DESIGN OF AN FM BUGGER CIRCIUT

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BY

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DECLARATION

This declaration is made on the 16th day of January 2016.

Student's declaration:

We Yahaya Ahmad H., Nzanzu Syayighosola Oscar hereby declare that the work entitled design of an fm bugger circuit is our original work. We have not copied from any other sources except where due reference or acknowledgment is made explicitly in the text, nor has any part been written for us by another person.

Nzanzu Syayighosola

Signature……………………….. Date………………………

Yahaya Ahmad H.

Signature……………………….. Date………………………

APPROVAL

It is certified that the work contained in the project titled "DESIGN OF AN FM BUGGER CIRCUIT" by Nzanzu Syayighosola Oscar BSTC/37523/122/DU, Yahaya Ahmad H. BSTC/37383/122/DF has been carried out in under my supervision and that this work has not been submitted elsewhere for a final year project.

Project Supervisor

Associate Prof. JANG CHOL U

Signature……………………….. Date…………………………

DEDICATION

This project is dedicated to the families of Engr. Hamza Yahaya Marke and Dr. Tsongo Kisokero Oscar and to our fellow students.

ACKNOWLEDGEMENT

We would like to express our gratitude to God for his guidance, care and support he has given us throughout the period of study.

It is a pleasure to express thanks to Associate Prof. Jang Chol U for the encouragement and guidance throughout the course of this project.

We thank our families, who gave us much care towards our life and base educational career.

We feel great pleasure to acknowledge all those involved in the process of our education and research.

ABSTRACT

FM bugger is a device which generates frequency modulated signal. It is one element of a radio system which, with the aid of an antenna, propagates an electromagnetic signal. Standard FM broadcasts are based in the 88 - 108 MHz range.

The signal (from the microphone) is fed into the audio frequency (AF) for amplification then to the modulator which combines the modulating signal with the carrier wave transports the modulated signal through (RF) for final amplification to the antenna.

Fm receivers can be operated in the very high frequency bands at which AM interference is frequently severe, commercial FM radio stations are assigned frequencies between 88 and 108 MHz and is the intended frequency range of transmission.

The FM bugger is a device which gives the information of one person to another in the remote location. Normally bugger is used for finding out the status of the person like where he is going, what he is talking etc. This FM bugger circuit is kept in a place where there is need of listening to a conversation. You can listen to this conversation using the normal FM radio set but a receiver circuit is designed for this project.

The project enhances one's practical skill and it involves both the electronics and telecommunication engineering fields. Theoretical knowledge such as circuit theory, electronic circuit and principles of telecommunication learned through several courses offered by the electrical and telecommunication program is applied in the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AF	Audio Frequency
AM	Amplitude Modulation
AMRAD	American Radio and Research Company
DC	Direct Current
FCC	Federal Communication Commission
FM	Frequency Modulation
IEEE	Institute of Electrical and Electronics Engineering
KGB	Komitet Gosudarstvennoĭ Bezopasnosti "Committee of State Security"
RF	Radio Frequency
RIPA	Regulation of Investigatory Powers Act
SHF	Super High Frequency
UHF	Ultra High Frequency
VHF	Very High Frequency

CHAPTER ONE

1.0 Introduction

This chapter provides an overview of the project by giving description of the problem. Chapter one discusses about the background of the project, problem description, aims and objective and project limitations.

1.1 Background

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 crisis come into play for the same information propagation to be transmitted from one point to another with the aid of radio communication which necessities the application of radio transmitter and receiver.

An FM bug is a device whose major function is to send information (intelligence) from one point to another in most cases the information to be transmitted are voice, music and code signals. In this project frequency modulation (FM) is used because it transmits radio signal which is less distorted than other wave bands like amplitude modulation and short wave band. The frequency on the tuning dial ranges from 88MH_Z to 108MH_z.

According to the Institute of Electrical and Electronics Engineering (IEEE) laws, the FM bug is a "free-use" device without license. The law is important since the usage of the device could invade privacy by retrieving other people's voices. There was then the need to protect the rights of users who were not authorities (European Academic Research, 2013).

This bugger is a device which gives the information of one person to another in the remote location. Normally bugger is used for finding out the status of the person like where he is going, what he is talking etc. This FM bugger circuit is kept in a place where there is need of listening to a conversation.

1.2 Statement of the Problem

Due to the high risking of lives, FM bugger circuit will be used to replace human spy for their protection. This circuit can be used at any place to transmit audio signals using FM transmission, especially at institutions and organizations.

1.3 Objective

The aim of this project is to design an FM bugger circuit for short distance communication which is capable of transmitting any audio signal from any audio source within the range of 50 meters to a location also capable of accepting the audio signals simultaneously and understand the concept of wireless telecommunication.

1.3.1 The Specific Objectives

- To design a transmitter circuit.
- To design a receiver circuit.
- To help prevent crimes.
- To replace the cable/wire with a wireless system.

1.4 Significance of the Project

The project signifies a lot in the electronic communication system which telecommunication is the vital aspect. The frequency modulation transmitter is applied in a lot of instance; frequency modulation is unavoidable used in FM radio stations scattered all over the country whose advantage is paramount compared to its counterpart AM frequency.

