Application of Chaos Theory Mode Hannon in Optical Communication by Mach-Zehnder Interferometer for Chaotic Information Transference

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ABSTRACT:
This project investigates chaos theory as a method for information cryptography in optical communication. Information security and communicated information error reduction are the main communication issues. Different methods including chaos theory have been suggested for its analysis. In addition to introducing the theory, this article investigates whether it could be used in optical communication and suggests a method to use the theory in the communication.

KEYWORDS: Optical Communication, Chaos Theory, Mach-Zehnder Interferometer.

1. INTRODUCTION

Using optic in communications as well as wired communication and wireless one has solved some problems of wired communication as well as some deficiencies of wireless communication. Since this communicative system optic is used as the connector and the conveyer of the information, so this communicative method has some properties as the followings:

1. Much more bandwidth than wired communication;
2. Meager weakening than wired communication;
3. Not needing particular frequency band for propagation;

Such properties have still attracted attention to optical communication as most technologies spread based on waves application.

On the other hand, this question arises that if optical communication can compensates security weakness of wire communications? Whether any cryptography in this communication exists as well? The main deficiency of wired communication is the restriction or the insecurity of communicated data, as the data communicated by this communicative method could be obtained by the least expenses. Hence, this question arises that how much is the security of optical communication compared to the wired communication?

Cryptography by algorithms and different methods has been studied a lot [4-2]. What is important in cryptography is a method which meets the following issues:

- Decreasing the inaccuracy of the information communicator channel
- Increasing the security of the communicated data

Using chaos theory in cryptography algorism is one of the significant cryptographic methods [6-5]. How would be the data cryptography in optical communication? Is it possible to convert the optic to code? Answering these questions makes it possible to compare optical communication security with other information communication methods.

Using chaos theory is one of the current methods in data cryptography communications. This theory has also been used in optical communications. As Figure (1) indicates, chaos theory in optical communication could be studied in three outlooks. Chaos theory is used in isolator to produce data based on chaos theory. In the modulation section, the purpose is to merge the data and conveyer wave chaotically. The purpose of transference is to use the chaotic semi-conductors [7] in producing the Lasers to transfer the data in the fiber.

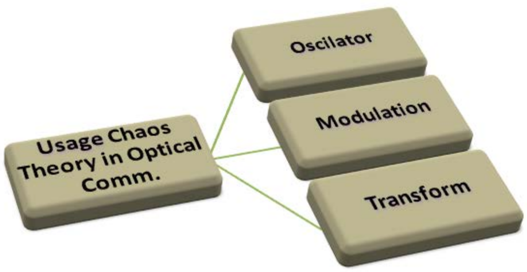

Fig. 1. Chaos theory application in optical communication

The current article investigates the chaos theory application in Mode Hannon to transfer information in the optical communications. It suggests interferometer Mach-Zehnder method to have access to Mode Hannon. The purpose of this method is to design interferometer Mach-Zehnder in a way that its output acts as a chaotic wave. Hence, chaos theory is introduced and its application in optical communications is discussed. Then, interferometer Mach-Zehnder is presented. Finally, by introducing the suggested method it is simulated.

2. CHAOS THEORY

Chaos means disorder and irregularity. It is a new scientific concept which has led researchers towards new horizons. It seems to be a random action which severely depends on initial conditions. Chaos is seen in many natural phenomena such as snowflakes when falling from the sky.

Despite noise which is a useless nature and causes turbulence and sometimes elimination in information, chaos could be useful. Using this theory has been considered in cryptography.

Since 1990, many methods have been used for information cryptography on the basis of dynamic chaos. In fact, dependence on the initial conditions and control parameters along with Orgadicity of their growth causes using chaos theory as a renewed cryptography organization [8].

There are a series of particular suppositions in chaos theory, such as baker, logistic, Hannon, etc. which indicate an irregular behavior in function, but they have mathematical connections and could be analyzed. Using these suppositions creates chaotic signals

3. USING CHAOS IN OPTICAL COMMUNICATIONS

The optic connection based on chaos is a method to improve protecting privacy and security in optical communication networks. Cryptographic quantum is a key to solve security problem in optical communications [9].

Lasers which radiate in chaos mood are used as a solution for information cryptography in optical communications.

Figure (2) shows transferring data by chaos conveyer in optical communications.

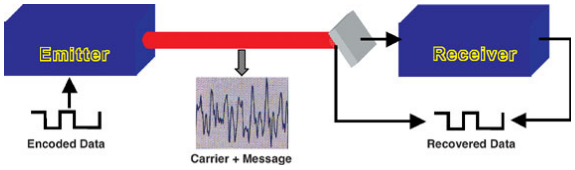

Fig. 2. Schematic transference of the cryptographic information [9]

Using chaotic conveyers enhances privacy in high rate of information transference. Figure (3) shows an electro-optic feedback which is useful in light production.

