International Journal of Engineering Technology, Management and Applied Sciences

IJETMAS

www.ijetmas.com June 2017, Volume 5, Issue 6, ISSN 2349-4476

Implementation of Chaos Masking Communication Scheme using Chaotic Electro Optic Modulator, Realized with the Help of OPAMP based Electronic Circuit.

Aditi Datta
Tripura University,Suryamaninagar, India
Anjan.K.Ghosh, Anjan Mukherjee.
Tripura University, Suryamaninagar,India.
Richa Debnath, Rakesh Dey, Somudeep Bhattacharya, Sayan Paul, Ujjayanta Dey.
TIT, Narsingarh, Tripura.

ABSTRACT

Chaotic systems provide a rich mechanism for signal design and generation, with potential applications to communications. Because chaotic signals are difficult to predict, they can be used in various contexts for masking information bearing waveforms. This paper describes communication with chaos. An information bearing signal is masked within the chaotic oscillations and recovered via chaos synchronization in a chaotic receiver. Two analog circuits, transmitter and receiver, simulate the system. The chaotic series obtained from the first circuit was modulated and transmitted to the second one which behaved like a receptor, demodulating the chaotic signal through synchronism. The goal of this experiment was to design a simple chaotic masking circuit using Electronic simulator for Electro Optic modulator, first in simulation using MULTISIM and subsequently realizing the whole setup physically with OpAmp based Electronic circuits.

Keywords

chaos; Electronic simulator for Electro Optic modulator; chaotic communication.

I.INTRODUCTION

A secure communication system as it is generally called, transforms the information signal in such a way that only an authorized receiver who has a prior knowledge of the transformation parameters can receive the information. In chaotic masking, two identical chaotic circuits are used: one at the transmitter end and the other at the receiver. As shown in Fig. 1, the message signal *m(t)* is added to the chaotic mask signal *c(t)* giving the transmitted signal *s(t)*. The chaotic system at the receiver end produces another copy of the chaotic mask signal $\hat{c}(t)$, which is subtracted from the transmitted signal *r(t)* to obtain the recovered message signal. Assuming a noise free channel and perfect synchronization between the two chaotic systems, $s(t)=r(t)$, $c(t)=\hat{c}(t)$ and $m(t)=\hat{m}(t)$. For higher security of the message signal, the message signal is typically made about 20dB to 30dB weaker than the chaotic signal[1,2,3]. In this report the masking scheme is implemented with the help of Electronic Simulator for Electro Optic (EO) modulator both as transmitter and receiver circuit. Simulators are OpAmp based electronic circuit having $\cos^2$ type of nonlinearity as those of EO modulators. The whole scheme is described in the following block diagram.

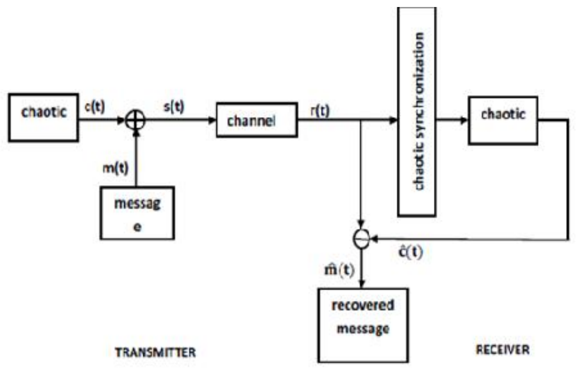


Figure 1 Chaotic communication scheme based on chaos synchronization and additive mixing of a message with a chaotic component.

Chaos communications is an application of chaos theory which is aimed to provide security in the transmission of information. By secure communications, one has to understand that the contents of the message transmitted are inaccessible to possible eavesdroppers. High sensitivity to initial condition makes chaotic signal unpredictable as time elapses. It makes chaos a good choice in communication world. Nonlinear optical devices with electronic feedback are used to produce chaos and so produced chaos is preferred in communication for their THz bandwidth. As the nonlinear optical devices are costly, here in this paper we have setup an chaotic optical communication link using simple electronic circuit, simulating the effect of nonlinear EO system.

