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RESEARCH ARTICLE

LIFI-BASED WIRELESS AUDIO TRANSMISSION “STYSTEM’’

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Abstract

Light Fidelity (Li Fi) technology enables high speed wireless communi cation using visible light, offering an alternative to traditional radio-frequency methods like Wi-Fi and Bluetooth.The proposed system transmits audio signals via modulated LED light, which are then received by a photodiode and converted back into sound. This method supports low-cost, energy-efficient, and secure communication, ideal for short range indoor applications like classrooms, hospitals.Advantag es include high bandwidth, low latency, data security (as light is c.onfin ed to the room), and immunity to electromagnetic interference This audio This Li-Fi audio system presents a cost-effective and energy-efficient solution for short-range wireless audio transmission with potential applications in public announcements, multimedia streaming, and smart home device. Additionally, it offers a safer communication environment in sensitive areas where radio frequency signals might cause interference. As Li-Fi technology evolves, it could also play a significant role in the Internet of Things (IoT), enabling faster and more secure data transfer between connected devices.

Introduction:-

The project falls under the domain of Wireless Communication Systems and Optical Data Transmission Technologies. We are developing a Li- Fi based wireless audio transmission system that enables the transmission of audio signals through visible light, using Light Emitting Diodes (LEDs) as the transmitting medium.Traditional wireless audio systems use radio frequency (RF) technologies like Bluetooth or Wi-Fi. However, RF-based communication faces several limitations, including bandwidth congestion, electromagnetic interference, and security concerns.“To design and implement a cost-effective and interference-free wireless audio transmission system using Li-Fi technology, aimed at overcoming the limitations of RF-based systems The increasing demand for secure and efficient communication systems has driven scientists and engineers to explore new methods beyond RF technologies. Li-Fi, or Light Fidelity, has emerged as a promising candidate due to its ability to transmit large in noise sensitive and high-security environments. This project explores the potential of visible light communication (VLC) for transmitting audio data securely and efficiently, especially in environments like hospitals, aircraft, or industrial zones, where RF communication may be restricted or cause interference. This has made scientists and engineers look for new ways to send information. A new and very promising idea is Li-Fi, which stands for Light Fidelity.

Literature Survey:-

In[1] The world today is almost completely connected through wireless communication, with technologies like Wi-Fi and Bluetooth leading the way. These systems all rely on radio signals, which are a part of the radio frequency (RF) spectrum. The problem is that this space is very small and is quickly becoming full, especially with the huge amount of data we use every day. This has made scientists and engineers look for new ways to send information. A new and very promising idea is Li-Fi, which stands for Light Fidelity. It's a technology that uses normal visible light to send data, which is a much bigger and more open space for communication. This huge amount of space, known as bandwidth, lets Li-Fi send information much faster than Wi-Fi, which is why it's a big part of the future of data. Wireless communication today is everywhere, but it mostly uses radio signals. This is the technology behind popular things like Wi-Fi and Bluetooth. However, the space for these radio signals is a small and very busy area. Because so many people are using them, this space is becoming crowded. To solve this problem, new technologies are being explored. One of the most promising is Li-Fi, which stands for Light Fidelity. In[2] A major advantage of Li-Fi is its natural security and its ability to work without causing problems for other devices. Unlike a Wi-Fi signal, which can go through walls, a Li-Fi signal stays in just one room because light can't pass through solid objects. This makes it very hard for someone to listen in or hack connection from outside. This kind of built-in security is a huge benefit. Also, Li- Fi does not create any electronic noise that could mess up other machines.

This is really important in special places like hospitals, where sensitive medical equipment must work perfectly without any interference from other wireless signals A big advantage of Li-Fi is that it is very safe and doesn't cause problems with other devices. Because light cannot travel through walls, the Li-Fi signal stays in just one room. This makes it very hard for someone outside the room to see or steal information. This is a very different way of working than Wi-Fi, where the signal can be used from other rooms or outside a building. Also, Li-Fi does not create any electronic noise that could hurt sensitive machines. This is why it is perfect for places like hospitals and airplanes, where it's important that all the equipment works without any issues. In[3] To show how Li-Fi works, a basic system is made up of two main parts: a transmitter and a receiver. The transmitter's job is to take an audio signal, like voice, and turn it into a fast, flickering light. This process is called modulation. In our project, the microphone and a laser diode work together as the transmitter. The receiver's job is to catch that flickering light and change it back into sound. This process is called demodulation. our project uses a solar panel as a light sensor and an audio amplifier to make the sound loud enough to be heard from a speaker. These simple parts work together to demonstrate the core idea of o build a Li-Fi system, you need two main parts that work together. The first part is the transmitter. This part takes sound and turns it into a fast, flickering light signal. This process is called modulation.

