



# Performance Evaluation of Modulation Techniques in Li-Fi

S. Nivetha, G.A. Preethi, C. Chandrasekar

**ABSTRACT:** Now days wireless communication is an essential replacement area and reflects enormous changes in day to day lives. Mobile communication, Digital Modulation is very much important for increasing the speed and capability of the wireless communication network. Now there is a growing technique called Li-Fi, which is wireless optical networking technology. The objective of the paper is describing the Li-Fi and its modulation techniques. Li-Fi uses Light Emitting Diodes (LED) for transmitting the data through illumination by changing the intensity which is quicker and offers security, higher bandwidth, efficiency, and avails. Li-Fi technology is replacement of radio frequency and also offers a high data rate, cost-effective. This will help to achieve a wireless communication with a better performance. It can apply to day to day activities and will adopt in devices in the future. In the future, Li-Fi can be several fields in traffic management, airlines, power plants and hazardous environment, underwater communications, giga speed technology, smart lighting, education system, disaster management and mobile connectivity. In the Digital modulation the message signal is in the digital type and, therefore, the carrier wave is in sinusoidal form. Li-Fi have a unique modulation technique called single carrier techniques multi-carrier techniques and color modulation techniques. Modulation techniques are as On-Off keying, Pulse width Modulation, Pulse Amplitude Modulation, Orthogonal Frequency Division Modulation and alternative digital modulation technique are summarized. Simulation is the imitation of the operation of a real-world methodology. The act of simulating requires that a model be developed and simulates the operation of the system over time. This paper tends to analyze the single carrier modulation techniques such as BPSK, QAM, and also tends to provide information on digital modulation technique parameters as Bit Error Rate, and its Performance.

**Keywords:** ASK, FSK, PSK, BPSK, 4-QAM, 16-QAM, 64-QAM

## I. INTRODUCTION

In telecommunication world, there is a need of higher bandwidth and secure data transmission. In order to provide a higher bandwidth and security, Telecommunication world can be classified into wired and wireless communication.

Wired communication is Coaxial cable, Twisted wire, Fiber optics, and wireless communication are Radio Frequency and Optical Wireless Communication. Li-Fi is one of the branches in wireless communication

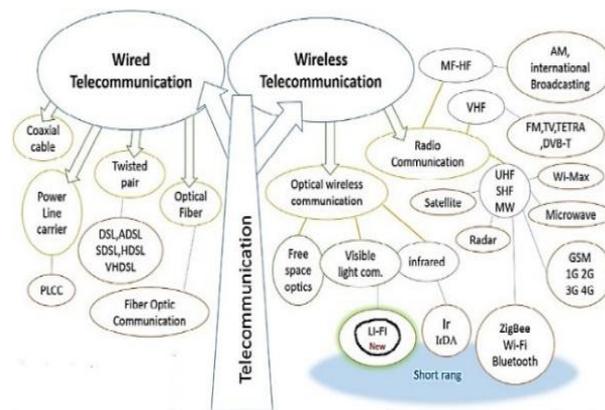


Fig.1 Types of Communication

Figure 1 Type of channels in telecommunication representing wired telecommunication and wireless telecommunication. Data can be transferred from one place to another is a daily activity. When a device is more connected to the networks, the internet gets slow. As the device connected to the internet increases, the bandwidth is more difficult to use the high transferring of data rates. For this problem, In the year 2011, German Physicist, Professor Harald Hass invented the Li-Fi. Hass proposes an applicable result, light can be used to transmit the data through Light Emitting Diode (LED) light bulbs. High definition on video to a computer is streamed with the help of Light Bulb which is equipped with signal processing technology, he showed that one-watt LED bulb would be helpful to offer internet connection for the computers. Instead of using a traditional Radio Frequency as in Wi-Fi, Li-Fi uses an optical wireless communication system in which light is used as a carrier signal [1]. Li-Fi conjointly called as Light Fidelity is to be achieved by LED bulbs as data Transmitter and Photodiode as Receiver. By the illumination of Light Emitting Diode varies the intensity faster than the human eye will catch. The main principle works in Li-Fi is Visible Light Communication (VLC) [2]. Li-Fi uses the visible spectrum along with ultraviolet radiation and infrared radiation.

### A.Reasons of Li-Fi

Light is helpful to transmitting the data in Li-Fi. It is high-speed which is 100 times faster than Wi-Fi,

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## Performance Evaluation of Modulation Techniques in Li-Fi

More Effectual, accessibility and security. Light gets stopped up due to any object, therefore it provides greater security may be achieved. Li-Fi is a class in Optical Wireless Communication. A unique feature of Li-Fi is that it combines illumination and data communication [3]. Reasons of Li-Fi few are as, Distance, Cost and Traffic Updates.

### B. Visible light communication

High-speed point to point communication as well as illumination system is referred as Visible Light Communication [4]. Li-Fi uses a visible wave in the electromagnetic spectrum to transfer data with the help of LED bulbs [5]. The range of visible spectrum shown in Figure 2.

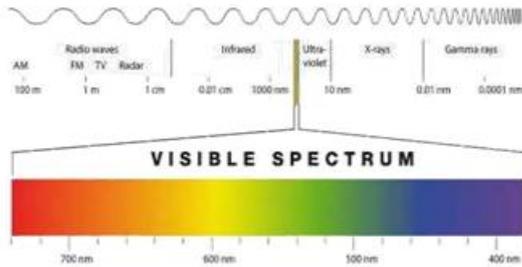


Fig 2: Visible Spectrum

Visible light between 400 THz and 800 THz as an optical carrier for data transmission and illumination that is used by VLC [6].

