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FPGA based Visible Light Communication

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ABSTRACT: The users' location in visible light positioning systems generally rely on three features of the received signals: time of arrival (TOA), angle of arrival (AOA), and received signal strength (RSS). RSS based techniques use the intensity of the signal to estimate the distance from the transmitter to the receiver. These techniques have the potential to achieve a high accuracy in visible light positioning systems because of the strong line of sight (LOS) signals, which are often not available in RF systems.

VLC is the way of communication using light which is visible to human eye. Here communication is achieved with the help of LEDs. We modulate the light at a very high speed such that the modulation is not visible to human eye by switching the LEDs on and off rapidly on the transmitter side. Like, photodiode is used on the receiver side to detect the modulation. Light Fidelity or Li-Fi is communication through light at a very high speed. It is based on Visual Light Communication system. Speed of Li-fi is about 224Gbps. Modulation of light using LEDs can be done using processors such as Arduino. Visible light communication is used in Li-Fi, which is a fastest growing technology, so it allows data transmission using light as a medium of communication.

KEYWORDS: Visible Light Communication, VLC, FPGA, Line of Sight, Received Signal Strength, RSS, Time of Arrival, TOA.

I. INTRODUCTION

The main objective of the project is to make use of light as a medium for communication. This project aims to demonstrate the use of visible light as a viable digital communication technology which can enable communication between various devices. VLC uses LED's to transmit data by flashing light at speeds undetectable by human eyes. Visible light communication (VLC) is a newly emerging communication technique, which uses visible light as a medium for communication. In this technology we use light emitting diode as the light source to transmit the data. LED blinks at rapid rate such that the human eye will not notice the

light intensity. But a light sensitive photodiode or phototransistor can detect the on-off behavior and decode the information embedded within it and at present, RF based communication systems like Wifi and Bluetooth are available. Because of the increasing number of devices using RF communication, the RF bandwidth will become congested, so the RF interference will increase. Since the wireless congestion problem has become significant, so we use visible light communication as an alternative.

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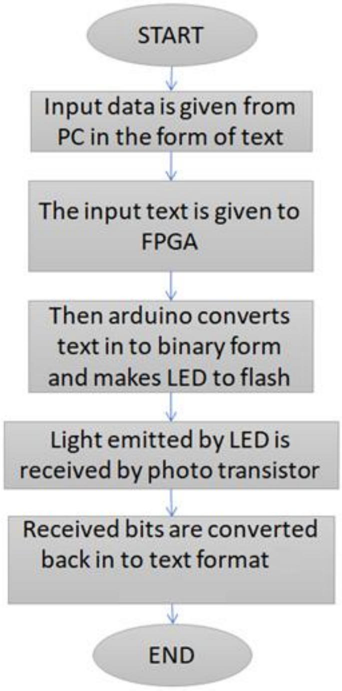

Fig.1 Proposed System Flow Diagram

A. Transmitter Section

The Arduino code converts in input text (alphanumeric) into its binary form and sends it in form of packets of 6 or 7 bits. Each symbol in the text is converted first into its ASCII form, and then to binary which is either 6 or 7 bits long. This bitstream is to be transmitted. In our initial prototype, 0 was represented by OFF led and 1 was represented by ON led and each bit was assigned a time interval (eg: 20 ms for 1st bit, next 20ms for 2nd bit and so on.). At first a handshake signal would be sent that would ensure that transmitter and receiver timers are in sync.

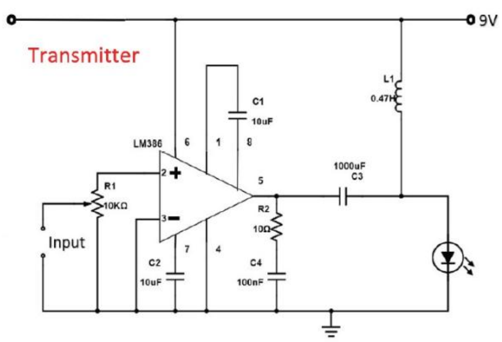

Fig.2 Proposed System Transmitter Circuit

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Then the data would have followed coherently. It was found that that the system becomes undependable at higher data speeds. Now since Arduino Uno is very sensitive to voltage fluctuations, we now use a fixed number of voltage fluctuations to represent 0 and 1. In the current prototype, 0 is represented by 3 fluctuations (meaning LED changes its state 3 times to transmit a single '0') and 1 is represented by 2 fluctuations. A small time interval after each bit separates it from the next bit. Also there is a guard bit at t he end that indicates completion of data transmission.

