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Study of the Performance of Free Space Optic Communication with Multiple Phase Encoded Signal under Different Weather Condition

K.M. Pandimeenal*, A. Sivanantha Raja* and S. Selvendren*

ABSTRACT

Free-space optical (FSO) communication is a more interesting alternative to radio frequency communication because of its superior performance. When the optical wave propagates through the turbulent transmission medium, the performance of the Free Space Optical (FSO) communication system is strongly affected by numerous atmospheric parameters. The transmission impairments of the FSO system due to atmospheric turbulence can be successfully mitigated by employing advanced modulation formats. In this paper, FSO system is analysed for M-ary PSK modulation format with a bitrate of 112 Gbps. Channel parameters were designed with five different atmospheric conditions. The link range and wavelength were considered as 0.5 Km and 850nm respectively. The responses ofdifferent modulation methods for FSO channel under different atmospheric conditions were compared to determine the optimum modulation technique. The system performance is analysed using parameters such as BER, SNR with Optisystem 13.The analysis of M-ary PSK method with QPSK, 8-PSK and 16-PSK reveals that QPSK has the lowest BER of -4.95 dB under strong turbulence conditionsand hence is a more suitable modulation method. However 16-PSK exhibits the highest bandwidth efficiency.

1. INTRODUCTION

Free-space optical communication (FSO) is a point to point line-of-sight (LOS) communication technology in which data is transmitted by the light propagating in the free space [1, 2]. On comparing FSO channel with radio frequency (RF) channel, FSO provides higher data rates, larger bandwidth, higher security, higher speed of communication and lower power. In most cases, optical data transmission is carried out through optical fibres since the fibres allow transmission over relatively large distances without excessive power losses, alignment issues, and disturbances caused by atmosphere conditions [2]. However, it is also possible to transmit data optically in free space without exploiting any kind of waveguide structure [10]. In FSO a large amount of data can be transmitted with high security though the major issue of concern is the influence of different environmental factors on light propagation characteristics resulting in spatial and temporal light intensity fluctuations [11, 12]. These factors define the system performance and channel behaviour. The various atmospheric conditions like rain, snow, fog and temperature conditions affect the light propagation by absorption and scattering mechanism [13]. To overcome this problem, advanced techniques of digital signal processing have been developed, which allow for reliable high-capacity optical links even through thick clouds [6, 7]. To retrieve the signal affected by atmospheric conditions, different modulation methods are used [2].

In this paper, the transmission characteristics are determined, under the five different atmospheric conditions, using M-ary techniques with PSK modulation methods. To characterize the channel behaviour

* Department of Electronics and Communication Engineering Alagappa Chettiar College of Engineering and Technology Karaikudi – 630003, India, *Email: mlpkp1989@gmail.com*

with modulated signal, measurement of Bit Error Rate (BER) is considered. The system consists ofa laser source, bit sequence generator and modulator at transmitter section. The channel is free space and the detector along with digital signal processor form the receiver section. In this paper, the system design is considered with laser power, wavelength and channel parameters.

Light absorption is caused due to rain, building motion while light diffraction occurs due to snow and fog. Rayleigh scattering is observed by molecules of atmospheric gases and Mie scattering is observed by aerosol particles [5]. A free space optical communication system is designed to communicate over a distance of 500m. In the transmitter section, at the end of the transmitter an aperture or lens is considered/placed whose diameter is 9cm. A lens with same diameter of 9 cm is also placed at the front end of the receiver.The wavelength of light propagating in the channel is 850nm and is considered to have a beam divergence of 3mrad. Table 1 defines the various parameters of the designed FSO system [1].

The analysis on the performance of designed FSO system is executed for five different atmospheric conditions such as rainy, winter, monsoon, summer and pre-summer. The attenuation parameter for the channel for the above specified 5 seasons is 4.9, 5.6, 6.45, 7.9 and 8.82dB/Km respectively and Table 2 enumerates these values [1].

