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Visible light communication using LED as receiver with the effect of ambient light

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Abstract An indoor wireless communication using LED as both transmitter and receiver is presented in this paper. Ambient light noise from natural and artificial sources, would easily saturate the LED acting as sensor and decrease the indoor VLC system performance. Hence the receiver structure is designed using RC high pass filter to mitigate the ambient light noise. The measurement results shows that it could effectively reduce noise and improve the VLC system's stability and reliability.

Keywords Ambient light noise · Light emitting diode · Transmitter · Receiver · Visible light communication

1 Introduction

Recent advancements in solid state electronic devices such as a light emitting diode (LED) have triggered the possibility of illumination along with communication which is popularly known as a Visible Light Communication system (VLC). This technology can be used to save lots of energy wasted in Wi-Fi, as radio frequency (RF) can be used for communication purpose only not illumination purpose. Moreover, VLC offers advantages such as high security, hazardless to human health because of electromagnetic wave, huge amount of unregulated bandwidth and license-free (Komine and Nakagawa 2003; Pathak et al. 2015; Dhatchayeny et al. 2015; Cheong et al. 2013). VLC is standardized by the Institute of Electrical and Electronics Engineers (IEEE) (IEEE Standards Association, IEEE Standard for Local and metropolitan area networks—Part 15.7: Short-Range Wireless

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Optical Communication Using Visible Light (IEEE std 802.15.7) 2011). Visible Light Communications Consortium (2008), Japan carried out an initial research on visible light communication. Now Asia, Europe, Wireless World Research Forum is also working in VLC research (Wireless World Research Forum http://www.wireless-world-research.org).

Usually in VLC systems, LED is used as optical transmitter and photodiode as optical receiver. On the other hand, if LED can be replaced by photodiode it can act as transmitter as well as receiver. The different colors of LED as photo sensor is also analyzed.

In Kim and Lee (2015), a half-duplex VLC system using LED as both transmitter and receiver are implemented. White-to-white LED VLC system is implemented for the data rate of 200b/s and the distance achieved between the transmitter and receiver was 10 cm. Blue-to-green LED VLC system is implemented for the distance of 50 cm. However, the effect of ambient light noise is not investigated. The receiver is also not designed to mitigate the ambient light noise and retrieval of the input signal.

In Varanva and Prasad (2013), red-to-red LED VLC system is implemented in the frequency of 1 kHz and the distance achieved between the transmitter and receiver was 7.6 cm. However, the receiver structure consists of only LED as receiver circuit and the circuit to reduce ambient light noise is not considered.

In Varanva and Prasad (2013), red-to-red LED VLC system is implemented in the frequency of 500 Hz, 3 kHz and the distance achieved between the transmitter and receiver was 7.6 cm. However, the receiver structure consists of only LED as receiver circuit and ambient noise reduction circuit nor the input signal recovery circuit is not designed.

In this work, the digital signal is transmitted using red-to-red LED VLC system. Next, the performance of this system is evaluated under ambient light conditions. Experimental results show that the ambient light affects the performance of the communication system. Hence an RC high pass filter is designed to mitigate the noise. After successful transmission and reception of digital signal, audio signal transmission in the red-to-red LED VLC system is also implemented.

This research paper is organized as follows; Sect. 2, describes characteristics of LED as VLC receiver. Section 3, VLC system using red LED as transmitter and receiver discussed; Sect. 4, describes the audio signal transmission in the red-to-red LED VLC system. Conclusion of the paper is presented in Sect. 5.

2 LED characteristics as VLC receiver

The LEDs used in the experiment are King bright WP710A-red, white, green, blue and orange mode, which can be purchased at a low price. The viewing angle of LEDs is 30° and diameter of LEDs is 3 mm. Table 1 shows the different colour LEDs with the photo sensing properties. The voltage across the LED is taken when light is thrown into it. The

Table 1 Different color LEDs with the photo sensing properties

Emitter/Receiver	Red	Orange	Green	Blue	White
Red	940	240	10	0	0
Orange	410	240	0	0	0
Green	110	100	70	0	0
Blue	30	20	560	28	5
White	130	100	30	20	6

investigation results reveal the VLC signal can be received only when the receiver LED colour is equal or longer than the transmitter LED colour. As shown in the table different colour LEDs have different properties, where red LED (TX) to red LED (Rx) show better performance. The voltage is measured by connecting anode to voltmeter and cathode to ground. It should be noted these values are for sensing purpose only.

