Studies on
Li-Fi (Light Fidelity)-The technology In Wireless Communication

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "**Studies on Li-Fi (Light Fidelity)-The Technology in Wireless Communication"**, is a bonafide work carried out by ARKAPRABHA DIAN (Examination Roll No.: M6ILT23007, Registration No. 154545 of 2020 – 2021) under my supervision and guidance for partial fulfilment of the requirement for the award of degree of Master of Technology in Illumination Technology & Design, School of Illumination Science, Engineering & Design, during the academic session 2020-2023.

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Abstract:

Internet usage and the need for data transfer are in high demand. Compared to earlier decades, people are more reliant on the internet. Spectrum is thus getting congested due to the rise of customers. Wi-Fi technology, which operates on radio frequency waves with limited bandwidth and is currently widely used, has been replaced by Li-Fi, which has a wider bandwidth and a higher data transfer rate. Recent studies indicate that Li-Fi has a range of about 10 meters. Additionally, it is unable to pass through walls or other solid objects. Therefore, the primary goal of this research is to extend the 10-meter range. This range is sufficient for an average-sized room. However, this range is insufficient if someone wants to give data within a long hallway or in any other large room. He needs to supply extra LEDs that are wired to the Li-Fi router. The goal of this research is to maximize LED usage while lowering costs. Here, two strategies to extend LED's range are suggested. One technique involves the placement of the LEDs, while another involves the use of a concave mirror. Better light coverage is produced by clever light positioning, which extends the LED's range. For a specific positioning of an item, a concave mirror provides a genuine and enhanced mirror, which is demonstrated both theoretically and mathematically.

Keywords: Light Emitting Diode (LED), Light Fidelity (Li-Fi), Solar Panel

Chapter One: Introduction

1.1 General Introduction:

Nowadays, there are internet users everywhere. One can browse the web via wireless internet in any location, including a street, park, car, home, or business. One can even steal bandwidth from their neighbour or compete for it at a conference, however, this causes poor speeds as many devices are tapped into a network [1]. As the number of users rises, the available radio frequency spectrum becomes insufficient to meet the demands of the internet [2]. Due to the lack of Radiofrequency (RF) resources, a severe issue may have arisen [3]. Since the need for data is gradually growing in relation to the radio spectrum, it is crucial to consider an alternate option that can quickly satisfy the need for data.

German physicist Harald Hass suggested a novel technique called Light Fidelity (Li-fi) to address this problem [4]. After starting his study in the area in 2004, University of Edinburgh Professor Harald Haas presented the Li-Fi prototype on July 12, 2011, at the TED Global conference in Edinburgh. In his demonstration, he used a table lamp with an LED bulb to transmit a video of flowers in bloom. Professor Harald Haas blocked the light from the lamp that was the source of the incoming data during the projection. Haas had demonstrated a data throughput of approximately 10 Mbps at TED Global, which is probably better than the UK broadband connection. After a few months, Haas hit 123Mbps [1].

The most recent example of ground-breaking technology in the area of indoor wireless communication systems is Li-fi, a short-range wireless communication system [5]. Visible light communication, or VLC, is the foundation of the Li-Fi system. VLC is an optical wireless connection that transmits data by modulating visible light, combining communication and illumination [6]. White LEDs, a more affordable transmitter, and a receiver in a VLC system are typically used in the design of Li-Fi communication systems. When using Li-fi technology, LEDs modulate so quickly that any change in the state of Light cannot be seen by human senses [7]. While data can be transmitted using light from a light-emitting diode, Li-fi can be crucial in meeting data needs.

Due to its large capacity, the visible light spectrum can accommodate all devices as their number rises in line with human demand because the radio spectrum cannot keep up with the exponential user increase. In contrast, since Li-Fi uses light waves on the electromagnetic spectrum to transport data, radio waves might distort signals owing to RF interference, whereas light rays are absolutely devoid of any hazardous radiofrequency radiation. With Li-Fi technology, now access the internet while using lamps, LED televisions, or other light sources. Li-fi adoption is also more affordable, quicker, and secure than Wi-fi. There is no need for a router with this technology.[10]

Simply point your smartphone or tablet at the lightbulb to browse the web with ease. Compared to more current technologies like Wi-Fi, this technology is an amazing finding. Li-fi is superior to Wi-Fi because it increases the speed and bandwidth of 3G and 4G. Li-fi, for instance, has a band frequency of 200,000 GHz while Wi-Fi has a maximum of 5 GHz, making it 100 times quicker and capable of sending more data per second [6], [8]. The position between the devices is also indicated by the Li-Fi communication technology in addition to data transmission [7, [8]]. The visible, ultraviolet, and infrared spectrums can all be used by the light communication system to send data. However, UV and infrared have limitations.

UV generally has a negative impact on health; it can lead to immune system suppression, chronic eye and skin damage, and more. High-power infrared waves can harm the eyes but are also inhibited by surfaces like walls and doors. Currently, only LED lights are employed to transmit visible light due to the aforementioned drawbacks.[12]

The primary distinction between Wi-Fi and Li-Fi is that Wi-Fi employs radiofrequency whereas Li-Fi uses modulation of light intensity. Visible Light Communication (VLC) is a wireless optical technology that transmits data by modulating light in the visible range. The modulated signal is encoded on the lighting source. Light illumination has the benefit of saving energy. in contrast to Wi-fi technology, Li-fi technology is considered as 'green and safe'. Utilising the infrastructure around us is one of the key benefits of VLC. [6], [9]

1.2 Literature Reviews:

1.2.1 Introduction:

A literature review discusses the state of the art in a particular subject area. It can be an analysis of literature or published sources, on a particular topic. A literature review is a simple summary of the sources, but it usually has an organizational pattern and combines both summary and synthesis A synthesis is a reorganisation or reshuffle of the material in a summary, which is a recap of the key points from the source. It could provide a fresh interpretation of dated information or blend fresh and outdated perspectives. Or it could outline the field's intellectual history, including significant arguments. The literature review may also assess the sources and advise the reader on which are the most topical or relevant, depending on the circumstances.

1.2.2 Survey of Related Work:

- In references [1] and [7], the basics of Li-Fi technology were discussed in references; Li-Fi is commonly implemented using white LED light bulbs. These gadgets are typically employed for lighting by passing a steady current via the LED. However, the optical output may be made to vary at extremely high speeds by making quick and small changes to the current. This variant is used to transmit high-speed data and is invisible to the human eye. The photodetector and LED lamp that make up a lithium-ion battery serve as the device's transmitter and receiver, respectively, of transferred data. The LED must be correctly operated using a lamp driver. Amplification and processing are typically used to conduct the photodetector signal.

- Following, in references [5],[12],[13], a white LED is used for transmission in a Li-Fi system, and a silicon photodiode serves as the reception element. To create digital strings of various combinations of 1s and 0s, LEDs can be turned on and off. By changing the LED's rate of flickering, it is possible to encrypt data in the light and create a new data stream. By modulating the LED light with the data signal, the LEDs can be utilized as either a sender or a source. Due to the LED's rapid flickering rate, the output of the LED looks continuous to the human eye.

The four parts of a Li-Fi-based LED bulb are listed below:

A) lightbulb;

B) RF power amplifier (PA)

C) PCB stands for printed circuit board.

D)enclosure

Complemented in Li-fi technology, an aluminium jacket known as the enclosure, which is made up of all the components, is what makes up an LED lamp. As a light source with an enclosure, a bulb is used. The PCB has functions for controlling the electric signal and managing lamps. The RF power amplifier is needed to produce the radio frequencies that are directed into the electric field around the bulb. The bulb sub-assembly is the brain of the Li-Fi emitter. A sealed bulb enclosed in a dielectric substance serves as its foundation. Traditional light sources that use electrodes in the bulb that break down perform worse than this idea. The dielectric material serves two purposes. It acts as a waveguide for the RF energy that the PA (Power allocation) transmits. It also acts as a concentrator of the electric field, focusing energy inside the bulb. The energy of the electric field quickly heats the material inside the lightbulb to a plasma state, which creates bright, full-spectrum light.
The references that follow explain that the Li-fi network is built on a few crucial potentials.

- Firstly, references [4], and [17], discussed the several access in the Li-fi network, which allows for the simultaneous allocation of network access to several users. For instance, angle diversity is used in optical space division multiple access (SDMA) as opposed to time division multiple

access (TDMA). The benefit of such multiple access networks is the careful design of the angle diversity transmitter. If not, multiuser access is immediately given using the OFDM approach. To maintain equity in the distribution of resources (subcarriers), OFDMA should employ the proper user-scheduling algorithms. The idea behind non-orthogonal multiple access (NOMA) was to take advantage of LEDs' broadcasting capabilities to boost throughput.
A Li-Fi network's performance could be greatly enhanced by adopting NOMA. Because NOMA uses a special, non-orthogonal resource allocation technique, it may service a greater number of users than typical multiple-access systems.

- Secondly, in [17], [18], [19], discussed the Li-fi-based internet access point (AP) where lights can act as an optical access point (AP) in an indoor Li-fi network. Indoor-based Li-fi networks include Li-fi access points (AP) and Li-fi terminals. A local area network (LAN) is made up of two levels, the MAC layer and the PHY layer. In Li-fi technology, a high-brightness LED bulb is regarded as its brain.

- The conception was presented. A hybrid indoor system based on Li-Fi and Wi-Fi, or a hybrid Li-Fi and Wi-Fi network, is envisioned for inside wireless communications and is expected to provide broad coverage by combining the high-speed data transmission of Li-Fi and the comparatively large coverage of Wi-Fi. A hybrid Li-Fi and Wi-Fi network (HLWNet), which combines the high-speed data transmission of Li-Fi and the extensive coverage of Wi-Fi, was initially introduced by Rahaim et al. in 2011. Later, Stefan et al. expanded the research to incorporate femtocells and Li-Fi. The development of hybrid RF/VLC as a desirable indoor broadcasting system is crucial. This system satisfies the end user's need for continuous data services, regardless of where are located.

The user terminals are required to be equipped with a selection device that can switch between RF and VLC links based on the signal-to-noise ratio (SNR).

In addition to its benefits, wireless technology has a number of drawbacks, some of which are discussed in Reference along with how affects the network's overall performance and efficiency.

- In references [19], [20], [21], talked about the downsides that are LED-related problems. The disadvantage of an indoor LI-FI network is caused by the LED lights' ON-OFF status. A system based on Li-Fi provides both illumination and data transfer simultaneously. The light is ON when data communication is successful. However, with a Li-fi network, the issue would occur when the light is turned off because data transfer is not possible when LED lights are turned off. Li-fi does not function when LED lights are out (LED lights can be dimmed but must be on to transfer data); this has a significant influence on the power bill and use. Only devices with a Li-Fi receptor (such as tablets, cell phones, etc.) can use it.

- Some of the references discussed how Li-fi and Wi-fi technology compare.

