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Data Transmission using Li-Fi Technology

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ABSTRACT: Light Fidelity (Li-Fi) technology for transmitting audio signal through Visible Light Communication (VLC). Unlike conventional wireless systems such as Bluetooth and Wi-Fi, which face limitations related to cost, security concerns, and higher power usage, Li-Fi employs visible light to achieve faster and more secure data transfer. Utilizing LEDs as transmitters, the proposed system offers a vast increase in bandwidth and can operate effectively in areas where radio frequency transmission is restricted. The research presents the development of a prototype capable of real-time audio broadcasting, demonstrating how illumination and light source distribution influence communication quality within an indoor environment, thereby highlighting the potential of VLC in enhancing wireless data transmission.

KEYWORDS: Light Fidelity (Li-Fi), Visible Light Communication (VLC)

I. INTRODUCTION

Wireless communication like Wi-Fi , Bluetooth uses radio wave frequencies for transmitting data, which supports finite bandwidth due to confined spectrum availability. The solution for this issue is possible with Visible Light Communication(VLC). It will be an affordable/cheaper way to transmit data at light speed.The idea behind the visible light communication/LiFi is transmission of ‘Data through illumination’. The light intensity can be varied according to the distance between sender and receiver.The light used in VLC is between 780-375 nanometres. Most modern VLC implementations are digital, but early uses included pre-radio transmission of sound by modulated sunlight in the photophone invented by Alexander Graham Bell in the 1880s. Although radio frequency is more commonly used for communications, VLC has several advantages over the invisible frequencies of radio. VLC offers very low latency and high bandwidth while radio has limited spectrum and potential for cross talk and interference than VLC.

Li-Fi is an implementation of wireless networking that uses VLC. Although VLC technologies have been historically uncommon, the draw of light-based communication is strengthening as the proliferation of wireless devices increases and radiowave's limited spectrum becomes more crowded. In IoT VLC technology is being used as a communication method to connect millions of consumer electronics and machine-to-machine (M2M) devices cost-effectively.

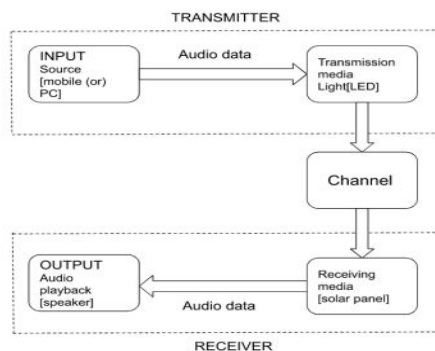


Figure 1: Block diagram of signal/data transmission system

In this method of transmitting data referring to Figure 1, called Li-Fi by light waves instead of radio waves.A light-emitting diode (LED) is a semiconductor device that generates light when current flows through it. White light is used



as it reflects all wavelengths and it is having equal intensity at low-end as well as high-end of the spectrum. Hence using LED, a setup consisting of transmitting and a receiving end is made then the implementation of Li-Fi technology is done for a small distance to understand the concept of the technology and the variation of light intensity with the transmitted sound is being measured and the distance is taken as a parameter which affects the quality of data transmission which can be measured and analysed.

II. RELATED WORK

This section provides an overview of different techniques and applications of Li-Fi (Light Fidelity) and VLC (Visible Light Communication) technologies. Each study employs distinct methodologies and hardware components to demonstrate the capabilities and advantages of light-based data transmission systems.

S. H. Ali, et.al.,[1], displays research on the Li-Fi dongles that are used to send audio and music files. The Common-Emitter amplifier circuit is also used to demonstrate the transmission range, demonstrating how the light intensity varies with the required transmission distance and how the data is received by speakers powered by solar cells. Additionally demonstrates the reliance on LED light can create their own arrangement and use it for personal purposes at home or the business. used mobile applications to assess the intensity.

