Implementation of Visible Light Communication Link

Project report submitted in partial fulfillment
of the requirements of B-Tech Project for the degree of

Bachelor of Technology
in
Electronics and Communication Engineering

by

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The LNM Institute of Information Technology
Jaipur, India

CERTIFICATE

This is to certify that the project entitled Implementation of Visible Light Communication Link, submitted by Anubhuti Jain (16UEC019), Jyoti Kumari (16UEC052),Shrutika Bansal(16UEC064) in partial fulfillment of the requirement of B-Tech Project for the degree in Bachelor of Technology (B. Tech), is a bonafide record of work carried out by them at the Department of Electronics and Communication Engineering, The LNM Institute of Information Technology, Jaipur, (Rajasthan) India, during the academic session 2019-2020 under my supervision and guidance and the same has not been submitted elsewhere for award of any other degree. In my opinion, this report is of standard required for the submission of B-Tech Project.

16/12/19
Date

Dr. Nikhil Sharma
Adviser: Name of B-Tech Project Supervisor

Acknowledgments

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Abstract

Present communication systems involve the transmission of data in the form of sound or radio frequency waves. Since radio waves cannot be used under water because these waves are strongly absorbed by sea water within feet of their transmission and this renders it unusable underwater. There is a need for a robust and reliable communication system which will not be affected severely due to thermal and chemical changes in water's composition.Our goal is to develop a prototype which is able to transmit information from one end to another in atmospheric conditions initially. In typical office or home, Visible Light Communication is a good alternative of WiFi for home networking. There are certain considerations that have to be kept in mind while viewing Visible Light Communication; the main challenges being high path-loss, multi-path dispersion, ambient light noise and limited bandwidth of white LED's. Link configurations also determines the performance of Visible Light Communication systems. In this paper we will discuss the simulation, theoretical and implementation aspects of a Visible Light Communication Link with a focus on Line of Sight and Blocking Scenario.

Chapter *1*

Introduction

1.1 The Area of Work

Communication has been integral part of the human evolution. It's most important aspect being the medium of communication. Communication means have now evolved to be fast, over long distances and convenient.This has largely being possible by use of Radio Frequencies to transmit data over long distances and instantaneously.But now in this age of data explosion and consumption the spectrum provided by RF is dwindling and is insufficient to cater to the next revolution of 5G and IoT. In view of the above it is essential to explore the possibilities opened by Visible Light Communication. The proposed project is to implement a basic prototype which will share data(bulk data) between two nodes using Visible Light Communication(VLC) and further study performance for different link configurations(LOS, Blocking scenario) for VLC systems. [1A][3].

1.2 Problem Addressed

As referred to in the area of interest; the surge in demand for data has posed a number of challenges which need to be overcome. The challenges include:

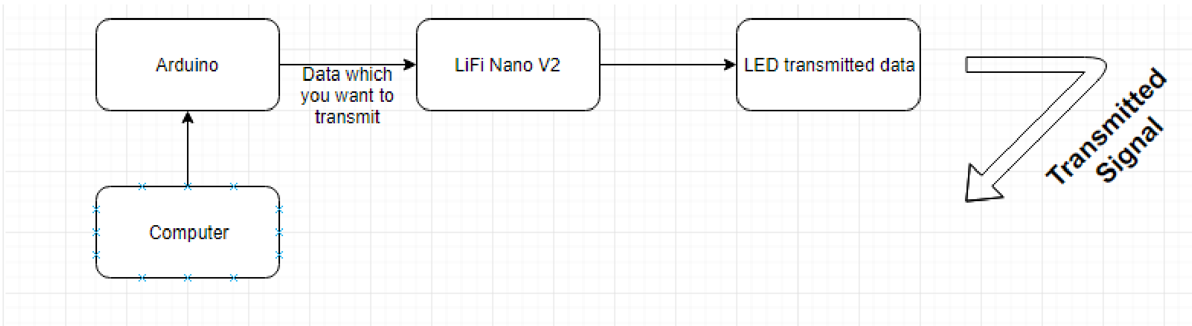
1. Diminishing RF Spectrum
2. Capacity Crunch
3. Interference
4. Security and Energy Efficiency

VLC has inert tendencies to overcome these challenges and can be used in collaboration with RF to deliver optimum data transmission under water. One specific application is LiFi which makes use of LEDs to transmit data. This report aims to implement two major tasks:-

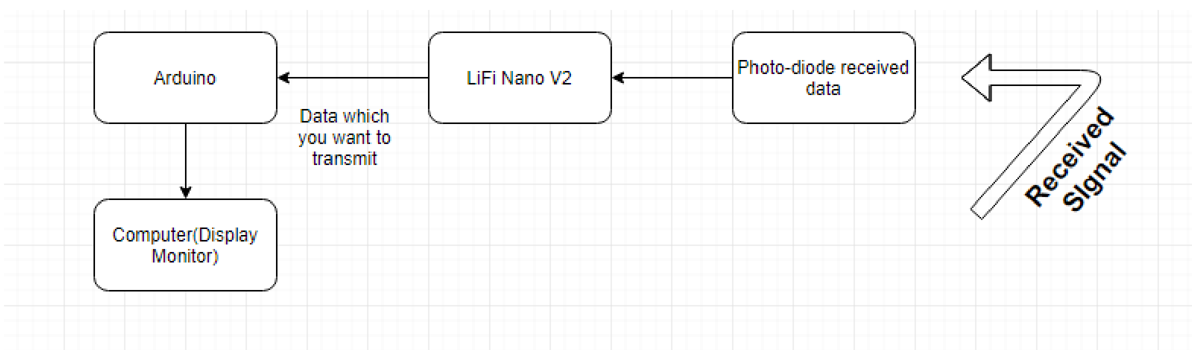
1. A basic LiFi design and have further an understanding so as to spur development to overcome the above challenges[1B].

2.We will be trying to study performance for different link configurations(LOS,Blocking scenario) for VLC systems.

