The Need for Laser: An Innovative Technology for Wireless Communication

A PROJECT REPORT

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of

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SCHOOL OF ENGINEERING

Under the Guidance of

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GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY

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Certified that this report "The Need for Laser: An Innovative Technology for Wireless Data Communication" is a bonafide work of "Ranjitha G R(20201ECE0079), Ravi Teja Sanka(20201ECE0083), Pavana M(20201ECE0098), Tarun N(20201ECE0107), Chethan B M(20201ECE0110), Hemanth M(20201ECE0119)", who have successfully carried out the project work and submitted the report for partial fulfilment of the requirements for the award of the degree of BACHELOR OF TECHNOLOGY in ELECTRONICS AND COMMUNICATION ENGINEERING during 2023-24.

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DECLARATION

We the students of final year B. Tech in Electronics and Communication Engineering at Presidency University, Bengaluru, named Ranjitha G R, Ravi Teja Sanka, Pavana M, Tarun N, Chethan B M, Hemanth M, hereby declare that the project work titled **"The Need for Laser: An Innovative Technology for Wireless Communication "** has been independently carried out by us and submitted in partial fulfillment for the award of the degree of Bachelor of Technology in Electronics and Communication Engineering during the academic year of 2023-24. Further, the matter embodied in the project has not been submitted previously by anybody for the award of any Degree or Diploma to any other institution.

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ABSTRACT

The Need for Laser: An Innovative Technology for Wireless Data Transmission

The increasing demand for high-speed and reliable data transmission in today's digital world has driven the exploration of innovative technologies beyond traditional radio frequency (RF) methods. Laser technology, with its potential for significantly higher data rates and reduced interference, emerges as a promising solution for wireless communication systems. This report delves into the necessity of laser technology for wireless data transmission, highlighting its advantages over conventional RF techniques, such as enhanced bandwidth, security, and efficiency. It examines the principles of laser communication, including Free Space Optical (FSO) communication, and discusses the challenges and advancements in this field. The primary focus is on the unique benefits of laser-based communication systems, including their ability to offer vast bandwidth, which translates to higher data transmission rates, and their capability to provide enhanced security due to the narrow beam divergence and line-of-sight nature of laser beams. Additionally, the report explores the efficiency of laser communication in terms of lower power consumption and reduced latency compared to RF systems. To provide a robust understanding, the report delves into the fundamental principles of laser communication, explaining the mechanisms of FSO communication, where data is transmitted through the atmosphere using laser beams. It discusses the technical aspects such as wavelength selection, modulation techniques, and the impact of atmospheric conditions on signal quality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 GENERAL REVIEW

In today's digital age, the demand for wireless communication is ever-increasing, leading to challenges such as limited bandwidth, security concerns, and inefficient power consumption associated with traditional radio wave-based technologies like Wi-Fi. These challenges have prompted the exploration of alternative solutions, one of which is laser-based communication technology. This report delves into the background, scope, design philosophy, problem statement, and intended market of laser-based communication technology, aiming to revolutionize connectivity across various sectors.

1.2 HISTORY OF LASER

LASER stands for Light amplification by stimulated emission of radiation. The history of lasers traces back to the early 20th century, with Albert Einstein's theoretical work on stimulated emission of radiation in 1917 laying the groundwork. The concept evolved further with the invention of the maser in the 1950s by Charles Townes and colleagues, which used microwaves for amplification. This led to the theoretical formulation of the optical maser (later termed laser) by Arthur Schawlow and Townes in 1958. The pivotal moment arrived in 1960 when Theodore H. Maiman constructed the first working laser using a synthetic ruby crystal. This breakthrough ushered in a new era of laser development, with researchers exploring various types such as gas, semiconductor, and dye lasers. Over the decades, lasers found wide-ranging applications in telecommunications, medicine, industry, research, and defense, catalyzing innovations like fiber optic communication and laser-based manufacturing. Today, lasers continue to evolve with advancements in ultrafast lasers, laser diodes, and applications in diverse fields, showcasing their enduring impact on science and technology.

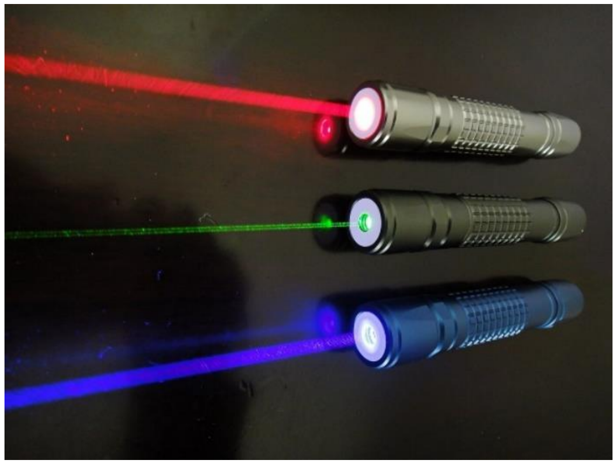

Fig. 1.1 Laser

1.3 WORKING OF LASERS

The functioning of a laser hinges on a process known as "stimulated emission of radiation," a phenomenon that magnifies light by interacting with atoms or molecules. This process unfolds in several stages. Initially, a state of "population inversion" is attained within a medium like a gas, liquid, or solid, where a greater number of atoms or molecules occupy higher energy levels compared to lower ones, contrary to typical thermal equilibrium. When a photon engages with an atom or molecule at a higher energy level, it triggers the emission of another photon of identical wavelength, phase, and direction, termed as stimulated emission. This cascade of emissions amplifies as the medium is placed between mirrors—one entirely reflective and the other partially reflective. Photons produced via stimulated emission ricochet between these mirrors, continuously fostering further emissions and intensifying the light. The partially reflective mirror permits some photons to escape, birthing a coherent, focused laser beam that exits the laser cavity. This resultant beam is marked by its concentrated intensity, monochromatic purity (single wavelength), and coherency (in-phase properties). The modulation and control of lasers are orchestrated by adjusting variables like the medium type, energy input (pumping), and mirror attributes, enabling tailored precision in laser output for diverse applications across industries.

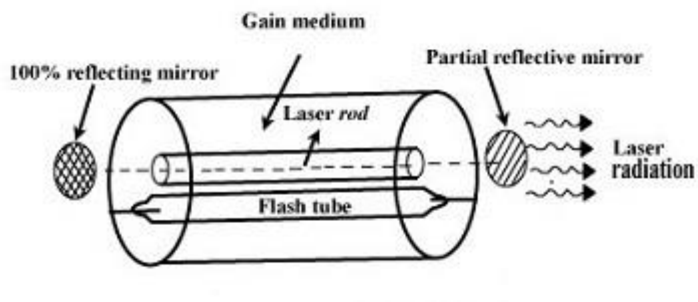

Fig. 1.2 Working of Laser

1.4 BACKGROUND OF THE PROBLEM

The current reliance on radio waves for wireless communication presents several drawbacks, including limited bandwidth, spectrum congestion, and security vulnerabilities. Additionally, radio waves cannot penetrate certain environments such as aircraft and hospitals, further restricting their applicability. The inefficiency of base stations, primarily attributed to cooling requirements, adds to the economic burden of traditional wireless technologies. Moreover, concerns regarding the penetrability and security of Wi-Fi networks underscore the need for a more robust and secure communication solution. These challenges highlight the necessity for a new invention that overcomes the limitations of existing technologies, paving the way for laser-based communication technology.

1.5 SCOPE OF THE PROBLEM

Laser-based communication technology offers a promising solution by leveraging laser beams for data transmission, which provides high bandwidth and enhanced security. With further development, laser-based communication systems have the potential to revolutionize communication by providing efficient, cost-effective, and secure data transfer. While laser-based communication addresses the shortcomings of radio wave-based technologies, it also presents its own challenges, including line-of-sight requirements and potential interference from environmental factors. Nevertheless, the coexistence of Wi-Fi and laser-based communication holds the promise of enhancing connectivity and quality of life.

1.6 DESIGN PHILOSOPHY USED IN THIS REPORT

The focus of this report is on the development and application of laser-based communication technology for data transmission across various sectors, including medicine, education, power plants, and aviation. By utilizing laser beams as a medium for data transfer, laser-based communication offers improved speed, security, and efficiency compared to traditional Wi-Fi technologies. The ultimate goal is for laser-based communication and Wi-Fi to complement each other, providing users with a seamless and enhanced connectivity experience.

1.7 PROBLEM STATEMENT

The inherent limitations of Wi-Fi, including speed bottlenecks, security vulnerabilities, high costs, and inefficient power consumption, necessitate the exploration of alternative communication technologies. Laser-based communication presents a viable solution that addresses these challenges and has the potential to revolutionize internet connectivity. Successfully implementing laser-based communication will not only overcome the drawbacks of Wi-Fi but also usher in a new era of efficient and secure data transmission.

1.8 BENEFICIARIES (INTENDED MARKET)

The rising demand for wireless connectivity, coupled with the limitations of existing radio wave-based technologies, creates a significant market opportunity for laser-based communication technology. Sectors such as aviation, underwater communication, medical applications, and power plants stand to benefit from the advantages offered by laser-based communication, including wider bandwidth, reduced energy consumption, and enhanced security. By tapping into laser technology, laser-based communication mitigates the spectrum shortage issues associated with traditional Wi-Fi, making it a compelling solution for various industries.

1.9 IDENTIFICATION OF THE PROBLEM

Initially, we identified a myriad of daily challenges, from plastic waste management to gas leakage detection. After careful consideration and consultation with mentors, we narrowed down our focus to two core issues: the need for higher data transmission speeds and the quest for alternatives to radio waves due to their harmful effects on users.

1.10 BRAINSTROMING AND IDEA GENERATION

Exploring various alternatives to radio waves led us to the concept of utilizing light waves for data transmission. We discovered LASER technology, which harnesses light waves for wireless communication. Recognizing the drawbacks of radio waves used in Wi-Fi, such as limited bandwidth and potential health concerns, we saw the potential of LASER to revolutionize wireless connectivity.

1.11 FEATURES OF LASER-BASED COMMUNICATION

LASER operates on the principle of simulated emission and population inversion. This technology offers numerous advantages including:

- **Enhanced Bandwidth**: Leveraging the expansive bandwidth of light waves, LASER enables higher data transmission speeds and improved network performance.
- **Security**: Unlike radio waves, light waves cannot penetrate opaque structures, ensuring that LASER signals remain confined within a room, enhancing data security.
- **Bidirectional Communication**: LASER facilitates bidirectional communication, allowing for seamless interaction between multiple users and devices.

1.12 MIND MAP AND IDEA SELECTION

In the process of selecting viable ideas for LASER implementation, we explored analog and digital data transmission modulation and demodulation methods, as well as the utilization of pre-existing light sources such as LASERS.

1.13 DECSION MATRIX

A decision matrix comparing LASER with other technologies revealed that LASER outperforms alternatives in terms of cost, reliability, feasibility, and usability. While technologies like modulated ultrasonic and the electromagnetic spectrum have limitations, LASER emerges as the most promising solution.

	Cost	Reliability	Feasibility	Usability
Modulated Ultrasonic	High	Low	Low	High
Electromagnet IC Spectrum	High	Low	High	High
Sound	Low	Low	High	Low
LASER	Low	High	High	High

TABLE. 1.1: Comparison of LASER with other techniques

1.14 PROPOSED SOLUTION

In light of the identified problems and the comparative analysis, we propose laser-based communication technology, specifically LASER, as the optimal solution. With its, high reliability, feasibility, and usability, LASER addresses the challenges of low data transmission speeds, the harmfulness of radio waves, and data privacy concerns effectively.

1.15 APPLICATIONS OF LASER

- Telecommunication and data transmission
- Medical and healthcare
- Industrial manufacturing and processing
- Scientific research and instrumentation
- Defense and security

2. LITERATURE REVIEW

2.1 GENERAL

Several researchers have carried out studies on laser communication. Studies have also focused on use of different modulation techniques. A brief summary of the studies reviewed are presented in the subsequent sections.

