PROJECT - II

Report on

Underwater Wireless Communication Using Li-Fi

Submitted in partial fulfillment of the requirements

of the degree of

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(Electronics and Telecommunication Engineering)

by

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Declaration

We wish to state that work embodied in this dissertation entitled "**Underwater Wireless Communication Using Li-F**"has been carried out under the guidance of "Mrs. Vishakha Gaikwad" at Department of Electronics and Telecommunication Engineering, Ramrao Adik Institute of Technology during 2022-2023.

We declare that the work being presented forms our own contribution and has not been submitted for any other Degree or Diploma of any University/Institute. Wherever references have been made to previous works of others, it has been clearly indicated. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

You've probably experienced dissatisfaction with the poor speeds that experience while using wireless internet when multiple devices are connected to the network, whether you're using it at a coffee shop, stealing it from the person next door, or fighting for bandwidth at a conference. It will become harder to grab onto a dependable signal as more people and their numerous devices use wireless internet due to congested airwaves. However, radio waves are not the only one that can carry our data. What if we could browse the internet using different waves? Dr. Harald Haas, a German scientist, has developed a remedy he calls "Data Through Illumination"- transferring data through an LED light bulb whose intensity changes quicker than the human eye can keep up. It's the same concept as infrared remote controllers, but much more powerful.He imagines a time where data is sent through a room's light to laptops, smartphones, and tablets. If you can't see the light, you can't access the data, thus security would be a breeze. Visible light communication, or Li-Fi, is a technology created by a group of researchers at the University of Edinburgh, including Dr. Gordon Povey, Prof. Harald Haas, and Dr. Mostafa Afgani.

In most cases, a network is used to transmit data for a variety of uses, including underwater communication and environmental monitoring, but because of the difficulties with setting up and maintaining the conventional wired network, wireless connectivity is very important. The suggested system is an underwater communication system that makes use of Li Fi technology. Li-Fi, also known as Light Fidelity, refers to Visible Light Communication (VLC) systems that use light-emitting diodes as a medium to high-speed communication medium. In the LI-FI system, photo sensors serve as the receiver while headlights, such as LEDs, act as the transmitter. By adjusting how quickly the LEDs turn on and off to produce different strings of 1s and 0s, it is feasible to encode data in the light. The goal of this project is to use the VLC technology to transmit text, audio, and images underwater.

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Chapter 1

Introduction

Air is a more efficient medium for wireless transmission than water. The use of current technology and the deployment of cutting-edge technologies make it feasible to communicate underwater successfully. Factors such as salinity, turbidity, pressure, temperature, the quantity of light entering the water surface, and their influence on waves all have an impact on underwater communication.The use of Li-Fi technology improves the Navy's and submarines' communication capabilities. This technology is suited for underwater communication due to its features including high-speed data transfer, excellent security, and energy-efficient behaviour.

Many applications, including deep-sea resource exploration, marine ecosystem monitoring, underwater rescue, and tactical surveillance, have seen an increase in interest in underwater operations. For the purposes described, remotely controlled vehicles (ROVs) and autonomous underwater vehicles (AUVs) are employed to cover a considerably greater observation area. Traditionally, the underwater vehicle connects to offshore or longshore stations by acoustic communication or cable transmission. Although it can allow long-distance transmission, acoustic communication has poor bandwidth, significant latency, and issues with Doppler spread and time-varying multipath propagation. The poor bandwidth and significant latency are caused by the low carrier frequency (kHz) and sluggish transmission speed (1.5 km/s) respectively.

To deliver comprehensive and timely information, wireless real-time video transmissions are preferred.The data rate of the transmission of surveillance video will, however, be far higher than the limit of acoustic communication. Cable-based communication allows for the conveyance of videos back to the control station, as well as the provision of control and electric power to ROVs. The umbilical cable, however, unavoidably restricts the mobility of ROVs, limiting their range of motion, agility, and freedom from cable entanglement with other ROVs. Undersea cables may also result in biological and environmental problems, such as marine life being suffocated by active or abandoned cables.

Due to water's low absorption of visible light, particularly in the blue to green spectrum, optical wireless communication (OWC) is a promising contender for short and medium range communication. OWC systems have definite advantages over conventional technologies that rely on acoustic signal, wireline communication, and radio frequency (RF) signal, including significantly higher bandwidth, comparatively better flexibility and mild water loss, respectively. Recent laboratory and field tests demonstrating high-speed (¿10 Gbps) and long-range (¿100 m) underwater communication applications have proven OWC's enormous potential.

1.1 Main section

Currently, there is a lot of interest in the Li-fi concept, not the least of which is that it provides a true and very effective replacement for RF. As more people and their newer devices use wireless internet, the airways are getting jammed and there aren't enough free bandwidths for every device, which makes it harder and harder to receive a dependable, high-speed signal. It is highly attractive to have the chance to utilise a whole other region of the electromagnetic spectrum. Other benefits of Li-Fi over Wi-Fi include its safety for usage in thermal and nuclear power plants, which are prohibited from using Wi-Fi. Only the visible light spectrum may be used to communicate safely in such stations because RF waves might be dangerous and cause accidents. In addition to unfavourable areas, Li-fi can be used anywhere Wi-Fi is permitted.

Li-fi is available anywhere there is light, therefore establishing hotspots exclusively in specific locations is no longer necessary. Li-Fi and Wi-Fi performance are evaluated based on four factors: capacity, efficiency, availability, and security. Both Li-Fi and Wi-Fi use the electromagnetic spectrum to transmit data, while Li-Fi uses visible light communication at speeds of up to 100Mb/s whereas Wi-Fi uses radio waves. Li-Fi can be conceptualised as a light-based version of Wi-Fi. In other words, it transmits information using light rather than radio waves. And Li-Fi would use transceiver-equipped LED lamps that can broadcast and receive information in place of Wi-Fi modems. Because simple light bulbs are used, there can theoretically be an unlimited number of entry points. This method makes use of an electromagnetic spectrum region that is currently underutilised. The range of visible light. Since light has existed for millions and millions of years, it has not significantly harmed our way of life. In addition, there is 10,000 times more spectrum space available, which doubles to 10,000 times more infrastructure availability solely based on the number of bulbs in use globally. It is possible to encode data in light by altering the pace at which the LEDs blink on and off, resulting in varied strings of 1s and 0s. The output seems constant because the LED intensity is changing so quickly that human eyes cannot notice it. More advanced methods could significantly boost VLC data rates.

Teams from the Universities of Oxford and Edinburgh are working on simultaneous data transmission utilising arrays of LEDs, with each LED transmitting a different data stream. Other teams are modifying the light's frequency by mixing red, green, and blue LEDs, with each frequency encoding a distinct data channel. The technology, known as Li-Fi, has already clocked blisteringly fast speeds in the lab. Using a regular white-light LED, scientists from the Heinrich Hertz Institute in Berlin, Germany, have achieved data speeds of over 500 megabytes per second.

1.2 Introduction to Li-Fi

Our lives are run by WiFi. In fact, according to an online study conducted by Opinium Research for Direct Line, it is the number one thing that their respondents couldn't live without. However, you've probably encountered issues with internet connectivity at some point, regardless of where you are in the world. Here comes Li-Fi, a wireless technology that has the potential to be up to 100 times quicker than WiFi.

Li-Fi (sometimes spelled LiFi) is a wireless communication technology that uses light to send data and position information between devices. Harald Haas coined the term during a 2011 TEDGlobal talk in Edinburgh.

Li-Fi is a light-based communication technology that can send data quickly over the visible, ultraviolet, and infrared spectrums. Currently, the only lights that can be utilised to transmit data in visible light are LED lamps.

Figure 1.1: Li-Fi Demonstration

How does Li-Fi Work?

Li-Fi is a Visible Light Connections system that transmits extremely fast wireless internet communications. The technology causes an LED light bulb to emit undetectable pulses of light, and data can move to and from receivers inside those pulses. The receivers then gather data and translate the delivered information. This is essentially comparable to deciphering Morse code, but it happens millions of times each second, which is significantly faster. LiFi transmission rates can exceed 100 Gbps, which is 14 times faster than WiGig, the world's fastest WiFi.

1.2.1 A Brief History of Li-Fi

Figure 1.2: Li-Fi Logo

The Li-Fi technology is credited to Professor Harald Haas, Chair of Mobile Communications at the University of Edinburgh. When he introduced this technology in his 2011 TED Global lecture and assisted in the founding of a firm to market it, he developed the acronym Li-Fi, which stands for light fidelity. According to this TED talk, light fidelity can be used in traffic control systems that use automobile headlights, as well as in chemical production factories where radio frequency is too risky and could produce antenna sparks. Li-Fi will enable internet access in locations that RF can't!

Haas co-founded pureLiFi, formerly known as pureVLC, a company that manufactures equipment for integrating LiFi products with current LED lighting systems.

The company unveiled the first commercially accessible Li-Fi technology in September 2013. The Li-1st introduced ground-breaking wireless communication technology and became the first commercial Li-Fi technology in history. The Li-Fi product called Li-Flame, which was introduced in February 2015, made the claim to be the first to provide mobile wireless communications. After being installed in several places, including Microsoft's Paris headquarters, pureLiFi and Lucibel, a French lighting business, introduced the first industrialised Li-Fi solution in the world a year later.

The LiFi-XC system was introduced in October 2017. This system is certified plug-and-play, compatible with USB devices, and compact enough to fit into your upcoming laptop, tablet, or smart appliance. And just last June, pureLiFi created a channel programme for IT resellers to add Li-Fi to their product line and provided starter kits for Li-Fi to academic researchers.

What Does Li-Fi Mean For Everyone?

Using LiFi is very similar to using WiFi, except that it would be much faster.

At the city level, street lamps could offer information to pedestrians, automobiles, and any other infrastructure elements that might require it. Even though the technology is now only being used in industrial applications, smart homes will soon benefit from it. Future home and building automation is expected to depend on LiFi because it is quick and secure.

Why is Li-Fi Important?

Consumption of wireless data increases by 60 percent every year. That means that the radio-frequency space is slowly becoming saturated which can lead to a phenomenon called a spectrum crunch. Spectrum crunch refers to the potential lack of sufficient wireless frequency spectrum needed to support a growing number of consumer devices, along with various government and private sector uses of radio frequencies within a broad spectrum allocated for different types of wireless communications. This poses challenges with wireless networks because it would negatively affect the speed of our internet usage. Eventually, WiFi will not be able to keep up with the demand for data.

What is so good about Li-Fi?

