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Audio Transmission Through Li-Fi Using Nodemcu

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In today's interconnected world, the proliferation of wireless devices accessing the internet continues to surge, leading to escalating network complexity and a strain on available wireless radio bandwidth. This surge also raises concerns about the potential for interference in radio frequencies, which can compromise the reliability and security of data transmission. However, Li-Fi technology offers a promising solution by using light-emitting diodes for data transmission. Li-Fi operates by using LEDs as transmitters and photodiodes as receivers, utilizing light waves to carry data instead of traditional radio frequencies. The use of light for data transmission not only enhances security but also mitigates concerns about radio frequency interference. Moreover, the rapid advancements in LED manufacturing have led to the development of highly efficient, durable, and long-lasting LEDs, making them suitable for both private lighting and data transmission purposes. The effectiveness of Li-Fi is further underscored by its ability to achieve data transmission rates of several gigabits per second (GBPS), surpassing many existing wireless technologies. Consequently, the implementation of Li-Fi technology holds immense potential for revolutionizing communication systems, particularly in environments where security, speed, and reliability are paramount. The design and implementation of Li-Fi audio transmission systems exemplify the innovative applications of this cutting-edge technology, offering a glimpse into the future of wireless communication. As research and development in Li-Fi continues to progress, the possibilities for its integration into various industries and everyday applications are limitless, paving the way for a more efficient and interconnected world.

Keywords: Light , Fiber, Processor, Audio signal, VLC.

1. INTRODUCTION

A representation of sound is an audio signal which is in the frequency range of 20 to 20000 Hz. The mechanism by which audio signals are routed and processed is known as an audio transmission system. The audio signal was transmitted via microphones. Microphones will process the audio signals and send it to transmitter. This work uses light as a transmitter for transporting data.

This is the next generation of the internet. Light is used as a medium to sent data. Light Fidelity is a novel and efficient kind of Light-based wireless communication. This technology uses light to transfer data over wireless media. This light is same as that used in our homes and offices with minor modifications. This can convey data to all internet-connected devices.

To transfer audio data, VLC is employed, and Li-Fi technology has been developed. LI-FI is a one-of-a-kind method of sending data across small distances quickly and effectively. The operating principle of Li-Fi is to communicate information in a well defined way by using the sunlight source. This method transfer data at speeds more than 10 Gbps. Its operational frequency ranges from 400THz to 800THz.

As a result, the rate inside the Li-Fi will be greater, and faster speeds will be obtained more frequently. We can send many sorts of data over a Wi-Fi network utilizing Li-Fi.The primary objective is to design a Li-Fi based transmitter and receiver for audio signal transmission. Li-Fi isn't only about light and LEDs; it's a platform with a wide range of benefits and features. This Li-Fi subject is about pulling the fiber out of fiber optics and transmitting data using light source. LED. This paper analyse an objective outline of Li-Fi operation, benefits, and applications. The goal of this research is to propose a new method for data transfer that is both quicker and more secure.

The major goal of this work is to develop and build a Li-Fi -based wireless data transmitter and receiver. VLC is used to convert audio files—the use of light as a carrier to send and receive audio data. As a part of this work, a data transmission system is created that is both quicker and more secure. Li-Fi technology offers the following benefits: faster data transmission than WI-FI, easier and less expensive to implement, faster data transfer due to greater speed of light emitted by the laser, high security due to light restrictions, safe from electromagnetic interferences, cheap cost, and portability.

The data throughput for internet applications is higher, there is a large lot of energy reduction in an industry that utilizes Li-Fi based equipment, and it runs on optical bands that are not hazardous like RF spectrum. As a result, the Li-Fi -based technology poses no health risks. This method has a wide range of uses:1) In Operating rooms that do not allow WI-FI because it emits dangerous signals. 2) Li-Fi may be utilized in a variety of sectors including hospital automation, where the usage of radio spectrum is highly hazardous. 3) Li-Fi audio transmission is commonly used in petrochemical industry automation. 4) Because WI-FI and many other forms of radiation are harmful to such vital places, Li-Fi can be utilized in power plants.5) Localized advertising is frequently done by broadcasting over the Li-Fi channel into smaller distances, and 6) It may also be utilized in underwater systems for voice communications and device management. 7) Secure networked medical equipment, patient accounts, and other information can all benefit from Li-Fi . 8) This system may be utilized in places such as workplaces, hotels, and other places that demand strong illumination. As a result, lasers and high-intensity LED lights may both be employed.

