International Journal of Nanoelectronics and Materials
Volume 14 (Special Issue) December 2021 [175-182]

Two Dimensional (2D) OCDMA Encoder/Decoder for Various Industrial Application

S M A Aljunid[1], M A Anuar[1], A A M Ismail[1], ND Keraf[3], R Matem[2], CBM Rashidi[1,2], N Ali[1,2*], M S Amirul[2], R Endut[1,2], N A M A Hambali[1,2] and S A Aljunid[1,2]

[1]Faculty of Electronic Engineering Technology (FTKEN), Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.
[2]Advanced Communication Engineering, Centre of Excellence (CoE), Universiti Malaysia Perlis, 01000, Kangar, Perlis, Malaysia.
[3] Department of Electrical Engineering, Politeknik Sultan Abdul Halim Mu'adzam Shah, 06000 Jitra, Kedah, Malaysia

ABSTRACT

Future telecommunication systems and networks are expected to provide a variety of integrated broadband services to the customers. There has been a tremendous interest in applying Code Division Multiple Access (CDMA) techniques to fiber optic communication systems. This technique is one of the multiple access schemes that is becoming popular because of the flexibility in the allocation of channels, ability to operate asynchronously, enhanced privacy and increased capacity in bursty networks. This project is focusing on designing 2D OCDMA system with the hardware implementation of design using FPGA. The coding techniques in OCDMA are time versus wavelength and amplitude versus phase. 2D OCDMA coding incorporates both wavelength selection and time distribution. The data bit would be encoded as consecutive chips with various wavelengths. The code architecture seeks to produce codes with high autocorrelation and low cross-correlation properties. Code length is an essential aspect of code and device architecture for coding characteristics. The hardware implementation of the system is designed by using FPGA De1-SoC. The FPGA have the abilities to enhance the transmission of data to the receiver in a short period of time. The performance of 2D OCDMA system is expected to surpass 1D OCDMA system in terms of BER and the number of simultaneous users that can be supported. The system encoder and decoder were designed using optical switch, splitter, combiner and modulator. The performance of 2D OCDMA system in terms of time spreading and wavelength spreading is also compared which shown a huge difference in the results. The best performance of the system is when the number of wavelength (M) is fixed to 18 and the number of times spreading (N) is 31 which can support 350 more simultaneous users.

Keywords: Optical Code Division Multiple Access (OCDMA), Multiple Access Interference (MAI), Flexible Cross-Correlation code (FCC), Field Programming Gate Array (FPGA), Bit Error Rate (BER)

1. INTRODUCTION

Optical networks are expected to provide variety of broadband services to the customers. The network must require an increase bandwidth as well as the throughput. The advanced in development of fibre optics has made all of this possible in transmission of data for modern communication technologies. Currently, all communication systems rely on fibre optic backbones. Increasing bandwidth demands mean more traffic to local antennas, making fibre more appealing. Most cellular users are upgrading older copper-wired [1] or wireless antenna [2,3] to fibre. A multiple access system is a communication system that allow a multiple user to share a common transmission medium to transmit the message into the specific destination.

*norshamsuri@unimap.edu.my

Optical Code Division Multiple Access (OCDMA) is one of the most important technologies nowadays. This OCDMA system can increase the number of transmission capacity of an optical fiber. OCDMA supports wide and narrow bandwidth application on the same network. The optical network supports various types of media transmission such as video, image and voice. Figure 1 shows the illustration of OCDMA system where OLT is Optical Line Terminal and ONU is Optical Network Units [4,5].

