Data Transmission through Light using Solar

Harshvardhan V. Patil, Srushti A. Mohite, Prof A.A.Mahind,Vishwaraj Kulkarni,Soham Sankpal

Undergraduate students, Professor Department of Electronics and Telecommunication, Rajarambapu Institute of Technology, Islampur, Maharashtra - India

[1]mahindashwini268@gmail.com, [2]harshpatil2634@gmail.com , [3]srushtimohite00@gmail.com

Abstract:

This paper describes a low-cost setup for a Visible Light Communication (VLC) system that uses Li-Fi technology for short-range data transmission. The transmitter includes an Arduino Uno and a high-intensity LED that encodes and sends digital data through on–Off Keying (OOK) modulation. On the receiving end, a solar panel serves as a photodetector. It converts the incoming modulated light into electrical signals. An Arduino Nano then decodes these signals and displays the information on an LCD module. Experimental results indicate that the system reliably transmits data in indoor settings with little interference from surrounding light. This setup shows that visible light can be a safe and energy-efficient option for communication, especially in places where avoiding electromagnetic interference is important.

1. INTRODUCTION:

In modern digital systems, wireless communication has become an essential component that helps in connecting consumer electronics, industrial automation, healthcare, and smart infrastructure. Most of the existing wireless technologies, such as Wi-Fi, Bluetooth, and cellular networks, have been using radio frequency communication. Such RF-based systems are facing several challenges related to limited bandwidth, electromagnetic interference, security vulnerabilities, and restrictions in sensitive environments such as hospitals, aircraft, and industrial plants.

VLC has emerged as a promising alternative to overcome these limitations by using the visible light spectrum for data transmission. VLC uses high-intensity Light Emitting Diodes (LEDs) to modulate information at high speeds imperceptible by the human eye. Dubbed popularly as Light Fidelity, or Li-Fi, this idea promises high data density, low interference, advanced security, and more spectrum availability.

It presents a low-cost VLC system that performs data transmission via visible light by using an Arduino-based prototype. The transmitter uses an LED for encoding binary data, utilizing On–Off Keying modulation, whereas the receiver employs a solar panel as a photodetector to convert optical signals back into electrical form. An Arduino Nano processes the received data and displays it on an LCD module. The proposed system justifies Li-Fi as a feasible and energy-efficient communication option at short-range applications.

a) Availability: The proposed Li-Fi system offers high availability due to its simple hardware, low power consumption, and minimal maintenance requirements. It functions effectively in indoor environments where line-of-sight is maintained and is suitable for areas where RF communication is restricted. However, its availability may decrease under strong ambient light or misalignment between the LED and solar panel.

b) Security: Li-Fi offers inherent physical security since visible light cannot penetrate walls or opaque objects, confining communication to the illuminated area. Only receivers within the line-of-sight of the LED can detect the optical signal, significantly reducing risks of eavesdropping and signal leakage compared to RF systems.

c) Efficiency: The Li-Fi system remains highly available in controlled indoor environments where a clear line-of-sight is maintained. Since it does not rely on RF communication, it can be used in places where radio signals are restricted. However, availability may decrease under strong ambient light or misalignment between the LED and solar panel.

Table 1: Advantages of Li-Fi

High Speed	Light can switch at very high frequencies, enabling fast data transfer
No RF Interference	Suitable for hospitals, aircraft, and industries where radio waves are restricted
High Security	Light cannot pass through walls, reducing chances of hacking or unauthorized access
Energy Efficient	LED consumes very little power and the solar panel works as a passive receiver
Low Cost	Uses simple components such as LED, solar panel, and Arduino
Large Bandwidth	Visible light spectrum is much broader than the RF spectrum
Safe for Humans	Light communication does not produce electromagnetic radiation

