



AUDIO TRANSMISSION USING VISIBLE LIGHT COMMUNICATION (VLC)

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ABSTRACT

Limited radio frequency spectrum (or bandwidth) is one of the major issues in wireless communication. Visible light communication (VLC) should be considered as the medium for wireless transmission because it has few advantages over other standard wireless transmissions. The advantages of VLC are low power consumption and can avoid interference occurs. The visible light spectrum have 10,000 times larger than the entire radio frequency spectrum which ranges from 428 THz to 750 THz. In this paper the performance of visible light communication have been tested on the variation of distance between transmitter and receiver. Besides that the influence of the additional amplifier at the transmitter and receiver on the VLC system has also been characterized. Based on the results and analysis the implementation of the amplifier circuit at the transmitter and receiver helps to improve the signal quality of the audio signal in the VLC system. However the amplifier also increased the noise in this system. Moreover, the distance between transmitter and receiver can influence the system performance too. The longer the distance means that the signal strength and voltage which has been received by the receiver decreased and cause the data loss in the system. As a conclusion this audio transmission in the VLC system have been successfully demonstrated. However the maximum of distance between transmitter and receiver is limited to 20 cm. We believe this VLC technology has many potential to be explore and implemented in the next generation in-home network and transportation network.

Keywords: wireless communication, visible light communication, audio transmission.

INTRODUCTION

Currently, advance of telecommunications technology has increased more rapidly. This is due to the increasing need for communication from year to year are always changing. One of the communication technology that have high demand is the wireless communication technology. This technology is able to facilitate communication that can support voice communication, images, and data. However, this technology is limited by the frequency of government regulation, as to avoid interference (Barney, 2014).

Radio frequency or microwave technology are now widely used in meeting the communication needs because due to several things including the availability of a receiver or receiver with high sensitivity levels and having coverage. However, it should be realized that the use of radio frequency transmission has several weaknesses, such as limited bandwidth due to the limited availability of frequency spectrum. Hence the need for other wireless technologies are required to solve this problem.

Visible light communication (VLC) is a wireless technology that uses light emitting diode (LED) as a transmission medium. Information will be converted into bits through several coding schemes by the microcontroller and will be sent using the LED light. Photodiode in the receiver will detect fluctuations in the LED of the transmitter and sends a signal to the microcontroller integrated with the computer to determine the information that has been sent (Barney, 2014).

VLC should be considered as a medium for wireless transmission because it has several advantages over other wireless transmission. The first reason is the bandwidth of the frequency spectrum of the light radiated by the LED, which range from 428 THz to 750 THz (Keiser, 2013). Bandwidth is certainly much greater than the bandwidth of radio frequencies, which range from 3 kHz to 300 GHz (Ziskin, 2005). With the greater bandwidth it can accommodate more users and potentially achieve higher transfer rate for each user with a larger bandwidth for transferring information.

Some research has been conducted by other researchers in the application of visible light communication system. In (Chieh, 2013), have successfully integrated audio, video, and data VLC transceiver system for smartphones and tablets. Furthermore, (Chieh, 2014) have demonstrated transmission of high quality audio for VLC system on commercial airliners. The transmitter circuits which carry the the audio signal have been integrated with LED reading lights above the passengers seats. The receiver circuits have been designed and embedded at the headphones. Wireless optical communication using visible light has the largest potential because they can be integrated easily into existing devices on the plane and do not interfere with the aircraft's control systems.

Transmission using wireless technology is generally used to transmit several types of information such as voice, image, and data. Such as transmitting information in the form of voice, for example, it is necessary that sufficient bandwidth and speed. Therefore



in this paper we successfully demonstrated an audio transmission by implemented in VLC system. The performance have been tested on the variation of distance between transmitter and receiver of the VLC system. Besides that the current, power loss have been calculated to analyze the performance of the VLC system.

VISIBLE LIGHT COMMUNICATION

Introduction to visible light communication

Visible light communication is a way of communication that use visible light wavelength ranging from 400 nm ~ 700 nm (428 THz ~ 750 THz) if converted to frequency (Pohlmann, 2010). There are various areas of VLC applications: communication between traffic light, location determination technology that inform indoor location information, broadcasting communication that delivers information through display or digital multi signboard, and LED lighting or communication that utilizes display infra.

Using visible light communication for data transmission entails many advantages and eliminates most drawbacks of transmission via electromagnetic waves outside the visible spectrum. For instance, few known visible light-induced health problems exist today, exposure within moderation is assumed to be safe on the human body. Moreover, since no interference with electromagnetic radiation occurs, visible light can be used in hospitals and other institutions without hesitation (Pohlmann, 2010).