- All the values are in milli-volt (mV)
- Distance between TX and RX is 12.7 cm
- Performed in normal room light condition

Figure 1 shows the frequency response when the red LED is used as a transmitter and a red LED is used as receiver. We will express this case as 'red-to-red LED VLC'.

In Fig. 1 it is observed that red-to-red LED operates up to 1 kHz or more.

3 VLC system using red LED as transmitter and receiver

From Table 1 it is confirmed that LED can also be used as VLC receiver. A simplex red-to-red LED VLC system, is demonstrated. Figure 2 shows the block diagram of VLC system using LED as receiver and Fig. 3 shows the circuit diagram of red-to-red LED VLC system.

Specifications of red LED as both transmitter as well as receiver is explained in Table 2.

VLC system has a transmitter which takes the digital data in the form of visible light. LED is modulated using OOK(On–Off keying). Line of sight (LOS) channel model is considered between transmitter and receiver. The receiver module mainly consists of red

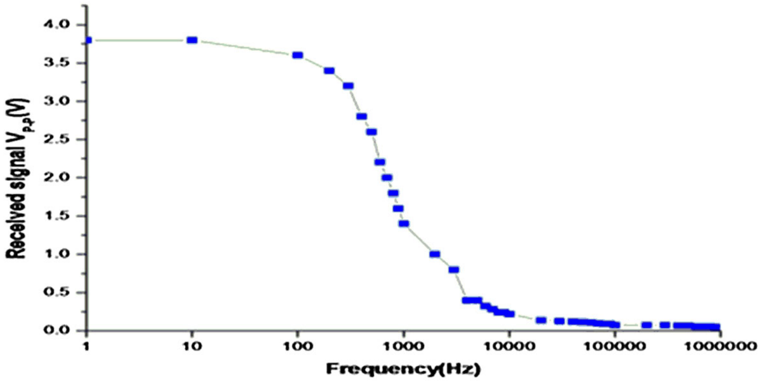

Fig. 1 Frequency response of red-to-red LED VLC system

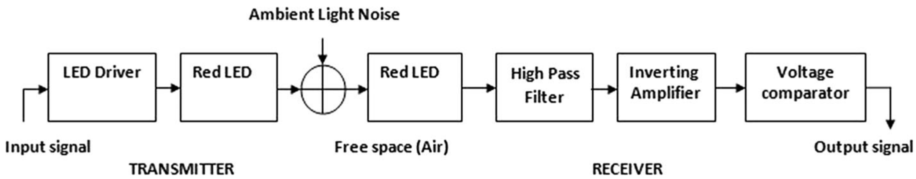

Fig. 2 Block diagram of VLC system using LED as both transmitter and receiver

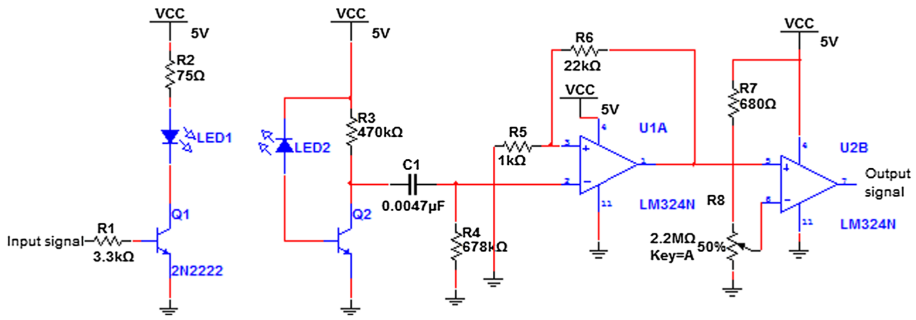

Fig. 3 Circuit diagram of red-to-red LED VLC system

Table 2 Specifications of red LED as both transmitter as well as receiver

Parameter	Value
Model	King bright WP710A10LSECK/J3
Viewing angle	34°
Forward current	2 mA
luminous intensity	0.55 Candela[cd]

