Wireless Communication using VLC and MIMO Technology

[1]Pavana K N, [2]Dr K L Sudha

[1]M.tech student, [2]Professor and PG Coordinator
Department of Electronics and communication,
Dayananda Sagar College of Engineering, Banglore,India

***Abstract*: Due to the rapid developments in Light Emitting Diodes (LED's) VLC (Visible Light Communication) has become an upcoming technology. This work aims at building a wireless VLC system capable of transmitting data between two computers using visible light. A LED array is used as the transmitter, air as the transmission medium and a Light Dependent Resistor (LDR) as the receiving component. Arduino UNO microcontroller board is used in both transmitter and receiver modules. Arduino IDE is being installed in two PC's and is used to interface software to the hardware. To check the performance VLC system with MIMO, commercial optical system simulation software called OptiSystem7.0 from Optiwave is used. The layout diagram for both SISO (Single Input Single Output) and MIMO (Multiple Input Multiple Output) communication has been generated and has been run and the BER (Bit Error Rate) performance is being analyzed. FSO (Free Space Optical) communication channel is used as transmission medium for both SISO and MIMO. Data transmission and reception for 100 meters is done using OptiSystem software. The eye diagram of BER analyzer showed that the maximum quality factor of MIMO is relatively large when compared to SISO.**

***Index Terms*: Visible Light Communication (VLC), Light Emitting Diode (LED), Arduino, SISO (Single Input Single Output), MIMO (Multiple Input Multiple Output).**

I. INTRODUCTION

The demand for data usage has increased exponentially in the last decade, people want to be connected to the internet all the time, on multiple devices, update the latest happenings etc. With the advent of IOT (Internet of Things) more devices will connect to the LTE which will result in congestion and decrease in speed. VLC itself is a category of Optical Wireless Communication (OWC). These techniques facilitate the communication, by modulating light in the visible spectrum, which is primarily used for illumination purposes [1]. This makes Li-Fi unique, as same light is used for communication and illumination purpose. Radio wave spectrum is limited and visible light spectrum is made use for the communication purpose.

Visible light communication, as the name says it is a communication technique based on visible light. This spectrum is a part of electromagnetic spectrum that is visible to human eye. The visible light in common terms is simply called as light itself. This mode of communication is wireless. Nowadays, IR (Infra Red) systems have been developed to provide more data rate, because the conventional systems such as Bluetooth, radio communication and wifi had low speed. VLC system uses different colored LED's and some colored LED combinations to produce white light. Some filters will be used in the receiver side to separate different colored lights. White LED's are the most widely used ones in visible light communication system. In order to achieve high data rate in our hardware, we made use of array of LED's. The array of LED's provides better illumination as well as to achieve peak data rate. New modulation and multiplexing techniques are developed and used by the researchers to provide high data rate. LED flashlights and lasers are used in some applications which require high intensity light for long distance communication [1].

Taking Li-Fi as a consideration, it is a type of visible light communication method. It offers unlicensed spectrum and thus users can utilize wider range of bandwidth. Data is transmitted with higher transmission rate because of the freely available bandwidth. Visible light is safe to use, as it does not cause any health hazards. This is because visible light does not penetrate through wall, whereas electromagnetic waves will easily penetrates through walls. The use of wifi is not allowed in some hospitals and aircrafts due to the harmful radiations. The direct line of sight (LOS) is one of the basic requirements for any kind of visible light communication. LOS between transmitter and receiver should be proper to achieve better data rate. If any obstacle/object or undesired wave comes in between transmitter and receiver, then the line of sight get disturbed causing denial of service (DoS). But the major advantage of using visible light spectrum is that, any hacker or intruder outside the room will not be able to utilize data. Because of this reason more secure communication takes place [2].

SISO (Single Input Single Output) systems are most of the times used for smaller applications. Adding MIMO (Multiple Input Multiple Output) technology along with VLC is a better idea for larger applications in real time. In this paper we have designed a hardware setup for PC to PC communication using VLC. This is a SISO system and an experimental setup for smaller distance. This can be further improved if high intensity light sources are used. And to check the advantages of including MIMO in VLC system, we did some simulations. The BER (Bit Error Rate) performance of both SISO and MIMO is analyzed. As this is indoor VLC application, distance between transmitter and receiver is set in terms of meters. In case of outdoor scenario, distance can be increased up to kilometer range. But the FSO (Free Space Optical) channel should be used and atmospheric conditions must be taken into consideration.