1.3 Block Diagram

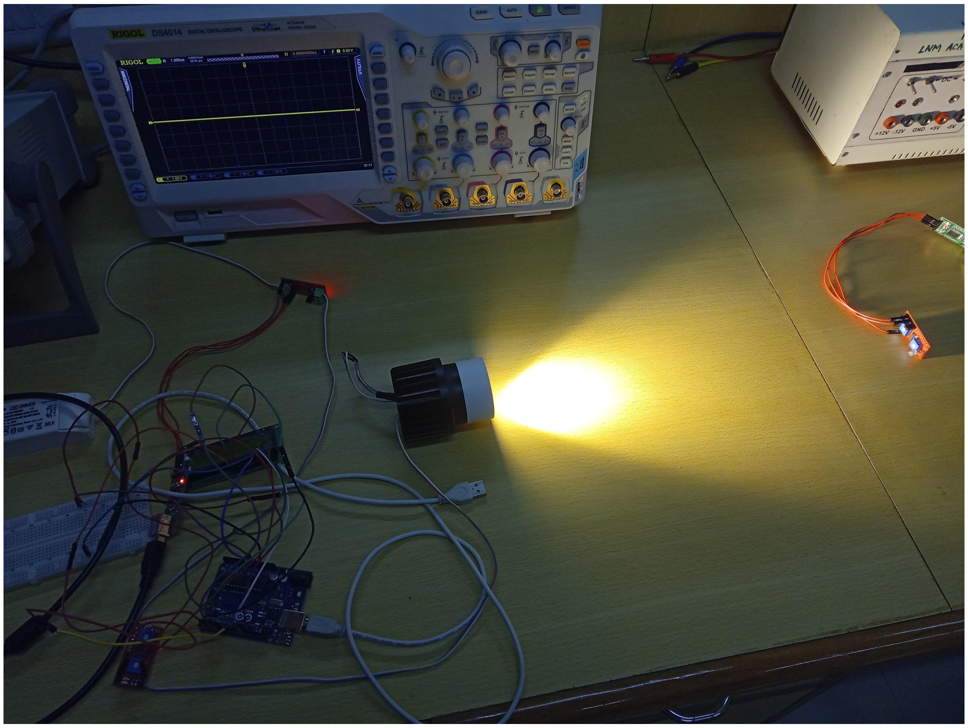


Block Diagram For Transmitter



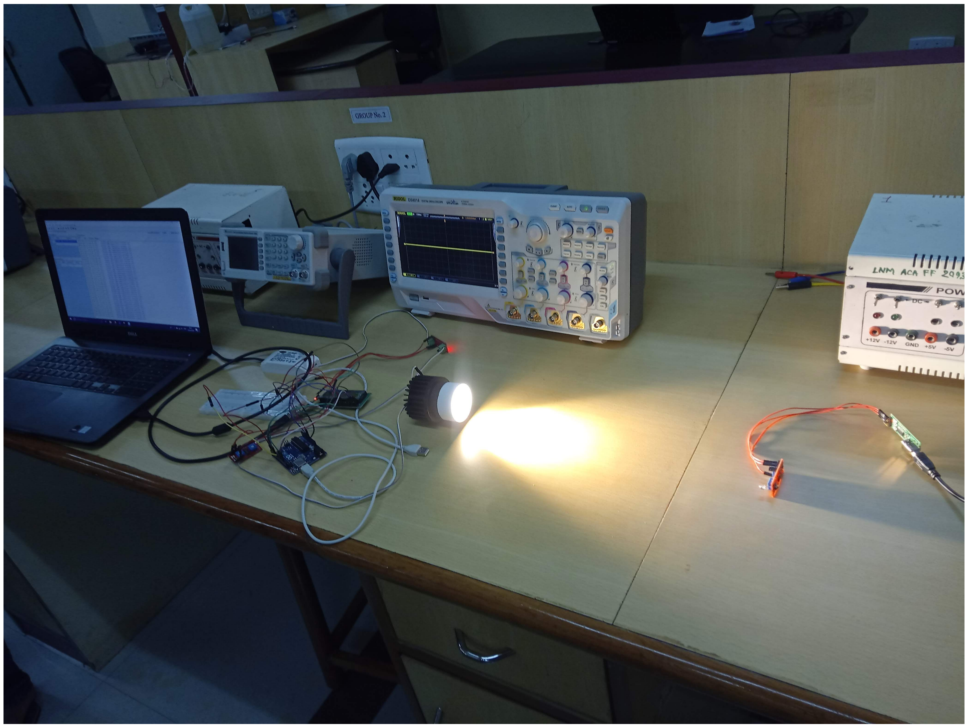
Block Diagram For Receiver

1.4 Establish Setup



Transmitter Side

Receiver Side



Complete Setup

Chapter *2*

Literature Survey

2.1 Introduction

In the ultimate ten year or so, Light emitting diodes (LEDs) has evolved as a promising illumination solution for each business and home uses. It can be anticipated that they are progressively replacing conventional phosphorescent LED bulbs and incandescent lamps due to the blessings of lower energy consumption, longer lifetime, non-toxic and safety. In addition to above benefits, it additionally possesses the fast-switching property, therefore can also be used as a transmitter for records transmission using '0's and '1's represented by using its on and off states, and this belongings is used inside the technology known as Visible light communications (VLC). Visible Light Communication (VLC) systems rent visible light for conversation that occupy the spectrum from 380 nm to 750 nm corresponding to a frequency spectrum of 430 THz to 790 THz.[8] Especially, in ordinary indoor scenarios, e.G. office or home, VLC is a sturdy competitor of WiFi for domestic networking and a reliable successor in cases where use of WiFi is concerned.

2.2 Advantages over RF communication

Since Radio Frequency (RF) conversation requires a separate setup for transmission and reception of RF waves, VLC has a big gain in this difficulty from the sizeable usage of LEDs for lighting. The restricted radio frequency band spectrum places some extreme constraints on the increasing demand for ubiquitous connectivity and excessive capacity. The RF communication suffers from diverse issues such as the following:
(a) Interference, consistent with Federal Aviation Administration (FAA) the use of mobile telephones on plane causes interference with conversation and navigational systems. Along with this, cellular telephones on plane will also cause disruption with ground machine towers as argued with the aid of the Federal Communication Commission (FCC).[8]
(b) In a wireless communication machine that needs low latency functioning (inclusive of in vehicular automation and communique, drones, protection systems etc.), the usage of radio frequency is not safe because of its bandwidth limitations resulting in excessive latency.

(c) Since Radio waves can without problems penetrate the walls and various obstacles, they suffer from critical security issues ensuing in being exploited which is once more dangerous for information-touchy networks.
(d) The exposure to multiplied transmission strength of the RF waves above a certain limit may be dangerous for human health. To triumph over the above-stated drawbacks of the RF conversation structures, there is a pressing want to design new communique technologies. Thus Visible Light Communication (VLC) is a preferred and best solution due to its excessive bandwidth, immunity to interference from electromagnetic resources and harmlessness for human health.

2.3 Applications

Among the many potential applications of VLC, some of them include Li-Fi, vehicle to vehicle communication, robots, communication in hospitals, and underwater communication.
1. Li-Fi(Light Fidelity) uses visible light for communication to provide high speed internet up to 10 Gbps, which is 250 times more than the speed of super-fast broadband [9]. It also lends support to the Internet of Things (IoT).
2. VLC can be used in vehicular communication for lane-change warning, pre-crash sensing and traffic signal violation warning to avoid accidents. These applications require communication with low latency which is provided by VLC because of its high bandwidth and easier installation due to the existing presence of vehicle lights and traffic signals.[10]
3. VLC also has applications in areas that are sensitive to electromagnetic waves, such as aircrafts and hospitals where the radio signals interfere with the waves of other machines.
4. RF waves do not travel well in sea water because of its good conductivity. Therefore, VLC communication should be used in underwater communication networks [11].

2.4 Challenges

A number of obstacles faced by Visible Light Communication systems need to be overcome to be available for a viable commercial deployment. In particular, the standardization, inter-operability with existing radio frequency based technology and the need to explore Visible Light Communication's possible use cases. Being a relatively modern technology, there is a need to explore more since there are some drawbacks with the LED based Visible Light Communication. Such as non-linearity of the LED, signal modulation, power delivery to the transceiver and limited LED bandwidth. Visible Light Communication can still well overcome these challenges by using the decades of research that has being done on RF which will only accelerate the development of Visible Light Communication. Making it a real-time system is also challenging. Furthermore, the current abundance and maturity of RF communications may impede the commercialization and standardization of VLC technologies.

Moreover, there are certain considerations that have to be kept in mind while viewing Visible Light Communication; the main challenges being high path-loss, multi-path dispersion, ambient light noise and limited bandwidth of white LED's. ”The performance of VLC systems strongly depends on the link configurations. In general, there are two main types of link configurations which are Blocking scenario, namely diffused link, and direct line-of-sight (LOS). LOS systems with their directionality are able to offer a high bit-rate up to several Gbps, however the system is sensitive to the link blockage. On the other hand, in diffused VLC systems the signal propagates from the transmitter to the receiver by several paths making the system more robust to link blockage and moving objects. This comes with the expenses of higher path loss and inter symbol interference stemmed from multi path propagation, which both significantly degrade the system performance. It is important to note that in current and foreseen lighting technology, diffused system have been being essential for indoor scenarios”[9].

Chapter *3*

Proposed Work

3.1 Working

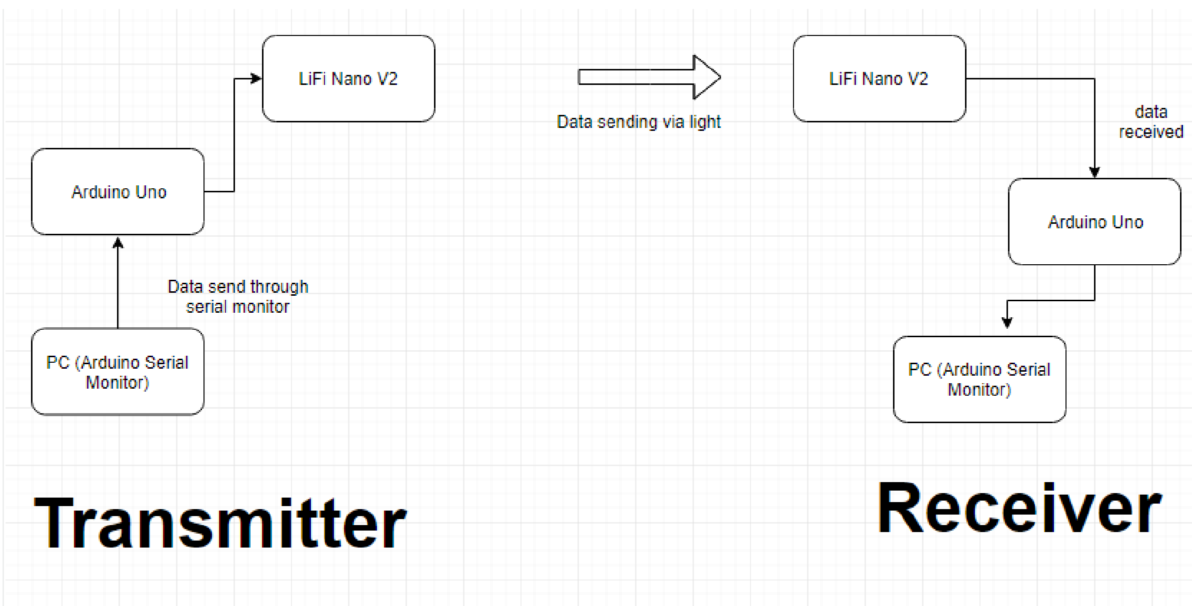
Technology Used: Visible Light Communication(VLC), Sensor Networking, IoT; The setup will be under water consisting of a transceiver pair where both nodes, each node can act as a transmitter as well as a receiver. Transmitter section will consist of a photon source (High powered LED) which will be mounted on first node and receiver will have photon detector mounted on the second node. To cover up the losses caused in the water appropriate modulation and amplification process will be adopted. We will be using edge device technology for better user readability on the surface. Different sensors on the divers suit will be used to acquire critical information like temperature, heartbeat and blood pressure, which will be transmitted using VLC to the surface. At the surface RF communication modules will be used to transfer the information to a centralized server. Resulting in a dual hop VLC-RF end-to-end communication system for acquiring mission critical underwater information.