LED and signal conditioning devices. The optical signal received at the red LED as receiver is interfere with ambient light noise. Hence high pass filter with a cut-off frequency of 50 Hz is used to reduce the noise. After filtration stage, the signal is amplified using inverting amplifier. Voltage comparator is used to convert the amplified data signal into digital data signal.

3.1 Experimentation and results

The proposed VLC system consists of red LED acting as both transmitter and receiver. Ambient light noise due to indirect sunlight and fluorescent light is a major concern that affects the performance of the communication system. Hence, the RC high pass filter is used to reduce the noise. Thus the transmitted signal is recovered back at the receiver with the reduced ambient light noise. The experimentation was performed inside the optical laboratory of B.S. Abdur Rahman University, which is considered as an indoor VLC system. The experimentation is carried out at the data rate of 1 Kbps and the communication distance of 12.7 cm is considered between the transmitter and receiver. The analyses of observations are discussed in the succeeding section.

This proposed VLC system consists of transmitter where the digital signal is transmitted via a red LED and the electrical signal is converted into an optical signal. Figure 4 shows the time-domain waveform the input electrical signal. The optical signal is transmitted via air as the free space medium and the optical signal is detected by the red LED as a sensor. Figure 5 shows the time-domain waveform of the received LED signal. The output signal retrieved from the LED suffers with the ambient light noise. The ambient sources of noise in the proposed VLC system include indirect sunlight and fluorescent light lamps operated by conventional ballast. Figure 6 shows the time-domain waveform of the ambient noise signal. Figure 7 shows the time-domain waveform of the high pass filter signal. Inverting amplifier is used to amplify the weak signal to the signal of appropriate amplitude of the