LiFi has unquestionable advantages due to the characteristics of light. It offers a highly wide and uncontrolled spectrum, as was already indicated, which can be used to produce very high data rates, particularly by transferring data over parallel wavelengths. Since light beams cannot pass through barriers and can be easily reconfigured by optical systems, LiFi offers greater security than Radio Frequency (RF) technologies and lowers the possibility of accidental eavesdropping.

LiFi is an intriguing alternative to RF because light does not interact with it, and it may be used to complement and offload the RF spectrum as well as to provide wireless access in areas where RF is not allowed due to electromagnetic interference or other safety concerns. One of the most cutting-edge LiFi concepts is to make use of the existing LED lighting infrastructure to enable network connectivity, as more than 70 percent of traffic really happens indoors. By doing so, the increasing demand for connectivity may be met with essentially no additional energy expenditure and without the need to build a new, specialised infrastructure, making LiFi a 'green' solution.

Does Li-Fi need a line of side?

The line of sight is the imaginary line drawn between an observer and the target. Line of sight in communications refers to both the straight path between a transmitter and a receiver and any potential obstacles in that path. Line-of-Sight communication is the only way to use LiFi efficiently. Miscommunication can occur if either the receiver or the transmitter shifts from its desired position. However, Jean-Paul Linnartz, a professor at the Eindhoven University of Technology and a Technical Leader ELIoT Signify Researcher, presented the LiFi MIMO strategy a few months ago. The use of a LiFi Multiple Input Multiple Output (MIMO) technique can help to reduce signal loss if the line of sight is interrupted.

Is Li-Fi faster than Wifi?

The answer is YES. At the Oxford University research labs, the fastest LiFi transmission speed ever measured was approximately 224 Gbps. The researchers transmitted six wavelengths at 37.4 Gbps apiece, for a total bandwidth of 224 Gbps, with a 60-degree field of view. Only three wavelengths with a combined bandwidth of 112 Gbps were conveyed when the field of view was reduced to 36 degrees.

Who is the father of Li-Fi?

Professor Harald Haas is widely regarded as the Father of LiFi in the LiFi community. In 2011, he coined the term Light Fidelity (LiFi) and gave a popular TEDTalk presentation on LiFi technology. Then, in 2021, He co-founded pureVLC, currently known as pureLiFi, with Dr. Mostafa Afgani.

The Future of Li-Fi

Currently, Li-Fi cannot completely replace WiFi as a connectivity source, but some Li-Fi businesses are making great efforts to create Li-Fi products and promote Li-Fi as the main wireless technology. Every day, there is a greater need for quick internet connectivity, and light fidelity might be the solution to fill that need.

Li-Fi is regarded as the internet's technological future. We are all excited about the bright future that lies ahead.

1.2.2 Li-Fi vs Wi-Fi

Feature	LiFi	WiFi
Full form	Light Fidelity	Wireless Fidelity
Operation	LiFi transmits data using light with the help of LED bulbs.	WiFi transmits data using radio waves with the help of WiFi router.
Interference	Do not have any intereference issues similar to radio frequency waves.	Will have intereference issues from nearby access points(routers)
Technology	Present IrDA compliant devices	WLAN 802.11a/b/g/n/ac/ad standard compliant devices
Applications	Used in airlines, undersea explorations, operation theaters in the hospitals, office and home premises for data transfer and internet browsing	Used for internet browsing with the help of wifi kiosks or wifi hotspots
Merits(advantages)	Interference is less, can pass through salty sea water, works in densy region	Interference is more, can not pass through sea water, works in less densy region
Privacy	In LiFi, light is blocked by the walls and hence will provide more secure data transfer	In WiFi, RF signal can not be blocked by the walls and hence need to employ techniques to achieve secure data transfer.
Data transfer speed	About 1 Gbps	WLAN-11n offers 150Mbps, About 1-2 Gbps can be achieved using WiGig/Giga-IR
Frequency of operation	10 thousand times frequency spectrum of the radio	2.4GHz, 4.9GHz and 5GHz
Data density	Works in high dense environment	Works in less dense environment due to interference related issues
Coverage distance	About 10 meters	About 32 meters (WLAN 802.11b/11g), vary based on transmit power and antenna type
System components	Lamp driver, LED bulb(lamp) and photo detector will make up complete LiFi system.	requires routers to be installed, subscriber devices(laptops,PDAs,desktops) are referred as stations

Figure 1.3: Li-Fi Vs Wi-Fi

Chapter 2

Literature Survey

2.1 Underwater Communication

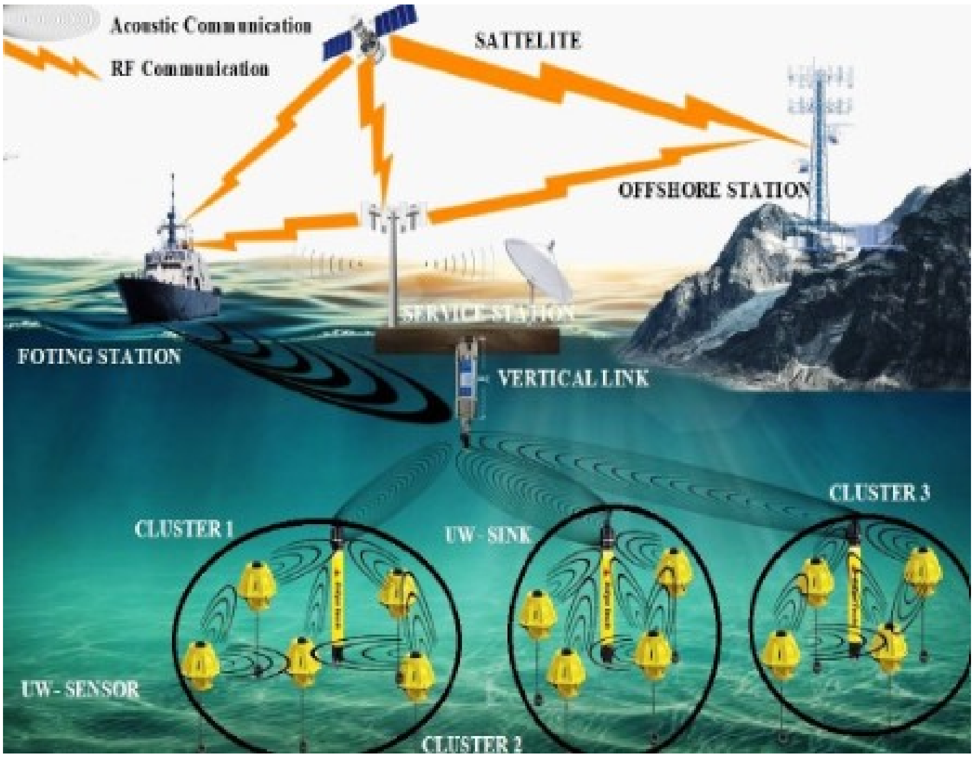

Figure 2.1: Acoustic and RF signal propagation between underwater sensor, nodes and terrestrial offshore station

The first interaction with underwater communication occurred during World War II; before to that, aquatic life was researched utilising echo ranging, commonly known as the Fessenden Oscillator. Leonardo Da Vinci invented the first method of underwater communication in the year 1490. This method entailed putting a tube into the water and listening to sound while utilising human hearing to identify vessels. In order to counter the growing threat of submarine warfare, this strategy was created during World War I. In 1918, a functioning passive SONAR system was used and gained popular. Focusing on the maritime environment and the data transmission method utilised in the undiscovered water medium, the research of underwater communication techniques

Three approaches have been developed to begin data/information communication in water. The earliest technology ever developed employed sound waves to transmit information or data that was previously used in submarine systems to determine how far away other devices were from the ocean floor. Later, as technology improved, underwater imaging began to utilise electromagnetic waves. The advanced submarine systems also employ the same technology. Due to improvements in 4G, 5G, data store and forward, cloud, and fog computing services, high and heterogeneous bandwidth demand, and reliable data transfer have increased during the previous decade. The usage of optical fibre cable-based backbone optical networks is required to meet the urgent demand for large bandwidth capacity. Oil and gas industries and plant monitoring can use the complex system of sensor networks and subsea fibercable networks. These methods assisted in the movement of critical commodities as well as data underwater.

2.2 Existing Systems for Underwater Communication

In the frequency ranges at which animal sensory systems operate the oceans are significantly more transparent to sounds than to light. As a result, it is not unexpected that both human and animal underwater communication systems rely on sound transmission.

Leonardo da Vinci is considered as the inventor of underwater communication because he realised that it was possible to listen through a long, submerged tube to hear approaching ships. However, World War II saw the beginning of the modernization of underwater communication, which was done for military purposes. Successful underwater communications can be achieved in one of two ways: wirelessly via acoustic, laser, or radio waves or by wires (submarine cables or tethers).

A typical underwater communications cable is comprised of a collection of wires that are stacked on the ocean's or sea's bottom and used to transmit various forms of data between users who are distant from huge bodies of water, most frequently to link continents and nearby islands. The first generation of submarine communication cables carried telegraphy traffic; subsequent generations were created for telephone traffic and data communications. All current undersea cables convey digital payloads, including telephone, Internet, and private data traffic, through optical fibres. Due to their high reliability, undersea cables carry the majority of subsea transcontinental data traffic. In the case of a cable break, this type of cable is constructed with numerous pathways. On the other side, geomagnetic field turbulences can disrupt satellite links that are located abroad. Due to the high expense of these submarine communication cables that connect continents and transmit terabits of data per second, several countries view them as being essential to their economy and have established protection zones that limit activities that could potentially harm the cables. The only continent where an underwater communication cable hasn't yet been laid is Antarctica. All communication, including voice, video, and email, must go through the still-not-very-reliable satellite in order to reach the rest of the globe. However, because of the severe weather on this continent, the expenses of installing submarine communication lines are very high. The first underwater telephone, intended to communicate with submarines at distances of many kilometres, was created in the United States. Thanks to VLSI technology, a new generation of underwater communication systems has emerged. Once tiny DSPs with low power requirements became accessible, advanced signal and data compression techniques could be deployed for the first time at the submerged end of an underwater communication system.

2.2.1 Underwater Acoustic Communication (UAC)

Marine organisms have employed underwater sound communication strategies for millions of years. In the year 1490, Leonardo Da Vinci used underwater acoustics as a science to find the vessels. He wrote " "If you cause your ship to stop and place the head of a long tube in the water, and place another end outer extremity to your ear, you will hear ships at a great distance from you." In 1877.