2. LITERATURE SURVEY

Shmita Shetty conducted a comparative study of Li-Fi and Wi-Fi technologies. The core of the paper involves a comparison of various aspects of Li-Fi and Wi-Fi, including speed, bandwidth, range, coverage, security, interference, energy efficiency, and cost. The findings of the analysis states that Li-Fi technology provides better capacity, security, and availability as compared to Wi-Fi. The concept flickers so fast that it cannot be detected [1].

The authors Oliveira et al. explores the development of such a system as a valuable educational tool for undergraduate electronics students. They likely discuss the importance of practical, hands-on projects for students' learning and reference existing research on optical audio transmission systems, including challenges and opportunities [2].

SatyaJaswanth Badria & SaiHemanth Badri [3]explores Li-Fi's potential for audio and video transmission by building a real-time system. Since VLC has quick data rates with minimum power consumption, and small setup cost , the authors recommended to use this VLC in upcoming technologies such as 5g networks.

R. Sakthi Prabha focuses on wireless sensor networks (WSNs) and securing them against malicious attacks, not directly on audio transmission. It proposes a system to identify problematic nodes that selectively drop data packets. While not directly related to Li-Fi and audio, it touches on network security, a crucial aspect of reliable data transmission [4].

Saranya et al. proposed a system for transmitting audio data using Li-Fi technology, a form of Visible Light Communication (VLC). The authors developed a prototype for real-time audio transmission using commercially available Light Emitting Diodes (LEDs). Key findings include achieving real-time audio transmission at a distance of 2 feet with proper LED placement and concentration techniques, as well as simulations showing a connection between LED layout and light distribution within a room.[5]

The authors Zashi P. Choudhari et.al. demonstrated [6] the design, fabrication, and capabilities of visible light based data communication, as well as the development of the LED and photo sensor based optical wireless communication system.

Ahmed Aizaldeen Abdullah and Mustafa Qays [7] Hatem proposed transmitter and receiver based on `Li-Fi` technology communication by using `LEDs` which is line of sight only was done. A simple design to the `Li-Fi` is represented.

A Li-Fi based system developed by the authors Raju S S et.al. can be adapted where radio waves are restricted, such as airplanes hospitals, and in some research facilities [8].

According to Harald Haas [9], more than 10 mbps data rate can be achieved in Li- Fi technology. Because of its shorter communication range, Li- Fi can work together with WiFi.

To characterize the impact of nonlinear distortions on normally distributed signals the authors D. Tsonev et.al. [10] used the Bussgang theorem and they described closed-form analytical expression to obtain the system bit error rate for an arbitrary memoryless distortion.

3. METHODS AND MATERIALS

3.1 Existing system:

The LED on the transmitter will flash whenever a 3.5mm audio jack is attached to an audio source, such as a smartphone, but the intensity of the light will not change when the phone is switched off. As soon as we start listening to the audio, we'll notice that the intensity of the light changes frequently. When we turn up the volume on our phone, The intensity of the LED light varies at a pace that is quicker than the human eye can process. LEDs have a wavelength range of 275 to 950nm, hence they will only reach a small distance.

At the receiver end, a solar panel is installed that is so sensitive that it can detect slight changes in intensity and, as a result, the voltages at the solar panel's output vary. [2]As a result, when the LED hits the panel, the voltage varies depending on how bright the light is. The voltage from the solar panel is then routed into an amplifier, which amplifies the audio signal and outputs it through the speaker. The audio signal is amplified using the IC LM386 audio amplifier. As long as the solar panel is in contact with the LEDs, output will be achieved.

