Experimental analysis of optical wireless system in LOS link using BPSK

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In this paper, a binary phase shift modulation (BPSK) method is used for indoor Optical wireless communication (OWC) system. BPSK modulation technique is used for transmitting data at low noise and to reduce noise interference. A practical design has been developed according to the modulation technique that can be applied to the optical transmission system. The system consists of a transmitter (LED) and a receiver (PIN diode) separated by a smaller distance in a confined area. The power is measured at the receiver by varying the distance (in terms of centimeters). The measured result of the visible light communication system is used to study the performance on the basis of path loss and Bit error rate (BER). They depend on the distance and height of the transmitter and receiver. Satisfactory data rate are achieved under line of sight (LOS) condition. The results for the experimental setup are shown and the valuable results can be used for new innovations.

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1. Introduction

Indoor optical wireless communication has been in use from the late nineteenth century and has been developing over the last 4 decades. It provides higher bandwidth, quality and speed. Its unregulated bandwidth offers high data rate and security to data with lower power consumption and cost [1]. OWC is an optical communication technology that uses light propagating in free space to wirelessly transmit data in different applications. Optical communication has been widely used in fiber optic communication links with ongoing research's to replace it with optical wireless communication. The devices will become mobile, reducing the cost of installing fiber cables. It requires light to be focused using either a Light Emitting Diode (LED) or Light amplification by stimulated emission of radiation (LASER) [1]. In previous studies, investigations provide the performance of optical wireless communication without adapting BPSK digital modulation technique. In this paper, we adapt BPSK modulation and demodulation technique considering the bit error rate and free space path loss performance [3]. The performance varies with difference in distance and height of the transmitter and receiver. Hence, an experimental analysis is performed for the indoor optical wireless communication by designing a transceiver with additive white Gaussian noise (AWGN) as communication channel [1]. The BER performance reduces due to the atmospheric conditions such as external light even at short distance communication.

Hence this paper is focused on evaluation of different cases by varying different parameters such as received signal power, distance, etc. This paper is organized as follows: In section II, indoor optical wireless system design channel, in section III, Experimental demonstration, in section IV, simulation results and discussions. Finally, conclusion is given in section V.

2. Indoor optical system design

In indoor optical wireless communication, different modulation techniques are used such as on off Keying (OOK) and pulse position modulation (PPM) because of simplicity and low cost design. In our previous studies the OOK modulation technique provides low data rate and selection of thresholds is very critical due to the fluctuation of optical signal intensity; threshold adjustment is not easy to accomplish performance. Furthermore, an alternative modulation technique, PPM has been proposed for indoor optical wireless communications. It has been found that PPM has superior power efficiency compared to OOK; however, it has poor bandwidth efficiency [6]. In this paper we utilize BPSK modulation that provides good BER performance and data rate. The optical wireless transceiver system design is shown in Fig. 1. Any digital data can be transmitted using the transceiver system by using an analog signal as carrier.

The carrier signal secures the message signal from getting affected by external disturbances. Minimum external components are required to design the system at low cost. Thus the size of the transmitter and the receiver is nearly the same and occupies less space. A prototype of the transceiver system is designed for digital transmission of data with LED as light source and PIN photo detector as receiver. The communication link can operate only at short distances such as 5cm for simplicity and its performance depends on the channel of operation. The carrier wave is phase locked using coherent BPSK modulation and demodulation technique.

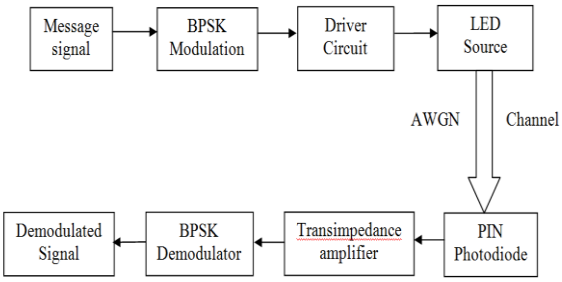

Fig. 1. Design of the optical wireless system.