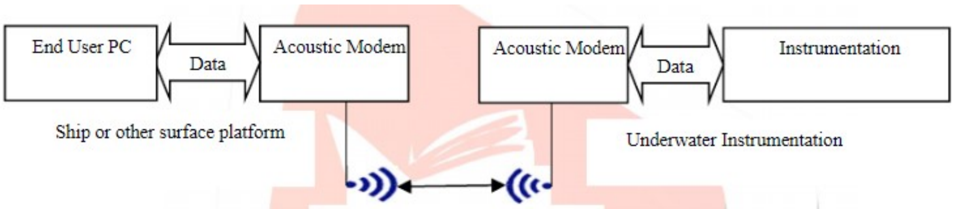

Figure 2.2: Acoustic Transducer

With the help of Figure, we can comprehend the operation of an acoustic modem, which is used to send data underwater in the same way that telephone modems transmit data via wired copper/optical cable lines. Digital information and data are converted into distinctive underwater sound waves by the acoustic modem. Here, the acoustic transducer takes in, transforms, and uses the sound waves for analysis. In this technology, acoustic signal transducers are mostly utilised. With the use of another acoustic modem, these impulses are transformed back into digital data. This design can be utilised for autonomous underwater vehicles, diver communication systems, and underwater monitoring.

Underwater acoustic communication systems operate by converting electrical signals into acoustic signals using transducers at both the transmitting and receiving ends of the communication chain. Depending on the purpose, underwater communication may be wireless or wired. The most effective way will depend on the specifics of the setting and the level of communication that needs to be established. Both of these methods have advantages and disadvantages. When communication must occur at depths where wire communication would be impractical or impossible, wireless communication is preferable.

Undersea communication still faces difficulties related to multi-path propagation, small bandwidth, serious signal attenuation over vast distances, and time variations of the channel, despite the significant financial investments made in this field and the intensive efforts made in it. In this instance, the biggest obstacle to underwater communication is the water itself. The clarity of underwater acoustic signals depends on several factors, including the kind of aquatic environment (fresh or salt water), impurity concentration, pressure, water composition, and temperature.

2.2.2 Underwater Electromagnetic Communication (UEC)

Due to water's high electrical conductivity and high permittivity, electromagnetic propagation through it differs significantly from that through air. Air attenuation of plane waves is low, and it rises quickly with frequency. Water has the highest permittivity of any medium, with a relative permittivity of 80, and this has a considerable impact on the angle of refraction at the air/water contact. Seawater conductivity is typically around 4S/m, whereas nominally 'fresh' water conductivity is highly variable but typically in the mS/m range. Despite having a similar permittivity as seawater, fresh water has substantially lower attenuation of em signals. Since the relative permeability is close to 1, the magnetic field component is not much impacted. Conduction's impact on the electric field component is a major cause of loss. Conduction results in a significant attenuation of electromagnetic propagating waves because propagating waves continuously cycle energy between the electric and magnetic fields.

Radio frequency (RF) spectrum electromagnetic waves are used in UEC. The transmitter in this approach emits electromagnetic waves, which are created by the acceleration of an electric charge and spread by the periodic variation of intensities of, often perpendicular, electric and magnetic fields. It has been noted that RF waves are significantly attenuated by sea water and that their attenuation rises with frequency. Recognizing the UEC's limitations, RF was used to create a rapid wireless transmission.

Heat and depth have little impact on RF waves. Attenuation of electromagnetic waves in water is a major challenge due to absorption and scattering. Seawater has a large loss and behaves very differently from typical water in terms of electromagnetic wave behaviour. In water, electromagnetic waves have a strong frequency deflection and are inversely proportional to frequency squared. Low-frequency, very-low-frequency, and extremely-low-frequency bands are especially useful for submarine communications since they can communicate through hundreds of metres of ocean.

Electromagnetic propagation is more than a hundred times faster than sound propagation above 10kHz. This has significant benefits for command latency and networking protocols, which need the interchange of several signals. Doppler shift is substantially smaller for electromagnetic signals since it is inversely proportional to propagation velocity. The impact of the air-water interaction is another crucial factor to take into account. An electromagnetic signal overcomes the air-to-water barrier and seems to radiate from a patch of water just above the transmitter due to propagation losses and the refraction angle. The high permittivity creates a wide refraction angle, which launches a signal that is practically parallel to the water's surface. Without the need of surface repeater buoys, this effect facilitates communication between shallow submerged stations and from submerged stations to land.

2.2.3 Underwater Optical Communication (UOC)

Due to the UAC and UEC's limits and the enormous bandwidth demand of the Internet caused by the recent surge in data usage, we had to modernise our current systems. The optical fibre cables we currently use as the fastest and most effective data transfer medium for on-the-ground and underwater wired connection. The idea for UOC was first put forth in 1990. The application of UOC technology has grown dramatically over the past three decades. To lessen the aiming requirements of UOC devices, several researchers use Photomultiplier Tubes (PMTs) as UOC receivers. The PMTs have big lenses with a wide field of view (i.e., a range of 10 to 500 mm)

The optical front end of the receiver can now vary FOV based on the angle of beam arrival thanks to the usage of electronic switches in UOC systems. Due to their monochromatic behaviour, high intensity, and low dispersion qualities, lasers are increasingly being used for this type of communication. All LED-based UOWC systems produce Mbps data rates in pure sea water, where transmission distance is limited by the radiation angle and light intensity distribution. Consequently, laser diode-based UOWC systems are created to offer greater data speeds and longer transmission distances.

All LED-based UOWC systems produce Mbps data rates in pure sea water, where transmission distance is limited by the radiation angle and light intensity distribution. Consequently, laser diode-based UOWC systems are created to offer greater data speeds and longer transmission distances.

2.3 Limitations of Underwater Communication System

One important factor to consider while evaluating the performance of the chosen technology is 'transmission loss'. Every piece of machinery causes some loss. These losses could occur while the data is being transmitted. Non-environmental factors have an influence on transmission loss. These elements include transmitter and receiver depth, transmitter and receiver frequency, and transmission range. As a result, the transmission distance, receiver depth, and transmission range are all implicitly indexed by the theoretical process that controls transmission loss. The transmission loss should be zero or as little as possible when selecting or using any technique.

Attenuation is caused by acoustic energy absorption, which converts to heat, scattering, refraction reverberation phenomena, and dispersion. The attenuation of acoustic waves is inversely related to the frequency of the waves and the depth of the water medium. A more accurate UOWC channel model should take into account actual environmental factors in addition to attenuation, such as ocean turbulence, ambient light, and air bubbles.

Cable-based communication allows for the transport of videos back to the control station, as well as the provision of control and electric power to ROVs. The umbilical cable, however, intrinsically restricts the mobility of ROVs, limiting their range of motion, agility, and freedom from cable entanglement with other ROVs. Undersea cables may also result in biological and environmental problems, such as marine life being suffocated by active or abandoned cables.

Acoustic communication in the underwater environment is a difficult phenomenon because many environmental conditions influence acoustic communication. Long propagation delays, external noise, path loss, Doppler spread, and multipath impact are some of these variable elements. The underwater environment has a lot of influence on acoustic channel. Additionally, they produce bandwidth dependence on both frequency and the separation of two nodes.

2.3.1 Path Loss

When sound propagates from an underwater environment, some of its energy is converted into heat. There are three basic categories of sound wave propagation energy loss, which are explained here.

1. **Geometric Spreading Loss** When an acoustic signal is generated, it travels away from the source in the form of wave fronts. It is frequency independent, however it is dependent on the length of the wave front. Geometric spreading is separated into two categories: spherical spreading, which represents communication in deep oceans, and cylindrical spreading, which represents communication in shallow water.

2. **Attenuation** Attenuation is described as "wave energy converted into some other form of energy", such as heat energy, and absorbed by the material used. This phenomenon is known to occur during auditory transmission because acoustic energy is transformed into heat. The undersea environment absorbs the converted heat. Attenuation is proportional to frequency and distance.

3. **Scattering Loss** A physical property is usually a deviation in a signal's line of sight or a change in angle. This feature, which affects how acoustic channel data is sent during communication, is also present in underwater channels. The increase in wind speed causes an increase in surface roughness. This increases the final scattering surface result. In addition to affecting delays, scattering surface also influences power loss.

2.3.2 Noise

Noise is a communication system quality that reduces the signal strength of any communication system. There are various types of noises in the case of an underwater acoustic channel. There are two main groups that make up underwater noises. These include both background noise and human-made noise. The next sections provide a detailed description of both types of noises.

1. **Noises by Human Beings** These noises are caused by the use of heavy machinery, shipping, fishing, military, sonar, aircraft, and heavy data traffic sending and receiving activities, which result in various types of disruption and interference during acoustic communication. Human-made noises can occasionally interfere with naturally occurring acoustic communication

2. **Ambient Noise** When it comes to underwater communication, ambient noise is a complicated phenomenon. A combination of various sources that cannot be identified specifically is another way to characterise it. Background noise that results from unclear sources is also known as ambient noise. These noises can be categorised into four main groups: wind, shipping, thermal, and turbulence. Wind noise is caused by wave breakup or by air bubbles. Because noise depends on wind speed, it is easy to anticipate and forecast noise from weather forecasts. If sound transmission is good enough, a big number of ships present at a great distance from a communication system in the ocean produce a lot of traffic noise. The primary human-made source of ambient noise is thought to be ships. Turbulence is defined as surface disturbance caused by waves or tides that generates low frequencies, resulting in continuous noise in auditory transmission. Underlying noise is defined as thermal noise in the absence of all other sources of noise, including self-noise. Thermal noise is inversely proportional to the acoustic communication frequency.

2.3.3 Multipath

Surface reflections affect sound propagation in shallow water whereas bottom reflections affect it in deep water, which results in a significant and varied communication delay in acoustic communication. Multipath effect is a key cause of weak acoustic signals, which also causes intersymbol interference, making acoustic data transfer challenging and error-prone. Compared to horizontal acoustic channels, vertical acoustic channels are less susceptible to the multipath effect.

To address the problem of long propagation delay and high light error rate, a routing protocol QERP was proposed to handle end-to-end delay, but this protocol still has to address mobility difficulties. Because of the varying sound speed, refraction of sound frequently causes multipath effects in acoustic channels in deep waters. Acoustic channel impulse response, which is governed by channel reflection and geometry, determines the number of propagation pathways, propagation delays, and its strength. There are many different paths in an acoustic channel, but only those paths with the least amount of energy loss and reflections are taken into account. There are only a finite number of pathways left for acoustic communication and data transfer after discarding all other paths.

2.3.4 Doppler Spread

Wireless signals experience a variety of degradations due to channel defects. For instance, interference, reflections, and attenuation have an impact on electromagnetic signals; the same types of elements also have an impact on underwater acoustic transmissions. Due to changes in both time and space, underwater acoustic channels are complex. Doppler shift refers to the motion between the transmitter and receiver that results in the mean frequency shift. Despite the fact that the fluctuation in frequency in this region of the Doppler shift is known as the Doppler spread, the Doppler Effect is seen to have two different types of effects on acoustic channels: first, a pulse's width will be compressed or stretched, and second, a frequency offset will occur as a result of the frequency offset compressing or expanding the signal time domain.