2.2 Balaji KA and Prabhu K "Optics Communications Performance evaluation of FSO system using wavelength and time diversity over Malaga turbulence channel with pointing errors" (2018)

In this study, the authors explore how different configurations of wavelength and time diversity can mitigate the adverse effects of scintillation and misalignment. Wavelength diversity involves using multiple wavelengths to transmit the same information simultaneously, while time diversity spreads the transmission over different time intervals. By simulating these techniques in an environment characterized by Malaga turbulence and pointing errors, the research aims to determine optimal operational parameters and configurations that maximize the system's performance in terms of BER (Bit Error Rate).

This paper is significant because it addresses the practical challenges of implementing FSO systems in less-than-ideal conditions, providing a comprehensive analysis of how diversity techniques can enhance reliability and performance. The findings are crucial for the design of robust FSO systems that need to operate effectively across various environmental conditions. The results suggest that employing these diversity techniques can significantly improve the resilience of FSO communications against the deleterious effects of atmospheric turbulence and alignment errors, which is pivotal for real-world applications where optical signals are susceptible to numerous disruptions. This research contributes to the ongoing development of more adaptive and fault-tolerant FSO communication systems.

2.3 Yalçın Ata and Kamran Kiasaleh, Senior Member, IEEE: "Analysis of Optical Wireless Communication Links in Turbulent Underwater with Wide Range of Parameters" (2021)

In this study, the paper delves into the complexities of deploying optical wireless communication (OWC) systems in underwater environments, which are subject to varying degrees of optical turbulence and differing water qualities. This research focuses on quantitatively evaluating the performance of underwater OWC links across a spectrum of water types, from clear to turbid, and examines how factors such as absorption, scattering, and turbulence influence signal degradation. The study employs a comprehensive modeling approach to simulate the behavior of light propagation in underwater channels, incorporating a variety of water parameters that influence visibility, such as particulate matter concentration and water composition.

The primary goal is to assess the feasibility and reliability of OWC systems under diverse underwater conditions, exploring both the theoretical and practical aspects of signal attenuation and its impact on communication efficiency. By systematically analyzing how different water qualities affect the path loss and ultimately the bit error rate (BER) of the communication link, the paper contributes valuable insights into the design and optimization of underwater communication systems. This analysis is crucial for applications ranging from data collection in oceanographic research to communication between submerged vehicles or infrastructure. The findings from this study highlight the need for adaptive communication strategies that can dynamically adjust to the changing conditions of underwater environments, thereby improving the robustness and effectiveness of optical wireless communication in such challenging settings.

2.4 M I Basudewa, Z H Bagaskara, S S A Damita1 R F Putra and D Ahmadi: "Bit Error Rate Performance Analysis for Free Space Optic Communication" (2019)

The paper offers a comprehensive investigation into the effectiveness of various modulation techniques—namely Pulse Position Modulation (PPM), Pulse Amplitude Modulation (PAM), and On-Off Keying (OOK)—in optimizing the bit error rate (BER) in free space optic (FSO) communications. This research is particularly focused on how these modulation schemes perform under different environmental conditions and over various transmission distances, employing a simulation approach conducted through MATLAB to generate empirical data. The study's primary objective is to identify which modulation method provides the most reliable performance in terms of BER, which is a critical factor for the quality of data transmission in optical communication systems.

By analyzing the signal-to-noise ratio (SNR) across different scenarios, the paper provides valuable insights into how atmospheric factors such as fog, rain, and other weather-related variables can influence the efficiency of FSO systems. Additionally, the research incorporates a correlational study to explore the relationships between BER, SNR, distance, and visibility, offering a nuanced understanding of the trade-offs involved in choosing a particular modulation strategy for FSO communication. This analysis is vital for designers and engineers in optimizing FSO systems to achieve the best possible performance, even under challenging environmental conditions.

2.5 Jurado-Navas, A., González Serrato, N., et al: "Error Probability Analysis of OOK and Variable Weight MPPM Coding Schemes for Underwater Optical Communication Systems Affected by Salinity Turbulence" (2018)

The paper published in OSA Continuum investigates the robustness and efficiency of two key modulation techniques—On-Off Keying (OOK) and Variable Weight Multi-Pulse Pulse Position Modulation (VW-MPPM)—in underwater optical communication systems (UWOC). The focus is specifically on how these systems are impacted by the unique challenge of salinity-induced turbulence, which can significantly affect signal integrity and communication reliability.

The research systematically analyzes the error probabilities associated with each modulation scheme under varying conditions of salinity turbulence, a factor that induces fluctuations in the refractive index of water and thereby affects the propagation of light. By employing a combination of theoretical models and simulation-based approaches, the study aims to quantify the performance degradation that occurs in UWOC systems operating in environments with different salinity levels. This analysis is critical because it directly addresses the trade-offs between communication efficiency (throughput) and reliability (error rate) in challenging underwater settings.

Key findings from the paper suggest that variable weight MPPM, which allows flexibility in the number of pulses and their positions within a given time frame, tends to offer better resilience against the effects of salinity turbulence compared to the more straightforward OOK scheme. This is attributed to the inherent redundancy and error correction capabilities of the MPPM scheme, which can be adapted dynamically based on the prevailing environmental conditions. The insights provided by this research are particularly valuable for the design and optimization of UWOC systems, where the operational environment can vary significantly. Such systems are increasingly relevant for a range of applications, including underwater sensor networks, communication between submerged vehicles, and data exchange with offshore installations. By enhancing our understanding of how different coding schemes perform under specific environmental impacts, this paper contributes to the development of more reliable and effective communication strategies for underwater environments.

2.6 Khalighi, C. Gabriel, and V. Rigaud, "Optical communication system for an underwater wireless sensor network," EGU General Assembly 14, 2685 (2012).

This study focuses on enhancing the capabilities and performance of underwater wireless sensor networks (UWSNs) through the application of optical communication technology. This research is crucial due to the increasing demand for reliable and efficient communication systems in underwater environments, where traditional acoustic and RF communication methods face significant limitations such as high latency, low bandwidth, and susceptibility to interference.

The paper provides an in-depth analysis of the design, implementation, and testing of an optical communication system specifically tailored for UWSNs. The primary objective is to overcome the challenges associated with underwater communication, such as high attenuation, scattering by particulates, and absorption of light. By leveraging the properties of optical waves, the system aims to offer higher data rates and lower latency compared to conventional methods, thus improving the efficiency of data transfer between sensors in the network. Key components of the research include the development of suitable modulation techniques, efficient encoding schemes, and the integration of advanced optical components such as lasers and photodetectors that are optimized for underwater conditions. The system's architecture is designed to ensure robustness against environmental disturbances and to facilitate scalable deployment of sensors over large areas.

Experimental results presented in the paper demonstrate the feasibility of using optical communication for UWSNs, showing promising improvements in transmission speed and reliability. The study also discusses various deployment scenarios, addressing the practical aspects of installing and maintaining an optical UWSN in challenging underwater environments.

Additionally, the research explores potential applications of optical UWSNs in fields like oceanography, environmental monitoring, and maritime security. The ability to transmit high-resolution data in real-time could significantly enhance operational capabilities in these areas, providing timely and accurate information for decision-making.

3. METHODOLOGY

3.1 ON OFF KEYING MODULATION(OOK)

On-off key (OOK) modulation is a modulation technique that represents digital data as the presence or absence of a carrier wave. It is a simplification of amplitude shift keying (ASK), a popular technique used in digital data communication. In OOK modulation, the source sends no carrier when it wants to send a "0". The presence of a carrier for a specific duration represents a binary one, while its absence for the same duration represents a binary zero.

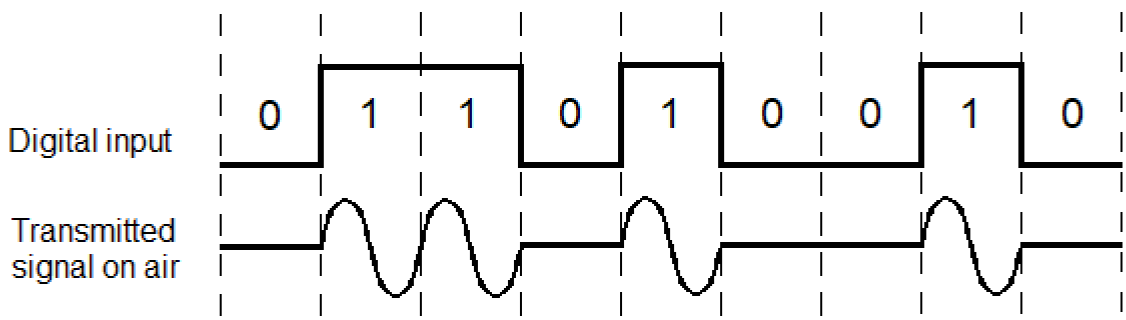

Fig. 3.1 Waveform for OOK Modulation

3.2 PULSE-POSITION MODULATION(PPM)

Pulse Position Modulation (PPM) is a signal modulation technique that encodes information by shifting the timing or position of pulses relative to a reference point. The position of the shifted pulse within a predefined time slot determines the transmitted data. PPM is an analog modulation system where the amplitude and breadth of the pulse remain constant, while the position of the pulse varies depending on the instantaneous value of the message signal.

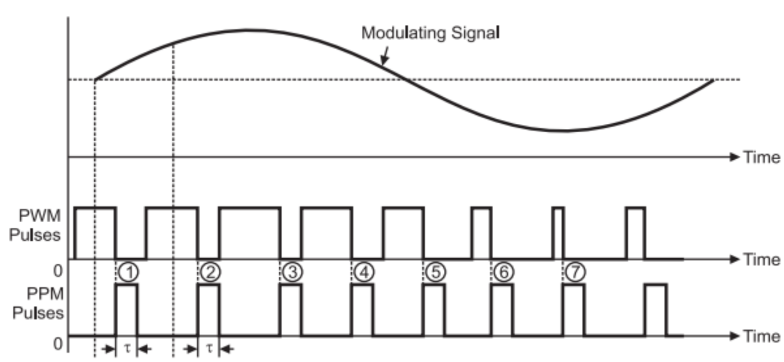

Fig. 3.3 Waveform for PPM Modulation

3.3 SIGNAL TO NOISE RATIO(SNR)

In analog and digital communications, a signal-to-noise ratio, often written S/N or SNR, is a measure of the strength of the desired signal relative to background noise (undesired signal). SNR can be determined by using a fixed formula that compares the two levels and returns the ratio, which shows whether the noise level is impacting the desired signal. The ratio is typically expressed as a single numeric value in decibels (dB). The ratio can be zero, a positive number or a negative number. A signal-to-noise ratio over 0 dB indicates that the signal level is greater than the noise level. The higher the ratio, the better the signal quality.

3.4 BIT ERROR RATE(BER)

In analog and digital communications, bit error rate (BER) is a measure of how many bits are received incorrectly out of the total number of bits transmitted. It's a key performance parameter for digital communication systems. A high BER means that more data needs to be retransmitted due to errors, which can negatively impact signal quality. For example, a BER of 10^{-6} means that one bit in every 1,000,000 transmitted bits is in error.

3.5 CHANNEL MODEL

In optical communication a channel model is a mathematical representation of the effects of a communication channel through which wireless signals are propagated. The channel model can represent the power loss incurred by the signal as it travels through the wireless medium. In a more general case, the channel model is the impulse response of the channel medium in the time domain or its Fourier transform in the frequency domain. The channel impulse response of a wireless communication system typically varies randomly over time.

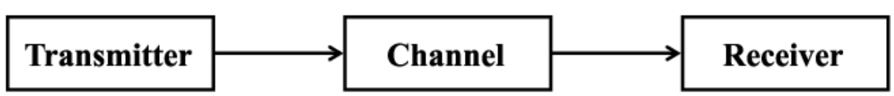

Fig. 3.4 Channel Model

3.6 SYSTEM MODEL

An optical communication system uses a transmitter, channel, and receiver to encode, carry, and reproduce a message using an optical signal. The transmitter encodes a message into an optical signal, the channel carries the signal to the destination, and the receiver reproduces the message from the received optical signal.

