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B.Eng. Final Year Project

LIGHT FIDELITY

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ACKNOWLEDGMENT

The project referred to in this document has been carried out by a team of two members. For this reason, it was a must for the two members to work together on each single detail beginning with the studying phase, passing by the implementation and ending by the documentation phase. That was useful actually, because it gave the members a wide understanding of the topic (which is a new technology).

DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Bachelor of Science in *Electrical Engineering* is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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ABSTRACT

This report represents a documentation of a project - in the field of wireless communication – called (Light Fidelity). The project is targeting a faster and sustainable way to transmit data. Now, the Wi-Fi is no longer satisfying the customer, because it's depending on the (RF) Radio Frequency spectrum which is now over-crowded and even too expensive.

But instead, it's found that the visible light spectrum can provide us with the wished data rate of transmission under the topic of Visible Light Communication (VLC), or sometimes called Optical Wireless Communication (OWC).

The next page has the table of the report's content; it will definitely guide you through your reading and will make it easier for you to address the desired section.

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LIST OF ACRONYMS/ABBREVIATIONS

Li-Fi	Light Fidelity
Wi-Fi	Wireless Fidelity
VLC	Visible Light Communications
OWC	Optical Wireless Communications
RF	Radio Frequency
AWGN	Additive White Gaussian Noise

Chapter One

1 CONCEPT

Today, Wi-Fi has become a utility just like electricity and water in the house. And being connected nowadays is such an essential need in everybody's life. Now, the question is:

Why would we think of a new data transmission methodology?

The answer is obvious, because all of us suffer from the exponential decreasing speed of Wi-Fi, the lack of security, the accessibility issues most of the time and even the cost.

But here comes an infant staged technology, no not depending on the RF band, instead it is depending on visible light. It may seem like the concept of fiber optics but with some major differences. I'm talking about a technology with which data are transmitted in the free space (not guided in any fixed channel like fibers).

According to properties of visible light, we are sure of the high degree of security provided by VLC systems because light does not travel through dense bodies. Also, many other reasons – will be explained in following sections – were the reason why scientists are now working on this technology and developing it to be available in our lives as a replacement to Wi-Fi.

Data transmission through free space is said to be a new technology, but actually it's not. The concept was used along ago but with a small scale of application and to transmit simple data and symbols. In the next section, the history of VLC will be briefly illustrated and also the concept and how it has been developed.

1.1 INTRODUCTION

To express the term (optical communication) in short words, we can say it is any type of data transmission using light as the transmission medium. Visible light provides a huge license-free spectrum of about 390 THz, for this reason OWC can have very high rate of data transmission.

A full networked solution is needed nowadays to off-load a significant portion of wireless data traffic. After a lot of researches in the field of OWC, it was found that the result which was referred to as Li-Fi was that fully-networked solution as it matches all the criteria (speed, mobility, OWC solution, networked, sustainable).

1.2 HISTORY

Yes, it is a new technology but it has roots from the past when the concept was used in very simple ways. The concept was always there when people used fire and smoke to express something. Semaphore is considered as one of the oldest visual signalling methodologies that was used to convey messages (information), using towers with movable paddles or blades. Where the position of these blades and some other mechanical elements is what determines the encoded information. In 1792, this system was firstly invented by a French engineer called Claude Chappe. This system was more efficient than post riders for long distances transmission.

As more modern semaphore, some derivatives of the semaphore system were used during the 1800s like the Heliograph which is optical telegraphy using mirror-directed sunlight reflectors.

In 1999, Gfeller and Bapst showed the potential of OWC for high in-house capacity networks promising hundreds THz bandwidth of electromagnetic spectrum in the optical domain. At a centre wavelength of 900 nm in the IR spectrum, the system was capable of achieving 1 Mbps using on-off keying (OOK) modulation and diffuses radiation for office room coverage.

In 1996, a 50 Mbps data rate was achieved by Marsh and Kahn who demonstrated an indoor diffuse OOK IR system. Later, a faster data rate of 50 Mbps was reached by a similar system. In 2003, OOK VLC was setup with up to 400 Mbps rate of transmission.

In 2006, (Afgani) showed for the first time, using a proof-of-concept demonstrator, that the high crest factor in orthogonal frequency division multiplexing (OFDM), typically a disadvantage in RF communication, can be turned into an advantage for intensity modulation and direct detection (IM/DD). He implemented the direct-current-biased optical OFDM (DCO-OFDM) transmission scheme, which was later used by other

research groups. Vucic et al. ascertained the potential of VLC systems with a demonstration of a 100 Mbps data rate.

Until that date, the VLC was not such a famous topic. But by 2011, Professor Harald Haas from university of Edinburgh has shown up in TEDGlobal where the term Light Fidelity Was firstly coined. Later on November 2012 he demoed what he calls (a massive extension for the internet) in 2012 TED Global conference in London. Within the talk he discussed the Li-Fi topic from another perspective. Where he focused on the energy saving concept by using solar panels to harvest power from the light and also work as a receiver.

It is expected that within 5 years - more or less –Li-Fi will be available in our devices.

1.3 SCIENTIFIC IDEA

In our daily lives we all use the remote controls, they are based on the scientific idea that the IR LED sends line of data stream whenever there is a button clicked, which is then detected by an IR detector. So why not use the same concept in sending thousands of data streams. The problem is that sending large messages using IR wave will need high input power which is not advisable. That's why scientists tended to think of sending these amounts of data by Visible Light.

Here comes another concept, the fibre optics. It depends on the transmission of data in the form of light guided in a certain type of fibres. Scientists then thought of mixing up the two ideas so that light can transmit data in the free space.

1.4 LI-FI

As in the optical fibres, the light source is LED or Laser diode. For the reason that they have the ability to switch on and off in very high speeds, even more than what a human eye can notice. So, in optical wireless communication (OWC), the light intensity of a

light emitting diode (LED) is modulated by a message signal. After propagating through the optical wireless channel, the light message is detected by a photodiode (PD).

