# DESIGN OF 10 Gbps FSO COMMUNICATION LINK UNDER QUADRATURE AMPLITUDE MODULATION

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***Abstract: As a fast growing era of modern communication techniques, the demand arises for consistent high data rate transmission. The growing field of FSO systems provides the arising needs of high data transmission in communication systems. A lot of performance improvement techniques are established for FSO systems and one of them is implementing different modulation technique which allows different bits per symbol achieving higher throughputs. M-ary Quadrature Amplitude Modulation (M-QAM) is one of extensively used modulation techniques in the practice because of its efficiency in power and bandwidth Therefore, a need of studying and evaluating the performance of QAM modulation schemes is an important task for effective communication point of view. In this paper, QAM modulation scheme for 32 bits per symbol at 10Gbps data rate is designed. Performance of the system under 32 QAM is analyzed in terms of BER with varying input power levels and attenuation.***

***Keywords: Bit error rate, Quadrature amplitude modulation***

## 1. Introduction:

The major turning milestone in the field include successful transmission of EM waves, Invention of telegraphy, transistors, IC’s, Led’s vacuum tubes etc. It was made possible the development of small-size, low-power, low-weight, and high-speed electronic circuits which are used in the development of satellite communication systems, wideband microwave radio systems, and light wave communication systems using fiber optic cables. In 1962 Telstar I which was a satellite was used to relay TV signals between Europe and the United States. Later in 1965 Commercial satellite communication services began with the launching of the Early Bird satellite. Since then, most of the wire line communication systems are being replaced by fiber optic systems which provide extremely high bandwidth and make possible the transmission of a wide variety of information sources, including voice, data, and video. Growth in Cellular radio has provided telephone service to people in automobiles, buses, and trains. It is the reason High-speed communication networks link computers and a variety of peripheral devices are literally running around the world. Today we are witnessing a significant growth in the introduction and use of personal communications services, including voice, data, and video transmission. Satellite and fiber optic networks both provide high-speed communication services around the world. Surely, this is the dawn of the modern telecommunication era. One of the fast growing communication network is Free space optical communication which uses light wave in free space for the transmission of the signal. A lot of methods have been introduced to enhance the performance of the FSO systems. One of the method is to implement an effective modulation technique in FSO communication systems. It has been proven that QAM is the better modulation scheme for FSO networks[1]. So in this paper we are analyzing the FSO network under QAM modulation with varying input power of laser.

## 2. QUADRATURE AMPLITUDE MODULATION

Quadrature amplitude Modulation (QAM) is a complicated name for a simple technique. It is basically the combination of amplitude modulation and phase shift keying. We can say quadrature amplitude modulation is a modulation in which data is transferred by modulating the amplitude of two separate carrier waves, mostly sinusoidal, which are out of phase by 90 degrees (sine and cosine) therefore due to this phase difference, they are called quadrature carriers. In simple (OOK) modulation signals exhibit only two positions enabling a transfer of either a 0 or 1 but in quadrature amplitude modulation, it is possible to transfer more bits per position as there are multiple points of transfer. In quadrature amplitude modulation, a signal obtained from the combination of amplitude and phase modulation of a carrier signal (a modulated sine and cosine wave or quadrature waves) is used for the data transfer. Thus for more number of transfer points we can covey more number of bits per position change and possible position of the points of a particular configuration can be best denoted using a constellation diagram. Constellation diagram consists of constellation points that are arranged in a square or a circular grid with equal horizontal and vertical spacing (other configurations are possible as well). In digital communication systems the data is in binary form, so the number of points in the grid usually will be a function of the power of 2 (2, 4, 8, etc). The most common ones are 4-QAM, 16-QAM, 32-QAM and 64-QAM. Even if it's possible to transfer more bits per symbol with higher order constellations, theoretically, an inherent technical problem may exist. In order to maintain the balance of a higher order constellation at the same level, it is imperative that the constellation points remain close to each other. Digital phase modulation techniques were popular in the 1950s. during the development of QAM[2]. It was taking an account of alternative to digital amplitude modulation[3]. QAM is a the combination of digital amplitude and phase modulation. It was first proposed in 1960 by C.R. Cahn, who published a paper describing such a system[4]. It was suggested that amplitude and phase modulation (AM-PM) systems would result in an increase in data throughput compared to an equivalent PSK system of 16 or more states. Soon after his publication, Calm’s work was expanded by Hancock and Lucky [5] in which they suggested that errors occur due to the presence of noise in the system. Quadrature amplitude modulation (QAM) which is a combination of amplitude modulation and noise immunity of phase modulation is a popular and time tested RF technique. Its greatest advantage was that it increases the transmitted data rate without increasing the transmission bandwidth. Due to this reason M-ary QAM is most effective modulation technique for wireless communication.