Table 1: Comparison between Li-Fi and Wi-Fi technology [4], [16], [28], [29]

Technology	**Li-Fi**	**Wi-Fi**
Source	LED bulbs	Radio frequencies
Data transmission	Data is transmitted through the light	Transmission of data is carried out by radiofrequency
Cost	High installation cost	Low cost
Accessibility	In Li-Fi, light is blocked by walls, and data is transferred securely	In Wi-Fi, a radio wave is not interfered with by walls and requires employing techniques for the achievement of secured data.
Data Rate	1Gbps	150Mbps, 1-2 Gbps
Frequency	400-700 THz	2.4GHz, 4.9GHz and 5GHz
Range	10m (indoor)	About 32 meters vary based on transmit power and antenna type
Network Topology	Point-to-point	Point -to-multipoint
Security	High	Less than Li-Fi
Interference	Do have low interference issues like radio frequency waves.	do have high interference issues from nearby access points(routers)
Blockage	There is a high probability of blockage	Blockage is limited
Shadowing	Presence of the shadowing effect	No shadowing effect
Outdoor and Indoor stability	Low and high respectively	Both are high
Signal-to-noise ratio	Very high	May be more
Availability	Where there is light there is Li-fi	limited

- Finally, in [22], [23], and [24], discussed the indoor navigation system, advantages, and goals. The indoor navigation system can be used in homes and hospitals. The indoor way is beneficial to everyone, but it is essential for those who are outwardly hampered. Li-fi is simple to use for an unrestricted, unfettered range and is unaffected by RF interference. Since Li-Fi cannot permeate through walls, indoor spaces have ample lighting and offer better security. The transmitter and receiver are the two halves of this system. The receiver section is utilized by people who are blind, whereas the transmitter section is frequently used indoors. The LI-FI receiver receives the data from the transmitter portion and outputs voice using a specific circuit that is located in the appropriate rooms and is controlled by the controller. For the user to roam around an indoor setting, Li-fi technology is quite helpful. An indoor navigation system's goal is to give users the knowledge needed to choose the best course of action in an interior environment at the right time. Whether LED lighting is being installed in pathway ceilings is a piece of precise positioning information that should be sent simply over the user's head.

Here discussed how Li-fi networks' intelligent features, which combine energy efficiency with the actual needs of the illuminated space while taking into account the availability of natural lighting, enable advanced functions like adjustable spectral reproduction and adaptive dimming [22]. Design engineers can transmit data and give illumination simultaneously with connected lighting systems (CLSs), which combine Internet of Things (IoT) connectivity and LED capabilities. Smart lighting systems feature a variety of wired and wireless interfaces designed to increase communication in smart grid systems and building management systems as digital connectivity choices proliferate. Integration of smart technology and systems into the building's operational policies, benchmarks, and constraints that regulate all of the numerous services put in place. All building systems, including but not limited to access control, fire alarm, lighting, HVAC, CCTV, and energy management, will be able to be accommodated by these systems. The majority of people are using Wi-Fi Internet devices, where data is transmitted through wireless media access covering our homes, offices, schools, and other public areas. Wi-Fi can cover an entire house, and school, and its bandwidth is restricted to 50-100 megabits per second (Mbps). Large data files like HD movies, music collections, and gaming libraries cannot be moved over Wi-Fi. Wi-Fi may not be sufficient to satisfy the increased needs, thus in 2011, a German scientist announced a new technology called Li-Fi at the University of Edinburgh. With Li-Fi, data is carried at a very high speed using lights. Li-Fi is light-based communications technology that delivers high-speed, bidirectional networked, mobile communications in a similar fashion as seen in Wi-Fi. Harald Haas has demonstrated the working of LI-FI technology with the use of LED lamps and photodiodes at TED Global talk. [16] photodiode is used as the broadband the most efficient way of transmitting data without any damage to data.[17] But as see recently Herald has come up with some new adulterant in Li-Fi technology which are beneficial for all and have a lot of advantages. Before Li-Fi was been in used with photodiodes for transmitting data but to overcome some of the limitations of photodiodes Herald at TED Global talk held in 2015 talked about the use of solar panels with Li-Fi[18].The solar panel is more beneficial because it can perform both functions of transmitting data and capturing energy whereas a photodiode requires an external device for the requirement of transmitting data Considering this new technology some more adulteration can be made to make it more efficient which is the main concern of this paper by using the solar concentrator. The solar concentrator is a device that magnifies the incoming solar radiation to increase the output power of the solar panel.[20] Earlier as it has been seen solar panels consist of solar cells which were used to cover the radiation coming from the sun into electricity but by the use of solar concentrators solar cells will be required which will result in cost reduction and the efficiency will be far better as compared to previous case in which solar concentrator was not used with solar panel.[19]

- Additionally, depicted Li-fi topologies like the hybrid and aggregated models in reference [7]. a prototype for proving something. VLC HetNet is a concept that uses a wide spectrum to offer high-quality service in an indoor setting. Two models, a hybrid model, and an aggregated model, are displayed in the proof-of-concept experiment. In a hybrid paradigm, the system connects to the internet via Wi-Fi, while a user's downlink is connected via a Li-Fi link. On the other hand, the combined system supports simultaneous user connections across Li-Fi and Wi-Fi. A unidirectional Li-Fi link is used in a hybrid system to support the Wi-Fi downlink. Wi-Fi and Li-Fi use bi-directional communication in an integrated system to improve performance and offer dependable connectivity.

A simple LiFi circuit is presented here final year project showing how to transmit music through LED light across a given distance, using only LED light without creating any in the LED while yet perfectly conveying the light. Similar to Wi-Fi, Light Fidelity (Li-Fi) is a bidirectional, fast, fully networked wireless communication technology. Some have referred to the quick and inexpensive wireless communication technology, known as Li-Fi, as the optical counterpart of Wi-Fi. Instead of Gigahertz radio waves, Li-Fi transfers data using visible light. Li Fi (light fidelity) is data through illumination-taking the fibre out of fibre optics by sending data through an LED light bulb that varies in intensity faster than the human eye can notice.[33]

A new generation of high-brightness LEDs form the basis of this technology.

A digital 1 is delivered while the LED is on, and a digital 0 when the LED is off. It can be switched on and off in order to transmit data continuously.

The novel technology Li-fi is discussed in this study's literature review because it could offer a more effective remedy for the impending radio frequency (RF) resource crisis. Some initial designs and the outcomes of small-scale prototypes are presented in accordance with the study of the literature review.

1.3 Problem Definition

However, Li-Fi replacing Wi-Fi systems due to more list of advantages. But in this research paper, it has research gaps also which are explained as follows:

Fig. 1.1: - The visible Light

A. Its coverage area is very limited i.e., 10 meters only. However, Wi-Fi coverage only extends about 32 metres. Li-Fi works only on the visible spectrum as shown in Fig: 1.1.

B. Li-Fi transmitters use solid-state LEDs integrated/embedded with controllers that receive data and modulate the light output of LED according to bits of data. The lighting devices are generally phosphor-based or RGB lighting and both have their own set of strengths and weaknesses. Phosphor-based light sources are less expensive than RGB-based ones, however because of their slow switching speeds, they offer less bandwidth than RGB sources. This isn't a big problem, however. One of the major financial hurdles in LiFi is as follows: Consider a scenario where want to implement LiFi at a location pre-installed with lighting fixtures. There seem to be two options: 1. replace the existing light source with a new one that contains an integrated VLC modulation controller, or 2. fix a new VLC-enabled light source None of the options above however solves the cost issue in LiFi and does not offer any cost savings. So, the integration with light sources in LiFi is a major problem.

1.4 Objectives

- Presenting the extensive literature review of Li-Fi (Light Fidelity) technology.
- Observing the comparison of Li-Fi with WiFi
- Designing a Li-fi Circuit
- Mainly focused on increasing the range of Li-Fi.

1.5 Methodology

The prototype design technique will be the main topic of this methodology section. Since both Li-Fi and Wi-Fi use electromagnetic waves to convey data, they are relatively similar. However, Li-Fi operates on visible light wavelengths while Wi-Fi employs radio frequencies. Visible Light Communications (VLC) is what Li-Fi is. This indicates that it has a photo-detector for capturing light signals and a signal-processing component for transforming the information into "steam able" content.

Because an LED light bulb is a semiconductor light source, its steady current of electricity may fluctuate up and down at incredibly fast speeds while remaining invisible to the human sight. For example, data is fed into an LED light bulb (with signal processing technology), and it then sends data (embedded in its beam) at rapid speeds to the photo-detector (photodiode) or solar panel, a block diagram shown below.

The tiny change in the rapid dimming of LED bulbs is then converted by the 'receiver' into an electrical signal.

The signal is then converted back into a binary data stream that would be recognized as web, video and audio applications that run on internet-enabled devices.

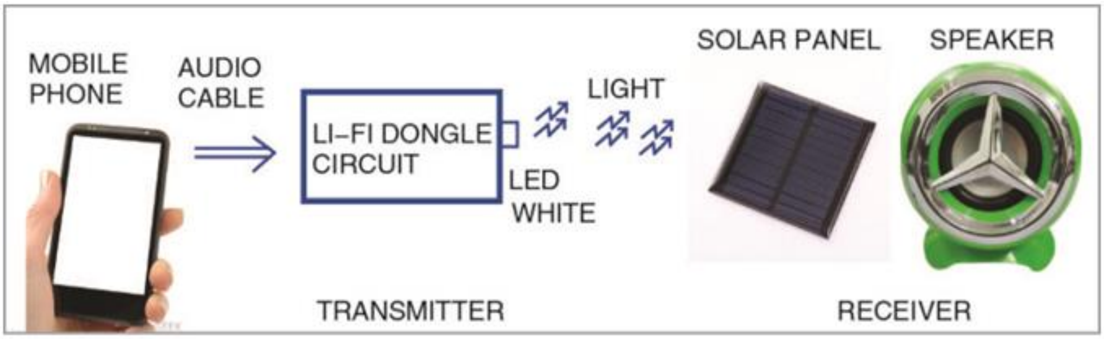


Fig 1.2: Block Diagram

The operation of this system will be similar to that of LI-FI technology, which makes use of photodiodes; however, here, solar panels will serve as broadband receivers. The encoded data will be fed from the lamp driver to the LED lamp, which will then pass it on to the solar cells in digital form. The benefit of this arrangement is that solar cells are self-sufficient in that can both transmit and capture energy. Incoming solar rays will be converted by solar cells into electricity, allowing for continuous energy capture and data transmission. The energy provided by the sun is infinite it is just the lack of knowledge and skill, that makes its use, limited. Solar panel is more beneficial because it can perform both functions of transmitting data and capturing energy whereas a photodiode requires an external device for the requirement of transmitting data Considering this new technology some more adulteration can be made to make it more efficient which is the main concern of this paper by using a solar panel.[19]

1.6 Thesis Outline

This paper focuses on exploring this new communication technology and gives a relative study on Li-Fi. Similar to more traditional wireless communication methods like Bluetooth and Wireless- Fidelity (Wi-Fi), Li-Fi uses the visible light portion of the electromagnetic (EM) frequency spectrum to exchange information. RF signals are used in more traditional wireless communication methods like Bluetooth and Wi-Fi to transmit data or information over wireless networks. A photosensitive detector, such as a solar cell, is used to demodulate the light signals and transform them back into electrical form as a receiver by varying the intensity of light sources like LEDs. This paper gives a thorough review of the need for Li-Fi, applications for Li-Fi, methods for extending Li-Fi' range, and Li-Fi potential in the future.

