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Audio Transmission Using Visible Light Communication Technology with Pre-Equalization Technique

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Abstract: The Visible Light Communication (VLC) is the emerging technology that aims to offer high speed internet access in indoor environment. This technology basically uses intensity modulation of current lighting infrastructure, which is provided by Light Emitting Diodes. During the implementation of this technology there may be Inter Symbol Interference (ISI) and power loss in free space channel, in order to overcome this problem and to utilize white light spectrum fully for effective transmission of data several techniques are followed. In this paper, the pre-equalization technique is chosen and implemented for audio transmission. The Pre-equalization of data is performed using MATLAB 2022a Graphical User Interface (GUI) and then feed to designed real-time VLC system. Pre-equalization of audio data improves sound quality and maintained it throughout the transmitting distance which is in Line Of Sight. The optical power distribution of the signal at an indoor environment for chosen white LED for audio transmission is also observed.
Keywords: Life fidelity, Visible Light Communication, Audio transmission, Pre-equalization, White light source

I. INTRODUCTION

The concept behind VLC technology is the use of LEDs for both illumination and data transmission. Solid-state lighting's rising popularity, high brightness and longer lifespans compared to conventional light sources, high bandwidth, power efficiency, reliability, data security, absence of any health risks are the key forces behind this technology. A wide range of intriguing applications have been made possible by the dual functionality offered by VLC (i.e., lighting and data communication from the same high-brightness LEDs), including but not limited to networking in indoor environments like home, office, hospitals, aeroplane cabins, in-train etc., The visible light, also known as white light is the portion of the electromagnetic spectrum that can be seen by human eyes has a wavelength that varies from 375nm to 780nm. Unrestricted visible spectrum, high data rate, high security, human safety, energy efficiency, resistance to electromagnetic interference and simple infrastructure requirements are all major advantages of VLC.

For incandescent and gas-discharge lamps, precise dimming looks to be difficult, but with LEDs, it is quite easy to manage the level of dimming. This is due to the quick response time of the LED during on and off switch operation. Consequently, it is possible to turn on and off LEDs by modulating the driver current at a rather high frequency which is imperceptible to human eyes. As a result, an LED emits light in the form of a stream of pulses with a repeated high frequency and low average power [1]. So, depending on the situation, an LED or a semiconductor laser can be used as transmitter. For VLC application, LED is preferred over laser.

White light can be generated from LEDs in one of two ways, as seen below:

1) Converting blue light to white light via fluorescence using a blue LED with a phosphor coating (Phosphorescent white LED).
2) Using red, blue, and green LEDs in correct proportion to create white light.

In phosphorescent white LEDs, the modulation bandwidth is constrained to a few MHz due to phosphor's slow response. This bandwidth limiting effect of the phosphor coating must be overcome in order to attain large data rates [1]. Several methods are to be followed to achieve the higher data rates upto few Gbps. Namely, Blue filtering at the receiver to remove components that induce delayed response [1], Pre-equalization at the LED driving module [2], Post-equalization at the receiver [3], combination of the three aforementioned methods, the use of more intricate modulation techniques such as optical OFDM [4,5,6] or discrete multitone modulation are combined with multilevel modulation methods like Quadrature Amplitude Modulation (QAM) [7,8].

Among these methods pre-equalization technique is chosen and analyzed with real time audio transmission VLC system in this proposed paper.

The audio signal to be transmitted is equalized using MATLAB GUI and intensity modulated at transmitter side. This signal is then fed to white light source, which converts electrical data to optical data and sends to receiver by means of free space. At receiver side, the photo detector receives the data and convert it back to electrical signal. The electrical signal obtained is then amplified and fed to speaker. The equalizer used here is digital equalizer with frequency dependent parameter settings, in which the suppressed frequencies of an audio is boosted and then fed to source so that the audio received at output side is having improved sound quality.
This paper is organized as follows. In Section II, the experimental setup of VLC system for audio transmission is described. Section III discusses the circuit description of designed VLC system. Section IV described the working of system. In Section V, results observed from designed system and optical power distribution of LED used in the design is described and conclusion is given in Section VI.

