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Optical Wireless System For Biomedical Sensing Data Transmission Through Visible Signal

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Abstract

The usage of radio-frequency communication technologies in biomedical or healthcare applications involves disturbances such as overlapping of signals with medical instruments and it is mainly hazardous for human health because of electromagnetic waves. In this paper, we demonstrate the method which uses visible light signal communication technology as a platform for transmission and to provide real-time monitoring of heart beats, blood pressure, temperature and various other parameters. LED beam is used as the illuminating source to simultaneously transmit biomedical signal as well as patient health condition. On-off Keying (OOK) modulation technique is used to modulate all the data onto the visible light beam. Both types of data will be transmitted using a single data packet. At the receiving end, a receiver circuit consisting of a high-speed PIN photo detector and a demodulation circuit is employed to demodulate the data from the visible light beam. The demodulated data is then serially transmitted to a personal computer where the biomedical signal, patient information and heart rate can be monitored in real-time.

Keywords: Visible light communication, LED, biomedical data, OOK modulation.

Introduction

In existing system, wireless sensor network based data transfer system is available like RF. This type of communication method needs power to transmit and receive the data. But the cost of the wireless sensor network is high and data losses will be there.

To overcome the above drawbacks we have used led and photodiode to transmit and receive the data. But cost of this product is very cheap, the durability of the product is high and data loss of the product is very less compared than the RF and get the patient's condition and other heath related information..

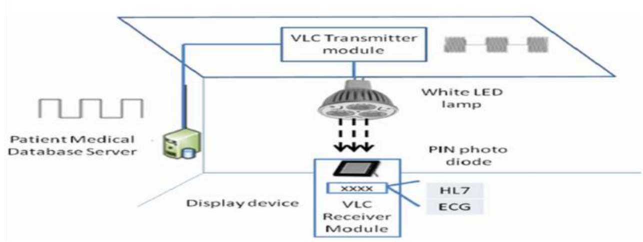

Figure 1.1: Architecture of indoor VLC system in an hospital environment using LED devices.

Nowadays, wireless communication technologies are employed in medical body area networks to enhance flexibility and convenience for caregivers and patients. However, there is always the risk of disturbance from electromagnetic waves toward precision medical equipment. This study demonstrates a novel design and implementation of a medical healthcare information system using the emerging wireless visible light communication (VLC) technology. consider the use of MRI scanners and the patient monitoring devices in the same room, if the doctor has to do MRI scanning of a person and to monitor that person at the same time then there will be a overlapping of radio waves of two different frequencies which leads to the improper diagnosis of patient, in order to overcome this we can implement li-fi in order to monitor the patients i.e., MRI scanners use radio waves for scanning so we can use li-fi to get internet access to monitor patients instead of another radio waves and causing overlapping of signals. There is a probation on the use of mobiles in few areas in the hospitals, this is because of the radio waves overlapping problems to overcome this drawback also we can implement light fidelity in hospitality system. If a doctor has to monitor a patient from his place or to know the information of appointments then they can use this li-fi technology which has a very high data rate. Where all we to need to access internet along with various EMI we can implement li-fi which provides internet access using visible light.

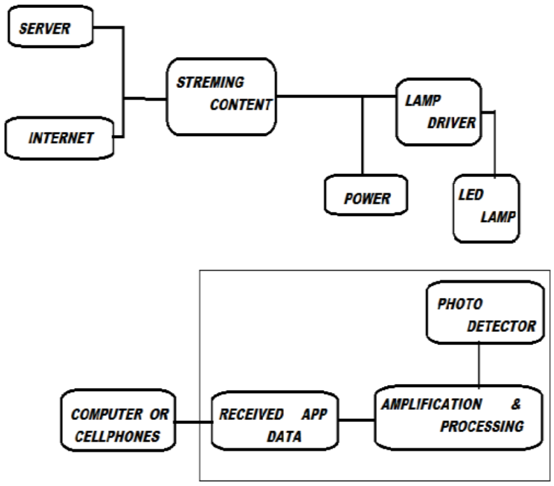

Figure 1.2: This Is For The Downlink Only, and A Parallel Similar System Is Needed For The Uplink

Scope of Visible Light Technology

VLC technology can be implemented using visible light emitting diodes (LED), which is expected to be the main lighting source in the near future due to its energy efficient characteristic compared to conventional incandescent and fluorescent lighting. By manipulating the fast switching characteristic of LEDs, these lighting devices can be used simultaneously for illumination and wireless data communication. The prototype design of the VLC-based medical healthcare system can be used to provide data service and monitoring in radio frequency restricted hospital areas.High brightness LED (HB-LED) is used in the transmitter module to transmit medical and healthcare information using optical modulation method. High speed photo detector is used to detect the optical signal, and then the signal is demodulated and conditioned at the receiver module. Medical caregivers or patients can download the biomedical data and healthcare information.

