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An Extensive Study on Under-water Communication using LED /LASER Enabled Li-Fi Modules

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ABSTRACT: LED is the future. An LED can form an optical communication system apart from just illuminating. An underwater LED enabled communication system is proposed in this paper. A communication system using LED was studied and deployed and various types of light sources and detectors were used in doing so. Multiple LED arrays are excluded due to multipath issues instead a study on LASER based communication is also made. A comparison between LED communication and LASER communication was made under different conditions. Based on the studies and experiments an ideal Li-Fi based communication system is proposed for underwater communications.

KEYWORDS: LASER, LED, LiFi, Visible light communication, Underwater communication

INTRODUCTION

Visible light communication has been a hot topic for some time now. Nowadays, the applications of LED are immense as they are seen for in houselight applications, traffic lights, hospitals, hotels, labs etc. where illumination devices based on visible LED lamps are used [1]. This paper deals with the application of LiFi for underwater communications. Under water communication is a real challenge and already a lot of technologies have been tried to make the communication easy. Most of them are complex architectures as they have to deal with water, mostly saline sea water. LiFi, on the other hand makes things easy by keeping things simple. LiFi generally can be realized using LEDs. There are various types of LEDs. But white LED formed by mixing of primary colours like red, green and blue seem to be dominating the future light applications because of its various characteristics like lower power consumption, lower voltage, longer lifetime, smaller size, and cooler operation. This work is based on the fact that the devices using LED or LASER as their optical choice for source can be also used as communications emitters. [2]

Light fidelity can utilize a wavelength in the range of 400 nm to 700 nm which is 10000 times broader than the existing radio spectrum. If the LED is ON it means digital data 1 is transmitted and if LED is OFF means digital data 0 is transmitted. As this system, does not require base stations, licensed spectrum, sophisticated transmitter, complex antenna structures etc., the system is simple, safe and hazard free [2].

The proposed work of an underwater wireless communication system that employs white LEDs for optical means of communication is a new challenge because the testing was done at the sea and the water was saline and contaminated. This system uses visible light as the communication medium, LED or LASER as their light source or transmitters and photodiodes like PIN or APD as their receivers. The data that has to be transmitted were sent as light in visible region and it appears to be a constant light for any one viewing it even though the data are been exchanged between the transmitter and receiver. This is based on the fast switching of LEDs and this is generally known as LED flickering [3].

This paper is organized as follows. In section I basic LiFi technology is explained. The related work in the area of underwater communication is briefed in section II, the overall structure of the proposed system is

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discussed in section III. In section IV, general description is organized. The feature experimental set up is detailed and is shown in section V, the influence of interference is discussed along with other possible issues is shown in section VI. In section VII, the findings are discussed. Finally, our conclusions are given in section VIII.

II. RELATED WORK

There are some methods adopted by different technologies to enable wireless data transfer possible through LiFi for underwater applications. Some involving the communication between source and receiver using LASER technologies with the help of modulation schemes. Some using microcontrollers and some without any micro devices[5]. There were experiments using water tank and light sources and receivers and this is done for experimental purpose only. In one of such cases where micro controller is involved, the user will send the data from PC or Laptop, and then it will be passed to the microcontroller. The micro controller will drive the light source. The light source which can be an LED panel or LASER are fitted inside the water tank. The source is fully protected from water by proper waterproof coating. Switching is possible with the sources depending upon our requirement. The tank that we have used is of average length such as 1 foot. The tank can be filled by clear water or saline water. At the other side the photodiode is also fitted inside the water tank similar to the source. As LOS is mandatory the photodiode is properly aligned with the light source. Photodiode senses the data and it is passed to the microcontroller, and further is obtained on PC or Laptop which is at the other end [6][7].