II. LITERATURE REVIEW

Some papers which are related to visible light communication, MIMO, LED, free space optics, etc are referred for this project work. Zashi P. Choudhari and Satish R. Devane has designed high sensitivity universal Lifi receiver. The main aim was to enhance

the data communication. In this paper authors describes the working and characteristic features of LED based visible light communication. They showcase the advantages of using non-hazardous LED light [3]. Shaik.Shakeera et.al designed a PC to PC File Transfer system using Li-Fi Technology. The main aim of their work was about text data transmission. Text transmission from PC to PC is executed with better speed than Wi-Fi. Their work is an inspiration to develop hardware model for Li-Fi. In future scope, authors highlighted about Li-Fi hotspots which can transmit in Gbps order [4].

Akash Gupta et.al developed a Cascaded FSO-VLC Communication System. Both VLC and FSO are the major areas of interest in our work. The performance of FSO-VLC system is being analyzed by them. Different indoor and outdoor parameters are considered in their work. Their work provides a solution to spectral congestion problem faced by most of the wireless communication types [5]. Chetna Verma and Chetan Selwal used diversity technique invisible light communication system. Along with that they included 4 QAM (Quadrature Amplitude Modulation) OFDM (Orthogonal Frequency Division Multiplexing) FSO (Free Space Optical) link. Authors simulated utilizing OPTISYSTEM 12 version. They designed 4QAM OFDM FSO link in three different stages. And also the performance of the system for different environmental conditions was simulated and analyzed [6].

Hammed G. Olanrewaju et.al illustrated MIMO-OFDM system in their paper. The BER plots obtained in their simulation show that high performance gains are achieved by using DPWC (Dual Pair-wise Coding) [7]. Fabian Harendran Jesuthasan et.al designed SISO-VLC and 2x2 MIMO setup. They transmitted the audio sound through both the setups. They concluded that quality and receiving range was improved in MIMO-VLC when compared to SISO-VLC system [8].

III. HARDWARE MODEL

The hardware model consists of two PC's (Personal Computers) at both transmitter and receiver side. And also two Arduino UNO boards are required at the transmitter and receiver modules. Arduino UNO is hardware which is used along with Arduino IDE software. The hardware board is based on microcontroller ATmega 328P. Arduino UNO microcontroller has 14 digital input/output pins, 6 analog inputs, a USB connection, a power jack, an ICSP header and a reset button and a 16 MHz quartz crystal [9]. LED array is used as a transmitter. It acts as both source of illumination and as data transmitter [10]. LED arrays provide high intensity light, so we have used LED array. The array of white LED's is being used in this hardware model. TIP122 transistor is used at the transmitter side circuit [11]. The hardware setup is as shown in **Fig.1**.

