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System design based on EDW code using FSO-FTTH network access

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Abstract
It is important to apply the field Programmable Gate Array (FPGA), and optical switch technology as an encoder and decoder for Spectral Amplitude Coding Optical Code Division Multiple Access (SAC-OCDMA) Free Space Optic Fiber to the Home (FSO-FTTH) transmitter and receiver system design. The encoder and decoder module will be using FPGA as a code generator, optical switch using as encode and decode of optical source. This module was tested by using the Enhanced Double Weight (EDW) code. Which is selected as an excellent candidate because it had shown superior performance were by the total noise is reduced. It is also easy to construct and can reduce the number of filters required at a receiver by a newly proposed detection scheme known as AND Subtraction technique. EDW code is presented here to support Fiber-To-The-Home (FTTH) access network in point-to-multipoint (P2MP) application. The conversion used a Mach-Zehnder interferometer (MZI) wavelength converter. The performances are characterized through BER and bit rate (BR), also, the received power at a variety of bit rates.

1. Introduction

OCDMA systems have been investigated for about two decades and received a lot of attention [10-12]. This is due to its excellent performance, such as asynchronous access to the networks [13], high-security operation [14], and high capacity in burst networks. In the recent years, optical-spectral-amplitude-coding CDMA (OSCDMA) system attracts more attention because its ability to reduce multiple access interference (MAI) by suing subtraction detection techniques with fixed in-phase cross correlation [16-17].

OSCDMA is a multiplexing technique adapted from the successful implementation in wireless networks. Many codes have been introduced for OSCDMA system. Among the popular codes are Hadamard code, modified quadratic congruence (MQC) code, M-sequence code, modified frequency hopping (MFH) code. However, these codes suffer from various limitations oneway or another. The code's constructions are either complicated or the cross-correlation are not ideal. This paper will discuss about the EDW code construction and its performance in the comparison with what have been presented.

In the area where unlimited bandwidth and faster internet connectivity are required, free space Optics (FSO) has emerged as a promising solution. It is due to the advantages of FSO. FSO is the best solution for last –mile bottleneck problem. It offers broader and unlimited bandwidth and licenses to free compare to deployment of a microwave link. FSO can be installed in a shorter time, and lower cost compare to laying down fiber optics cable.

FSO can deliver the same bandwidth as optical fiber but without the extra cost of right way and trenching, without the electromagnetic interference due to the nature of the information carrier photons unlike the RF based system, it has light weight and is very compact and consumes low power [2]. Free space optical communication systems use an optical carrier signal to transfer information through the air (free space) between two or more optical receivers or transceivers. Figure1. Below shows-free space optical (FSO) transmission, systems lose some of their energy from a signal scattering, absorption and scintillation. Optical signal scattering occurs when light signals are redirected as they pass through water particles. Optical signal absorption occurs as some optical energy is converted to heat as it strikes particles (such as smog). Scintillation occurs when heated (such as from smokestacks) air cause a bending of the optical beam. The atmospheric attenuation

Coefficient is uncontrollable in an outdoor environment and is roughly independent of wavelength in heavy attenuation conditions. Unfortunately, the received power is exponentially dependent on the product of the atmospheric attenuation coefficient and the range; in really atmospheric situations, for carrier-class products (i.e., availabilities at 99.9% or better) this term overwhelms everything else in the equation. This means that a system designer can choose to use huge transmit laser powers, design large apertures, and employ very tight beam divergences, but the amount of received power will remain essentially unchanged.

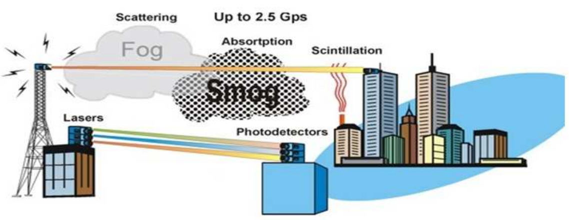


Fig 1. *Free Space Optics – FSO Diagram.*

2. Review of EDW CODE

EDW code [7] is another version of DW code [6]. The EDW code weights can a variable weight that is grater than one. In this paper, the EDW with the weight of three is used as an example. As a family of DW code, EDW can also be represented by using the KxN matrix. The essential EDW code denoted by (6, 3, and 1) is shown below

$$H1= \left|\begin{array}{cc|cc|cc} 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \end{array}\right| \quad (1)$$

