Topic

"PERFORMANCE ANALYSIS OF FSO SYSTEM USING QAM, BPSK AND DPSK"

DISERTATION-II REPORT

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By

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ABSTRACT

In telecommunication, to send information through atmosphere free space optical (FSO) communication has been use modulated optical signal beams. The light communication concept in FSO communication is not new. It invented in 1880 by Alexander Graham Bell through his photo phone. He developed that modulated optical signal used to transmit telephone signal up to 200 meters through the air (or space). Due to atmospheric effects, the intensity and phase of received signal always are varying. So we need to use some modulation techniques to improve the performance of FSO system. Different modulation techniques have their different meaning to use. Although, they have different needs for implementing them in various practical areas.

Digital modulation schemes play an important role in the performance of wireless transceivers. In this paper, the comparative performance analysis of different modulation schemes compared over AWGN channel. In design of any digital communication system, the main goal is to receive the more approximated data to the transmitted from transmitter. To compare the system performance we analyzed the probability of error of the different modulation schemes. As modulation schemes are affected by random noises so they have different performance.

The comparative performance analysis of different modulation schemes compared over AWGN channel. In design of any digital communication system, the main goal is to receive the more approximated data to the transmitted from transmitter. To compare the system performance we analyzed the probability of error of the different modulation schemes. As modulation schemes are affected by random noises so they have different performance. The mathematical expressions and simulation results are explained for performance analysis of different modulation techniques. This paper focused on performance comparison of basic modulation schemes like OOK, BPSK, DBPSK, PPM, Mary PAM, Mary QAM and Mary PSK. The simulation results state that with increasing M value BER also increases. Here, results are compared without any interference.

CERTIFICATE

This is to certify that the declaration statement made by this student is correct to the best of my knowledge and belief. The Dissertation II thesis Proposal based on the technology / tool learnt is fit for the submission and partial fulfilment of the conditions for the award of M.Tech in ECE "Electronics and Communication Engineering" from Lovely Professional University, Phagwara**.**

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Designation: …….

Signature of Supervisor

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It is my profound pleasure to express my deep sense of gratitude to **Mr. RAJAN MIGLANI** for his valuable guidance, constructive suggestions and perpetual encouragement. I am very thankful to him as he has devoted his valuable time for us.

No appropriate words could be traced in the present lexicon to express my sublime obeisance to my family members whose supreme sacrifice, blessings, whole-hearted dedications were the correct source of inspiration.

In the end, I would like to thank all those persons whose names have not been figured in this write up but their contributions were not less important.

DECLARATION

I hereby declare that the project work entitled "Performance analysis of FSO Modulation techniques like QAM, DPSK and BPSK" is an authentic record of my own work carried out as requirements of Dissertation II for the award of degree of M.Tech in ECE (Department of Electronics and Communication) from Lovely Professional University, Phagwara, under the guidance of Mr. Rajan Miglani (Assistant Professor), during January to May, 2015).

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1. INTRODUCTION

1.1 Overview of FSO

The development of full duplex FSO analogue and digital system has been deal with laser communication link of free space optical (FSO). The growing need for high speed, bandwidth for communication channel is increasing. For a solution on these demands FSO is introduced which is easy to install, free to implement and of very high bandwidth. In FSO systems, visible optical beam are modulated and transmit through the air under different atmospheric conditions. A photo detector used to detect the signal at receiver side of FSO system. it demodulated the received signal to extract the information again.

The major advantages of FSO systems are having high speed which measure in the order of tens of nanoseconds. If wireless technologies which are faster measure in the order of hundreds of microseconds compare to this the advantage is automatically clear. Another advantage of FSO is security. FSO light beams have very small diameter which makes it virtually impossible to tap say by placing a mirror which would have to be in the middle link to be able to intercept both directions of communication. Communication must be disturbed due to different turbulence conditions. FSO does not require license to operate. Anyone can deploy FSO systems.

This line of sight technology in FSO system uses light to process information where both transmitter and receiver are in visual mode. FSO is capable of sending data, voice and video up to 1.2 Gbps to 10 Gbps simultaneously through the air. It enables optical communication at speed of light without requiring physical fibre optic cable.

The type of beam used differentiates which FSO system used for particular task. Traditionally wavelength range 700-800 nm in lasers were used but this has expanded over time to comprise additional bands on both side of spectrum. Free space optics has outdoor wireless capabilities. This means that the people who use this FSO technology will have greater mobility and flexibility than they would otherwise have with a fiber optic system. This type of communication system will have same speed as fibre has, but without being use of wires. Another important feature of FSO is that it is less affected by electromagnetic interference and radio frequency interference.

1.2 Working of FSO

The free space optical communication system consists of four major parts in its block circuit. The analogue transmitter, analogue receiver, digital transceiver and voice unit meter. This block circuit of FSO work on line of sight and full duplex phenomena in free space [1]. The complete system consists of two transceivers which is capable of transmission and reception of data simultaneously. Data should either in analogue form or digital. Two switches are used to control laser transmitter and phototransistor receiver. The analogue and digital information travels in opposite direction to each other.

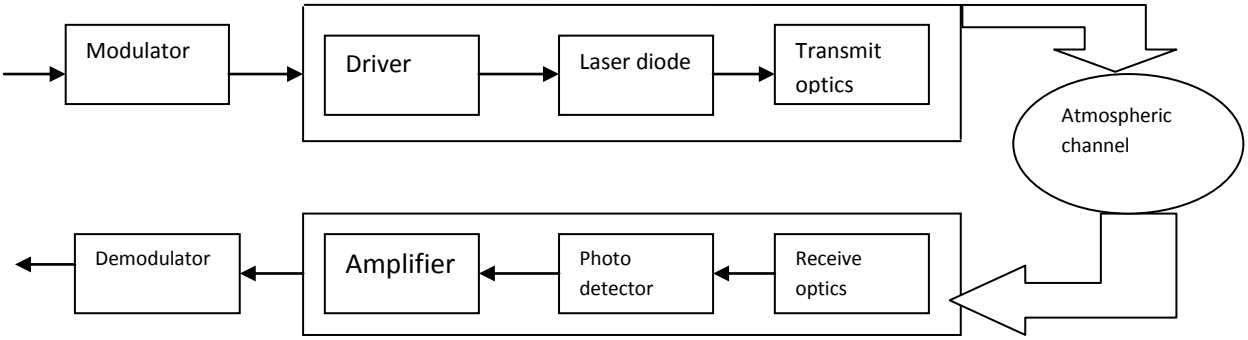


Fig 1: - FSO overview

In transmitter side, when analogue or digital input signal supplied the amplitude modulation of the laser diode performed. The circuit built for laser diode in protection that the input signal amplitude is too high. Transmitter portion is more complex as compared to receiver side in FSO block diagram. In receiver side, demodulation performed on analogue signal which extracted by phototransistor. To make the system connection easier and protect the listener from unrequited high pitch sounds used VU meter during alignment process. The complete system performed analogue modulation, digital modulation and display of received signal.

1.3 FUNDAMENTALS OF FSO

FSO is basic term that used to transfer information signal in form of data, voice or video whatever the requirement of a user between two points using optical radiations as a carrier signal through the air or atmospheric channel. The data had been modulated in form of intensity of the optical carrier. It can also be modulated in frequency and phase of the optical carrier. Both transmitter and receiver are placed visual to each other; there is no obstruction in their path for the communication link to be established. It means that FSO based on line of sight. The unguided channel may be any of the combination of the space, sea water and the atmosphere.

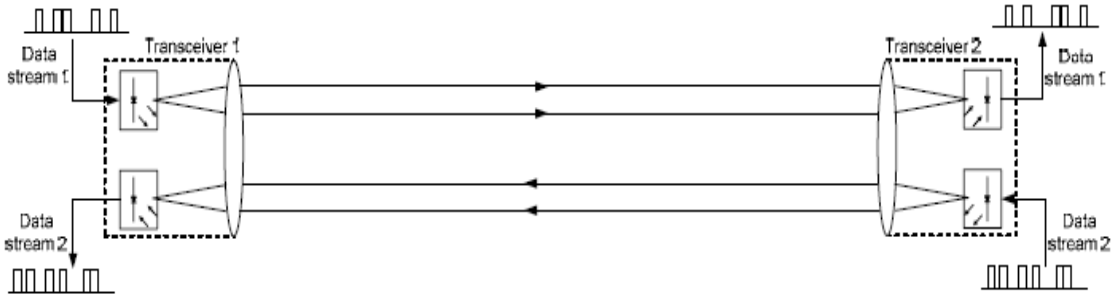


Fig 2: - conventional FSO system

This first diagram is for point to point communication with two transceivers. This allows the full duplex communication. In second diagram, continuous wave laser beam out to the retro reflector. Modulated retro reflector modulates that beam with the input data signal. The destination device recovers the data stream after collecting the return beam. Two way communications can be achieved by adding a photo detector to the modulated retro reflected.

1.4 BRIEF HISTORY ABOUT FSO

In the previous times, FSO system had been developed by the military and NASA to provide fast communication links in remote locations. The first Prototype of free space optical system developed by Lightpointe's chief scientists in their labs in Germany in the year of 1960's before the invention of fiber optic cable. While FSO used for secure communication especially by the German army during World War II. Recent advancements in FSO technology had been opened up with main requirements of communications uses; from short-term solutions on short distance network bridges had an attractive and viable alternative for service providers to deliver all the promise of all-optical based networks. Free space optics (FSO) had been introduced 20 years before to provide good access on fast and reliable communication in now days. As FSO system is new but it has achieved then huge acceptance for new technologies to transmit data from one place to another more quickly.

It uses similar bandwidth on what amount use to extract services in fibre optic with the new feature without using any wires or cables. On June 3, 1880, Alexander graham bell invented his work with the help of the first wireless telephone message on his newly invented "photo phone". Bell believed on that photo phone which was his most contributed invention in optical communication. This device worked on principle as projecting voice through an instrument toward a mirror in the Bell's photo phone. Some vibrations generated by voice in that scenario as same amount we have from the mirror also. Bell captured the sunlight to analyze the behaviour of sunlight in his invention work. The vibrations had been transmitted back to the receiver to analyzing their behaviour to get appropriate ideas on it. FSO contains many application on the basis of require cost and other fundamental quantities.

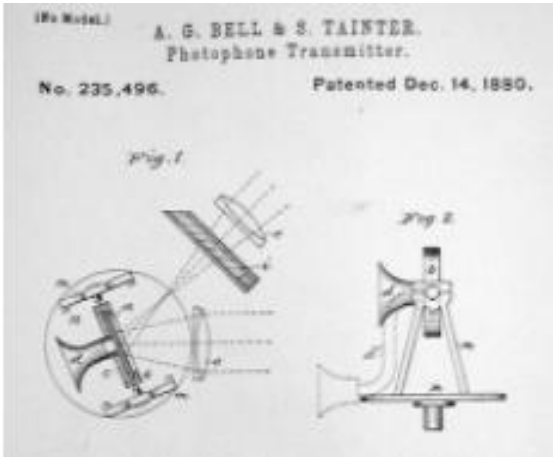


Fig 3: - Photo phone

1.5 FSO FEATURES

FSO is Optical or Wireless?

FSO is clearly an optical technology not a wireless technology for two primary reasons. One reason states that FSO enables optical transmission at speeds of up to 2.5 Gbps and in the future they are planning to achieve 10 Gbps using WDM through FSO communication system.

Huge modulation bandwidth: - In generally, FSO contains optical carrier frequencies far greater than RF which includes infrared, visible and ultra violet frequencies. The bandwidth of the modulated carrier is directly been related to the amount of data transported in any communication system. 20% of the carrier frequency is the allowable data bandwidth. On the rate of 2000 THz data capacity valuable by using optical carrier signals whose frequency range from 10^{12} to 10^{16} Hz. The growing range of information capacity had been guaranteed by optical communication. A factor of 10^5 in the RF frequency range is comparatively lower the usable frequency bandwidth.

Narrow beam size: - A typical laser beam had been diffraction limit on the range of divergence in between 0.01-0.1 mrad with an extremely narrow beam has the optical radiation pride itself. Within a very narrow area the transmitted power is only counted. By the potential interferes, FSO link providing with adequate with spatial isolations.

Unlicensed spectrum: - Major problem facing wireless RF communication is due to the RF spectrum interferences from adjacent carriers. Regulatory authorities put stringent regulations in place to minimize this interference. Therefore requires a huge fee or month's bureaucracy to be allocated a slice of RF spectrum. From now optical frequencies are free from this all. The deployment time are reduced by initial set up cost and in far more quickly the return on investments begins.

Cheap: - With a comparable data rate the cost of deploying FSO is lower than the RF. Without the extra cost of right of way and trenching FSO can deliver the same bandwidth as optical fibre delivers.

Quick to deploy or redeploy: - The time taken by FSO link could be as long as four hours for become fully operational with initializing from implementation down to link communication. The line of sight is required between transmitter and receiver to achieve FSO communication.

Weather dependent: - The performance of FSO clearly dependent on atmospheric conditions. The greatest challenged taken by the unfixed properties of the FSO channel.

1.6 AREA OF APPLICATIONS

To explore free space optics applications and security with the use of wireless optics that is considering important. There are so many applications for this type of technology and it offers a secure environment as well.

(a) **Last mile access**: - FSO can be able to use on high bandwidth need between the destination and the communication channel in form of cable. FSO provide ranging varying from 50 m to few kilometres with having data rate capabilities from the range of 1 Mbps to 2.5 Gbps in the market growth.

(b) **Optical fibre back up link**: - Against loss of data or communication breakdown, FSO used to provide backups in the event of damage or unavailable of the main optical fibre link.

(c) **Cellular communication links**: - In the $3^{rd}/4^{th}$ generation of communication networks, FSO had been used for data traffics between base stations and intermediate centres. From micro and macro-cell sites to the base station transmission of IS-95 code division multiple accesses (CDMA) signals.

(d) **Disaster recovery**: - In the event collapse of an existing communication networks for achieve connectivity, the technology fin applications where alternate link is needed to perform for FSO system.

(e) **Multi campus communication network**: - FSO can be used to interconnect many campus networks under the efficient manners.

(f) **Difficult terrains**: - FSO is an attractive data bridge in some instances where right of way is not available or too expensive.

1.7 TURBULENCE MODEL

Through the statistics and probability theory, the gamma-gamma distribution model is structured from continuous probability distribution. The exponential and chi squared distribution are the basic block cases of gamma-gamma distribution model.

In information theory, additive white Gaussian noise (AWGN) is structured noise model which contain all the effects of natural random processes. The term 'additive' indicates the noise added (not multiply) internally to the required information system. Whereas term 'White' indicates having uniform power for information system frequency bands and 'Gaussian' due to normal distribution in time domain.

