# ONE WAY FIBRE-OPTIC AUDIO LINK

BY

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(99/8243 EE)

IN THE DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

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A DESIGN AND CONSTRUCTION PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.)

IN THE DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

2004/2005

# DECLARATION

This is to certify that this project was carried out by Nuruddeen M. Abdulbaqi, with Reg. No 99/8243EE and that the project has the minimum standard acceptance by the Department of Electrical and Computer Engineering, Federal University of Technology, Minna.

# APPROVAL PAGE

This Project has been read and approved by the undersigned on behalf of the Department of Electrical & Computer Engineering, Federal University of Technology, Minna.

| | | |
|---|---|---|
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| PROJECT SUPERVISOR | NAME | DATE |
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| EXTERNAL SUPERVISOR | NAME | DATE |

# DEDICATION

This Project is dedicated to my father, Alhaji Muhammad Abdulbaqi, my mother, Hajiya Ummah Muhammad, my step-mums, my brothers, my sisters, my friends, my Project Supervisor as well as the entire Staff and students of Electrical and Computer Engineering Department, Federal University of Technology Minna, Niger State.

## ACKNOWLEDGEMENT

All Praise be to Almighty Allah; The Lord of the worlds, Most Gracious, Most Merciful, for His guidance and protection. Indeed, to Him goes all the credit for granting me the resources, wisdom and the ability to read and understand.

I am very grateful to my parents for their parental care and everything. Without you, my world is incomplete. I am equally indebted to all my brothers and sisters for their enourmous support and understanding. Also, the entire family of Mallam Bello Sule for their kind gesture, may Allah (S.W.A.) reward you all abundantly, ameen.

My sincere and deep appreciation goes to my supervisor, Mr. D. S. Umar. He is my lecturer who offered me advice, and encouragement. Quite obviously I will continue to cherish and uphold his pain-staking search for truth, hardworking and moral uprightness.

I also appreciate the ready assistance, support and friendly gesture accorded me by all my concerned and close friends, may Allah (S.W.A.) bless you all abundantly, ameen.

# ABSTRACT

This design and construction project tends to provide a working solution to ever increasing demand for means of short distance communication that are efficient, reliable and yet cost-effective in terms of maintenance. The Fibre-Optic Audio Link allows one to send sound/voice signals from one point to another using one circuit board transmitter at one end, and a circuit board Receiver at the other end, linked physically by a Fibre-Optic cable as its medium of transmission.

The project design and construction is desired to objectively explore and incorporate the making use of the new and by far, the most advanced technology of the day as far as the medium of transmission in telecommunication is concerned; the fibre-optic cable. In addition to this, the project went further to establish the possibility of a "splice-free" fibre-optic cable termination by successfully achieving the desired objective without making use of a single special fibre-optic "terminating-connector".

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# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1 THE NEED FOR COMMUNICATION

Communication is a vital part of personal life which is so important in the life of a human being; his business, education, and any other situation where people encounter each other. Communication between two people is an outgrowth of methods developed over centuries of expression. Gestures, the development of language, and the necessity to engage in joint action all played a part.

Humans are not the only creatures that communicate; every other animal exchange signals and signs that help them find food, migrate, or reproduce. The 19th-century biologist Charles Darwin showed that the ability of a species to exchange information or signals about its environment is an important factor in its biological survival.

In today's world of highly communication-dependent environment, where time, efficiency, prompt execution of orders and instructions are becoming part of the basic needs and requirements of our daily life businesses, the need for appreciating and widely putting into application, the newly introduced and by far, most sophisticated technology of communication, together along with its means, methods and modes cannot be over emphasized.

## 1.2 DEFINITION AND CONCEPT OF COMMUNICATION

In the light of the importance of communication and the need for it by all living creatures for natural survival, it is vital to have its meaning better understood.

In Electrical Engineering term, communication could be defined as "the sending, processing and reception of message signals in terms of audio, video or data through a medium such as microwave, optical fibre, satellite and the internet between any pair of desired locations". Hence, a communication link can be defined as the means of sending, processing and reception of message signals from one transmitting end to another receiving end.

Further more, Transmission of signals from one point to another can either be in simplex or duplex form. Simplex Communications can go in only one direction, so the sender can use the whole of the available bandwidth. Both parties involved cannot transmit at the same time. Example includes the use of walkie-talkie. It is a one way mode of communication.

The other mode of signal transmission is the Duplex mode of transmission. This involves the transmission and reception of signals simultaneously. Since the signals transmitted and the signals received follow different paths, there is no jamming or conflict of signals, so signals can go either way at the same time. Example includes the use of the telephone. However, the message signals can be sent from one sender to a single receiver (point-to-point) or from one sender to many receivers (point-to-multipoint).

## 1.3 THE ONEWAY FIBRE-OPTIC AUDIO LINK IN COMMUNICATION

The fibre-optic audio link allows one to send sound signals through fibre optic (FO) cable from one point to another. The audio link comprises of one circuit board transmitter (Tx) at the transmitting end and one circuit board receiver (Rx) at the receiving end.

On the transmitter (Tx) circuit board, there is a microphone and a circuit made to modulate the light emitted from an LED (light emitting diode). This circuit is made in such a way that the LED is contained in a plastic case which allows easy connection of the FO cable. On the receiver (Rx) board there is the photo-Darlington receiver unit, a speaker and a circuit to convert and amplify the detected signal back into a sound wave.

As the signal travels in the FO cable as a light wave, it is immune to any electrical or magnetic fields along its path. This makes the fibre-optic audio link very much applicable even in electrically noisy environments. The link is suitable for communicating between two points in industrial/manufacturing plants, industrial complex, processing plants and workshops. Also, it can be used in places of large population or gathering such as the theaters, prison yards, schools hostels and hospital wards.

The fibre-optic audio link can suitably be applied for internal communication at some strategic locations such as a point from the front gate to the front door of a residential building.

The audio link is very efficient and sophisticated, yet cost-effective a means of communicating between pair of two points as it is powered by DC source, while the speaker at the Receiving end is powered independently by an AC power supply for a laudable sound output. The link is independent of any operator or even subscription from any telecommunication service provider. Also, requires no telephone heads for its operation.