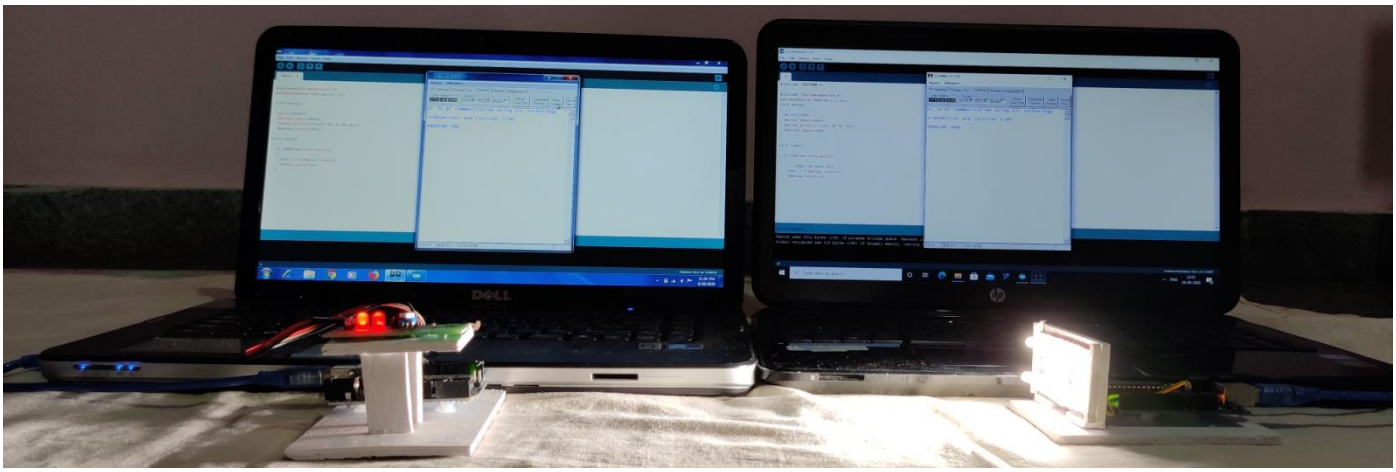

Fig.1: The hardware setup of PC to PC communication transmitter and receiver

In the receiver side there is a LDR Sensor Module. This module is used to detect the presence or absence of light. The light dependent resistor is used to measure the intensity of light. The output becomes high in the presence of light and becomes low in the absence of light [12]. A single LDR module is used and is capable of detecting the light for around 15 centimeter distance. The Arduino IDE and X-CTU software (serial terminal software) was installed in both laptops/ PC.s. The embedded C programming is done on Arduino IDE of both transmitter and receiver side and are compiled. Once both transmitter and receiver side codes are compiled without error. The programs are then dumped into Arduino UNO boards after connecting the PC using USB connector. Once connections and program dumping is over, the message is typed on the serial monitor of transmitter side PC. The same message will be displayed on the receiver side PC's serial monitor. The text transmission was successful for smaller distance that is around 15 centimeters. To further check the performance of Visible light communication for larger distance and for real time applications, layout design and simulations are done using OptiSystem software.

IV. SIMULATION SYSTEM MODEL

In this proposed system, commercial optical system simulation software (OptiSystem7.0) from Optiwave is used. The layout diagram for both SISO (Single Input Single Output) and MIMO (Multiple Input Multiple Output) communication has been generated and has been run and the BER(Bit Error Rate) performance is being analyzed. A CW (Continuous Wave) laser diode is used at transmitter side with 1W power and visible light frequency. A CW laser with frequency of red color is used, that is 700 nm. A pseudo random bit sequence generator is used for data bits generation which supports a high data rate of about 35G bits/second. Both data bits and laser light will be fed into a Mach-Zehnder (MZ) modulator. This MZ modulator is used for controlling the amplitude of an optical wave. Optical amplifier is used to increase the signal strength. FSO (Free Space Optical) Channel is used

as communication channel. This FSO is not only meant for indoor communication, it is suitable for free space communication as well [13]. FSO is a form of optical communication technology where larger distances can be covered [14]. I have done data transmission and reception for 100 meters. But it is even possible to communicate in terms of kilometers. As this project is based on indoor VLC, a 100 meter distance is more than enough for indoor applications.

At the receiver side, Avalanche photodiode (APD) is used. It is highly sensitive semiconductor photodiode that exploits the photoelectric effect to covert light into electricity. For long range communication, this APD is very much suitable when compared to other diodes [15]. 3R regenerator is a subsystem based on the Data Recovery component and a NRZ (Non Return to Zero) pulse generator. Instead of connecting the bit error rate analyzer to input signals, this component 3R regenerator can be used to recover the bit sequence. The reference signal is nothing but the output signal itself [16]. Electrical and optical power meters are connected to some components to check the power dissipation over distance.