II. EXPERIMENTAL SETUP

The Block diagram of VLC system for audio transmission is shown in Fig. 1. The setup consists of a transmitter, channel and a receiver. VLC uses white LED and the data is in audio form. The input is transmitted in free space which is just the air, an optical medium. For the transmission of data from transmitter to receiver, both transmitter and receiver must be in Line Of Sight (LOS), as LOS acts as the link between these two components without any physical contact. The receiver used here is solar panel of $70X70mm^2$. After reception of data, it is amplified using the amplifier that is designer with NPN transistor BC548 and then feed to speaker, which gives the transmitter audio.
An equalizer is designed using MATLAB 2022a Graphical User Interface. For equalization to be performed the data must be in digital form [9]. So, the audio in .mp3 format is converted to .wav format, which is the digital form. This format converted audio is then equalized by adjusting frequencies (i.e.,) the low frequencies are boosted thereby improving quality of signal. Fig.2 represents designed MATLAB GUI equalizer. Fig. 3 shows an equalized audio signal example.

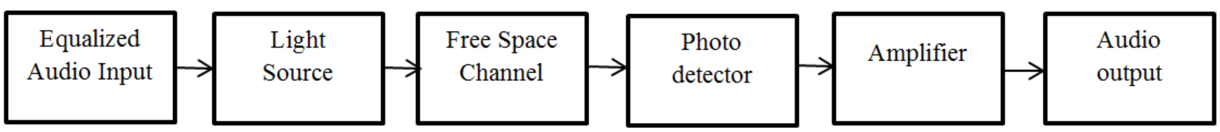

Fig.1 Block diagram of VLC system for audio transmission

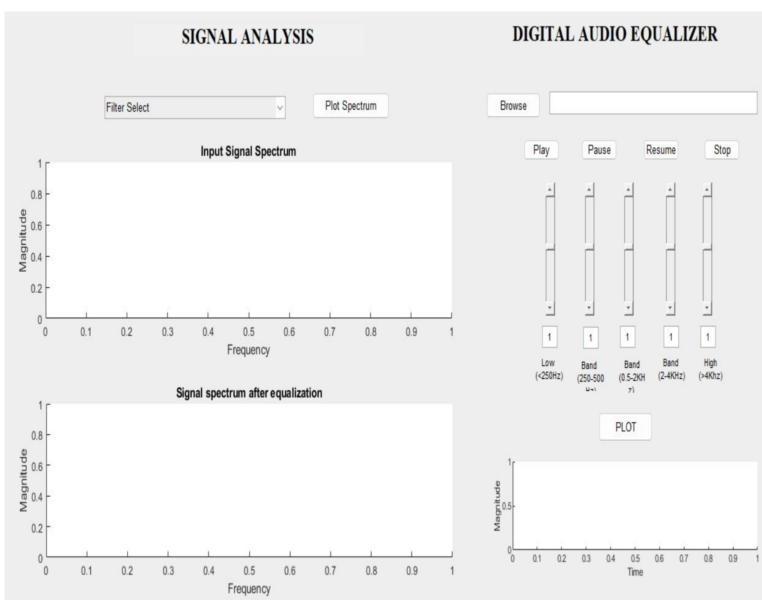

Fig. 2 Digital equalizer with frequency dependent parameter settings designed in MATLAB GUI

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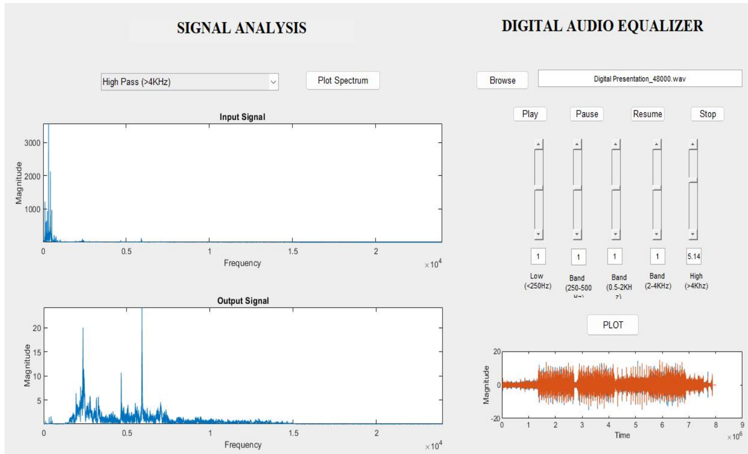

Fig. 3 Equalized audio signal example

III. CIRCUIT DESCRIPTION

Table I shows the specification for component used to design this VLC system. Fig. 4 and 5 represent the circuit of the designed VLC system for audio transmission and the setup of LED and Photo detector respectively.