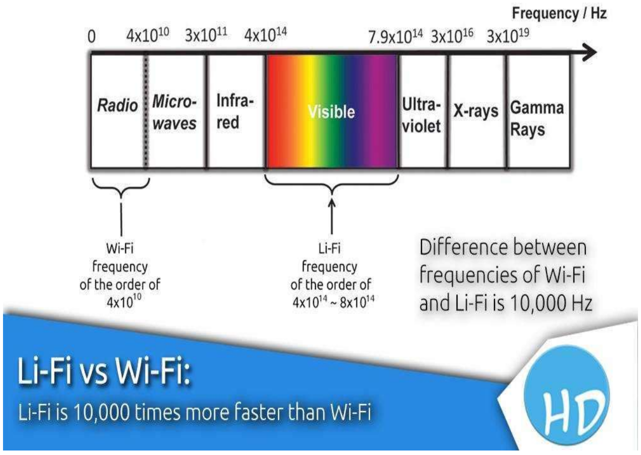

Fig 1: Li-Fi and Wi-Fi Spectrum Usage

Table-2: Comparison between Li-Fi and Wi-Fi

Parameter	**Li-Fi**	**Wi-Fi**
Speed	High	High
Spectrum	broader	Narrow
Data density	High	Low
Security	High Security	Low Security
Reliability	Medium	Medium
Bandwidth	High due to broad spectrum	Low
Transmit/receive power	High	Medium
Ecological impact	Low	Medium
Device-to-device connectivity	High	High
Obstacle interference	High	Low
Bill of materials	High	Medium
Market maturity	Low	High
Latency	microseconds	milliseconds

2. THEORY AND WORKING OF SYSTEM

2.1 Theory: The project "Data Transmission through Light" is based on the concept of Li-Fi (Light Fidelity), which is a type of Visible Light Communication (VLC). Unlike traditional wireless communication systems such as Wi-Fi or Bluetooth that use radio frequency (RF) waves, Li-Fi uses visible light to transmit information. Light emitted from an LED can be switched on and off at extremely high speeds that are imperceptible to the human eye. By controlling these light pulses, binary data (0s and 1s) can be encoded and transmitted wirelessly. The transmission process involves modulating the intensity of the LED based on the digital data. The LED turns ON to represent a binary '1' and OFF to represent a binary '0'. These changes occur at high frequency, allowing for fast data transfer. The receiver detects these light variations using a solar panel or photodiode, which converts the light signals into corresponding electrical signals. The receiver then decodes these electrical signals back into the original data using a microcontroller, such as an Arduino Nano. In this project, the Arduino Uno acts as the transmitter, sending the data through an LED, while the Arduino Nano receives the signals through a solar panel and displays the decoded data on an LCD screen. The entire system is programmed using Arduino IDE. The programming ensures proper modulation, transmission, reception, and decoding of data to maintain accuracy and reliability. Li-Fi is also considered a promising technology for smart lighting systems, where LEDs provide both illumination and data communication simultaneously. It has potential applications in areas such as indoor communication, underwater data transfer, and environments where RF communication is limited. In summary, the theory behind this project demonstrates that visible light can be used as an effective medium for wireless communication, and simple components like Arduino boards, LEDs, and solar panels can be used to build a functional system. This project serves as a practical demonstration of Li-Fi principles and introduces students to the field of optical wireless communication.

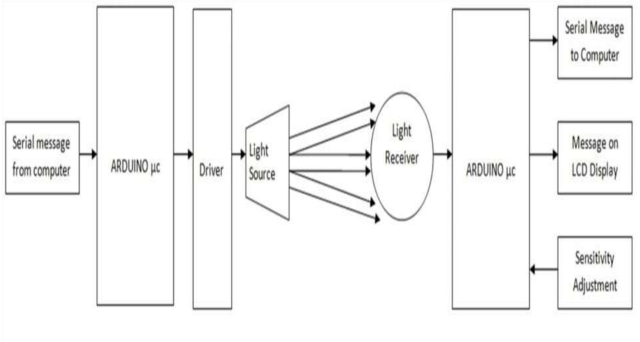

Fig 2 Block Diagram

Fig 2 illustrates the basic components and data flow of a light-based communication system, likely involving a modulated light beam (like visible light or infrared) to transmit data. System Explanation The system can be conceptually divided into three main sections: the Transmitter, the Communication Channel, and the Receiver. Transmitter Section The transmitter section is responsible for converting a digital message into a light signal. Serial Message from Computer: This is the input data to the system, typically a stream of digital information (e.g., text, control signals) sent over a serial interface (like USB or RS-232) to the Arduino.

ARDUINO : The Arduino Microcontroller receives the serial data. It is programmed to encode the message into a format suitable for transmission. This often involves modulating a carrier signal (turning the light on and off rapidly, a process called modulation), perhaps using a standard protocol like Morse code, PWM (Pulse Width Modulation), or other specialized light communication protocols. Driver: The driver circuit acts as an interface between the low-power output of the Arduino and the Light Source. It provides the necessary current and voltage to power and control the Light Source effectively based on the Arduino's modulated signal.

Light Source: This is the component that generates the optical signal, such as an LED (Light Emitting Diode) or a laser. It converts the electrical signal from the driver into a light beam that carries the encoded data. Communication Channel Light Source \to Light

Receiver: The space between the Light Source and the Light Receiver represents the communication medium or channel, where the encoded information is transmitted via the light beam. This is typically a wireless (line-of-sight) optical link. Receiver Section The receiver section captures the light signal and converts it back into a usable digital message.