## 1.4 OBJECTIVE OF STUDY

This project was embarked upon so as to develop a cheap, simple, efficient and yet cost-effective means of short distance communication even in an electrically noisy environments.

Interesting improvements for efficiency and simplicity were made over similar previous works, as the use of ordinary copper cables and codes for establishing such audio/voice links was replaced with the use of fibre-optic cable.

No single fibre-optic "terminating-connector" is used in the project. This was purposely designed so as to avoid the use of highly technical and tedious method of fibre-optic "splicing" used in joining or terminating fibre-optic cables which normally involves the use of highly expensive equipments.

A simple but efficient means of short distance communication through the application of fibre-optic system without being too expensive is the ultimate focus of this study.

## 1.5 SCOPE OF STUDY

This project limits itself to finding a suitable solution to ever increasing need for a cheap, yet efficient means of short distance communication that requires neither antenna nor satellite or its subscription from any telecommunication company. The project used a matched Transmitter (Tx) and Receiver (Rx) constructed on two circuit boards with a microphone onboard at one end and a speaker at the other end, linked by a fibre-optic cable. The audio/voice link allows one to send sound only within a maximum range of about 2OO meters.

To achieve a longer communication distance than the one specified, a same principle could be established but with Transmitter, Receiver and the fibre-optic link; all of higher capacity and higher specifications.

## 1.6 PROJECT METHODOLOGY

On the fibre-optic Transmitter circuit board, the voice signal begins as a sound wave. It is converted to an electrical signal by the electret microphone in the Tx circuit. This signal is amplified by the LM358 audio amplifier and converted to an optical signal by switching the voltage to the LED via a signal transistor. This optical signal is fed into the fibre-optic cable for transmission.

On the fibre-optic Receiver circuit board, i.e. at the receiving end of the audio/voice link, the optical signal is directed at a photo-Darlington in the receiver which converts it to an electrical signal again. The signal is amplified and fed into a speaker where it becomes a sound wave. A voltage regulator has been used in the circuit to overcome feedback in the circuit.

Both the Transmitter (Tx) and the Receiver (Rx) circuit boards including all components on board are powered by 2 x 9V DC batteries (150mA max. used), one for each board, while the speaker at the Receiving end is powered independently by an AC power supply for a meaningful sound output.

The 9V DC power supply is basically controlled and regulated by 78L05 linear IC voltage regulator; a device used to hold the output voltage from a dc power supply relatively constant over a wide range of line and load variations.

## 1.7 JUSTIFICATION

In our daily lives, communication is an essential tool for smooth running and conduct of our personal life and business affairs. Quite often, those frequent and short messages or announcements are so important and regular, even though, walking a whole distance just to deliver them might not sound a meaningful effort. An organization that tries to maintain a high efficiency level as well as keeping over-head cost as low as possible, might find itself in a dilemma between having those messages delivered or canceled, hence the need for a justifiable solution.

The One-way fibre-optic audio link which is very cheap to maintain, transmits audio and voice messages efficiently. The Transmitter is powered by a DC source and the link is independent of any operator or even subscription from any telecommunication service provider. Also, it requires no telephone heads for its operation; all as earlier stated. Indeed, this project provides beyond any doubt, an ultimate solution to the problem earlier mentioned to all such organizations and as well, carters for the needs of even residential settings at large.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

In 1837, the first electrical telegraph instruments were invented by Samuel Morse in the United States and by Sir Charles Wheatstone and Sir William F. Cooke in Britain. Morse sent the first public telegraph message in 1844; the technology that has led to one of the best creations, if not the most fascinating invention of the $20^{th}$ century. Soon the technology developed, and a lot was achieved, amazingly, over a relatively short period of time that no one had ever imagined.

Wires and cables were the original medium for telecommunications and are still the primary means for telephone connections. Wireline transmission evolved from telegraph to telephone service and continues to provide the majority of telecommunications services.

In the early 1950s, Abraham van Heel of the Delft University of Technology in The Netherlands introduced "cladding" as a way to reduce light loss in glass fibres. He coated his fibres with plastic. Even with cladding, however, light signals in glass fibres would fade after traveling only a few meters.

In 1967, electrical engineers Charles Kao and George Hockham of Britain's Standard Telecommunications Labs speculated that these high losses were due to impurities in the glass, and put forward the theory that information could be carried using optical fibres. Within two decades, engineers solved the impurity problem. Presently, silica glass fibres of sufficient purity can carry infrared light signals for 100 km or a bit more without repeaters.

Today, Optical-fibre forms the backbone of the global transmission network that delivers the modern telephone network connectivity, the GSM (Global System for Mobile Communications), the networks that carry the voice traffic, data transmission, picture messaging, as well as the information-superhighway that supports all other forms of digital transmission networks, including the Internet.

## 2.1 COMMUNICATION SYSTEM

An electrical communication system is basically a system that involves data sourcing, source coding, channel/link, source decoding and a data terminal that are all followed and executed in a sequential order. This is normally achieved by the provision of a transmitter, a receiver, a channel, cable, exchange and many other several components such as switches, alarms and power source. The One-way fibre optic audio link communication system could be simplified in a block diagram shown below;

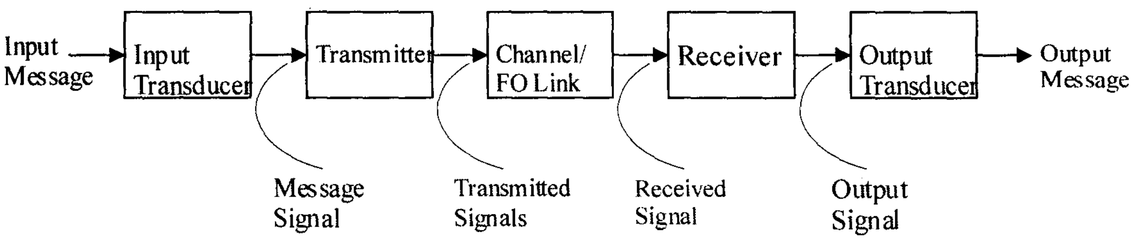


Fig. 2.1: Simple Block Diagram of a Communication System

## 2.2 INPUT TRANSDUCER

A transducer is a device that converts an input energy into an output energy. Because of the ease with which electrical energy may be transmitted and amplified, the most useful transducers are those that convert other forms of energy, such as heat, light, or sound, into electrical energy.

