A PROJECT REPORT

ON

Data Transmission Using Li-Fi

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CERTIFICATE

This is to certify that **Abhay Maurya (15405), Abhishek Kumar (15406), Abhishek Sonker (15408), Ajay (15411)** have carried out the project work in this report entitled **"Data Transmission using Li-Fi"** submitted in partial fulfillment of the requirements for the award of degree of Bachelor of Technology in Electronics Engineering from Kamla Nehru Institute of Technology, Sultanpur (U.P.)-228118 under our supervision during the academic session 2018-2019.

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PREFACE

Whether you’re using wireless internet in a coffee shop, stealing it from the guy next door, or competing for bandwidth that a conference, you have probably gotten frustrated at the slow speeds you face when more than one device is tapped into the network. As more and more people and their many devices access wireless internet, clogged airwaves are going to make it. One German physicist. Harald Haas has come up with a solution he calls “data through illumination” –taking the fiber out of fiber optic by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. It’s the same idea band behind infrared remote controls but far more powerful.

Haas says his invention, which he calls delights, can produce data rates faster than 10 megabits per second, which is speedier than your average broadband connection. He envisions a future where data for laptops, smartphones, and tablets is transmitted through the light in a room. And security would be snap if you can’t see the light, you can access the data. That data will be delivered to you with the same speed as in brighter light. The power required for transferring the data will be not much more. You can say we age getting the data a no cost because of that amount of power will be negligible in comparison to the power used for light.

We are making our full effort to implement most of the features of Visible light communication. This project will consist of audio and text transmission with the help of Arduino Uno. Audio transmission could be made by solar panel and LDR, whereas text transmission could be made using Arduino

We know that spectrum is a rare coin for communication engineers. Nowadays, with the rapid growth of wireless communications, the problem of using spectrum efficiently has become more important. Many solutions have been proposed to solve this issue; one of these solutions is the usage of visible light frequencies to send data. These frequencies are already free and unused. Light Fidelity (Li-Fi) is a new short-range optical wireless communication technology which provides the connectivity within a local network, by using Light-Emitting Diodes (LEDs) to transmit data depending on light illumination properties.

We shall explain in this report the basic foundation of this new technology and its important applications. Then we discuss its challenges and implemented projects all over the world.

CONTENTS

INTRODUCTION

Transfer data from one place to another is one of the most important day-to-day activities. The current wireless networks that connect us to the internet are very slow when multiple devices are connected. As the number of devices that access the internet increases, the fixed bandwidth available makes it more and more difficult to enjoy high data rates and connect to a secure network. Nowadays, Everyone is interested in using his mobile phone, laptop to communicate with other people through Wireless-Fidelity (Wi-Fi) systems, and this technology, Wi-Fi, is widely used in all public areas like home, cafes, hotels, and airports by people, also the time usage of wireless systems is increasing exponentially every year; but the capacity is going down, due to the limitation of Radio Frequency (RF) resources, so we are going to suffer from severe problem.

In order to overcome this problem in the future, Professor Harald Haas, an expert in optical wireless communications, proposes in 2011 a brilliant and applicable solution by using light to transmit data, he demonstrated how a Light-Emitting Diodes (LED) bulb equipped with signal processing technology could stream a high-definition video to a computer and he showed that one watt LED light bulb would be enough to provide net connectivity to four computers.

Professor Harald Haas coined the term "Li-Fi" at his 2011 TED Global Talk where he introduced the idea of "wireless data from every light". He is a Chair Professor of Mobile Communications at the University of Edinburgh, and the co-founder of pureLiFi along with Dr. Mostafa Afgani.

The general term "visible light communication" (VLC), whose history dates back to the 1880s, includes any use of the visible light portion of the electromagnetic spectrum to transmit information. The D-Light project at Edinburgh's Institute for Digital Communications was funded from January 2010 to January 2012. Haas promoted this technology in his 2011 TED Global talk and helped start a company to market it. PureLiFi, formerly pureVLC, is an original equipment manufacturer(OEM) firm set up to commercialize Li-Fi products for integration with existing LED-lighting systems. Oledcomm, a French company founded by Pr Suat Topsu from Paris-Saclay University. In October 2011, companies and industry groups formed the Li-Fi Consortium, to promote high-speed optical wireless systems and to overcome the limited amount of radio-based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. A number of companies offer uni-directional VLC products, which is not the same as Li-Fi - a term defined by the IEEE 802.15.7r1 standardization committee. VLC technology was exhibited in 2012 using Li-Fi. By August 2013, data rates of over 1.6 Gbit/s were demonstrated over a single color LED. In September 2013, a press release said that Li-Fi, or VLC systems in general, do not require line-of-sight conditions. In October 2013, it was reported Chinese manufacturers were working on Li-Fi development kits.

In April 2014, the Russian company Stins Coman announced the development of a Li-Fi wireless local network called BeamCaster. Their current module transfers data at 1.25 gigabytes per second (GB/s) but they foresee boosting speeds up to 5 GB/s in the near future. In 2014 a new record was established by Sisoft (a Mexican company) that was able to transfer data at speeds of up to 10 GB/s across a light spectrum emitted by LED lamps. Recent integrated CMOS optical receivers for Li-Fi systems are implemented with avalanche photodiodes (APDs) which has a low sensitivity. In July 2015, IEEE has operated the APD in Geiger-mode as a single photon avalanche diode (SPAD) to increase the efficiency of energy-usage and makes the receiver more sensitive. This operation could be also performed as quantum-limited sensitivity that makes receivers able to detect weak signals from a far distance.

Li-Fi (*light fidelity*) is wireless communication technology, which utilizes light to transmit data and position between devices. In technical terms, Li-Fi is a visible light communications system that is capable of transmitting data at high speeds over the visible light, ultraviolet, and infrared spectrums. In its present state, only LED lamps can be used for the transmission of visible light. In terms of its end use, the technology is similar to Wi-Fi - the key technical difference being that Wi-Fi uses radio frequency to transmit data. Using light to transmit data allows Li-Fi to offer several advantages, most notably a wider bandwidth channel, the ability to safely function in areas otherwise susceptible to electromagnetic interference (e.g. aircraft cabins, hospitals, military), and offering higher transmission speeds. Visible light communications (VLC) works by switching the current to the LEDs off and on at a very high speed, too quick to be noticed by the human eye, thus, it does not present any flickering. Although Li-Fi LEDs would have to be kept on to transmit data, they could be dimmed to below human visibility while still emitting enough light to carry data.

Li-Fi has the advantage of being useful in electromagnetic sensitive areas such as in aircraft cabins, hospitals, and nuclear power plants without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible light, Ultraviolet, and Infrared. While the US Federal Communications Commission has warned of a potential spectrum crisis because Wi-Fi is close to full capacity, Li-Fi has almost no limitations on capacity. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum. Researchers have reached data rates of over 224 Gbit/s, which was much faster than typical fast broadband in 2013. Li-Fi is expected to be ten times cheaper than Wi-Fi. Short range, low reliability, and high installation costs are the potential downsides.

We use the visible light as a signal carrier instead of traditional RF carrier as in Wi-Fi. Professor Harald Haas coined the term "Light-Fidelity" and set up a private company, called “Pure Visible Light Communication”, to exploit that technology.

CHAPTER ONE

Problems of Wireless Communication Systems

In this Chapter, we will talk about the severe problem in a communication system called “Spectrum Crunch”, and the suggested solutions to solve it. One of the solutions is the use of visible light. we will describe it briefly and talk about Visible Light Communication (VLC) systems and their components.

1.1 What is the Problem?

Despite continuous improvements in wireless communication systems, e.g. 3G, 4G, etc.., a coming crisis is expected due to the lack of sufficient Radio Frequency (RF) resources, this limitation in bandwidth can‟t support the growth in demand for high data rates and the large numbers of communication systems, as shown in Figure 1, within the bandwidths between 300 kHz and 4 GHz. That‟s known as “Spectrum Crunch”.

Although, spectrum congestion decreases when we use high frequencies to transfer data, this not a practice solution, because this part of the spectrum requires complex equipment and causes high-cost systems. To provide a high-speed internet connection to everyone companies prefer to increase the frequency of the signal. Which consume not only very large power but also dangerous to environment humans animals. Because of high radiations, it seems plants are getting damaged by theses radiation. Rules and regulations have been made by our government but companies do not follow. They have to install more towers to provide coverage to that area hence will cause more cost. They simply increase the power of the signal to cover a larger area. But due to these high power radiation causes cancer to humans and animals. Plants are getting affected. If someone is exposed such radiation continuously his life get half. Someone could say that then avoid using such technology but it could not be. Everyone need information hence needs connectivity. Then what could be the solution that both problems could be resolved without affecting our nature and living bodies? it comes in mind is that Li-Fi, yes. We could resolve almost some of the problem with Li-Fi because it is not dangerous to anyone even you exposed to this system lifetime. It is efficient in each and everything such as power, speed, reliability, etc. only one issue that could occur line-of-sight but not everywhere but at some public places, we could implement.

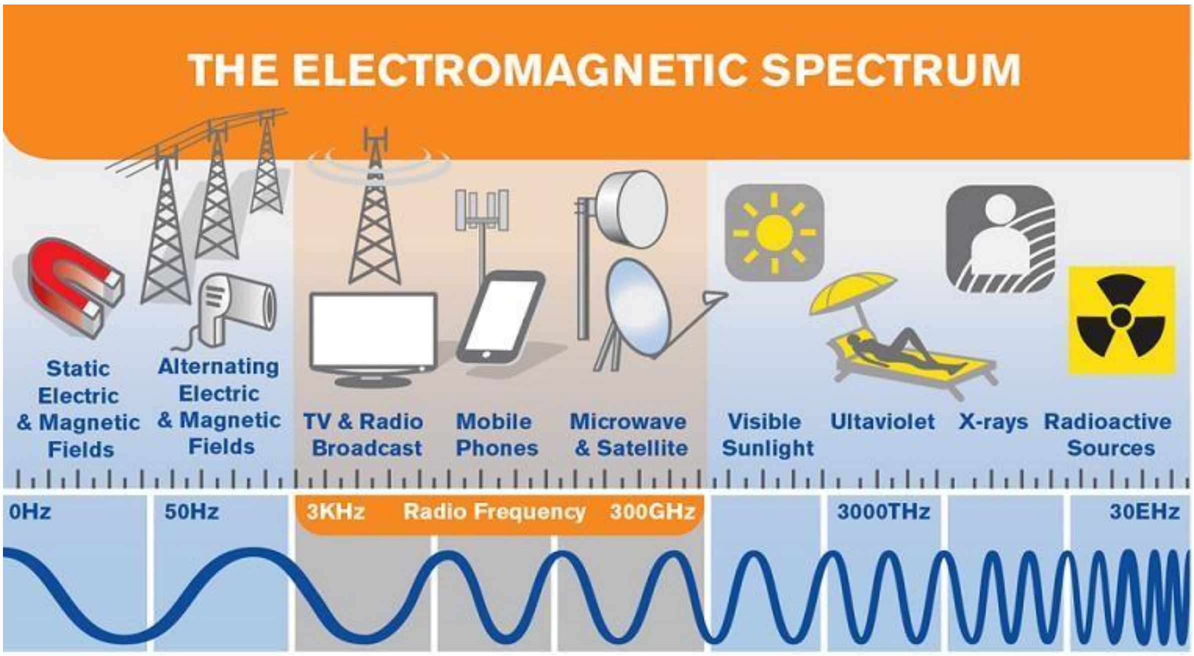


Figure 1.1: Multiple communication systems cause Spectrum Crunch.