Chapter Two: Li-Fi (Light Fidelity)-The technology

2.1 What is a Li-Fi?

Light-emitting diodes (LEDs) are a type of wireless optical networking technology that is also referred to as "Light Fidelity" (LiFi). At the TED (Technology, Entertainment, Design) Global Talk on Visible Light Communication (VLC) in 2011, Professor Harald Haas gave a LiFi demonstration.

It has some similarities to the current WiFi technology, but it also differs significantly. To put it another way, visible light, like that produced by a typical lamp or bulb, is how LiFi operates!

Life has received a lot of attention recently as numerous businesses have entered this market. The Lifi market is anticipated to increase by 11.8% by 2026, reaching 115 billion in 2022.[4]

2.2 History of Li-Fi:

In his 2011 TED Global Talk, Professor Harald Haas, Professor of Mobile Communications at the University of Edinburgh, suggested the concept of "wireless data from every light" and is credited with coining the name "Li-Fi."

Any use of the visible light region of the electromagnetic spectrum to convey information falls under the broad term "visible light communication" (VLC), whose history stretches back to the 1880s. The Institute for Digital Communications in Edinburgh received funding for the D-Light project from

January 2010 to January 2012. Haas assisted in founding a business to advertise it.

In order to advance high-speed optical wireless systems and get around the finite amount of radio-based wireless spectrum that is currently available, industry companies and the research organization Fraunhofer IPMS founded the Li-Fi Consortium in October 2011. [8]

In 2012, VLC technology was shown using Li-Fi. Data rates of around 1.6 Gbit/s were demonstrated over a single-color LED by August 2013. According to a press release from September 2013, line-of-sight conditions are not necessary for Li-Fi or VLC systems in general. Chinese manufacturers were reportedly working on Li-Fi development kits in October 2013 [15]. The APD was used as a single photon avalanche diode (SPAD) in Geiger mode by IEEE in July 2015 to improve energy economy and boost the receiver's sensitivity. This process could potentially be used to achieve quantum-limited sensitivity, which enables receivers to pick up faint signals from a great distance away. [9]

Li-Fi passed a test by a BMW plant in Munich in June 2018 for working in an industrial setting.

Kyle Academy, a secondary school in Scotland, piloted the deployment of Li-Fi in the building in August 2018. Through a connection between their laptop computers and a USB device that converts the quick on-off current from the ceiling LEDs into data, students can get information. [11]

2.3 How does Li-Fi work?

LiFi is a type of fully networked, high-speed, bidirectional wireless data connection. A wireless network made up of several lightbulbs is called LiFi.

A LED light bulb emits a stream of light (photons) when an electrical current is supplied to it. Since LED lights are semiconductor devices, it is possible to change the brightness of the light passing through them very quickly. This translates to the ability to send a signal by modulating light at various rates. A detector can then pick up the signal and translate the variations in light intensity (the signal) into data. Additionally, you communicate a digital 1 when the LED is ON and a 0 when it is OFF. [31]

The users can connect everywhere there is LiFi-enabled light, as shown in fig. 2.1, because the intensity modulation cannot be seen by the human eye and connection is therefore as seamless as with conventional radio systems. This method enables rapid data transmission from an LED light bulb and back.

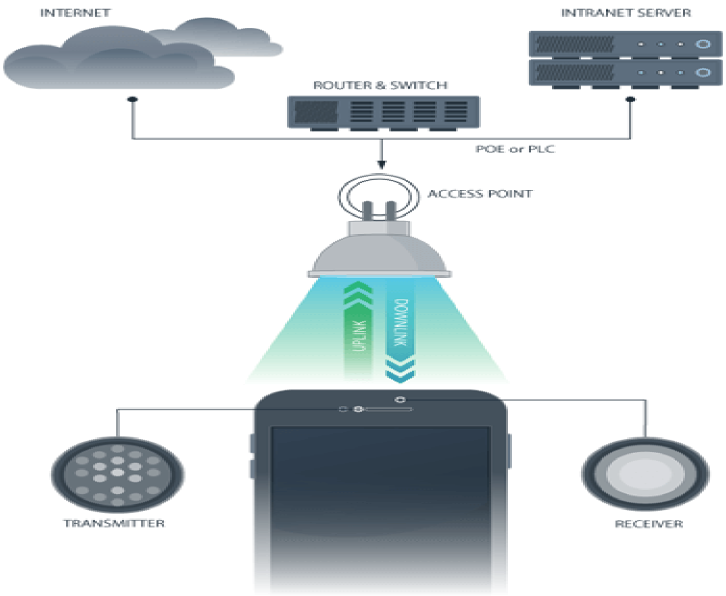


Fig 2.1 LiFi - How LiFi work?

2.4 Inverse Square law model

In this section, Inverse square law is studied for designing the proposed path loss model. The for-modulation technique of Li-fi system, ASK (Amplitude Shift Keying), theories of ASK modulation is studied later in this section.

This law says intensity is inversely proportional to the square of the distance from the source. The following can be expressed

$$E_1 {D_1}^2 = E_2 {D_2}^2 \quad (1)$$

$$or, \frac{E_2}{E_1} = \left(\frac{D_1}{D_2}\right)^2 \quad (2)$$

Where E_1 is Energy Measurement at source unit in Flux; E_2 is Energy Measurement within distance unit in Flux; D1 is Distance source to first measurement unit in Meter; D2 is Distance source to second measurement unit in meter

2.5 Illuminance Measurement:

The illumination metric is used to determine how much light is present in a space. In footcandles or lux, the amount of light (lumens) that falls on a surface (over any given square foot or square metre) is measured.

Illuminance measurement is required to have the real statistical data of the light intensity where a unit is taken in terms of lux. The term lux is also needed to create a new proposed path loss model and evaluate the inverse square law model.

2.6 Amplitude Shift Keying (ASK) modulation in Li-fi technology

ASK is also known as On-Off keying since carrier waves switch between 0 and 1 concerning low and high levels of input signal respectively. In OOK, the value 1 or 0 of the input message signal decides whether bursts of a carrier wave are transmitted, or nothing is transmitted. ASK is regarded as an analogue amplitude modulation's digital equivalent. In ASK, when binary 1 appears a burst of radiofrequency is transmitted and stopped when binary 0 appears [45], [46].

A binary amplitude-shift keying (BASK) signal can be defined by,

$$s(t)=A\, m(t)\cos 2\pi f_c t, \quad 0 \leq t \leq T \qquad (3)$$

Where *m(t) is the Message signal in bits 1 or 0; fc is Carrier frequency; T is Bit duration.*

ASK Demodulator

It is classified into two techniques. They are as follows-

Asynchronous ASK Demodulation/Detection

Synchronous ASK Demodulation/Detection

The synchronous method refers to the match of the clock frequency at the transmitter to the clock frequency at the receiver, as the frequency gets synchronized. Instead, it is referred to as asynchronous.

Asynchronous ASK Demodulator

The modulated ASK signal is fed into the rectifier, which provides a positive half-wave output. The higher frequencies are inhibited by the low pass filter and deliver an envelope-detected output from which the comparator gives a digital output [39].

Synchronous ASK Demodulator

The ASK-modulated input signal is given to the square-law detector. It makes the output voltage proportional to the square of the amplitude-modulated input voltage. The higher frequencies are minimized by the low pass filter, eventually, a clear digital output is obtained by the comparator and the voltage limiter [39].

2.7 VLC principles and LiFi

In the last decade, it has seen a dramatic increase in the traffic carried by the telecommunication networks, with mobile traffic representing one of the main contributors: the last forecasts indicate that the total mobile data traffic is expected to rise at a compound annual growth rate of 42% and the monthly global traffic will surpass 100EB in 2023 [6].

These figures mostly reflect the desire of people to communicate at any time and from any place, which has been met by wireless technologies:

Wireless devices, applications and services have become very pervasive in our life, changing it radically. Therefore, in order to keep pace with this growing demand, it has been defined a new set of standards for wireless and wire communications, the 5G (fifth generation) [37].

With the term Wireless communication, usually refer to technologies that use radio waves to transfer information between two or more points without using a "wire" (electrical conductor). The Radio Frequency (RF) band, which lies between 30 kHz and 300 GHz of the Electromagnetic (EM) spectrums, has been the most used portion for communication purposes, mainly due to little interference in the frequency band and wide area coverage. However, the RF is just a part of the EM spectrum, as shown in Fig 2.2.

OWC is a technology that complements RF and offers potential that are currently mostly underutilized. against their RF counterparts. OWC displays superior characteristics such ultra-high bandwidth (in the THz range), resistance to electromagnetic interference, a high degree of spatial confinement allowing almost infinite frequency (or wavelength) reuse, and built-in physical security. Additionally, because OWC technologies can operate in the unlicensed spectrum, they offer cost-effectiveness for a variety of applications.

Visible Light Communication (VLC) is the name given to an OWC system that employs wavelengths between 390 and 700 nm (Fig.). This region of the electromagnetic spectrum is notable for having waves that can activate photoreceptors in the human cornea.[30]

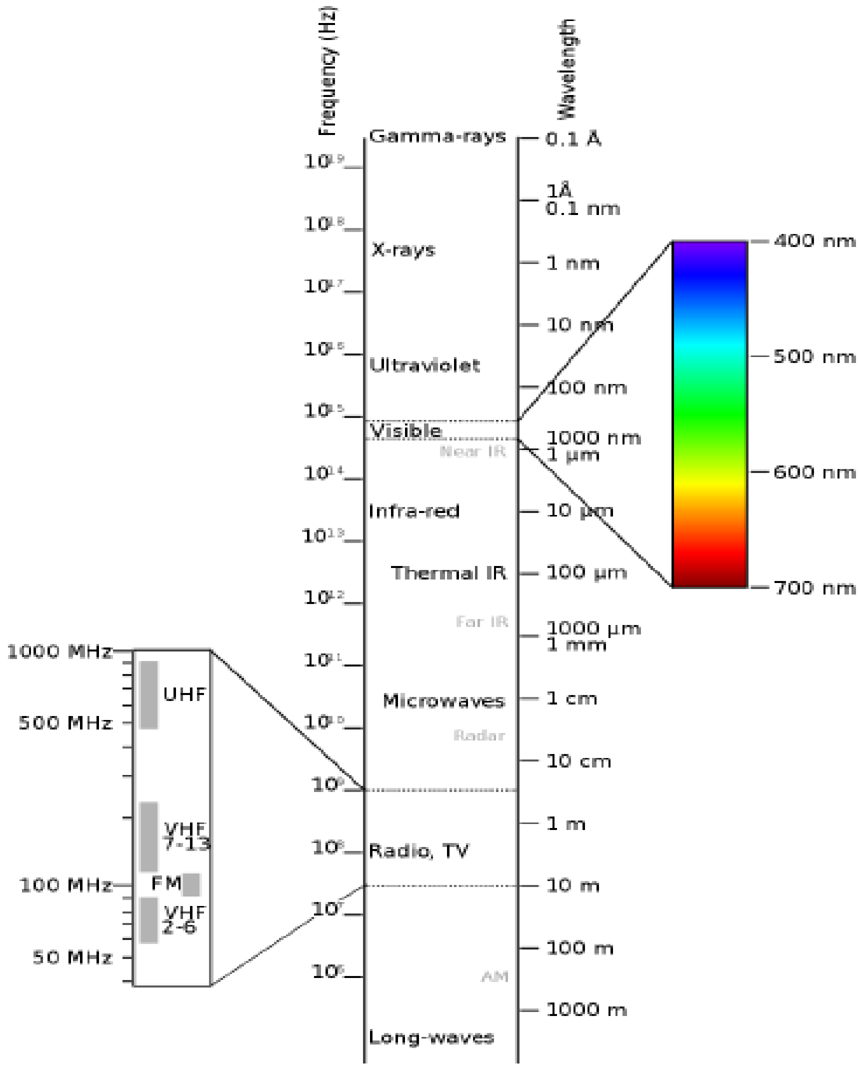


Fig 2.2. The Electromagnetic spectrum (source Wikipedia)

VLC exploits solid-state lighting such as LEDs for data communication, modulating and transmitting a data stream by varying the intensity of luminaires. In other words, an LED can serve as a dual-purpose device, offering lighting and communication simultaneously, providing a viable solution to alleviating the spectrum shortage in the RF band [39].