II. DESIGN OF TRANSMITTER AND RECEIVER CIRCUIT

Nonlinear optical systems with an electronic or optical feedback can produce chaotic response. So produced optical signals can be utilized in secure encryption in optical communication systems. A large no of nonlinear optical systems have been explored to produce chaotic optical signals. These include (a) lasers with external feedback, (b) nonlinear optical loop mirrors using Er-doped fiber amplifiers or semiconductor optical ampliers, (c) EO modulators with feedback, (d) Acousto-optical (AO) modulators with feedback, and many others. Among them EO modulator based systems have nonlinearity with sinusoidal characteristics. In such system the transfer characteristics of the optical device is of the form $\cos^2$[4,5,6]. However nonlinear optical devices are expensive and optical components are not readily available in our laboratory in remote part of India, so one option is to switchover to simple electronics circuit with same type of nonlinearity as those of the optical chaotic systems, Hence to perform experiments on chaotic optical communication system, we have taken the help of nonlinear electronic analog computing system capable of producing chaotic signals similar to those produced by a nonlinear EO or AO system.

Oscillators having such type of nonlinearity have been employed as transmitter and receiver circuit in the chaos masking communication scheme. Circuits for transmitter and receiver have been developed based on the block diagram as shown in the figure-2. The idea is based on the Taylor series expansion of $\cos^2 X$ term.

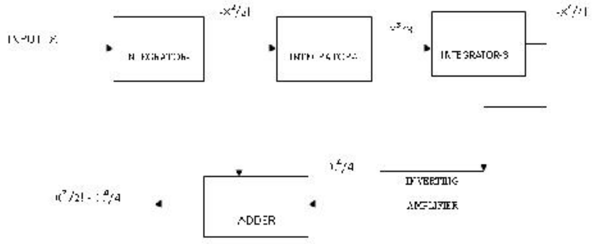


Figure-2 Block diagram of the transmitter/ receiver circuit with $\cos^2$ type of nonlinearity.

Three integrators have been placed in cascade to realize the terms X^2, X^3, X^4 from input X. At the output terminal of the adder we obtain an output of nature $(\frac{x^2}{2!}-\frac{x^4}{4!})$. Rearranging the terms at the adder terminal we realize

$$1-(1-\frac{X^2}{2!}+\frac{X^4}{4!}) \approx 1-\cos X \approx 2\sin^2\frac{X}{2}$$

Thus the circuit produces an output of nature $\sin^2 X$ for an input X. Similarly we can obtain $\cos^2 X$ type of nonlinearity if we pass the signal through a subtractor as explained below.

$$2(1-\sin^2\frac{X}{2}) = 2\cos^2\frac{X}{2}$$

The gain of the system can be adjusted with the help of an amplifiers.

In our laboratory we have fabricated an analog computing system, mentioned above, in bread-board using Op Amp based integrators, adders, subtractors and amplifiers.

If we consider the input resistance and the feedback path capacitor C of an Op Amp integrator are R and C respectively, then the outputs from 1st, 2nd and 3rd integrator are given by $-\frac{x^2}{(RC)2!}$, $\frac{x^3}{(RC)^2 3!}$ and $-\frac{x^4}{(RC)^3 4!}$ respectively. Expression of the output at the subtractor terminal then is $2(RC)\cos^2\frac{X}{2(RC)}$. This output is passed through an amplifier having gain A. Hence our final output is $2A(RC)\cos^2\frac{X}{2(RC)}$. Thus we produce a signal similar to that of EO modulator. It is clear from the above expression that by varying R and C we can alter the system dynamics.

Aditi Datta, Anjan.K.Ghosh, Anjan Mukherjee, Richa Debnath, Rakesh Dey, Somudeep Bhattacharya, Sayan Paul, Ujjayanta Dey

We can also think of a $\sin^2 X$ type of nonlinear transmitter and receiver. As the expression of entropy called Lyapunov Exponent(LE) remains same both for $\sin^2$ or $\cos^2$ type of nonlinear circuit, nature of the output from the both circuit will remain same for same set of system parameter. As an example we can cite the case of EO optic and AO optic modulator. Both of the modulator exhibits same system dynamics for same set of system parameter as the expressions for LE for both of the modulator are same.

III.SIMULATION OF CHAOS MASKING COMMUNICATION SCHEME USING MULTISIM

Before establishing the experimental set-up using hardware circuitry we have simulated the whole set-up in MULTISIM platform. The transmitter circuit is simulated with R=100ohm and C=100uF. The input signal applied is peak to peak 8 V with frequency 3kHZ as given in figure-3. The output from the transmitter is enclosed in figure-4.