1.2 How can we solve this problem?

Actually, there are numbers of technologies that provide realistic and applicable solutions to this issue. One of them is “Cognitive Radio”. It is a new sort of wireless communication with a transceiver architecture that can intelligently detect which communication channels are in use and which are not, and instantly move into empty channels to use them to transmit data. Another solution is the transmission of data using visible light illumination which use very high frequency. In general, this technology is known as Visible Light Communication (VLC). Li-Fi has the advantage of being useful in electromagnetic sensitive areas such as in aircraft cabins, hospitals, and nuclear power plants without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilizes radio waves, Li-Fi uses visible light, Ultraviolet, and Infrared. While the US Federal Communications Commission has warned of a potential spectrum crisis because Wi-Fi is close to full capacity, Li-Fi has almost no limitations on capacity. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum. Researchers have reached data rates of over 224 Gbit/s, which was much faster than typical fast broadband in 2013. Li-Fi is expected to be ten times cheaper than Wi-Fi. Short range, low reliability, and high installation costs are the potential downsides.

CHAPTER TWO

Visible Light Communication

2.1 Definition

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 over short distances. Systems such as RONJA can transmit at full Ethernet speed (10 Mbit/s) over distances of 1–2 kilometers (0.6–1.2 mi). 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 (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. VLC is an optical communication technology that uses visible light rays, these rays locate between [400-800] THz, as an optical carrier for data transmission by illumination. It uses fast pulses of light, which cannot be detected by the human eye, to transmit data. It includes any use of the visible light portion of the electromagnetic spectrum to transmit information. The VLC standardization process is conducted within the IEEE wireless personal area networks working group (802.15).

One of VLC‟s features is providing wide bandwidth as illustrated in Figure 2. We can obviously see that using the optical portion of spectrum guarantees about 10,000 times greater bandwidth compares to the usage of the RF frequencies.

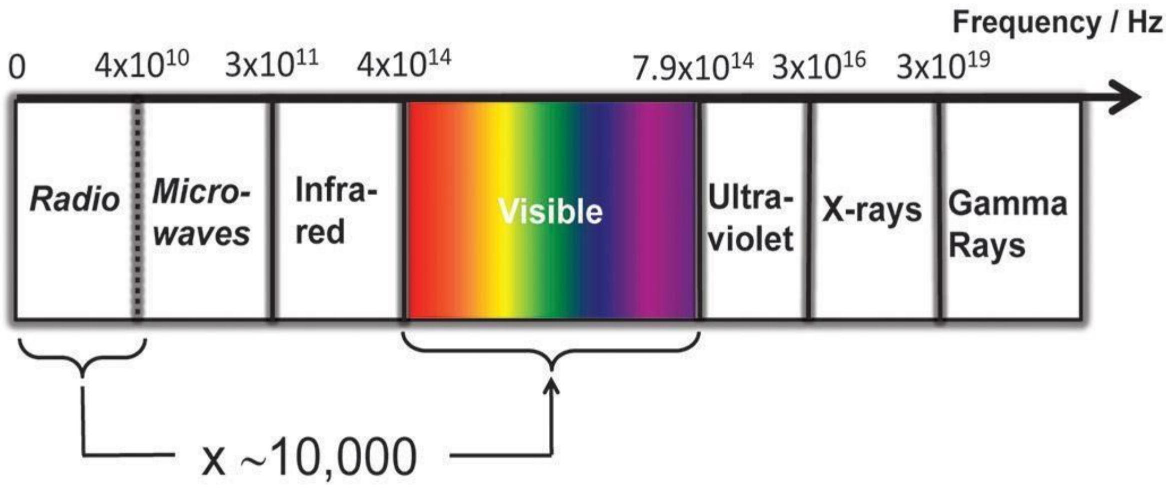


Figure 2.1: Location of visible light and RF frequencies at the electromagnetic spectrum.

2.2 Components

As we see in the previous paragraph, VLC is a communication system which consists of a transmitter, a receiver and a communication channel. The main components of VLC systems are:

- High brightness Light-Emitting Diodes (LEDs) or any light sources, which acts as a transmitter.
- A silicon photodiode has the role of a detector and it shows a good response to the visible wavelength. The communication channel is air or fiber optics.

Usually, we add to these components some necessary circuits like a driving circuit and a receiving circuit. The driving circuit consists of a control circuit and output stage to modify the data and make it ready to be sent and the receiving circuit consists of a filter to select the required band, amplification stage to provide the required Signal to Noise ratio in order to demodulate the signal. We show a block diagram of the VLC system in Figure 3.

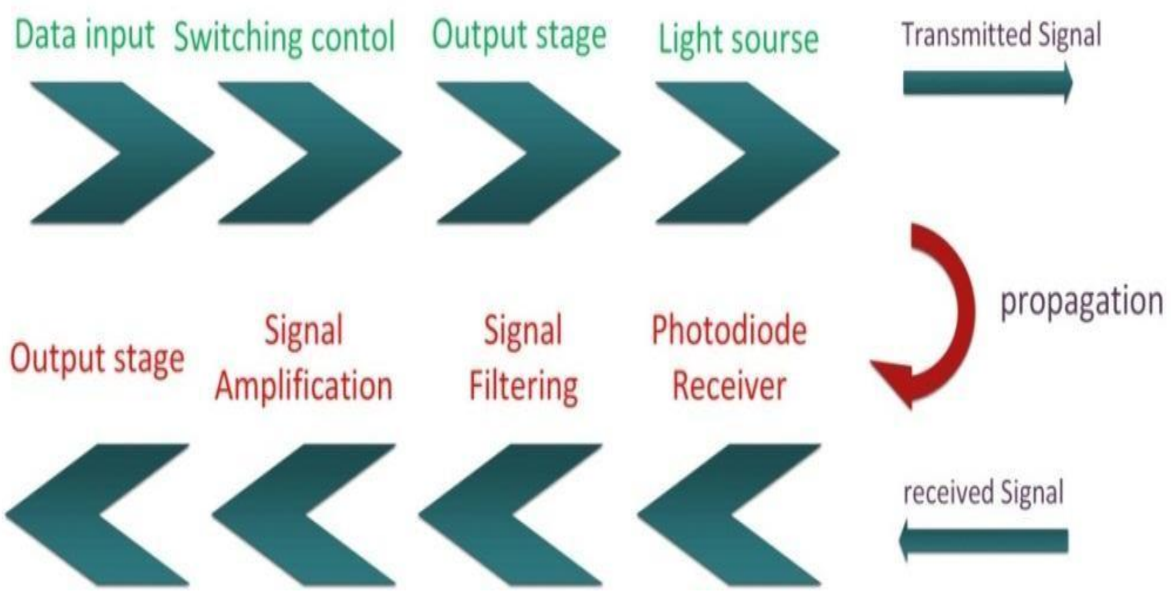


Figure 2.3: Block diagram of the VLC system.

2.3 History

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 photophone, 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. Since then there have been numerous research activities focussed on VLC.

In 2006, researchers from CICTR at Penn State proposed a combination of power line communication (PLC) and white light LED to provide broadband access for indoor applications.[4] This research suggested that VLC could be deployed as a perfect last-mile solution in the future.

In January 2010 a team of researchers from Siemens and Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute in Berlin demonstrated transmission at 500 Mbit/s with a white LED over a distance of 5 meters (16 ft), and 100 Mbit/s over longer distance using five LEDs.[5]

The VLC standardization process is conducted within the IEEE 802.15.7 working group.

In December 2010 St. Cloud, Minnesota, signed a contract with LVX Minnesota and became the first to commercially deploy this technology.

In July 2011 a presentation at TED Global.[7] gave a live demonstration of high-definition video being transmitted from a standard LED lamp, and proposed the term Li-Fi to refer to a subset of VLC technology.

Recently, VLC-based indoor positioning systems have become an attractive topic. 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, ByteLight filed a patent on a light positioning system using LED digital pulse recognition in March 2012. 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.

In May 2015, Philips collaborated with supermarket company Carrefour to deliver VLC location-based services to shoppers' smartphones in a hypermarket in Lille, France. In June 2015, two Chinese companies, Kuang-Chi, and Ping An Bank partnered to introduce a payment card that communicates information through a unique visible light. In March 2017, Philips set up the first VLC location-based services to shoppers' smartphones in Germany. The installation was presented at EuroShop in Düsseldorf (March 5 – 9 the). As the first supermarket in Germany, an Edeka supermarket in Düsseldorf-Bilk is using the system, which offers a 30-centimeter positioning accuracy can be achieved, which meets the special demands in food retail. 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 a wireless network that for data transmission uses visible light, and does not use intensity modulation of optical sources. The idea is to use vibration generator instead of optical sources for data transmission.

Here we could summarise as:

- 2011, Haas promoted this technology in TED global talk and helped start a company to market it.
- October 2011, companies and industry groups formed the Li-Fi consortium, to promote high-speed optical wireless systems and to overcome the limited amount of radio-based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum.
- 2012, VLC technology exhibited by using Li-Fi Consortium.
- October 2013, Chinese manufacturers work on Li-Fi development kits.
- April 2014, the Russian company Stins Coman announced the development of a Li-Fi wireless local network called BeamCaster. Their current module transfers data at 1.25 Gbps. 333

CHAPTER THREE

Li-Fi Definition

In this chapter, we will talk about Li-Fi technology in detail and show its history, describe the first project; which called D-Light. In this field, we explain the working principle for this technology and its advantages.

3.1 What is Li-Fi?

Li-Fi is a new technology for short-range wireless communication system; which is suitable for data transmission via LEDs by illumination. It uses the visible light, a part of the electromagnetic spectrum that is still not greatly utilized, instead of RF part.