Perceive that a similar structure of the basic DW code is still maintained with a minor modification, whereby, the double weight pairs are maintained in a way to consent to only two overlapping chips in every column. Thus, the 1, 2, 1 chips combination is maintained for every three columns as in the basic DW code [4, 6]. This is important to maintain $\lambda=1$. The same mapping technique as for DW code is used to augment the number of user. The example shows that we can increase the number of users from three to six while the weight is still fixed at three. An EDW code with weight of four denoted by (N, 3, 1) for any given code length N, which can be related to the number of user K through.

$$N = 2K + \frac{4}{3}\left[\sin(\frac{K\pi}{3})\right]^2 \left[\frac{8}{3}\left[\sin(\frac{(K+1)\pi}{3})\right]^2 + \frac{4}{3}\left[\sin(\frac{(K+2)\pi}{3})\right]^2\right] \quad (2)$$

3. Performance Analysis

The performance of MDW, MFH and Hadamard codes was simulated by using commercial simulation software, OptiSystem Version 7.0. A simple schematic block diagram consisting of 4 users is illustrated in Fig. 2. Each chip has a spectral width of 0.8 nm. The test was carried out at the rate of 10 Gbps for 70 km distance with the ITU-T G.652. Standard single mode optical fiber. All the attenuation (i.e. 0.25 dB/km), dispersion (i.e. 18 ps/nm-km) and non-linear effect was activated and specified according to the typical industry values to simulate the real environment as close as possible. The performance of the system was evaluated by referring to the bit error rate, BER and the eye pattern.

At the receiver side of the system, the incoming signal splits into two parts, one to the decoder who has an identical filter structure with the encoder and the other to the decoder who has the AND filter structure. A subtracted is then used to subtract the overlapping data from other users. The results (eye pattern) taken after the subtraction for MDW, Hadamard MFH codes.

4. AND- Subtraction Detection Technique for EDW Code

In This example shows that it is possible to transmit multiple light wave signals on different wavelengths

(WDM) to increase the overall data transmission rate. In most researches [4-6-9], complementary method has been used at the receiver side to recover the original signal. In this paper, we introduce a new approach called AND subtraction technique. The purpose of this new subtraction is to reduce the receiver complexity and at the same time to improve the system performance AND-Subtraction detection technique[12] under EDW code designed is shown in Fig.3 for a weight code equal to three and user's code sequences: user 1 code sequence=0,0,λ3,λ4,0,λ6,; user 2 code sequence =0,λ2,0,0,λ5,λ6, user 3 code sequence= λ1, λ2, 0, λ4,0, 0,.

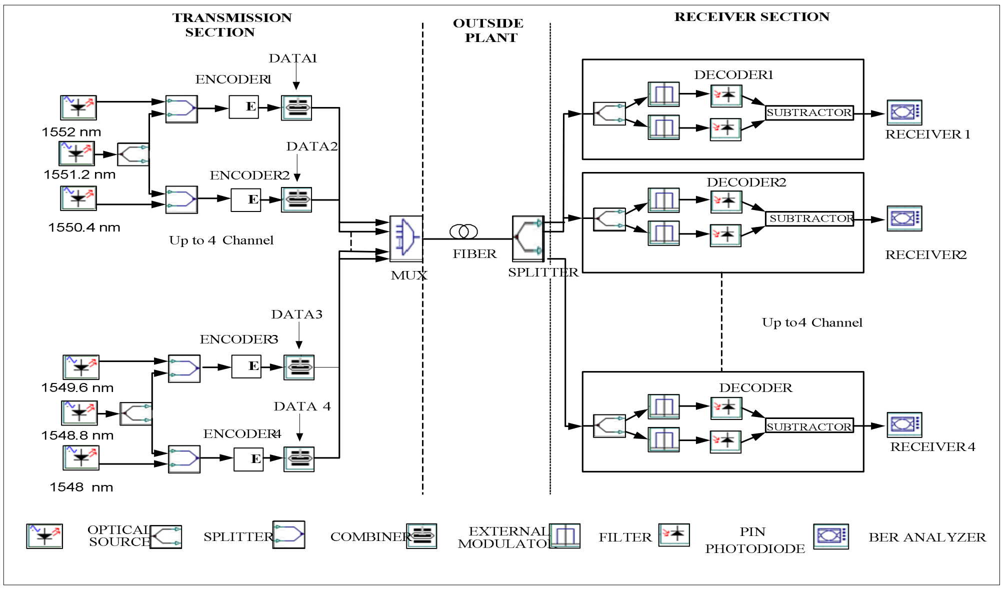


Fig 2. The system architecture of the OCDMA network.

The spectral amplitude signal at the receiver side splits into two branches. The upper branch has the signal for use X, including the overlapped chips between X and Y and the lower branch have the overlapped chips only. These overlapped chips can be represented mathematically by AND operation between X and Y.