Realizing the importance of this project, this device is reliable in terms of transmitted information compared to human nature.

1.5 Scope of Work

This project is limited to the designing of an FM bugger circuit for educational perspective, utilizing basic discrete components.
It is intended to be received within a distance of 50 meters and a 9v DC battery is used to make it a very portable.

The bug would not be able to transmit to longer distances. This is because of the detective qualities and sensitivity which limits its distance. The limited reach is caused by transmission capabilities of the antenna and the amount of power supply to the FM bug. The range of the FM bug is 50 meters. Anything beyond the range will not be transmitted clearly and will be quite noisy. This is as a result of distortions caused by obstacles. An open field that is beyond 50 meters will still be transmitted effectively because there will be no obstacles such as trees, buildings and bad weather. Hence a circuit switch is included in the design to preserve energy during its idle time.

CHAPTER TWO
LITERATURE REVIEW

2.1 Basic history of FM radio transmitter

The first primitive radio transmitters (called Hertzian oscillators) were built by German physicist Heinrich Hertzian 1887 during his pioneering investigations of radio waves. These generated radio waves by a high voltage spark between two conductors. These spark-gap transmitters were used during the first three decades of radio (1887-1917), called the wireless telegraphy era. Short-lived competing techniques came into use after the turn of the century, such as the Alexanderson alternator and Poulsen Arc transmitters. But 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). This made possible commercial radio broadcasting, 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 UHF and microwave ranges, using new devices such as the magnetron and travelling wave tube. In recent years, the need to conserve crowded radio spectrum bandwidth has driven the development of new types of transmitters such as spread spectrum(European Academic Research, 2013).

2.2 Frequency Modulation (FM)

Frequency Modulation (FM) is the method of varying a carrier wave's frequency proportionally to the frequency of another signal, in our case the human voice. This compares to the other most common transmission method, Amplitude Modulation (AM). AM broadcasts vary the amplitude of the carrier wave according to an input signal. Standard FM broadcasts are based in the 88 - 108 MHz range; otherwise known as the RF or Radio Frequency range.

However, they can be in any range, as long as a receiver has been tuned to demodulate them. Thus the RF carrier wave and the input signal can't do much by themselves they must be modulated.

An FM bug is a device which generates frequency modulated signal. It is one element of a radio system which, with the aid of an antenna, propagates an electromagnetic signal. Some of its applications include:

- Non-commercial broadcasting
- Commercial broadcasting
- Television audio
- Public Service communications
- Radio Service Communications
- Point-to-point microwave links used by telecommunications companies.

FM transmitters work on the principle of frequency modulation which compares to the other most common transmission method, Amplitude Modulation (AM). That is the basis of a transmitter.

2.3 Invention of radio

James Clerk Maxwell showed mathematically that electromagnetic waves could propagate through free space. Heinrich Rudolf Hertz and many others demonstrated radio wave propagation on a laboratory scale. Nikola Tesla experimentally demonstrated the transmission and radiation of radio frequency energy in 1892 and 1893 proposing that it might be used for the telecommunication of information. The Tesla method was described in New York in 1897. In 1897, Tesla applied for two key United States radio patents, US 645576, first radio system patent, and US 649621.Tesla also used sensitive electromagnetic receivers that were unlike the less responsive coherers later used by Marconi and other early experimenters. Shortly thereafter, he began to develop wireless remote control devices. In 1895, Marconi built a wireless system capable of transmitting signals at long distances (1.5 mi. / 2.4 km).

From Marconi's experiments, the phenomenon that transmission range is proportional to the square of antenna height is known as "Marconi's law". This formula represents a physical law that radio devices use. The term wireless telegraphy is a historical term used today to apply to early radio telegraph communications techniques and practices, particularly those used during the first three decades of radio (1887 to 1920) before the term radio came into use. Guglielmo Marconi demonstrated application of radio in commercial, military and marine communications and started a company for the development and propagation of radio communication services and equipment. The field of radio development attracted many researchers, and bitter arguments over the true "inventor of radio" persist to this day (Ahmed, Menbere, and Yewlsew,June 2012).

2.4 Turn of the 19th to 20th century

Around the turn of the 19th to 20th century, the system was developed by Adolf Slaby and Georg von Arco. In 1900, Reginald Fessenden made a weak transmission of voice over the airwaves. In 1901, Marconi conducted the first successful transatlantic experimental radio communications. In 1904, The Office reversed its decision, awarding Marconi a patent for the invention of radio, possibly influenced by Marconi's financial backers in the States, who included Thomas Edison and Andrew Carnegie. This also allowed the U.S. government (among others) to avoid having to pay the royalties that were being claimed by Tesla for use of his patents.

