DESIGN AND CONSTRUCTION OF A 950 MILLWATT SOLAR-POWERED FM TRANSMITTER

BY

AKINFEMIWA, OLATUNDE PETER

EEE/11/0380

A PROJECT SUBMITTED TO THE

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE

AWARD OF BACHELOR OF ENGINEERING

(B. ENG.) DEGREE IN

ELECTRICAL AND ELECTRONICS ENGINEERING

FACULTY OF ENGINEERING

FEDERAL UNIVERSITY, OYE-EKITI

EKITI STATE

SEPTEMBER, 2016.

DECLARATION

I, AKINFEMIWA OLATUNDE PETER, hereby declare that this project work carried out is a result of my personal effort and has not been submitted elsewhere for this purpose. All sources of information are duly acknowledged by means of references.

.... 14/11/2016 ....

Signature Date

CERTIFICATION

This is to certify that this project work has been approved and meets the requirement for the award of Bachelor of Engineering (B. Eng.) degree in the Department of Electrical and Electronics Engineering, Federal University, Oye-Ekiti, Ekiti State.

14/11/06 .... 14/11/2016

Engr. Gbenga D. Obikoya Date

(Project Supervisor)

.... 19/11/16

Dr. Engr. O. Akinsanmi Date

(Head of Department)

....

Dr. Engr. A. O. Melodi Date

(External Examiner)

DEDICATION

This work is dedicated to Almighty God, the Giver of life, my Heavenly Father, for His blessings, mercies, opportunities, love and support now and forever.

ACKNOWLEDGMENTS

To God Almighty, I give thanks to the creator of all creatures who has in His infinite mercy guides and protects me throughout my educational career in the University.

I would love to acknowledge and recognize the patience, guidance and help shown by my project supervisor, Engr. Gbenga D. Obikoya. His support, monitoring, suggestions and constructive criticism at every stage have contributed immensely to the successful completion of this project report.

Particularly, I wish to put all record of the various forms of assistance both financially and morally, received from my Dearest Parents, Dr. and Mrs. Festus Akinfemiwa, towards the successful completion of my project.

Worthy of deep appreciation to my Head of Deaprtment, Dr. Engr. O. Akinsanmi and other members of staff in the Deaprtment of Electrical and Electronics Engineering, Faculty of Engineering at the Federal university Oye-Ekiti for their contribution. May God bless you all (Amen).

Finally, acknowledgement goes to my course mates and reading partners. I appreciate you all, thank you so much.

ABSTRACTS

The project is aimed at designing and constructing a 950mW solar powered FM transmitter that uses a 9 Volts rechargeable battery as the input signal. The battery is being charged with a solar panel. The project is designed to produce an output frequency of 104.4 MHz at the power output of 950mW, which covered a distance of about 100 meters. Three design stages is used in this project and these includes pre-amplification stage, oscillator stage and power amplifier stage. After the whole construction, the project was taken to the laboratory to check conformity with the desired design. Field test was also carried out and the receivers at various locations were able to receive a clear signal from the transmitter, within the range of 100m.

TABLE OF CONTENTS

CHAPTER TWO: LITERATURE REVIEW

CHAPTER THREE: DESIGN METHODOLOGY

CHAPTER 4 CONSTRUCTION, TESTING, RESULTS AND DISCUSSION

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

FM	Frequency Modulation
AM	Amplitude Modulation
LED	Light Emitting Diode
AC	Alternating current
DC	Direct Current
IC	Integrated Circuit
LCD	Liquid Crystal Display
PLL	Phase Locked Loop
RF	Radio Frequency
VCO	Voltage Controlled Oscillator
CMOS	Complementary Metal Oxide Semiconductor
TTL	Transistor-Transistor Logic
PCB	Printed Circuit Board

CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

Information transmission is very vital to human life just as the early men used sticks to produce sound which indicates the location of each other as they wander about. Also down to the middle era when town criers come into play for the same information propagation to be transmitted from one point to another with the aid of radio communication which necessitates the application of radio transmitter and receiver.

Communication system engineers attempt to design communication system that transmits information at a higher rate with a higher performance, using minimum amount of transmitted power and bandwidth. The purpose of any communication system is to transmit information signals from a source located at one point in space to the user (destination) located at another point. The originating input is frequently referred to as the source, whereas the terminating end is frequently referred to as the sink. If the message is understandable, then the information are been converted from the source to the destination. Mostly, the message produced by the source is not electrical in nature. But to carry them over an electrical system, the message must be converted to an electrical signal. In the same manner at the receiving ends, the electrical signal must be reconverted into an appropriate form [1].

A radio transmitter is a device whose major function is to send information from one point to another. In most cases the information to be transmitted are voice, music and code signals. However the transmission of radio signal is done with the aid of electrical resonance. This is when the frequency of the receiver is equal to the incoming one from the transmitter [2].

1.2 STATEMENT OF PROBLEMS

This project will also solve the problem of information problem in university environments. The alternative source of power supply (which is the use of solar panel) used in this project cater for the problem of interrupted power supply that frequently occur in the university campus. This new innovation will help the FM transmitter to function for a longer time because the solar panel will always be available to charge the battery attached to the FM transmitter.

1.3 AIM AND OBJECTIVES

Aim: The aim of this project is to design and construct a 950mW solar powered FM transmitter for information dissemination in the university environment.

Objectives: The objectives of the projects are:

(i) To improve on previous studies on transmitters.

(ii) To develop a low power FM transmitter powered by a 9V rechargeable battery (that is been charged with a 12V solar panel) to be used on the campus for communication purpose.

(ii) To provide a reference for further study in a similar streams having ambition to deal with low power FM transmitter design

(iii) To make recommendations based on findings on the project.

1.4 SCOPE OF STUDY

Basically this project focuses on a low FM transmitter powered by a 9V rechargeable battery, which is charged using a solar panel. The transmitter should be able to transmit at a fixed frequency 104.4MHz (though it could be varied). The low power FM transmitter is intended to make personal broadcasting more accessible to listener through home and FM receiver stereos. It does so in a cost efficient and highly functional design. The FM transmitter will have an overall power of 950mW which can cover a distance of 50 to 150 meters under normal condition.

1.5 SIGNIFICANCE OF THE PROJECT

The low power FM transmitter is intended to make personal broadcasting more accessible to listen to through home and FM receiver stereos. Considering the power failure issues occurring in the society (University campus as a case study), the project helps to reduce this limitation with the application of a rechargeable battery to power the FM transmitter which will be charged by a solar panel. This project will solve the problem of information dissemination in the campus i.e. the use of the transmitter would help to disseminate information on the campus.

1.6 METHOD OF STUDY

Methods of study used in this project are the following:

(i) *Visitation to the Library*: The library was consulted for journals and text books that are related to the project topic so as to understand some basic knowledge of the project. It helps to also to find the full text of an article based on the project topic.

(ii) *Using the Internet*: The internet was consulted to find relevant information and necessary journals, in order to get adequate knowledge about the project.

(iii) *Interview with the professional:* Discussion with professionals on this project help in accomplishing some major task, such as how to start the construction processes.

(iv) *Design and Construction:* Different stages of the transmitter were design before proceeding the construction stage. The transmitter circuit was initially constructed on a breadboard before finally transferred to a vero board for final soldering.

1.7 REPORT OUTLINE

The structure of this work titled "Design and construction of a 950mW solar powered FM transmitter" consists of five chapters. Chapter two concentrates on the literature review in which extensive survey work has been accounted with respect to the FM transmitter system. It gives the comparison between the previous work and the current research and explains the merits and demerits of all the FM transmitter systems, which was taken through research papers published during the period of 1998-2014. Chapter three shows the step-by-step procedure used for the hardware implementation of the FM transmitter system of the project. Chapter four focuses on the construction and testing of the FM transmitter system unit anywhere applicable most especially in the rural and urban areas. Finally, chapter five gives the conclusion, limitations and recommendations for future work on this research project.

CHAPTER TWO

LITERATURE REVIEW

2.1 TECHNICAL BACKGROUND

Voice or information that is going to be transferred is termed as information signal. If the distance between communication parties is too large, direct voice communication is impossible. The method of message sender is needed; the function of message sender is just to carry the information to the desired destination. Thus the message sender can be said to be a carrier. The carrier merely sends the information and needs not to be intelligent. The information signal is sometimes called the intelligence signal.

The first primitive radio transmitters (called Hertzian oscillators) were built by German physicist Heinrich Hertzin 1887 during his pioneering investigations of radio waves. The generation of the radio waves was by a high voltage sparks between two conductors. These sparks were used during the first three decades of radio (1887-1917), called the wireless era. Shortly after then, competing techniques came into use after the turn of the century, such as the Alexander son alternator and Arc transmitters [3].

