Is Li-Fi the near future wireless technology?

Abdelghani Harrag, Ahmed Oussama Bouzaher, Abbes Remita

Abstract—**Li-Fi is transmission of data using visible light by sending data through a LED light bulb that varies in intensity faster than the human eye can follow. If the LED is on, the photo detector registers a binary one; otherwise it's a binary zero. This paper introduces the visible light communication technology as a solution for the current telecommunication crunch, also deals with the implementation of the most basic Li-Fi based system to transfer data from one computer to another. Also we have demonstrates the working of Li-Fi by simulating and implementing a simple circuit which gave us the required output. Furthermore we managed to achieve transmission data until 1 meter in daily room with an acceptable noise by using a 10mm ordinary LED and without any encryption technique. This work was done by using Matlab/Simulink code as well as Proteus software for the simulation and the emulation.**

Keywords- Li-Fi, VLC, optical wireless communication, LED communication

I. INTRODUCTION

Nowadays, Transfer of data from one place to another is one of the most important day-to-day activities. Communication is a process in which we can transfer information to any place we want and it could take many forms, from signals language and voice communication which is the simplest mode to communicate to the electromagnetic waves systems. Moreover, information could be in any form like Voice, Data, Video, Graphics etc. At present telecommunication knows a huge growth in the global usage, overtaking the 10 Exabyte's line per month. In this context, the limited radio frequency spectrum (from around 3kHz to 300GHz) puts constraints on the increasing demand for ubiquitous connectivity and high capacity. According to CISCO, there will be an 11-fold increase in mobile data traffic in 2018 compared to 2013 as shown in Fig. 1[1].

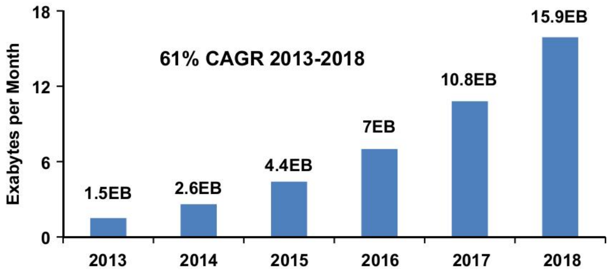

Fig. 1.1 Global mobile data traffic [1].

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The increase of devices accessing the internet is the primary reason for the dramatic increase in mobile data traffic. Also the development of online social media like Facebook and Twitter has further increased the mobile data traffic. Apart from the spectrum deficiency issues in RF wireless communication, interference is another problem since most wireless devices are electromagnetic [2].

To overcome the drawbacks of the RF communication systems, it is imperative to design new communication technologies. Visible Light Communication (VLC) systems employ visible light for communication that occupies the spectrum from 380nm to 750nm corresponding to a frequency spectrum of 430THz to 790THz. The low bandwidth problem in RF communication is resolved in VLC because of the availability of the large bandwidth as illustrated in Fig 2.

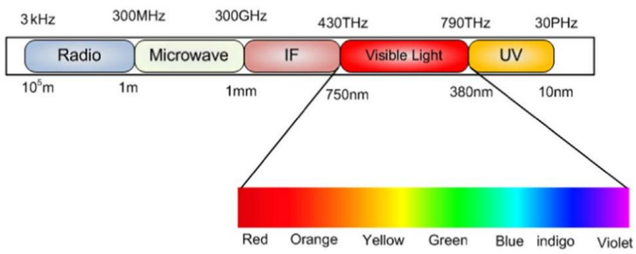

Fig. 2 VLC frequency spectrum.

The VLC receiver only receives signals if they reside in the same room as the transmitter, therefore the receivers outside the room of the VLC source will not be able to receive the signals and thus, it has the immunity to security issues that occurs in the RF communication systems. As a visible light source can be used both for illumination and communication, therefore, it saves the extra power that is required in RF communication. Keeping in view the above advantages, VLC is one of the promising candidates because of its features of non-licensed channels, high bandwidth and low power consumption. Potential applications of VLC include Li-Fi [3].

Li-Fi is the term some have used to label the fast and cheap wireless communication system, which is the optical version of Wi-Fi. Li-Fi uses visible light instead of Gigahertz radio waves for data transfer. The idea of Li-Fi was introduced by a German physicist, HARALD Hass, which he also referred to as data through enlightenment. The term Li-Fi was first used

Haas in his TED Global talk on Visible Light Communication. According to Hass, the light, which he referred to as D-Light, can be used to produce data rates higher than 10 Gigabits per second just by sending data through an LED light bulb that varies in intensity faster than the human eye can follow achieving high rate in data transferring which is much faster than our average broadband connection [4-5].