### C. Block diagram of Li-Fi

There are two main elements used in Li-Fi, one is the transmitter and another is receiver. The input at the transmitter are going to be modulated with a particular, specific time and then send the data by using LED bulbs in 0's and 1's. The flashes of LED bulbs are represented with 0's and 1's type.

Photodiode receives the LED bulb flashes and then converted into an electrical signal. In receiver section aspect, the photodetector receives the initial data and obtaining amplified by the inverting amplifier. The binary data are converted to the initial data message and given to the output signal. Therefore, major elements in a Li-Fi are Lamp driver, LED bulb and Photodetector.

### D. Working of Li-Fi

The light source is present at one end and photodetector is placed at the other end. LED bulbs are used for illumination. The quick differences in current the light output is varied at high speeds. The zeroes and one's data are grasped by lights and put in every form of gadgets like computers to the tablet, to phones and others. Any lamp or light will prove to be a hotspot. Figure 3 describes working of Li-Fi.

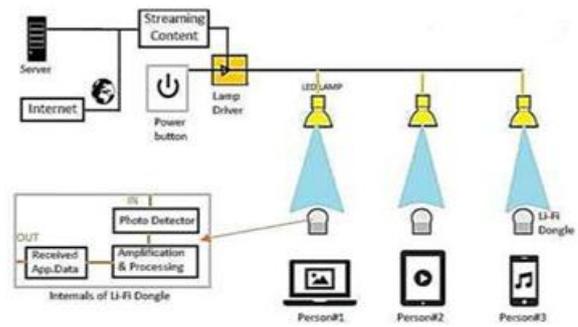


Fig 3: Working of Li-Fi

If the LED is on then the photo detector registers a binary one and LED is off photo detector registers zero. The adequate times of flash message by the LED build up a message. The models of Li-Fi LED Lights are shown in the Figure 4.



Fig 4: LED Lights

## II. ARCHITECTURE OF LI-FI

In a layered architecture, Li-Fi consists of three stage application layer, MAC layer, and Physical Layer [7][8]. IEEE 802.15.7 explains solitary two standards, i.e. PHY and MAC layer [7][8].

### A. Phy layer

Transmission and response, detection of the state of the channel whether it is idle or busy, activation and deactivation of optical transceiver are main responsible of PHY layer [7][8]. The variations of every operation mode are shown in Table 1[7],[8]

Table 1: Variations of Operation Modes [7],[8]

OPERATION MODES	CATEGORIES	RATE
PHY I	LOW	11.6 Kbps – 266.6 Kbps
PHY II	MODERATE	1.25 Mbps – 96 Mbps
PHY III	CSK MODULATION	12 Mbps – 96 Mbps

### B. Mac layer

The tasks performed by Medium Access Control [MAC] layer contain Mobility support, Dimming support, Security support, Schemes for mitigation of flickering, Visibility support, Color function support,

VPAN disassociation and association support, Network beacons generation if the device is a coordinator delivering a consistent link between two peer MAC entities[7],[8].Peer to Peer, star, and broadcast are outlined in MAC layer [7],[8].

- Peer to Peer- Two devices are communicated, one amongst them is acting as a coordinator.
- Star- Many devices are communicated. One is acting as a coordinator and its castoff as an illumination infrastructure.
- Broadcast-A co-ordinator sends data to many devices. Communication is a unidirectional way.

### C. Propagation layer

Line Of Sight and Non-Line Of sight are the characterized by the propagation layer. The unclogged path is obtainable between the source and the destination is a LOS condition. In NLOS channel light is spread via reflections from walls and ceiling [7][8].

## III. RELATED WORK

Imran Siddique et.al., [1] demonstrated the close view of Li-Fi. Li-Fi is a technology which is incredibly high over Wi-Fi because visible light spectrum can be able to use the 60 GHz spectrum. Li-Fi confers LED bulbs provide a transmission of data as faster over lighting. Li-Fi technology is developed by Professor Harald Hass, which is well illuminated and faster. Li-Fi is secured because the signals cannot travel via walls. Anwasha Chakraborty et. al.,[2] discussed the era of modernization transfer and sharing of data are incredibly abundant necessary for varied routine activities. Wireless communication was introduced as a result of it provides quicker data transmission. When connecting to multiple devices, there is problem with bandwidth, so wireless networks is not faster for communication. The solution to the weakness is Li -Fi technology. Li-Fi technology employed in the ideology of VLC and also explains systematic study of Li -Fi technology. Prateek Gawande et. al.,[5] proposed the Li -Fi modulation techniques. In Generally Radio Frequency Communication can be practical to Li-Fi technology with required variations. In VLC binary one and binary zero are representing the LED is on and LED is off. OOK, PPM, OFDM and CSK are compared with the parameters as Bit rate, Efficiency, Samples per symbol, Sampling time and Eb/No values. Mohammed Sufyan et. al.,[9] discussed about modulation techniques such as single-carrier and multi-carrier modulation techniques. In general Li-Fi single carrier modulation techniques are suitable when low-to-moderate data rate applications are needed. Switching of the LED “on” and “off” states, the arriving bits can be modulated into the intensity of light. Power, spectral and efficiency are provided by the multi-carrier modulation techniques in Li-Fi. The paper surveys the modulation techniques for Li-Fi with based on time, frequency and color domains.