In 1907, Marconi established the first commercial transatlantic radio communications service, between Clifden, Ireland and Glace Bay, Newfound land. Donald Manson working as an employee of the Marconi Company (England, 1906).Julio Cervera Baviera developed radio in Spain around 1902. Cervera Baviera obtained patents in England, Germany, Belgium, and Spain. In May– June 1899, Cervera had, with the blessing of the Spanish Army, visited Marconi's radiotelegraphic installations on the Channel, and worked to develop his own system. He began collaborating with Marconi on resolving the problem of a wireless communication system, obtaining some patents by the end of 1899. Cervera, who had worked with Marconi and his assistant George Kempin 1899, resolved the difficulties of wireless telegraph and obtained his first patents prior to the end of that year. On March 22, 1902, Cervera founded the Spanish Wireless Telegraph and Telephone Corporation and brought to his corporation the patents he had obtained in Spain, Belgium, Germany and England.

He established the second and third regular radiotelegraph service in the history of the world in 1901 and 1902 by maintaining regular transmissions between Tarifa and

Ceuta for three consecutive months, and between Javea (Cabo de la Nao) and Ibiza (Cabo Pelado). This is after Marconi established the radiotelegraphic service between the Isle of Wight and Bournemouth in 1898. In 1906, Domenico Mazzotto wrote: "In Spain the Minister has applied the system perfected by the commander of military engineering, Julio Cervera Baviera (English patent No. 20084 (1899))."Cervera thus achieved some success in this field, but his radiotelegraphic activities ceased suddenly, the reasons for which are unclear to this day. Using various patents the company called British was established in 1897 and began communication between coast and ships at sea. This company along with its subsidiary American Marconi, had a stranglehold on ship to shore communication. It operated much the way American Telephone and Telegraph operated until 1983, owning all of its equipment and refusing to communicate with non-Marconi equipped ships. Many inventions improved the quality of radio, and amateurs experimented with uses of radio, thus the first seeds of broadcasting were planted.

In April 1909 Charles David Herrold, an electronics instructor in San Jose, California constructed a broadcasting station. It used spark gap technology, but modulated the carrier frequency with the human voice, and later music. The station "San Jose Calling" (there were no call letters), continued to eventually become today's KCBS in San Francisco. Herrold, the son of a Santa Clara Valley farmer, coined the terms "narrowcasting" and "broadcasting", respectively to identify transmissions destined for a single receiver such as that on board a ship, and those transmissions destined for a general audience. (The term "broadcasting" had been used in farming to define the tossing of seed in all directions.) Charles Herrold did not claim to be the first to transmit the human voice, but he claimed to be the first to conduct "broadcasting". To help the radio signal to spread in all directions, he designed some omnidirectional antennas, which he mounted on the roof tops of various buildings in San Jose. Herrold also claims to be the first broadcaster to accept advertising (he exchanged publicity for a local record store for records to play on his station), though this dubious honour usually is foisted on WEAF (1922).

On March 8, 1916 Harold Power with his radio company American Radio and Research Company (AMRAD), broadcast the first continuous broadcast in the world from Tufts

University under the call sign 1XE (it lasted 3 hours). The company later became the first to broadcast on a daily schedule, and the first to broadcast radio dance programs, university professor lectures, the weather, and bedtime stories.

Inventor Edwin Howard Armstrong is credited with developing many of the features of radio as it is known today. Armstrong patented three important inventions that made today's radio possible. Regeneration, the super heterodyne circuit and wide-band frequency modulation or FM. Regeneration or the use of positive feedback greatly increased the amplitude of received radio signals to the point where they could be heard without headphones. The super-heterodyne simplified radio receivers by doing away with the need for several tuning controls. It made radios more sensitive and selective as well. FM gave listeners a static-free experience with better sound quality and fidelity than AM.

In the mid-30s, Major 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's still considered the most prolific inventor in radio's history. Even though he had improved AM radio in significant ways, Armstrong was well aware of AM radio's major limitations: static interference from household appliances and lighting limited audio quality (frequency response and dynamic range) nighttime interference between many stations (co-channel interference), because of ionospheric refraction. Armstrong's new approach to encoding audio for transmission eliminated these problems. Armstrong took his invention to a friend, David Sarnof, who was head of RCA and who said he would help him develop it. RCA bought into the patents and helped Armstrong develop an experimental radio station. But, then it became evident that Sarnof and RCA were out to protect their existing AM radio empire and they didn't want the competition from a new (although much better) form of radio. Years of costly legal battles ensued that RCA could afford and Armstrong couldn't. Strongly believing in his invention, Armstrong started to develop FM radio on his own. He sold rights to manufacture FM radios to several companies. By 1941, 50 FM stations were on the air. Then the Japanese bombed Pearl Harbor. The ensuing war diverted resources and froze development. David Sarnof and RCA, still out to hold control of their radio empire, pressured the FCC to change all of the FM radio frequencies a move they knew would instantly obsolete all of the exiting FM radios, and cause Armstrong to lose his personal investment in FM radio. Listeners were understandably upset at having their radios suddenly rendered useless. And having been "burned once," they were reluctant to immediately go out and buy new FM radios (Louis, 2008).

On January 31, 1954, Edwin Armstrong, gave up his long, taxing battle against Sarnof and RCA. He wrote a note to his wife apologizing for what he was about to do, removed the air conditioner from his 13th story New York apartment, and jumped to his death. A few weeks later RCA announced record profits. Armstrong never lived to see the great success of his invention. Nor will we know what other inventions this genius of electronics might have contributed if his personal and financial resources hadn't been devastated by years of legal battles.