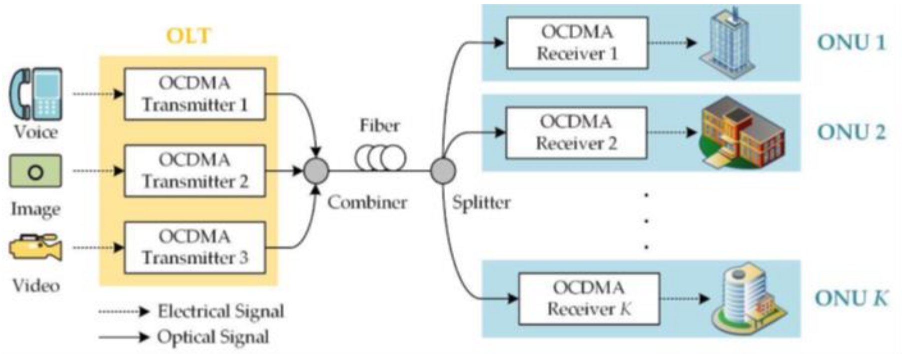


Figure 1. Illustration of OCDMA System [4].

In OCDMA systems, each user is assigned with a sequence code that serves as its address. The principle of OCDMA encoding involves multiplying the data bit by a code sequence either in the time domain or in the wavelength domain or known as 1D coding. On the other hand, a combination of both can also be used which is referred to as 2D coding. There are 2 types of OCDMA system which is 1D and 2D. One dimensional (1D) systems OCDMA use frequency domain or time as signal encoding while Two dimensional (2D) systems OCDMA use both time and frequency domain to encode the signals [6].

2. THE IMPLEMENTATION 2D OCDMA

This project is focusing on designing 2D OCDMA system with the hardware implementation of design using FPGA. The coding techniques in OCDMA are time versus wavelength and amplitude versus phase. 2D OCDMA coding incorporates both wavelength selection and time distribution. The data bit would be encoded as consecutive chips with various wavelengths. The code architecture seeks to produce codes with high autocorrelation and low cross-correlation properties. Code length is an essential aspect of code and device architecture for coding characteristics. The larger the code length, the similarity properties between codes also increases, thereby increase the device efficiency in terms of MAI, bit error rate (BER) and throughput. The key to an effective OCDMA system is the choice of efficient address codes with good or almost zero correlation properties for source encoding. This property can easily distinguish each codeword from any other sequence of addresses [7].

2.1 2D OCDMA Code Construction

The 2D OCDMA code were designed by using Spectral/Spatial Coding scheme. The 2D OCDMA system shows an enhanced performance to 1D OCDMA system in term of low power lost, high cardinality, high data transfer rate, minimum cross-correlation and high autocorrelation with minimum side-lobes. Many codes have been introduced in 2-D to overcome the problem faced in 1-D OCDMA code. The construction of the code is focused on designing an efficient code and architecture of the system to suppress the influence of Multiple Access Interference (MAI) and Phase Induced Intensity Noise (PIIN) [7 - 9]. To minimize the MAI and obtain high SNR, a code has been constructed and owned by both 1-D FCC [11] and 1-D MDW [12]. The combination of this code formed 2D FCC-MDW OCDMA code. The construction of the code begins with determining the codes for wavelength and time-spreading patterns. The code use 1D MDW as wavelength encoding pattern while 1D FCC code is sequenced as time spreading pattern. Given that $X = \{x0, x1, \ldots\ldots, xM - 1\}$ represents 1-D MDW code sequences while 1-D FCC code sequences represented by $Y = \{y0, y1, \ldots\ldots, yN - 1\}$ [6-11].

Next, the length of the code, code weight and the number of users must be determined. This code is denoted by (M × N, w, λa, λc) with the number of wavelengths M, temporal code length N, code weight w, λa is auto-correlation and λc is a cross correlation. the code lengths of X and Y are represented by $M = 3\sum_{j=1}^{\frac{k1}{2}} j$ and $N = K\,k2 - (K - 1)$. Therefore, the basic code sequences for 1-D MDW with [000011011], [011000110] and [110110000] is a wavelength encoding pattern. Furthermore, the time-spreading patterns employ the basic code sequences of 1-D FCC with [110] and [011]. Table 2 show the basic code construction for 2D FCC-MDW for k1=4, k2=2 where k is the code weight [6,8-12].