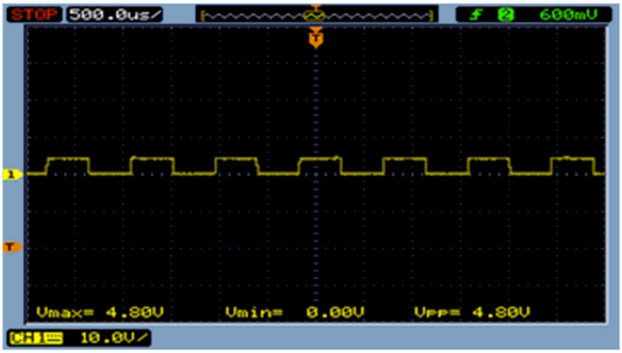

Fig. 4 Time-domain waveform of input signal

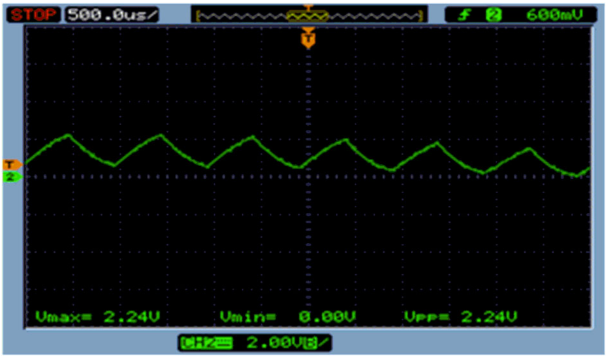

Fig. 5 Time domain waveform of received LED signal

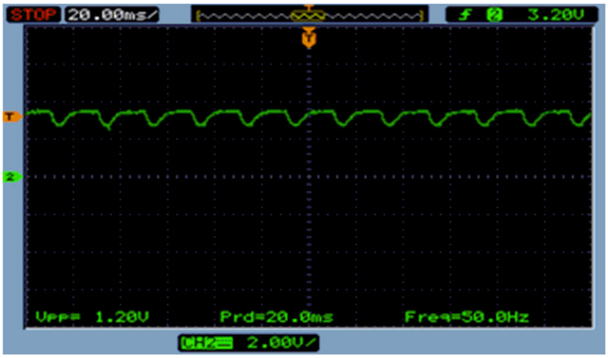

Fig. 6 Time-domain waveform of ambient noise signal

input signal. Figure 8 shows the time-domain waveform of inverting amplifier signal. The amplified signal is converted to digital signal using voltage comparator. Figure 9 shows the time-domain waveform of voltage comparator signal. Thus the transmitted signal is recovered back in the receiver side. The experimental test bench of the proposed VLC system is shown in Fig. 10.

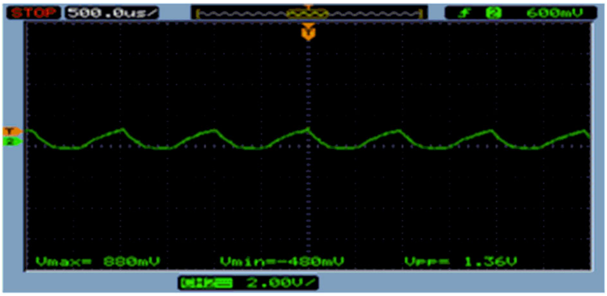

Fig. 7 Time-domain waveform of high pass filter (HPF) signal

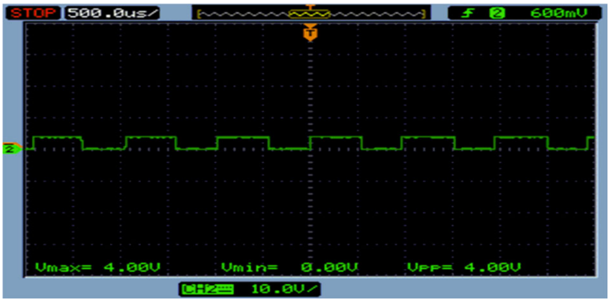

Fig. 8 Time domain waveform of inverting amplifier signal

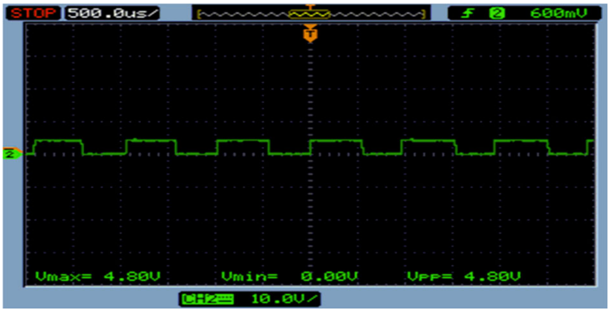

Fig. 9 Time domain waveform of recovered output signal

Figure 11 shows the graph of the output voltage produced in the receiver LED for the different vertical distance between the transmitter and receiver up to 12.7 cm.

It is observed from the Fig. 11, the output voltage is inversely proportional to the communication distance between the transmitter and receiver.

4 Audio signal transmission in red-to-red LED VLC system

Figure 12 shows the block diagram of our proposed audio transmission in VLC system using LED as receiver.