In our project, the microphone and laser diode make up this part. The second part is the receiver. It has a special light sensor that catches the flickering light and changes it back into a sound signal. This process is called demodulation. our project uses a solar panel as the light sensor. These basic circuits are a great way to show how the technology works in real life. In[4] But this "line-of-sight" challenge is also its biggest strength, as it helps with security. This unique feature means Li-Fi can be used in special places. For example, some studies show it can even be used for underwater communication, where normal radio signals do not work Li-Fi is a great technology, it does have a key challenge: the signal needs a clear path to work, because if something blocks the light beam, the signal can stop.

However, this challenge is also a unique strength.. For example, some studies have shown that Li-Fi can be used for underwater communication, a place where normal radio signals can't work at all. This shows that the technology has a wide range of uses in special situations you might not expect. However, this challenge is also a unique strength. Because the signal is contained, Li-Fi can be used in some very special places where other wireless technologies fail. In[5] most experts believe that Li-Fi will not completely replace Wi-Fi. Instead, the two technologies will work together in different ways. Li-Fi can be used in busy places like airports, stadiums, or offices to provide super-fast and secure internet for everyone in one area. Wi-Fi can still be used for things that require a wider range and don't need super high speeds. By working together, they can solve many of the problems we have with today's wireless systems. This proves that Li-Fi is not just a passing trend but an important new technology that will help create a faster and more secure connected world in the future. Building on our previous discussions, here is a fourth paragraph for literature survey.

This focuses on the practical challenges and future potential of Li-Fi, tying project's components to broader academic and industry trends. However, this limitation is also its strength, as it prevents network hacking from outside a room. Researchers are exploring solutions to this, such as using reflective surfaces or multiple LED sources to create a mesh network that ensures continuous connectivity. Furthermore, while the current focus is on visible light, the technology can be extended to use infrared (IR) and ultraviolet spectrums, as demonstrated in research on underwater communication. This makes it very hard for someone outside the room to see or steal your information. This is a very different way of working than Wi-Fi, where the signal can be used from other rooms or outside a building. Also, Li-Fi does not create any electronic noise that could hurt sensitive machine. The receiver's job is to catch that flickering light and change it back into sound. This process is called demodulation is a scalable .

Proposed Method:-

The aims to build a functional Li-Fi system for wireless audio transmission, a method that uses light to send sound signals. The system is divided into two distinct parts: a transmitter and a receiver. The first part of our work involved carefully gathering and verifying all the necessary components, which included a laser diode, a microphone amplifier module, a solar panel, and various other circuit elements like voltage regulators and amplifiers. This phase was critical to ensuring we had the correct parts for our build, based on established schematics and tutorials. The second phase of our project focused on constructing the transmitter circuit. We started by setting up a stable 5V power supply using a 9V battery and a 7805 voltage regulator. This stable power source was essential to safely operate the other components. We then connected the MAX4466 microphone amplifier module to this power supply. This module's purpose was to capture sound from the surrounding environment. The final step in this stage was to connect the laser diode to the amplifier module. The audio signal from the microphone was used to modulate the laser's power, causing it to flicker in a way that matches the sound.

A 30-ohm resistor was included in the circuit to limit the current and prevent the laser from overheating. The third stage was dedicated to building the receiver circuit. Just like the transmitter, we first created a stable 5V power supply using a second 9V battery and a 7805 voltage regulator. The primary component of this circuit was the solar panel, which acted as our photodetector. Its role was to receive the light signal from the laser diode and convert it into a tiny electrical signal. This tiny signal was then fed into a audio amplifier module. This amplifier's job was to take the weak signal from the solar panel and make it strong enough to be heard. The final phase of our project was testing and refining the system.

