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BER Performance Analysis of an OFDM QPSK FSO System Considering AWGN Channel

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***Abstract*—** FSO is a communication system that uses light to transmit information in free space which acts as a medium between transmitters and receivers. This system is cost effective and easy to install. FSO has many advantages like low bit error rate and immunity to RF interference. The transmission in FSO can be difficult because of physical obstructions, atmospheric turbulence, pointing error, geometric losses, etc. Orthogonal frequency division multiplexing (OFDM) is a modulation technique where data is encoded on multiple sub-carrier frequencies. Despite having problems like peak to average noise ratio, OFDM system has received significant attention due to its high data rates, less intersymbol interference and unlimited bandwidth. A simulation approach is made to analyze the BER and SNR performances. The results are evaluated by MATLAB, thus it can be useful for designing, predicting and evaluating an improved FSO system in the existing communication system. Results are calculated in terms of SNR and BER. If OFDM-QPSK is used instead of other modulation schemes then nearly 6dB gain can be obtained at a bit error rate of 10^{-4}.

***Keywords*—** free space optic, quadrature phase shift keying, orthogonal frequency division multiplexing, bit error rate, signal to noise ratio, additive white Gaussian noise.

I. Introduction

In the FSO or Free Space Optical communication method, the light signal travels through the optical channel and transmit information from one point to another. For the signal transmission, air or vacuum space is used as the channel [1]. Sending modulated light signals through the air is not a new concept and many improvements have been made in this type of communication scheme in the past few years. A narrow light beam is transmitted from a transmission station and via the atmosphere, it travels through and then received by a receiver station. Both free space and optical fiber transmission systems offer greater bandwidth capabilities. However, FSO uses no fibers and therefore known as the Optical Wireless Transmission technique [2].

QPSK is a type of modulation method to transmit digital data across an analog channel. Data bits are grouped into pairs and each pair is represented by a particular waveform, called a symbol, to be sent across the channel after modulating the carrier [3]. However, in this process the frequency and amplitude remain constant. QPSK can be used to double the data rate compared with a BPSK system while it maintains the same bandwidth of the signal [1]. Some of the methods of digital modulation such as on-off keying, amplitude shift keying, frequency-shift keying transmits signal which contains only one bit, either binary-0 or binary-1. Each bit is considered as a symbol. With four phases, QPSK modulator can encode two bits per symbol [4]. So, instead of discrete signal 0 or 1, QPSK gives 00,01,10,11 signals.

Orthogonal Frequency Division Multiplexing (OFDM) is a digital modulation technique in which data stream is transmitted using a large number of parallel narrow-band sub carriers instead of a single wide-band carrier [5]. OFDM system supports high data rates by splitting a high-rate data-stream into a number of low-rate data-streams and this system transmits these over a number of narrowband subcarriers [6]. This system is a combination of modulation and multiplexing [7]. The choice of the modulation technique to be used by the transmitter for its next OFDM symbol is determined by the channel quality estimate of the receiver based on the current OFDM symbol [8]. The OFDM system inserts cyclic prefix to eliminate the effect of Intersymbol Interference. OFDM brings in unparalleled bandwidth savings, leading to higher spectral efficiency [9].

In our paper BER performance analysis was proposed for an OFDM-FSO system using QPSK modulation. During transmission, a number of factors, such as- noise, interference, fading, and other types of distortion affecting the transmitted signal can cause incorrect decisions to be made by the receiver, resulting in bit errors. The ratio of bit errors to received bits is called the bit error rate (BER) [10]. The BER curve can illustrate the relationship between power of the transmitted signal in terms of signal-to-noise ratio (SNR) and the resulting BER of the system. By analyzing the BER curve for a given system, we can find the minimum SNR that is required to achieve a particular BER [11]. For this purpose AWGN (Additive White Gaussian Noise) was used as channel model. The AWGN Channel sums the white Gaussian noise to a real or complex input signal. When the input signal is real, this channel sums real Gaussian noise and produces a real output signal. When the input signal is complex, this channel sums complex Gaussian noise and produces a complex output signal [12].