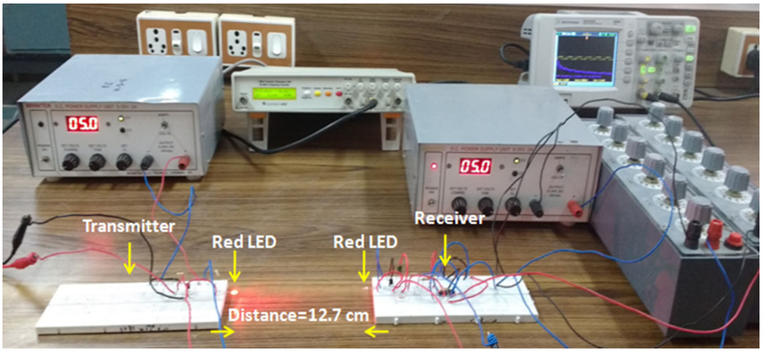

Fig. 10 Experimental test bench of the proposed VLC system using LED as receiver

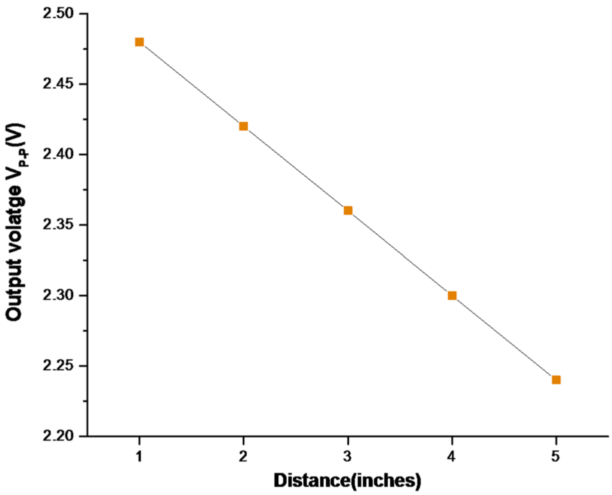

Fig. 11 The graph of the vertical distance between transmitter and receiver versus output voltage produced in the receiver LED

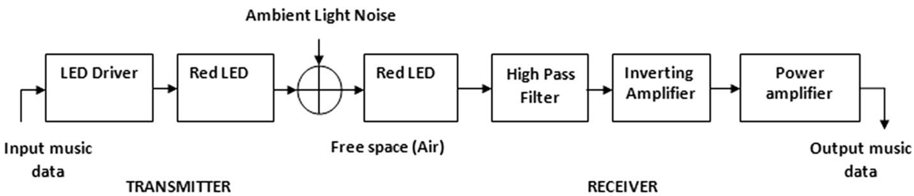

Fig. 12 Block diagram of our proposed audio transmission VLC system using LED as receiver

4.1 Experimentation and results

The audio data transfer in VLC system consists of the transmitter, atmospheric channel and the receiver. The transmitter consists of standard 3.5 mm audio jack to supply the input of MP3 audio signal from laptop and 2N2222 transistor is used for transmitting the audio via a red LED which is driven by 5 V DC power supply. Figure 13 shows the time-domain waveform of the input music signal. Thus the electrical audio signals are converted into an optical signal using a red LED on the receiver side. The signal is transmitted via free space channel. The output signal received from the LED is very weak. Figure 14 shows the time-domain waveform of the received LED signal. The quality of the signal gets affected by the ambient light noise from indirect sunlight and fluorescent lamp driven by conventional ballast. Figure 15 shows the time-domain waveform and spectrum of the ambient light noise signal. An RC high pass filter with a cut-off frequency of 50 Hz is used to mitigate the ambient light noise. Figure 16 shows the time-domain waveform of the high pass filter