Professor Harald Haas, the original founder of Li-Fi technology, in his Technology Entertainment Design (TED) global talk on Li-Fi says: “At the heart of this technology is a new generation of high brightness LEDs”, he also explains “Very simply, if the LED is on, you transmit a digital 1, if it‟s off you transmit a 0, they can be switched on and off very quickly, which gives nice opportunities for transmitted data.” It is possible to encode data in the light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. Figure 4 illustrates the idea of data transmission using light. The LED intensity is modulated so rapidly that the human eye cannot notice, so the output appears constant; also more sophisticated techniques could dramatically increase Li-Fi data rates such as using an array of LEDs, where each LED transmits a different data stream, to provide parallel data transmission. Other ideas are using mixtures of red, green and blue LEDs to alter the light frequency encoding a different data channel. In the next paragraphs, we will talk about the history of technology, its working principle, and its various advantages.

Figure 3.1: Data transmission via LEDs

CHAPTER FOUR

Working Principle

Li-Fi technology is implemented using white LED light bulbs used for illumination by applying a constant current. However, by fast variations of the current, the light output can be made to vary at extremely high speeds. If the LED is on, it transmits a digital 1otherwise it transmits a digital 0. The LEDs can be switched on and off quickly to transmit data that can‟t be detected by a human eye.

So what we need at all for sending data are some LEDs and a controller that codes data into those LEDs and for receiving data, we need an Image Sensor, Photodiode which is used as a detector, these components are shown in Figure 5.

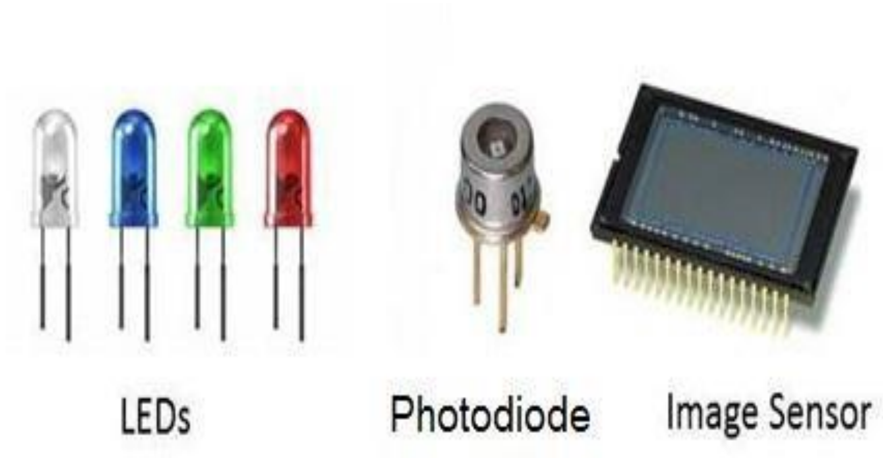


Figure4.1 : The main component of Li-Fi system: LEDs, Photodiode and Image sensor.

The LED bulb will hold a microchip that will do the job of processing the data. The light intensity can be manipulated to send data by tiny changes in amplitude.

Figure 6 shows the working principle of Li-Fi system, for data transmission; it can be done by a single LED or multi-LED. On the receiver side, there is a photo-detector, which convert this light into electric signals and it will give the electric signals to the device connected to it. Voltage regulator and level shifter circuits are used on both sides to convert or maintain a voltage level between transmitter and receiver.

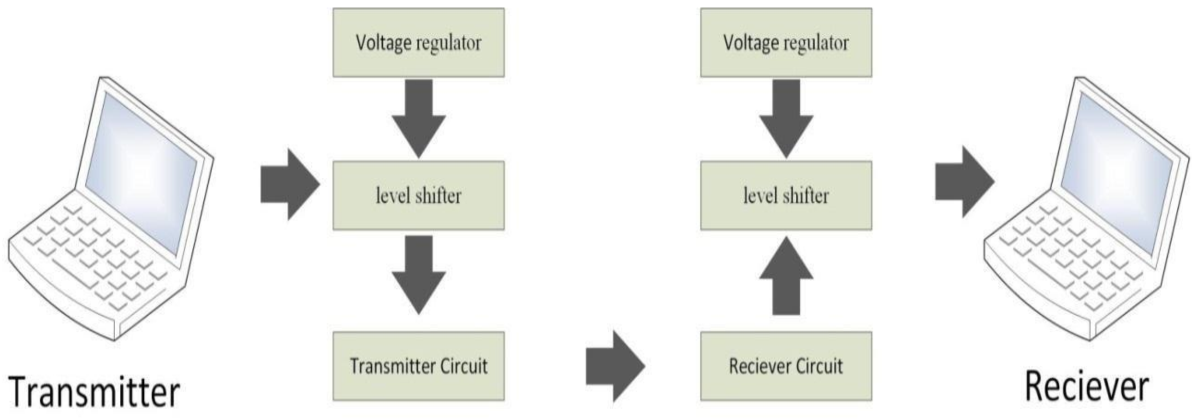


Figure 4.2: The working principle of the Li-Fi.

4.1 How does Li-Fi works?

All the existing wireless technologies utilize different frequencies on the electromagnetic spectrum. While Wi-Fi uses radio waves, Li-Fi hitches information through visible light communication. Given this, the latter requires a photo-detector to receive light signals and a processor to convert the data into streamable content. As a result, the semiconductor nature of LED light bulbs makes them a feasible source of high-speed wireless communication.

So, how does it work? Let's look at the working of Li-Fi: When a constant current source is applied to an LED bulb, it emits a constant stream of photons observed as visible light. When this current is varied slowly, the bulb dims up and down. As these LED bulbs are a semiconductor, the current and optical output can be modulated at extremely high speeds that can be detected by a photo-detector device and converted back to electrical current. The intensity modulation is too quick to be perceived with the human eye and hence the communication seems to be seamless just like RF. So, the technique can help in transmitting high-speed information from an LED light bulb. However, it's much simpler, unlike RF communication which requires radio circuits, antennas, and complex receivers. Li-Fi uses direct modulation methods similar used in low-cost infrared communications devices like remote control units. Moreover, infra-red communication has limited powers due to safety requirements while LED bulbs have intensities high enough to achieve very large data rates.

In a digital transmission system, data will be converted into binary bits in the form of zeros and ones equivalent to ‘on’ and ‘off’ states. Visible light is an ultra-fast electromagnetic wave with unlimited bandwidth to utilize. High-speed switching of light can’t be detected by human eyes but highly sensitive photodiodes can efficiently detect the modulation of light interact with the detectors.

Compared radio waves used in conventional wireless systems, visible light has a thousand times higher bandwidth. Unlimited bandwidth makes it one of the most efficient solutions for data-intensive applications. Li-Fi technology is fast, full duplex and a bidirectional communication system capable of data rate up to 224 gigabits per second.

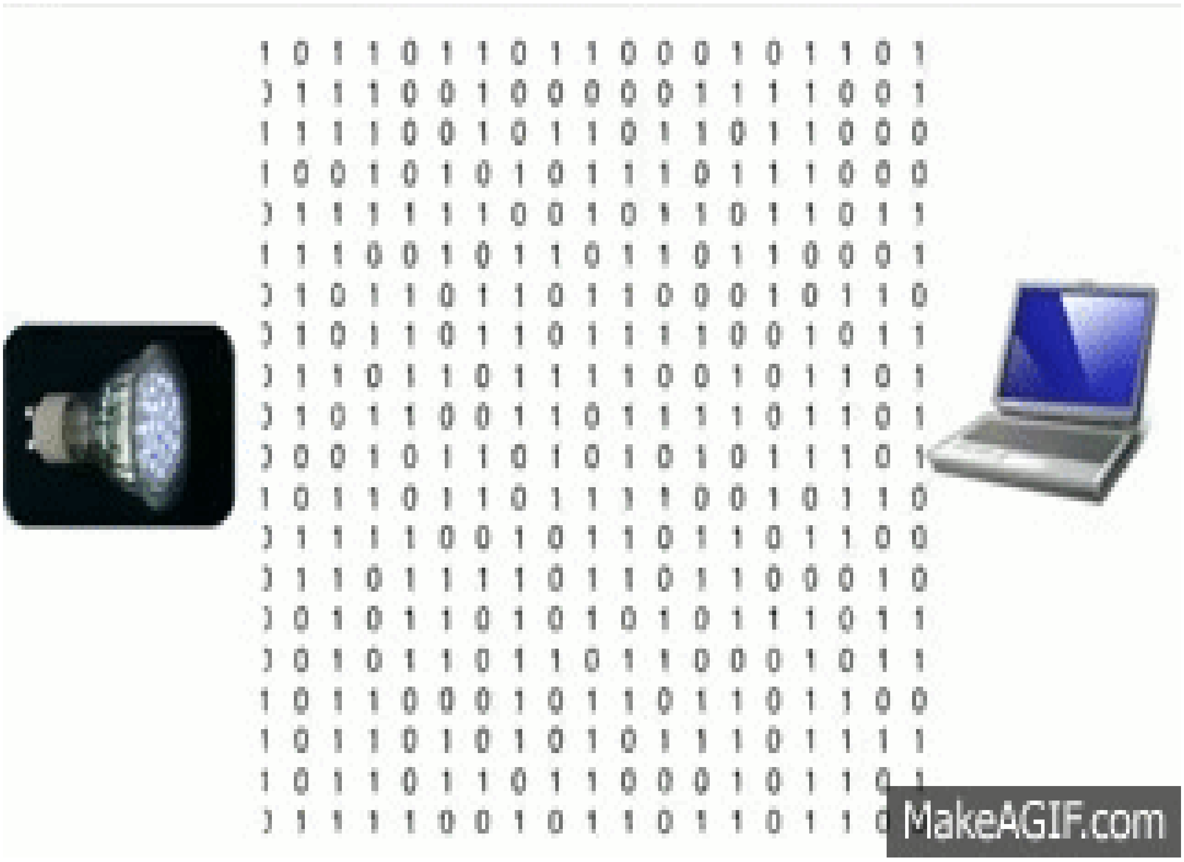


Fig: 4.3 dital data transmission

Li-Fi is a Visible Light Communications (VLC) system for data transmission. A simple VLC system has two qualifying components: 1) at least one device with a photodiode able to receive light signals and 2) a light source equipped with a signal processing unit. A

VLC light source could comprise a fluorescent or light emitting diode (LED) bulb. Since a robust Li-Fi system requires extremely high rates of light output, LED bulbs are most ideal for implementing Li-Fi. LED is a semiconductor light source, which implies that LED light bulbs can amplify the light intensity and switch rapidly. Therefore, LED cells can modulate thousands of signals without the human eye ever noticing. In turn, the changes in light intensity from the LED light source are interpreted and converted as electrical current by the receiving photodiode device. Once the electronic signal is demodulated, it is converted into a continuous stream of binary data comprising of audio, video, web, and application information to be consumed by any Internet-enabled device.