Examples of use:

- Embassies and other diplomatic posts are often the targets of bugging operations.
    - Extensive bugging of the West German embassy in Moscow by the KGB was discovered by German engineer Horst Schwirkmann, leading to an attack on Schwirkmann in 1964.
    - The Great Seal bug was hidden in a copy of the Great Seal of the United States, presented by the Soviet Union to the United States ambassador in Moscow in 1946 and only discovered in 1952. The bug was unusual in that it had no power source or transmitter, making it much harder to detect, it was a new type of device, called a passive resonant cavity bug. The cavity had a metallic diaphragm that moved in unison with sound waves from a conversation in the room. When illuminated by a radio beam from a remote location, the cavity would return a frequency modulated signal.
    - The United States Embassy in Moscow was bugged during its construction in the 1970s by Soviet agents posing as laborers. When discovered in the early 1980s, it was found that even the concrete

columns were so riddled with bugs that the building eventually had to be torn down and replaced with a new one, built with U.S. materials and labor. For a time, until the new building was completed, embassy workers had to communicate in conference rooms in writing, using children's "Mystic Writing Tablets".

- In 2003, Alastair Campbell (who was Director of Communications and Strategy from 1997-2003 for the UK PM) in his memoirs The Blair Years: The Alastair Campbell Diaries alleged that two bugs were discovered in the hotel room meant for visiting British PM Tony Blair planted by Indian intelligence agencies. The alleged bug discovery was at a hotel during PM Tony Blair's official visit to New Delhi in 2001. Security services supposedly informed him that the bugs could not be removed without drilling the wall and therefore he changed to another room.
- In 2004, a bug was found in a meeting room at the United Nations offices in Geneva.
- In 2008 it was reported that an electric samovar presented to Elizabeth II in about 1968 by a Soviet aerobatic team was removed from Balmoral Castle as a security precaution amid fears that its wiring could contain a listening device (Fitzgerald, 2007).

2.5 Listening devices and the law

The use of listening devices is permitted under the law providing that they are used in compliance with Data Protection and Human Rights laws. If a government body or organisation intends to use listening or recording devices they must follow the laws put in place by the Regulation of Investigatory Powers Act (RIPA). It is usually permitted to record audio covertly in a public setting or one's own home, providing one is not doing so to collect confidential information, and of course it is illegal to do so for unlawful purposes. Members of the public using listening devices should check with a legal expert before doing so.

2.5.1 Legal use of listening and recording devices

It is legal to use listening or recording devices in private areas such as an office, business area, or in one's own home. Many people use listening devices to record evidence or even just to take notes for their own reference.

2.5.2 Illegal use of listening and recording devices

It is illegal to use listening devices on certain Military band and Air Band UHF and FM frequencies people. In the past, who have not followed this law have been fined over £10,000. This is because the use of a radio transmission bug that transmits on restricted frequencies contravenes the Telecommunications Act and is illegal. It is also against the law to place a listening or recording device in someone else's home. Due to privacy and human rights laws, using a listening or recording device to intrude on the reasonable expectation of privacy of an individual is highly illegal, i.e. placing gadgets in someone's home or car to which one does not have permitted access.

2.6 Description of components

2.6.1 Microphone

The type of microphone used is the 'Dynamic microphone'. It is made up of carbon and a semiconductor material such as silicon. The surface of the microphone is covered with a very thin dielectric diaphragm. We refer to this microphone as a current control microphone. This is because the sensitivity depends on the amount of current flowing through the terminals. The terminals are (-) negative and (+) positive polarities. The positive terminal is connected to R1 and C1. This shows that the positive end is the main terminal. Meanwhile, the negative terminal is always connected to the ground plane of the supply voltage. Since the bug is a small device and should be concealed there is a need to use a small type of microphone.

The function of the microphone is to pick up sound or audio waves via its openings (diaphragm), which is converted into electrical energy and back to sound energy or audio signals(European Academic Research, 2013).

2.6.2 Transistors

Basically, the transistors used for the FM bug are Bipolar Junction Transistors (BJTs) and a type of the BJT which is NPN transistors.

The 2N2222A is a medium gain, general-purpose transistor purposely for signal generation, audio amplifiers applications and low power consumptions. Usually the frequency transmitted is about 250MHz and has a gain of 330. The dc gain and frequency transmission ensures wide usage (European Academic Research, 2013).

Other features include:

- AF amplification
- Oscillation
- Switching capabilities

2.6.3 FM Oscillator Stage

The next stage is the FM oscillator stage with a capacitor acting as a decoupling capacitor.The amplified microphone signal is injected into the oscillator circuit so as to modify its frequency and subsequently generate a frequency modulated (FM) oscillator. The fact is that every transmitter needs an oscillator to generate RF carrier waves. The coil, the transistor, and the feedback capacitor constitute the oscillator circuit. At this stage an input signal is not needed to sustain the oscillation given that the base-emitter current of the transistor vary at the resonant frequency. This will result in the emitter-collector current varying at the same frequency. Finally the antenna connected to the output of the oscillator picks up this signal and is radiated as radio waves. Its critical nature only means it must not be touched when the transmitter is in operation as this will detune the circuit completely. The oscillator coil is made out of tinned copper wire and does not need any insulation. This is not normal practice but since the coil is small and rigid, the turns are unable to touch each other and short-out.