Chapter 3

Components

3.1 Arduino UNO

Figure 3.1: Arduino UNO

A microcontroller board called Arduino Uno is based on the ATmega328P. (datasheet). It has a 16 MHz ceramic resonator (CSTCE16M0V53-R0), 6 analog inputs, 14 digital input/output pins (of which 6 can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It comes with everything required to support the microcontroller; to get started, just use a USB cable to connect it to a computer, or an AC-to-DC adapter or battery to power it. It is used in the receiver section of the project.

3.1.1 Why we use Arduino UNO?

The hardware of Arduino is open source which means any developer can create a code or use pre-existing codes to run on Arduino. The developers provide design and documentation for each Arduino boards freely for developers.

There are so many boards available on market but advantages like Arduino's accessibility, easy-to-understand hardware design, and simple software make an ideal choice. The Arduino IDE software which is used to program Arduino can run on different operating systems like Windows, Linux or MAC.

3.2 Arduino NANO

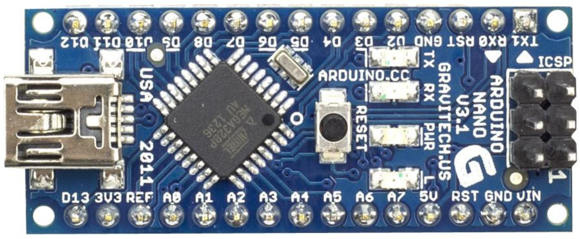

Figure 3.2: Arduino NANO

Based on the ATmega328P, the Arduino Nano is a compact, comprehensive, and breadboard-friendly board that was introduced in 2008. In a more compact design, it provides the same connections and specifications as the Arduino Uno board. The Arduino Nano has 30 male I/O headers that are arranged in a DIP-30-like format and can be programmed using the Arduino Software integrated development environment (IDE), which is available both online and offline and is shared by all Arduino boards. The board can be powered by a 9 V battery or a type-B mini-USB connection. It is used in the transmission section of our project.

3.2.1 Why we use Arduino NANO?

Although there are many different Arduino boards available, the Nano is a flexible board that may be used for practically all DIY electronic projects. These small microcontrollers make compact DIY hardware development more accessible than ever before. Arduino NANO's compact size makes it ideal for use in projects that require a small form factor. NANO has exactly the same capabilities as UNO but at a lower cost.

3.3 LDR Sensor

Figure 3.3: LDR Sensor

LDR stands for Light-Dependent Resistor. LDR Sensor is used as a receiver in our project. An LDR Sensor can be connected with light-based data communications, or Li-Fi, which employs LEDs to generate networked communications, to create a self-powered Li-Fi receiver. The LDR Sensor receives light from the LED and also receives light from the network to act as the broadband receiver.

The LDR and a potentiometer (potmeter or pot) are nearly identical devices. To vary the resistance of the pot, the knob must be twisted, but in the case of LDR resistance is solely affected by the amount and intensity of light falling on its surface. The amount of light falling on the LDR's surface is indirectly proportional to resistance, so if the amount of light falling on the LDR's surface increases, the resistance of the LDR decreases, and vice versa.

3.3.1 How is LDR made?

A semiconductor with a very high resistance is used to create an LDR. However, no P-N junction exists. Due to its composition of semiconductors like cadmium sulfide, LDR exhibits all of their properties. In addition to these semiconductors, cadmium selenide, lead selenide, indium antimonide, etc. are utilized to create LDR. To create an LDR, the semiconductors are held in a zigzag pattern. Metal contacts are positioned on the semiconductors' two ends to help in connecting them to the LDRs. A transparent layer is coated over these semiconductors, or photosensitive materials, to protect them. In addition, the clear coating used to shield the LDR allows light to pass through, which aids in the LDR's overall performance.

3.3.2 Working of the LDR

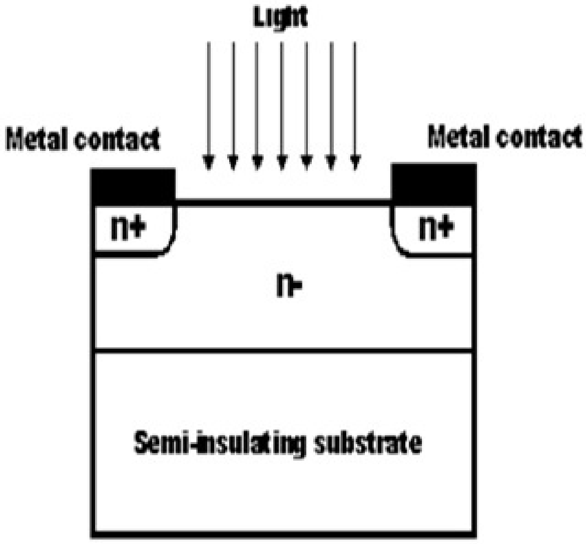

Figure 3.4: Working of LDR Sensor

The LDR sensor works on the principle of Photoconductivity. As the LDR is made of a photoconductive material, it absorbs the energy of the light that strikes its surface. As a result of this energy absorption, the electrons in the valence band of the photoconductive material become excited and move into the covalent band, increasing the conductivity of the LDR. This impact is caused by an increase in the amount of light falling on the LDR's surface.

It is critical for the LDR to absorb energy because the falling light is greater than the bandgap energy, allowing electrons in the Valence band to be energized and move into the conduction band. The resistance of the LDR reaches its highest when it is dark, and it is calculated to be roughly 1012 ohms. Additionally, as the brightness of the light increases, its resistance lowers.

If we draw the graph of resistance and intensity of light then it will have a hyperbolic shape.

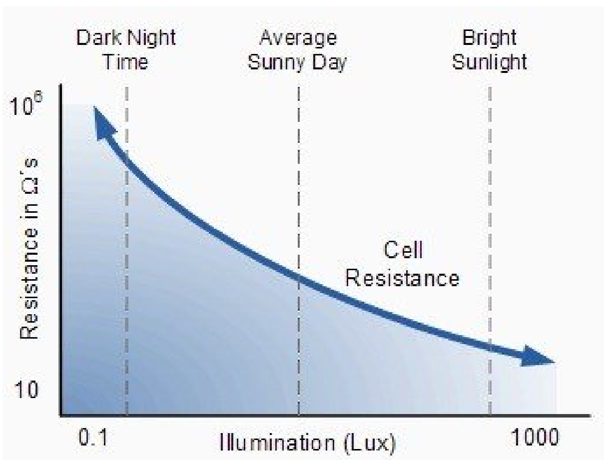

Figure 3.5: Working of LDR Sensor

3.4 Transmitter

Figure 3.6: LED

In our project we use a simple LED as a transmitter, we can also use laser light. A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. LED have many advantages including lower energy consumption, longer lifetime, smaller size and faster switching

Because LEDs are semiconductors, the current and output can be modified at fast speeds, which is detected by the photo detector device (the equivalent of a Wi-Fi networking card in PC). The electrical current from the optical output is then processed and supplied as data to the device. The fluctuating light intensity is imperceptible to the human eye, making it roughly as obvious as Wi-Fi signals.

3.4.1 Working Principle of LED

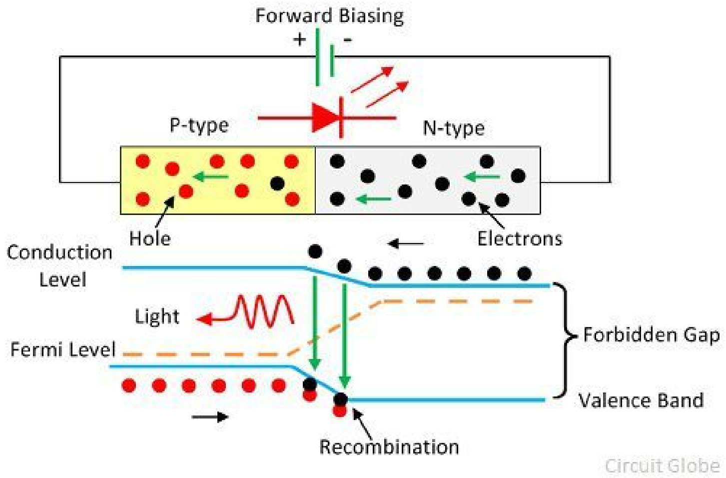

Figure 3.7: Working principle of LED

The working principle of a light-emitting diode is based on quantum theory. According to quantum theory, the photon releases energy when the electron falls from a higher to a lower energy state. The energy difference between these two energy levels is equal to the energy of the photon. When the PN-junction diode is forward biassed, current flows through it.

Current flow in semiconductors is created by the flow of holes in the opposite direction of the current and the flow of electrons in the current direction. As a result of the movement of these charge carriers, there will be recombination. The recombination means that electrons in the conduction band move to the valence band. The electromagnetic energy is released by the electrons as photons when they move from one band to another band, and the photon energy is equal to the forbidden energy gap.

White LED's

There are two methods that can be used to produce LEDs. In the first method, red, green, and blue LED chips are combined in a single package to produce white light, whereas phosphorescence is used in the second method. The fluorescence within the phosphor can be summarised within the epoxy surrounds, and the LED will be activated utilising short-wavelength radiation via the InGaN LED device. The various colour lights, such as blue, green, and red, are combined in variable amounts to generate a different colour sensation known as primary additive colours. The white light is created by evenly combining these three light intensities.

White LED product lines are mostly based on a single LED chip with a phosphor coating. When this coating is exposed to ultraviolet radiation instead of blue photons, white light is produced. The same theory also applies to fluorescent lamps; an electric discharge inside the tube will emit UV, which will cause the phosphor to blink white. Although this LED technique can produce a variety of hues, variances can be controlled through screening. White LED-based devices are screened using four accurate chromaticity coordinates that are adjacent to the centre of the CIE diagram. The CIE diagram describes all possible colour coordinates within the horseshoe curve. The arc's clean colours are spread out, but the white tip is in the middle. Four points that are shown in the centre of the graph can be used to represent the white LED output colour. Even if the four graph coordinates are close to pure white, these LEDs are not as effective as a common light source in lighting up coloured lenses.

These LEDs are most beneficial for white, otherwise transparent lenses with opaque backlight. White LEDs will undoubtedly become more popular as a source of illumination and an indicator as long as this technology keeps developing.