There is ample room for growing innovation in Li-Fi technology. Like conventional broadband and Wi-Fi, Li-Fi can also function as a bidirectional communication system. By interchanging visible light and infrared light from a photodetector, a mobile device connected to that photodetector can send data back to the light source for uplink. Also, multi-colored RGB (Red/Green/Blue) LED's at retina size could be engineered to send and receive a wider range of signals than single-colored phosphor-coated white LED's.

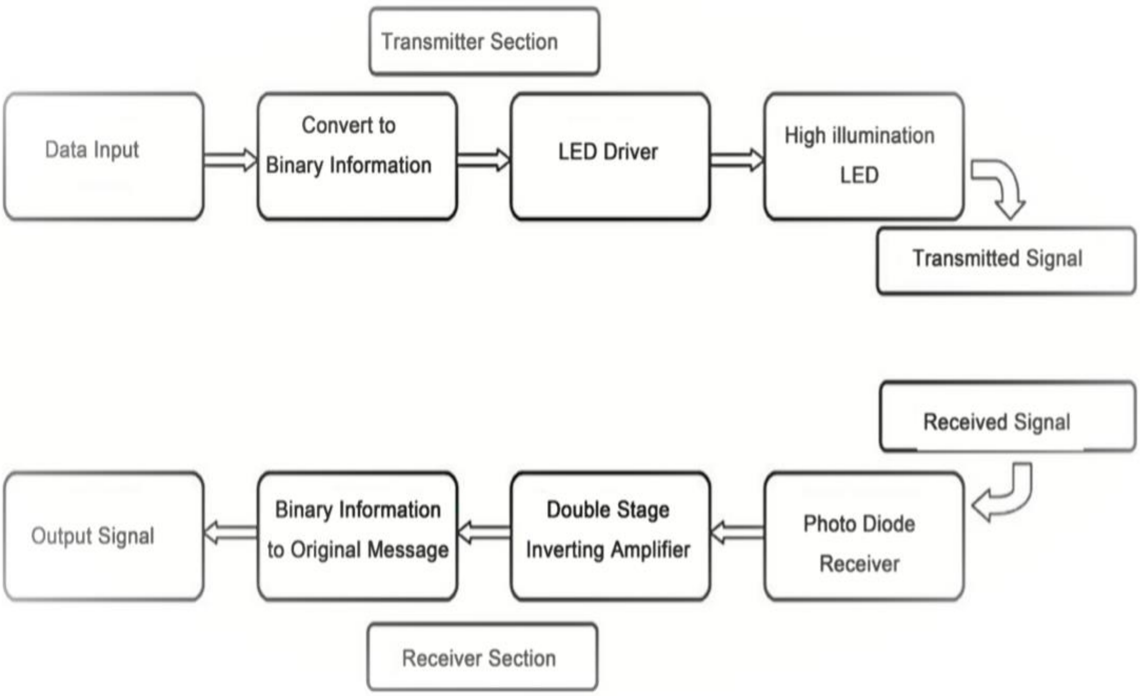
4.2 Data Access Point

The data access point connects the Li-Fi enabled data transmission system with the internet via a high-speed router and switch. Basically, it acts as a smart hub which establishes connectivity between Li-Fi enabled devices and the internet. Higher level modulation schemes and encryption techniques are being used to ensure secure communication.

4.3 Li-Fi enabled Light Source

Since the light source used in Li-Fi technology – LED bulbs are semiconductors, the same light can be used for transmitting data with fast switching of an LED light according to high-end modulation schemes. Sophisticated transceiver act as a light source (for visible light) and data transmission node capable of sending and receiving high-speed data securely.

Visible light is the medium for high-speed uplink and downlink transmission. LED is a semiconductor that produces light. When electrons enter the semiconductor they bond with holes in the substrate and energy is released in the form of photons. There are several variables that need to be considered when choosing an LED and these variables have to be weighed against each other. The maximum intensity of the LED affects the rise time. A low intensity makes it possible to have a short rise time and increasing the intensity increases the rise time. The more intensity a LED generates, the more power it needs, and the more heat it produces. The Arduino has a maximum voltage output of 5 V, the maximum current output of 1 A and can send a square wave with a maximum frequency of 50 kHz. To meet these criteria the OSRAM LED was chosen.



4.4 Li-Fi enabled smart device (transceiver)

A Li-Fi enabled smart device has a photodetector (works as a receiver) and light emitter (works as a transmitter) for uplink and downlink. Once the device moves from the vicinity of one light source to another light source, the system re-establishes the connectivity like the traditional cell concept.

Currently, our smart devices are not equipped with light detection sensors and transmitters. With modern semiconductor technology, Li-Fi can be integrated into a chip easily add into future smart devices. PureLiFi and Philips are the notable names in the research of Li-Fi technology.

4.5 Photodiode

The photodiode is a semiconductor converting light into an electrical current. Most of the photodiodes in the market are produced for the purpose of fiber optics. In applications concerning fiber optics, the radiant sensitive area of the photodiode is small and the rise/fall time is short. With increased radiant sensitive area, the response time will be slower. Without fiber optics, a larger radiant sensitive area allows for more light to be captured by the receiver. Therefore, the choice of the photodiode is limited. The requirements of the photodiode are quick response time, spectral sensitivity in the visible spectrum and large radiant sensitive area. The size of the radiant sensitive area is crucial and therefore the photodiode used is VISHAY BPW21R . It has a suitable wavelength peak sensitivity at 565 nm. The spectral bandwidth is from 420 nm to 675 nm and gives a perfect range for the intended application. It has a linear light intensity to the current ratio and the radiant sensitive area is 7.5 mm2, which was larger than most photodiodes found. It has a rise and fall time of 3 µs each, which provides a switching frequency of 166 kHz. 3. Design of a Li-Fi System Main objective is to build a prototype using off the shelf electronic devices, establish a successful link for the transmission of digital data and provide a working Li-Fi system. To achieve this goal, an open source Arduino development board is used, as shown in Figure 5. AVR atmega16 microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. They can either be powered through the USB connection from the computer or from a 9 V battery. AVR atmega16 can be controlled by the computer or programmed to work independently.

CHAPTER FIVE

Design of a Li-Fi System

The main objective is to build a prototype using off the shelf electronic devices, establish a successful link for the transmission of digital data and provide a working Li-Fi system. To achieve this goal, an open source Arduino development board is used, as shown in Figure 5. Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. They can either be powered through the USB connection from the computer or from a 9 V battery. Arduino can be controlled by the computer or programmed to work independently.

5.1 Encoding Style (On-Off Keying):

This section describes the most commonly used encoding method that was used during this project. On-off keying (OOK) is the simplest method to represent data. The logic value zero corresponds to LOW and the logic value one to HIGH. In the VLC case, this means the LED is turned off to transmit a zero and turned on to transmit a one. Let P eS and P eM are the error probability of a high bit being received as a low bit and a low bit being received as a high bit, respectively, then for a coherent receiver we have.

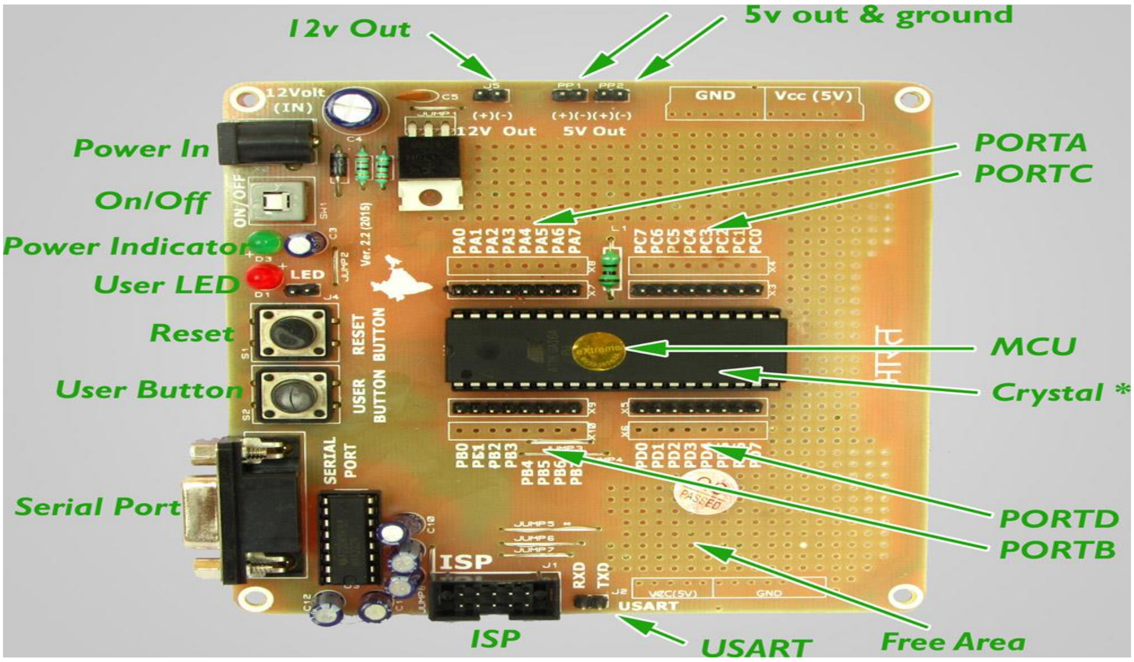


Figure 5.1. Avr atmega 16 development board.

5.2 Transmitter Hardware Design:

The task of the transmitter is to convert digital data into visible light. An LED was a suitable component because of its relatively linear relationship between current and light intensity . The general idea is to modulate the light intensity of the LED i.e., the intensity of the light corresponds to the symbol transmitted. The AVR atmega16 ports are not capable of delivering the right amount of current to make the light intensity strong and fast enough. To get around this problem a transistor is used as a switch, which made it possible to switch a larger current faster. In Figure 6, the schematic is shown to give an overview of the transmitter. The PCB for the transmitter is designed using the following steps:

1) The transmitter PCB design was done by converting the circuit's schematic diagram into a PCB layout. The software used for PCB layout is Cadsoft Eagle.

2) After designing the PCB layout, the printout of the circuit board is taken out on glossy paper.

3) Then the copper plate is cut for the circuit board. Also, the top oxide layer is rubbed away.

4) After this, the PCB print is transferred onto the copper plate.

5) Next, the circuit from the paper is ironed onto the PCB plate.

6) Next step is to etch the plate.

7) Then the etching solution is carefully disposed of and the board is cleaned properly.

