UNDER WATER LI-FI COMMUNICATION FOR MILITARY PEOPLE

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ABSTRACT

In recent years, underwater acoustic communication has played a crucial role in wireless communication. It is widely used for obstacle detection and the protection of endangered marine species. Traditional systems relied on electromagnetic waves, which proved to be less efficient in underwater environments.
The proposed system overcomes these limitations by utilizing Light Fidelity (Li-Fi) technology for underwater communication. This system is designed to establish data transmission between a transmitter submarine and a receiver submarine using light waves with minimal noise interference. The communication system supports the transmission of voice signals, text, and images with improved efficiency.
Initially, the voice signal is digitized, and these digital values are then transmitted as light waves to the receiving submarine. The primary objective of this project is to achieve accurate image transmission using Visible Light Communication (VLC). The software implementation was carried out using MATLAB, including the development of a Graphical User Interface (GUI) to facilitate the process.

Key Words:
Li-Fi: Transmitter, Receive, Visible Light Communication (VLC), Data Transmission Model,
Under Water Communication

I INTRODUCTION

In today's world, most individuals rely on the internet for completing tasks through wireless communication. Over the past three years, significant advancements have been made in underwater acoustic communication, improving its performance and reliability compared to earlier communication systems.

Electromagnetic waves are inefficient for underwater communication as they experience high attenuation in seawater. High-speed communication through underwater acoustic channels presents several challenges, including limited bandwidth, severe signal fading, and low data transmission speed due to refraction effects [2][6]. Traditional methods such as radio frequency and acoustic technology suffer from multipath propagation and low transmission rates.
However, light-based communication offers high data transmission capabilities in underwater environments. Technologies utilizing focused blue/green lasers show great potential for achieving high-bandwidth underwater communication [4]. One key application is the transmission of audio signals between submarines. Underwater acoustic communication involves transmitting and receiving data below the water surface. While various methods exist, the most common approach involves using hydrophones.

Despite its potential, underwater communication faces challenges such as multipath signal propagation, channel variations, limited bandwidth availability, and significant signal attenuation, particularly over long distances [14]. The performance of underwater communication systems is typically analyzed through theoretical models [7].

Unlike terrestrial communication, underwater systems operate at lower data rates because they rely on acoustic waves rather than electromagnetic waves. In the early 20th century, ships used underwater bells for signaling, which was competitive with the rudimentary maritime radio navigation systems of that time. Later, the Fessenden oscillator improved communication between submarines.

II LITERATURE SURVEY

Underwater communication often relies on acoustic waves because of their ability to transmit over long distances. While effective for deep-sea scenarios, this method is hindered by low data transmission rates, signal degradation, and notable delays. Furthermore, the quality of communication can be compromised by multipath propagation and interference from background marine noise. RF signals are generally ineffective in underwater settings, especially in saltwater, due to significant absorption and signal loss. Although short-range communication is feasible, it necessitates large antennas and consumes a considerable amount of power. Consequently, this approach is seldom applied in underwater contexts due to its lack of efficiency.

Optical waves can provide high data transmission rates and minimal latency; however, they are susceptible to absorption and scattering in aquatic environments. Research indicates that blue and green light (with wavelengths ranging from 450 to 550 nm) is most effective for underwater communication. This form of communication is ideal for short-distance, highspeed data transfers. High Data Transmission Rates: Li-Fi technology is capable of achieving data transfer speeds that can reach gigabits per second. Reduced Latency: It provides significantly lower delays in comparison to conventional acoustic communication methods. Energy Efficiency: The light-emitting diodes (LEDs) employed in Li-Fi systems demonstrate greater energy efficiency than those used in radio frequency (RF) based systems. Minimal Disruption: Li-Fi does not interfere with marine ecosystems or disrupt existing RF communication networks.

III EXISTING SYSTEM

1. **University and Research Institution Prototypes**
   Several universities and research institutions have developed experimental Li-Fi-based underwater communication model.
   Studies have demonstrated successful data transmission using blue and green light, achieving speeds up to gigabits per second over short distances.
   Research focuses on optimizing modulation techniques and enhancing photodetector sensitivity to improve performance.

2. **Hybrid Li-Fi and Acoustic Communication Models**
   Some systems integrate Li-Fi with acoustic communication to extend range while maintaining high-speed data transfer.
   Acoustic waves are used for long-distance transmission, while Li-Fi enables high-speed data exchange over short distances.
   This hybrid approach improves reliability but requires efficient switching between communication modes.