All these early technologies were replaced by vacuum tube transmitters in the 1920s, because they were inexpensive and produced continuous waves which could be modulated to transmit audio (sound) using amplitude modulation (AM) and frequency modulation (FM) techniques. This made possible the commercial radio which began about 1920. The development of radar before and during World War 2 was a great stimulus to the evolution of high frequency transmitters in the ultra-high-frequency (UHF) and microwave range transmitters, using new devices such as the magnetron and traveling wave tube. In recent years, the need to conserve crowded radio spectrum bandwidth has driven the development of new types of transmission such as spread spectrum technology [3].

Harold Power and Research Company in 1916 broadcast the first continuous broadcast in the world from Tuft sunder which has the call sign 1XE (which lasted 3 hours). The company later became the first to broadcast on a daily schedule, and the first to broadcast radio dance programs. This project could not serve for a longer time in that it could only last for three hours.

Edwin Howard Armstrong in the mid-30s is credited with developing many of the features of radio as it is known today. He patented three important inventions that made today's radio possible. Examples of such inventions are regeneration of super heterodyne circuit and wide-band frequency modulation. Edwin Armstrong, an inventor who had already devised a successful circuit to improve AM radio, came up with a whole new approach to transmitting radio signals. Armstrong was clearly a technical genius. Although his life was cut short, he is still being considered the most prolific inventor in radio's history. Even though he had improved AM radio in significant ways, his transmitter could not transmit more than one kilometer.

The comparatively low cost of equipment for an FM broadcasting station, resulted in rapid growth in the years following World War II. Within three years after the close of the war, 600 licensed FM stations were broadcasting in the United States and by the end of the 1980s there were over 4,000. Similar trends have occurred in Britain and other countries. Because of crowding in the AM broadcast band and the inability of standard AM receiver to eliminate noise, the tonal fidelity of standard stations is purposely limited. FM does not have much drawbacks and therefore can be used to transmit music, reproducing the original performance with a degree of fidelity that cannot be reached on AM bands. FM stereophonic broadcasting has drawn increasing numbers of listeners to popular as well as classical music, so that commercial FM stations draw higher audience ratings than AM stations [4].

A typical broadcast transmission has the following specifications:

Frequency Band (f_c)..88-108MHz

Chanel Bandwidth..200 kHz

Frequency Stability ....±2 kHz

Frequency Deviation (at 100%)........................ ......±75 kHz

Frequency Response..50Hz – 15 kHz

Harmonics.. 3.5%

Maximum Power..100 kW

2.1.1 Frequency Modulation Fundamental

The information signal can rarely be transmitted as it is, it must be processed. In order to use electromagnetic transmission, it must first be converted from audio into an electric signal. The conversion is accomplished by a transducer. After conversion, it is modulated with a carrier signal. A carrier signal is used for two reasons [1]:

(i) To reduce the wavelength for efficient transmission and reception (the optimum antenna size is $\frac{1}{2}$ or $\frac{1}{4}$ of a wavelength), and to allow simultaneous use of the same channel, called multiplexing.

(ii) Each unique signal can be assigned a different carrier frequency (like radio stations) and still share the same channel. The phone company actually invented modulation to allow phone conversations to be transmitted over common lines. The process of modulation means to systematically use the information signal (what you want to transmit) to vary some parameter of the carrier signal. The carrier signal is usually just a simple single-frequency sinusoid (varies in time like a sine wave).

The basic sine wave is given by:

$$V\ (t) = v_o \sin\ (2\ \pi f\ t + \phi)$$

Where, V(t) = the voltage of the signal as a function of time.

V_o = the amplitude of the signal (represents the maximum value achieved each cycle) the frequency of oscillation, the number of cycles per second

ϕ = phase of the signal, representing the starting point of the cycle [1].

In FM, information is transferred through a carrier by varying its instantaneous frequency. Frequency modulation uses the information signal, to vary the carrier frequency within some small range about its original value. Here are the three FM signals in mathematical form:

Information: $V_{im}(t)$

Carrier: $V_{ic}(t) = V_{cosin}\ (2\ \pi\ f\ ct + \phi)$

FM: $V_{mt}\ (t) = V_{cosin}\ [2\pi(fc + \frac{\Delta f}{V_{mo}})\ V_{im}(t)]\ V_{im}(t).$

The carrier frequency term is been replaced, with a time-varying frequency. A new term has to be introduced: Δf = the peak frequency deviation. In this form, the carrier frequency term:

fc+ $(\frac{\Delta f}{v_{mo}})\, v_{im}(t)$. It varies between the extremes of f_c – Δf and f_c+ Δf. The interpretation of Δf becomes clear: it is the farthest away from the original frequency that the FM signal can be. Sometimes it is referred to as the "swing" in the frequency.

We can also define a modulation index for FM, analogous to AM as

$$\beta = \frac{\Delta f}{f_m}$$

Where, f_m = the maximum modulating frequency used.

The simplest interpretation of the modulation index, β, is as a measure of the peak frequency deviation, Δf. In other words, β represents a way to express the peak deviation frequency as a multiple of the maximum modulating frequency, f_m i.e.

$$\Delta f = \beta f_m$$

2.1.2 Frequency Modulation Performance Characteristics

The performance characteristics of a FM signal is measured by the following parameters:

Bandwidth: As it has already been shown above, the bandwidth of a FM signal may be predicted using

$$BW = 2\,(\beta + 1) f_m$$

Where β = modulation index

and FM = maximum modulating frequency used

FM radio has a significantly larger bandwidth than AM radio. The bandwidth of an FM signal has a more complicated dependency than in the AM case (recall, the bandwidth of AM signals depend only on the maximum modulation frequency).

In FM, both the modulation index and the modulating frequency affect the bandwidth. As the information is made stronger, the bandwidth also grows.

Efficiency: The efficiency of a signal is the power in the side-bands as a fraction of the total power. In FM signals, because of the considerable side-bands produced, the efficiency is generally high. The conventional AM is limited to about 33 % efficiency to prevent distortion in the receiver when the modulation index is greater than 1. FM has no such problem. The side-band structure is fairly complicated, but it is safe to say that the efficiency is generally improved by making the modulation index larger (as it should be). If the modulation index large, the bandwidth will also be large (unlike an AM). As is typical in engineering, a compromise between efficiency and performance is struck. The modulation index is normally limited to a value between 1 and 5, depending on the application [1].

Noise: FM systems are far better at rejecting noise than AM systems. Noise generally is spread uniformly across the spectrum (the so-called white noise, meaning wide spectrum). The amplitude of the noise varies randomly at these frequencies. The change in amplitude can actually modulate the signal and be picked up in the AM system. As a result, AM systems are very sensitive to random noise [1]. An example is an ignition system noise in your car. Special filters need to be installed to keep the interference out of your car radio. FM systems are inherently immune to random noise. In order for the noise to interfere, it would have to modulate the frequency somehow. But the noise is distributed uniformly in frequency and varies mostly in amplitude. As a result, there is virtually no interference picked up in the FM receiver. FM is sometimes called "static free," and this is referring to its superior immunity to random noise [2].

2.1.3 Benefits and Limitations of a Frequency Modulation

FM transmitter is widely used because of the many advantages of frequency modulation. An understanding of the disadvantages and advantages of FM will enable the choice of the best modulation format to be made [1].

Advantages of Frequency Modulation: Resilient to noise is one of the main advantages of frequency modulation that has been utilized in the broadcasting industry. As most noise is amplitude based, this noise can be removed by running the signal through a limiter so that only frequency variations appears, provided that the signal level is sufficiently high to allow the signal to be limited.

Resilient to signal strength variations is another advantage of a FM. In the same way that amplitude noise can be removed, so too can any signal variations. This means that frequency modulations does not suffer audio amplitude variations as the signal level varies, and this makes FM ideal for use in mobile applications where signal levels constantly vary, provided that the signal level is sufficiently high to allow the signal to be limited. The signal does not require linear amplifiers in the transmitter. As only frequency changes are required to be carried, any amplifiers in the transmitter do not need to be linear.

The nonlinear amplifier enables greater efficiency than many other modes. The use of non-linear amplifiers, e.g. class C, and so on means that transmitter efficiency levels will be higher, linear amplifiers are inherently inefficient.

Disadvantages of Frequency Modulation: One of the minor disadvantages of frequency modulation is that the demodulator is a little more complicated, and hence slightly more expensive than the very simple diode detectors used for AM. Also requiring a tuned circuit increases cost. Nevertheless, the advantage of frequency modulation is that it is an ideal format for many analogue applications [6].

2.2 COMPARISON OF PREVIOUS STUDIES WITH CURRENT RESEARCH

Goh Han Shin (1998) at the University of Malaysia carried out a research on frequency modulation transmitter and receiver. He made emphasis on the various transmitter and receiver architectures. He discovered the reason why heterodyne is the architecture that was selected for most of the cellular handsets in the past, but as IC process and technology evolves, other approaches, such as homodyne, have also become a plausible solution to some of the design problems. His project could not go beyond the University environment; the distance of transmission is within the campus alone.