**3 MATHEMATICAL MODEL OF QUADRATURE AMPLITUDE MODULATION:** The mathematical model of any digital modulation technique can be represented in a multitude of forms using variety of techniques derived from the three basic forms of frequency, amplitude, and phase keying. And modulated signal of QAM can be represented as:

$$s(t)=\sqrt{\frac{2E_{min}}{T_s}}a\ \cos(2\pi f_c t)+\sqrt{\frac{2E_{min}}{T_s}}b\sin(2\pi f_c t)\quad 0\leq t\leq T; i=1,2\ldots..$$

where:

$E_{min}$= Energy of the signal with the lowest amplitude.

a and b= Pair of independent integers.

M ary QAM does not have constant distant or constant energy between possible symbol states that is the reason values of s(t) will be detected with higher probability than others.

**4 System description**

The design and simulation of the system was done in the powerful software Opti system 15.0 and the layout of FSO system under Quadrature amplitude modulation was taken for different parameters as summarized in the table 1.

| Parameters | Values |
|---|---|
| i)Data Rate | 10Gbps |
| ii)Input power | 0-20dBm |
| iii)Wavelength | 1550nm |
| iv)Reciever Aperture | 20cm |
| v)Transmitter Aperture | 5cm |
| vi)Attenuation | 0.34 – dB/km |

Table 1 Various parameters for system Design of FSO under M-ary QAM

Initially Pseudo random bit generator generates the bit sequence i.e. in binary form. and transmits to the QAM sequence generator, which generates two parallel M-ary electrical signals from binary signals using quadrature amplitude modulation (QAM).Then this electric signal is transferred to two input ports of OFDM. Orthogonal Frequency Division Multiplexing (OFDM) modulates a digital signal into multiple orthogonal sub-carriers. The outputs from OFDM are connected by filters to remove noise in the signal. Then the Mach-Zehnder(MZ) modulator modulates the input signal with the carrier wave. The carrier wave of 1550nm is generated by the optical source. The optical source used here is a continuous wave laser in which power was varied from 0-20dbm.Then the signal from MZ modulator was transmitted in free space of 5 km using the free space component of opti system . Opti system enables the variation of attenuation in free space component therefore attenuation was varied from 0.34-3dB/km and results where evaluated on input power from 0-20dBm. The detector used in our system is a PIN Photodiode which is used to convert an optical signal into an electrical current based on the device‘s responsivity. After the detection of our electric signal by pin photodiode its output is given to Quadrature demodulator which demodulates the signal and then OFDM demodulator is used for the demodulation of OFDM signal. The optical signal is converted in electric signal by NRZ pulse generator to analyze the signal and to obtain the BER used for the demodulation of OFDM signal. The optical signal is converted in electric signal by NRZ pulse generator to analyze the signal and to obtain the BER..

**5 Result and discussion:** The performance of 32-QAM FSO system is analyzed in terms of BER and received power .In order to study the impact of environmental conditions on system, the input power of laser and the attenuation of the channel is varied. **T**he In-Phase and Quadrature-Phase electrical signals are presented in a constellation diagram sown in figure 1. It also display the polar diagram and estimate the probability of symbol error for M-ary signals. As 32-Qam is implemented so the symbols will be in four Quadrants . After the signal gets modulated it gets spread out as shown in figure 2 of output constellation diagram. For 32-QAM thirty two symbols are displayed in four different Quadrants.

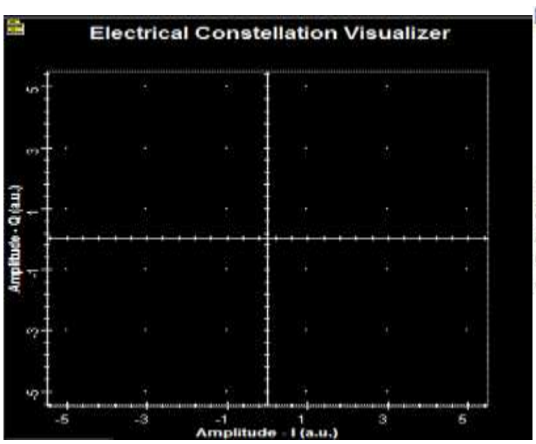



Figure 1 32-QAM constellation diagram(Input).