3. **Autonomous Underwater Vehicles (AUVs) and Remotely Operated Vehicles (ROVs)**

Experimental Li-Fi communication systems have been tested on AUVs and ROVs for real time data exchange.
These systems allow underwater robots to transmit high-resolution images and sensor data to surface stations.
Challenges include maintaining stable optical alignment and minimizing signal distortion caused by water movement.

4. **Underwater Sensor Networks**
Researchers are developing Li-Fi-enabled underwater sensor networks for applications such as marine research and environmental monitoring.
These systems facilitate high-speed data transfer between underwater sensors and surface buoys.
Limitations include range constraints and sensitivity to water turbidity.

IV DISADVANTAGES

One of the primary disadvantages of acoustic communication systems is their low data transmission rate. While acoustic waves can travel long distances underwater, they are limited to kilobits per second, making them unsuitable for high-speed applications such as live video streaming or large data transfers. Additionally, acoustic signals experience high latency due to the slow speed of sound in water, leading to delays in real-time communication. These systems are also affected by multipath fading, signal absorption, and interference from marine noise, further degrading their performance in noisy underwater environments.

Radio frequency (RF)-based communication: also has significant drawbacks. RF signals experience severe attenuation in water, particularly in saltwater, which drastically limits their transmission range. To compensate for this, RF systems require large antennas and high-power consumption, making them impractical for deep-sea applications. The efficiency of RF communication is limited to very short distances, often in the range of a few meters, restricting its use in large-scale underwater networks.

Optical wireless communication systems, including: Li-Fi technology, offer high-speed data transmission but suffer from limited range. Optical signals, particularly in the visible light spectrum, are absorbed and scattered by water molecules and suspended particles. This results in a rapid reduction in signal strength, limiting the effective communication distance to a few tens of meters. Unlike acoustic or RF systems, optical communication requires a clear line of sight between the transmitter and receiver, making it highly susceptible to misalignment caused by water currents, turbulence, or movement of underwater devices.

Another major drawback of Li-Fi-based underwater communication is its sensitivity to environmental factors. Water turbidity, temperature variations, and biological organisms can obstruct or weaken light signals, leading to signal degradation and loss of data integrity. Additionally, beam divergence in water causes the light signal to spread out, reducing its intensity and making precise alignment critical for effective data transmission. These challenges make Li-Fi less reliable in dynamic underwater environments where conditions are constantly changing.

V PROPOSED SYSTEM

Light Source (Transmitter):
High-power LEDs or laser diodes are used to transmit data in the form of modulated light pulses. Blue and green wavelengths (450–550 nm) are chosen for optimal penetration in water.

Photodetector (Receiver):
A high-sensitivity photodiode or an avalanche photodetector (APD) is used to detect light Convert the signals into electrical form for processing.

Modulation and Encoding Unit:
Sophisticated modulation methods like Orthogonal Frequency Division Multiplexing (OFDM) and Pulse Position Modulation (PPM) are used to optimize data transmission and minimize signal distortion.

Synchronization and Alignment System:
An AI-based adaptive beamforming mechanism is integrated to automatically adjust the alignment between the transmitter and receiver, ensuring stable communication despite water movement.

Error Correction and Noise Reduction:
Machine learning algorithms are used to predict and correct signal distortions caused by water turbulence, improving data integrity.

Hybrid Communication Support:
To extend communication range, the system incorporates an acoustic fallback mechanism, which activates when the Li-Fi signal is weak or obstructed.

VII ADVANTAGES

Li-Fi technology enables data transfer at extremely high speeds, reaching the Gbps range. This is significantly faster than traditional underwater communication methods such as acoustic and radio frequency (RF) systems, which suffer from low data rates due to signal attenuation and interference in water.

The use of visible light waves for data transmission allows for real-time communication with minimal delay. This low-latency feature makes Li-Fi highly suitable for applications such as underwater robotics, surveillance, and sensor networks, where instant data exchange is critical.

Unlike acoustic waves, which have limited bandwidth, Li-Fi provides a broader spectrum for data transmission. This increased bandwidth supports high-definition video streaming, fast data exchange, and efficient underwater networking, making it ideal for applications such as deep-sea exploration and marine research.

Li-Fi technology is inherently more energy-efficient compared to acoustic and RF communication systems. Since light-based communication requires less power, it is wellsuited for long-duration underwater missions, such as ocean monitoring, submarine communication, and deep-sea data collection.

