International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013
ISSN 2229-5518

Analysis optimum transmit power of 10 Gbits optical CDMA system in fiber-to-the-home access network

N. Ahmed, S. A. Aljunid and R. B. Ahmad

Abstract— In this paper, the optimum transmits power for an optical code division multiple access (OCDMA) is analyzed at different data rates and transmission distance. We used Enhance Double Weight (EDW) codes as a signature address in designing the system because this code can accommodate more number of simultaneous users under considerable standard Bit-Error-Rate (e.g. ≤ 10^{-9}). The induced EDW codes for OCDMA system can suppress multiusers interference and increase the bit-error-rate performance with optimum transmit power. The numerical simulations have been taken into the account to carry out analysis. We ascertained by simulation results that the optimum power is decreases with the distance and high bit rate and maintain error floor transmission rate ($10e^{-09}$).Therefore this system can be considered as a promising solution for optical access network such as Fiber-to-the-Home access network.

Index Terms— Optical Code Divission Multiple Access (OCDMA), Enhance Double Weight (EDW), Fiber Brag Grating (FBG), NAND subtraction, AND Subtraction, Fiber –to-the-Home (FTTH), Multiple Access Interference (MAI).

1. INTRODUCTION

MORE than one decade, the rapid advance has been realized in the optical fiber communication technology with significant reduction of loss in single mode fiber. The main progress has been obtained in high sensitivity and high-speed optical detectors, development of high-speed semiconductor laser diodes, and the advance of optical amplifiers to the fiber communication transmission capacity. These advances have had an important impact on the field of optical telecommunications system and widely used in many more applications of communication engineering [1]. Optical Code Division Multiple Access (OCDMA) has been recognized as one of the most important technologies for supporting many users in shared media simultaneously, and in some cases can increase the transmission capacity of an optical fiber [2]. OCDMA has been exciting developments in short haul optical networking because this system can supports both wide and narrow bandwidth applications on the same network. In addition, it connects large number of asynchronous users with low latency. The jitter, permits quality of service guarantees to be managed at the physical layer which offers robust signal security and has simplified network topologies. In order to suppress the MAI effect sufficiently, many subtraction techniques with codes fixed in-phase cross correlation have been proposed [3-4].

The detection is one of the important processes to design the system transmitter and receivers. In general, there are two well known basic detection techniques, namely coherent and incoherent [5]. The knowledge of the phase information of the carriers keeps big impact when coherent detection send detection signal. On the other hand, the incoherent detection has no such kinds of information. Alternatively, the incoherent OCDMA is performed in a unipolar approach and coherent is performed in a biopolar behavior with the coding operation. The less hardware complexity of incoherent detection makes a popular candidate compared to coherent detection. Moreover, the incoherent detection does not need phase synchronization. The application of the coherent technique will be more difficult than incoherent technique. Therefore, we have chosen the incoherent detection technique based on spectral-amplitude-coding (SAC) for this research. However, the cross correlation function is always generated in the incoherent code words. As results, the multiple access interference (MAI) is generated in the system due to this cross correlation, which can be reduced by using a suitable detection technique in OCDMA systems.

Many kinds of detection techniques are available and already proposed by many researchers [3, 6, 7 and 8]. The well known detection techniques are the complimentary subtraction technique [6 and 7], the AND subtraction technique [7], the spectral direct detection technique (SDD) [8] and the XOR subtraction technique [4]. However, all these detection techniques have various limitations. Although some of these detection techniques has successfully reduced the MAI effect but still suffering from the poor signal quality, which is considered as a big limitation of the existing detection techniques. The Enhance Double Weight (EDW) [8] code was successfully applied in the complimentary and AND subtraction techniques but the problem of poor signal

- *Dr. N. Ahmed is currently workingas senior lecture in school of computer and commuinication engineering in University, Malaysia Perlis (UniMAP)PH-+6049798686. E-mail:nasim751@yahoo.coml.com*
- *Pro.Dr.S.A.Aljunid is currentlyworking as dean of R&D in University, Malaysia Perlis (UniMAP). E-mail:syed@ unimap.edu.my*
- *Prof. Dr. R. B. Ahmad is currently working as a dean of school of computer and communication engineering, University Malaysia Perlis(UniMAP. E-mail:badly@ unimap.edu.my*

quality remain the same. In order to solve this problem, we introduce a new detection technique named the NAND subtraction detection technique [9], which can reduce the MAI in a significant amount. OCDMA is a multiplexing technique taking the advantage of the large bandwidth of fiber and flexibility of code division multiple accesses. Now it is getting more and more attention, because of its prominent advantages, such as unique confidentiality, scalability, asynchronous access, convenient network management and etc [10]. Therefore, this proposed OCDMA system would then be a prospective candidate for the future FTTH access network.