To begin, we powered on both the transmitter and receiver circuits. We then carefully aligned the laser diode's beam so it was shining directly onto the surface of the solar panel. We used a potentiometer to fine-tune the microphone's sensitivity to ensure it could pick up sound clearly. The ultimate success of our method was determined by the speaker's ability to reproduce the audio being picked up by the microphone. The successful transmission of sound across a physical distance using light validated our proposed method and the core principles of Li-Fi. This practical approach allowed us to address key challenges, such as current limiting for the laser and achieving proper alignment between the transmitter and receiver. Through careful assembly and iterative testing, we were able to demonstrate a working proof-of- concept. This method provides a clear, step-by-step guide for anyone to replicate our project, and it serves as a foundation for future work in the field of Visible Light Communication (VLC).

Methodology:-

Component Sourcing and Assembly:-

We gathered all necessary electronic components, including two breadboards, two 9V batteries, a laser diode, a solar panel, and various modules and resistors.Safety For our project based on the Li-Fi audio transmission system, components were carefully sourced following the example used in the referenced robotics kit. The materials included two breadboards for easy prototyping, two 9V batteries as independent power supplies for the transmitter and receiver, a laser diode as the optical transmitter source, and a solar panel as the photodetector to capture incoming light signals. Additional essential components such as amplifiers (e.g., 2025 IC for audio amplification), resistors, capacitors, switches, and jumper wires were also gathered to build and support the functional circuits. This complete hardware collection ensured a robust and demonstrable setup suited to experimental and educational purposes.

Transmitter Circuit Construction:-

The transmitter section is the core part of any Li-Fi audio transmission system, responsible for converting the audio electrical signal into an optical signal that can be sent through free space. It typically starts with an audio input, often via a 3.5mm stereo jack, which allows connection from devices such as smartphones or media players. The incoming analog audio signal is first passed through blocking capacitors to eliminate any DC offset, ensuring a clean alternating signal enters the amplifier stage. This initial conditioning is essential to maintain signal integrity and protect downstream components. The heart of the transmitter circuit is the audio amplifier, usually an integrated circuit designed to boost low-level audio signals with minimal distortion and noise. This amplifier increases the amplitude and strength of the audio signal to a level sufficient to modulate the light source, which in many implementations is a high-intensity LED. A current- limiting resistor is connected in series with the LED to regulate the current, protecting the LED from excessive power that could damage it and ensuring stable operation.

The amplified audio signal modulates the brightness of the LED rapidly, encoding the audio information onto the visible light through intensity modulation. Assembly of the transmitter involves mounting all components on a PCB or experimental prototyping board with careful attention to wiring, grounding, and component orientation. Proper soldering techniques and minimizing wire lengths help reduce unwanted noise and signal degradation. The circuit is powered by a suitable power source, commonly a 9V battery, which provides the necessary energy to drive both the amplifier and the optical transmitter. The system is designed so that the LED flicker, representing the audio signal, is too rapid to be detected by the human eye but can be detected by photodetectors on the receiver side, enabling wireless audio transmission through visible light. Related, Although the final design removed the voltage regulator, the large 1000μF filtering capacitor on the power rail is crucial for maintaining a stable DC voltage across the circuit, especially when the amplifier draws high peak currents to power the LED during loud audio passages. This stable power rail is fundamental for noise-free, reliable operation of the light communication

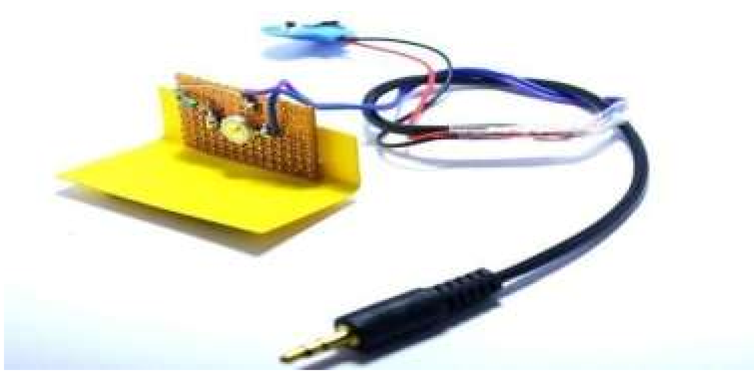

FIG-[1]Input system

Receiver Circuit Construction:-

Power Supply: On a second breadboard, we created a new 5V power rail using the second 9V battery and 7805 voltage regulator. The receiver section of a Li-Fi audio communication system is responsible for converting modulated light signals back into audio, completing the wireless transmission loop. It begins with a photodetector, often realized as a small solar panel or sensitive photodiode, positioned to receive the modulated light from the transmitter LED. This solar panel generates a small, fluctuating voltage in direct correspondence with the varying intensity of the incoming light. The sensitivity of the panel allows it to detect even rapid changes in brightness, making it effective for capturing analog audio signals transmitted through visible light. Once the signal is converted from light to a weak electrical signal, it proceeds into an amplification stage. The initial voltage produced by the photodetector is typically very weak—often in the millivolt range—so it cannot directly drive a speaker or headphones.