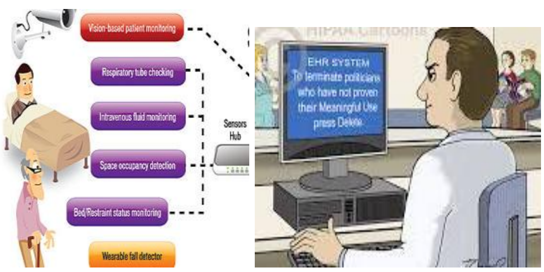

Figure 1.3: Real Time Example of Implementation of Visible Light Communication In Hospitals

How The Basic Light Is Converted Into Electricity

Vacuum equations, electromagnetic waves and speed of light

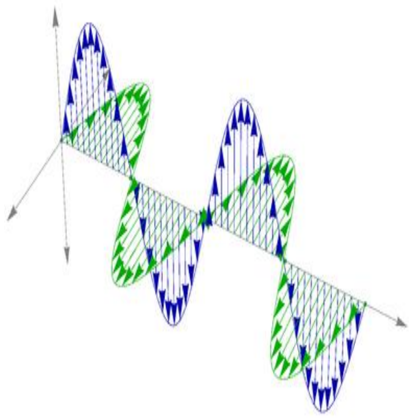

Figure 1.4: is a 3D diagram shows a plane linearly polarized wave propagating from left to right with the same wave equations from left to right

Where $E = E_0 \sin(-\omega t + k \cdot r)$ and $B = B_0 \sin(-\omega t + k \cdot r)$

In a region with no charges ($\rho = 0$) and no currents ($J = 0$), such as in a vacuum, Equation 1 is reduced Maxwell's equations:

$$\nabla \cdot \mathbf{E} = 0 \qquad \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t},$$
$$\nabla \cdot \mathbf{B} = 0 \qquad \nabla \times \mathbf{B} = \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}. \qquad \ldots(1)$$

Taking the curl (∇×) of the curl equations, and using the curl of the curl identity $\nabla\times(\nabla\times X) = \nabla(\nabla\cdot X) - \nabla^2 X$ we obtain the wave equations (2)

$$\frac{1}{c^2}\frac{\partial^2 \mathbf{E}}{\partial t^2} - \nabla^2 \mathbf{E} = 0, \quad \frac{1}{c^2}\frac{\partial^2 \mathbf{B}}{\partial t^2} - \nabla^2 \mathbf{B} = 0, \qquad \ldots(2)$$

Which identify

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 2.99792458 \times 10^8 \text{ m s}^{-1}$$

C is the speed of light in free space. In materials with relative permittivity ε_r and relative pe rmeability μ_r, the phase velocity of light becomes

$$v_p = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$$

which is usually less than *c*.

In addition, E and B are mutually perpendicular to each other and the direction of wave propagation, and are in phase with each other. A sinusoidal plane wave is one special solution of these equations. Maxwell's equations explain how these waves can physically propagate through space. The changing magnetic field creates a changing electric field through Faraday's law. In turn, that electric field creates a changing magnetic field through Maxwell's correction to Ampere's law. This perpetual cycle allows these waves, now known as electromagnetic radiation, to move through space at velocity *c*.

Bound Current and Charge

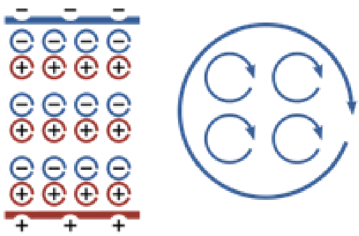

Figure 1.5: Left: schematic view of how an assembly of microscopic dipoles produces opposite surface charges as shown at top and bottom. Right: How an assembly of microscopic current loops add together to produce a macroscopically circulating current loop. Inside the boundaries, the individual contributions tend to cancel, but at the boundaries no cancelation occurs.

When an electric field is applied to a dielectric material its molecules respond by forming microscopic electric dipoles – their atomic nuclei move a tiny distance in the direction of the field, while their electrons move a tiny distance in the opposite direction. This produces a macroscopic bound charge in the material even though all of the charges involved are bound to individual molecules. For example, if every molecule responds the same, similar to that shown in the figure, these tiny movements of charge combine to produce a layer of positive bound charge on one side of the material and a layer of negative charge on the other side. The bound charge is most conveniently described in terms of the polarization P of the material, its dipole moment per unit volume. If P is uniform, a macroscopic separation of charge is produced only at the surfaces where P enters and leaves the material. For non-uniform P, a charge is also produced in the bulk.