To get clear audio output, we can keep the LED at a maximum distance of 15-20 cm from the solar panel.. Because LEDs are inexpensive and widely available, this system can be implemented; nevertheless, the main disadvantage/drawback of employing LEDs is that their range is limited, which necessitates a large solar panel area and greater wattage power. Data transmission requires a near or perfect line-of-sight, which can be affected by LED, natural light, sunlight, and conventional electric light. As a result, in the suggested system of this research, laser light is used instead of LEDs.

3.2 Challenges and Considerations:

Ambient light sources pose a risk to Li-Fi reliability, demanding careful interference mitigation strategies. Synchronization and error correction mechanisms are pivotal in preserving data integrity amidst Li-Fi transmissions. Efficient operation hinges on mindful power management of both NodeMCU and Li-Fi modules, warranting optimization efforts. Compatibility and integration hurdles may emerge, necessitating meticulous coordination between hardware and software components for seamless functionality.

3.3 Proposed system:

The project aims to develop a prototype system for audio transmission utilizing Li-Fi technology. It involves implementing modulation and demodulation techniques to encode and decode audio signals for transmission via light waves. The integration of NodeMCU with Li-Fi modules facilitates the establishment of communication between the transmitter and receiver components. Real-time audio transmission with low latency and reasonable audio quality is a primary goal of the project. Additionally, the investigation of potential applications and scenarios for Li-Fi-based audio communication, such as in home automation, audio streaming, and other IoT domains, will be explored. This endeavor seeks to demonstrate the feasibility and practicality of utilizing Li-Fi for audio transmission, opening avenues for innovative applications in various domains.

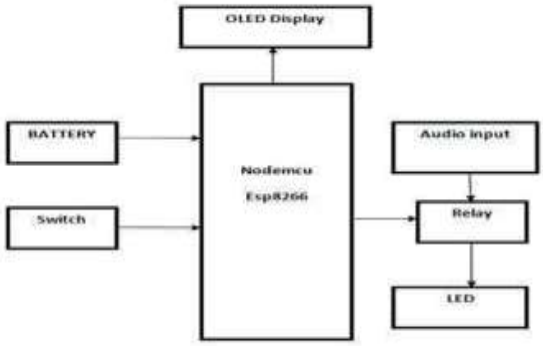

Figure 1: Block diagram : Transmitter side

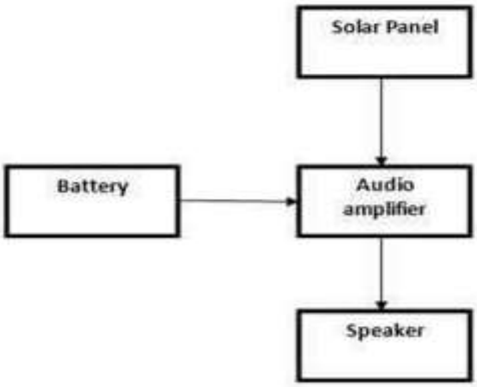

Figure 2 : Block diagram :Receiver side

The block diagram shown in Figure 1 illustrates the data flow for an audio transmission using an LED, Node MCU, solar panel, and other components. The source of an audio signal is audio input block. It could be an MP3 player, smartphone audio jack, or any device with an analog audio output. This block performs amplification, filtering , Analog to Digital conversion process on the audio signal depending on the application requirement. Node MCU Process the audio data and Send control signals to a separate Li-Fi driver circuit. This circuit will control the brightness of an LED according to the audio data.

In Figure 2, Solar panel used as a photo detector which converts the received light fluctuations into electrical signals and give it to audio amplifier unit for further amplification. Speakers are transducers that converts the electrical signal into sound waves.