III. THE PHYSICAL STRUCTURE OF THE LI-FI SYSTEM

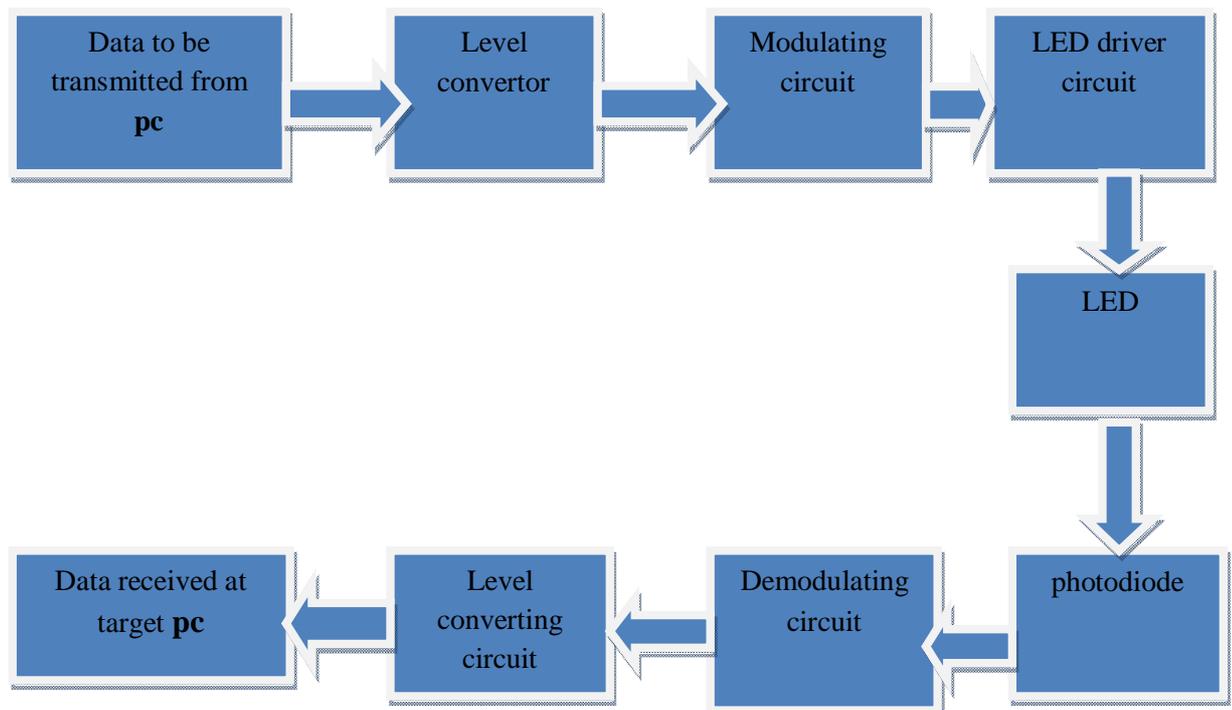


Fig1. Basic block schematic of LiFi enabled system

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The block diagram consists of the data that has to be transferred to the LED should reach the LED after proper levels of conversion and modulation. There can be an array of LEDs if we wish to communicate at different levels, different wavelengths and different speeds. If an LED with high density has been deployed, there are chances that the receiver may not be able to receive properly due to multipath problems. Attenuation in underwater may be due to absorption by materials contaminating the water, scattering by suspended particles etc. All these issues cause the received data to be inadequate or inaccurate. At the receiver end, the data will be received in the form of light and will be converted to electrical form by the photo diodes. This data is converted to the levels understood by the target pc after proper demodulation of received data stream.

IV. GENERAL DESCRIPTION

Under water is the communication medium. A small 20 micro meter white LED is the source of light and the silicon based photo diode is used for the realization of the system. LASER can also be used as an alternative for LED. The transmitter will be sending signal pulses around 10 ns duration. This light is allowed to fall in the photo diode and by using the interference filter, any possible stray of radiation can be omitted. These are then fed to the demodulator and then to the PC for signal restoration.