2.8 Benefits of VLC:

Implementing VLC has various advantages, including the following:

- VLC systems facilitate simple co-channel interference management and offer a high level of communication security. In indoor scenarios, the signals from VLC systems are confined by the walls of rooms, preventing interference by VLC systems in other rooms and potential eavesdropping.
- VLC is energy-efficient. Traditional indoor lighting or illumination is ubiquitous in the modern world and accounts for approximately 7% of the total electricity consumption in the USA [11]. Since in the last years environmental health and safety has become an important topic, governments around the world are encouraging the replacement of energy-inefficient halogen lamps and incandescent lamps with energy-efficient LEDs. As LED illumination spreads widely, this technique is laying the groundwork for the creation of ubiquitous VLC systems.

- Furthermore, the energy used for communication in VLC is essentially free, as lighting is required anyway.

- VLC not only has the potential to offer higher data rates but also has various important applications in the IoT, intelligent transportation systems, indoor positioning, and entertainment.[10]

A comprehensive networking solution is necessary for the realization of genuinely mobile communication systems, which gives rise to the idea of Light-Fidelity (LiFi), which is the opposite of Wi-Fi. High-speed, bidirectional, completely networked communications are demonstrated by LiFi, a subset of

VLC. The term was introduced for the first time by Professor Harald Haas in [12][34]. For instance, in order to achieve communication with multiple VLC receivers in an indoor environment, a cellular network structure composed of several small optical Atto cells has been proposed [13]. The goal is to provide seamless coverage and high spectral efficiency to multiple users simultaneously. In practice, an optical Atto cell network can be realized by installing multiple LiFi access points in the ceiling of a room.
The VLC system architecture, together with the channel model and the modulation schemes will be now introduced.

It includes Infrared (IR), Visible and Ultraviolet (UV) light and these wavelengths are used in the so called Optical wireless communications (OWC) as unguided lights carrying a signal.

Wi-Fi is the very common medium of data transmission. It uses 2.4-5 GHz Radio Frequency (RF) to transmit data. Wi-Fi works when the Internet or bandwidth is available. Without Internet or bandwidth Wi-Fi cannot transmit data.This is one of the main problems of Wi-Fi. Here speed limitations are also a major issue.
Tried to find out the solutions to this problem, and to working on it I got modern technology which is Li-Fi. Li-Fi fixed the Wi-Fi problems and transmits data more accurately.
Studied different papers related to Li-Fi Technology and got various problems and solutions. But didn't getany solutions for Li-Fi range. I know, that more range can cover a large area of data transmission. So, I found that the Li-Fi range is one of the major issues while I tried to study it and continue our research on the Li-Fi range.

2.9 Problems of Wireless Communication

A new technique to increase Li-Fi range. As there is no available research on this topic, I have faced many problems and I tried my best to solve those problems with suitable mathematical and geometrical solutions.

A. *Problems of Wireless Communication Systems*

Despite continuous improvements in wireless communication systems, (for example 4G, 5G, etc.) an impending crisis is predictable due to the lack of adequate Radio Frequency (RF) resources, this limitation in bandwidth can’t support the progress in demand for high data rates and the large numbers of communication systems, within the bandwidths between 300 kHz and 4 GHz. That’s known as “Spectrum Crunch”.[40]

Although, Spectrum fulfillment shrinks when high frequencies to transfer data are used, but this is not a practice and proper solution, because this part of the spectrum entails complex equipment and causes excessive cost systems.

B. *So how does the problem can be solved*

There are various technologies that provide applicable and realistic solutions to this concern. One of them is the “Cognitive Radio”. [6,7,37] It is a new category of wireless communication built with a transceiver architecture. It can perceptively detect which communication channels are in use and which are not, and immediately move into empty channels to use them to transmit data. The alternative solution is the transmission of data using visible light illumination. It uses very high frequency. The term "Visible Light Communication" (VLC) refers to this technology.

There are also many brilliant and efficient solutions, such as Light Fidelity (Li-

Fi) technology, which is based on VLC.

C. *Visible Light Communication:*

Visible Light Communication is an optical communication technology that uses visible light rays, these rays locate between [400-800] THz, as a visual carrier for data transmission by radiance. It uses fast pulsations of light It is invisible to the human eye. To transmit data. [8,9,10] It includes any usage of the visible light portion of the electromagnetic variety to transmit information. The VLC standardization process is conducted within the IEEE wireless personal area network working group (802.15) [11]. Wide bandwidth is one of VLC's capabilities, as seen in the illustration. It can be see that usage of the optical portion of the spectrum guarantees about 10,000 times greater bandwidth compared to the usage of the RF frequencies. The location of visible light and RF frequencies in the electromagnetic spectrum is shown in Fig 2.2.

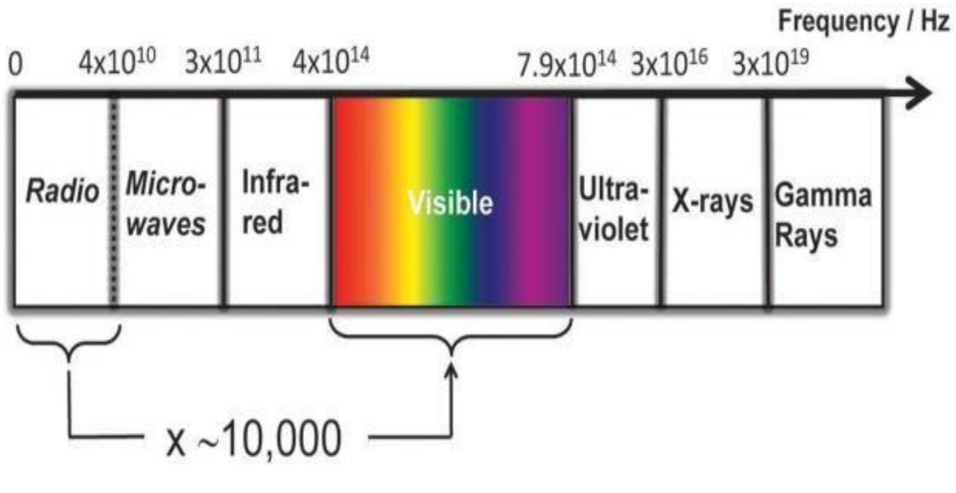


Fig 2.2. Location of visible light and RF frequencies at the electromagneticspectrum

2.10 The benefits of LiFi:

LiFi offers numerous advantages, including:

- Impregnable technology: Data communicated by LiFi is limited to the authorized area, unlike WiFi, where radio frequency waves can be vulnerable to external hackers. This benefit is crucial for government agencies, legal firms, and other groups that handle sensitive data and are susceptible to cybercrime.
- Fast connectivity with up to 1 Gbps of speed.
- Consistent connection allows multiple users to browse simultaneously without latency, making it ideal for schools and open spaces where uninterrupted Internet access is crucial for work and learning.
- No radio frequency pollution that can impact health, particularly in settings such as hospitals, nurseries, and kindergartens where the well-being of vulnerable individuals is paramount.
- LiFi installations result in remarkable cost savings and a reduced carbon footprint in the transportation and aeronautics sectors.

  Due to the fact that LiFi uses light waves rather than radio frequency waves, it can be used with other wireless communication technologies including WiFi, 4G, and 5G. As a result of its interoperability with onboard technology, it is also the best option for flight travel.

2.11 Li-Fi Technology: Challenges:

Li-Fi technology is struggling with issues like

- Li-Fi entails line of sight (LOS) and the receiving device can’t be shifted indoors.

- A key challenge is how the receiving device Li-Fi Technology will transmit the data back to the transmitter.
- Another significant issue is an intrusion from external light sources like normal bulbs, sun light; dense materials in the path of transmission will cause disruption in the communication.

Another drawback is that Li-Fi isn't light-up in the dark. As light can't pass through objects, if the receiver is inadvertently blocked in any way, then the signal will instantly cut out. And the signal might be easily blocked by someone simply walking in front of the LED source. At present Li-Fi technology uses light that cannot go outside of any room or cannot pass any solid object that stops light. In future research this limitation can be considered, and a solution can be found regarding this. Also, our proposal of increasing the range of light can be proved by implementing it in real life. As the range of Li-Fi is limited nowadays and soon it will be the broadly used technology, it is really important to increase the range of Li-Fi.

2.12 Future of LiFi

LiFi will undoubtedly alter how people connect to the Internet. There is a possibility that will ultimately have access to a variety of technologies and be able to select the best one. It is believed that having that flexibility is the most desirable scenario. In India, various companies as well as the Student's Educational and Cultural Movement of Ladakh (SECMOL) have started using Light Fidelity (Lifi) technology for their school.

Chapter Three: Proposed Method

3.1 Introduction:

A simple LiFi circuit is presented here for showing how to transmit music through LED light across a given distance, using only LED light without creating any fluctuations in the LED and yet transferring the light with perfection. Light Fidelity (Li-Fi) is a bidirectional, high-speed, fully networked wireless communication technology similar to Wi-Fi. Some have referred to the quick and inexpensive wireless communication technology, known as Li-Fi, as the optical counterpart of Wi-Fi. Instead of Gigahertz radio waves, Li-Fi transfers data using visible light.

By delivering data through an LED light bulb whose intensity changes more quickly than the human eye can perceive, LI FI (light fidelity) removes the fibre from fibre optics.

A new generation of high-brightness LEDs form the basis of this technology. If the LED is on a digital 1 is transmitted, if the LED is off then a digital 0 is transmitted. It can be switched on and off in order to transmit data continuously.

3.2 Experimental Setup

It is crucial to extend Li-Fi's range because it is now constrained and because it will soon be a widely used technology. One voltmeter, one lux meter, and one variable light source are used in this arrangement of equipment to measure the illuminance and solar panel voltage. Both the voltage of the solar panel and the illuminance were measured and recorded while the voltage of the light source was gradually increased.

