ARPN Journal of Engineering and Applied Sciences

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SIMULATION RESEARCH OF FREE-SPACE OPTICAL COMMUNICATION BASED ON LINEAR POLARIZATION SHIFT KEYING MODULATION

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ABSTRACT

Free-space optical communication is utilized for transmitting data between the source and destination using light traveling through free space. In this paper, the modulation technique applied to the propagating light is linear polarization shift keying. An FSO system is simulated in Optisystem software using the aforementioned modulation technique under different weather conditions. The performance analysis of the system is carried out by examining minimum BER values and the corresponding transmission distance achieved with different specific attenuations.

Keywords: free-space optical communication, linear polarization shift keying (LPolSK), simulation, transmission distance, bit error rate (BER).

INTRODUCTION

Free-space optical communication has a lot of potential for wireless communication. It has the combined advantage of high bit rates, low bit error rates, immunity to Electromagnetic interference etc. Since the system uses the atmosphere as the medium for propagation, it is susceptible to atmospheric losses [4]. This causes the received signal to be highly attenuated resulting in higher BER due to beam broadening, beam wander etc. [2]. Light, being an electromagnetic wave has a vector characteristic. Thus, the polarization shift keying enables us to encode and modulate the polarization states of light for binary modulation. Most of the various schemes proposed for FSO transmission have high power and cost constraints further fueled by complexity issues. Hence, we have used linear polarization shift keying as the states of polarization (horizontal and vertical) do not alter under various atmospheric disturbances thereby enhancing the reliability [3].

PRINCIPLE AND MODEL OF FSO SYSTEM BASED ON LPOLSK

A. Principle of linear polarization shift keying

Light, being an electromagnetic wave has a vector characteristic. Thus, the linear polarization shift keying enables us to encode digital bits as polarization states (vertical and horizontal) that are preserved over the course of time [1]. The output power of the laser source can thereby be efficiently utilized.

The transmitter consists of a continuous wave laser having a power of 200mW. The light from the laser is passed to a linear polarizer angled at 45 degrees. The output of this polarizer is a +45° linearly polarized light which then goes to a polarization beam splitter. The light is split into its vector components (x and y components). The binary data to be encoded is first given to a NRZ pulse generator that generates Non-Return-to-Zero pulses. As shown in Figure-1, the amplitude modulators connected to different vector components are modulated by polar opposites of the same data stream. The resultant modulated light components are then combined to a single source of light using the polarization beam combiner. Using a polarization analyzer at the output of the transmitter, it can be shown that '1' is represented by horizontal LPolSK and '0' is represented by vertical LPolSK. Hence the binary data is successfully encoded in the polarization states.

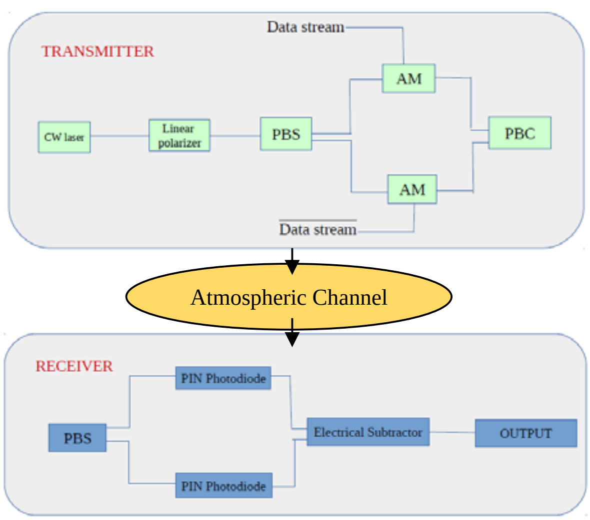

Figure-1. Block diagram of FSO system.

The standard FSO channel provided by Optisystem software is used to model the propagation medium for the simulation. It allows us to select the range

VOL. 10, NO. 14, AUGUST 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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of the system as well as the specific attenuation of the channel. The following table lists the specific attenuation of various atmospheric conditions used in the simulation.

The receiver consists of a polarization beam splitter that again splits the received light into its orthogonal components. The pin photodiode detectors convert the incoming light intensity signal to electrical signal. The power of the electrical signal depends on the input signal power. An electrical subtractor gives the difference between the electrical signals produced by the two photodiodes. An oscilloscope visualizer connected to the output of the subtractor shows that the received signal is the same as the signal generated by that generated by the NRZ pulse generator.

