Chapter One

Introduction

1. Introduction

Li-Fi (Light fidelity) this upcoming communication technology uses light as a mode of transmission. Li-Fi operates in the visible light spectrum which is 10 thousand times that of the radio wave spectrum. (Himank K., 2017)

1.1 Background

Communication means transferring thoughts, information, emotion and ideas through gesture, voice, symbols, signs and expressions from one person to another. Three things are most important and essential in any communication process they are Sender, Receiver and the Channel (medium).

The Sender is encoding the messages in any form like voice, written or any signs. So they often called as Encoder. The Receiver is decoding the message from the sender to understand the message. So they often called as Decoder.

Channel: Any message or Information needs some channel or a medium. Example: television is an audio visual medium which decode the electronic signals into an audio-visual to the audience. (Communication Theory, 2019)

Sound wave can be transferred through LiFi by fed into an LED light using signal processing technology; it then sends data rabidly to the solar cell. The small variation of the density of LED light is transformed by the “receiver” to electrical signal. The signal is then transformed back to binary data stream that recognized as sound wave. (Ahmed A.A., 2018)

1.2 Research Problem

Today Wi-Fi is used as wireless communication medium but Wi-Fi uses radio waves which are not allowed everywhere due to radio waves effect or their radiations effect which create disturbance in areas like hospital (in medical equipment like MRI scanner), power plant, chemical reactors, petrol pumps and airlines, but now wireless communication facility can be used in this areas or many other crowded public areas because of Li-Fi (Light Fidelity).

Li-Fi use visible light waves. Since light cannot penetrate walls, it provides privacy and security that Wi-Fi cannot.

1.3 Goals and Features

The goals of this research are to design a simple Li-Fi (Light Fidelity) communication system.

Use this system to transmit an audio signal, use red LEDs to transmit the signal.

Increase the latitude between the transmitter and the receiver more than 1 meter.

1.4 Previous Studies

One of the earliest inventions of major significance to communications was the invention of the electric battery by Alessandro Volta in 1799. This invention made it possible for Samuel Morse to develop the electric telegraph, which he demonstrated in 1837. The first telegraph line linked Washington with

Baltimore and became operational in May 1844. Morse devised the variable-length binary code, in which letters of the English alphabet were represented by a sequence of dots and dashes (code words).

The Morse code was the precursor to the variable-length source-coding methods. It is remarkable that the earliest form of electrical communications that was developed by Morse, namely telegraphy, was a binary digital communication system in which the letters of the English alphabet were efficiently encoded into corresponding variable-length code words having binary elements.

Nearly forty years later, in 1875, ´ Emile Baudot developed a code for telegraphy in which each letter was encoded into fixed-length binary code words of length 5. In the Baudot code the binary code elements have equal length and are designated as mark and space.

An important milestone in telegraphy was the installation of the first transatlantic cable in 1858 that linked the United States and Europe. This cable failed after about four weeks of operation.

A second cable was laid a few years later and became operational in July 1866.

Telephony came into being with the invention of the telephone in the 1870s. Alexander Graham Bell patented his invention of the telephone in 1876, and in 1877 established the Bell Telephone Company. Early versions of telephone communication systems were relatively simple and provided service over several hundred miles. Significant advances in the quality and range of service during the first two decades of the twentieth century resulted from the invention of the carbon microphone and the induction coil. (John G.Proakis, 2001)

The invention of the triode amplifier by Lee De Forest in 1906 made it possible to introduce signal amplification in telephone communication systems and, thus, to allow for telephone signal transmission over great distances. For example, transcontinental telephone transmission became operational in 1915.

Two world wars and the Great Depression during the 1930 must have been a deterrent to the establishment of transatlantic telephone service. It was not until 1953, when the first transatlantic cable was laid, that telephone service became available between the United States and Europe.

Automatic switching was another important advance in the development of telephony. The first automatic switch, developed by Strowger in 1897, was an electromechanical step-by-step switch. This type of switch was used for several decades. With the invention of the transistor, electronic (digital) switching became economically feasible.
After several years of development at the Bell Telephone Laboratories, a digital switch was placed in service in Illinois in June 1960.

During the past thirty years there have been numerous significant advances in telephone communications. Fiber optic cables are rapidly replacing copper wire in the telephone plant and electronic switches have replaced the old electromechanical systems. (John G.Proakis, 2001)

Wireless Communications. The development of wireless communications stems from the works of Oersted, Faraday, Gauss, Maxwell, and Hertz. In 1820, Oersted demonstrated that an electric current produces a magnetic field. On August 29, 1831,
Michael Faraday showed that an induced current is produced by moving a magnet in the vicinity of a conductor. Thus, he demonstrated that a changing magnetic field produces an electric field. With this early work as background, James C. Maxwell in 1864 predicted the existence

of electromagnetic radiation and formulated the basic theory that has been in use for over a century. Maxwell's theory was verified experimentally by Hertz in 1887.

In 1894, a sensitive device that could detect radio signals, called the coherer, was used by its inventor Oliver Lodge to demonstrate wireless communication over a distance of 150 yards at Oxford, England. Guglielmo Marconi is credited with the development of wireless telegraphy. Marconi demonstrated the transmission of radio signals at a distance of approximately 2 kilometers in 1895.Two years later, in 1897; he patented a radio telegraph system and established the Wireless Telegraph and Signal Company. On December 12, 1901, Marconi received a radio signal at Signal Hill in New found land, which was transmitted from Cornwall, England, a distance of about 1700 miles.