ISSN: **3107-6513**

Light Receiver: This component, often a photodiode or a phototransistor, detects the incoming light beam and converts the variations in light intensity back into a corresponding electrical signal (current or voltage).

ARDUINO: This second Arduino Microcontroller receives the electrical signal from the Light Receiver. It is programmed to decode or demodulate the signal, reconstructing the original digital message by interpreting the rapid on/off patterns or intensity changes. Outputs and Control: The decoded message is then routed to various outputs: Serial Message to Computer: The recovered digital message is sent to a computer via a serial interface for storage, analysis, or further processing.

Message on LCD Display: The message can be displayed locally on an LCD (Liquid Crystal Display) for immediate viewing by a user. Sensitivity Adjustment: This input allows a user or an external circuit to tune the light receiver's sensitivity manually or automatically (e.g., adjusting a threshold voltage) to ensure reliable signal detection under varying ambient light or distance conditions. This is a form of feedback or configuration for the receiver circuit. The entire system thus enables one-way communication of digital data using light.

2.2 Working of system: Microcontroller (Arduino): The Arduino serves as the central controller that reads and processes the data to be transmitted. This data may originate from a computer, a sensor, or can be pre-programmed within the microcontroller. The Arduino encodes this data into binary form and controls the LED accordingly. LED (Light Emitting Diode): The LED is used to transmit data in the form of light pulses. The Arduino rapidly switches the LED ON and OFF at a very high frequency that is not perceivable to the human eye. This process follows the On-Off Keying (OOK) modulation technique, where:

- LED ON represents binary '1'
- LED OFF represents binary '0'

These rapid changes in light intensity carry the digital information through the air, forming a stream of optical signals that represent the transmitted data. 2. Transmission Medium The visible light emitted by the LED acts as the medium of data transmission. The modulated light waves travel freely through the air and reach the receiver. A clear line of sight between the LED (transmitter) and the solar panel (receiver) is essential for efficient communication. The system performs best in indoor environments where interference from external light sources is minimal. 3. Receiver Section The receiver detects the transmitted optical signals and converts them back into electrical signals, which are then decoded to retrieve the original data.

Solar Panel: The solar panel functions as a light sensor, detecting variations in light intensity. When the LED is ON, the panel generates a high voltage (binary 1), and when the LED is OFF, it produces a low voltage (binary 0). Thus, the solar panel converts the incoming light pulses into corresponding electrical signals.

Signal Processing and Data Reconstruction: The electrical signals from the solar panel are fed into the Arduino or a suitable processing circuit. The microcontroller decodes these signals to reconstruct the original binary data that was transmitted.

Output Display: Finally, the decoded data is displayed on an LCD screen or a serial monitor, confirming that data has been successfully transmitted through light.