Here, an electret microphone is used as the input transducer. Electret microphones are very sensitive, durable, and extremely compact in size and have low power requirements. It converts sound waves in the frequency range of 0.30 KHz – 3.50 KHz to electrical signal that is fed to the transmitter.

## 2.3 TRANSMITTER

A transmitter is a "team" of electrical components that couples the input signal to the terminal. The processing of the audio/voice signal transmission begins on the transmitter circuit. Here, the transmitter circuit converts the sound wave of the voice signal into electrical signal by the use of an electret microphone. The electret microphone exploits changes in capacitance due to mechanical vibrations to produce voltage variations proportional to the fed-in sound waves. This signal is then amplified by the LM358 audio amplifier and further converted to an optical signal by switching the voltage to the LED (Light Emitting Diode) via a signal transistor; all on the transmitter board.

## 2.4 CHANNEL/LINK

A channel or link is the transmission medium through which the transmitted signals get to the Receiver. The medium may be guided or unguided; where guided media is a copper cable or Fibre Optic cable and unguided media refers to Wireless transmissions. The common characteristics of all transmission media are the attenuation (loss of signal over distance), distortion, background noise, and other factors.

The Fibre optic cable is the medium of transmission used in this study. Information (data and voice) is normally transmitted through the fiber digitally by the use of high speed LASERs (Light Amplification through the Simulated Emission of

Radiation) or LEDs (Light Emitting Diodes). Each of these methods create a highly focused beam of light that is cycled on and off at a very high speed.

## 2.5 THE OPTIC FIBRE CABLE

Optical fibres are very fine fibres of glass. They consist of a glass core, roughly fifty micrometres in diameter, surrounded by a glass "optical cladding" giving an outside diameter of about 120 micrometres. Optical Fibres are optical waveguides. This means that wherever the fibre goes, the light which is confined to the core of the fibre also goes, making it possible; the interesting capability of making light to bend round corners.

### 2.5.1 THE STRUCTURE OF THE FIBRE OPTIC CABLE

The core has a higher refractive index than the cladding. Although the cladding does not carry light, it is nevertheless an essential part of the fibre. The cladding is not just a mere covering. It keeps the value of the critical angle constant throughout the whole length of the fibre. The diagram of a typical FO cable can be seen below:

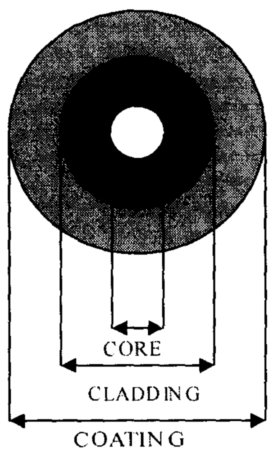


Fig. 2.5.1 Cross section of a typical Optical fibre

Optical Fibres are optical waveguides. This means that wherever the fibre goes the light, which is confined to the core of the fibre, also goes. So, optical fibres can be used to make light bend round corners.

## 2.5.2 PROPAGATION OF LIGHT IN THE FIBRE OPTIC CABLE

A principle called total internal reflection allows optical fibers to retain the light they transmit. When light passes from a dense substance into a less dense substance, there is an angle, called the "Critical angle", beyond which 100% of the light is reflected from the surface between substances, a phenomenon called "Total Internal Reflection". An optical-fiber core is clad (coated) by a lower density glass layer. Light traveling inside the core of an optical fiber strikes the outside surface at an angle of incidence greater than the critical angle so that all the light is reflected toward the inside of the fiber without loss.

The core has a higher refractive index than the cladding. Refractive index is defined as:

$$n = C/V \qquad \ldots\ldots\ldots\ldots\ldots\ldots 1.0$$

*Where; **n** is the refractive index, **C** is the speed of light in a vacuum and **V** is the speed of light in the material*

Although the cladding does not carry light, it is nevertheless an essential part of the fibre. The cladding is not just a mere covering; it keeps the value of the critical angle constant throughout the whole length of the fibre. By illustration;

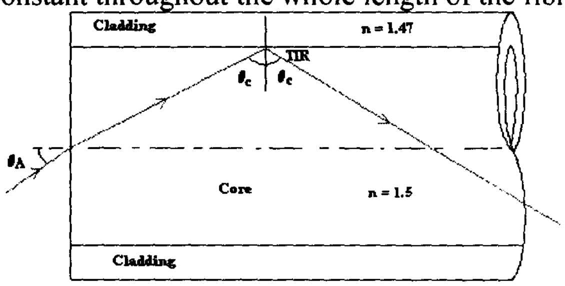


Fig.2.5.2a: Propagation of Light in a Fibre

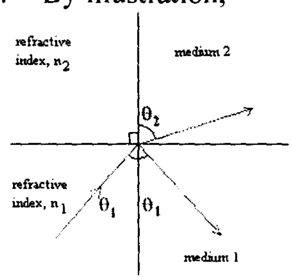


Fig.2.5.2b: Total Internal Reflection

From the second diagram above, $\theta_2$ is always greater than $\theta_1$. So, as $\theta_1$ is increased, eventually $\theta_2$ will reach $90^o$ before $\theta_1$ does. At this point where $\theta_1$ has reached a value called the critical angle ($\theta_c$), the transmitted ray now tries to travel in both materials simultaneously For various reasons which is physically impossible. Hence , there is no transmitted ray and all the light energy is reflected back into the core and none escapes into the cladding. This is true for any value of $\theta_1$, the angle of incidence, is equal to or greater than $\theta_c$ .

## 2.6 RECEIVER

This is the board circuit at the receiving end that extracts and process the desired signal from the received transmitted signals at the output. In other words, it selects "well" the desired signal and rejects "well" any unwanted transmitted signal.