The path loss is the primary characteristic of the channel. An accurate representation of the light distribution in an indoor setup was obtained by means of a Monte Carlo ray-tracing (MCRT) simulation. It confirmed that the path loss in dB is linear over logarithmic distance, and it ranges between 22 dB and 40 dB for line-of-sight (LOS) and non-line-of-sight (NLOS) communication scenarios in the considered setup.

More information about the modulation techniques, path loss and how we applied them on our prototype will be discussed in the following sections.

1.4.1 Advantages

Light has been an essential thing in our life, it helped in creating every feature of life around us so it can never be harmful or have any health restriction as long as eye safety regulations are fulfilled.

On considering the disadvantages of Wi-Fi that have been increasing lately, the Li-Fi comes to turn these Wi-Fi disadvantages into advantages. How??

Let's begin by illustrating each Wi-Fi disadvantage and how it turned then as a bonus for Li-Fi.

- 1- Efficiency: VLC has been identified as a potential solution for mitigating the looming RF spectrum crisis. VLC is particularly enticing as lighting is a commodity that has been integrated into virtually every inhabited environment, and sophisticated infrastructures already exist. The use of the visible light spectrum for high-speed data communication is enabled by the emergence of the LED, which at the same time is at the heart of the next wave of energy-efficient illumination. In that sense, the concept of combining the functions of illumination and communication offers the potential for tremendous cost savings and carbon footprint reductions. The energy used for communication is significantly reduced as a result of the piggybacking of data on illumination.

- ϣ- Capacity: Visible light spectrum is 10 thousand times wider than the radio spectrum including the 60 GHz band, they are used now and crowded (almost full) and it is even very expensive.
- ϣ- Availability: Lighting is on most of the time in indoor environments even during day time. So in the places where you are asked to turn off any network connection on your laptop or mobile phone (on planes or in hospitals) you can find an alternative way to stay connected (USING LIGHT).
- ϣ- Security: When Li-Fi is used to transmit data in a room, light will not pass the wall to the room next to it. due to the fact that light does not propagate through opaque objects and walls, optical wireless signals can be confined within a room., so it is impossible for another user to get the data.

1.4.2 Applications

Wherever it is hard for to access the internet, it is the place where the Li-Fi can be the alternative connection utility. For example:

- Aeroplanes: where the signals of Wi-Fi and all RFs can interfere with those signals received and transmitted by the plane so it might be of a great risk. Li-Fi can replace it to keep you connected.
- Hospitals: RFs are unhealthy so Li-Fi has an advantage here.
- Buses: Where roads don not always have good network coverage
- Factories
- Indoor communications
- Underwater communications

Chapter TWO

۲ MODULATION

Now let's talk communication wise, let's talk about the wave form traveling in the channel and how the signal is modulated and what are the latest studies concerning this topic. Actually research papers are being released daily because it is a new field of study.

۲.۱ OFDM

OFDM is a combination of modulation and multiplexing. In this technique, the given resource (bandwidth) is shared among individual modulated data sources. Normal modulation techniques (like AM, PM, FM, BPSK, QPSK, etc..) are single carrier modulation techniques, in which the incoming information is modulated over a single carrier. OFDM is a multicarrier modulation technique, which employs several carriers, within the allocated bandwidth, to convey the information from source to destination

OFDM plays a great role in solving the crowded band problem, as it really makes use of the given bandwidth. OFDM enables low-complexity equalization and adaptive bit loading in a frequency selective channel. It is even very effective for communication over channels with frequency selective fading (different frequency components of the signal experience different fading). It is very difficult to handle frequency selective fading in the receiver, in which case, the design of the receiver is hugely complex. Instead of trying to mitigate frequency selective fading as a whole (which occurs when a huge bandwidth is allocated for the data transmission over a frequency selective fading channel), OFDM mitigates the problem by converting the entire frequency selective fading channel into small flat fading channels (as seen by the individual subcarriers). Flat fading is easier to combat (compared to frequency selective fading) by employing simple error correction and equalization schemes.

2.2 MIMO TECHNIQUES

Within this section we discuss the MIMO techniques which we study for indoor OWC. MIMO (multiple-input, multiple-output) takes advantage of multiplexing to increase wireless bandwidth and range. The algorithm of MIMO sends information out over two or more antennas (array of antennas) and the information is received via multiple antennas as well. On normal radio, multiplexing would cause interference, but MIMO uses the additional pathways to transmit more information and then recombines the signal on the receiving end. MIMO systems provide a significant capacity gain over conventional single antenna systems, along with more reliable communication. The benefits of MIMO led many to believe it is the most promising of emerging wireless technologies.

