DIGITAL CHAOS SYNCHRONIZATION IN OPTICAL NETWORKS

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ABSTRACT

A possible approach to the synchronization of chaotic circuits is reported. It is based on an Optically Programmable Logic Cell and as a consequence its output is digital. Its application to cryptography in Optical Communications comes directly from its properties. The model here presented is based on a computer simulation.

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In the last years there has been a considerably interest in utilizing chaotic circuits to implement secure communication systems. One of the main problems to be attended is the one concerning synchronized circuits. The idea that chaotic systems could synchronize was first put forth in a paper almost ten years ago [1]. Several authors have followed the lines indicated in that paper [2] as well as schemes using Chua's circuit [3]. But if chaotic circuits are going to be employed in Optical Communications two main conditions should be satisfied: to use as much as possible just optical components and to get a digital chaotic signal. The first condition has been verified in some cases but with elements no normally employed in optical communications. The second one has not been achieved because in almost every case the obtained chaos is analogic, when a digital one is needed a conversion has to be carried out.

A new scheme is proposed in this paper. The basis is the use of an Optically-Programmable Digital Circuit, reported previously by us [4]-[5], and able to process two input binary signals. Its two outputs are logical functions of these inputs. The type of processing is related to the eight main Boolean Functions, namely, AND, OR, XOR, NAND, NOR, XNOR, ON and OFF. The programmable ability of the two outputs, as it has been described, allows the generation of several data-coding for optical transmission. Moreover, as it was shown, this circuit has the possibility to the generation of periodic and even chaotic solutions. A precise analyzes of the output characteristic versus the main variable parameters, as control signal level and data signal level, has been reported [6]. With this configuration, the above mentioned digital character of the signal is directly obtained. Its main blocks are shown in Fig. 1. Two devices, P and Q compose the circuit with non-linear behaviour. The outputs of each one of them correspond to the two final outputs, O_1 and O_2, of the cell. Four are the possible inputs to the circuit. Two of them are for input data, I_1 e I_2, and the other two, g and h, for control signals The way these four inputs are arranged inside the circuit, is also represented in Figure 1. A practical implementation we have carried out of the processing element has been based on an optoelectronical configuration. Lines in Fig. 1 represent optical multimode fibers. The indicated blocks, placed in order to combine the corresponding signals, are conventional optical couplers. In this way, optical inputs arriving to the individual devices are multilevel signals. The characteristics of the non-linear devices are also shown in Fig. 1. Device Q, corresponds to a thresholding or switching device, and device P is a multistate device, being the response of this non-linear optical device the one represented in Fig. 1. This response is similar to the behaviour of a SEED device.

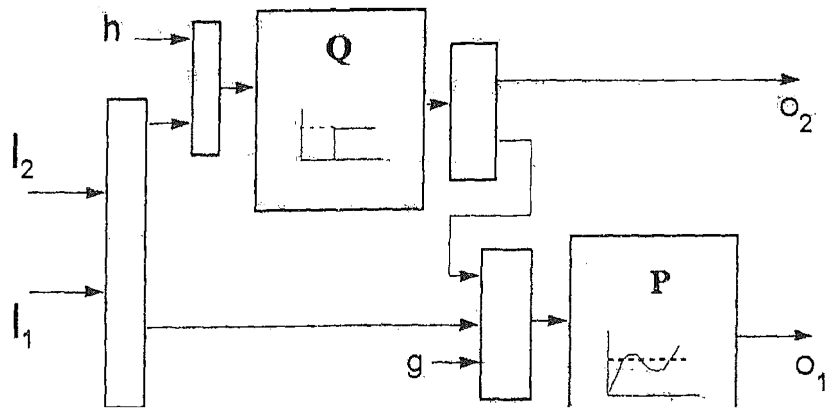

Figure 1.- Detail of the internal configuration of the optical programmable logic cell.

The characteristics of the non-linear devices are also shown in Fig. 1. Device Q, corresponds to a thresholding or switching device, and device P is a multistate device, being the response of this non-linear optical device the one represented in Fig. 1. This response is similar to the one had by a SEED device.

A non-linear behaviour can be expected from the above reported cell, if some kind of feedback should be applied. The feedback we have applied to the system, among the different possibilities, is the one corresponding from the output O_1 of Q-device (see Fig. 1) to the control input, ***g***, of P-device. No other additional control signal has been used. A chaotic output is obtained when the internal response time equal to zero or much smaller than the external one. Some results have been reported by us [5].

If two identical cells, as the above mentioned, with feedback, are parallel connected and the same signals arrives to their inputs, an identical chaos is obtained at their outputs. This situation corresponds to two identical and ideal configurations working under identical conditions.

The behaviour becomes more critical when the simulation tries to be close to a real situation. In this case, if both systems are not feed by exactly the same signal, the obtained outputs, although chaotic, are different. Hence, no possible relation between then should be feasible.

The solution we have adopted is presented in Fig. 2. Both systems, drive and response, are located at different places. As a consequence, there is no possibility to introduce the same input signals to their corresponding input ports. But because just one of these two input signals is needed to generate both, this signal is the one sent to both structures. The corresponding circuit, either optical or electronic locally generates the second one, depending on the type of system. A variable time delay is added to the first system in order to obtain the same retard. The time delay has to be varied around a certain range. These variations are imposed by the signal obtained at block C, where the two chaotic signals are compared. This signal is the feedback to the time delay generator τ that controls the time delay to the OPLC2 cell. When the chaotic signals are synchronize the data signal is added and sent.

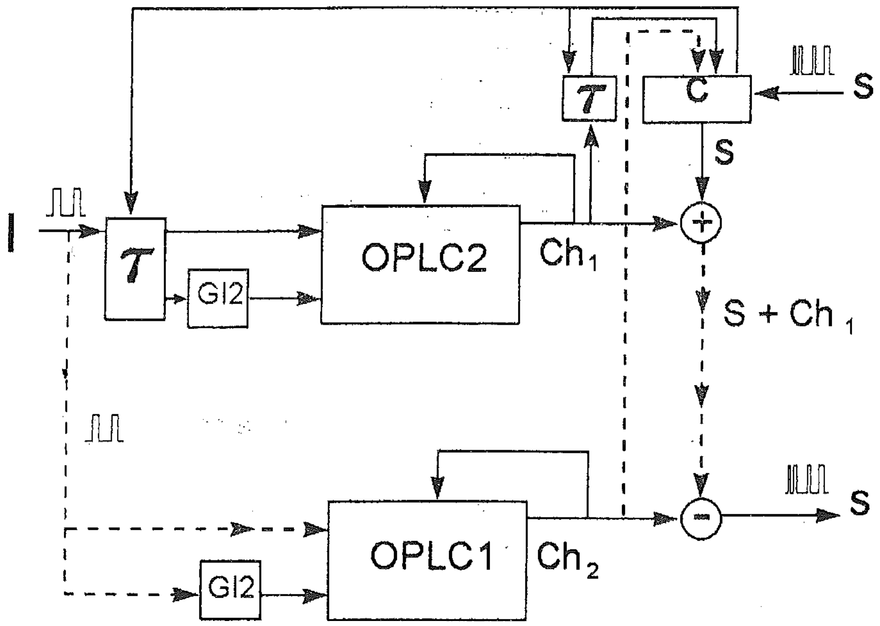

Figure 2.- General scheme of the chaos synchronization between two optical programmable logic cells.

In present paper, some results will be reported concerning the influence of the time delay on the obtained signal at block C. We will show that, after a certain time depending on the difference between the propagating time and the imposed delay time, a chaos synchronization can be obtained. Some particular transmission cases will be presented.

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