DESIGN AND CONSTRUCTION OF A FREQUENCY MODULATION (FM) TRACKINS SYSTEM

BY

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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CERTIFICATION

This is to certify that the project work title " design and construction of FM tracking device" was carried out by Korede Olafimihan under the supervision of Engr. Rumala and submitted to the department of Electrical and Computer Engineering for the award of B. Eng in Electrical and Computer Engineering of the Federal University of technology, Minna.

.... 7th Dec. 2004

Date

Engr. S. N. Rumala

(Project Supervisor)

.... 31/12/2004

Date

Dr. M. D. Abdullahi

(Head of Department)

....

(External Examiner)

....

Date

DECLARATION

I hereby declare that this thesis is my original work and has never been printed elsewhere for award of any degree.

Information derived from published and unpublished work of others has been acknowledged in this project write up.

KOREDE G. OLAFIMIHAN 19 – 11 – 04

DEDICATION

To Jesus Christ who is the greatest source of motivation, knowledge and understanding

And

To the greatest parents in the world Barrister Tokunbo and Mrs Amen Olafimihan; thank you for your support in all aspects of my life. I love you both.

ACKNOWLEDGEMENT

I owe so much to so many who gave so freely of their knowledge, experience, expertise, time, effort and technical resources to make this project a reality. Profound gratitude also goes to my able, diligent and kind-hearted supervisor Engr. Rumala for his meticulous scrutiny of this project work and his assistance in terms of advice and knowledge to make this degree course a success. I forever will owe the authors of the books and articles they`ve written a debt of gratitude for putting their thoughts and observations on paper and on the web, so that I could draw from them. Seun was invaluable in the development of this work. He unselfishly applied his almost unmatched technical expertise to ensure its absolute integrity. Thank you for your friendship, guidance and your technical assistance. My special thanks goes to my caring Father Barrister Tokunbo Olafimihan, my mother Mrs Amen Olafimihan. Profound gratitude also goes to my able, diligent and kind-hearted supervisor Engr. Rumala for his meticulous scrutiny of this project work and his assistance in terms of advice and knowledge to make this degree course a success. I am also indebted to my friends Tunji Olorukoba, Seun Adekunle, Gbenga Olakunle, Amakiri Welekwe and others who encouraged and stood by me through out the degree course. May you be blessed as you have blessed me.

Gratitude also goes to Professor Fasanya and Engr for their care and concern.

Most for all I am forever indebted to my parents, Barrister Tokunbo and Mrs Amen Olafimihan. Your love and care for me ahs made me work harder to make you proud. I can only hope that I succeeded, for you are truly treasures.

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LIST OF FIGURES

ABSTRACT

This project is on the design and construction of a Frequency Modulation Tracking System. It involves a transmitter and receiver for sending and receiving a signal in which the receiving device uses the signal transmitted to locate or track the source or transmitter.

In FM, the AF energy coming from the Microphone or transducer is amplified to the required power level by low distortion amplified operating class A. The high quality audio thus produced is used to modulate the radio frequency carrier. The radio frequency carrier wave is generated by a stable oscillator usually low power, which is usually LC controlled to achieve long distance coverage of transmission. That the carrier wave is only a constant amplitude, high frequency a.c wave until it is modified in some way to convey intelligence.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

Communication generally defined can be said to be the exchange or sending of information from one person to another.

Telecommunication can be defined as the transfer of information (communication) from a transmitter or sender to a receiver across a distance (tele).

Some form of electromagnetic energy is employed to represent the data, usually through a physical medium, such as a copper wire (twisted pair/coaxial cable) or a glass fibre. A wireless medium such as radio or infrared light may also be employed (microwave, satellite, cellular).

A no of intermediate devices are typically involved in setting up a path for the information transfer and for maintaining adequate signal strength.

A typical communication system/ process most have a transmitter otherwise known as the sender or source and is the device where the information transfer originates.

The information is usually then encoded and sent through a channel, which could be defined as a one – way connection between transmitter and receiver.

The information is then decoded and finally rests at the receiver also called the sink or destination device, which receives the information transfer. Most devices have both transmitter and receiver functions contained under the skin of the same box: exceptions include broadcast radio and TV devices.

Application of this type of system covers a wide range, from broadcasting, public address system to walkie – talkie devices or transceivers to security systems and tracking devices.

The use of wireless technology in the form of radio waves since the discovery of waves by a German Scientist named Heinrich Rudolf Hertz and its transmission by Gugleilmo Marconi, its applications have grown exponentially.

The first commercial application of radio technology was that of broadcast radio introduced in the United States in 1920.

Estimates from Allied Business Intelligence place the total number of wireless users world wide at between 429 million – 777 million by 2002.

Wireless is about more than being unplugged. Wireless in full form speaks to a fundamentally different way of working and living. Wireless communications adds the element of mobility, thereby removing the constraints of constant attachment to a physical space such as an office, building, school, hospital or home.

AIMS AND OBJECTIVES

The aim and objectives of this project is to design and construct an FM tracking device that will transmit and receive an audio signal increasing in strength as the transmitter draws closer in proximity with the receiver.

Radio receivers and transmitters are part of the devices used in communication systems.

The transmitting process involves the generation and transmission of pulses. These pulses are modulated and carried into the space.

The receiving process involves the reception of the pulses. The pulses are demodulated and the source is tracked down.

PROJECT OUTLINE

In the previous chapter effort was made to introduce this project by discussing and analysing what communication was and the process involved.

The purpose was to give an example of modulation in the transmission of pulses.

Consequently, I modulated a radio frequency signal (the carrier) with the speech frequency (the modulating signal) in order to broadcast it; the pulse is finally demodulated and the receiver uses the pulse to track the source.

In Chapter two, the system analysis and design is given its functional description from the transmitter, its frequency modulation to the receiver including their block diagrams.

In chapter 3, a concise detailed explanation on construction, testing and result was explained with development of the casing.

Presented in Chapter 4 were conclusion, recommendations, references and appendix (ces) of the system.

LITERATURE IN REVIEW

In 1876 Alexander Graham bell demonstrated the telephone at the Centennial exposition of the United States in Philadelphia, Pennsylvania. From that simple exposition of one – way transmission over a distance of a several hundred feet, the copper based telephone network grew at an astounding rate [6].

In 1880 Bell invented the first wireless communications system, using reflected sunlight and photoelectric selenium receivers. He transmitted intelligible speech using this technique a distance of up to 700 feet. He named this invention "photophone" and alter renamed it radiophone. The German naval Command made limited use of advanced devices of this sort during World War 2 [3].