Table 1 Basic Code Construction 2D FCC-MDW for k1=4, k2=2 [6]

$A_{g,h}$	[000011011]	[011000110]	[110110000] X_g
$\begin{bmatrix}1\\1\\0\end{bmatrix}$	$\begin{bmatrix}000011011\\000011011\\000000000\end{bmatrix}$	$\begin{bmatrix}011000110\\011000110\\000000000\end{bmatrix}$	$\begin{bmatrix}110110000\\110110000\\000000000\end{bmatrix}$
$\begin{bmatrix}0\\1\\1\end{bmatrix}$	$\begin{bmatrix}000000000\\000011011\\000011011\end{bmatrix}$	$\begin{bmatrix}000000000\\011000110\\011000110\end{bmatrix}$	$\begin{bmatrix}000000000\\110110000\\110110000\end{bmatrix}$
Y_h			

3. TECHNIQUE AND METHODS

The OCDMA system design consist of transmitter (LED, Encoder, Modulator) and receiver (Decoder, Receiver) as shown in Figure 2. This system uses the basic flow system of Optical CDMA but with some improvement of the output devices. The code generator uses FPGA to generate code to the optical switch as implemented in one of our group implementation on quantum system [13]. The optical switch is presents in encoder and decoder.

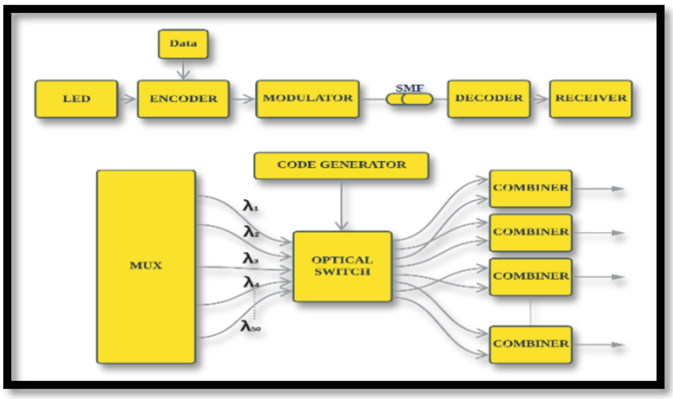


Figure 2. 2D OCDMA System Block Diagram

OCDMA are operated by code, instead of by using time slot or frequency. Since no synchronization between transmitter and receiver required in OCDMA system so there is no waiting time for its turn to transmit data signal. Figure 3 shows the illustration of the OCDMA code. Wavelength and time domain are used for developing the 2-dimensional coding area. Each wavelength channel in rows Nw, one-bit period is divided into time slots, Lt and it is indicated the number of chips available in the bit period per wavelength. The W of the code is the number of chips in which a light pulse.