3.2 Serial Data Transmission

Our main aim was to transmit data (numerical and char) from serial monitor of transmitter side to that of receiver side. Working:-
Model used for implementation of above task was LiFi Nano V2.
Were able to transfer small streams of data from the transmitter to the receiver after setting up a connection which is shown in diagram shown below:

3.2.1 Components required

1) 2 x Arduino Uno R3 Board
2) 1 x LiFi Nano V2
3) 2 x Laptops with Processing software



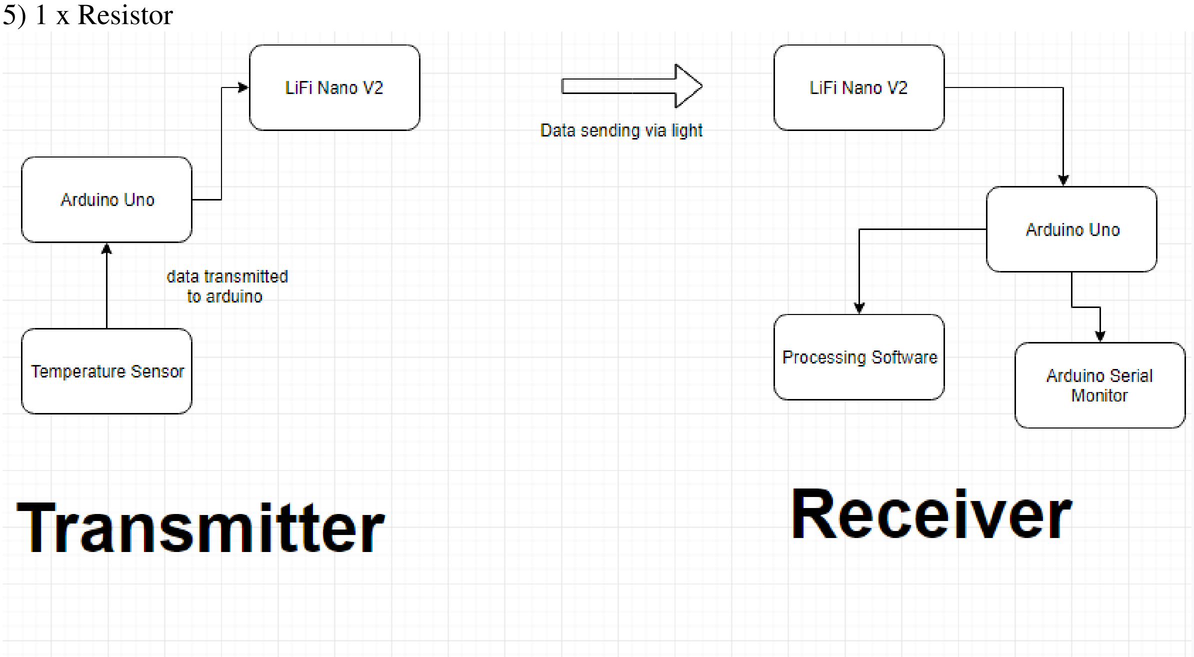
Block Diagram for Serial Data Transmission

3.3 Transmission of Sensor Data

Our main aim was to transmit data received from temperature sensor from serial monitor of transmitter side to that of receiver side and plot real time graph of the same.. Working:-
Temperature Sensor was connected to the Arduino and the received temperature values were Transmitted via the LiFi Transmitter and the values received at the receiver of the LiFi Module were then plotted by using Arduino and Processing.
Software used to plot graph-Processing.

3.3.1 Components required

1) 2 x Arduino Uno R3 Board
2) 1 x LiFi Nano V2
3) 2 x Laptops with Processing software
4) 1 x Temprature sensor(LM35)
5) 1 x Resistor



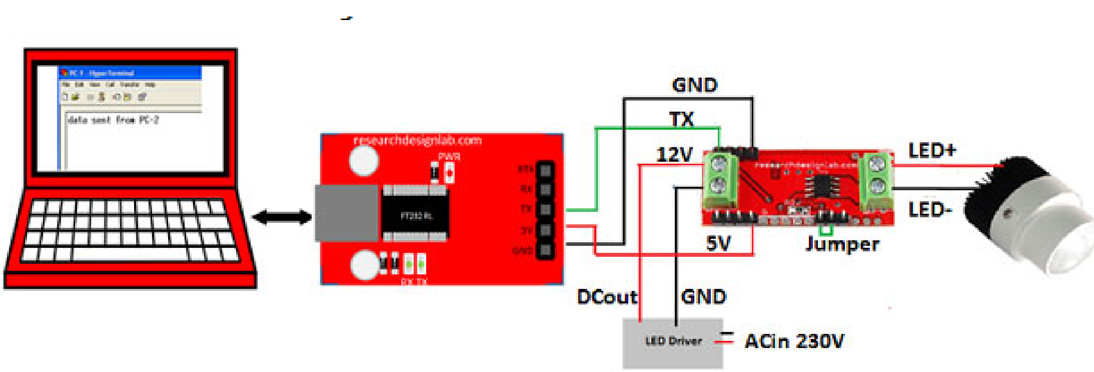
Block Diagram for Transmission of Sensor Data

3.4 Bulk Data Transmission

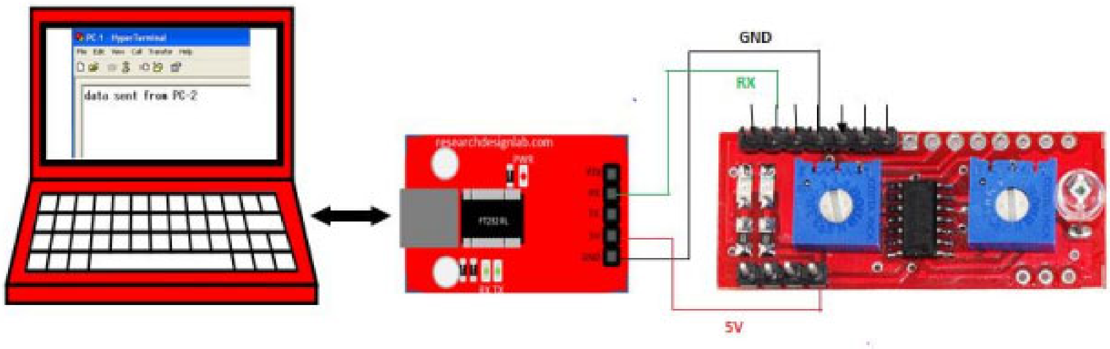
Our main aim was to transmit data image from transmitter side to receiver side.
Working:-
1.Model used for implementation of above task was LiFi Nano V2.
2.Once the connection was set up,We firstly converted image file into its corresponding numerical matrix.
3.DCT of image values was calculated (MATLAB) and stored in text file.
4.Then we tried to transmit the text file to receiver side. The received data were stored in text file through processing tool.
5.IDCT of data values was taken to reconstruct back the actual transmitted image .

Components required

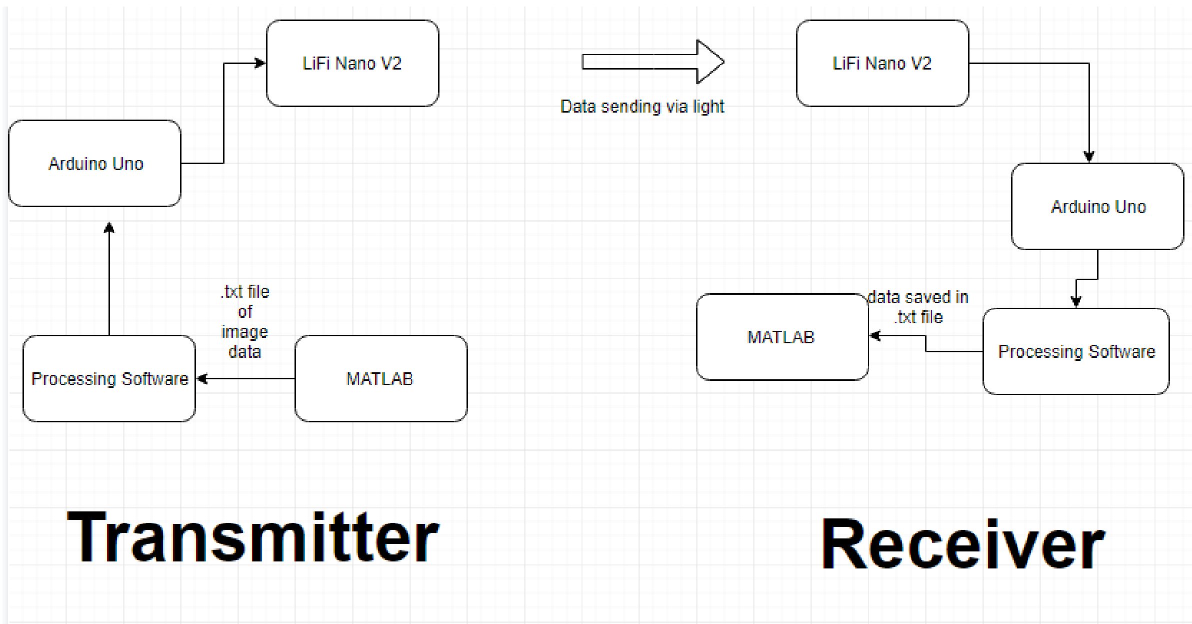
1) 2 x Arduino Uno R3 Board
2) 1 x LiFi Nano V2
3) 2 x Laptops with Processing software



LiFi Nano V2 transmitter



LiFi Nano V2 receiver



Block Diagram for Image Transmission.

