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Optical Conveyance of Audio Signals: Pioneering Li-Fi Technology for High-Fidelity Data Transmission

Saiful Islam Tuhin[1*], Sadia Mehrin Rahi[2], Istiyak Hasan Maruf[3], Sanjida Khanom[4], Ayesha Siddika[5]

[1]Department of Electrical & Electronic Engineering (EEE), Faculty of Engineering and Applied Sciences, Bangladesh University of Business & Technology (BUBT), Dhaka, Bangladesh.*
[2,3,4,5]Department of Computer Science and Engineering (CSE), Faculty of Engineering and Applied Sciences, Bangladesh University of Business & Technology (BUBT), Dhaka, Bangladesh.

Email: [2]sadia.mehrin.rahi@gmail.com, [3]maruf333444@gmail.com, [4]sanjidasathi333@gmail.com, [5]ayesha2223099@gmail.com
Corresponding Email: [1]saifulislamtuhin15@gmail.com*

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Abstract: This paper explores the integration of Li-Fi technology for transmitting high-fidelity audio signals in modern communication systems. Li-Fi, a wireless communication technology utilizing light signals, offers numerous advantages over traditional radio frequency-based methods, including higher data rates, reduced electromagnetic interference, and enhanced security. Leveraging the unique properties of Li-Fi, such as its ability to transmit data through light waves, this study investigates its potential application in audio signal transmission. Through experimental analysis and theoretical considerations, we demonstrate the feasibility and efficacy of Li-Fi for delivering high-quality audio signals in various scenarios. Our findings contribute to advancing the understanding of Li-Fi technology and its potential role in shaping the future of wireless audio communication.

Keywords: Li-Fi, Audio Signal Transmission, Wireless Communication, Light Waves, Data Rates, Electromagnetic Interference.

1. INTRODUCTION

The fidelity of audio transmission has relentlessly improved over the years, with advancements in digital formats and lossless compression techniques. However, traditional copper cables used for audio data transfer remain susceptible to electromagnetic interference (EMI) and signal degradation over long distances[1]. This is where Li-Fi (Light Fidelity) emerges as a

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revolutionary technology, leveraging the power of light to transmit audio signals with unparalleled clarity and potential[2].

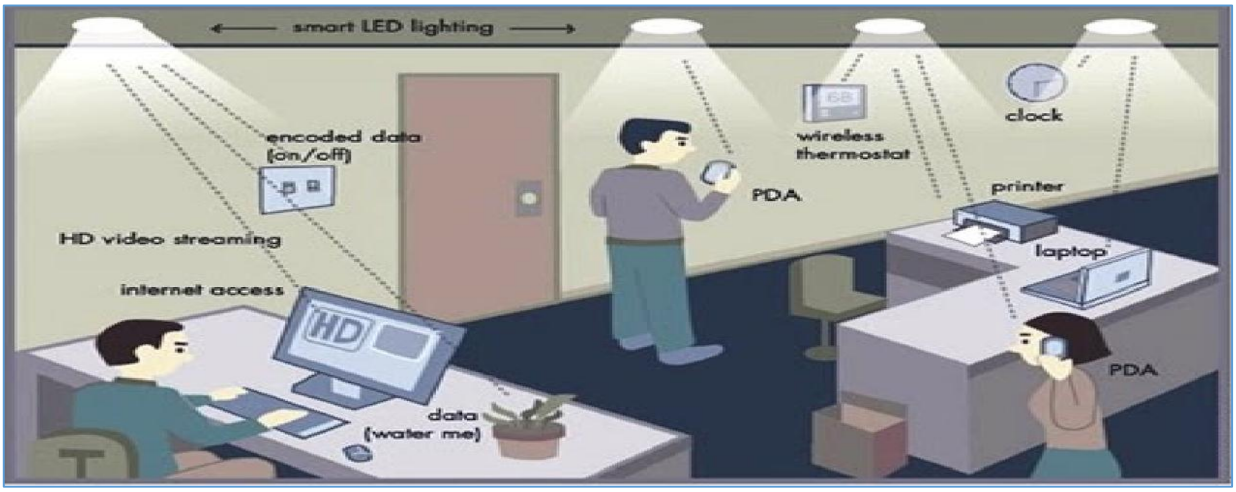

Figure 1: The Future of the Internet- Li-Fi

Li-Fi, also known as Visible Light Communication (VLC), utilizes light-emitting diodes (LEDs) to encode digital information, including audio data. Unlike traditional radio waves employed in Wi-Fi, Li-Fi transmits data by rapidly flickering the intensity or color of LEDs. These imperceptible flickers carry the encoded audio information, which can be received by a photodetector on the receiving end and decoded back into its original form [3].