Gaussian distribution had not accounted for other techniques like non linearity, frequency selectivity, dispersion and fading. The probability distribution function p(z) is given by

$$P(z)=\frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{z-a}{\sigma}\right)^2\right] \quad (1)$$

Where 'σ' is the variance, 'z' is any random signal and 'a' is mean of z.

For evaluating BER for FSO communication system gamma-gamma distribution is used. It is given by [2]:

$$\rho(I)=\frac{2}{\Gamma(\alpha)\Gamma(\beta)I}(\alpha\beta I)^{\frac{\alpha+\beta}{2}}K_{\alpha-\beta}(2\sqrt{\alpha\beta I})$$

$$\text{For } I>0 \qquad (2)$$

Where, I is the normalized irradiance, α and β are parameters of PDF, Γ is the gamma function and $K_{\alpha-\beta}$ is the modified Bessel function of the second kind of order α-β [3]. The parameters α and β are given by their expressions:

$$\alpha=\{\exp[0.49\sigma^2/(1+1.11\sigma^{12/5})^{7/6}]-1\}^{-1} \quad (3)$$

$$\beta=\{\exp[0.51\sigma^2/(1+0.69\sigma^{12/5})^{5/6}]-1\}^{-1} \quad (4)$$

α and β are large scale and small scale log irradiance variances. σ^2 is Rytov variance [4].

In gamma-gamma distributed channel transmitted signal has faced many other parameters that affect its performance such as intensity fading. The received signal that we get represented with the expression as:

$$Y=hx+n=\eta Ix+n \quad (5)$$

Where parameter representation as h-stands for gamma-gamma channel gain, x-stands for transmitted signal, n-stands for additive white Gaussian noise with having zero mean and $N_0/2$ variance and η-stands for photo current conversion ratio [5],[6].

1.8 ATMOSPHERIC EFFECTS ON FSO

The use of intensity modulation (IM) on the basis of direct detection system had involved by the most practical installation for FSO communication. On off keying intensity modulated the transmit data which goes through an air or free space to the receiver. The received optical signal collected by the receiver aperture and focuses it onto a photo detector which converts the instantaneous optical signal into the electrical signal form for the reception process. The received signal has some random intensity fluctuations in the presence of atmospheric disturbance on different turbulence conditions between the transmitter and receiver.

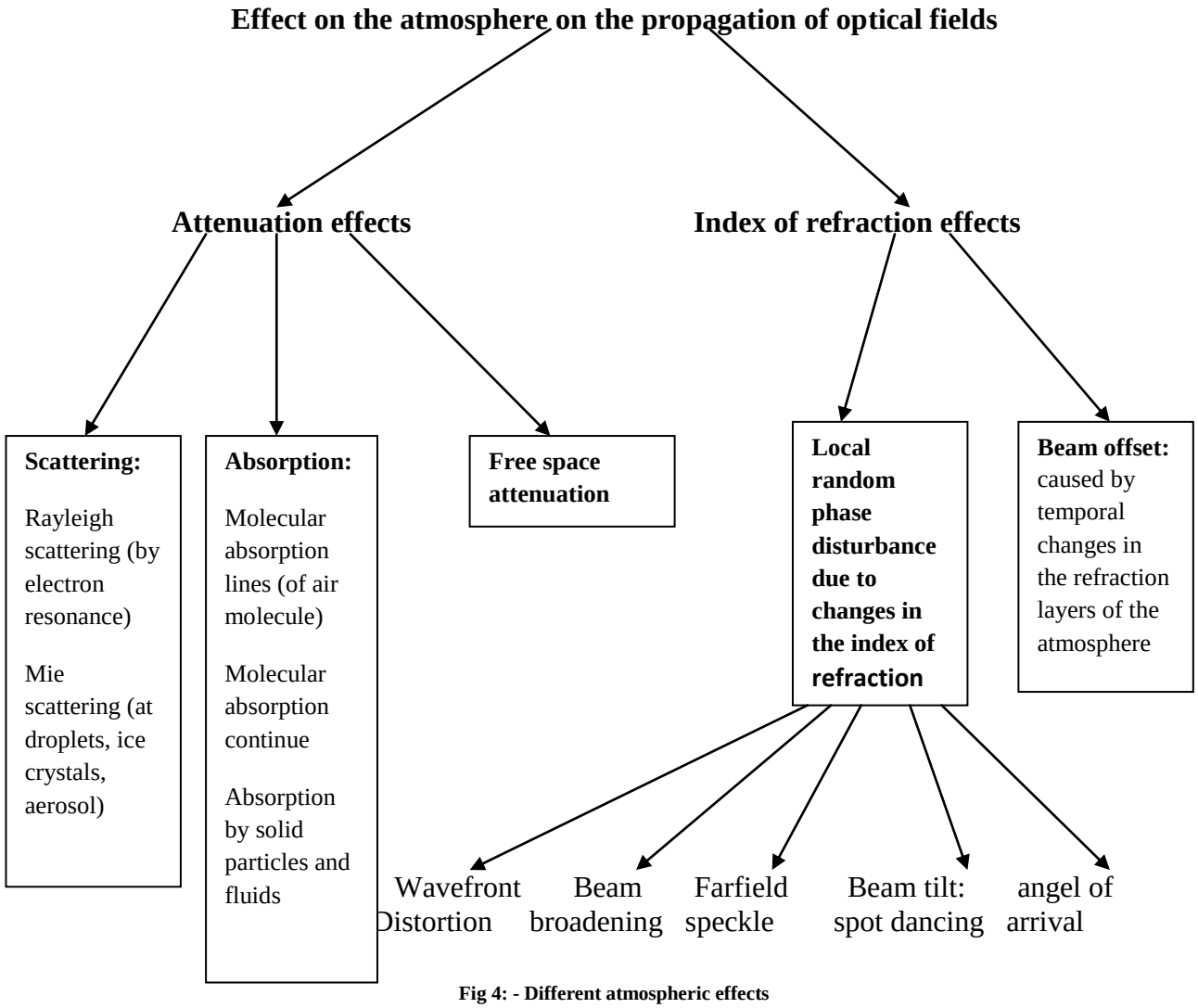


Fig 4: - Different atmospheric effects

1.8.1 Absorption: - Water vapour and carbon dioxide affected the channels in FSO. As compare to the infrared and ultra violet region of spectrum, the clean atmosphere has good absorption of radiation. Main absorbing agents in the atmosphere are water vapour, ozone, nitrous oxide, carbon dioxide, atomic oxygen and nitrogen. Ultra violet has less absorption bands as compare to the infrared because ultraviolet has transmission at low wavelength approximately at 0.3μm. In visible region on clear day, there is little absorption and when water content is low it is negligible.

1.8.2 Scattering: - FSO channels also affected by dust particles and water droplets. Scattering affected the performance of FSO system whether loss of energy is not released. At the receiver location, there is a reduction in received light intensity due to redistribution of light. The type of scattering determines by the physical size of the scatter. When the wavelength size is larger than scatter it is a Rayleigh scattering and when it's of measureable size with wavelength then this is termed as Mie scattering. If the wavelength size is much smaller than the scatter it is known as non selective scattering. In scattering, the energy is neither loss its redistribution of light which has some affect on beam light intensity for longer distances.

1.8.3 Scintillation: - Heat cause the burning of light waves which is scintillation phenomenon. FSO affected by scintillation process. Spatial diversity has different paths induced by multi beam approach in which multiple ways transmit same information on multiple beams. Scintillation is not effected metropolitan deployment because above the ground the deployment is high. It's not possible that the same pocket hit by same beam.

(a) Beam Wander: - Beam is smaller than the beam wander which is caused by turbulent eddies.
(b) Beam Spreading: - An optical beam had beam spreading concept in long term and short term spread which is further propagate through the atmosphere.

1.8.4 Fog: - Fog is the major challenge for FSO communication. FSO has little effect of rain and snow but fog is different. A summation under different techniques of absorption, scattering and reflection could be modifying light characteristics which are few hundred microns in diameter. Water droplet's vapour composed is fog. FSO link distances deploying FSO through a network design that is primary way to encounter the fog and add network redundancies.

Carrier-class reliability has successfully achieved in foggy cities such as San Francisco by FSO installations.

1.8.5 Physical obstructions: - : A single beam can block by flying birds. Transmissions are easily and automatically resumed to cause shorter interruptions. Other atmospheric conditions addressed by this issue by light Pointe uses multi beam system for greater availability provided.

1.8.6 Building sway/seismic activity: - The transmitter and receiver alignments can upset by the movement of buildings. Connectivity maintained by Light Pointe which used as a divergent beam. In ultra high speed FSO systems developed a tracking device is Light Pointe which mounted on freestanding towers.

1.8.7 Safety: - As technology uses lasers as transmission so safety is concern to those unfamiliar with FSO. This concern based on perception more than reality. When lasers had been appeared in different laboratories more than two decades ago which have been discussed proper use and safety of lasers. Human exposure to laser beam, the power supplies and high voltages within the laser system are two major concerns involved in FSO devices. Our FSO system has been set for performance and laser safety on these standards.

1.9 Different modulation techniques

Digital modulation techniques in communication system mostly divided into three categories: bandwidth efficiency, power efficiency and cost efficiency. Bandwidth efficient explained that use of modulation scheme within the given bandwidth. Power efficient is how much system is reliable for transmission of information on the minimum power requirement. They should be less expensive to encourage more users is explaining the concept of cost efficiency.

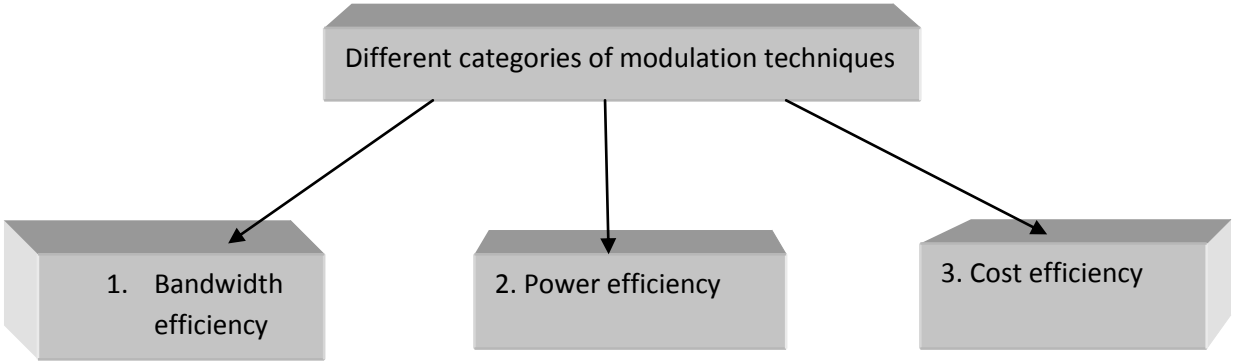


Fig.5 Different categories of modulation schemes

It is very difficult to handle these categories because if we going to increase one, another will automatically decreases with it. Due to all these effects the system becomes more difficult and performs not so well in different environment. For more understanding and comparison of the performance analysis of different modulation techniques we have to focus on bit error rate and symbol error rate firstly. Different modulation techniques have their different requirements on the application manners.

For optical wireless communication systems there are different types of modulation schemes. One of them is family of pulse modulation schemes. As we know that the emitted optical power is limited and if different modulation techniques are compared on the basis of average received optical power to achieved a required bit error rate on given data rate. To maximize the ratio of peak to average power is desirable by power efficient modulation scheme. FSO system based on performance analysis of modulation schemes: - On-off keying (OOK), pulse position modulation (PPM) and subcarrier intensity modulation (SIM) for non ideal channels. Modulation schemes are popular by their qualities in power efficient or bandwidth efficient for indoor and outdoor optical wireless communication applications.

1.9.1 OOK (On-off keying)

As per the implementation OOK (on-off keying) is the simple circuit modulation technique. It achieves data rate 1 bit per symbol. For binary logic 1, the pulse is present at the output waveform (on) and for 0 there is no pulse (off) this statement gives the meaning of what name indicate in OOK. Bit error rate (BER) performance of the OOK for AWGN is given by [7]

$$P_e = \frac{1}{2}\text{erfc}\left(\sqrt{\frac{E_b}{2\sigma^2}}\right) \quad (6)$$

Where E_b is normalized bit energy and σ^2 is the variance.

$$\text{erfc}(x) = \frac{2}{\sqrt{\pi}}\int_x^{\infty} \exp\left(-\frac{t^2}{2}\right) dt \quad (7)$$

In decibels, signal to noise ratio (SNR) is defined by

$$\text{SNR(dB)} = 10\log\left(\frac{E_b}{\sigma^2}\right) \quad (8)$$

To analyze the performance of OOK, we took comparative results of BER with varying SNR (signal to noise ratio).

1.9.2 BPSK (Binary phase shift keying)

BPSK (Binary phase shift keying) is also a simplest modulation technique on the basis of implementation circuitry. In BPSK, data information varies with two phases which are 180 degrees apart from each other. The performance of BPSK in terms of BER is given by [8]

$$P_e=0.5\text{erfc}\left(\sqrt{\frac{E_b}{\sigma^2}}\right) \quad (9)$$

As we know that today all technologies are bandwidth hungry, due to achieve all this things we have to increase the data rate of modulation techniques to have more number of bits per symbol.

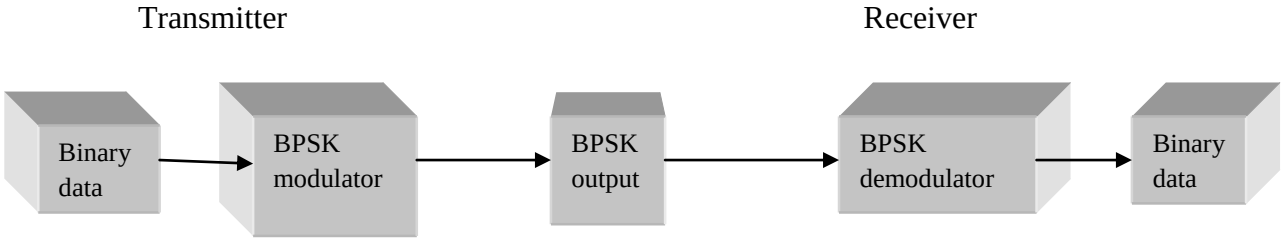


Fig 6.BPSK block diagram

For Mary PSK, BER is represented as [8]

$$P_e=\frac{1}{k}erfc\left(\sqrt{\frac{kE_b}{N_0}}sin\left(\frac{\pi}{k}\right)\right) \quad (10)$$

1.9.3 QAM (Quadrature amplitude modulation)

QAM (Quadrature amplitude modulation) technique is the combination of amplitude and phase modulation used into a single channel to achieve the double effective bandwidth. QAM uses two carrier signals at same frequencies but having different phases which are differing by 90 degrees (one quarter of cycle) to each other. On the mathematically, one carrier signal is represented by sine wave and another by cosine wave.