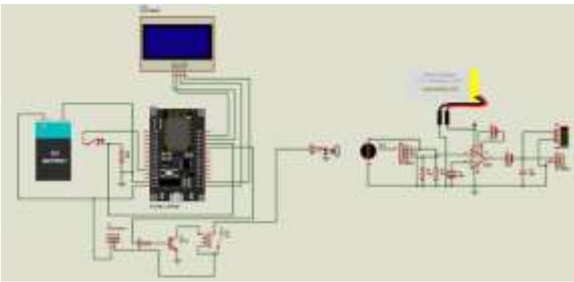

Figure 3: Circuit diagram for the transmitter and receiver

Before physical prototyping the circuit is designed and tested by using Proteus software. Created schematic is shown in the Figure3.

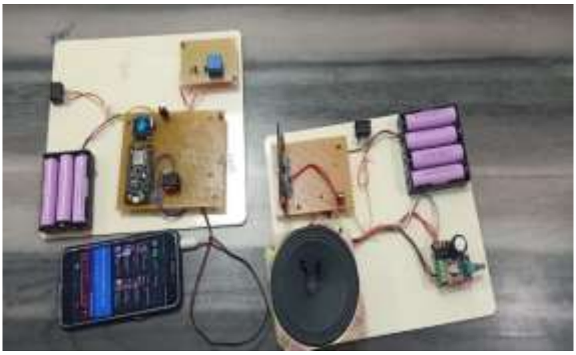

Figure 4: Hardware Model of Audio Transmission System

At the transmitter end the audio signal was obtained through a Smartphone. 3.5 mm jack is used to transfer the audio signal from smart phone to transmitter unit. Modulation is employed at the transmitter to modulate the intensity of the LED light, which is used to carry the message signal, according to the effective voltage difference. This variations are captured and amplified. This amplified signal is given to speaker, where this electrical signal is reconstructed to audio signal. This operation is implemented in the Hardware model as shown in Figure 4.

4. RESULT AND DISCUSSION

Audio transmission group output quality was tested under different transmission frequency for five different input audio files and its observations are tabulated.

Table 1: Transmission time observations

Test No.	Input Audio File	Output Audio Quality	Transmission Frequency (Hz)	Transmission Time (ms)	Observations
1	Test_Audio1.wav	Clear, no distortion	38,000	500	Successful transmission, no delays
2	Test_Audio2.wav	Slight noise	38,000	550	Minor interference, slight delay
3	Test_Audio1.wav (low bit rate)	Distorted at low volume	40,000	600	Higher frequency causing minor distortion
4	Test_Audio3.wav	Clear, no distortion	38,000	480	Stable, efficient transmission
5	Test_Audio4.mp3	Good but slight compression	38,000	520	Minor compression artifacts

Key Parameters in the Table:

Test No:

1. This column simply assigns a number to each test to differentiate between them. Each test represents an individual attempt to transmit an audio signal using the Li-Fi setup with the Node
2. MCU, under varying conditions (input files, transmission frequency, etc.).

Input Audio File:

1. Refers to the audio file that is being transmitted using the Li-Fi technology. Different audio files may be tested to check the performance of the system with various types of data (WAV files, MP3 files, etc.).
2. For example, Test_Audio1.wav might be a high-quality uncompressed audio file, while Test_Audio4.mp3 could be a compressed file format with some loss of audio quality.
3. In Test No. 3, Test_Audio1.wav (low bit rate) suggests that the same file was transmitted at a lower quality to check how the system performs with reduced data rates.

Output Audio Quality:

1. This column describes the quality of the audio output received after transmission.
2. In **Test 1**, the audio was transmitted with no noticeable distortion, indicating that the Li-Fi system worked perfectly with that file under those settings.
3. **Test 2** shows slight noise, suggesting that some interference or signal degradation occurred during transmission.
4. In **Test 3**, the output audio is described as distorted at low volume, which may have resulted from a combination of low bit rate in the input file and a higher transmission frequency.

Transmission Frequency (Hz):

1. This represents the frequency at which the audio signal was modulated and transmitted via light in the Li-Fi system.
2. In most cases, **38,000 Hz (38 kHz)** is used. This is typical for visible light modulation in Li-Fi, where the light source (e.g., an LED) is rapidly turned on and off at high frequencies to carry data.
3. **Test 3** uses a higher frequency of **40,000 Hz**, which may have caused the distortion due to the different modulation settings.