3.5 LCD Display

Figure 3.8: LCD Display

LCD is an abbreviation for liquid crystal display. It is a particular type of electronic display module used in a wide array of circuits and devices, including mobile phones, calculators, computers, TVs, and other electronics. These displays are mostly preferred for seven segments and multi-segment light-emitting diodes. The main advantages of adopting this module are its low cost, ease of programming, animations, and unlimited ability to display bespoke characters, unique animations, etc.

We used 16*2 LCD Display for our project which shows the data that is transmitted through a transmitter.

Chapter 4

Block Diagram

4.0.1 Transmitter

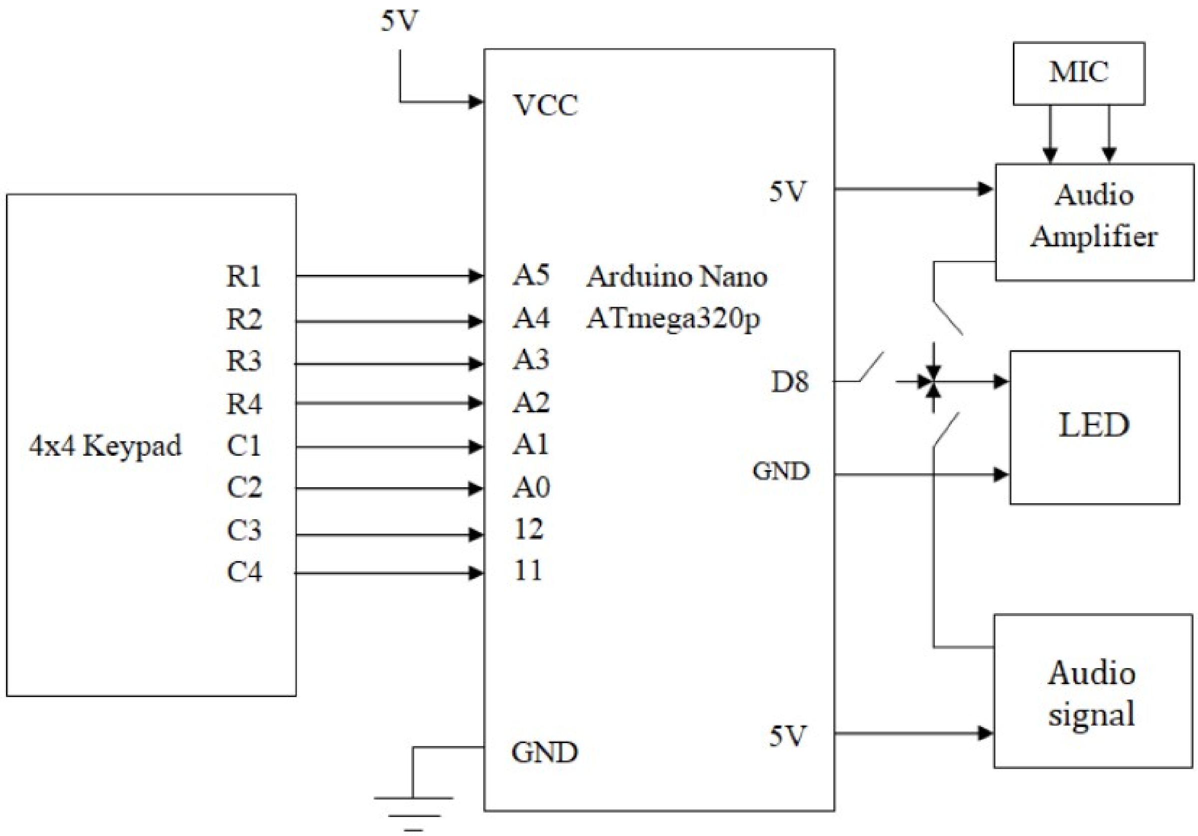

Figure 4.1: Transmitter

Fig 3.6 is the transmission circuit diagram, the circuit contains Arduino Nano which operates with 5V/12V power supply. It also contains 4x4 Keypad, Audio Jack, MIC, Audio Amplifier, and output LED. In our system LED is the main transmitter part or component, it has two pins, GND to ground and pin to output pin (D8) with a resistor 220 ohm connected to Arduino Nano. And VCC is connected to 5v, GND to ground.

4.0.2 Receiver

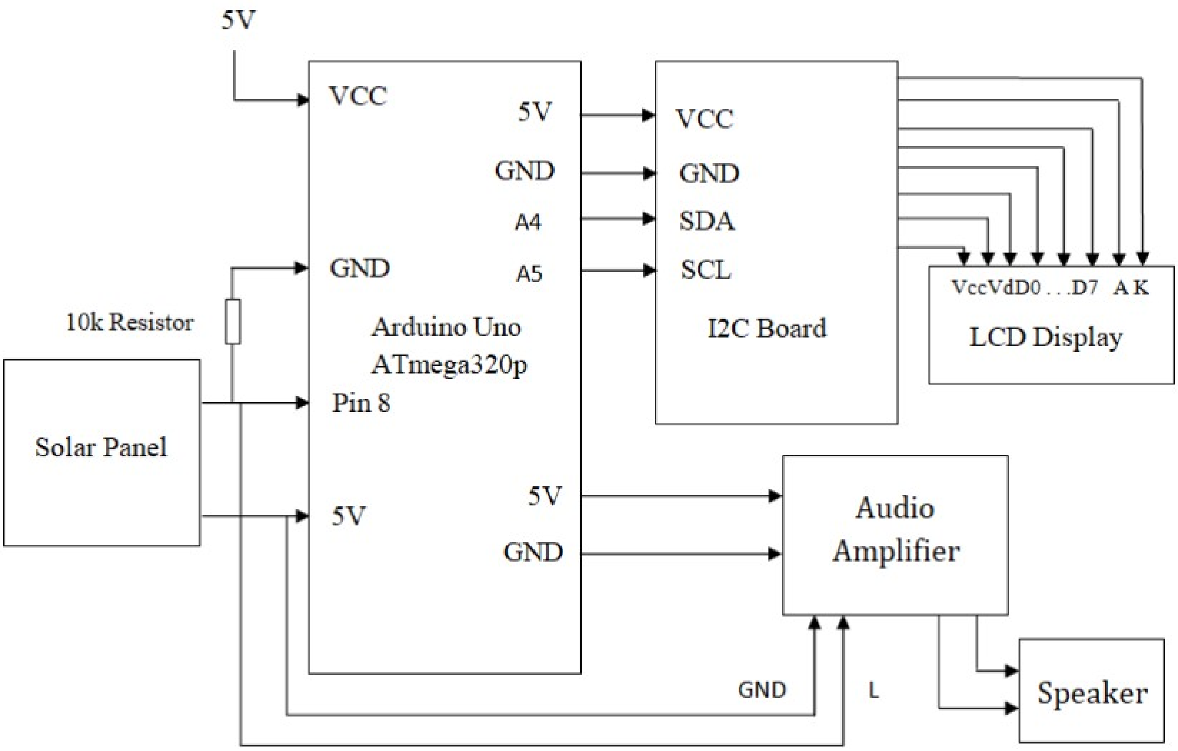

Figure 4.2: Receiver

This is the receiver circuit diagram. It contains Arduino Uno, LCD Display, I2C board, Solar Panel and Speaker. Keypad is connected to Arduino Nano as input, it has 4 rows and 4 columns which are R1,R2,R3.R4 And C1,C2,C3,C4 are connected to analog pins of Arduino Nano, VCC is connected to 5v, GND to the ground. In the receiver section solar panel is connected to pin 8 of Arduino UNO and also 5V with a resistor 10k ohm and GND to the ground. Arduino UNO board has VCC connected to 5V, GND to ground. The LCD display is interfaced with the I2Cboard, It has 4 pins VCC are connected to 5v, GND to ground. On Arduino UNO board, SDA (data line) is on analog pin 4, and SCL (clock line) is on analog pin 5. In receiver section the input solar panel is directly connected to the audio amplifier, the Amplifier is connected to 5V power supply and GND to the ground. And the output pins are connected to the speaker.