Non-return to zero (NRZ) is the most common modulation format used in most of the optical communication systems. It is often called OOK (On-Off Keying) as during transmission the light source is switched on and off depending on the logical value of binary data signal. The light intensity is high for logical one and low for logical zero. OOK bit pattern is always shown in a form of an eye diagram. Eye diagram is a basic indicator of the transmission quality. Eye diagram can also be used for signal impairment detection in OOK signalling.BER analyzer is used at the receiver to know the BER performance [17]. As both SISO and MIMO layouts are designs. BER performance of MIMO over SISO is compared. The layout diagram of SISO VLC is as shown in **Fig.2**. A single transmitter and single receiver with one FSO channel are used in layout. The BER analyzer automatically calculates the bit error rate and Q-factor (Quality factor).

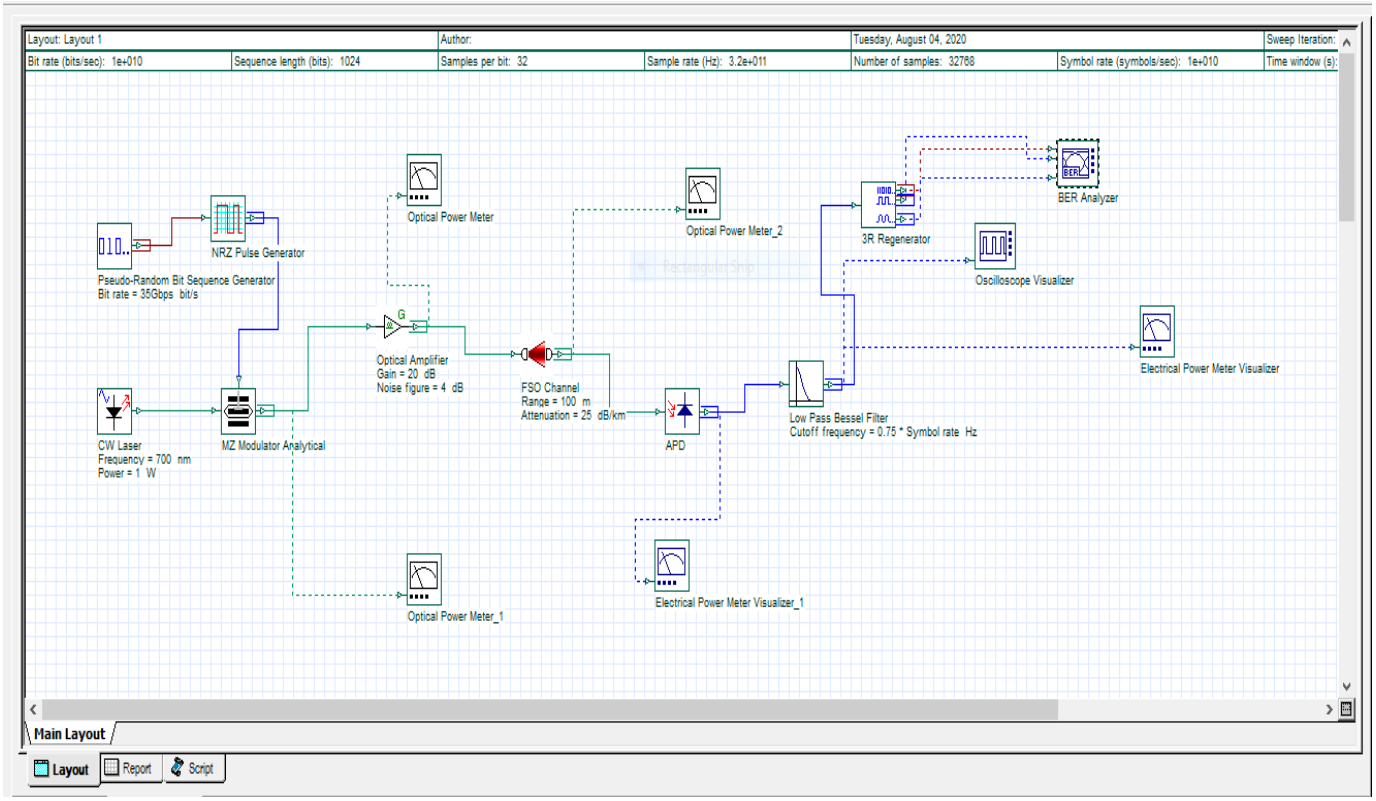

Fig.2: The layout of SISO (Single Input Single Output) Visible light communication transceivers using FSO channel.