FM radio stations operate on frequencies between 88 and 108 MHz. The variable capacitor and self-made inductor constitute a parallel LC circuit. It is also called a tank circuit and will vibrate at a resonant frequency, which will be picked up the FM radio.

In tank circuits, the underlying physics is that a capacitor stores electrical energy in the electric field between its plates and an inductor stores energy in the magnetic field induced by the coil winding. The mechanical equivalent is the energy balance in a flywheel; angular momentum (kinetic energy) is balanced by the spring (potential energy). Another example is a pendulum where there's a kinetic versus potential energy balance that dictates the period (or frequency) of oscillations (McSwiggan, April 1998).

2.6.4 Antenna Length

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. Antennas can be vertically or horizontally polarised, which is determined by their relative position with the earth’s surface (i.e. antenna parallel with the ground is horizontally polarised). A transmitting antenna that is horizontally polarised transmits better to a receiving antenna that is also horizontally polarised; this is also true for vertically polarised antennas. The antenna either with a piece of solid strand 22 gauge wire 30 inches long or used a telescopically extendable antenna. Its length should be approximately 1/4 the FM wavelength; recall that multiplying frequency and wavelength equals the speed of light. It’s most probably be operating the transmitter near 108 MHz (McSwiggan, April 1998).

CHAPTER THREE

METHODOLOGY

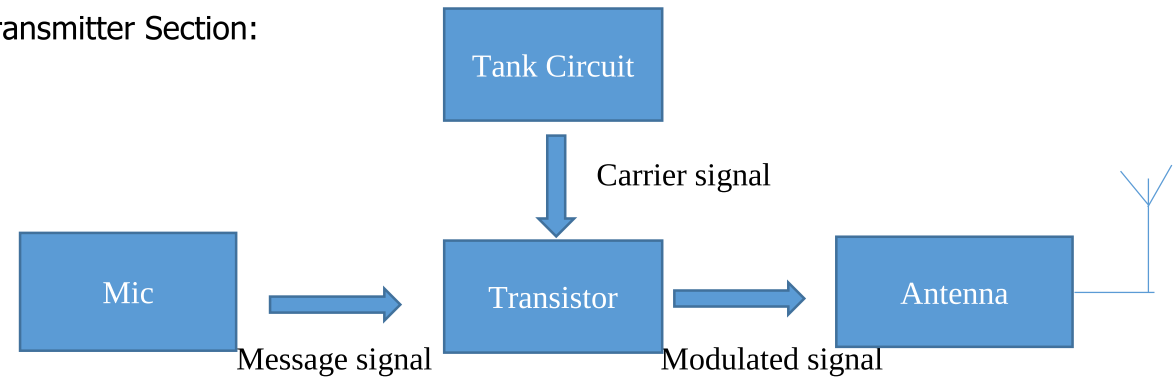
3.1 Introduction

This section briefly explains about the complete device, components that are used and the block diagram. This device operates only using the hardware.

3.2 System Block Diagram

When creating a system for transmitting a frequency modulated wave, a number of building blocks have to be considered, the diagram below gives a very broad impression of the transmitter, receiver and their individual parts.

Transmitter Section:



Receiver Section:

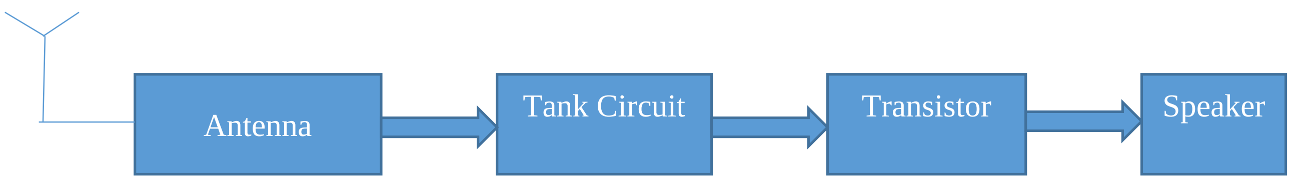


Figure 1: FM Bug Block Diagram

From the block diagram, it is understood that the message signal or conversation signal is modulated with the carrier frequency which is generated by the tank circuit. The message signal and carrier signal is modulated by the transistor and transmit the modulated signal in the air through the antenna. The modulated signal is received by the receiver antenna and gives to the FM radio where the user can listen to the conversation. User should adjust the receiver frequency for receiving the signal from the transmitter.

On the block diagram, the conversation of people is received by the MIC and is modulated to the carrier signal and transmitted. There are different types of analogue modulation in which one type of modulation is amplitude modulation. Another type of modulation is angular modulation in which the frequency modulation and phase modulation will come. For this case FM modulation is used. In FM modulation, frequency of the carrier signal is varied in accordance to the instantaneous amplitude of the modulating signal. Normal FM bug will use this type of modulation to transmit signals; frequency modulation will give high throughput and efficiency when compared to amplitude modulation. MIC is placed in the room in which you want to listen to the conversation of the people and MIC will decode the conversation in to the signal which is given. The tank circuit will produce the carrier signal for the conversation or message signal a transistor will be used to amplify both the signals and send to air through the antenna.

