Analysis of an Optical CDMA Communication System Model

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Abstract— The main of our work was to simulate the transmission of a binary signal from one point to another. To achieve our objective we proceeded to carry out a simulation in MATLAB code in SIMULINK. The simulation program contains two parts: the transmitter block and the receiver block. Note that the transmission channel intervenes only for its additive noise. The data signal in binary code is introduced into the transmitter and begins with a coded narrowband signal, which allows the distribution of the use of Walsh codes, for a bandwidth of 1.23MHz. When the signal is received, it is filtered and processed to recover the desired signal. The signal is spread out and is subsequently introduced into a Gaussian white noise transmission channel. On receipt, the reverse operations are performed. Dispreading is performed by multiplying the signal received by the same code as at transmission. After demodulation, the emitted signal is restituted.

Keywords— CDMA, Correlator, FO-CDMA, Hard limiter, OCDMA, OOC codes, Walsh codes.

1. Introduction

The Multiple Access code division method (CDMA) adapted from the cellular telephone network appeared several years ago in fiber optic networks as multiple access to the solution for LANs. This technique has called optical CDMA (OCDMA). In this case, it is a question of assigning to each user a specific code and which allows access to the access and the diffusion on the network avoiding the interferences between Messages from users. Reduction of IAM is not available in the case of the use of strictly orthogonal code sequences. Choosing a family of codes with better correlation properties minimizes multiple access interference (IAM) and ensures better performance to OCDMA systems, [1,2].

Unlike CDMA radiofrequency systems where the use of bipolar codes does not present difficulties, the implementation of codes in optical systems is faced with non-conservation of the phase of optical signals. For this purpose, unipolar optical codes have been developed.

The first codes used in optical CDMA are Orthogonal Optical Codes (OOC).

Moreover, the receiver structure used at the end of the transmission chain is a very important element whose function is to receive the signal transmitted in the optical fiber and then, from this signal, to estimate the data transmitted by the user longed for. Different reception structures can be used for OCDMA systems, [3,4].

.II. A MODEL OF SIMULATION OF AN OPTICAL CDMA SYSTEM

The functional simulation scheme model of an optical communication system using CDMA using orthogonal optical codes for user signature sequences active in a common optical channel with i pairs of transmitters and receivers , is shown in Fig.1.

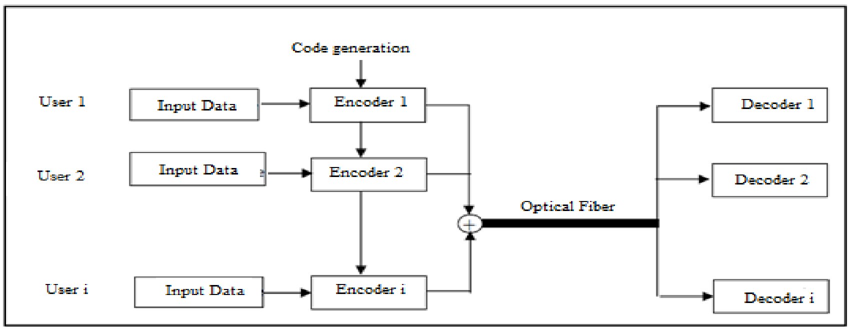

Fig.1 Block diagram of a simulation model of an optical communication system

The emitter in the block diagram includes blocks of the input data, which are used to form a template for the various messages and user blocks, and provide the encoding of the data using a proper signature code sequence. This signature code is an element of the family of orthogonal optical codes (OOC), [5,6].

III . OPTICAL ORTHOGONAL CODES

To reduce crosstalk between users, a significant property of the sequences (code words) is that they produce a low correlation. OOC is a set of binary sequences with special autocorrelation and correlation properties. Since the correlation is small, each sequence of the code can easily be distinguished from a shifted version of the code, i.e., the autocorrelation is small and it is easy to distinguish any combination of shifted versions of one- Other C sequences, i.e. the intercorrelation is small, [7].

OOC codes and unipolar components (0,1) is characterized by four parameters (L, W, λ_a and λ_c)

- L is the length of the code sequence
- W is the code weight, which represents the number of chips at "1"
- λ_a and λ_c are respectively the constraints

The OOC code sequences must satisfy the following two conditions:

- There is a good autocorrelation function with all relative offsets, such that detection is acceptable.

$$\sum_{t=0}^{n-1} x_t x_{t+\tau} = \begin{cases} W \\ \lambda_c \end{cases} \qquad 1 < \tau < n-1 \qquad (1)$$

For x Є $\not{C}$ and τan integer0 $< \tau < n$

It should also have a satisfactory cross-correlation function between any two sequences in the same set to minimize IAM.

$$\sum_{t=0}^{n-1} x_t y_{t+\tau} = \begin{cases} W \\ \lambda_a \end{cases} \qquad 1 < \tau < n-1 \qquad (2)$$

For x # y€ ₡ , andτ integer.

