
ABSTRACT

Since two decades wireless transmission technology is providing more compatibility to the end users. In coming future omnipresence of LEDs, visible light transmission by using free space is more advantage than radio frequency communication due to its less power consumption, high bandwidth capacity and security. The present study is aimed to design the optical light communication system to transmit the stereo audio signals and studied the effect of light wavelength, distance and delay analysis on the output audio signals. Using the red, blue and white LEDs, the distance between the LED and photodiodes was measured and blue LED is shown the long distance compared to red and white LEDs to transmit the noiseless audio signals. The delay analysis is shown 100 ms time difference between transmitted and received signals. This paper is also shown the hardware setup of the designed system.

KEYWORDS: Delay analysis, Distance analysis, Optical light communication, Radio frequency, Visible light transmission.

INTRODUCTION

Light emitting diode (LED) technology, a rapid growing technology not only implementing in indoor lighting systems but also its research is focusing in development of optical light communication (OLC). LEDs are superior in long life mercury free, colour mixing, fast switching etc., when compare to more power consumption lights such as incandescent bulbs and fluorescent lamps. Due to its special advantage i.e., their light output can be modulated with high-frequency signals, LEDs are used for wireless optical communications, which is also called optical light communication [1-2]. Nowadays, OLC has becoming as a significant tool for future indoor wireless communication because of the following advantages like long life, unregulated huge bandwidth and not causing electromagnetic interference [2]. A part from the indoor wireless communications, OLC technology can also be applied in outdoor wireless optical communications [3-4] and other application such as the VLC between a traffic light and a vehicle [5].

The major advantage of LEDs is their easy and progressive construction illumination and because of those LEDs are using in various applications. LEDs are safe when compared to radio frequency that enhances their utility in different ways [6]. Hence OLC is an important tool for short distances and medium bandwidth applications in cramped spaces like aircraft cabins, hospitals, coal mines, fuel stations, and chemical research labs where the application of radio frequency communication is complicated. In urban areas, people spend most of their time indoors, so OLC technology is most useful for indoor wireless communication systems.

The present research is aimed to design and construct the OLC system to transmit stereo audio signals up to the distance of one meter approximately. In this study, the effect of light wavelength on the transmission efficacy using different colour LEDs. From the back ground of following research on VLC systems, the present study was developed. Grantham Pang *et al.*, described the different audio signals are broadcasting by using VLC rays on/off technique achieved the distance 40 cm without lens and 200cm with lens [7]. In a study developed by Do KY Son *Et Al.*, transmitted the digital audio signals using the Sony/Philips Digital Interconnect Format with 192 KHz sampling, 24-bit resolution with distance with 100 cm by using VLC [8]. Stefan Schmid *et al.*, implemented VLC extension device

to transmit the wireless signals by using mobile phone internal audio signal processor to encode and decode the light signals [9]. Sung-Man Kim *et al.*, developed the half-duplex VLC using an led as both a transmitter and a receiver using different colour LEDs [10].

From the above existed backgrounds, the practical issues will be described in system viewpoint with the recent developments and research results. The characteristics of an LED source are explained in Section 2. The OLC system audio transmitter and receiver block diagram is explained in section 3. OLC transmitter and the OLC receiver are described in section 4 and 5. Section 6 is about OLC audio noise filter.

CHARACTERISTICS OF LEDS AND PHOTODIODE FOR AN OLC

The present study is used the different colour LEDs to evaluate the effect on audio signals transmission efficacy. Three different colours of LEDs red, blue, white (RBW) are used for an OLC transmitter and a photodiode acts as a receiver. The output powers of the LEDs were measured to be 509 mw, 728 mw, 624 mw for the red, blue, and white LEDs respectively when 9 V was applied to the LEDs with a serial resistance of 220 Ω. The LEDs used in the experiment are generating a luminous flux of about red: 50 lm and blue: 30 lm at 350 mA bias currents with 140° lambertian emission. Figure -1 shown the spectra of the red, blue and white (RBW) colours of LEDs used in the experiment. The centre wavelengths of the RBW are 625 nm, 455 nm and white colour produce with combination of red, green and blue colour led wavelengths.

