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# IMPLEMENTATION OF VISIBLE LIGHT COMMUNICATION BASED SYSTEM FOR INDOOR POSITIONING

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## Abstract

*Visible light communication (VLC), have gain much interest in past decade in indoor communication. In particular, it is use for illumination and communication simultaneously. White light emitting diodes which are used as a transmitter for VLC are potential candidates for* *localization. Conventionally global positioning system (GPS) has very poor performance in indoor environments. Assisted global positioning system (AGPS) has positioning accuracy in few meter range. WLEDs can be used in small cell area inside the room hence indoor positioning can be measured accurately in centimeter. In this paper a WLEDs based indoor position system is investigated, the position was accurately confined in 11cm with low cost and on the shelf components.*

**Keywords**

Optical wireless communications, Indoor positioning, Optical transmitter, Optical reciever

## 1. Introduction

Since last two decade Optical Wireless communication (OWC) has gain much attention in transmission of data. OWC deals with the data transmission through free space or air using infrared (IR) or visible light communication (VLC) (Komine & Nakagawa, 2004). Infrared was used for data transmission however it is not safe to human eye hence VLC is prefer over IR for data transmission. The transmitter of VLC is either laser diode (LD) or Light Emitting Diode (LED), whereas the receiver consists of photodiode (PD) and transimpedance amplifier (TIA). VLC is the communication technology which uses visible light as a source and air as a propagation medium. VLC, a new field of indoor communication, is more interactive and is comfortable wire free (Schill, Zimmer, & Trumpf, 2004). LEDs are preferred as they provide smart lighting in the building, reducing the energy consumption and require less wiring in the building (Sagotra & Aggarwal, 2013). Conventionaly light sources can not transmit the light signal due to their low switching applications moreover the efficiency of an incandescent ordinary lamp is limited up to 52 lm/w and that of ordinary fluorescent lamp is 90 lm/w. On the other hand the LED have its peak value up to 260 1m/w (Kim & Schubert, 2008), and operate on low voltage compared to other conventional sources. The use of LED in the field of research gains much because it has high bandwidth, low energy consumption and security.

To increase the growth of female flowers LED light of different colors were used. The red, blue and yellow (RBY) colors LED ( Muhammad Fahri Riadi, Rizkita Rachmi Esyanti & Achmad Faizal, 2015) with different ratios were optimized and show that RB have greater growth rate than the RBY in the same cucumber lines. Moreover, LEDs are recently considered as fast switching component in high speed data communication. Other than this LEDs are used as transmitter in OWC such as in the room, office, school etc. The current application of RGB and yellow LEDs were used to increase the production of flower on the basis of production of Cucumber fruit. Two cucumber fruits Mercy and KE27187 were tested on various hours. LED conformed that the Mercy flower has short day plant and KE27187 has a long day plant (Muhammad Maulana Malikul Ikram, Rizkita Rachmi Esyanti & Ahmad Faizal, 2015).

Advantages of WLEDs over radio waves and infrared rays like it do not harm the eye retina. It has high brightness and more efficiency rather than ordinary. Recently WLEDs are proposed for indoor positioning. Conventional RF based localization system indoor position system has the much power loss due to absorption in walls other indoor objects. In addition, its confinement inside a room with accuracy less than a meter is not feasible for implementation. A part from this, they also cause electro-magnetic (EM) interference. Moreover, there are environments where RF interference with electronic and electrical instruments and is prohibited. VLC based indoor position system have been reported in the literature. The position of users or their devices in Personal network can be found by indoor positioning system (IPS) while measuring the position of their devices in an indoor environment (Dempsey, 2003). IPS can also determine the location of a person or things inside the hospital, gymnasium or school (Vossiek et al., 2003). The strength of received signal is depend upon the angle of arrival (AOA), time of arrival (TOA), time difference of arrival (TDOA) (Jung, Hann & Park, 2011).