B. Receiver Section

A photodiode array is connected in a voltage divider circuit with a variable resistance and Arduino Uno. The variable resistance controls sensitivity of the receiver. The photodiode senses the incoming fluctuation, Arduino decides whether it's a 0 or 1 and stores it a 7 bit array called 'bin'. The binary array is converted to its decimal form (ASCII) and then to text format and is printed on the screen. Then 'bin' is freed up for the next incoming symbol. Moreover the receiver will only respond to a certain fluctuation frequency, this makes the system resistant to ambient light fluctuations (unless ambient light is too bright). This process is independent of time division and is also non coherent, so there is no error at higher data speeds. The only errors are caused when transmission speeds reach close to Arduino Uno's processing speed.

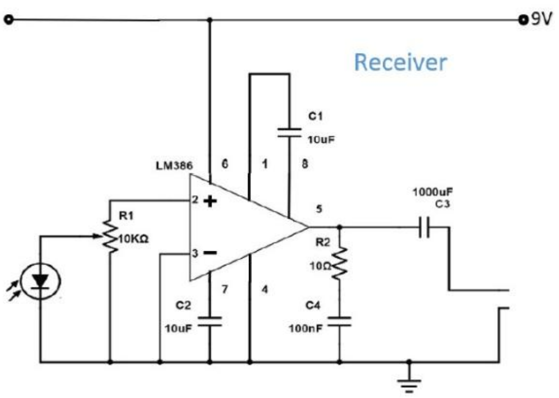

Fig.3 Proposed System Receiver Circuit

II. SYSTEM ANALYSIS

A. Existing System Summary

In existing system, light is transmitted directly with the help of a function generator and a LED driver circuit. The driver circuit is used to analyze the performance of the LED to LED links and choosing suitable driver for visible light communication. In existing system we all know the communication such as Bluetooth, ZigBee and Radio Frequency (RF). All these communications are falling into certain limitations such as range and speed. GSM is an option to tolerate the range, but it cannot be used in deep sea. Slower Communications between transmitter and receiver end. Performance is low, because of its time taken procedures and Cost is high.

Disadvantages

- Coverage range is short.
- Transmission efficiency is less.
- Less secure.

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III. RELATED WORKS

(a) IEEE 802.15.7 visible light communication: modulation schemes and dimming support - Rajagopal, S., Roberts, R.D., Lim, S.K. - 2012

Visible light communication refers to shortrange optical wireless communication using visible light spectrum from 380 to 780 nm. Enabled by recent advances in LED technology, IEEE 802.15.7 supports high-data-rate visible light communication up to 96 Mb/s by fast modulation of optical light sources which may be dimmed during their operation. IEEE 802.15.7 provides dimming adaptable mechanisms for flicker-free high-data-rate visible light communication.

(b) A new modified MPPM for high-speed wireless optical communication systems - Mehdi, R., Riad, A.B., Mohammad, E.C-.B. - 2013

Previous work proposed combining multipulse pulse position modulation (MPPM) with pulse amplitude modulation to form multipulse amplitude and position modulation (MPAPM), which is a hybrid modulation that results in an improvement in bandwidth efficiency but a degradation in power efficiency. In this paper, to achieve greater power efficiency and a better data rate, we propose multipulse dual amplitude-width modulation, based on MPAPM and pulse width modulation. The proposed scheme shows a remarkable improvement in data rate and a 1.5-dB improvement in power efficiency over MPAPM, while sustaining the bandwidth efficiency. After introducing symbol structure, we present the theoretical expressions of spectral efficiency, the power requirements, and the normalized data rate, as well as the results of comparing the proposed modulation to MPPM and MPAPM.

(c) High efficiency wireless optical links in high transmission speed wireless optical communication networks - Rashed, A.N.Z. - 2014

Power link budgets are prepared for wireless optical communication systems to illustrate the optical losses that happen during transmission. This paper has presented optical wireless links, which offer ultra multi gigabit per second data rates and low system complexity. For ground space and/or terrestrial communication systems, these links suffer from atmospheric loss mainly due to fog, and scintillation. Optical wireless links provide high bandwidth solution to the last mile access bottleneck. However, an appreciable availability of the link is always a concern. Wireless optical links are highly weather dependent, and fog is the major attenuating factor reducing the link availability. Link margin, received signal power, transmission bit rate, bit rate distance product, signal-to-noise ratio, and BER are the major interesting design parameters in the current study.