SIMULATION AND ANALYSIS

A. The simulation of LPolSK modulated system

This research paper uses the software Optisystem by Optiwave to establish a 2.5Gbps atmospheric optical communication system model using LPolSK. We have chosen 3 atmospheric conditions (light haze, moderate fog and heavy fog), each having a specific attenuation value [5] (dB/km) as shown in Table-1.

Table-1. Atmospheric conditions used in simulation.

Atmospheric conditions	**Specific attenuation** (dB/km)
Light haze	3
Moderate fog	25
Heavy fog	120

The source of the transmitter is a continuous wave laser emitting a 1550 nm beam of light of power 200mW. This beam is then fed to a 450 linear polarizer and then split into its orthogonal components using a polarization beam splitter. A user-defined bit sequence generator operating a bit rate of 2.5Gbps and Non-Return-to-Zero pulse generator are incorporated in the transmitter to provide a steady input binary stream. NRZ pulse generator is set to normalize the values between 1 and 0 for the amplitude modulator as shown in Figure-2. A 1x2 splitter replicates the input stream so that one of the copies can be inverted using a NOT gate. A separate NRZ pulse generator is set to produce a stream of only 1's. It supplements the NOT gate in giving power to the amplitude modulator in the event of NOT gate producing a 1.

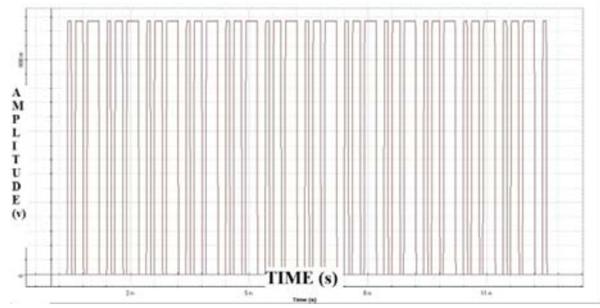

Figure-2. Input electrical signal.

Each of the vector components are fed to an amplitude modulator which modulates the power of input optical signal based on the data stream provided to the amplitude modulators as illustrated in Figure-3. Hence, both the modulators are provided with polar opposites of the electrical signal. A polarization beam combiner combines the outputs of the modulators into a single beam of light. Using a polarization analyzer at the output of the transmitter, it can be shown that '1' is represented by horizontal LPolSK and '0' is represented by vertical LPolSK. Hence the binary data is successfully encoded in the polarization states.

An FSO channel provided by Optisystem is modelled to manifest 3 different atmospheric conditions i.e. light haze, moderate fog and heavy fog according to the specific attenuation values provided in Table-1. This has a direct connection to the transmission distance.

The signal received from the FSO channel is passed to a polarization beam splitter. Photodiodes connected to each perpendicular component convert the optical signal into an electrical voltage. The difference in electrical voltage is calculated by an electrical subtractor. If this difference is positive then a binary '1' is inferred, else '0'. An oscilloscope visualizer connected to the output can be used to view the electrical signal received. The Bit Error Rate can be tested using a BER Analyzer as shown in Figure-3.

The criterion for BER that we have set for finding the optimum transmission distance in different atmospheric conditions is of the order 10-9. For the above mentioned BER criterion the system achieves a range of 2 km at BER value of 1.23495e-09 under light haze specific attenuation of 3dB/km. Under moderate fog conditions (25dB/km) we obtain a range of 650m at BER value 2.389e-09. The range achieved under heavy fog condition (120dB/km) is 220m at a BER level of 9.15164e-09. These results have been compiled in Table-2.

VOL. 10, NO. 14, AUGUST 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Table-2. Results of simulation.

Atmospheric conditions	Transmission distance (km)	BER value (10^{-09})
Light haze	2	1.23
Moderate fog	0.65	2.389
Heavy fog	0.22	9.15

B. Performance analysis

Performance of the system is tested through simulation and detailed analysis is conducted on BER and transmission distance with specific attenuation as mentioned in Table-1.The BER criterion used is of the order 10^{-09}. Table-3 summarizes the input parameters that have been used in the simulation.

Table-3. Parameters used in simulation.

Parameters	Values	Units
Transmitted power	200	mW
Wavelength	1550	nm
Receiver diameter apperture	20	cm
Transmitter diameter angle	2	mrad
Receiver responsitivity	1	A/W

The Bit Error Rate is the ratio of the number of bits in error to the total number of bits that have arrived in a given time interval. BER is a dimensionless value and can be used as a quantitative measure of the reliability of a communication system. Table-2 shows the concluded ranges of the system under the three aforementioned conditions. Under light haze condition, a range of 2km is recorded against a BER of 1.24e-09. Similarly, for moderate fog condition a range of 650m is obtained for a BER value of 2.389e-09. Lastly under heavy fog condition a BER value of 9.15e-09 corresponds to range of 220m.