3.5 Problem faced:-

3.5.1 Image Transmission

1.We are not able to retrieve the exact data values. Around 60-70% values obtained are correct values.
2.Data received is not arriving uniformly. Due to which we are facing problem in reconstructing back the image.
3.Calibration of the Module for the appropriate distance proved to be a challenge.

3.6 Steps taken to overcome the problems

1.Introducing an end marker for each data transmission.
2.Making use of guard bits at start of transmission.
3.Making use of guard bits at end of transmission.
4.Padding the data segment with white spaces to prevent synchronization loss.

Chapter *4*

Simulation and Results

4.1 Code for Serial Data Communication

4.1.1 Transmitter Code

```
void setup() {
  Serial.begin(38400);
}

void loop() {
  if(Serial.available()>0)
  {
    Serial.write(Serial.read());
  }
}
```

4.1.2 Receiver Code

```
void setup()
{
  Serial.begin(38400);
}

void loop() {
  if(Serial.available()>0)
  {
    Serial.write(Serial.read());
  }
}
```

4.2 Code for Sensor Data Transmission

4.2.1 Transmitter Code

```
int inPin = A1; // analog pin
#include <stdlib.h>
int radix=10;
char val[3];
char cel[3];
char fah[3];
void setup()
{
 Serial.begin(38400);
}

void loop()
{
            float value = 100;//analogRead(inPin);
            float millivolts = (value / 1024) * 5000;
            int celsius = (int)millivolts / 10; // sensor output is 10mV per degree Celsius
            int fahrenheit=(celsius * 9)/ 5 + 32;
            //Serial.write(itoa(value,val,radix));
            //Serial.write(" > ");
            Serial.write(itoa(celsius,cel,radix));
            //Serial.write(celsius);
            //Serial.write("degrees Celsius, ");
            //Serial.write( itoa(fahrenheit,fah,radix ));// converts to fahrenheit

            delay(1500); // wait for one second
}
```

4.2.2 Receiver Code

```
void setup()
{
  Serial.begin(38400);
}

void loop() {
  if(Serial.available()>0)
  {
    Serial.write(Serial.read());
  }
}
```

4.3 Code for Image Data Transmission

4.3.1 Transmitter Code(Arduino)

```
const byte numChars = 70;
char receivedChars[numChars];   // an array to store the received data
boolean newData = false;

void setup() {
    Serial.begin(38400);
}
void loop() {
    recvWithEndMarker();
    showNewData();
}

void recvWithEndMarker() {
    static byte ndx = 0;
    char endMarker = '\n';
    char rc;

    while (Serial.available() > 0 && newData == false) {
        rc = Serial.read();

        if (rc != endMarker) {
            receivedChars[ndx] = rc;
            ndx++;
            if (ndx >= numChars) {
                ndx = numChars - 1;
            }
        }
        else {
            receivedChars[ndx] = '\0'; // terminate the string
```

4.3.2 Receiver Code(Arduino)

```
const byte numChars = 70;
char receivedChars[numChars];   // an array to store the received data
boolean newData = false;

void setup()
{
    Serial.begin(38400);
}

void loop()
{
    recvWithEndMarker();
    showNewData();
}

void recvWithEndMarker()
{
    static byte ndx = 0;
    char endMarker = '\0';
    char rc;
    int i=3;
    //memset(&receivedChars[0],0,sizeof(receivedChars));
    while (Serial.available() > 0 && newData == false ) {
        rc = Serial.read();
        if (rc != endMarker)
        {
            receivedChars[ndx] = rc;
            ndx++;
            if (ndx >= numChars)
```

```
    char rc;
    int i=3;
    //memset(&receivedChars[0],0,sizeof(receivedChars));
    while (Serial.available() > 0 && newData == false ) {
        rc = Serial.read();
        if (rc != endMarker)
        {
            receivedChars[ndx] = rc;
            ndx++;
            if (ndx >= numChars)
            {
                ndx = numChars - 1;
            }
        }
        else
        {
            ndx = 0;
            newData = true;
        }
    }
}

void showNewData() {
    if (newData == true)
```

4.3.3 Transmitter Code(Processing Software)

```
import processing.serial.*;
printArray(Serial.list());
Serial myPort;
myPort = new Serial( this, Serial.list()[0], 38400 );
String line="          "+"0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000"+"          "+System.lineSeparator(); /
myPort.write(line);
println(line);
String[] lines=loadStrings("datafile_1.txt");
int k=0;
int c=0;
for (int i = 0 ; i <3240; i=i+90)
{
  String sub=lines[0].substring(i,i+90);
  sub="          "+ sub +"      " +  System.lineSeparator();  // Padding the data at start and end. Also attaching an end marker.
  myPort.write(sub);
  print(sub);
  c=i;;
 //delay(1);
}
String sub=lines[0].substring(c,c+75);
sub="      "+ sub +"      " +  System.lineSeparator();
print(sub);
sub="      "+ sub +"      " +  System.lineSeparator();
String end ="          "+"00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000"+"          "+System.lineSeparator(); // Gu
myPort.write(end);
print(end);
print(lines.length);
myPort.stop();
```

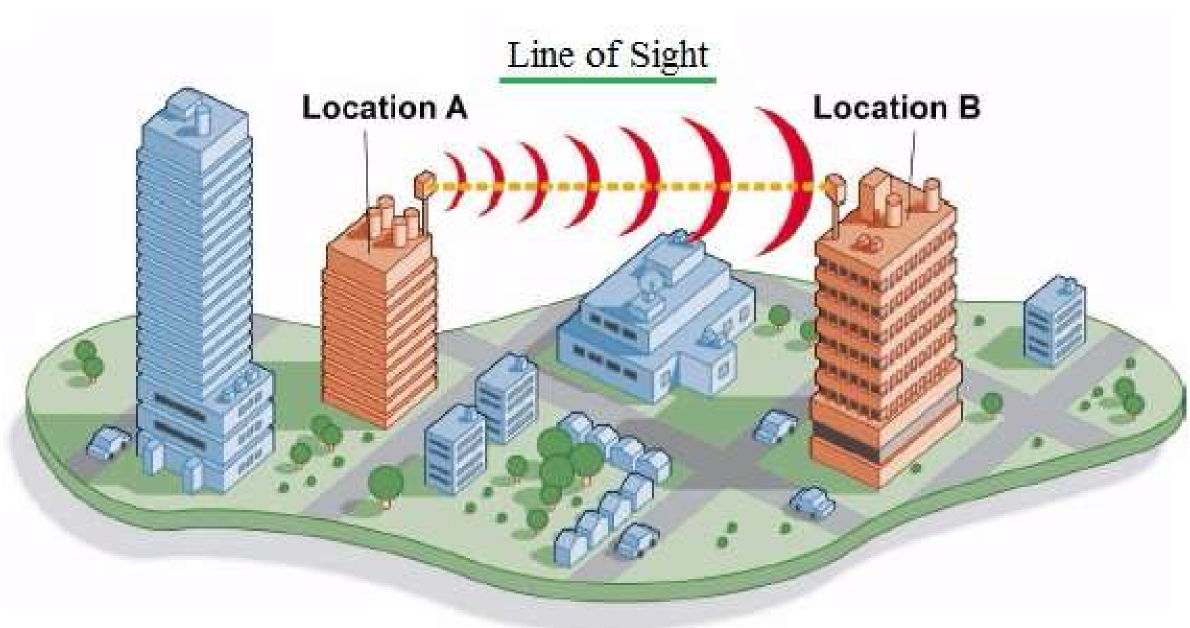
4.3.4 Receiver Code(Processing Software)

```
import processing.serial.*;
Serial mySerial;
PrintWriter output;
void setup() { // Setup the connection to the Serial Port.
   mySerial = new Serial( this, Serial.list()[0], 38400 );
   output = createWriter( "data.txt" );
}
void draw() { // Listens on the Serial Port for any incoming character and save it to a text file.
    if (mySerial.available() > 0 ) {
         String value = mySerial.readString();
         if ( value != null ) {
              output.println( value );
         }
    }
}

void keyPressed() {
    output.flush();  // Writes the remaining data to the file
    output.close();  // Finishes the file
    exit();  // Stops the program
}
```