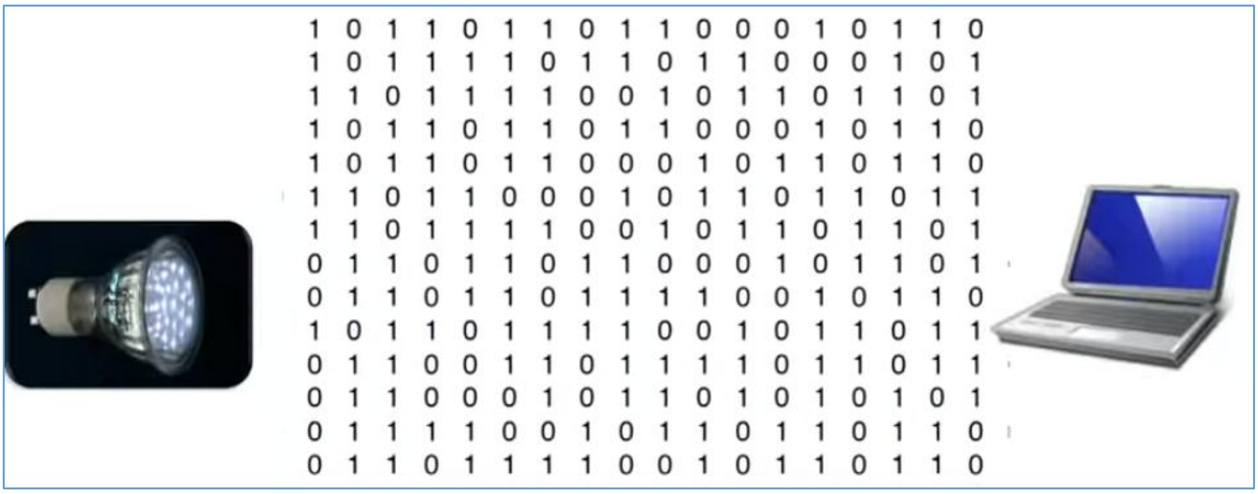

Figure 2: Li-Fi Transmission

In this research, we explore the exciting potential of combining Li-Fi technology with mini solar panels to create a self-powered audio transmission system. This integration eliminates the reliance on conventional power sources, making the system ideal for remote locations, off-grid applications, and environmentally conscious deployments. We delve into the realm of Li-Fi-enabled audio signal transmission, exploring its feasibility, advantages, and challenges.

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Through a comprehensive examination of the underlying principles and experimental demonstrations, we aim to shed light on the potential of Li-Fi technology to transform the landscape of wireless audio communication[4]. Furthermore, we present a conceptual framework illustrating the integration of Li-Fi into audio systems, highlighting its implications for enhancing user experience and expanding the capabilities of modern communication networks[5].

2. RELATED WORKS

Literature Review: Li-Fi technology originated in the 1990s in countries like Germany, Korea, and Japan. Researchers discovered that light-emitting diodes (LEDs) could be switched on and off to transmit information, laying the foundation for this revolutionary method of wireless communication [6]. During a TED talk, Harald Haas demonstrated a data transmission rate of approximately 10 Mbps initially, akin to a typical UK broadband connection. In a span of two months, this rate surged to an impressive 123 Mbps, showcasing the rapid progress and potential of Li-Fi technology.[7]. On July 12th, 2011, Harald Haas demonstrated Li-Fi by projecting a video of blooming flowers using a table lamp with an LED bulb. He periodically blocked the lamp's light to confirm it as the data source, showcasing Li-Fi's potential for wireless data transmission.[8].