The FM radio receiver will be adjusted to the assigned frequency for listening to the conversation.

3.3 FM Bug Transmitter Circuit Design

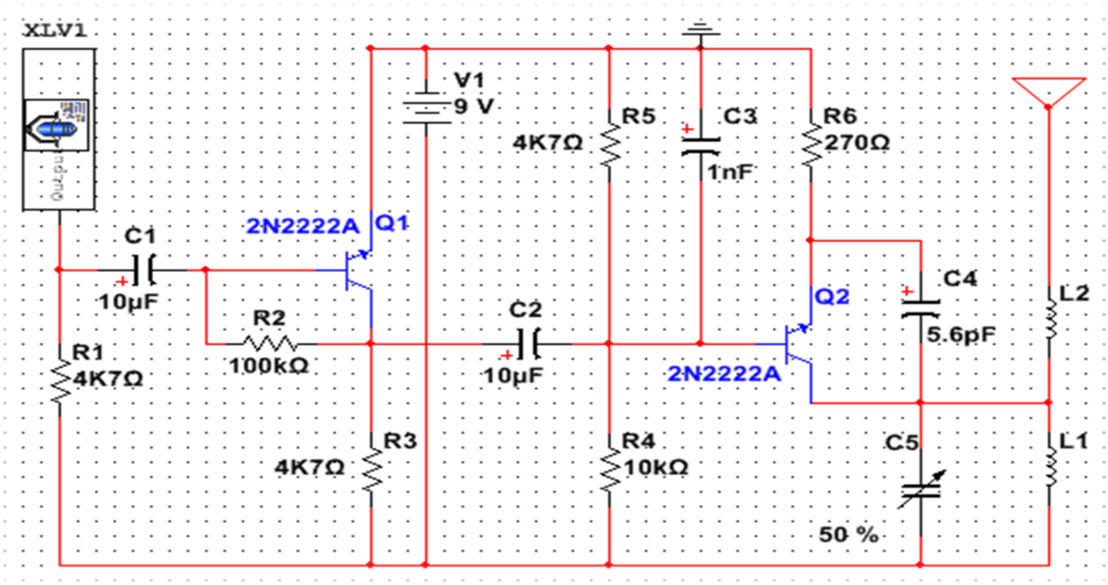


Figure 2: FM Bug Transmitter Circuit Design

The Microphone is placed where you want to listen to the conversation of the people and it will decode the conversation in to the signal which is given to the capacitor C1, where C1 is used for removing the noise and turning the transistor Q1 in on mode to amplify the audio signal.

Audio signal from the microphone has very low level signal, of the order of milli volts. This extremely small voltage needs to be first amplified. A common emitter configuration of a bipolar transistor Q1 is biased to operate in class A region, produces an amplified inverted signal. The basic idea at work for amplifier used in the FM Bug is that the 100kΩ resistor biases the transistor in a way that when the Audio input goes into the base pin of the 2n2222A it is multiplied to be many times larger by the time it hits the Collector point of the transistor.

Another important aspect of this circuit is the oscillator circuit. This is an LC oscillator where energy moves back and forth between the inductor and capacitor forming oscillations. It is mainly used for RF application.

When this oscillator is given a voltage input, the output signal is a mixture of the input signal and the oscillating output signal, producing a modulated signal. In other words, the frequency of the oscillator generated circuit varies with the application of an input signal, producing a frequency modulated signal.

The tank circuit (capacitor C5 and L1, L2) which produce the carrier signal for the conversation or message signal, the transistor Q2 will amplify both the signals and send to air through the antenna.

The capacitor C5 is variable because it can be adjusted to produce a carrier signal. Remember carrier signal should be in range of 88 to 108 MHz so that FM radio receiver set can receive your transmitted signal.

The FM radio receiver set is adjusted to your frequency for listening to the conversation.

3.3.1 FM Bug transmitter principle

FM transmission is done by the process of audio amplification, modulation and then transmission. Here the same formula is adapted by first amplifying the audio signal with the NPN transistor, generating a carrier signal using an oscillator and then modulate the carrier signal with the amplified audio signal. The frequency is set at anywhere between the FM frequency range from 88MHz to 108MHz.

Selection of Vcc:

The NPN Bipolar Junction Transistor, 2N2222 is selected. Since V_{CEO} for this transistor is around 40V, a much lesser Vcc of about 9V is used.

Selection of Load Resistor R3:

The need to calculate the quiescent collector current is vital to get the value of a load resistor. Now, assuming this value to be about 1mA. The collector voltage needs to be about half of Vcc. This gives the value of load resistor, R3 as: Vc/Iq = 4.5KΩ. Now a 4.7KΩ resistor is selected for better operation.