8) Lastly, the final touches are given to the circuit board in Figure. Receiver Hardware Design The receiver converts the incoming light into current using a photodiode. For a digital signal, the AVR atmega16 cannot receive a voltage above 5 V. Therefore, the electrical circuit between the photodiode and the AVR atmega16 needs to process the electrical signal so it can be interpreted correctly. The receiver's electronics need to convert the current to voltage in order to amplify and compare it. Distance between the transmitter and the receiver can be varied, but in order to avoid too small or too high signal, an automatic gain controller (AGC) can be designed, instead, a variable resistor is used here. This component amplifies or reduces the input voltage to a selected output voltage. To make sure the signal is digital and stable before the Avr, an Op-Amp comparator is used here. The schematics are shown in Figure 8 and the receiver PCB layout is shown in Figure 9 with soldered components shown in Figure 10.

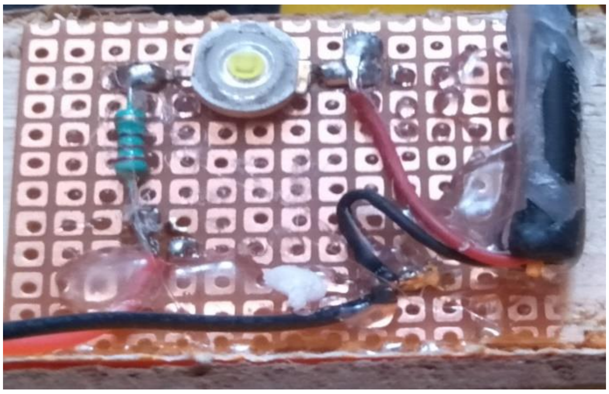


Figure 5.2. (a) PCB layout; (b) Components soldered.

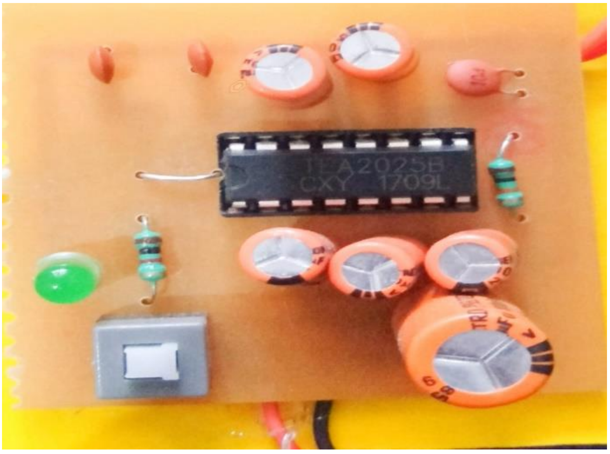


Figure 6.3. Components soldered on receiver PCB.

5.3 Software:

The software implementation of the project consists of the following separate parts:

1) Data packaging;

2) Hardware control;

3) Transmission synchronization;

4) Transmission encoding and decoding;

5) Error handling.

Whenever a user wants to send data to another user, the following steps will take place by using JAVA codes:

1) The application used by the user will notify the Operating System (OS) that it wants to send data, what the data is, and where it should be sent.

2) The kernel will take the data and hand it to the network module.

3) The network module will buffer it and start transmitting it over the channel.

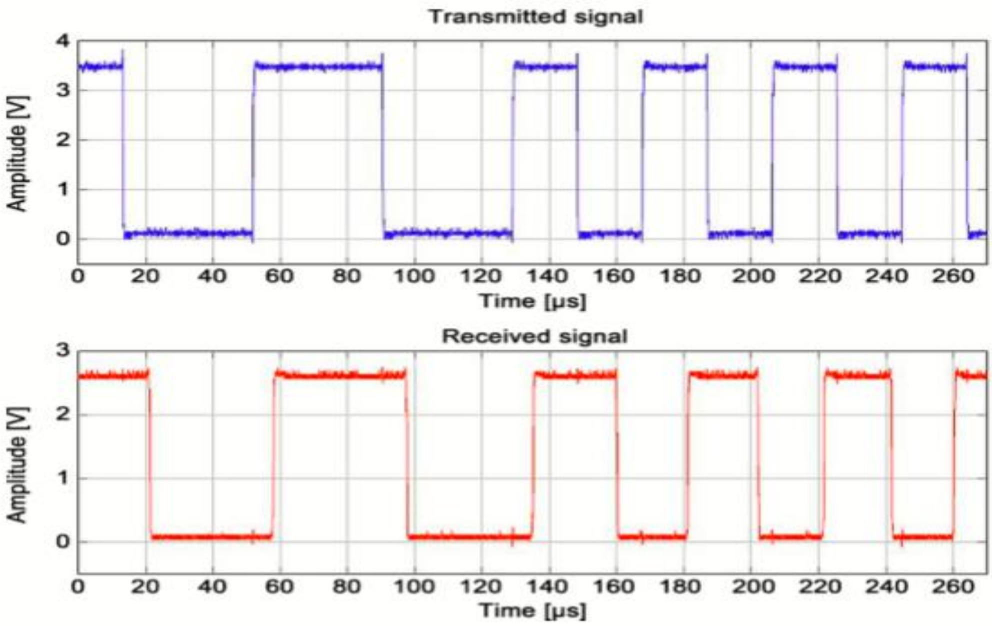
4) The network module on the receiving computer will collect the packet from the channel, and hand it to the kernel of the receiving computer.

5) If the data is intended for an application, such as a web browser, the data will be handed to that application.

5.4 Transmitter:

The transmitter receives a signal from the PC using USB Cable then from GPIO pins on the AVR atmega16, this signal controls the transistor which open and close the power supply to the LED. The LED voltage levels are shown in Figure 12, here it can be noted that both 12 v and 5 v supply can be used in the transmitter for powering the LED but for simplicity 5 v supply is preferred for low power operation. 4.3. Receiver The receiver converts the incoming light into an electrical signal and feeds it into the microcontroller. The receiver filters and amplifies the signal. After amplification, the signal is in analog form; hence ADC operation is performed, before providing it to the AVR atmega16 . Figure 13 shows the measured signal at the output of the amplifier. The current which is generated by the photodiode is of very low value; hence a high-value resistor is used to convert it to voltage. Now this voltage is further amplified for the comparator to give proper transmitted bits. The amplitude of amplified voltage which is the output of the 741 op-amps is shown in Figure 13. The signal value can be further increased by using a higher DC voltage. 4.4.

Proposed Prototype of Li-Fi Transceiver In Figure 14 the proposed schematic of Li-Fi transceiver has been illustrated. This schematic was designed using Proteus Design tool (version 8),



5.5 Receiver:

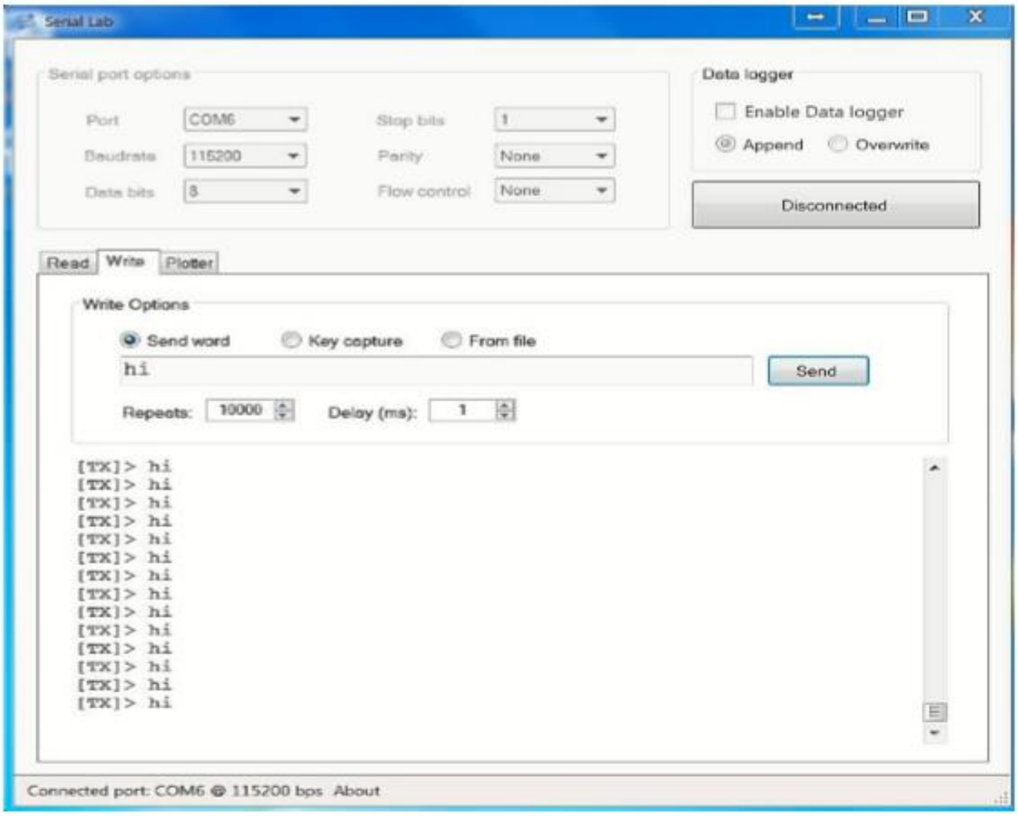


Figure 5.4. Data string which is transmitted from the pc on serial ports

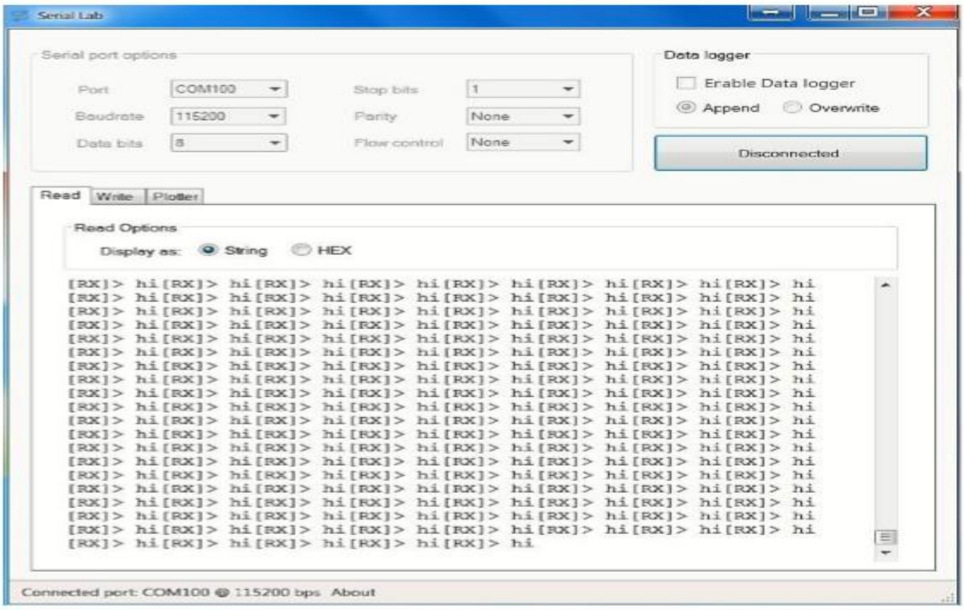


Figure 5.5. Data string received on another computer serial port.