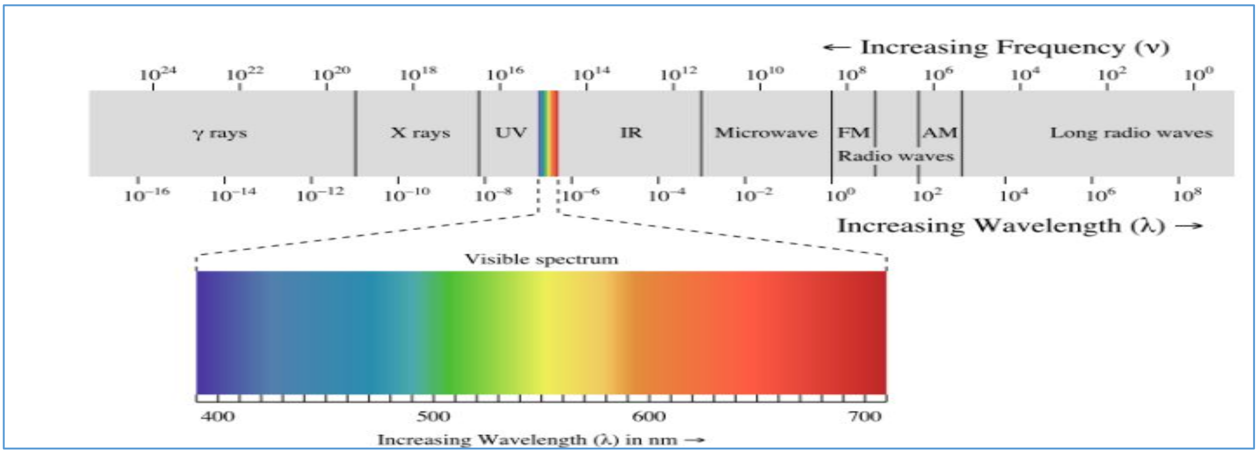

Figure 3: Electromagnetic Spectrum

Table 1: Comparison of Speed of Various Wireless Technologies [9].

Technologies	Speed
Wi-Fi – IEEE 802.11n	150 Mbps
Bluetooth	3 Mbps
IrDA	4 Mbps
Li-Fi	>1 Gbps

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Table 2: Comparative Analysis of End-User Connectivity Technologies [9].

Technology	Connection	Security	Reach	Impact	Cost	Bandwidth Expansion
Wi-Fi	Wireless- EMF	Good	Excellent	unknown	Good	Limited
Hardwired	Cables	Excellent	Fair	None	Good	Limited
Li-Fi	Wireless- Light	Excellent	Excellent	None	Low	Exceptional

Background: Traditional methods of audio data transfer, reliant on copper cables, face challenges such as electromagnetic interference and signal degradation. Li-Fi (Light Fidelity), utilizing LED lights for data transmission, offers a promising solution. It provides higher data rates, immunity to electromagnetic interference, and potential integration with existing lighting infrastructure. This research explores the feasibility of integrating Li-Fi into audio transmission systems, aiming to enhance clarity and reliability while addressing traditional method limitations[10].

Motivation: Li-Fi, short for "Light Fidelity," represents the future of internet connectivity, utilizing light as a medium for data transmission. With the speed of light significantly surpassing that of radio waves used in Wi-Fi, Li-Fi offers higher data transfer rates. While Wi-Fi remains a versatile and effective technology for wireless communication, it faces challenges such as capacity constraints, availability issues, efficiency concerns, and security vulnerabilities due to multiple accesses. Moreover, Wi-Fi emits radio waves that can pose risks to patients and interfere with medical instruments, making it unsuitable for certain environments such as hospitals and research facilities. To address these limitations, our focus lies in developing a Li-Fi-based system and assessing its performance. Li-Fi technology eliminates radio interferences in confined spaces, making it suitable for environments where radio waves are restricted, including airplane cabins and medical facilities. Li-Fi holds promise for applications in biosensors for measuring various health parameters, leveraging its high-density wireless data transfer capabilities. Envisioning a future where data transmission for laptops, smartphones, and tablets occurs through an economical and eco-friendly medium like light within enclosed spaces, Li-Fi represents a transformative leap towards efficient and secure wireless communication [11].

Objective: 1.The primary objective of this endeavor is to develop an efficient, cost-effective, secure, digitally controlled, and rapid data transfer method as a viable alternative to conventional Wi-Fi data transmission techniques. 2. Concurrently, the project endeavors to harness a more efficient light source, namely LED technology, to enhance the overall performance and reliability of the data transfer system. 3. Additionally, our efforts are directed towards creating a communication tool for use in public spaces, facilitating swift data transfer across a broad spectrum, thereby addressing the need for faster connectivity in high-traffic areas.[12].

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3. METHODOLOGY

There are two main parts in this technology. One is Transmitter, and another is Receiver. Transmitter which emits the Li-Fi Signals.