4.1 Circuit Diagrams

4.1.1 Transmitter

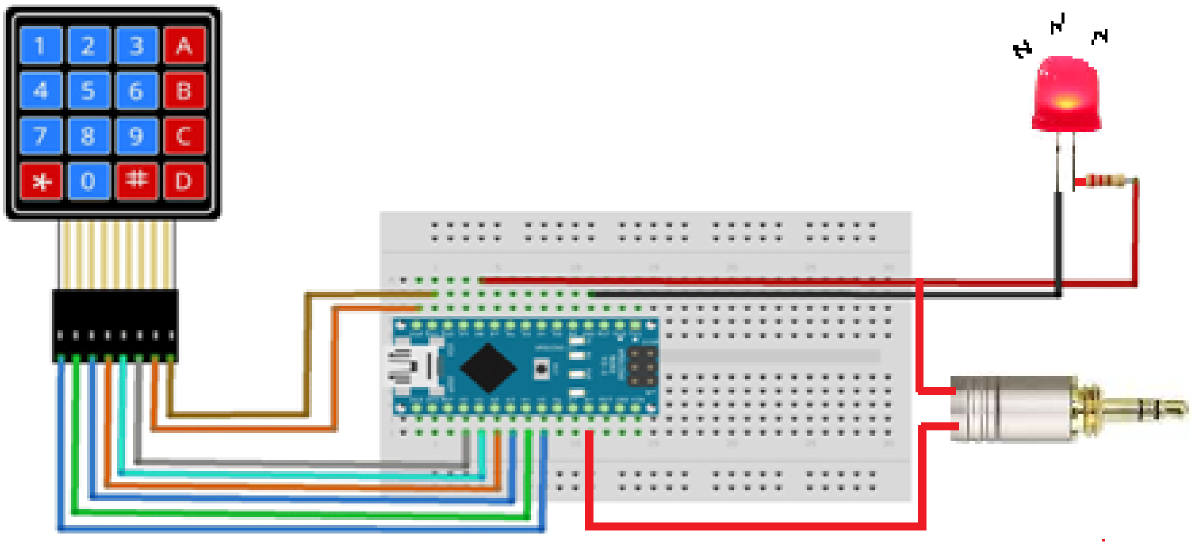

Figure 4.3: Transmitter Circuit Diagram

4.1.2 Receiver

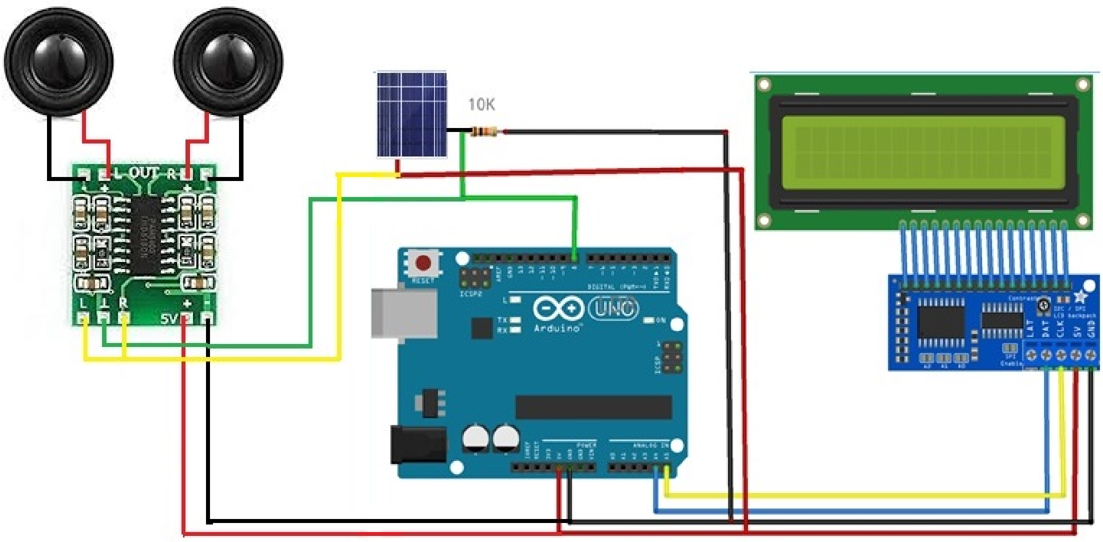

Figure 4.4: Receiver Circuit Diagram

4.2 Working

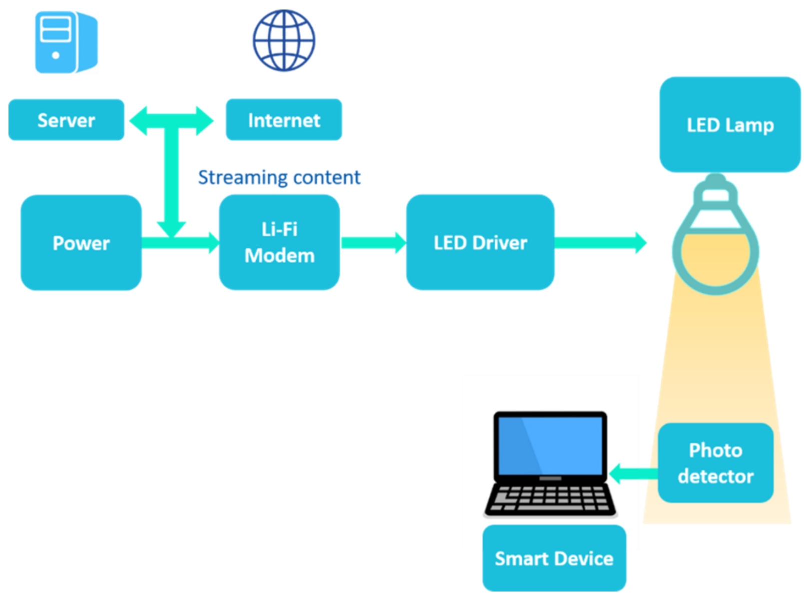

Figure 4.5: Receiver Circuit Diagram

Li-Fi is high speed, bidirectional, and fully networked wireless communication of data using light. Li-Fi constitutes of several light bulbs that form a wireless network. When an electrical current goes through to a LED light bulb, a stream of light (photons) emits from the lamp. LED bulbs are semiconductor devices, which means that the brightness of the light flowing through them can change at extremely high speeds. The signal is sent by modulating the light at different rates.

The signal can then be received by a detector that interprets the changes in light intensity (the signal) as data. Also when the LED is ON, you transmit a digital 1, and when it is OFF, you transmit a 0.The human eye can not see the intense modulation taking place. With this technique, data can be transmitted from a LED light bulb and back at high speeds.

First, we use the laptop or keyboard to enter data into this system. In this section, we construct a message that will be sent from the transmitter circuit to the receiver circuit and displayed at the receiving end. The Arduino is programmed in such a way that when data is sent to the Arduino circuit, the Arduino will encrypt the program and convert it into a different form. The LIFI transmitter circuit will get this data after that. Using the light sensor, we will transfer data to the receiver side of this lifi transmitter circuit. We'll utilize water as a medium between the transmitter and receiver circuits. The data will be received at the receiver end before being given to the receiver Arduino circuit with a description program. The data will be specified by the Arduino and then presented to the screen on the receiver side end.

4.2.1 Basic Concept

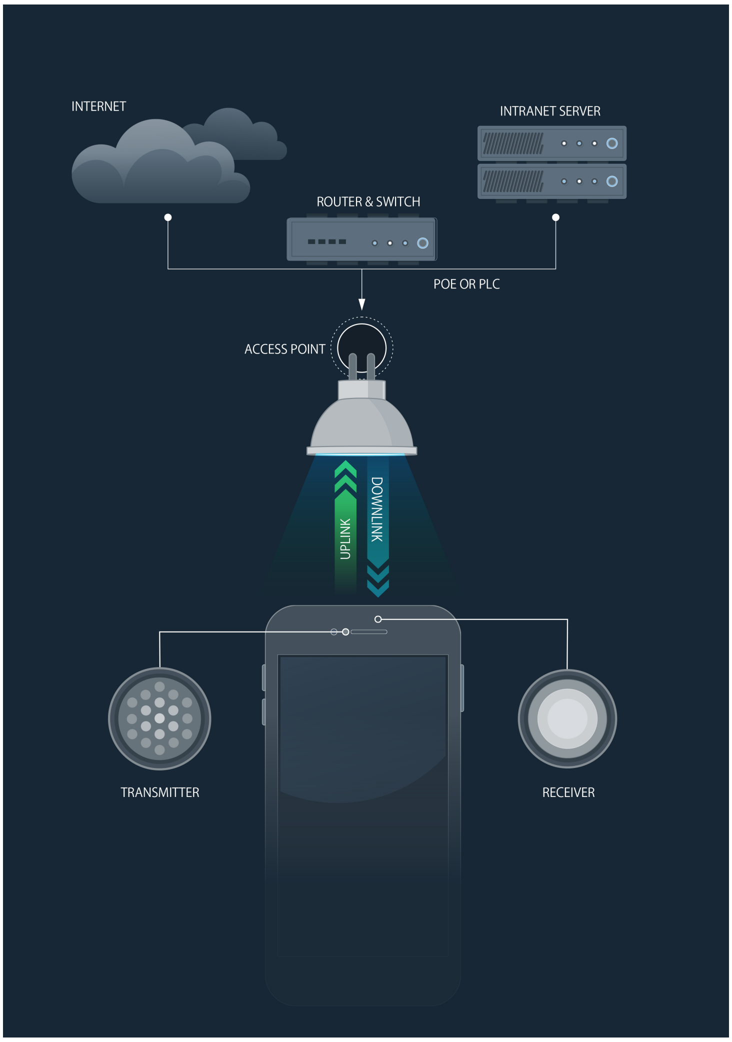

Figure 4.6: Li-Fi Demonstration

Light Fidelity (Li-Fi) technology is a wireless communication system that uses visible light frequencies ranging from 800 THz to 400 THz. Li-Fi uses the optical spectrum, or visible light portion of the electromagnetic spectrum, as opposed to Wi-Fi which uses the radio part of the spectrum. The foundation of Li-Fi is the well-defined and standardised process of transferring data through amplitude modulation of the light source. Since LEDs operate at a pace of less than 1 microsecond, they can be turned on and off more quicker than the human eye can see. Binary coding is used for data transmission through this stealthy on-off process. Depending on whether the LED is on or off, a digital '1' or '0' is communicated. The fact that these LEDs can be turned on and off fast and don't interfere with other light frequencies the way radio frequencies do in Wi-Fi provides us a great opportunity to transfer data through LED lights. Since Li-Fi is estimated to be 80 percent more effective, it can travel at speeds of up to and even past 1Gbps. Because the Li-Fi protocol layers are appropriate for wireless communication over short distances (up to 10 meters), Li-Fi varies from fibre optic technology. This places Li-Fi in a unique position of exceptionally fast wireless communication over short distances.

4.2.2 How It Works?

Li-Fi operates in a fairly straightforward manner. An LED transmitter serves as the light emitter on one end, and a photo detector (light sensor) serves as the opposite end. The data input to the LED transmitter is encoded in the light (officially known as Visible Light Communication) by adjusting the flickering rate at which the LEDs flash 'on' and 'off' to generate distinct strings of 1s and 0s. The on-off activity of the LED transmitter, which appears to be invisible (the LED intensity is modulated so quickly that the human eye cannot notice, so the light of the LED appears constant to humans), enables data transmission in light form in accordance with the incoming binary codes: switching ON an LED is a logical '1', switching it OFF is a logical '0'. Information can be encoded in the light to different combinations of 1s and 0s by changing the pace at which the LEDs turn on and off.

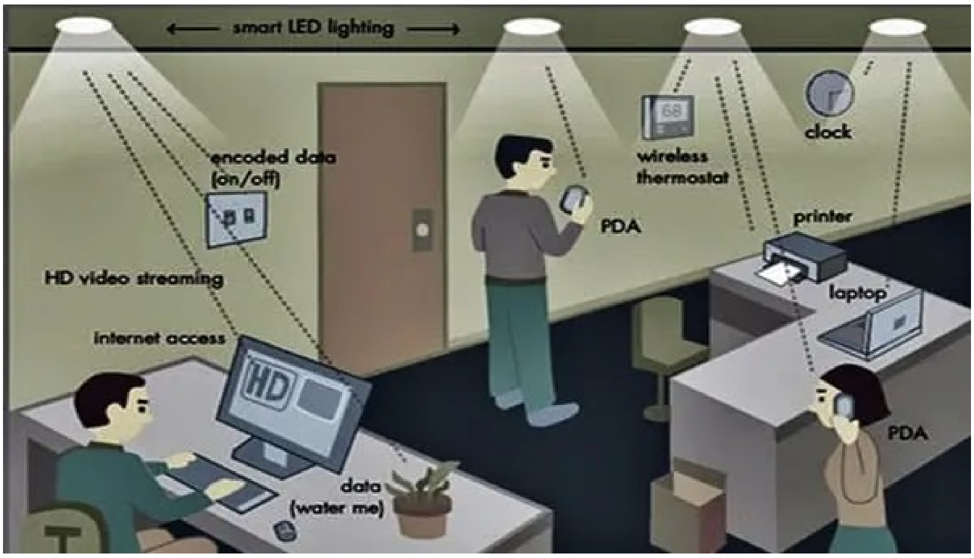

Figure 4.7: Li-Fi practical example

In a typical setup, the receiver (photo detector/light sensor) on the receiving end receives the data as a light signal and decodes the information, which is then displayed on the device connected to the receiver. The transmitter (LED) is connected to the data network (Internet through the modem). When the transmitter (LED) is on, the receiver (photo detector) records a binary '1' and when the transmitter (LED) is off, a binary '0'. Thus, utilising an array of LEDs (perhaps in a few different colours) or repeatedly flashing the LED will eventually result in data rates in the hundreds of Mbps range. Therefore, all that is needed is a controller that controls/encodes data into a set of LEDs or an array of LEDs. All that has to be done is change how quickly LEDs flicker in response to data input. Additional data rate improvements can be obtained utilising an array of the LEDs for parallel data transmission or by varying the light's frequency with a combination of red, green, and blue LEDs, with each frequency encoding a different data channel.