MIMO makes use of spatial diversity and receive multiple independent copies of the same signal at the receiver. The major advantage is that, this system results in increased signal to noise ratio and BER [8]. The optical amplifier power is increased in the layout design, as we have to transmit more power through four FSO links. The MIMO technology can increase the data rate, capable of improving the system reliability through spatial diversity [7]. In the layout of MIMO transceiver, four transmitters and receivers are used. A 1 to N fork is used to multiply the number of transmitters. And power combiner is used at the receiver side to multiply the receiver blocks. The layout designed for MIMO VLC system using OptiSystem software is shown in **Fig.3 below:**

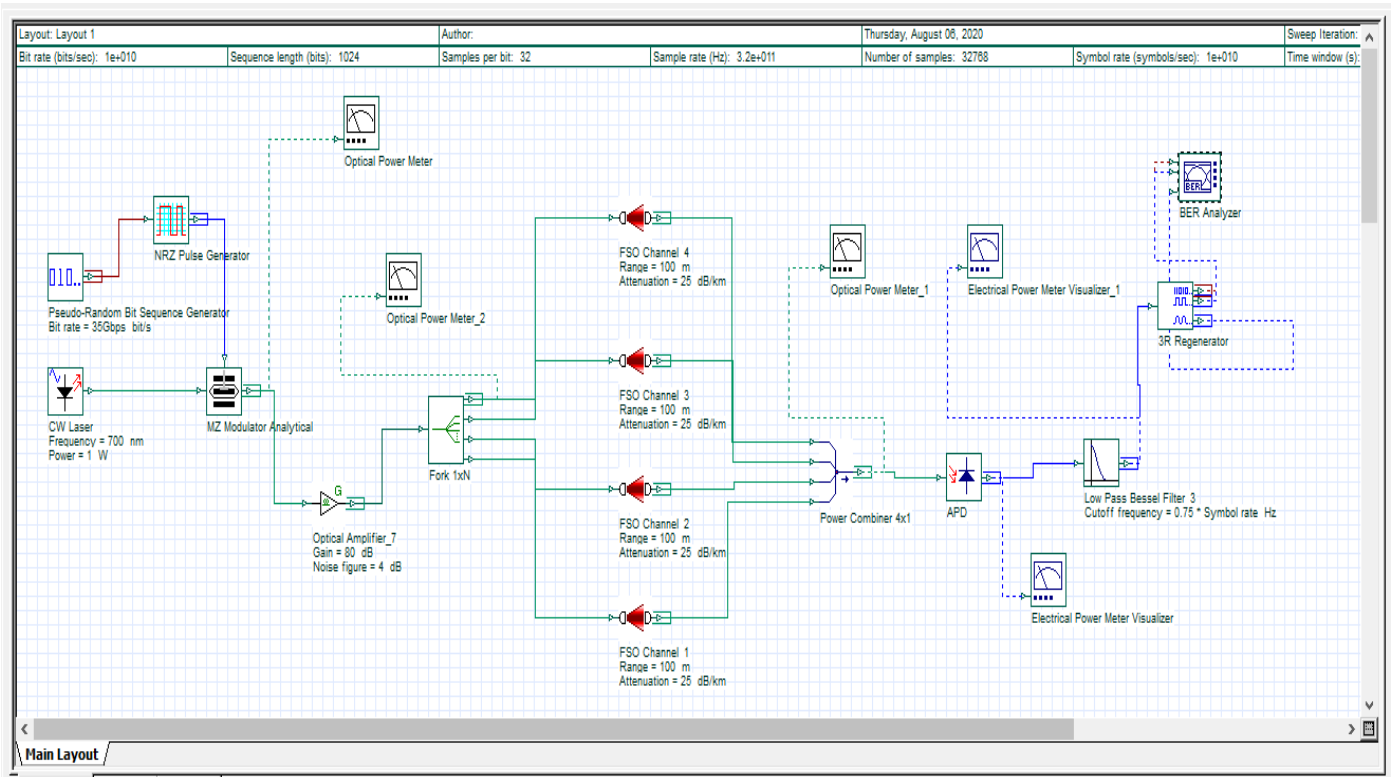

Fig.3: The layout of MIMO (Multiple Input Multiple Output) Visible light communication transceivers (4x4 MIMO) using 4 FSO channels.