An issue and challenge to VLC is the multipath interference which causes the low accuracy moreover, VLC is a low power system (Liu, Darabi, Banerjee, & Liu, 2007). Inter cell interference is a serious issue in the single channel system in order to reduce the inter cell interference a carrier allocation (CA), VLC system is reported (Kim et al., 2012). Indoor localization system based on VLC using LEDs to find the position of an object that is depend upon the AOA time of arrival (TOA), TDOA and also upon the received signal strength indication(RSSI), openly used method. But it have also some disadvantages and synchronization problem of the transmitter and receiver delay control (Jung& Park, 2013). A method of indoor positioning based on VLC using LEDs as a transmitter for estimation to reduce the error and mitigate the interference between the different transmitter located at different places (Yang et al,. 2013), each transmitter transmit the power signal and the receiver received the signal in term of the ratio of output power to the input power called extension ratio. This paper describe a low cost implementation of an indoor positioning system based on WLEDs and the data transmission is based upon intensity modulation (IM) of WLEDs. Section (2) consist system design of transmitter and receiver, section (3) describe result and discussion. Conclusion is the content of section (4).

## 2. System Design

We proposed a simple and low cost implementation of indoor localization system based on VLC. Proposed system design for indoor positioning of is shown in Figure.1. To generate the basic code for the specified location, a software programming of Visual studio 2008 based on c# language is used. A USB to RS232 serial port connected with computer PC. While Max 232 is used to convert the serial data to TTL based voltage (0 to5). The TTL output is connected with LEDs drive circuits which are used to drive the current through LED panels specified as LED1 and LED2 respectively. LED1 panel contains 15 WLEDs which are used to send the generated code, position1, from the computer PC through OWC. LED2 also containing 15 WLEDs send another code position2 through same medium. The data in tem of light signal transmitted by air medium and a microcontroller based receiver placed at 100cm received the light signal consists of data and display to LCD.

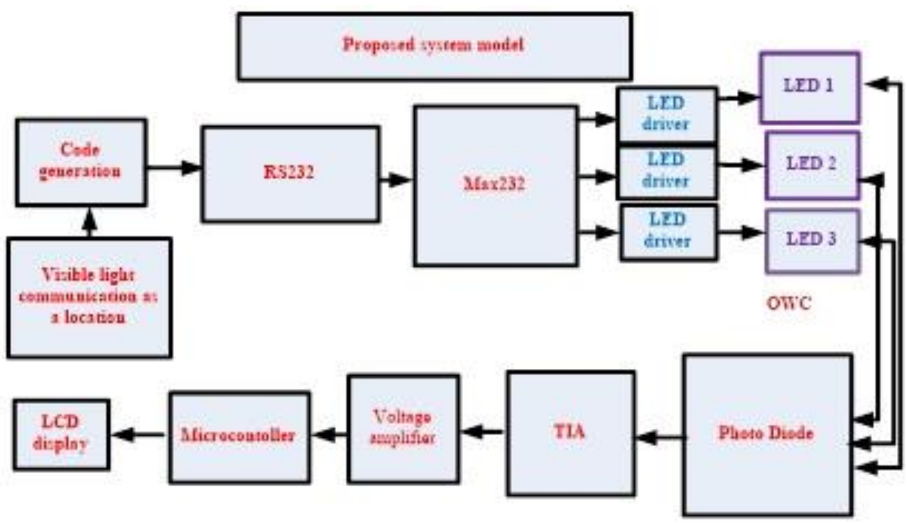


**Figure 1:** *Block diagram of proposed VLC based system for indoor positioning.*

The value of current is depend upon the brightness of WLEDs, greater the intensity of light large current can be obtained. While the input of microcontroller is in the form of voltage. To convert the current in to voltage a transimpedance amplifier (TIA) circuit is used with open loop gain and get 5v at the output voltage which is sufficient for the working of microcontroller.

Microcontroller first save the received information transmitted from the computer PC in data storage buffer and then again send this coded information to liquid crystal display (LCD) of 24×2 character and display it in to two rows it is experimentally observed that all the data transfer through optical wireless communication.

### 2.1 Optical transmitter for positioning

Cree model LED C503c-WAN is used as a transmitters for an indoor positioning system based on VLC. It have maximum current conduction 30 mA. The power consumption of single LED used in the system is about 100 mW. While each LED panel unit consists of 15 WLEDs and the distance between the designed transmitters and receiver is 1 m. The data transmitted from both the transmitters in term of light were considered in unidirectional and line of sight with the microcontroller based receiver. To increase the cell area of transmitted signal a large number of LEDs are used in rows and columns this type of LEDs panel increase the intensity level and photocurrent. Figure.2 show an optical transmitter and receiver room scenario.