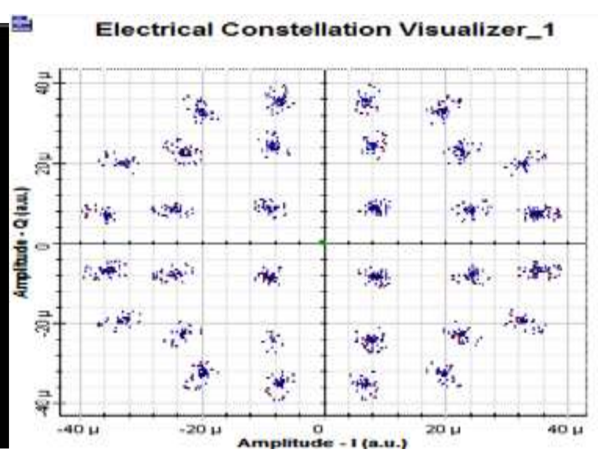
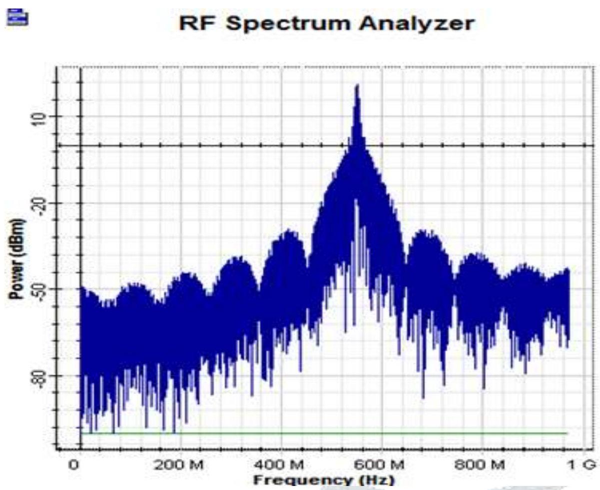



Figure 2 32-QAM constellation diagram(Output).

.RF spectrum for 32-QAM is shown in figure 3 which displays the signal in frequency domain. The corresponding electric signal at the output is displayed through eye diagram as shown in figure 4



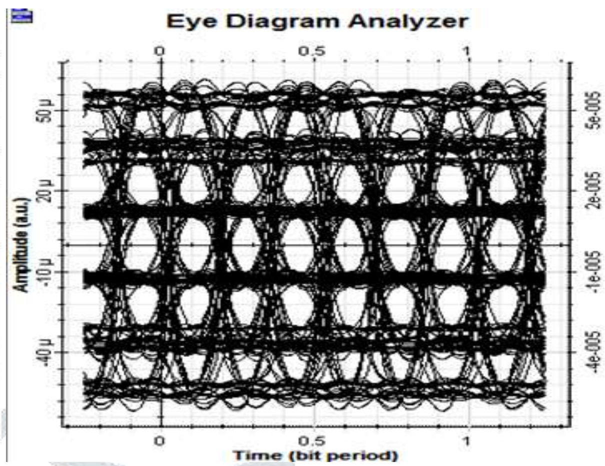
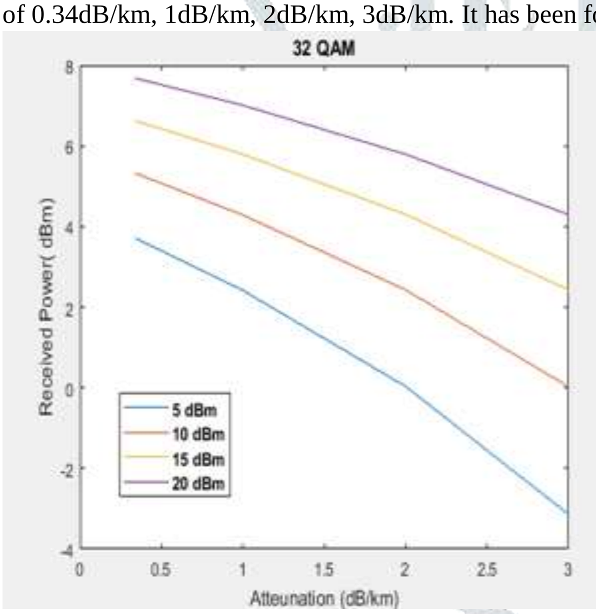