V. Simulation Parameters and Results

The Q factor is a measure of how noisy a pulse is, this is for analysis purposes. The oscilloscope will typically generate a report that shows the Q factor number. A larger number of Q factor in the result means that the pulse is relatively free from noise. The eye diagram of BER analyzer shows that the maximum Q factor of MIMO is relatively large when compared to SISO. The BER analyzer output for SISO and MIMO is as shown in Fig.6 and Fig.7 respectively. That is 10381.4 and 10902.6 is the maximum Q factor for SISO and MIMO system respectively . Hence the pulse is relatively free from noise indicating better performance. As the distance between transmitter and receiver is 100 meters, this can be implemented in SISO form and also as MIMO form for larger applications.

Almost all the parameters considered for SISO and MIMO are same except optical amplifier gain. As the number of transmitters and receivers are more in MIMO and there are four FSO channels. The optical amplifier gain is multiplied by four. The simulation parameters and their values are listed below in tabular form. Table 1 show the parameters which are considered for the simulation purpose.

Table 1 Simulation Parameters

Component	Parameter	value
PR bit sequence generator	Bit rate	35Gbps
CW laser	Frequency Power	700nm 1Watt
Optical Amplifier	Gain Noise figure	20dB (SISO) 80dB (MIMO) 4dB
FSO channel	Range Attenuation	100 m 25dB/Km