(d) Indoor optical wireless communication: potential and state-of-the-art - Elgala, H., Mesleh, R., Haas, H. - 2011

In recent years, interest in optical wireless (OW) as a promising complementary technology for RF technology has gained new momentum fueled by significant deployments in solid state lighting technology. This article aims at reviewing and summarizing recent advancements in OW communication, with the main focus on indoor deployment scenarios. This includes a discussion of challenges, potential applications, state of the art, and prospects. Related issues covered in this article are duplex transmission, multiple access, MAC protocols, and link capacity improvements.

(e) Entertainment lighting control network standardization to support VLC services - Lim, S.K., Karl, R., Kim, I.S. - 2013

VLC technology is receiving increasing attention in research and product development these days because high lumen/watt LEDs are becoming the dominant sources for artificial lighting. Successful VLC data transmission from luminaires requires that the data first be moved to the luminaires over a backbone network. This article addresses the lighting control network as a backbone for VLC services and describes a standards-drafting project, designated BSR E1.45, for entertainment lighting control to support the transmission of data for VLC from luminaires. E1.45 specifies a data frame format that can coexist with ANSI E1.11 messages on lighting control network, and thus deliver VLC data to luminaires for transmission from those luminaires.

(f) Mitigation of optical background noise in light-emitting diode (LED) optical wireless communication systems - Chow, C.W., Yeh, C.H., Liu, Y.F. - 2013

One challenge faced by the in-home light-emitting diode (LED) optical wireless communication is the optical noises. Here, we first experimentally characterize the effect of optical background noise to the performance of the LED optical wireless communication channel. We demonstrate using Manchester coding for the LED to mitigate the optical noise. No adaptive monitoring, feedback, or optical filtering is required. The theoretical and numerical analysis of Manchester decoding process to mitigate the optical background noise is provided. Our experimental result shows that Manchester coding can significantly eliminate optical noise generated by the AC-LED operated at <; 500 kHz and fluorescent light.

*B. **Proposed System Summary***

In this project FPGAs are used to convert the parallel data in to serial data and Arduino converts the input text in to its binary form. LED are used to transmit the light and the light is received by the photodiode, then again Arduino is used to convert the binary form in to text format and the text is printed on the screen. Advanced LiFi technology is used instead of regular communication principles. It can be used in both indoor and outdoor communication system. Speed is amazing and unpredictable compare to the other communication devices. Good in Performance because of its fast transmission. Circuit Designing is simple and Cost effective.

Advantages

- Better bandwidth.
- More secure than other communication.
- Cost efficient and high performance.

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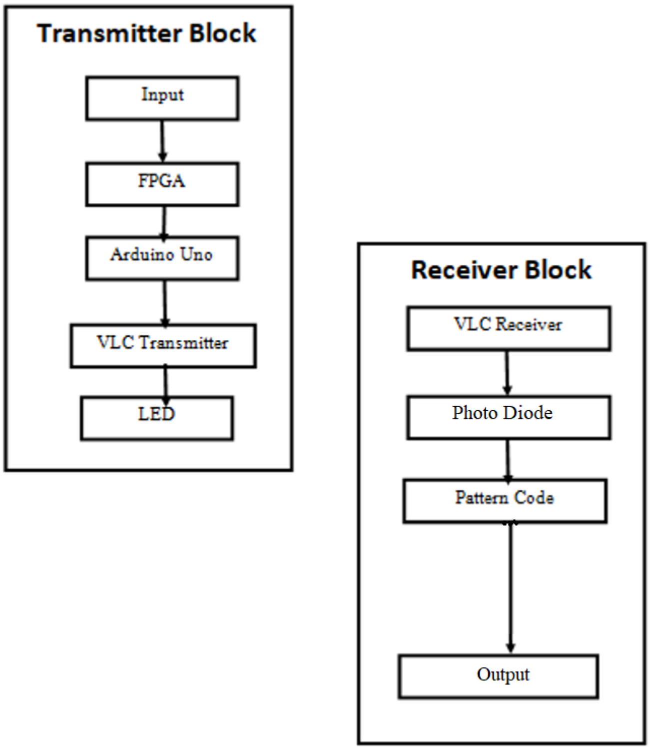

Fig.4Proposed System Block Diagram

IV. SYSTEM IMPLEMENTATION

A.Arduino UNO

Arduino is an open-source project that created microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices. The project is based on microcontroller board designs, produced by several vendors, using various microcontrollers. These systems provide sets of digital and analog input/output (I/O) pins that can interface to various expansion boards (termed shields) and other circuits.