The invention of the vacuum tube was especially instrumental in the development of radio communication systems. The vacuum diode was invented by Fleming in 1904 and the vacuum triode amplifier was invented by De Forest in 1906, as previously indicated.

The invention of the triode made radio broadcast possible in the early part of the twentieth century. Amplitude modulation (AM) broadcast was initiated in 1920 when radio station KDKA (Kristiansand D Kinoallians As), Pittsburgh, went on the air. From that date, AM radio broadcasting grew rapidly across the country and around the world. The super heterodyne AM radio receiver, as we know it today, was invented by Edwin Armstrong during First World War. Another significant development in radio communications was the invention of Frequency modulation (FM), also by Armstrong. In 1933, Armstrong built and demonstrated the first FM communication system. However, the use of FM was slow to develop compared with AM broadcast. It was not until the end of Second World War that FM broadcast gained in popularity and developed commercially. (John G.Proakis,(2001))

The first television system was built in the United States by V. K. Zworykin and demonstrated in 1929. Commercial television broadcasting began in London in 1936 by the British Broadcasting Corporation (BBC). Five years later the Federal Communications Commission (FCC) authorized television broadcasting in the United States.

The Past Fifty Years. The growth in communications services over the past fifty years has been phenomenal. The invention of the transistor in 1947 by Walter Brattain, John Bardeen, and William Shockley; the integrated circuit in 1958 by Jack Kilby and Robert Noyce; and the laser by Townes and Schawlow in 1958, have made possible the development of small-size, low-power, low-weight, and high-speed electronic circuits which are used in the construction of satellite communication systems, wideband microwave radio systems, and light wave communication systems using fiber optic cables. A satellite named Telstar was launched in 1962 and used to relay TV signals between Europe and the United States. Commercial satellite communication services began in 1965 with the launching of the Early Bird satellite.

Currently, most of the wire line communication systems are being replaced by fiber optic cables which provide extremely high bandwidth and make possible the transmission of a wide variety of information sources, including voice, data, and video.

Cellular radio has been developed to provide telephone service to people in automobiles, buses, and trains. High-speed communication networks link computers and a variety of peripheral devices literally around the world.

Today we are witnessing a significant growth in the introduction and use of personal communications services, including voice, data, and video transmission. Satellite and fiber optic networks provide high-speed communication services around the world.

Indeed, this is the dawn of the modern telecommunications era.

There are several historical treatments in the development of radio and telecommunications covering the past century. (John G.Proakis, 2001)

Professor Harald Hass, from the University of Edinburgh in the UK, is widely recognized as the original founder of Li-Fi. He coined the term Li-Fi and is chair of Mobile Communication at the University of Edinburgh and co-founder of pure Li-Fi. The general term visible light communication (VLC), include any use of the visible light portion of the electromagnetic spectrum to transmit information. The D-Light project (company) at Edinburgh's Institute for Digital Communications was funded from January 2010 to January 2012. Hass promoted this technology in his TED (Technology Entertainment Design) Global talk in 2011 and helped start a company to market it. Pure Li-Fi, formerly pure VLC, is an Original Equipment Manufacturer (OEM) company setup commercializes Li-Fi products for integration with existing LED-lightings systems.

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 one directional VLC products which is not the same as Li-Fi. VLC technology was exhibited in 2012 using Li-Fi. By August 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 manufactures 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 Beam Caster. Their current module transfers data at 1.25 GB/sec. but foresee boosting speeds up to 5 GB/sec. in the near future. (Pushpendra Verma, 2015)

In March 2015 a team of students_ Shrider Ambady, Megan Breads, Calvin Nguyen_ are design and build a VLC system (Li-Fi system). The system attained a transmitting distance of 2/3 of a meter, with the potential to be increased to an even greater distance with ease, at a transmission rate of just 1.2 kbps while operating in an ambient light setting, but it is not able to transmit an audio signal. (Professor Lifeng Lai, 2015)

1.5 Wireless communication

Wireless communications is, by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public. Cellular systems have experienced exponential growth over the last decade and there are currently around two billion users worldwide. Indeed, cellular phones have become a critical business tool and part of everyday life in most developed countries, and are rapidly supplanting antiquated wire line systems in many developing countries. In addition, wireless local area networks currently supplement or replace wired networks in many homes, businesses, and campuses. Many new applications, including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine, are emerging from research ideas to concrete systems. The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers indicate a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. (Anderea Goldsmith, 2005)

1.6 Wi-Fi

Wi-Fi is a one type of wireless technology. It is commonly called as wireless LAN (local area network).

Wi-Fi stands for **Wi**reless **Fi**delity. Wi-Fi is based on the IEEE (Institute of Electrical and Electronics Engineers) 802.11 family of standards and is primarily a local area networking (LAN) technology designed to provide in-building broadband coverage.

Current Wi-Fi systems support a peak physical-layer data rate of 54 Mbps and typically provide indoor coverage over a distance of 100 feet.