V. EXPERIMENTAL SET UP

The information from a personal computer (PC) in any kind of format is first coded into a string of pulse electrical signals by microcontroller (MCU) using the interface circuit. These signals drive LED using a LED driver circuit. As a result, there will be signal conversion from electronic to optical level. Due to flickering property of LEDs, the information and light will only be appearing as normal light from an LED for an observer. This information is then sent over the channel depending on the various channels we have to experiment on. Our channels include, air, fresh and saline water. At the receiver, the photodiode will detect the optical signal and then convert into electrical signal. The signals thus detected can be amplified using an amplifier setup. The data thus received after amplification or signal processing will be sent to the PC receiver using the RS -232 interface. The experiment is repeated in 3 different scenarios.

VI. THE EFFECT OF INTERFERENCE

The effect of interference is high as the communication is involving light. The communication is limited by factors like distance, number of proper receivers, effect of saline water in underwater communications etc. Different digital modulation schemes are deployed to reduce the signal error rate and enhance the received signal power. The underwater communication was a real challenge due to the effect of saline water. The distance measured between transmitter and receiver was different in clear water and saline water. Its due to the saline nature of water. The results are plotted in table no 1.

VII. SIMULATION AND RESULTS

There should be line of sight between the transmitter and receiver. Else the communication will be suspended[8]. The speed of transmission and the size of LED are related inversely. A simple microchip LED can generate speeds upto 150 Mbps. A LED smaller than that can generate speeds in Giga Hertz range. The field of view should be less to have a better performance. Field of view is the angle of spread from the light source. Variation of intensity is a challenging factor which is depending on the distance between transmitter and receiver. When we increased the current to the LED, the intensity was good and it yielded better results. But it will damage the LED[9]. When LEDs (white LED) are used for communication, the range was very less; in the order of centimetres. When replaced by LASER (650 nm red dot) the range substantially increased to several meters.

The effect of natural light was found minimal as the receiver is capable of distinguishing the flickering of LED from natural light. Still, experiments in dark environment gave fast and clear results. The

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temperature ranges while experiment was conducted was in the range of 25 to 30 degrees. When more LEDs were attached to the transmitter thus forming an array of LEDs, it is found that there is significant amount of Inter Symbol Interference in the received signal due to spread of the signal. The use of directive LEDs reduced the interference to a good level [10][11].

The number of LEDs were then increased to three to see how the distance affects faithful reproduction [12]. The distance, as expected is a factor as the information was not received after a particular distance. The details are listed in the table. The PIN photodiode was used and MSM metal semiconductor Metal photodetectors were also used while testing. Omitted Avalanche photodiode due to cost.

Distance between transmitter and receiver (cm)	Clear water (data status)	Saline water (data status)
5	Yes	Yes
10	Yes	Y
15	Yes	No
20	No	No

Table 1 Effect of saline water in visible light communication.

Distance between photo diode and LEDs	Faithful reproduction
1	Yes
5	Yes
10	Yes
20	Yes
30	Yes
40	Yes
50	No

Table 2. Distance between transmitter and receiver outside water

From the table it's clear that as the distance between source and receiver is increased above a limit, there can't be proper communication possible as its light fidelity based communication. We also measured signal intensity using an LED array and function generator setup and holding the receiver at a distance to measure the maximum distance of signal reception. The results are shown in the graph