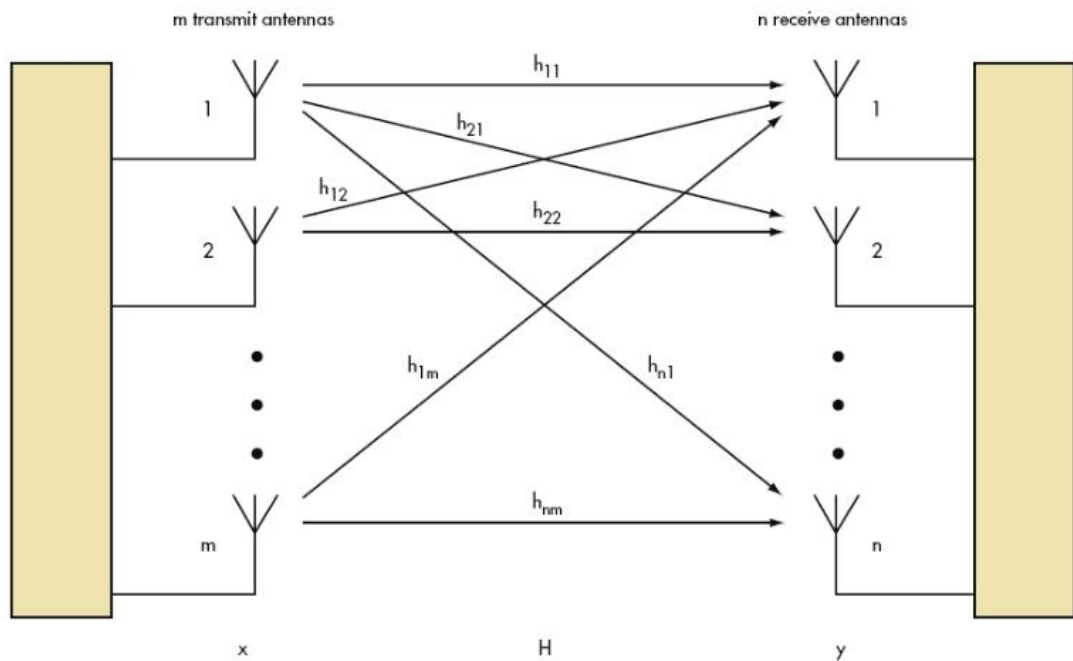


Figure 1 - MIMO diagram

The simplest MIMO transmission technique is RC which simultaneously emits the same signal from all transmitters. Therefore, for RCs $s_1 = s_2 = \dots = s_N$ holds. RC is known to achieve good performance in free-space OWC because of transmit-diversity.

۲.۳ SPATIAL MODULATION

SM is a combined MIMO and digital modulation technique. In SM, the conventional signal constellation diagram is extended to an additional dimension, namely the spatial dimension, which is used to transmit additional bits. A unique binary sequence, i.e. the spatial symbol, is assigned to each transmitter in the transmitting array.

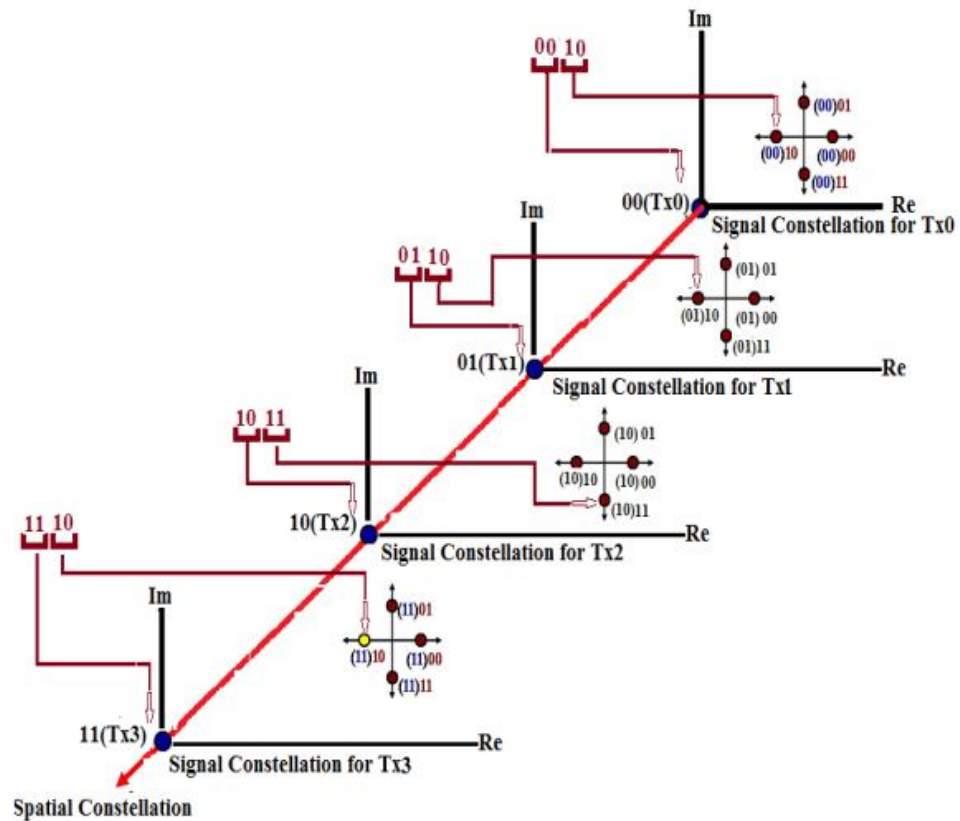


Figure ۲ - Spatial modulation diagram

A transmitter is only activated when the random spatial symbol to be transmitted matches the pre-allocated spatial symbol of the transmitter. Thus, only one transmitter is activated at any PAM symbol duration. Therefore, there is only one non-zero element in the signal vector $\mathbf{x}_t$ to be transmitted at a time instant, and this element is the digitally modulated signal.

۲.۳.۱ SM-OFDM in MIMObased VLC

This is how the transmitter and the receiver will look like if we mixed the previous techniques all together to get the advantages of summed up in one system.