Now we considered as *k* number of bits mapped on one of the *M* phase of carrier signal. For Mary QAM, BER is represented as [8]

$$P_e=\frac{2}{k}\left(1-\frac{1}{\sqrt{M}}\right)erfc\left(\frac{x}{\sqrt{2}}\right) \quad (11)$$

1.9.4 PPM (Pulse position modulation)

In FSO system PPM is the modulation technique from pulse family. This modulation technique is energy efficient. In PPM modulation technique the amplitude of the pulse is constant for avoiding different noise disturbances. PPM can demodulate data through both the ways synchronously and asynchronously. Synchronous demodulation process is quite difficult due to it need synchronization of the transmitter and receiver.

One of the most advantages of PPM system is it can implement non-coherently.

Due to non coherent implementation it does not need of phase locked loop for carrier phase synchronization. As we know that coherent modulation and demodulation is complex and very difficult.

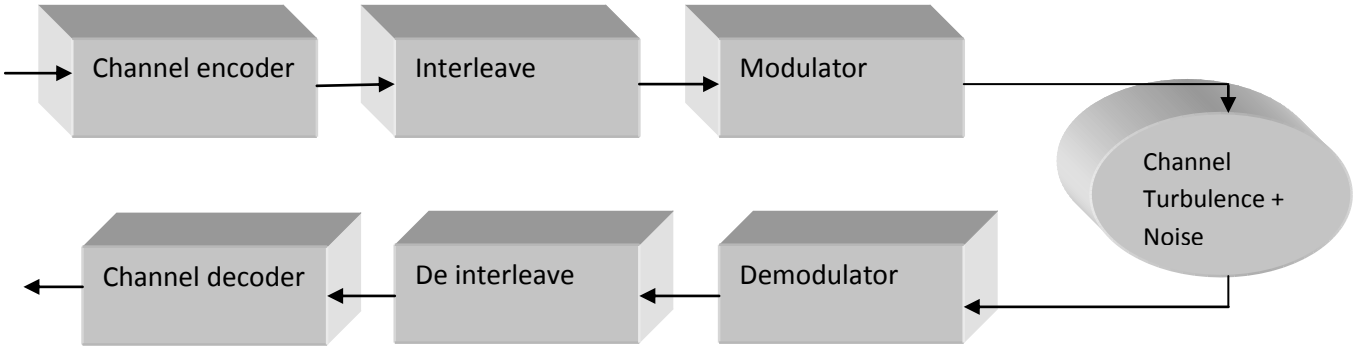


Fig 7.PPM block diagram

1.9.5 DPSK (Differential phase shift keying)

DPSK is also a kind of phase shift keying modulation technique. It changes the phase of the carrier signal for the purpose to convey the data information. The general BPSK encoding changing phase of 180 for logic 1 and 0 for logic 0 but in DPSK +90 for logic 1 and -90 for logic 0.

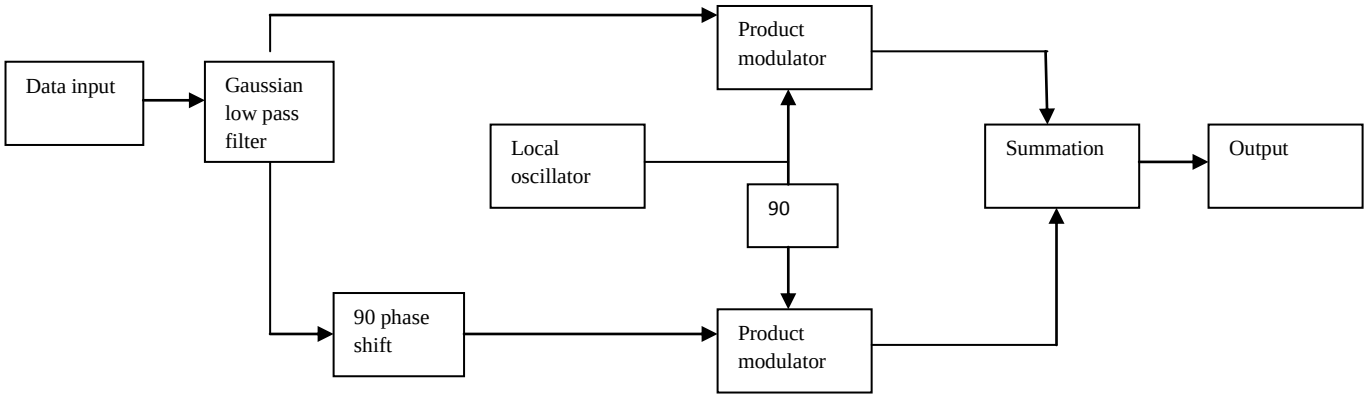
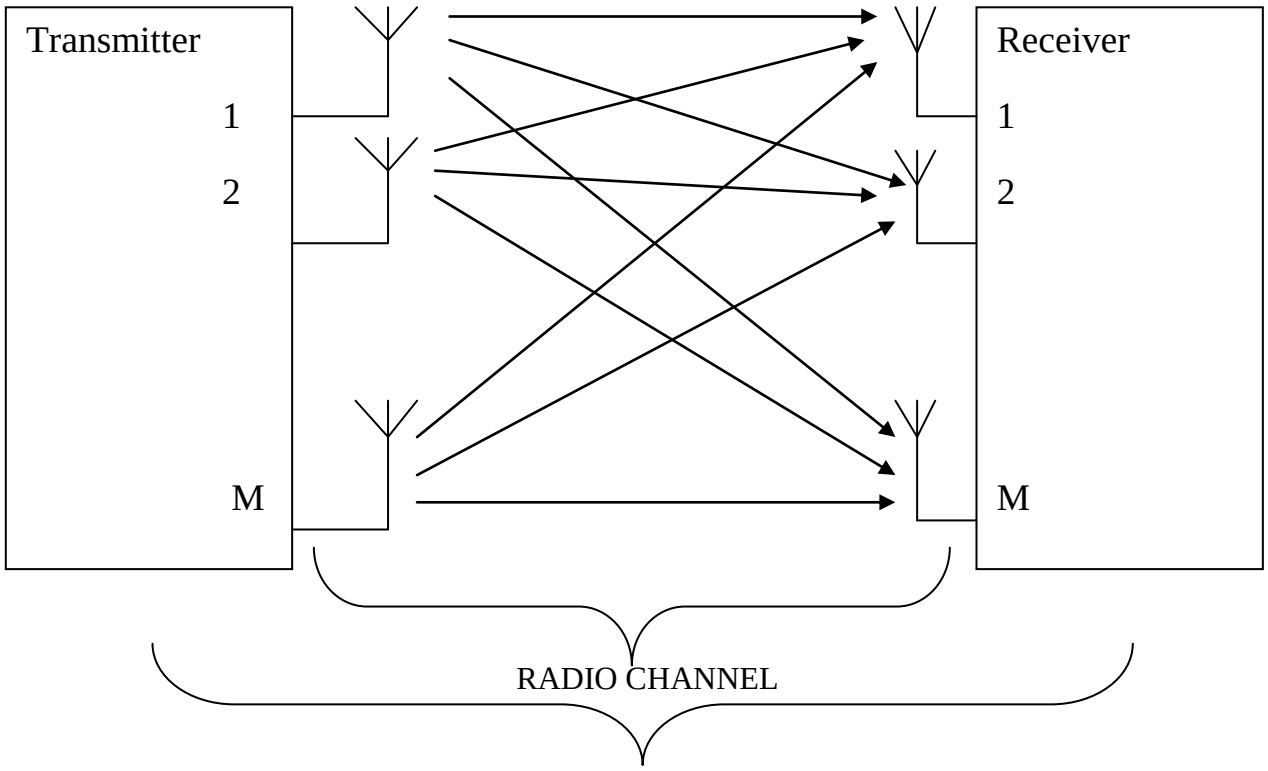


Fig 8.DPSK block diagram

1.9.6 MIMO (Multi input multi output)

In a free space communication, for transmitting data in the order of mega bits and giga bits, mostly radio frequency is used; even an attractive technique Free Space Optical communication can also be used. As the medium of transmission is air it easily affected by environmental conditions when passed light through it. These conditions create some challenges on the performance of the system. Due to some random variations in the temperature and the pressure of the atmospheric region by which the Free Space signal has to pass created atmospheric turbulence. Compare to large data rates, scintillation process is slow in optical transmission.



MIMO SYSTEM

Fig 9.Block diagram of MIMO

MIMO can be used for multiple transmitting and receiving antennas. This system improves the communication performance. Multiple antennas performed some functions based on smart antennas. With the help of these features the performance of the communication system should increase. It should also increases the spectral efficiency means more required bits had been transmitted with the use of MIMO system. MIMO system can be capable of transmitting independent information streams through multiple smart antennas and may transmit multi dimensional signal also.

MIMO system is not limited under the wireless communication features. It should also used in wire line communication also. MIMO is the more efficient radio communication technology that been used in many new technologies now day. It basically used to increase the link capacity with spectral efficiency to get the reliability in the communication system for data transmission.

Different modulation techniques have different applications. They are widely used in practical applications for different purposes. Application area of modulation techniques are categories as [9]

Table1. Applications of different modulation techniques

Modulation format	**Applications**
BPSK	Cable modems and space telemetry
QPSK	Satellite, CDMA, cable (return path)
8-PSK	Satellite, aircraft, for monitoring broadband videos used in telemetry pilots
16-QAM	Microwave digital radio, modems , DVB-C,DVB-T
32-QAM	Terrestrial microwave, DVB-T
64-QAM	DVB-C, modems, broadband set top boxes
256-QAM	Modems, DVB-C (Europe), digital videos (US)

2. Review of literature

Paper 1: Bykhovsky, D. Electro-Opt. Eng. Unit, Ben-Gurion Univ. of the Negev, Beer-Sheva, Israel Arnon, S. **"Multiple Access Resource Allocation in Visible Light Communication Systems"** in 2014, IEEE journal [10]

In this paper, the author states that, the effectiveness of the proposed MA-DMT scheme increases with the number of users. In his work done he propose an algorithm that manages interference-constrained subcarrier reuse between different transmitters and power redistribution between different subcarriers in a heuristic manner. The efficiency of multiple access (MA) DMT communication in the presence of interference and power constraints increases in reuse of the subcarriers. With a conventional DMT method, in the average bit-rate

compared by the algorithm simulation shows an improvement. For visible-light communication an efficient single-transmitter technique is known as discrete multi-tone (DMT) modulation. In order to exposes the full potential of spatial multiple-transmitter diversity, environment requires effective subcarrier and power allocation design in a multiple transmitter used this technique.

Paper 2: Zixiong Wang Sch. of Electr. & Electron. Eng., Nanyang Technol. Univ., Singapore, Singapore Wen-De Zhong ; Changyuan Yu. **"Performance Improvement of OOK Free-Space Optical Communication Systems by Coherent Detection and Dynamic Decision Threshold in Atmospheric Turbulence Conditions"** in 2012, IEEE journal [11]

In this work by author, in atmospheric turbulence conditions improved on-off-keying free-space optical communication due to coherent detection and the dynamic decision threshold (DDT) scheme. The DDT scheme is related to the strength of amplitude and phase fluctuations, not to the power of the local oscillator achieved the improvement in addition. With the conventional fixed decision threshold scheme, power reduction for achieving a bit error rate of 10-3 compared analytical results show that the DDT scheme provides a 5.7-dB.

Paper 3: Vavoulas, A. Dept. of Inf. & Telecommun., Univ. of Athens, Lamia, Greece Sandalidis, H.G.; Varoutas, D**" Weather effects on FSO network connectivity"** in 2012, IEEE journal[12]

In this paper the author states that mitigating impairments of the performance of free space optical system is one of the most promising methods with the use of relays. It also helps to extending their limited transmission range. Significant link performance degradation depends on several factors that contribute. In this paper he considered the node are distributed with a multiple hop FSO networks at fixed position on a given path link. For the node isolation probability derived analytical expressions of the most critical weather phenomena i.e. fog, rain and snow, assuming a suitable path loss factor. To achieve the reliable performance the number of transceivers for given path link in order can be founded. For known number of FSO transceiver the total service length can be funded. To design such networks in practise constitutes by a valuable tool for telecom researchers. The performance of FSO networks degraded with the addressed analytical frame work that offers significant insights into the main factors. The impact by FSO modulation also is considered in this paper.

Paper 4: Tian-Peng Ren Sci. & Technol. on Aerosp. Flight Dynamics Lab., Beijing Aerosp. Control Center,Beijing, China Chau Yuen ; Yong Liang Guan ; Ge-Shi Tang **"High-Order**

Intensity Modulations for OSTBC in Free-Space Optical MIMO Communications" in 2013, IEEE journal[13]

In this paper the author states that high order modulation with optical OSTBC (orthogonal space time block coding) schemes extended the investigation. Diversity gain provided the proposed modulation schemes that can be used with shift OSTBC to mitigate inter symbol interference (ISI) from different transmitters that arrived at the receiver with timing misalignment in asynchronous FSO MIMO channels. To maintain the orthogonality of the applied OSTBC is derived and four Q-ary intensity modulation schemes satisfying this condition are proposed a necessary and sufficient condition for the higher order intensity modulation. To support free space optical multi input multi output (MIMO) systems with OSTBC modified the binary pulse position modulation that requires the use of negative symbols.

Paper 5: Zixiong Wang, Wen-De Zhong, Senior Member, IEEE, and Changyuan Yu, Member,*"* **Performance Improvement of OOK Free-Space Optical Communication Systems by Coherent Detection and Dynamic Decision Threshold in Atmospheric Turbulence Conditions***"*in 2012 IEEE journal [14]

In this letter author did some performance improvement techniques to analyse the performance of ON OFF keying with the help of dynamic decision threshold and coherent detection on different atmospheric turbulence conditions. With the help of DDT (Dynamic decision threshold) got improvement in OOK performance. He reduced 5.7 dB power for taking bit error rate at 10^{-3}. The improvement detected with the help of these techniques was based on amplitude and phase variations only. It did not depend on power of the local oscillator.

Paper 6: Xuan Tang, Zhaocheng Wang, Senior Member, IEEE, Zhengyuan Xu, Senior Member, IEEE, and Zabih Ghassemlooy, **Senior Member, IEEE" Multihop Free-Space Optical Communications Over Turbulence Channels with Pointing Errors using Heterodyne Detection"** in 2014 IEEE journal [15]

This paper proposed by author on turbulence channels. Here multi hop free space optical communication technique was used with binary phase shift keying modulation. This work performed on turbulence fading channel to analyse the performance with the help of it. Fixed gain relays can be used in basic model of FSO system to developed pointing errors and different effects due to path loss. With the help of Meijer's G function, the formulated expressions probability density function, moment generating function etc. of multi hop FSO

channel can be detected. The outage probability and symbol error rate had been derived with these fundamental functions derivation. Turbulence strength is varying from weak to moderate and then moderate to strong turbulence conditions. The effect of these conditions gave geometric loss and pointing error on the FSO system.