G.W. Brogan (2007) carried out a research on a small but quite powerful FM transmitter having three RF stages, incorporating an audio preamplifier for better modulation. It has an output power of 4 Watts and works on 12-18 V_{DC} which makes it easily portable. It is the ideal project for the beginner who wishes to get started in the fascinating world of FM broadcasting and wants a good basic circuit to experiment with. His limitation was that His FM transmitter could not cover a long range because of its output power of 4 watts.

Yewlsew (2012) carried out a research on design and implementation of FM transmitter with a variable inductor. The FM transmitter was a able to broadcast at frequency 104.5 MHz. A lot was learnt from the experiment with the aid of variable inductor schematic. A better understanding of BJT transistor, amplifiers, modulators, oscillators, capacitors and inductors were developed.

Pooja Kumari and Mona Kumari (2014) carried out a research on a low power FM transmitter. Their research talked about the method of design of a FM transmitter with a frequency of 100 MHz in a range of 100m under favorable condition. They were able to design and construct a low power FM transmitter that uses either 9 to 12V input voltage which could cover the distance stated above. The limitation of the project is that the project is for security purpose alone and the transmitting length cannot go beyond 100m.

The current project focuses on a low FM transmitter powered by a 9V rechargeable battery, which is charged using a solar panel. The transmitter should be able to transmit at a fixed frequency 104.4MHz (though it could be varied). The low power FM transmitter is intended to make personal broadcasting more accessible to listener through home and FM receiver stereos. It does so in a cost efficient and highly functional design. The FM transmitter will have an overall power of 950mW which can cover a distance of 50 to 150 meters under a normal condition. The project description is a bit different from some previous works such that the project employed the use of a 9V rechargeable battery that will be charged by a solar panel attach to the transmitter. The solar panel voltage rating is higher than the input voltage of the transmitter; it is a 12V solar panel will be used to charge a 9V battery.

2.3 THEORY OF ELECTRONIC COMPONENTS

2.3.1 Resistor

A resistor is a passive device that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor. For a resistor the voltage dropped across it is proportional to the amount of current flowing through it i.e.

$$V_R = IR$$

Any current waveform through a resistor will produce the exact same voltage waveform across it. The physical structure and the circuit symbol of a resistor are shown in Fig. 2.1

(a) Physical Structure

(b) Circuit Symbol

Fig. 2.1: Resistor

2.3.2 Inductor: An inductor is a passive electronic component that stores energy in the form of a magnetic field. In its simplest form, an inductor consists of a wire loop or coil. The inductance is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of material around which the coil is wound

i.e.

$$V_{inductor} = L\frac{dI}{dt}$$

The physical structure and the circuit symbol of inductors are shown in Fig. 2.2.

(a) Physical Structures (b) Circuit Symbol

Fig. 2.2: Inductors

2.3.3 Capacitor

Capacitor is a passive device used to store electric charge. It acts as a short circuit with AC and an open circuit with DC. The voltage across a capacitor lags the current through by 90°, applying the same logic to the capacitor as was used for the inductor, the reason for this lag in voltage is that the voltage is proportional to the integral of current entering the capacitor i.e.

$$I_{capacitor} = C\frac{dv}{dt}.$$

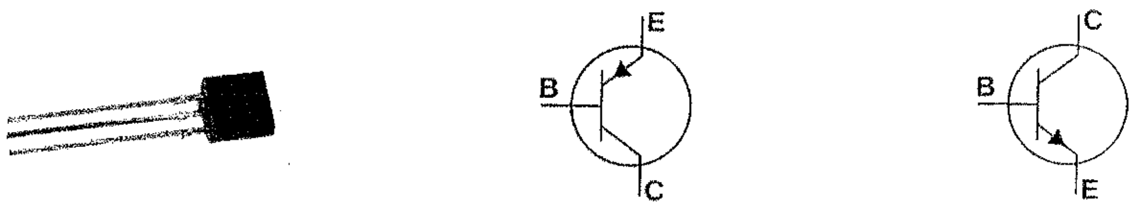
There are two types of capacitor based on polarity. These are electrolytic capacitor and non-electrolytic capacitor. Also, capacitor can be fixed or variable as shown in Fig. 2.3.

(a) Physical Structure (b) Fixed (c) Variable (d) Electrolytic

Fig. 2.3: Capacitors

2.3.4 Bipolar Junction Transistor (BJT)

A Bipolar Junction Transistor, or a BJT, is a solid-state active device in which the current flow between its two terminals (the collector and the emitter) and is controlled by the amount of current that flows through a third terminal (the base). The physical structure and the circuit symbol of BJT transistors are shown in Fig. 2.4.



(a) Physical Structure (b) PNP (c) NPN

Fig. 2.4: Bipolar Junction Transistors

2.3.5 Solar Panel

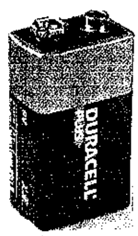
A solar panel is a collection of solar cells. Lots of small solar cells spread over a large area can work together to provide enough useful power. The more light that hits a cell, the more electricity it produces. They are often located on the roof of buildings where they can receive the most sunlight. The solar panel used for this project is a 12 Volts solar panel. This physical structure and the circuit symbol of a typical solar panel are shown in Fig. 2.5.

(a) Physical Structure (b) Circuit Symbol

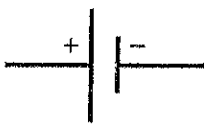
Fig. 2.5: Solar Panel

2.3.6 Battery

A battery is an electrochemical cell (or enclosed and protected material) that can be charged electrically to provide a static potential for power or released electrical charge when needed. The physical structure and the circuit symbol of a battery are shown in Fig. 2.6.



(a) Physical Structure

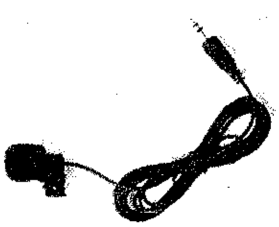


(b) Circuit Symbol

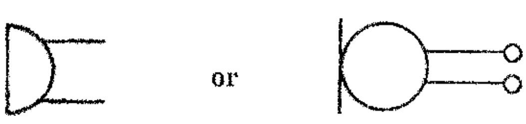
Fig. 2.6: Battery

2.3.7 The Microphone

A microphone is a transducer that converts an acoustic signal to electrical transducers. The four best known variations of these are the moving coil (dynamic), ribbon, piezo-electric (crystal), and electret (Capacitor). The physical structure and the electrical symbol of a microphone are shown in Fig. 2.7.



(a) Physical Structure



(b) Electrical Symbol

Fig. 2.7: Microphone

2.3.8 Antenna

Antenna is a device that convert an electrical signal in a guided medium into an electromagnetic waves, which are radiated into the atmosphere. Antennas can be vertically or horizontally polarized, which is determined by their relative position with the earth's surface (i.e. antenna parallel with the ground is horizontally polarized). A transmitting antenna that is horizontally polarized transmits better to a receiving antenna that is also horizontally polarized, this is also true for vertically polarized antennas [4]. The physical structure and the circuit symbol of an antenna are shown in Fig. 2.8.

(a) Physical Structure (b) Circuit Symbol

Fig. 2.8: Antenna

CHAPTER THREE

DESIGN METHODOLOGY

3.1 DESIGN THEORY

The transmitter will be designed to take a signal in the audio range (20 Hz – 20 kHz) and prepare it for transmission through the air. A signal path for the transmitter is depicted in the Fig. 3.1.