Optical code-division multiple access (CDMA) systems have received more and more attractive in the field of all optical communications as multiple users can access the network asynchronously and simultaneously with a high level of security. Optical spectrum code-division multiple -access (OSCDMA) is a multiplexing technique tailored from the successful implementation in a wireless network [8, 15].

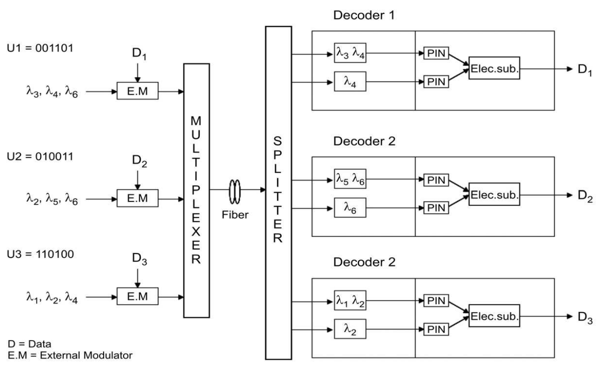


Fig 3. OCDMA system using AND-Subtraction detection technique Under EDW code.

5. Simulation Setup

The simulation has been carried out by using opt system software version 7.In order to study the FSO using EDW code in fiber to the home (FTTH) access network for three users. In point-to-multi-point (P2MP), the network has been divided into two sets, which are: with (EDFA) amplifier and without (EDFA) amplifier. A simple schematic block diagram for P2MP is illustrated in Figure 3. The system is represented by three sections: transmitter section, free space optics section and receiver section. In the transmitter part for P2MP each of optical line terminal (OLT) consists of five components: pseudo random bit sequence (PRBS), non-return-to-zero (NRZ) pulse generators, single light source diode (LED), filters and external modulators. In this occupation, we used two models one used RZ pulse generator, with and without erbium doped fiber amplifier (EDFA), and the second model by using the NRZ pulse generator also with and without erbium doped fiber amplifier (EDFA).The fiber Bragg grating (FBG) is used as a filter as encoder and decoder. The function of the encoder is to encode the source signals according to the specific code it uses (Fig.4). The modulators are Mach-Zehnder modulator, which is an intensity modulator based on an interferometer principle. The signals that coming from the transmitter will be combined by multiplexer and drive through Free Space Optical (FSO). The Free Space length section used for the transmission at 1550 nm wavelength. At the receiver part, it shows the equipment at the customer premises (Fig.5). The incoming signal is split into two parts, one to the decoder who has an identical filter with the encoder and the other to the decoder who has the complementary filter. An electric subtracted is used to subtract the overlapping data from the wanted one. The performance of the system referring to the bit error rate (BER) at BER analyzer with the same setup, we place the EDFA with 20 dB gain, immediately after the transmitter to launch power signals into the fiber to see the difference of performance on FTTH system by using an OSCDMA multiplexing scheme [5, 9].