The remainder of this paper is organized as follows. In Sec II, we review MDW code construction. We discuss about detection technique in Sec III. The Sec IV shows the system architecture. Network simulation setup is shown in Sec V. Results and discussions are shown in Sec VI, and finally some conclusions are drawn in Sec VII

2. EDW Code Construction

The basic matrix for the EDW code consists of $K \times N$ matrix depending on the value of the code weight. The general form of the basic matrix of an EDW code with weight *W* is shown in Fig. 1, where all the component matrices [A_1], [A_2], .., [A_w] depend on *W*. The basic matrix consists of the minimum number of *K* and *N* for the specific number of code weight. From the basic matrix, a larger number of *K* can be achieved using the mapping technique as bellow:

$$[H] = \begin{bmatrix} & \vdots & & \vdots & & \vdots & \\ & \vdots & & \vdots & & \vdots & \\ A_1 & \vdots & A_2 & \vdots & \dots & \vdots & A_w \\ & \vdots & & \vdots & & \vdots & \\ & \vdots & & \vdots & & \vdots & \end{bmatrix}$$

Fig.1. General form of the EDW code matrix [12].

The size of each matrix consist of $K_a \times N_a$, Where:

$$K_a = W \qquad (1)$$

and

$$N_a = \frac{\sum_{j=1}^{w} j}{W} \qquad (2)$$

The basic matrix for EDW consists of a 3×6 matrix. The component matrices are [A_1], [A_2], and [A_3]. The size of matrix [A] is 3×2, after using Eqs. (1) and (2). The combination sequence for each matrix is 2 and 1. The basic EDW code denoted by (6, 3, 1) is shown [9]. The basic matrix consists of a chip-combination sequence of 1,2,1,2… (alternating 1's and 2's) for the columns. A chip combination is defined as the summation of the spectral chips (1's and 0's) for all users (or rows) in the same column with each code sequence allowed to overlap at most, once with every other sequence in the columns of the matrix.

2.1. NAND Subtraction Technique

The mobility of the digital electrons in NAND gate is three times higher than AND gate as well as NOR gate [11]. This statement refers to the digital logic gates (AND, OR, NAND). However, in our proposed system the idea of NAND is used as an operation, not as a digital gate. Considering this point of view, the authors brought the concept of the NAND subtraction technique in our study. In the NAND subtraction detection technique, the cross-correlation $\theta_{\overline{X}Y}(K)$ is substituted by $\theta_{(\widetilde{XY})Y}$, where $\theta_{(\widetilde{XY})}$ represents the NAND operation between X and Y sequences. For example, let $X = 1100$ and $Y = 0110$ therefore the NAND is $(\widetilde{XY})Y = 0010$. Fig. 2 shows the implementation of NAND subtraction detection technique and Table 1 shows the comparisons between complementary and NAND subtraction detection technique using EDW codes.

Table.1Comparison of complementary and NAND subtraction detection technique

	Complementary Subtraction				NAND Subtraction			
	λ_1	λ_2	λ_3	λ_4	λ_1	λ_2	λ_3	λ_4
X	1	1	0	0	1	1	0	0
Y	0	1	1	0	0	1	1	0
	$\theta_{XY} = 1$				$\theta_{XY} = 1$			
	$\overline{X} = 0011$				$\theta_{\widetilde{XY}} = 1011$			
	$\theta_{\overline{X}Y} = 1$				$\theta_{(\widetilde{XY})Y} = 1$			
Z	$Z = \theta_{XY} - \theta_{\overline{X}Y} = 0$				$Z = \theta_{XY} - \theta_{(\widetilde{XY})Y} = 0$			

Note that λ_i (where i is 1, 2…..N) is the column number of the codes which also represents the spectral position of the chips. Therefore, MAI can be cancelled using both techniques. However, NAND subtraction detection technique can generate extra weight as shown in Table 1. This is due to the fact that when the code weight is increased, the signal power increases as well; hence, increases the signal-to-noise ratio. Therefore, The OCDMA performance is improved significantly using the NAND subtraction detection technique.