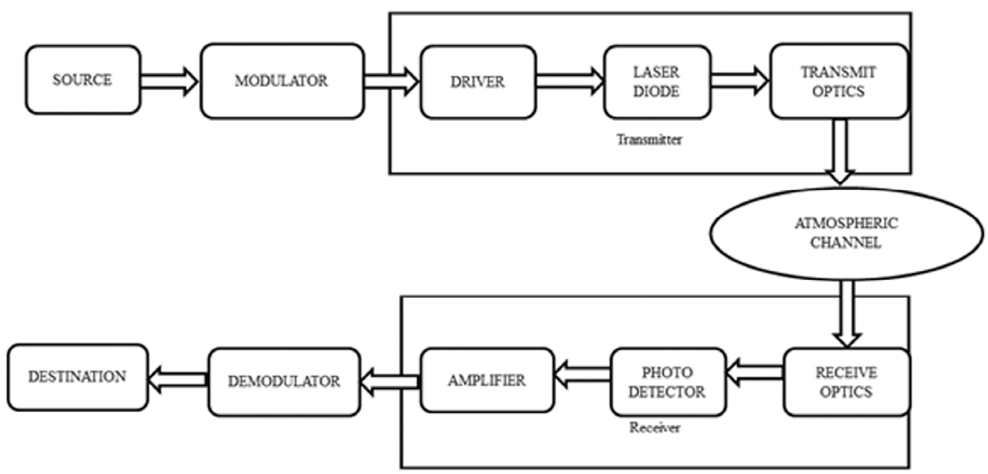


Figure 1: Schematic diagram of FSO system

Table 1
Parameters of FSO system

Length of the channel	0.5Km
Transmitter Aperture Diameter	9 cm
Receiver Aperture Diameter	9 cm
Beam divergence	3mrad
Wavelength of the laser	850 nm

Table 2
FSO channel conditions with the corresponding attenuation

Seasons	*Attenuation*
Rainy season	4.9dB/Km
Winter season	5.6dB/Km
Monsoon season	6.45dB/Km
Summer season	7.9dB/Km
Pre-summer season	8.82dB/Km

The transmission impairments due to the atmospheric turbulence can be successfully overcome by opting advanced modulation formats [2]. The system is analysed with advanced modulation M-ary PSK technique. M-ary PSK method can be of QPSK, 8-PSK or 6-PSK based on the number of bits per symbol transmitted, where $M = 2^m$and *m* denotes the number of bits per symbol. The performance of the system is analysed using BER reports.

2. PSK

In phase shift keying (PSK), the phase of the carrier signal is modulated based on the binary data. Each phase of the signal modulates the equal no of binary bits. PSK modulation uses a unique pattern to represent the binary data and these signals are very sensitive to the multichannel effects. In the receiver section, the reference signal is compared received signal phase.

3. M-ARY PSK

Increasing the number of phases leads to the improvement of spectral efficiency and also it increases the bit error rate. More number of bits can be transmitted using M-ary PSK and the modulated phases represent the transmitted bits per symbol with the power of 2. QPSK will transmit 2 bits per symbol with 4 phase components. The phase components can be analysed by inphase and quadrature phase components with complex plane. Using M-ary PSK, bandwidth efficiency gets increased. In this paper bits per symbol used are 2, 3 and 4. The usage of 4 bits per symbolin 16 PSK will provide the better efficiency than others.

4. DESIGN

The parallel converted data signal is applied to PSK sequence generator and then to M-ary pulse generator. The output from M-ary pulse generator and the light signal which is dually polarized are modulated using Mach-Zehnder modulator. The modulated output is further transmitted to the FSO. The DP-QPSK receiver receives the signal from the channel and demodulates it using demodulator unit.

Demodulator unit consists ofan electrical amplifier and low pass filter section or DSP unit. The universal DSP can be used with selected modulation formats. After the DSP, decision device is used asa threshold detector whose output is later fedto the PSK decoder. The output of the decoder is converted serial data and fedinto the BER test set. BER test set can also be used as a Pseudo Random Bit sequence generator as it generates the data to the unit.