The received data string is shown on to other pc. The x-axis range from 0 to 12 dB and the BER starts from close to 100 and begins to decrease as the SNR values start increasing. At 2 dB the value of BER falls to 10−1 and keeps falling as the SNR values increase further. At about 12 dB the BER falls down below 10−4. So there is a stringent improvement in bit error rate as the value of the signal to noise ratio increases for the on-off keying encoding. The parameters used for MATLAB simulation are as follows: 1) Charge of electron (q) = 1.6 × 10−6 C; 2) Background current noise and interference-2.02 × 10−4 A; 3) Noise Spectral Density (NO)-6.46 × 10−23 W/Hz; 4) Photodetector Responsivity (R) = 1; 5) Bit Rate (Rb) = 106; 6) Number of bits-105; 7) Samples per symbols-10; 8) Eb/NO = 1/12. In Figure 16 and Figure 17, it is shown that the data string of "hi" is transmitted from "COM port 6" at 115,200 bps and received onto "COM port 100" at 115,200 bps. The program used is a serial port monitor; it is an open source software for visualizing serial data communication. Figure 18 depicts the transmitted video and received frames are shown in Figure 19. This interface has been designed in JAVA applet. This video transmission will work smoothly only when the light from LED is interpreted properly by a photodiode. In case of any inconsistency in video transmission, the frames can be synchronized by using a buffer.

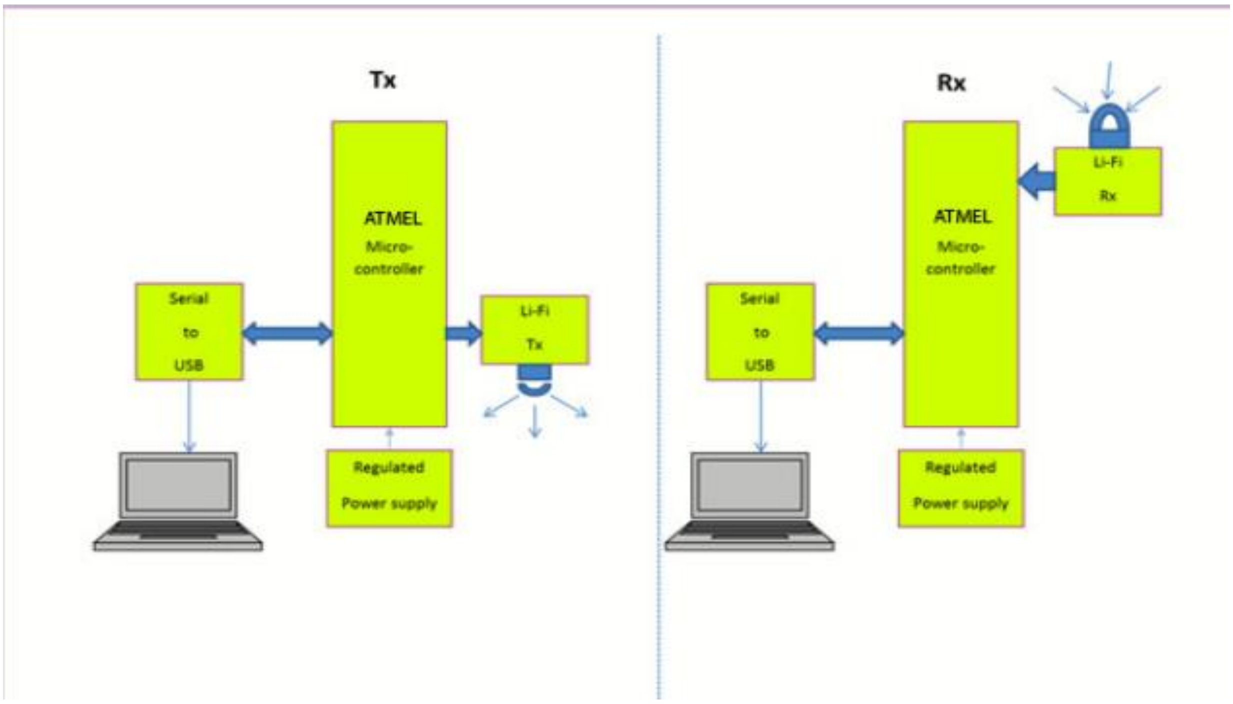


Figure 5.6.Final Block diagram for Li-Fi transmission with Atmega 16 Microcontroler.

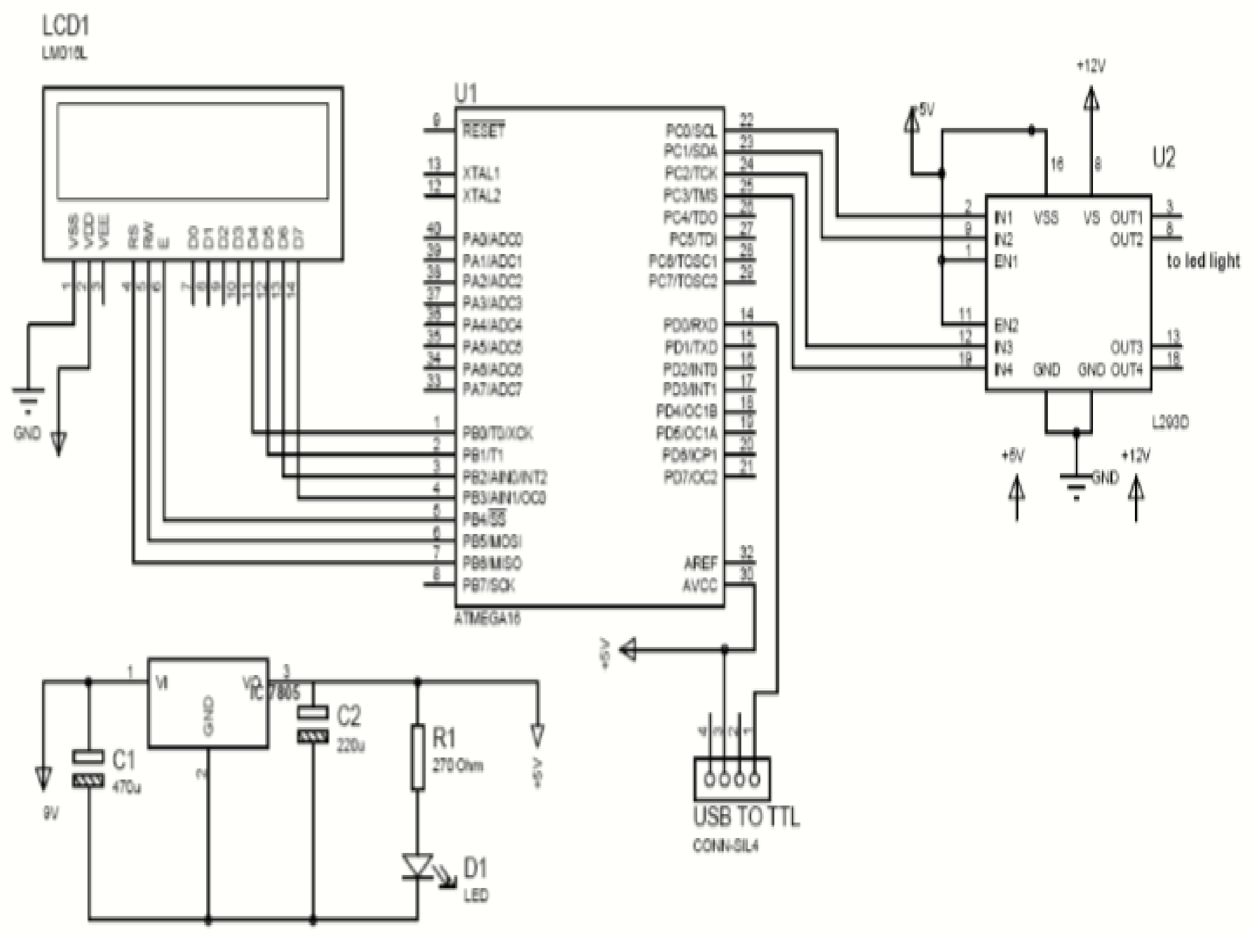
5.6 Design Verification:

Tests were conducted to verify the design and see if the right properties were achieved. These tests were mainly done using Java and MATLAB. The prototype is calibrated by sending text as a test signal so as to adjust the proper resistance values for amplification. The final design verification was done using the complete system; transmitter, receiver, and software Results In this section, a summary of the design choices made during the research work and the achieved results are described. 4.1. Hardware The transmitter and receiver results of AVR atmega16 based Li-Fi system is described in the sections below. Figure 11 displays the signal from the AVR ATMega 16 when it is propagated through the transmitter and receiver. The resulting propagated signal is nearly identical to the transmitted signal. There are a small phase difference and difference in duty cycle between the received and the transmitted signal. This is due to noise in the wireless channel and capacitive effects. The transmission efficiency of the prototype designed in the research work can be measured in terms of power. The transmitted power is 0.5 W and received power is 0.01 W at the photodiode. Hence efficiency is the ratio of received power to the input power. Hence the transmission efficiency is 0.02% or 2%.