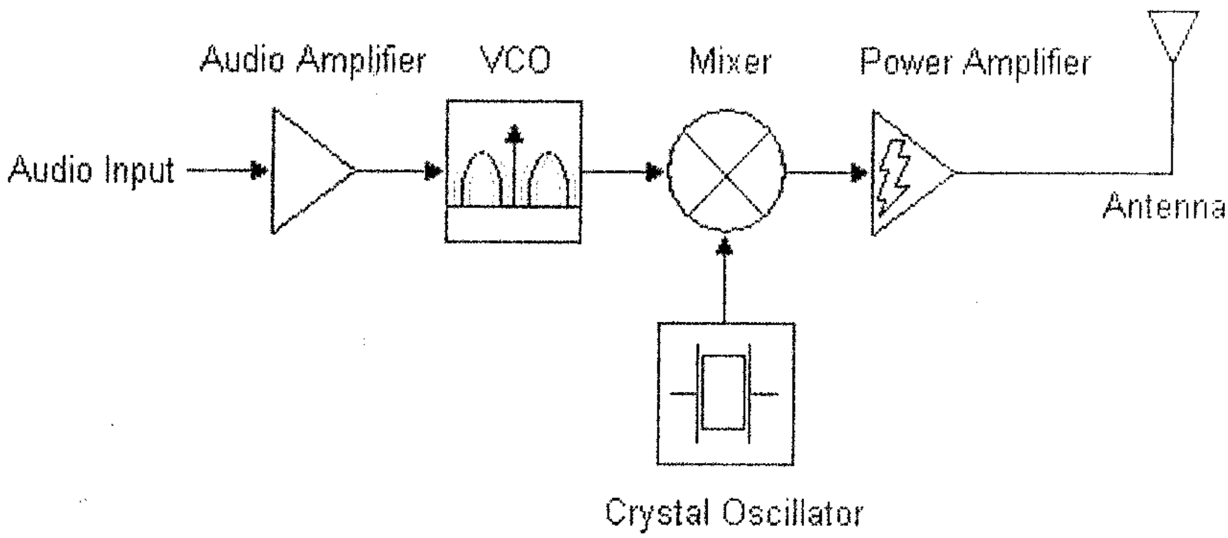


Fig. 3.1: Stages of a FM Transmitter [3]

Two modulation stages perform the up-conversion. The voltage controlled oscillator (VCO) implemented through the LM566, converts the base-band signal into the frequency of a square wave. With only a DC input, the VCO is set to output at exactly 300 kHz. To control both the DC level and the maximum AC variation at the VCO input, an audio amplifier is placed between the VCO and the audio source. Following the VCO, the mixer up-converts the VCO output to the transmission frequency at 104.4 MHz. A crystal provides the mixer with its 24MHz local oscillator reference.

The mixer output can be technically used for transmission, but it is generally too weak to be sent for a long distance. A power amplifier that provides 20 dB of power gain is placed between the mixer and the antenna to boost the actual output. Since power is the primary concern at this stage, impedance matching between the mixer and the power amplifier is needed to minimize transfer loss. With adequate output power, this transmitter is able to send signals out to decent distance. The key figure of merit for this project is illustrated in the table 3.1.

Table 3.1: Key Figure of merit of a 950 mW Transmitter

<table>
<tr><td colspan="3">Overall Output Power
= 950 mW</td><td rowspan="3">9V Battery Life
= 3hours, 6 minutes</td><td rowspan="3">System Bandwidth
= 100 kHz
(3 dB cutoffs)</td><td rowspan="3">Transmittable Audio Range
20 Hz – 20 kHz</td></tr>
<tr><td colspan="2">Audio Amplifer
80 mW</td><td>4.5V Regulator
95 mW</td></tr>
<tr><td>VCO
75 mW</td><td>Mixer
100 mW</td><td>Power Amplifier
600 mW</td></tr>
</table>

3.2 DESIGN OF AN AUDIO PRE-AMPLIFIER

A simple single stage common emitter amplifier is used as a pre-amplifier as shown in Fig. 3.2.

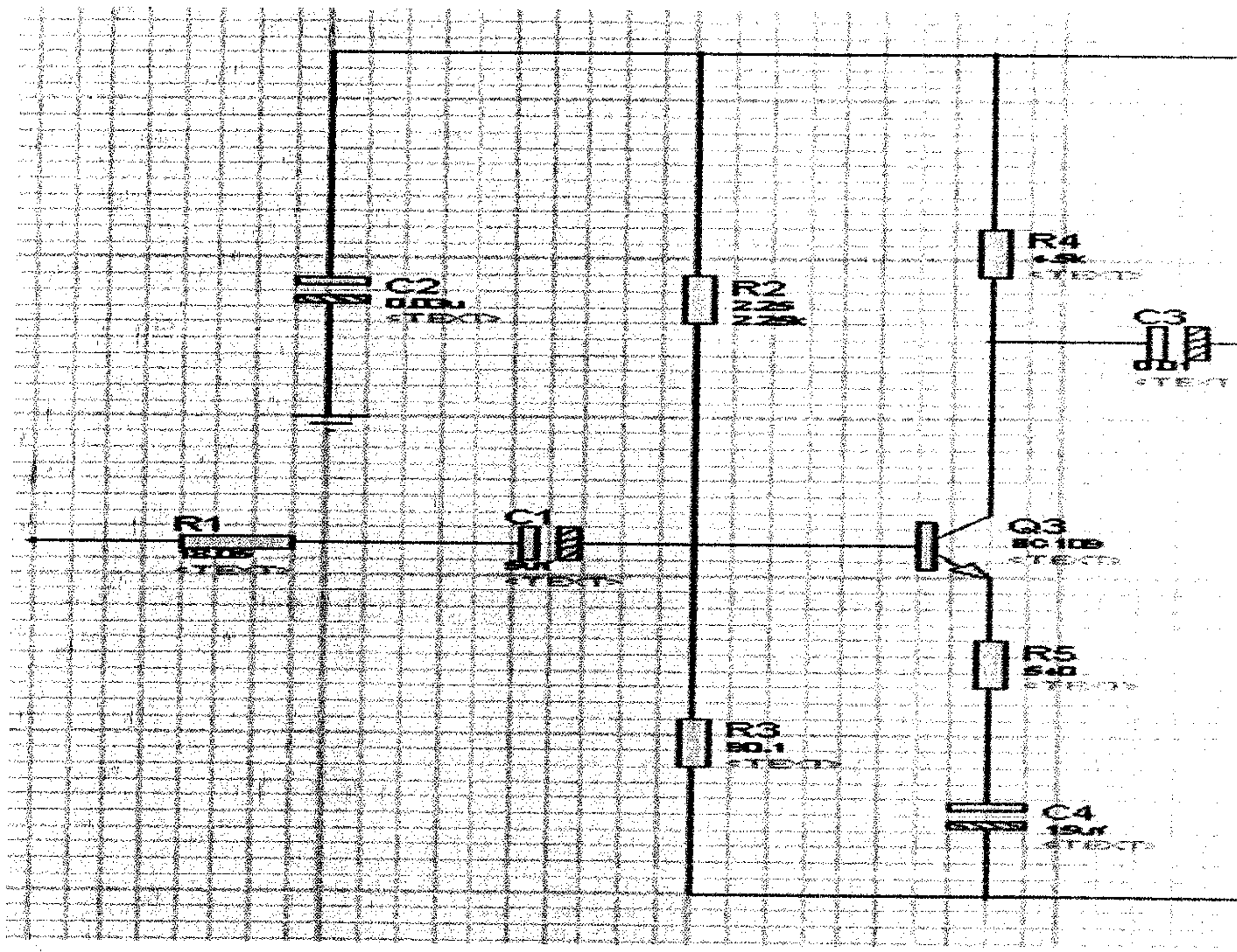


Fig. 3.2: Audio Pre-amplifier Circuit

The design selection of different component in the audio pre-amplifier state are stated as follows:

(a) *Selection of* V_{cc}: Since V_{CEO} for NPN Bipolar function transistor, BC109 is around 40V, choosing a much lesser V_{cc} of about 9V will be preferred.

(b) *Selection of Load Resistor* R_4: To calculate the value of load resistor, it is necessary to calculate the quiescent collector current I_{CQ}. Let the value to be about 1mA. The collector voltage needs to be about half of V_{cc} . This gives the value of load resistor, R_4 as

$$R_4 = \frac{V_{CC}}{I_{CQ}} = \frac{9/2V}{1mA}$$

$$R_4 = 4.5\ k\Omega$$

Selecting a 5kΩ resistor will be preferable for better operation.

(c) *Selection of Voltage Divider Resistors,* R_2 *and* R_3: To calculate the value of the voltage divider resistors, it is necessary to calculate the bias current as well as the voltage across the resistors. The bias current is approximated to be 10 times the base current. Now base current, I_B is equal to the collector current divided by the current gain. This gives the value of I_B to be 0.08mA. The bias current is thus 0.08mA.The voltage across the base V_B is assumed to be 0.7V more than the emitter voltage V_E. Now assume the emitter voltage to be 12% of V_{cc}.

$$V_E = 12\% \text{ of } V_{cc}$$

$$\text{i.e. } V_E = \frac{12}{100} \times 9V$$

$$\therefore V_E = 1.08\ V$$

$$V_B = V_E + 0.7V$$

$$\therefore V_B = 1.08 + 0.7 = 1.78\ V$$

This gives V_B to be 1.78V. Thus

$$R_2 = \frac{V_B}{I_{bias}}$$

$$R_2 = \frac{1.78}{0.08}$$

$$\therefore R_2 = 22.25 \text{ k}\Omega$$

Selection of a 22 kΩ resistor will be okay.

$$R_3 = \frac{V_{CC} - V_B}{I_{bias}}$$

$$R_3 = \frac{9V - 1.78V}{0.08mA}$$

$$\therefore R_3 = 90.1 \text{ k}\Omega$$

Here, selecting a 90kΩ resistor will be preferable.