II. MATERIAL AND METHODS

A. Working block diagram of Li-Fi System

There are many processing diagrams of Li-Fi with different block range but all of them have the same basic idea. In this paper we discuss Pc to Pc sending data system (Fig. 3).

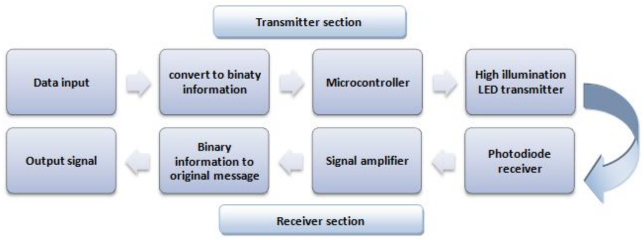

Fig.3 Li-Fi Transmitter and Receiver general block diagram.

First, the input data from personal computer (PC) transmitter is coded into a string of pulse electrical signals by microcontroller unit though the interface circuit. Secondly, the electrical signals powered LED source directly through a LED driver circuit, with which the electronic pulse converted to optical signals, this optical signals will received by a photo detector and do the optical to electronic conversion.

In transmitter section the microcontroller circuit drives the high illumination LED and switched it on and off in high speed, which provides nice opportunities for transmitted information. In receiver section, the photo-detector receives and amplifies the information by the amplifier circuit.

It is feasible to encrypt information within the light-weight by varied the speed at that the LEDs flicker on and off to offer completely different Strings of 1s and 0s.

B. Design Approach for Li-Fi

When designing or creating a Li-Fi System, a number of procedures are required. Selections of components are very important to build robust system. This process of component selection would be repeated as needed for every additional component that was to be selected. Once the initial components were selected, the circuit for both the receiver and transmitter were designed and tested in simulations. After that, we would order the components, then simulate, and finally build and test the circuits. Once the circuits were shown to function correctly when observed with an oscilloscope, they were connected to their respective microcontroller, which connects to the PC, and the digital portion of this project would be addressed.

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B.1 Component Selection

Since we have a rough idea of what the Li-Fi system would be like, and to know exactly which component is the most suitable for our circuit several tests are achieved. The selection process is comprised of a value analysis to place emphasis on certain desirable features of each component so that the best component of its group for the circuit could be determined. As the circuit was tested, it was expanded upon to fix problems and allow for greater functionality. A few of the components that were added also needed to be selected through analysis.

B.2 LEDs

In order to choose the most optimal LEDs, we considered the important factors shown in Table I below. Also we organized the importance of each feature in this table to aid in the selection of the best LED. For our project, there are two main goals: to transmit data as an ASCII message from the transmitter to the receiver and have it transmitted across different distances and different frequencies.

TABLE I. IMPORTANT SELECTION REQUIREMENTS FOR LEDS [6].

Category	*Importance*	*Desirable*	*Undesirable*
Brightness	1	> 10000 mcd	< 1000 mcd
Frequency Speed	1	> 1 MHz	< 100 KHz
Price (Unit Cost)	3	Less than $0.25	More than $1
Wave length	2	400-750 nm	Out of the visible range

A high level of brightness is preferable so that data can be transmitted reliably under ambient light and across larger distances. The frequency speed is also crucial. In order to transmit data quickly enough, the LEDs have to turn on and off quickly. Table II represents some information about the LEDs that we used in our experience; the table also summarizes their main features. All these LEDs are available in our electronics and electricity lab.

TABLE II. COMPARISONS BETWEEN DIFFERENT USED LEDS

Desc.	*Brigh. (mcd)*	*View. Angle (°)*	*Freq. (MHz)*	*Price ($)*	*Wave length (nm)*	*Max Current (mA)*
10mm Round Transparent Blue LED Diode	8000-10000	30	> 1	0.025	445-460	20
10mm Round Transparent green LED Diode	20000-22000	30	> 1	0.027	520-525	20
5mm Round Transparent red LED Diode	5000-6000	30	Unlisted	0.01	620-625	20

B.3 Photodiodes

When selecting the photodiodes, a number of features need to be taken into account. These features are listed in Table III.

Each of the features was rated for its importance. The most important feature was the response time. If the photodiode was incapable of detecting the flashing of the LED fast enough, then it would be incapable of meeting our design requirement.