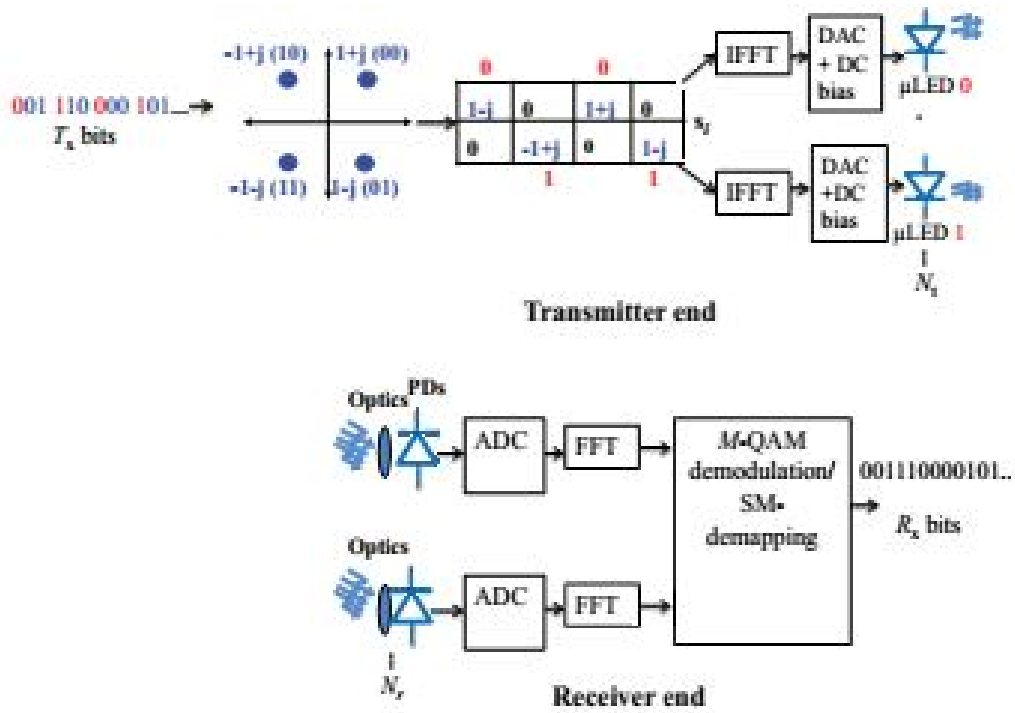


Figure ۳ SM-OFDM

In this study, we assume that non-linear effects in the system are insignificant. Hence, the system equation for the received SM symbol corresponding to the i -th sub-carrier can be written as follows:

$$Y_i = H_i S_i + W_i$$

Here, Y_i is the i -th column of Y . Furthermore, H_i denotes the optical MIMO channel gain between the N_t μ LEDs and the N_r photo-detectors for the i -th sub-carrier. The effect of shot noise and thermal noise in the system is represented by W_i

. In general, W_i can be modelled as additive white Gaussian noise (AWGN), uncorrelated with the signal.

Chapter Three

۳ THE PROTOTYPE

۳.۱ TRANSMITTER

The main component in a Li-Fi device is the LED which acts like the transmitter. It can be a single LED or an array of them just like the concept of array antennas.

۳.۱.۱ Hardware and Schematic

In our prototype we used ۱۰ LEDs of LW۴۱۰ type, and the selection was upon the following reasons:

- Frequency
- Brightness
- Affordable Cost
- The viewing angle



Figure ۴ LW۴۱۰

The schematic:

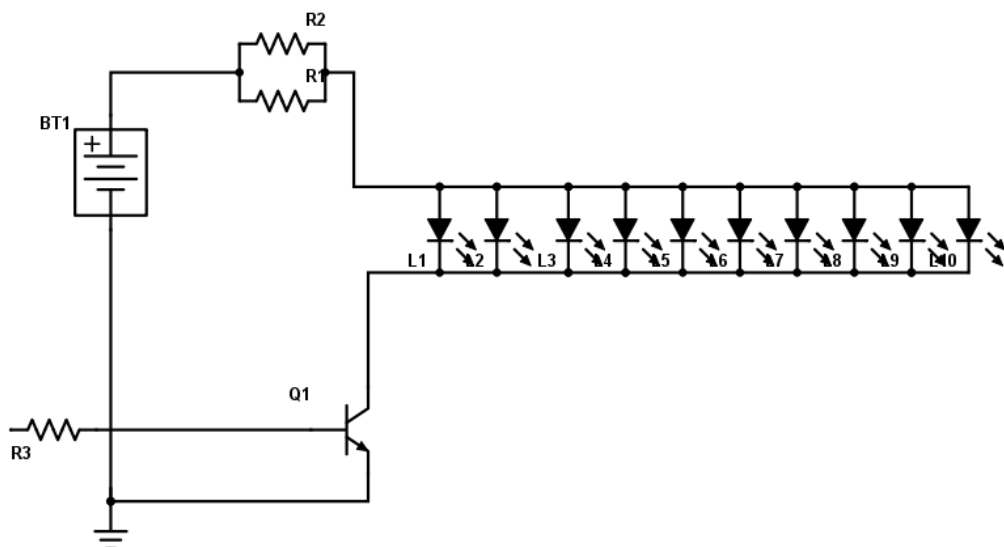


Figure ۵ Transmitter schematic

- The NPN BJT acts as a switch, which turns on when a sufficient valued signal is coming from the MCU letting power reach from the batteries to the LEDs.
- R_B is a limitation on the current flowing in the base of the BJT.
- The MCU is Nano-Arduino

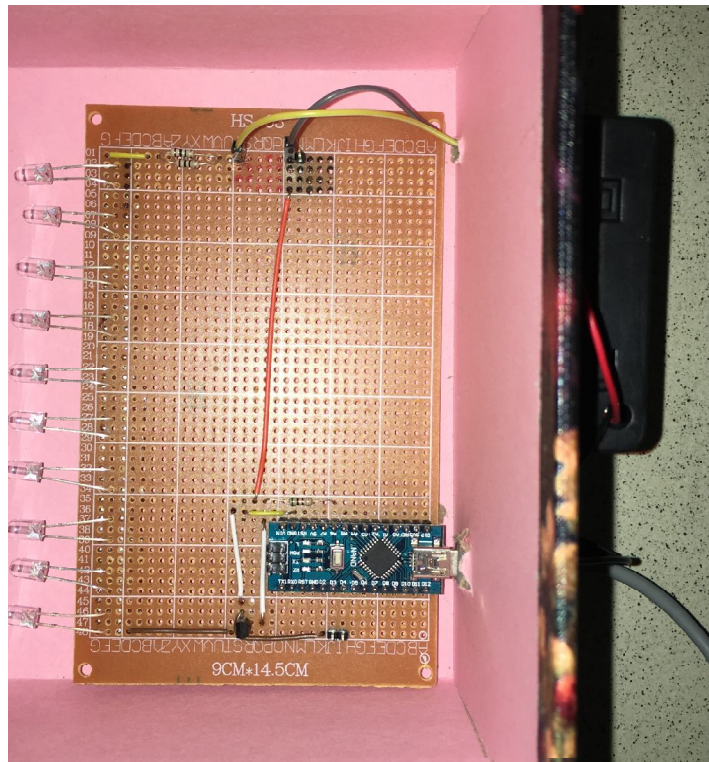


Figure 3 Transmitter circuit

3.1.2 Software

We used Nano-Arduino as MCU, to send a signal to the LEDs and to manage the transmission process.