Chapter *5*

Simulation of Optical Wireless Communication Channel

5.1 LOS channel

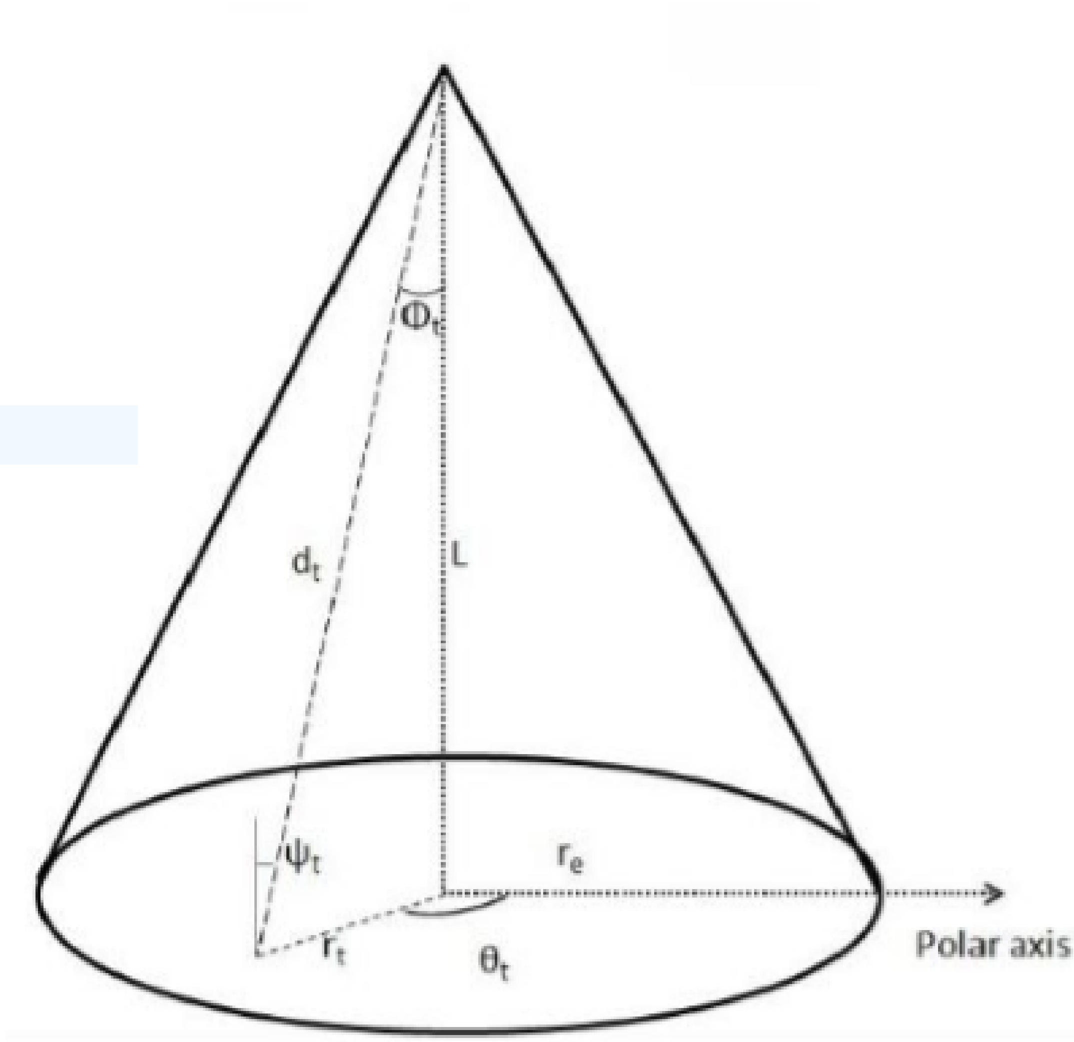


Line Of Sight deployment occurs when there is no obstruction between base station (BS) and mobile fixed subscriber stations (SSs).In simple terms, LOS communication occurs when there is no obstruction between transmitter and receiver.Due to less attenuation in the LOS communication, it offers good signal strength and higher amount of throughput compare to Blocking scenario counterpart.

The LED lamp is placed at height L from the tth end user located with angle t and radius rt on the polar coordinate plane. The maximum radius covered by an LED cell is re. It is observed that the LED follows a Lambertian radiation pattern with order

$$m = \frac{-1}{log2(\phi_{\frac{1}{2}})}$$

m:-Lambertian radiation pattern order



5.1.1 Channel Gain Equation

DC channel gain of the LOS link between LED and t'th user is given as:-

$$h_t = \frac{A(m+1)(R_p}{2\pi(d_t)^2} \cos{(\phi)}^m U(\psi_t) g(\psi_t) \cos{(\psi_t)}$$

where
A = the detector area
Rp = the responsivity of photodetector
dt = Euclidean distance between LED and tth user

U(t) and g(t) = the gain of optical filter and optical concentrator
d$_t = (r_t^2 + L^2)^{\frac{1}{2}}$
cos$(\psi) = cos(\phi) = \frac{L}{dt}$

The expression of Channel Gain in LOS Scenario can also be written as:

5.1.2 Parameters used in the simulation

A : Area of the detector where lie Receiver samples (meter square)

$\phi_{\frac{1}{2}}$:Half-power semi-Angle of the LED cone (degree)
m : Order of Lambertian Emission
T_s : Gain of Optical Fiber

ψ_c : Field of view at the Receiver (degree)
n : Refractive Index
L : Height of Transmitter from base (meter)
samples : No. of Receiver samples at different distances

r_e : Radius of the LED cone

ϕ : Angle of Irradiance (degree)