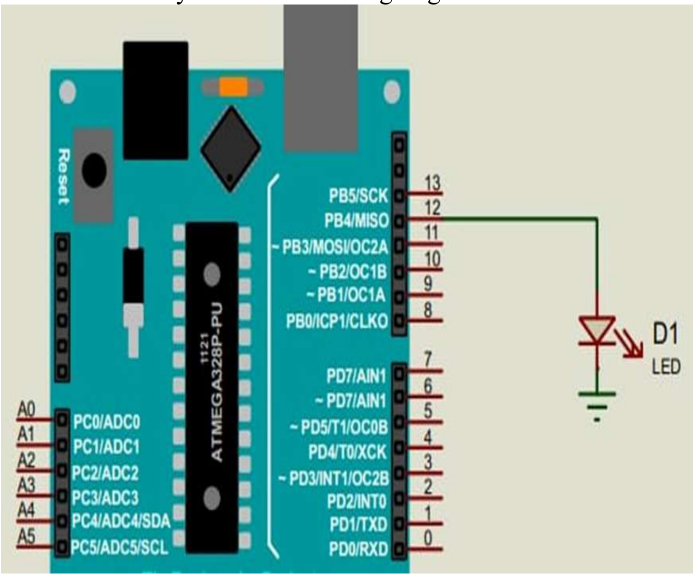

Fig 3: Diagram of Data Transmission through Light For transmitter

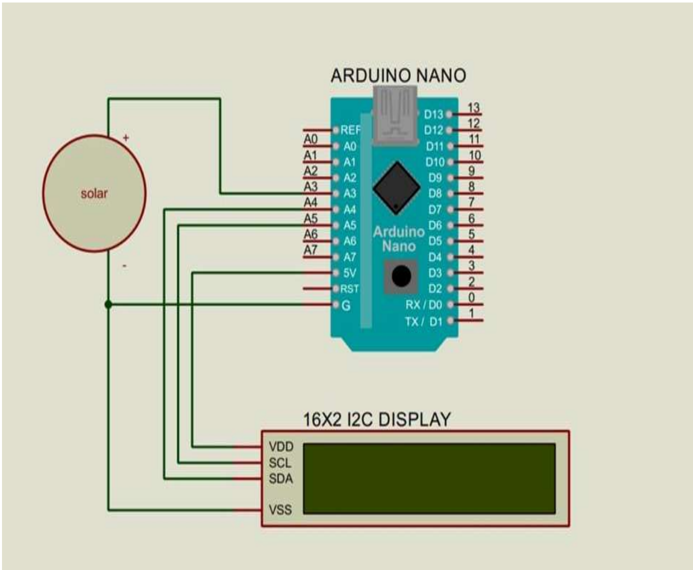

Fig 4: Diagram of Data Receiver through Light For transmitter

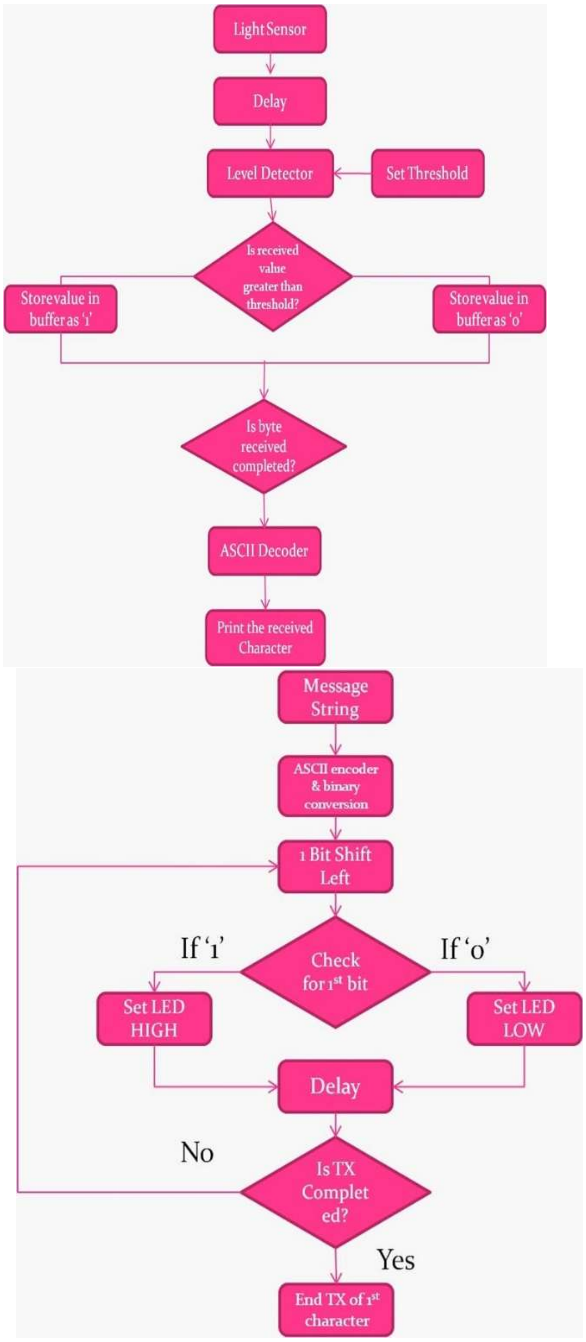

Fig 5: Flowchart for Transmitter and Receiver

Fig 5 represents flowchart of a visible light communication system in which digital information is transmitted using light intensity variations from an LED and received using a light-sensing device. The complete system is divided into a transmitter section and a receiver section.

At the transmitter side, the input message is first taken as a character string. Each character is converted into its corresponding ASCII value and then transformed into a binary sequence. The binary data is transmitted bit by bit using an On–Off Keying (OOK) technique. For each bit, the system checks the most significant bit after a left-shift operation. If the bit value is logic '1', the LED is driven to a HIGH state, causing it to emit light. If the bit value is logic '0', the LED is turned OFF or set to a LOW state. A fixed delay is introduced to maintain uniform bit duration and ensure reliable transmission. This process continues until all bits of a character are transmitted, after which the system proceeds to the next character until the entire message is sent.

At the receiver side, the transmitted light signal is captured using a light sensor such as a solar panel or photodetector. The received signal is passed through a delay stage to stabilize sampling and reduce noise effects. A level detector then compares the received signal strength with a predefined threshold value. If the detected light intensity exceeds the threshold, the bit is interpreted as logic '1'; otherwise, it is considered logic '0'. Each detected bit is stored sequentially in a buffer. Once a complete byte is received, the binary data is processed by an ASCII decoder to reconstruct the original character. The decoded character is then displayed or printed as the final output.