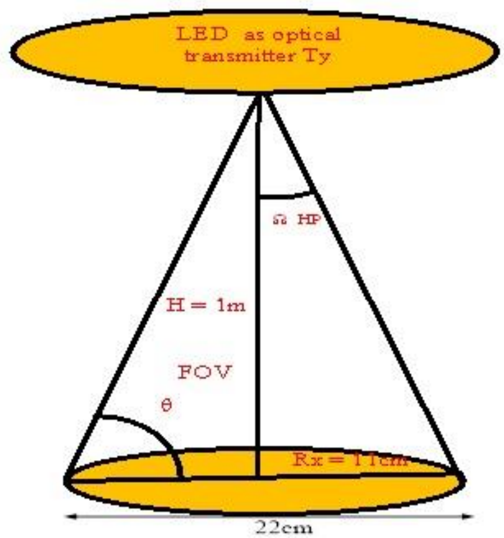


**Figure 2:** *Optical Transmitter and receiver scenario.*

A brief introduction of system model is explained. We proposed a low cost and optimized transmitter prepared in telecommunication laboratory. It consists on number of WLEDs unit. It is cheap and easily available in the market with high power its power range is from mille watt to several Watt. We proposed WLEDs panel as a transmitter which also support the communication channel. Figure.3 shows the arrangement of WLEDs in rows and columns which can also be seen in real circuit diagram (figure.4). A single transmitter is consist of 15 WLEDs unit and the total number of LEDs used in two transmitter circuits are 30 arrange in rows and columns while the distance between the consecutive LEDs is taken 5 mm..

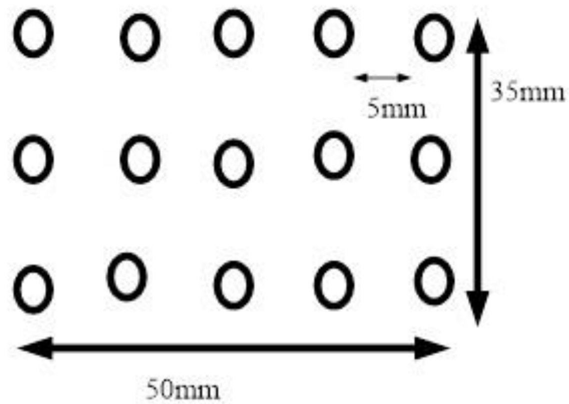


**Figure 3:** *LEDs panel 50mm length and 35mm width while the distance between LEDs are 5mm along rows and columns.*

LED1 and LED2 showing in system model are acting as transmitters and each LED panel consists of 15 WLEDs. The data transmitted from both the transmitters in term of light were considered in unidirectional and line of sight with the microcontroller based receiver. To increase the cell area of transmitted signal a large number of LEDs can be used in rows and columns. This type of LEDs panel increases the intensity level and photocurrent. We implemented a low cost and optimized transmitter in telecommunication.

**Table 1:** *An Optical indoor positioning system parameter*

| Parameters | Values |
|---|---|
| Power of each LED in panel | 3.3×30 mA≈ 0.099 w |
| Number of LEDs In panel | 3×5=15 |
| Power of LEDs in each panel | 1485 mw =1.485 w |
| Luminance intensity | 7000 mcd=7 cd |
| Operating voltage of LEDs panel | 5 volts |
| Cell diameter | 22 cm |
| Distance between transmitter and receiver | 100 cm |