IV CDMA OPTICAL CDMA SYSTEM

(FO-CDMA) is a technique allowing several users to transmit simultaneously on the same optical fiber. In this system, each user is described by a data source containing the data to be sent after having been encoded by an encoder and then by a laser which transforms the signal from the electrical form to an optical pulse sequence. At the end, at the receiver, an optical correlator is used to extract the encoded data, [8,9].

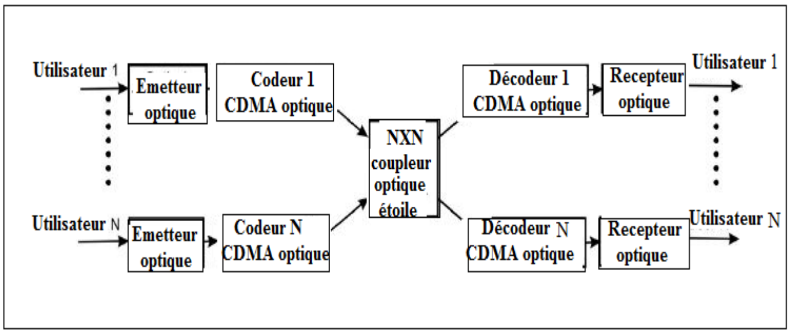

Fig.2 Optical CDMA Network Diagram

Simulation model of CDMA in an optical communication system is presented in Fig.3. This simulation is presented graphically by the Matlab Simulink application.

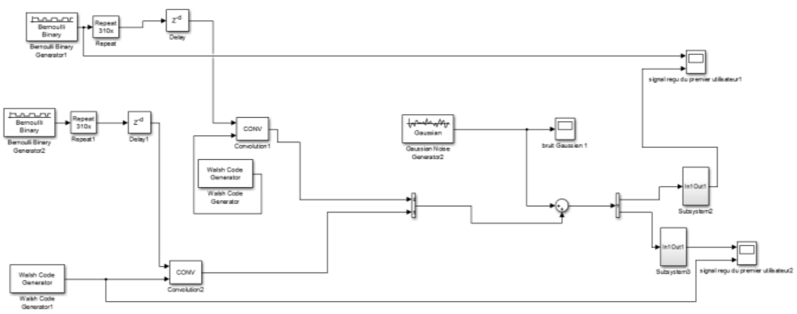

Fig.3 Simulation of optical CDMA by Simulink, case of two users

The emitter of the simulation model is shown in Fig.4, it comprises the random sequence of data of the information signal.

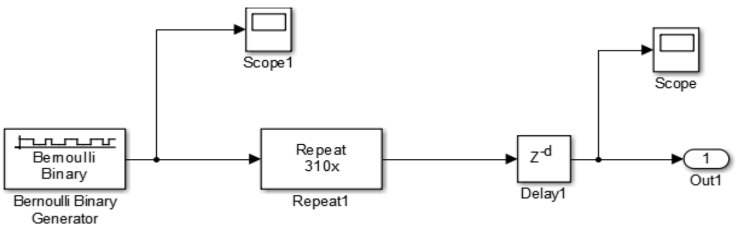

Fig. 4: Model for generating a random data sequence of the first user

The data sequence of the first user is illustrated in Fig.5.

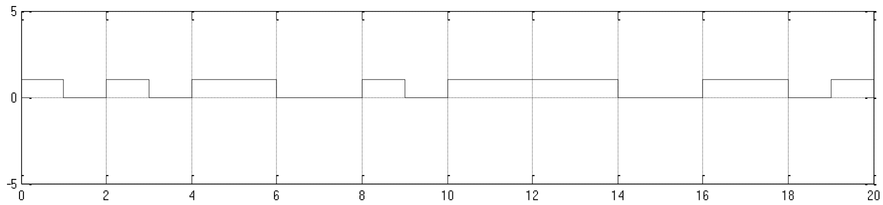

Fig.5 Generation of a first user random data sequence

The generated data sequences of each user are encoded by a Walsh signature code (see Fig.-6)

