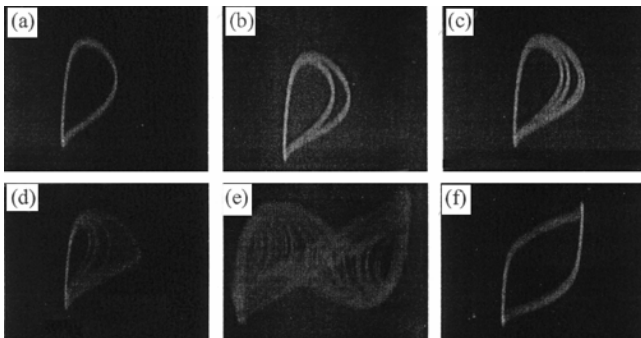


Fig. 2 — Phase-portraits of (a) Period-T limit cycle, (b) Period-2T limit cycle, (c) Period-4T limit cycle, (d) One-band chaos, (e) Double-band chaos and (f) Boundary

through the channel to the receiver as well as used to drive the transmitter chaotic system using the concept of self-modulation<sup>14</sup>. For reception, at the receiver module upon synchronization, the same op-amp subtraction operation is performed with the regenerated chaotic transmitting digital signal. The performance analysis of circuit results of the present optical transmission scheme with autonomous van der Pol-Duffing oscillator circuit system is discussed.

**2 Experimental Set-up and Results**

The actual circuit realization of the chaos based signal transmission scheme for the case of autonomous van der Pol-Duffing oscillator circuit is shown in

Fig. 1. In the circuit, B corresponds to buffer. The Module-2 operation is realized experimentally with the operational amplifier circuit (adder and subtractor circuit) for both the transmitter and receiver. The control parameter  $p$  is realized with the potential divider R. By fixing the circuit parameters at  $C_1 = 10nF$ ,  $C_2 = 100nF$  and  $L = 47mH$  and by reducing variable resistor ( $R$ ) from  $5000\Omega$  towards zero, autonomous van der Pol-Duffing oscillator circuit is readily seen to exhibit a sequence of bifurcations, (which is called an  $R$  sequence) from DC equilibrium through a *Hopf* bifurcation and period doubling sequence to a spiral-chaotic and a double-scroll chaotic attractor, as shown in Fig. 2. A two-dimensional projection of the attractor is obtained by connecting  $v_1$  and  $v_2$  to the X and Y channels, respectively, of an X-Y Oscilloscope. The ring structure configuration of autonomous van der Pol-Duffing oscillator circuit<sup>6</sup> is adapted for the present study to implement the self-modulation of the information signal into the chaotic circuit to minimize the signal recovery error. Upon synchronization and after the reception rule, the information signal  $r(t)$  is recovered, as shown in Fig. 3. In this figure,  $x(t)$   $y(t)$  [ $x(t) + y(t) = d(t)$ ] and [ $(x(t) + y(t)) - y(t) = x(t) = r(t)$ ] correspond to the digital information signal, output digital transmission from the op-amp adder