S. S, et.al.,[2], research into Visible Light Communication (VLC), a form of Li-Fi technology that creates a light spectrum that is ten thousand times broader than radio frequencies. The audio jack that connects to the phone, the resistors that light the LED, and the power supply are all connected. The quality of audio transmission up to the wavelength range of commercially available LEDs is demonstrated and appropriately implemented, demonstrating the safer transmission. The light from the LED is only available there and cannot be accessed by anyone from outside, showing the safer transmission.

K. Hocaoglu, A. Adar, et.al.,[3], a prototype Visible Light Communication/LiFi system that can play music and videos is used for its design. The video is divided at the transmitter before being transferred to the HDMI-AV converter, which turns the digital video into analogue audio signals for the left and right channels as well as the Composite Video Baseband Signal (CVBS)

D. Samudika et.al.,[4], assesses and puts into practise two stereo audio streaming prototypes, namely MP3 and Pulse Code Modulation streaming. The streaming server searches the media file that contains the audio stream to find its index. Audio readings are assembled after being packetized. The USB to serial interface receives the compiled frame after which sent over the VLC channel to the client. Results demonstrate that an error-free channel was produced using just one optical lens and no correction.

X. Jiang, H. Gao et.al.,[5], LEDs, resistors, capacitors, and transistors are used to build VLC system. An oscilloscope waveform is measured in order to provide the main experiment data, which is used to examine the performance of audio signals during transmission. The system's maximum transmission distance is 2 metres, and the waveform is obtained at the receiving end after the electric signal is supplied and sent into the loudspeaker. The gain is nearly the same from 30 Hz to 10 kHz. This demonstrates that the model's sound signal is conveyed with higher quality range.

A. Baklanov et.al.,[6], BC337 transistors are being used in research on data transmission using VLC technology. A few frequency studies including signal distortion and noise level were conducted. The study looked at the data dependence of light signals on distance. Thus, it implies that it is preferable to use a conventional LED with an embedded microcontroller for a high-quality audio signal when using the TDA1010. The experiment was conducted in a dimly lit room with no natural light. Therefore, the distance is anticipated to rise by about 40 times with a lamp power of 40 W, and a ceiling height of 2.5 to 3.5 metres will be ideal for data transmission.

Dileep reddy bolla et.al.,[7], Explains the audio transmission where the audio signal is transmitted using a mobile transmitter which transmits analog signal, text to speech conversion. The navigation system with Li-Fi receiver is used to receive data for indoor navigation for visually impaired and also showed that the area covered is directly proportional to the number of users present. The comparative study of data rates compared to other means of communication is also shown.

Y.K Cheong et.al.,[8], evaluates and implements a VLC system in a hospital setting that transmits biological data using already-installed white LED bulbs. The LED is installed in a PCB with On-Off Keying (OOK). The VLC



transmitter module uses a microcontroller, and the needed data is stored in a PC database. Without the use of collimating lenses, it was discovered that the system could transmit data at a rate of 56 kbps and with BER quality of 10^{-6} at a distance of half a metre.

Pradeep Kumar Sharma et.al.,[9] Integrated EH-WSN and IoT are used to construct the proposed communication model. It is a hybrid network-based EH-HL concept for smart homes that enables efficient device-to-device communication inside a secure setting. Units for modulation and demodulation are crucial to communication. MATLAB is employed as a source of programming for simulation-related reasons. Indoor simulation study was conducted, and variables like colour emission, receiver position, and field of view were measured. The outcome demonstrates that the system is reliable and effective for users with many access points and that bidirectional multi-access hybrid communication is possible.

R Mahendran et.al.,[10] Using lighting, visible light technology is used for communication. An ARM microcontroller is utilised in the system, which uses serial communication as a source and transmits data serially at baud rates. The most popular 32-bit embedded microprocessor with an image compression and decompression method is the ARM7TDMI core. Any type of data, including images, is transformed to binary bits of 0s and 1s and sent serially to the receiver component. Receiving digital data and decoding it into an original image is the aim of the receiver portion. The data rate, which is greater than radio waves, is discovered to be 100 gbps.