Towards the end of the 19th Century and not long after Bells demonstration, a young German scientist named Heinrich Rudolf hertz discovered the phenomenon of invisible force waves emanating from several meters around an electric spot of sufficient intensity [6].

Shortly thereafter Gugleilmo Marconi transmitted these Hertzian waves over several kilometres. He named the new technology "radio" because the waves appear to radiate from the transmitter [6].

In 1886 Marconi was granted a patent for the first practical wireless telegraph.

The first commercial application of radio technology was that of broadcast radio, introduced in the United States in 1920[6].

Wireless radio technology was deployed in maritime communications or ship to shore telephony and telegraphy. The first terrestrial mobile application was a one –way system employed in police radio dispatch trials in 1921 at the Detroit Michigan Police Department.

The wireless industry has experienced exponential growth over the last decade, growth that is expected to continue at a pace unprecedented in the history of communications

CHAPTER TWO

SYSTEM ANALYSIS AND DESIGN

INTRODUCTION

Design of this FM tracking device is better presented in its function description, which is divided into 2 parts viz, the transmitter and the receiver.

In FM, the AF energy coming from the oscillator is amplified to the required power level by low distortion amplified operating class A. the high quality audio thus produced is used to modulate the radio frequency carrier. The radio frequency carrier wave is generated by a stable oscillator usually low power, which is usually LC controlled to achieve long distance coverage of transmission. That the carrier wave is only a constant amplitude, high frequency a.c wave until it is modified in some way to convey intelligence.

2.1 TRACKING TRANSMITTER

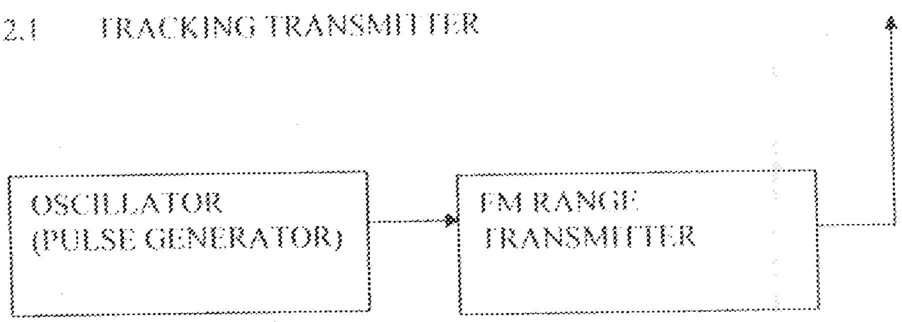

Fig 2.1 BLOCK DIAGRAM OF TRACKING TRANSMITTER

The FM transmitter comprises of an audio frequency oscillator, FM modulator and FM Oscillator with an attached antennae.

Oscillators are electronic devices used for generating an a.c signal voltage. The frequency of the generated signal depends on the circuit constants [2]. Oscillators are used in radio and television receivers, radar, transmitting equipment and in military and industrial electronics. Oscillators may generate sinusoidal or non – sinusoidal waveforms from very low frequencies up to very high frequencies[3]

.The audio frequency oscillator used for the tracking transmitter is the 4060B called a CMOS (Complementary Metallic Oxide Semi conductor) Oscillator Divider. This Oscillator could either be RC or crystal applied. It also possesses a power range of 3 – 15V. The frequency of the pulse generated can be calculated thus:

$Fo/2^4 = 1/\ 2.3RC/2^4$

$= 1/\ (2.3 \times 33 \times 10^3 \times 0.001 \times 10^{-6})/\ 2^4$

$= 823Hz$

This pulse emerges from pin 7 of the 4060B IC. The advantage of the 4060B to other oscillators is its flexibility and efficiency especially where a range of frequencies is needed. The oscillator divider divides an incoming frequency into staged. It also divides errors minimising the level of disruptions immensely.

To enable this device operate we need to use an FM signal which ranges from 88 to 108MHz. In order to avoid interference a range of 60 – 70 MHz was selected.

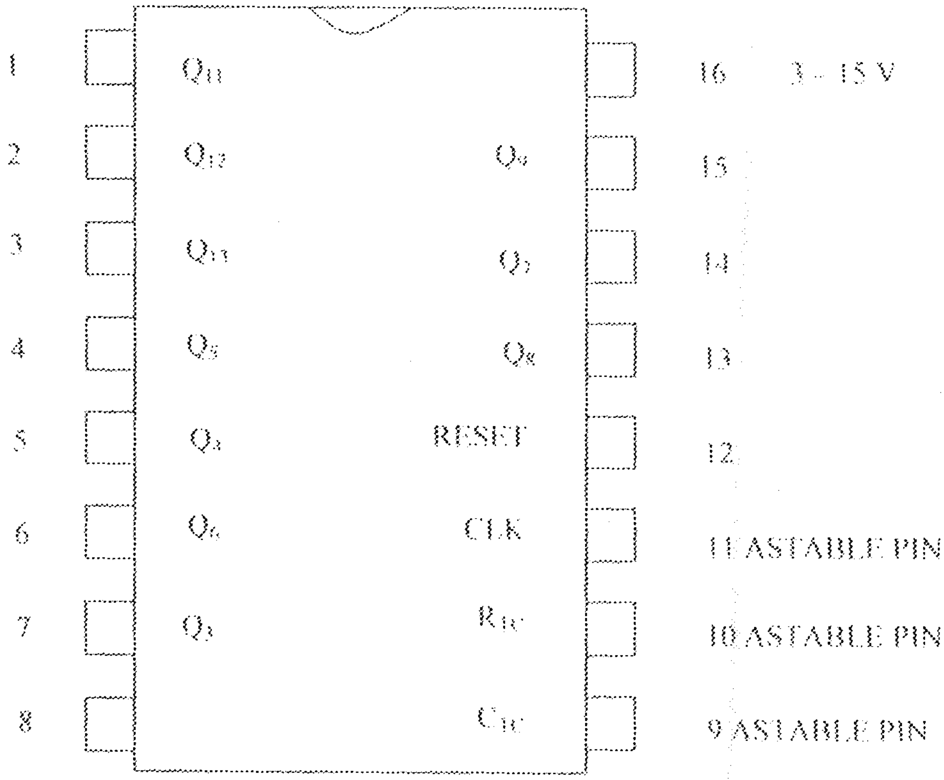

FIG 2.2 4060B OSCILLATOR / DIVIDER

Modulation is the process of combining an **audio frequency** (AF) signal with a **radio frequency** (RF) carrier wave. The AF signal is also called a **modulating wave** and the resultant wave produced is called modulated wave. [7].