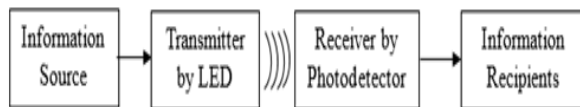


Figure-1. Visible light communication system.

Visible light communication have two main component which are transmitter and receiver as shown in Figure-1. To transmit the information, visible light communication used LED to transmit the modulation signal wirelessly. At the receiver, the signal will be captured by the photodetector and the signal are demodulated to get back the original information.

Light emitting diode (LED) as transmitter

Light-emitting diodes are semiconductor devices that are directly modulated by varying input current. They are usually made of aluminum gallium arsenide (AlGaAs). These devices can emit light in both the visible and infrared regions of the spectrum. Unlike a semiconductor laser (a laser pointer for example), a light emitting diode spews light in all directions and has low irradiance. Power from LEDs generally is in the microwatt range up to maybe a few milliwatts. LEDs are small in size, low temperature, rugged, and inexpensive devices.

The wavelength of light emitted by the LED is inversely proportional to the bandgap energy. The higher

the energy the shorter the wavelength. The formula relating electron energy to wavelength is shown in the following equation:

$$\lambda = \frac{hc}{\epsilon_{ph}} = \frac{1.24}{\epsilon_{ph}(eV)} \quad (1)$$

λ = wavelength in microns,
 h = Planck's constant = 6.63×10^{-34} J.s,
 c = speed of light = 3×10^8 m/s,
 ϵ_{ph} = photon energy in eV

This means that the materials of which the LED is made determine the wavelength of light emitted (Senior, 1951).

PIN photodiode as receiver

The most common photodetector is the semiconductor PIN photodiode. The device structure consists of p and n semiconductor regions separated by a very lightly η doped intrinsic region. In normal operation a reverse-bias voltage is applied across the device so that no free electrons or holes exist in the intrinsic region.

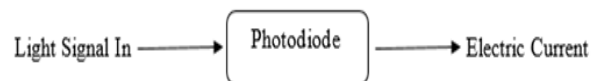


Figure- 2. Visible light communication system.

Figure-2 shows the photodetector senses the light signal falling on it and converts the variation of the optical power to a correspondingly varying electric current. Since the optical signal generally is weakened and distorted when it emerges from the end of the fiber, the photodetector must meet strict performance requirements such as high sensitivity to the emission wavelength range of the received light signal, minimum addition of noise to the signal and fast response speed to handle the desired data rate.

Experimental setup of the VLC system

Figure-3 shows the basic transmission system of visible light communication that has been successfully developed for this project.

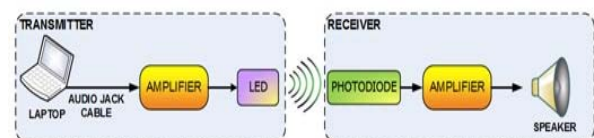


Figure-3. Visible light communication basic block diagram.

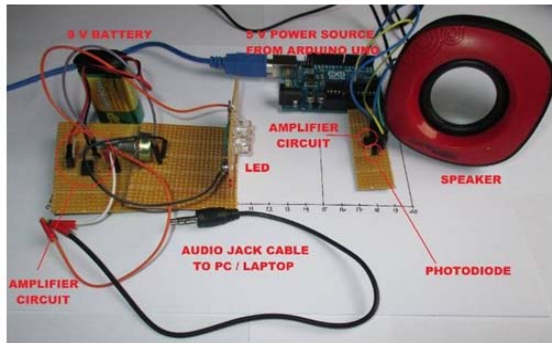


Figure-4. Experimental setup of the VLC system.

Figure-3 shows the basic transmission system of visible light communication and Figure-4 shows VLC system that has been successfully developed for this project. Based on the block diagram this system consist of two main part; transmitter and receiver. At transmitter system, we can see that the system consist of laptop for data source, audio jack cable for transferring audio signal from the laptop to amplifier. Amplifier is needed for amplifying the audio signal from the laptop. The signal is directly modulated through audio signals generated in real-time from the laptop and been transmitted wirelessly at a certain distance. At the receiver, the signal has been detected by the photodetector. Finally, the decoded audio signal can be retrieved from the speaker.