4.3 Advantages of Li-Fi

Quicker Data Transmission than Wi-Fi

The fact that Li-Fi technology transmits data more quickly than Wi-Fi is a key selling point. The transmission capacity of visible light is many times greater than that of microwave and the entire radio frequency spectrum. According to researchers at the University of Oxford, they successfully tested a trial Li-Fi application with a bidirectional speed of 224 gigabits per second.

Simple and Inexpensive to Deploy

Remember that the existing operational concepts and trial Li-Fi innovation utilizations center on the use of LED lighting. This suggests that a Li-Fi organisation can be successfully integrated with current LED lighting systems. Basically, access to the Internet is possible anywhere there is a light source. It is also important to note that the market price of LED lights is somewhat modest, and their delivery costs are reasonable. Li-Fi organisation would be significantly less expensive than Wi-Fi, according to researchers. Additionally, they use less energy than fluorescent and radiant lights.

Security Due to the Limitations of Light

Li-Fi also has the notable benefit of being safer than Wi-Fi, which is why it is recommended. Remote communication technologies reliant on radio waves and microwaves are more susceptible to eavesdropping, signal eavesdropping or unauthorised interference, beasts power attacks, and impromptu organisational affiliations. Remember that doors and partitions cannot let light waves through. They also have a more constrained range. Both infrared and brilliant radiation are equivalent. A Li-Fi device can only send signals and convey information within a closed area, such a room or lobby. Organizational admission is limited. This suggests that Li-Fi technology provides an extra degree of protection over Wi-Fi.

Safe From Electromagnetic Interferences

Additionally, Li-Fi offers a small margin of immunity to electromagnetic impedances that hinder radio-based remote communication improvements. Since it doesn't create electromagnetic interference, the technology is also useful in places that are electromagnetically sensitive, such as aeroplane hangars, hospitals, and atomic power plants, among others. Keep in mind that some medical equipment used in clinics, just like the radar and communication systems aboard a flight, are sensitive to radio recurrence.

Efficiency

The usage of LED lighting, which is now accessible in homes, businesses, malls, and other places for lighting purposes, can reduce energy consumption. As a result, data transmission requires negligible additional power, making it incredibly cost and energy efficient.

An Unstoppable Signal

Cybercrime is at its prime in a hyperconnected society where the most private data is digitalized and shared over WiFi. A single WiFi access point does, in fact, have an average range of 250 metres outside and 35 metres inside, making this technology the optimal environment for hackers who are able to snare the signal from external structures. LiFi offers a straightforward solution to this problem that is becoming more and more important in the modern world. LiFi does not transfer data via the room's walls; instead, it only transmits data in the light beam that is projected from the ceiling (or desk lamp) to the workstation(s). In other words, any room with a LiFi system installed is fully resistant to outside noise, and it is even feasible to change the access point's coverage angle so that it only feeds a certain portion of the space. For the military, government agencies, academic institutions, and the realms of science and medicine, this is a true revolution.

Non harmful technology

In contrast to WiFi, LiFi is completely free of radio frequency electromagnetic waves because it only depends on the variations in light intensity of an LED bulb. While WiFi employs radio waves from the electromagnetic spectrum, LiFi uses its visible portion, commonly known as the optical spectrum. In areas where radio frequencies are not preferred, it is essential to democratizing a healthy and effective WiFi alternative at a time when the effects of radio waves on health, particularly for the most vulnerable, are a matter of concern. Because of this feature, LiFi is a popular wireless communication option for schools, hospitals, senior homes, and any other facility that serves a vulnerable population.

Light and unobtrusive installation

The lightness of the installation setup of lifi is far greater than wifi technology, especially in air transport systems, While an airplane's WiFi equipment weighs almost 1.3 tonnes because of the shielded leather cables necessary to minimize interference, LiFi can cut that weight in half while providing similar or even better performance. As a result, fuel and maintenance expenses as well as CO2 emissions are significantly decreased. The same is true for school computer labs, which can now do without the bulky and risky cable tangles. LiFi can be implemented without extensive infrastructure change or ongoing development. LiFi could possibly be integrated into current lighting systems to produce a discreet and useful outcome because it has few hardware and regulatory restrictions.

4.3.1 Disadvantages of Li-Fi

Restricted Range and Connectivity

Li-Fi has an edge over Wi-Fi in terms of security thanks to the obstructions caused by the perceptible light. However, these restrictions also create burdens. Actual constraints, like barriers and doors, for example, restrict how far a Li-Fi-powered LED light may operate. Remember that information transmitted by a Li-Fi device is confined to a surrounding area because light can't penetrate misty objects and has a shorter range. To increase the Li-Fi network's range in structures like houses and buildings, powered LED lights should be strategically placed in rooms, hallways, and other areas. A single Wi-Fi switch has a wider and longer range than a single Li-Fi switch. Due to these limitations, Li-Fi is also not recommended for usage in open Wi-Fi networks.

Inaccessibility of Compatible Technologies

It will take a long time for Li-Fi to become more valuable than Wi-Fi. Modern devices like PCs, smartphones, and tablet computers actually use the equipment for Wi-Fi arranging. These devices lack the necessary equipment information, therefore they would not immediately function with a Li-Fi network. Li-Fi is not immediately backward compatible. It is also vital to note that until Internet speed from specialized organizations improves, the faster information transfer pace of this technology will remain irrelevant or meaningless. It would be absurd to transport a Li-Fi organization to areas or countries that are well-known for having Internet speeds that are slower than those of their neighbors. Thus, advancing the widespread selection of this innovation will require coordination between many businesses and places.

Conceivable Cost Implications

Due to the low cost associated with producing LED lights, sending Li-Fi is conceivably economical. In spite of this, installation costs may be more than Wi-Fi transmission because technology is typically new, interest is still low, and there aren't many specialised experts available. The fact that a single residence needs several Li-Fi switches to expand the organisation and accessibility of Internet availability may also result in higher buy and setup expenses. Keep in mind that a single Wi-Fi switch is adequate for a typical-sized home.

4.4 Applications

Li-Fi is used everywhere, which makes it a very dominant option for the future of technology and communication. These technologies are effective, quick, accessible, and most importantly, safe. Li-Fi systems could make it possible for the general public to access the internet via common household appliances and can be crucial to the realisation of the Internet of Things (the communication of all electrical devices via the internet).

Li-Fi systems can be utilised in locations where Wi-Fi cannot be used or where radio interference poses a serious threat, such as hospital rooms where radio waves could expose patients to radiation. Li-Fi use will not only improve the control of medical equipment but may also provide rural hospitals with internet connectivity while carrying out a significant surgery or operation that will be managed remotely by top experts. Li-Fi systems can be used in aircraft to give passengers with inexpensive, quick internet access that doesn't interfere with the radio communication of the aircraft.

The above-proposed architecture can be used in underwater vehicles, which need long connections for communication and power supply, because it allows for the simultaneous flow of energy and information through a single transmitter source and receiver. In settings where radio communication is deemed harmful, such as nuclear power facilities that need the monitoring of core temperatures, Li-Fi offers a safer alternative to radio transmission.

Future Li-Fi systems will unavoidably be required to support free internet access on the street, communication between cars via their headlights and traffic lights to control them, security of sensitive information within buildings with restricted access, and widespread use in educational systems. Disaster management and mobile connectivity will be the forces behind the creation of this communication system in the future.

Education systems

Li-Fi is the most recent technology that can deliver the quickest Internet connection speeds. Therefore, it can supplement or take the place of Wi-Fi in businesses and educational institutions so that users there can benefit from high-speed Li-Fi.

Medical applications

Wi-Fi is not permitted in operating rooms (OTs) because to radiation safety issues. The signals for monitoring equipment are interfered with or blocked when Wi-Fi is used in hospitals. Therefore, it may have a dangerous impact on the patient's health as a result of the medical equipment not functioning properly. To get over this and teach OT how to utilise technology, Li-Fi can be used to access the internet and manage medical devices. For doing robotic operations and other automated procedures, this will be advantageous.

Cheaper internet in aircrafts

Aircraft passengers can get Internet at a very high cost and at a very low speed. Wi-Fi is not used either since it can obstruct the pilots' navigational systems. Li-Fi can be used for data transfer in aircraft. Li-Fi can simply give high-speed Internet access through any light source found inside the aircraft, including reading lights, etc.

Underwater applications

Remotely operated vehicles (ROVs) that operate underwater are powered by sizable cables that also enable them to receive signals from their pilots above. However, the ROVs' usage of chains prevents them from exploring wider areas. They would be much freer to roam if their wires were replaced with light, such as from a submerged, high-powered lamp. Additionally, they may interact by using their flashlights to process data independently and periodically transmit their discoveries back to the surface. Li-Fi can even function underwater, where Wi-Fi is entirely unusable, creating countless options for military activities below the surface.

Disaster management

When a crisis like an earthquake or a hurricane strikes, Li-Fi can be a valuable communication tool. The typical person might not be familiar with the procedures during such calamities. Li-Fi is unaffected by train stations and tunnels, which are typically dead zones for emergency communications.

Traffic management

Li-Fi can be used in traffic signals to communicate with passing vehicles (through the LED lights of the cars, for example), which can aid with improved traffic management, resulting in a smoother flow of traffic and a decrease in accident numbers. Additionally, LED car lights can warn drivers when other cars are approaching too closely.

Mobile connectivity

Smartphones, tablets, computers and other mobile devices can all simply connect to one another. Li-Fi's short-range network can produce incredibly high data rates and improved security.

Equivalent for other technologies

Li-Fi doesn't use radio waves to operate. Because of this, it can be used without difficulty in locations where Bluetooth, infrared, Wi-Fi, and other technologies are prohibited.