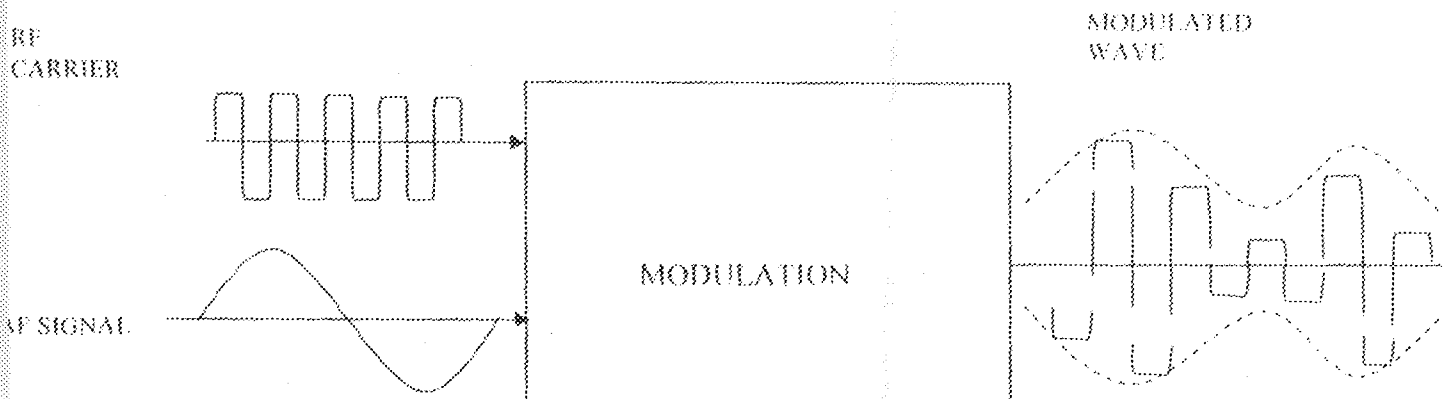

FIG 2.3 BLOCK DIAGRAM OF SIMPLE MODULATION PROCESS

Modulation becomes necessary because of the low frequency, which cannot travel long distances unlike the carrier, which is capable of doing so. Two methods can be used in this regard. These are **Amplitude modulation** (AM) and **Frequency modulation** (FM). For the purpose of this project we shall disregard AM and focus on FM.

This is the process by which we vary the frequency of the carrier wave with respect to the amplitude of the modulating signal. The power associated with an FM wave is constant due to the fact that the amplitude of the carrier wave is kept constant during modulation.

When the modulated signal amplitude is zero, the modulated signal possesses the same frequency as the carrier wave.

When the modulated signal voltage is positive the frequency of the modulated signal is greater than the unmodulated carrier signal and when the modulating signal is – ve, the frequency of the unmodulated signal is less than that of the unmodulated carrier.

The maximum frequency of the modulated signal clearly occurs when the modulating signal is at its maximum positive value; the minimum frequency of the modulated signal occurs when the modulating signal is at its maximum negative value.

Let the instantaneous wave carrier be

$$Vc = Ac\cos(Wct + \phi)$$

$$= Ac\cos(2\pi fct + \phi)$$

$$fd(t) = KfVm(t) = (1/2\pi)(d\phi(t)/dt)$$

where fd(t) is instantaneous frequency deviation and its proportional to the message or modulating signal kf is the frequency deviation constant.

$Vc(t) = Ac\ Cos\ [Wct + 2\pi Kf \int Vm(t)dt]$

The modulator is a circuit that super impulses a low frequency voice information component on a high frequency carrier signal, which is generated by the Oscillator.

This comprises of the following components

i. Variable comparator – a device used to pick up a range between 5 – 60pf

ii. Limiting resistor (R3) – a device used to stop errors in modulation

iii. The common – base amplifier and dynamic signal condition

$V_{EE} = I_E R_E + V_{EB}$

$V_{EE} = I_E R_7 + V_{EB}$

$V_{EB} = 0.7$ Silicon transistor, $Ic = I_E = 8 \times 10-3$

$R_7 = V_{EE} - V_{EB} / I_E$

$= \frac{9 - 0.7}{8 \times 10 - 3}$

$= 1038\Omega$

$R2 = 1k\Omega$

This is known as the emitter resistance

TO find the inductive value R_L

$V_{CB} = 1/3\ V_{CC}$

$= 1/3 \times 9$

$= 3V$

$V_{EE} = V_{CB} + V_{RL}$

$V_{RL} = 9 - 3 = 6V$

$I_C = I_L$

$I_C R_L = V_{RL}$

$8 \times 10^{-3} = 6$

$R_L = 6/8 \times 10^{-3} = 750\Omega$

$R_L = 750\Omega$

To find the input signal current (i.e.) firstly, we determined the value by the signal source.

Applying the approximation (junction resistance)

$rj = 26mV/ I\ d.c$

becomes $r'e\ 26mV/I_E$

where, $r'e = 26mV/ 8 \times 10^{-3}$

$r'e = 3.25\Omega$

The total Capacitance Ct of the Oscillator

$Ct = C_5 + C_8 + C_9$

$Ct = 7 \times 10^{-12} + 5 \times 10^{-12} + 2 \times 10^{-12}$

$= 25 \times 10^{-12} F$

Calculating the value of inductor used in the oscillating task.

$F = 103.7MHZ$

$$F = \frac{1}{2\pi\sqrt{LC_T}}$$

$$L = \left(\frac{1}{2\pi F}\right)^2 \times \frac{1}{C}$$

$$L = \left(\frac{1}{2 \times 3.142 \times 103.7 \times 10^6}\right)^2 \times \frac{1}{125 \times 10^{-12}}$$