VLC system performance evaluation before and after employed an amplifier

In this subsection the analysis are divided into two parts. The first part is the effect of the VLC performance and the characteristic of the signal waveform have been analyzed before the amplifier and the second part is to analyze the VLC performance after employed the amplifier.

Table-1. Power and loss measurement (a) before amplifier, and (b) after amplifier at the transmitter and receiver.

	Transmitter			Receiver			Loss (dB)
	Voltage (mV)	Current (mA)	Power (μ W)	Voltage (mV)	Current (mA)	Power (μ W)	
(a) Before amplifier	280	0.2×10^{-3}	0.056	60	0.1×10^{-3}	0.006	-9.7
(b) After amplifier	2620	44	115280	1000	0.4	400	-24.59

Effect of various distance in VLC system

In this subsection the analysis are divided into two parts. The first part is the effect of various distance againsts the VLC performance. The second part is the effect of various distance againsts the characteristic of the signal waveforms. In Table 1(a) the calculation results shows the power at the transmitter is 0.056 mW at the receiver is 0.006 mW before the amplifier. The calculation

shows this system have loss of -9.7 dB. During the transmission, the audio signal can't be heard clearly at the receiver. So we decided to add the amplifier circuit at the transmitter and also at receiver.

After the amplifier have been added at the transmitter and also at the receiver, it shows that the power is increased by 115280 mW at the transmitter and 400 mW at the receiver. The calculation shows this system have loss of -24.59 dB. From this results we can see that the amplifier boost the signal power at the transmitter and also at the receiver. However, we observed the loss in the system are also increased when the amplifier has been added to the system. This is because the amplifier not just increased the power of the audio signal, but also can increased the noise power too.

Table-2. Power and loss measurement on transmitter and receiver with variation of distance.

Distance	Transmitter			Receiver			Loss (dB)
	Voltage (mV)	Current (mA)	Power (μ W)	Voltage (mV)	Current (mA)	Power (μ W)	
5 cm	2620	44	115280	1000	0.4	400	-24.59
10 cm	2600	44	114400	920	0.4	368	-24.93
15 cm	2680	44	117920	900	0.4	360	-25.15
20 cm	2720	44	119680	820	0.4	328	-25.62

Based on the calculation result which has been shows in Table 2, the system loss at 5 cm, 10 cm, 15 cm, and 20 cm have been increased simultaneously from -24.59 to -25.62 dB.

From this results we can see that the parameter of distance between transmitter and receiver can influence the value of voltage, power, and system loss. We observed the system loss is increased as the distance between transmitter and receiver are increased. This is because the sensitivity of the photodetector are less sensitive at the longer distance.

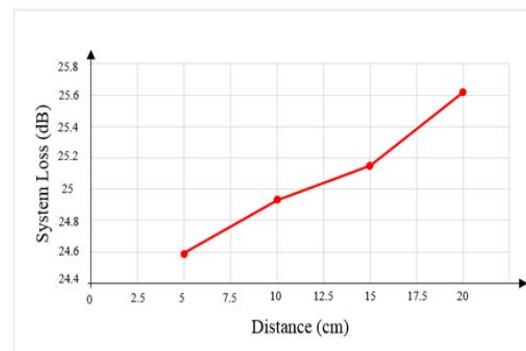


Figure-5. Analysis of system loss versus various distance.

Figure-5 shows the relationship between the system loss against the distance between the transmitter and receiver in the VLC system. This figure shows the longer the distance, means higher signal loss.



CONCLUSIONS

In this paper, two objectives have been successfully achieved. Firstly, the Visible Light Communication (VLC) system for audio communication has been successfully designed. Secondly, the performance parameter of VLC such as voltage, current and power have been measured and analyzed.

Based on the result and analysis which has been presented, the implementation of the amplifier circuit at the transmitter and receiver helps to improve the signal quality of the audio signal in the VLC system. Based on the data that have been analyzed, the use of amplifier circuit in the transmitter and receiver amplify the audio signal and makes the voltage reading increased at the transmitter and receiver. However the amplifier can also increase the noise in this system.

Based on the experimental demonstration work that have been conducted on various distance, we can see that the distance between the transmitter and receiver can influence the system performance. The longer the distance means that the signal strength and voltage which has been received by receiver decreased and cause the data loss in the system. We can conclude that the maximum distance in this work can be achieved only at 20 cm. However in the real implementation of the VLC system we need to have a longer transmission, so that this system is reliable for the future technology. We need to identify more suitable LED and photodetector for the VLC system to ensure the transmission distance could be increased.

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