TABLE III. SELECTION REQUIREMENTS FOR PHOTODIODE [6].

Category	*Importance*	*Desirable*	*Undesirable*
Response Time	1	< 10 ns	> 100 ns
Wavelength Range	2	Difference of 700 nm or more	Difference of 300 nm or less
Price	4	Less than $0.50	More than $1
Field of Vision	3	> 30°	< 10°
Response Time	1	< 10 ns	> 100 ns

C. Proposed system

We have designed a prototype Li-Fi system to transfer text message. The same method can be used to transfer and sharing other files. Our idea is to send data as serial information using RS232 communication protocol from one PC to another PC using visible light.

In order to achieve this goal we proposed an electronic circuit for both transmitter and receiver section. Initially, a basic receiving and transmitting circuits were simulated and implemented. The purpose of implementing the circuits is to understand the main and basic concepts of optical wireless communication using LEDs as transmitter and a photodiodes as receiver. Matlab program was written for coding, sending and receiving data. The simulation of the circuit was designed and tested on Proteus and Simulink

III. RESULTS AND DISCUSSION

A. Descriptions of the main section in our system

A.1 LED driver circuit for data transmission

Fig. 4 shows the LED driver circuit for transmission of data. ULN2803 is used as the driver IC in LED driver circuit. This IC is connected to eight NPN Darlington transistors (two transistors) which are directly compatible to TTL families. The maximum output voltage is about to be 50V and it can handle 500mA of output current. The input data is directly given to ULN2803 through RS232 to USB port converter. The positive power supply is directly connected to the anode terminal. The output of ULN2803 is connected to the cathode terminal of LED.

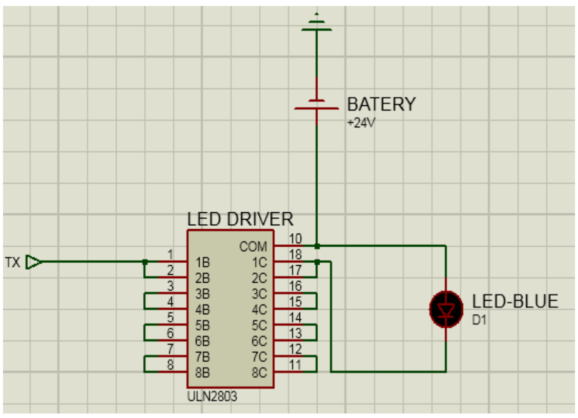


Fig.4 transmitter circuit.

A.2 Photo diode receiver circuit

The photo detector receiver circuit is shown in Fig. 5. The receiver circuit consists of LM339 which acts as a comparator. LM339 is an open collector comparator. The current of photo diode changes according to the variation in the illumination of light. There are two stages in receiver circuit. In first stage the photo detector current is converted into voltage. The second stage is inversion of voltage level to get the original information.

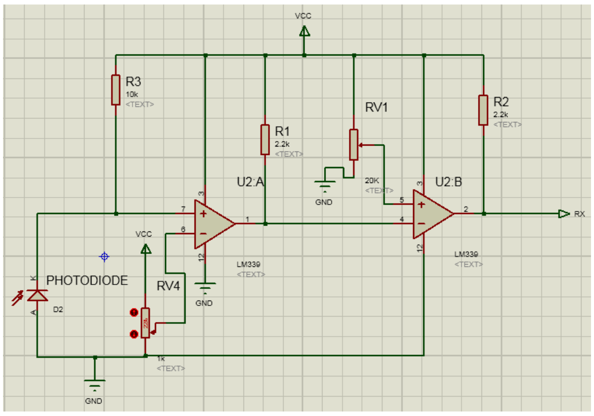


Fig 5 receiver circuit.

We are in order to test our circuit in four different scenarios, in the first scenario we confirmed that our system is functioning well by simulating the transmitter and receiver circuit. Secondly we emulate our system by the use of a real oscilloscope. Then in the third & the fourth scenario, we study the effect of different distances and frequencies in the performance of data transmitting.