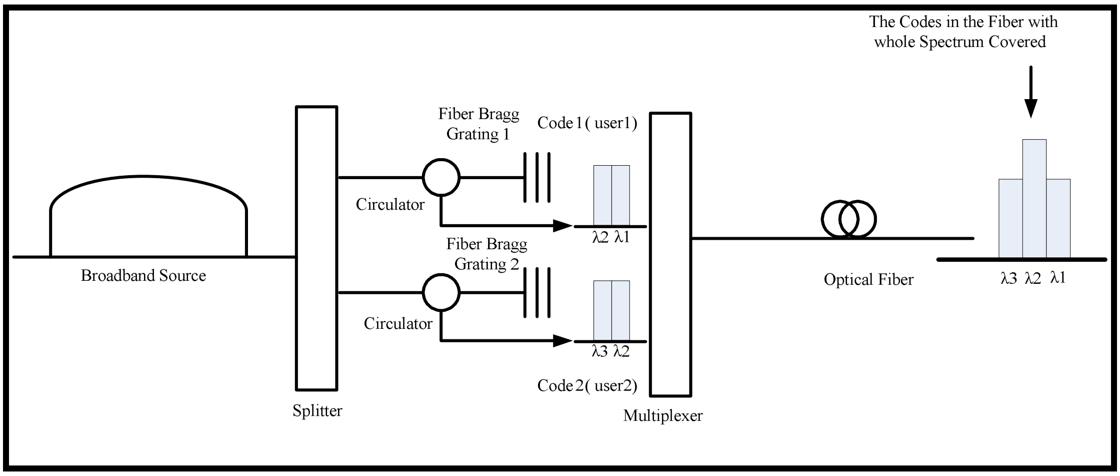


Fig 4. *Encoder Configurations and Encoding Process (Evolution of Spectrum).*

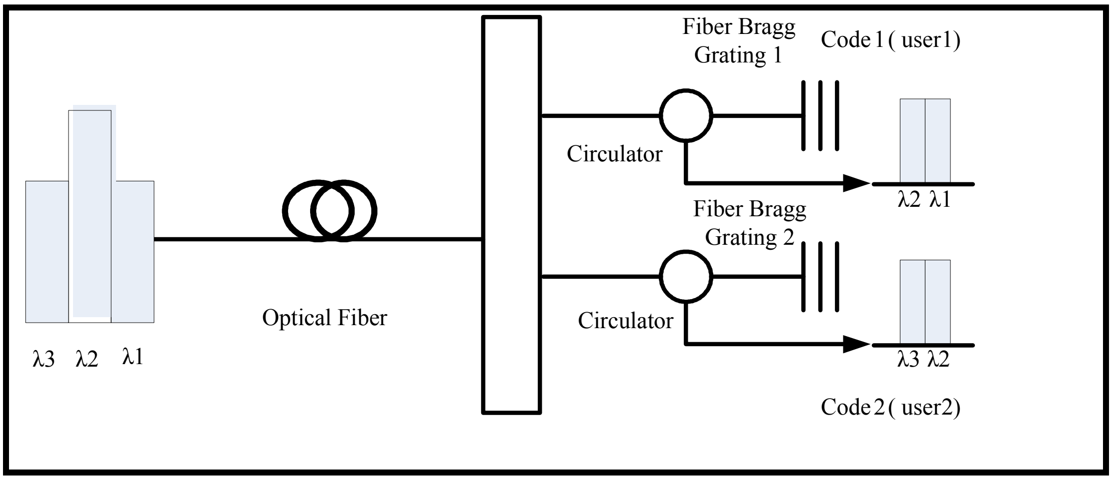


Fig 5. *Decoder Configurations and Decoding Process.*

6. Presentation Analysis

Referring to figure 6, we can see that in free space, we transmit the data for more than 100 km, at very stable system. The transmitter uses a LED source with a maximum optic's power of 6 dBm and a wavelength of 1550 nm. To ensure the linearity of the system, the LED is properly biased and the peak-to-peak voltage of the input signal cannot exceed the specified values. So it's illustrated that at 100km distance, the data can transfer clearly as BER equal to the value of $10e^{-9}$while in the 10 km the BER will be at value of $10e^{-24.}$

Hence, we can say this is a good result for this system. For these results, the following parameters were used: line width thermal noise= $3.75x10^{12}$ Hz; electrical bandwidth = 80 MHz at the operating wavelength of 1550 nm.

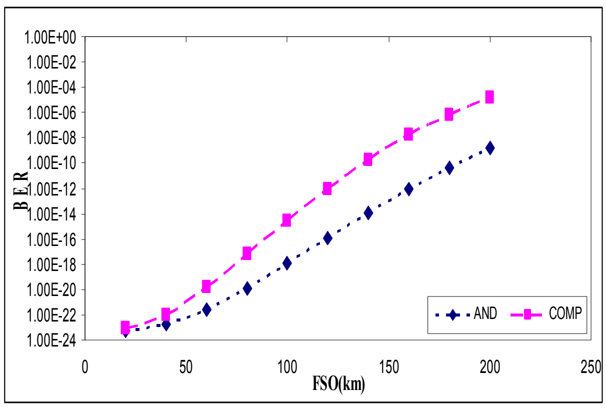


Fig 6. *BER versus fiber length for EDW code.*

Furthermore, in this system we use two types of receiver detection techniques in the same design, AND-Subtraction and Complementary – subtraction detection technique. For EDW code the more suitable technique is AND-Subtraction as appearing from the results we can obtain from the software optisystem used. In figure 4 it seems that for long FSO distances 200km, the BER will be $1.7x10^{-9}$,$1.37x10^{-5}$ for AND and Complementary detection respectively. Also for data rate comparisons as from figure 5 the BER values for at 1 Gbps, $4.74x10^{-17}$ and $5.99x10^{-15}$ for AND-Subtraction and Complementary –Subtraction respectively.