## IV. MODULATION TECHNIQUES

Li-Fi relies on electromagnetic radiation for information transmission. According to [5] On-Off Keying Pulse Position Modulation, Pulse Amplitude Modulation, M-Quadrature Amplitude Modulation, Variable Pulse Position Modulation, Optical Spatial Modulation, Pulse Width Modulation, Carrier – less Amplitude and Phase Modulation

are single-carrier modulation. Orthogonal Frequency Division Multiplexing, Direct Current Optical Orthogonal Frequency Division Multiplexing, Asymmetrically Clipped Optical Orthogonal Frequency Division Multiplexing, Unipolar Orthogonal Frequency Division Multiplexing Pulse-Amplitude-Modulated Discrete Multitone Modulation are multi-carrier modulation [9]. Superposition OFDM, Hybrid and other MCM are applied in Li-Fi [9].

### A. Single carrier modulation

Single carrier modulation techniques in Li-Fi are stay appropriate to the low-to-moderate data rate applications. First proposed for IM/DD optical wireless communications in single-carrier modulation techniques is based on infrared communications [10]. The variety of LED flashes as “on” and “off” states are bits which are modulated into the light intensity. The illumination is controlled by the light intensity between the “on” and “off” states. Modulation techniques such as On-Off Keying, Pulse Position Modulation, Pulse Amplitude Modulation, M-Quadrature Amplitude Modulation, Variable Pulse Position Modulation, Optical Spatial Modulation, Pulse Width Modulation, Carrier – less Amplitude and Phase Modulation are implemented in Li-Fi.

#### 1. On-Off Keying

OOK provides a useful trade-off between system performance and complexness and it is one amongst the well-known and simple modulation schemes [5]. The presence and absence of the carrier wave can be represented digitally by the On-Off Keying techniques. The LED maintain a constant rate. The communication may vary at the time of low dimming levels of the LED bulbs.

#### Amplitude shift keying

Amplitude Shift Keying modulation technique denotes digital data as disparities in the amplitude of a carrier wave [11]. ASK two different amplitudes of carrier frequency represent zero and one. This can call as On-Off Keying. The amplitude of a wave can be speckled based on the signal. Frequency and phase of the signal in ASK are persistent.

#### Frequency shift keying

Digital data is transmitted through discrete frequency variations of a carrier signal which is denoted as frequency modulation [11]. FSK allows the changes in the frequency of a carrier signal whenever the digital information is transmitted. Frequency-Shift Keying has two binary states, logic zero (low) and one high and one (high) and a logic zero has described a wave at a selected frequency, and logic one is represented by a wave at a distinct frequency.

#### Phase shift keying

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by modulating the phase of a carrier wave [11]. In binary PSK signal with message symbol, 1 and 0 are transmitted by two different phases two different phases.

Symbol '0' is transmitted with 0 phase change in carrier signal and Symbol '1' is transmitted with the phase shift in the carrier.

2. Binary phase shift keying

BPSK is also usually referred to as Phase reversal keying, or 2PSK. BPSK is the best form of Phase-Shift Keying. BPSK uses two phases are separated by 180° which is called as 2-PSK [12]. The signal state can change from 0 to 1 or 1 to 0, then the phase of the wave changes by 180 degrees. It is capable to modulate at 1 bit /symbol and it is more robust. The constellation diagram for BPSK is two constellation points wholly positioned on the in-phase. No projection on the quadrature.

3. M-pulse amplitude modulation

PAM is a modulation technique where the amplitude of pulse varies equivalently with the amplitude of the analogical signal and the width and position of pulse are constant [13]. The parameter M is the range of points in the signal constellation.

It should be an even integer. A PAM modulation system in which the signal is appraised at regular intermissions and every sample is formed related to the amplitude of the signal at the moment of sampling [14].

4. M-quadrature amplitude modulation

QAM is a modulation technique where its amplitude is allowed to vary with the phase. The modulation of the amplitudes of two carrier waves conveys two digital bit streams which is called QAM. The two carrier waves are the identical frequency unit of phase with one another by 90 degrees is called as orthogonality quadrature [15]. The main advantage of QAM is blend of two amplitude modulated signals in the identical channel. In QAM, amount of the bandwidth is doubles, thus construction it more efficient [16]. In, QAM there are many various points which will be used, they are a definitive value of phase and amplitude. This is often referred as a constellation diagram. The constellation points are generally organized in an exceedingly square grid. The constellation will have a square with the number of points adequate to an influence of two i.e. 4,16,64 i.e. 4 QAM,16QAM,64QAM, etc., The process flow to simulate the single carrier modulation techniques BPSK, and QAM are shown in the Figure 5.

Li-Fi Modulation Techniques Single Carrier Modulation Technique -BPSK, QAM

Illumination in LED bulbs as Zeros and Ones. Implemented in MATLAB R2018a Using Simulink. Give the values for Simulink Parameters for BPSK and QAM.

Random Integer Generator, BPSK Modulation and Demodulation, QAM Modulation and Demodulation with its Constellation Diagrams, AWGN, Error Rate Calculation and Display.