Paper 7: A. Gatri1, Z. Ghassemlooy, A. Valenzuela, O. Strobel and R. Rejeb Optical Communications Research Group, NCRLab, Faculty of Engineering," **Experimental Study of coherent detection BPSK Modulated Communication Link under Controlled Fog Atmospheric Conditions**" in 2014 IEEE journal [16]

In this paper, author proposed the effect of fog on the performance of FSO system. This whole work detected with the help of binary phase shift keying (BPSK). This whole performance done in controlled laboratory. In laboratory environment they generated fog and took impact of this fog on FSO link. After this experiment, the experimental data was compared with the theoretical values. This paper presented the performance of the FSO system on the basis of different fog conditions. This paper also studied on to improve FSO link performance with the use of combination of concave and convex mirrors for improved beam spot size.

Paper 8: Harjot Kaur, Bindiya Jain, Amit Verma, Dept. of ECE, DAVIET, Jalandhar, Punjab, IndiaDept. of ECE, Rayat and Bahra Institute of Engg. and Technology, Mohali, Punjab, India" **Comparative Performance Analysis of M-ary PSK Modulation Schemes using Simulink**",IJECT 2011[17]

In this paper, author tried to explain the concept of using modulation on received data. Author had analyzed the performance of the system in the form of probability of error which further intended by the bit error rate along with signal to noise ratio for Mary-PSK. In this paper, author purposed different simulation results of different PSK techniques on the error rate basis. Also mentioned the marks by which can estimate about on what particular range the number of bits increased to transmit on single time. As graphs also indicated that the bit error rate is also decreases with the increase in signal to noise ratio.

Paper 9: Nitin Shankar Singh, Gurpartap Singh,Dept. of Electronics and Communication Lovely Professional UniversityPhagwara, India," **Performance Analysis of OFDM-FSO System using BPSK, QPSK and 8-PSK Modulation Techniques**", International Journal of Computer Applications (0975 – 8887)Volume 66– No.17, March 2013 [18]

In this paper, author outlined the comparative performance of BPSK, QPSK and 8-PSK modulation techniques on the basis of their performance. FSO had been modelled under gamma-gamma distribution of atmosphere in this paper for achieved higher data rate transmissions using with the help of modulation techniques. Due to atmospheric disturbances the performance of communication system gets affected, to improve this performance authors had use many technologies. So that has data less corrupted in form of unwanted data bits. In modulation techniques, as we increasing the modulation levels the data rate also increased. With increasing data rate error also introduced so we have some limitations in using any communication system. We only wished to enhance one quantity, the other one has affected automatically through it.

Paper 10: Laith Awda Kadhim,A-Khwarizmi College of Engineering, Mechatronics Engineering Department, University of Baghdad, Iraq," **16/64QAM Modulation Technique for Free Space Optical Communication System",** Photonic Technology Lab (PTLab), Centre for Research in Photonics, University of Ottawa,Canada [19]

In this paper, author had worked on QAM modulation which is further combined from amplitude and phase modulation. It used to work on both either to modulate phase or amplitude of the signal. In this 16-QAM compared with 64-QAM on different sets of conditions like how much data rate could be achieved by any of them. With the increasing growth of capacity the attenuation also affects the channel with more easy rates. On same power and bandwidth increased data rate from 16 to 64-QAM has some limitations like circuit implementation also become more complex and attenuation also increases.

Paper 11: Z. Wang,W.-D. Zhong, Senior Member,S. Fu,C. Lin, Fellow, "**Performance Comparison of Different Modulation Formats Over Free-Space Optical (FSO) Turbulence Links With Space Diversity Reception Technique**", Volume 1, Number 6, December IEEE 2009 [20]

In this paper author mentioned about the comparative performance analysis of different modulation techniques on FSO system with considering effect of different turbulences with space diversity reception technique. Author focused on how performance of FSO system degraded from different atmospheric conditions with using different modulation techniques OOK, DPSK, DQPSK etc. It contained theoretical and simulated analysis on gamma-gamma channel model. Using space diversity analyzed that the same BER achieved at 3.2 dB instead of

achieved at 19 dB. Whether turbulence is moderate or strong, DPSK and DQPSK has same performance for FSO system on different conditions of atmosphere.

Paper 12: W.O. Popoola and Z. Ghassemlooy, Fellow IET, Senior Member IEEE, E.Leitgeb," **Free-Space Optical Communication in Atmospheric Turbulence using DPSK Subcarrier Modulation**", Optical Communication Research Group, NCRLab, Northumbria University, Newcastle upon Tyne, UK [21]

In this paper, author had done work on DPSK under different atmospheric disturbances. It outlined about how the different turbulence models are suitable for different atmospheric regions. Some factors on atmosphere have corrupted the performance of every communication system. FSO also corrupted but having high speed and more data rates. With the help of different modulation techniques, every communication system performance gets enhanced.

3. Present work

3.1 Scope of study

Presently all technologies are bandwidth hungry because they have huge demand of differential data services. They forcing the bandwidth and storing data capability with keep increases the network traffic after few months. Communication is relayed on speed always. Faster the system speed indicates the effective communication. In 21 century, the wireless networking is more popular due to its speed and ease of deployment and high network robustness features. With the invention of laser in 1958 the optical communication originated.

We all think about optical fibres when we heard something about the optical communication. But in today we have wire free optics means optical communication without fibres. Optical communication processes its data rates from gigabits/sec to terabits/sec.

Free space optics or FSO is based on transmission of modulated visible light through the free space (or atmosphere) to acquire optical communication. FSO is line of sight technology can able to operate over distances of several kilometres. There are various fields of research in FSO like modulation techniques, channel capacity, channel modelling etc. In this work estimated different modulation techniques to enhance the system performance of FSO system. Different modulation techniques considered as OOK (On-off keying), BPSK (Binary phase shift keying), QAM (Quadrature amplitude modulation), PPM (Pulse position modulation) etc are used to modulate data to enhance FSO system performance. As now days we cannot go through with modulate single bit and transmit it. We need to achieve more data bits to transmit on faster

mode. So we moving to studied about Mary modulation schemes that provide capability of more data bits modulated and send. Due to atmospheric disturbances causes intensity fluctuations which introduced bit error in FSO data rate performance. FSO system has different service provider applications.

3.2 Objective

(a) Digital bit stream data or analogue data need to modulate on higher frequency sine waves in communication.
(b) In today, we have so many modulation schemes to modulate our data.
(c) These modulation techniques affect the proposed work of the system in form of bit error rate and bandwidth requirement.
(d) Simulation with the different modulation schemes on the different parameters like error rate probability, power efficiency and probability density function.
(e) If we modulate digital bit stream data, we simply have two states of amplitude i.e. 'logic 1' and 'logic 0'. Here we need to change the carrier wave when data changes between 0 and 1. This process simply known as amplitude modulation.
(f) If we modulate analogue data, it is continuous in time and value. We simply make the carrier amplitude at instantaneous value of the signal at a given proportional time.
(g) Comparison between the different modulation techniques on the basis of their benchmarks.

3.3 Research methodology

Communication is the way to transfer data from one place to another through different communication channels. Examples of different communication channels are optical fibres, copper wires, computer buses, storage devices and wireless communication channels. Data should always in the form of analogy or digital. FSO system is also a kind of communication link that provide high speed, licence free spectrum with wireless features. In today world, all technologies are bandwidth hungry. So to take these advantages FSO is more efficient communication channel. FSO is better than RF wireless channel due to RF gets signal fading in multipath propagation. But FSO also has some certain limitations on the basis of effects by atmosphere. Atmospheric conditions also affect the performance of the FSO system.

To overcome this drawbacks there are many atmospheric channel models in free space optics. In theses channel models Lognormal, Negative exponential and Gamma-gamma channel models are mostly used. Lognormal model is used for low turbulence and for high turbulence Negative exponential model is used. Gamma-gamma channel model widely used by low to high turbulence. To enhance the performance these models play an important role in FSO communication.

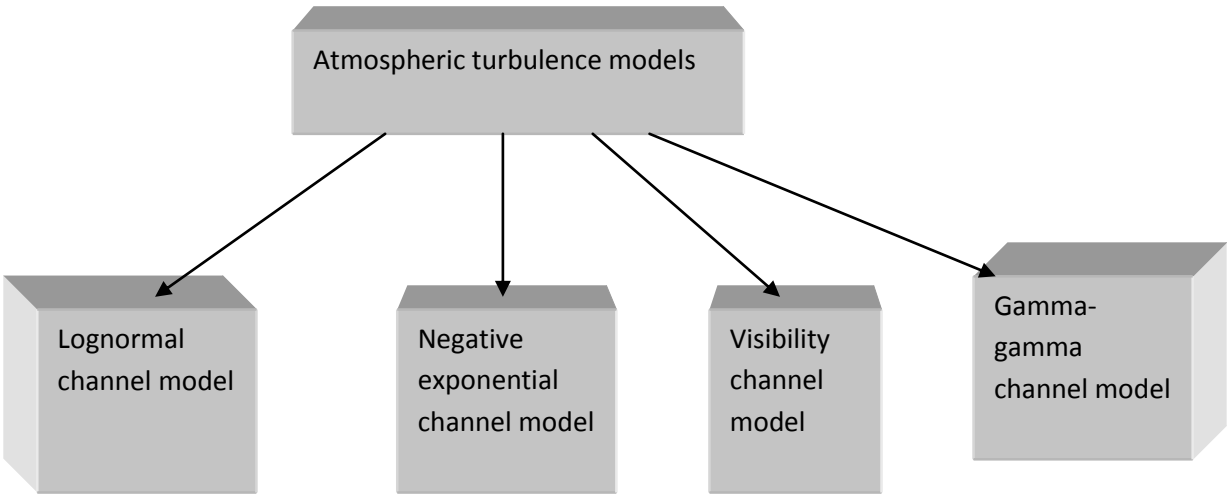
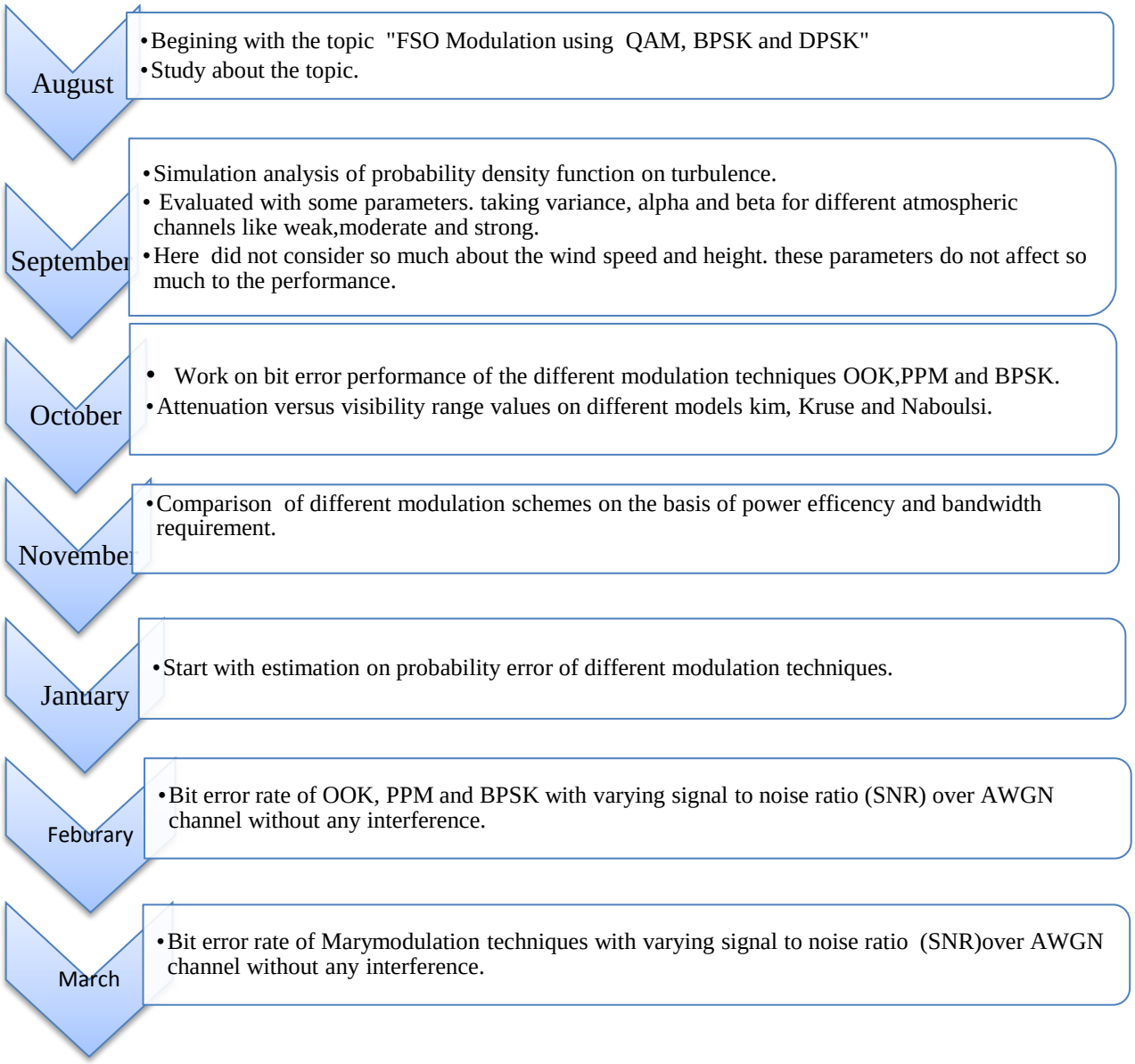