Here are the Steps for Constructing the Transmitter:
1. Start by linking the negative (-) terminal of the LED to the GROUND terminal of the headphone jack.
2. Then, connect the resistor to the positive (+) terminal of the LED.
3. Proceed by attaching the positive (+) terminal of the 9-volt battery to the resistor.
4. Conclude the assembly by joining the negative (-) terminal of the battery to the common wire of the LEFT and RIGHT terminals from the 3.5mm jack, thus completing the circuit [13].
Below are the steps for assembling the receiver:

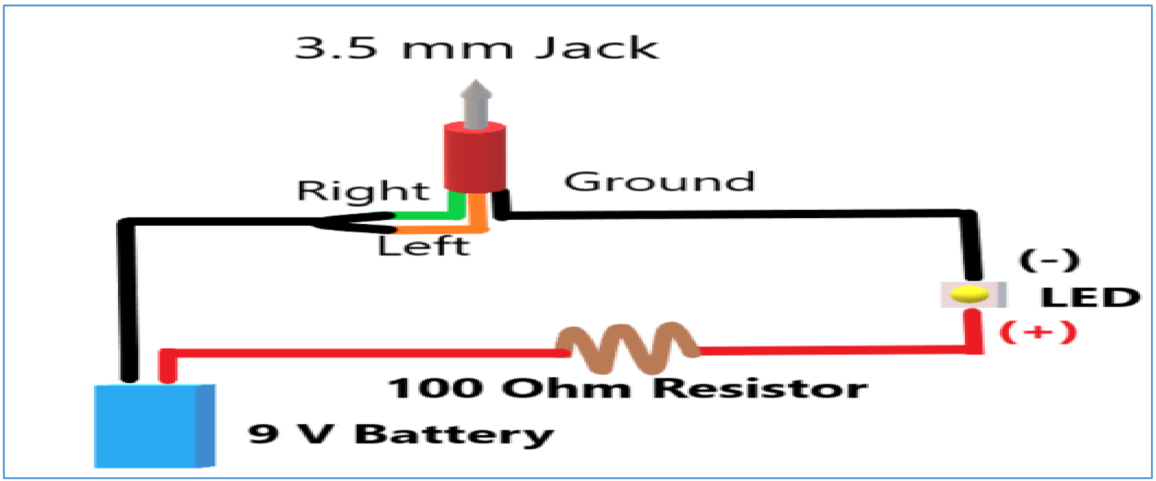

Figure 4: Transmitter Circuit Diagram

1. Begin by soldering the wires onto the positive (+) and negative (-) terminals of the solar panel.
2. Proceed by linking the negative (-) terminal to the GROUND terminal of the other jack.
3. Next, establish a connection from the positive (+) terminal of the solar panel to the common wire of the LEFT and RIGHT terminals from the jack to ensure circuit completion.
4. Once the receiver circuit is fully assembled, consolidate both circuits into a cardboard box to complete the setup [14].

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Figure 5: Receiver Circuit Diagram

Required Components: 1. Audio input from Mobile phone 2. LED 3. Mini Solar 4. Speaker 5. 9v Battery 6. Aux Cable 7. 1k Resistors [15].

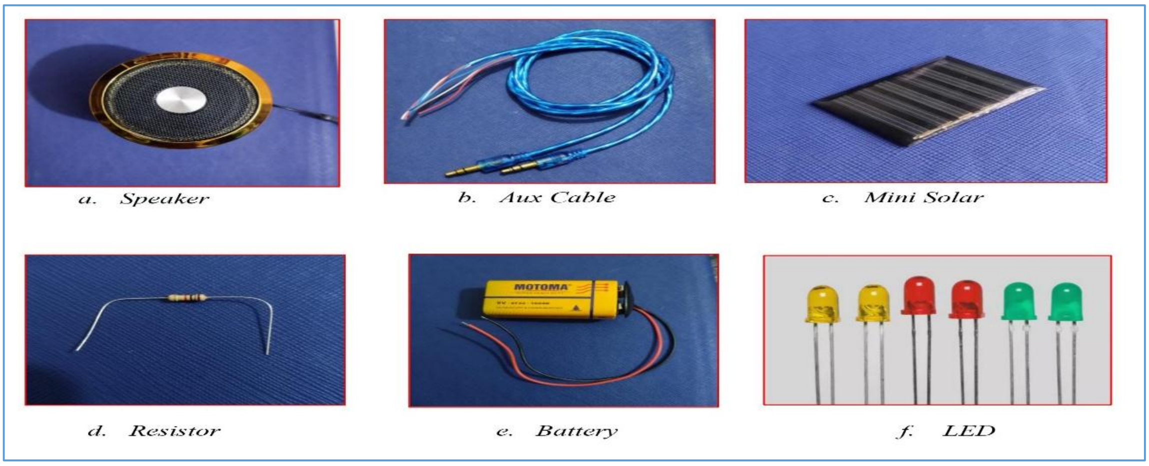

Figure 6: Components for Li-Fi Transmission

Block Diagram:

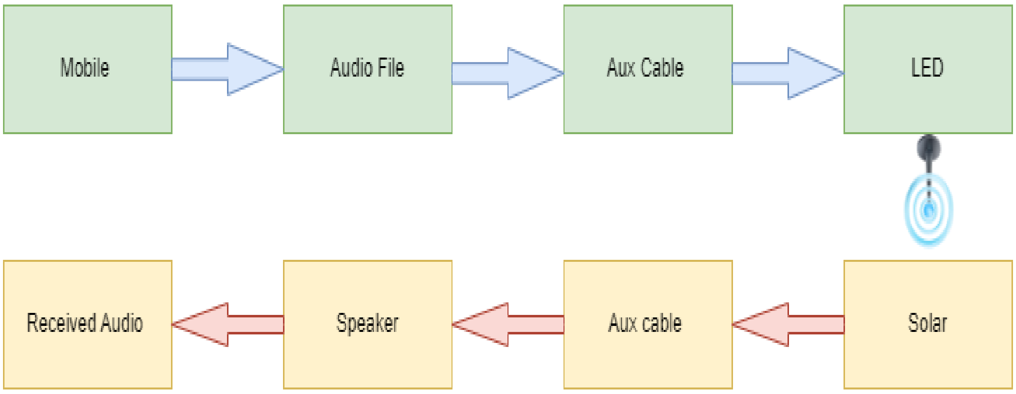

Figure 7: Block diagram for Transmitting Audio Signals

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4. RESULTS AND DISCUSSION

We have successfully designed and implemented a wireless communication device capable of transmitting audio messages wirelessly, known as "Light Fidelity" (Li-Fi). The project consists of two main sections: the transmitter and the receiver. In the transmitter section, incoming audio messages are modulated and transmitted as visible light using LEDs. On the other hand, the receiver section interprets the incoming light using a solar panel and converts it back into audible sound signals with the assistance of a speaker. This innovative system enables seamless Wireless communication through the transmission of audio signals via light, offering a promising alternative to traditional radio frequency-based methods.

Figure 8: Hardware Prototype of Li-fi Technology

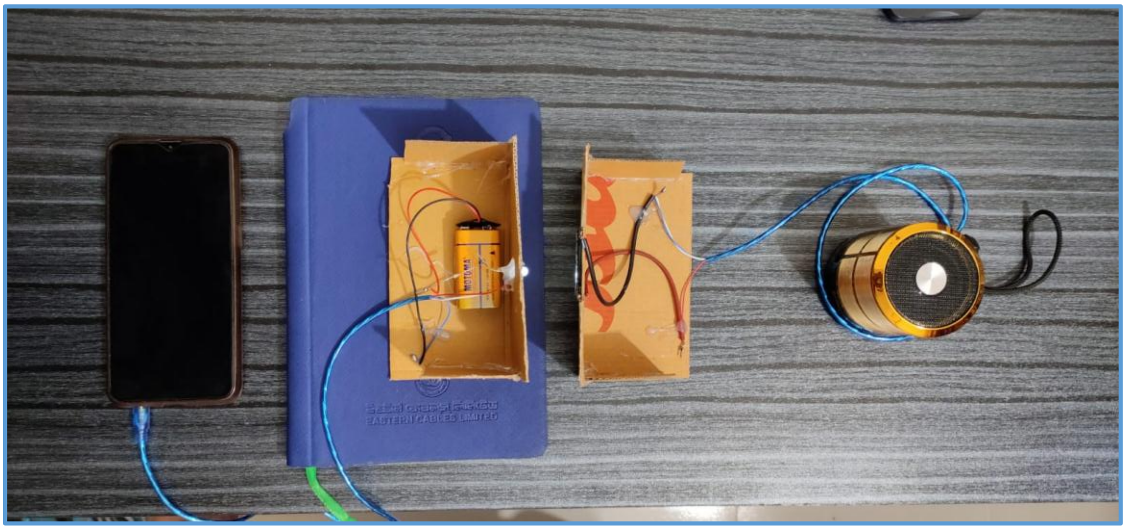

Figure 9: Signal Transmission through LED and Solar of: Li-fi Technology

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5. CONCLUSION

This technology is still undergoing research and promises to be a breakthrough in communication. It guarantees data speeds of up to 100 Gbps, far surpassing those of radio waves. The potential scope of Li-Fi technology is vast, with light offering a bandwidth 400 times wider than that of radio waves. Moreover, since light sources are already ubiquitous, Li-Fi benefits from existing infrastructure. Its high-speed capacity ensures that a large number of users can be connected without experiencing slowdowns. Additionally, Li-Fi offers secure, low-cost, and straightforward data transmission, making it suitable for various applications including industrial, medical, and military sectors. While Li-Fi is still in its early stages, rapid advancements are being made, suggesting its imminent integration into daily life. This project report aims to lay the groundwork for further research and development in this field.

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