ψ : Angle of Incidence
d : Distance between Transmitter and Receiver

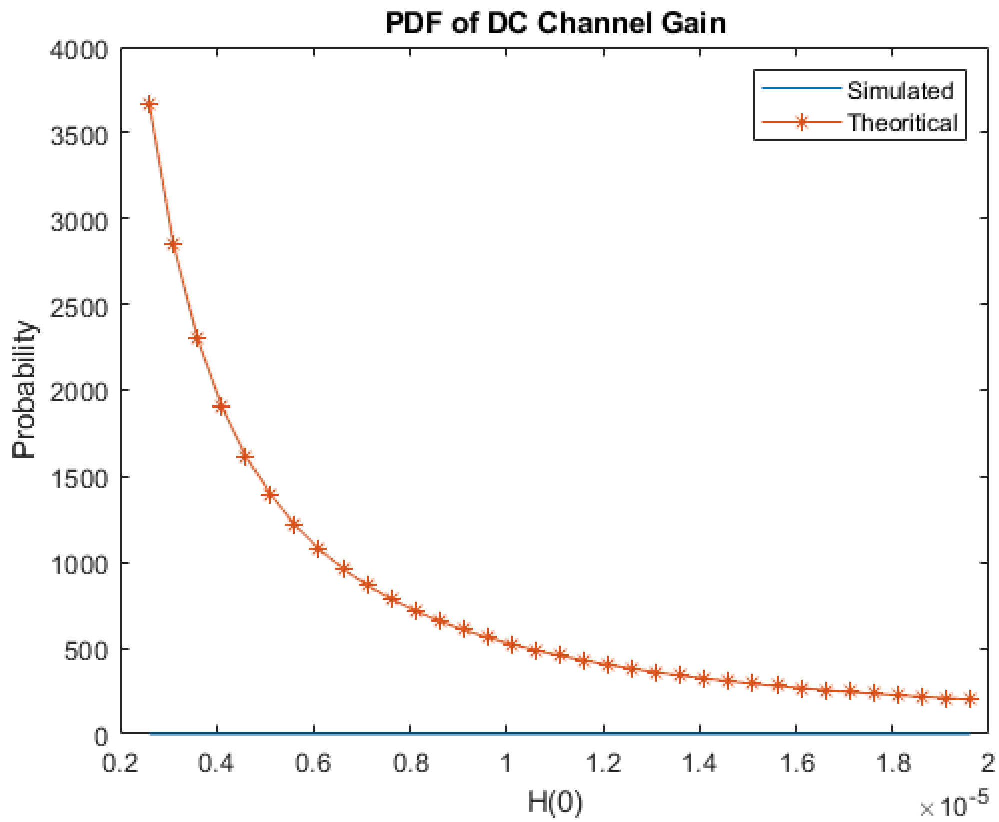
5.1.3 Matlab codes and Results

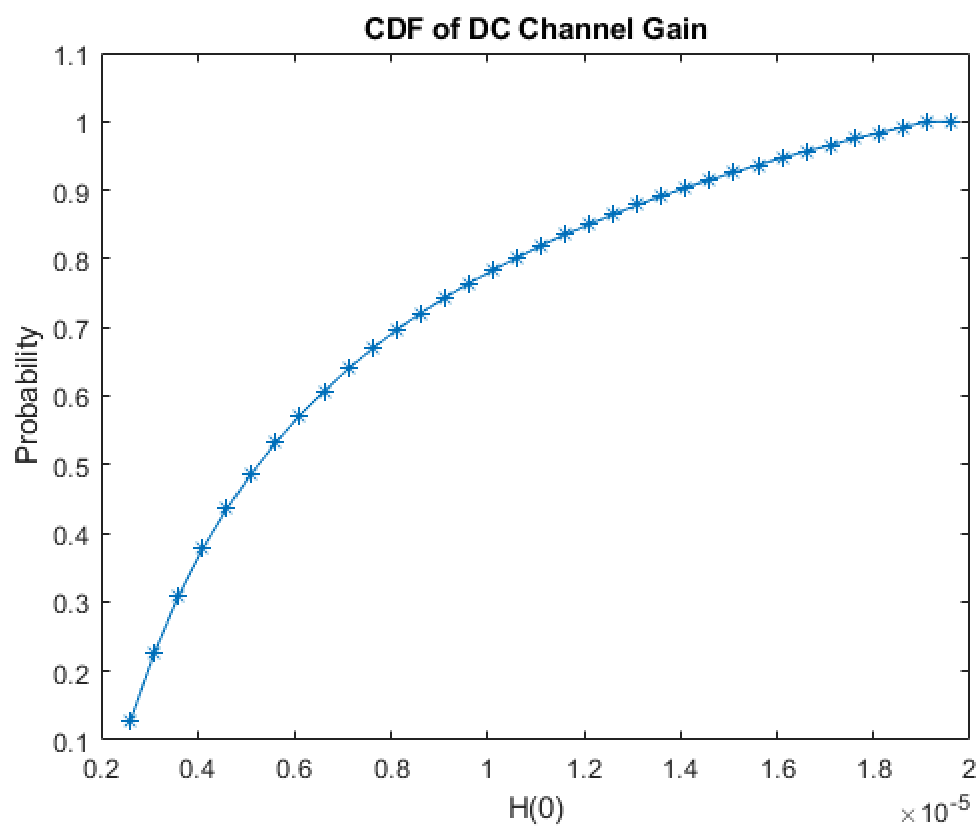
```
close all;
clear variables;

% Taking values from the Paper https://ieeexplore.ieee.org/stamp/
stamp.jsp?tp=&arnumber=1205458&tag=1

% Distance b/w Tx & Rx.(Meter Square)
A = 0.0001;

% Half-Power Semi-Angle (Degree)
THETA = 50;
THETA = deg2rad(THETA);

% Order of the Lambertian Emissison
m = -1*(log(2)/log(cos(THETA)));

% Gain of Optical Filter
Ts = 1;

% Field of View at the Receiver (Degree)
Psi_c = 60;
Psi_c = deg2rad(Psi_c);

% Refractive Index
n = 1.5;

% Height of Tx from base (Meter)
height = 2.5;

% Number of Rx Samples at different Distances
samples = 200000;

% Radius of the Cone
radius = height*tan(THETA);

% Location of Rx on 2D Co-ordinate system with center at (0,0)
[x,y] = randcircle(samples, height*tan(THETA));

% Angle of Irradiance (Degree)
D  = sqrt((x.^2+y.^2));
% for i=1:1:samples
Phi = atan(D./height);
% end

% Angle of Incidence (Degree)
Psi = Phi;

% Distance between Transmitter and Receiver (Meter)
% d = height*tan(Phi);
d = sqrt(D.^2 + height^2);

% H(0) Channel DC Gain
```

```
G = zeros(1,samples);
H = zeros(1,samples);
const1 = (1/(2*pi)* A * Ts);

for i=1:1:samples
    if Psi(i) > Psi_c
        G(i) = 0;
        H(i) = 0;
    else
        G(i) = const1 * (n*n)/(sin(Psi_c)*sin(Psi_c));
        H(i) = (G(i)*(m +1)*(height^(m+1)))/((d(i))^((m+3)));
%         H(i) = ;
    end
end
count=1;
H = sort(H);
interval = min(H):0.0000005:max(H);
for i=1:1:length(interval)
    max = interval(i)+0.0000005;
    min = interval(i) - 0.0000005;
    interval1(i) = 0;
    for j=count:1:samples
        if(H(j)>= min && H(j)< max)
            interval1(i) = interval1(i) + 1;
            count=count +1;
            interval2(i)= count;
        else
            break;
        end
    end
    interval1(i) = interval1(i)/samples;
    interval2(i) = interval2(i)/samples;
end
```

PDF Theoritical

```
theoreticalPDF = theoriticalPDF(interval,const1,height,radius,m);
plot(interval,interval1,'-');
hold on
plot(interval,theoreticalPDF,'-*');
hold off
title("PDF of DC Channel Gain");
ylabel("Probability");
xlabel("H(0)");
legend("Simulated","Theoritical");
figure
plot(interval,interval2,'-*')
title("CDF of DC Channel Gain");
ylabel("Probability");
xlabel("H(0)");
```

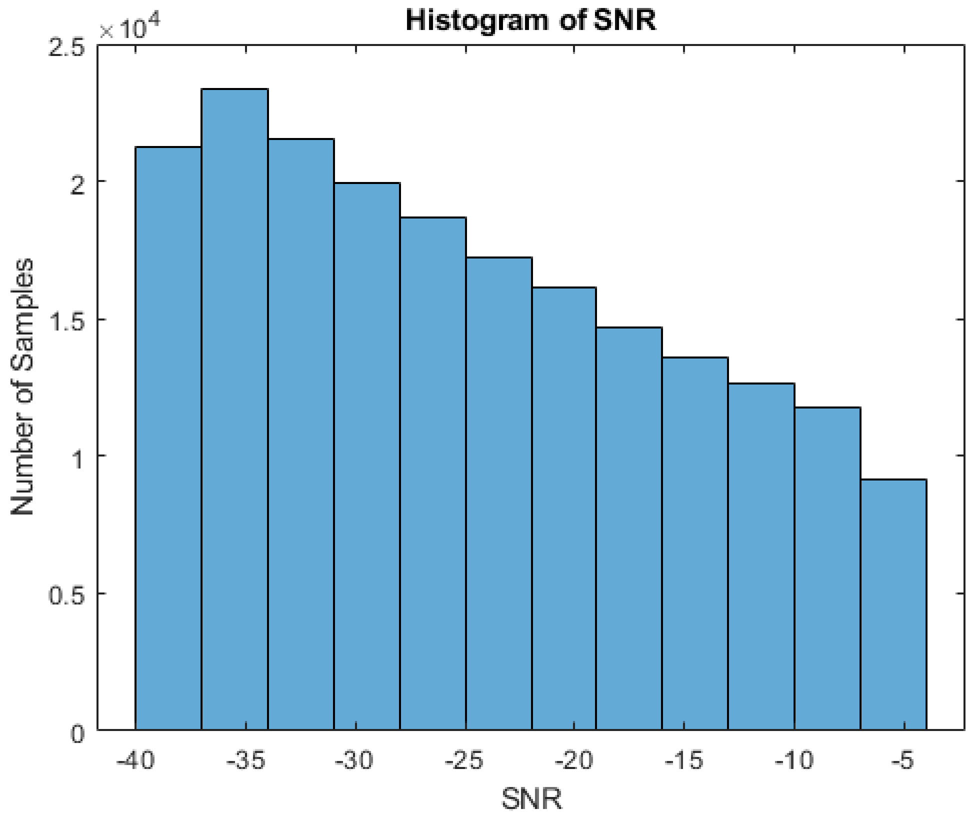

PDF of DC Channel Gain
Simulated
Theoritical
Probability
4000
3500
3000
2500
2000
1500
1000
500
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
H(0)
×10^-5

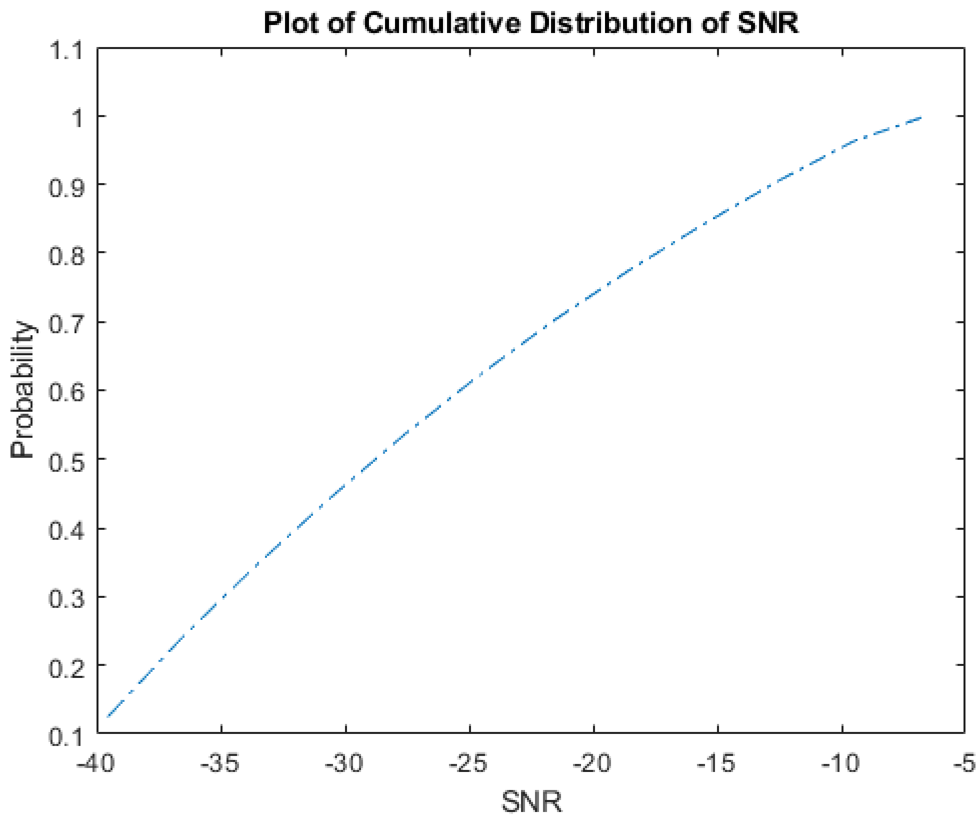

CDF of DC Channel Gain
Probability
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
H(0)
×10^-5

SNR Calculation:

```
% Transmit Power
Pt=0.004; % in Watts

% O/E Conversion
R = 0.53; % A/W

% Bandwidth in hertz
B = 22000;

% Elementary Charge in Columbs
q = 1.6*(10^-19);

% Background PSD
Pbg = 10^-9;

% Received Power
Pr = (H.^2).*(Pt);

% SNR
SNR = 10*log10(((R^2)*Pr.^2)/(B*q*R*Pbg));

% Histogram
count=1;
MIN = SNR(1);
MAX = SNR(length(SNR));
min = MIN - 3;
max = MIN + 3;
i=1;
while count < length(SNR)
    interval4(i) = (min + max)/2;
    interval3(i) = 0;
    for j=count:1:samples
        if(SNR(j)>= min && SNR(j)< max)
            count=count +1;
            interval3(i)= count;
        else
            break;
        end
    end
    interval3(i) = interval3(i)/samples;
    i=i+1;
    max = max + 3;
    min = min + 3;
end

figure
histogram(SNR,12);
xlabel("SNR")
ylabel("Number of Samples")
title("Histogram of SNR")
figure
```

```
plot(interval4,interval3,'-.');
title("Plot of Cumulative Distribution of SNR")
ylabel("Probability");
xlabel("SNR");
```