Somewhat similarly, in all materials the constituent atoms exhibit magnetic moments that are intrinsically linked to the angular momentum of the components of the atoms, most notably their electrons. The connection to angular momentum suggests the picture of an assembly of microscopic current loops. Outside the material, an assembly of such microscopic current loops is not different from a macroscopic current circulating around the material's surface, despite the fact that no individual magnetic moment is travelling a large distance. These can be described using the magnetization M.

The very complicated and granular bound charges and bound currents, therefore can be represented on the macroscopic scale in terms of P and M which average these charges and currents on a sufficiently large scale so as not to see the granularity of individual atoms, but also sufficiently small that they vary with location in the material. As such, the Maxwell's macroscopic equations ignores many details on a fine scale that can be unimportant to understanding matters on a gross scale by calculating fields that are averaged over some suitable volume. This Table 1 shows Maxwell's equations.

Table 1: Electromagnetic Equation's

Table 1. Electromagnetic Equation

Name	Integral Equations	Differential Equations
Gauss's Law	$\oiint D \cdot dS = \iiint_{\Omega} \rho_f \, dV$	$\nabla \cdot D = \rho_f$
Gauss's Law for magnetism	$\oiint_{\partial\Omega} B \cdot dS = 0$	$\nabla \cdot B = 0$
Maxwell-Faraday equation	$\oint_{\partial\Sigma} E \cdot d\ell = -\frac{d}{dt}\iint_{\Sigma} B \cdot dS$	$\nabla \times E = -\frac{\partial B}{\partial t}$
Ampere circuital law	$\oint_{\partial\Sigma} H \cdot d\ell = \iint_{\Sigma}\left(J_f + \frac{\partial D}{\partial t}\right) \cdot dS$	$\nabla \times H = J_f + \frac{\partial D}{\partial t}$

Working

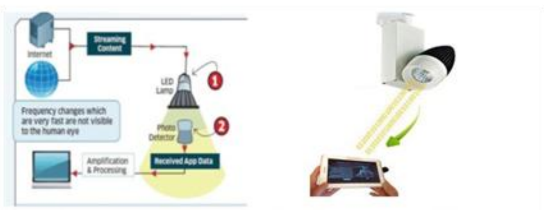

Figure 1.6: The Working Illustration of VLC

In Fig1.6 shows the binary data are captured by few light receptors are required, and are installed on all types of connected devices, from computers to tablets, to phones, televisions or appliances. Matter experts make clear that the light pulses are imperceptible to the human eye, without causing damage or discomfort of any kind. In addition, any lamp or flashlight can become a hotspot. How Li-fi works is simple: You have a light on one end (an LED), and a photo detector (light sensor) on the other. If the LED is ON, the photo detector registers a binary one; otherwise it's a binary zero. Flash the LED enough times and you build up a message. Use an array of LEDs, and perhaps a few different colours, and very soon you are dealing with data rates in the range of hundreds or megabits per second, this is accomplished by the flickering of LED light bulbs to create binary code (on = 1, off = 0), and is done at higher rates than the human eye can detect. The more LEDs in your lamp, the more data it can process.

Fig1.6 shows brief connection of internet with LED and information retrieved on the computer. One LED transfers data at a slower rate, so millions of LEDs with one micron size are installed in the bulb. The reduction of size of LEDs does not decrease its capability to transfer data or intensity on the opposite it increases the efficiency of one light bulb to transmit the data at an unexpectedly higher rates. Furthermore, these micro-LEDs are ultimately just pixels — and at one micron, these LEDs would be a lot smaller than those in your Smartphone's retina display. You could have a huge array of these LEDs that double up as a room's light source and a display— and provides networking capability on the side. Perhaps a next-next-generation console would communicate with your gamepad, Smartphone, and other peripherals via a Li-Fi-equipped TV. It indeed provides a highway lighting that illuminates the road, provides up-to-date traffic info/warnings, and provides internet access to your car, plus all of the devices on-board.