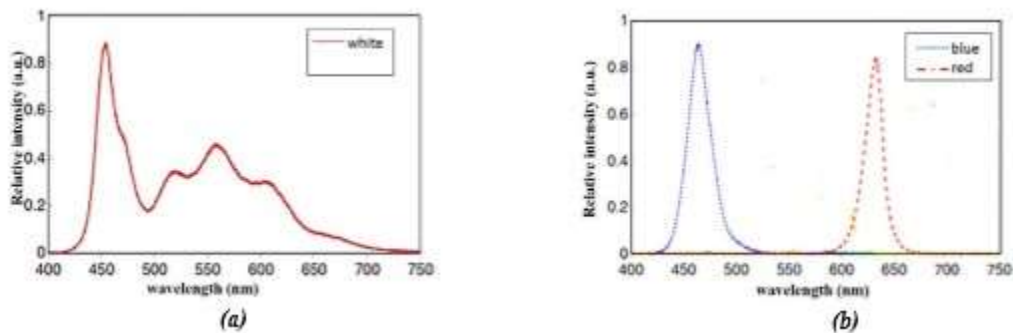


Figure 1. Spectra of two different colours of LEDs used in the experiment. [1] White LED (b) Red and blue LEDs.

PROPOSED VLC AUDIO SYSTEM DESIGN

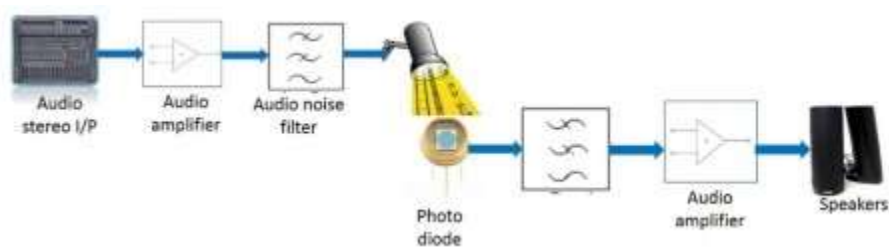


Figure 2. Block diagram of OLC stereo audio broadcasting system.

Figure 2 is explained the block diagram of OLC audio broadcasting system that consists of an optical wireless communication (OWC) based line of sight (LOS) link station. The LOS link between transmitters to receiver creates the wide channel bandwidth and high radiation power [11]. The detailed explanation is given as below:

VLC Transmitter

The schematic diagram of VLC transmitter for audio signals is shown in Figure 3. Using 3.5 mm audio jack plug, audio signals were captured from sources like computer, laptop or audio player. Then the audio signals were amplified and converted into stereo format with the help of dual audio power amplifier with very low quiescent current and low crossover distortion. The left channel audio input is applied to the amplifier pin-6 and the right channel audio input is applied to the pin-7 through R and C of first and second built in amplifier. To control the volume in left and right channels correspondingly, RV1 and RV2 potentiometers were used as the volume controllers. From the pin 1 and pin 3 of audio amplifier, the audio signals were obtained for driving the left and right channels. Then the output stereo audio signals were fed to the audio noise filter to remove the noise and C7 is act as the power supply filter capacitor. Then the resistor capacitor branch is connected across LED to improve the high frequency stability and to prevent the oscillations. Finally the output audio signals were superimposed onto a LED circuit. The output light rays intensity is changed according to the variation of audio signals. A Reflection cup is mounted on LED for the purpose of gaining high line of sight.

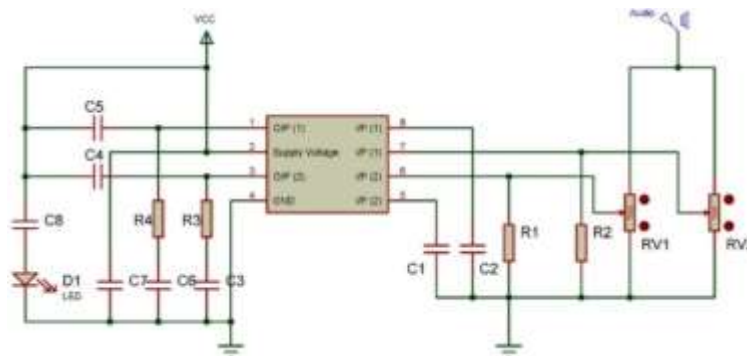


Figure 3. Schematic diagram of OLC stereo audio transmitter.

VLC Receiver

A highly sensitive Si PIN photodiodes (PD) were act as the receiver, to detect light transmitted over an optical channel. The position of PD is aligned properly to receive the most intense portion of the emitted light beams.