Figure 4 show the implemented LEDs transmitter. The total power consumed by each LEDs Field of view which is the maximum (FOV) signal strength that can transmit from the transmitter while half power (HP) angle is the highest signal that can received by receiver at some distance and given as

$$\theta = \tan^{-1}(\frac{R_x}{H}) = \text{ Field of view (FOV)}$$

$$\theta = \tan^{-1}(\frac{11cm}{100cm}) = 6^\circ$$

$$\Omega = \tan^{-1}(\frac{2R_x}{H}) = \text{ Half power angle (HP)}$$

$$\theta = \tan^{-1}(\frac{22cm}{100cm}) = 12^\circ$$

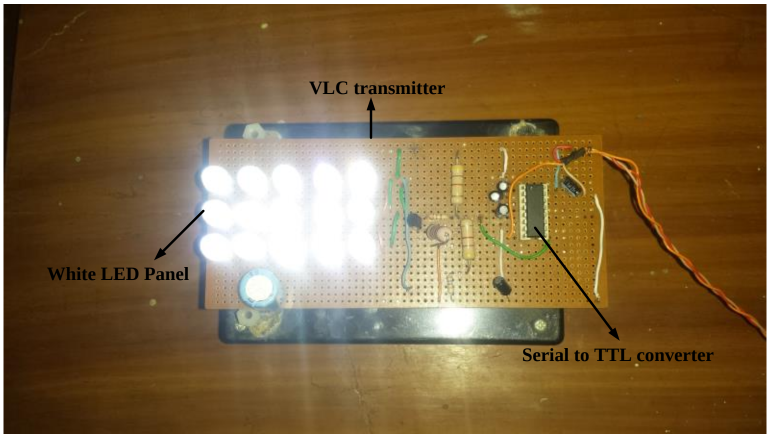


**Figure 4:** *LEDs acting as an Optical transmitter in operational mode.*

### 2.1.1 Optical reciever

The block diagram of the optical receiver used for VLC based indoor position is depicted in Figure.3.8 The photodiode convert the light in to current. Greater the light intensity of optical transmitter large current can be obtained. A high Speed photodiode of model BPW34 is a type of PIN (p-type intrinsic n-type) photodiode followed by TIA. For TIA, an operational amplifier of model LM6364 is selected as it is a high speed and large bandwidth. A microcontroller of 89S52 from ATMEL is used to receive the position signal from TIA and display it to LCD. Figure.5 is the flow chart of an optical receiver and explained above.

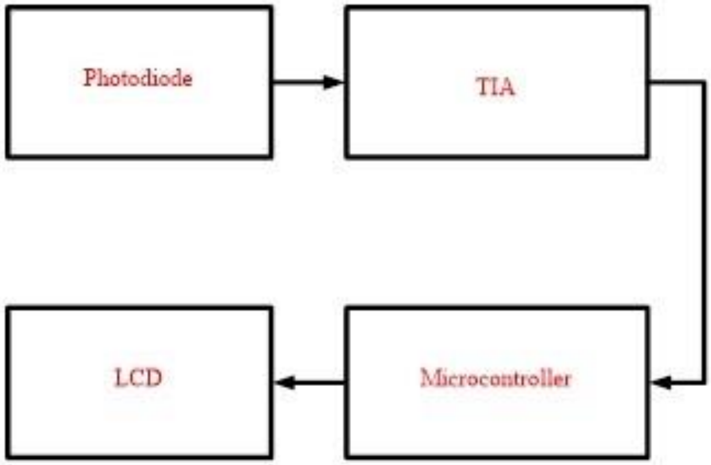


**Figure 5:** *Flow chart of VLC based optical receiver.*

### 2.1.2 Microcontroller programing for VLC based receiver

ATMEL 89S52 model is a microcontroller used in system it is a low power and high performance system programmable flash memory with many input and output pin configuration. The whole setup work of 5v making it computable to any USB power supply. A software of visual studio 2008 is used to generate the basic code in c- language this code is process by microcontroller and is display on LCD. Figure.6 is the complete experimental setup of receiver circuit containing microcontroller of model 89s52, LCD and TIA.