$L = 94 \times 10^{-9}$ H

2.2 TRACKING RECEIVER

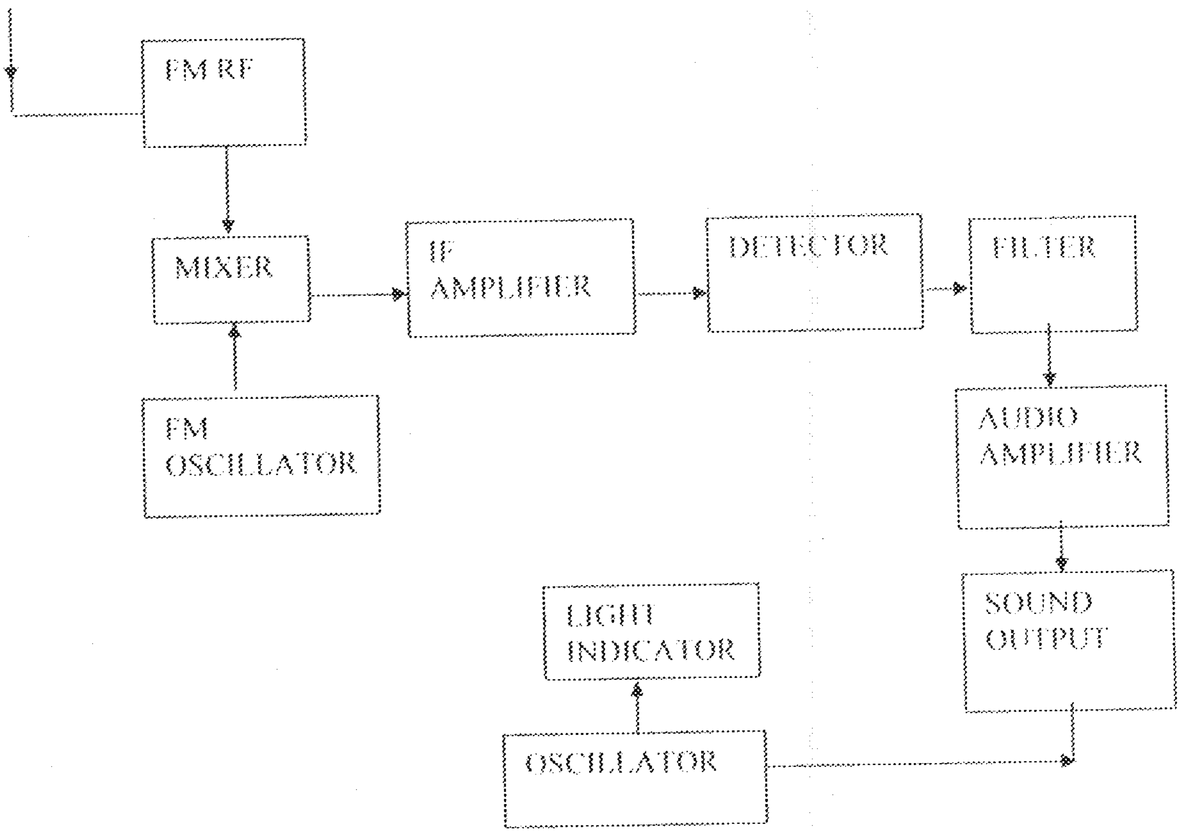

FIG 2.4 BLOCK DIAGRAM OF TRACKING RECEIVER

FM receiver contains an antennae connected to the FM RF circuit, which is followed by a mixer and load oscillator, IF amplifier, demodulator, AF amplifier and sound output which is connected to another oscillator and a light indicator.

KA2297 is a Samsung design radio integrated circuit, which has both FM and AM modes. Pins 1 and 2 of the leading IC deal with the antenna circuit. They aid the radio reception.

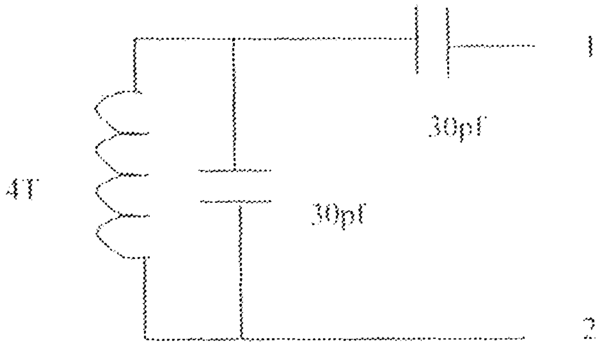

FIG 2.5 ANTENNA CIRCUIT

The circuit above is a specified type for the antenna circuit from the manufacturer.

The RF circuit is simply of an inductor – capacitor type. Its designed to tune or select a particular frequency through an LC tank. The only frequency of resonance passes into the integrated circuit.

e.g $fo = 1/ 2\pi\sqrt{LC}$

In order to boost the incoming signal strength the tuned frequency is mixed with another close frequency produced by the local oscillator. The frequency is 10.7MHz higher than the incoming frequency.

The mixture produces four frequencies

1 The Radio frequency (RF) frequency
2 The local oscillator frequency
3 The difference of the RF and Local Oscillator frequency – usually 10.7MHz and called the **intermediate frequency** (IF).
4 The addition of the frequencies mentioned in 1 and 2

10.7 MHz is the strongest and is the frequency required.

The IF amplifier takes the intermediate frequency its tuned to through a device known as a crystal filter. A 10.7MHz from a pin 3 back into the IC at pin 8. Pin 10 requires the use of 2 terminal crystals, which are scarce, so therefore, a 10.7MHz IF transformer was used instead. Pin 9 is the ground or negative terminal. Pin 5 is connected to the ground through a specified 33µf, 16V capacitor for smoothening the internal operation of the integrated circuit.

The intermediate frequency is further amplified by tuning pin 10 with an LC tank. The inductor used is 9 turns, diameter 0.8 cm and coupled through a 45pf capacitor specified by manufacturer.

Pin 11 holds the demodulated signal

This is an RC circuit, which receives the demodulated signal. Its values are 47KΩ and 0.01µf. The 0.01µf is a coupling capacitor.

The function of the **limiter** is to remove all amplitude variations (caused by noise) from IF signal which might have crept into the FM signal. This removal of amplitude variations is necessary for distortionless demodulation.

When the RF modulated waves, radiated out from the transmitter antenna, after travelling through space, strike the receiving aerials; they induce very weak RF currents and voltages in them. If these high – frequency currents are passed through head phones or loudspeakers, they produce no effect on them because all such sound producing devices are unable to respond to such high frequencies due to large inertia of vibrating discs etc. neither will such RF currents produce any effect on the human ear because their frequencies are much beyond the audible frequencies (20 to 20000Hz approximately). Hence it is necessary to demodulate them first in order that the sound producing devices may be actuated by audio – frequency current similar to that used for modulating the carrier wave at the broadcasting station. This process of recovering AF signal from the modulated wave is known as **demodulation** or **detection.**

2.3 AUDIO – AMPLIFIER / SOUND OUTPUT

This is in the form of a LM386 amplifier connected to an earphone, which as a transducer converts electrical impulses into acoustical energy. Hence in the circuit it brings out the amplified sound waves. The ear phones used is a 0.25W, 16Ω

2.4 OSCILLATOR

The 4060B is a multi function oscillation / Divider. In the circuit it's used to cause a breaking at the earphone through an NPN transistor (25C945). 0.001μf is a filter capacitor. For 4060B, the operating frequency is fo = ½.3RC where R = 33kΩ, C = 0.01μf

$$fo = 1/2.3\,(33 \times 10^3)(0.01 \times 10^{-6}) = 13168Hz$$

Based on the IC configuration

$$W_1 = \frac{1317.52}{2^{12}} \qquad W_2 = \frac{1317.52}{2^{14}}$$

Where W_1 = pin 1 frequency

W_2 = pin 2 frequency

2.5 LIGHT INDICATOR

The light indicator was accomplished using light emitting diodes. As the name implies, it is a forward biased P- N junction, which emits visible light when energised.