Fig 10.Categories of turbulence model

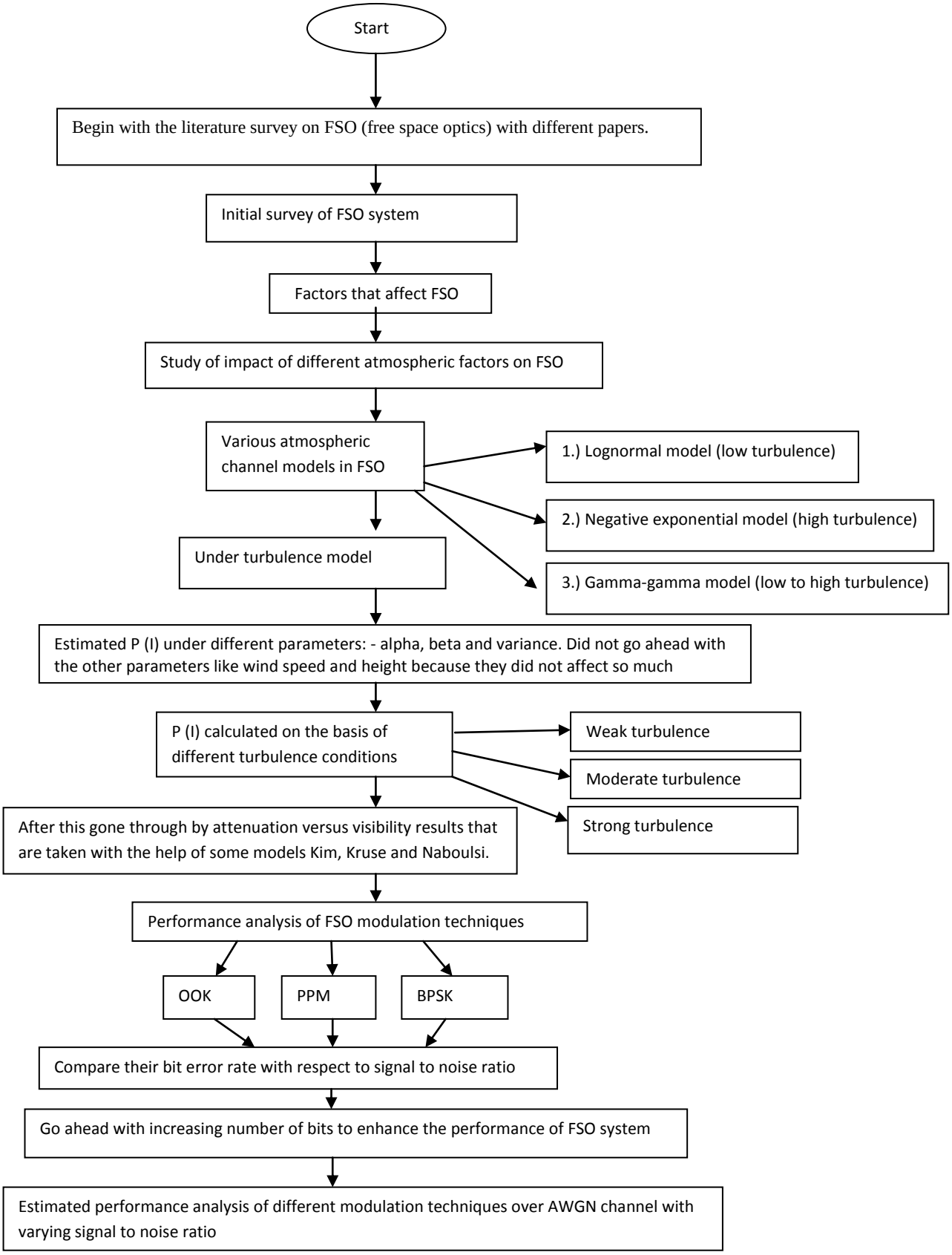
FSO links performance degraded by atmospheric disturbances which causes some variations in the intensity of the light. With the help of space diversity and advanced modulations we can enhance the transmission and reception of the FSO system.

With the help of modulation techniques we can increase the performance analysis of the FSO communication system. There are so many modulation schemes have now for take efficient performance on the basis of different application requirements. Examples of different modulation techniques are OOK (On-off keying), BPSK (Binary phase shift keying), DPSK (Differential phase shift keying), QAM (Quadrature amplitude modulation) and PPM (Pulse position modulation).

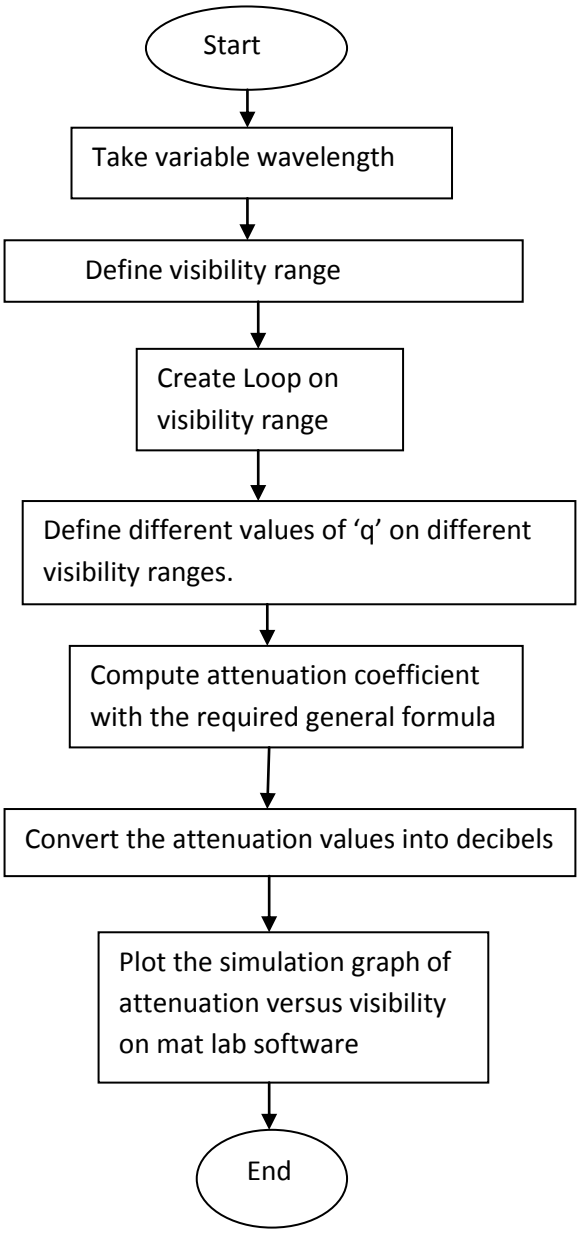
3.4 Work timeline



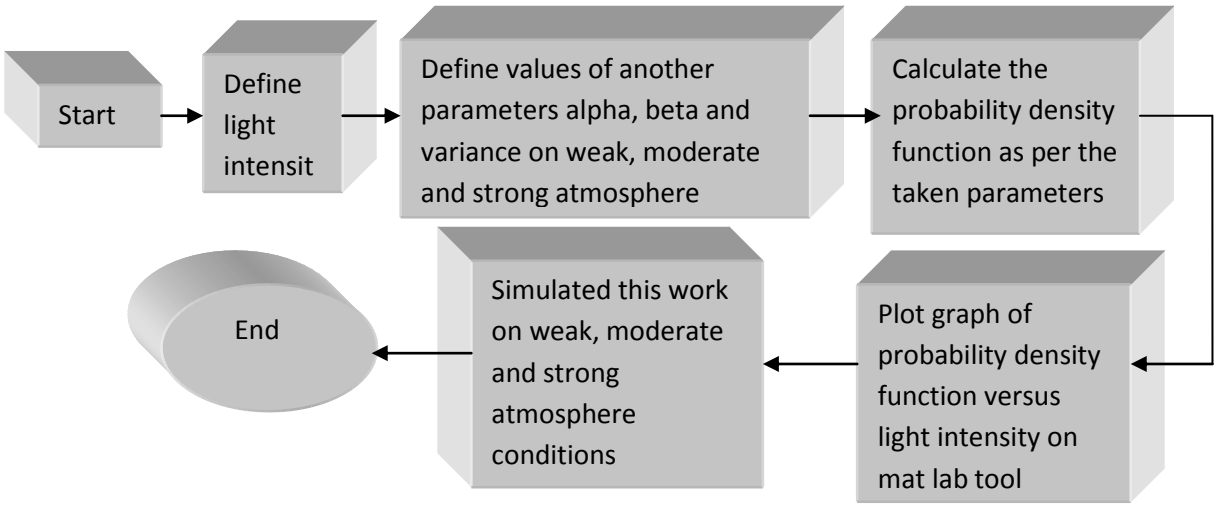
3.5 WORK FLOW CHART



3.6 VISIBILITY FLOW CHART



3.7 TURBULENCE MODEL CHART



4. Results and Discussions

4.1 Simulation results and their discussions

4.1.1 Turbulence model

FSO system is capable of full duplex high speed wireless communication that provides license free spectrum. FSO is the line of sight communication technology which differs from the radio frequency systems that suffered signal fading due to multipath propagation. In weak turbulence conditions, we have probability density function to model irradiance which gives us optical beam power density.

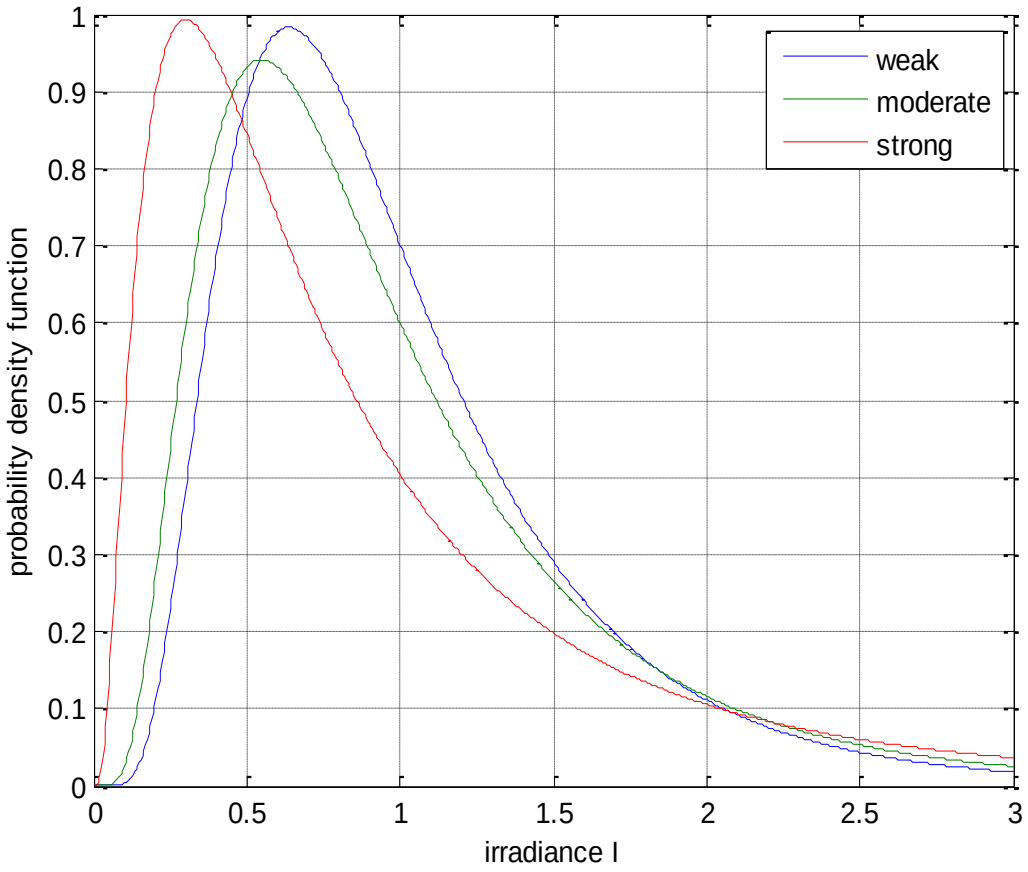


Fig 11.PDF curve on turbulence conditions

Table2. PDF curve

Turbulence region	PDF value at I=1
Strong	0.4
Moderate	0.6
Weak	0.7

As the above curve has indicates that different turbulence regions have different PDF values on same intensity 'I'. On the value of I=1, PDF value for strong, moderate and weak turbulence has 0.4, 0.6 and 0.7 respectively. It means on the same amount of intensity, we get PDF at 0.7 in weak turbulence conditions and at 0.4 we get same in strong turbulence.

This plot shows the variation of probability density function with respect to the irradiance on different turbulence conditions. Graph given different wave curves for weak, moderate and strong conditions. As the curves state that in strong turbulence conditions, at very small value of irradiance the probability density function becomes high. This is opposite in weak turbulence condition. Curve placed in between on moderate conditions this plot taken with the help of parameters alpha, beta, variance and irradiance of light. These parameters have experimental values for different atmospheric conditions. Those values are been used to plot that simulation.

4.1.2 Estimated work on Modulation techniques: - Atmospheric conditions are the main problem in performance of Free Space optics (FSO). As heavy fog in atmosphere affects the intensity of light that propagates through the thick fog atmosphere gets reduced.

For performance measurement of FSO communication bandwidth efficiency is the best method for evaluation. Bandwidth efficiency states that how faster in speed bits are transmitted in particular assigned bandwidth. With the help of formula, bandwidth efficiency defined as

$$\text{Efficiency}=\frac{bit\ rates\ R_b}{required\ bandwidth\ B_{req}}$$

Table 3.Bit rate and baud rate comparison

Modulation techniques	Baud rate	Bit rate
ASK,FSK,PSK	N	N
QPSK	N	N
4-PSK	N	2N
8-PSK	N	3N
16-QAM	N	4N
32-QAM	N	5N
64-QAM	N	6N
128-QAM	N	7N
256-QAM	N	8N

Higher data transmission rates are possible at required bandwidth with the help of data compression. The relationship between the number of modulated bits, the required minimum bandwidth and how many possible output conditions for ASK, FSK, PSK and QAM for bit rate f_b bare given below: For performance measurement of FSO communication bandwidth efficiency is the best method for evaluation.

On the basis of BER performance OOK modulation is good but it has low data rates. As we know, in present has huge demand of high data rates.

The simplest form of phase shift keying (PSK) is BPSK. In BPSK, the conveyed information gets change with modulating carrier signal phase (or reference signal). It has two phases which are separated by 180 to one another. Like OOK BPSK is not good in bandwidth efficiency. In BPSK, transmitted carrier signal used for 1 bit. It is fully wastage of bandwidth.

To overcome these disadvantages PPM is powerful solution for this. In PPM, we get the advantage of power/energy efficiency. For further advantage PPM can be implemented as MPPM (multi pulse PPM). For optimal detection, PPM has not required dynamic thresholding. As PPM is power efficient modulation technique it also increased the demodulation complexity.

Table4. Minimum bandwidth requirement

Modulation	Modulated scheme	Possible outputs	Minimum bandwidth
ASK	1 bit	2	f_b
FSK	1 bit	2	f_b
BPSK	1 bit	2	f_b
QPSK	2 bits	4	$\frac{f_b}{2}$
QAM	2 bits	4	$\frac{f_b}{2}$
8-PSK	3 bits	8	$\frac{f_b}{3}$
8-QAM	3 bits	8	$\frac{f_b}{3}$
16-PSK	4 bits	16	$\frac{f_b}{4}$
16-QAM	4 bits	16	$\frac{f_b}{4}$
32-PSK	5 bits	32	$\frac{f_b}{5}$
32-QAM	5 bits	32	$\frac{f_b}{5}$
64-PSK	6 bits	64	$\frac{f_b}{6}$
64-QAM	6 bits	64	$\frac{f_b}{6}$
128-PSK	7 bits	128	$\frac{f_b}{7}$
128-QAM	7 bits	128	$\frac{f_b}{7}$

4.1.2.1 OOK:

In wireless optical communication system, OOK is dominant modulation scheme due to its simplicity in circuit implementation and resistant to laser nonlinearity. It can be use any of technique either non return to zero (NRZ) and return to zero (RZ) formats. In OOK, logical 1 represent the optical pulse is present and the other hand logical 0 represent the absence of the optical pulse. In NRZ technique had pulse with duration equal to the bit duration which transmitted to represent 1 and in RZ pulse can occupy the partial duration of bit. OOK-RZ has requirement of bandwidth is double as compare to OOK-NRZ because the pulse if half wider.

