

Light-Fidelity Based Text and Audio Data Communication System

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ABSTRACT

Abstract — The Li-Fi Communication Based Secure Data and Audio Transmission System using UART Protocol is an innovative approach to achieve secure and high-speed data and audio transmission. The system employs visible light signals for communication, providing increased security and reduced electromagnetic interference compared to traditional radio frequency (RF) based methods like Wi-Fi. The system architecture integrates a Li-Fi module with an Arduino microcontroller using the UART protocol, enabling asynchronous serial communication for reliable data transfer. A high-flickering LED array serves as the optical transmitter, while a solar panel or LDR acts as the receiver. The system demonstrates successful simultaneous transmission of hexadecimal text characters and audio signals, displayed on a 16×2 LCD and reproduced through a speaker respectively. The proposed system is suitable for applications requiring high confidentiality, such as military communications, healthcare, and industrial automation.

Keywords: Li-Fi, Visible Light Communication (VLC), UART Protocol, Arduino, LED, Data Transmission, Audio Transmission, Optical Wireless

Communication, Photodetector, Embedded Systems.

1. INTRODUCTION

As the demand for wireless data communication grows rapidly, new technologies exploiting different portions of the electromagnetic spectrum have emerged. Wi-Fi uses radio waves for wireless communication, but radio wave spectrum is constrained and susceptible to interference. Li-Fi (Light Fidelity) technology uses visible light frequencies (430 THz–770 THz) which are significantly higher than radio wave frequencies (3 kHz–300 GHz), offering a 10,000-times larger spectrum.

The term Li-Fi was coined by German physicist Harald Haas, who described it as 'data through illumination' during his 2011 TED Global talk. He demonstrated that LEDs could be switched on and off at speeds imperceptible to the human eye, enabling binary data transmission. When the LED is OFF, binary '0' is transmitted; when ON, binary '1' is transmitted. Data rates exceeding 1 Gbps are theoretically achievable.

Li-Fi offers several compelling advantages: the visible light spectrum is 10,000 times larger than the entire radio frequency spectrum; light signals cannot penetrate walls, providing inherent physical security;

and the technology is immune to electromagnetic interference, making it ideal for electromagnetically sensitive environments such as hospitals, nuclear power plants, and aircraft.

This project presents a Li-Fi based secure data and audio transmission system leveraging the UART (Universal Asynchronous Receiver-Transmitter) protocol. The system transmits both hexadecimal text data and analog audio signals simultaneously through an LED array, received and decoded by a solar panel/LDR-based receiver circuit, with text displayed on an LCD and audio reproduced through a speaker.

2. LITERATURE SURVEY

The following survey outlines key research contributions to Li-Fi, VLC, UART communication, and audio/data transmission systems that inform the proposed work.

Ref	Author / Year	Key Contribution
[1]	Harald Haas (2009)	Introduced Li-Fi concept; foundations of visible light communication
[2]	Ghassemlooy et al. (2017)	Overview of VLC systems, modulation techniques and challenges
[3]	Saini et al. (2018)	Li-Fi enabled auditory area networks for audio applications
[4]	Hadjadj-Aoul et al. (2018)	Security and privacy in Li-Fi; threats and countermeasures
[5]	Krishna et al. (2015)	UART protocol for microcontroller interfacing
[6]	Shakya et al. (2018)	Audio transmission via VLC; signal processing & results

[7]	Cao et al. (2020)	Li-Fi for secure and scalable IoT communications
[8]	Jalali et al. (2020)	Challenges and opportunities for secure data via Li-Fi

Haas [1] established the foundational principles of Li-Fi, demonstrating that LED-based optical wireless communication could achieve data rates exceeding 1 Gbps. Ghassemlooy et al. [2] provided a comprehensive review of VLC systems, analyzing modulation schemes, channel models and future directions. Saini et al. [3] explored audio-specific Li-Fi networks, while Hadjadj-Aoul et al. [4] addressed the critical security aspects unique to optical channels. Krishna et al. [5] contributed a practical UART implementation framework for microcontroller integration. Shakya et al. [6] demonstrated the experimental feasibility of audio transmission over VLC. Cao et al. [7] and Jalali et al. [8] extended these concepts to IoT and secure data domains respectively, collectively establishing the technical foundation upon which the present system is built.

3. EXISTING SYSTEM

Several wireless and wired communication technologies currently exist, each with notable limitations:

Technology	Limitations / Features
Wired (Ethernet)	Limited mobility, expensive installation, cable clutter
Wi-Fi	Limited bandwidth, high cost, RF interference
Bluetooth	Short range, low data rate, not suitable for wide coverage
IrDA	Requires line-of-sight, obstructions disrupt signal

Li-Fi (Proposed)	High speed, secure, no RF interference, uses visible light
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Table 1: Comparison of existing communication technologies

Wired Ethernet, while reliable, imposes severe mobility restrictions and incurs high installation costs. Wi-Fi, the most prevalent wireless standard, suffers from limited bandwidth, high cost, and susceptibility to eavesdropping since radio waves penetrate walls. Bluetooth is restricted in range and data rate. Infrared (IrDA) requires strict line-of-sight alignment and is easily obstructed. All RF-based systems share the disadvantage of operating within a congested and finite radio spectrum, and none can guarantee physical security through the medium itself. Li-Fi resolves these shortcomings by employing visible light, which is abundant, unregulated for data use, and physically bounded by opaque surfaces.