The digital data is modulated using a BPSK modulator combining it with the carrier signal. Then the driver circuit drives the LED, converting the electrical energy into light energy. The light beam from LED is directed towards the receiver. At the receiver, the PIN photo-detector collects the transmitted light and converts it into photo current. The photo current thus produced is converted to voltage by using a trans-impedance amplifier. Then, the signal is demodulated to obtain the original signal or the message signal. This can be used for communication in indoor environment and will lead to new innovations in optical wireless communication system.

2.1 Optical transmitter

A bright visible LED is chosen for implementing the transmitter. The digital message signal is BPSK modulated with an analog carrier signal. The modulated signal is transmitted using a LED that is driven by a driver circuit as shown in Fig. 2. Two inputs, the message and carrier signals are given to the four quadrant analog multiplier. IC AD835 acts as a BPSK modulator.

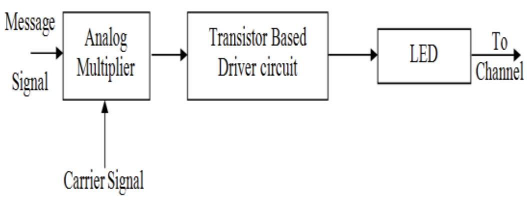

Fig. 2. Block diagram of optical transmitter.

The output of the four quadrant multiplier is a modulated signal. It is given to the driver circuit. A transistor is used to design a driver circuit [2].

2.2 Optical receiver

The stages required obtaining the original or message signal from the received light is shown in Fig. 3. The PIN photodiode collects the light transmitted by LED and converts it into current. The signal is BPSK demodulated to obtain the original message signal.

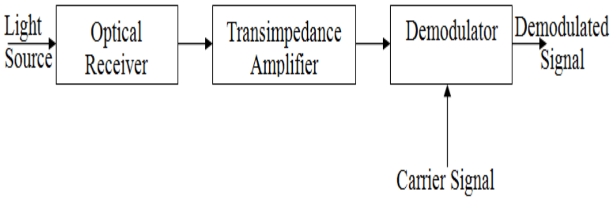

Fig. 3. Block Diagram optical receiver.

The photo-detector used is SFH203P PIN photo-detector from OSRAM opto semiconductors. The op-amp used is JFET input signal operational amplifier TL074 with well matched, high-voltage JFET and bipolar transistor in a monolithic integrated circuit. This device has high slew rate, low input bias, offset currents and low offset voltage temperature co-efficient. It can produce a slew rate of 16V/µs. A feedback resistor R_f of 250kohm is used for the current to voltage conversion. AD 835 IC is the first monolithic four quadrant voltage output multiplier. It provides high input impedance. Its high output current capability allow low impedance load to be driven. When an op-amp operates in open loop configuration, it may be used as a comparator. Hence, TL074 is used as a low-performing comparator [2].

3. Experimental demonstration

The designed optical wireless communication system is analyzed experimentally. The experimental setup is as shown in Fig. 4. The all the designed circuits are constructed on a bread board and tested with a cathode ray oscilloscope (CRO). The designed transceiver system is a prototype. Modulation technique is adapted for providing security to the data transmitted through the system. The design is tested in a confined area under minimum light conditions. The performance of the receiver system is calculated in terms of SNR and Path Loss.

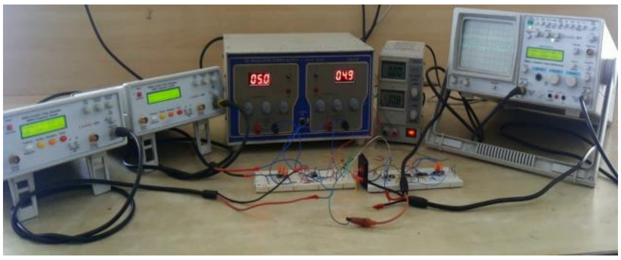

Fig. 4. Experimental setup.

The transmitter design is a simplified circuit which requires very less external components. The transmitter setup is as shown in Fig. 6.