Both OOK-NRZ and OOK-RZ has same power efficiency but different bandwidth efficiency because bandwidth is depending on duty cycle. At the receiver side OOK-RZ does not support the clock recovery because it has long low signal with 0 and 1 transition.

Bit error rate (BER) performance plotted against normalized signal to noise ratio (SNR) in atmospheric turbulence. The effect of turbulence strength required to maintain an error performance level on the given SNR value.

If we see the graph carefully, at 2 dB SNR value the level indicate 0.1 values on bit error rate axis. It means OOK error performance is 1 bit get corrupted at this level on clear atmospheric conditions. It should vary with different conditions. This shows that OOK is more efficient technique in terms of error performance. On the other side, it tells OOK is not a power efficient modulation technique because if we take one advantage then we have automatically dropped by other things too. OOK used less bandwidth because it transmits a single bit per symbol. The Euclidean distance between the symbols are more so having less probability to get error? As we increases the number of bits transmitted, the Euclidean distance between them gets decreased and higher the probability of error there. It also needs higher bandwidth.

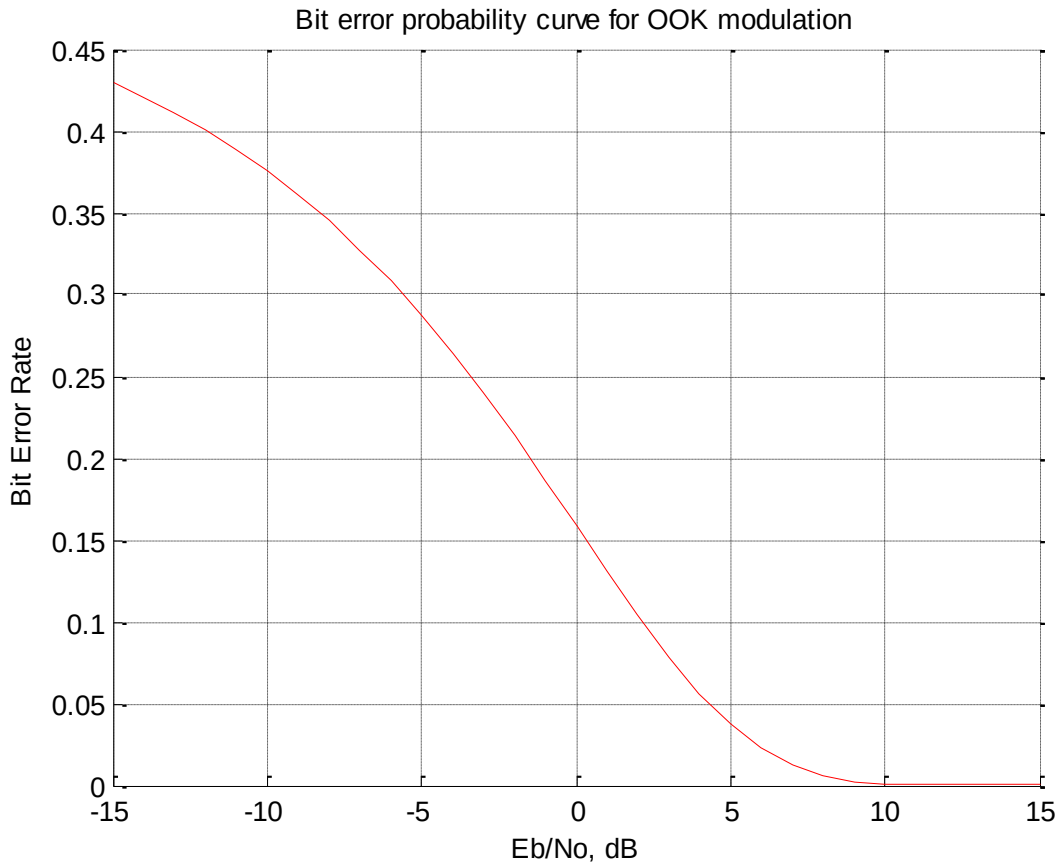


Fig 12.BER of OOK

Table.5 BER of OOK

Eb/N0 (signal to noise ratio in dB)	Bit error rate
-10	0.37
-5	0.29
0	0.15
5	0.04
10	0

4.1.2.2 PPM: -

PPM improves the power efficiency of the OOK but at the cost increased bandwidth requirement too. As the bandwidth increases it makes complex to the system. In PPM, every symbol having a constant power pulse on one slot. M-PPM used to define the order. For demodulator, on PPM receiver will need both symbol and slot synchronization because information is encoded on the pulse position. Due to its power efficiency PPM is more effective modulation technique for FSO in deep space laser communication. At all times between transmitter and receiver a complete synchronization is maintained. The graph shows the bit error rate (BER) performance of the PPM with respect to the normalized signal to noise ratio (SNR). As per the plot at -5 dB, PPM has 2 or 3 bits erroneous.

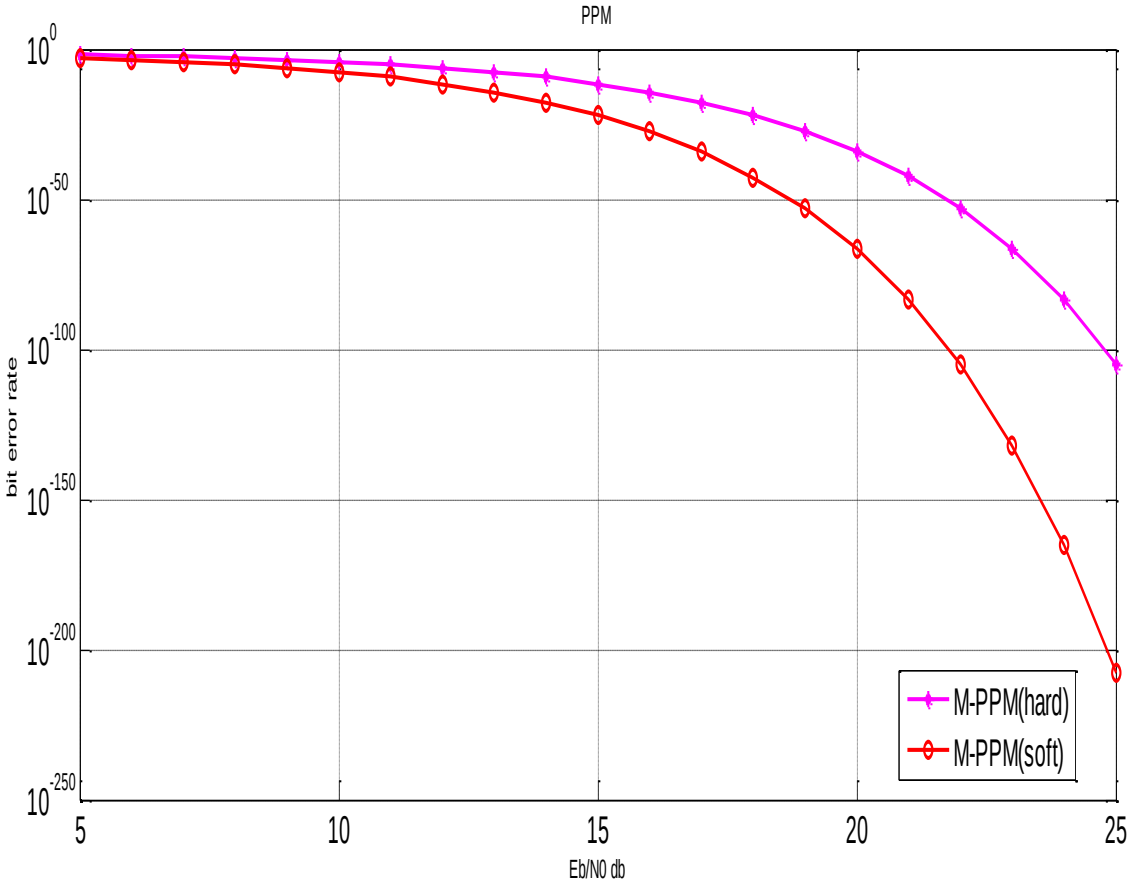


Fig 13.BER of M-PPM

Table.6 BER of PPM

Eb/N0 in dB	BER of PPM (soft)	BER of PPM (hard)
5	1	1
10	10^{-10}	10^{-8}
15	10^{-25}	10^{-15}
20	10^{-70}	10^{-40}
25	10^{-201}	10^{-101}

Probability density function graph of 8, 16, 64-PPM:-

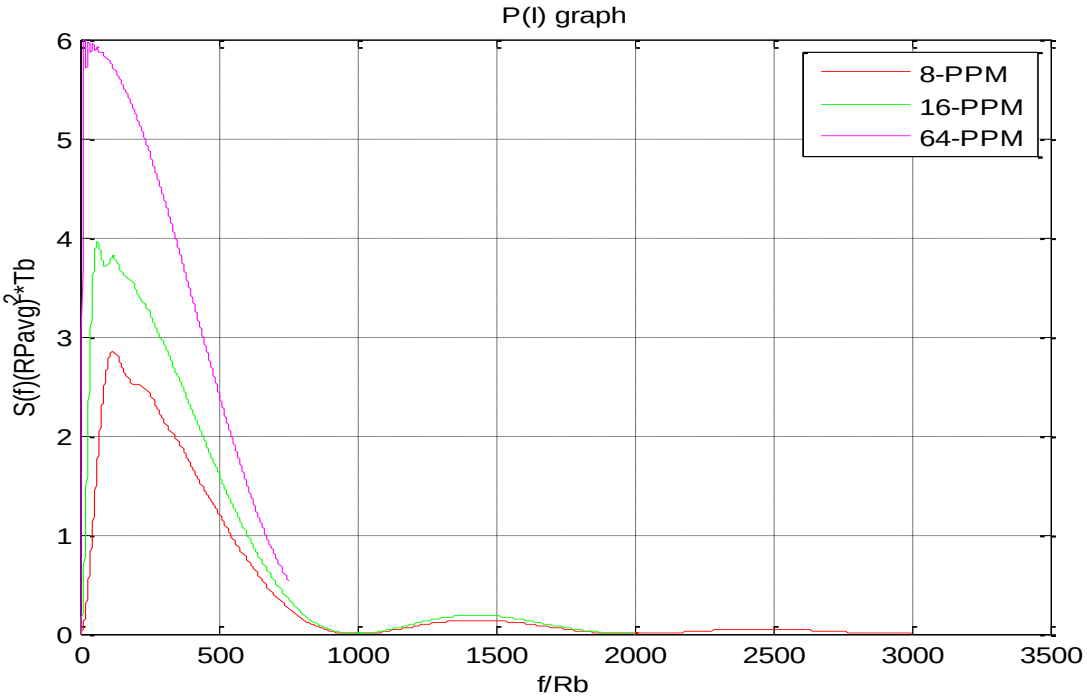


Fig 14.PDF curve of M-ary PPM

4.1.2.3 BPSK: -

BPSK is also an important modulation technique. It is also more effective on the basis of bit error performances. It should modulate a single bit so it uses more bandwidth as compare to the other modulation techniques. Similar to OOK BPSK is not a power efficient. The simulation graph shows the bit error rate (BER) performance of the BPSK along with the normalized signal to noise ratio (SNR).

If we see the graph carefully, at SNR 2 dB the probability of error in bits is either 1 or 2. It states that at that amount we get 1 or 2 bits corrupted. This analysed that BPSK is error efficient modulation technique as compare to the other modulation schemes. To acquire that result, the number of bits used is 10^6.

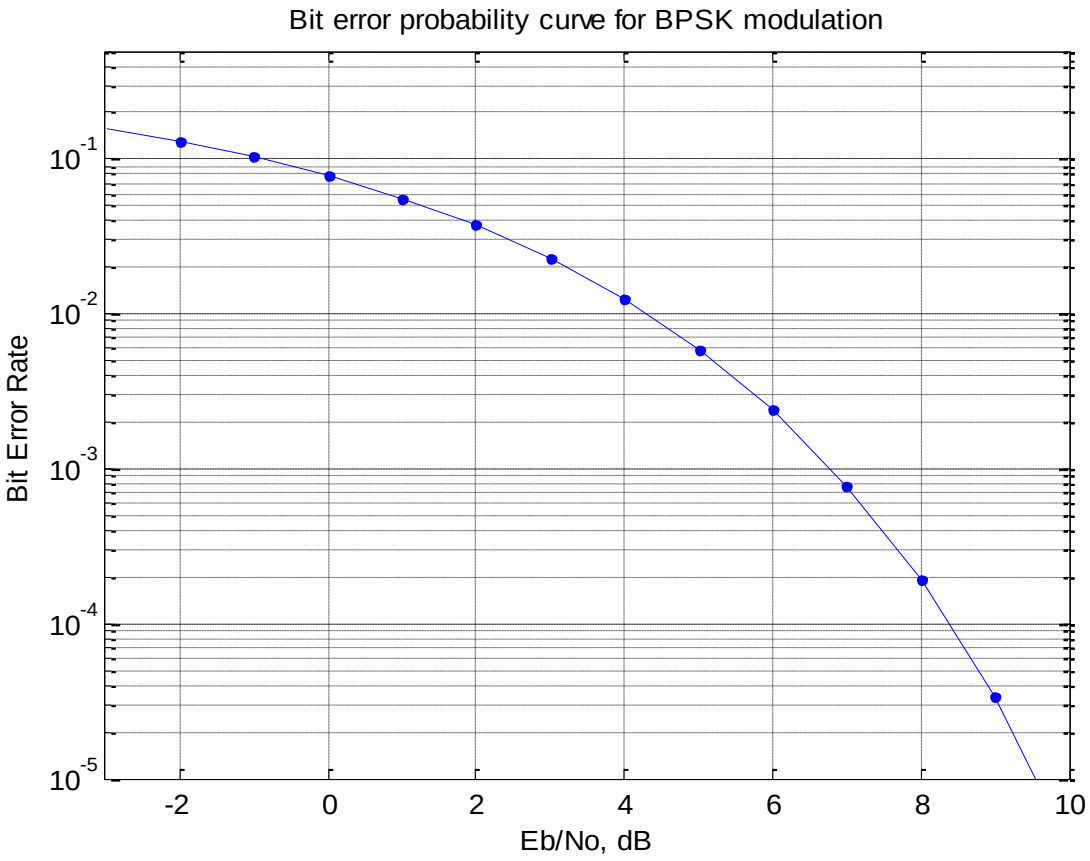


Fig 15.BER curve of BPSK

The mathematical analysis and simulation states that BER performance for M-ary PSK digital modulation schemes decreases with increasing signal to noise ratio (Eb/N0). In practically, 8-PSK uses one third bandwidth of BPSK. The transmission of information with 8-BPSK contained thrice the bit error rate as compare to the BPSK. From simulation results and mathematical analysis, as we increasing the value of M the probability of error also increases because the distance comes closer in constellation points. Results indicate that the higher order modulation has higher data rate along with higher error rate. With increasing data rate, SNR also increases. It introduced more bit error rate which caused more noise as more transmitted bits are packed closer. That's why SNR value is limited we cannot increase it at certain level due BER rate also increases. Generally, we have to compromise for one between data rate and amount of noise that our receiver can handle.