This method demonstrates a simple and effective approach for wireless data communication using visible light, offering advantages such as low electromagnetic interference, enhanced security, and suitability for short-range communication applications.

3.METHODOLOGY

The methodology for the "Data Transmission Through Light" project involves a structured approach encompassing hardware assembly, software programming, calibration, testing, and evaluation. The first step is system assembly and hardware setup, where the Arduino Uno is configured as the transmitter and connected to a high-intensity LED, while the Arduino Nano is set up as the receiver with a solar panel and an LCD display. All components are properly powered and connected with appropriate resistors and wiring to ensure correct operation. Following hardware assembly, sensor calibration and circuit adjustment are carried out. The solar panel is calibrated to accurately detect variations in light intensity, while the LED brightness and pulse frequency are adjusted to achieve optimal data transmission. Next, mechanical arrangement optimization is performed by aligning the LED and solar panel to maintain a clear line-of-sight, reducing interference from ambient light and ensuring maximum signal reception. In parallel, software programming and control logic are developed using the Arduino IDE. The Arduino Uno is programmed to convert data into binary form and modulate the LED using On-Off Keying (OOK), where LED ON represents binary '1' and LED OFF represents binary '0'. The Arduino Nano at the receiver side reads the electrical signals from the solar panel, decodes the binary data, and displays it on an LCD screen or serial monitor. Once programming is completed, testing and result validation are conducted. The system is evaluated for transmission accuracy, distance range, and reliability under different lighting conditions. Any errors or inefficiencies are addressed through circuit tuning or software adjustments. After successful validation, production and expansion planning is considered to explore scaling the system for longer distances or multiple transmitter-receiver setups. Finally, monitoring and evaluation are carried out to ensure consistent performance and to document the effectiveness of the Li-Fi system in transmitting data through visible light.

This methodology ensures a systematic approach to implementing a low-cost, energy-efficient, and secure short-range communication system using visible light, demonstrating the practical application of Li-Fi technology.

3.1.1 System Assembly and Hardware Setup:

In the system assembly and hardware setup(fig 3,fig 4), the Arduino Uno is configured as the transmitter, while the Arduino Nano serves as the receiver. A high-intensity LED is interfaced with the Arduino Uno to transmit data in the form of light pulses, and a solar panel is connected to the Arduino Nano to detect these light signals at the receiver end. Additionally, an LCD display is connected to the Arduino Nano to provide a visual output of the received data. All components are carefully wired, with appropriate resistors and a reliable power supply, to ensure proper operation and stability of the system.

3.1.2 Sensor Calibration and Circuit Adjustment:

In the sensor calibration and circuit adjustment stage, the solar panel is carefully calibrated to accurately detect variations in light intensity from the transmitter LED. This ensures that the receiver can reliably distinguish between the high and low signals corresponding to binary data. Simultaneously, the LED's brightness and switching frequency are adjusted to optimize signal transmission, allowing the light pulses to be transmitted at a speed that is both imperceptible to the human eye and suitable for accurate data reception. These adjustments are crucial for achieving consistent and error-free communication between the transmitter and receiver.

3.1.3 Mechanical Arrangement Optimization:

In the mechanical arrangement optimization stage, the LED at the transmitter and the solar panel at the receiver are carefully aligned to maintain a clear line-of-sight, which is essential for effective data transmission. Any potential obstacles between the transmitter and receiver are minimized, and interference from external light sources is reduced to ensure that the transmitted light signals are accurately detected by the solar panel. Proper alignment and positioning are critical to achieving reliable and consistent communication in the Li-Fi system.

3.1.4 Software Programming and Control Logic:

In the software programming and control logic stage, the Arduino Uno is programmed to encode the data into binary form, preparing it for transmission through the LED. The LED is then modulated using the On-Off Keying (OOK) technique, where turning the LED ON represents a binary '1' and turning it OFF represents a binary '0'. At the receiver end, the Arduino Nano is programmed to read the electrical signals generated by the solar panel, decode the binary data, and reconstruct the original information. The decoded data is then displayed on an LCD screen, allowing users to verify that the transmission has been successfully received.

3.1.5 Testing and Result Validation:

In the testing and result validation stage, the Li-Fi system is thoroughly evaluated to ensure reliable and accurate data transmission. The system is tested under various conditions, including different transmission distances, LED brightness levels, and ambient lighting environments, to assess performance and identify any potential issues. The solar panel's response to light pulses is monitored to verify that binary data is correctly received and decoded by the Arduino Nano. Any errors or inconsistencies observed during testing are addressed through adjustments in hardware alignment, sensor calibration, or software timing. The transmitted data is compared with the received output on the LCD screen to validate accuracy, confirming that the system successfully converts digital data into light signals and back with minimal error. This stage ensures that the Li-Fi setup operates efficiently and meets the intended objectives of short-range, secure, and energy-efficient communication using visible light.