Fig.5Arduino UNO

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The boards feature serial communication interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on a programming language named Processing, which also supports the languages, C and C++. Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter. Arduino Uno has a number of facilities for communicating with a computer, another Arduino board, or other microcontrollers.

B. Visible Light Communication (VLC)

Visible light communication (VLC) is a data communications variant which uses visible light between 400 and 800 THz (780–375 nm). VLC is a subset of optical wireless communications technologies. The technology uses fluorescent lamps (ordinary lamps, not special communications devices) to transmit signals at 10 kbit/s, or LEDs for up to 500 Mbit/s. Low rate data transmissions at 1 and 2 kilometres (0.6 and 1.2 mi) were demonstrated. RONJA achieves full Ethernet speed (10 Mbit/s) over the same distance thanks to larger optics and more powerful LEDs. Specially designed electronic devices generally containing a photodiode receive signals from light sources, although in some cases a cell phone camera or a digital camera will be sufficient. The image sensor used in these devices is in fact an array of photodiodes (pixels) and in some applications its use may be preferred over a single photodiode. Such a sensor may provide either multi-channel communication (down to 1 pixel = 1 channel) or a spatial awareness of multiple light sources. VLC can be used as a communications medium for ubiquitous computing, because light-producing devices (such as indoor/outdoor lamps, TVs, traffic signs, commercial displays and car headlights/taillights) are used everywhere. Using visible light is also less dangerous for high-power applications because humans can perceive it and act to protect their eyes from damage.

Fig.6Visible Light Communication Module - View

The history of Visible Light Communications (VLC) dates back to the 1880s in Washington, D.C. when the Scottish-born scientist Alexander Graham Bell invented the photo phone, which transmitted speech on modulated sunlight over several hundred meters. This pre-dates the transmission of speech by radio. More recent work began in 2003 at Nakagawa Laboratory, in Keio University, Japan, using LEDs to transmit data by visible light. A prototype of VLC had been presented by three undergraduate students at Universidad de Buenos Aires in 1995, resorting to the amplitude modulation of a 532 nm laser diode of 5 mW and photodiodes detector. Since then there have been numerous research activities focussed on VLC, notably by Smart Lighting Engineering Centre, Omega Project, COWA, ByteLight, Inc.,D-Light Project, UC-Light Centre, and work at Oxford University.

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Fig.7VLC – Working Model

ABI research forecasts that it could be a key solution to unlocking the $5 billion "indoor location market". Publications have been coming from Nakagawa Laboratory, COWA at Penn State and other researchers around the world. Another recent application is in the world of toys, thanks to cost-efficient and low-complexity implementation, which only requires one microcontroller and one LED as optical front-end. VLCs can be used for providing security. They are especially useful in body sensor networks and personal area networks. Recently Organic LEDs (OLED) have been used as optical transceivers to build up VLC communication links up to 10 Mbit/s. In October 2014, Axrtek launched a commercial bidirectional RGB LED VLC system called MOMO that transmits down and up at speeds of 300 Mbit/s and with a range of 25 feet. In May 2015, Philips collaborated with supermarket giant Carrefour to deliver VLC location-based services to shoppers' smartphones in a hypermarket in Lille, France. Indoor positioning systems based on VLC can be used in places such as hospitals, eldercare homes, warehouses, and large, open offices to locate people and control indoor robotic vehicles. There is now a lot of talk about Visible Light Communication (VLC) and indeed this blog site is dedicated to the topic, but what is VLC ? On this site when we talk about VLC we tend to be referring to an illumination source (e.g. a light bulb) which in addition to illumination can send information using the same light signal. So in our terms:

VLC = Illumination + Communication (1)

C. RS232-Interfacing

This module is used to transmitting data from PC HyperTerminal to Spartan6 FPGA Development Kit and feedback to PC at 9600 Baud Rate.