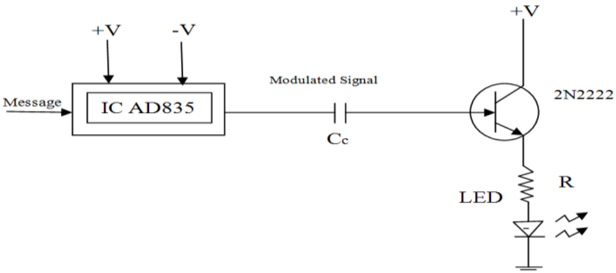

Fig. 5. Optical transmitter design.

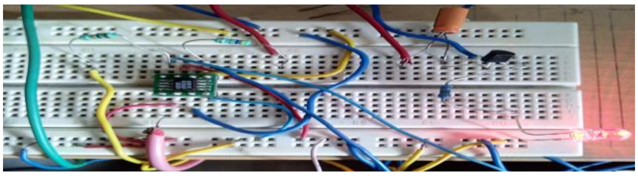

Fig. 6. Optical transmitter setup.

To perform BPSK modulation, the message and carrier signals are provided from two function generators to the modulator. Here, modulator used is BPSK modulator for which an analog multiplier IC is used in the circuit [4]. This BPSK modulated signal is given to the driver circuit. A capacitor is connected to the driver circuit called the coupling capacitor that blocks the DC voltage from the driver circuit that may affect the modulator. Through the coupling capacitor the modulated signal is given to the base of the transistor. The power supply of +3V is given to the driver circuit through a single RPS. It is connected at the collector terminal through a current limiting resistor to the anode of LED and the cathode is grounded. The receiver design is as shown in Fig. 7. The demodulator circuit consists of two important components which are analog multiplier IC and a comparator IC [4]. Received signal is a modulated signal which is given to input of the multiplier and the same phase carrier signal is given to input of the multiplier. Two phase shift occurs between 0s and 1s. One is positive and another in negative.

A positive phase shift considered above the zero level and the negative phase shift is considered below the zero level. The output of the multiplier is given to the comparator. The comparator compares the voltage level of the input signal and produces either +5 V when the level is above zero and -5V when the level is below zero.

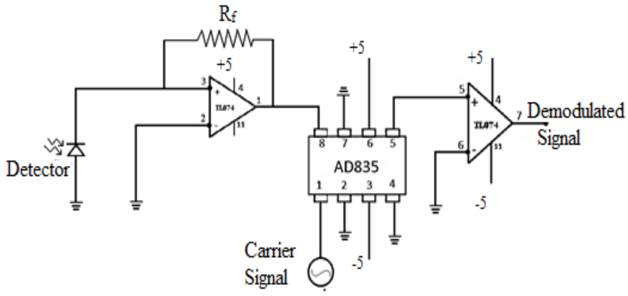

Fig. 7. Optical receiver design.

Fig. 8. Optical receiver setup.

4. Results and discussion

From the experimental setup we have obtained values for received power by varying the distance between the transmitter and receiver by using optical power meter. With the help of these values path loss and SNR can be derived. The received power that given by

$$P_{rx} = P_{tx} H(0) \tag{1}$$

Where, P_{tx} is transmitted optical power and $H(0)$ is channel impulse response. The performance of indoor optical wireless links is related to the receiver electrical SNR and measurement of path loss. The optical wireless system performance is estimated by SNR under natural and artificial light sources [5]. The average signal to noise ratio is given by

$$\mathrm{SNR}=\frac{R^2 H^2(0) P_{rx}^2}{R_b N_0} \tag{2}$$

The path loss is given by

$$Path\ loss = -10 \log_{10}[H(0)] \tag{3}$$

Path loss is defined as the ratio of the transmitted optical power to the received optical power. It is measured in dB [5]. Where, R is Responsivity, R_b is bit rate and N_0 is noise power. Where; q is charge and I_B is basing current.

$$N_0 = 2qI_B \tag{4}$$

The experimental parameters and results are given Table 1 and Table 2.

Table 1. Experimental parameters.