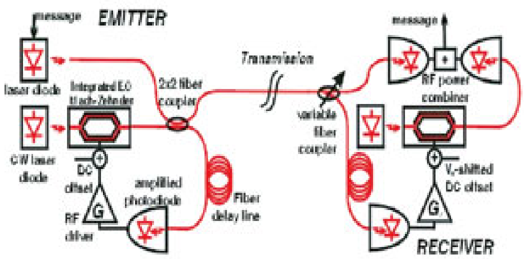

Fig. 3. Electro-optic [9]

Feedback ring in the electro-optic feedback includes a DFB laser which is supplied by Mach-Zehnder interferometer. The feedback output is transferred to a light-sensitive diode through a delayed line and becomes a chaotic light.

4. DESIGNING THE SUGGESTED SYSTEM

Could there be chaos theory in optical communications? As it was observed, the answer is yes. So we study how chaos theory could be used in optic communications in two ways:

- Data cryptography based on chaos theory before loading the information on the light in the optical communications and then sending them out (chaotic message).
- Using chaos theory in chaotic quantum to send information (chaotic conveyer)

In the first method, information is encoded before being sent by chaos theory and many works have been done on this issue [5-6]. This method brings about security for optical communications and makes it impossible to access the data, unless the key is decoded.

In the second method, chaotic conveyer is used. It involves chaotic light and the light is needed to be in a chaotic form. Using Mach-Zehnder to produce chaotic light has been considered so much [10]. The present article investigates Mach-Zehnder application to produce chaotic light in Hannon Chaos Mode. Hannon Mode is as the following:

$$\begin{cases} x_{n+1} = y_n + 1 - a x_n^2 \\ y_{n+1} = b x_n \end{cases} \qquad (1)$$

Which its graph is as Figure (4):

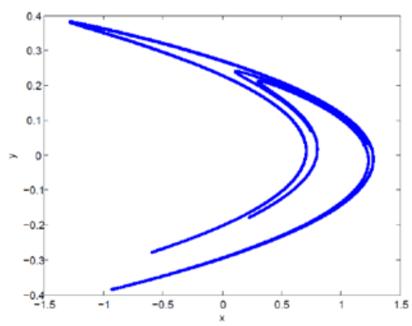

Fig. 4. Hannon Mode

Dynamic equation of a chaotic optical system is as:

$$x(t) + \tau \frac{dx(t)}{dt} + \frac{1}{\theta}\int x(s)ds = \beta \cos^2\left(x(t+T) + \phi\right) \qquad (2)$$

Which to produce such a chaotic wave, it is necessary to have a derivative operator to produce $\frac{dx(t)}{dt}$ and an integrator operator to produce $\int x(s)ds$. If we consider:

$$\begin{aligned} &y = \beta\cos^2\big(x(t+T)+\phi\big) \\ &a = 0 \\ &b = 1 \end{aligned} \tag{3}$$

Through mode Hannon, we would have:

$$\begin{cases} x_{n+1} = \beta\cos^2\big(x(t+T)+\phi\big) \\ \\ y_{n+1} = x_n \end{cases} \tag{4}$$

The aforesaid relations result in an optical chaotic wave. Interferometer Mach-Zehnder, in Figure (5), is used to cause chaos in light. In a way that it postpones a part of the light and the postponed wave accumulates with the non-postponed light at the output of the interferometer. As a result, it produces the modulated (chaotic) light.

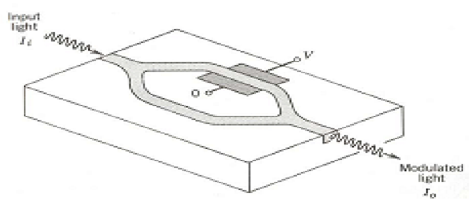

Fig. 5. Interferometer Mach-Zehnder

Figure (6) shows how the chaotic wave is produced by interferometer Mach-Zehnder.