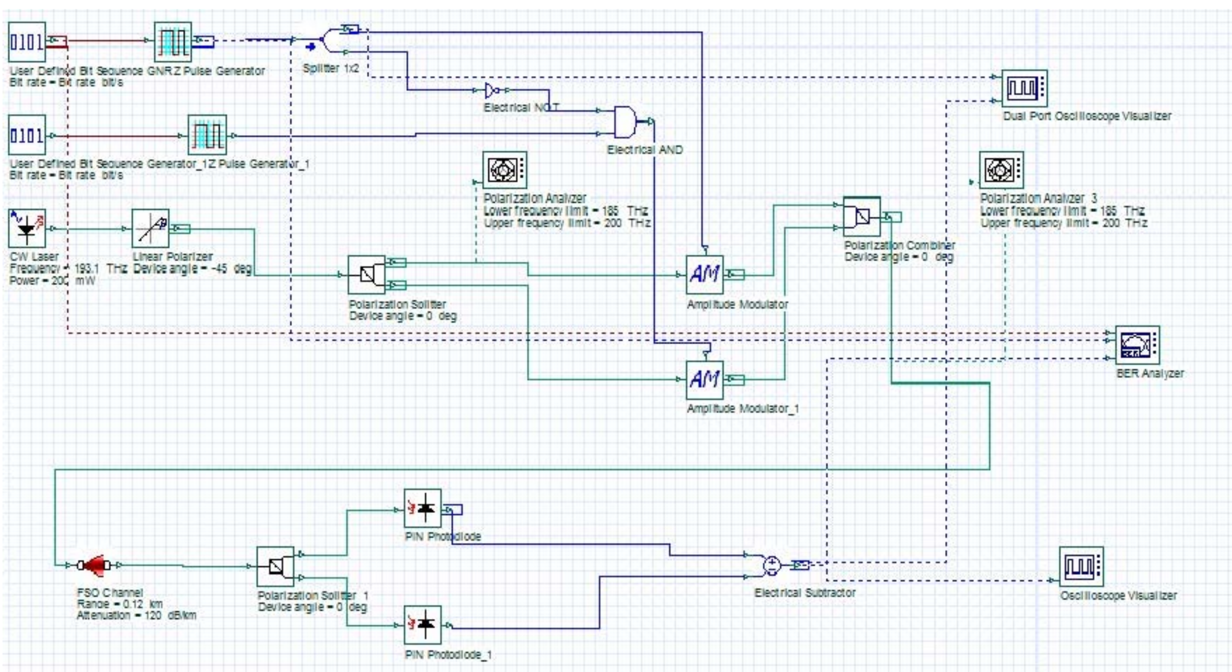

Figure-3. Simulation layout.

The input signal is a NRZ pulse between 0 and 1 volts corresponding to a bit stream of 010110111. The output signal obtained in Figure-4 clearly represents the same input signal albeit at a different voltage level due to losses incurred in the channel.

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

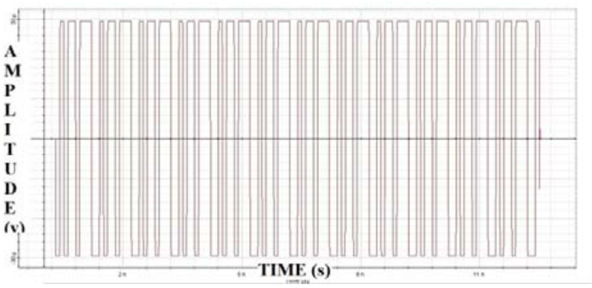

Figure-4. Output signal.

Clear eye diagrams of all the three atmospheric conditions are obtained and optimized for minimal losses as shown in Figure-5.

It is shown in Figure-6 that as the transmission distance increases the BER value also increases, thus putting an upper limit on our range for the given BER criterion of 10e-09.