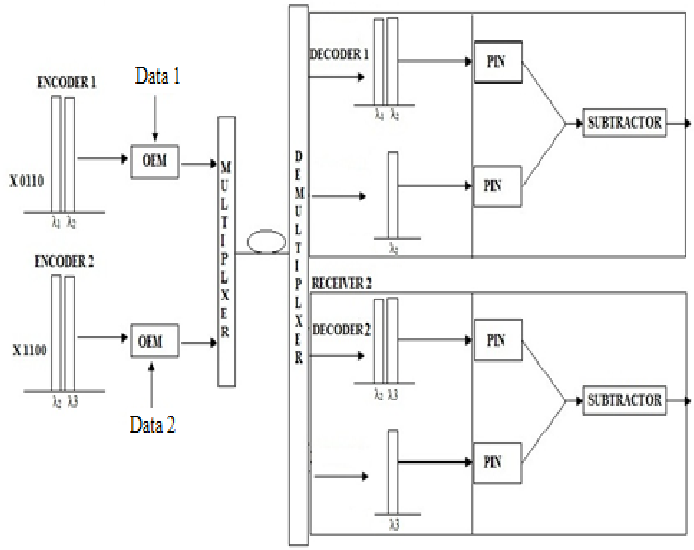


Fig.2. Implementation of NAND subtraction technique

3. Network Simulation Setup

A simple schematic block diagram consisting of three users are illustrated in Fig. 3. This system each chip has a spectral width of 0.8 nm. The tests were carried out at the rate of (10 Gbits), for 30 km. The fiber used had the values of parameters taken from the data which are based on the G.652 Non Dispersion Shifted Fiber (NDSF) standard. This included the attenuation, group delay, group velocity dispersion, dispersion slope and effective index of refraction, which were all wavelength dependent. The non-linear effects such as the Four Wave Mixing and Self Phase Modulation (SPM) were also activated and specified according to the typical industrial values to simulate the real environment as close as possible. The system specifications listed in Table 1 were used throughout the simulation. At 1550 nm wavelength, the attenuation co-efficient was 0.25 dB/km, and the chromatic dispersion co-efficient was 18ps/nm-km and the polarization mode dispersion (PMD) co-efficient was 0.5 ps/sqrt (km). The transmit power used was between -5 dBm to 5 dBm out of the broadband source. The noises generated at the receivers were set to be random and totally uncorrelated. The dark current value was 5 nA and the thermal noise co-efficient was 1.8×10^{-23} W/Hz for each of the photodetectors. The performance of the system was evaluated by referring to the bit error rate, received power, transmit power and the eye pattern. Fig.3 shows the system simulation setup which has transmitter and receiver. At the transmitter, the coherent light (Lesar) source is used. The pseudo-random bit sequence generator and non-return-to-zero (NRZ) pulse generator to generate the input signals, an external modulator to modulate the input signal into the optical signal. The modulated signal is transmitted through single mode optical fibe. The function of the encoder was amplitude spectrally encode the source according to the specific used code which is Enhance Double Weight (EDW) code with a weight three. At the receiver side consist of FBG which act as a decoder, PIN photo-detectors and low pass filters. The decoding scheme used was NAND subtraction. A subtractor is used for subtract the overlapping data from the desired one.

Tabel.1: Summary of system specifications

Data rate	10 Gbits, 2.5 Gbits and662 Mb/s
Channel spacing	0.8-nm
Insertion loss	0.25 dBm
Mux/Dmux insertion loss	2 dBm
Fiber attenuation	0.25dB/km

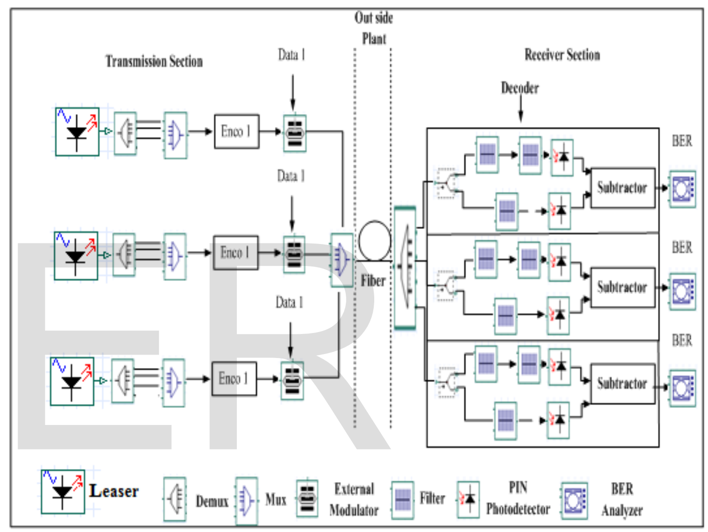


Fig.3. Simulation setup for the OCDMA system with NAND subtraction detection technique