A. Transmitter

1) The audio jack pin is connected to devices like Laptop/Mobile phones.
2) Red and blue wires of audio jack represents right and left audio respectively, both are connected to negative terminal of LED. Green or Copper colored wire of audio jack is ground which is connected to negative terminal of battery.
3) Positive terminal of battery and LED are connected together.

TABLE I
SPECIFICATION FOR COMPONENTS

Function performed	Componenet specification
Source	CREE 5000A LED Flashlight
To send input	Earphones jack 3.5mm
Power supply for light source	9V Battery
Photodetector	AMBERT 6v-100maH Solar Panel in Square Shape (70mm X 70mm)
Audio output	Speaker 8 ohm, 0.5W
Amplifier	BC548 or BC547 transistor - NPN

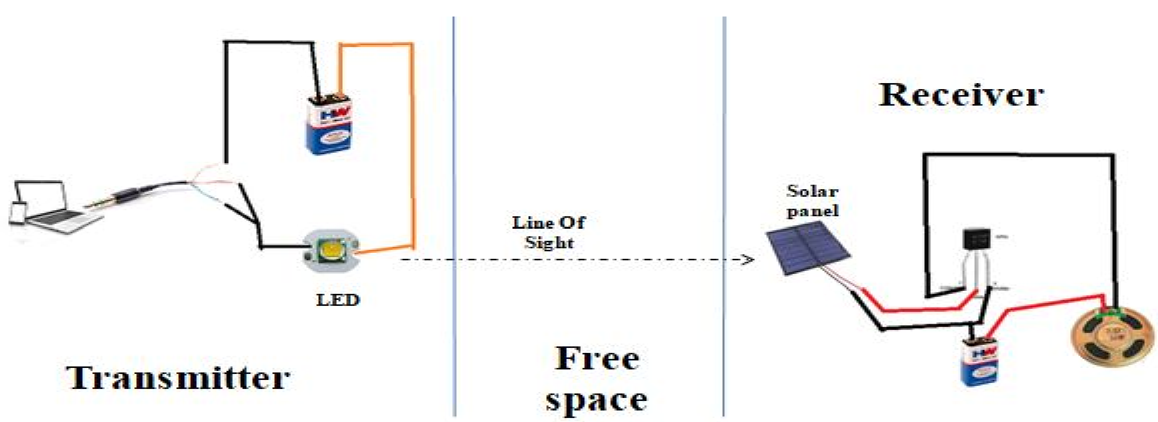

Fig. 4 Circuit of designed VLC system for audio transmission

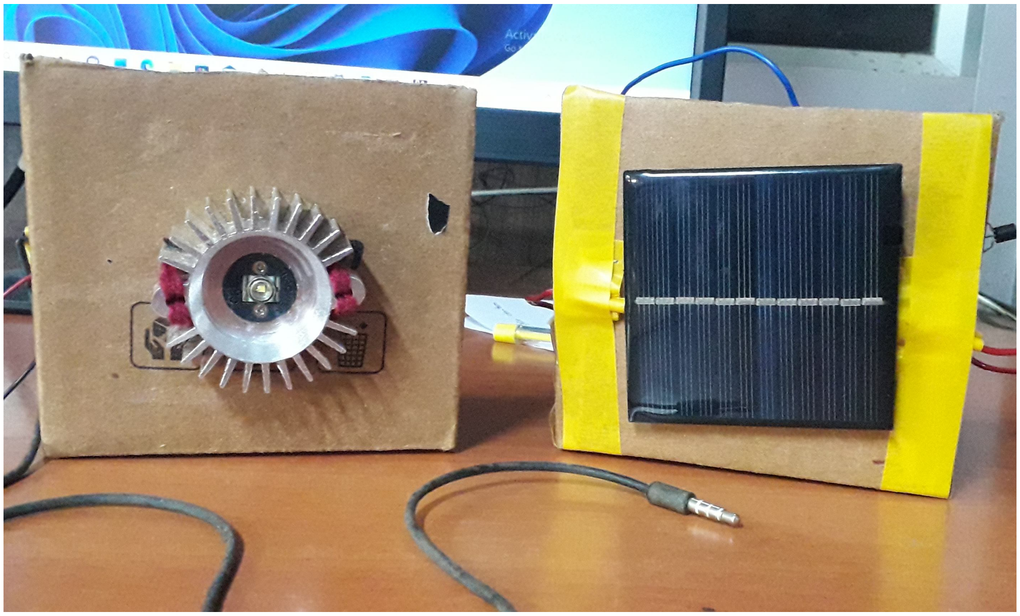

Fig. 5 Setupof LED and Photo detector

B. Channel

This system uses free space as a channel to transfer data from transmitter to receiver.