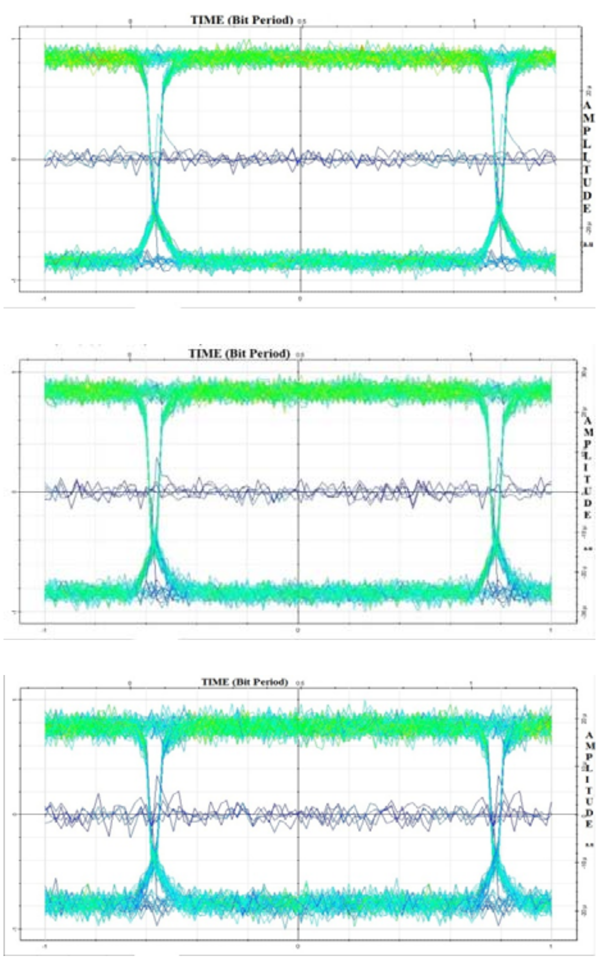

Figure-5. BER Pattern (a) light haze (b) moderate fog (c) heavy fog.

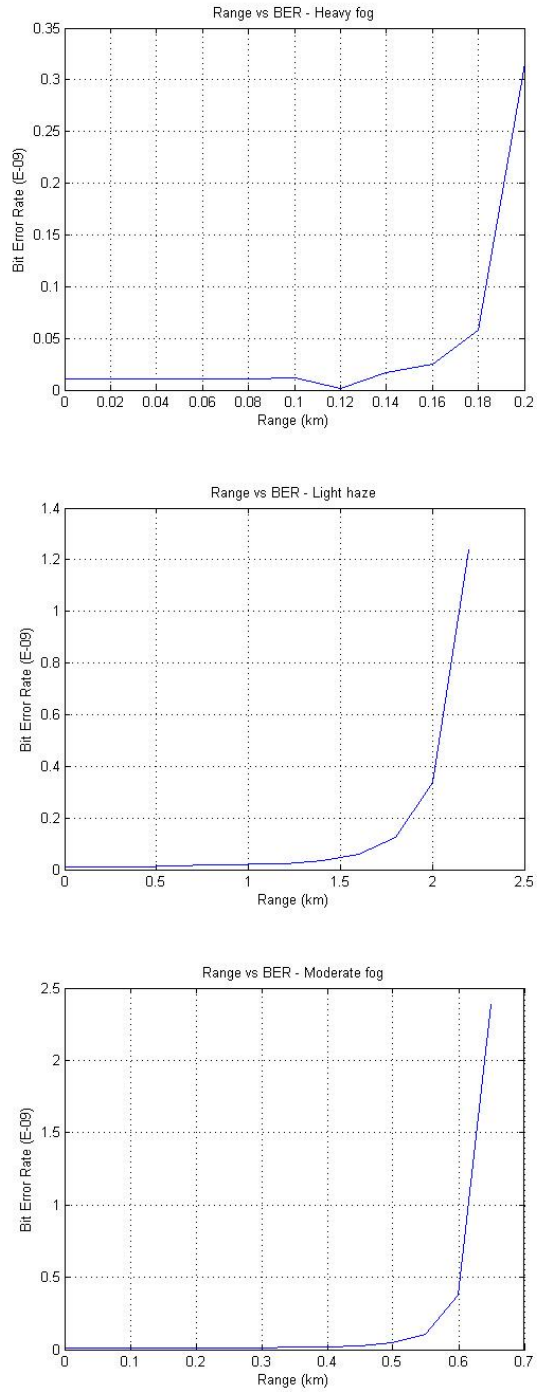

Figure-6. Transmission distance vs. bit error rate.

CONCLUSIONS

The advantages of linear polarization shift keying make it an apt replacement for other free space optical modulation techniques. In this paper, we have modelled an FSO system using LPolSK scheme. The performance of

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the model was investigated by simulation and analysis of the system metrics such as Bit Error Rate and transmission distance was carried out for three different atmospheric conditions, namely, light haze, heavy fog and moderate fog. It was observed that the BER value increased with the transmission distance. The range of visibility i.e. transmission distance decreased with increase in specific attenuation as modelled in three different scenarios. Light haze condition gave the best transmission distance of 2km while heavy fog conditions gave the least range of 220m. Hence the system has the potential for practical applications requiring low power consumption and low transmission losses.

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