This paper is organized as follows, Section I contains the introduction of free space optical communication, quadrature phase shift keying, orthogonal frequency division multiplexing, bit error rate, signal to noise ratio, additive white gaussian noise. Section II contains the system model, Section III describes the results and discussions, and Section IV presents the conclusion and scope of future works.

II. System Model

A complete block diagram representation of an OFDM-FSO System using the QPSK modulation technique is shown in fig. 1. This system consists of Transmitter and Receiver.

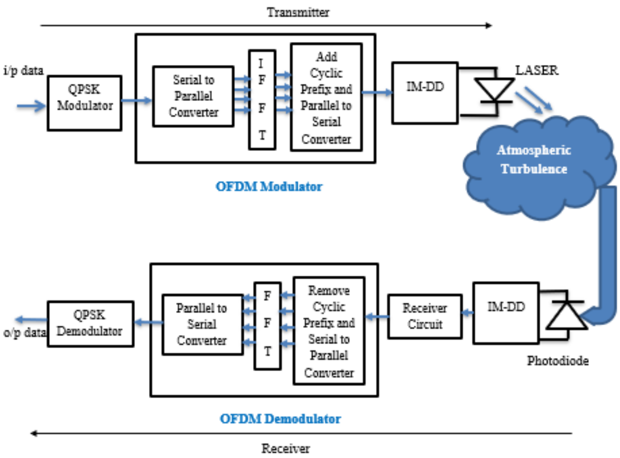

Figure 1: System model of an OFDM-FSO system using QPSK modulation

At the transmitter side, a bit sequence of input data is mapped using the QPSK modulation technique. A QPSK modulated carrier undergoes through four changes in phase that are represented as symbol [13]. Each symbol consists of two binary bits of data. Then the serial input data goes through serial to parallel converter and Inverse Fast Fourier Transformation (IFFT) is performed in each parallel data. IFFT Block converts each signal from time domain to frequency domain. After IFFT block, cyclic prefix is added and parallel to serial operation is performed to the data stream. Then the output of this p/s block goes through Intensity Modulation-Direct Detection (IM-DD). Since the whole system is designed for free space optical communication, data are sent here as the form of light. Light is always real and positive, so the signal to be transmitted should be real and positive. Thus, this IM-DD block discards the imaginary data and varies the intensity of the light of LASER according to the real data and directs this to the receiver side.

At the receiver side, the light sent from LASER goes through the atmospheric turbulence and is received by a photodiode. Photodiode converts the light signal to electrical current. After that, electrical current is sent to the receiver circuit. Receiver circuit is a type of decision circuit which decodes the data stream from the electrical current. Then a reverse operation is occurred at the receiver side. After removing the cyclic prefix and serial to parallel operation, Fast Fourier Transformation (FFT) block converts the data stream from time domain to frequency domain. Finally, data stream goes through QPSK demodulator which demodulates the data stream to recover the transmitted data.

III. Results And Discussion

In this chapter, the results represent the BER performance of different modulation schemes, considering an FSO link. The behavior of the SNR vs. BER curves for different modulation schemes can be observed from the graphs.

A. QPSK-FSO with OFDM over without OFDM

The BER performance comparison curve between OFDM-QPSK modulated system and QPSK modulated system without considering OFDM is shown in fig.2.