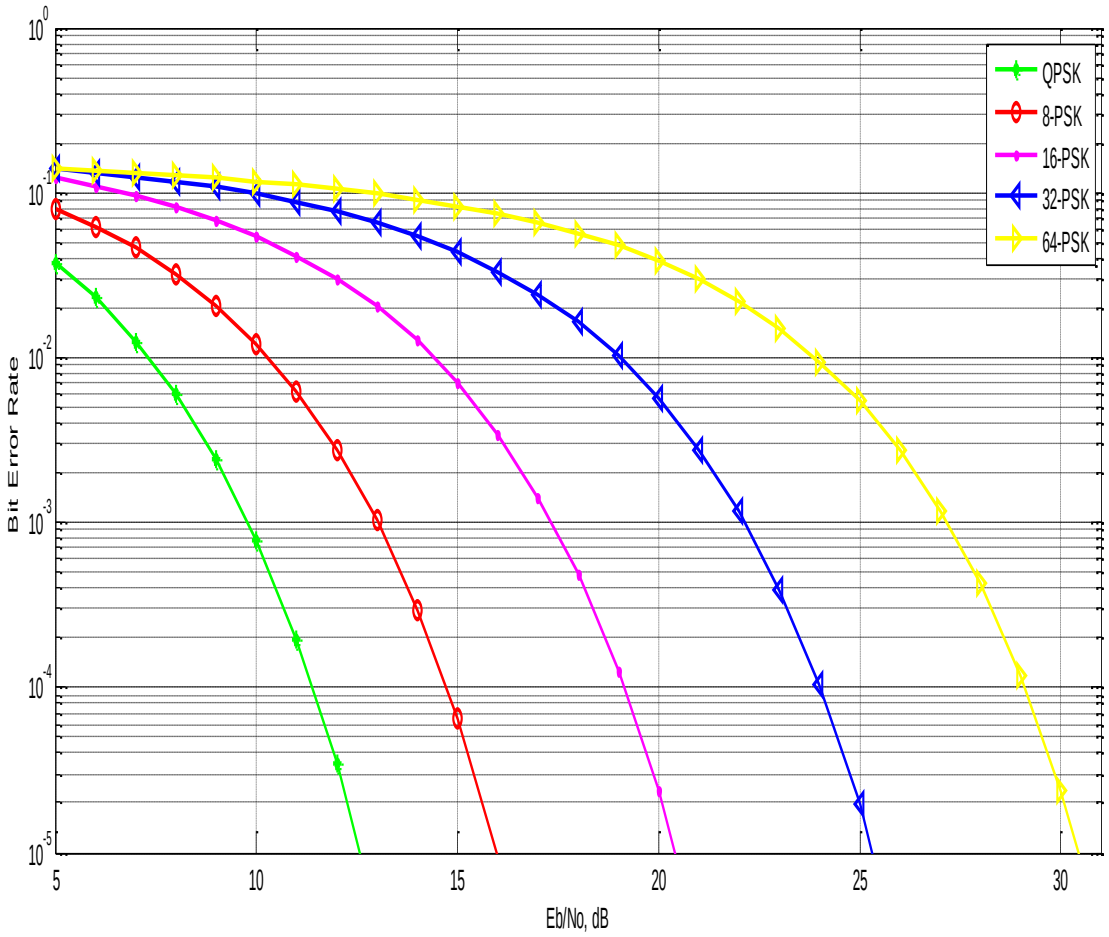


Fig 16.BER performance of Mary-PSK

Table.7 BER of Mary-PSK

Eb/N0 in dB	BER of QPSK	BER of 8-PSK	BER of 16-PSK	BER of 32-PSK	BER of 64-PSK
5	$10^{-1.7}$	$10^{-1.5}$	10^{-1}	10^{-1}	10^{-1}
10	$10^{-3.2}$	10^{-2}	$10^{-1.5}$	10^{-1}	10^{-1}
15	0	$10^{-4.4}$	$10^{-2.1}$	$10^{-1.5}$	$10^{-1.2}$
20	0	0	$10^{-4.9}$	$10^{-2.4}$	$10^{-1.5}$
25	0	0	0	$10^{-4.9}$	$10^{-2.2}$
30	0	0	0	0	$10^{-4.8}$

4.1.2.4 QAM

Previously modulation techniques are only able to modulate 1 bit per symbol and transmit it. This much data rate was not sufficient for next generation communication system. So Mary modulation techniques are used for higher data rates to provide required bandwidth efficiency. Energy per symbol is not constant in case of Mary-QAM. The most factor of our work is to highlight the performance of Mary-QAM. Mary-QAM bit error rate (BER) performance have compared with varying signal to noise ratio (SNR) in Gaussian (AWGN) channel without any interference. AWGN contained both backward radiation and thermal noise. As we increases the value of M=2, 4, 8, 16……so on the error probability of the system also gets affected.

Our basic goal in this paper is to compare performance analysis of Mary-QAM on different M values. The performance of Mary QAM is compared by measuring its probability of error over additive white Gaussian noise (AWGN) without any interference. Simulation tools provide a simplified environment for simulation results of every communication system.

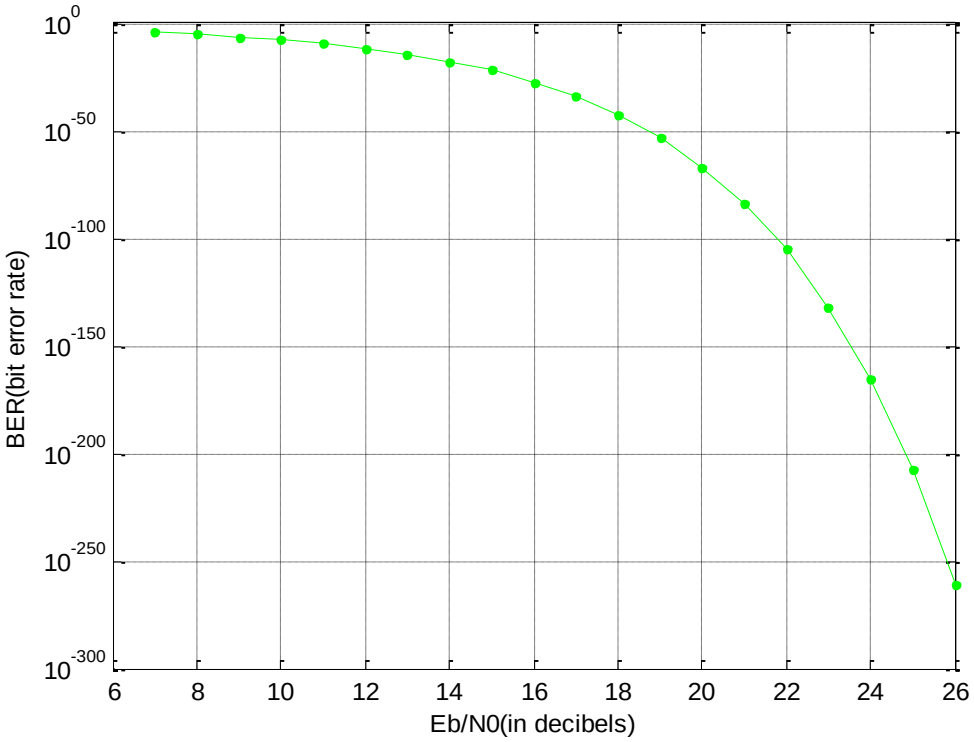


Fig 17.BER performance of QAM

Table.8 BER performance of QAM

Eb/N0 in dB	BER (bit error rate)
6	1
8	1
10	10^{-10}
12	10^{-20}
14	10^{-30}
16	10^{-40}
18	10^{-45}
20	10^{-70}
22	10^{-100}
24	10^{-160}
26	10^{-260}

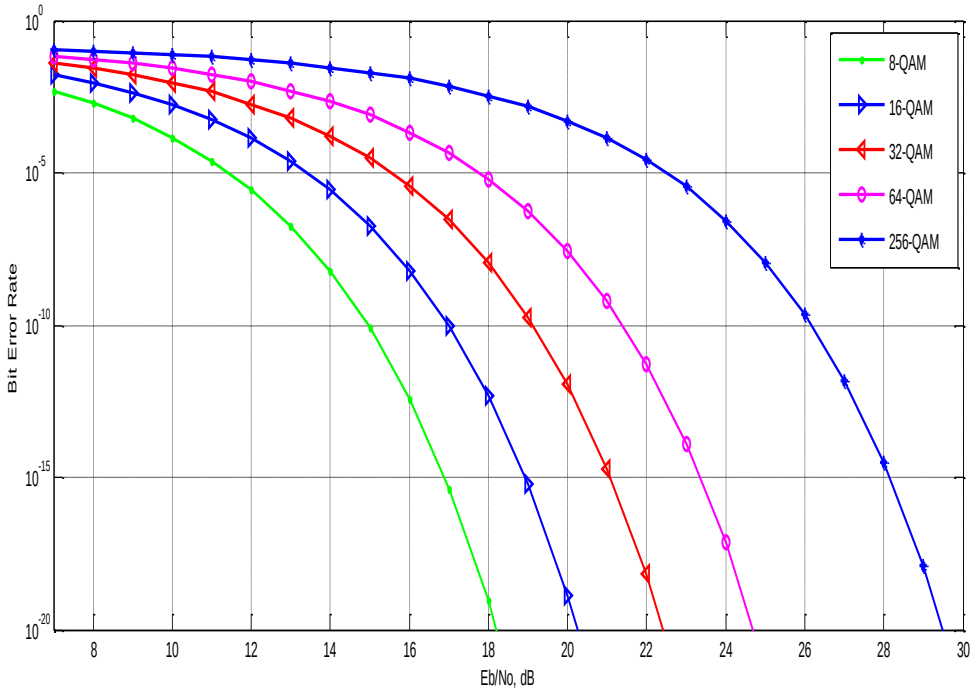


Fig 18.BER performance of Mary-QAM

The mathematical analysis and simulation states that BER performance for Mary QAM digital modulation schemes decreases with increasing signal to noise ratio (Eb/N0). In practically, 8-QAM uses one third bandwidth of QAM.

Table.9 BER of Mary-QAM

Eb/N0 in dB	BER of 8-QAM	BER of 16-QAM	BER of 32-QAM	BER of 64-QAM	BER of 256-QAM
8	$10^{-2.3}$	10^{-2}	$10^{-1.9}$	$10^{-1.6}$	$10^{-1.5}$
10	10^{-4}	10^{-3}	10^{-2}	$10^{-1.7}$	$10^{-1.5}$
12	$10^{-5.5}$	10^{-4}	10^{-3}	10^{-2}	$10^{-1.5}$
14	10^{-8}	$10^{-5.5}$	10^{-4}	10^{-3}	$10^{-1.5}$
16	10^{-12}	10^{-8}	10^{-5}	10^{-3}	10^{-3}
18	10^{-19}	10^{-12}	10^{-8}	10^{-5}	$10^{-2.5}$
20	0	10^{-19}	10^{-12}	10^{-8}	10^{-3}
22	0	0	10^{-18}	10^{-11}	10^{-5}
24	0	0	0	10^{-17}	10^{-6}
26	0	0	0	0	10^{-10}
28	0	0	0	0	10^{-14}
30	0	0	0	0	0

The transmission of information with 8-QAM contained thrice the bit error rate as compare to the QAM. From simulation results and mathematical analysis, as we increasing the value of M the probability of error also increases because the distance comes closer in constellation points. Results indicate that the higher order modulation has higher data rate along with higher error rate. With increasing data rate, SNR also increases. It introduced more bit error rate which caused more noise as more transmitted bits are packed closer. That's why SNR value is limited we cannot increase it at certain level due BER rate also increases. Generally, we have to compromise for one between data rate and amount of noise that our receiver can handle.