On the other hand, the space between the light source and the solar panel has gradually changed, and measurements of the brightness of the solar panel's surface have been made.

Secondly, measured the voltage between the two terminals of a solar panel by changing the distance of the light source. A block diagram is shown below.

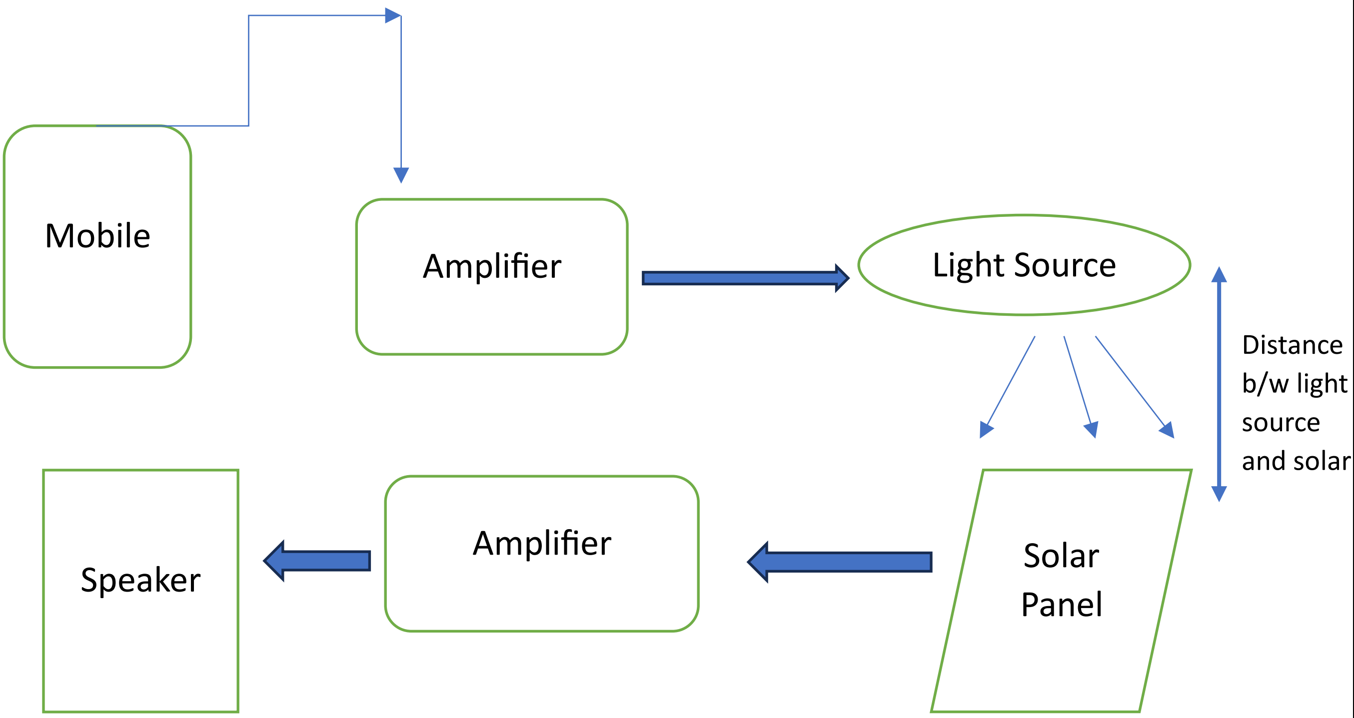


Fig 3.1: Block Diagram

3.3 List of Equipment:

1. Variable Light source
2. Multimeter (for measuring the voltage)
3. Lux Meter
4. One Measuring scale

Chapter Four: Design and Development of Proposed Circuit

The purpose of this project is to demonstrate how wireless optical networking technology known as LI-FI transmits data using light-emitting diodes (LEDs). It is used to create LED light bulbs that resemble the ones that are already in use in many energy-conscious households and workplaces.

4.1 Hardware Components:

1. TEA2025B IC
2. 1000UF 25 VOLT CAPACITOR (1 QTY)
3. 100UF 25 VOLT CAPACITOR (5 QTY)
4. 0.1 OR 104 CAPACITORS (3 QTY)
5. 10K ,1 K RESTORE (2 QTY)
6. Switch
7. PCB
8. Battery Cap
9. 9 Volt Battery
10. LED 3Watt
11. Small Speaker
12. Stereo Pin
13. 3.5 MM Lead
14. 220 OH Resistor
15. 4 Volt small Solar Plate

4.2 Components:

4.2.1. light-emitting diode (LED):-

A semiconductor light source known as an LED produces light when current passes through it. Electrons can reunite with electron holes inside the diode when a current passes across it, releasing energy in the form of photons. Electroluminescence is the name of this phenomenon. The semiconductor's energy band gap determines the colour of the light, which corresponds to the energy of the photons. A layer of light-emitting phosphor or several semiconductors can be used to create white light on a semiconductor device.

The flat bottom surfaces of the anvil and post embedded inside the epoxy serve as anchors to prevent the conductors from being forcibly dragged out by mechanical strain or vibration, as shown in Fig. 4.3, which shows the components of a standard LED.

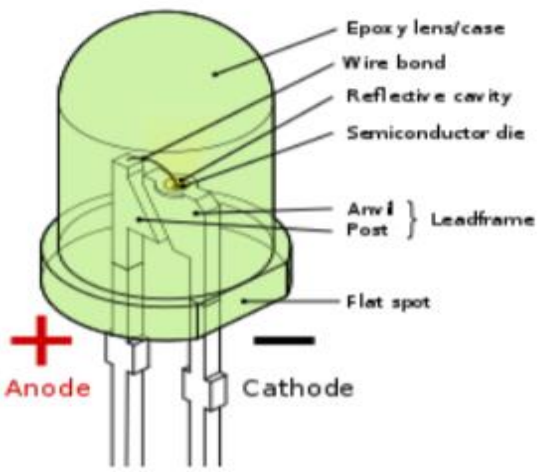


Fig 4.3: LED

4.2.2. Solar:

Solar-powered photovoltaic (PV) panels work by harnessing photons from the sun to excite electrons in silicon cells, which in turn creates energy. Your home or place of business can then be supplied with green energy using this electricity. Sunlight may be used to create electricity using solar cells. A device that transforms light energy into electrical energy is this one. The word photovoltaic cell is used when the light source is not known, whereas the term solar cell is sometimes reserved for devices particularly designed to capture energy from sunlight, such as the solar panel in Fig. 4.4.

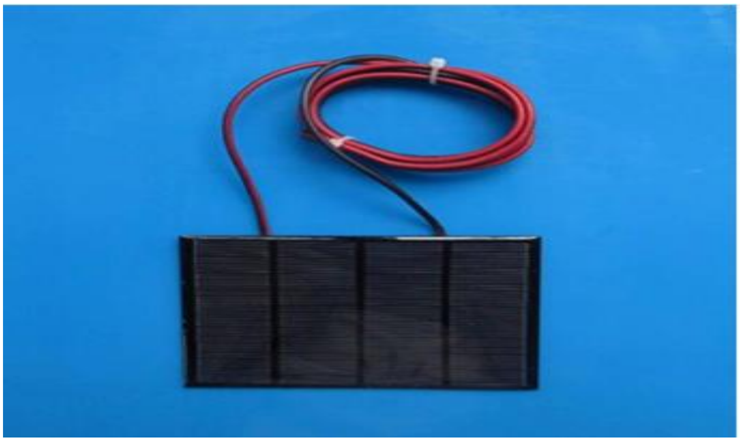


Fig 4.4: Solar Plate

4.2.3. Speaker:

An electronic device called an audio amplifier boosts the power (amplitude) of audio signals that travel through it. As seen in Fig., an audio amplifier increases low-power audio signals to a volume appropriate for driving loudspeakers.

Fig 4.5: - Speaker

4.2.4. Capacitor:

When a capacitor is linked to its charging circuit, it can store electric energy. It may release the stored energy when the charging circuit is cut off, allowing it to function as a temporary battery. Electronic equipment frequently use capacitors to maintain power while batteries are being changed. In Fig. 4.6, a capacitor is displayed.

Fig 4.6: - Capacitor

4.2.5. 3.5MM Jack Cable:

An audio signal is a representation of sound, typically as an electrical voltage for analog signals and a binary number for digital signals. Audio signals have frequencies in the audio frequency range of roughly 20 to 20,000 Hz (the limits of human hearing).

Fig 4.7: - 3.5mm Jack

4.2.6. Resistor:

it is an electrical device that may be a passive two-terminal electrical part that implements resistance as a circuit component. In electronic circuits, the resistors' unit of measurement is accustomed to reducing current flow, altering signal levels, dividing voltages, bias active components, and terminating transmission lines, among completely different uses.

Fig 4.8: - Resistor

4.2.7. Battery:-

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load.

Fig 4.9: - Battery

4.2.8. Wire:-

A wire is a flexible strand of metal. The wire is commonly formed by drawing the metal through a hole in a die or draw plate. Wire gauges come in various standard sizes, as expressed in terms of a gauge number or cross-sectional area.

Wires are used to bear mechanical loads, often in the form of wire rope. In electricity and telecommunications signals, a "wire" can refer to an electrical cable, which can contain a "solid core" of a single wire or separate strands in stranded or braided forms.

A length of such material, consisting either of a single filament or of several filaments woven or twisted together and usually insulated with a dielectric material, is used as a conductor of electricity.

Fig 4.10: Wire

4.3 MUSIC CIRCUIT:

This project is about making a 5-watt stereo audio amplifier using the UTC TEA2025 IC chip.

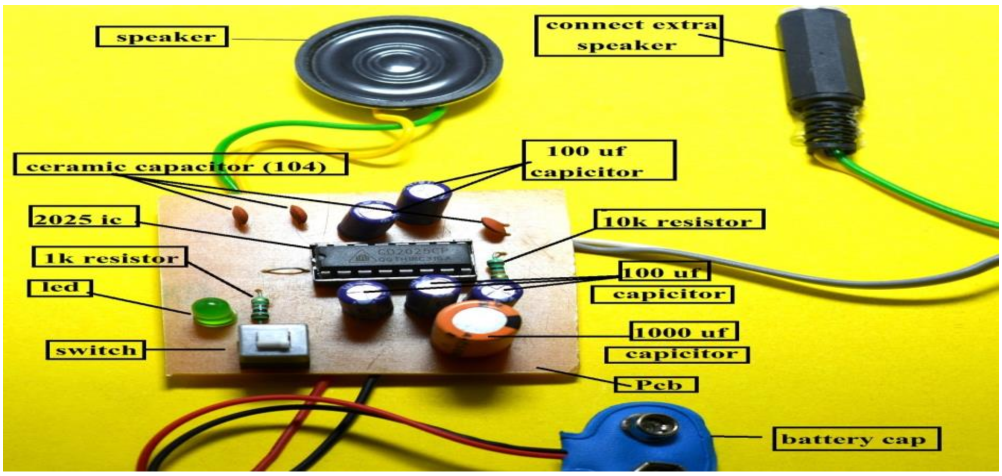


Fig 4.11: - Music Circuit

A monolithic twin in-line audio amplifier IC with 16 plastic pins is called the TEUTC TEA2025B. Although it was initially intended for portable cassette players and radios, it works well as a stereo audio amplifier for MP3 players. It only needs a small number of external components and can function with a power supply as low as 3 V. The stereo application circuit and the TEA2025 pin schematic are shown below.