In this study the transmitter is made up of a circuit board on which a coupled photodarlington converts the received optical signal into an electrical signal again. The phodarlington is contained in a Plastic housing with cinch nut and acts as an internal active element photodetector. The housing holds the active element and optimizes the physical connection between the optical fiber and the active component. While, the cinch nut holds the fiber in place. The signal is amplified and fed into a speaker where it becomes a sound wave.

## 2.7 OUTPUT TRANSDUCER

Output transducers are those devices that transform current/voltage signals back into useful physical form. This subsystem unit reverses the process of the input transducer with help of various devices performing specific functions on the Receiver circuit board. In this system of communication, a loudspeaker is used as the output transducer.

### 2.7.1 MECHANISM OF A LOUDSPEAKER

The heart of a loudspeaker is the solenoid, or voice coil; a long coil or wire wrapped around an iron cylinder. When electric current flows through the wire in a solenoid, it produces a magnetic field and the solenoid behaves like an ordinary bar magnet. The strength of the magnetic field and the magnetism of the solenoid changes, depending on the amount of current that flows through the wire. A solenoid is however, normally placed inside a hollow, cylindrical permanent magnet and attached to a paper cone that is held steady at the open end by a metal. When current flows through the solenoid, the interaction between the permanent magnet's magnetic field and the solenoid's changing magnetic field causes the solenoid to move, making the cone vibrate. As the cone vibrates, it produces the original sound. The vibration of the cone is proportional to the current in the solenoid, which, in turn, represents the original sound earlier converted into an electric signal by the microphone.

## 2.8 THE THEORY OF OPERATIONAL AMPLIFIERS

An operational amplifier or op-amp is a very high-gain amplifier which has two inputs, one inverting ($_-$) and the other; non-inverting ($_+$). A typical circuit symbol for an op-amp looks like this:

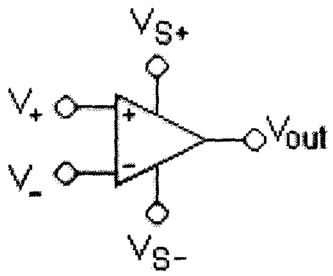


Fig. 2.8.1: A typical circuit symbol for an op-amp

*Where; $V_+$: non-inverting input, $V_-$: inverting input, $V_{out}$: output, $V_{S+}$: positive power supply and $V_{S-}$: negative power supply*

The output voltage is the difference between the $_+$ and $_-$ inputs, multiplied by the open-loop gain: $V_{out} = (V_+ - V_-) * G_{openloop}$. ………………… *1.2*

The power supply pins ($V_{S+}$ and $V_{S-}$) can be labeled many different ways. For FET (field effect transistors) based op-amps, the positive, common drain supply is labeled $V_{DD}$ and the negative, common source supply is labeled $V_{SS}$. For BJT (Bi-junctional transistors) based op-amps, the $V_{S+}$ pin becomes $V_{CC}$ and $V_{S-}$ becomes $V_{EE}$. They are also sometimes labeled $V_{CC+}$ and $V_{CC-}$, or even $V_+$ and $V_-$, in which case the inputs may be labeled differently while the function remains the same.

Operational amplifiers have a wide variety of applications in electrical engineering, and most particulary in the field of electronics. These include audio and video pre-amplifiers and buffers, voltage comparators, differentiators and integrators, filter, prescission rectifiers, voltage and current regulators, analogue calculators, analogue-to-digital converters, digital-to-anlogue converters, oscillators, waveform generators, and many more.

## 2.9 BASIC OP-AMP CIRCUITS

The generic op-amp has two inputs and one output. (Some are made with floating, differential outputs.) The output voltage is a multiple of the difference between the two inputs: $Vout = G(V+ - V-)$ .............. 1.3

G is the open-loop gain of the op-amp. The inputs are assumed to have very high impedance; negligible current will flow into or out of the inputs. Op-amp outputs have very low source impedance. If the output is connected to the inverting input, the circuits results into what is known as the "Non-inverting" amplifier.

### 2.9.1 Non-inverting amplifier

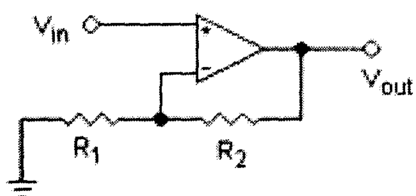


Fig. 2.9.1: Non-inverting amplifier configuration

After being scaled by a voltage divider,

$V_+ = V_{in}$ ............................*1.4*

$V_- = K\ V_{out}$ ...............................*1.5*

*since* $R_1$ *and* $R_2$ *control the voltage gain of the amplifier, if this gain is represented by* K, *then;*

K *(represents i.e.)* $= R_1 / (R_1 + R_2)$ ............................*1.6*

*Substituting (1.4 & 1.5) into 1eqn. 1.3, the* $V_{out}$ *becomes;*

$$V_{out} = G(V_{in} - K\,V_{out}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.7$$

*Solving for* $V_{out} / V_{in}$, *the result is a linear amplifier with gain:*

$$V_{out} / V_{in} = G / (1 + G\,K) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.8$$

*If* G *is very large,* $V_{out} / V_{in}$ *comes close to* 1 / K, *i.e*

$$V_{out} / V_{in} \approx 1 / K \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.9 \quad \textit{then;}$$

$$V_{out} / V_{in} = 1 + (R_2 / R_1) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.0$$

*Hence, the output voltage of a Non-inverting amplifier can be presented as;*

$$V_{out} = V_{in}\,(1 + R_2 / R_1) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

This negative feedback connection is the most typical use of an op-amp, but many different configurations are possible, making the operational amplifiers to be one of the most versatile of all electronic building blocks.