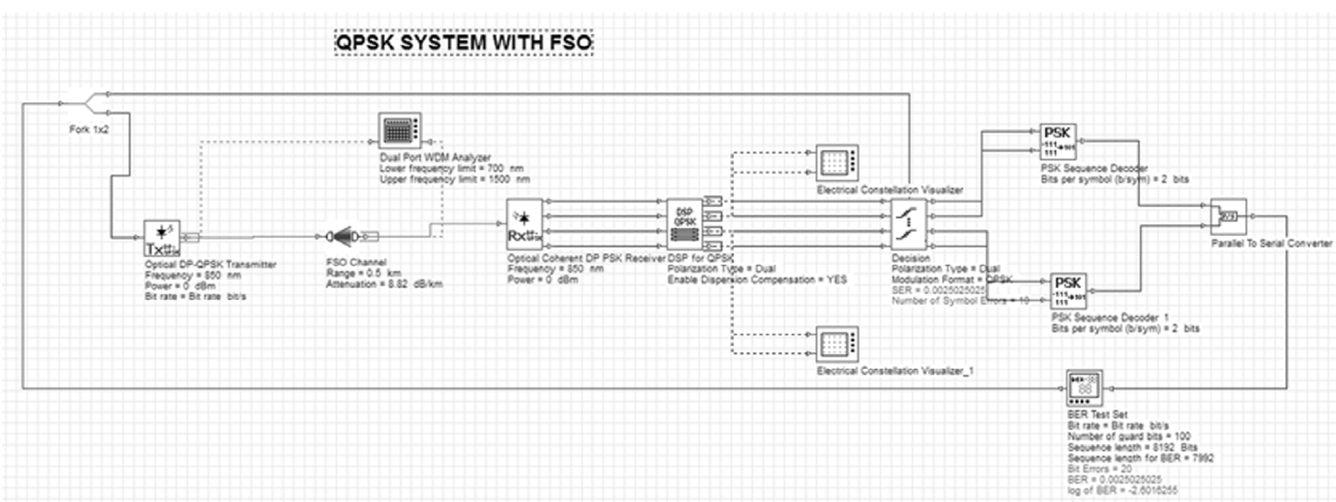


Figure 2: Simulation layout of FSO system with QPSK modulation format

The QPSK transmitter consists of a laser source and QPSK modulator which are connected to a FSO channel. The QPSK modulation format selects "*m*" value that is bits per symbol used as 2. The signal is received by coherent PSK receiver and then processed by DSP processor with selected modulation format. Figure 2 shows that the light signal is modulated with QPSK format and then transmitted through the FSO signal. BER test set is used to analyse the performance.

For 8-PSK, the value of m considered is 3. 8-PSK system consists of DP 8-PSK transmitter subsystem instead of QPSK transmitter which consists of a PSK sequence generator and m-ary pulse generator. Light signal is modulated with input data signal using Mach-Zehnder modulator and then modulated signal is transmitted through FSO channel.The received signal is processed using DSP. In universal DSP, modulation format is selected as 8-PSK and the polarization type is selected to be dual. In decision device also, modulation format and polarization type has to be selected in order to achieve better BER performance. FSO channel is considered for five different channel conditions and the laser source power is varied from 1 to 10dB.

Similar to 8-PSK system, 16-PSK system is designed with value of "*m*" as 4 as in layout for 8-PSK shown in fig 3. The outputs are obtained from the constellation diagram and BER test set.