A unique characteristic of the TEA2025 is that it has a built-in heat protection circuit. If you want to use the circuit at its 5 W maximum output, a heat sink must be added. If you don't, the device won't suffer any damage; instead, the internal thermal protection will reduce output power when an excessive junction temperature is discovered. The volume control feature can be provided at the input stage by a logarithmic dual taper potentiometer (10 or 20 K). The input side 0.22 F capacitors aid in reducing any noise brought on by fluctuating resistor contact. The output end's 0.15 F capacitors are there to maintain frequency. The use of other value capacitors could result in unwanted oscillations at the output. A suitable architecture of the circuit PCB is crucial since long wire connections and ground loops in the circuit may also result in oscillations. I built the circuit, which is shown below, using a general-purpose prototype circuit board that is 5 cm by 9 cm in size. The speaker, stereo input terminals, and power supply connections are dragged out of a 6 cm by 11 cm plastic shell that houses the circuit. The circuit can be powered by a power supply with a 3 to 12 V operating range. This is powered by a 9.6V rechargeable battery that was left over from a broken remote-control toy. I'm satisfied with the TEA2025's performance as a stereo audio amplifier.

4.4 COMPONENT USING MUSIC CIRCUIT:

4.4.1. Capacitor:

A capacitor resembles a battery in certain ways. Batteries and capacitors both store electrical energy, while operating in entirely different ways. You already know that a battery has two terminals if you've read How Batteries Work. Chemical processes taking place inside the battery cause electrons to be produced on one terminal and absorbed on the other. Because it can create new electrons rather than just store them, a capacitor is much simpler than a battery. The capacitor's terminals are connected to two metal plates that are spaced apart by a dielectric material. A capacitor can be readily made from two pieces of aluminium foil and some paper. In terms of storing capacity, it won't be a particularly effective capacitor, but it will still function.

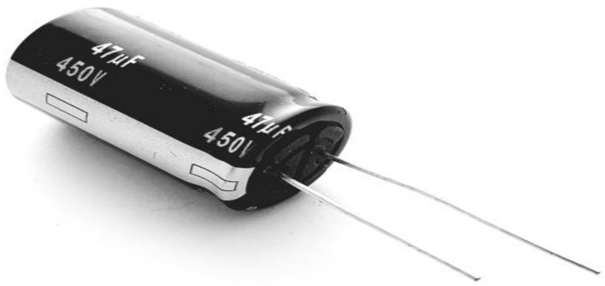


Fig 4.12: -Capacitor

4.4.2. TEA2025B IC:

A monolithic twin in-line audio amplifier IC with 16 plastic pins is called the UTC TEA2025. It may be used to create a reasonably good stereo audio amplifier for an iPod or MP3 player despite the fact that it was initially intended for portable cassette players and radios. It only needs a small number of external components and can function with a power supply as low as 3 V. The TEA2025's pin diagram and the stereo application circuit are given below.

Fig 4.13: - IC Diagram

4.4.3. Speaker:

When a person speaks commands to a piece of software, they are referred to as speakers. A cone, an iron coil, a magnet, and a housing (case) make up a speaker. The speaker moves back and forth as it receives electrical input from a device since the current is sent via it. This movement then causes the outer cone to vibrate, producing sound waves that are detected by our ears.

Fig 4.14: - speaker

4.4.4. Resistance:

A passive electrical component called a resistor is used to make current flow more difficult. You can find almost all electrical networks and electronic circuits. Ohms are used to measure resistance. When a resistor has a one-volt drop across its terminals and a current of one amp passing through it, the resistance is measured in ohms. The voltage across the terminal ends determines how much current flows.

This ratio is represented by Ohm's law: $R = \frac{V}{I}$

There are numerous applications for resistors. Electric current delimitation, voltage division, heat production, matching and loading circuits, control gain, and fixed time constants are a few examples. has resistance values that span more than nine orders of magnitude and are readily accessible on the market. It might be smaller than a square millimetre for electronics or utilized as electric brakes to dissipate kinetic energy from trains.

Fig 4.15: - Resistor

4.5 IC Component:

4.5.1 TEA2025 IC:

A monolithic twin in-line audio amplifier IC with 16 plastic pins is called the UTC TEA2025. Although it was initially intended for portable cassette players and radios, it works well as a stereo audio amplifier for MP3 players. It only needs a small number of external components and can function with a power supply as low as 3 V. The TEA2025's pin diagram and the stereo application circuit are given below.

Fig 4.16: - IC Diagram

The TEA2025B is a monolithic twin in-line audio amplifier integrated circuit with 16 plastic pins. Although it was first created for portable cassette players and radios, it may be used to produce a fairly good stereo audio amplifier mp3 player. It simply requires a limited number of extra parts and can run on as little as 3 V of power. The pin diagram for the TEA2025 is shown in Figure 4.18.

The fact that the TEA2025 features a built-in heat protection circuit is an intriguing feature. You need to include a heat sink in the circuit if you wish to use it at its maximum output of 5 W. If you don't, the internal thermal protection will prevent any harm to the device; instead, it will just lower output power when an excessive junction temperature is detected.

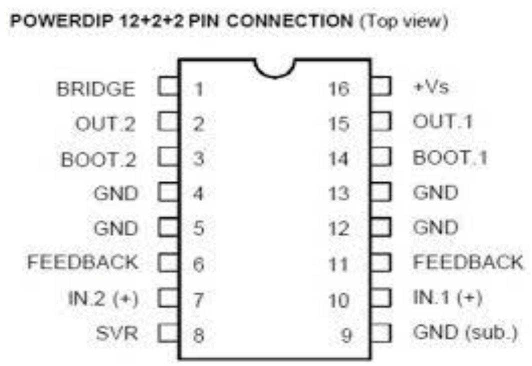


Fig 4.17: Pin Diagram of IC

A logarithmic dual taper potentiometer (10 or 20 K) can be used at the input stage to give the volume control function. The input side 0.22 F capacitors aid in reducing any noise brought on by fluctuating resistor contact. The output end's 0.15 F capacitors are there to maintain frequency. The usage of capacitors with different values could cause undesirable oscillations at the output. A suitable architecture of the circuit PCB is crucial since long wire connections and ground loops in the circuit may also result in oscillations. The circuit is constructed as illustrated below using a general-purpose prototyping circuit board measuring 5 cm by 9 cm. The circuit is housed in a 6 cm by 11 cm plastic shell, from which the speaker, stereo input terminals, and power supply connections are dragged out. A power supply with a range of 3 to 12 V can power the circuit.

4.6 Circuit Diagram

Fig. 4.20 depicts a circuit. In the experiment, it is employed. All equipment is also identified below.

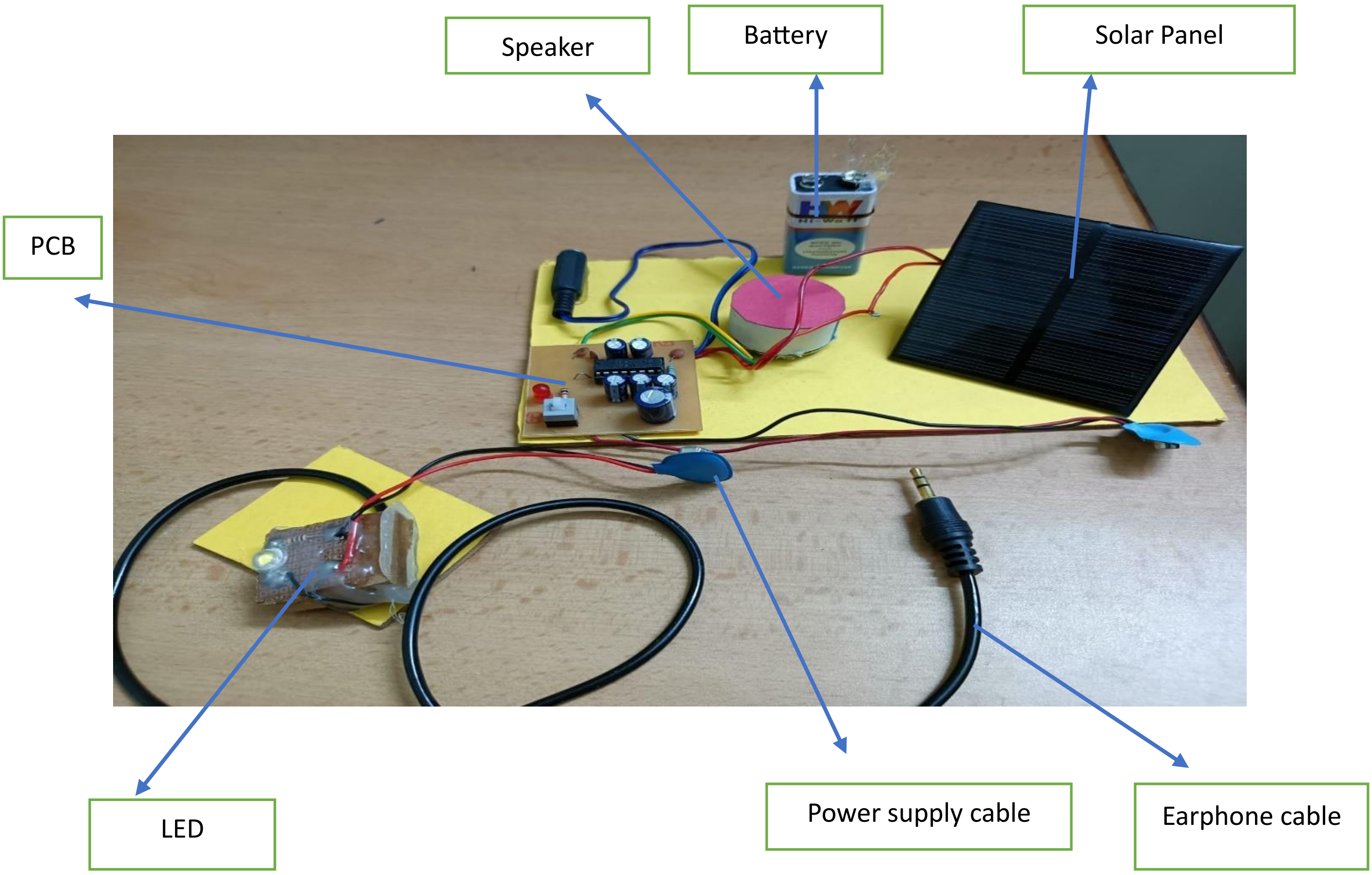


Fig 4.18: Circuit Diagram

Chapter Five: Result

Numerous issues and solutions are detected after studying various articles on Li-Fi technology. However, unable to find Li-Fi range solutions. So, it is found that the Li-Fi range is one of the major issues while studying it and continuing the research on Li-Fi. Mathematical computations and analysis are provided below.