For Ge and Si junctions, a greater percentage of this energy is given up in the form of heat so that the amount emitted as light is insignificant. But in the case of Galliom arsenide phosphide (GaAsP), Gallium arsenide (GaAs) and Gallium phosphide (GaP), a greater percentage of energy released during recombination is given out in the form of light. If the semi conductor material is transluscent, light is emitted and the junction becomes a light source i.e. a light emitting diode (LED) as shown schematically in Fig. 2.5 below

The yellow light emitting used in this device is for searching indication (blinks) while the red light emitting diode is for power indication.

The colour of the emitted light depends on the type of material used as given below:

1 GaAS – infrared radiation (invisible)

2 GaP – red or yellow light

3 GaAsP – red or yellow (amber) light.

LEDs emit no light when reversed biased. In fact operating LEDs in reverse direction will quickly destroy them.

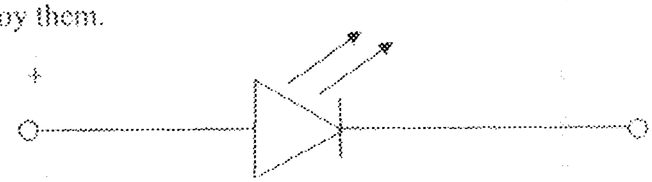

FIG 2.6 CIRCUIT REPRESENATTION OF A LIGHT EMITTING DIODE

CHAPTER THREE

CONSTRUCTION PROCEDURE

INTRODUCTION

Construction simply means the practical aspect of the fabrication of the entire project. This involves several processes, which include component assembly and testing. The construction procedure could be divided into the electronics and the casing parts.

The electronics part consist of the audio amplifier, modulator and the oscillator at the transmitter section and the radio frequency circuit, mixer, oscillator, intermediate frequency amplifier, demodulator network, audio amplifier, sound output and light indicator at the receiver section. All these were constructed one after the other as designed and analyzed in the design aspect of the project in the previous chapter.

After all necessary calculations and design modifications had been made, the components with the preferred values were bought and arranged on a bread board.

Polarities of all the components used were carefully considered as a wrong fixture of any component could result in the overheating or damage of the entire circuit. After all components were set up satisfactorily it was cross checked thoroughly to ensure that there were no errors of omission or inappropriate inoperation of any component. The transmitter output was also tested with digital multimeter and with conventional general receivers in the market.

The receiver was subjected to similar test and it was initially used to receive any transmitting FM station example 91.2 crystal FM Minna

After all components and connections on the bread board was tested and functioning satisfactorily, the stages in both transmitter and receiver were transferred and soldered onto the Vero board using a soldering iron and soldering lead.

A lot of care was taken when soldering the IC so as to avoid damage to it due to overheating. The soldering iron and lead should be supplied to the desired pin within a short contact period. After successfully building the individual units they were linked using flexible wires running between terminals on the final routine check was carried out carefully to ensure no errors had been made during construction.

The system was then run and its functionality tested.

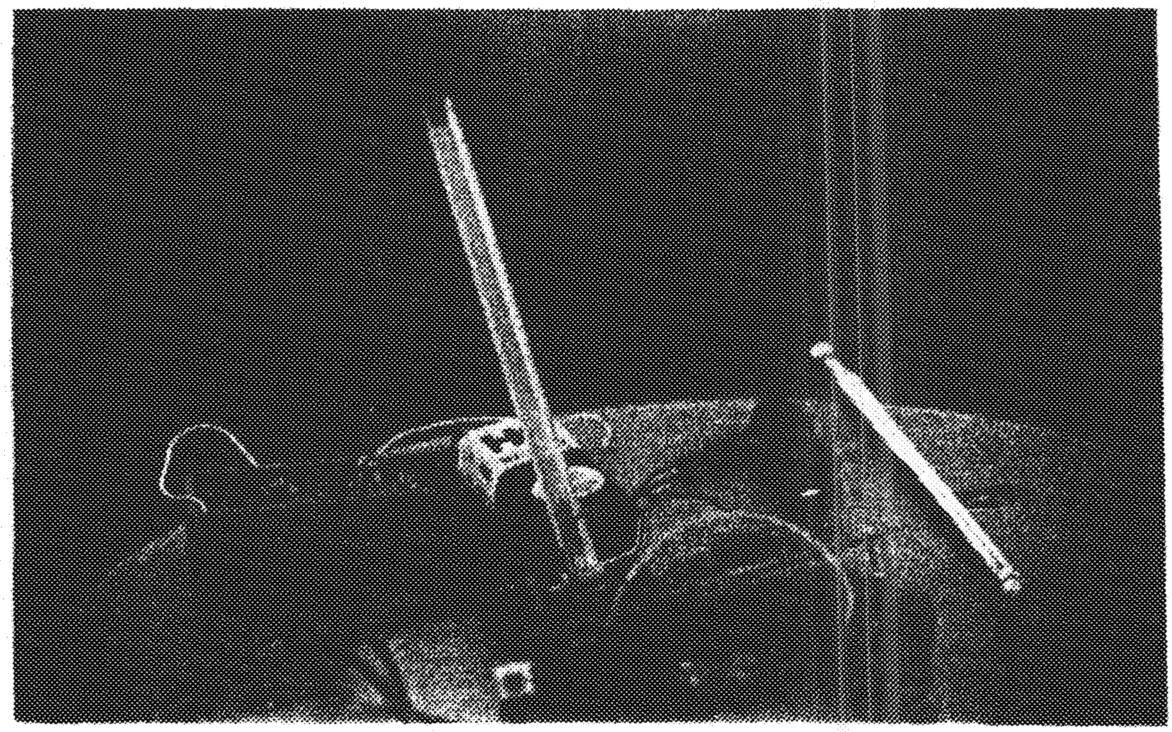

FIG 3.1 INTERNAL PICTORIAL DIAGRAM OF TRACKING SYSTEM ON VERO BOARD

SAFETY PRECAUTIONS

1. The device was not exposed to rain, moisture or humidity
2. The device was always switched off when not in use
3. The specified battery sizes were used.