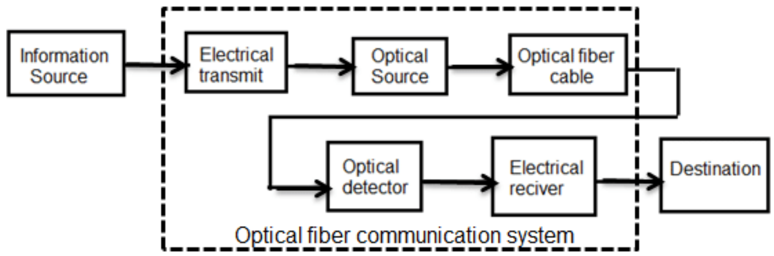

Fig. 3.5 System Model

4. EMBODIMENT AND DETAILED DESIGN

4.1 WORKING PRINCIPLE

The amplified signal is then fed to a Laser diode which converts the electrical signal into a light signal and transmits it into free space. The transmitter attains modulation of the Laser signal which acts as a carrier by the modulating signal from condenser mic or audio jack input.

4.2 BLOCK DIAGRAM

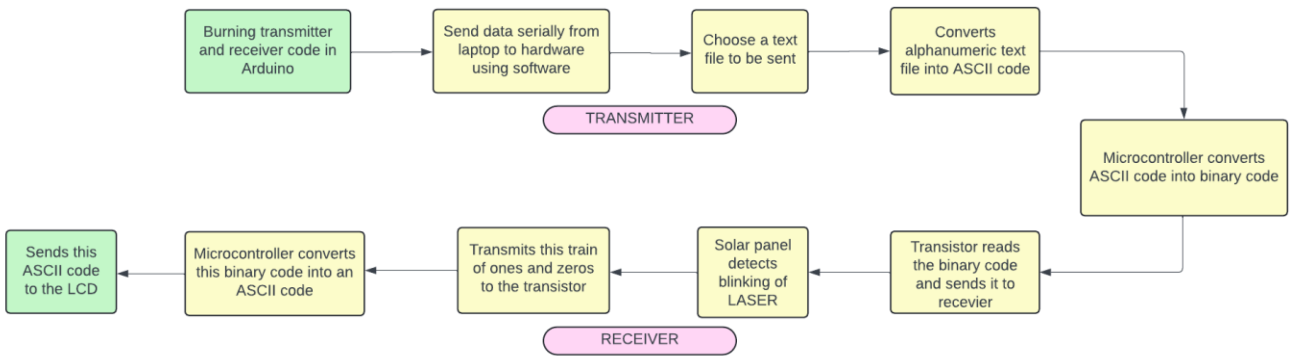

Fig. 4.1 Block Diagram

4.3 SHORTLISTING OF DESIGNS

We have our aim defined that we want to work with LASER but as this technology is not well developed, we went through so many models and failures of design to come up with a final model.

1. **Sound Transmission**

   We brainstormed about using sound as our form of data. We collected all the components - Speaker, aux cable, solar panel and Laser light. We made the circuit and try to transfer to sound but there was a lot of noise and 17 interruptions. We thought of possible errors and after discussing and brainstorming we found out that we need solar panels of less voltage compared to what we have.

2. **Text Transmission**

   After enough experimentation we finally consider text as out form of data transfer. We read the documentation available and then come up with a simple model. We made an app for the same for light transmission to LDR, then data is processed by Arduino uno and output is available on the LCD screen.

3. **Image Transmission**

   After text transmission we moved to image transmission and made our final model.

4.4 COMPONENTS

1. **LASER**

   A laser is a device that emits light through a process called Light Amplification by Stimulated Emission of Radiation (LASER). Lasers are electromagnetic machines that produce weak, coherent electromagnetic radiation through optical amplification.

Fig. 4.2 Laser

2. **Solar Panel**

   Solar panel is an assembly of photovoltaic cells mounted in a framework for generating energy. The solar panel is used as light receiver.

Fig. 4.3 Solar Panel

3. **LM2596 Buck Converter**

The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. It is used for lowering the voltage level from 12V to 5V because the voltage requirement for a microcontroller is 5V.

Fig. 4.4 LM2596 Buck Converter

4. **ARDUINO NANO CH340G**

Based on the AT mega 328P, 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 price of the Arduino Nano CH340 is less than the Arduino Nano with the FTDI USB-Serial Chip used in earlier versions of the Arduino Nano. Based on the ATmega328, the Arduino Nano is a compact, comprehensive, and breadboard-friendly board (Arduino Nano 3. x).

Fig. 4.5 Arduino Nano CH340G

5. **Potentiometer**

Potentiometer A potentiometer is a three- terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

Fig. 4.6 Potentiometer

6. Transistor

A semiconductor device known as a transistor can be used to conduct and insulate electric current or voltage. In essence, a transistor serves as both a switch and an amplifier. A transistor is a tiny device that is used to regulate or control the flow of electronic impulses, to put it simply.

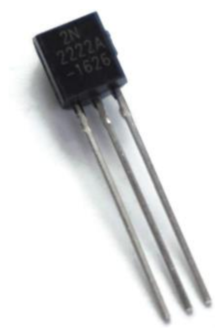

Fig. 4.7 Transistor

7. Push Button

Push button is a simple switch mechanism to control some aspect of a machine or a process. We used two push buttons, one for transmission of image and other for transmission of text.

Fig. 4.8 Push Button

8. 16 x 2 LCD Screen (JHD162A)

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols.

Fig. 4.9 LCD Screen

9. Graphical LCD

A Graphic LCD display is just as its name implies. This LCD module is able to display images, letters and numbers that are generated through the customer's software. Dot Matrix displays are identified by two sets of numbers. An example of this is a 128 x 64.

Fig. 4.10 Graphical LCD

10. 6” x 4” PCB

General purpose prototyping board, commonly known as Vero Board or Zero PCB. This product is of size 6 inches by 4 inches. It has hole spacing of standard 2.54mm. The solder pads are tin coated which makes it soldering friendly.

Fig. 4.11 PCB

11. 12V/2A DC Power Supply

Unregulated 12VDC power supplies are basic power supplies with an AC input and an unregulated 12VDC output. The output voltage changes with the input voltage and load.

Fig. 4.12 Power Supply

4.5 PIN CONFIGURATIONS

1. Arduino Nano

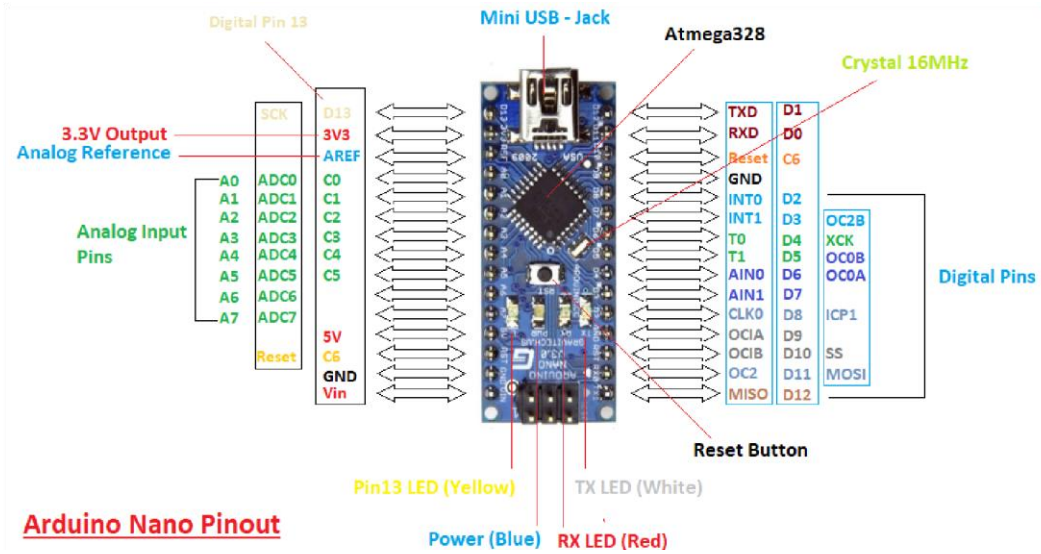

Fig. 4.13 Pin Configuration for Arduino Nano

2. 16 x 2 LCD Screen (JHD162A)

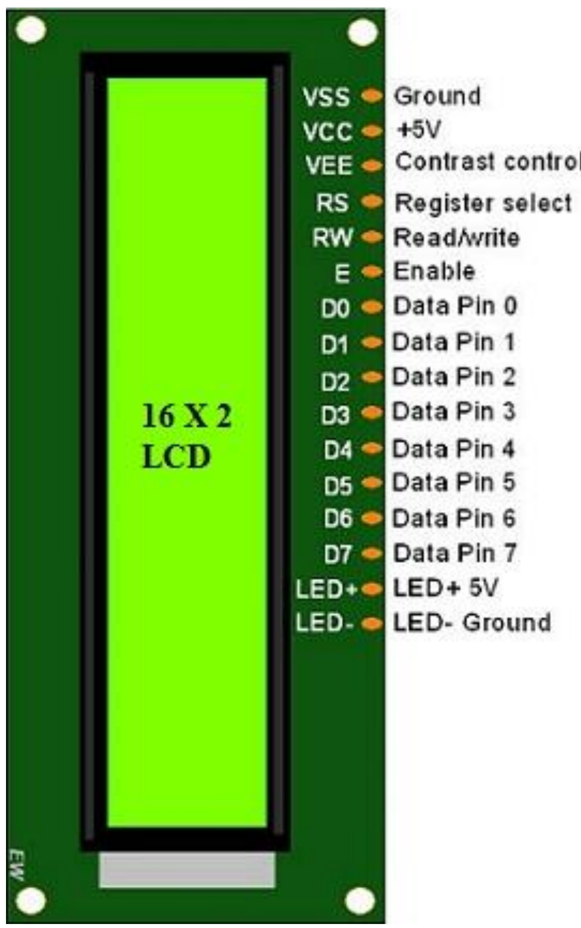

Fig. 4.14 Pin Configuration for 16x2 LCD

Pin No	Symbol	Description	Function
1	VSS	Ground	0V(GND)
2	VCC	Power supply for logic circuit	+5V
3	VEE	LCD contrast adjustment	
4	RS	Instruction/Data	RS=0: Instruction Register RS=1: Data register
5	R/W	Read/Write selection	R/W=0: Register Write R/W=1: Register Read
6	E	Enable signal	
7 8 9 10 11 12 13 14	DB0 DB1 DB2 DB3 DB4 DB5 DB6 DB7	Data Input/Output Lines	8 bits:DB0-DB7
15	LASER+	Supply voltage for LASER+	+5V
16	LASER-	Supply voltage for LASER-	0V

Table. 4.1 Pin Configuration for 16x2 LCD

4.6 SCHEMATIC

- **Transmitter Circuit**

  Transmitter circuit consists of LASER for transmitting light signals processed by a microprocessor board. The push buttons control the transmission of image and text respectively. We used the Ac to DC buck converter for converting the 12V coming from 12V/2A DC power supply to 5V as per the circuit requirement.