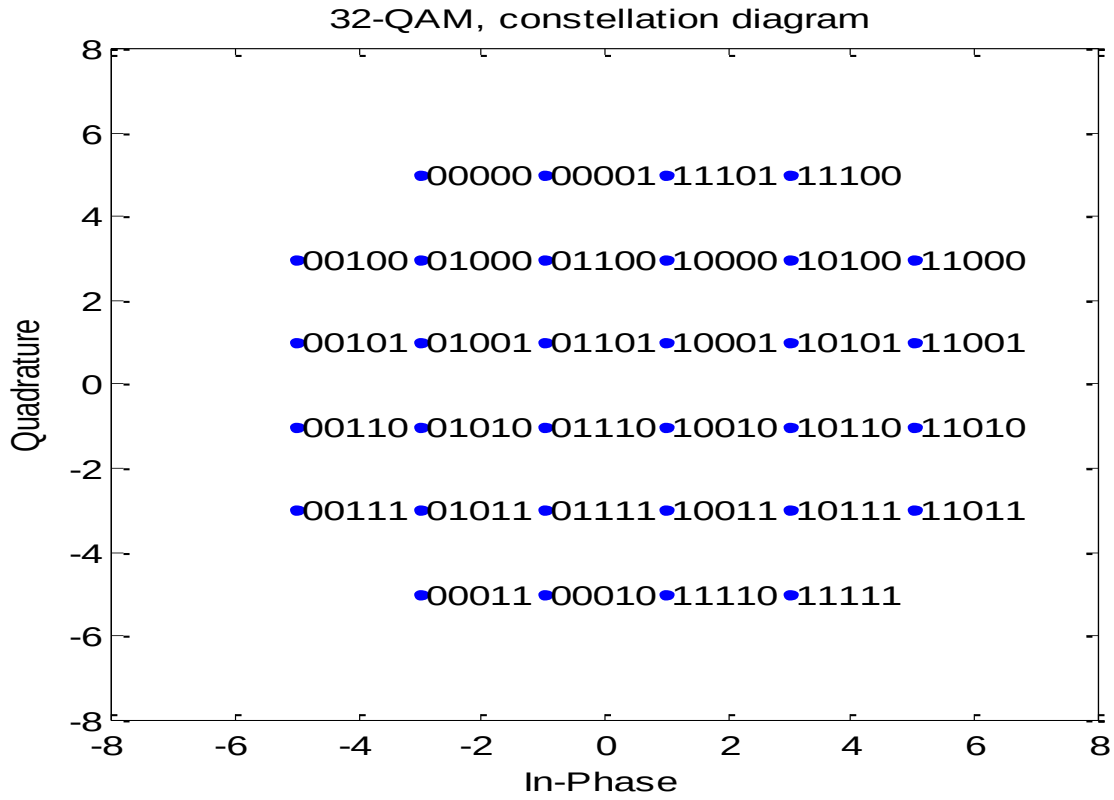


Fig 19.32-QAM constellation diagram

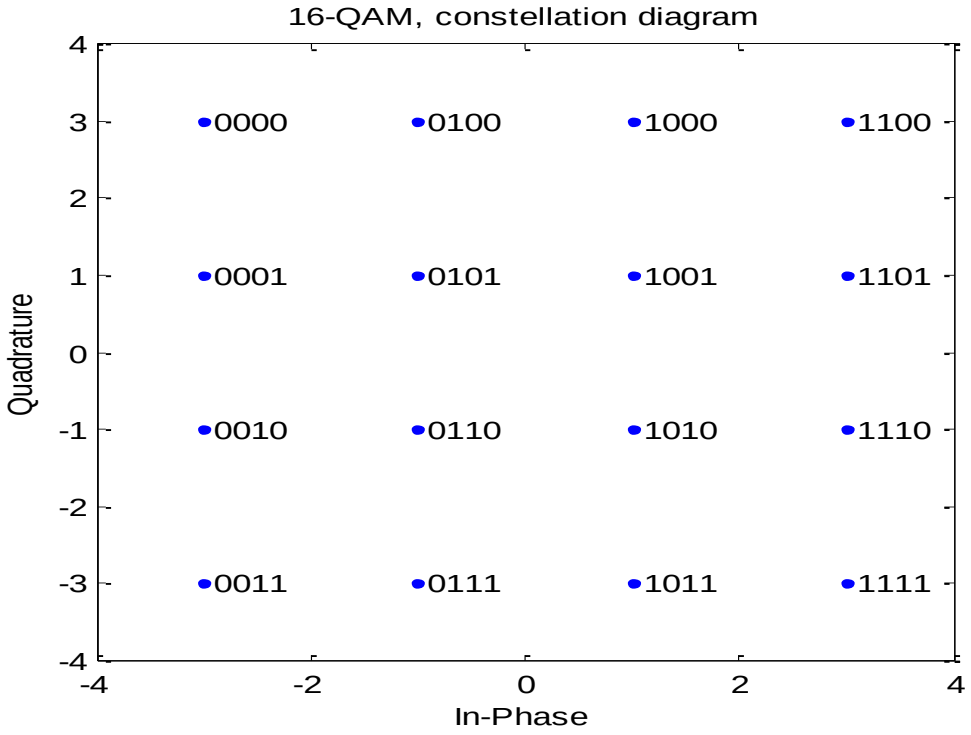


Fig 20.16-QAM constellation diagram

4.1.3 Fog and visibility in atmospheric channel losses:

As we know that the fog creates the attenuation in the signal in atmospheric channels of FSO communication system. Basically, fog reduced the visibility. Different type of fog gets the different type of optical losses. The different types of fog presented in the atmosphere are in form of convection and advection. Due to the ground cooling by radiation created the convection fog. The movement of wet and warm air masses above the surfaces generated the advection form of fog. This things give result in the manner attenuation in the channel varies the visibility of the system. Attenuation versus visibility has some models the give the appropriate data on their relation.

The different models are: -

(i) Kruse model

(ii) Kim model

(iii) Naboulsi model

Table.10 Weather conditions and their visibility range values

Weather condition	Visibility range (in metres)
Thick fog	200
Moderate fog	500
Light fog	770-1000
Thin fog/ heavy rain	1900-2000
Haze / medium rain	2800-40,000
Clear drizzle	18,000-20,000
Very Clear	23,000-50,000

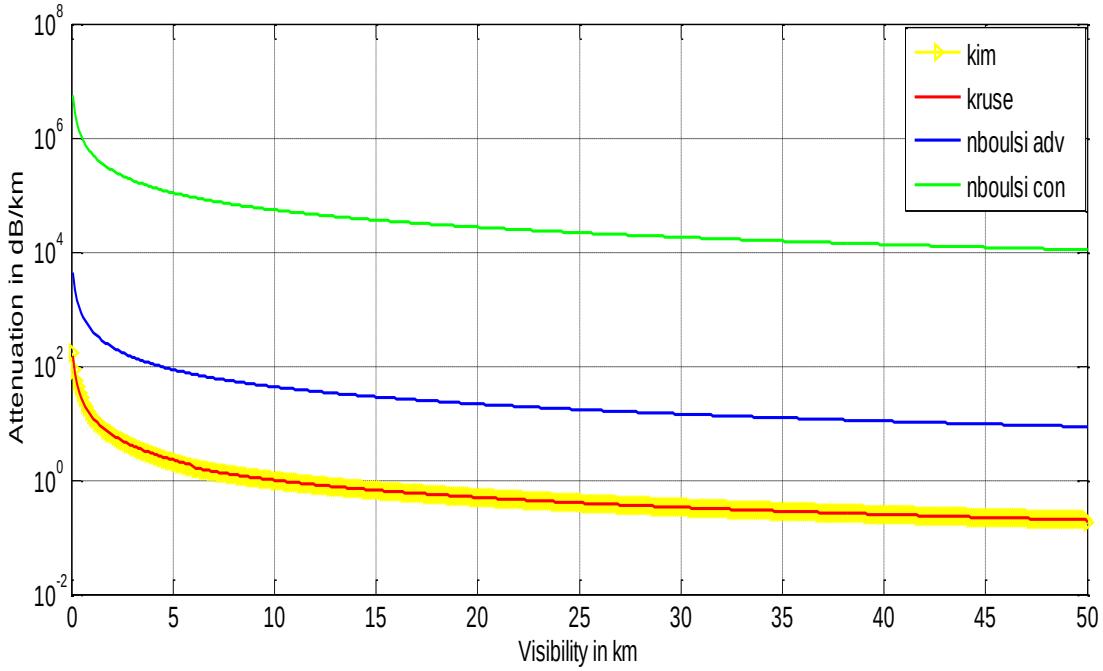


Fig 21.Visibility versus attenuation curve

This graph shows the relation of attenuation with respect to the visibility on different models. Plot states that with the Kim and Kruse model has low attenuation variation the signal with visibility. In Naboulsi conditions attenuation is more versus visibility.

Table.11 Visibility versus attenuation

Visibility in Km	Attenuation of Kim in dB/km	Attenuation of Kruse in dB/km	Attenuation of Nboulsi adv in dB/km	Attenuation of Nboulsi conv in dB/km
0	1	1	10^4	10^7
5	1	1	10^2	10^5
10	1	1	10^3	10^5
15	1	1	10	10^5
20	1	1	10^3	10^5
25	1	1	10^3	10^4
30	1	1	10^3	10^4
35	1	1	10^3	10^4
40	1	1	10^3	10^4
45	1	1	10^3	10^4
50	10^{-1}	10^{-1}	10^3	10^4

4.1.4 Comparison of modulation schemes in terms of power versus bandwidth

When we talked about the comparison of the different baseband modulation schemes we take care about the important parameters are power efficiency and the bandwidth requirements. These things are interrelate to each other with some fundamental relations.

As wireless channels is power limited due to some constraints like safety limitations. The major issue comes in known is power efficiency. Power requirements also generate the effects of error probability. The minimum bit duration in the modulation technique defined by the requirement of bandwidth.

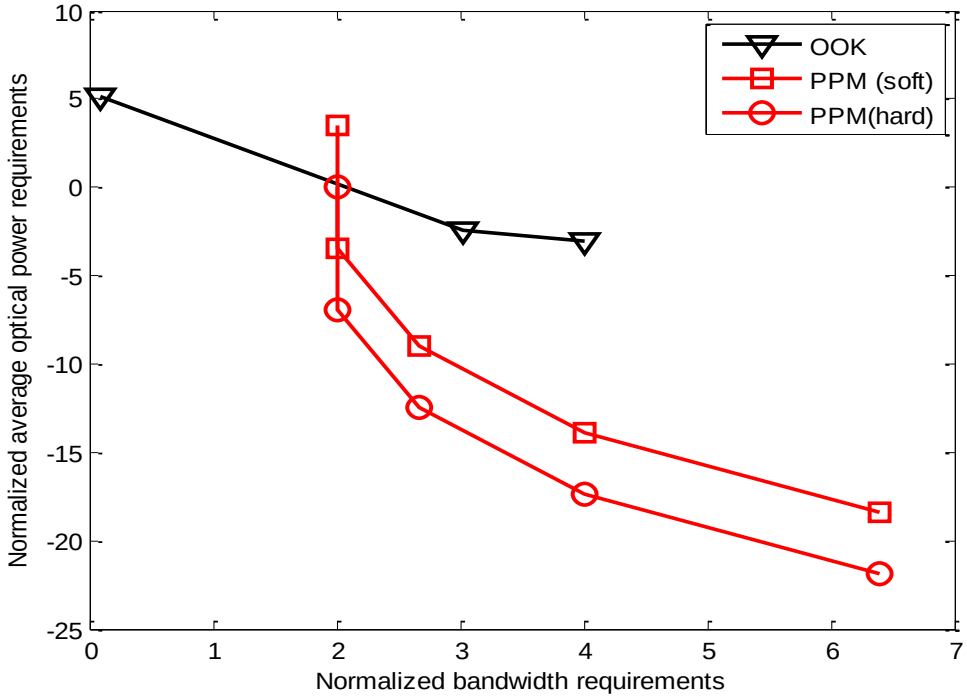


Fig 22.Comparison of OOK and PPM

The simulation analyses plot gives the result OOK modulation should need the more bandwidth requirement as compare to the PPM soft and hard decoding. PPM is more power efficient as compare to the OOK. The graph displays that the power requirement is decreases with the duty cycle but the bandwidth requirement is increases accordingly.

5. Conclusion and future scope

Simulation performance of Free Space Optics (FSO) system has shown bit error rate analysis of the different modulation techniques. It showed the bit error rate (BER) performance of the theoretical model. The parameters that are used in this simulated work are for clear atmosphere setup. The bit error probability varies with the normalized signal to noise ratio (SNR). As graph indicates bit error rate probability decreases with increases the signal to noise ratio. With increasing signal to noise ratio the probability of signal is more in combination of both signal and noise. If the presence of signal is more then there are very less probability of the number of bits get erroneous.

If we focused on graph clearly, at 2 dB signal to noise ratio probability of corrupted bits is 1 in OOK, 1 in BPSK, 5 in PPM(hard) and 9 in PPM(soft). So we can get the idea on bit error performance of the different modulation techniques. On the basis of bit error performance, OOK and BPSK are more efficient techniques for modulate data as compare to the PPM. On the other hand they are not suitable on power efficient manners. PPM techniques are more power efficient as compare to them.

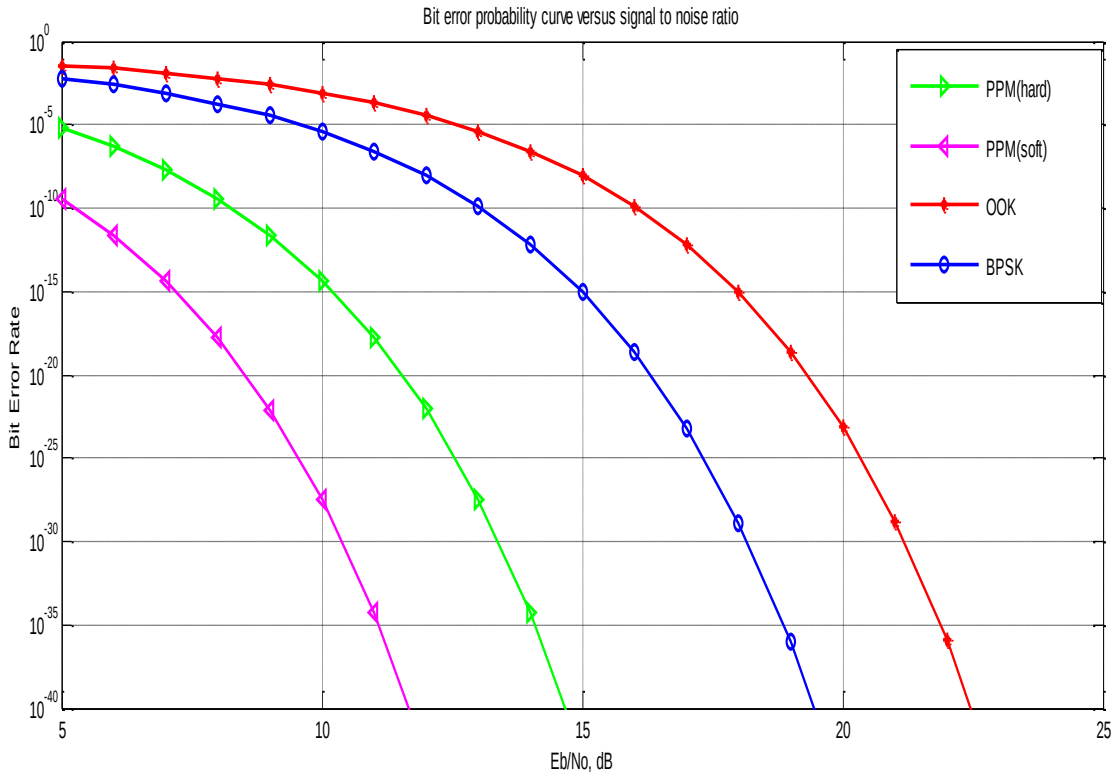


Fig 23.BER comparison on different modulations

Up to this did some simulation based on modulation techniques, probability density function and relation of attenuation with respect to visibility.

In modulation techniques, compared bit error rate BER performance with normalized signal to noise ratio SNR. With the help of appropriate graphs estimate the error performance of different modulation techniques OOK, PPM and BPSK.

Simulation of probability density functions with light irradiance on different atmospheric conditions like weak, moderate and strong. To estimate probability density function, taken some parameters alpha, beta and variance. There values have the experimental values of them on different atmosphere.

Using different models Kim, Kruse and Naboulsi, estimate the variation of attenuation on different visibility ranges. However the visibility reduces on which range.

Modulation techniques of FSO system can be used in many new techniques at higher levels. Some higher modulation techniques are keys in data transmission on new widely used technologies. Huge of work perform in now days on MIMO with wireless links. There are so many other techniques that been used with FSO system to enhance the data transmission at required levels. FSO system also has good implementation with other higher modulation techniques also.

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