Calculate Bit Error Rate By changing multiple  $E_B/N_0$  values for Theoretical and Simulated BER values. Calculate Symbol

Error Rate for multiple  $E_S/N_0$  values 4-QAM,16-QAM, 64 QAM

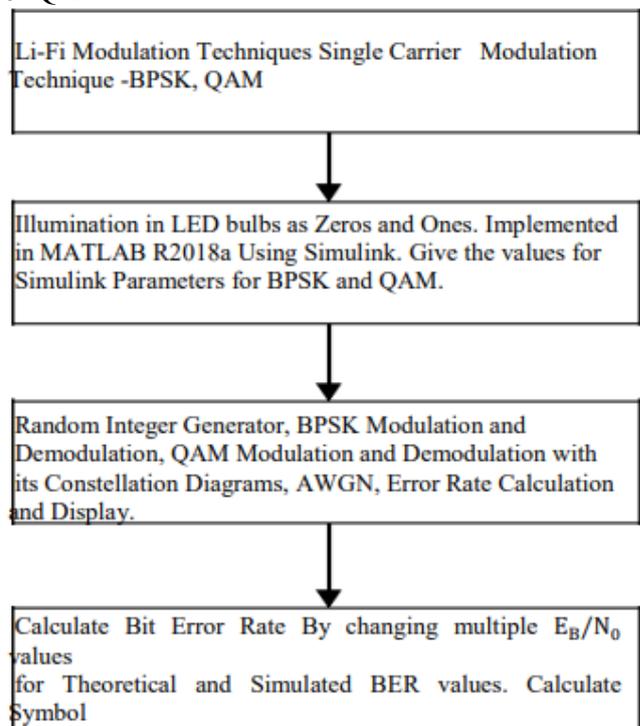


Fig 5: Process Flow for Li-Fi BPSK, QAM Modulation Techniques

5. Pulse width modulation

In modulated signal (PWM), the width of pulses varies proportionally with the amplitude of the analogical signal and the amplitude, position of pulses are remains constant [13].

Pulse Width Modulation is an approach of dropping the common power delivered by an electrical signal, by successfully chopping it up into distinct components. The period of time the signal is during in on the state as a percentage of the complete time to finish one cycle is referred to as duty cycle.

**B. Multi carrier modulation**

Multi-carrier modulation techniques such as OFDM can convert the frequency discerning fading of the communication channel into a smooth fading which is computationally effective [9].

According to [9] Multi-carrier Modulation includes Orthogonal Frequency Division Multiplexing, Direct Current Optical Orthogonal Frequency Division Multiplexing, Asymmetrically Clipped Optical Orthogonal Frequency Division Multiplexing, Unipolar Orthogonal Frequency Division Multiplexing, Asymmetrically Hybrid Optical Orthogonal Frequency Division Multiplexing, Pulse-Amplitude-Modulated Discrete Multitone Modulation etc....,

**1. Orthogonal frequency division multiplexing**

The encrypting digital data on several carrier frequencies is referred as Orthogonal Frequency Division Multiplexing. OFDM is a frequency-division multiplexing (FDM) is employed as a digital multi-carrier modulation method [17]. In the source, the serial data is transformed into parallel form and then the 16-QAM modulation is applied. IFFT is used to change the frequency into the time domain signal. Next AWGN noise can be passed to the channel. On the receiver side, FFT is applying to convert time domain into frequency domain signal. Demodulation is applied to it. Finally, the recovered signal is found again by passing its parallel to serial converter.

**V. PARAMETER FOR BPSK AND QAM**

**A. Bit error rate**

The number of bit errors per unit time is denoted as Bit Error Rate [18]. The error that occurs in transmission system is referred to as Bit Error rate. The number of errors that occur in a string of a stated number of bits [19]. Bit Error Rate is also called as Probability of Error (POE). The bit error rate can be demarcated as

$$BER = \frac{\text{Errors}}{\text{Total NumberOfBits}}$$

Bit Error Rate can be reduced by Lower order modulation and reduced bandwidth.

- Lower order modulation schemes will be employed, but it leads to fewer data throughput.

- Bandwidth ends up in the lower level of noise and thus signal to noise ratio (SNR) will progress.  
The energy per bit,  $E_b$ , can be outlined by dividing the carrier power by the bit rate and is a measure of energy with the dimensions of Joules and  $N_0$  is a power per Hertz [20].  
Symbol Error Rate (SER) is the probabilities of receiving a symbol and bit in error, respectively.

$$SER = \frac{\text{NO OF SYMBOLS IN ERROR}}{\text{TOTAL NO OF TRANSMITTED SYMBOLS}}$$

**B. Additive White Gaussian Noise channel**

AWGN is noise which can be added to the channel. Additive as a result of the arriving signal is equal to the transmitted signal, White as a result of rent less power spectral density, Probability distribution function is Gaussian, Noise distorts the received signal. Deep space communication links and satellites communications are applicable to the AWGN model [21].

**VI. SIMULATION RESULT**

In this paper, MATLAB R2018a is used to simulate the performance of the digital modulation scheme BPSK and QAM, and their performance is evaluated by finding BER over AWGN. The Simulink model for BPSK,4-QAM,16-QAM,64-QAM and OFDM is shown in the Figure 6,7,8,9 and 10.

**A. Bit Error Rate-BPSK**

The design is simulated and implemented on MATLAB R2018a for the BPSK,4-QAM,16-QAM.