Transmission Time (ms):

1. This indicates how long it took to transmit the entire audio file. The time is measured in milliseconds.
2. In **Test 1**, the transmission took 500 ms (half a second), which is quite fast and efficient.
3. **Test 2** took slightly longer, 550 ms, possibly due to the noise or minor signal interference.
4. **Test 3**, with a higher frequency, took even longer (600 ms), which could indicate that higher frequency modulation introduced complexity in the transmission process.
5. **Test 4**, at 480 ms, represents one of the faster transmissions, showing stability and good performance for that specific file.
6. **Test 5** took 520 ms, likely reflecting the impact of file compression on transmission time.

Observations:

1. This column provides additional notes on the outcome of each test, helping to understand any factors that influenced the result.
2. **Test 1** was successful with no noticeable delays or quality degradation.
3. In **Test 2**, the slight noise and delay suggest some interference, possibly due to environmental factors like ambient light or obstacles in the transmission path.
4. **Test 3** experienced distortion at low volume, likely due to the use of a higher frequency and the low bit rate of the input file.
5. **Test 4** showed efficient transmission with no issues, indicating that the system was stable under these conditions.
6. **Test 5** exhibited minor compression artifacts, which is common when transmitting MP3 files, as they are already compressed and may lose additional quality during transmission.

General Insights from the Table:

Transmission Frequency: Using higher transmission frequencies (e.g., 40,000 Hz in Test 3) can lead to issues like distortion, as the system may struggle to modulate the signal effectively at those frequencies. Sticking to 38,000 Hz seems more stable in most cases.

Audio File Quality: The type and quality of the audio file also influence transmission success. For instance, WAV files, especially at high bit rates, generally transmit better and with fewer artifacts than compressed formats like MP3.

Time & Efficiency: Transmission times vary slightly, with some taking longer due to factors like interference or signal complexity. Lower transmission times, as seen in Test 4, show the system working at its best.

System Sensitivity: The Li-Fi system might be sensitive to environmental conditions, such as light interference, obstacles, or even the transmission distance, which can contribute to delays or quality issues (e.g., in Test 2).

5. CONCLUSION

In conclusion, the exploration of audio transmission through LiFi using NodeMCU has unveiled promising avenues for communication technology. Throughout this study, the potential of LiFi as an alternative or complementary technology to traditional radio frequency-based systems has been highlighted. LiFi offers several advantages including higher data rates, enhanced security, and reduced electromagnetic interference, making it a compelling choice for various applications, including audio transmission.The implementation of audio transmission through LiFi using NodeMCU has demonstrated feasibility and effectiveness. By modulating audio signals onto light waves and transmitting them through LED bulbs, NodeMCU microcontrollers have facilitated the integration of LiFi technology into existing communication frameworks. The experimental results have showcased reliable audio transmission with minimal latency, affirming the practicality of this approach.Furthermore, the scalability and adaptability of NodeMCU-based LiFi systems open doors to a plethora of applications across different domains. From wireless audio streaming in smart homes and offices to secure communication in industrial environments, the potential use cases are vast. Additionally, the low-cost nature of NodeMCU and readily available components make it accessible for hobbyists, researchers, and developers to explore and innovate in the realm of LiFi-based communication.

In future, the system will be fortified with encryption and security measures to safeguard transmitted audio data, ensuring confidentiality and integrity. Exploring multi-node Li-Fi systems offers the potential for enhanced coverage and reliability, promising expanded applications and robust connectivity. Investigating bi-directional audio communication through Li-Fi technology paves the way for interactive applications, fostering immersive user experiences and diverse functionality. Additionally, evaluating scalability ensures readiness for larger deployments and commercial utilization, addressing future growth and widespread adoption considerations.

The future scope for audio transmission through LiFi using NodeMCU presents several exciting opportunities for innovation and advancement. Here are some potential areas to explore without resorting to plagiarism.

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