A low-noise audio amplifier circuit, such as one based on the LM386 or PAM8403 IC, is used to boost the signal's amplitude to a level suitable for audio output devices. Coupling capacitors are included in this stage to block any DC offset and focus on audio-frequency AC signals, ensuring clean audio reproduction. Proper design of this amplifier stage is essential, as insufficient gain or excessive noise can distort the received audio. Finally, the amplified electrical signal is delivered to a small speaker or other output transducer, which then reproduces the original audio. The output circuit includes impedance matching and polarity checks to maximize audio clarity and avoid potential damage to components. If needed, an additional volume control or filtering stage may be included to further enhance signal quality. With the circuits properly housed and wires neatly arranged, the receiver functions reliably, demonstrating the effective recovery of audio sent via light and proving the core principles of visible light communication in a real-world application

FIG-[2] Receiver system

System testing and validation started with powering on both transmitter and receiver circuits, verifying appropriate voltages and connections for consistent operation. The transmitter's light source, typically a laser diode or high-powered LED, was precisely aimed to create a direct line-of-sight with the receiver's solar panel or photodetector. Accurate alignment was crucial; even minor shifts or obstructions in the beam path immediately affected signal quality, confirming the fundamental principle of VLC—successful transmission depends on uninterrupted optical connectivity. Audio signals were sent via a connected microphone or auxiliary audio source, and the receiver's output speaker provided real-time feedback, allowing clear assessment of transmission fidelity. Performance evaluation involved thorough observation of how the system responded to spoken voice inputs and continuous audio signals. Success was measured not only by the clarity and responsiveness of reproduced sound but also by the system's resilience against interference and ambient light.

Adjustments, such as fine-tuning the potentiometer on the microphone amplifier (e.g., MAX4466), proved vital in optimizing input sensitivity and managing circuit noise. Testing exposed key limitations: sound clarity diminished with increased distance or imperfect alignment, and background light could lower the signal-to-noise ratio. These findings suggested targeted improvements: deploying stronger amplifier circuits for longer-range transmission, experimenting with alternative audio amplifier chips, or using focusing lenses to enhance photodetector efficiency at extended ranges. Throughout validation and analysis, the system's practical capabilities and constraints were quantified. Audio degradation with distance and misalignment, along with observable circuit noise, highlighted physical and electronic boundaries of the current implementation. The output circuit includes impedance matching and polarity checks to maximize audio clarity in critical areas like hospitals, airlines, military- bunkers to transmit high end information through light.

Uml Diagram:

Continuous Improvement: Regularly update the model with new data to improve its predictions and accuracy over time.