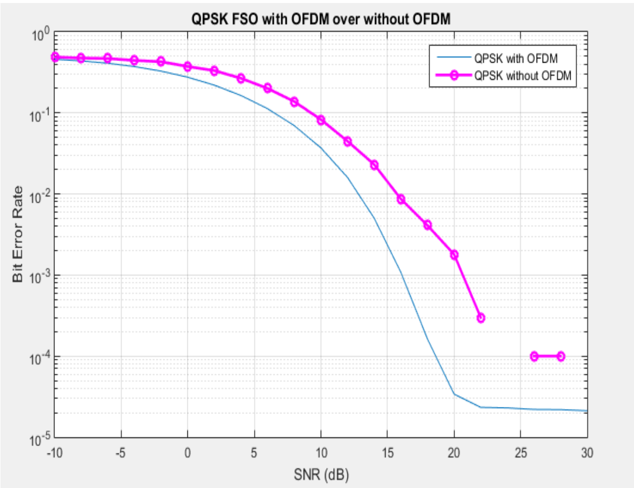

Figure 2: Difference in BER vs SNR curve for OFDM-FSO system with QPSK modulation over without OFDM.

At a BER of 10^{-4}, SNR of QPSK without OFDM is 24 dB, whereas SNR of QPSK with OFDM is 18dB. Results show that, at this point, QPSK with OFDM gives almost 6dB improvement in terms of SNR. Similarly, at BER of 10^{-3} and 10^{-2}, almost 5dB and 3dB improvement can be observed for QPSK with the OFDM system.

B. Difference between various modulation schemes with OFDM-FSO link

The BER performance comparison curve for OFDM-FSO system with a different modulation scheme is shown in fig.3.

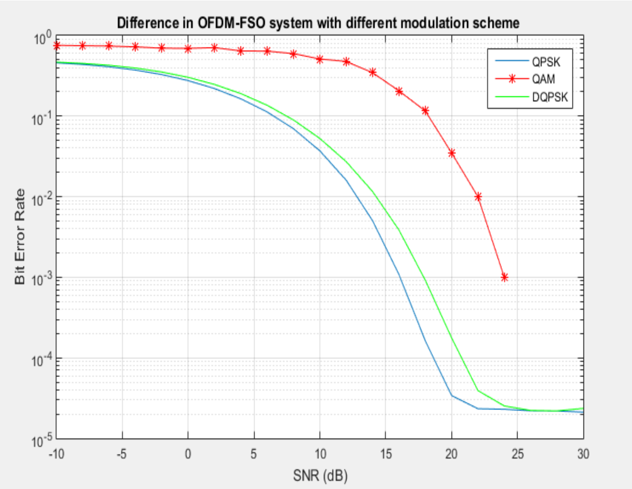

Figure 3: Difference in BER vs SNR curve for OFDM-FSO system with different modulation scheme.

i. At BER of 10^{-3} and 10^{-2}, SNR of QAM-OFDM are 24dB and 22dB, whereas SNR of QPSK-OFDM are 16dB and 13dB.Results show that, QPSK-OFDM system provides almost 8dB and 9dB improvement over QAM-OFDM system.

ii. At BER of 10^{-3} and 10^{-2}, SNR of DQPSK-OFDM system are 18dB and14dB.Considering the same BER values for the QPSK-OFDM system, it can be seen that, QPSK-OFDM system gives almost 4dB and 1dB improvement over DQPSK-OFDM system.

IV. CONCLUSION

In today's world, the FSO system may provide enhanced capabilities as a communication system to maintain the demand of the rapidly growing population. This paper contains data that can be analyzed to propose better links in specific areas. We have utilized multiple modulation techniques and analyzed their BER performances. According to these data, we can conclude that the QPSK-OFDM modulation technique provides better performance than others. Although our research may help to improve the performance of the FSO communication system, it is still not enough to replace the mainstream communication methods. There are several scopes where future research can be done to reduce turbulence errors and heighten the performance of the FSO system. Besides, in the future, we may combine satellite and FSO techniques to advance mobile communication and establish a point-to-point connection. This paper gives a brief review of the FSO system and its components. Since FSO communication system provides a larger bandwidth, it can be applied to improve the existing systems, such as LAN, inter-satellite links, airborne equipment to a satellite link, MAN and many more.

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