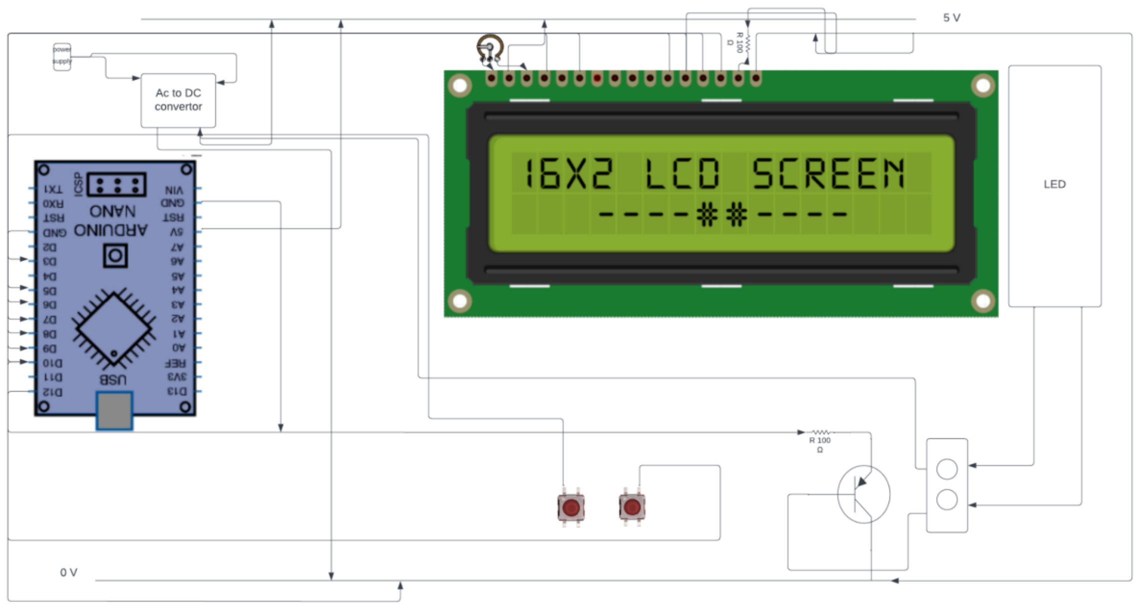

Fig. 4.15 Circuit Diagram of Transmitter

- **Receiver Circuit**

  Receiver is consisting of the solar panel for receiving the light signal coming from the LASER. We used a potentiometer for voltage regulation in the circuit. The resistor in the circuit is used to control the current level in the circuit. It lower down the value of the current. The graphical LCD 128 x 64 is used for displaying the text and image. The whole graphical LCD is working as a matrix of size 128 X 64 and we can regulate each pixel for the display of images and text.

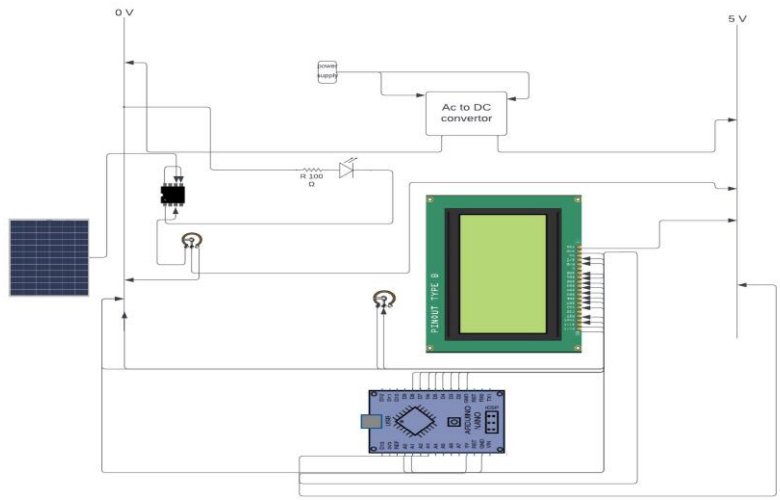

Fig. 4.16 Circuit Diagram of Receiver

4.7 HARDWARE ASPECT

1. The There is a solar panel and a LASER transmitter, as is evident (light emitter). By varying the pace at which the LASER flash "on" and "off," to form various strings of 1s and 0s, respectively, the data that we enter into the LASER transmitter is encrypted into the light. The on and off activity of LASER transmitters appears invisible to humans because the light's intensity varies so quickly that a normal human eye cannot notice it. When the LASER switch is turned ON, the binary code is "1," but when it is turned OFF, the binary code is "0." We can encrypt our information in the light by varying how quickly the transmitter turns on and off.
2. The receiver, which is a solar panel on the receiving end, receives the data from the LASER transmitter (light emitter), which is connected to the data network. The data is received as a light signal by the light sensor, which decrypts it before sending it to the receiver-connected device where it is displayed.
3. As the solar panel receives the data in the form of light signals, the photodiode converts light signals into electrical signals because the signal needs to be processed.
4. The Arduino performs signal processing, allowing us to simply alter the amount of current produced by the photodiode by varying the amount of lightning. When 0 volts are applied to the pin, we read 0 and this situation takes place when the light is extremely dim, and vice versa.
5. After that signal processing is done Arduino will further send the data to the LCD.

4.8 SOFTWARE ASPECT

We used coolterm software for converting the data into binary form so that we can transmit the data as 0's and 1's. We designed an app through which we can transmit the message from our phone. We named our application as LiFiVerse.

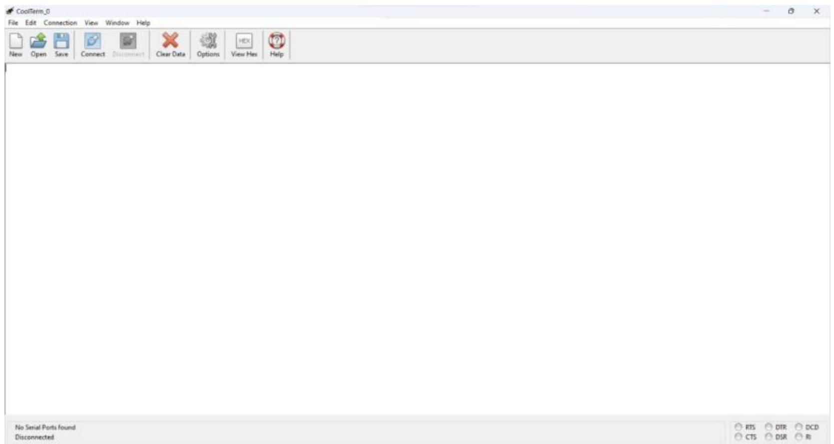

Fig. 4.17 Software

CoolTerm Software

CoolTerm is a simple serial port terminal application (no terminal emulation) that is geared towards hobbyists and professionals with a need to exchange data with hardware connected to serial ports such as servo controllers, robotic kits, GPS receivers, microcontrollers, etc. We use this to transfer our binary number string generated from ASCII code of text and image to our Arduino.

4.9 WORKING

- **Transmitter Circuit**

  The transmitter section comprises a keyboard connected with a PS2 connector and interfaced directly with microcontroller IC AT89S52. IC AT89S52 also referred to as 8051, is a 40 pin IC, used to provide serial data communication. A crystal oscillator with a frequency of 11.0592 MHz is used to provide the desired clock frequency to the microcontroller for its working. Two paper capacitors of 27 pf are used to stabilize the clock frequency. A 9v dc voltage is provided to the transmitter section with the help of a battery, which is step down to 5v using voltage regulator IC 7805. A capacitor of 10uf and a resistor of 10k ohms are connected with the microcontroller to provide the reset function. Two transistors, one NPN (IC TIP L6 122) and the other PNP (IC BC5578) are together used as a Darlington pair and are used to provide push pull amplification. The output of this transistor pair is connected to a LASER. A green led is used which glows if the caps lock key is on. The keyboard can be used to send alphanumeric data. The spacebar, backspace, delete and enter commands can also be used. If the caps lock key is on then alphabets in the uppercase and special characters (!,@, #, $, %, ^, &, *, (,)) can also be transmitted. When a key is pressed on the keyboard, the ASCII code of that key is sent directly to the microcontroller. The microcontroller converts the ASCII code into binary and sends this data to the transistor pair. The PNP transistor works at off state i.e. it reads zero in the binary code, while the NPN transistor works at on 30 states i.e. it reads one in the binary code. This transistor pair then sends the binary pulse containing zeros and ones to the led torch. The LASER is on when it reads a one and is off when it reads a zero. The blinking of LASER is so fast that it cannot be detected by a human eye.

- **Receiver Circuit**

  The receiver section comprises a photodiode connected to the PNP transistor (IC BC 5578). A 9v battery is attached to the circuit to provide the power supply. A voltage regulator IC 7805 is used to step down the 9v dc supply to 5v dc supply for the working of the microcontroller AT89S52. The microcontroller is connected with a crystal oscillator of 11.0592 MHz to provide the clock frequency, along with two paper capacitors of 27pf to stabilize this frequency. A 10 uf capacitor is also connected to the microcontroller to provide the reset function. A button switch is used to provide the manual reset function. The microcontroller is interfaced with the 16x2 LCD to display the data that is sent by the transmitter. The light from the LASER is made to fall on the photodiode. The photodiode detects the blinking of the led, and transmits this train of ones and zeros to the transistor. The PNP transistor is in one state when a zero is detected by it and is in off state when a one is detected. This on and off state of the transistor is read by the microcontroller and it converts this binary code formed as a result of on and off, into an ASCII code. The microcontroller then sends this ASCII code to the 16x2 LCD for display, which is directly interfaced with the microcontroller.

5.RESEARCH PAPER

Bit Error Rate performance and analysis on different modulation schemes under Malaga distribution considering atmospheric attenuation and pointing errors

5.1 GENERAL REVIEW

We have a research paper under review with the title "*Bit Error Rate performance and analysis on different modulation schemes under Malaga distribution considering atmospheric attenuation and pointing errors*". This paper explains about the effects of turbulence on Malaga across different modulation techniques.

5.2 INTRODUCTION

We In the realm of underwater communication, the demand for high-data-rate capabilities has become increasingly pivotal across various applications such as offshore exploration, environmental monitoring, and military operations. Underwater Optical Communication (UWOC) has emerged as a promising solution, offering the potential for enhanced data rates and heightened communication security. We consider two modulation techniques for UWOC systems: On-Off Key (OOK), Pulse Position Modulation (PPM). These modulation schemes offer different trade-offs in terms of spectral efficiency, complexity, and resilience to channel impairments. By comparing the performance of these modulation techniques under turbulent underwater conditions, we aim to identify the most suitable scheme for UWOC applications. To address these challenges comprehensively, this study introduces a novel approach towards the Malaga distributions equations. These distributions provide a more accurate representation of fading effects induced by environmental factors such as salinity, temperature, bubbles, and turbidity. This approach not only aligns with the pursuit of higher data rates but also contributes to the broader goal of establishing reliable and secure communication in challenging underwater scenarios. The subsequent exploration and validation of these techniques through Monte-Carlo simulations provide insights crucial for the practical implementation of UWOC systems in real-world scenarios.

5.3 FSO CHANNEL MODEL

The current study examines the optical channel model denoted as I_m, which is expressed as the product of three components: atmospheric loss(I_l), atmospheric turbulence (I_a), atmospheric turbulence(I_p). This relationship is described by Equation

$$I_m = I_l * I_a * I_p \qquad (1)$$

5.4 ATMOSPHERIC LOSS

Here, I_l signifies atmospheric loss, I_a represents atmospheric turbulence, I_p stands for pointing errors. The term I_l represents atmospheric loss, which is modeled using Beer-Lambert's law as indicated in reference Table 5.1. The expression for I_l is given by equation

$$I_l = e^{-\sigma L} \qquad (2)$$

Here, σ denotes the attenuation coefficient, and L signifies the link length. The value of σ, dependent on various weather conditions at a wavelength of 630 nm is chosen and values adopted can be found in Table 5.1. For this calculation, the link length is assumed to be 1 km.