Nami Susan Kurian et.al.,[11] The primary objective of this proposed system is to develop an environmentally friendly monitoring solution for industrial settings, leveraging visible light technology to ensure secure data transmission, high transfer speeds, and a pollution-free environment. To build a dependable prototype, components such as an Atmega microcontroller, Arduino in the transmission section, and the ADXL335 accelerometer are incorporated. The Arduino UNO Atmega328, which features 6 analog inputs, 14 digital I/O pins, and operates at 5 volts, receives data from a photodetector in the receiver module and transmits it to the Arduino UNO. This system functions independently of internet connectivity, with LEDs used to represent data in binary form, facilitating effective environmental monitoring.

Soumyajit Chattarjee et.al.,[12] Due to its larger bandwidth, the communication will function as a replacement for Wi-Fi in this situation. Previously, Oledcomm created a ceiling light called LiFi-Max that provides internet connectivity to 16 users simultaneously at a speed of roughly 100Mbps. Here, the transmitter component will connect each Arduino Uno chip to an LED for transmitting and a PIN diode for receiving. Text input is converted to binary by the Arduino code, which then transfers data in packets of 6 or 7 bits. Text symbols are first transformed into ASCII and then into binary. It is received by a second Arduino Uno, translated to decimal form using ASCII, and then printed on the screen in text format.

S. Chergui et.al.,[13] analysed and researched the Li-Fi technology with the help of two Arduino boards. The Arduino was programmed to convert the text provided as ASCII code to bits and given to the led at the transmitter side and the Arduino at the receiver side. Each one is used as a transmitter and receiver. The transmitting side uses a powerful led to transmit the data, and the receiving side uses a photodiode to receiver. Coding and encryption method are used to protect the information sent as text. This prototype reaches a transmission distance of more than 2 metres without errors.

N garg et.al.,[14] A prototype was tested and a module was developed to show how a VLC link could be made between two computers to transfer data at a rate of 300 bits per second with a coverage of 2 metres. The module employed lasers for both downstream and upstream to maintain an equal data rate. This prototype can handle text, video, and audio data connection and connects devices to each other simply and plug-and-play. The software used to send data is entirely open-source, and the data is sent to the led using a USB port.

Igor L et.al.,[15] A transceiver device (STM Microcontroller) is used to send information and control the light intensity. This device was examined and created to share data between mobile devices utilising a mobile application. The module is connected to an ADC where the data is transformed. Two DACs are used, the first to feed data from the mobile device to the jack and the second to supply data from the transmitter to the receiver at the reception side.



Table 1: Comparison of different techniques used for data transmission

SL NO:	PROTOCOLS USED:	SOFTWARE USED:	PARAMETERS:	BEST PROTOCOL:	FURTHER WORK:
S. H. Ali, et.al.,[1]	Li-Fi dongle, CE Amplifier	Lux Meter App	Range of transmission, light intensity and voltage	CE Amplifier	Increasing range of communication
S. S, et.al.,[2]	Intensity modulation, Route error, AV-USB converter	-	Distance, brightness of LED, quality of audio	Route error	Communication link and real-time broadcasting of video, compensate for LED non-linearity
K.Hocaoğlu,A. Adar, et al.,[3]	HDMI–AV converter, Trans-impedance Amplifier (TIA),op-amp	-	Distance, Noise and Power	HDMI–AV converter	Realistic indoor space
D.Samudika et. al.,[4]	Pulse Code Modulation, On-Off Keying(OOK)	PCM streaming software	Audio quality, optical signal to noise ratio (OSNR), channel length	On-Off Keying(OOK)	Data rate increasing can increase error which can be reduced using algorithms.
X. Jiang, H. Gao et. al.,[5]	Fresnel lens, Amplifiers	-	Amplitude ratio and Distance	Direct coupling amplifier	Bandwidth expansion and optimized modulation coding
A.Baklanov et.al.,[6]	LM3861 chip, TDA1010A micro circuit, BPW34 photodiode	-	Amplitude, Distance and Frequency	-	Organising data network
Dileep reddy bolla et.al.,[7]	Arduino Nano microcontroller, USB Converter,	Python	Data Rate, Distance covered	Serial to USB converter	Application based data transfer
Y.K Cheong et.al.,[8]	On-Off Keying(OOK)	-	ECG values, Time	On-Off Keying(OOK)	Higher BER quality data transmission with maximum distance
Pradeep Kumar Sharma et.al.,[9]	Integrated EH-WSN model, EH-HL model	MATLAB	Data range, traffic, Distance, position, BER and SAR	EH-HL model	Multi-user hybrid communication and IoT device
R Mahendran et.al.,[10]	ARM7TDMI microcontroller,R	MATLAB	Range of transmission,	ARM7TDMI	Secure and fast data transfer