### 2.9.2 Inverting amplifier

This inverts and amplifies a voltage. The input resistance of this amplifier is easily determined from the figure below;

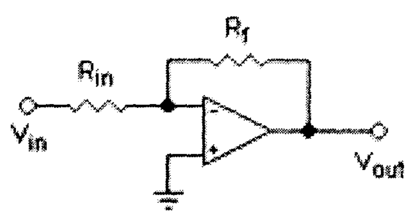


Fig. 2.9.2: Iinverting amplifier configuration

*Where* $\mathbf{R_{in}}$ *is the input resistance,* $\mathbf{R_f}$*: feed-back resistance,* $\mathbf{V_{in}}$*: Input voltage,* $\mathbf{V_{out}}$*: output voltage.*

In the case of this amplifier, the nature of the output signals is basically controlled by both the input resistance ($R_{in}$) and the feed-back resistance ($R_f$ ) as presented below:

$V_{out} = -V_{in} (R_f / R_{in})$ ………………………………*2.2*

A careful selection of a range of values of these resistances for the amplifier units is always very important. A value too small for the devices causes excessive current flow and possible damage to the device. However, chosing a value too high than what is necessarily required causes excessive thermal noise.

Generally speaking, in most applications, external circuit elements such as resistors and capacitors should be connected to the terminal of an op-amp to obtain a useful circuit. Very few practical applications exist in which the op-amp is used alone.

# CHAPTER THREE

## 3.0 CIRCUIT DESIGN AND ANALYSIS

The one-way fibre optic audio link comprises of two circuit boards ( a receiver and a transmitter), constructed on separate circuit boards and linked physically, by about 5m length, single mode fibre optic cable. This fibre optic audio communication link allows one to send sound/voice messages from one end to another via the said medium of transmission.

Each board requires a 9V battery. However, the speaker at the "Receiver" end is powered independently by an AC power supply through the use of 240/9V, 1.5A AC Transformer, for enhanced and laudable sound output. This audio-link can be used to send a signal efficiently in about 200m of FO cable length.

## 3.1 CHOICE OF COMPONENTS AND SPECIFICATIONS

In this project, various forms of Integrated circuits (ICs), digital and analogue discrete components were used towards achieving the desired goal. The system design ratings could be listed as follows:

- Maximum voltage used: 9V DC
- Maximum current used: 150mA
- Analogue and digital Integrated circuits (ICs); used
- Type & length of fibre optic cable used: Single mode of about 5m length
- Special MFOD73 photo-detector device & 5mm red LED emitter
- Special 5mm splice-free fibre optic coupling tube
- Special thermal protection 8-pin IC sockets

- Input and output transducers: An electret microphone and 8Ω speaker; respectively
- Audio amplifiers: Dual LM358 and LM386 ICs.
- 78L05 9V DC voltage regulator IC
- Single-sided printed circuit board (PCB), Schematic were used to design these boards

### 3.1.1 CHOICE OF RESISTORS & TRANSISTORS

Various types of resistors and transistors were used in this project construction, whose values were mostly chosen based on the required specifications by the manufacturer's data-sheets of the IC components used. Resistors of values ranging between 100Ω and 1MΩ, including a single potentiometer (variable resistor) of 100K value were used in the circuit design. On the transistors part, a single BC547 IC transistor was used on the transmitter circuit board.

### 3.1.2 CHOICE OF CAPACITORS

Capacitors of basically three types; electrolytic, mono-block and Mylar were used in the construction. Specifically, 2 no. of 10 uF electrolytic, 1 no. of 100 uF electrolytic, 5 no. of 0.1 uF mono-block, 1 no. of 2200 uF and 2 no. of 10nF Mylar capacitors were used.

## 3.2 OPERATING PRINCIPLE OF THE DESIGN

### 1. <u>THE TRANSMITTER</u>

On the transmitter (Tx) circuit board, there coupled a microphone and a circuit, made to modulate the light emitted from a light emitting diode (LED). The LED is contained in a plastic case which allows an easy splice-free FO cable connectivity.

### 3.2.1 OPERATING PRINCIPLE OF THE TRANSMITTER

The signal received through the electret microphone, is fed into an operational amplifier (LM358) wired in the non-inverting mode to boost its relatively low input voltage to a level that can conveniently drive the amplitude modulator stage following it.

To match the high source impedance of the microphone, its amplifier is connected as a non-inverting amplifier, the various circuit resistances shape the input and output impedances of the overall amplifier. Considering the circuit below

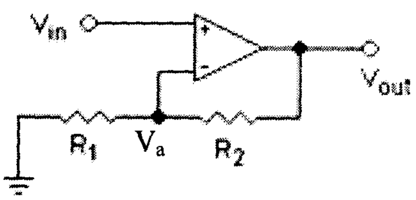


Fig. 3.2.1.: Non-inverting amplifier configuration

From previous analysis, $V_a = V_{in}$, and driving $V_a$ from the potential divider;

$V_a = \{R_1 / (R_1 + R_2)\} * V_{out}$ ............ *1.0* *Setting $V_a = V_{in}$, we obtain:*

Gain = $V_{out}/V_{in} = 1 + \{ R_2/R_1 \}$ ......... *1.1* *For the microphone amplifier;*

*$R_2 = 22K\Omega$ & $R_1 = 100\Omega$, hence, the maximun gain of the amplifier is:*

Gain = 1+ {22,000/100} = 221 .............................. *1.2*

*The frequency of the ampliifer could then be;*

$f = 1/\{2\pi RC\}$ ........................... *1.3*

$f = 1/\{2\pi * RC\} = 1/(2\pi * 0.1\mu * 100) \approx = 16KHz$ ................. *1.4*

The insertion of capacitance in series with with $R_1$ reduces the effect of finite input offset voltge, without wich the amplifier will saturate by the closed loop gain which is high enough to multiply the attenual voltage, thereby causing an imbalance for the mic amplifier.