Figure 3 RF Spectrum for 32-QAM Figure 4 Eye Diagram for 32-QAM

The magnitude of attenuation directly influenced the power being transmitted for different attenuation levels (0.34, 1, 2,3) is in figure 5. The evaluated impact of input power on BER the different laser sources of power (0-20dBm) is used. The Performance of system is measured for attenuation levels of 0.34dB/km, 1dB/km, 2dB/km, 3dB/km. It has been found BER increases with increase in attenuation as in figure 6.



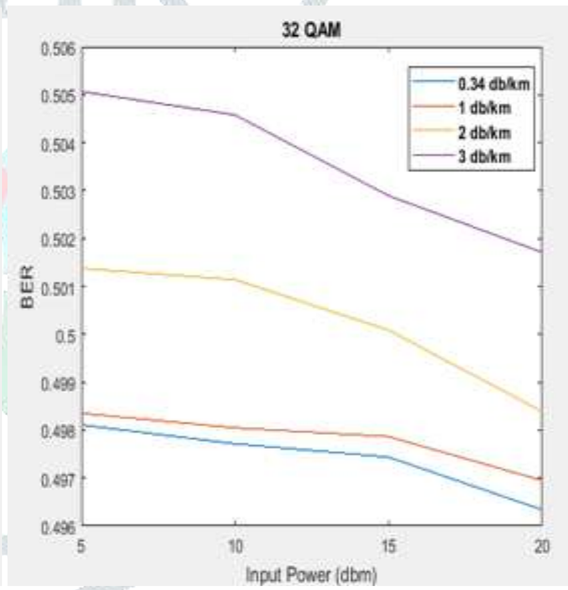




Figure 5. Received power vs Attenuation for 32-QAM Figure 47 Input power vs BER for 32-QAM

To study the impact of input power on BER the different laser sources of power (0-20dBm) is used. The Performance of system is eualvated for attenuation levels of 0.34dB/km, 1dB/km, 2dB/km, 3dB/km,which is shown in figure 7.

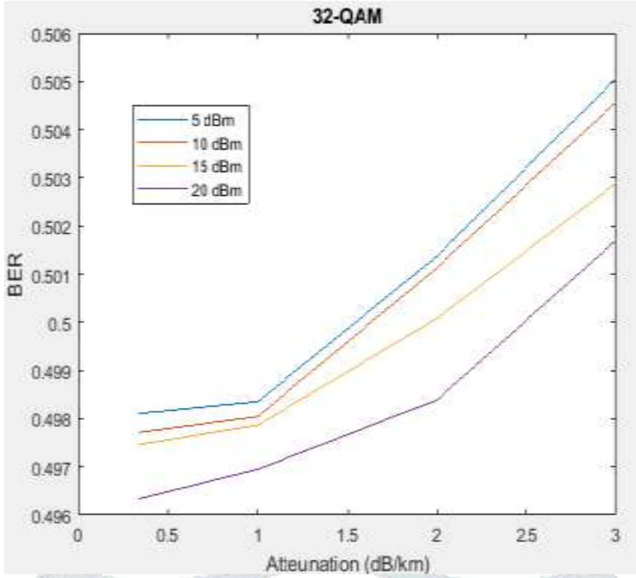


Figure 7 Attenuation vs BER for 32-QAM

**6. Conclusion**

The major concern in the field of wireless communication mainly in FSO communication systems is to transfer information as efficiently as possible through a limited bandwidth, though some of the information bits may be lost during transmission of the signal , in most of the cases and the signal initially transmitted will face degradation or fading. To minimize the effect of signal degradation in FSO system the BER should be as minimum as possible, with high power efficiency. In this paper 32-QAM modulation technique was analyzed at attenuation (0.03 – 3dB/km)and input power level(0 – 20dBm) in order to evaluate their BER performances in FSO system. The results show that increase in input power levels decreases the BER and hence the system performance is enhanced. Also increase in attenuation levels may degrade the system as it increases the BER.

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