C. Receiver

1) The Positive terminal of solar panel that contains audio output is connected to base of the transistor. The transistor BC548 acts as amplifier. The amplifier needs power supply of 4V to 9V.
2) The negative terminal of solar panel and battery is connected to emitter of transistor.
3) Positive and negative terminal of speaker is connected to transistor's collector and battery's positive terminal respectively.

IV. WORKING

For working of the system following steps are to be followed:

1) At first, the designed audio system in MATLAB GUI is to be run manually.
2) Click browse option and select audio file.
3) Make sure that the audio file is in same path where MATLAB GUI code exists or add the full path of audio file in "select" option.
4) On clicking "play" button, the audio plays and then click "plot" button to observe time domain visualization.
5) Click "Plot spectrum" button to see frequency spectrum and then adjust frequencies of the audio signal.
6) Observe output spectrum, which boosts lower frequencies of input spectrum.
7) Feed the equalized audio signal via audio jack to White LED.
8) Make sure that the transmitter and receiver are in Line Of Sight.
9) By varying the distance between transmitter and receiver, observe how much distance the audio is transmitted.

V. OBSERVATION

While transmitting audio, a slight variation in the intensity of light is observed. This kind of variation represents the transmission of data through LED and it is due to changes in magnitude of signal. The signal transmitted is imperceptible to eyes. The designed system transmits data upto 2 meters without any beam focussing process. If the data is send without equalization, the sound of audio decreases as distance increases. After equalization the audio data's sound quality is good throughout the 2m distance.

The optical power distribution of light, if it is placed in centre of room is also observed using MATLAB coding, by using Lambertian radiation pattern assumption. Fig. 6 shows observed optical power distribution for 5X5X3 m^3 room environment. By using this, we can understand easily that power is more at the regions near LED and less at regions away from LED. If the photo detector is placed at floor, then there is no reception of signal. So, the detector must be placed atleast 0.85m above the floor.

If two or more LEDs are placed at a room, the overlapping of signals occur which leads to inter symbol interference. This overlapping is due to semiangle of LED. If semiangle is more, then the light is said to be more diverged. It is good for lighting and transmission of data too. But wherever more LEDs placed in a single room then fading of signal occurs in the region where two or more LED intensities got intersected. Only one LED in a room is also not a good choice, as it is not sufficient to meet the lighting requirements of a room. So, the receiver positions are to be examined or the pre-equalization technique is to be done in order to overcome fading and ISI that occurs in the signal. Also, the Field of View of detector must be high in order to collect the data effectively.

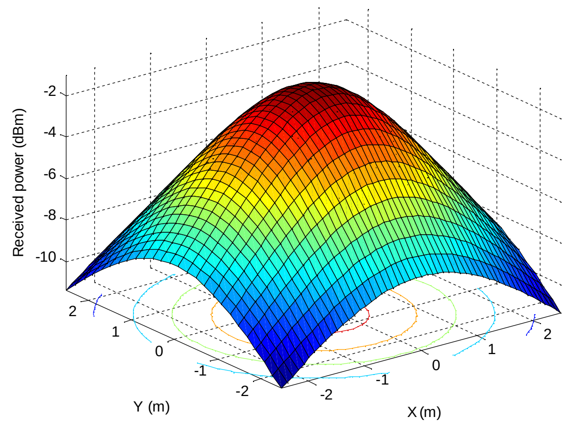

Fig. 6 Optical power distribution

VI. CONCLUSION

In this paper, the pre-equalization technique is tested with real-time VLC system for audio transmission. The designed system transmits data upto 2 meters without any beam focussing process. Whenever the data is send without equalization, the sound of audio decreases as distance increases.