Wi-Fi has become the *de facto* standard for *last mile* broadband connectivity in homes, offices, and public hotspot locations. Systems can typically provide a coverage range of only about 1,000 feet from the access point. (Wi-Fi Tutorial-Tutorials point, 2019)

The Wi-Fi was invented by NCR (National Cash Register) corporation /AT&T (American Telephone and Telegraph) in Netherlands in 1991. By using this technology we can exchange the information between two or more devices. Wi-Fi has been developed for mobile computing devices, such has laptops, but it is now extensively using for mobile applications and consumer electronics like televisions, DVD (Digital Video Disc) players and digital cameras. There should be two possibilities in communicating with the Wi-Fi connection that may be through access point to the client connection or client to client connection. Wi-Fi allows local area networks to operate without cable and wiring. It is making popular choice for home and business networks. A computer's wireless adaptor transfers the data into a radio signal and transfers the data into antenna for users. (Wi-Fi (Wireless Technology) Working Principles, 2019)

Figure 1.1: Wi-Fi technology

1.6.1 Wi-Fi work

Wi-Fi is used radio waves to transmit data. Radio waves are electromagnetics disturbances that radiate out in all directions. When a current passes along a wire, it generates a magnetic field around that wire. Wi-Fi transmitters exploit this factor to pulse a current out on to the copper wire inside an antenna. The wire is grounded at one end and unattached at the other end. The grounding means each signal dissipates almost immediately, but the presence of the charge on the wire momentarily creates a force field that generates a radio wave.

As the radio wave signal beams out from the transmitter, it will "stick" to any metal object it encounters. It then diverts and runs along the length of that metal object. That is why large metal objects, like fridges, block Wi-Fi signal and creates dead zones. The signal passes through the plastic casing of the receiving antenna and strikes the copper wire within. It then travels along the length of that wire, which leads to a wireless network adapter. The network adapter interprets the electronic pulse into data and passes it to the computer or router that it serves.

The method of transmit and receive data is Wi-Fi transmitters generate a carrier wave. This is a standard wave pulsing out at the system's frequency. The wireless network adapter converts computer data into an electronic pulse, which also has a wave form. It merges the data wave with the carrier wave for transportation. This is called "modulation." When the receiving network adapter gets the wave, it subtracts the carrier wave and converts the recovered data wave into binary data for the computer or router. This is called "demodulation." (Visual Networking, 2019)

1.6.2 Advantages and disadvantages of Wi-Fi

Wi-Fi communication has many advantages and disadvantages, comparing with another old communications types.

1.6.2.1 Advantages of Wi-Fi

- Wireless laptop can be moved from one place to another place.
- Wi-Fi network communication devices without wire can reduce the cost of wires.
- Wi-Fi setup and configuration is easy than cabling process.
- It is completely safe and it will not interfere with any network.
- We can also connect internet via hot spots.
- We can connect internet wirelessly. (Wi-Fi (Wireless Technology) Working Principles, 2019)

1.6.2.2 Disadvantages of Wi-Fi

- Wi-Fi generates radiations which can harm the human health.
- There are some limits to transfer the data; we can’t able to transfer the data for long distance.

- Wi-Fi implementation is very expensive when compared to the wired connection. (Wi-Fi (Wireless Technology) Working Principles, 2019)

Chapter Two

Basic Concepts

2. Basic Concepts

According to Cisco's Global IP traffic forecast there will be 28.5 billion networked devices by 2022, up from 18 billion in 2017. (Visual Networking, 2019) However, the availability of current forms of wireless is very limited, and it is not necessarily safe to implement wireless radio, making it necessarily to explore other alternatives to wireless communication to allow continued expansion upon communication systems and to ensure safe use. (What We Do. FCC, 2019)

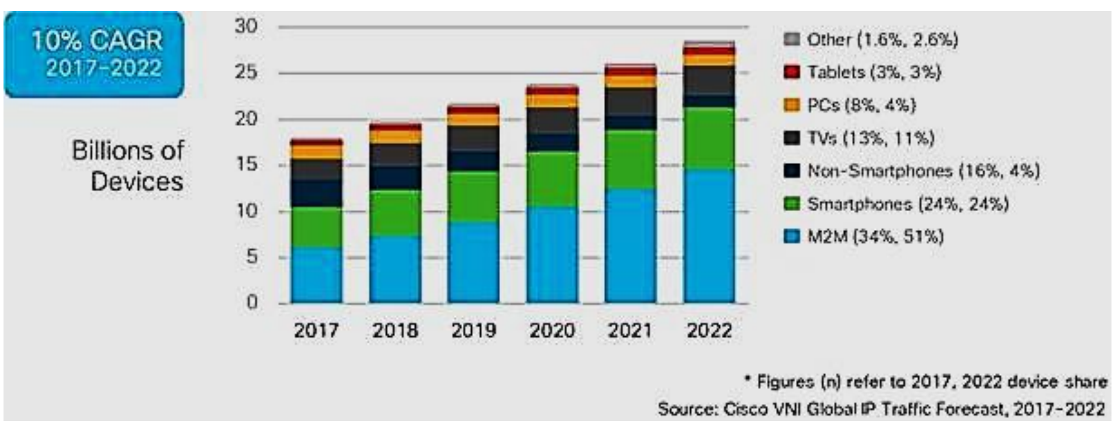

Figure 2.2:2017 to 2022 device share

Li-Fi technology can be used in areas where Wi-Fi is not allowed. This technology will not only improve communication but also illuminate work place, and many public places like hospitals, chemical plant, public transport stations, so this will create nice opportunity to create wireless communication using light. There are two basic types of wave motion for mechanical waves: longitudinal waves and transverse waves. In a longitudinal wave the particle displacement is parallel to the direction of wave propagation; a sound wave traveling through air is a classic example of a longitudinal wave; sound wave is a mechanical wave that results from the back and forth vibration of the particles of the medium through which the sound wave is moving. In a transverse wave the particle displacement is perpendicular to the direction of wave propagation; electromagnetic waves (light, microwave, etc.) are example of transverse wave. Sound wave can be sent through light by using Li-Fi technology. Li-Fi not only gives opportunity to create wireless communication but it also helps to save energy as technology uses LED (Light Emitting Diode) lights which consume very less electricity. (Adwait R.Pinglikar, Priyanka A.Shandilya, 2014)