4. Results and Discussion

Fig. 4 depicts the relationship between received power and the measured BER for NAND subtraction technique at (10 Gbits, 2.5 Gbits and 622 Mbps) data rates. The optical fiber length was fixed (30 km) for the analysis. It clearly shows that, the system using NAND subtraction technique at various bit rate 10 Gbits, 2.5 Gbits and 622 Mbps the BER is $4.05e^{-10}$, $2.02e^{-24}$ and $1.63e^{-39}$ respectively when the minimum transmit power is -2 dBm. (10^{-13}) and received power -19.189 dBm, -20.586 dBm and -21.700 dBm respectively. The Fig. 4 demonstrates that at low bit rate (622 Mbps) BER and received power is better as compare to high bit rate. However, at high bit rate (10 Gbits) the system can have standard error free transmission value BER $4.05e^{-10}$ with optimum received power (19.189 dBm). The main objective of this analysis is to find out the optimum received power with standard error free ($10e^{-09}$) transmission value for high bit rate system. On the other hand Fig.5 presents the effect of transmit power against BER at various bit rate 10 Gbits, 2.5 Gbits and 622 Mbps for fixed fiber length (30 km). As it is seen from Fig. 5 that at 10 Gbits the system require -2 dBm transmit power to maintain the error floor transmission rate where as 2.5 Gbits and 622 Mbits require transmit power -4 dBm and -5 dBm. Although, is this study we have considered maximum input power 5 dBm. At transmit power 5 dBm the system BER is 2.83e^{-33}.

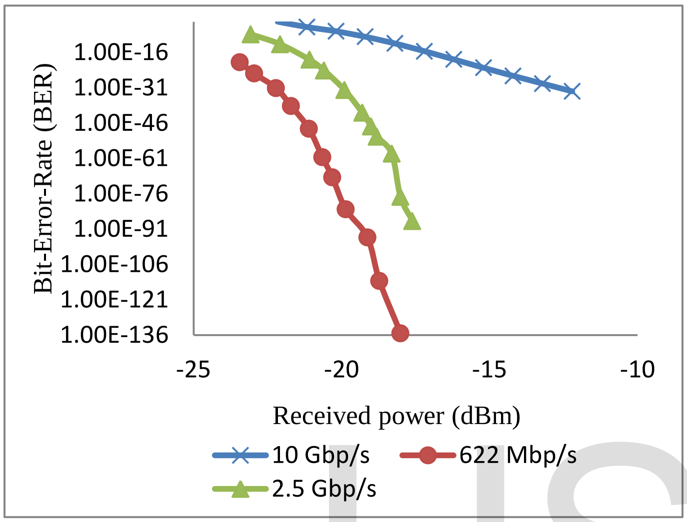


Fig. 4. Received power versus BER for different bit rates and a fixed transmission distance (30 km)

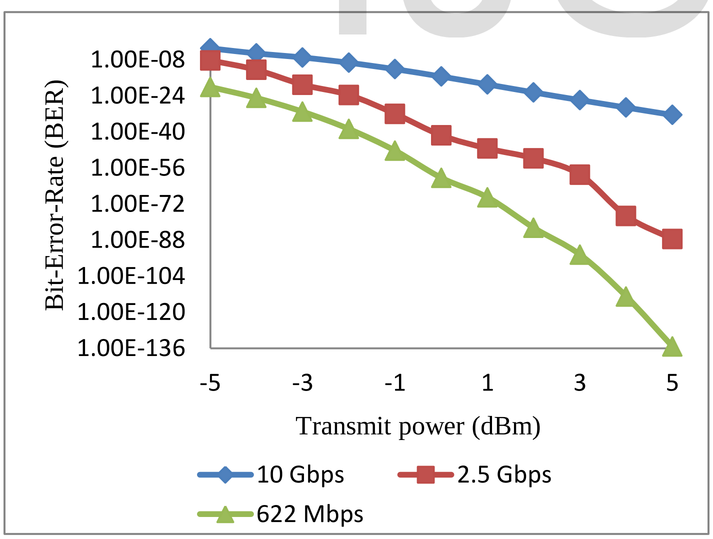


Fig. 5. Transmit power versus BER for different bit rates and a fixed transmission distance (30 km)