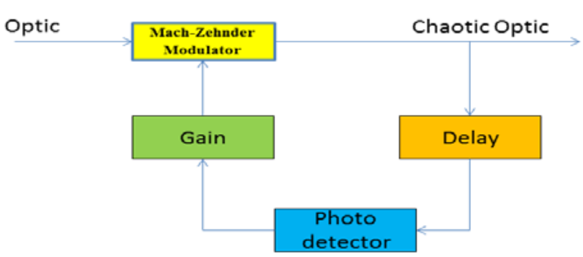

Fig. 6. Production of the chaotic light

What is important is to determine gain, deferment, and designing photo detector to produce chaotic light in Hannon Mode. The interferometer output is as [11]:

$$I = 2A^2\big(1+\cos(\Delta\phi)\big) \tag{5}$$

In which $\Delta\phi$ is the optical phase shift. By adding equation (5) to the equation of chaotic optical system (equation (2)), we have:

$$\begin{aligned} &2A^2\big(1+\cos(\Delta\phi)\big)+\tau\frac{dI}{dt} \\ &\quad +\frac{1}{\theta}\int I\,ds = \beta.\cos^2\big(I+\phi\big) \end{aligned} \tag{6}$$

Since none of the parameters in Relation (5) depend on "t", some parts of the equation could be simplified. Then, we have:

$$\tau\frac{dI}{dt} = 0 \tag{7}$$

Integrator operator could also be neglected, because the parameter in the integral does not depend on "t". Hence, it could be neglected by defining a range for the integral. Therefore, we have:

$$\begin{aligned} &2A^2\big(1+\cos(\Delta\phi)\big) = \\ &\quad \beta\cos^2\Big(2A^2\big(1+\cos(\Delta\phi)\big)+\phi\Big) \end{aligned} \tag{8}$$

Having simplified the second part of equation (8), we determine the deferment degree in the suggested system. It is necessary to remind that the resulting deferment in the suggested system is produced by phase shift of the interferometer Mach-Zehnder. Triangular relations indicate that:

$$Cos^2(\alpha) = \frac{1+Cos(2\alpha)}{2} \tag{9}$$

Now, we use this equation to simplify the equation (8) as the following:

$$\beta \cos^2\left(2A^2\left(1+\cos(\Delta\phi)\right)+\phi\right) = \beta \frac{1+\cos\left(4A^2\left(1+\cos(\Delta\phi)\right)+2\phi\right)}{2} = \frac{\beta+\beta\cos\left(4A^2\left(1+\cos(\Delta\phi)\right)+2\phi\right)}{2} \quad (10)$$

Using $\cos(\Delta\phi)$ and applying approximations, we simplify the equations:

$$\left(1+\cos(\Delta\phi)\right) = \begin{cases} 2 & 0 \le \cos(\Delta\phi) \le 1 \\ 0 & -1 \le \cos(\Delta\phi) < 0 \end{cases} \quad (11)$$

Through this approximation, equation (10) is simplified as the following:

$$\beta \cos^2\left(2A^2\left(1+\cos(\Delta\phi)\right)+\phi\right) = \frac{\beta+\beta\cos\left(4A^2\left(1+\cos(\Delta\phi)\right)+2\phi\right)}{2} = \begin{cases} \dfrac{\beta+\beta\cos\left(8A^2+2\phi\right)}{2} & 0 \le \cos(\Delta\phi) \le 1 \\ \dfrac{\beta+\beta\cos\left(2\phi\right)}{2} & -1 \le \cos(\Delta\phi) < 0 \end{cases} \quad (12)$$

Comparing the second part of equation (12) through equation (8), gain and deferment could be obtained for the suggested chaotic system. Using equations (8 and 12), we have:

$$2A^2\left(1+\cos(\Delta\phi)\right) = \begin{cases} \dfrac{\beta+\beta\cos\left(8A^2+2\phi\right)}{2} & 0 \le \cos(\Delta\phi) \le 1 \\ \dfrac{\beta+\beta\cos\left(2\phi\right)}{2} & -1 \le \cos(\Delta\phi) < 0 \end{cases} \quad (13)$$

Finally, we have:

$$2A^2 = \frac{\beta}{2} \Rightarrow \beta = 4A^2 \quad (14)$$

$$\Delta\phi = \left(8A^2+2\phi\right) \quad (15)$$

That is, choosing gain as $4A^2$ and deferment (phase difference) as $8A^2+2\phi$, Hannon Mode could be obtained in optical communications by the interferometer Mach-Zehnder.

5. CONCLUSION

This article sought to use the chaotic theory in optical communications and produce the chaotic light, and design a system for using the Hannon Mode in optical communications. For designing the system, the gain (advantage) and also the deferment of the applied system should be obtained; these two parameters were obtained by using the current equations for the chaotic optical system and the output light from Mach-Zehnder interference. The outcomes of this article could be mentioned as the followings:

1. Employing the chaotic theory is applied as a method for information cryptographic.
2. There are two general methods for using the chaotic theory in optical communications; using the chaotic conveyer and the chaotic message.
3. Mach-Zehnder interferometer is used to produce the chaotic light.

4. The suggested ideas were about using Hannon Mode to produce the chaotic light by Mach-Zehnder interference.

Finally it should be mentioned that using the chaotic theory increases the information security and privacy in the optical communications; and using this method increases the data transference better than the existing methods.

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