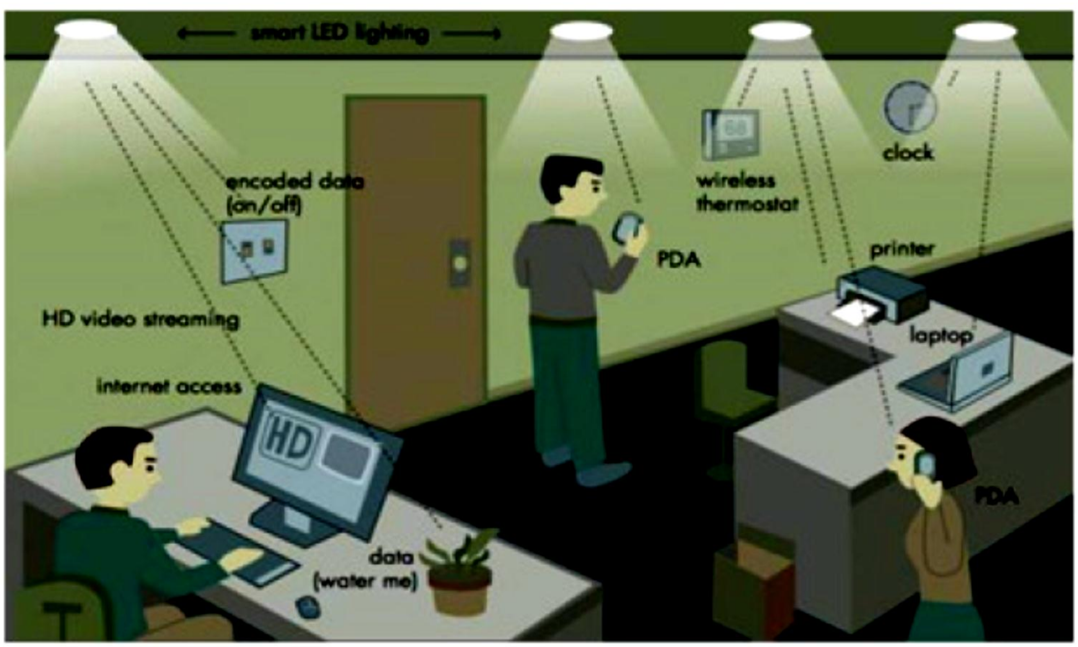

Figure 2.3: Li-Fi (Light Fidelity) in office room

2.1 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. (Teleinfo, 2012, Jan)

Li-Fi technology uses frequency from 300 GHz-30 PHz and wavelength from 1mm-10nm. This electromagnetic spectrum is 100 times more than radio wave spectrum. Li-Fi is not only technology it is actually framework for all new capabilities to current and future services applications and end users. (Adwait R.Pinglikar, Priyanka A.Shandilya, 2014)

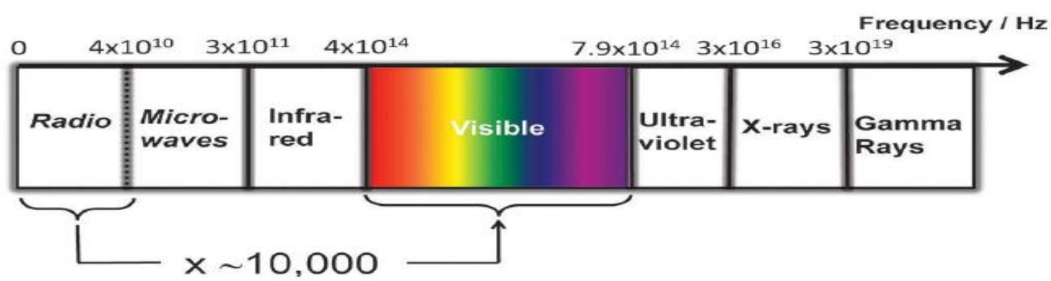

Figure 2.4: Location of visible light and RF at electromagnetic spectrum

Professor Harald Hass, the original founder of Li-Fi technology, in his Technology Entertainment Design (TED) global talk in Li-Fi says: "At the heart of the 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 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. (Dr.N.Zarka, 2015)

Figure 2.5: The idea of data transmission using light

2.1.1 Comparison between Li-Fi and Wi-Fi

Li-Fi as discussed is a term 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 radio. Wi-Fi is great for general wireless coverage within buildings and Li-Fi is ideal for high density wireless data coverage in confined area and for relieving radio interference issues, so the two technologies can be considered complimentary. (Prena Chauhan, Rilika Tripathi Jyoti Rani, 2012)

Table 2.1: comparison between Li-Fi and Wi-Fi

technology	Bandwidth Expansion	Speed	Data Density	Rang	Security	Power available	ecological impact	Cost
Wi-Fi	Limited	150 Mbps	Low	medium	Good (medium)	Low	medium	medium
Li-Fi	Exceptional	>10 Gbps	High	Low	Excellent (High)	High	Low	Low

2.2 Li-Fi work

When an electrical current is applied to a LED light bulb a stream of light (photons) is emitted from the bulb. LED bulbs are semiconductor devices, which mean that the brightness of the light flowing through them can be changed at extremely high speeds. This allows us to send a signal by modulating the light at different rates. The signal can then be received by a detector which interprets the changes in light intensity (the signal) as data.