S.No	Particulars	Values
1	P_{tx}	1.17mW
2	λ	635nm
3	R	0.7A/W
4	q	1.6e-19 C
5	I_B	28.6mA

Table 2. Experimental results.

Distance (cm)	Received Power (mW)	Path Loss (dB)	Impulse Response H(0)	SNR (dB)	Bit Error Rate
1	0.63	1.85	0.66	65.81	9.41e-31
2	0.26	4.5	0.35	60.29	6.47e-28
3	0.16	7.31	0.18	54.71	2.52e-25
4	0.12	9.75	0.10	50	2.09e-23
5	0.09	13	0.05	43.40	1.92e-20
6	0.07	16.71	0.021	35	3.59e-17
7	0.06	19.5	0.011	30	1.11e-14
8	0.04	29.25	0.001	9.4	1.10e-5

The relation between SNR and horizontal separation between optical transmitter and receiver is shown in Fig. 9. Theoretically, SNR and distance are inversely proportional. The graph is plotted for the practical value calculated the SNR increases with the decrease in distance. Relationship between the horizontal separation and the path loss is shown in Fig.10. They are proportional to each other. Hence, with the increase in path loss, horizontal separation increases. Relationship between the BER and the SNR is shown in Fig. 11. They are inversely proportion to each other. Hence, with the increase in SNR, the BER decreases.

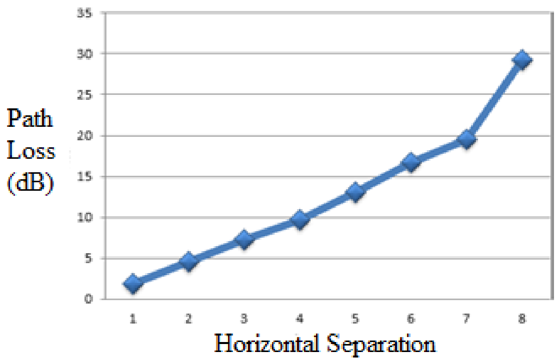

Fig. 10. Path loss Vs Horizontal separation.(cm)

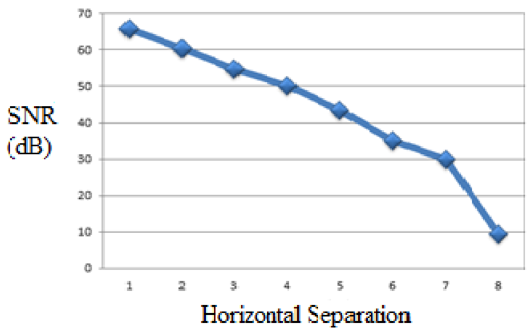

Fig. 9. SNR Vs Horizontal separation (cm).

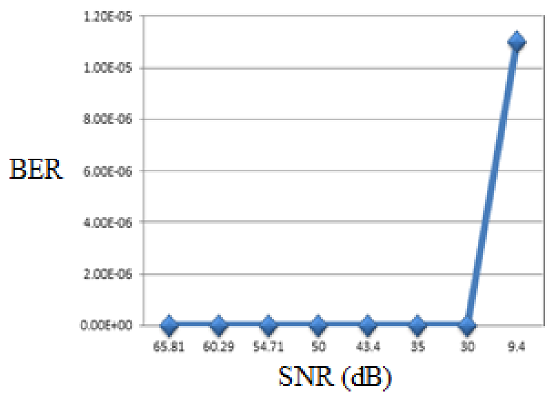

Fig. 11. BER Vs SNR.

5. Conclusion

The optical wireless communication system adapting BPSK modulation technique was analyzed. The experimental design provides simple circuitry to allow modulation in the optical transmission system. The design can be adopted to reduce the complexity and noise interference in optical communication system. The power of the system is calculated by varying the distance between transmitter and receiver. The relationship between path loss, SNR and the BER are calculated and represented graphically. The value achieved shows that the performance of the system depends on the application. The system analyzed in this paper to some extent represents the BPSK based OWC. This system may be combined with wavelet packet transform based de-noising receiver which may lead to creating a system that can use a more compact receiver. This is worthy of future work for indoor optical wireless communication.

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