Weather condition	**Attenuation σ (dB/KM)**
Very clear air	0.0647
Haze	0.7360
Light fog	4.285

Table. 5.1 Attenuation coefficients for different weather conditions

5.5 ATMOSPHERIC TURBULANCE INDUCED FADING

It addresses the impact of misalignment errors between the transmitter and receiver, referred to as pointing errors, which are crucial to mitigate for efficient FSO systems. The model described below encompasses three optical beam components: (A) the line of sight (LOS) component with power Ω, (B) the scattered component coupled to the LOS component with power $2pb_0$., and (C) the scattered component independent of the previous components with power $2(1-\rho)b_0$. Thus, the total power of the scattered components amounts to $2b_0$. The parameter q signifies the degree of coupling between the scattered and LOS components

where

$$f_{I_m}(I_m) = A_m \sum_{k=1}^{b} a_{K_m} I_m^{\frac{a_{m+K}}{2}-1} K_{a_m-k}\left[2\sqrt{\frac{\alpha_m\beta_m I_m}{\gamma\beta_m+\Omega}}\right] \quad (3)$$

$$A_m = \frac{2\alpha_m^{\frac{\alpha_m}{2}}}{\gamma^{1+\frac{\alpha_m}{2}}\Gamma(\alpha_m)}\left(\frac{\gamma\beta_m}{\gamma\beta_m+\Omega'}\right)^{\beta_m+\frac{\alpha_m}{2}} \quad (4)$$

$$a_{K_m} = \begin{bmatrix}\beta_m - 1\\ K-1\end{bmatrix}\left[\frac{\gamma\beta_m+\Omega'}{K-1!}\right]^{1-\frac{K}{2}}\left[\frac{\Omega'}{\gamma}\right]^{K-1}\left[\frac{\alpha_m}{\beta_m}\right]^{\frac{K}{2}} \quad (5)$$

The parameter α_m is a positive value associated with the effective number of large-scale cells in the scattering process, while β_m is a natural number. Although a generalized expression for β_m as a real number can be derived using an infinite summation, it is less favored due to the high degree of freedom of the proposed distribution. The PDF (Probability Density Function) demonstrates excellent agreement with the data owing to its simple functional form, particularly emphasized by the fact that β_m is a natural number, enabling a closed-form representation. This characteristic is particularly advantageous for practical applications, where β_m represents the fading parameter. For simplicity, we denote $\gamma = 2(1-\rho)\,\beta_0$. Lastly, the parameter

$$\Omega' = \Omega + 2\rho b_0 + 2\sqrt{2b_0\Omega\rho}\cos(\emptyset_A - \emptyset_B) \quad (6)$$

signifies the average power from the coherent contributions. Here, $\emptyset_A$ and $\emptyset_B$ denote the deterministic phases of the LOS and the scattered components coupled to the LOS, respectively.

5.6 POINTING ERRORS

In Free-Space Optical (FSO) communication systems, the alignment accuracy between the transmitter and receiver is crucial for determining the link's performance and reliability. Yet, misalignment issues arise from various factors such as the sway of buildings due to wind loads, thermal expansion, and minor seismic activities, leading to pointing errors and signal fading at the receiver. Pointing errors are represented by I_p, which will be elaborated upon below

$$f_{I_p} = \frac{g^2}{A_0^{g^2}} (\, I_{\,p})^{\, g^2-1}, 0 \leq I_{\,p} \leq A_0 \qquad (7)$$

where $A_0 = [\mathrm{erf(v)}]^2$ is the fraction of the collected optical power with v $= \sqrt{\frac{\pi}{2}}\frac{a}{w_z}$, a denotes the radius of the receiver and w_z is the beam width at the distance L. The effective beam width is given by the expression $w_{zeq} = \left[\frac{\sqrt{\pi} ef(v) w_z^2}{2ve^{-v^2}}\right]^{\frac{1}{2}}$ where $g_m = \frac{w_{zeq}}{2\sigma}$ is the ratio between the effective beam width and the jitter standard deviation σ_s.

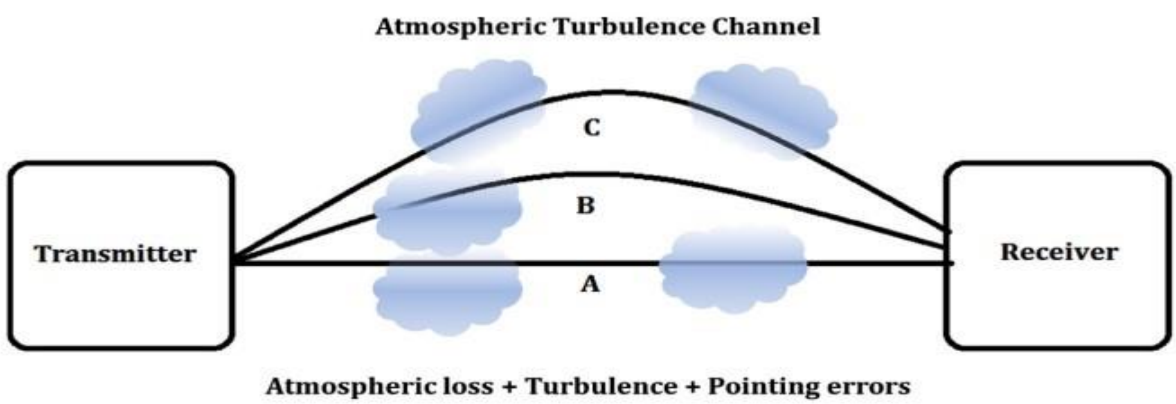

Fig. 5.1 Channel Model

5.7 SYSTEM MODEL

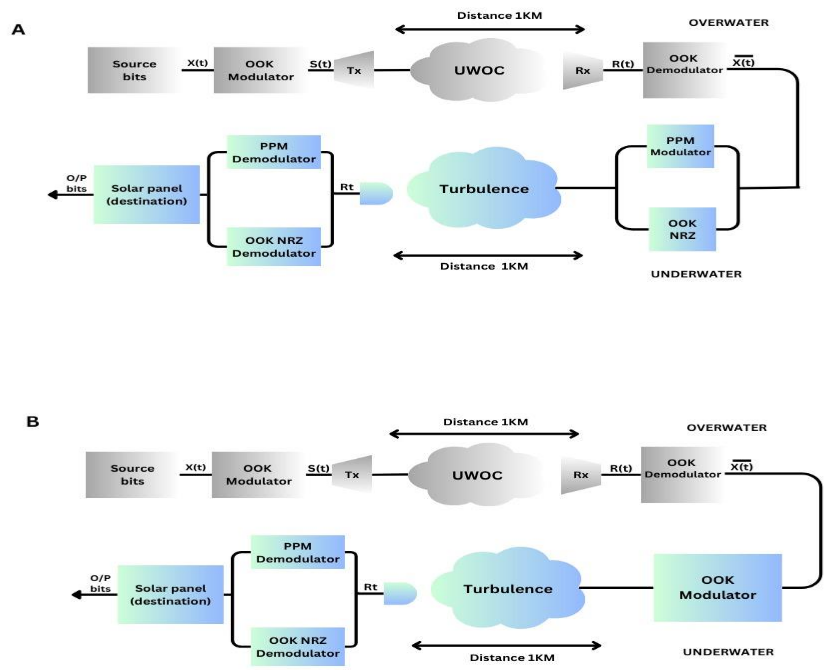

Fig. 5.2 System Model

The BER performance of a UWOC system in underwater medium is investigated and results are derived only in terms of wide range turbulence effect. The received signal (current in the output of the load resistance) for an optical wireless communication (OWC) system using intensity-modulated/direct detection (IM/DD) implementation and on-off-keying (OOK) and pulse position modulation (PPM) scheme can be modeled as

$$\boldsymbol{y}(\boldsymbol{t}) = \boldsymbol{h}\,\boldsymbol{x}(\boldsymbol{t}) + \boldsymbol{n_0}(\boldsymbol{t}) \qquad (8)$$

The equation represents the output of a photodetector in a communication system, where the output depends on various factors such as the received optical power, data symbols, pulse shape, and channel conditions. Specifically, it describes how the photodetector responds to the incoming optical signal, taking into account the data symbols, their timing, and the effects of underwater turbulence and additive noise.

5.8 TURBULENCE MODEL

Turbulence models often utilize probability distribution functions (pdf) to characterize these fluctuations, with prominent distributions including the Log-Normal, K-distribution, and Gamma–Gamma distribution. The Log-Normal distribution is commonly employed for characterizing weak oceanic turbulence, while the K-distribution finds application in strong atmospheric turbulence scenarios. The Gamma–Gamma distribution is versatile, capable of describing moderate to strong turbulence states, making it widely adopted in underwater communication models. A more recent entrant in this domain is the Malaga distribution. The Malaga equation is expressed as follows

$$f_1(I) = A * \sum_{m=1}^{\beta} [a_m * I_a * K(\alpha - m)\left(2 * \left(\sqrt{\frac{\alpha\beta I_a}{g\beta+\Omega'}}\right)\right) \quad (9)$$

Where

$$A \triangleq \frac{2\alpha^{\frac{\alpha}{2}}}{g^{1+\frac{\alpha}{2}}\Gamma(\alpha)} [\frac{g\beta}{g\beta+\Omega'}]^{\beta+\frac{\alpha}{2}} \quad (10)$$

$$a_m \triangleq \begin{bmatrix} \beta - 1 \\ m - 1 \end{bmatrix} \frac{(g\beta + \Omega')^{1-m/2}}{(m-1)!} \left[\frac{\Omega'}{g}\right]^{m-1[} \frac{\alpha}{\beta}]^{m/2} \quad (11)$$

α is a positive parameter related to the effective number of large-scale cells and β is the amount of fading parameter and is a natural number.

5.9 EQUATIONS FOR BIT ERROR RATE

$$f_1(I) = A * \sum_{m=1}^{\beta} [a_m * I_a * K(\alpha - m)\left(2 * \left(\sqrt{\frac{\alpha\beta I_a}{g\beta+\Omega'}}\right)\right) \quad (12)$$

$$A \triangleq \frac{2\alpha^{\frac{\alpha}{2}}}{g^{1+\frac{\alpha}{2}}\Gamma(\alpha)} [\frac{g\beta}{g\beta+\Omega'}]^{\beta+\frac{\alpha}{2}} \quad (13)$$

$$a_m \triangleq \begin{bmatrix} \beta - 1 \\ m - 1 \end{bmatrix} \frac{(g\beta + \Omega')^{1-m/2}}{(m-1)!} \left[\frac{\Omega'}{g}\right]^{m-1[} \frac{\alpha}{\beta}]^{m/2} \quad (14)$$

5.10 AVERAGE BIT ERROR RATE FOR OOK MODULATION

The analytical expression for the Average Bit Error Rate (ABER) in an Underwater Optical Communication (UWOC) system employing Intensity Modulation/Direct Detection (IM/DD) and On-Off Keying (OOK) signaling is derived. Initially, the Conditional Bit Error Rate (CBER) is computed for a specific Electrical Signal-to-Noise Ratio (SNR) under ideal conditions, assuming an Additive White Gaussian Noise (AWGN) channel and the absence of turbulence (referred to as SNR0). This analysis considers each transmitted symbol as equally likely, and the conditional bit error probabilities for transmitted "0" and "1" bits are assumed to be equal. The CBER for IM/DD with an AWGN channel using OOK modulation is expressed accordingly.

$$P_b(e|b) = \frac{1}{2} erfc\left(\frac{is_0 I}{2\sqrt{2\sigma_N}}\right) = \frac{1}{2} erfc\left(\frac{SNR_0 I}{2\sqrt{2}}\right) \qquad (15)$$

Therefore, the ABER, P_b(e), can be obtained by averaging P_b(e| I) over the PDF of the irradiance, f_1(I). Hence:

$$P_b = \int_0^{\infty} \frac{1}{2} erfc\left(\frac{SNR_0 I}{2\sqrt{2}}\right) f_1(\mathrm{I})\mathrm{dI} \qquad (16)$$

Multiplying equation (9) and (16) we get: To multiply the expression, distribute the multiplication across the terms.

$$\int_0^{\infty} A * \sum_{m=1}^{\beta}[a_m * I_a * K(\alpha - m)]\left(2 * \left(\sqrt{\frac{\alpha\beta I_a}{g\beta+\Omega'}}\right)\right) * (\int_0^{\infty} \frac{1}{2} erfc\left(\frac{SNR_0 I}{2\sqrt{2}}\right)] f_1(I)dI \qquad (17)$$

Multiplying the equation we get:

$$P_b = \int_0^{\infty} A * \sum_{m=1}^{\beta}[a_m * I_a * K(\alpha - m)\left(2 * \left(\sqrt{\frac{\alpha\beta I_a}{g\beta+\Omega'}}\right)\right) * \int_0^{\infty}[\frac{1}{2} erfc\left(\frac{SNR_0 I}{2\sqrt{2}}\right)] f_1(I) \qquad (18)$$