5.1. Wireless communication system issues

Despite ongoing advancements in wireless communication technology (such as 4G and 5G), a catastrophe is predicted to occur because there are not enough Radio Frequency (RF) resources available. This bandwidth restriction makes it impossible to support the number of communication systems and the increasing demand for high data rates within the range of 300 kHz to 4 GHz. "Spectrum Crunch" is the term for that. High frequencies cut down on the amount of spectrum needed for data transmission, however this strategy is rarely recommended because it requires expensive, complicated equipment.

5.2. So how can the issue be resolved?

There are a variety of technologies that provide pertinent and useful solutions to this problem. One of them is the "Cognitive Radio". It is a novel class of wireless transceiver-based communication systems. It can migrate into the empty channels and begin transmitting data there after being able to perceptually distinguish between which communication channels are being used and which are not. An alternate method of data transport is lighting using visible light. It heavily relies on frequency. "Visible Light Communication" (VLC) is the name of this technique.

There are also many creative and efficient alternatives, such as Light Fidelity (Li-Fi) technology, which is based on VLC.

Visible light communication, an optical communication technique, uses visible light beams with frequencies between [400-800] THz as visual carriers for data transfer by radiance. It employs brief light pulses. It is invisible to the unaided eye. Any information transmission utilizing electromagnetic radiation from the visible light spectrum is included in this. The VLC standardization process is conducted inside the IEEE wireless personal area network working group. One of the advantages of VLC is the wide bandwidth provision, as depicted in Figure. Using the optical spectrum ensures a 10,000 times larger bandwidth than using RF frequencies, as seen by the comparison.

The purpose of this is to increase the range of Li-Fi technology. The idea is to use a concave mirror to widen the angle and increase the distance to increase the range of visible light. The properties of light, electromagnetic waves, mirrors, and lenses should all be familiar to us by this point. No techniques exist to increase the Li-Fi range. The gadget is implemented to use a concave mirror.Since it successfully reduces the number of LEDs while increasing their range. Numerous sources cited in the literature review chapter observed that the effective range of LEDs increases with LED intensity. As a result, concentrated on intensity and discovered some methods, including giving the LEDs additional voltage but both of these techniques shorten the life of the LED. Intensity can also be increased by using mirrors and lenses. Because mirrors are more readily available and cheaper than lenses.

There are many applications for mirrors, including the following: Mirrors can be used by strategically angling them such that LED light can bounce off of one mirror and onto another since mirrors reflect light off of objects. However, there are a few drawbacks to this approach, such as the inability to precisely predict the increased light intensity in the region and the challenge in determining the proper angle.

5.3. Spherical mirrors

Another way is to use spherical mirrors. which are

- Convex mirror.
- Concave mirror

1. Convex Mirror:

Convex mirrors never give any real image. The Fig. 5.1 shows that in each case, the image is

o located behind the convex mirror

o a virtual image

An upright image

o reduced in size

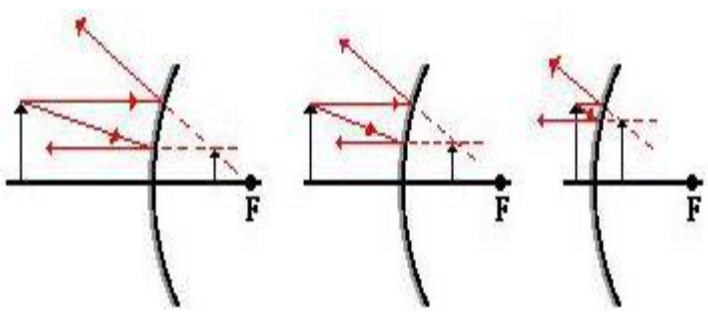


Fig 5.1. Image of Convex mirror

2. Concave Mirror:

The concave mirror gives a real and extended image when the object is located between the centre of curvature and the focus.

The illustrations above demonstrate how the picture is concave mirror.

o A real image.

o A downright image.

o Increased in size.

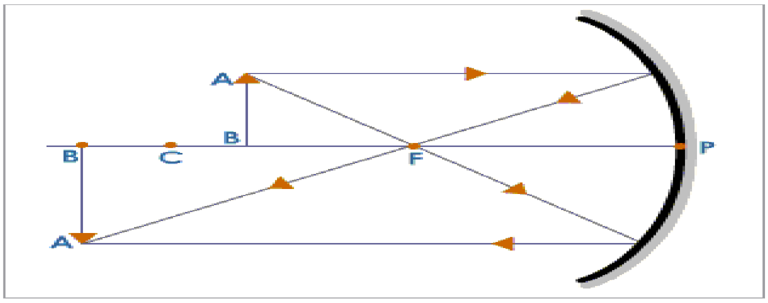


Fig 5.2. Image of Concave mirror

Electromagnetic wave: Light

The intensity of light is given by a pointing vector. It defines the power output per unit area (w/m2) of the electromagnetic wave. Simply it is the changing rate of energy per unit area of any electromagnetic wave.

Luminous Flux and Luminous Intensity:

Luminous flux is the measure of the perceived power of visible light. Unit is lumens (lm). Simply put, the quantity informs us of the strength of a particular light wave.

$683\text{lm} = 1\text{watt of power carried by the light of wavelength } 555\text{nm}.$

Luminous intensity is defined as the luminous flux per solid angle. Luminous intensity expresses the directionality of the energy emitted by the light.
Solid angle: This is defined as a two-dimensional angle defined using units known as steadies.

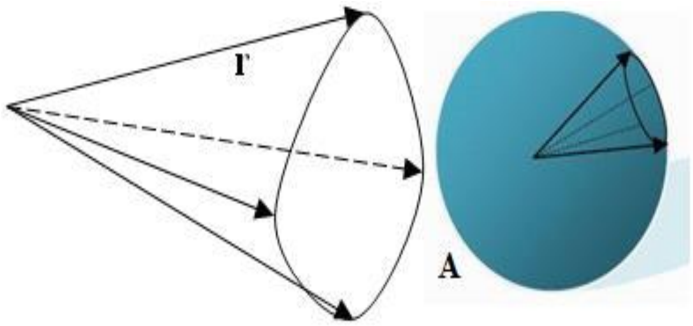


Fig 5.3. Solid angle and solid angle in a sphere

Solid angle= Area/ *r*2
In Fig 5.3, **A** is the surface area on a sphere with radio **r**
Luminous intensity can be defined as luminous flux/solid angle.

5..4. Light Projection:

Visible light is known to propagate as a cone and as the distance widens, the intensity diminishes. Now imagine a light source without a mirror in front of it. the origin. Because of this, let's think it as a cone.

Now there are 2 things to be concerned,

- What happens if the angle is expended
- How the angle can be expended

As seen by the solid angle definition,

Angle=Area/ $r2$

or, $Area = angle/r2$

Therefore, from the equation that the area increases as the angle decreases. This suggests that more area may be covered if the angle can be raised. I advise using a concave mirror to enlarge the view. As was previously mentioned, the image seems inverted but still real and larger than usual when an object is placed in between the centre of curvature and the main focus. The LED will therefore offer an expanded true picture of the LED if it is placed between the mirror's main focus and its centre of curvature. Because it has a greater light output intensity and a wider angle of light projection, a bigger LED immediately increases its range. In accordance with the typical arrangement of home lighting, Li-Fi may be mounted on the ceiling and connected to a Li-Fi router. The way light is projected makes it appear as though a cone will protrude from the ceiling. Here recommends a different approach to set up the router-connected lamp. It is necessary to arrange the lights vertically in a typical rectangular room so that fewer LEDs can produce the same quantity of light throughout the entire area.

LED counts fall if they are configured in an optimistic manner. Now obtain a real increased image and a greater angle than the actual LED thanks to the concave mirror's capabilities, therefore by employing the concave mirror, will obtain a greater angle. As mentioned before

$$Area = angle \times r2$$

That means the greater the angle is greater the area will be.

Assume a concave mirror with a 10 cm focal length. So, f=10.

So that the distance of the centre of curvature

$$C = 2f = 2 \times 10 = 20cm$$

According to the properties of the concave mirrors, to get a real and bigger image, LED has to be set in between the centre of curvature and the main focus, Let the distance of LED be placed u = 18cm. LED size h = 9cm.So if the image size is h' and the distance of the image is v, then from magnification it is known m= - v/u,

Now, to find the distance v,

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

Or, $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$

Or, $\frac{1}{v} = \frac{1}{10} - \frac{1}{18}$

Or, $\frac{1}{v} = 0.0444$

V= 22.50 ………………………………. (5.1)

So, the distance of the image is 22.5cm which is 4.5cm ahead of the LED.

Now, inserting (1)'s values for v, u, and h,

$$\frac{h'}{h} = -\frac{v}{u}$$

Or, $h' = -\frac{vh}{u}$

Or, h' = $-\frac{22.5 \times 9}{18}$

Or, h' = - 11.25 ……………………………….(5.2)

Here the − (minus) sign represents that the image is inverted.

So, the Image height is 11.30cm which is 2.30cm bigger than the real LED.

As it is known a bigger LED can project light with a greater angle than the smaller one. Also, a bigger LEDhas more intensity than a smaller one. So, the increased image of LED will give more angle and intensity.

As it is known from the characteristics of light and light projection, it is a cone shape inside a sphere of radius R which is also the side of the cone.

If the height of the cone is **h** and the radius of the base is **r**, then the volume of cone

$$V = \frac{\pi r^2 h}{3} \qquad \text{..............................} \ (5.3)$$

The base area of a cone is a 2D circle of radius r. If the angle increases, so does the radius of the base.

Let's assume 2 cones with the same height butdifferent angles, that means the different base radius

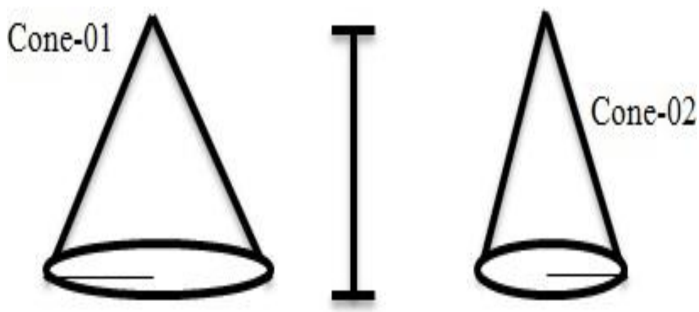


Fig 5.4. Cone

For cone 01, let's assume, Height h = 14cm

Base radius r = 5cm

$$A = \pi r^2$$

$$\Rightarrow A = 3.1416 \times 5^2$$

$$\Rightarrow A = 78.84 cm^2$$

And volume,

$$V = \frac{\pi r^2 h}{3}$$

$$V = \frac{3.141 \times 5^2 \times 14}{3}$$

Or, V = 366.50 cm^3 ………………………. (5.4)

Again, for cone 02, as the height remains the same, so Height h = 14cm

Base radius r = 2.5cm

So, area $A = \pi r^2$

$$\Rightarrow A = 3.1416 \times 2.5^2$$

$$\Rightarrow A = 19.635 cm^2$$

$$V = \frac{\pi r^2 h}{3}$$

$$V = \frac{3.141 \times 2.5^2 \times 14}{3}$$

Or, V = 91.60 cm^3 ……………………….(5.5)

From this calculation it is seen if the angle is increased, the area as well as the volume both also increases. That means, if mirror is used to get a greater angle, then when the angle increases, it covers more area or in 3D it covers more space of a room. It automatically increases the range of Li-Fi.