One of the key advantages of Li-Fi is its high security due to the restricted propagation of light signals in water. Unlike RF signals, which can travel over long distances and are susceptible to interception, Li-Fi signals remain confined within a specific underwater zone, making it difficult for unauthorized entities to access the data.

Traditional underwater communication methods, such as acoustic waves, can disrupt marine life by producing noise pollution. In contrast, Li-Fi uses non-intrusive light waves that do not interfere with aquatic ecosystems, making it an eco-friendly communication solution for underwater applications.

VI BLOCK DIAGRAM

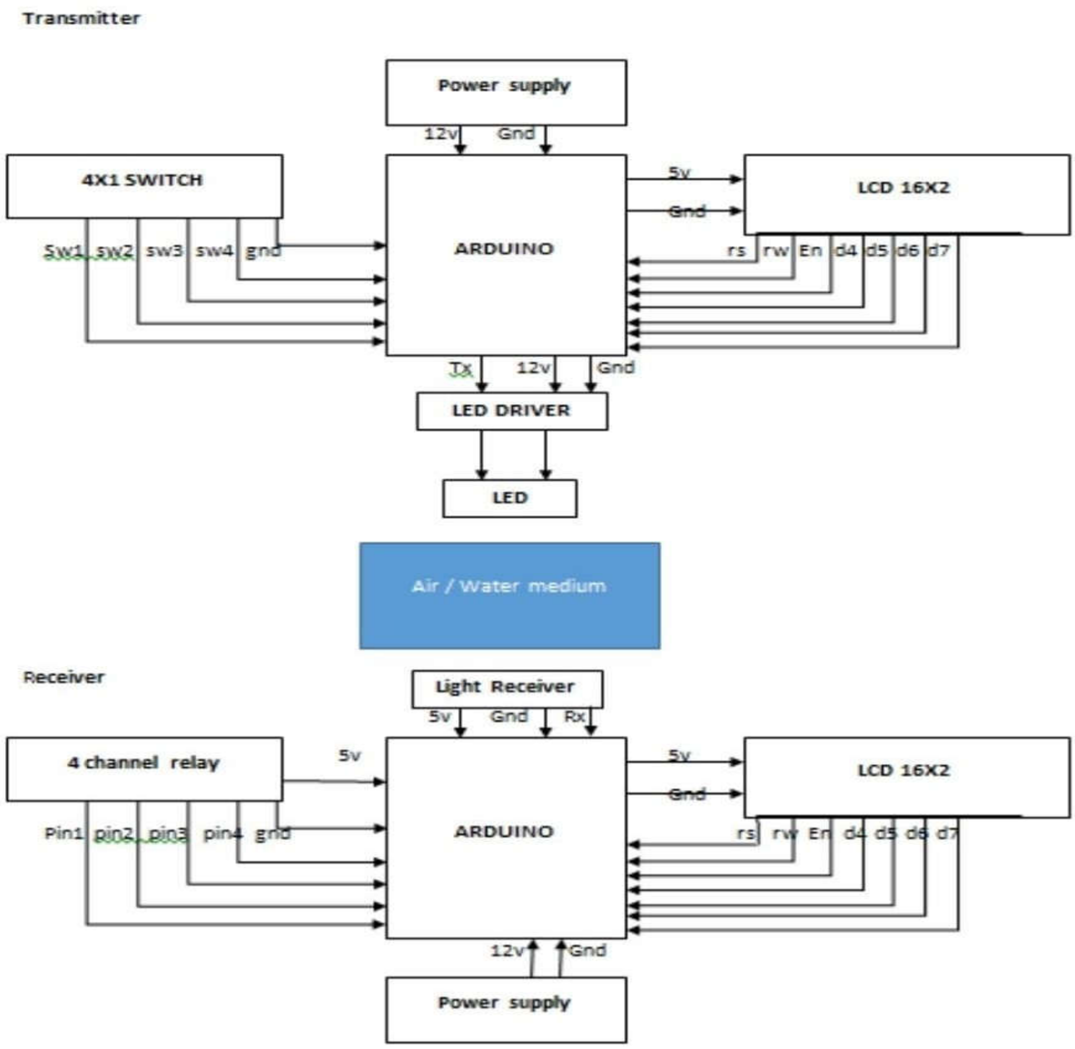

Fig.1 Block diagram Li-Fi data transmition model

1. **Transmitter Section:**

Power Supply: Supplies the necessary 12V power and ground connections to the Arduino.