(d) *Selection of Microphone Resistor,* R_1: The purpose of this resistor is to limit the current through the microphone, which should be less than the maximum current a microphone can handle. For this project the maximum current rating for the microphone is 1.5mA. Let us assume the current through microphone to be 0.4mA. This gives the value of R_1 to be

$$R_1 = \frac{V_{CC} - V_B}{I_{mic}}$$

$$R_1 = \frac{9V - 1.78V}{0.4mA}$$

$$R_1 = 18.05 \text{ k}\Omega$$

Here selecting an 18kΩ resistor will be preferable.

(e) *Selection of Emitter Resistor,* R_5**:** The value of R_5 is given by

$$R_5 = \frac{V_E}{I_E}$$

Where I_E = emitter current and is approximately equal to the collector current.

This gives

$$R_5 = \frac{V_E}{I_E},$$

$$R_5 = \frac{1.78}{3.3mA}$$

$$\therefore R_5 = 540\ \Omega$$

Here selecting a 500 Ω resistor will be preferable. This resistor serves the purpose of bypassing the emitter current.

(f) *Selection of coupling capacitor,* C_1**:** This is a capacitor used for stopping the passage of direct current from one circuit to another while allowing alternating current to pass. Here this capacitor serves the purpose of modulating the current going through the transistor. A large value indicates low frequency (bass), whereas a lesser value increases treble (higher frequency). Selecting a value of 5 uF will be preferable because it will serve the purpose of modulating the current going through the transistor.

(g) *Selection of Bypass Capacitor,* C_4: Here an electrolyte capacitor of 15 uF is selected, which bypasses the DC signal.

3.3 DESIGN OF OSCILLATOR CIRCUIT.

The oscillator circuit used in this project is shown in Fig. 3.3.

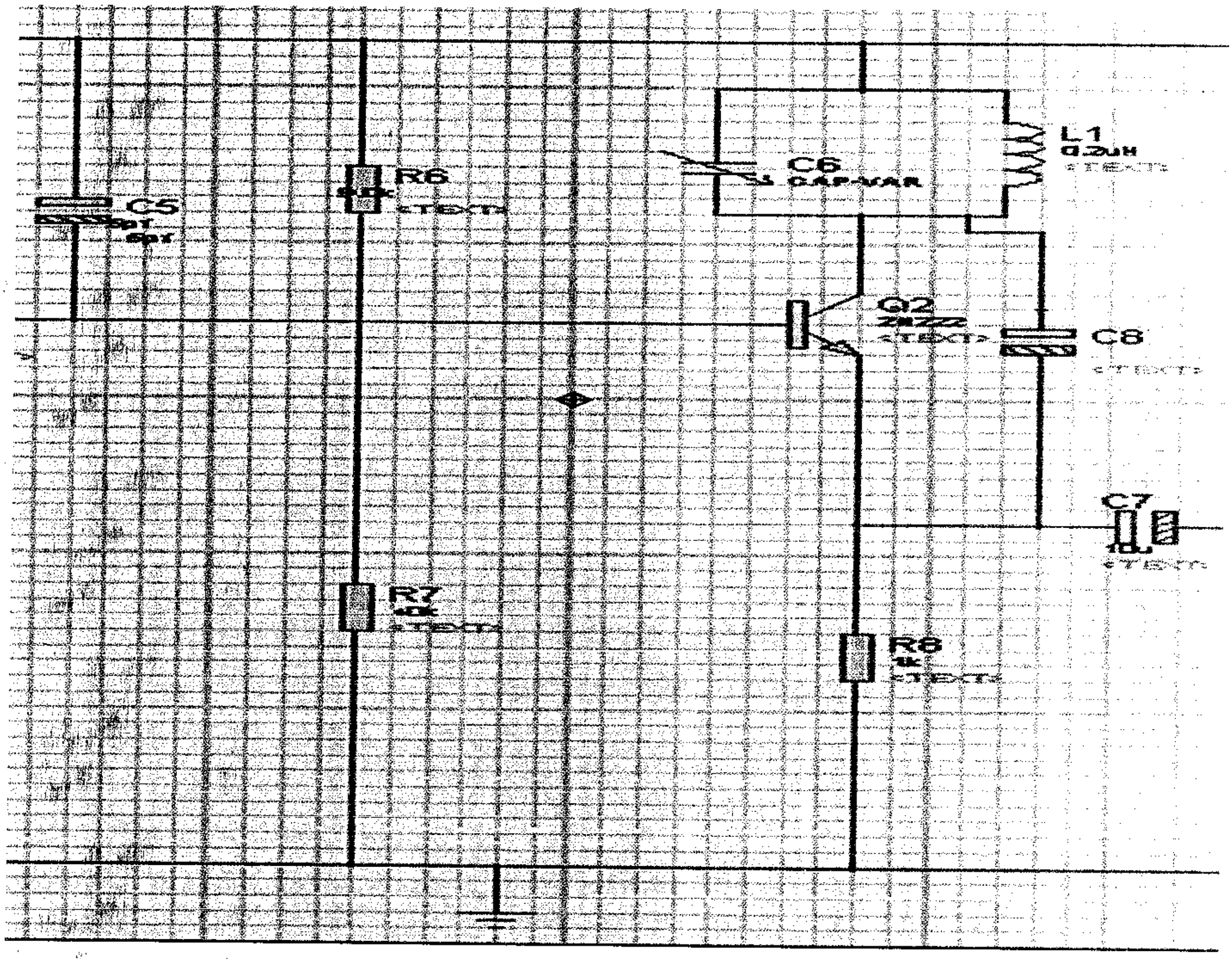


Fig. 3.3: Oscillator Circuit

An electronic oscillator is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave. Oscillators convert direct current (DC) from a power supply to an alternating current signal.

(a) Selection of tank circuit components L_1 and C_6: The frequency of oscillations for this design is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Square both sides of the above equation

$$f^2 = \frac{1}{4\pi^2 LC}$$

$$C_6 = \frac{1}{4\pi^2 f^2 L}$$

$$\therefore C_6 = \frac{1}{4 \times 3.142^2 \times 104.4^2 \times 0.2 \times 10^{-6}}$$

$$C_6 = 0.162\text{uF}$$

For a frequency of 104.4 MHz, assuming $L = 0.2\ \mu H$ inductor is been selected. This gives value of C_6 to be around 0.162uF.

(b) Selection of Tank Capacitor, C_9:: This capacitor serves the purpose of keeping the tank circuit to vibrate. Since here we are using BJT 2N222, we prefer the value of C_9: between 4 to 10pF. Selection of a 5 pF capacitor might be preferable.

(c) Selection of bias resistors R_6 and R_7 : Using the same method for calculation of bias resistors, as in the preamplifier design, we select the values of bias resistors R_6 and R_7: to be 9 kΩ and 40 kΩ respectively.

i.e.

$$R_6 = \frac{V_{CC} - V_B}{I_{bias}}$$

$$R_6 = \frac{9 - 1.78V}{0.8mA}$$

$$R_6 = 9\ \text{k}\Omega$$

Also,

$$R_7 = \frac{V_{cc} - V_B}{I_{bias}}$$

$$R_7 = \frac{9 - 1.78V}{0.18mA}$$

$$R_7 = 40\ \text{k}\Omega$$

(d) Selection of coupling capacitors, C_3: An electrolytic capacitor of about 0.01 uF is selected as the coupling capacitor. This is a fixed value for this particular project

(e) Selection of emitter resistor, R_8: Using the same calculation as for the amplifier circuit, The value of emitter resistor was gotten to be around 1kΩ i.e.

$$R_8 = \frac{V_{CC} - V_B}{I_{bias}}$$

$$R_8 = \frac{9 - 1.78v}{0.00179mA}$$

$$\therefore R_8 = 1\text{k}\Omega$$

3.4 DESIGN OF POWER AMPLIFIER CIRCUIT

The power amplifier circuit used in this project is shown in Fig. 3.4.