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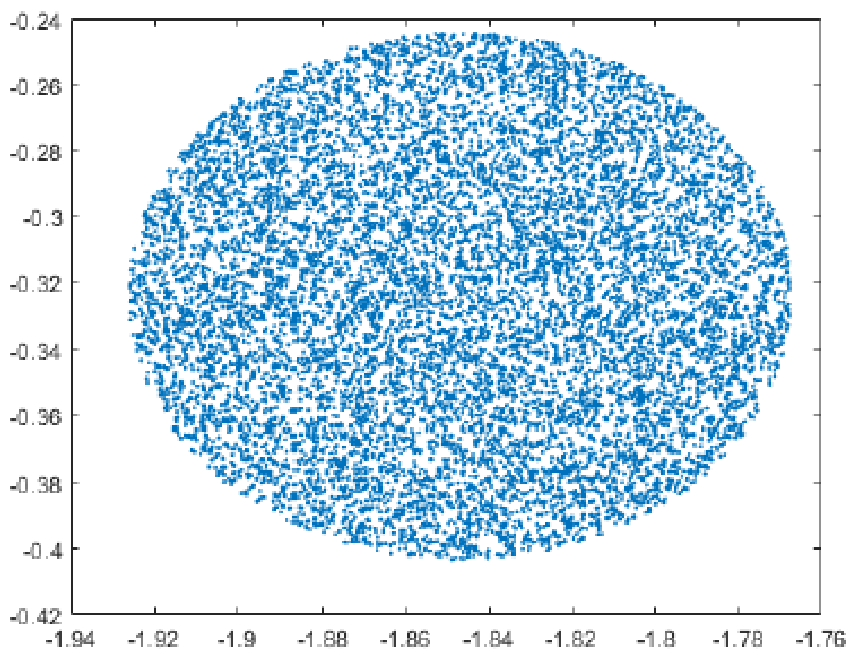
5.1.4 Random circle

```
% Data
n = 10000;
radius = rand;
xc = randn;
yc = randn;

% Engine
theta = rand(1,n)*(2*pi);
r = sqrt(rand(1,n))*radius;
x = xc + r.*cos(theta);
y = yc + r.*sin(theta);

% Check
plot(x,y,'.')

% Bruno
```



5.2 Blocking Scenario

A blocked scenario refers to the case where certain of the UE equipments aka Photodetector are completely blocked(hidden) from the Photo Source as compared to the LOS links. By using the Poisson Distribution to do so since blocking is a rare occurrence and the number of the total samples used are large during a given time interval T.
When we have large number of possible events, and each of them is rare then we apply Poisson distribution.

$f(k;\lambda) = Pr(X = k) = \frac{\lambda^k e^{-\lambda}}{k!}$

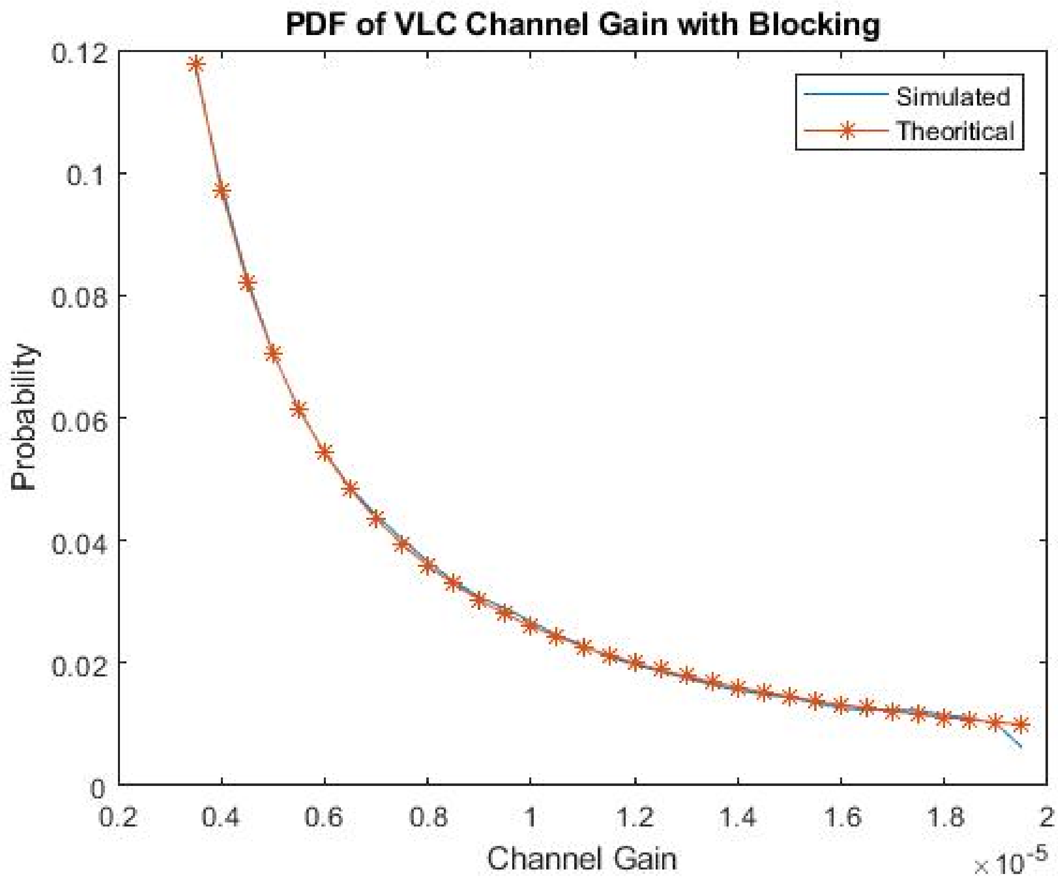
where e = Euler number(2=2.1728...)
k! = factorial of k

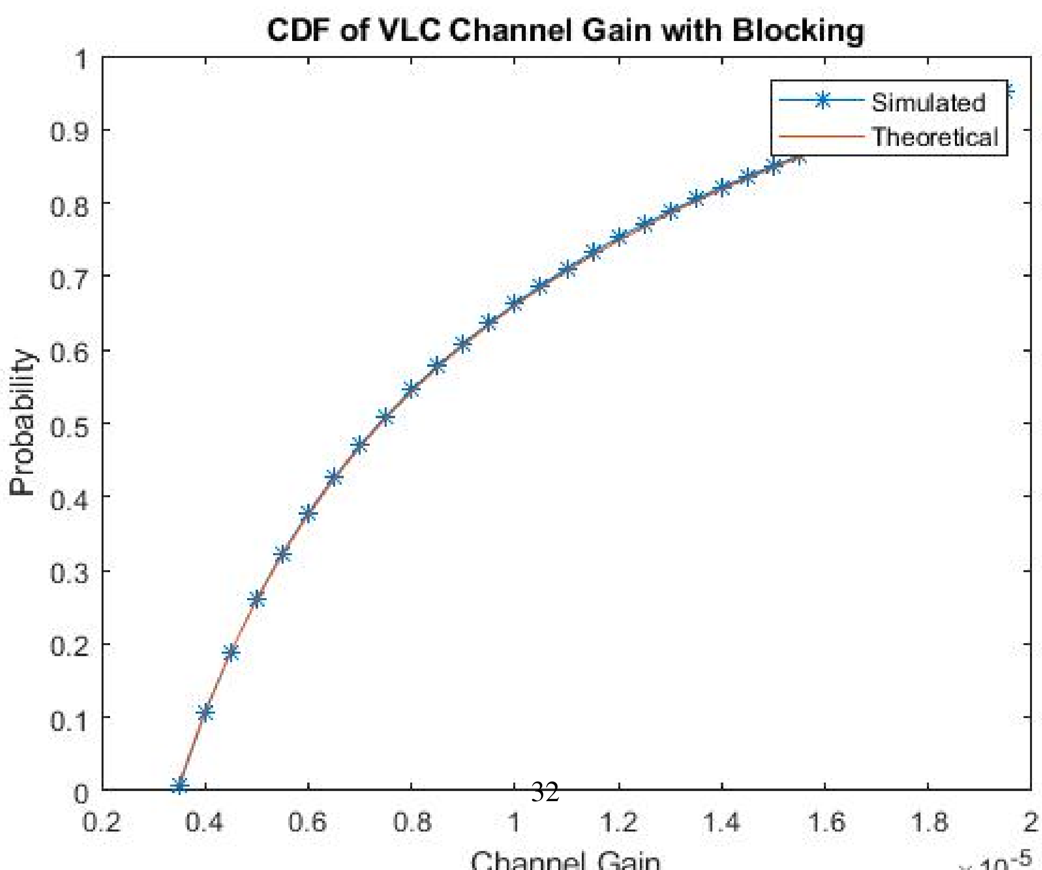
$f(k,h) = (\lambda T)(f_{blocking}(h)) + (1 - \lambda)(T)(f_{los}(h))$