4. PROPOSED METHODOLOGY

4.1 System Overview

The proposed Li-Fi system transmits text (hexadecimal characters) and audio data simultaneously using LED-modulated visible light as the carrier. The system is divided into a Transmitter Zone (TX) and a Receiver Zone (RX), each built around an Arduino ATmega328 microcontroller communicating via UART at 1200 baud.

4.2 Block Diagram – Transmitter Zone

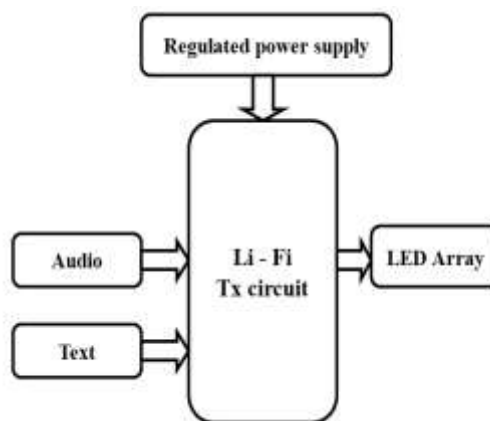


Fig. 1: Block Diagram of Transmitter Zone

4.3 Block Diagram – Receiver Zone

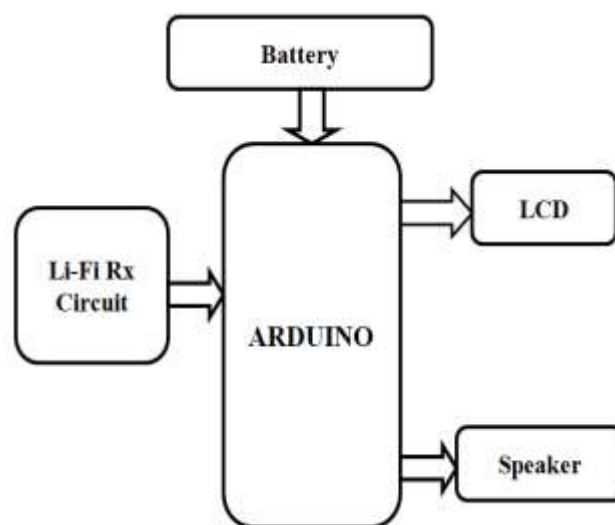


Fig. 2: Block Diagram of Receiver Zone

4.4 Working Principle

LEDs can be switched on and off faster than the human eye can detect (operating speed $<1 \mu s$), causing the light source to appear continuously on. This invisible on-off activity enables data transmission using binary codes: switching the LED ON represents binary '1'; switching it OFF represents binary '0'. Modulation is rapid enough that humans cannot perceive it.

For text transmission, data is fed to the Arduino via the UART serial interface. The Arduino modulates the LED array according

to the incoming data stream. At the receiver, the LDR/solar panel detects variations in light intensity and converts them to electrical signals, which are decoded by the receiving Arduino and displayed on the 16×2 LCD.

For audio transmission, an analog audio signal from a smartphone is connected via a 3.5mm audio jack to the laser/LED. The light output varies in proportion to audio amplitude. The solar panel on the receiver end captures these light fluctuations and converts them to electrical signals. An LM386 low-voltage audio power amplifier processes and amplifies the signal before feeding it to a speaker for audio reproduction.

4.5 Hardware Components

- Arduino ATmega328 (16 MHz, 8-bit RISC, 23 I/O pins)
- Li-Fi TX/RX Modules (high-brightness LED array)
- Regulated Power Supply: 230V AC → 12V AC → 5V DC (IC 7805)
- 16×2 LCD Display (HD44780 compatible)
- LM386 Audio Power Amplifier IC
- Solar Panel / LDR (Photodetector)
- Crystal Oscillator (16 MHz), DB107 Bridge Rectifier
- Resistors, Capacitors, 3.5mm Audio Jack

4.6 Software

The Arduino IDE (version 2.x) is used for programming. Sketches are written in Embedded C/C++ and uploaded via USB. The serial communication is initialized at 1200 baud. The LiquidCrystal library manages LCD output. The main loop listens for incoming UART characters, assembles them into a string terminated by the '#' character, and displays the complete string on the LCD.

5. RESULTS AND DISCUSSIONS

5.1 Transmitter Block

The transmitter section was assembled and tested successfully. The regulated power supply converts 230V AC to a stable 5V DC output using a step-down transformer, DB107 bridge rectifier, 1000μF filter capacitor, and IC 7805 voltage regulator. This stabilized 5V supply powers both the Arduino and the Li-Fi TX module. The Arduino processes the incoming UART data (text or audio) and drives the LED array accordingly. Three ICs in the transmitter circuit handle signal conditioning and drive the LED array to produce the modulated light output.