As shown in Fig.6, that the system using new detection technique shows BER in fixed bit rate in respect to the different fiber length (15 to 30 km). It is found that the system can transmit excellent signal up to 30 km at 10 Gbits. The transmit power 0 dBm is taken for analyzing the performance. It is also seen from fig.6 that as the distance increase the error floor become worst and received power is high. Though, the received power is slightly high but the signal quality is exactable range which satisfies the error free transmission rate (10e^{-09}). On the other hand, Fig. 7 shows the effect of transmit power on the BER. It is also found that, as the input power is increased the error floor is decries. To conclude all the results, we found that the system pwer distribution and BER is very much depended on bit rate. Moreover, the performance of the NAND subtraction technique is evident at all rates with supportable distance to support by the conventional technique. In Fig. 7 (a, b and c) shows the measured eye patterns at (10 Gbits, 2.5 Gbits and 622 Mbps). It clearly illustrates that using new detection technique the system had a better performance with a larger eye opening at 10 Gbits data rate.

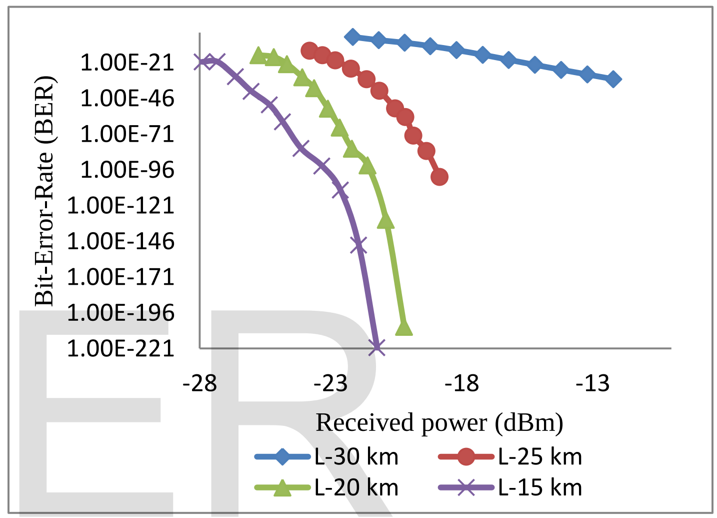


Fig.6. Received power versus BER for different transmission distance with a fixed bit rate of 10 Gbits

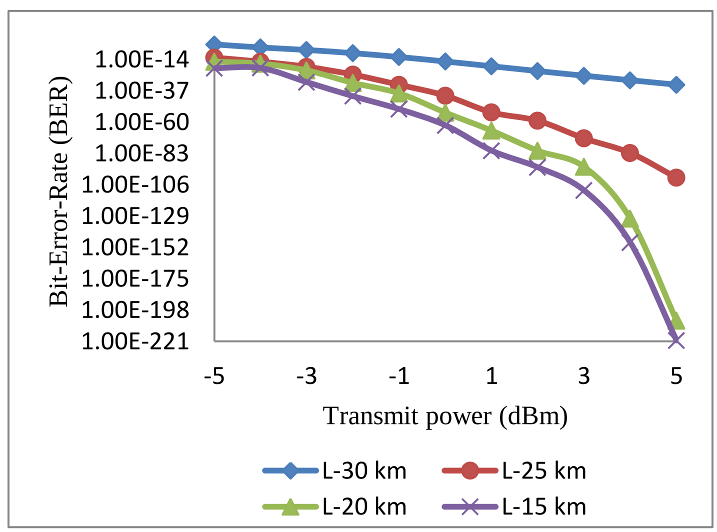
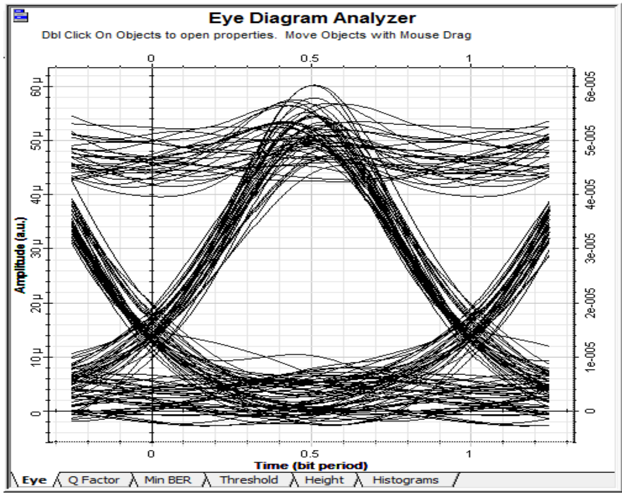
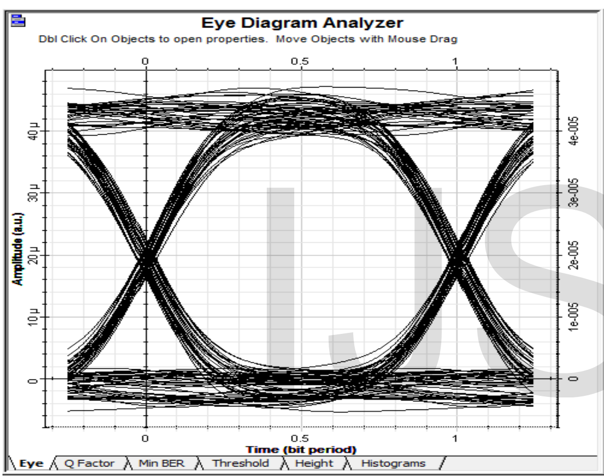