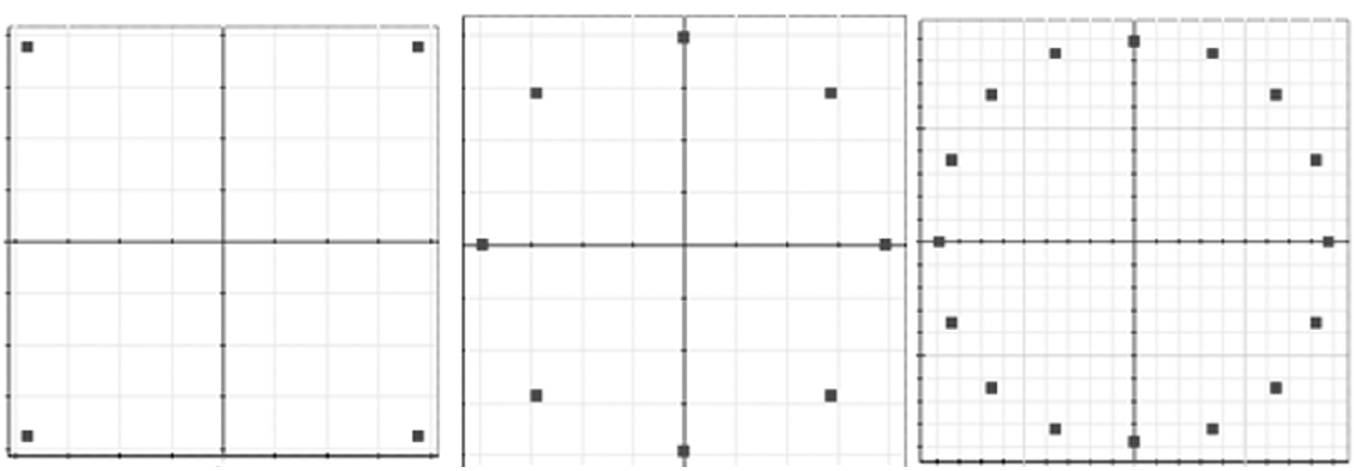
5. RESULTS AND DISCUSSION

The FSO transmission system is considered with the atmospheric turbulences. Channel parameters such as channel range, transmitter aperture diameter, receiver aperture diameter and beam divergenceare also considered as designed values. FSO channel is considered with different atmospheric condition having different attenuation values.

QPSK modulation system considersm as 2 and generates 4 constellation points which are shown in fig 3a. Where as in 8-PSK modulation system provides an output of 8 constellation points with m value as 3 and is shown in figure 3b. In 16-PSK system 16 constellation points are produced for m-value 4 as illustrated in fig 3c.

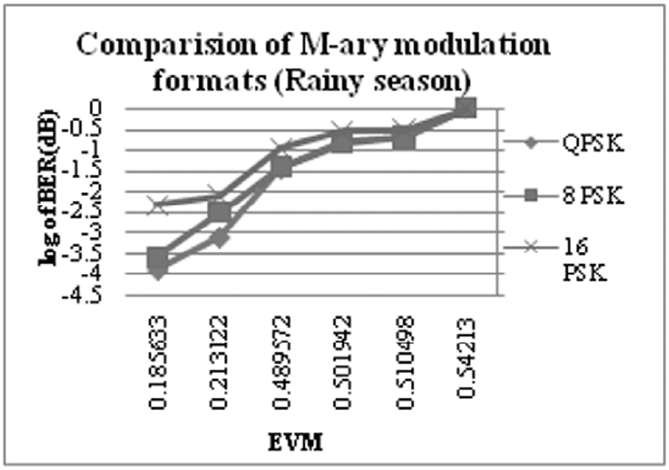
To analyse the system performance for identifying the optimum modulation method having minimum error, the results of the system are compared for different M-ary techniques under the 5 seasonsusing various parameters like BER, EVM and SNR.

The FSO transmission system with different environmental conditions behaves depending on the factors considered. During rainy season, the channel parameters are designed with an attenuation value of 4.6dB/Km and the response of the channel is reported with BER, SNR and EVM. From figure 4a, EVM and BER both get

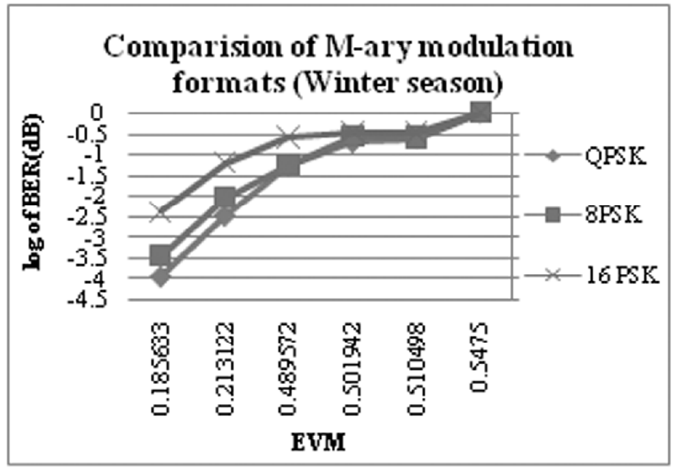


(a) Constellation of QPSK **(b) Constellation of 8-PSK** **(c) Constellation of 16-PSK**

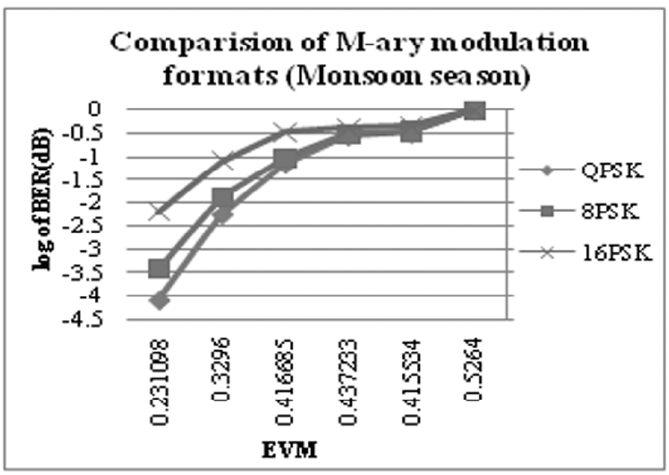
Figure 3:



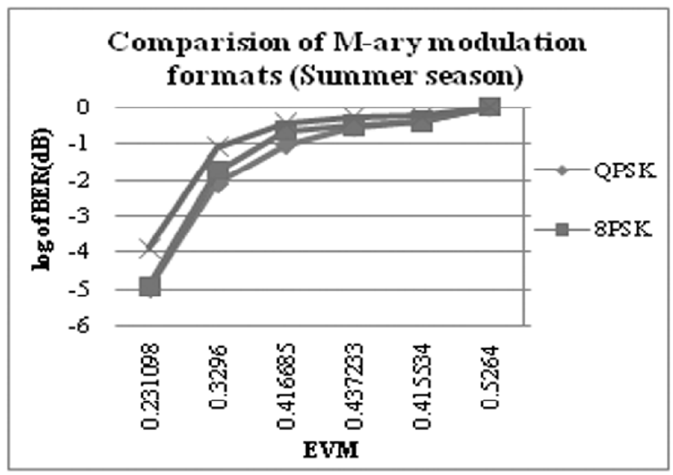
(a) log of BER with EVM relation for rainy season



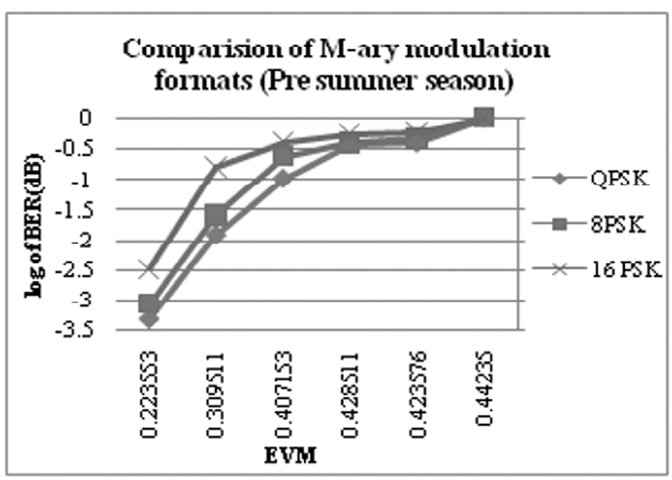
(b) log of BER with EVM relation for rainy season



(c) log of BER with EVM relation for monsoon season



(d) log of BER with EVMrelation for summer season



(e) log of BER with EVM relation for pre-summer season

Figure 4:

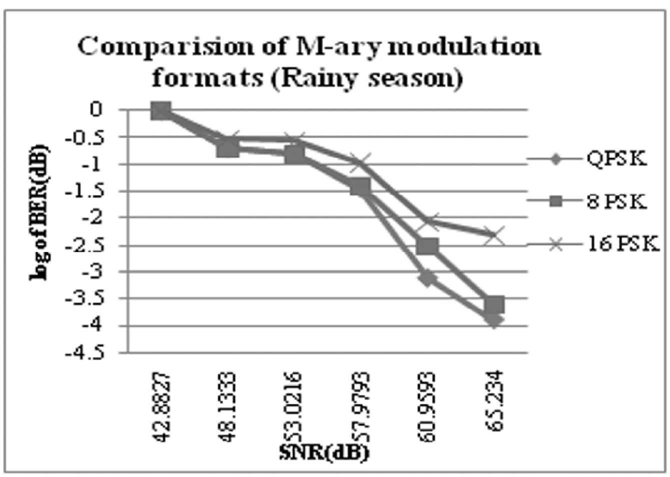
decreased as the power is increased. At EVM value of 0.1856, QPSK ha a difference of 0.30dB of log of BER with 8 PSK and 1.59dB of log of BER with 16 PSK. QPSK is the most suitable modulation method since it gives very less error.Winter season has an attenuation value of 5.6dB/Km and from figure 4b, it is reported that QPSK has a difference of 0.48dB of log of BER with 8 PSK at 0.1856 EVM and has the difference of 1.54dB of log of