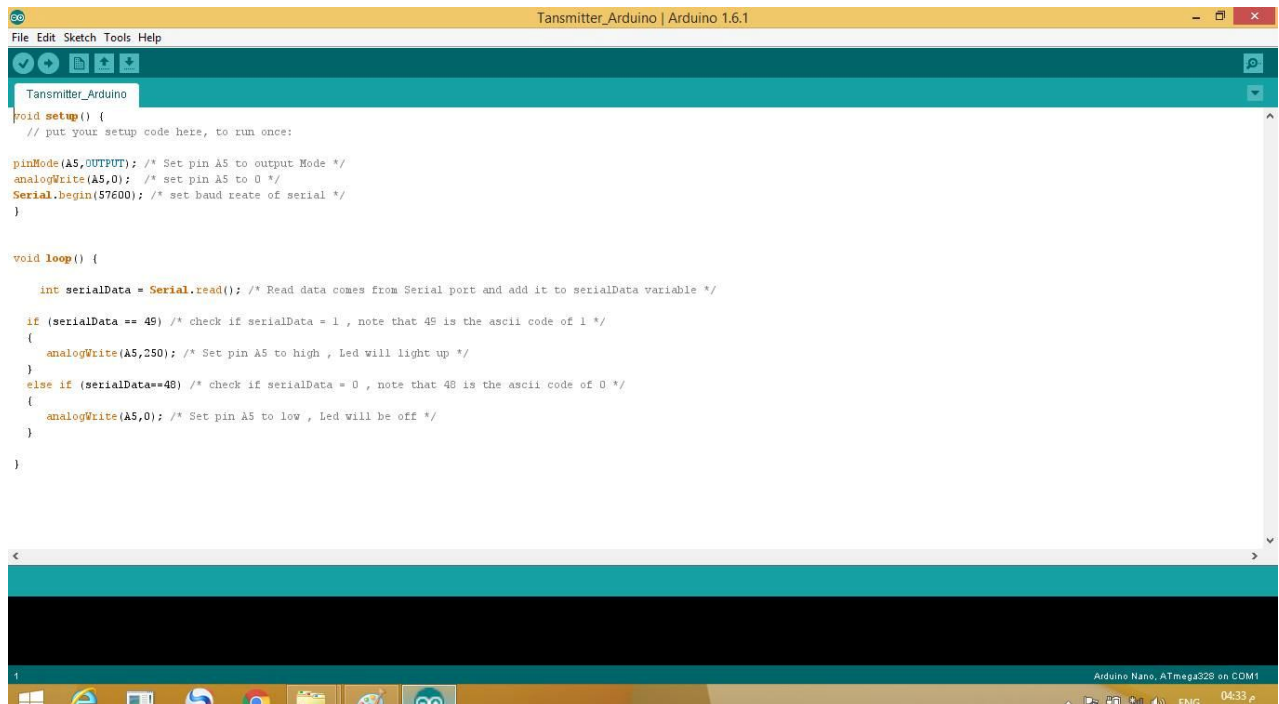


Figure V Transmitter Arduino code

But what played a greater role was the C#. Which we used to build a windows applications to facilitates data transmission from one serial port to a laptop on another one on the same laptop.

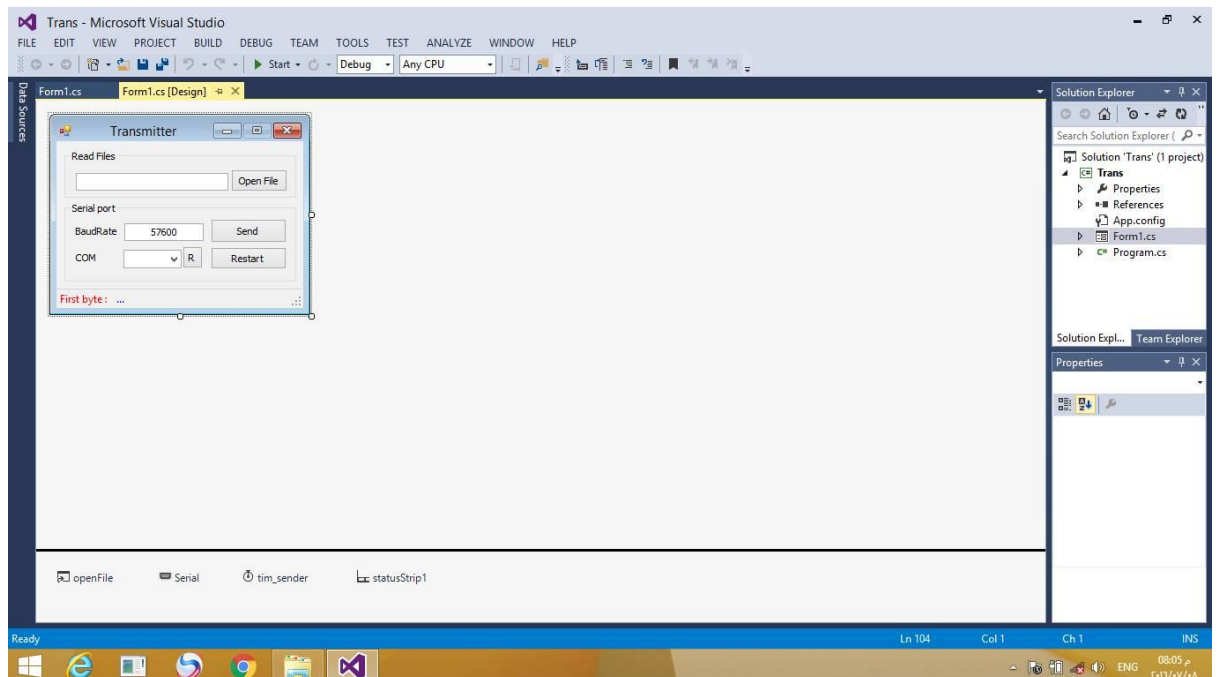


Figure ^ Transmitter form

- Open file: to choose file and load it to be sent
- COM: Shows the used serial port for the transmitter

۳.۲ RECEIVER

۳.۲.۱ Hardware and Schematic

The Main component of a Li-Fi device receiver is the photo detector. In our prototype we used the SFH۳۳۳ photodiode for the following reasons:

- Affordable Cost
- Field of visibility
- Response time
- Range of wavelengths

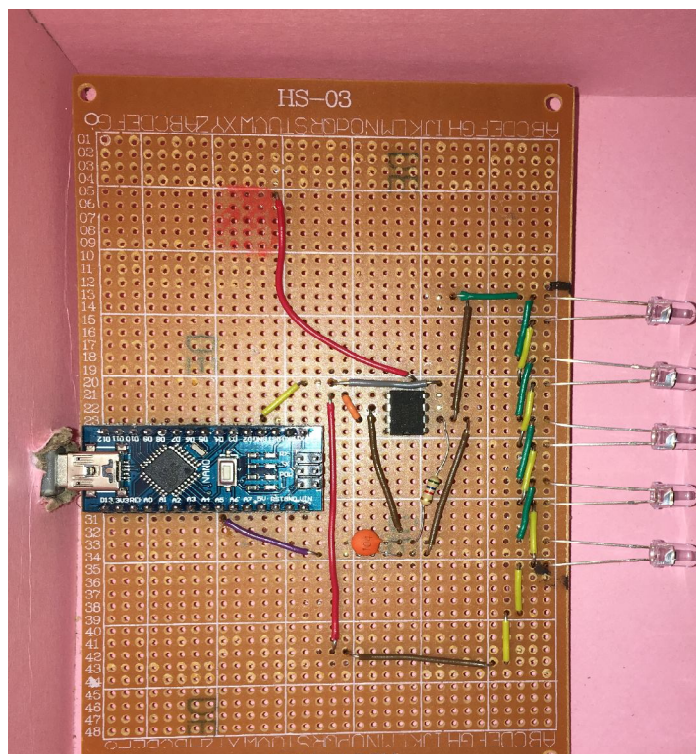


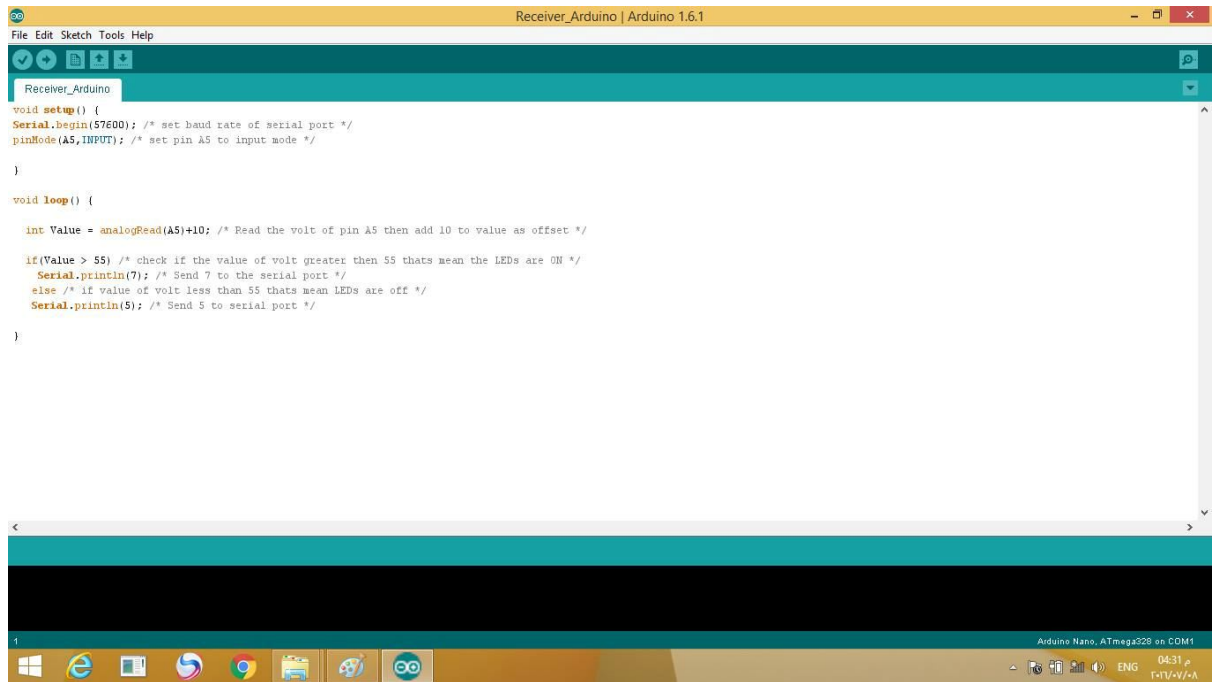
Figure ۹ Receiver Circuit

During the experiment we began by using one photodiode then we increased their number until we reached sufficient results with least number of them.

- The Op-amp used to amplify the signal, to give a higher peak to peak voltage value for the output to decrease the effect of noise.

۳.۲.۲ Software

- The Arduino code let us read the received signal faster than depending on the C# code first.



```

Receiver_Arduino
void setup() {
  Serial.begin(57600); /* set baud rate of serial port */
  pinMode(A5,INPUT); /* set pin A5 to input mode */
}

void loop() {
  int Value = analogRead(A5)+10; /* Read the volt of pin A5 then add 10 to value as offset */

  if(Value > 55) /* check if the value of volt greater then 55 thats mean the LEDs are ON */
    Serial.println(7); /* Send 7 to the serial port */
  else /* if value of volt less than 55 thats mean LEDs are off */
    Serial.println(5); /* Send 5 to serial port */
}
  
```

Figure ۱۰ Receiver Arduino code

The C# receiver form:

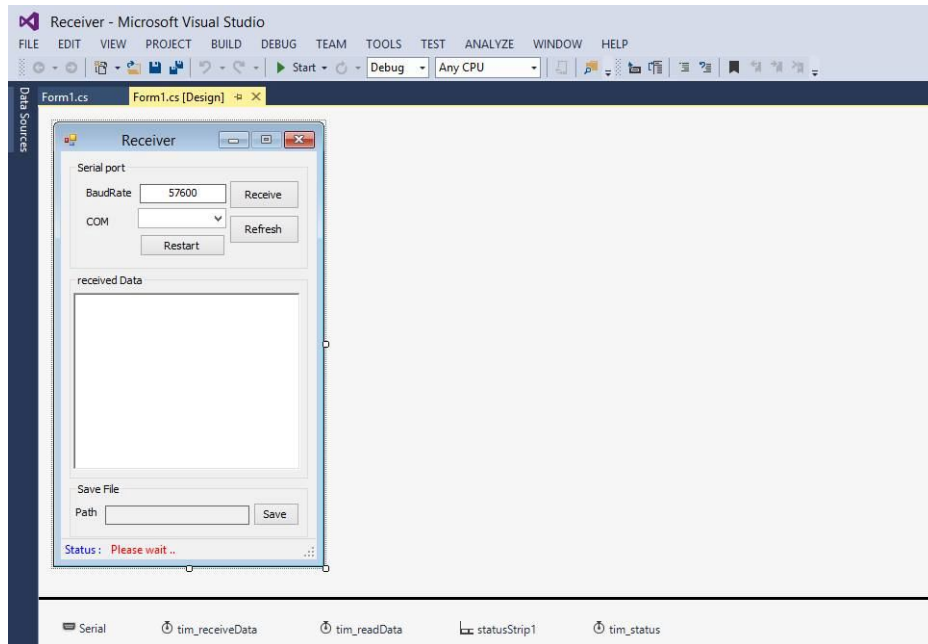


Figure 11 Receiver form

- The receive button activates the photodiode to be able to receive data.
- The received bits are written in the blank window.
- Save button is used after the transmission is accomplished.

Chapter Four

❖ **CONCLUSION**

Our journey with this project was an experiment, a literal one. The field is brand new for us to deal with so we suffered in the beginning then we got to understand the concepts. That's why it was all a challenge to get to any results and make the prototype able to send and receive data correctly with the least error as much as possible. Even if those results were far from the estimated ones but at least the concept was proved.

Challenges and future work

Companies which work and has interests in this field can help start-ups like us to continue their studies and researches so that this technology get to the customer as a product or a facility in their daily used devices.

We are thinking of expanding this field's applications by changing the light source to a laser diode to be able to transmit data over kilometres distance, and then these beams are received by solar panels which also harvest power from the surrounding light.

This technology could be able to transmit TV signals over long distances and other usages.

Chapter Five

• CODES

•.1 C#

•.1.1 Transmitter

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;
using System.IO;

namespace Trans
{
    public partial class Form1 : Form
    {
        public Form1()
        {
            InitializeComponent();
        }

        string Data = null; /* Variable to receive data from serial port = nothing "" */
        int counter = 0;
        private void btn_openFile_Click(object sender, EventArgs e)
        {
            openFile.FileName = "";
            DialogResult res = openFile.ShowDialog(); /* Open the 'Open File dialog Box' and store user choice in 'res' variable */
            if (res == System.Windows.Forms.DialogResult.OK) /* If user selects file then press 'Ok' button */
            {
                txt_path.Text = openFile.FileName; /* Add the selected file path to the 'txt_path' TextBox */
                byte[] fileBytes = File.ReadAllBytes(txt_path.Text); /* read file as bytes and store it in byte array 'fileBytes' */
                StringBuilder sb = new StringBuilder();
                foreach (byte b in fileBytes) /* loop on the fileBytes array and append elements together */
                {
                    sb.Append(Convert.ToString(b, 2).PadLeft(8, '0')); /* Convert Bytes to 2's base then padding there left side by Zeros and append them */
                }
                Data = sb.ToString(); /* fill Data variable with binary results */
                Data = Data + "001011110011111001011100"; /* adding stop button to end of the data /\ */
            }
        }
    }
}
```

```
/* Data = sb.ToString(); /* fill Data variable with binary results */
/* Data = Data + "001011110011111001011100"; /* adding stop bytes to end of the data /\ */
/* lbl_fileSize.Text = Data.Substring(0, 6); /* show the first 6 bits from data in status bar on the form */
groupBox2.Enabled = true; /* Enable buttons and textBoxes in the groupBox on form */

private void btn_send_Click(object sender, EventArgs e)
{
    if (Serial.IsOpen == false) /* Check if the connection with serial port isn't open */
    {
        Serial.BaudRate = Convert.ToInt32(lbl_baudRate.Text); /* set baud rate */
        Serial.PortName = com_portName.Text; /* set the com port name */
        Serial.Open(); /* open connection */
    }

    Serial.WriteLine("1"); /* send start bit */
    counter = 0; /* reset 'counter' variable */
    timer_sender.Enabled = true; /* start timer */
}

private void btn_stop_Click(object sender, EventArgs e)
{
    Serial.Dispose(); /* disconnect serial port connection */
    Application.Restart(); /* restart application */
}

private void timer_sender_Tick(object sender, EventArgs e)
{
    if (counter.ToString().Length > 8 && counter <= Data.Length - 1) /* check if counter value less than Data length */
    {
        Serial.WriteLine(Data[counter].ToString()); /* Data variable is array of bits , therefore send bit at index 'counter' from 'Data' array to
        counter++; /* increase counter by 1 */
    }
}
```

```

Receiver - ReceiverForm1 - Form1
private void tm_readData_Tick(object sender, EventArgs e)
{
    try // try & catch are used to ignore any error
    {
        string value = Serial.ReadExisting().Replace("\n", "").Replace("\r", ""); // Read data from Serial port and remove empty lines
        Data = value[value.Length - 1].ToString(); // Serial.ReadExisting() read many data we need only the last data because of this we just take the
        // the last value received and add it to Data variable
    }
    catch { } // If there is any error do nothing
}

private void btn_refresh_Click(object sender, EventArgs e)
{
    btn_refresh.PerformClick(); // press refresh button automatically
}

private void tm_status_Tick(object sender, EventArgs e)
{
    lbl_status.Text = "Ready to receive!"; // change state text in status bar
    lbl_status.ForeColor = Color.Green; // change the color of
}

private void btn_refresh_Click(object sender, EventArgs e)
{
    string[] portNames = System.IO.Ports.SerialPort.GetPortNames(); // get port names connected to computer
    lbl_portName.Items.Clear(); // clear comboBox items
    foreach (string port in portNames) // loop on port names
    {
        txt_portName.Items.Add(port); // add names to comboBox
    }
}

```

2.1.2 Receiver