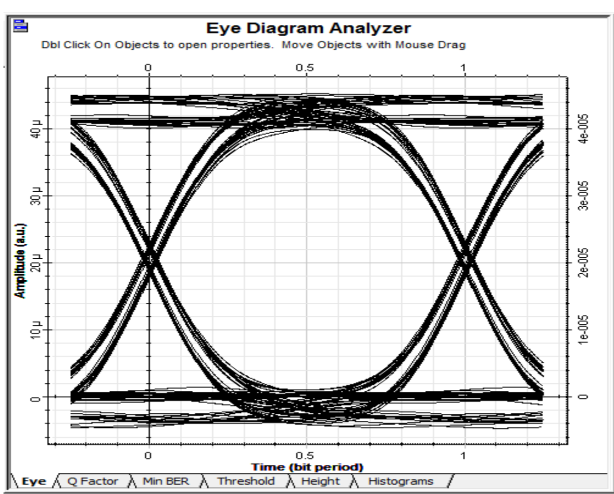
Fig. 7. Transmit power versus BER for different transmission distance with a fixed bit rate of 10 Gbits



(a). 10 Gbits bit rate



(b). 2.5 Gbits



(c). 622 Mbps

6. Conclussion

In this paper, optical CDMA system has been analyzed using numerical simulation to find out the optimum transmit power at different bit rates and transmission distance. The NAND subtraction technique has been applied in the receiver to improve the system performance. The Enhance Double Weight (EDW) code is used as a signature address of the system. The analysis has revealed that the system at 10 Gbits, the received power is acceptable when transmitting power is -2 dBm. It has been also shown that the system can maintain error floor transmission rate ($10e^{-09}$) with low transmit power (-4 dBm) for 30 km. To consider these advantages, it is concluded that the proposed system can be suitable for Fiber-to-the-Home (FTTH) access network to fulfill the consumer's demands.

References

[1] A.F. Hillal, S. A. Aljunid and R. B. Ahmaad, "Effect of random diagonal code link of an OCDMA scheme for high-speed access networks," Journal of Opt. Fiber Technol, vol. 15, no. 3, pp. 237-240, June 2009, doi.org/10.1016/j.yofte.2008.11.001. (Optical Fiber Technology)

[2] Z. H. Wei and Ghafouri-Shiraz, "Codes for spectral-amplitude-coding optical CDMA systems," Journal of Lightwave Technol, vol. 50, no. 8, pp. 1284–1291, Aug 2002, doi:10.1109/JLT.2002.800301, 2002.12.10. (Lightwave Technology)

[3] E.D.Smith and R. J. Blaikie,"Performance enhancement of spectral-amplitude-coding optical CDMA using pulse-position modulation," IEEE Trans. Commun., vol. 46, no. 9, pp. 1176-1185, Sep 1998, doi:10.1109/26.718559, 6-08-2002 (IEEE Transactions)

[4] H.Y.Ahmed, I.Faye, N.B.M.Saad and S.A.Aljunid," OCDMA system: new detection scheme and encoder- decoder structure based on fiber bragg gratings (FBGS) for Vcc code," Int. Journal of Computer and Application vol.32, no.4, pp. 2878-2881, April 2010, doi: 10.2316/Journal.202.2010.4.202-2881 (Int. J. of Comp. Appl.)