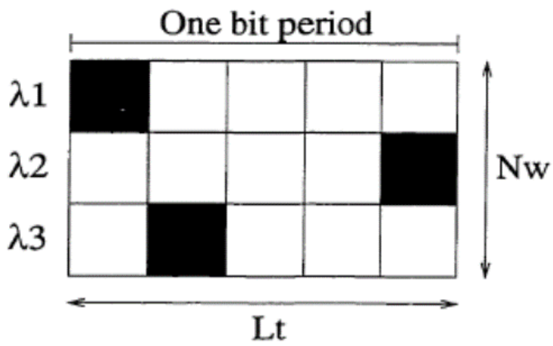


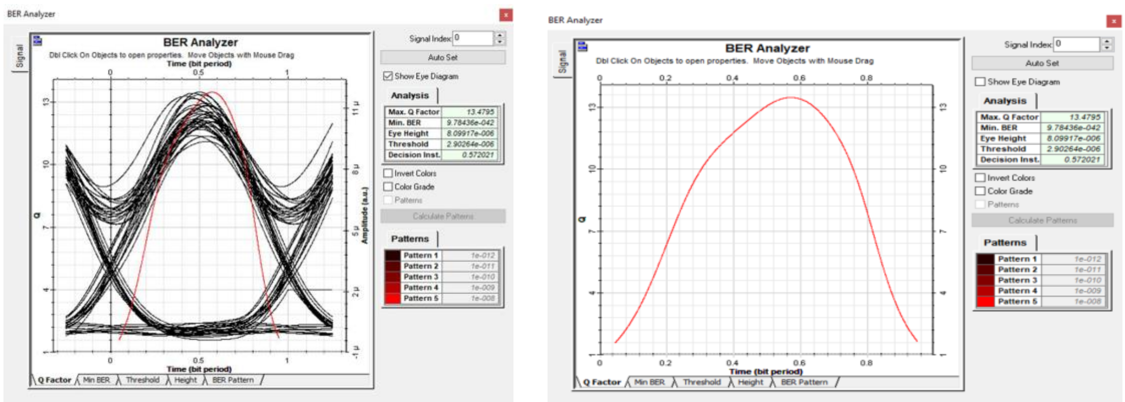
Figure 3. Illustration of OCDMA code

4. RESULTS AND DISCUSSION

The results are obtained by analyzing the performance of 2D OCDMA System using Optisystem software, FPGA clock performance and practical results.

4.1 2D OCDMA System Performance

The performance of 2D OCDMA systems is based on the output of receiver (Bit Error Rate) by using Optisystem software. Bit Error Rate (BER) obtained has passed the minimum value of 10^{-9} [14]. Figure 4(a) shows the eye diagram for the receiver receives information from transmitter. The BER is 9.78436×10^{-42} which is lower than 10^{-9}. Figure 4(b) shows the Q factor graph for this system. Q factor is an important parameter which determines the reliability of the communication. Q factor must be greater than six for error free optical communication. The value of Q factor for the first receiver is 13.4795.



(a) (b)

Figure 4. (a) Eye Diagram from the Receiver and (b) Q factor versus time

The wavelength spreading or number of wavelengths is represented by M, while the number of time spreading is represented by N. A suitable combination of code size (M x N) contributes an important feature to the code and system design.

The effect for the number of simultaneous users caused by the changes in the number of wavelengths and time spreading is shown in Figure 5(a). The curves in Figure 5(a) shows the variations combination of M and N of 2D FCC-MDW which include (M =9, N=10), (M =30, N=9) and (M =45, N=12). The data transmission rate is at 622Mbps and the effective power, Psr at -10dBm. The effect of varied wavelength and time spreading has been done separately. Figure 5(b) shows the graph with the number of wavelengths M, varies at 18, 30 and 84 while the number of time spreading, N is kept fix to 4. It can be observed that the varying value of number of wavelengths, M only makes a small difference in the number of simultaneous users. The BER against the number of simultaneous users for 2D FCC-MDW with the number of wavelengths, M fixed at 18 and variations of time spreading at 4, 10 and 31 is shown in Figure 5(c).