## 3.2.2 THE MICROPHONE AMPLIFIER

The amplifier is biased to a steady dc operatmg point by a fixed potential divider relative to its non-inverting input as shown below:

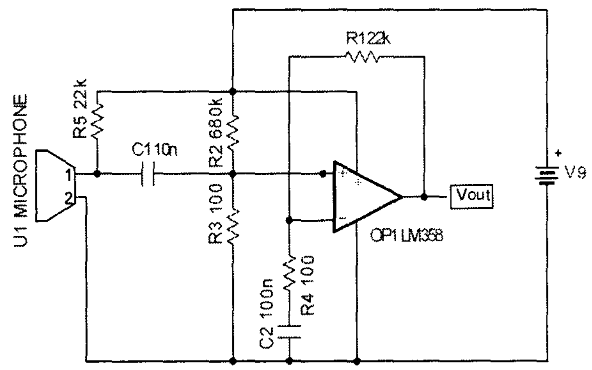


Fig. 3.2.2 $V_{+(dc)}$ of the Microphone Op-amp

*From above, the dc voltage of the output would be*

$V_{+(dc)} = \{R_2/ (R_2+R_3)\} * V_{in}$ ……………………………*1.5*

$V_{+(dc)} = \{(100K)/(680K+100K)\} * 9V$ = 1.154V…………*1.6*

Hence, the voltage at the output is a 1.154V biase upon which will be impressed after application.

## AMPLITUDE MODULATOR

The approximate circuit of the voltage-to-current amplitude modulator subsystem is schematically expressed below:

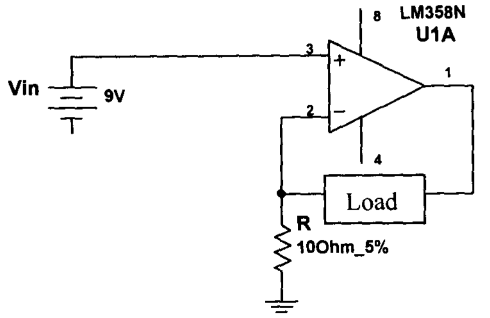


Fig. 3.2.2 Approximate cct. For the V- I Modulation

Negative feedback results in $V_{in}$ at the inverting input producing a current $I = V_{in} / R$ through the load. However, as the modulation takes place, the ½LM358 also performs an operation as the LED-driver as shown below:

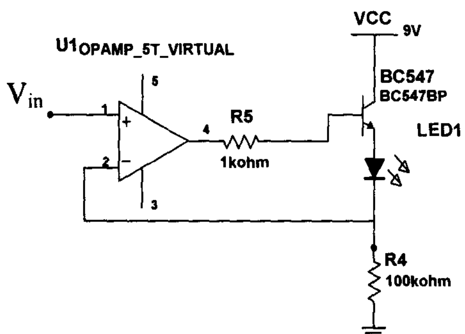


Fig. 3.2.3 Modulation Circuit on the Tx

For every value $V_{in}$ from the microphone amplifier, a current, $I = V_{iv}/R = V_{in}/100\Omega$ is forced through the LED so that $V_{in(+)} = V_{in(-)}$ to make the differential input voltage zero as is needed for op-amps. The variation of $I_{LED}$ for every $V_{in}$ (analog signal), allows the analog voltage to modulate the brightness of the LED, which in turn is passed down the

FO cable as an amplitude modulated sound wave. The complete circuit for the FO Transmitter is shown below:

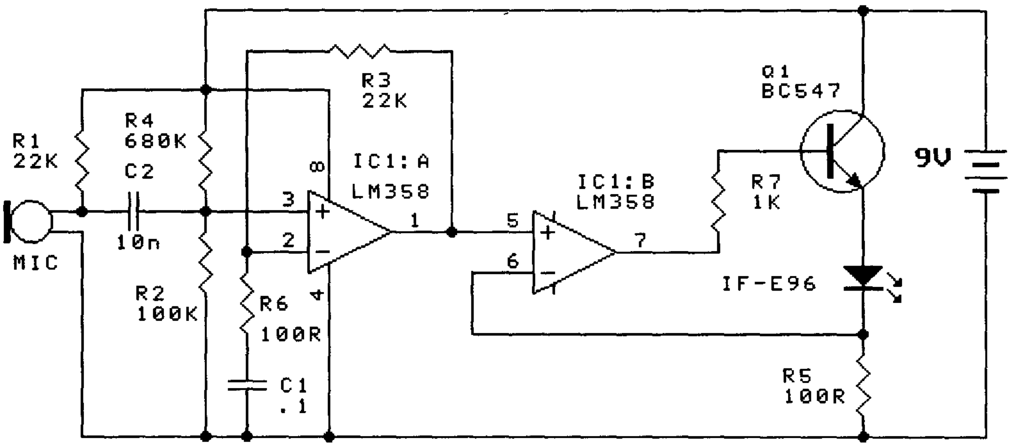


Fig.3.2.1: The Fibre optic audio link Transmitter Circuit

## 2. THE RECEIVER

The fibre optic Receiver circuitry is powered by a 78L05 5V, 100mA regulator on a 9V DC battery source. However, the speaker at this "Receiver" end is powered independently by an AC power supply through the use of 240/9V, 1.5A AC Transformer, for enhanced and laudable sound output. The AC power supply circuit could be seen below:

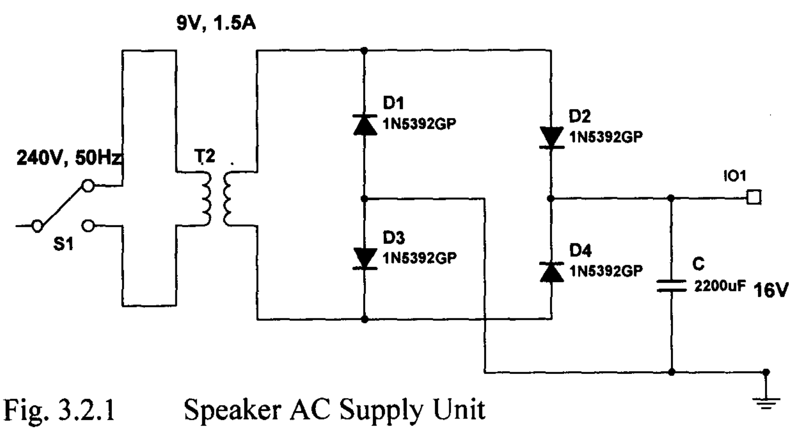


Fig. 3.2.1 Speaker AC Supply Unit

The Receiver circuitry comprises an MFOD73 photo resistor specified for fibre optics application, an LM358 preamplifier and an audio power amplifier built around the LM386.