	S232		Data rate		
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III. METHODOLOGY

The transmitter and receiver pieces, as well as other materials listed in the design approach shown in Figure 2, are used to build the circuit. The transmitter also has an audio connector for connecting music from a phone to the LED as input data. The solar panel that receives the light from the LED converts it back into electrical energy. This electrical energy is then amplified in the amplification circuit, which is made up of capacitors, resistors, and an integrated circuit (IC), amplifying the signal received from the LED and sending it to the audio jack that is connected to the speaker, where the output is audible.



Figure 2:Circuit setup

In Figure 3, it can be seen that the circuit is installed in a dark space. This is done so that the data transmitted by the LED light will be properly recorded by the solar panel and not interfere with by outside light.

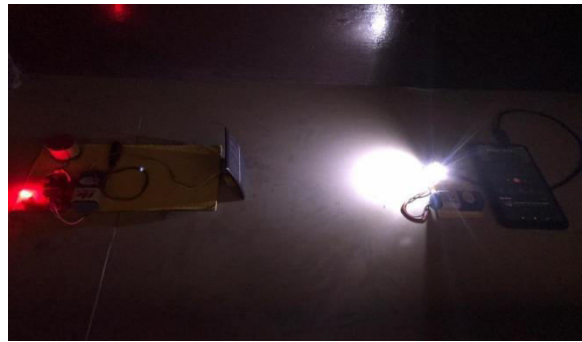


Figure 3:Circuit setup in dark room

The sound emitted by the speaker is measured by moving the LED closer at even intervals, and the values at that particular distance are measured with the sound obtained at that distance, as the data is transmitted using an app that aids in determining the intensity of light falling on the solar panel.

Utilizing Li-Fi technology, the audio data is successfully delivered with little interference from the outside world. By adding up the values for distance (in cm), light intensity (in LUX), and sound (in dB), and then plotting the graph, the range of transmission is determined.



Table 2: values of distance in cm for which the light intensity in lux, sound in dB is obtained

Distance in (cm)	Light intensity in (Lux)	Sound in(dB) or voice signal
65	5.7	17.1
60	6.0	23.7
55	6.2	23.8
50	6.8	25.4
45	7.3	27.5
40	8.8	27.5
35	11	32.6
30	15	33.4
25	22	36.8
20	26	37.9
15	32	42.9
10	62	51
5	130	54.5

Table 2 shows Values of distance, light intensity, sound obtained The Table 1 consists of experimental values obtained by performing the transmission of data by decreasing the distance between the transmitting end that transmits data which consists of light and the receiving end which consists of solar panel by 5 cm after every trail. As distance between the transmitter and the receiver is decreased the light intensity starts increasing and it increases rapidly when the distance is very less. Similarly, the sound obtained at the output also starts increasing as the distance is increased with the increase in the light intensity obtained at the output. It can also be observed that there is a rapid increase in light intensity when the light is nearer to the panel since light captured is more and external interference are much lesser.