B. Experiences

B.1. First experience

The voltage representative of data from the source is changing between 0V and 5V.When voltage is low there will be no current passing through the LED. Thus, the LED should be off. Similarly, when the voltage is high the current will pass through the LED. Consequently, the LED is on. After that we sent an ASCII code from Matlab throughout a virtual serial port (RS232) to Proteus, the result of simulation shows below in Fig. 6**.**

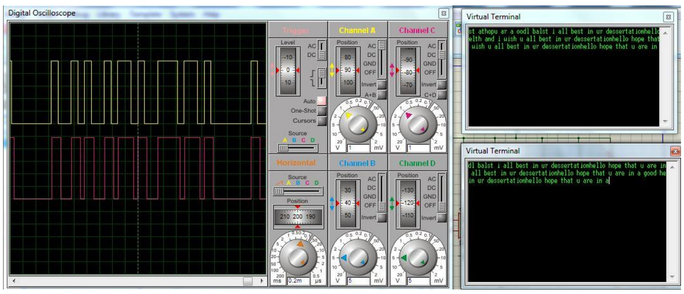


Fig. 6 Simulation output for data transmitter (yellow signal) and received (red) signal.

This result shows that the data sent and received are compatible, also the text message are similar in both screens.

B.2. Second experience

In this step we are going to test the simulation result with a real oscilloscope, in order to do that, we sent a binary data with frequency of 3 KHz throughout RS232 serial port with 9600 baud rate. The Fig.7 below represents the obtained result. As we see the yellow signal is the one measured from serial port (original signal) and the blue is the signal captured by the photodiode. We can say the result has an acceptable noise in the captured signal since it obtained in normal daily room.

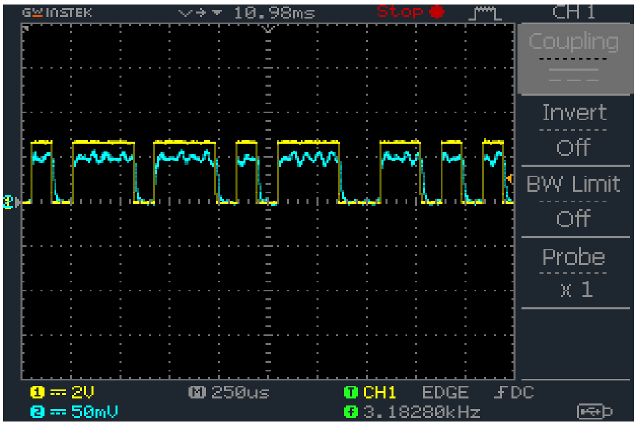


Fig. 7 Superposed signals (Original+ Captured signal).

B.3. Third experience

In this part we tried to study distances effect on data transmission, using a single ordinary blue LED (10mm) and UPD-300-UP an ultrafast photo detector also we used an optical condenser to collect the maximum rays and focus them directly on the photo detector. The optical assembly of this experience illustrates bellow in Fig. 8.

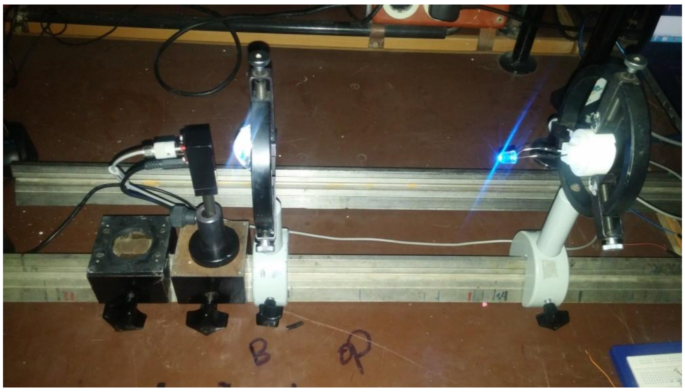


Fig. 8 the optical assembly.

The same message was send in same baud rate 2400, but with different distance (5 10 20 30 40 50 60 70 80 90 100cm).

This graph in Fig.9 shows voltage rate in distance function for 10 different positions of the emitter and receiver. Overall we see that there is a gradual decrease in the voltage value whenever the distance increases. So that in distance of 5cm the voltage rate was 75.95mV as a maximum value, then it fell slightly to stabilize at 20cm with 71.19mV. The strength signal kept stagnant until in the 50cm distance which declined in dramatically rate, to achieve 36.64 at one meter, the noise ratio was also increased whenever the distance growth.