Here we use the Meijer-G function to replace the error function from the Eqn. (18)

$$erfc(x) = \left(G\,^{1,1}_{1,2}\right)\left(x^2 \middle|\, {}^{1}_{\left(\frac{1}{2}\right),0}\right) \qquad (19)$$

Equating Equation (19) in Equation (18) we get the equation for Malaga as:

$$P_b = A * \sum_{m=1}^{\beta} [a_m * I_a * K(\alpha - m)(2 * \left(\sqrt{\frac{\alpha\beta I_a}{g\beta + \Omega'}}\right)) * \left(\frac{1}{2}\right) * \left(G\,^{1,1}_{1,2}\right) \left(\frac{(SNR_0 I)^2}{8}\right) | \left(\begin{smallmatrix} 1 \\ \left(\frac{1}{2}\right), 0 \end{smallmatrix}\right))] \qquad (20)$$

The algorithm of the calculating of integrals

$$\int_0^{\infty} x^{\alpha-1} G^{g\ t}_{u\ v} [\sigma_x \,|\, {}^{(o_u)}_{(d_v)}]\, G^{mn}_{pq} \left[w x^{\frac{l}{k}} \,|\, {}^{(a_p)}_{(b_q)} \right] dz =$$

$$\frac{k^{\mu + \alpha(v-u) - 1} \sigma^{-\alpha}}{(2\pi)^{b^*(l-1) + c^*(k-1)}} G^{km+lt,\, kn+ls}_{kp+lv,\, kq+lu} \left(\frac{w^k k^{k(p-q)}}{\sigma^l\, l^{l(u-v)}} \,\middle|\, \begin{matrix} \Delta(k, a_1), \dots, \Delta(k, a_n), \Delta(l, 1-\alpha-d_1), \dots \Delta(l, 1-\alpha-d_v), \Delta\left\langle {}^{(k, a_{n+1})} \right\rangle, \dots, \Delta(k, a_p) \\ \Delta(k, b_1), \dots, \Delta(k, b_m), \Delta(l-\alpha-c_1), \dots \Delta(l-\alpha-c_u), \Delta\left\langle {}_{(k, b_m)} \right\rangle, \dots, \Delta(k, b_q) \end{matrix} \right) \qquad (21)$$

Where $c^* = m + n - \frac{p+q}{2}$, $\mu = \sum_{j=1}^{p} b_j - \sum_{j=1}^{q} a_j - \frac{p-q}{2} + 1$, $b^* = s + t - \frac{u+v}{2}$,

$$\rho = \sum_{j=1}^{v} b_j - \sum_{j=1}^{u} c_j + \frac{u-v}{2} + 1,\ \Delta(k, a) = \frac{a}{k}, \frac{a+1}{k}, \dots \dots, \frac{a+k-1}{k}, \sigma = \frac{I}{BA_0 I_1},\ c = 1 + g^2, d = g^2, \alpha, k \quad (22)$$

Where u=1, v=3, s=3, t=0, l/k =2, a=1, b=1/2, 0, m = n = p = q = 1

After comparing equation (21) and equation (20) we get:

$$P_b = \frac{g^2 A}{2} \int_0^{\infty} \sum_{k=1}^{\beta} I^{-1} \left[a_k \left[\frac{1}{\beta}\right]^{\frac{\alpha+k}{2}} \right] \frac{2^{\alpha} \frac{I^{-\frac{\alpha+1}{2}}}{BA_0 I_1}}{2\pi} G^{1,7}_{7,4} \left[\frac{\frac{SNR}{8}}{\frac{I^2}{BA_0 I_1} 2^{-4}} \,\middle|\, \begin{matrix} 1, 2, -\left(\frac{\alpha+2+2g^2}{2}\right), \frac{1-3\alpha}{2}, \frac{\alpha+1}{2}, 2, -\left(\frac{\alpha+2K-1}{2}\right) \\ \frac{1}{2}, \frac{3}{2}, 2, -\left(\frac{\alpha+1-2g^2}{2}\right) \end{matrix} \right. \qquad (23)$$

The final equation for OOK modulation is:

$$\boldsymbol{BER_{OOK} = \frac{g^2 A 2^{\alpha} dc}{4\pi BA_0 I_2} I^{-\frac{\alpha+1}{2}} \sum_{k=1}^{\beta} a_k \left(\frac{1}{\beta}\right)^{\frac{\alpha+1}{2}} G^{1,7}_{7,4} \left[\frac{\frac{SNR}{8}}{\frac{I^2}{BA_0 I_1} 2^{-4}} \,\middle|\, \begin{matrix} 1, 2, -\left(\frac{\alpha+2+2g^2}{2}\right), \frac{1-3\alpha}{2}, \frac{\alpha+1}{2}, 2, -\left(\frac{\alpha+2K-1}{2}\right) \\ \frac{1}{2}, \frac{3}{2}, 2, -\left(\frac{\alpha+1-2g^2}{2}\right) \end{matrix} \right]} \qquad (24)$$

5.11 AVERAGE BIT ERROR RATE FOR PPM MODULATION

Bit Error Rate (BER) is a measure of the proportion of erroneous bits received compared to the total number of bits transmitted. It serves as a standardized metric for evaluating the quality of digital communication systems. The value of BER is influenced by factors such as the Signal-to-Noise Ratio (SNR) and the modulation technique employed, reflecting the system's resilience to noise and interference. Pulse Position Modulation (PPM) is a digital modulation technique used in communication systems to encode information in the timing of pulses. Instead of varying the amplitude or frequency of a continuous waveform, PPM encodes data by varying the position of pulses within a fixed time period. There is an advantage in PPM and OOK Modulation in the form of high efficiency of the power used but it has disadvantages in bandwidth.

$$PPM = \frac{1}{2} erfc\ \left(\frac{1}{2\sqrt{2}}\sqrt{SNR}\,\frac{L}{2}\,log2L\right) \tag{25}$$

Multiplying equation (9) with equation (25) we get:

$$\mathrm{BER}_{PPM} = \left(\frac{g^2 A}{2}\int_0^\infty \sum_{k=1}^{\beta} I^{-1}\left[a_k\left[\frac{1}{\beta}\right]^{\frac{\alpha+k}{2}} G_{1,3}^{3,0}\left[\frac{I}{BA_0 I_l}\,\Big|_{g^2,\alpha,k}^{1+g^2}\right]\right]\right) * \left(\frac{1}{2} erfc\left(\frac{1}{2\sqrt{2}}\sqrt{SNR}\,\frac{I}{2}\,log2I\right)\right) \tag{26}$$

To calculate the “I” value refer equation (22)

The final equation for PPM modulation after comparing equation (26) and equation (21) we get:

$$\boldsymbol{BER_{\ PPM}} = \frac{g^2 Acd I^{-\frac{\alpha+1}{2}}}{2BA_0 I_1}\sum_{k=1}^{\beta} a_k\left(\frac{1}{\beta}\right)^{\frac{\alpha+1}{2}} G_{4,2}^{1,4}\left[\frac{\frac{SNR}{8}}{\frac{I}{BA_0 I_1}1^{-2}}\,\Big|_{1,-\left(\frac{\alpha+1+2g^2}{2}\right)}^{0.5,1,-\left(\frac{\alpha+2+2g^2}{2}\right),\frac{1-3\alpha}{2}}\right. \tag{27}$$

6. RESULTS AND DISCUSSIONS

6.1 EXPERIMENTAL RESULTS

This experiment gave us a glimpse into a new technology that will be used for data communication: LASER. In this experiment, alphanumeric data was communicated using a straightforward 8052 microcontroller, which made it possible for the data to be effectively delivered and received. We also came to the conclusion that any LASER with embedded microprocessor functionality might be used for data transmission and reception. Additionally, if the light is visible, an increase or decrease in intensity will not interfere with communication between the transmitter and receiver. However, data transfer is not possible when a barrier stands between the light and the photodiode. Therefore, clear lighting is necessary for ongoing conversation. Although this technology cannot transmit over opaque or solid objects, it can still be advantageous because it is more secure and safer than WIFI because data theft is not a concern. The goal of the project is to create a straightforward and inexpensive data communication system that sends numeric data and supports audio communication utilizing LASER, DTMF transmitter and receiver, LCD, and ATMEGA-8 microcontroller units. The project module is now designed to read numeric data and special characters *, # and enable audio communication, but it can be further improved to read alpha-numeric data and to enable video communication via a camera or other digital device. There are several options that can be investigated further. If this technology can be implemented practically, every LASER could be utilized as a Wi-Fi hotspot to send wireless data, and we would be moving toward a future that is cleaner, greener, safer, and brighter. Li-Fi is a notion that is now generating a lot of interest, not least because it might provide a true and highly effective replacement for radio-based wireless. The airways are getting increasingly congested as more people and their numerous devices use wireless internet, making it harder and harder to receive a dependable, high-speed connection. This may address difficulties like the lack of radio-frequency bandwidth and provide internet access in places where conventional radio-based wireless is prohibited, such airplanes and hospitals. However, one drawback is that it only functions in a straight line of sight.

6.2 RESEARCH PAPER RESULTS

- **OOK MODULATION IN DIFFERENT TURBULANCES**

The below figure shows the bit-error rate (BER) plotted against the signal-to-noise ratio (SNR) for on-off keying (OOK) modulation for different turbulence levels (Strong, Moderate and weak turbulence levels) using equation (24). These four situations are described in from experimental measurements. The Monte Carlo simulations for each turbulence condition are also plotted. The values for strong turbulence: $\alpha = 1,\ \beta = 2,\ k = 3,$ for moderate turbulence: $\alpha = 3.3, \beta = 3, k = 3$ and for week turbulence: $\alpha = 2.5,\ \beta = 1, k = 3$. The x-axis represents the signal-to-noise ratio measured in decibels (dB). The y-axis represents the bit-error rate (BER). The graph shows that the BER decreases as the SNR increases for all turbulence levels. This means that the probability of a bit error goes down as the signal gets stronger relative to the noise. The higher the turbulence, the greater the BER for a given SNR. For example, for SNR = 20dB, the BER is $10^{-20}\ for\ strong\ turbulence, 10^{-18}, 10^{-19}$ for moderate and week turbulence respectively while maintaining the same level of SNR_o. In other words, more turbulence causes a higher probability of bit errors. As a final remark, For ABERs lower than 10^{-1} we observe that the numerical results slightly diverge from analytical results. For Average Bit-Error Rates (ABERs) lower than 10^{-1}, slight divergence between numerical and Monte Carlo results is observed. This indicates that the numerical results deviate slightly from Monte Carlo predictions for very low error rates.

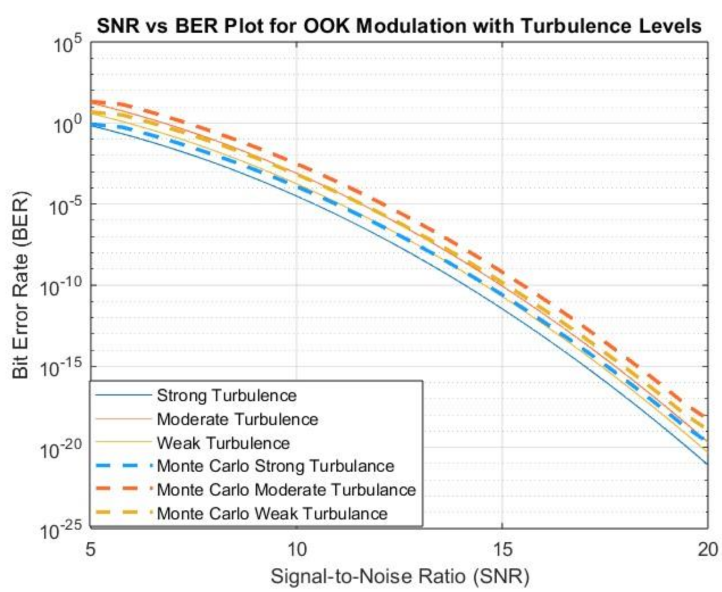

Fig. 6.1 SNR VS BER Plot for OOK Modulation for Different Turbulence Levels

- **OOK MODULATION IN DIFFERENT WEATHER CONDTIONS**

Below figure shows the bit-error rate (BER) plotted against the signal-to-noise ratio (SNR) for on-off keying (OOK) modulation for different weather conditions (clear air, Haze, light fog). The x-axis represents the signal-to-noise ratio measured in decibels (dB). The y-axis represents the bit-error rate (BER). The graph shows that the BER decreases as the SNR increases for all turbulence levels. This means that the probability of a bit error goes down as the signal gets stronger relative to the noise. For example, for SNR = 20dB, the BER is 10^{-2} for Light fog, $10^{-6}, 10^{-7}$ for Haze and clear air respectively while maintaining the same level of SNR_0.