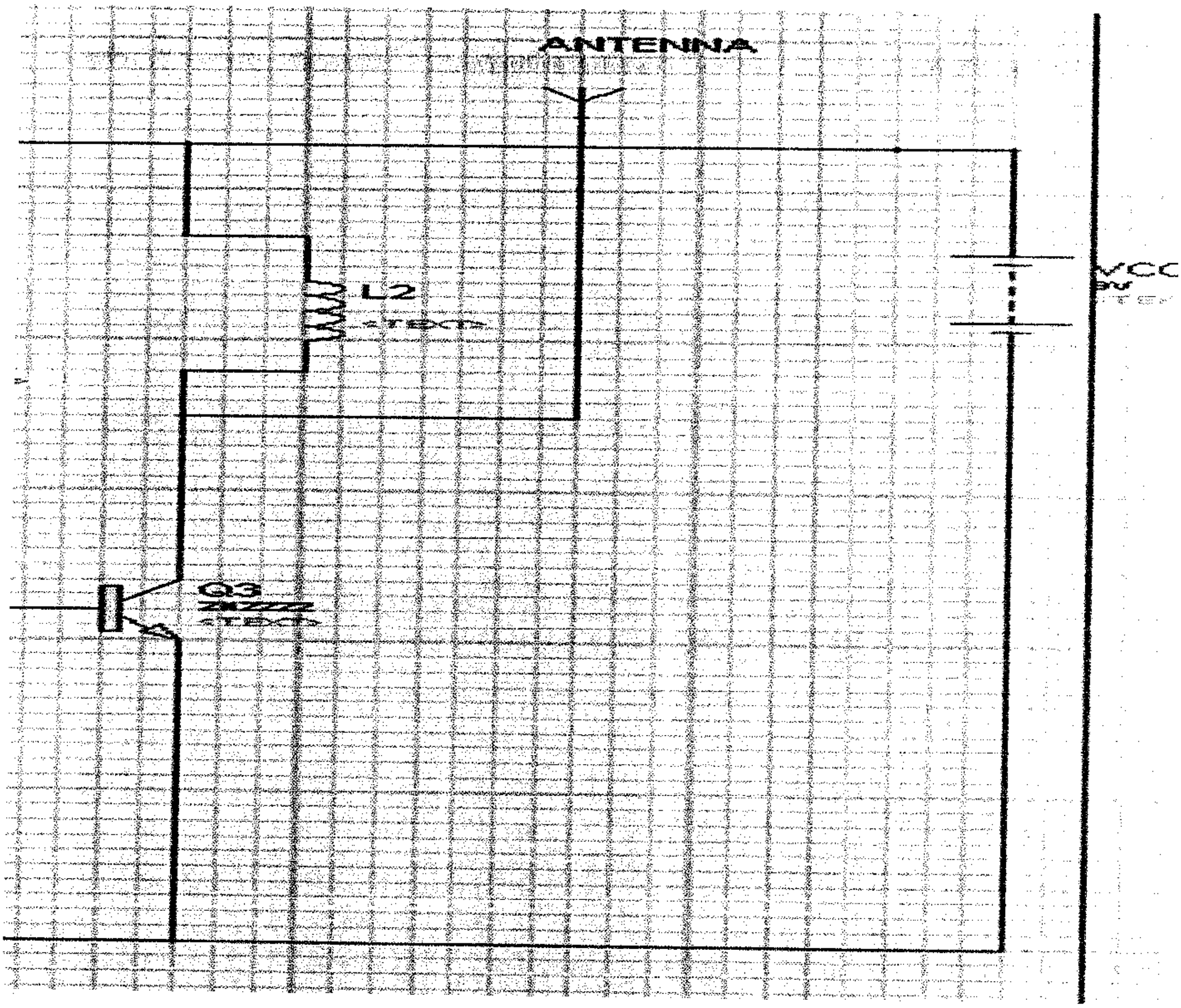


Fig. 3.4: Power Amplifier Circuit

Since the design specification requires a low power output, it is preferable to use a class A power amplifier with LC tank circuit at the output.

3.5 SELECTION OF ANTENNA

The final stage of any transmitter is the antenna; this is where the electronic FM signal is converted to electromagnetic waves, which are radiated into the atmosphere. Antenna could be vertically or horizontally polarized, which is determined by their relative position with the earth's surface (i.e. antenna parallel with the ground is horizontally polarized). A transmitting antenna that is horizontally polarized transmits better to a receiving antenna that is horizontally polarized; this is also true for vertically polarized antenna. One of the intended uses for the transmitter is as a tour guiding aid, where a Walkman radio receiver shall be used as the receiver. A vertically polarized whip antenna will be the chosen antenna for this particular project, since the range is less than 300m, we can prepare an antenna using a stick antenna or a wire of about 75 *cm* approximately which would be about $1/4^{th}$ of the transmitting wavelength.

The relationship between the antenna height and the frequency can be illustrated below:

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 m}{104.4 \times 10^6\ Hz}$$

$$\lambda = 2.874\ m$$

For a monopole antenna, length of the antenna can be calculated using

$$L = \frac{\lambda}{4}$$

$$L = \frac{2.874}{4}$$

$$L = 0.718\ m \text{ or } 71.8\ cm$$

Therefore, the average length of the antenna should be 71.8 *cm* long.

3.6 DESIGN AND CALCULATION OF OUTPUT POWER

The calculation for the output power of the transmitter can be calculated using the value of the load resistor which is 21.31Ω. The maximum power transfer can be calculated as follows:

$$P = \frac{V^2}{4R_L}$$

$$P = \frac{(9V)^2}{4 \times 21.31\Omega}$$

$$P = \frac{81}{85.24}$$

$$P = 0.9489\text{W}$$

$$P = 950\text{mW}$$

Therefore the power output of the FM transmitter is 950mW.

3.7 DESIGN CALCULATION OF THE BATTERY DURATION

When the transmitter is transmitting the maximum output power, the discharging current of the battery is calculated using

$$I_{in}V_{in} = P_{out}$$

$$\therefore \quad I_{in} = \frac{P_{out}}{V_{in}} = \frac{950 \times 10^{-3}\text{W}}{9V}$$

$$\therefore \quad I_{in} = 0.10556 \text{ A}$$

Since the capacity of the given battery is 325 mAh, the duration of the battery is given by

$$\text{Q} = I_{in}\text{t (ah)}$$

$$\therefore t = \frac{Q}{I_{in}} = \frac{325 \times 10^{-3} Ah}{0.10556\,A}$$

t = 3.079 hours   or   3 hours, 6 minutes

Therefore, the duration of the battery, while the transmitter is transmitting a 950 mW output power, is approximately 3 hours and 6 minutes.

CHAPTER FOUR

CONSTRUCTION, TESTING, RESULTS AND DISCUSSION

4.1 CONSTRUCTION

The construction of the solar powered transmitter entails both the internal construction and the external construction.

4.1.1 Internal Construction

The components were initially mounted on a breadboard and tested. During the mounting of the components the jumper wires were not properly fixed, and due to this the circuit did not work well when powered. The mistake was corrected (by making sure that the jumper wires were properly fixed to the bread board) before finally being transferred onto the Vero board for permanent soldering. The complete circuit was built and tested for a period of time and it worked as expected.

Since the power supply is the hub of the circuit, it made use of 9V rechargeable battery powered by a 12V solar panel. The solar panel is used to charge the battery to avoid low battery voltage as shown in Fig. 4.1. This battery cannot be over charged because, when transmitting, the battery discharges at this point, the solar panel charge the battery so as to avoid low battery which is not good during transmission.

During the construction of the output power amplifier, special attention was given to the positive rails (a rail is a voltage distributed to several parts of a circuit). When a 9V battery was connected, one of those connections is the positive rail and one is the negative rail) and they were located at appreciable distance from each other to avoid accidental contact (short circuit); the third power terminal which is the ground was such that it formed a mesh around the circuit.

This was to avoid problems due to floating ground effect, which can also be eliminated by adequate earthing. Therefore high performance and better reliability was achieved.

Due to the presence of some components, such as power transistors which generate heat, there is need for heat dissipation so as to avoid damage to the transmitter circuit which can reduce the system's reliability and efficiency. Heat dissipation in this project was effected by incorporating heat sink in the circuit which will stabilize the temperature of the entire system. Fig. 4.1 The internal view of the constructed FM transmitted as connected to the solar panel for charging purpose.