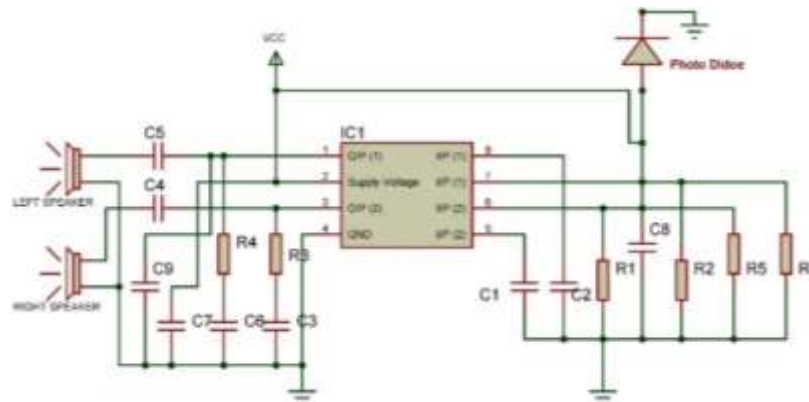


Figure 4. Schematic diagram of OLC stereo audio receiver.

Then the detected light signals were converted into electric current that is proportional to the variation of incident light. Due to the random variations in the current it needs to amplify before the signals delivered into the speakers, which then is amplified by using stereo audio power amplifier and filtered by audio noise filter. The resistor capacitor branch connected across speakers to improve the high frequency stability and also to prevent the oscillations. Finally, the audio is played on 8 ohm computer speakers. In the prototype, transmission distance of nearly one meter can be achieved without any light focusing lens.

Audio noise filter

The audio noise filter is a band pass filter for audio frequency band that placed before the LEDs and speakers to filter unnecessary signals that are further than the audio frequencies. The band pass filter characteristics can be changed by altering the value of the capacitor and resistors. To raise the bottom cut off frequency, C6 and C7 values were reduced and increased them to lower the bottom cut off frequency. In case of the top cut off frequency, use values R3 and R4 values like above.

ANALYSIS AND RESULTS

Distance analysis

In the present study, distance analysis was carried to explain the effect of LEDs colour i.e., wavelength on the transmission efficiency of audio signals. In this experiment, figure 5 shown hardware setup of the different wavelengths of LEDs i.e., red, blue and white were used and measured the distance between transmitter and receiver to gain noiseless output audio signals. Figure 6 shown the maximum vertical distance of transmitter with red, blue and white LEDs versus receiver output voltage. 100 mv voltage is taken as the standard i.e., minimum value to get the clear audio signals. Then using the different LEDs (different wavelengths), calculated the distance that gave 100 mv voltage to photodiode.



Figure 5. Experimental setup for OLC based stereo audio system.

From the results, the red colour LED, due to its high wavelength (620-630 nm) and luminous intensity (20-50 lm) produced the clear audio signals up to 100 cm without noise. After this point, sound is decreased proportionally by increasing the distance. But using red LED, photodiode received the audio signals up to 2.5 meters with less audio sound. In case of blue LED, that has 460-470 nm wavelength and 10-30 lm luminous intensity, it produced the clear audio signals up to 150 cm without noise but received up to 3 meters with less audio sound. But it was found to be 70 cm and 2.5 meters distance to produce the clear audio signals and noise audio with white LEDs. Hence among the three LEDs, blue LED was shown the long distance to transmit the clear audio signals.

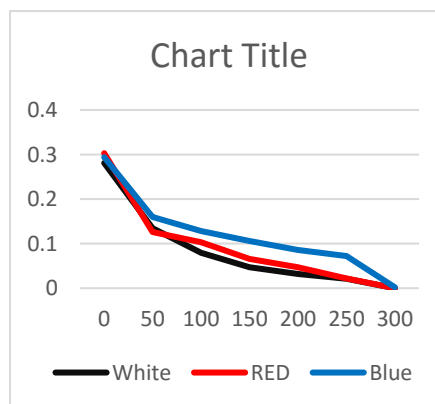


Figure 6. Vertical distance of transmitter with different LEDs Vs receiver output voltage graph.

Delay analysis

Delay analysis was performed in this experiment to find if any delay in the signal receiving from LED transmitter to speakers. Figure 6 is shown the signal comparison between transmitter and its corresponding speaker through audio amplifier transformation at the speed of 192 kHz. From the above Figure, yellow colored audio signal signified the transmitted audio signal while the blue colored audio signal showed the regenerated stereo audio signals at the destination speaker. The Figure 6 also shown the similarity in two signals has almost the same shapes. In comparison of both signals, it was found only 100 ms time difference between the transmitted and received signals. The hardware setup was given in Figure 5 and both the channels have the same time delay from their original signals, respectively.