The intensity modulation cannot be seen by the human eye, and thus communication is just as seamless as other radio systems, allowing the users to be connected where there is Li-Fi enabled light. Using this technique, data can be transmitted from a LED light bulb at high speeds. (Pure LiFi, 2019)

2.3 Advantages and Disadvantages of Li-Fi

According to above comparison between Li-Fi and Wi-Fi, we count the advantages and disadvantages for Li-Fi.

2.3.1 Advantages of Li-Fi

- Li-Fi can solve problems related to the insufficiency of radio frequency bandwidth because this technology uses Visible light spectrum that has still not been greatly utilized.
- High data transmission rates of up to 10 Gbps can be achieved.
- Since light cannot penetrate walls, it provides privacy and security that Wi-Fi cannot.
- Li-Fi has low implementation and maintenance costs.
- It is safe for humans since light, unlike radio frequencies, cannot penetrate human body. Hence, concerns of cell mutation are mitigated. (Study Mafia, 2019)

2.3.2 Disadvantages of Li-Fi

- Light can't pass through objects.
- A major challenge facing Li-Fi is how the receiving device will transmit back to transmitter.
- High installation cost of the VLC systems.

- Interferences from external light sources like sun, light, normal bulbs, opaque materials.(Study Mafia, 2019)

2.4 Possible applications

Due to its advantages, Li-Fi has a lot of life applications. Here are some important applications of it.

a. 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. (Ruanak, 2014)

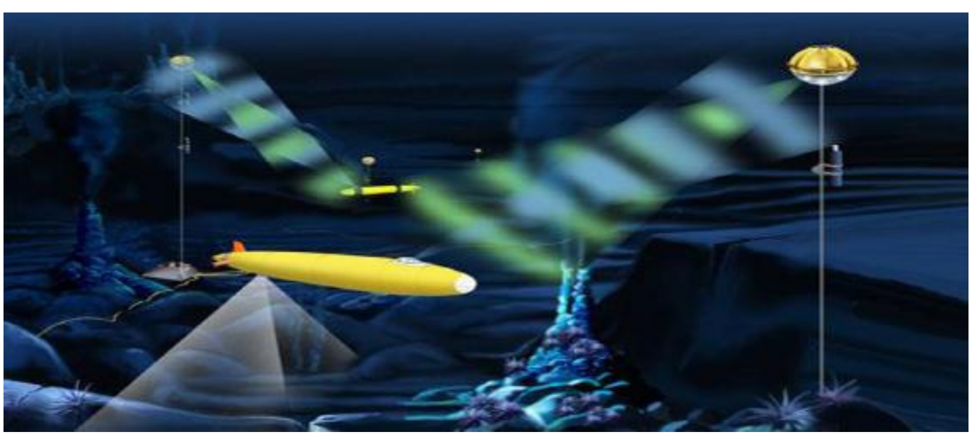

Figure 2.6: Optical Underwater Communications system

b. 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.

Traffic light can play the role of 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 8. (Ruanak, 2014, Pure LiFi, 2014) 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. (Dharmrajsinh N.Parmar, 2014)

Figure 2.7: Vehicle Visible Light Communications

c. Airways

We have to switch off mobiles in aircrafts 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. (Pure LiFi, 2014) Since it data is present where light is present, we can use the lights above the seats in the plane as hotspot. (Dharmrajsinh N.Parmar, 2014)

d. 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) does 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. (Ruanak, 2014)

e. 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 9. LED lights 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. (Top IEEE Visible Light Communication (LiFi) Projects, 2014)

Figure 2.8: Indoor Navigation System for Blind People

f. In Sensitive Areas or in Hazardous Environments

Li-Fi provides a safe communication in environments such as mines and petrochemical plants, because it doesn'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. (Pure LiFi, 2014)

For example, power plants like nuclear power plants require grid integrity and monitoring of the station temperature that need fast, inter-connected data system. 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. (Ruanak, 2014)

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

g. 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 station 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. (Ruanak, 2014)

Chapter Three

Design Approach

3. Design Approach

This chapter wills discus the specification required for each block of the system structure, and how it was affected.

3.1 Functional Block Diagram

Figure 10: shows the overall functional block diagram of the system. The transmitter side consists of a signal source, and analog circuitry incorporating LEDs, all of which are powered in some fashion. The receiver side is similar, containing analog circuitry incorporating solar cell, and a device capable of receiving and interpreting the output, all of which are also being powered in some fashion.