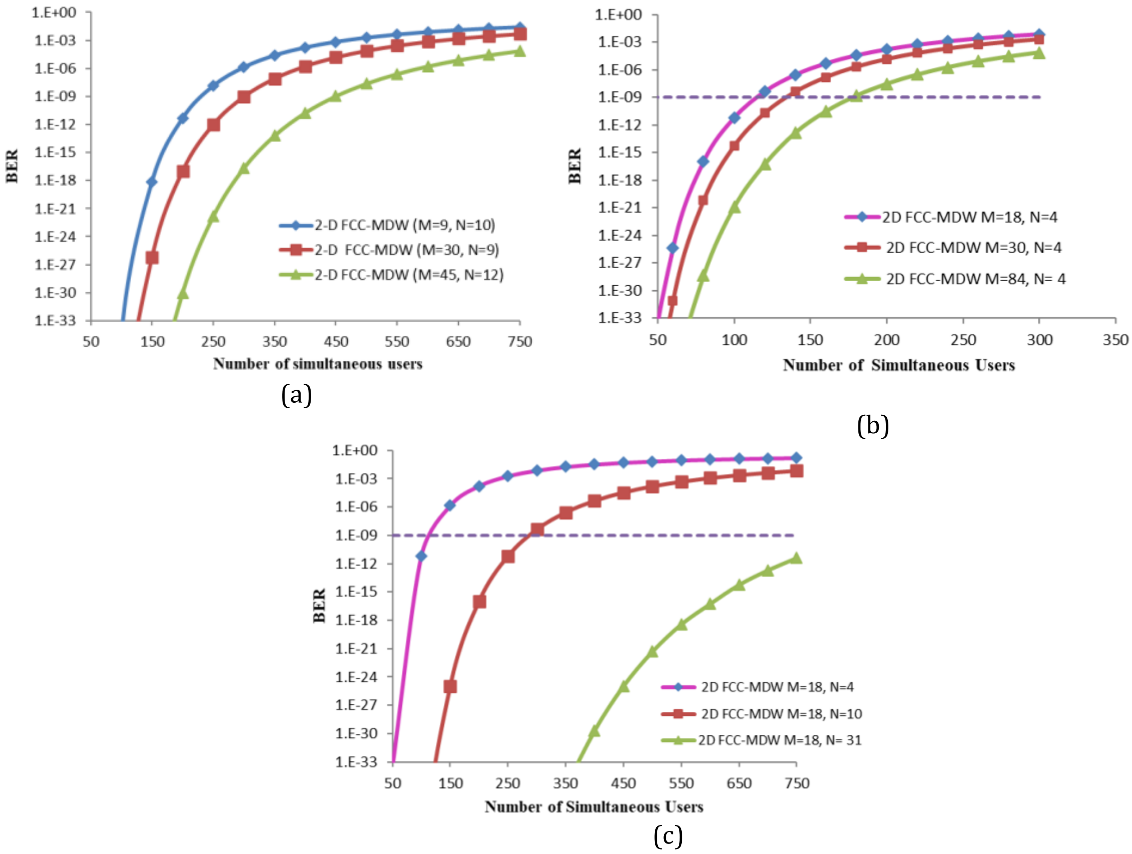
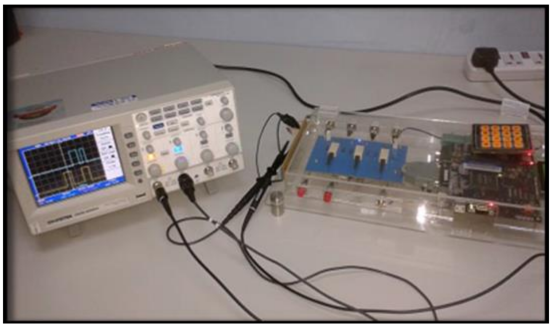


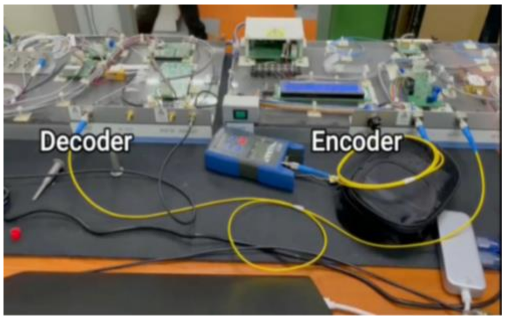
Figure 5. (a) Performance of BER against the number of simultaneous users for 2D FCC-MDW with the different number M and N, (b) Performance of BER against the number of simultaneous users for 2D FCC-MDW with the different number M and N and (c) Performance of BER against the number of simultaneous users for 2D FCC-MDW with the fixed value of M