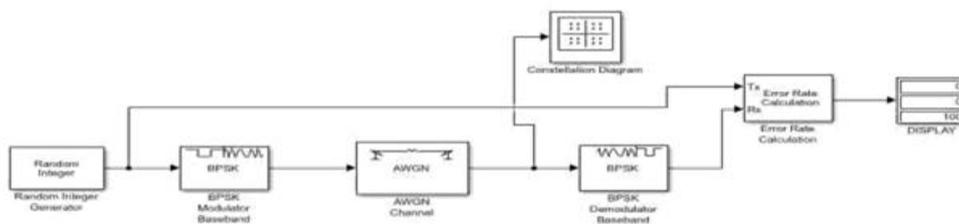
STEP 1: Generation of random BPSK modulated symbols +1 and -1.

STEP 2: Passing through Additive White Gaussian Noise Channel.

STEP 3: Calculating the received bit based on the location in the constellation.

STEP 4: Counting the number of errors.

STEP 5: Repeat the steps for calculating multiple  $E_b/N_0$  values.



**Fig 6: Simulated Model-BPSK**

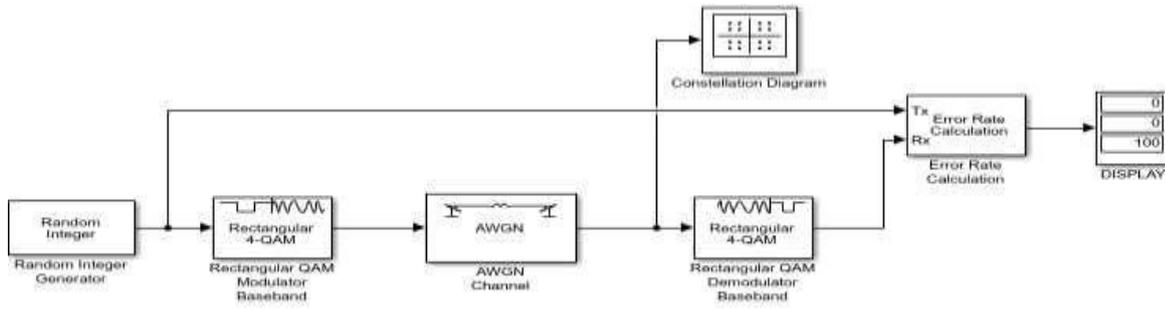


Fig 7: Simulated Model 4-QAM

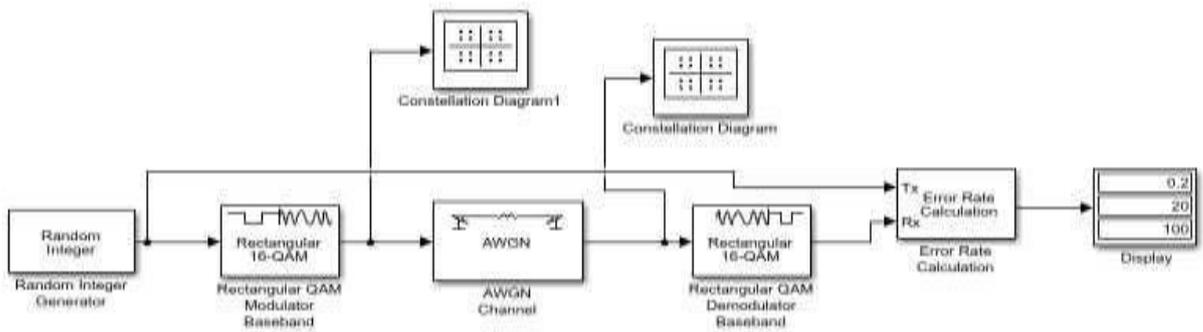


Fig 8: Simulated Model 16-QAM

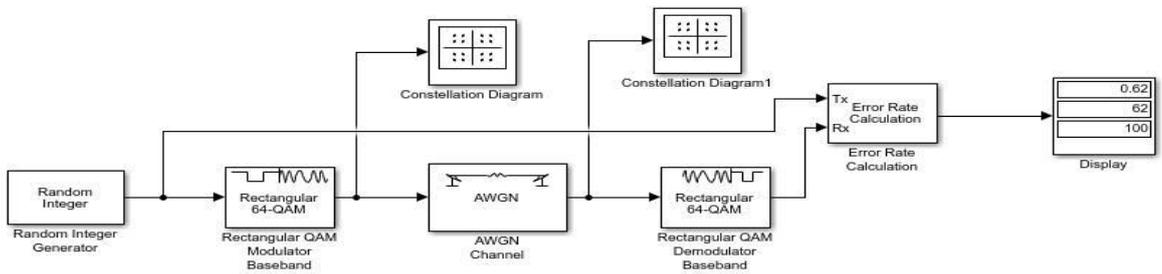


Fig 9: Simulated Model 64-QAM

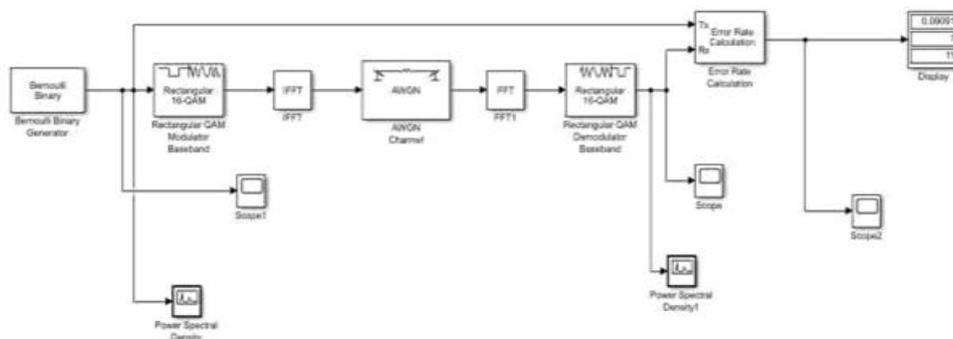


Fig 10: OFDM Simulated Model

**Table 2: Theoretical Bit Error Rate and Simulated Bit Error Rate -BPSK,4-QAM,16-QAM,64-QAM**

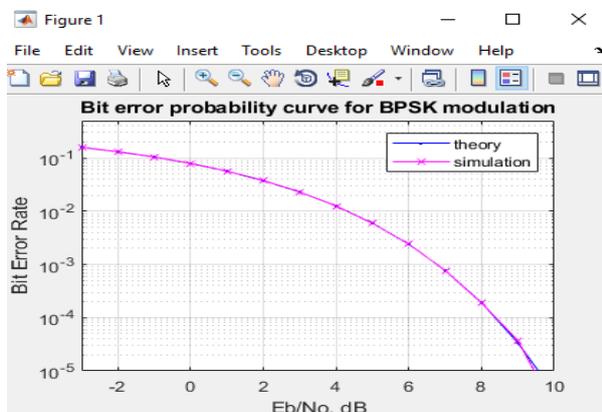
BPSK		4-QAM		16-QAM		64-QAM	
THEO BER	SIM BER						
0.1584	0.1589	0.3953	0.2622	0.1392	0.1399	0.9821	0.7420
0.1306	0.1311	0.3585	0.2387	0.1183	0.1197	0.9237	0.7090
0.1038	0.1042	0.3194	0.2133	0.0976	0.0983	0.8601	0.6765
0.0786	0.0791	0.2787	0.1867	0.0774	0.0777	0.7914	0.6354
0.0563	0.0565	0.2371	0.1576	0.0586	0.0585	0.7177	0.5880
0.0375	0.0377	0.1955	0.1307	0.0419	0.0413	0.6397	0.5379
0.0229	0.0230	0.1552	0.1037	0.0279	0.0281	0.5583	0.4795
0.0125	0.0125	0.1176	0.0781	0.0170	0.0171	0.4751	0.4205
0.0060	0.0059	0.0841	0.0571	0.0092	0.0091	0.3919	0.3545