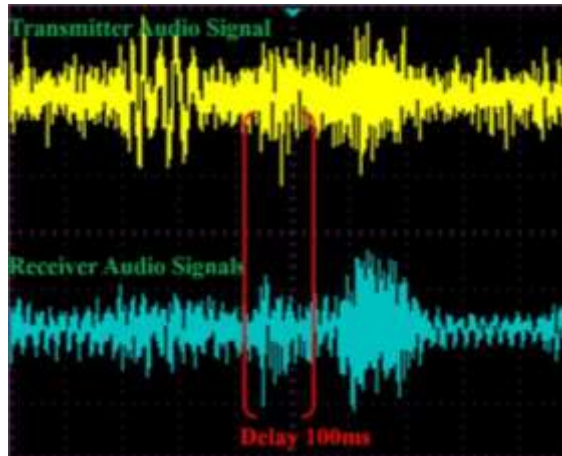


Figure 7. Delay time between transmitter and receiver audio signals.

CONCLUSION

An attempt was made to design and construct the optical light communication system to transmit the stereo type audio signals from the audio source to speakers. In this design, the commercial LED lamps were used to transmit the data and audio signals that received by photodiode receiver. This experiment is mainly designed to study effect of LED wavelength on the transmission efficiency to gain the noiseless audio. Different wavelengths of LEDs i.e., red, blue and white were used and measured the distance between transmitter and receiver and from the experimental results, blue LED was shown the long distance (150 cm) to transmit the clear audio signals. From the delay analysis, it was found only 100 ms time difference between the transmitted and received signals. Thus the proposed OLC system can be used efficiently for wireless optical transmission of audio signals between any kinds of devices.

REFERENCES

- [2] Jovicic A, Li J, Richardson T, “Visible light communication: opportunities, challenges and the path to market” in IEEE Communication Magazine, Vol. 51, No. 12, 2013, pp .26–32.
- [3] Kim S-M, Kim S-M, “Wireless visible light communication technology using optical beamforming”, in Optical Engineering, vol 52, No. 10, 2013.
- [4] Zhou X, Zhang D, Yang Y, Obaidat MS, “Network-coded multiple-source cooperation aided relaying for free-space optical transmission”, in International Journal of Communication Systems vol. 25, pp.1465–1478, 2012.
- [5] Rashed ANZ, “High efficiency wireless optical links in high transmission speed wireless optical communication networks”, International Journal of Communication Systems, Article first published online: 29 May 2013. DOI: 10.1002/dac.2550.
- [6] Cui K, Chen G, X Zhengyuan, Roberts RD, “Traffic light to vehicle visible light communication channel characterization”, Applied Optics vol. 51, no. 27, pp. 6594-6605, 2012.
- [7] Chow CW, Yeh CH, Liu YF, Liu Y, “Improved modulation speed of LED visible light communication system integrated to main electricity network”, Electronics Letters vol 47, no. 15, pp.867–868, 2011.
- [8] Pang, G. ; Ho, K.-L. ;Kwan, T. ; Yang, E, “Visible Light Communication for Audio Systems” in IEEE Transactions on Consumer Electronics, vol. 45, No. 4, Nov 1999.

- [9] Do Ky Son ; Dept. of Electron. Eng., Chosun Univ., Gwangju, South Korea ; Eun Byeol Cho ; Chung Ghiu Lee, “Demonstration of visible light communication link for audio and video transmission”, Published in: Photonics Global Conference (PGC), 2010; 14-16 Dec 2010, Page: 1 – 4.
- [10] Schmid, S. ; Dept. of Comput. Sci., ETH Zurich, Zurich, Switzerland; Schwyn, D. ; Aksit, K. ; Corbellini, G., “From sound to sight: Using audio processing to enable visible light communication”, Globecom Workshops (GC Wkshps), 2014, 8-12 Dec. 2014,Page: 518 – 523.
- [11] Sung-Man Kim and Hyun-Jun Lee, Half-duplex visible light communication using an LED as both a transmitter and a receiver; INTERNATIONAL JOURNAL OF COMMUNICATION SYSTEMS Int. J. Commun. Syst. (2015) Published online in Wiley Online Library (wileyonlinelibrary.com).
- [12] J. M. Kahn and J. R. Barry, “Wireless Infrared Communications,” Proceedings of the IEEE, vol. 85, no. 2, pp. 265–298, Feb. 1997.