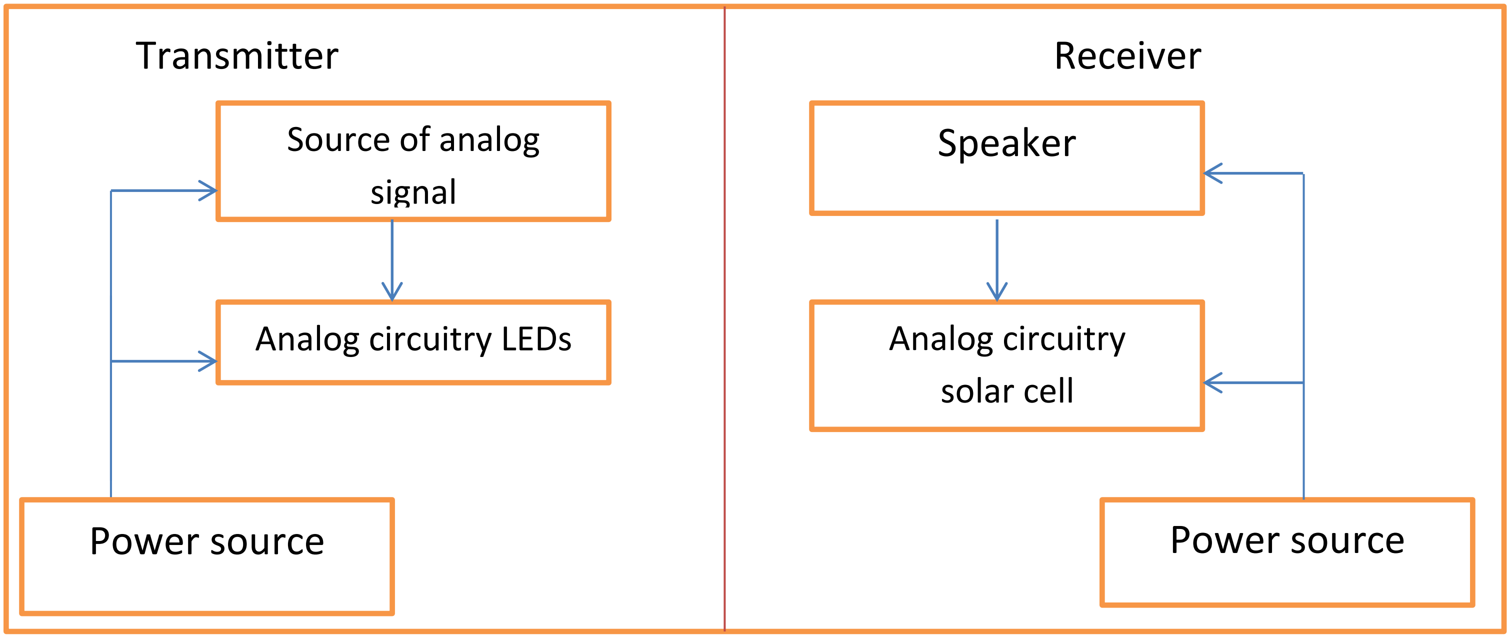

Figure 3.9: Functional Block Diagram

3.2 Component Selection

Each block has its own components that need to be met in order for the system to function. The following sections will address these components.

a. Power Source

Both transmitter and receiver need some source of power; however, each component needs varying amount of power. The transmitter end of design uses the same power source but converts that power differently for different components. The speaker in the receiver part use a wall output with 120V AC output; however it’s connected directly to the AC power.

The signal source (cell phone) has an inner power source (battery) with 9V DC input, which connected to the analog circuit by 3.5mm jack pin with 1.5V AC. The analog circuit also connected to a power supply with 9.5V DC.

b. Signal Source

In the transmitter side, the signal that will be transmitted is an audio signal. This signal could be produced by a cell phone or any other audio sources. This signal will be sent to the analog circuit. On the receiver side speaker needs to be able to interpret the original signal by tacking the received signal from the solar cell and converted it to sound.

c. 3.5mm jack

Input audio from the cell phone is converted from digital to analog signal by the 3.5mm audio jack. A typically 3.5mm audio jack has three output lines namely right, left, and the ground. The left and right have the audio input signal, which is connected to the resistor then the base of the transistor. The ground of the 3.5mm jack is given to the negative of the power supply and the emitter of the transistor.

d. Resistors

The resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission liens, among other uses. (Wikipedia, 1970b, January 1)

In this circuit there is 47Ω resister after the power supplies to divide voltages throw the LEDs. And there is 10Ω resister after the signal source to adjust signal levels.

e. Transistor (BJT)

The 2N3904 transistor in the transmitter analog circuit is used as a switch. The transistor would connect the input signal source to the LEDs. That way, more current/power would flow through the LEDs. This would result in brighter LEDs, achieving farther transmitting distance.

When the transistor receives a logic high, or 3.3V signal at the base, the transistor would turn on meaning it would allow current to go through from the external signal source to the LEDs to ground. When it is off, no current would travel.

f. LEDs

The purpose of the LEDs in this system is to transmit audio data from the transmitter. In this circuit there are five red LEDs with wavelength (620-625nm), luminous intensity (2000-3000mcd), viewing angle 30 degree, forward voltage 2V and forward current 20mA. They controlled by the transistor to convert the audio signal in to light to transmit data to the receiver.

g. Solar Cell

In the receiver side the transmitted light from the LEDs would receive by solar cell (3-6V DC). Then the solar cell would convert this signal in to electrical signal.

When the transmitted light from the LEDs is perpendicular to the solar cell, the irradiance incident to the solar cell has the highest possible power density.

h. Speaker (Computer Speaker)

The last component in the receiver side is a computer speaker, which is connected to the solar cell to convert the electrical signal to an audio signal.