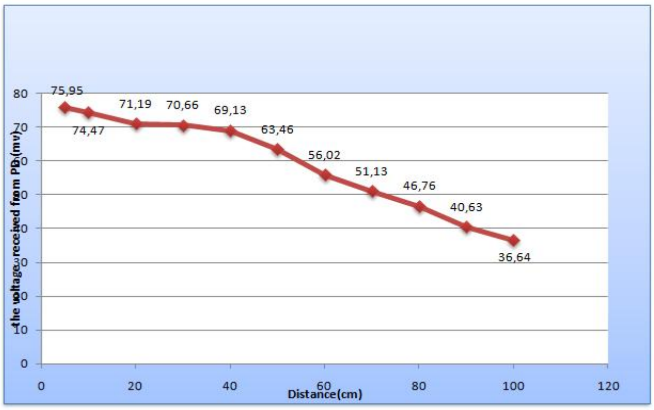


Fig.9 Summarized results.

The line graph in Fig.9 summarizes the results obtained. From these results we can say that the quality of signal is acceptable until 50 cm where the voltage strength start declined slowly. Note that all these results were done by an ordinary blue LED with 10mm diameter; furthermore this experience was done in daily room condition.

B.4. Fourth experience

To study high frequencies effect on the performance of our system. We powered the circuit with different baud rate from the lowest 300 to the highest 57600 using three different LEDs, red green and blue, which consists of the three main colors in the nature (RGB). For this experience we used Matlab program to send data through serial port toward Arduino UNO board, where the LED powered by the Arduino output TX. For receiving data from LED we used ultrafast photo detector and POSCOPE to interpret the signals. The circuit that we used is represented in Fig 10.

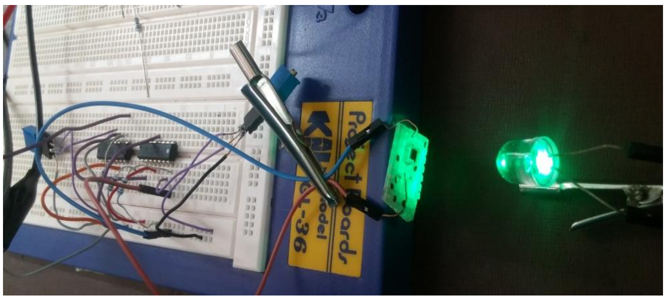
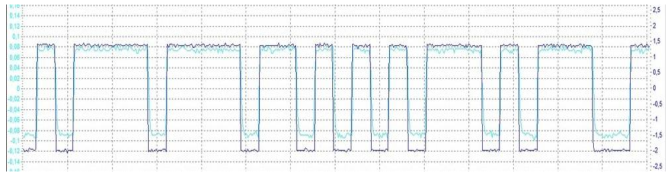
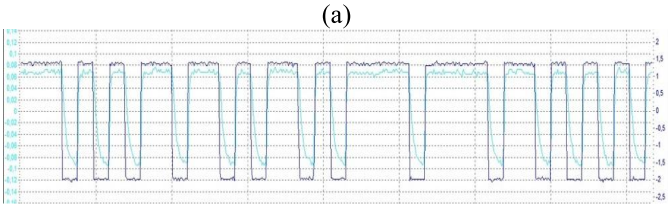


Fig. 10 electrical circuit for testing frequency effect.

The results obtained are illustrated in figures bellow(Fig. 11, 12 and 13), these figures show that every time we powered the LEDs with a high frequencies, signals captured become misshapen this is mainly due to the characteristics of LEDs that we used, which they couldn't afford high speed of on and off. Also we see that the voltage ratio was getting up every time we increase the baud rate. Moreover, there is a slightly difference between the three LEDs in the ratio of the voltage captured and this return to the spectral sensitivity of the photodiode.



(a)



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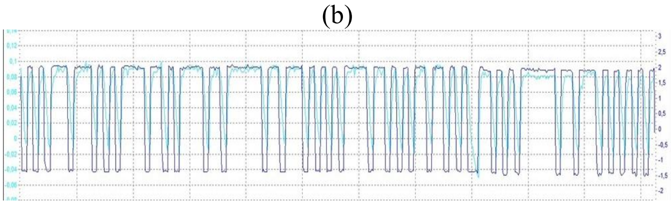
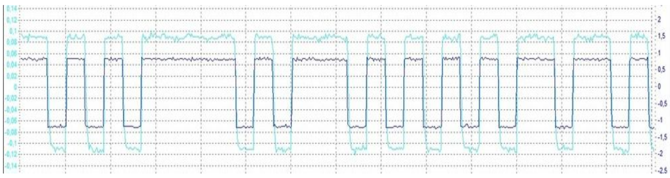


(c)

Fig. 11 Blue LED: a) 1200 baud, b) 4800 baud, c) 19200 baud.