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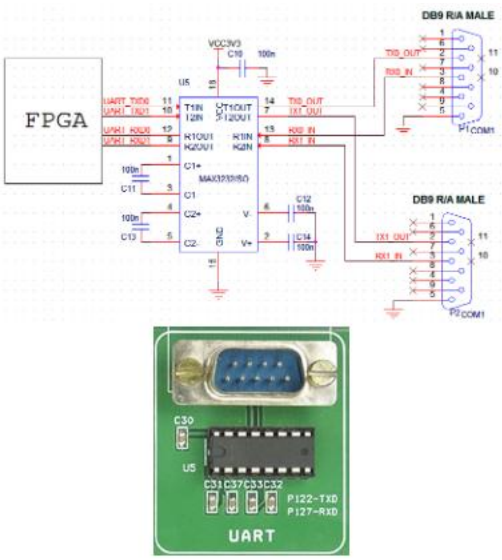

Fig.8RS232 – Interfacing Module Circuit

V. RESULTS AND DISCUSSION

The following figure, Fig.9illustrates the Transmission end view of the proposed system, in which this page allows the user to enter the data to be transmitted to the destination using Arduino Serial COM Port, COM4.

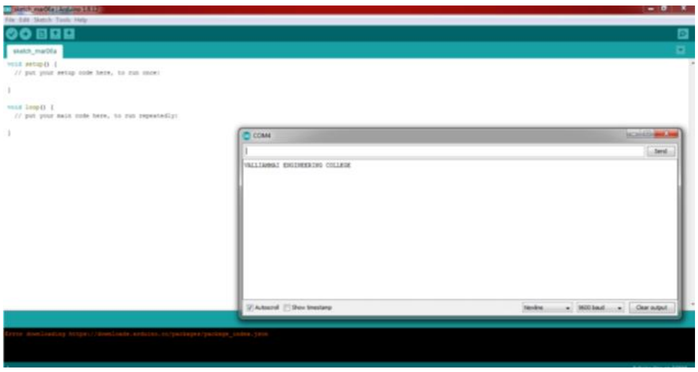

Fig.9VLC Transmission View

The following figure, Fig.10 illustrates the Receiving end view of the proposed system, in which this page allows the user to receive the data from transmission end over the destination using Arduino Serial COM Port, COM3.

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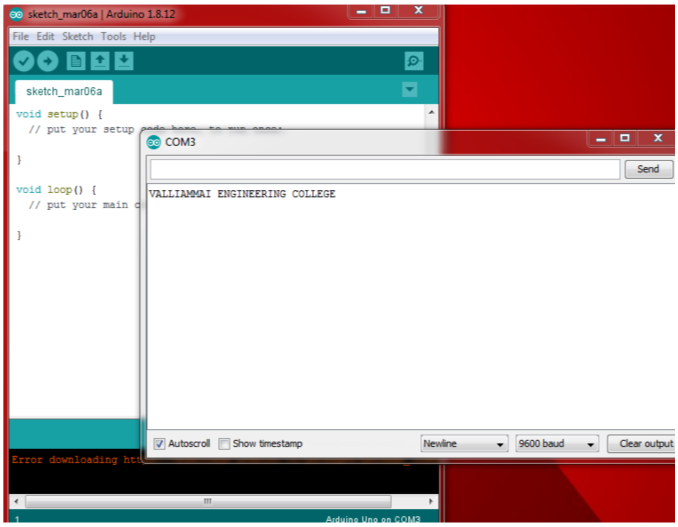

Fig.10 VLC Receiver View

The following figure, Fig.11 illustrates the major and exact Hardware unit view of the proposed system.

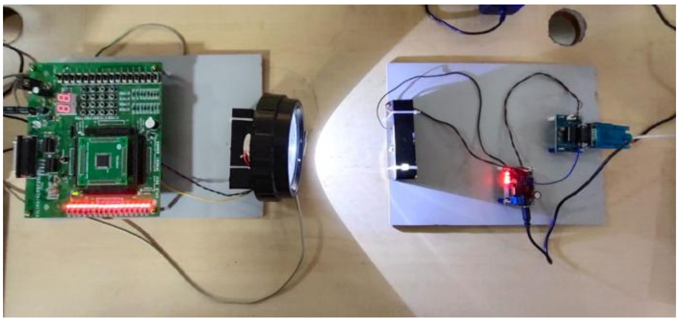

Fig.11 VLC Hardware View

VI. CONCLUSION

The exploitation of LiFi Transmitter and Receiver results in commissioning procedures for data oriented communications and commissioning time is drastically reduced. With this configuration, data transmission configuration is more ease to use with light house oriented communications is possible. For all the result of this system is a data based efficient LiFi Communications with innovative transceiver unit.

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