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AUDIO TRANSMISSION AND COMPARATIVE ANALYSIS OF DIFFERENT LED FOR VISIBLE LIGHT COMMUNICATION

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***Abstract*—Visible Light Communication (VLC) is an emerging technology which uses light source LEDs to transmit data. VLC uses 400 to 800 THz (780nm to 375nm) of frequency / wavelength. The comparison between different colors of LED was done by varying distance between the LEDs and Photodiode. The result from different LEDs were quite comparable to each other as wavelength varies with the variable distance between source and receiver. Results were compared in terms of voltage at receiver photodiode and waveform at oscilloscope for different color of LEDs. VLC was used for transmission of composite video signal.**

Keywords—Visible Light Communication (VLC), Light Emitting Diode (LED), Photodiode, Composite video.

I. INTRODUCTION

The history of visible light communication dates back to 1800s when Alexander Graham Bell invented phone, which transmitted speech on modulated sunlight over hundred meters. While the radio spectrum is limited, the demand for wireless data transmission system. Recently, visible light communication (VLC) has been proposed as an alternative means of wireless communication. The idea is to modulate LEDs transmitting electromagnetic waves in the visible light frequencies to communicate between devices within the same room.

Light has indeed been used for some time to transfer data. As everyday example is the infrared (invisible) light in remote controllers, used only send a short control signal. When data transfer is the main intension, the transmitting frequency must be very high, hence visible light will be perceived as a continuous light rather than an irritating flicker. Data transfer with light, VLC uses the same principles as the well-established fiber optical technology, but for wireless transmission.

Visible light communication (VLC) is an exciting prospect, with a long historical background, but have never become popular for various reasons. However, currently interest for this kind of communication is increasing, and the technology for making it possible is constantly become more easily available.

VLC uses the visible light spectrum between (400 to 800THz) as the communication medium. The transmission of data use LEDs, which is operate in high frequency so, human eye cannot perceive any difference in light compared to that when there is no modulation. As a result, VLC transmitters can used for lighting and data communication simultaneously. VLC receiver consists of photodiode either as standalone element or in the form of image sensor to receive information from varying lighting intensities.

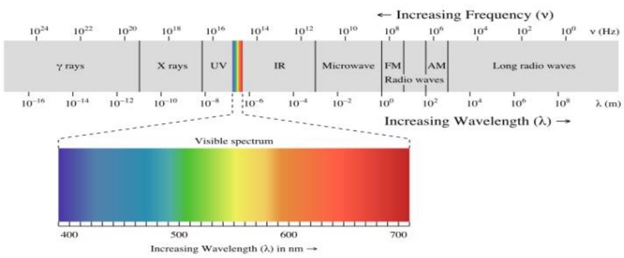

Figure 1: Visible spectrum

II. EASE OF USE

A. *Maintaining the Integrity of the Specifications*

while performing the experiment on transmission of audio signal using visible light, normal white LEDs and the easily available RGB LEDs were used. But there were other LEDs available which performed better and even on higher speed and provided with higher data rate with high intensity for long distance transmission. Hence normal LEDs were easily available to be used.

III. OBJECTIVE

- Audio signal transmission using LEDs.
- Comparison of performance between different colors of LED.

IV. Statement of Problem

The limited radio frequency spectrum puts constraints on increasing demand for ubiquitous connectivity a high capacity. The increase in the number of devices accessing the mobile networks is the primary reason for drastic increase in mobile traffic

Not only are most of the frequencies reserved, but also the cost to reserve a free spectrum can be used. There is low bandwidth problem in RF communication. As RF waves are available both in LOS and non-LOS regions of transmitter, it can be easily intruded by hackers and crucial personal/official data can be decoded for malicious motives. Uncontrolled radiation of RF affects health of public.

V. Literature Review

VLC is a data communications variant which uses visible light (780-350 nm). The technology uses a LEDs or a Fluorescent lamp to transmit the data which is then received by a photodiode. Various researches have been made on VLC to transmit audio and video signals. Some of them are mentioned below:

Parth H. Pathak, and et.al made a journal article on networking and sensing of the Visible Light Communication. On the survey, the possible challenges and potentials were evaluated. VLC needs LOS, which is the great challenge during communication [1]

Toshihiko Komine, and et.al published a paper on fundamentals of VLC using LED lights and also verified that the optical wireless system is more feasible than the radio as it is low cost and offers high bandwidth [2].

Harald Burchardt, and et.al made a report beyond point-to-point communication using VLC. In this system VLC has been introduced as a unique and viable alternative to RF indoor communication strategies [3].