The measured distance, intensity of sound and sound is plotted in a graph to understand the variations caused in the system:

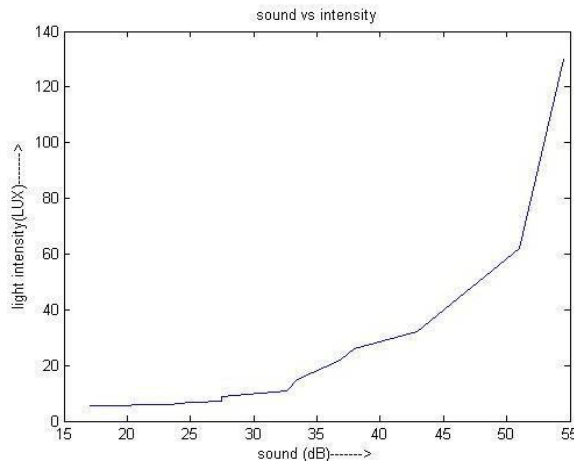


Figure 4: Sound vs Intensity



From Figure 4 it is clear that at the beginning of the transmission there is no much increase in the value of sound but after the increase in the intensity of light around 45 dB, there is an increase in the sound obtained at the output. After 50dB there is a linear increase in the value of intensity of light. Hence it can be concluded that the light intensity and sound are proportional to each other.

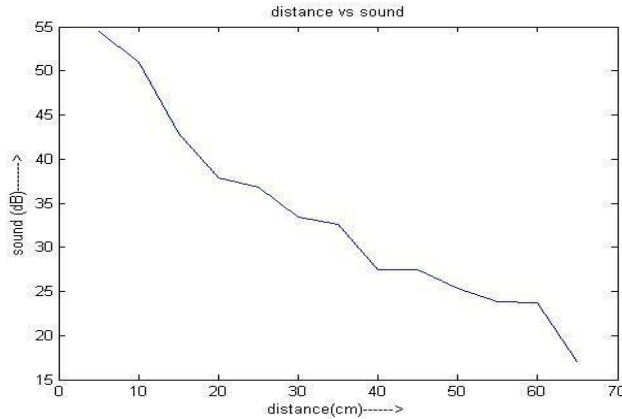


Figure 5:Distance vs Sound

From Figure 5 shows the transmission is highest when the panel is kept close by to the receiving solar panel. As the distance between the transmitter end and the receiver end is increased the graph drops indicating the decrease in sound obtained at the output. At the farthest point after 65 cm the sound obtained is least. Hence it can be concluded that the distance between the mediums and sound obtained are inversely proportional to each other.

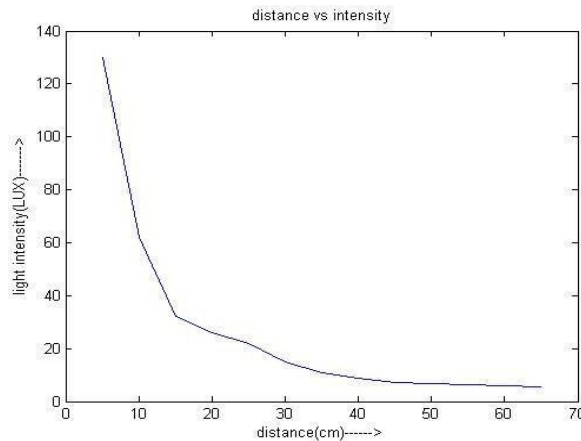


Figure 6:Distance vs Intensity

From Figure 6 it is clear that the light intensity is highest at a lesser distance and rapidly decreases as the distance between the transmitter end and the receiving end is increased. Hence it can be concluded that the distance and the light intensity are inversely proportional to each other.