2.3 COMPONENT LIST

2.3.1 TRANSMITTER SECTION (Reference Appendix 1)

R_1 ---- 10kΩ resistor

R_2 ---- 1kΩ resistor

R_3 ---- 33kΩ resistor

R_4 ---- 100kΩ resistor

C_1 ---- 0.01μf capacitor

C_2 ---- 2 – 5pf capacitor

C_3 ---- 0.01μf capacitor

C_4 ---- 69μf capacitor

C_5 ---- 0.001μf capacitor

C_6 ---- 0.01μf capacitor

C_7 ---- 220μf, 10V capacitor

Q_1 ---- Transistor, NPN silicon (2SC1675)

ICs – 4060B

2.3.2 RECEIVER SECTION (Reference Appendix 2)

R_1 ---- 50kΩ resistor

R_2 ---- 4.7kΩ resistor

R_3 ---- 100kΩ resistor

R_4 ---- 33kΩ resistor

R_5 ---- 470kΩ resistor

R_6 ---- 1kΩ resistor

R_7 ---- 1kΩ resistor

C_1 ---- 30pf capacitor

C_2 ---- 330μf, 16V capacitor

C_3 ---- 0.01μf capacitor

C_4 ---- 47μf capacitor

C_5 ---- 15pf capacitor

C_6 ---- 0.001μf capacitor

C_7 ---- 0.01μf capacitor

C_8 ---- 100μf, 16V capacitor

C_9 ---- 0.01μf capacitor

C_{10} ---- 100μf, 16V capacitor

C_{11} ---- 30pf capacitor

C_{12} ---- 0.001μf capacitor

L1 = 4T open air

L2 = 2T open air

4060B pll

KA 2297 Rf Oscillator

10.7 MHz ceramic

CASING

After construction was completed and the workability of the transceiver ascertained, the circuitry board was cased using wooden materials as a box. This was due to its cost effectiveness.

Portability and easy handling was considered during case design. Testing in the box gave a satisfactorily result. The casing is shown below

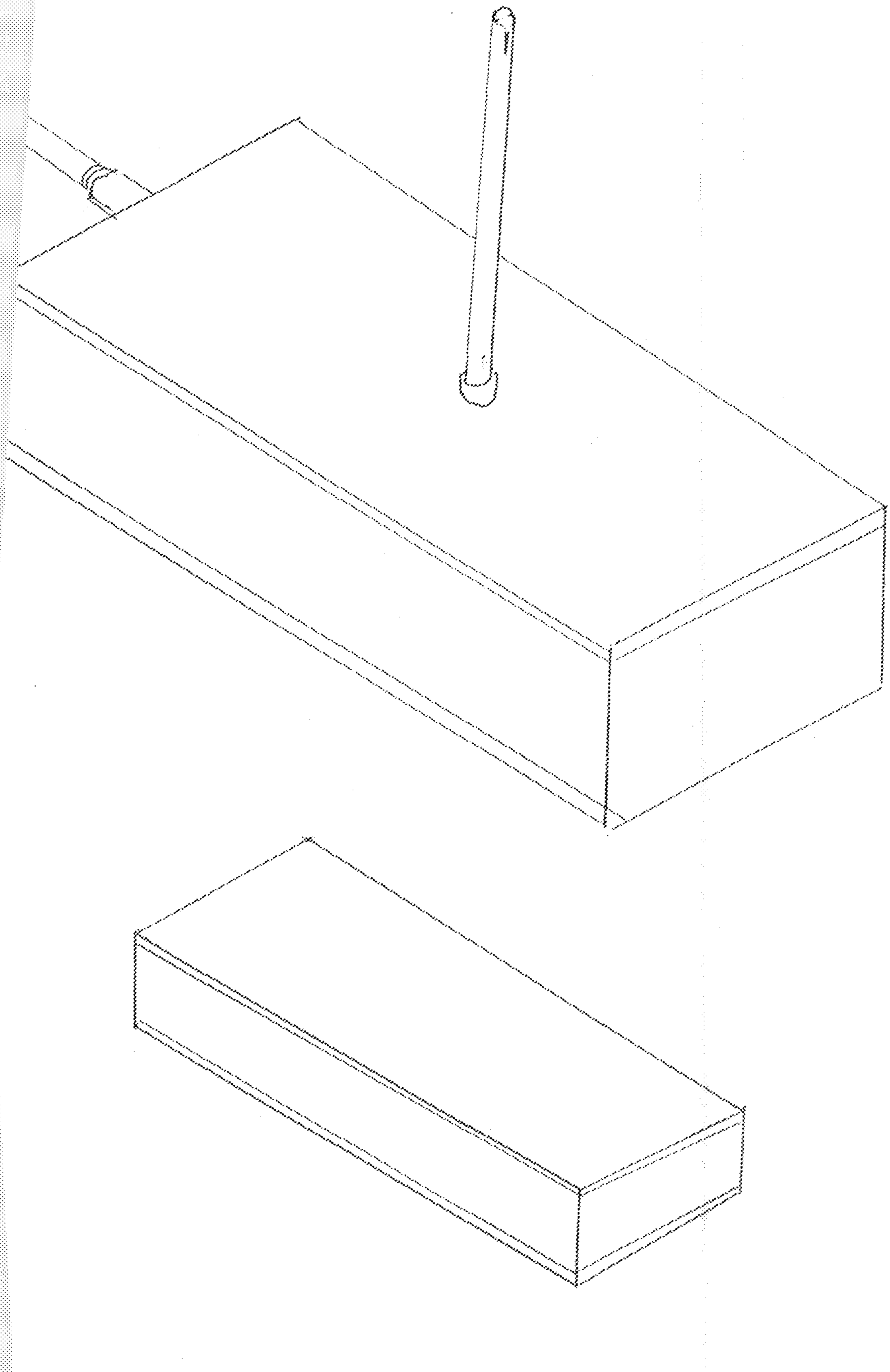

FIG. 3.2 SCHEMATIC DIAGRAM OF CASINGS FOR TRACKING SYSTEM

RESULTS AND DISCUSSION

The design and construction of an FM tracking device was completed with the test result being fairly adequate.