Taner Cevik, and et.al published a journal article on overview of visible light communication. The paper explains the efficiency, durability and long-life span of LEDs.Furthermore LEDs consume less power during transmission of data [4] .

Pritpal Singh, and et.al published a journal paper on the methods of resolving traffic logjams by implementing VLC. The system can be implemented in the dashboards of all the vehicles where the front vehicle conveys information about the traffic system further [5].

Shek Sharuk, and et.al made a journal paper on broadcasting information using VLC. Light being a prominent method to convey information in range of line of sight. VLC is a fast data transmitter and consumes less power [6].

Fabian Harendran Jesuthasan, and et.al made a report about the impact of visible light communication for audio and video transmissions. The VLC is growing due to its high data rate, high bandwidth a secure medium as it doesn’t transmit through walls [7].

Simona Riurean, and et.al published a journal article about visible light communication for audio signals. Total radio frequency (RF) wireless data traffic exceeds 11 Exabyte per month, creating a 97% gap between the traffic demand per device and the available data traffic per device in the mobile networks. So Optical Wireless Communication has been established [8].

Alain Richard Ndjiongue, and et.al made an article report on VLC technology resenting the overall VLC communication system: The Transmitter, the receiver and the Channel. The LEDs used in transmitter, and the photodiode in the receiver section to communicate information [9].

Himank Kumawat, and et.al published a journal article about audio transmission using Visible Light Communication whose data transmission speed is higher as compared to other communication medium [10].

Carlos Medina, and et.al made a journal article on the basis of a survey implementing LED, where an overview of comparison of RF and VLC and future direction in the field of high-speed LED [11].

S.Poorna Pushkala, and et.al made a journal article about Li-Fi based high data rate which uses visible light portion of electromagnetic spectrum to transmit information. In this project the data and audio were transmitted through light [12].

Rama Krishnan, and et.al published a journal article on high speed communication using LEDs. Since LED sends the data faster, the communication is effective. Also the optical wireless communication is safer as compared to other communication system [13].

Lih Chieh Png made a research article on fully integrated audio, Video, and Data VLC transceiver system for Smartphones and tablets where real time video and pulse-position modulated stereo audio signals are transmitted via LED [14].

E. Fred Schubert, and et.al made a report on light emitting diode explaining the diode to be environmentally friendly and energy saver [15].

Alwain Poulose Palatty made a research article for his master’s degree in Technology in Communication System and confined that the VLC worked the same way as optical fiber [16].

Yuyang Tao, and et.al published a journal article on “scheduling for indoor visible light communication based on graph theory” which explained Visible Light Theories with optical fiber. LEDs transmit data using optical fiber communication system [17].

Yingjie He, and et.al published a journal article on real time audio-video transmission based on visible light communication which proposed a prototype of real time audio broadcast system [18].

Alain Richard Ndjiongue, and et.al made a research about Visible Light Communication in which the visible spectrum is modulated to transmit data. It presents the transmitter, receiver and the channel [19].

A Vinnarasi, and et.al made a journal article on Transmission of Data, Audio signal and text using LI-FI where the data is transmitted in several bit-streams through high speed flickering of LED bulb [20].

Harish Kalla, and et.al proposed a journal article on design of optical light communication system which studied about the effect of light wavelength on transmission efficiency using audio signals [21].

Sarah Monica, and et.al published a journal article on implementation of high-speed data transmission using VLC where LED is used for data transmission by switching it on and off [22].

A. PHOTODIODE [23]

A photodiode is a p-n junction diode that can absorb photons and generate either a photo voltage or free carrier that can produce photocurrent. They are used for detection of optical signal and for conversion of optical power to electrical power.

The figure shows a p-n junction diode with a heavily doped p-side. The donor concentration on the n-side of the junction is less than the accepter concentration on the p+ side. The p-layer is very thin and is formed on the front surface of the device by thermal diffusion or ion implementation on an n-type silicon. The active area is coated with an antireflection coating of material (like silicon nitride) so that most of the light falling in the device can be trapped by it. Metalized contacts provide the terminals.

Silicon is the most favored material for a photodiode. With a band gap of 1.1eV. Its peak sensitivity is in I.R between 800 to 950nm. The sensitivity drops at shorter wavelengths. For wavelength greater than 700 nm, the light gets absorbed in the p-layer before reaching the junction. Thus, in order to increase sensitivity at shorter wavelength, the width of the p-layer should be smaller.