0.0024	0.0024	0.0560	0.0374	0.0044	0.0043	0.3113	0.2867

**Table 3: Theoretical System Error Rate and Simulated System Error Rate - 4-QAM,16-QAM,64-QAM**

4-QAM		16-QAM		64-QAM	
THEO SER	SIM SER	THEO SER	SIM SER	THEO SER	SIM SER
0.4216	0.4219	0.9821	0.7420	0.9237	0.9238
0.3814	0.3811	0.9237	0.7090	0.9134	0.9134
0.3381	0.3388	0.8601	0.6765	0.9011	0.9008
0.2921	0.2912	0.7914	0.6354	0.8865	0.8864
0.2447	0.2452	0.7177	0.5880	0.8692	0.8692
0.1972	0.1959	0.6397	0.5379	0.8485	0.8485
0.1516	0.1514	0.5583	0.4795	0.8239	0.8237
0.1098	0.1102	0.4751	0.4205	0.7948	0.7947
0.0739	0.0736	0.3919	0.3545	0.7605	0.7609
0.0455	0.0448	0.3113	0.2867	0.7204	0.7201

The experimental resulted values for Bit Error Rate and System Error Rate are shown in Table 2 : Theoretical Bit Error Rate and Simulated Bit Error Rate for BPSK,4-QAM,16-QAM,64-QAM and Table 3: Theoretical System Error Rate and Simulated System Error Rate - 4-QAM,16-QAM,64-QAM.From these result QAM is efficient which is used as one of the single-carrier modulation techniques in Li-Fi.

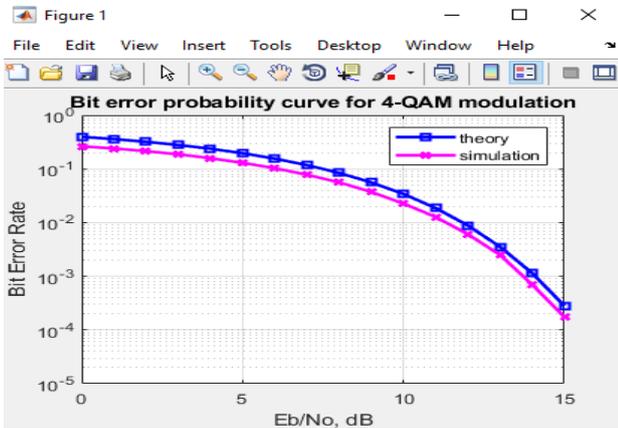
Figure 11 shows bit error rate curve vs  $E_b/N_0$  – BPSK Comparing and reviewing the results of the BPSK modulation can be concluded that the Theoretical Bit Error probability and Simulation Results are the same order and that there are minimal differences between them. So simulated results work better in noisy channels.