BER with 16 PSK. From figure 4c, the attenuation value of monsoon season is 6.45dB/Km. QPSK has the log of BER difference of, at 0.2310 EVM, 0.65dB and 1.88dB with 8 and 16 PSK respectively. From figure 4d, summer season has the attenuation of 7.9dB/Km. QPSK has the difference of 0.15dB of log of BER with 8 PSK at 0.2310 EVM and has the difference of 1.07dB of log of BER with 16 PSK. From figure 4e, the attenuation for pre-summer season is 8.82dB/Km. QPSK will have the difference of 0.25dB of log of BER with 8 PSK at 0.2235 EVM and have the difference of 0.83dB of log of BER with 16 PSK.

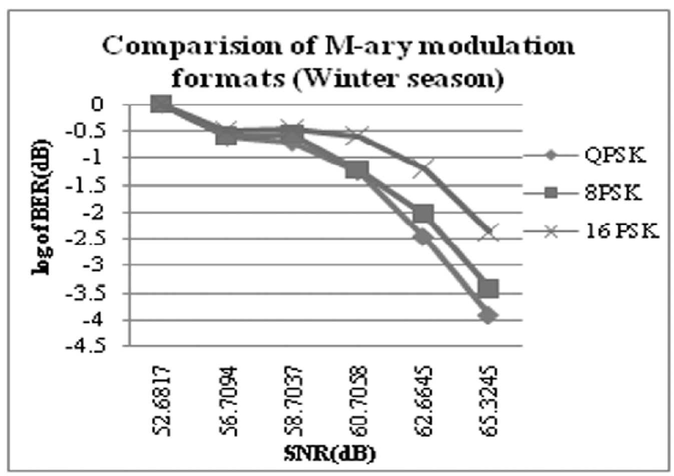
On consolidating the analysis, the QPSK performs better than other PSKs. While increasing the number of bits per symbol for transmission, BER also increases. Hence at all seasons, QPSK emerges as the suitable modulation method to retrieve the signal with least error.

Table 3
System performance of various modulation methods in terms of BER

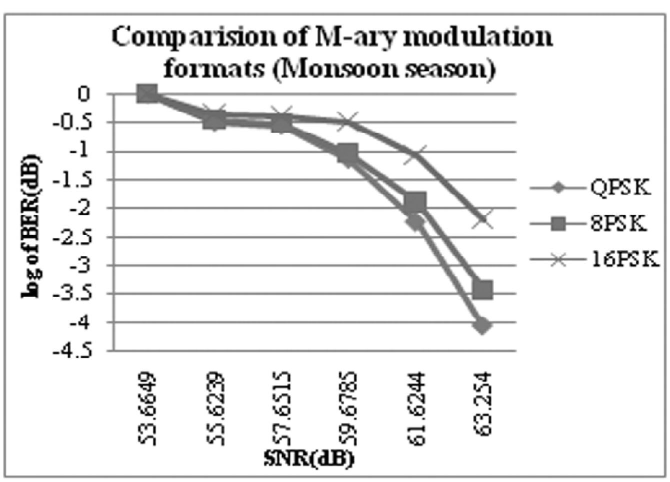
Season	EVM	Log of BER		
		QPSK	8-PSK	16-PSK
Rainy	0.1856	-3.91	-3.60	-2.32
Winter	0.1856	-3.90	-3.42	-2.36
Monsoon	0.2310	-4.07	-3.42	-2.19
Summer	0.2310	-4.95	-4.8	-3.88
Pre-summer	0.2235	-3.30	-3.05	-2.47



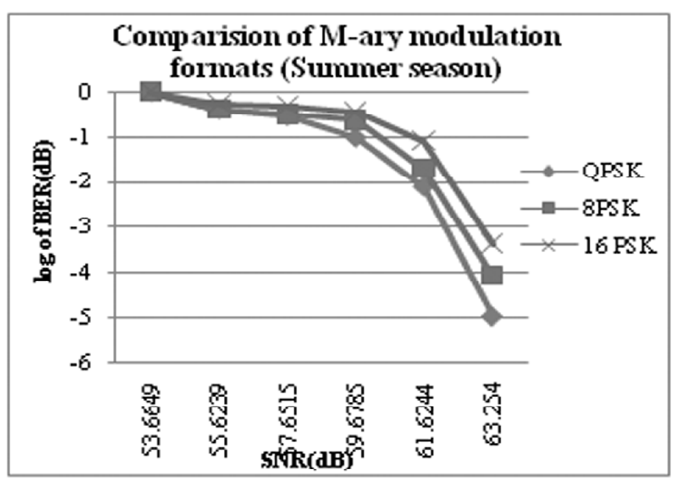
(a) log of BER with SNR relation for rainy season