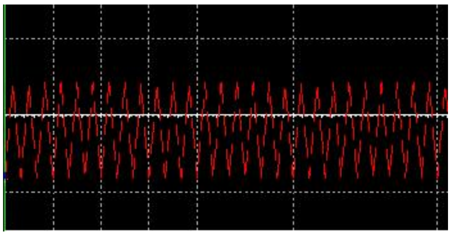


Figure-3 Input signal to the transmitter.

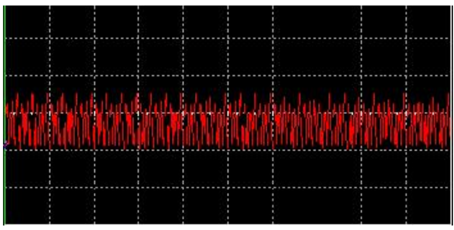


Figure-4 Chaotic output from the transmitter(LE=0.2997)

As we know LE provides a direct measure of sensitivity to initial conditions by quantifying the exponential rate at which two nearby trajectories converge or diverge as the system evolves in time. When the attractor is chaotic, the trajectories diverge, LE becomes positive. Similarly LE becomes negative for converging trajectories. Analytically we can calculate LE of an EO system from its equation, but when the equations describing the dynamical system are not available, one can calculate LE from time series obtained at the output of the system using the Rosenstein algorithm[7,8,9].

Using Rosenstein algorithm we have calculated the LE of the signal of figure-4 produced by the analog computer circuit and it was found to be 0.2997.

A message signal as shown in figure-5 is added with the chaos, generated from the transmitter. The carrier signal makes the message unrecognizable. The mixture of message and chaos generated from the transmitter drives the receiver circuit as described in figure-1. The chaotic system at the receiver end produces another copy of the transmitter side chaos which is subtracted from the transmitted signal (mixture of chaos and message) to recover the message signal[4]. The schematic diagram of the communication scheme is described below. The schematic diagram is developed based on figure-1.

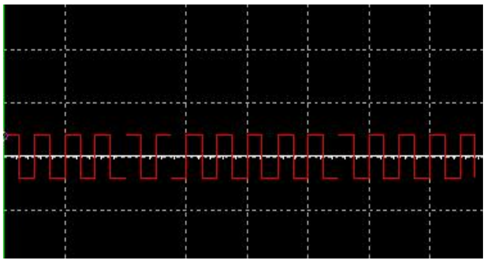


Figure 5-Message Signal.

The transmitted signal $s(t)= r(t) = c(t) + m(t)$. It is assumed that for masking, the power level of $m(t)$ is significantly lower than that of $c(t)$. If the receiver is synchronised with transmitter replica of the chaotic carrier is produced at the receiver i.e. $c(t) \cong \hat{c}(t)$.The fact is described in figure-7.Though exact replication of the chaotic signal isn't possible, we can make them approximately of same nature by matching the LE of the two signal. Consequently $m(t)$ is recovered as $\hat{m}(t) \cong s(t) - \hat{c}(t)$ [10,11]. Figure-6 illustrates the approach. Nature of the retrieved message signal depends on the proper synchronization between the transmitter and receiver. In figure-7 a little mismatch is shown between the transmitter and receiver side chaos, which is reflected in the values of LE of the two chaotic time series. We found that this little mismatch in the values of LE has great impact in message recovery. For our case we have seen that amplitude of the retrieved message is quite less than the original message. Figure-8 shows this fact. Synchronization between transmitter and receiver may be controlled by varying the resistance in the voltage divider circuit as shown in figure-6. The function of this voltage divider circuit is to account for attenuation of transmitted signal through channel.

After doing these experiments in MULTISIM platform we have proceeded towards the fabrication of the proposed scheme in bread board. The results we got in software simulation were quite satisfactory. The same experiments we have repeated in hardware platform, almost same results were obtained. Hardware set-up along with results have been explained in the next section.