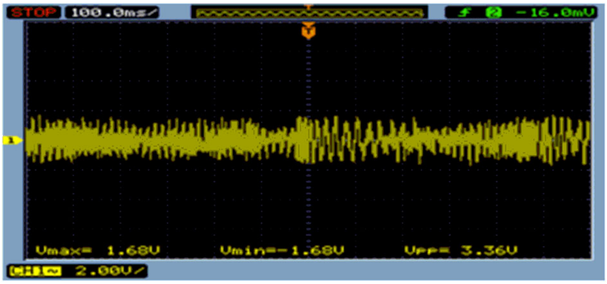

Fig. 13 Time-domain waveform of input music signal

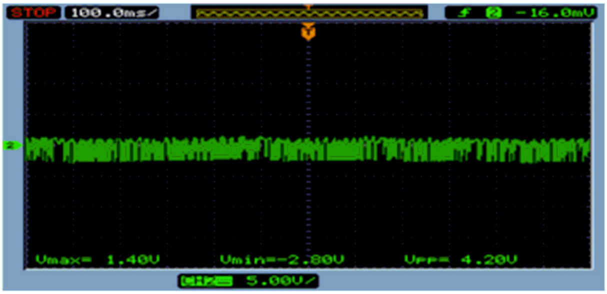

Fig. 14 Time-domain waveform of received LED signal

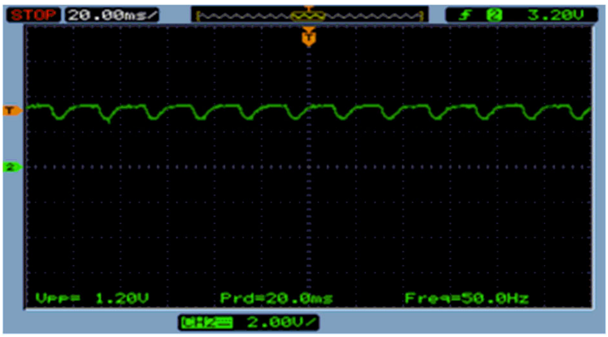

Fig. 15 Time-domain waveform of ambient noise signal

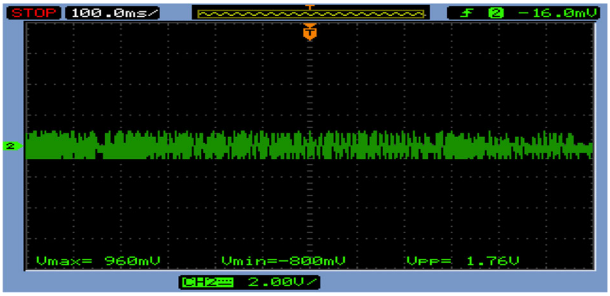

Fig. 16 Time-domain waveform of high pass filter (HPF) signal

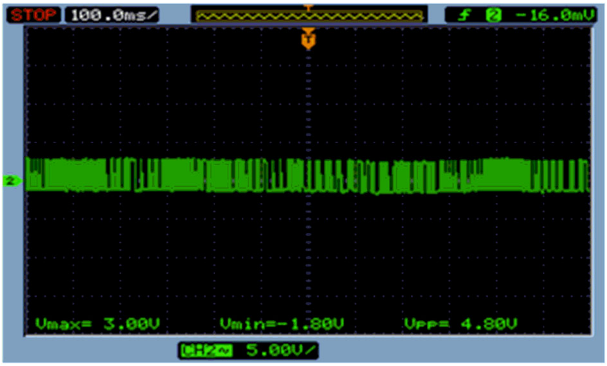

Fig. 17 Time-domain waveform of power amplifier signal

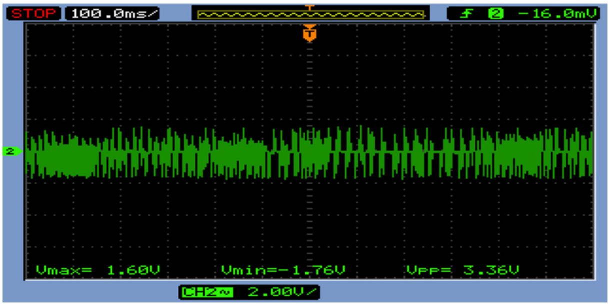

Fig. 18 Time domain waveform of recovered music signal

(HPF) signal. The ambient noise reduced signal is very weak. Hence it is amplified using power amplifier. Figure 17 shows the time-domain waveform and spectrum of the power amplifier signal. The music signal is recovered back at the receiver using a demodulator circuit. The distance achieved between the transmitter and receiver is 7.6 cm. Figure 18 shows the time-domain waveform and spectrum of the output signal. Figure 19 shows the time-domain waveform and spectrum of transmitted input signal and the received output signal. The experimental test bench of the proposed audio transmission in VLC system is shown in Fig. 20.