This speaker has an internal amplifier and it's directly connected to wall output with 120V AC output; however it's connected directly to the AC power.

i. Digital Oscilloscope (TDS 220)

The oscilloscopes display the change of an electrical signal over time, with voltage and time as the y- and x- axes, respectively, on a calibrated scale. (Wikipedia, 1970a, January 1) TDS 220 is a digital real-time oscilloscope which used to display the signal of the transmitter and the receiver.

3.3 Analog design

After collecting the components, the circuit design had begun. Any communication system includes a transmitter and a receiver.

3.3.1 Transmitter

The objective of the transmitter is to send the audio signal to the receiver side after reducing it to light. In the analog design of the transmitter LEDs where use to transmit light, which would be used to transmit the audio signal (data).The source of the audio signal is a cell phone. A power supply with 9.5V DC was used as a power source of the LEDs, a 47Ω resistor was used to reduce current flow. After the resistor five red LEDs were used to transmit the audio data. The audio signal was firstly connected to a 10Ω resistor to adjust signal levels then a

2N3904 transistor was used as a switch. Then the transistor switches the LEDs on and off to transfer the audio signal to light.

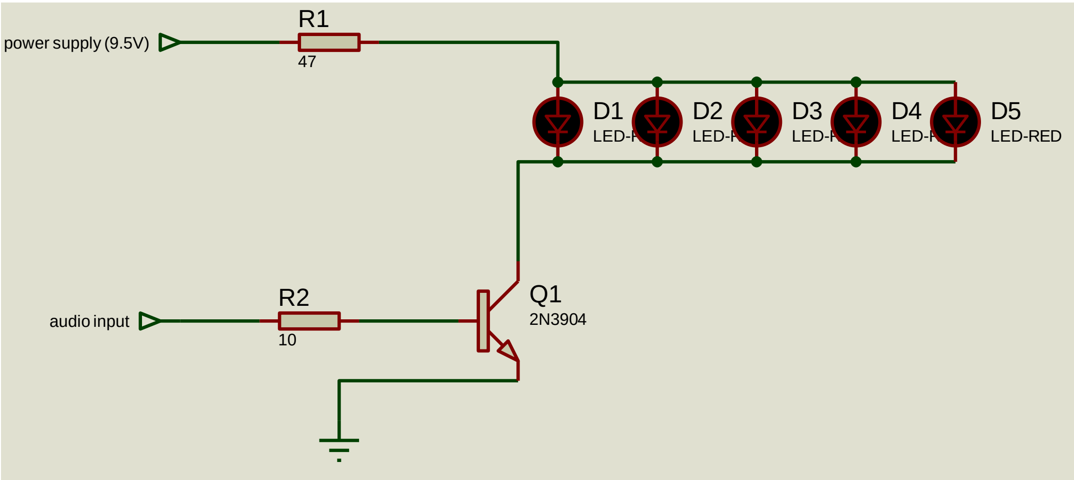

Figure 3.10: Analog Transmitter Circuit Design

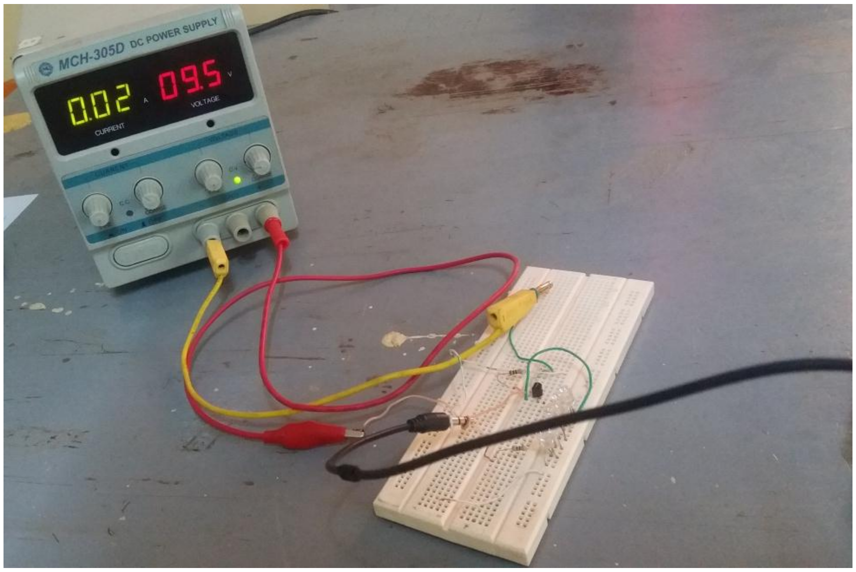

Figure 3.11: Transmitter Circuit

3.3.2 Receiver

The objective of the receiver is to receive the light signal from the transmitter side and transfer it into sound. In the analog design of the receiver solar cell was used to receive light, which would be used to transmit the audio signal (data).The solar cell then transfer the light signal into electric signal, this electric signal then went to the speaker to amplifier and change it to sound(audio signal).