CHAPTER SIX

CODE IMPLEMENTATION

6.1 Transmitter Code



Transmitter circuit Fig no-6.1

```
#define F_CPU 2000000UL

#include <avr/io.h>

#include <util/delay.h>

#include <stdio.h>

#include <stdlib.h>

#include<string.h>


#define LCD_DATA PORTB // In my case PORTB is the PORT from which I send data to my LCD
```

```
#define Control_PORT PORTA // In my case PORTC is the PORT from which I set the RS , R/W and En

#define En PORTA7 // Enable signal

#define RW PORTA6 // Read/Write signal

#define RS PORTA5 // Register Select signal


void init_LCD();// Function to initialize the LCD

void LCD_cmd(unsigned char cmd);// Function to send command to th LCD

void LCD_write(unsigned char data);// Function to display character on LCD


unsigned int value;

float data;

unsigned char a=0,b=0,x,y,z;

int cor,n;


void usart_init(void)

{

        UCSRB |= (1 << RXEN) | (1 << RXCIE) | ( 1<<TXEN );// Turn on the transmission and reception

        UCSRC = ( 1<<UCSZ1 ) | ( 1<<UCSZ0 ) | ( 1<<URSEL );

        UBRRL = 0X0C; //  FOR 2000000MHZ   9600 br
```

```
}


void usart_send(unsigned char data)
{

	while(! (UCSRA & (1<<UDRE)));
	UDR = data;
	_delay_ms(5);
}

void usart_SendString(char *str)
{
	unsigned char j=0;

	while (str[j]!=0)		/* Send string till null */
	{
		_delay_ms(20);
		usart_send(str[j]);
		j++;
	}
}
```

```
void LCD_cmd(unsigned char cmd)
{
LCD_DATA=cmd;
Control_PORT =(0<<RS)|(0<<RW)|(1<<En);       // RS and RW as LOW and EN as HIGH
_delay_ms(10);
Control_PORT =(0<<RS)|(0<<RW)|(0<<En);       // RS, RW , LOW and EN as LOW
_delay_ms(10);
return;
}

void LCD_write(unsigned char data)
{
LCD_DATA= data;
Control_PORT = (1<<RS)|(0<<RW)|(1<<En);      // RW as LOW and RS, EN as HIGH
_delay_ms(10);
Control_PORT = (1<<RS)|(0<<RW)|(0<<En);      // EN and RW as LOW and RS HIGH
_delay_ms(10);  // delay to get things executed
return ;
}
```

```
void init_LCD()
{

LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);

}

void LCD_write_string(unsigned char *str) //take address vaue of the string in pionter *str
{
int i=0;
while(str[i]!='\0') // loop will go on till the NULL charaters is soon in string
{
LCD_write(str[i]); // sending data on CD byte by byte
i++;
}
return;
```

```
}




int main(void)
{

DDRA=0xf0;
DDRB=0xff;
DDRC=0X00;
DDRD=0xff;

PORTD |= (1<<PD7);  /// set high

UCSRB = ( 1<<TXEN ) | ( 1<<RXEN ) ;
UCSRC = ( 1<<UCSZ1 ) | ( 1<<UCSZ0 ) | ( 1<<URSEL );
UBRRL = 0X0C; //9600 br

_delay_ms(2000);

LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
```

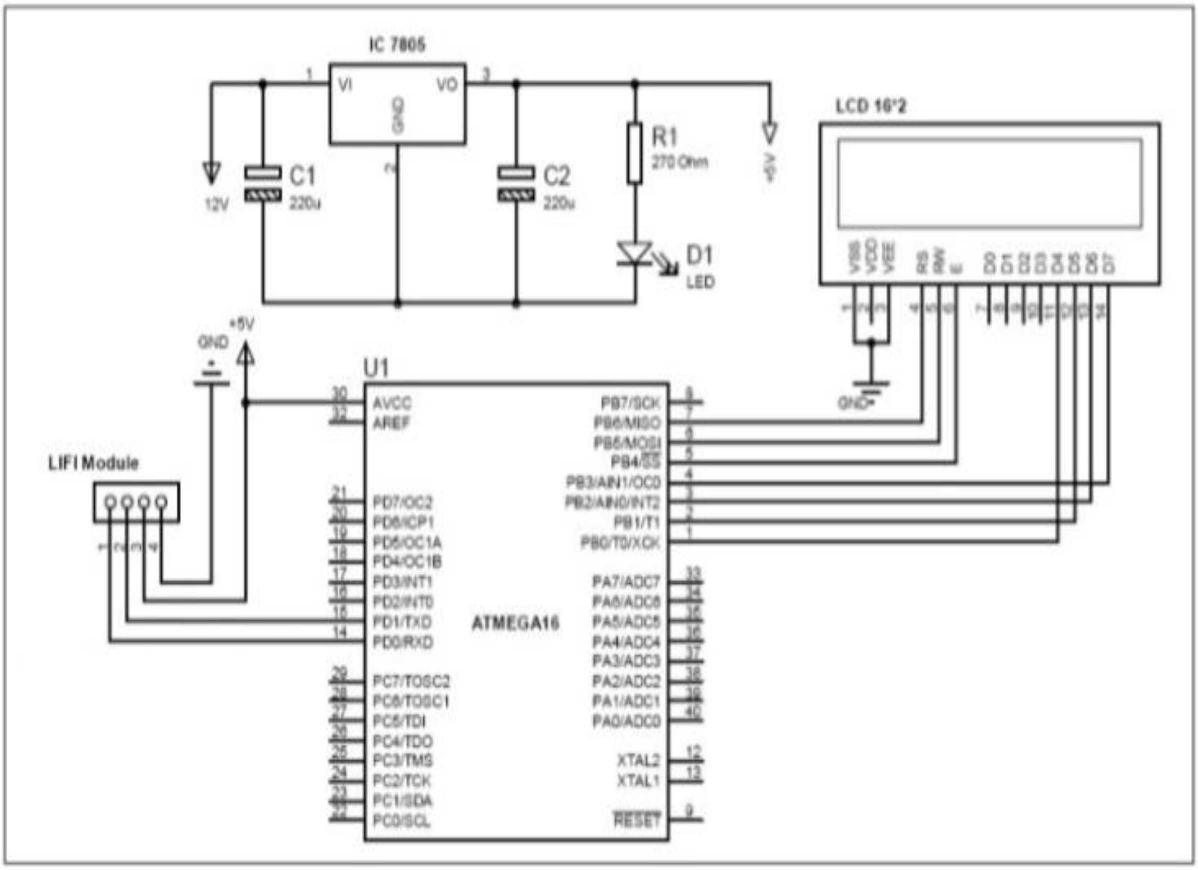
```
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);


LCD_write_string("LiFi Transmitter");
_delay_ms(2000);

LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);

while(1)
{

PORTD |= (1<<PD7);  /// set high

while(! (UCSRA & (1<<RXC)));
cor = UDR ;
```

```
_delay_ms(1000);

PORTD &= ~(1<<PD7);  // set low
_delay_ms(5);
PORTD |= (1<<PD7);  /// set high
_delay_ms(5);
PORTD &= ~(1<<PD7);  // set low
_delay_ms(5);
PORTD |= (1<<PD7);  /// set high
_delay_ms(5);
PORTD &= ~(1<<PD7);  // set low
_delay_ms(5);
PORTD |= (1<<PD7);  /// set high
_delay_ms(5);
PORTD &= ~(1<<PD7);  // set low
_delay_ms(5);
PORTD |= (1<<PD7);  /// set high
_delay_ms(5);



usart_send(cor);
_delay_ms(10);

LCD_write(cor);
```

```
_delay_ms(1000);


if(cor == '#' )

{
LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);


LCD_write_string("Enter New message");
_delay_ms(2000);

LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
```

```
LCD_cmd(0X80);
_delay_ms(10);
}

else

{

}




}



return 0;
}
```

6.2 Receiver Code



Receiver circuit   Fig no-6.2

```
#define F_CPU 2000000UL
#include <avr/io.h>
#include <util/delay.h>
#include <stdio.h>
#include <stdlib.h>
#include<string.h>

#define LCD_DATA PORTB // In my case PORTB is the PORT from which I send data to my LCD
#define Control_PORT PORTA // In my case PORTC is the PORT from which I set the RS , R/W and En
```

```
#define En PORTA7 // Enable signal

#define RW PORTA6 // Read/Write signal

#define RS PORTA5 // Register Select signal


void init_LCD();// Function to initialize the LCD

void LCD_cmd(unsigned char cmd);// Function to send
command to th LCD

void LCD_write(unsigned char data);// Function to display
character on LCD


void usart_init(void)

{

        UCSRB |= (1 << RXEN) | (1 << RXCIE) | ( 1<<TXEN );//
Turn on the transmission and reception

        UCSRC = ( 1<<UCSZ1 ) | ( 1<<UCSZ0 ) | ( 1<<URSEL );

        UBRRL = 0X0C; //  FOR 2000000MHZ   9600 br

}



void usart_send(unsigned char data)

{


        while(! (UCSRA & (1<<UDRE)));

        UDR = data;

        _delay_ms(5);

}
```

```
void usart_SendString(char *str)
{
        unsigned char j=0;

        while (str[j]!=0)        /* Send string till null */
        {
                _delay_ms(20);
                usart_send(str[j]);
                j++;
        }
}

unsigned int value;
float data;

void LCD_cmd(unsigned char cmd)
{
LCD_DATA=cmd;
Control_PORT =(0<<RS)|(0<<RW)|(1<<En);      // RS and RW as LOW and EN as HIGH
_delay_ms(10);
Control_PORT =(0<<RS)|(0<<RW)|(0<<En);      // RS, RW , LOW and EN as LOW
_delay_ms(10);
```

```
return;
}

void LCD_write(unsigned char data)
{
LCD_DATA= data;
Control_PORT = (1<<RS)|(0<<RW)|(1<<En);      // RW as
LOW and RS, EN as HIGH
_delay_ms(10);
Control_PORT = (1<<RS)|(0<<RW)|(0<<En);      // EN and RW
as LOW and RS HIGH
_delay_ms(10);  // delay to get things executed
return ;
}

void init_LCD()
{


LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
```

```
_delay_ms(10);

}

void LCD_write_string(unsigned char *str) //take address vaue
of the string in pionter *str
{
int i=0;
while(str[i]!='\0') // loop will go on till the NULL charaters is
soon in string
{
LCD_write(str[i]); // sending data on CD byte by byte
i++;
}
return;
}


unsigned char a=0,b=0,x,y,z;
int cor,n;

int main(void)
{

DDRA=0xf0;
```

```
DDRB=0xff;
DDRC=0X00;
DDRD=0xff;


UCSRB = ( 1<<TXEN ) | ( 1<<RXEN ) ;
UCSRC = ( 1<<UCSZ1 ) | ( 1<<UCSZ0 ) | ( 1<<URSEL );
UBRRL = 0X0C; //9600 br



LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);


LCD_write_string("LiFi Receiver");
_delay_ms(2000);

LCD_cmd(0X38);
```

```
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);

while(1)

{

while(! (UCSRA & (1<<RXC)))

{

if( PINA & (1<<0))
{



}



else
```

```
{
LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);


LCD_write_string("Align Transmiter");
_delay_ms(1000);


LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);
}
```

```
}

cor = UDR ;

if( PINA & (1<<0))
{

_delay_ms(1000);
LCD_write(cor);
_delay_ms(1000);

if(cor == '#' )
{
LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
```

```
LCD_cmd(0X80);
_delay_ms(10);



LCD_write_string("Enter New message");
_delay_ms(2000);

LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);
}

else

{

}

}
```

```
else
{

LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);


LCD_write_string("Align Transmiter");
_delay_ms(1000);


LCD_cmd(0X38);
_delay_ms(10);
LCD_cmd(0X01);
_delay_ms(10);
LCD_cmd(0X0C);
_delay_ms(10);
LCD_cmd(0X80);
_delay_ms(10);
```

```
}

}

return 0;
}
```

CHAPTER SEVEN

Li-Fi versus Wi-Fi

Wi-Fi is the popular name for the wireless Ethernet 802.11b standard for Wireline local area networks (WLANs). It is the name of a popular wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections. This technology works with no physical wired connection between sender and receiver by using RF, a frequency within the electromagnetic spectrum associated with radio wave propagation. When an RF current is supplied to an antenna, an electromagnetic field is created that then is able to propagate through space.