System Description

The implementation of wireless information communication technology systems allows medical personnel to gain direct access to real time and supplementary patient information, thus enhancing the quality, efficiency, and accuracy of healthcare. Radio frequency (RF) wireless technology is the most commonly used method. However, RF use is controversial due to the long-term negative effects of exposure to RF radiation on patient health and electromagnetic interference with precision medical equipment. This problem escalates especially in RF-restricted zones such as emergency rooms and intensive care units. Many regulation issues exist in RF based wireless communication and single-channel bandwidth problems that limit high data rate applications.

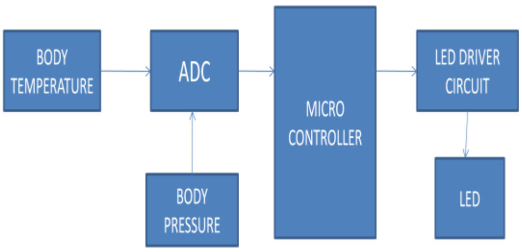

Figure 1.7: The block diagram of VLC transmitter

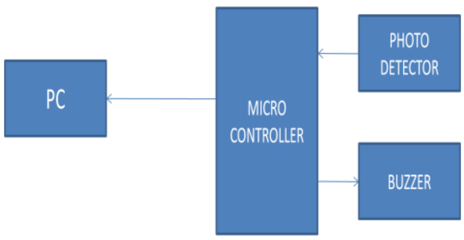

Figure 1.8: The block diagram of the VLC receiver

Herein, we propose the use of VLC wireless technology for transmitting biomedical data and healthcare information using white LED lamps as emitters. Our system was successfully employed to transmit electronic healthcare information, in accordance with the Health Level Seven (HL7) standard protocol, and analog biomedical ECG signals. Due to the energy-efficient and power-saving characteristics of LED lamps, hospitals and healthcare centres choose to install LED lamps rather than traditional lamps. Fig. 1 shows the experimental setup of our proposed VLC system that uses pre-installed white LED lamps for transmitting biomedical data. The LED emitter was fitted to a VLC transmitter module on a printed circuit board (PCB) designed by the USN lab. This PCB consists of an on-off keying (OOK) non-return to zero (NRZ) modulation circuit that generates a carrier signal. OOK is a type of amplitude shift keying (ASK), which is the simplest form of band pass data modulation. The main advantage of NRZ over other formats, e.g., return-to-Zero (RZ) and short pulse, is that the bandwidth used by the signal is approximately half of that used in the RZ format. In this experiment, a carrier signal with a frequency of 100 kHz is selected to ensure that the LED appears illuminated to the human eye while transmitting data. A microcontroller was used to interface the VLC transmitter module with the PC database containing the desired information. The modulated LED white light is transmitted via the wireless optical link and received by a silicon-based PIN photo-detector with a detection wavelength range of 350–1100 nm, responsivity of 0.72 A/W, and an active area of 100 mm2. The received data signal is then amplified and demodulated in VLC receiver module in the PCB, also designed by USN lab, for noise removal and signal reconstruction. This VLC receiver module is connected to a microcontroller display device for displaying the received information.

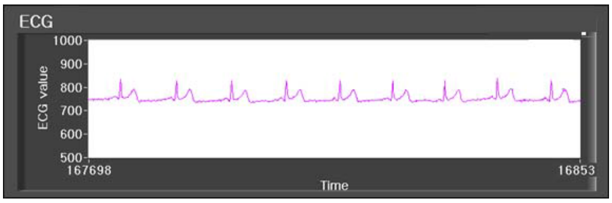

Figure 1.9: ECG signals received via VLC medical information system

Conclusion

On implementing this technology it is possible to use every bulb as a hotspot, which produces a safer environment. As radio waves are hazardous to living creatures and leads to endangering of birds we try to reduce this complication using light fidelity which works on visible light frequency and doesn't harm the nature. Another advantage of visible light technology is reduction in the power consumption and transfer of data at higher data rate which Wi-Fi finds difficult to reach. Using this technology in medical field makes diagnosis faster and allows to access internet along with the radio waves based devices. There are disadvantages too in this technology i.e. there should be a particular line of sight and also depending on the bulb used efficiency differs. So with the implementation of this technology it's possible to solve issues such as the shortage of radio-frequency bandwidth and also allow internet where traditional radio based wireless isn't allowed such as aircraft or hospitals. A VLC system using a commercial white LED device for transmitting clinical healthcare text data and analog physiological signals was developed. By the use of the OOK modulation format, we achieved data transmission at a rate of 56 kbps and BER quality of 10^{-6} at a distance of half a meter without the use of a collimating lens. The developed system was found to be suitable for data transmission at illumination levels that are 90% of the nominal optical power of the lamp.

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