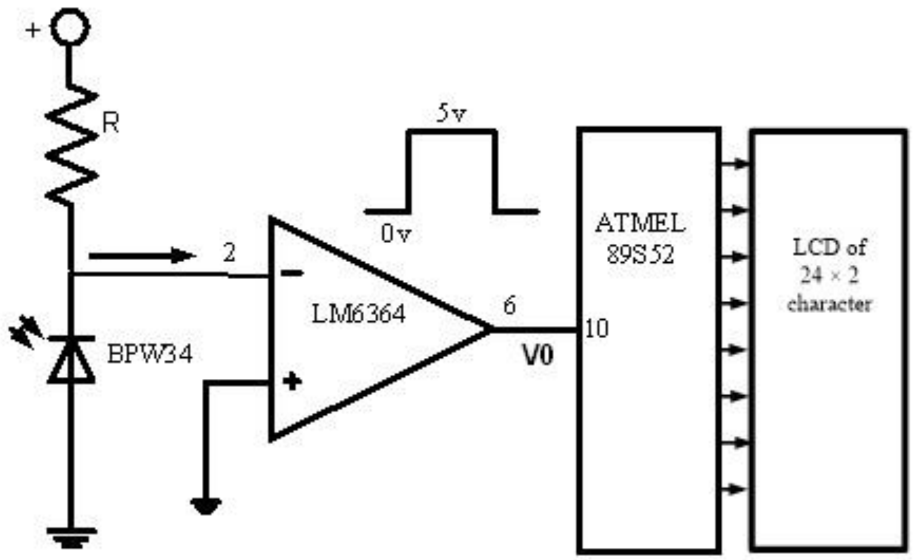


**Figure 6:** *Circuit design of microcontroller based receiver.*

## 3. Result and Discussion

A complete prototype transmitter with LCD for indoor position is successfully implemented and displaying two different position to the LCD. In this experimental setup the transmitter is placed at fixed position while the receiver is moveable horizontally. It is necessary to mentioned that the two location code were send by single computer PC. The diameter of each cell measured is 21cm both the transmitter were in LOS with receiver. When the receiver moved linearly more than 11cm of the cell radius the fluctuation and distorted signal were observed on LCD. Figure.7 shows two different locations (positions1 and postion2) display on the LCD.


**Figure 7:** *LCD Display indoor position via OWC.*

A portable photodiode of area 3 mm×3 mm is placed on the table. The two transmitter placed neck and neck and a distance of 100cm from receiver. It is care that the transmitter and receiver are in LOS. Figure.8 is the complete implementation of indoor position in room scenario. The transmitted power of single LEDs panel was calculated and it is 1485mW To find the received power at receiver can be calculated by the following mode (Kim et al., 2013).

$$\mathrm{Pr} = \frac{Pt}{\mathrm{d}^2} R(\varphi) Aeff(\psi) \quad (1)$$

Where *Pt* is the transmitted power of single LEDs panel, d is the distance between transmitter and receiver, R (φ) is the transmitted radiant intensity and $A_{eff}$ (ψ) is the effective area of optical receiver which is $9mm^2$ 0f the proposed optical receiver. The radiant intensity of transmitted signal can be calculated

$$R(\varphi) = \frac{m+1}{2\Pi[\cos^m \theta]} \quad (2)$$

Where m is the mode number related to **Ω** which is the transmitted semi-angle (at half power), and calculated as

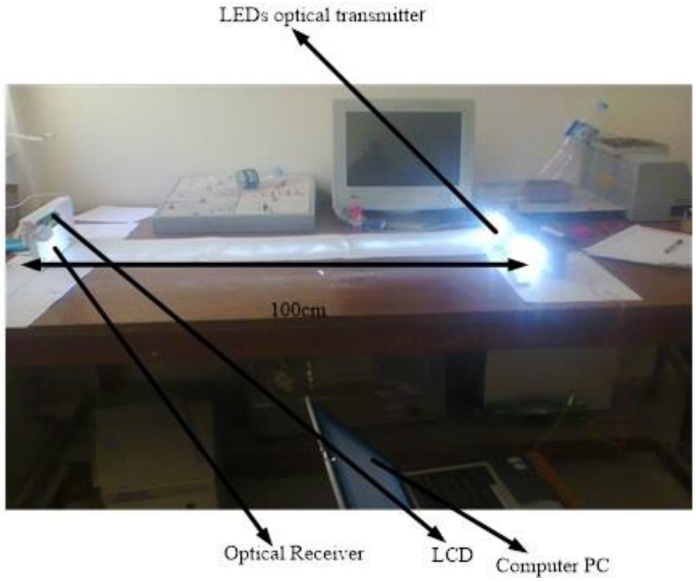


**Figure 8***: Optical transmitter and receiver circuit at 100cm away from each other with LCD.*

$$m = \frac{-\ln 2}{\ln \cos \Omega} \quad (3)$$

using Ω = 12° in equation (3) than we get m = 31.