A 220KΩ resistance in the emitter circuit is designed to generate a voltage, V, that is a function of the photo-transistor's IC, since V = IR. The amplification factor of the circuit is made variable so that the Receiver's output could be adjusted at various levels of output modulation.

The gain-determining elements comprise a 1MΩ resistor, a 100KΩ variable resistor (potentiometer), a fixed value of 10KΩ resistance and a 0.1μF – series capacitor as shown below:

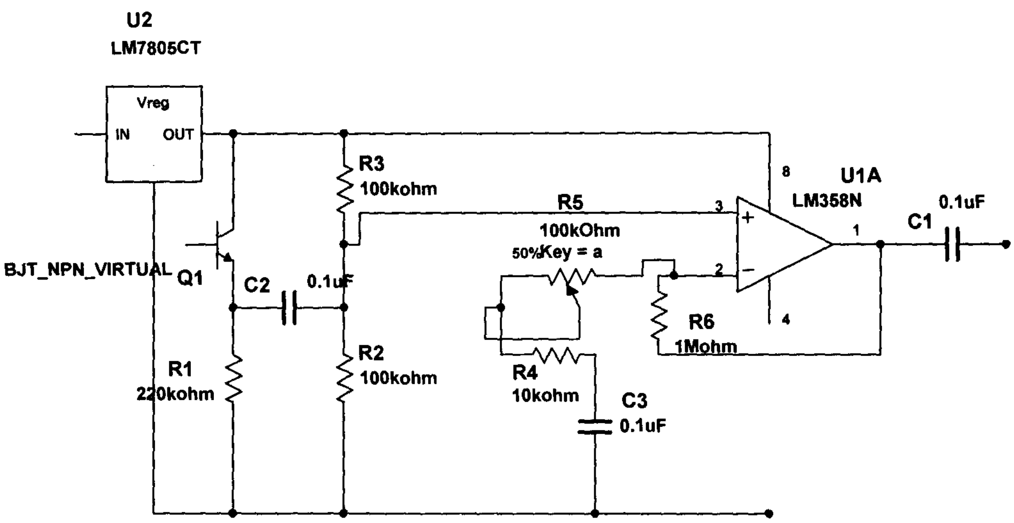


Fig. 3.2.2 Gain-determining circuit of the Rx

*With the components shown above, it could be deduced that;*

$V_{out}/V_{in} = 1 + (R6/R5)$ ………………1.7

*As R5 is designed to be a potentiometer, the gain can be varied;*

*From;* $1 + \{1M\Omega / 10K\Omega\} = 101 = AV_1$ …………1.8

*To* $1 + \{1M\Omega / 110K\Omega\} = 10.09 \approx 10 = AV_2$ ………………1.9

Where $AV_1$ is the circuit closed loop gain with the potentiometer set to minimum value i.e. zero, sand $AV_2$ is the gain value with the maximum value of 100KΩ variable resistor introduced into the circuit. This span of adjustable gain range is very satisfactory for most applications. It is however, worth noting that even with the minimum value of the variable resistor; i.e. zero, there is a fixed input resistance of 10KΩ to the op-amp.

The output of the amplifier is then eventually fed into an LM386 audio power amplifier from National Semiconductor, to generate an output that is powerful enough to drive an 8-16Ω loudspeaker, so that the recovered audio/voice transmitted over the optical link can be heard by a transformation of its electrical nature to its equivalent analogue quantity as sound waves.

The full circuit diagram for the one-way fibre optic communication link Receiver is shown on the next page.