From figure 8 the eye diagram gives a quick examination of the quality of the optical signal. It's clearly depicted that the EDW code system gives a better performance, having a large eye opening. The vertical distance between the top of the eye-opening and the maximum signal level gives the degree of distortion. The more the eye closes, the more difficult it is to distinguish between 1s and 0s in the signal. Hence in our results in the low data rate the eye patterns will be equal to $10e^{-24}$ for 155 Mpbs, while BER at high data rate will be equaled to 10^{e-6} at 2Gpbs.Refering to the Figure 8(a) and (b) respectively.

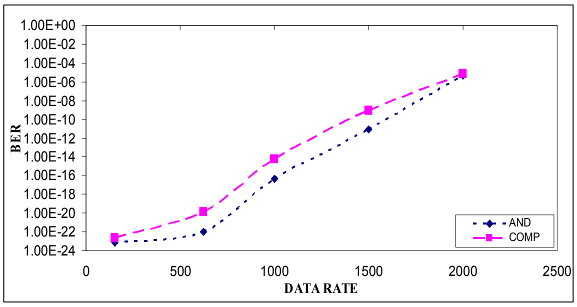
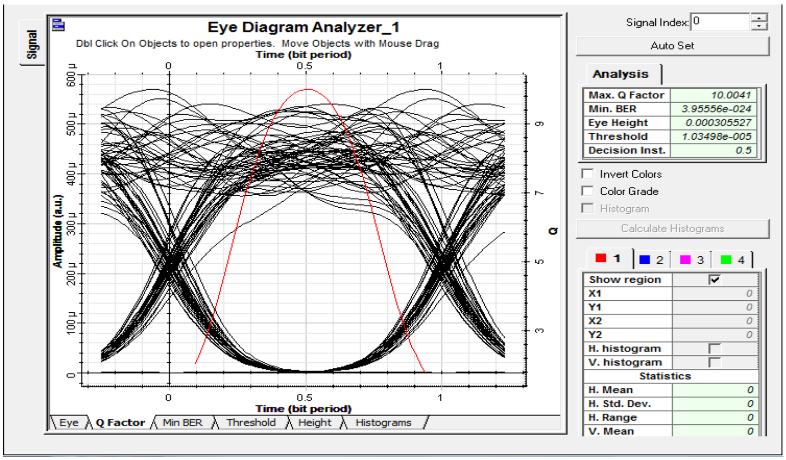
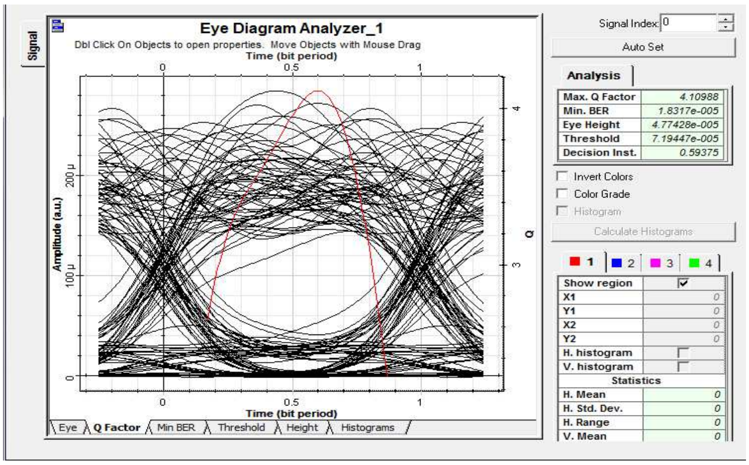


Fig 7. *BER versus Bit rate for EDW code.*



(a) 155 Mpbs



(b) 2Gpbs

Fig 8. *The eyes diagram for three users using AND subtraction technique.*

7. Conclusion

The unlicensed, higher speed, broader and unlimited bandwidth, low-cost solution, and shortest deployment time frame are some of the drive to deploy FSO. In this paper, we have discussed that to transfer data (voice, sound and data) through two buildings. We can use a modified laser with high data rate up to 2.5 Gbps using EDW code in free space with AND-Subtraction detection technique, which is more suitable for system stability, also make a comparison between the two detection technique AND-

Subtraction and Complementary –Subtraction and seem that AND is better than Complementary in this system design based on EDW code in FTTH network access. This will be reducing the longer fiber length besides increasing the data rate to be transferred. From the results optioned at 100 Km distance using free space optics (FSO) to transfer data to the receiver's, the BER.EDW code is a double Weight (DW) code family variation that has weight greater than one. This code possesses numerous advantages, including the efficient and easy code construction. Finally, we can see that an EDW code design application based on FSO has a great potential to become one of the optical communication suitable system for OCDMA implemented in FTTH application. And by using the FSO the OCDMA network will be expanding directly.

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