For maximum value of radiant intensity the transmitter and receiver considered in LOS, and given as by taking θ = 0° in equation (2) we get

$$R(\varphi) = 5.095 \frac{w}{sr}$$

$$\Pr = 1.485 \times 5.095 \mu w = 68.094 \mu w$$

Again using equation (2), when transmitter and receiver is in non LOS, using θ = 6°

$$R(\varphi) = 4.297 \frac{w}{sr}$$

$$P(R) = 1.485 \times 4.297 \times 9 \mu w = 57.429 \mu w$$

The SNR values can be find by the following formula.

$$SNR = 10 \log(\frac{\Pr}{PR}) dB \quad (5)$$

$$SNR = 10 \log(\frac{68.094 \mu w}{57.429 \mu w}) dB = 0.739 dB$$

Figure.9 show the microcontroller based receiver displaying text messages on LCD and successfully in operational mode.

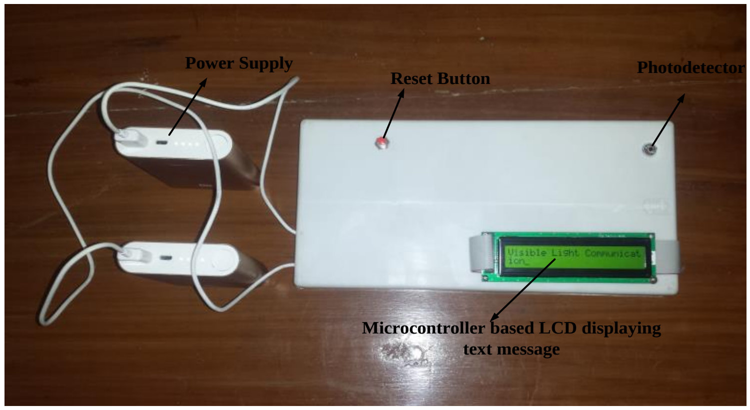


**Figure 9:** *Optical Receiver in operational mode.*

## 4. Conclusion

GPS and AGPS are conventionally used for positioning. However for indoor their performance is degraded due to loss in RF power. Moreover they have poor accuracy of the order of meters when used in indoor application. GPS has very poor performance in indoor environments with accuracy in meter. Assisted global positioning system (AGPS) has positioning accuracy in few centimeter range. Hence an indoor based localization was investigated in the proposed research. In this thesis a VLC based localization system for indoor positioning has been proposed. The system comprised of VLC based transmitter and VLC based receiver. The circuit for transmitter and receiver were designed by circuit analysis and successfully implemented in laboratory of telecommunication. The prototype is low cost and tested for 100cm. the cell radius measured for each location was 11cm. The transmitted and received power was measured 1.485w and 68.094 uw respectively. The result show that the VLC based system have accuracy of 21cm. A USB to RS232 converter was used to send indoor location via LED panels LED1 and LED2. The receiver consisting of photodiode, TIA, Microcontroller and a LCD successfully display the location on LCD of $24 \times 2$ character. The receiver is portable and was moved along the horizontal direction while the transmitter is placed at fixed position. The sensitivity of receiver is measured in term of SNR and measured SNR value is 0.739dB to display a location accurately.

In order to improve the data transmission utilizing VLC based OWC indoor positioning one can reduce the interference and ambient light in optical system which directly affect the transmitted power received at the PD. It is one of the big challenge and open question in the field of OWC to the researcher in future that, how ambient light can be reduced and enhance the transmitted power and received power. It can be possible using mirrors and lenses that can increase the received power. Another option is also valuable to decrease the interference between the transmitters sending the data utilizing OWC, using the signal carrier also called multicarrier signals. Multi input multi output (MIMO) carrier allocation (CA) system may also consider in indoor positioning using number of LEDs in rows and columns with in room.

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