**Fig 11: Bit Error Rate Vs  $E_b/N_0$  –BPSK**

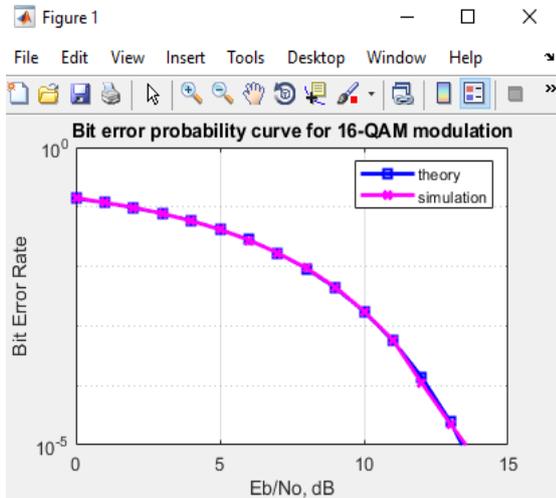
**A. Bit Error Rate-M-QAM**

- STEP 1: Generation of random 4-QAM ,16-QAM,64-QAM modulation.
- STEP 2: Passing through Additive White Noise Channel.
- STEP 3: Calculating received bit based on the location in the constellation.
- STEP 4: Counting the number of errors.
- STEP 5: Repeat the steps for calculating multiple  $E_b/N_0$  values.



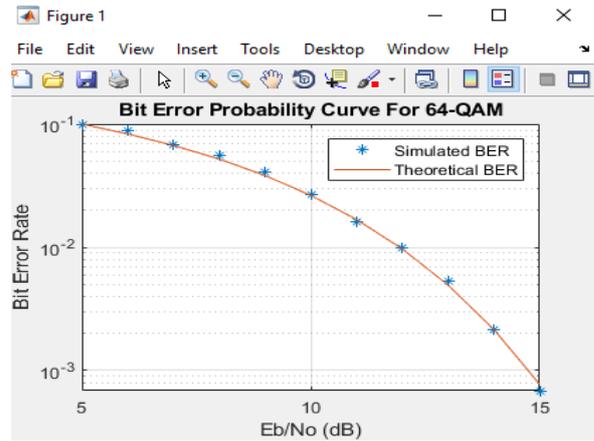
**Fig 12: Bit Error Rate Vs  $E_B/N_0$  -4 QAM**

Figure 12 describes bit error rate curve vs  $E_B/N_0$  4-QAM. Comparing and reviewing the results of the 4-QAM modulation can be concluded that Simulation results are better than the Theoretical result. So Simulated results work best in the noisy channel than BPSK modulation.



**Fig 13: Bit Error Rate Vs  $E_B/N_0$  16-QAM**

Figure 13 shows bit error rate vs  $E_B/N_0$  16-QAM. Comparing and reviewing the results of the 16-QAM modulations can be concluded that the Theoretical Bit Error Probability and Simulation Results are the same order and that there are minimal differences between them. So Simulated results work better in noisy channels.

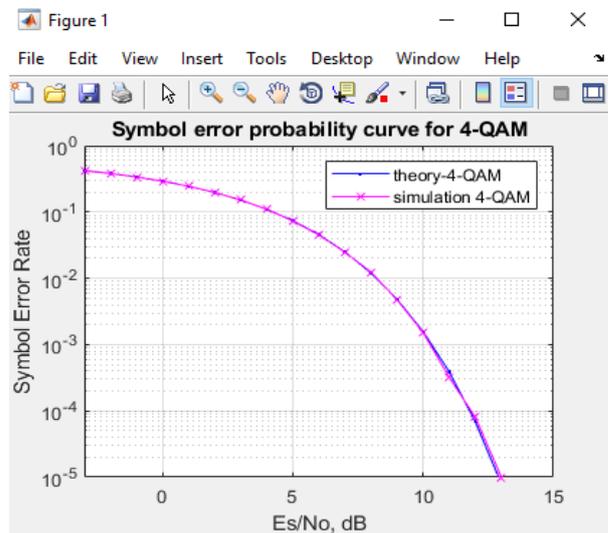


**Fig 14: Bit Error Rate Vs  $E_B/N_0$  64-QAM**

Comparing and reviewing the results of the 64-QAM techniques can be concluded that the Simulation results are better than the theoretical Bit Error Probability. So Simulated result works better in noisy channels. Figure 14 shows bit error rate vs  $E_B/N_0$  64-QAM.

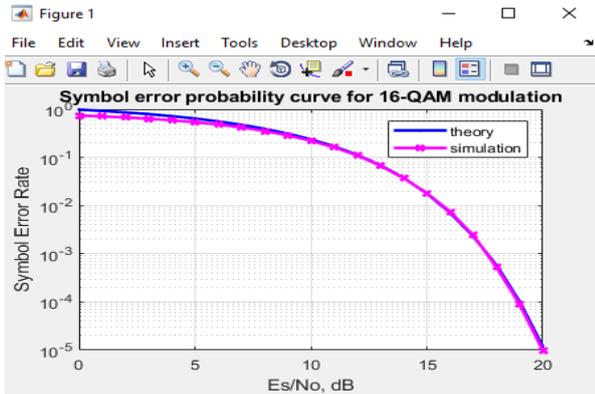
**B. Symbol Error Rate-M-QAM**

For Generating  $E_s/N_0$  for M-QAM transmission with AWGN channel and decode the received symbol. Figure 15 shows symbol error probability curve vs  $E_s/N_0$  4-QAM.