As p-type region has an excess of hole and n-type region an excess of electrons, the holes diffuse towards n-side and electrons to the p-side in a built-in electric field gradient from n-side to p-side. The built electric field has a strength such that there is no further movement of charges through the depletion region. The depletion region extends well into the light doped n-side.

N_a per unit volume, equal amount of mobile carriers are annihilated from the two sides leaving fixed charges on the p+ and sides. The charge density distribution is as shown. The condition of charge neutrality requires

$$qN_a x_p = qN_a x_n \quad \ldots\ldots (1)$$

Where, q is the magnitude of electronic charge and $x_p$and x_n are respectively the widths of the depletion region in the p-side and n-side.
One can determine the electric field on both sides by using Gauss's law of electronics,

$$\nabla . \vec{E} = \rho/\epsilon_o k \quad \ldots\ldots (2)$$

Where k is the dielectric constant and p is the charge density.

For $< x < d + x_p$,$p = -N_a q$, so that

$$E(x) = \int_d^x \frac{\rho}{\epsilon_o k}\, dx = -\frac{N_a q}{\epsilon_o k}(x - d)(A) \ldots\ldots (3)$$

Where we have used,

$$E(x = d = 0), d + x_p < x < d + x_p + x_n , p = N_d q$$

$$E(x) = \frac{N_d\, q}{\epsilon_o k}(x - d - x_p - x_n)(B) \ldots\ldots (4)$$

The maximum magnitude of the field occurs at $x = d + x_p$ and is given by

$$E_g = -\frac{\text{q Na}\, x_p}{\varepsilon_o k} = -\frac{\text{q}\, N_d\, x_n}{\varepsilon_o k} \ldots\ldots (5)$$

The two expression above for ε_o are equal bye the condition of charge neutrality. The negative sign indicates that the direction of the electric field n side to the p side.

Built in potential:

One can obtain an expression for the potential drop across the junction by integrating the electric field

$$V = V(d + x_p + x_n) - V(d) = -\int_d^{d+x_p+x_n} E(x)dx \ldots (6)$$

To obtain

$$V = \frac{q}{2\varepsilon_o\, k}(N_a x_p^2 + N_d x_n^2)(C) \ldots\ldots (7)$$

A. THE VLC CHANNEL

One of the major requirements of VLC is direct line-of-sight (LOS) in case of outdoor like ITS. The emitted light from LED carries data information in wireless medium. Thus, the intensity of light of the emitter becomes an important parameter in which range of transmission depends. There are many external light noise sources such as Sun light. These are the major issues to be considered in link design. They deteriorate/deceive the intensity of emitter light and may cause false triggering of the photo diode. Optical filters, IR filter should be used to minimize this effect.

VI. METHODOLOGY

A. System Block Diagram

The transmission of audio as well as video signal in a VLC via LED includes various steps such as converting the audio file into (.WAV file), amplifying the signal having low strength, sending it via LED to photodiode and finally amplifying the received signal. These processes have been illustrated in below mentioned block diagrams and each module has been briefly described below:

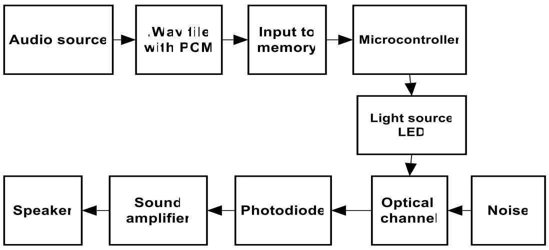

Figure 1: Block diagram of audio transmitter and receiver system

The above block diagram consists of Transmitter, Receiver and the channel part which have been briefly discussed below:

An audio transmitter module contains audio source which is in the form of digitally encode .wav file format. Then for the storage of such audio file we use micro SD card and using the SPI protocol. We use microcontroller as a master and micro SD card adapter as a slave device and the protocol is set up between master and slave and then the PWM output from the microcontroller is feed into LED whose amplitude vary as the data come from the PWM pin and the LED illuminate as audio amplitude.

And other side to receive the transmitted signal from LED we can use photodiode. Which detect the ON/OFF switching of LED as intensity vary the photodiode produce current respectively. Which is very week signal. So, we need to amplify it before further use. And then the received audio is listen using speaker.