4X1 Switch: Comprises four switches (sw1, sw2, sw3, sw4) that interface with the Arduino, facilitating input selection.

Arduino: Serves as the central processing unit, interfacing with various components: LCD 16X2: Functions to display information.

LED Driver: Regulates the brightness of the LED in response to the data being transmitted.

LED Driver and LED: The driver modulates the LED to convey data through light signals.

Air/Water Medium: Represents the medium through which the data is transmitted. Microcontroller.

2. Microcontroller:

The microcontroller implemented in this system is the ATmega328P, a robust and adaptable element within the Li-Fi communication framework. Below are its significant attributes: UART Communication: The ATmega328P facilitates serial communication through its transmitter (Tx) and receiver (Rx) pins, which allows for efficient data transfer between devices.

Operating Voltage: This microcontroller functions at a voltage level of 5V, ensuring compatibility with a range of peripherals, including sensors and communication modules.

Software Libraries: The ATmega328P utilizes Arduino software libraries, which simplify the integration of functionalities such as TWI (Two Wire Interface) and SPI (Serial Peripheral Interface) communication protocols.

Driverless Communication: This microcontroller does not necessitate external drivers for standard USB COM interactions, promoting ease of connection and setup.

3. Receiver Section:

Light Receiver: This component is responsible for capturing light signals emitted by the transmitter and relaying them to the Arduino for further processing.
4 Channel Relay: This device interfaces with the Arduino, enabling the control of multiple output channels.
Arduino: The Arduino is linked to the light receiver, along with additional components such as a 4-channel relay and a 16X2 LCD display for presenting information.

Power Supply: Supplies the necessary 12V power to the Arduino.

This configuration is intended to leverage Visible Light Communication (VLC) for transmitting data. The underlying technology operates by modulating an LED to encode information into light signals, which are subsequently detected and decoded by the light sensitive elements of the receiver. This method is notably efficient and capable of achieving rapid, error-free transmission of text, audio, and images.

4. Graphs:

The diagrams were designed to provide a clearer representation of the variations in the characteristics.