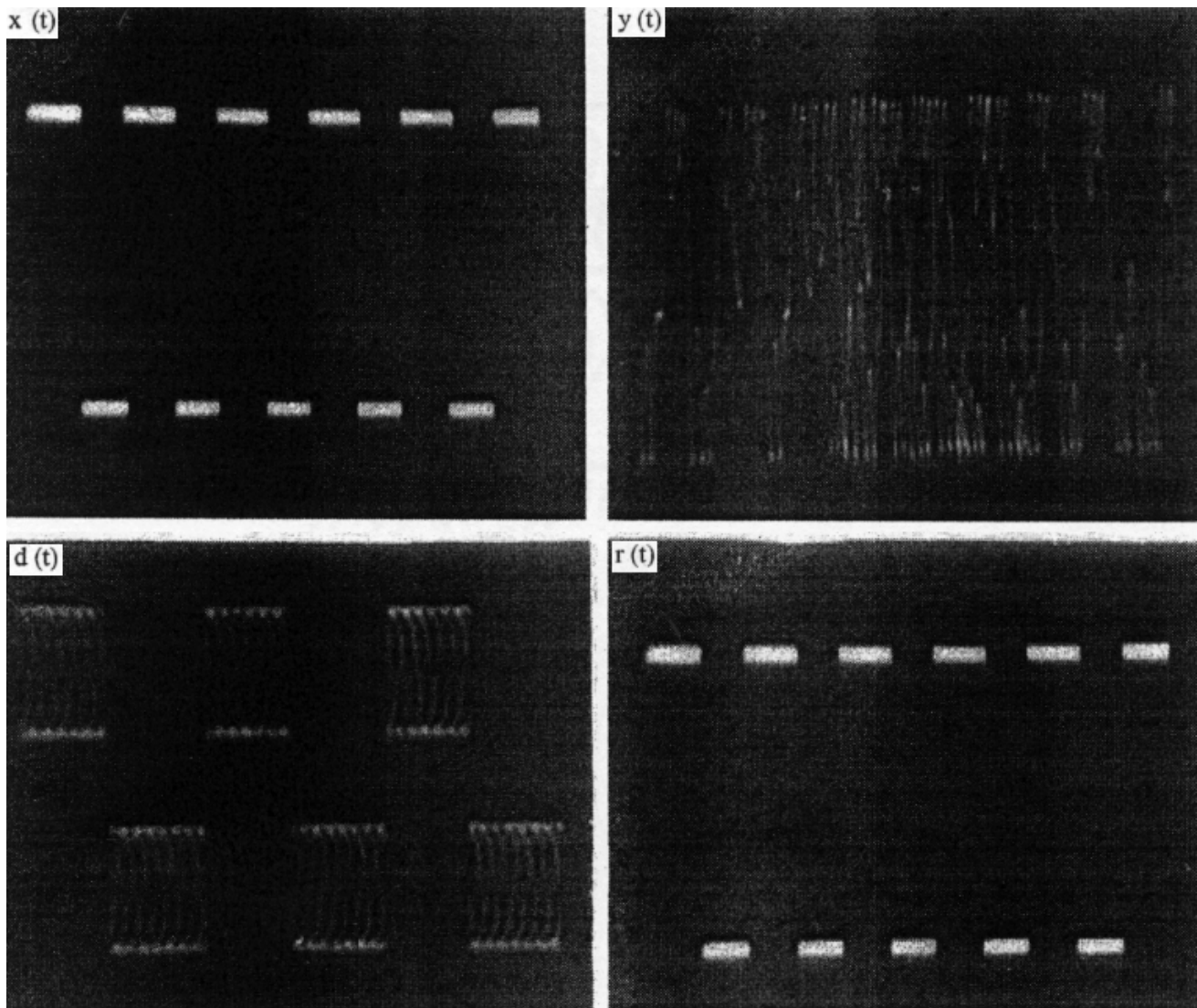


Fig. 3 — Signal transmission and recovery with autonomous van der Pol-Duffing oscillator circuit system. Here  $x(t)$  = information signal,  $y(t)$  = chaotic signal  $d(t)$  = modulated signal and  $r(t)$  = recovered information signal

circuit, actual transmitted chaotic signal to the receiver, recovered digital transmission signal from the op-amp subtractor circuit at the receiver and the recovered information signal<sup>14</sup>. Thus the above optical communication scheme using chaos based signal transmission can be experimentally achieved with minimal circuit configurations.

### 3 Conclusions

A new chaos based optical communication scheme by combining the strengths of conventional transmission methods and chaos based communication methods is presented. The communication of information across an Additive White Gaussian Noise (AWGN) channel has been carried out

by using a pair of synchronized chaotic circuits. The chaotic signals from the same transmitter and receiver pair have been utilized to transmission and reception of the information signal, respectively. The security of the system is potentially increased due to the op-amp addition operation between the digital information signal and the chaotic digital transmission signal as op-amp addition operation masks the information of both the chaotic transmission and the message signal efficiently. Also due to the flexibility of using different linear or non-linear signals for generating chaotic transmitting signal, potentially further enhanced the security of information signal transmission. The effect of perturbing factors like channel noise and parameter mismatch is studied and their corresponding

performance analysis is discussed. This signal transmission scheme leads itself to very cheap implementation and can therefore be used effectively for ensuring security and privacy in commercial consumer electronic product. It has been shown that up to a certain level of noise intensity and parameter mismatch, signal recovery is possible by using op-amp subtraction operation.

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