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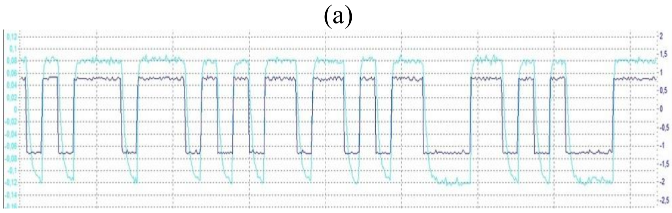

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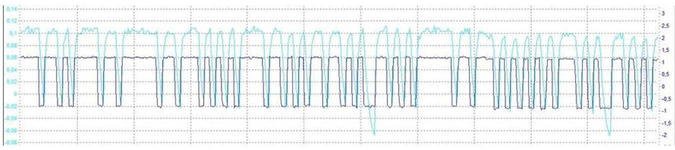
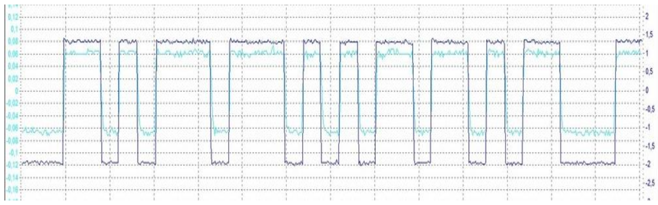


(c)

Fig. 12 Red LED: a) 1200 baud, b) 4800 baud, c) 19200 baud.



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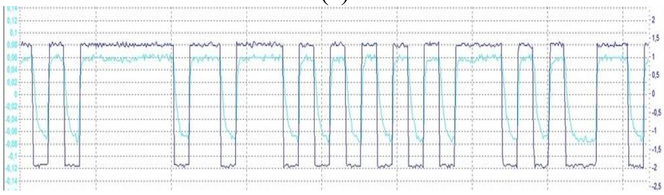

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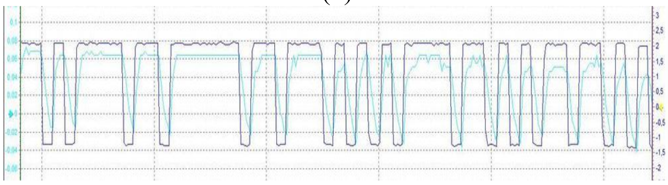

(c)

Fig. 13 Green LED: a) 1200 baud, b) 4800 baud, c) 19200 baud.

After these results we can say clearly that the LEDs that we used can work at 4800 baud rate with an acceptable performance.

The main results are summarized in Table IV.

TABLE IV. SUMMARIZED RESULTS.

Scenarios	*Descriptions*	*Results*	*Comments*
First experience	Simulation of the system by sending and receiving ASCI data through virtual serial port	The data sent and received are compatible without any noise	This experience shows that the system should works perfectly without any materials problem
Second experience	Emulation of the system by sending ASCI data through serial port & receiving it on a real oscilloscope	The result has an acceptable noise in the captured signal since it obtained in normal daily room.	We tested the output data by an oscilloscope and we found that the transmitted signal is pretty much similar to the original.
Third experience	Testing the distance effect on the system performance by using an optical assembly	Transmission of data across 1 meter with a normal 10mm LED	The distance has an important effect in the system performance, we noticed every time we increased the distance the loss of signals rise. Also LEDs brightness is very important to achieve the highest transmission distance
Fourth experience	Testing the frequency effect on the system performance by using different & by applying different frequencies	Achieve a transmission of data under frequency of 4800 baud rate	The LED that we used can't work at high frequency due to its characteristics

IV. CONCLUSION

In this paper, data transmission at indoor environment using visible light was presented. Till now, LEDs were mostly used for lighting purposes. This project gives a new dimension to them as data transmitter. The main result that we obtained and observed is that the distance between the receiver and transmitter can easily increased by using some optical lenses and high brightness LED. Also, when we applied high frequencies signals captured were fully misshapen due to the LED and PD characteristics. Currently, no modulation technique has been employed in the prototype, which increases the chances of data being corrupted and affected by ambient light. With further improvements in the project, data rates and distance of transmission can be increased by using suitable modulation techniques such as CSK or VPPM. Also, by using a high brightness LEDs arrays could easily raise the transmission distance. Furthermore, we still can use this kind of system within the short distances for high and secure data rate.

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