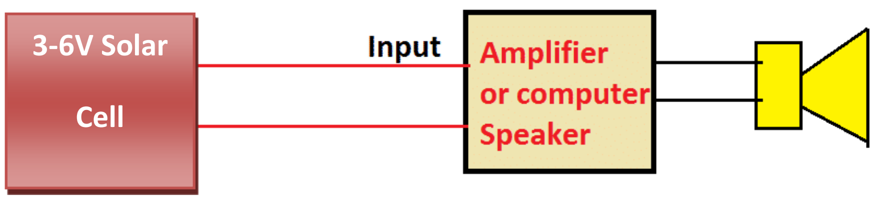

Figure 3.12: Analog Receiver Circuit Design

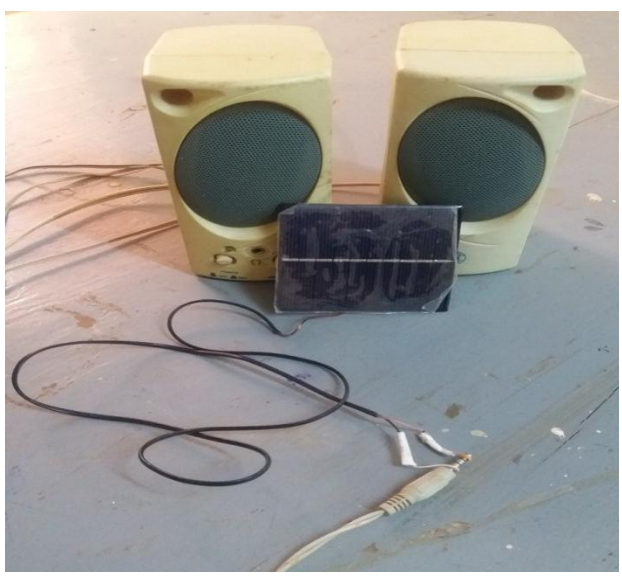

Figure 3.13: Receiver Circuit

Chapter Four

Result and Discussions

4. Results and Discussions

This chapter will discuss the results of the Li-Fi audio transmission system.

4.1 The Results

Firstly the audio signals that have been received at the end of the receiver were tested. The signal at first received at the receiver as a sound with a very high disturbance because of the other light sources surrounding the system. The louder and most clear sound was received at distance 11cm between the transmitter and the receiver, and the receiver can receive signal until the distance became almost 60cm. Then the experiment done in less surrounding light sources then the system can transmit and receive signal until the distance become 1 meter.

Secondly the signals from transmitter and receiver were tested by digital oscilloscope to compare about them. Figure 13: illustrate the signals from the transmitter and the receiver.

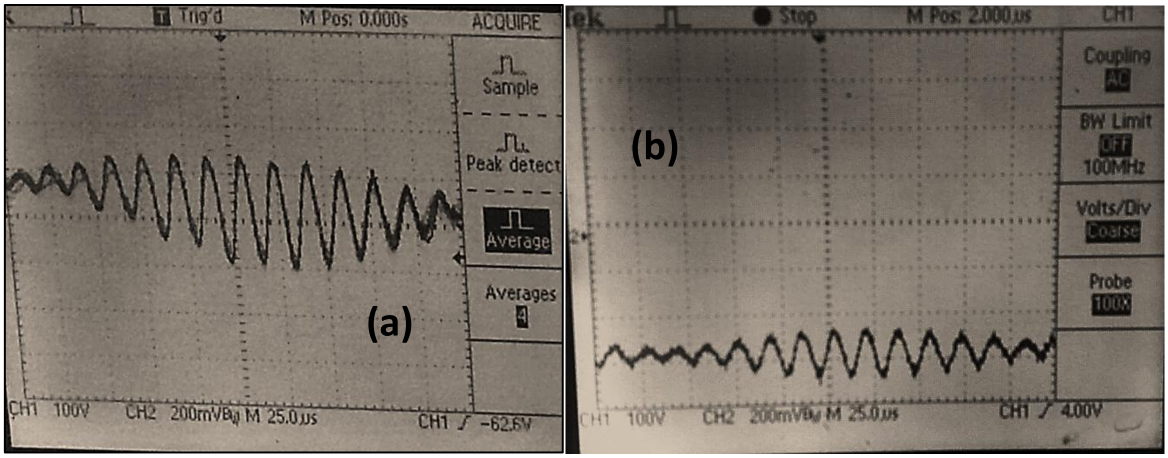

Figure 4.14: The signals from transmitter and receiver, (a) The signal from the transmitter, (b) The signal from the receiver.

4.2 Discussions

The design of Worcester Polytechnic Institute team was used as a reference in this design, but the receiver circuit was changed with solar cell and computer speaker to allow it to receive an audio signal, and then the transmitter circuit was simplified.

At the first result it was observe that the received signal in the receiver side has noises because of the surrounding light source, and then if the system was in a dark room then the sound would be much clear. Also the signal can be received till the distance between the transmitter and the receiver be more than 1 meter, but the sound will be lower when the distance between the transmitter and the receiver be longer.

In the second result we observe that the signals from the transmitter and the receiver are similar on the wavelength and the frequency but different on the amplitude. See figure 13.

We induce from this observation that the signal that transmitted through the red LEDs and the signal that received by the solar cell have the same energy, because the wavelengths are the same. And from the difference in the amplitude we induced that the number of photons that transmitted from the LEDs in the transmitter side are more than the number of photons that received by the solar cell in the receiver side.

4.3 Conclusion

A simple Li-Fi communication system was designed and it was used to transmit an audio signal through red LEDs. The latitude between the transmitter and the receiver was increased to more than 1 meter.

4.4 Recommendations

1. In the transmitter side I propose to exchange the red LEDs with white LEDs.
2. Use an Op-Am (Operational Amplifier) to amplify the audio signal.
3. In the receiver side I propose to add a rectification circuit to diminish the noises in the received signal.
4. And the last recommendation is to work in a dark room.

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