3.1.6 Production and Expansion Planning:

In the production and expansion planning stage, strategies are developed to scale and enhance the Li-Fi system for broader applications. This involves exploring ways to increase the transmission range, integrate multiple LEDs and receivers, or deploy the system in larger networks while maintaining reliable communication. Considerations are also made for optimizing hardware design, improving energy efficiency, and reducing production costs for practical implementation. Expansion planning may include modular system designs that allow easy addition of new transmitters or receivers and adapting the system for various indoor environments with minimal interference. The objective is to ensure that the Li-Fi setup is not only functional on a small scale but also scalable, adaptable, and capable of meeting future communication needs while retaining its efficiency, security, and short-range reliability.

3.1.7 Monitoring and Evaluation:

In the monitoring and evaluation stage, the performance of the Li-Fi system is continuously assessed to ensure reliable and efficient data transmission. Key parameters such as signal accuracy, error rate, transmission distance, and response to varying ambient light conditions are regularly monitored. Any fluctuations or performance issues are recorded and analyzed to identify areas for improvement, whether in hardware alignment, sensor sensitivity, or software timing. This ongoing evaluation helps maintain the stability and consistency of the system while providing feedback for potential upgrades or optimization. By systematically monitoring and evaluating the setup, the project ensures that the Li-Fi communication system remains a robust, energy-efficient, and secure method for short-range data transmission using visible light.

3.2 System Requirement:

3.2.1 Hardware Requirements:

The hardware requirements for the Li-Fi system include all components necessary for both transmission and reception of data through visible light. The transmitter side uses an Arduino Uno microcontroller to encode and control the data signal, along with a high-intensity LED bulb to transmit information in the form of light pulses. On the receiver side, an Arduino Nano is used to decode the signals received by a solar panel, which acts as a light sensor. Additionally, an LCD display is required to visually present the decoded data. Supporting components such as resistors, connecting wires, and a stable power supply are also essential to ensure proper functioning and reliable operation of the system. These hardware elements together form the foundation of the Li-Fi setup, enabling efficient, secure, and low-cost short-range communication using light.

3.2.2 Software Requirements :

The software requirements for the Li-Fi system include the Arduino IDE, which is used to program both the Arduino Uno and Arduino Nano microcontrollers. The Arduino Uno is programmed to encode data into binary form and control the LED for transmitting light signals using the On-Off Keying (OOK) modulation technique. The Arduino Nano is programmed to read the signals from the solar panel, decode the received data, and display it on an LCD screen or serial monitor. Additional software libraries, such as the LCD library, are required to facilitate proper data display and user interface functionality. The software ensures accurate encoding, transmission, decoding, and visualization of data, making it a critical component for the smooth operation of the Li-Fi communication system.

4.Use of solar panel instead of photodiode:

Solar panels are increasingly used as receivers in low-speed Li-Fi and visible light communication (VLC) systems because they combine light sensing, energy harvesting, and simplicity in a single device. Their large surface area allows them to collect a higher amount of optical power compared to photodiodes, which is especially useful when the transmitted light is weak, scattered, or misaligned. This makes solar-panel-based receivers more tolerant to positioning errors and suitable for practical indoor and outdoor environments.
A key advantage of solar panels is their ability to harvest energy while receiving data. The same optical signal used for communication can be converted into electrical energy, enabling self-powered or energy-assisted receivers. This feature is particularly valuable in applications such as wireless sensor nodes, IoT devices, and remote monitoring systems, where replacing or recharging batteries is difficult. In contrast, photodiodes require a dedicated external power supply and separate energy management circuitry.
From a hardware design point of view, solar panels provide higher output voltage and current, which reduces the need for high-gain, low-noise amplifiers. This results in simpler receiver circuits, lower component count, and improved system reliability. Solar panels are also cost-effective and widely available, making them attractive for student projects, prototypes, and large-scale deployments, whereas photodiodes are relatively expensive and more sensitive to handling and operating conditions.
Another important benefit is their robust performance under strong ambient light conditions, such as sunlight or indoor illumination. Photodiodes can easily saturate in the presence of background light, which degrades signal detection unless complex filtering is used. Solar panels, however, are designed to operate efficiently in high-illumination environments, making them more suitable for real-world VLC scenarios.
Although solar panels have limited bandwidth due to their large junction capacitance, restricting them to low data rates, this limitation is acceptable for many applications. They are well suited for low-speed communication tasks such as text transmission, environmental sensor data, control commands, and status monitoring. Overall, using a solar panel as a Li-Fi receiver improves energy efficiency, system sustainability, and practical usability, making it an effective choice for low-data-rate visible light communication systems.