VII. RESULTS

After the overall design, the system was tested by observing the respective waveforms of the input audio and video signal, amplified audio and video signal and the output audio and video signals in a digital oscilloscope as shown below:

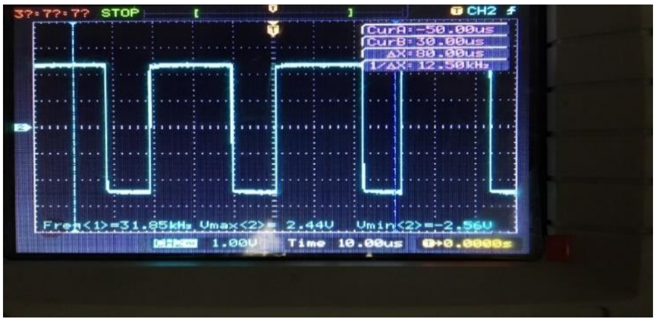

Figure 2: Audio input signal

The figure 2 was taken from oscilloscope which shows the audio signal that is to be transmitted using LED. The audio is first converted into digital audio file like (.WAV file) which is digitally encoded audio file. And requirement for the audio is to transmit using LED. And the LED is driven using PWM output from the Arduino which limits the sampling frequency of audio. So, the audio file must have following characteristic as audio file is mono type, PCM unsigned 8bit modulation type and 16000Hz sampling frequency.

Figure 3: Noise signal at photodiode

The figure 3 is the photodiode noise signal which is taken from the receiver module. When no data is transmitted from the transmitter module the sun light or surrounding or channel noise from the photodiode is as shown in figure above.

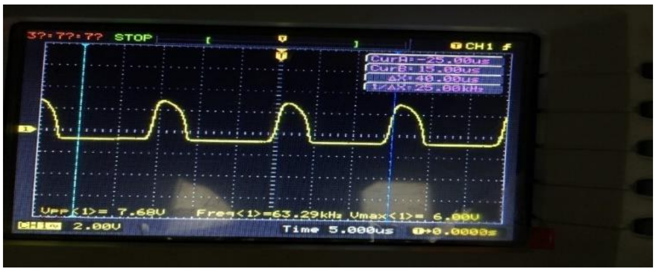

Figure 4: Received audio signal at photodiode

The figure 4 shows the received audio signal of photodiode which is then amplified to play using speaker. The amplifier used for audio signal amplification is LM386.

The received amplified audio signal output by varying the transmitter receiver distance was taken from oscilloscope as shown in figure 5:

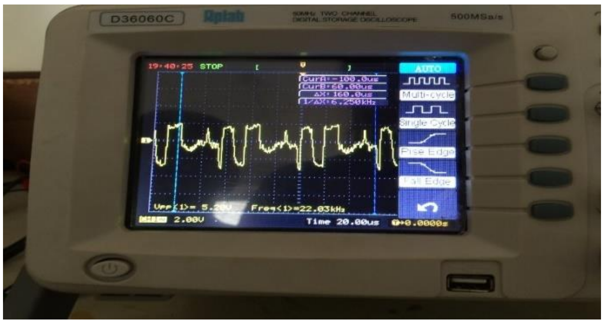

Figure 5: Amplified received audio output

The received analog audio signal is as shown in figure 5 which is the amplified output signal which is then fed into speaker to listen the audio sound. Same signal is distorted or noise is introduced by the day light so, the output signal is not same as the input signal. Here the distance between the transmitter and the receiver is quite close to each other.

The Table 1 and Table 2 is the test for different color led. Which tends to different wavelength of light source and different frequencies of Red, Green, Blue and white LEDs respectively. The data from short distance up to 10cm is same for all the LEDs. While amplitude decreases as distance between the LED and photodiode increases.

Table 1: V_{pp} at receiver side op-amp using oscilloscope

S.N	Distance (cm)	RED LED (Vpp)	GREEN LED (Vpp)	BLUE LED (Vpp)	WHITE LED (Vpp)
1	3	1.07	1.30	1.29	1.33
2	6	0.96	1.25	1.20	1.29
3	9	0.72	1.22	1.30	1.30
4	12	0.28	1.42	0.98	1.22
5	15	1.08	0.70	0.92	1.18
6	18	0.72	0.30	0.88	1.51
7	21	1.05	0.10	0.78	0.98
8	24	0.94	xxx	0.30	0.70
9	27	0.4	xxx	0.33	0.53
10	30	0.2	xxx	0.30	0.40