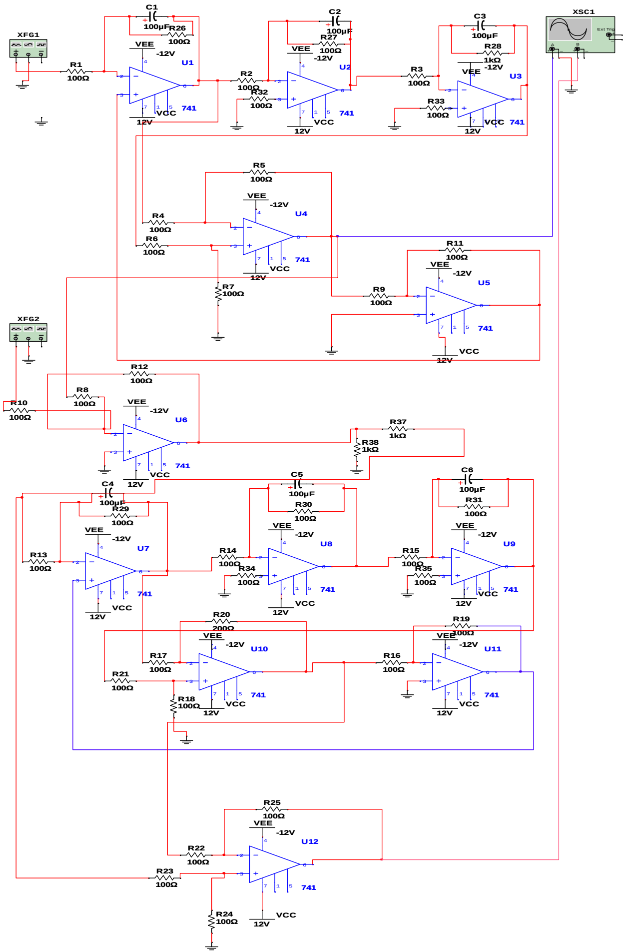


Figure-6 Schematic diagram of chaos masking communication scheme.

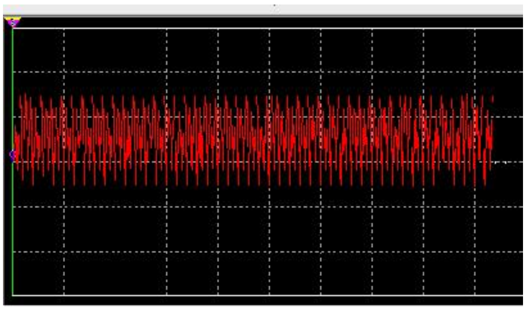


Figure -7 Replication of transmitter side chaos at receiver(Lyapunov Exponent=0.3).

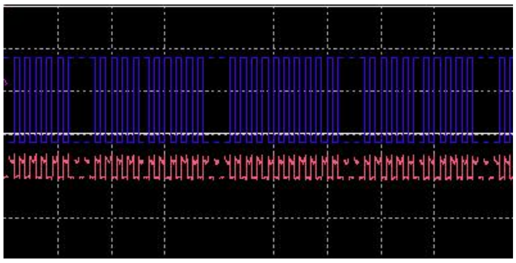


Figure-8 Original (blue, $V_{p=}$ 2V) and retrieved (red, V_p =0.8V) message.

IV.HARDWARE IMPLEMENTATION OF CHAOS MASKING COMMUNICATION SCHEME AND RESULTS

The approach shown in schematic figure-6 have been fabricated in bread board using the following components

i. µA 741 OpAmp

ii. Registors(R).

iii. Capacitors (C).

The Nature of the output either from transmitter or receiver changes with the change in R, C and input amplitude level. Output generated at the transmitter terminal with R=100 ohm, C=100uF and input peak to peak 8V ramp signal, frequency 3kHZ, is attached below in figure 10.

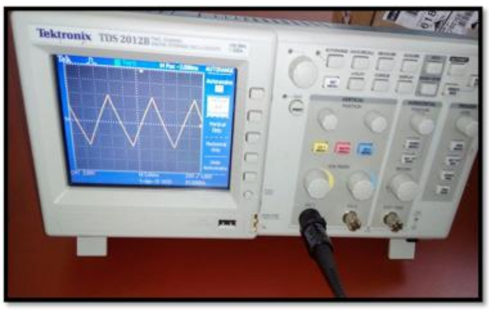


Figure-9 Input Ramp Signal.