4.2 2D OCDMA System with FPGA as Code Generator

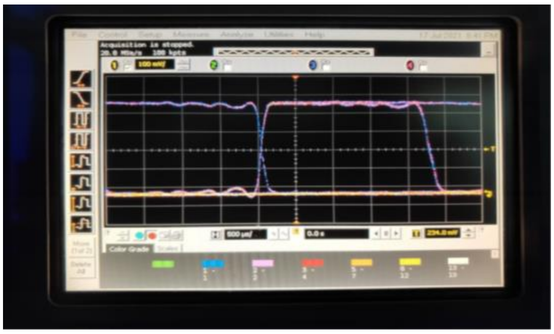
Code Generation for 2D FCC-MDW OCDMA is generated by using FPGA which based on 50 MHz clock signal which is shown in Figure 6(a). This clock signals are used to determine the switching speed of optical switch for data transmission and receiver. The FPGA is used to enhance the performance of data transmission with its massive parallel processing, fast and efficient system and ideal for real time applications. The FPGA shows a promising result by generating a code based on 50 MHz clock. This code is supplied to optical switch which presence at encoder and decoder. Figure 6(b) shows the encoder and decoder for 2D OCDMA system. The LED has a bandwidth of 30 nm is used for data transmission. The encoder and decoder consist of optical switch for channel selection. The selection is based on code generated by FPGA with 50 MHz clock signal. This enhances the security and speed of data transmission to the receiver. Each user is assigned by different code which data can transmit securely. The modulator is used to modulate the signal and carry to the optical fibre. A 50 km of optical fibre wire is used for testing. Figure 6(c) shows the eye pattern for the system by using Oscilloscope (Practical Testing).



(a)



(b)



(c)

Figure 6. (a) Practical Results for FPGA as Code Generator, (b) 2D OCDMA Encoder and Decoder and (c) Eye Diagram for 2D OCDMA System Using Oscilloscope

5. CONCLUSION

In OCDMA systems, each user is assigned with a sequence code that serves as its address. An OCDMA user modulates its code (or address) with each data bit and asynchronously initiates transmission. Hence, this modifies its spectrum appearance, in a way recognizable only by the intended receiver. The advantages of CDMA technique over other multiple access scheme such as TDMA and WDMA are numerous 2D OCDMA codes have been introduced to overcome the problem faced in 1D OCDMA code in terms of low power lost, high cardinality, high data transfer rate, minimum cross- correlation and high autocorrelation with minimum side-lobes. By using

FPGA as code generator (encode/decode), the transmission data speed has been increased. The clock generated by FPGA is 50 MHz which is for code generation in 2D OCDMA system. The performance of 2D OCDMA system in terms of time spreading and wavelength spreading is also compared which shown a huge difference in the results. The best performance of the system is when the number of wavelength (M) is fixed to 18 and the number of times spreading (N) is 31 which can support 350 more simultaneous users.

ACKNOWLEDGEMENTS

The research has been carried out under Malaysia Technical University Network (MTUN) 2019 Matching Research Grant 9028-00004 provided by the Ministry of Higher Education of Malaysia (MOHE). S M A Aljunid would like to acknowledge the support from the Centre of Excellence Advance Communication Engineering (ACE) Optics especially Optic group team for providing place and technical support for the experimental setup.

REFERENCES

[1] Norizan, M. N., Jamaludin, R., Mohamad, I. S., Li, T. C. and Zainal, M. S., “GSM remote sensing for copper cable transmission line monitoring system using FPGA” in 2nd International Conference on Electronic Design, ICED 2014 (IEEE), (2014) pp. 421–6.

[2] Murad, S. A. Z., Ahmad, M. F., Mazalan, M., Shahimin, M. M., Rais, S. A. A. and Norizan, M. N., “A design of 5.2 GHz CMOS up-conversion mixer with if input active balun ISWTA,” in 2011 IEEE Symp. Wirel. Technol. Appl, (2011) pp. 1–4.

[3] Natashah, N. M., Muammar, M. I., Soh, P. J., Azremi, A. A. H. and Norhawati, A., “Design of a microstrip patch antenna using Low Temperature Co-Fired Ceramic Technology 2008,” in Int. Conf. Electron. Des, (2008) pp. 1–3.