Table 2: RMS voltage at receiver op-amp

S.N	Distance (cm)	RED LED	GREEN LED	BLUE LED	WHITE LED
1	3	-0.35	0.24	0.5	0.25
2	6	0.14	0.21	0.24	0.21
3	9	0.15	0.17	0.16	0.20
4	12	0.10	0.15	0.04	0.22
5	15	0.11	0.19	0.10	0.19
6	18	0.28	0.02	0.15	0.17
7	21	0.19	0.01	0.10	0.15
8	24	0.09	xxx	0.19	0.13
9	27	0.19	xxx	0.20	0.19
10	30	0.18	xxx	0.10	0.10

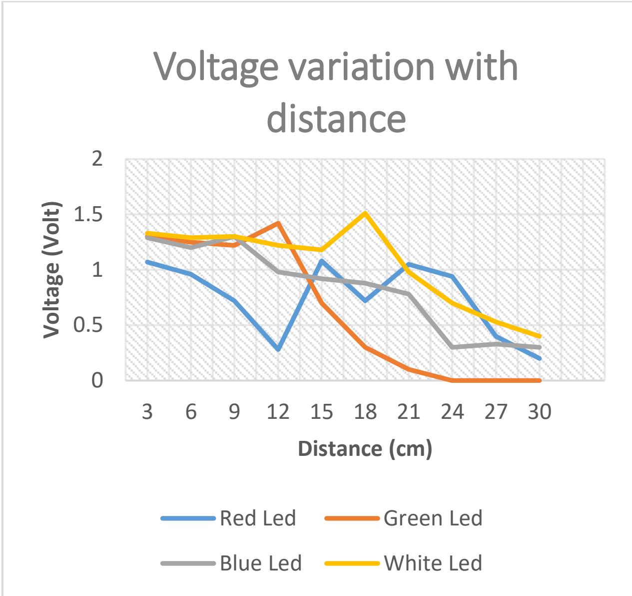

Figure 7: Showing peak-to-peak voltage variation with distance

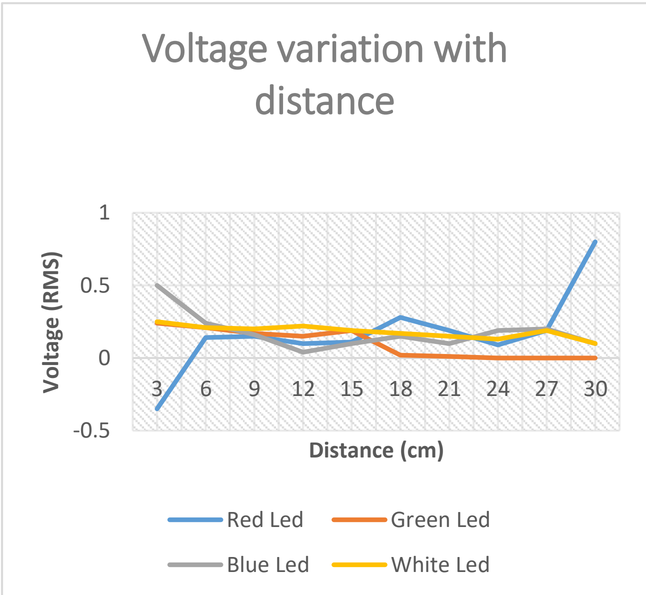

Figure 8: Showing RMS voltage variation with distance

VIII. LIMITATION

Even though Visible Light Communication uses light to transmit data and its data rate is high and more secure compared to RF communication but it has got certain limitations. Some of them are described below:

- The signals from the LED are absorbed by atmosphere at a great amount.
- It is interfered by background light sources like sunlight.
- Low intensity LED hampers in long range data transmission.
- Line of sight is required to transmit data.

IX. DISCUSSION

As the above experiment is about the transmission of audio signal using visible light communication. Then for the video transmission using LEDs is difficult because the video signal is very high frequency signal approx. 5 MHz to 10 MHz as for composite video signal and the peak to peak voltage of audio signal was 1V for composite video. As we were working with the LEDs. LEDs required minimum of 3.3V of voltage to fully operate. As we absorb the composite video signal peak to peak is 700mV so, we have to use suitable video amplifier with gain of at least 5 to obtain 3.5V to drive the LEDs and as a whole video signal were transmitted using LEDs. We must remember that the video amplifier should amplify video signal up to 10MHz.

In this way we can transmit composite video signal using LEDs and display it on a analog TV as well.

X. CONCLUSION

Hence it has come to the conclusion that the audio transmission using different color LEDs has been successfully done. The desire audio signal have been transmitted through LEDs. The voltage of audio signal displayed through an oscilloscope. The performance of different color of LEDs were absorbed in terms of sound quality in a speaker.

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