Chapter 5

Result

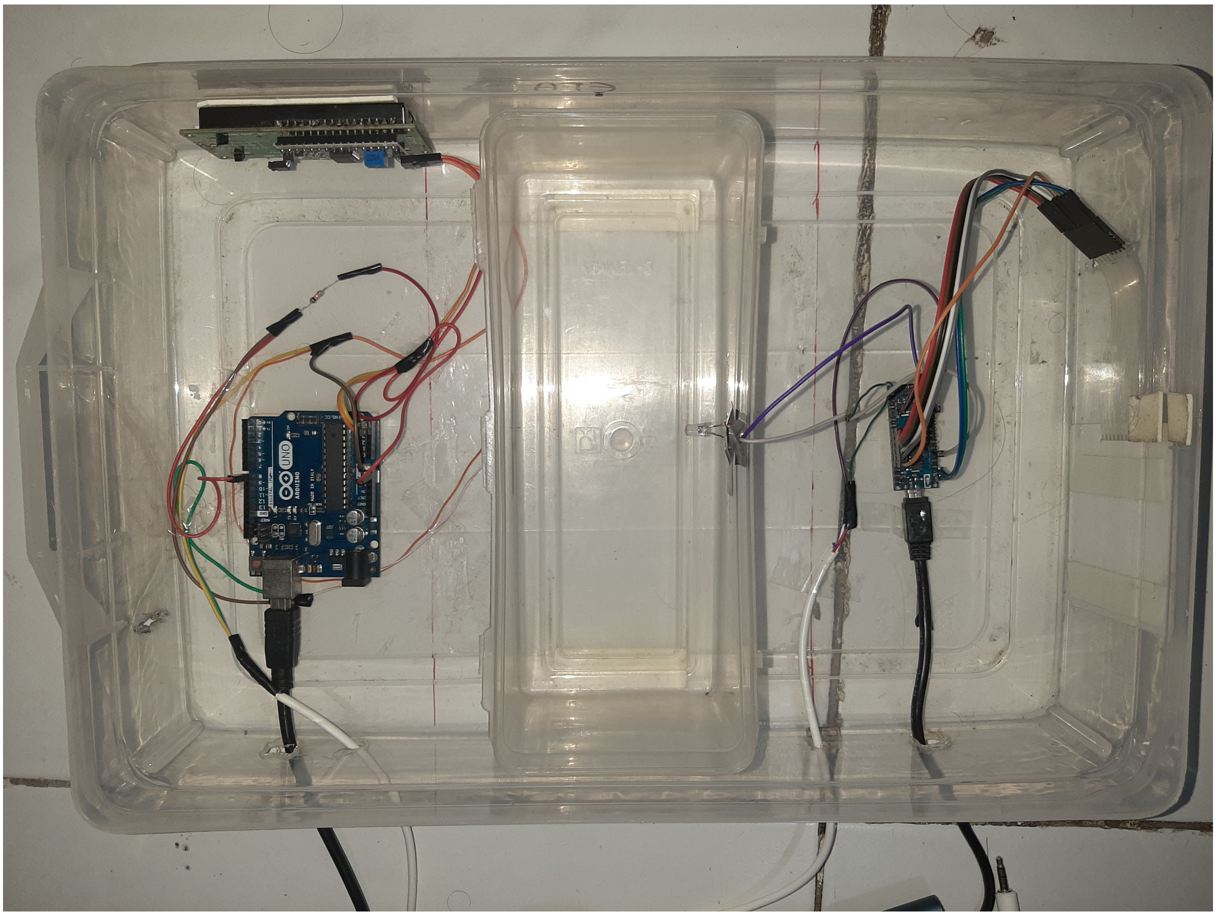

Figure 5.1: Project Setup

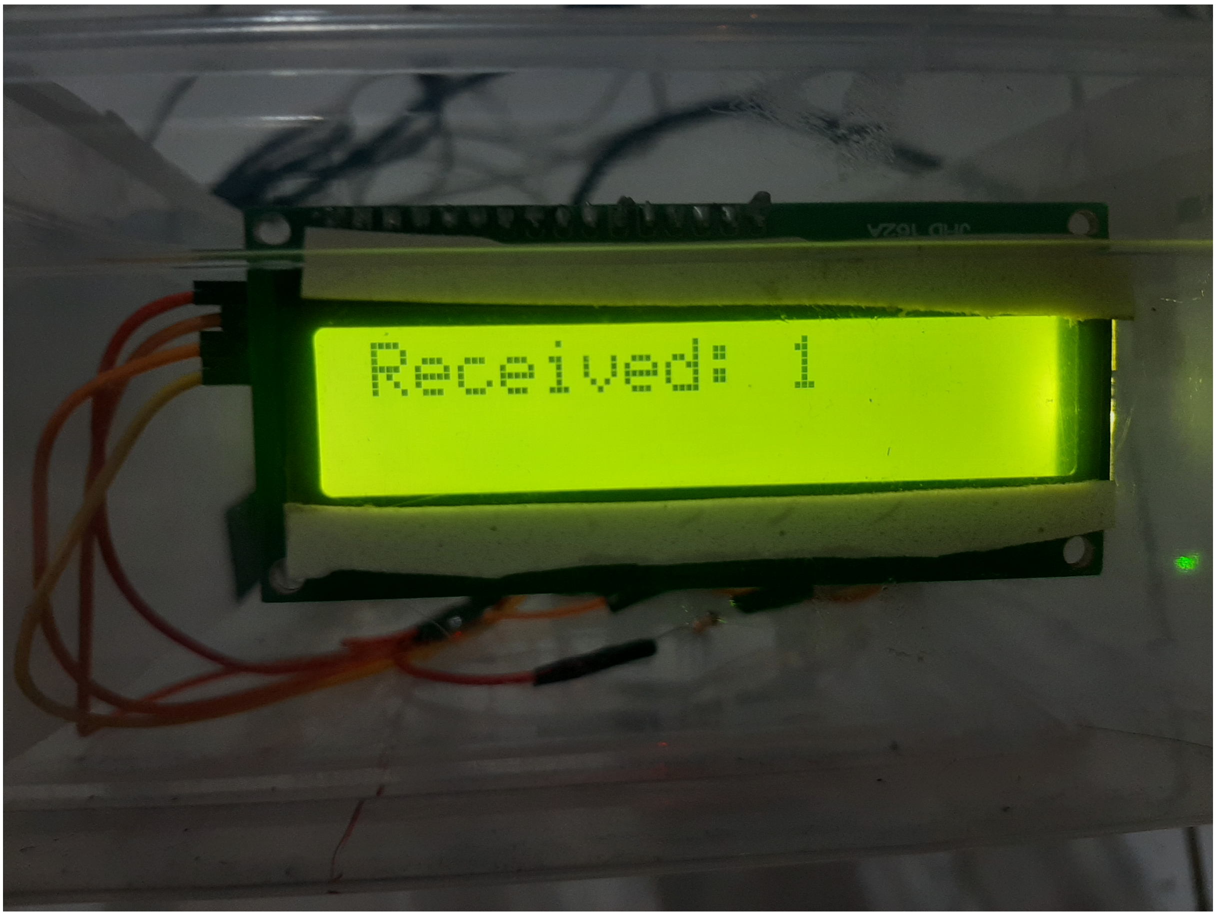

Figure 5.2: Received Output

In this project our objective was to transfer text data and audio data using light, this technology is known as Li-Fi or Light Fidelity. Li-Fi uses Visible Light to transfer data in binary form by changing the intensity of light. We used different mediums like air, clean water, salty water and muddy water and compare all the results which are given below in the table.

The results for different mediums which we had tried are as follow:

Air Medium

For air medium, we did not notice any delay and all inputs were the same as we type on the keypad. And for audio transfer, audio was clearly audible on the receiver side without any decline in volume. We used a portable speaker on the receiver side to clearly hear audio send using LED. From this, we can conclude that air does not affect lifi communication system for both audio and text.

Clean water

The main aim of this project is to transfer data underwater without affecting the data and with the lowest delay as possible. For clean water, the audio was clearly audible without any distortion or effect on the volume. and we received all the text on LCD correctly as we typed. Like air medium water also does not affect lifi communication. As long as there is no disturbance between the transmitter and receiver, water depth does not affect light communication.

Salty water

For salty water, we received different results than air and water medium. Approximately 2 out of 10 keypad presses were not received by ldr sensor. and for audio, we did not notice any latency or distortion in audio clarity but we did notice a decline in volume level this decline was approximately 20% to the overall volume. From these results, we can conclude that salty water is not as good medium as air and water but this shortcoming can be dissolved by using different color LED or by using LASER.

Muddy water

For muddy water, we received completely different results than all of the above mediums. We won't able to receive text data as we type but we received audio without any delay and distortion but the effect on volume level was very noticeable, nearly 50% of the original volume. From these results, we can say that we have to either change LED parameters(color, type) or the light detector sensor to a more sensitive sensor to receive correct outputs.

5.0.1 Text Data Transfer

Medium	Accuracy(in percentage)	Delay	Impact	Refractive index
Air	100%	No	No	1.0003
Clean water	100%	No	No	1.33158
Salty water	80%	Yes	2 Out of 10 char	NA
Muddy water	0%	NA	Not possible with normal LED	NA

5.0.2 Audio Transfer

Medium	Accuracy(in percentage)	Delay	Impact	Refractive index
Air	100%	No	No	1.0003
Clean water	100%	No	No	1.33158
Salty water	100%	No	Effect on audio by 20%	Na
Muddy water	100%	No	Effect on audio by 50%	Na

Chapter 6

Conclusion

The possibilities are numerous and can be explored further. If his technology can be put into practical use, every bulb can be used as something like a Wi-Fi hotspot to transmit wireless data.

The concept of Li-Fi is currently attracting a great deal of interest, not least because it may offer a genuine and very efficient alternative to radio-based wireless.

As a growing number of people and their many devices access wireless internet, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal.

This may solve issues such as the shortage of radio-frequency bandwidth and also allow internet where traditional radio-based wireless isn't allowed such as aircraft or hospitals. One of the shortcomings however is that it only works in direct line of sight.

Although there is still much work to be done before this technology becomes commercially viable, it holds immense promise for the future of wireless internet. This idea, which claims to address the issues of a shortage of radio spectrum, available space, and of slow internet connection speed, is currently the focus of a sizable number of researchers and businesses. By implementing this technology, we can transition to communication networks that are greener, cleaner, and safer. The mere idea of Li-Fi makes promises to address problems like a lack of radiofrequency bandwidth and the shortcomings of radio communication technology. Li-Fi is a new and evolving technology that serves as a catalyst for a number of other emerging and novel ideas and technologies. Therefore, the creation of future Li-Fi applications that can be expanded to multiple platforms and diverse spheres of human existence is assured.

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