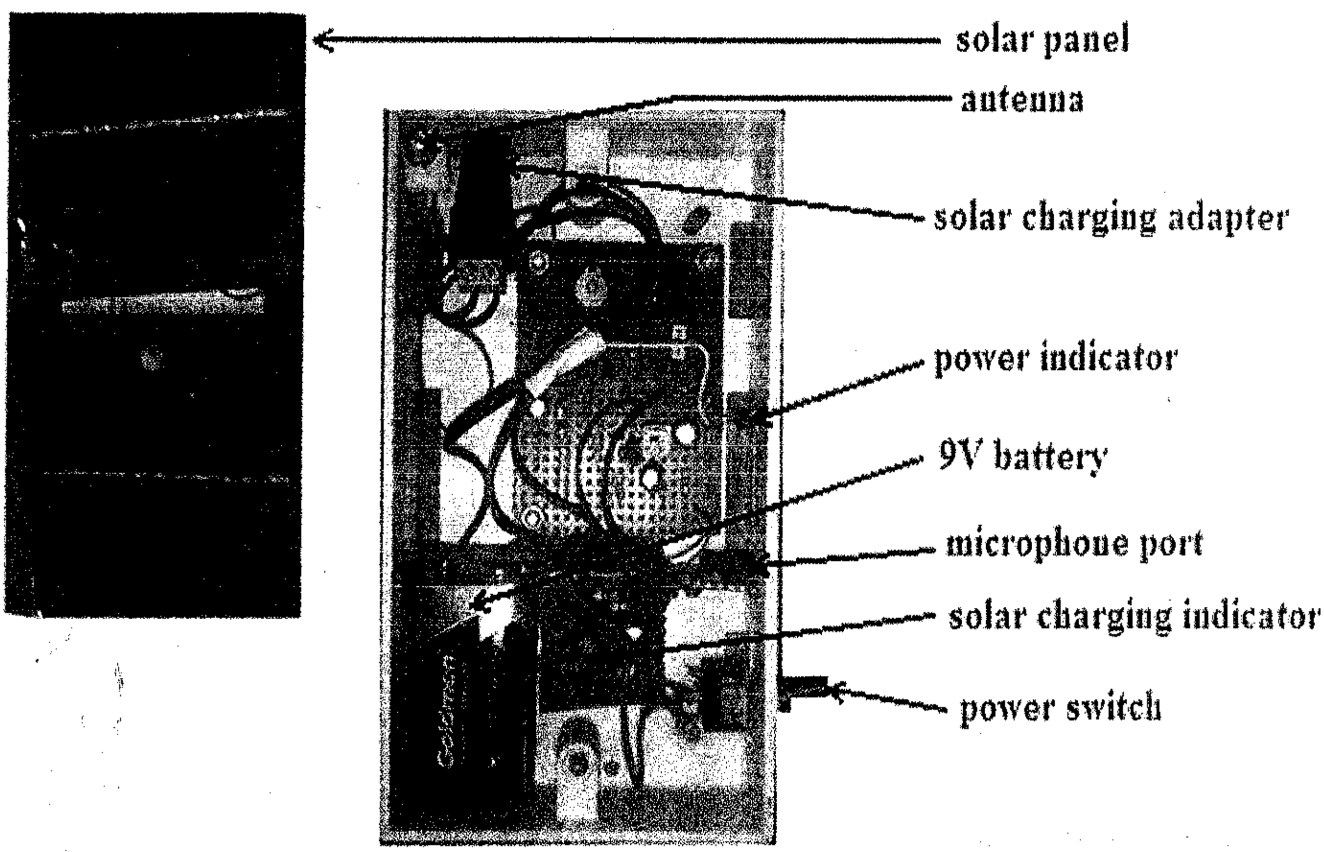


Fig. 4.1: Internal View of the Constructed FM transmitter and the Solar Panel

4.1.2 External Construction

Every quality and good product is often determined by how it is packaged. Packaging the circuit is a very convenient way in other to avoid damage to components [6]. Therefore, it was decided that a non-conductive material will be used for this purpose. A plastic casing was preferred in the packaging. In choosing this medium, considering the power rating of the system and the frequency characteristics such that the casing will not in any form cause interference with the working frequency. The external casing of the FM transmitter is shown in Fig. 4.2.

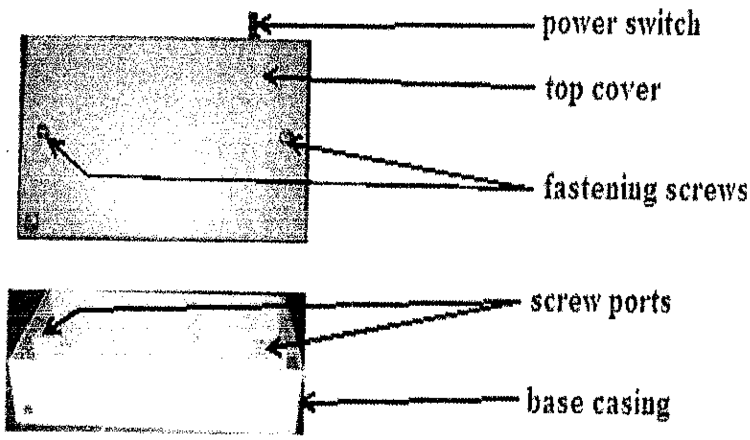


Fig 4.2: The External Casing of the FM transmitter

4.2 TESTING AND RESULTS

4.2.1 Laboratory Testing

In the laboratory, the testing of the circuit was done with the use of laboratory equipment such as Oscilloscope, a frequency meter, digital multi-meter and an analogue and digital FM radio receiver was used.

An oscilloscope's primary function is to provide a graph of a signal's voltage over time. For this project, the oscilloscope was used to measure clock frequencies, duty cycles of pulse-widthmodulated signals, propagation delay and signal rise and fall times. It was also used to check the type of waveform that was generated.

The frequency meter has a maximum frequency of 120MH_Z and this was used to check the output frequency of the oscillator. To effectively use this instrument, an impedance of 20 Ω was attached to the meter's probe and placed at the output of the transmitter; this was used to properly match the 50 Ω transmission line of the probe with that of the transmitter output.

Digital multimeter was used to measure the voltage and current at each unit of the FM transmitter.

An analogue (dial turn) and a digital (push-button) receiver was used in demodulating the modulated carrier wave generated by the transmitter. The experimental setup during testing is shown in Fig. 4.3.

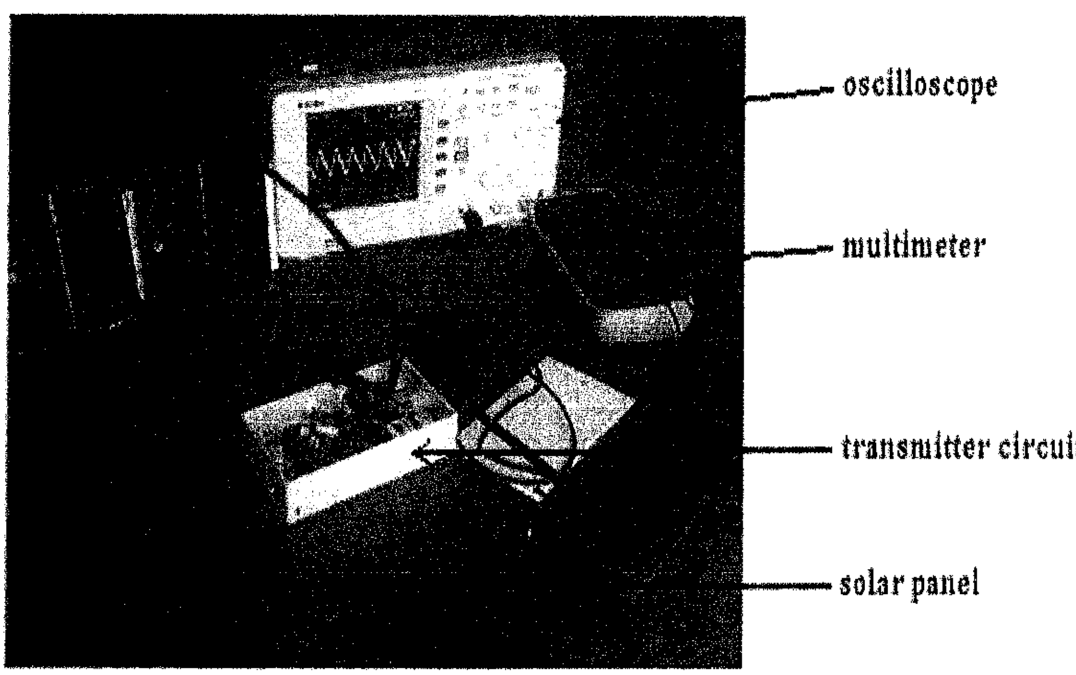


Figure 4.3: Laboratory Setup during Testing

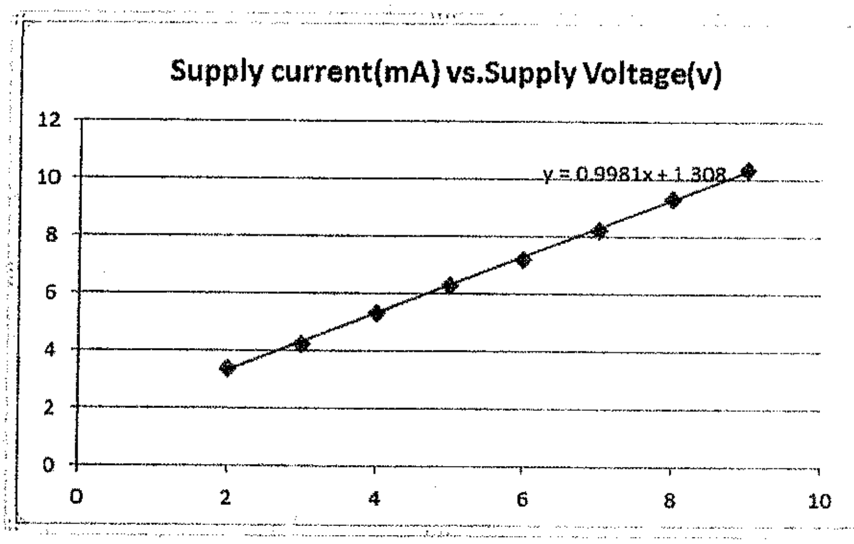


Fig. 4.4: Plot of the Supply Current (Vertical Axis) against the Battery Voltage of the Battery (Horizontal Axis)