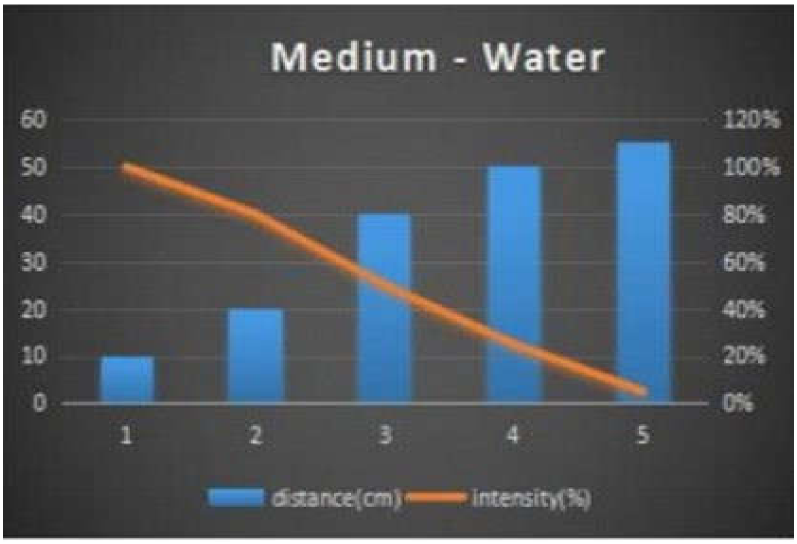

Fig: 2 Illustrates VLC in a Water Medium,

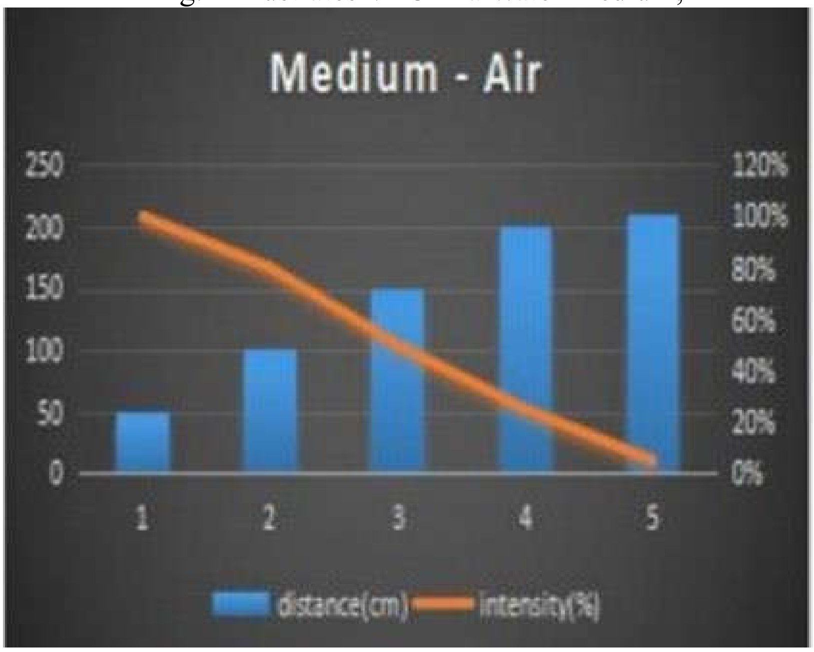

Fig: 3 Depicts VLC in an Air Medium.

VIII RESULT

The Li-Fi system introduced in this study is designed to transfer data, such as text, images, and audio, between two devices at speeds of a few kilobits per second. The operational model and results of the Li-Fi communication for transmitting audio, text, and images are demonstrated in this paper.

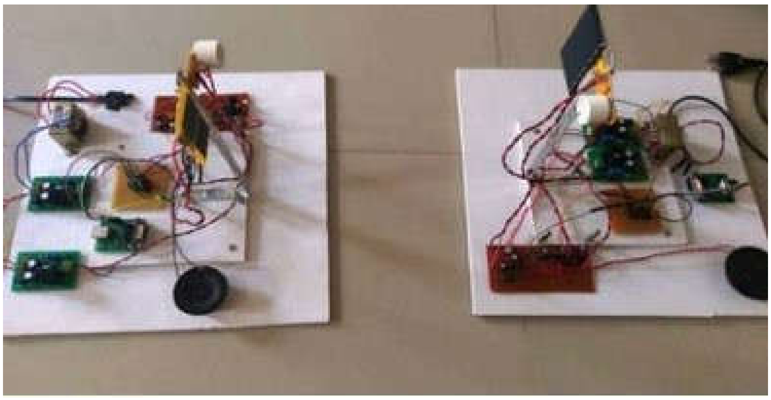

Fig: 10 Operational Framework of Li-Fi Communication

The fundamental requirement for effective communication is a clear line of sight between the transmitter and the receiver, which allows for data transmission through water. Achieving error-free communication has been realized in text transmission. Data can be sent serially via an LED using UART, where text is converted into ASCII before transmission. The baud rate can be set within a range of 19200, facilitating faster data transfer. With standard LEDs, communication over short distances has been observed. However, employing higher quality LEDs and photodiodes can enable two-way communication over significantly longer distances. Li-Fi technology allows for the wireless transmission of speech signals without interference. The audio quality is both clear and loud, and using a focusing lens further enhances the output received.

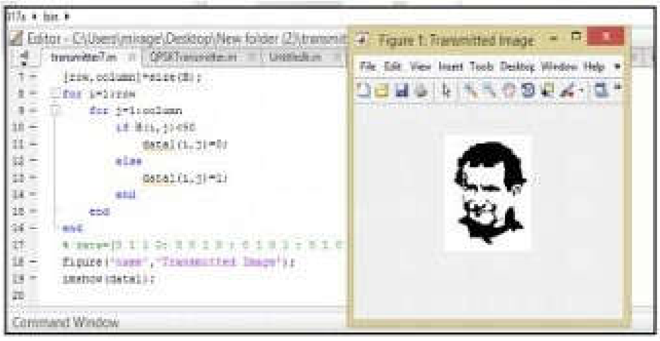

Fig.11 Transmitted image

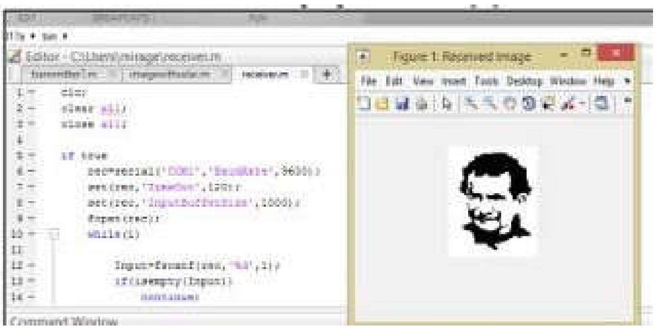

Fig.12 Received Image

In the event of image transmission, a 100-pixel (10x10) .jpg image is sent, as shown in figure 11. This image is successfully received at the destination, as illustrated in figure 12. Similarly, the system can transmit small-sized images, which are effectively received at the end point.