[5] W.Huang, M.H.M. Nizam, I. Andonovic and M. Tur," Coherent Optical CDMA (OCDMA) Systems used for High Capacity Optical Fiber Networks System Description, OTDMA Comparison, and OCDMA/WDMA Networking," Journal. of Lightwave Technol, vol.18, no.6, pp. 765-778, June 2000, doi:10.1109/50.848384 (Lightwave Technol)

[6] L. Nguyen, B. Aazhang, J. F. Young, "All-Optical CDMA With Bipolar Codes," Elect. Letters, vol.31, no.6, pp. 469-470, March 1995, doi: 10.1049/el: 19950296 (Electronic letters).

[7] S.A. Aljunid, M.Ismail, A.R. Ramli, M. A. Borhanuddin, and Mohamad Khazani Abdullah, "A New Family of Optical Code Sequences for Spectral-Amplitude-Coding Optical CDMA Systems," IEEE Photon Technol. Letters, vol. 16, no.10, pp. 2383-2385, October 2004, doi: 10.1109/LPT.2004.833859, (IEEE photonic letters).

[8] M. K. Abdullah, N. Feras. Hasoon, S.A. Aljunid, Sahbudin Shaari, "Performance of OCDMA Systems with new spectral direct detection (SDD) technique using enhanced double weight (EDW) code," Journal of Optical Communication, vol. 281, no. 18, pp. 4658-4662, Sept 2008, doi: http://dx.doi.org/10.1016/j.optcom.2008.06.029, (Optical communication)

[9] N.Aahmed, S.A.aljunid, R.B. Ahmad, H. A. Fadhil, and M.A. Rashid," Performance Improvement of Spectral Amplitude Coding-Optical Code Division Multiple Access Systems Using NAND Detection with Enhanced Double Weight Code" Optical Review, vol. 19,

no.1, pp. 1-6, Oct 2011, doi: 10.1007/s10043-012-0001-2, (Optical review)

[10] J. Huang, Y. Chang and C. Hsu, "Hybrid WDM and Optical CDMA Implemented over Waveguide-Grating-based FTTH Networks," Optical Fiber Technolo, vol 13, no. 3, pp. 215-225, July 2007, doi: 10.1016/j.yofte.2007.02.002, (Optical Fiber).

- *Dr. N. Ahmed is currently workingas senior lecture in school of computer and commuinication engineering in University, Malaysia Perlis (UniMAP)PH-+6049798686. E-mail:nasim751@yahoo.coml.com*
- *Pro.Dr.S.A.Aljunid is currentlyworking as dean of R&D in University, Malaysia Perlis (UniMAP). E-mail:syed@ unimap.edu.my*
- *Prof. Dr. R. B. Ahmad is currently working as a dean of school of computer and communication engineering, University Malaysia Perlis(UniMAP. E-mail:badly@ unimap.edu.my*

- *Dr. N. Ahmed is currently workingas senior lecture in school of computer and commuinication engineering in University, Malaysia Perlis (UniMAP)PH-+6049798686. E-mail:nasim751@yahoo.coml.com*
- *Pro.Dr.S.A.Aljunid is currentlyworking as dean of R&D in University, Malaysia Perlis (UniMAP). E-mail:syed@ unimap.edu.my*
- *Dr. N. Ahmed is currently workingas senior lecture in school of computer and commuinication engineering in University, Malaysia Perlis (UniMAP)PH-+6049798686. E-mail:nasim751@yahoo.coml.com*
- *Prof. Dr. R. B. Ahmad is currently working as a dean of school of computer and communication engineering, University Malaysia Perlis(UniMAP. E-mail:badly@ unimap.edu.my*
- *Pro.Dr.S.A.Aljunid is currentlyworking as dean of R&D in University, Malaysia Perlis (UniMAP). E-mail:syed@ unimap.edu.my*
- *Prof. Dr. R. B. Ahmad is currently working as a dean of school of computer and communication engineering, University Malaysia Perlis(UniMAP. E-mail:badly@ unimap.edu.my*