5.5. Calculation result and Analysis:

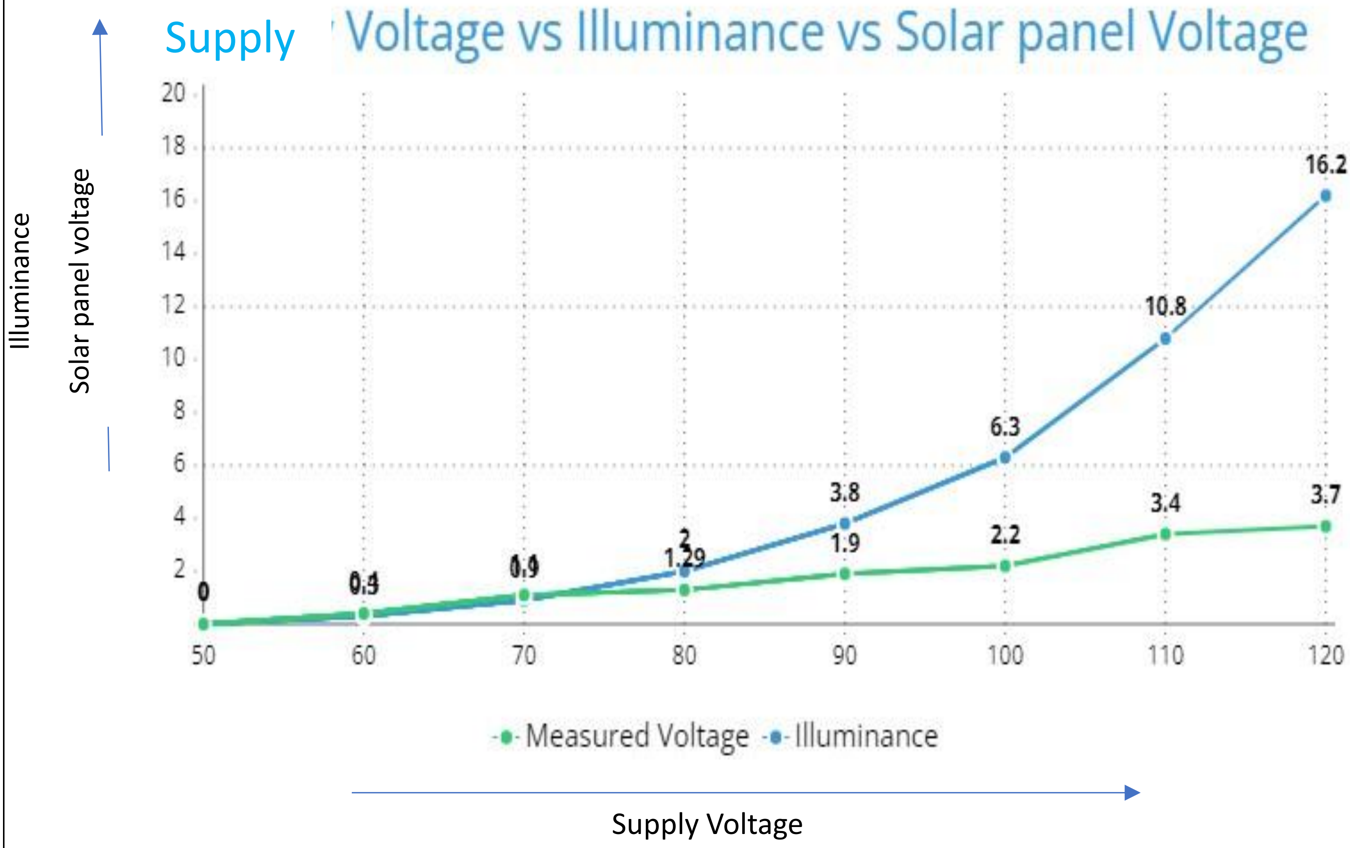
An LED lamp, a solar panel, and a music system make up the system as it is described here. All of the data from the Internet is now piped into a lamp driver. The data is passed from the lamp driver to an LED bulb, which then sends the encoded information to solar cells. LED lamp transmits encoded data, which solar cell decodes. A abrupt change in the light signal's brightness is used to encrypt the data.

The operation of this system will be similar to that of earlier LI-FI technology, which made use of photodiodes; however, here, solar panels will serve as broadband receivers. The encoded data will be fed from the lamp driver to the LED lamp, which will then pass the data to the solar cells in digital form. The benefit of this arrangement is that solar cells are self-sufficient in that they can both transmit and capture energy. Incoming solar rays will be converted by solar cells into electricity, allowing for continuous energy capture and data transmission.

Illuminance and voltage across the solar panel are measured in this case using a varied source. One graph was created once the readings were taken.

Table 2: Supply Voltage vs Illuminance vs Solar panel Voltage

Supply Voltage(V)	50	60	70	80	90	100	110	120
Illuminance	0	0.3	0.9	2	3.8	6.3	10.6	16.2
Measured Voltage	0	0.4	1.1	1.29	1.9	2.2	3.3	3.7

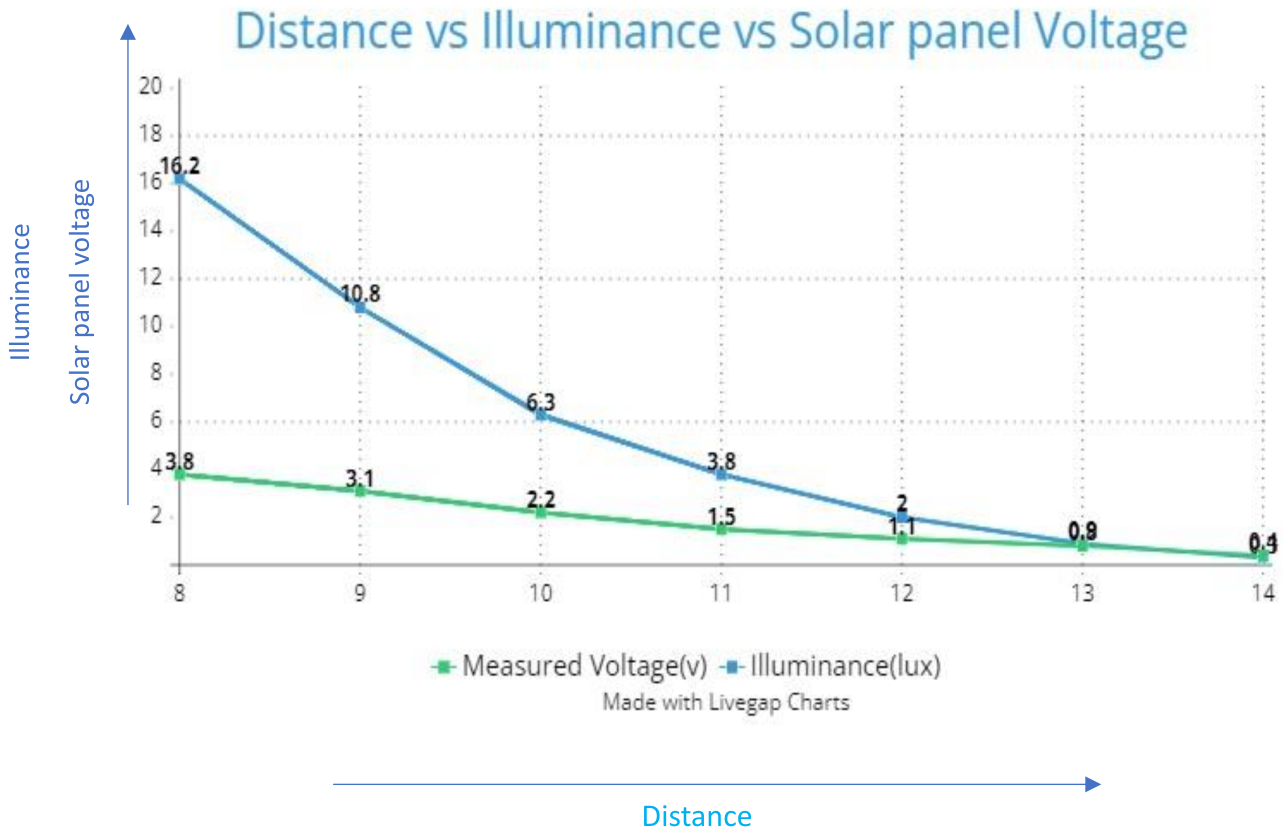


Li-Fi coverage area is very limited. But Wi-Fi coverage area is large. Now measure the illuminance and solar panel voltage by changing the distance between the LED light and the solar panel.

For this measurement one voltmeter, one lux meter and one scale is used to measure the distance between LED and solar panel. Below I attached the results which got from this measurement. Also, one graph is plotted between Distance and Illuminance, Distance and Solar panel Voltage.

Table 3: Distance vs Illuminance vs Solar panel Voltage

Distance(cm)	8	9	10	11	12	13	14
Illuminance(lux)	16.2	10.8	6.3	3.8	2	0.9	0.3
Measured Voltage(v)	3.8	3.1	2.2	1.5	1.1	0.8	0.4



From the graph above, it is clear that the Li-Fi coverage area is very limited. And it varied with the distance between the light and the solar panel.

The Li-Fi range must be increased because it is now confined and because it is expected to become a widely utilized technology shortly. The arrangement of the concave mirror and LEDs that recommendation will increase the range of each LED separately. Clever light arrangement increases the LED's range and results in better light coverage. Concave mirrors provide images with a wider angle and field of view, which increases the picture created in front of the LED and the light's horizontal coverage area.

Chapter Six: CONCLUSION & FUTURE WORK

6.1 CONCLUSION:

Li-Fi has to have an increase in range because it is now limited and considering it is going to become a widely used technology. It has been suggested that using a concave mirror and strategically arranging the LEDs will extend their individual range. Better light coverage is produced by clever light positioning, which extends the LED's range. Concave mirrors provide images with a broader field of view and a greater angle, which expands the light's horizontal coverage area and the picture formed in front of the LED. Although it may not be feasible in modern times to extend the range from one room to another, the strategy will enable to cover a large space.

6.2 FUTURE WORK:

- The light used by current Li-Fi technology cannot flow through any solid object that blocks light or outside of any room. Future research can take this restriction into account and come up with a fix for it. Additionally, the idea of extending the range of light can be demonstrated in practice. It is possible to test whether or not the LED's inverted picture produces corrupted data. The intensity might be increased by using a lens in addition to a mirror rather than just mirrors alone.

- The system defined here, consist an LED lamp, and solar panel only, if solar concentrator is used, all the data from the Internet is streamed into the lamp driver. The lamp driver will pass the data into a led lamp, which will further send the encoded data to solar cells. Solar cell decodes encoded data transmitted by LED lamp. The data is encoded with a sudden change of the brightness of the light signal. The solar concentrator is placed before the solar panel, which will increase the intensity of solar cells rapidly so that the data can be transmitted for a longer duration of time.

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