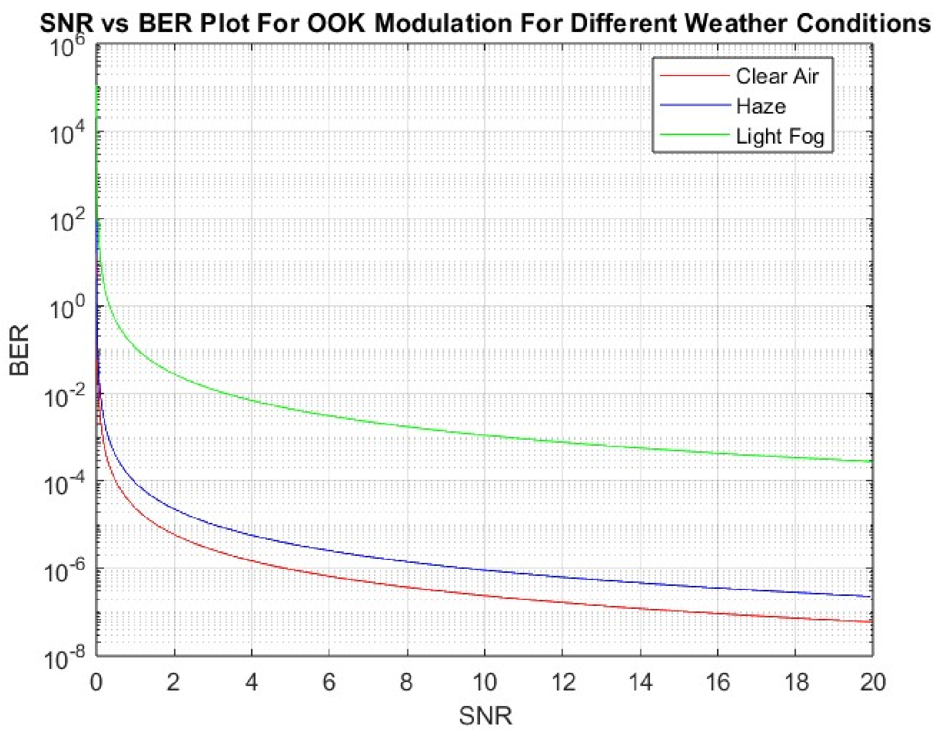

Fig. 6.2 SNR VS BER Plot for OOK Modulation for Different Weather Conditions

- **PPM MODULATION IN DIFFERENT TURBULANCES**

Below graph of the bit-error rate (BER) plotted against the signal-to-noise ratio for PPM modulation for different turbulence levels. The x-axis represents the signal-to-noise ratio measured in decibels (dB). The y-axis represents the bit-error rate (BER). The graph shows three lines, each representing a different level of turbulence: weak, moderate, and strong plotted using eqn (27). The values for strong turbulence: α=1, β=2, k=3, for moderate turbulence: α=3.3, β=3, k=3 and for week turbulence: α=2.5, β=1, k=3. As you can see, for a given SNR, the BER is higher for stronger turbulence levels. This means that the probability of a bit error goes down as the signal gets stronger relative to the noise, and also increases with more turbulence. For example, for SNR = 20dB, the BER is 10^{-33},for strong turbulence, $10^{-27}, 10^{-29}$for moderate and week turbulence respectively while maintaining the same level of SNR_0.. As a final remark, For ABERs lower than 10^{-5} we observe that the numerical results slightly diverge from analytical results. Similar to Figure 6.1, for ABERs lower than 10^{-5}, there is slight divergence between numerical and Monte Carlo results. This divergence suggests that numerical results deviate slightly from Monte Carlo predictions for lower error rates

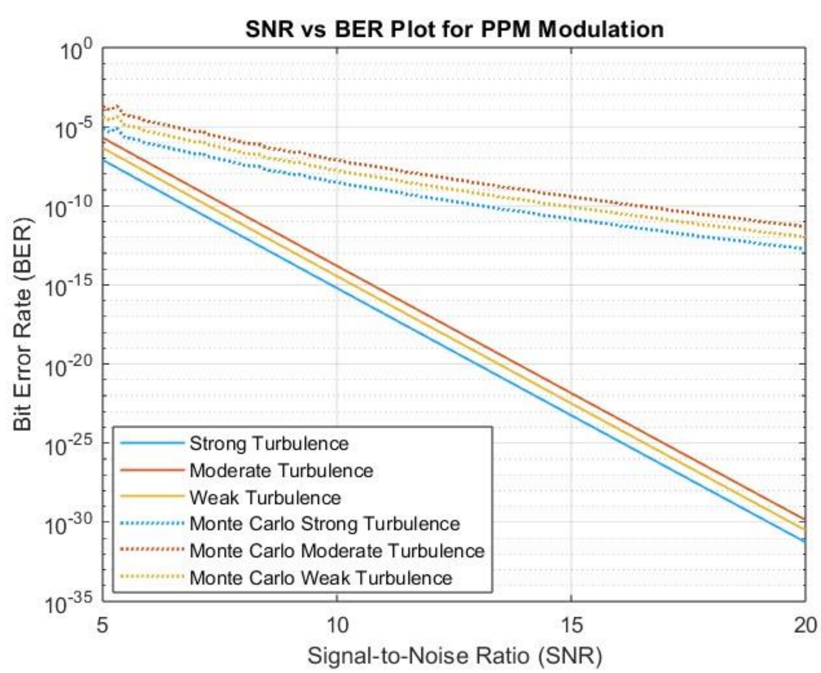

Fig. 6.3 SNR VS BER Plot for PPM Modulation for Different Turbulence Levels

- **PPM MODULATION IN DIFFERENT WEATHER CONDITIONS**

Below graph shows the bit-error rate (BER) plotted against the signal-to-noise ratio (SNR) for on-off keying (OOK) modulation for different weather conditions (clear air, Haze, light fog). The Monte Carlo simulations for each turbulence condition are also plotted. The x-axis represents the signal-to-noise ratio measured in decibels (dB). The y-axis represents the bit-error rate (BER). The graph shows that the BER decreases as the SNR increases for all turbulence levels. This means that the probability of a bit error goes down as the signal gets stronger relative to the noise. For example, for SNR = 20dB, the BER is 10^{-4} for Light fog, 10^{-6}, 10^{-6} for Haze and clear air respectively while maintaining the same level of SNR_o.

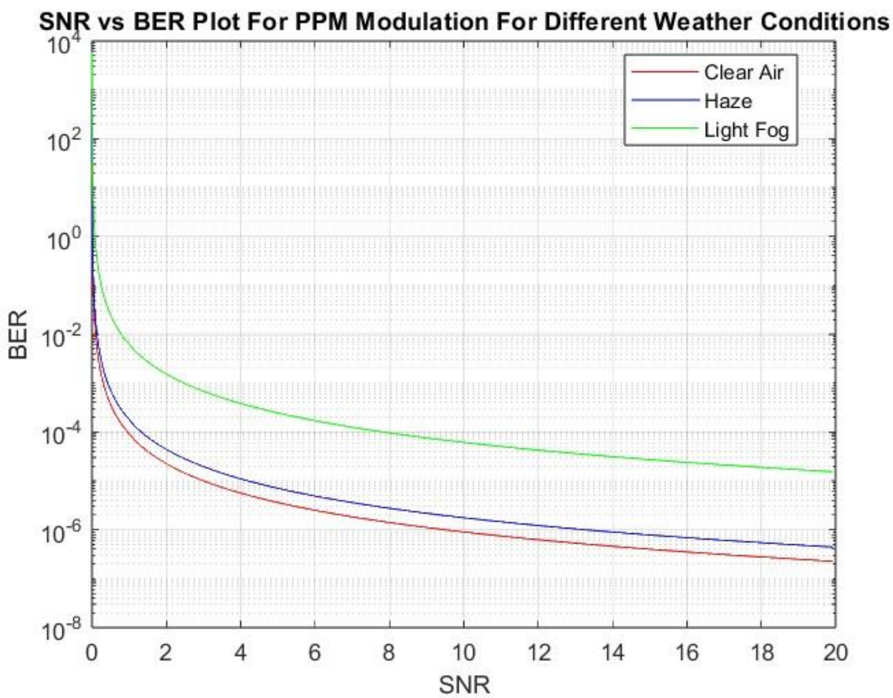

Fig. 6.4 SNR VS BER Plot for PPM Modulation for Different Weather Conditions

- **BIT ERROR RATE IN VARIOUS MODULATION**

Turbulence types	**OOK** (SNR = 20dB)	**PPM** (SNR = 20dB)
Strong turbulence	10^{-20}	10^{-33}
Moderate turbulence	10^{-18}	10^{-27}
Weak turbulence	10^{-19}	10^{-29}

Table. 6.1 SNR and BER Values for Different Modulations with Different Turbulence Models

7. CONCLUSIONS

7.1 EXPERIMENTAL CONCLUSION

In conclusion, the advent of laser technology heralds a new era in wireless communication, offering unparalleled speed, efficiency, and security. Propelled by the visionary work of scientists like Harald Haas, laser technology presents a promising alternative to traditional Wi-Fi, leveraging light as a medium for data transmission. With its ability to alleviate the strain on radio spectrum and provide high-speed connectivity in confined spaces, laser technology holds immense potential across a multitude of applications, ranging from public internet access to inter-vehicle communication.

However, while laser technology offers significant advantages over existing technologies, it is not without its limitations, such as limited range and dependence on light sources. As a result, it is unlikely to entirely replace Wi-Fi but instead complement it, offering synergistic benefits when used together.

Looking ahead, the development and adoption of laser technology are poised to revolutionize wireless communication infrastructure, paving the way for a future characterized by faster, more efficient, and secure connectivity. Whether through further advancements in laser technology or the integration of emerging technologies like Laser-Fi, the journey towards a connected world continues, driven by innovation and the pursuit of seamless communication solutions.

7.2 RESEARCH PAPER CONCLUSION

The paper investigates the influence of atmospheric turbulence on the performance of the Malaga distribution across various modulation schemes, including On-Off Keying (OOK)and Pulse Position Modulation (PPM) encoding. The study categorizes turbulence effects into three levels—strong, moderate, and weak—and considers different weather conditions such as haze, light fog, and clear air, with a fixed wavelength of 630nm and a transmission distance of 1km.Through both theoretical analysis and simulations, we evaluate how turbulence affects the error rates of these modulation schemes. Our findings reveal that OOK modulation exhibits favorable performance in terms of error rates under turbulent conditions. We support our theoretical analysis with numerical results obtained through Monte Carlo simulations, thus validating the accuracy of our derived analytical expressions. Overall, this study underscores the importance of considering atmospheric turbulence effects when designing and implementing optical communication systems. The insights gained from our investigation can inform the development of robust modulation schemes resilient to turbulence-induced impairments, ultimately enhancing the reliability and performance of optical communication systems in real-world scenarios.