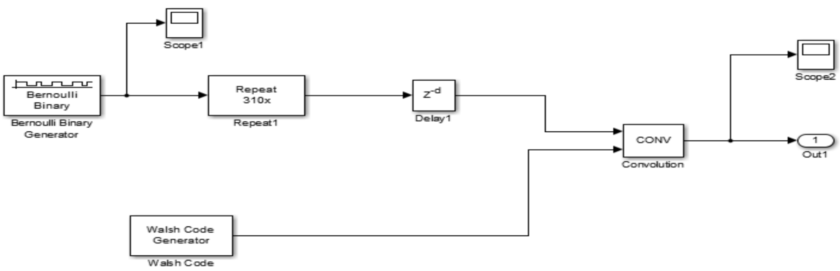

Fig. 6 Random sequence Walsh coding Block of the first user

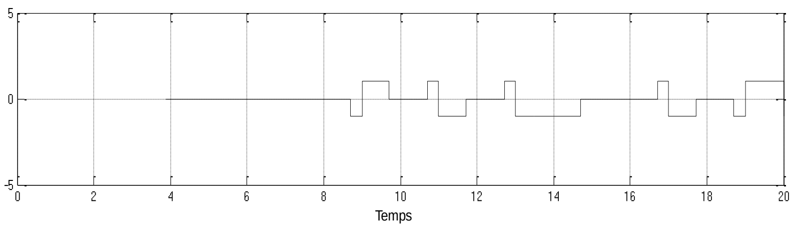

Fig.7 Random sequence Walsh coding of the first user

The coded sequence of the first user is given in Fig.7, we consider an optical CDMA system, with N pairs of transmitters and receiver, even the optical channel, following a star topology. Each bit of information of the k^{ith} user is coded in a code-word defined by:

$$C_k(t) = \sum_{i=1}^{n} C_k(i) P_k(t - iT_c) \quad (3)$$

Where n is the code-word length

$C_k(i)$ $\in\{0,1\}$ for $1 \leq i \leq n$ is the value of the i^{th} code-word chip of the k^{ith} user, and T_c is the chip duration.

The received signal is the sum of all the signals of the active K users:

$$R(T) = \sum_{K=1}^{K} B_K C_K(T - \tau_k) \quad (4)$$

Where, $b_k \in \{0,1\}$ is the information bit of the u k^{ith} user and $0 \leq \tau_k \leq T$ is the delay time for $k = 1,.....,K$.

The receiver uses an optical correlator to the received signal to extract the desired information bit. It is assumed that the signal of the desired user is denoted by k = 1.

The signal from the correlator is expressed by:

$$Y_1 = \int_0^T C_1(T) R_1(T) = B_1 \quad (5)$$

The encoded information signals of each user are summed and sent in optical line, where the existence of noise modeled by a Gaussian white noise generator (AWGN), so that the signal summarized in an optical common channel in the presence of Noise ratio is shown in Fig.8.

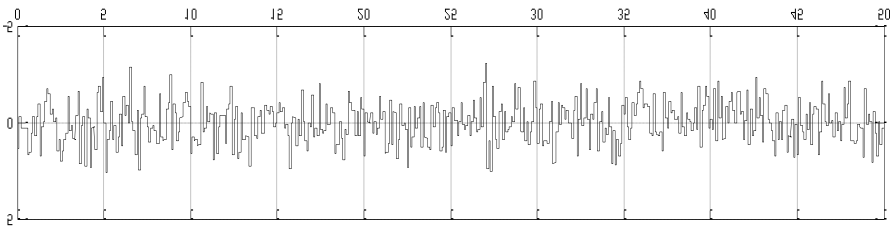

Fig.8 White noise in the common optical channel

At the receiver, a function called Hard Limiter (HL) is added, the purpose of which is to clipping the received signal, it suppresses part of the received power in order to finally have a signal each chip of which contains zero power Or equal to '1' (Fig.9).

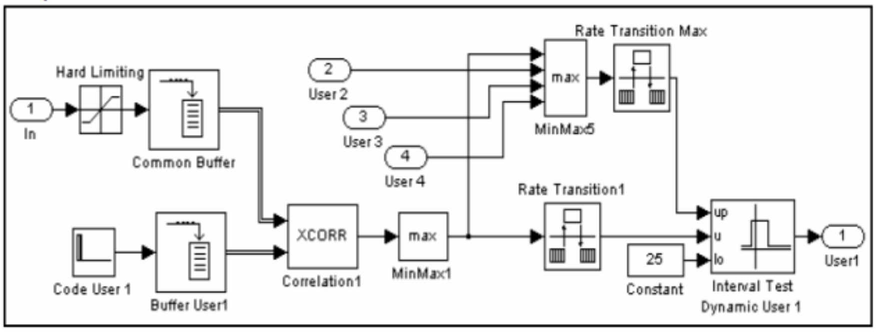

Fig.9 Receiver model of each user

The signals received by the hard limit are defined by:

$$G(X) = \begin{cases} 1 & X \geq 1 \\ 0 & 0 \leq X < 1 \end{cases} \quad (6)$$

Therefore, if an optical light intensity (x) is greater than or equal to one, Hard limit would reduce the intensity to one, and if the intensity of the optical light is less than one, the response of the hard optical limiter would be equal to zero.