(b) log of BER with SNR relation for winter season



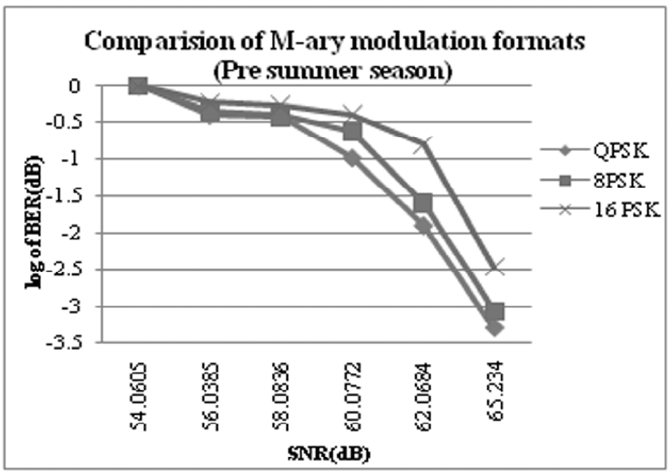
(c) log of BER with SNR relation for monsoon season



(d) log of BER with SNR relation for summer season

In figures 5 a, b, c, d and e, log of BER with respect to SNRis plotted and it shows that the SNR gets increased with increase in input power. When comparing the error performance of modulation methods, QPSK performs better than other formats and has the lowest BER.

From figure 6, it is observed that when input power increases spectral efficiency also increases. Spectral efficiency is theinformation rate that can be transmitted over a given bandwidth in a specificcommunication system. It is high when more number of bits is transmitted. The spectral efficiency of 16 PSK is greater than 8 PSK and QPSK. At the input powerlevel of 2dB, spectral efficiency for 16 PSK is 0.038 bits/s/Hz more than8 PSK and 0.138 bits/s/Hz more than QPSK. While considering the spectral efficiency 16 PSK performs better than others since more number of bits are transmitted.



(e) log of BER with SNR relation for pre-summer season

Figure 5:

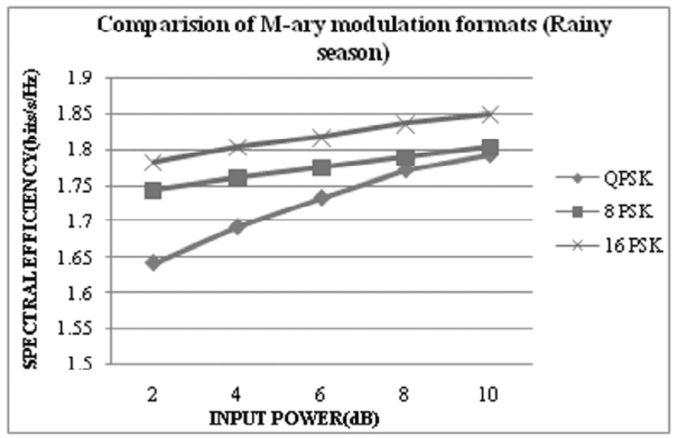


Figure 6: Spectral efficiency for rainy season

6. CONCLUSION

From the analysis of the FSO transmission system under various conditions of environmental factors, it is proved that performance degradationarising due to channel behaviour can be successfully overcome by employing advanced modulation techniques. In this paper, M-ary PSK modulation method was used with five different channel conditions. At all conditions, QPSK proves to be the most suitable modulation method to retrieve the signal affected by atmospheric turbulences. It is reported that QPSK exhibits superior error performance characteristics to retain the signal and 16 PSK displays the highest spectral efficiency than others with more number of bits to be transmitted. From the analysis of M-ary PSK method with QPSK, 8-PSK and 16-PSK which is concluded that QPSK has the lowest BER of -4.95 dB under strong turbulence conditions and hence is a more suitable modulation method. While considering the analysis of spectral efficiency, 16 PSK is more efficient than others about 0.038bit/s/Hz difference with 8 PSK and 0.138 bits/s/Hz difference with QPSK.

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