5.RESULT & DISCUSSION

The experimental results confirm that the proposed Li-Fi system can successfully transmit digital data using visible light in a short-range indoor environment. The Arduino-controlled LED was able to convert digital data into light pulses, and the solar-panel-based receiver accurately detected these variations in light intensity. The received data was correctly decoded and displayed on the LCD, demonstrating reliable end-to-end communication.
The system showed stable performance under normal indoor lighting conditions, with improved accuracy when proper alignment was maintained between the transmitter and receiver. Minor errors were observed when strong ambient light or misalignment was introduced, indicating sensitivity to external light interference. Despite these limitations, the setup achieved consistent and fast data transfer for low-data-rate applications. Overall, the results validate the effectiveness of using a simple Arduino-based Li-Fi system for low-cost, secure, and interference-free wireless communication in indoor environments.

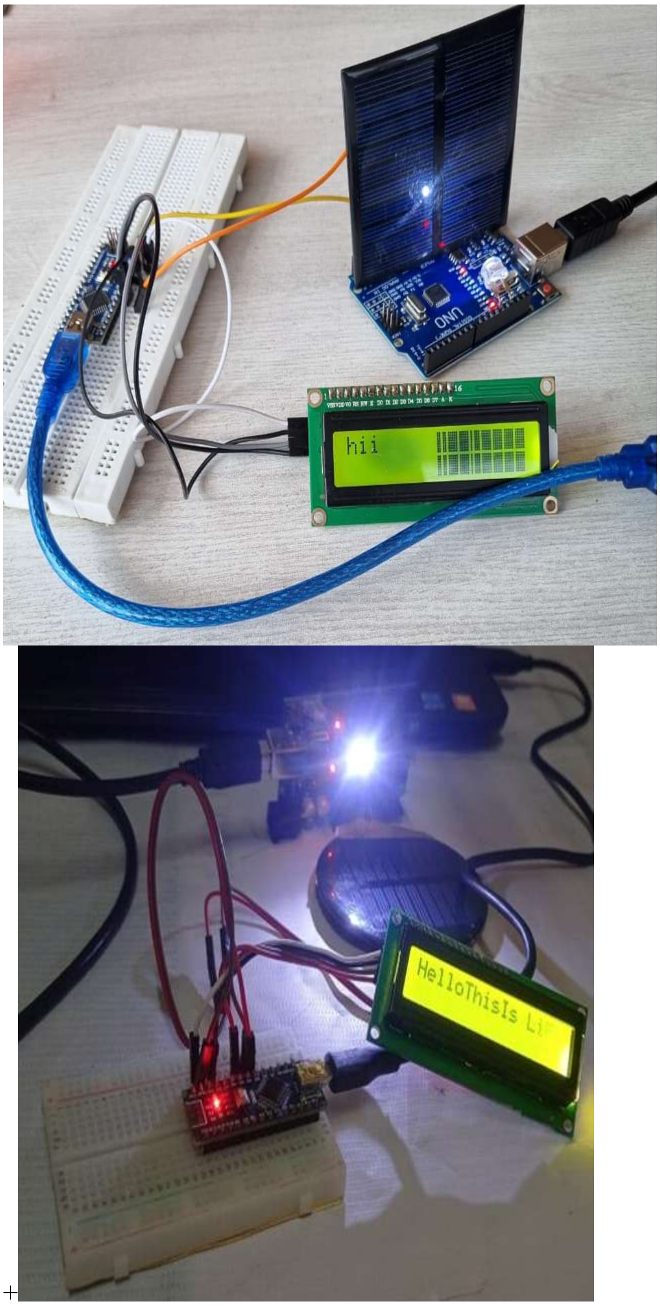

Fig 7: Transmitting data (hii) with light

 ISSN: 3107-6513

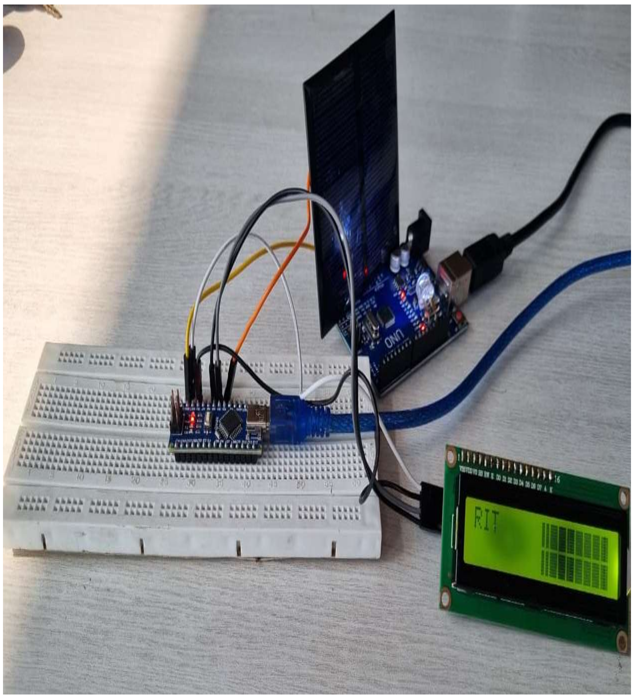

Fig 8: Transmitting data (RIT) with light

This project shows a simple way to send data using light instead of wires or radio signals**.** Here, an Arduino sends information by turning an LED ON and OFF very fast. When the LED is ON, it represents a '1', and when it is OFF, it represents a '0'. These light signals travel through the air. On the other side, a solar panel receives the light and converts it into electrical signals. Another Arduino reads these signals, understands the data, and shows the message on an LCD screen. This project helps us understand how visible light can be used for communication in a safe, low-cost, and interference-free way, especially for short-distance indoor communication.

6. CONCLUSION

This project shows that sending data through light using Li-Fi is practical and works well for short distances. By using simple Arduino boards, an LED, and a solar panel, the system was able to transmit and receive data accurately and display it on an LCD. The On-Off Keying method made the communication easy to understand and reliable for basic data transfer. Although the system needs proper alignment and works best in controlled lighting conditions, it clearly proves that Li-Fi can be a low-cost, secure, and energy-efficient alternative to traditional wireless communication. Overall, the project confirms the potential of visible light communication for indoor use, smart systems, and small-scale real-world applications.