8. LIMITATIONS AND CHALLANGES

- The product's most obvious shortcoming is that both devices must be in the line of sight. Other than that, the separation between the transmitter and the receiver is smaller than that of traditional WIFI since it utilizes radio waves. They scatter less because they have a longer wavelength as compared to visible light, infrared light travels farther and silently having a significant impact on the signal without any disturbances
- In regards to the integration of LASER with present-day WIFI technology, at the moment, our product has been developed to show off 2-way Li-Fi connectivity (i.e. from laptop/mobile to the LCD screen). Currently, it cannot work with Wi-Fi networks
- Fewer gadgets are capable of using LASER because it is a relatively new technology. It's doubtful that we will see LASER enabled personal gadgets in the next several years because the majority of the devices we use now still utilize the hardware for Wi-Fi networking.
- Lack of resistance to light occlusion and the growth of light contamination are two further LASER drawbacks. We have to be aware that while this technology is immune to electromagnetic impedances, other sources of light may interfere with signal. LASER powered light signals can be affected by daytime lighting. Managing these symptoms may be difficult for the related recipient. Interference with the web is possible. Additionally, since powered LASER must remain on, they can contribute to increased light pollution.
- Data transmission through any channel is not error-free, so we constantly have some issues with our data that was sent (due to bit flips). Right now, there is no method to prevent this mistake or fix it, this causes risk to our secure data transmission.
- The product made by us currently can only be used by a single receiver and transmitter.

9. SCOPE OF FUTURE WORK

The future scope of work in laser communication is quite promising and expansive. Here are several key areas where significant advancements and developments are expected:

- Data Rate Enhancement: There will be a continuous push to increase the data rates in laser communication systems. This involves improving modulation techniques, optimizing laser sources for higher frequencies, and enhancing receiver sensitivity to extract more information from the received signals.
- Longer Range Communication: Efforts will be made to extend the range of laser communication links, both in terrestrial and space applications. This includes developing more powerful laser transmitters, designing efficient beamforming techniques, and exploring methods to mitigate atmospheric effects over longer distances.
- Inter-Satellite Communication: As the demand for satellite-based services grows, there will be a focus on developing laser communication systems for inter-satellite links. This involves creating compact and energy-efficient laser terminals suitable for space environments, along with robust protocols for seamless inter-satellite data exchange.
- Secure Communication: Laser communication offers inherent advantages in terms of security due to its narrow beam and low probability of interception. Future work will explore advanced encryption methods, quantum key distribution techniques, and secure protocols to ensure the confidentiality and integrity of data transmitted via laser links.
- Miniaturization and Integration: There will be efforts to miniaturize laser communication components, making them suitable for integration into small satellites, unmanned aerial vehicles (UAVs), and other compact platforms. This involves developing lightweight optics, efficient power management systems, and ruggedized designs for reliable operation in diverse environments.
- Commercial Applications: Laser communication is expected to find widespread use in commercial applications such as high-speed internet services, remote sensing, disaster management, and telecommunication networks.

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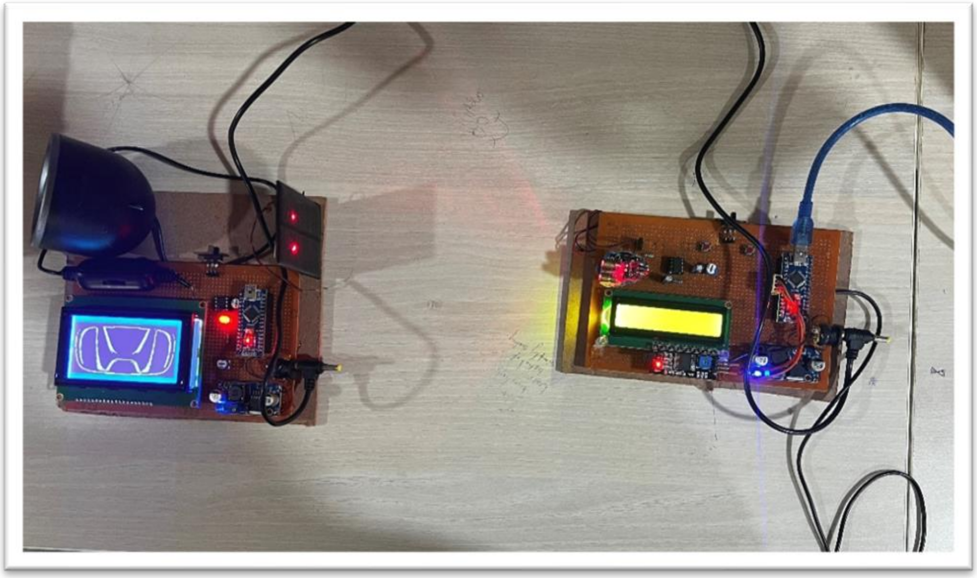
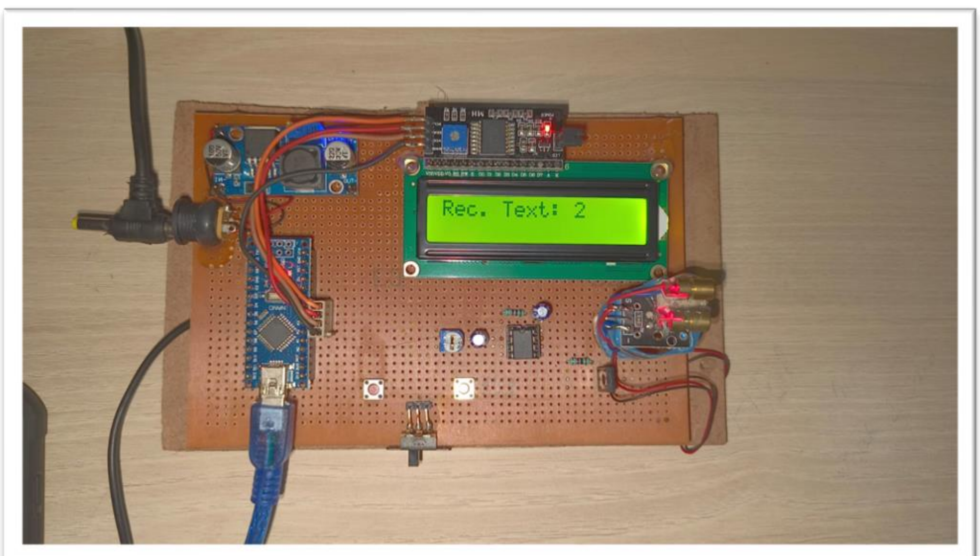
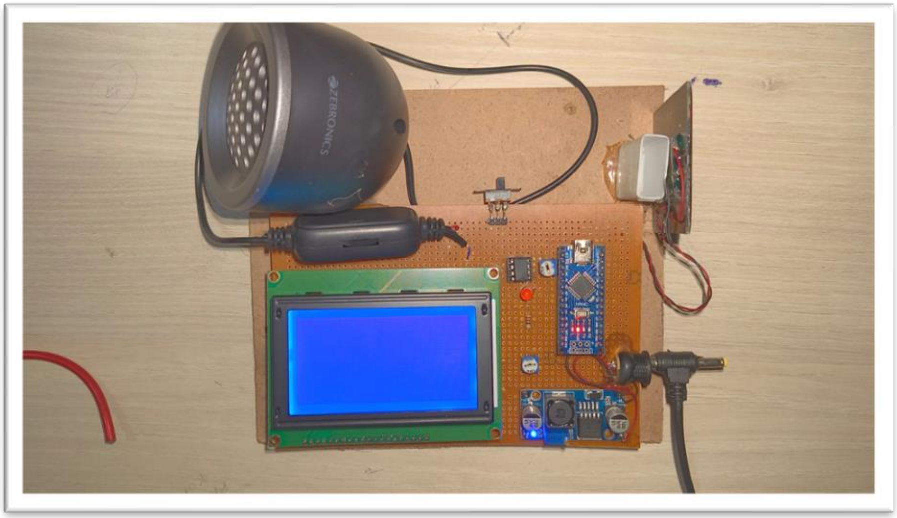
Photo Gallery



Experimental Setup



Transmitter



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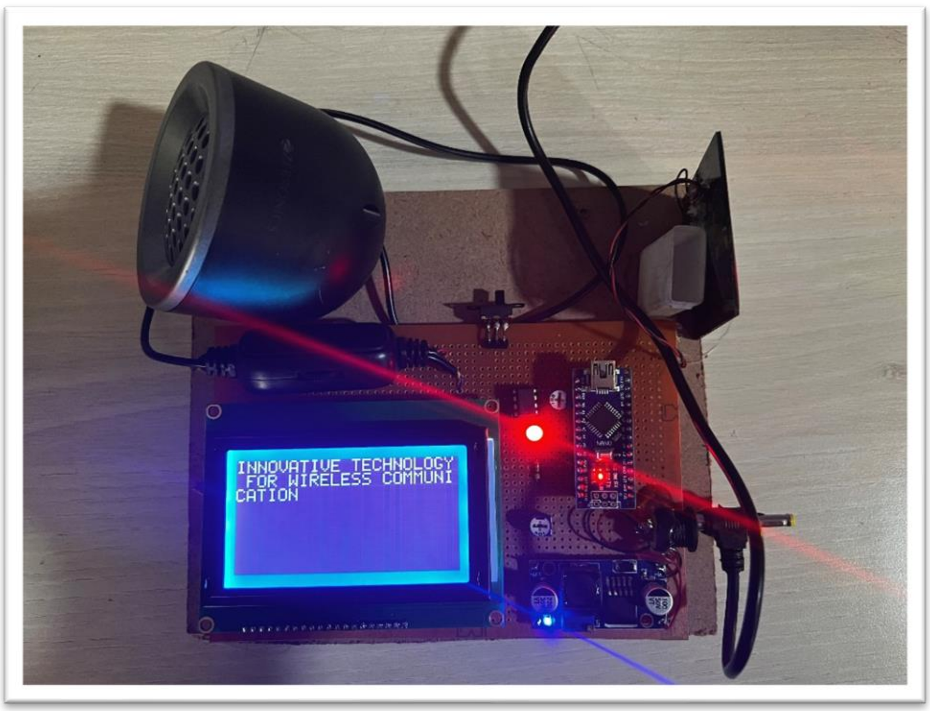

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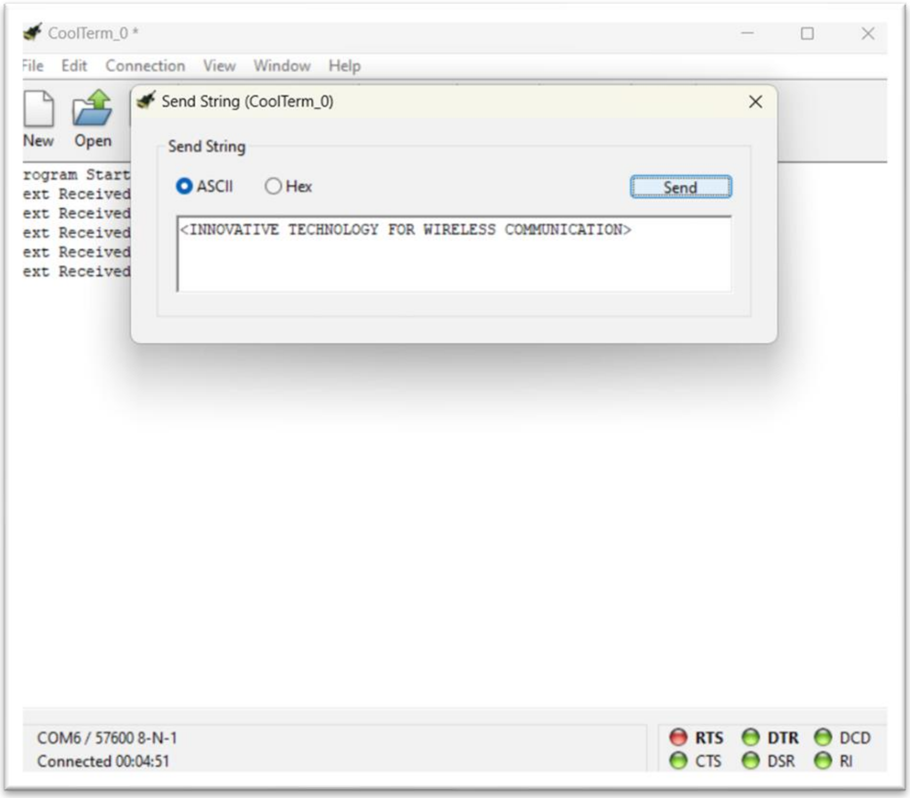

Text Input

Image Transmission