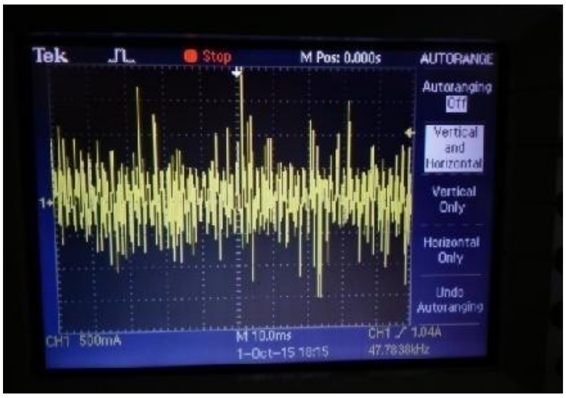


Figure-10 Chaotic carrier generated at transmitter.

A square wave signal of peak to peak 5V and frequency 1kHz is considered to be the message signal. This message signal is encrypted inside the chaotic carrier generated at the transmitter terminal. Encryption is done by adding the message signal with the chaotic signal by using an OpAmp based adder and is feed into the receiver. The signal after the adder drives the receiver.

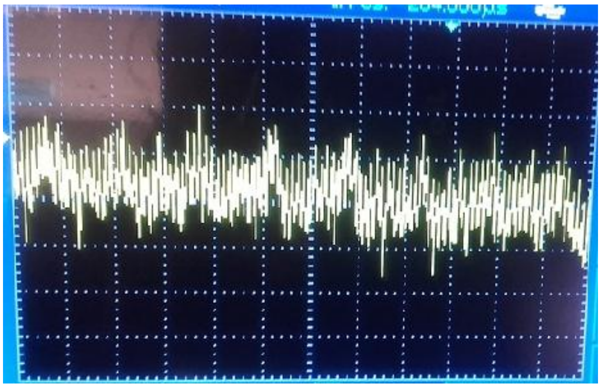


Figure-11 message encrypted inside the chaos.

It is necessary to make sure the parameters of transmitter and receiver are identical for implementing the chaotic masking communication. A voltage divider circuit is placed in between adder and receiver. The function of this voltage divider circuit is to attenuate the chaotic signal and to synchronize the transmitter circuit with receiver circuit simply by varying the resistances of the circuit. Figure-12 given below shows the moments during the synchronization of receiver with transmitter.

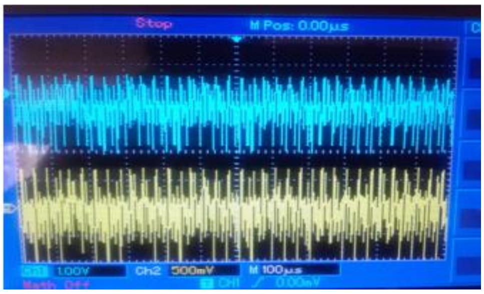


Figure-12 Synchronization of Receiver with transmitter.

The chaotic signal is regenerated at the receiver side allowing a subtraction from chaos encrypted message signal. Thus, as it can be shown from Figure-13, the message signal has been almost perfectly recovered by using the signal masking approach through the synchronization of chaotic transmitter and receiver circuits. Amplitude of the retrieved message signal is ten times lesser than the actual signal.

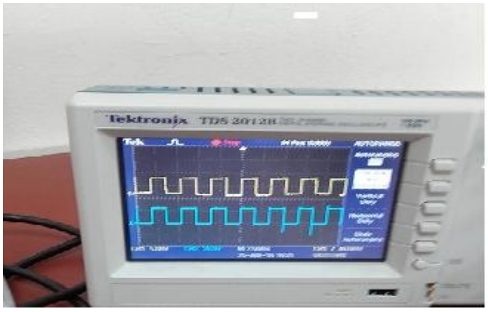
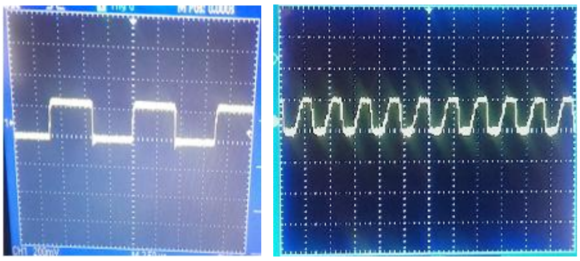


Figure-13 original(blue) and retrieved(yellow).message.