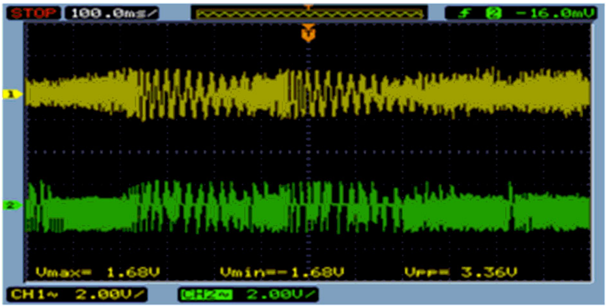

Fig. 19 Time-domain waveform of input and recovered music signal

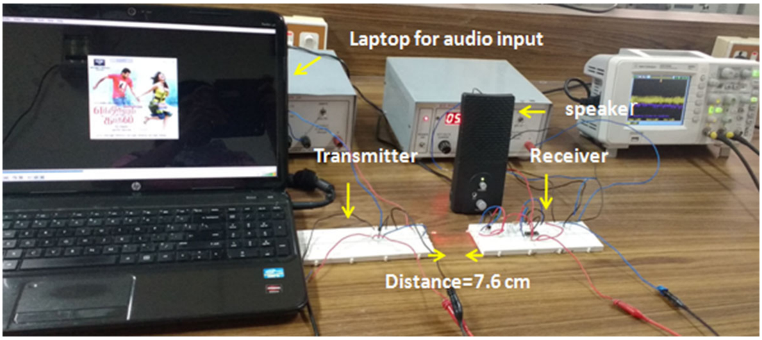

Fig. 20 Experimental test bench of the proposed audio transmission in VLC system using LED as receiver

5 Conclusion

In this paper, an indoor VLC system using red LED as both transmitter and receiver is demonstrated. The receiver circuit is designed to mitigate the ambient light noise and recovery of the input signal. A data rate of 1 Kbps and a distance of 12.7 cm is achieved between the transmitter and receiver of the digital data transmission. After successful transmission and reception of digital data, audio signal is transmitted and received using the same circuit for distance of 7.6 cm. Thus cost effective VLC system is implemented using LED as sensor. The communication distance can be further improved by using more number of LEDs or magnifying lens or high-gain amplifiers.

References

Cheong, Y.K., Weing, X., Youn, Chung W.: Hazardless biomedical sensing data transmission using VLC. IEEE Sens. J. **13**, 3347–3348 (2013)

Dhatchayeny, D., Sewaiwar, A., Tiwari, S., Chung, Y.: Experimental biomedical EEG signal transmission using VLC. IEEE Sens. J. **15**(10), 5386–5387 (2015)

IEEE Standards Association, IEEE Standard for Local and metropolitan area networks—Part 15.7: Short-Range Wireless Optical Communication Using Visible Light (IEEE std 802.15.7) (2011)

Kim, S., Lee, H.: Half-duplex visible light communication using LED as both a transmitter and a receiver. Int. J. Commun Syst **29**(12), 1889–1895 (2015)

Komine, T., Nakagawa, M.: Integrated system of white LED visible-light communication and power-line communication. IEEE Trans. Consum. Electron. **49**(1), 71–79 (2003)
Pathak, P.H., Feng, X., Hu, P., Mohapatra, P.: Visible light communication, networking and sensing: a survey, potential and challenges. IEEE Commun. Surv. Tutor. **17**(4), 2047–2077 (2015)
Varanva, D.J., Prasad, K.: LED to LED communication with WDM concept for flashlight of mobile phones. Int. J. Adv. Comput. Sci. Appl. **4**(7), 28–31 (2013a)
Varanva, D.J., Prasad, K.: LED to LED communication using WDM. Int. J. Comput. Appl. **72**(19), 36–38 (2013b)
Visible Light Communications Consortium. http://www.vlcc.net (2008). Accessed 02 July 2016
Wireless World Research Forum. http://www.wireless-world-research.org (2008). Accessed 02 July 2016