The threshold value can be chosen under the condition value: $0 \leq$ threshold $\leq$ w

The properties of OOC optical orthogonal codes ensure correct extraction of information data sequence for each user. There is an automatic detection activity mechanism for any user in the simulation of the CDMA optical system model.

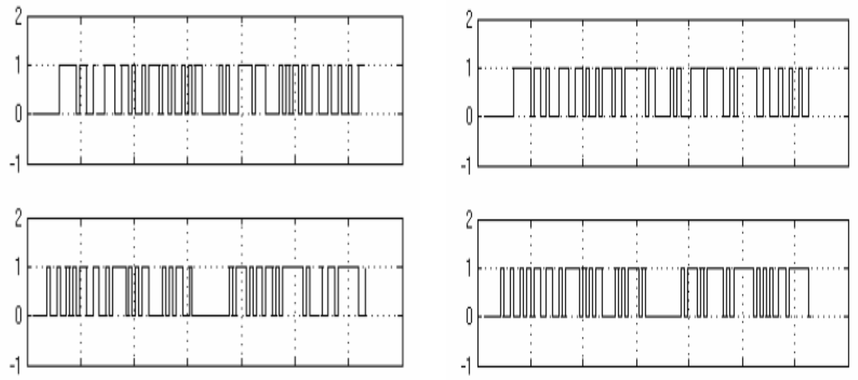

Fig.10. Comparison between data transmitted and received for both users.

The simulation model compares the transmitted and received data for each user (see Fig.10) and records the number of error bits and an error probability for a user (calculation of the error rate of the block in the Fig.11 and Fig.12). The error probability is defined as a function of the weight and the length of the OOC code:

$$P_E = \frac{1}{2}\sum_{I=T_H}^{K-1}\binom{K-1}{I}\left(\frac{W^2}{2N}\right)^I\left(1-\frac{W^2}{2N}\right)^{K-1-I} \tag{7}$$

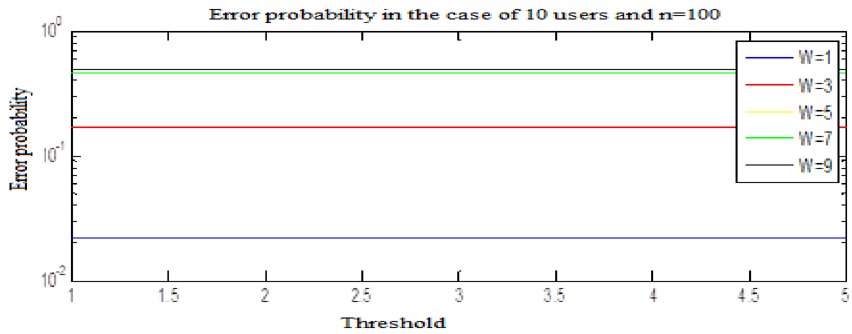

Fig.11 Dependency Error probability-code weight

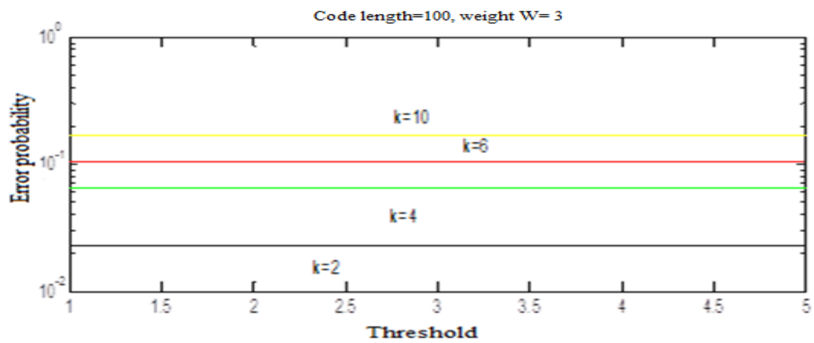

Fig.12 Dependency Error probability-users number

V CONCLUSION

The simulation model is developed in the Matlab Simulink graphical application. It comprises modules for transmitters and receivers for two users and it can ensure the possibility of arbitrary asynchronous access to the optical channel. The model can be developed and generalized for an arbitrary number of users. It will analyze and evaluate the parameters and characteristics of orthogonal optical codes with the existence of random noise sources in the common communication channel.

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