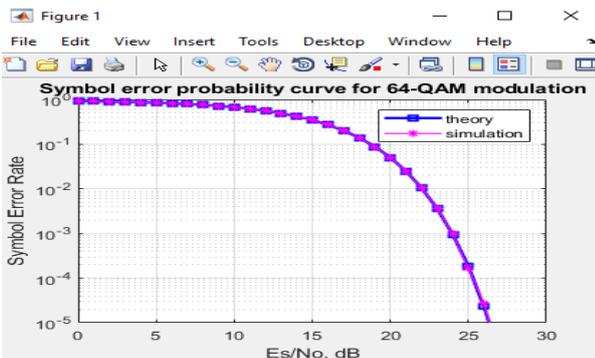
**Fig 15: Symbol Error Probability Curve Vs  $E_S/N_0$  4-QAM**

Comparing and reviewing the results of 4-QAM modulations can be concluded that the Theoretical System Error Probability and Simulation Results are the same order and that there are minimal differences between them. Hence the decoding on Symbol Error Rate is less.



**Fig 16: Symbol Error Probability Curve Vs  $E_s/N_0$  16-QAM**

Comparing and reviewing the results of the 16-QAM techniques can be concluded that Simulation System Error Probability results are reasonably less than the theoretical System Error Probability. Hence the decoding on Symbol Error Rate is less. Figure 16 shows symbol error probability curve vs  $E_s/N_0$  16-QAM.



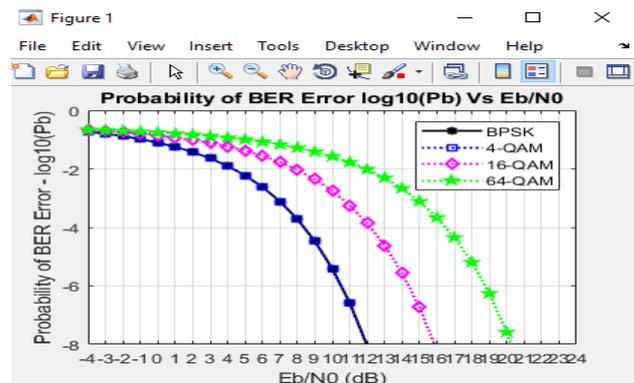
**Fig 17: Symbol Error Probability Curve Vs  $E_s/N_0$  64-QAM**

Figure 17 shows bit error probability curve vs  $E_s/N_0$  64-QAM. Comparing and reviewing the results of these 64-QAM techniques can be concluded that the theoretical bit error probability and simulation results are minimum differences between them. Hence the symbol decoding is less.

**C. Bit Error Rate**

The simulation has been done in MATLAB simulation environment. Modulation techniques (BPSK and QAM) which is bandwidth efficient that can be relate its performance situated on Theoretical Bit Error Rate over AWGN channel. Figure 17 shows the bit error rate comparison of BPSK, 4-QAM, 16-QAM and 64-QAM modulation schemes. The Figure clearly shows 4-QAM has a better error rate compare to BPSK. One bit is carried by one single analog carrier for the BPSK modulation technique. Therefore, data rate in bits per second is same as symbol rate. BPSK is not a bandwidth efficient modulation.

BPSK modulation has less noise, but not robust. Hence QAM is suitable than the BPSK. QAM is used because it provides a better distribution of the signals in constellation diagrams and a variety of shapes can be achieved. QAM has a superior bit packaging structure and also the lowest probability of error performance. QAM gives better performance because it can easily change the order of modulation ( $M=16,64$ ) than BPSK. BER for 4-QAM modulation techniques lies as same as BPSK modulation. BPSK is not robust, hence the performance of the QAM is best using the AWGN channel. The modulation techniques are 4-QAM, 16-QAM and 64-QAM found that higher modulations are more spectrally efficient. Hence QAM is adaptable to Li-Fi modulation technique



**Fig 18: BER Comparison Of BPSK, 4-QAM, 16-QAM, 64-QAM**

**VII. CONCLUSION**

We have presented Li-Fi and its modulation techniques which is essential for communication. Li-Fi is the upcoming technology of data communication. Since it is simple to generate light waves,

it is appallingly advantageous and simply implementable in varied fields. Li-Fi technology is very advanced to the LAN. It has wider bandwidth, fast response time and quicker than Wi-Fi. Each light in the world will be replaced by the LEDs and would act as data hotspot. As it is very low-cost, each and every one can afford it. The problem of radio frequency bandwidth is solved by using Li-Fi. Frequency flat Li-Fi and Low to Medium data Rates are done by single carrier modulation techniques. High data rate, which is easily adapted the system

performance done by Multi-Carrier Modulation. The Color dimension offer unique modulation techniques in Li-Fi. Time, Frequency, Space, Color dimension is the mixtures of Li-Fi Modulation Techniques.

The simulation model and the output waveform of the various digital modulation techniques are mentioned clearly. These modulation techniques must satisfy the illumination, quality of service that are very helpful for communication. The quality of service provided by wireless communication system is often greatly increased with the help of correct choice of modulation techniques.



The work is to measure Bit Error Rate of BPSK, 4-QAM, 16-QAM and 64-QAM modulation schemes and arrives with the best configuration to achieve higher consumption of bandwidth. The Bit Error Rate displays the implementation of the QAM modulation technique in the AWGN channel as same as BPSK modulation techniques. BPSK experiences less noise, but not robust. From this it is concluded that BER over AWGN channel conditions, QAM gives less bit error rate and better spectral efficiency. Finally, Li-Fi is a promising technology and also provides authentic and implemented in different fields.

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