After equalization the audio data’s sound quality is good throughout the 2m distance. The equalizer used here is digital equalizer with frequency dependent parameter settings designed using MATLAB 2022a GUI. The optical power distribution for a chosen LED is also observed using MATLAB code.

The currently designed system is simple one, as audio does not need much processing techniques. But transmission of an image and video needs more processing of data. So, the future scope of this research is to extend this research to image and video transmission using VLC system with pre-equalization techniques.

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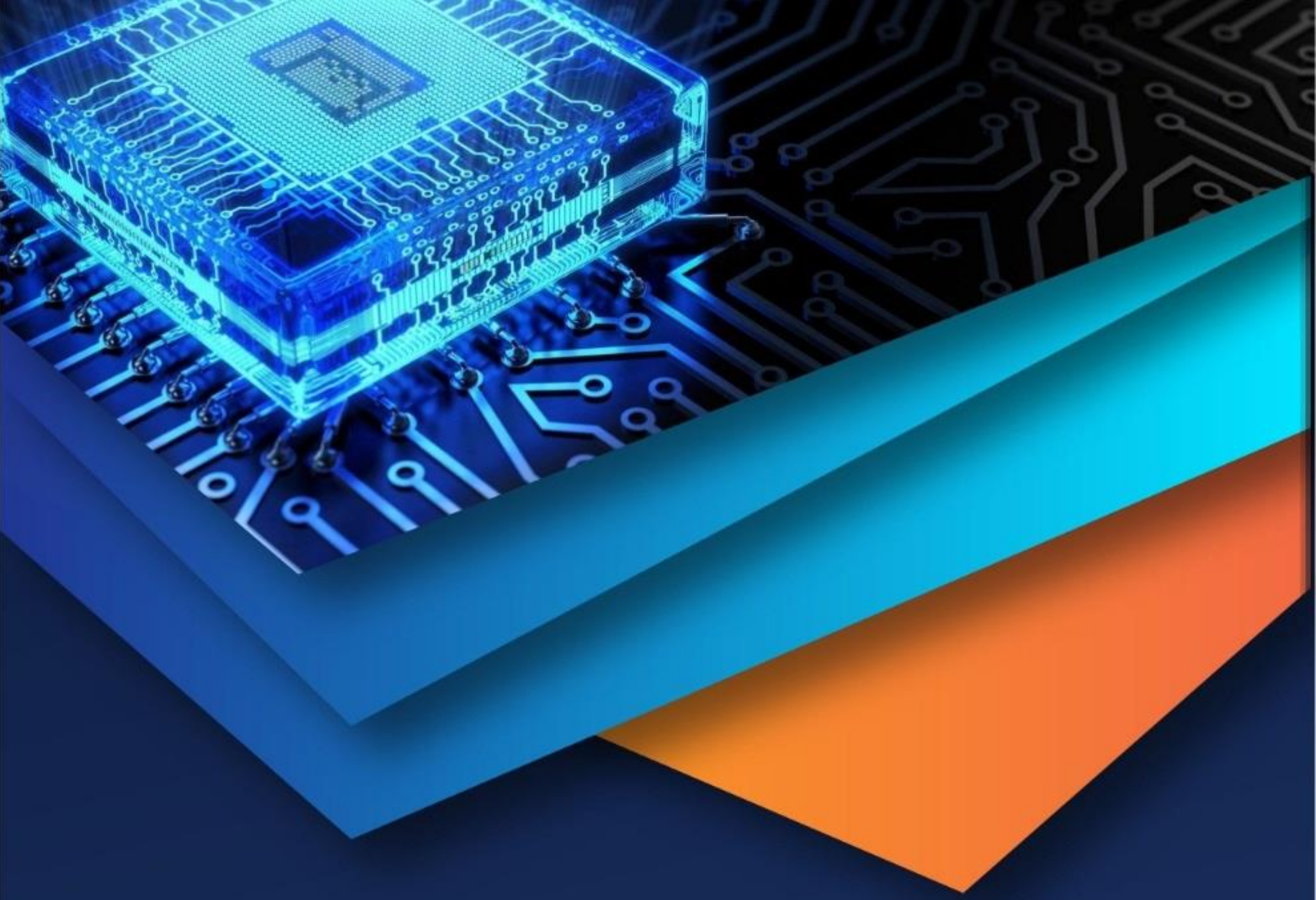

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