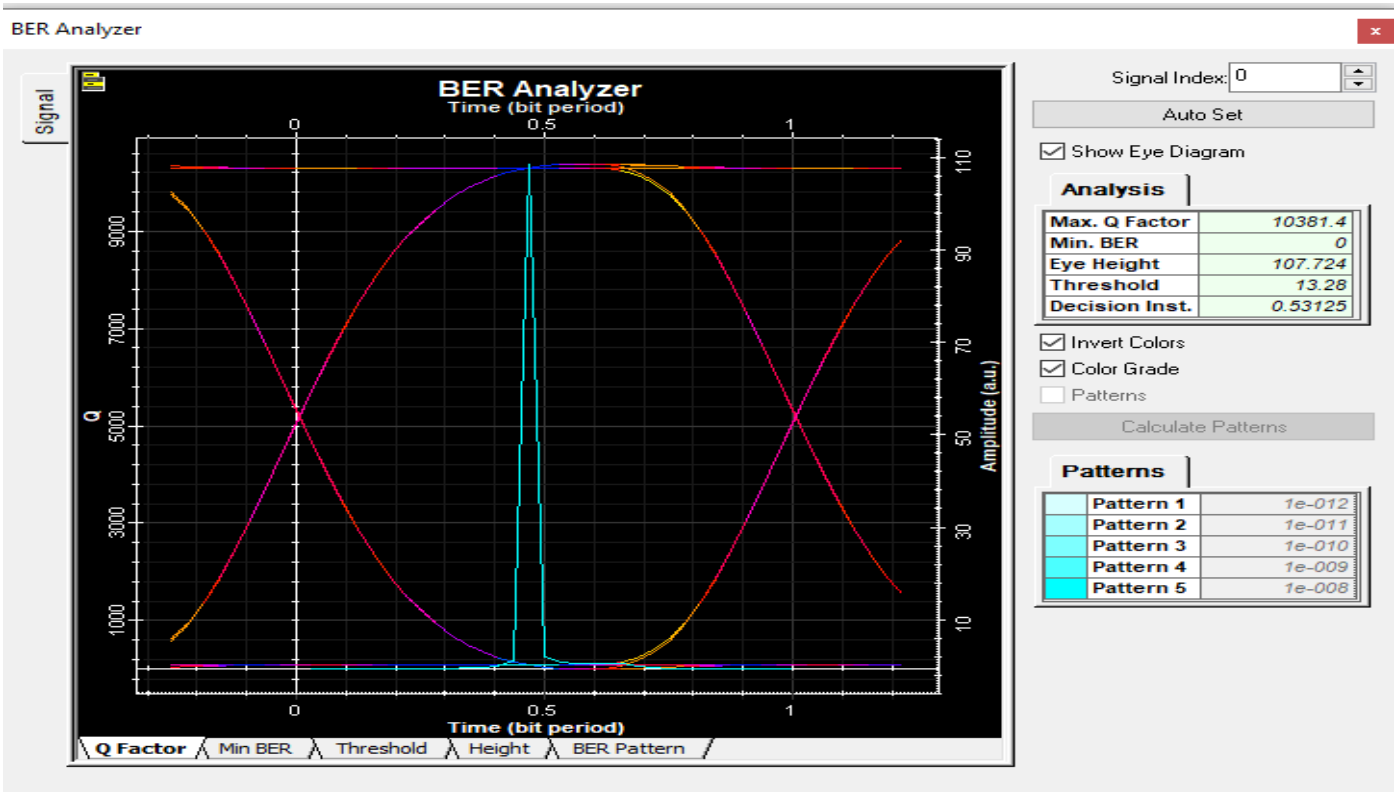

Fig.6: BER analyzer output of SISO (Single Input Single Output) Visible light communication transceivers using FSO channel.