Fig-[3]Uml diagram

Result and Discussion:-

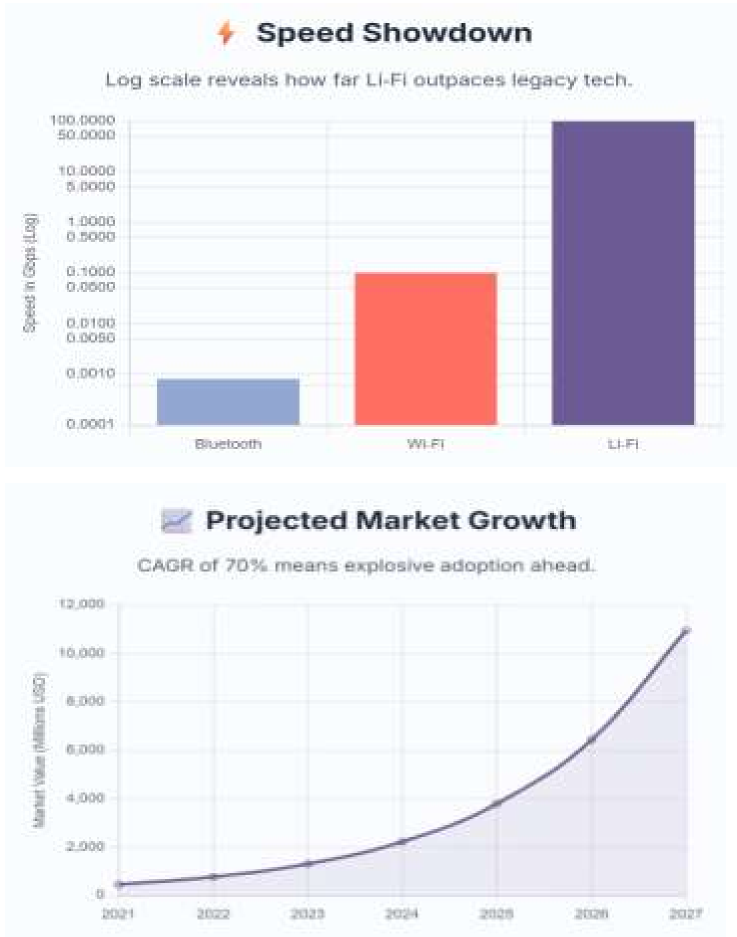

FIG-[4]project growth diagram

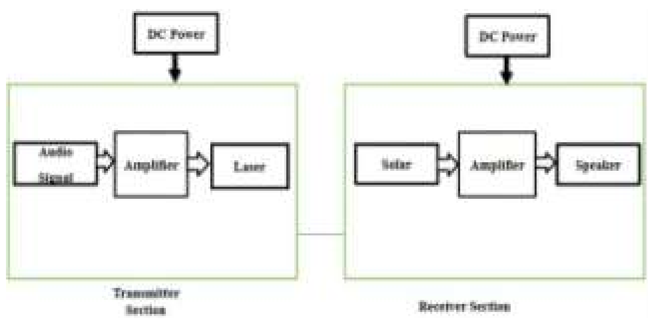

Fig-[5]Circuit Diagram

Li-Fi, or Light Fidelity, is an advanced wireless communication technology that uses visible light to transmit data, setting it apart from Wi-Fi's use of radio waves. This fundamental difference gives Li-Fi a significant advantage in speed and bandwidth; laboratory tests have shown speeds of up to 224 Gbps, and its use of the visible light spectrum provides 10,000 times more bandwidth than Wi-Fi. The technology's reliance on light also provides enhanced security, as the signal cannot pass through walls. This makes Li-Fi ideal for high-security and high-density environments like hospitals and airplanes. The market for this technology is experiencing rapid growth, with projections estimating a rise from $434.4 million in 2023 to over $7.7 billion by 2030, driven by a strong Compound Annual Growth Rate.

Fig[5] – Demonstartion of project

The project successfully demonstrates an analog Li-Fi system that transmits audio wirelessly using a laser diode transmitter and a solar panel receiver. The system is a low-cost, easy-to-replicate model, designed to be an educational tool for understanding the core principles of light-based communication. It proved to be resilient to electromagnetic interference, a significant advantage over traditional radio frequency systems like Wi-Fi. The system's main limitation is its reliance on a direct line of sight and a gradual decrease in signal strength over long distances. The project's key achievement is its ability to bypass electromagnetic interference, making it a viable solution for secure and specialized environments. While the analog system has limitations, such as a reliance on a direct line of sight and a decrease in signal strength over distance, it serves as a strong proof of concept and a foundational educational tool for future advancements in light-based communication.

Conclusion:-

These methods are able to recognize The"Li Fi Based Wireless Audio Transmission System"project successfully demonstrates the core principles of Li-Fi technology by creating a functional, analog audio transmission system. By using a laser diode to modulate the audio signal and a solar panel for reception, the students proved that light can serve as a secure and reliable medium for communication, free from the electromagnetic interference that plagues Wi- Fi and Bluetooth. The project's findings highlight both the potential and current limitations of this approach. While it effectively transmitted audio, the system requires a direct line of sight and shows a decrease in signal strength over distance, as seen in the provided graphs. However, the system's resilience to electromagnetic interference and its low-cost, replicable design make it a valuable educational tool and a solid proof of concept. Looking forward, this foundational work provides a clear path for future enhancements, such as transitioning to digital modulation to enable higher data rates and incorporating error correction to improve long-range performance. Ultimately, this research contributes to the broader goal of developing Li-Fi into a viable, high- speed, and secure communication standard for specialized environments.

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