Selection of Microphone Resistor R1:

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. Assuming the current through microphone to be 0.4mA. This gives the value of R1 = (Vcc-Vb)/0.4
The voltage across the base, Vb is assumed to be 0.65V more than the emitter voltage Ve. Assume the emitter voltage to be 70% of Vcc, i.e. 6.3V. This gives Vb to be 7V.
R1= (9 - 7)/0.4= 5KΩ, here a 4.7kΩ resistor is selected.

Selection of Emitter Resistor R6:

The value of R6 is given by Ve/Ie, where Ie is the emitter current and is approximately equal to the collector current.
The bias current is approximated to be 10 times the base current. Now base current, Ib is equal to the collector current divided by the current gain. This gives the value of Ib to be 0.08mA. The bias current is thus 0.8mA.

This gives R6 = (Ve/Ie) = 200ohms but 270ohms is selected.

Selection of Voltage Divider Resistors R4 and R5:

To calculate the value of the voltage divider resistors, the bias current as well the voltage across the resistors are calculated.

Thus, R4 = Vb/I_{bias} = 8.7KΩ but 10KΩ resistor is selected.

R5= (Vcc-Vb/0.4mA) = 5KΩ but 4.7KΩ resistor is selected.

Selection of coupling capacitor C1:

An electrolyte 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) and also bypasses the DC signal. A value of 10uF is selected.

Selection of coupling capacitor C2:

At this stage an electrolyte capacitor of about 10uF is selected as the coupling capacitor using the NI measurement tool.

Selection of Bypass Capacitor C3:

Here an electrolyte capacitor of 1nF, which bypasses the DC signal is selected.

Selection of Tank Capacitor C4:

This capacitor serves the purpose of keeping the tank circuit to vibrate. Since the transistor is NPN 2N2222A, the value of C4 is between 4 to 10 pF. A value of 5.6 pF capacitor is suitable.

Selection of tank circuit components L and C5:

The resonant frequency of oscillations is given by the formulae;

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

Here the frequency required is between 88 MHz to 100 MHz. A value of 0.15μH is suitable for this inductor. This gives value of C5 to be around 18pF. Variable capacitor in the range of 5pF to 30pF also inductor in range of 0μH to 1μH are selected.

With L=0.15μH, C=18pF, and f = 97 MHz

3.4 FM Bug Receiver Circuit Design

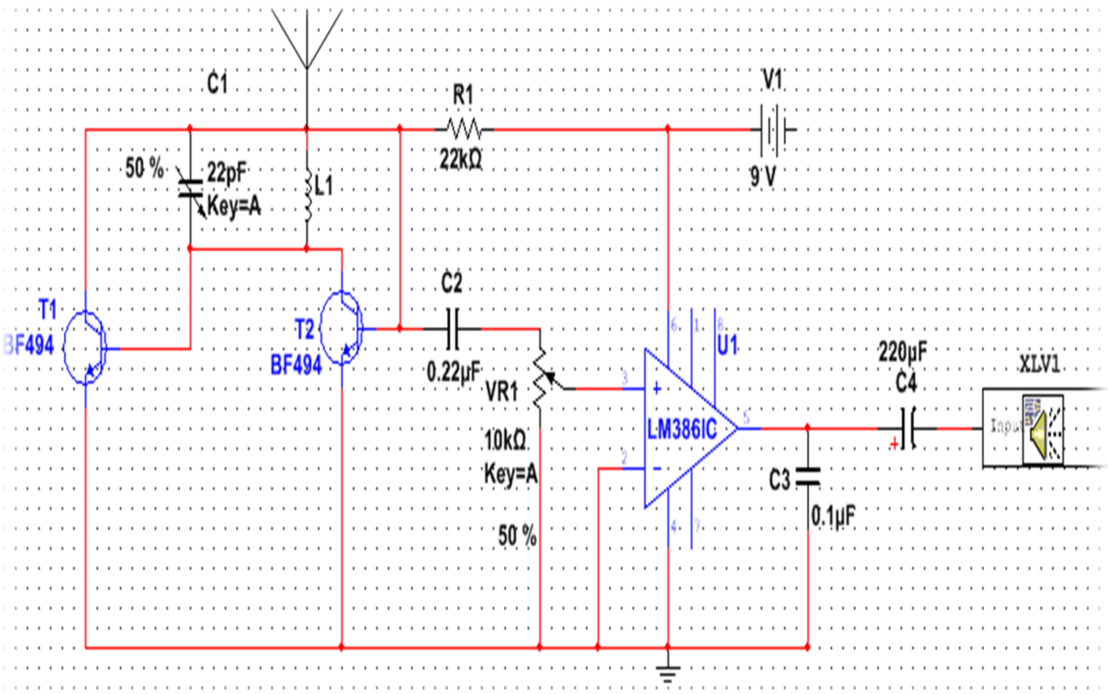


Figure 3: FM Bug Receiver Circuit Design

3.4.1 FM Receiver Circuit Principle:

Receiver is the reception of electromagnetic wave through air. The main principle of this circuit is to tune the circuit to the nearest frequency using the tank circuit. Data to be transmitted is frequency modulated at the transmission and is demodulated at the receiver side. Modulation is nothing but changing the property of the message signal with the respect to the carrier frequency. Frequency range of FM signal is 88MHz to 108MHz. The output can be heard using speaker or headphone, but will not be as loud.