The result of the project showed that the radio signals are received when the oscillations in the receiver coil equal that of the incoming signals. The oscillation of the radio circuit is achieved by the use of variable capacitor, which changes the circuit´s frequency until resonance occurs. Radio stations were received and the receptions were observed to be clearer in cases where the antenna was extended higher above, and the sensitivity appears to be more clear when it is cooler, thus suggesting radio waves travel better through cool air, where the air is more condensed and closely packed

The research and construction work also showed that the strength of radio signals transmitted depends on the total area of the antenna provided the radius does not extend beyond the wave length of the wave and the reception quality appears very poor when the antenna is touched and to this it becomes advisable to keep some distance away from the gadget when system is in use.

CHAPTER FOUR

4.1 RECOMMENDATION AND CONCLUSION

My recommendations in relation to this project are as follows:-

i. Application of this write up is highly recommended to anyone who wishes to carry out tests or repairs on a device of this nature.

ii. Providing more amplifier stage at output can modify the FM transmitter, thereby making the output sound to be louder.

iii. Interested researchers, the Federal Government, private corporate bodies can modify the design and construction of this project to produce devices more ingenious, workable and efficient for future use.

iv. The inclusion of a project each semester / year as part of the course prerequisites for the award of a B.Eng certificate.

4.2 PROBLEMS ENCOUNTERED

The problems encountered included the following:

1. Scarcity of some components used which necessitated travelling to places where they were available
2. Replacement of burnt components
3. Unavailability of power supply.

CONCLUSION

The aim and objective of the project, which was to design an FM tracking device, was achieved with available equipment and components. Effective communication can be achieved while transmitting from the constructed transmitter to the receiver enabling the tracking of the source.