Table 3. Proposed method Accuracy

Data	**Li-Fi Technology (Proposed method) Accuracy (%)**
Text	100%
Audio	96%
Image	94%

IX CONCLUSION

In this study, we explore remote communication facilitated by VLC technology, which enables the transmission of data, audio, images, and text. The results demonstrate high efficiency in sending these various forms of information. The paper focuses on the communication link established between two submarines using LI-FI technology. This innovative approach allows for rapid data transfer, offering numerous advantages. By harnessing this technology, we can move towards a more sustainable, secure, and cleaner future. Looking ahead, the capability can be enhanced to meet the demand for transmitting high-definition images and audio by utilizing advanced LED and LDR technologies.

X REFERENCE

1. P. A. Haigh, F. Bausi, T. Kanesan, S. T. Le, S. Rajbhandari, Z. Ghassemlooy, I. Papakonstantinou, et al. "A 20-Mb/s VLC link utilizing a polymer LED and a multilayer perceptron equalizer," 2014.
2. R. Karthika and S. Bala Krishnan, "Exploring Wireless Communication through Li-Fi Technology," 2015.
3. Jay H. Bhut, Dharmrajinh N. Parmer, Khuhbu Mehta, "Li-Fi Technology: An Overview of Visible Light Communication," International Journal of Engineering Development and Research, 2014.
4. P. A. Haigh, F. Bausi, Z. Ghassemlooy, I. Papakonstantinou, H. Le Minh, C. Flechon, and F. Cacialli. "Advancements in visible light communications: Achieving 10 Mb/s with polymer light-emitting diodes," presented at the Optical Fiber Communications Conference and Exhibition (OFC), 2014.
5. C. Gabriel, M.A. Khalighi, S. Bourennane, P. Leon, and V. Rigaud, "Monte Carlo-based channel characterization for optical communication systems in underwater environments," IEEE/OSA Journal of Optical Communications and Networking, vol. 5, no. 1, pp. 1–12, 2013.
6. Ruonan Ji, Shaowei Wang, Qingquan Liu, and Wie Liu, "High-Speed Visible Light Communications: Key Technologies and Current Developments," MDPI Applied Sciences, Vol. 8, no. 4, 589, 2018.
7. Mazin Ali A. Ali, "Characteristics of Transmitter Inclination Angles for Underwater Optical Wireless Communication Using Various APD Detectors," World Scientific News, 2016.
8. C. Gabriel, M.A. Khalighi, S. Bourennane, P. Léon, and V. Rigaud, "Evaluation of Effective Modulation Techniques for Underwater Wireless Optical Communications," Proceedings of the International Workshop on Optical Wireless Communications (IWOW), pp. 1–3, 2012.

9. Z. Ghassemlooy, A. Hayes, N. Seed, and E. Kaluarachchi, "Digital Pulse Interval Modulation Techniques for Optical Communication," IEEE Communications Magazine, vol. 36, no. 12, pp. 95–99, 1998.
10. Zubin Thomas, Nikil Kumar, and D. Jyothi Preshiya, "Li-Fi Module for Automatic Billing Systems," presented at the International Conference on Communication and Signal Processing, 2016.
11. Vyom Shah, Disha Purohit, Prajakta Samant, Ruhina Karani, "Transmission of 2D Images Using Light Fidelity Technology," International Journal of Innovations & Advancement in Computer Science, Vol. 4, Issue 4, 2015.
12. Lih Chieh Png and Kiat Seng Yeo, "Principles of Visible Light Communication Circuits," 2016.
13. Anwesha Chakraborty, Trina Dutta, "Recent Developments in Light Fidelity (Li-Fi) Technology," International Journal of Advance Research in Computer Science and Management Studies, 2017.
14. Balaji K, Sakthivel M, "Implementing IoT in Underwater Communication with Li-Fi," International Journal of Recent Technology and Engineering, 2019.