7. REFERENCES

1. H. Haas, L. Yin, Y. Wang, and C. Chen, What is LiFi?, Journal of Lightwave Technology, vol. 34, no. 6, pp. 1533–1544, Mar. 2016.
2. D. Karunatilaka, F. Zafar, V. Kalavally, and R. Parthiban, LED Based Indoor Visible Light Communications: State of the Art, IEEE Com … Tutorials, vol. 17, no. 3, pp. 16 …
3. S. Rajagopal, … Visible Light Communication: Modulation Schemes and Dimming Support," IEEE Communications Magazine, vol. 50, no. 3, pp. 72–82, Mar. 2012.
4."Visible Light Communicati … and Li-Fi Technology," International Journ … ng Research & Technology, vol. 6, no. 2, Feb. 20 …
5.S. Pathak, X. Feng, P. Hu, and P. Mohapatra, "Visible Light Communication, Networking, and Sensing: A Survey, Potential and Challenges," IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2047–2077, 2015.
6. Various 2024 overviews (engineering reviews / conference papers) — e.g., *Li-Fi based wireless communication through VLC* (AIP/2024) and late-2024 review notes — useful for the latest small advances and practical system descriptions.
7. AIP Conference / Li-Fi related paper (Faruq et al., 2023 / conference article). Li-Fi based long range free-space
8. Zhang, S., et al. (2023). Recent Progress in Visible Light Positioning and Communication Systems. IEICE Transactions / Global Communications (2023). (Good for combined VLC & positioning systems — explains localization+comm tradeoffs).
9. Aboagye, S., et al. (2023). RIS-Assisted Visible Light Communication Systems. IEEE Communications Surveys & Tutorials / COMST (DOI: 10.1109/COMST.2022...). (Tutorial on using reconfigurable intelligent surfaces in indoor VLC to improve coverage/throughput)
10. Loureiro, P. A., et al. (2023). Visible Light Communications: A Survey on Recent High-Capacity Demonstrations. Photonics (MDPI), 2023. (Focus on high-capacity demos and DSP techniques used to reach multi-Gb/s in VLC).
11. Oyewobi, S. S., et al. (2022). Visible Light Communications for Internet of Things. Technologies (MDPI), 2022. (Comprehensive review of VLC for IoT use-cases, architectures and challenges).
12. Badeel, R., et al. (2021). A Review on LiFi Network Research: Open Issues and Future Directions. Applied Sciences (survey focusing on LiFi network architectures, resource management and open problems).
13. Elgala, H., Mesleh, R., & Haas, H. (2020). Indoor Visible Light Communication: A Tutorial and Survey. [Tutorial & survey covering PHY/MAC, modulation, channel and applications].