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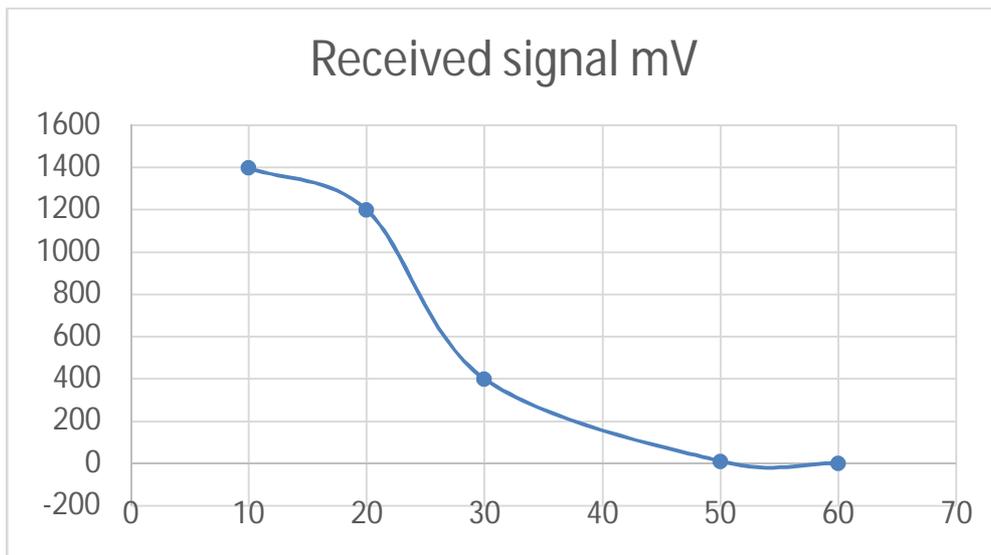


Fig 2 Received signal strength with distance in cm

The received signal is in milli Volts and its plotted against distance in centimetres. There was minimal background noise as the transmitter and receiver were arranged properly.

The experiment is repeated underwater and the transmission distance was poor in the range of few centimetres. So repeated the same experiment with LASER to get a better result. The blue green LASER with a wavelength of 470-570 nm was used for the purpose. The result thus obtained is shown in graph. The measurement is made around 10 times and the number of successful data transmission were plotted for a distance of 1 meter between transmitter and receiver.

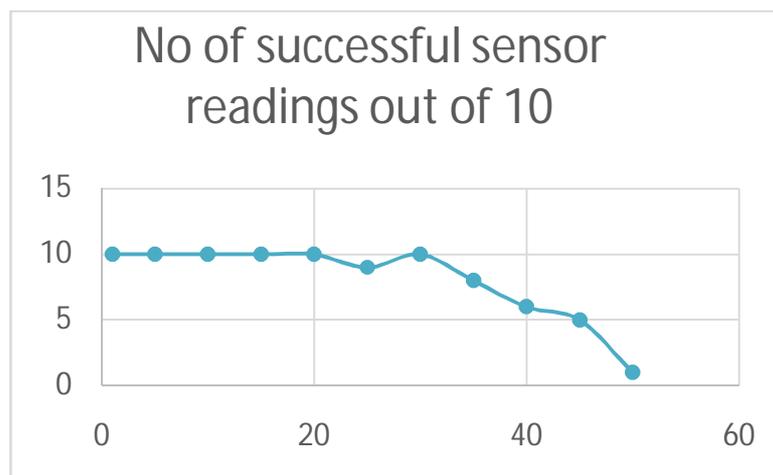


Fig 3. Faithful reproduction under water using LASER

The above figure shows the number of successful readings possible while trying with LASER as light source. When the distance is increased, the number of successful readings are reduced in number and understandably so as we are dealing with light fidelity.

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VIII. CONCLUSION

In this paper, we discussed the fundamental analysis about the underwater communication using LiFi. LED enabled LiFi system can be used in under water communication. By using LASER as the light source, the distance between transmitter and receiver can be increased. The proposed system using LiFi is safe and getting expected results. By using different wavelength LEDs, it is found that, directive LEDs give better and fast results as they are subjected to less beam spread. It is important to have the transmitter and receiver to be in line of sight failing which the system fails to deliver any result. While connecting more LEDs like an array there are chances of inter symbol interference and performance degradation. Although LEDs are a cheaper option in underwater communications, LASERS proved to be more effective considering the distance that can be covered.

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