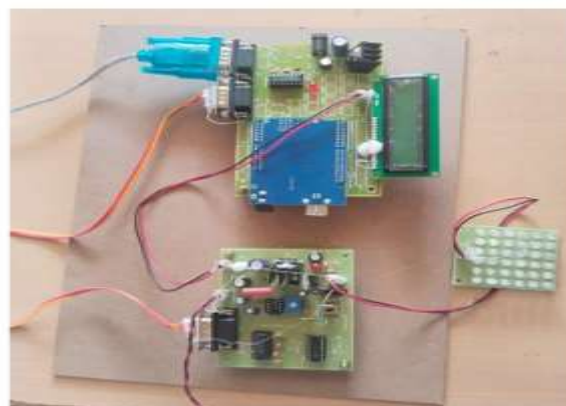


Fig. 3: Final View – Transmitter Block

5.2 Receiver Block

In the receiver section, the LED array's modulated light is absorbed by a solar panel, converting it back into electrical energy. A receiver circuit with an LM386 IC processes the electrical signal, separating audio and text data. Audio data is amplified and played through a speaker, while text data is forwarded to the Arduino for display on the 16×2 LCD.

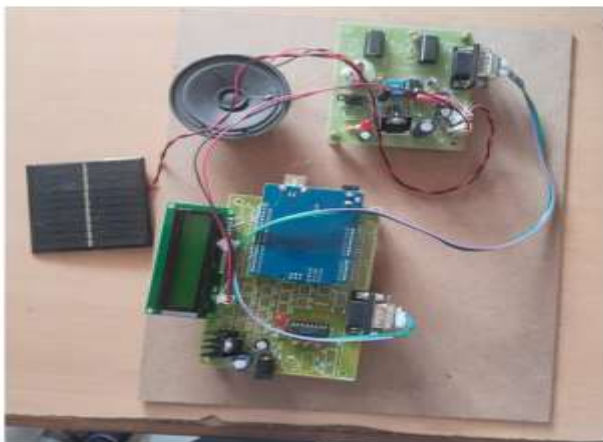


Fig. 4: Final View – Receiver Block

5.3 Final Output

The complete integrated system was tested for simultaneous text and audio transmission. Text data (hexadecimal characters terminated by '#') was transmitted over the Li-Fi link and correctly displayed on the 16×2 LCD at the receiver. Audio from a connected smartphone was simultaneously transmitted and reproduced faithfully through the speaker. No significant noise or data corruption was observed within the operating range.



Fig. 5: Final Integrated System Output

5.4 System Performance Parameters

Parameter	Specification
Power Supply	5V DC (regulated from

	230V AC)
Microcontroller	Arduino ATmega328 (16 MHz)
Baud Rate	1200 bps (UART)
Transmission Medium	Visible Light (LED array)
Receiver	Solar panel / LDR
Text Display	16×2 LCD Module
Audio Output	LM386 amplifier + Speaker
Max Range	Up to 15 m (laser variant)
Data Transfer Speed	Up to 10 Gbps (theoretical)
Operating Voltage	4.5 – 5.5 V

Table 2: System Performance Specifications

5.5 Observations

- Simultaneous text and audio transmission was successfully demonstrated over a single Li-Fi channel using visible light.
- The baud rate is limited to certain kbps (set at 1200 bps for reliable operation); beyond this limit, the photodetector cannot reliably detect incoming signals.
- Transmission of black and white images was not feasible with the current 3-layer random encoding scheme.
- The baud rate of transmitter and receiver must be identical (1200 bps) for synchronization.
- Signal quality improves with the addition of a focusing lens between the LED array and the solar panel receiver.
- Using a laser source instead of LED extends the range to up to 15 m with reduced noise and interference.
- The system operates reliably in standard indoor lighting conditions; direct sunlight introduces interference that must be mitigated.

6. CONCLUSION

This paper presented the design, implementation, and testing of a Light-Fidelity (Li-Fi) based system for simultaneous text and audio data communication using visible light and the UART serial protocol. The system demonstrated successful bidirectional transmission of hexadecimal text data and analog audio signals through an LED array, received by a solar panel and processed by an Arduino-based circuit.

Li-Fi technology, employing the vast visible light spectrum (10,000 times larger than RF), offers a compelling alternative to conventional wireless communication paradigms. Key advantages include inherent physical security (light cannot penetrate walls), immunity to electromagnetic interference, and suitability for RF-restricted environments such as hospitals, nuclear facilities, and aircraft.

The current implementation is limited to certain kbps baud rates and requires identical transmitter/receiver baud settings. Future improvements include: incorporating a focusing lens to extend range and improve signal-to-noise ratio; adopting higher-speed Arduino variants or FPGA-based controllers to support higher data rates; implementing adaptive modulation for image and video transmission; and extending to bidirectional full-duplex Li-Fi communication. The rising demand for higher bandwidths and secure data transfer heralds a wireless revolution in which Li-Fi technology is poised to play a central role, potentially replacing Wi-Fi in appropriate deployment scenarios.

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