[4] Chen, K., Chen, Y. and Liao, L., “Advancing High-Speed Transmissions over OCDMA Networks by Employing an Intelligently Structured Receiver for Noise Mitigation,” Applied Sciences vol. **8**, issue 12 (2018) pp. 2408.

[5] S. M. H. Al-Junid, S. Shaari, S. A. Aljunid and M. S. Anuar, "Design of Encoder and Decoder module for Optical Code Division Multiple Access (OCDMA) systems for Zero Cross Correlation (ZCC) Code Based on Arrayed Waveguide Gratings (AWGs)," in 2008 International Conference on Electronic Design, Penang, (2008) pp. 1-4.

[6] Ghazi, A., Aljunid, S.A., Idrus, S.Z.S., Fareed, A., Al-dawoodi, A., Hasan, Z., Endut, R., Ali, N., Mohsin, A.H. and Abdullah, S.S., “Hybrid Dy-NFIS & RLS equalization for ZCC code in optical-CDMA over multi-mode optical fiber,” Periodicals of Engineering and Natural Sciences (PEN) vol. **9**, issue 1 (2021) pp. 253-276.

[7] Ghazi, A., Aljunid, S.A., Idrus, S.Z.S., Fareed, A., Hamood, L., Endut, R., Ali, N., Rashidi, C.B.M., Fakhrudeen, A.M., Al-Dawoodi, A., Matem, R. & Abdullah, S.S., "Comparison of MD & ZCC one dimension code for optical-cdma over multi-mode fiber based on laguerre-gaussian modes," Journal of Engineering Science and Technology, vol. **16**, issue 4 (2021) pp. 3588-3599.

[8] Ahmad, N.A., Junita, M.N., Aljunid, S.A., Rashidi, C.B.M. and Endut, R., “Analysis of hybrid subcarrier multiplexing of OCDMA based on single photodiode detection,” EPJ Web of Conferences vol. **162** (2017) pp. 01028.

[9] C. B. M. Rashidi, S. A. Aljunid, M. S. Anuar, A. K. Rahman, M. Jusoh and M. N. Junita, "Design and demonstration of a novel flexible cross correlation (FCC) code for an evasion of PIIN in OCDMA system," in 2015 International Conference on Computer, Communications, and Control Technology (I4CT), Kuching, (2015) pp. 593-597.

[10] M. S. A. Azura, C. B. M. Rashidi, S. A. Aljunid, A. K. Rahman and M. S. Anuar, "Noise suppression of optical CDMA system via utilizing wavelength/time 2-D MDW code," in 3rd International Conference on Electronic Design (ICED), Phuket, (2016) pp 146-150.

[11] C. B. M. Rashidi, S. A. Aljunid, M. S. Anuar, A. R. Arief and F. Ghani, "Enhanced the correlation effects for OCDMA systems based on algorithm of novel flexible cross correlation (FCC) code," in IEEE 5th International Conference on Photonics (ICP), Kuala Lumpur, (2014) pp. 253-255.

[12] S. A. Aljunid, M. D. A. Samad, M. Othman, M. H. Hisham, A. H. Kasiman and M. K. Abdullah, "Development of modified double-weight code and its implementation in multi-rate transmissions," in 13th IEEE International Conference on Networks Jointly held with the 2005 IEEE 7th Malaysia International Conf on Communic, Kuala Lumpur, (2005) pp. 5.

[13] Aseri, N.S.M., Ali, N., Yusof, N.R., Endut, R., Hambali, N.A., Shahimin, M.M., Rashidi, C.B.M. and Aljunid, S.A., "FPGA based Quantum Key Distribution Electronic System for Multipurpose Optical Setup and Protocols," Journal of Physics: Conference Series vol. **1755**, No. 1, IOP Publishing, (2021) pp. 012047.

[14] Anis, A.A., Rashidi, C.B.M., Rahman, A.K., Aljunid, S.A. and Ali, N., "Analysis of the effect of BER and Q-factor on free space optical communication system using diverse wavelength technique," EPJ Web of Conferences vol. **162** (2017) pp. 01024.