The same experiment we have repeated for lesser amplitude of message signal. The quality of retrieved message degrades with the decrease of signal amplitude. The fact is revealed in figure-14. Amplitude of the original message is 200mV peak to peak, where as the amplitude of the retiieved message is 10mV peak to peak.



(a) (b)

Figure-14 original(a) and retrieved(b).message.

Aditi Datta, Anjan.K.Ghosh, Anjan Mukherjee, Richa Debnath, Rakesh Dey, Somudeep Bhattacharya, Sayan Paul, Ujjayanta Dey

V.CONCLUSION

Different electronic circuits such as Chua's circuit, Jerk circuit etc have been used as chaos producing device[12,13], but we have designed an electronic circuit to simulate the effect of EO system. This electronic simulator circuit has given us the capability to replace the high cost EO modulator with a simple electronics. Here we have described an experimental chaos encoding communication system based on this electronic simulator. This analog computing circuit, replacement for EO system producing high complexity chaos is used as transmitter and receiver for the chaos encoded communication scheme. The scheme was successfully implemented by regenerating the message at receiver terminal. The information signal is transformed in such a way that only an authorized receiver who has a prior knowledge of the transmitter parameters can decipher the information at the receiver side.

REFERENCES

[1] Pecora, L.M., and Carroll, T.L.: 'Synchronization in chaotic systems', Phys. Rev. Lett., 1990, 64, (8), pp. 821–824.

[2]H. S. Kelvin M. Coumo, Alan V. Oppenheim, "Roubustness and Signal Recovery in a Synchronized Chaotic System.," *Int. J. Bifurc. Chaos.*, vol. 3, no. 6, pp. 1629–1638, 1993.

[3].N. Gastaud, S. Poinsot, L. Larger, J. Merolla, M. Hanna, J. Goedgebuer, and F. Malassenet, "Electro-optical chaos for multi-10 Gbit /s optical transmissions," *Electron. Lett.*, vol. 40, no. 14, pp. 40–41, 2004.

[4] Michael Peil, Maxime Jacquot, Yanne Chembo, Laurent Larger, and Thomas Erneux. Routes to chaos and multiple time scale dynamics in broadband bandpass nonlinear delay electro-optic oscillators. Physical Review E, 79(2):026208, February 2009.

[5] A K Ghosh and P Verma. The Lyapunov Exponent of Chaos Generated by Acousto optic Modulators with Feedback. Optical Engineering, 50:1-20, 2011.

[6] Gaurav Narula Ghosh, A K. Influence of Lyapunov Exponent on the characteristics of chaotic optical signals from bistable Acousto or Electro Optic, 2012.

[7] S. H. Strogatz, Nonlinear Dynamics and Chaos with Application to Physics, Biology, Chemestry and Engineering. 1994.

[8].M. T. Rosenstein, J. J. Collins, and C. J. De Luca, "A practical method for calculating largest Lyapunov exponents from small data sets," no. 617, 1992.

[9] J. B. Gao, J. Hu, W. W. Tung, and Y. H. Cao, "Distinguishing chaos from noise by scale-dependent Lyapunov exponent," *Phys. Rev. E*, pp. 1–9, 2006.

[10] V. V Bykov, "On Bifurcation Leading to Chaos in Chua's Circuit," vol. 8, no. 4, pp. 685–699, 1998.

[11] M. Halimi, K. Kemih, and M. Ghanes, "Circuit Simulation of an Analog Secure Communication based on Synchronized Chaotic Chua ' s System," vol. 1516, no. 4, pp. 1509–1516, 2014.

[12] B. M. H. P. Ambaum and R. G. Harrison, "The Chaos Machine," Analog Computing Rediscovered(1), Retronics, no. 1, 2011.

[13]. Lawrence E Larson, Lev S Tsimring, Henry D I Abarbanel, Jiaming Liu, Kung Yao, Alexander R Volkovskii, Nikolai F Rulkov, and Mikhail M Sushchik. An Overview of Digital Communications Techniques Using Chaos and Nonlinear Dynamics. Institute of Nonlinear Science., pages 1-27, 2006.