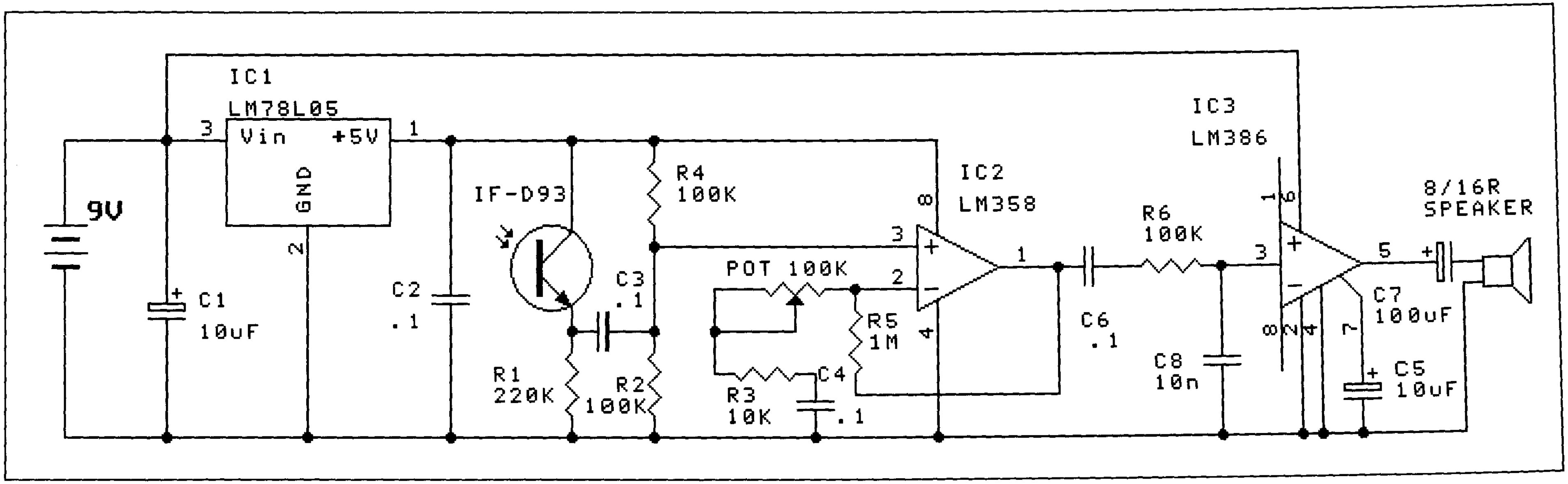


Fig.3.2.3: The One-way Fibre Optic Receiver Circuit

## 3.3 COMPLETE LIST OF COMPONENTS

| S/N | COMPONENT | QTY. |
|---|---|---|
| | **RESISTORS 1/4W, 5%:** | |
| 1 | 100R (brown, black, brown) | 2 |
| 2 | 1K (brown, black, red) | 1 |
| 3 | 10K (brown, black, orange) | 1 |
| 4 | 22K (red, red, orange) | 2 |
| 5 | 100K (brown, black, yellow) | 4 |
| 6 | 220K (red, red, yellow) | 1 |
| 7 | 680K (blue, grey, yellow) | 1 |
| 8 | 1M (brown, black, green) | 1 |
| 9 | 100K trim-pot (104) | 1 |
| | **CAPACITORS:** | |
| 10 | 16V, 2200uF Capacitor | 1 |
| 11 | 10 uF electrolytic | 2 |
| 12 | 100 uF electrolytic | 1 |
| 13 | 0.1 uF monoblock (104) | 5 |
| 14 | 10nF Mylar (103) | 2 |
| | **OTHER COMPONENTS:** | |
| 15 | Fibre optic cable | About 5 Meters |
| 16 | Speaker (8 Ω, 30W) | 1 |
| 17 | 240/9V, 1.5A AC Transformer | 1 |
| 18 | 78L05 regulator | 1 |
| 19 | IN5392 Diode | 4 |
| 20 | BC547 transistor | 1 |
| 21 | MFOD73 detector | 1 |
| 22 | 5mm Red LED transmitter | 1 |
| 23 | 5mm Plastic tubing | 1 |
| 24 | Electret microphone | 1 |
| 25 | 9V DC battery & snap | 2 |
| 26 | LM358 IC | 2 |
| 27 | LM386 IC | 1 |
| 28 | 2 pole terminal block | 3 |
| 29 | 8-pin IC sockets | 3 |
| 30 | Printed Circuit Board (PCB) | 2 |

# CHAPTER FOUR

## 4.0 TESTING THE FIBRE OPTIC AUDIO LINK

Before the actual construction work on the complete transmitter and receiver circuits units commenced, each of the subsystem circuits described earlier were simulated using the *"Multi-sim 2001"* simulation software of the electronic workbench, and were latter tested on the boards to make sure that they work properly as expected.

- After the units were built up, the 9V battery was first connected to the Tx unit, the red LED (emitter) was observed on.
- On the Rx unit, the battery was then connected; this caused the speaker to make a noise. The volume was then turned down through the adjustment of the potentiometer (variable resistor).
- The Tx unit was then placed in one room near a tape recorder. The fibre optic cable was then unwound, making sure that there were no loop-backs or kinks along the cable length.
- At the Rx end, it was carefully observed that the end of the fibre optic cable shows red light coming from the transmitter. The fibre optic cable was waved 1" - 2" in front of the receiver, one could hear the sound which is being picked up by the Tx unit in the other room. The fibre optic cable was then pushed into the receiver and the plastic nut was tightened. The sound was heard very clearly.

The results obtained could be summarized in the table given below:

| SUBSYSTEM | PARAMETER TESTED | TEST EQUIPMENT | RESULT |
|---|---|---|---|
| Transmitter Emitter | LED Emitter Signal | 9V DC Supply | Satisfactory |
| Amplifier Circuits | Noise | 9V DC Supply and Voice input signal | Satisfactory |
| Power Supply Units | Appropriate Nodal Voltages | Power Supply & Digital Multi-meter | Satisfactory |
| Fibre-Optic cable | Signal Transmission | Transmitter Light Signal Input | Satisfactory |
| Complete System | Maximum Communication Distance | Fibre-Optic Transmission Cable | Not Practically determined due to unavailability of lengthy cable |

Table 4.0 Tests and Results Obtained

## 4.1 PRECAUTIONARY MEASURES

- Special 8-pin IC sockets were used so as to protect all the ICs on-board from excessive temperature while soldering, after which all components were carefully tested for continuity against poor/dry soldering.
- All stipulated permissible range of voltage/current ratings of various ICs and discrete components used from their respective manufacturers' data-sheets, were carefully noted and complied with, for successful results.
- Special printed circuit boards (PCBs) were used for good and enhanced mounting of all components on board.
- It was made sure before and after the project construction that, the fibre-optic cable wasn't bent too much; a specified radius of curvature of over 1 inch (2 cm) while bending was always maintained as all fibre-optic cables are fragile.

- To get the highest transmission efficiency, it was made sure that the ends of the FO cable were square cut cleanly, as so much level of its efficiency lies on the degree of its smoothness and how its two ends were better finished.

## 4.2 MODIFICATION

The successful use of fibre-optic cable in this link of audio communication is the special modification achieved over the various types and similar of such projects earlier undertaken and, this modification still remains the glorious objective of this study.

Whenever efficiency, sophistication, good protection against signal-interference in electrically noisy environments, and many not mentioned of FO cable are considered, the importance of this modification cannot be over emphasized.

# CHAPTER FIVE

## SUMMARY AND CONCLUSION

### 5.1 CONCLUSION

This project report covers extensively, the design and construction of a One-way Fibre-Optic Audio Communication Link. The audio transmission link was successfully designed and constructed to enhance efficiency in a short distance form of communication under a justifiable cost of maintenance.

### 5.2 LIMITATIONS

The utmost capability of this project design was brought to restrictions due to some limiting factors whose basis were mainly financial. Two important features would have been better designed, incorporated and achieved in the construction as pointed below:

- The one-way path design of the audio link transmission could have been effectively made to be a two-way type (Duplex) by simply building on each transmission end, a unit that comprises a pair of both the transmitter and the Receiver on-board. This consequently, demands almost twice the cost of the constructed design.
- A better communication distance could have been achieved if a longer length of the fibre-Optic cable would have been used in the design. This of course, requires more financial involvement as well.

## 5.3 RECOMMENDATIONS

The success achieved so far could further be celebrated if those restrictions earlier mentioned could be properly addressed. Making the design construction to operate in duplex mode would indeed enhance and much better improve the performance as well as the utilization of the constructed design; as both ends can feed back each other effectively.

With a much longer fibre-Optic cable, a better communication distance could be achieved, making the desired goal more meaningful.

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