Li-Fi is a term of one used to describe visible light communication technology applied to high-speed wireless communication. It acquired this name due to the similarity to Wi-Fi, only using light instead of the radio. Wi-Fi is great for general wireless coverage within buildings, and Li-Fi is ideal for high-density wireless data coverage in a confined area and for relieving radio interference issues, so the two technologies can be considered complementary. Li-Fi provides better bandwidth, efficiency, availability, and security than Wi-Fi and has already achieved blisteringly high speed compared with Wi-Fi. It is low-cost technology because of the nature of LEDs and lighting units and there are many opportunities to exploit this medium. Table 1 shows a comparison between LiFi and Wi-Fi.

Table 1: comparison between Li-Fi and Wi-Fi

Techno-logy	**Bandwidth Expansion**	**Speed**	**Rang**	**Security**	**Power available**	**Cost**
Wi-Fi	Limited	150 Mbps	medium	Good (medium)	Low	medium

Li-Fi	Exceptional	>10 Gbps	Low	Excellent (High)	High	Low

CHAPTER EIGHT

Advantages

Li-Fi is ideal for high-density wireless data coverage in a confined area and for reducing radio interference issues. Its features include benefits to the capacity, energy efficiency, safety and security of a wireless system; now, we will talk briefly about each one of these advantages.

8.1 Efficiency

The efficiency of each radio station is just 5%due to the fact that most of the energy is used for the cooling system in the base of the radio station. Li-Fi is highly efficient because LED consumes less energy. It is effective in terms of low cost, low required energy and for various Environments. In this topic there are some main and important points:

- ✓ **Low cost:** Requires fewer components than radio technology, due to the cheap price of the LEDs and Digital components compared with the microwave equipment.
- ✓ **Energy:** LED illumination is already efficient and the data transmission does not require, additional power because most energy dissipation in LEDs requires a little amount of energy.
- ✓ **Environment:** RF transmission and propagation in water is extremely difficult but Li-Fi works well in this environment.

8.2 Capacity

Any lighting devices like car lights, ceiling lights, street lamps, etc. are used as a hotspot. It means that any light spread the internet using VLC which helps us to lower cost architecture for a hotspot. The most important issues here are Bandwidth, Data density, and speed.

- ✓ **Bandwidth:** The visible light spectrum more abundant 10,000 times compared with the RF spectrum.

- ✓ **Data density:** Li-Fi can achieve about 1000 times the data density of Wi-Fi because visible light can be well contained in a tight illumination area, whereas RF tends to spread out and cause interference.
- ✓ **High speed,** Very high data rates can be achieved as high as 500mbps or 30GB per minute due to the low interference, high device bandwidths, and high-intensity optical output.

8.3 Safety

Light is all around us – it is a natural part of life – and as such there are no health concerns associated with its use as a communications medium. It never gives any side effects on any living thing like radio waves and other communication waves which can dangerously interfere with electronic circuits and have effects on birds and humans.

8.4 Security

"If you can't see the light, you can't access the data!"

Because of the signal will not travel through walls, it is difficult to eavesdrop on Li-Fi signals. You can also see where the data is going, so there is no need for additional security such as pairing for RF interconnections like
Bluetooth.

CHAPTER NINE

Applications of Li-Fi

The applications of Li-Fi are unlimited and promising for the future of communications on the planet. In this Chapter, we will talk about some of its applications. Due to its advantages, Li-Fi has a lot of Life applications. Here we will talk about some important applications of it.

9.1 Underwater Communications

Using RF signals is impractical due to strong signal absorption in water. Li-Fi provides a solution for short range communications. Submarines could use their headlamps to communicate with each other, process data autonomously and send their findings periodically back to the surface in Underwater Remotely Operated Vehicles (ROV). Another important issue is that Li-Fi can even work underwater where Wi-Fi fails completely, thereby it‟s open for military operations.

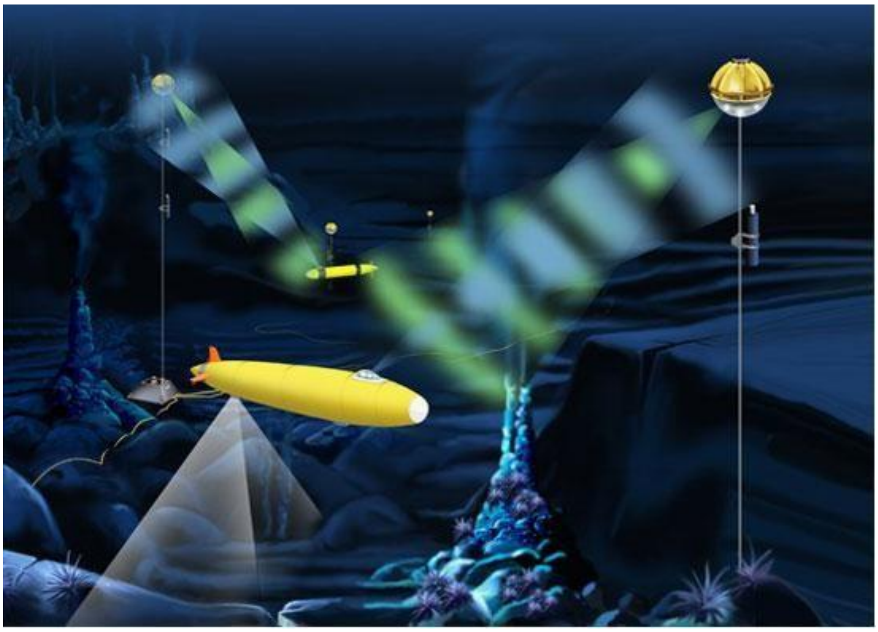


Figure 9.1: Optical Underwater Communications system.

9.2 Traffic Management

Li-Fi can help in managing the traffic in a better manner and the accident numbers can be decreased. Traffic lights can communicate to the car and with each other to manage the traffic in the street.

A traffic light can play the role of the sender of the data to provide information to the car on the status of the road or about the situation of other cars as shown in Figure 9. Also, cars can communicate with each other and prevent accidents by exchanging information. For example, LED car lights can alert drivers when other vehicles are too close.

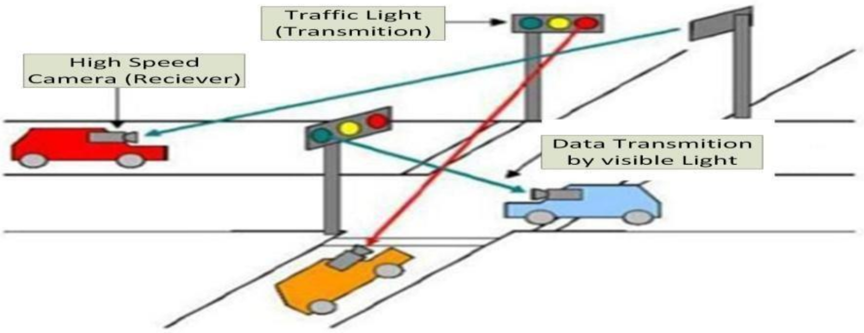


Figure 9.2: Vehicle Visible Light Communications.

9.3 Airways

We have to switch off mobiles in aircraft to prevent overlapping of mobile phone signals with navigation and control signals used by aircraft. Li-Fi can be safely used on planes because it doesn't interfere with RF. Since Data is present where light is present, we can use the lights above the seats in the plane as a hotspot.

9.4 Medical Applications

One of the most important features of Li-Fi is that it could be used in hospitals and medical settings that require the lack of RF signals which affect the medical equipment. For example, OTs (Operation theatres) do not allow using Wi-Fi due to radiation concerns because usage of Wi-Fi blocks the signals for monitoring equipment‟s. So, it may be dangerous to the patient's health.

9.5 Blind Indoor Navigation System

Indoor navigation is convenient for everyone, and it is especially indispensable for the visually impaired. We proposed such a navigation system for the visually impaired as shown in Figure 10. LED lights to emit visible light with location data and an embedded system or smartphone with a visible light receiver which receives the data. The embedded system or smartphone calculates the optimal path to a designation and speaks to the visually impaired through a headphone.

Figure 9.3: Indoor Navigation system for Blind people.

9.6 In Sensitive Areas or in Hazardous Environments

Li-Fi provides safe communication in environments such as mines and petrochemical plants because it doesn't"t cause electromagnetic interference which appears in RF communications. Li-Fi can also be used in petroleum or chemical plants where other frequencies could be hazardous.

For example, power plants like nuclear power plants require grid integrity and monitoring of the station temperature that need fast, inter-connected data systems. Wi-Fi and many other radiation types are bad for sensitive areas surrounding the power plants. Li-Fi could offer safe, abundant connectivity for all areas of these sensitive locations.

Moreover, this technology also enables us to control plants and their growth without direct presence.

9.7 Disaster Management

Li-Fi can be used as a powerful means of communication at times of disaster such as earthquake or hurricanes, for example, places like subway stations and tunnels which are common dead zones for most emergency communications, don‟t pose obstruction for Li-Fi, so it can be used there, as emergency communication

CONCLUSION

The possibilities are numerous and can be explored further because the concept of Li-Fi is currently attracting a lot of eyeballs because it offers a genuine and very efficient alternative to radio-based wireless. It has a good chance to replace the traditional Wi-Fi because as an ever-increasing population is using wireless internet, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. In the future, data for laptops, smartphones, and tablets can be transmitted through light in the room by using Li-Fi. Researchers are developing micron-sized LED which is able to flicker on and off around 1000 times quicker than larger LED. If this technology can be put into practical use, every bulb can be used as a WiFi hotspot to transmit wireless data and we will proceed toward the cleaner, greener, safer and brighter future. This concept promises to solve issues such as the shortage of radio-frequency bandwidth and boot out the disadvantages of Wi-Fi. Li-Fi is the upcoming and on growing technology acting as competent for various other developing and already invented technologies. Hence the future applications of the Li-Fi can be predicted and extended to different platforms and various walks of human life.

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