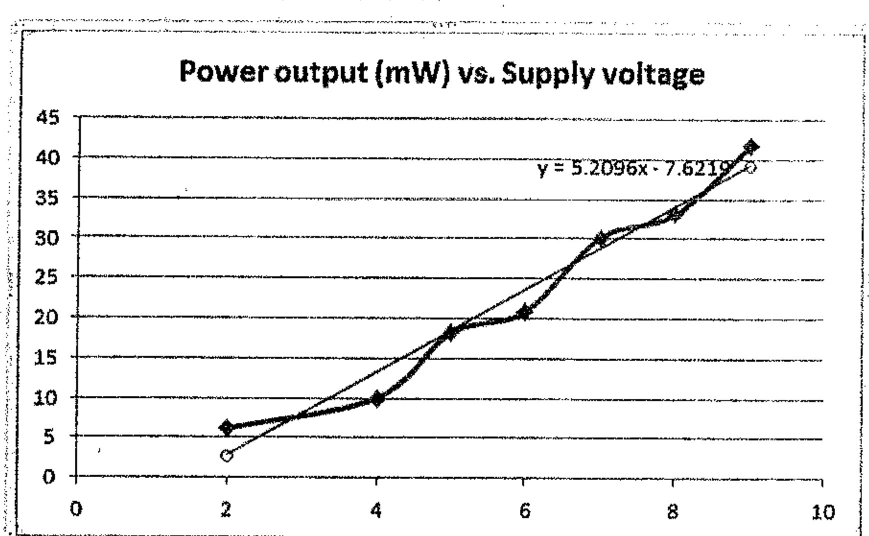


Fig. 4.5: Plot of the Output Power (Vertical Axis) against the Supply Voltage (Horizontal Axis)

It can be seen from Fig. 4.5 and Fig. 4.6 that the supply current decreases linearly as the supply voltage supplied from the battery decreases, also the output power decreases as the voltage supply to the transmitter decreases. The typical voltage input from the battery source will be 9.2V in the first 30 minutes of operation decreasing to the 8.8 V to 7 V band in the next 2 hours of continuous operation

4.2.3 Field Test and Results

The first walk was on an evening, after the rain subsided. The transmitter was connected to the roof of the engineering building and sent out a simple music piece. A good signal reception was gotten as far as the school mosque (less than 60 m). Along the way, dead spots occurred most frequently in the presence of trees. Sometimes, standing in front of tall buildings helped reception, probably because some signals bounced off the building in the direction of the receiver. One problem that plagued the latter half of the tests was a faulty batter clip, causing the receiver to be powered only intermittently.

Second walk was most enjoyable in that the testing was done around the entire engineering building and the transmitter was able to transmit and get a good signal with the FM receiver. The receiver was taken as far as the school canteen and still receives a clear signal. Further towards the ICT hall, the signal to noise ratio (SNR) degraded faster than it did on my previous field test.

Several factors could have been detrimental to receptions, and these are unfavorable weather condition and the newly created metal enclosure (for the receiver) actually hurt reception. Fig. 4.6 depicted the schematic diagram of the various field test carried out.

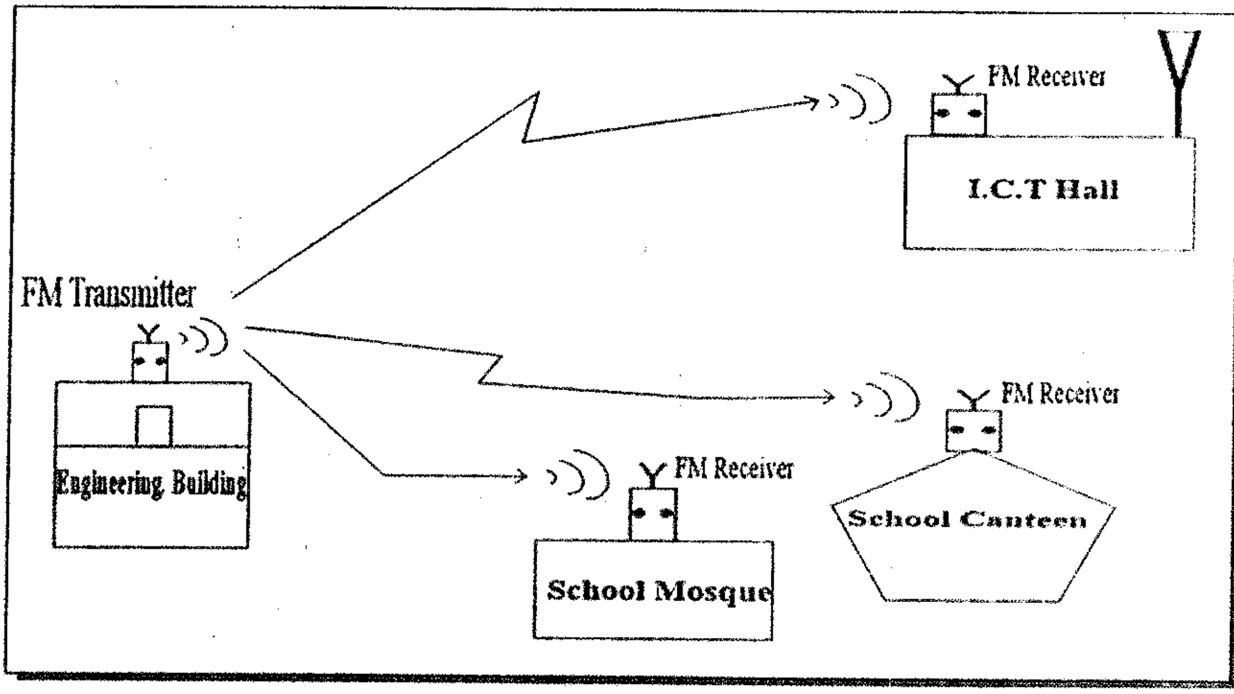


Fig. 4.6: Schematic Diagram of Various Field Tests and Results

4.3 DISCUSSION

While testing this project, it was observed that when it is a raining day, the transmitter signal is weak compared to a sunny day. It was also observed that when the solar panel was placed outdoor under the sun it gives an accurate reading of 11.98V which is able to charge the 9V battery. The solar panel could not produce 11.98V during the rainy day and this affected the charging rate of the battery. Also during the testing of the project it was observed that moving the transmitter up and down led to signal distortion. Therefore, it is advisable to station the transmitter in a particular location before transmission so as to get a clear signal.

4.4 PROBLEMS ENCOUNTERED

While doing the construction process it was observed that soldering of several components on the Vero board were not as easy as they look. Therefore, some component burnt out due to short-circuiting of some component terminals. These burnt components were later replaced with new ones and they were carefully soldered to the Vero board.

After the construction of the project, the desired output was not achieved. Therefore, the design was re-visited and some components were adjusted to get the desired output.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This project entails the design and construction a 950 mW solar powered FM transmitter. The FM transmitter was design using electronic components such as transistors, resistors, capacitors, inductors, light emitting diode (LED), voltage regulator and so on. The operating frequency is between 88 – 108 MHz ±5% (for this project, the centre frequency is 104.4 MHz). Its transmitting distance is 100 meters this gives best range and least interference. This transmitter is powered with a 9V DC battery and two solar panels of $10V_{dc}$ 1240mA (5V each). This transmitter can be used to transmit audio signal using a MP3 player and could also serve the purpose of public information dissemination.

When the sound wave is sent into the condenser microphone, it convert the sound waves into an electrical waves, this wave is too weak to be feed directly to a speaker so it is necessary to amplify the wave using a power amplifier. This amplified wave is transmitted to the air using a carrier wave which transmit the amplified wave electromagnetically into the air to form a superimpose wave which is then transfer to the antenna, which can then be transmitted to the receiver in another location. At this point the receiver converts the electrical wave into sound wave to be received by the listener.

This project can be used in the university community to disseminate information to both staff and students. It has a unique advantage such that it can be used without AC input source from the utility power source Rather, it uses a 9V rechargeable battery which is been continuously charged by solar panel.

5.2 RECOMMENDATIONS

The following are the recommendations based on findings from the project:

- The reliability of the transmitter depends largely on the power source. Failure of the battery in case of low battery strength will make the system stop operation. Therefore, utility AC supply can also be used to charge the battery, in addition to the solar panel.
- The transmission range of the constructed transmitter cannot exceed the distance of 100 meters. Therefore, the power output of the transmitter can be increased in order to increase the transmission distance.
- The transmitter can be improved upon by inculcating an infrared switching circuit in order to enable it (transmitter) to be turned on with a remote control.