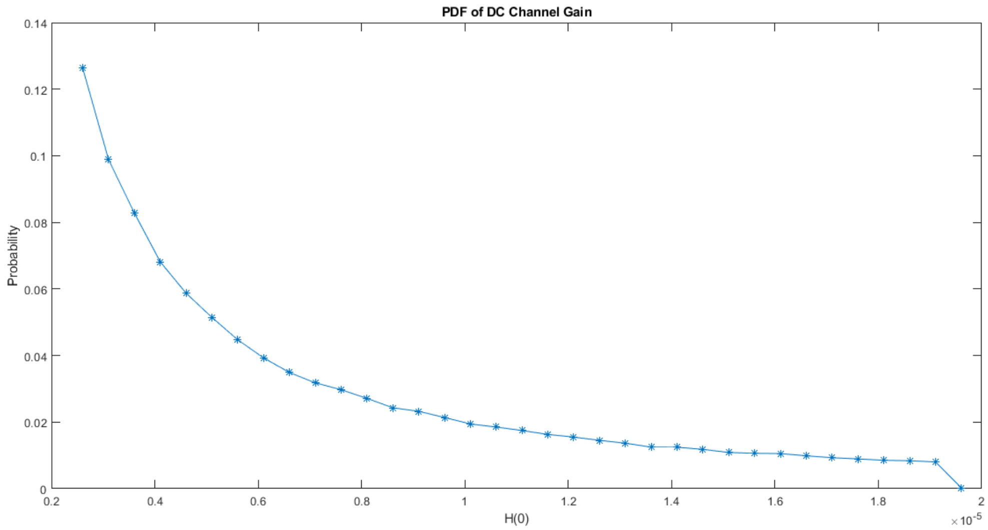
k= Number of occurrences of blocked UE.
λ = Poisson Distributed Random Variable
h = Channel Gain
T = The duration of the Process (taken to be one for simplicity)
t = The duration of the Process (taken to be one for simplicity)

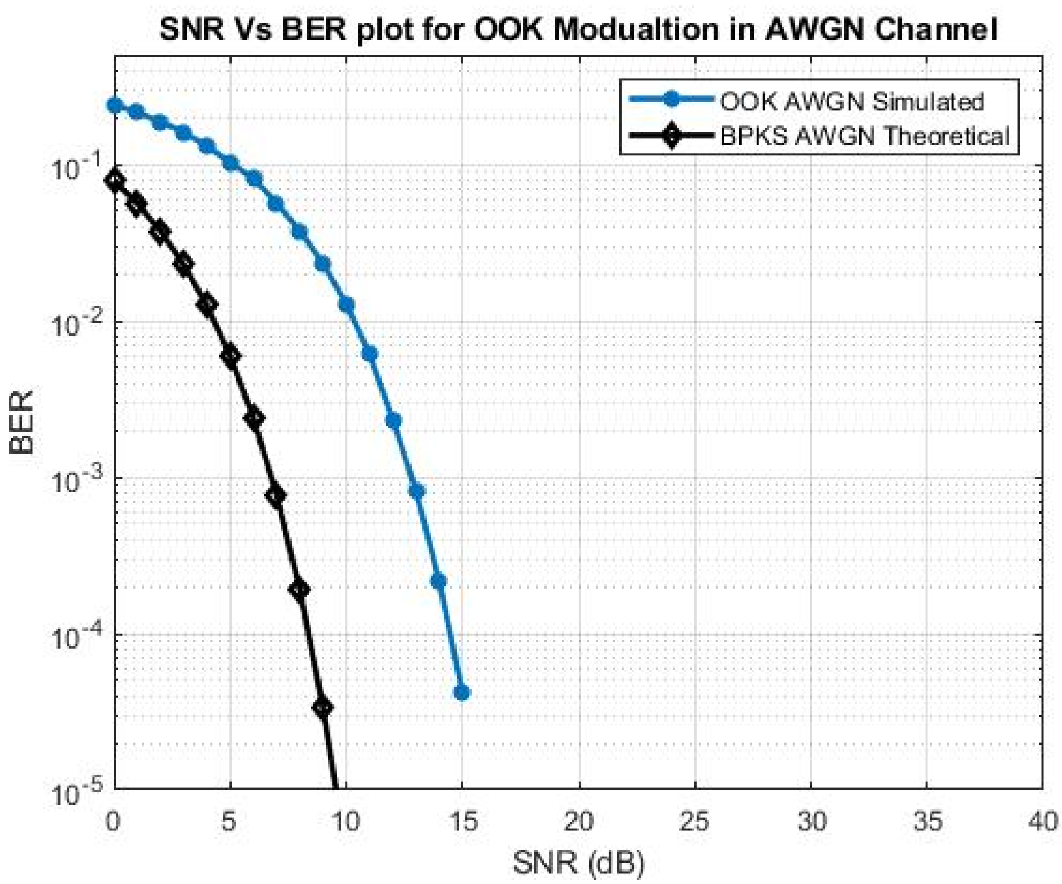
Note: Since we are consider only blockage $f_{blocking}(h)$ = 0

5.2.1 Results


PDF of VLC Channel Gain with Blocking
Simulated
Theoritical
Probability
Channel Gain
$\times 10^{-5}$


CDF of VLC Channel Gain with Blocking
Simulated
Theoretical
Probability
Channel Gain
$\times 10^{-5}$


PDF of DC Channel Gain
Probability
H(0)
$\times 10^{-5}$
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


SNR Vs BER plot for OOK Modualtion in AWGN Channel
OOK AWGN Simulated
BPKS AWGN Theoretical
BER
SNR (dB)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
5
10
15
20
25
30
35
40

Chapter *6*

Conclusions and Future Work

6.1 Conclusion

The shortcomings of RF communication in terms of spectral and bandwidth motivates the research into visible light communication. Now with the surge in LED usage has thrown open the door for many VLC potential. One of which is LiFi capability. This report has sought to verify its usage as a possible data transmission means which has been successfully collaborated by the results.This report strives to enhance the physical implementation of VLC technology for indoor purposes by making a working model of such a prototype which can be further improved upon with the basic understanding derived.Next task was to do Simulation of Optical Wireless Communication Channel.Certain issues faced in the prototype are interference, noise and shadowing which need to be further investigated. These issues are been dealt with by various research groups to make it a promising technology for the future. The results conclusively proves VLC as the mode of last mile connection in 5G. VLC can also lead to Smart Grid enhancements.

6.2 Scope of further work

The proposed work for the future can be broadly divided into 4 categories:
1. Free Space Optical Wireless Communication Infrared, Visible light and Ultraviolet light make up the optical domain. In Free Space Communication this domain can be utilized for very high speed data transmission over moderate distances. This can be achieved by using laser or LED based methods. An important aspect of this method is the security, high speeds and unlicensed spectrum being used. The future works will make use of laser based VLC to achieved its basic understanding, efficiencies and shortcomings. To explore this avenue Koruza units will be used to for physical implementation and further enhancements looked into.

2. Wireless Underwater Optical Communication System Acoustic modems have long been the default wireless communication method for underwater applications due to their long range, the need for high speed communication for underwater applications has prompted the exploration of non-acoustic meth-

ods that have previously been overlooked due to their distance limitations. The proposed work aims to setup an optical communication using LED's so as the improve the speed over moderate distances with the use of low power and low complexity communication systems. The proposed work looks to use super bright blue LED based transmitter system and a blue enhanced photo-diode based receiver system with the goal of transmitting data at rates of 1 Mbps over distances of at least 10 meters. This work will be beneficial to assess the effectiveness of Visible Light Communication as an alternative in underwater communication. Its applications include but not limited to Unmanned Vehicle communications with the oil rigs, data transfer at high rates. It will make use a Blue light LED's, LED driver and photo-diode to accomplish the task.

3. Water pollution measurement using Visible Light Chemical composition and physical properties of any water source is measured by water testing which require a lab setup, special equipment, trained personnel and long turnaround time for information. Our aim is to reduce this turnaround time with the use inexpensive equipment by making use of the visible light communication techniques and water properties.Previous research has shed some light as to the achievement of this as shown in the paper by Tamás Szili, Balázs Matolcsy, and Gábor Fekete. The proposed work intends to improve upon these results to achieve higher accuracy and precision by making use of specific light wavelengths to assess the presence of specific components in water. Further improvement based on data models is also an avenue of investigated.

A brief overview of the method employed: The channel caused attenuation are measured for different wavelengths of light . If there is a connection between the detected power and the channel type (e.g. it is tap water or salty water), the composition of the medium can be determined. It makes possible the detection of water pollution without any expensive investigations in a laboratory. Future works will investigate the connection between the detected power of the emitted light and the different kinds of polluted water, where it was propagated. To verify this model the setup will include an LED based underwater communication device altered to detect power.

4. LED based indoor visible light communications. This report exclusively dealt with the LiFi technology by making use of LEDs to transmit data while at the same time acting as a source of light. LEDs due to their unique characteristic of high switching rate can be used for transmission of data by on-off keying which can be perceived by a photodiode. The genesis of further work in this domain makes use of RGB LEDs based on Nitride and aims to achieve indoor a LiFi prototype based on FPGA to augment the LiFi research efforts.

Chapter 7

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