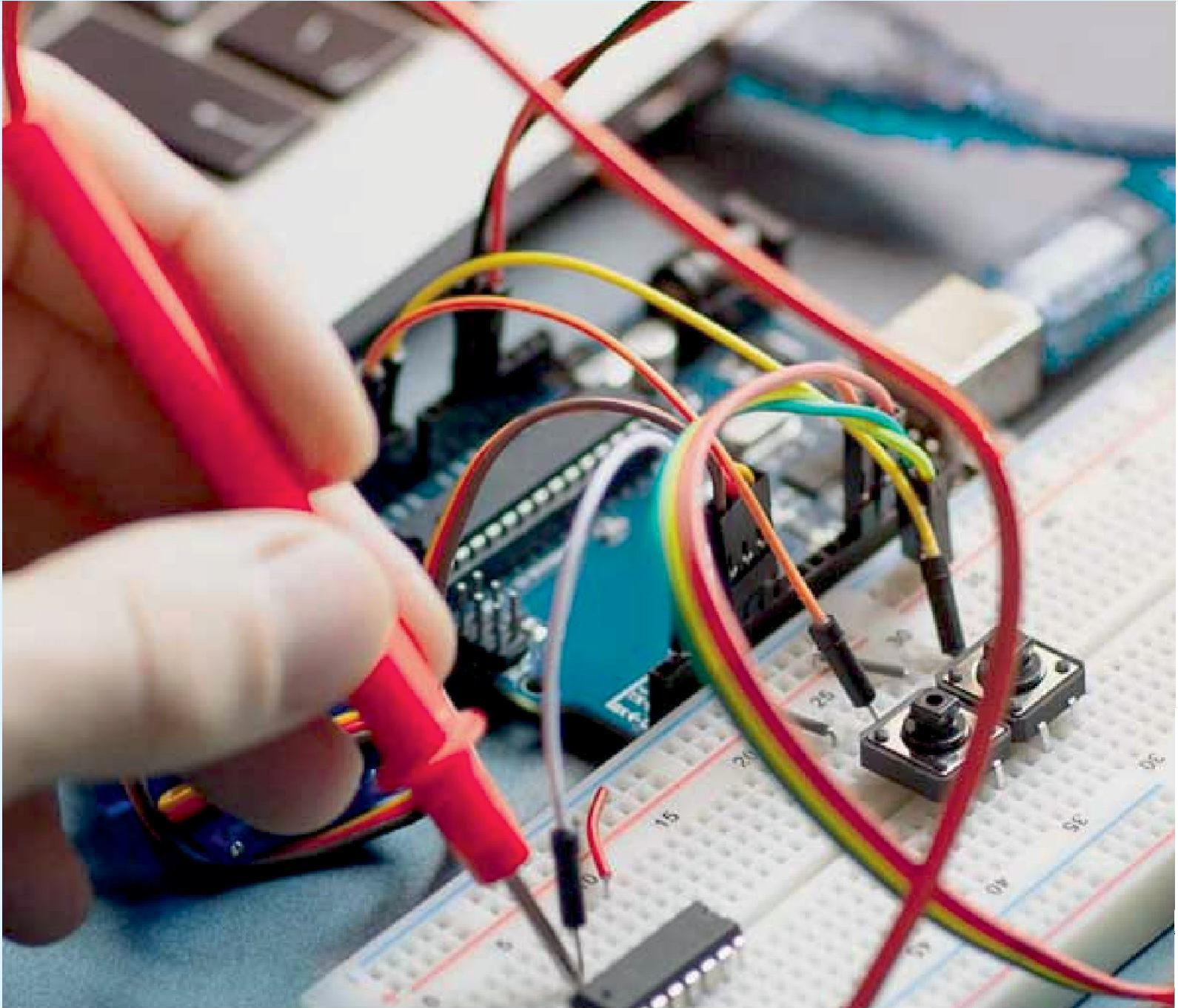
IV. CONCLUSION

A prototype designed for live audio streaming through LED lighting. The system works by transforming data into audio signals, allowing for clear and high-quality sound transfer within the range of standard LEDs in indoor settings with moderate ambient light. Proper focus adjustment between the transmitter and receiver enhances the transmission quality. The findings suggest that light is a promising medium for data exchange between devices, and future work could explore transmitting images and text by employing more advanced processing and coding methods. Overall, the research demonstrates that light-based communication can be an efficient and secure alternative for data transfer.



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