```

Form1.cs [Design] - ReceiverForm1 - Form1
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;

namespace Receiver
{
    public partial class Form1 : Form
    {
        public Form1()
        {
            InitializeComponent();
        }

        int dataSplitter = 0;
        string Data = "";
        bool start = false;
        private void btn_receive_Click(object sender, EventArgs e)
        {
            if (Serial.IsOpen == false) // check if connection with serial port is open
            {
                Serial.BaudRate = Convert.ToInt32(lbl_baudRate.Text); // set baud rate
                Serial.PortName = txt_portName.Text; // set com port name
                tm_receive.Enabled = true; // start timer receive data
                tm_readData.Enabled = true; // start timer read data
                Serial.Open(); // open connection
            }
            tm_status.Enabled = true; // start status timer
        }

        private void btn_stop_Click(object sender, EventArgs e)
        {
            Serial.Close(); // close serial port connection
            Application.Shutdown(); // end application
        }
    }
}

```

```

Receiver - ReceiverForm1 - Form1
private void btn_stop_Click(object sender, EventArgs e)
{
    Serial.Close(); // close serial port connection
    Application.Shutdown(); // end application
}

private void tm_receiveData_Tick(object sender, EventArgs e)
{
    // if Data is contain "" that mean the LRS are on but if this the first time to read / in Data this mean it was the start bit
    // so we will set the variable 'start' to true to inform program that the start bit has been received
    if (Data.Contains("") && start == false) // check if LRS are on and this is the first time to receive
    {
        start = true;
    }
    else if (Data.Contains("0") && start == true) // check if LRS are on and this is the first time to receive 0
    {
        rich_receivedData.Text += "0"; // write 0 in textbox named 'rich_receivedData'
    }
    else if (Data.Contains("1") && start == true) // check if LRS are off and start bit already received
    {
        rich_receivedData.Text += "1"; // write 1 in textbox named 'rich_receivedData'
    }
}

private void rich_receivedData_TextChanged(object sender, EventArgs e)
{
    // The TextChanged event happens when data changes in textbox
    dataSplitter++; // increase dataSplitter variable by 1
    if (dataSplitter == 8) // Check if dataSplitter equal to 8, that means we received 8 bit
    {
        rich_receivedData.Text += ","; // write comma in textbox
        dataSplitter = 0; // reset dataSplitter variable
    }
}

if (rich_receivedData.Text.Contains("00000001,00000001,00000001,00000001")) // check if textbox named 'rich_receivedData' contains 4 zeros

```

```

Receiver
- ReceiverForm1
- Form1()

if (rich_receivedData.Text.Contains(",00101111,00111110,01011100,")) /* Check if textBox named 'rich_receivedData' contains stop bytes */
{
    rich_receivedData.Text = rich_receivedData.Text.Replace(",00101111,00111110,01011100,", ""); /* remove stop byte from data */
    rich_readData.Enabled = false; /* stop timer read data */
    tim_receiveData.Enabled = false; /* stop timer */
    MessageBox.Show(null, "File received successfully", "Data received", MessageBoxButtons.OK, MessageBoxIcon.Information); /*show msg */
    group_save.Enabled = true; /* enable group box and its elements */
}

private void button1_Click(object sender, EventArgs e)
{
    SaveFileDialog save = new SaveFileDialog();
    save.Title = "Save File as ...";
    DialogResult res = save.ShowDialog(); /* open 'Save file as' dialog box and store user selection to 'res' variable */
    if (res == System.Windows.Forms.DialogResult.OK) /* Check if user press ok not cancel */
    {
        txt_path.Text = save.FileName; /* Add path to textBox named 'txt_path' */
        string[] binary = rich_receivedData.Text.Split(','); /* Split data by comma I.O.W (group every 8 bits in one row in string array) */
        byte[] recfile = new byte[binary.Length]; /* create a new byte array with length equal to length of Data */
        int count = 0;
        foreach (string byt in binary) /* loop on binary array and take every row then add it to string variable named byt */
        {
            recfile[count] = Convert.ToByte(byt, 2); /* add value of string byt to row in 'recfile' array in index 'count' */ /*just type masking
            count++; /* increase counter by 1 */
        }
        System.IO.File.WriteAllBytes(save.FileName, recfile); /* write all data(recfile) to file in location 'save.FileName' */
    }
}

private void tim_readData_Tick(object sender, EventArgs e)
{
    try // try & catch are used to ignore any error
    {
        rxtion value = Serial.ReadExisting();
    }
}

```

```

Trans
- TransForm1
- btn_send_Click(object sender, EventArgs e)

count = 0; /* increase counter by 1 */
if (count > (data.Length - 1)) /* count > data.Length means all data has been sent */
{
    Serial.WriteLine(""); /* turn off all lines */
    Serial.Dispose(); /* disconnect serial port connection */
    count = 0; /* reset counting */
    tim_send.Enabled = false; /* stop timer */
    MessageBox.Show(null, "File sent successfully", "Completed", MessageBoxButtons.OK, MessageBoxIcon.Information); /* show msg */
}

private void btn_refresh_Click(object sender, EventArgs e)
{
    string[] portNames = System.IO.Ports.SerialPort.GetPortNames(); /* get all port names that connected to computer and add them to string array */
    comboBox1.Items.Clear(); /* clear all comboBox data */
    foreach (string port in portNames) /* loop on port names */
    {
        comboBox1.Items.Add(port); /* add port name to comboBox */
    }
}

private void form1_Activated(object sender, EventArgs e)
{
    btn_refresh.PerformClick(); /* when application opened press refresh button automatically */
}

private void toolStripStatusLabel1_Click(object sender, EventArgs e)
{
}

private void timer1_Tick(object sender, EventArgs e)
{
}

```

Chapter Six

6 REFERENCES

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