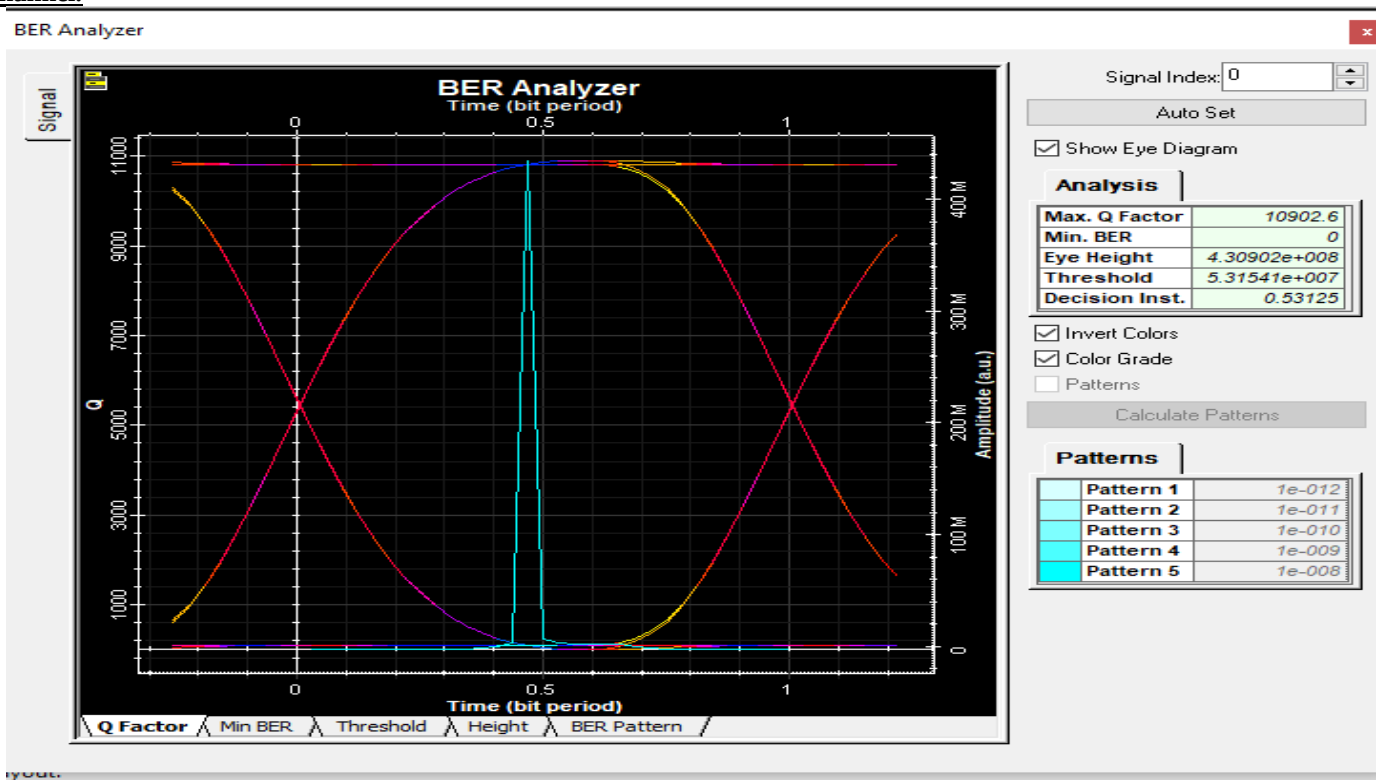

Fig.7: The BER analyzer output of MIMO (Multiple Input Multiple Output) Visible light communication transceivers (4x4 MIMO) using 4 FSO channels

VI. CONCLUSION

This paper is all about data transmission through visible light. Using the visible light spectrum, data transmission from one PC to another is successfully done for smaller distance. For longer distance communication, simulations are done by transmitting data at a bit rate of 35Gbps. Both SISO and MIMO VLC systems are designed and simulated. The distance is set to 100 meters and is sufficient for indoor VLC system. In future work, FSO channels can be implemented for outdoor communication purpose with distance in terms of kilometers. But, in outdoor VLC, atmospheric conditions should be taken into consideration for speedy communication.

REFERENCE S

[1] Sandip Das Ankan Chakraborty, Debjani Chakraborty and Sumanjit Moshat "PC to PC Data Transmission using Visible Light Communication". 2017 International Conference on Computer Communication and Informatics (ICCCI -2017), Jan. 05 – 07, 2017, Coimbatore, INDIA.

[2] Shaik.Shakeera,P.SaManideep,M.Shahin Begum,V.V.Bharga and, P.D.N.Malleswara Rao." PC to PC File Transfer using Li-Fi technology"IJET, Volume-6.

[3] Zashi P. Choudhari and Satish R. Devane. "High sensitivity universal Lifi receiver for enhance data communication". Online International Conference on Green Engineering and Technologies (IC-GET), 2016, Mumbai, INDIA.

[4] Shaik.Shakeera et.al. "PC to PC File Transfer using Li-Fi Technology". International Journal of Engineering Trends and Technology (IJETT) – Volume 46 Number 3 April 2017.

[5] Akash Gupta et.al." Cascaded FSO-VLC Communication System". IEEE Wireless Communications, 2017.

[6] Chetna Verma and Chetan Selwal "Visible light communication system (VLC) Using Diversity Technique with 4 QAM OFDM FSO Link", IEEE Xplore , 2018.

[7] Hammed G. Olanrewaju et.al. "Pairwise Coding for MIMO-OFDM Visible Light Communication". IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, 2019.

[8] Fabian Harendran Jesuthasan et.al." Implementation and Performance Evaluation of a MIMO-VLC System for Data Transmissions". IEEE, 2019.

[9] https://www.arduino.cc/en/Main/Boards

[10] https://www.prophotonix.com/resources/technical-overviews/led-array-methods/

[11] http://henrysbench.capnfatz.com/henrys-bench/arduino-output-devices/tip122-arduinorelay-tutorial/

[12] Liang K., Chow C.W., Liu Y. "RGB visible light communication using mobile-phone camera and multi-input multi-output". Opt. Express.2016.

[13] Zhitong Huang et.al." Hybrid Optical Wireless Network for Future SAGO-Integrated Communication Based on FSO/VLC Heterogeneous Interconnection". IEEE Photonics Journal, 2017.

[14] Milica Petkovic." Outage Probability Analysis of RF/FSO-VLC Communication Relaying System". IEEE.

[15] https://en.wikipedia.org/wiki/Avalanche_photodiode

[16] https://optiwave.com/forums/topic/3r-regenerator/

[17] Sreejith S and K. C. Raveendranathan. "Simulation of MIMO System with 2-D and 3-D Optical Orthogonal Codes using MATLAB and OptiSystem". International CET Conference on Control, Communication, and Computing (IC4), July 05 – 07, 2018, Trivandrum, 2018.