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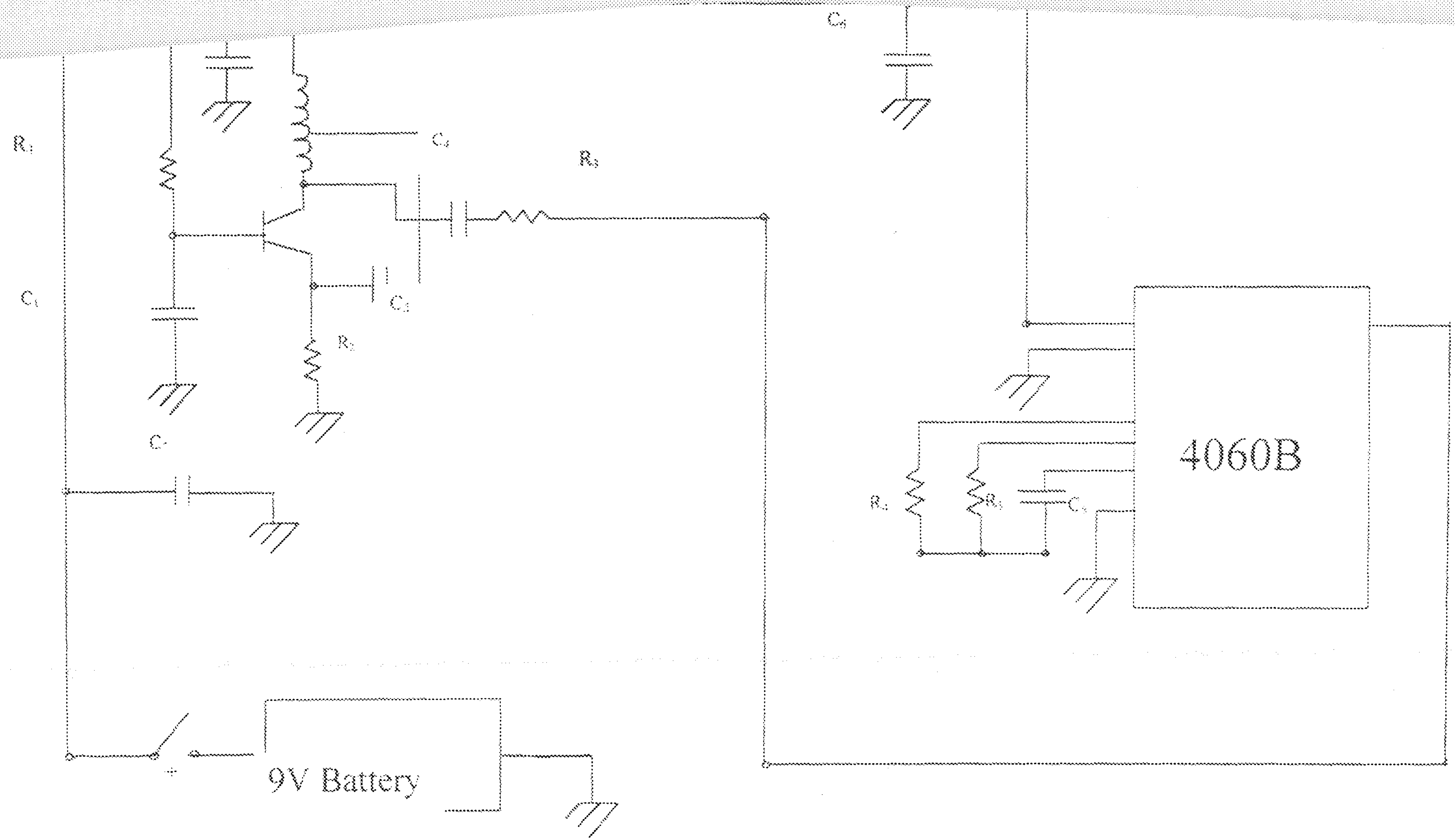
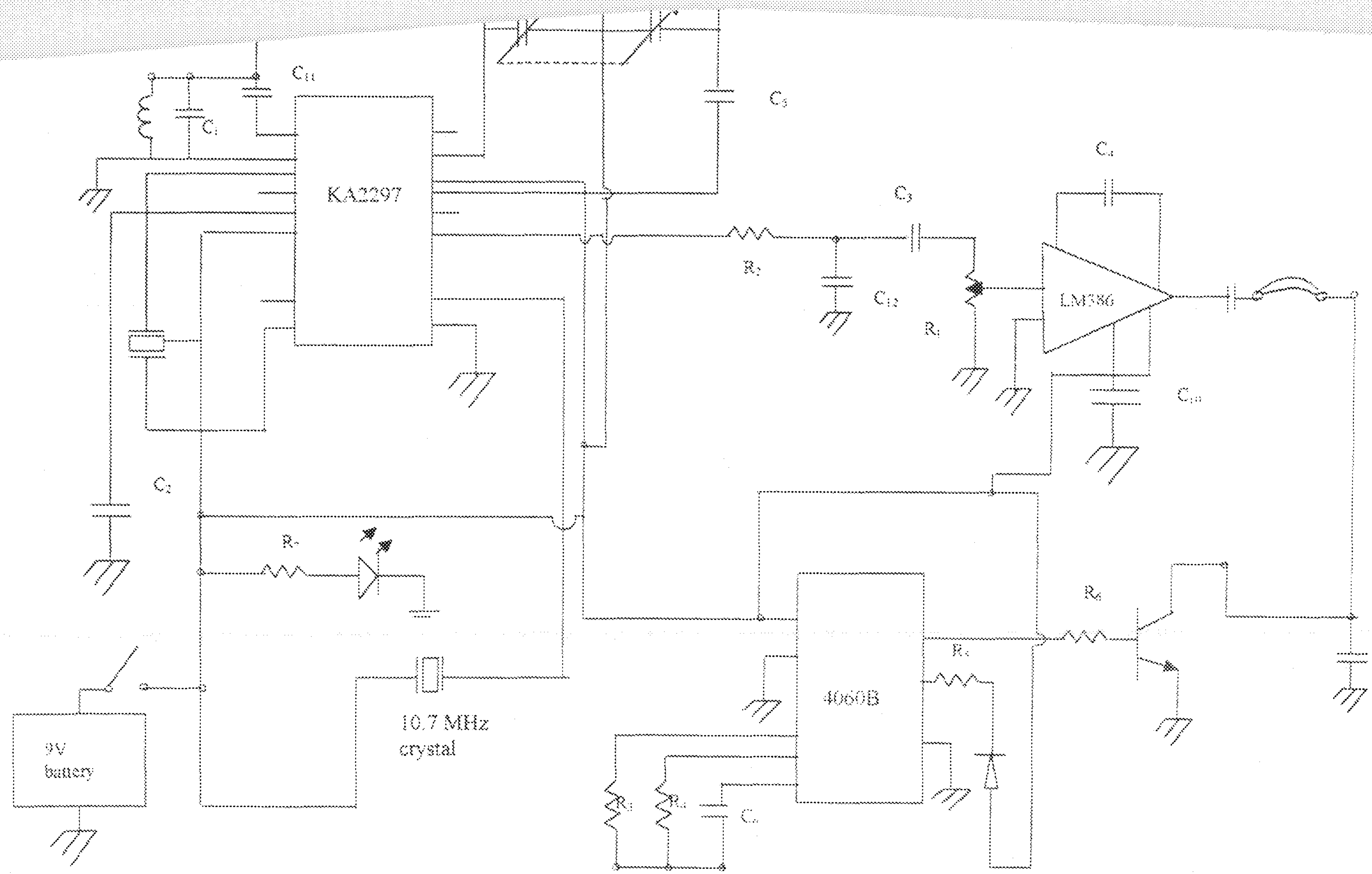
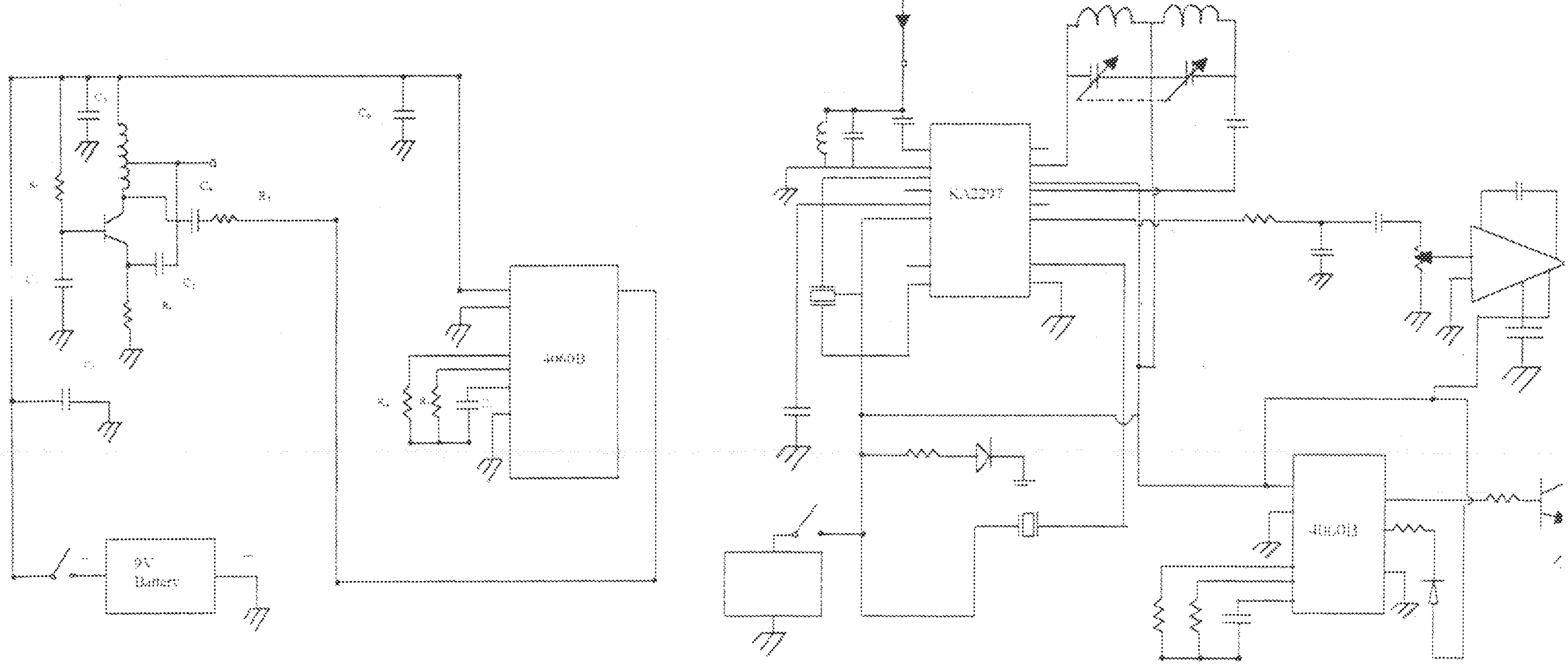


COMPLETE CIRCUIT DIAGRAM OF THE FM TRANSMITTER



COMPLETE CIRCUIT DIAGRAM OF THE FM TRACKING RECEIVER

APPENDIX 3



COMPLETE CIRCUIT DIAGRAM OF FM TRACKING SYSTEM