3.4.2 FM Receiver Circuit Design:

The FM Radio circuit mainly consists of LM386 IC. This is a low voltage audio power amplifier. It has 8 pins. It operates at a supply voltage of 4-12 volts. It has an op-amp internally, which acts as an amplifier. The non-inverting pin is connected to the variable resistor of 10K Ohms. Inverting pin of the LM386 IC is connected to the ground. Sixth pin is connected to the VCC. Fourth pin is connected to the ground. Fifth pin is output and is connected to the capacitor which is connected to the speaker or microphone. Another capacitor is connected to ground pin. Sixth pin is the supply pin connected to the supply voltage. This amplifies the incoming frequency modulated signal.

BF494 is an NPN RF transistor. Initially it is open circuited. It starts conducting only when base gets the required cut off voltage. Base of the transistor T2 is connected to the base of the variable resistor through a capacitor of 0.22uF. Emitter pin is connected to the ground. Collector is connected to the tank circuit. Base of transistor T1 is connected to the tank circuit. Emitter pin is connected to the ground and collector is connected to the supply through a resistor of 22K ohms. The variable resistor controls the volume to the input amplifier. These transistors are used for detecting the frequency modulated signals.

Output of the IC is connected to the headphones or Mylar speaker through a capacitor of 220uf rated. The head phone or speaker will have two wires out. One is connected to the output of the capacitor and the other pin is connected to the ground pin.

Tank circuit consists of an inductor coil and a variable capacitor. This is connected to the antenna. This is the main part of the circuit as it tunes the radio to the required local frequency. In this tank circuit coil plays a main role. Coil is a copper wire wind into fixed number of turns.

The FM receiver section has two RF transistors T1 and T2 to detect the Frequency Modulated signals. Coil L1 and the variable capacitor form the tuned tank circuit to tune the receiver to the best FM station with strong signals. The signals are capacitor coupled through C2.

The balance of the inductor at the transmitter circuit of value 0.15μH is here considered to build the tank circuit of the receiver with the inductor requiring 4 turns of air core, 5mm diameter and 3.5mm length of the wire. These are then converted to get its real value to form a tank circuit at the receiver section with a capacitor substituted from the formulae.

$$\boldsymbol{f} = \frac{\mathbf{1}}{(\mathbf{2}\boldsymbol{\pi}\sqrt{\boldsymbol{LC}})}$$

Where; frequency used is in the range stated earlier used is 97MHz,

$$\mathbf{97MHz} = \frac{\mathbf{1}}{(\mathbf{2\pi}\sqrt{\mathbf{LC}})}$$

This value of variable capacitor is in the range of5pF to 30pF where the 22pF is selected for better output.

The inductor coil value will be between 0.1uH to 1uH where 0.12uH is selected. For loudspeaker/headphone reproduction an amplifiers are used. Since in these amplifiers a battery with voltage bigger than 3 V is used. The R1 is counted from the formula.

$$\mathrm{R1} = \frac{\mathrm{Vcc} - 3\mathrm{V}}{0.167}\mathrm{K\Omega}$$

Where Vcc is battery voltage, and 0.167mA is the current through R1, which supplies T1 and T2.

$\mathrm{R1} = \frac{9\mathrm{V}-3\mathrm{V}}{0.167} = 34\mathrm{K\Omega}, \mathrm{but}\ 22\mathrm{K\Omega}\ \mathrm{is\ used}$ after manipulation.

Capacitors C1 and C2 combine together with R1, a pass-filter for very low frequencies, is used to separate the HF and LF parts of the receiver.

CHAPTER FOUR

RESULTS AND DISCUSSION

When testing the transmitter, the oscillator coil is tuned properly so that it transmits at the right frequency. This is done using a plastic aligning stick for the adjustment. The operating frequency of the oscillator is supposed to be very high so every precaution is taken to avoid the use of tools such as a metal screw driver, or even bare fingers which can detune the oscillator. Both the FM transmitter bug and FM bug receiver are switched on with the bug sited at one spot and the FM receiver moved within the maximum specified distance of 50 meter. The receiver is then tuned to the specified frequency 97MHz of the transmitter and a voice message is then received. Instantly the background noise diminished and audible voice message is heard. This was done within a building. To further test the tenacity of the transmitter bug, the receiver is taken out into the open way beyond the 50 meter transmitting range. Under this condition a voice message was still audibly received except it was weaker and weakened further as the distance from the transmitter increased.
So tuning takes a little patience but is not difficult. The reason that there must be at least 10 meters separation between the radio and the FM transmitter is that the FM transmitter emits harmonics; it does not only emit on one frequency but on several different frequencies close to each other. You should have little difficulty in finding the transmitting frequency when you follow this procedure.

One big advantage of the FM bug is the absence of wires. The current that it also draws is in the range 3-12A so that cell could last for months. The most critical part of the entire circuit is the oscillator. Thus it must not be fidgeted with in any way when the transmitter is in operation because this will detune the circuit completely. Since the coil is made of tinned copper, it does not need any form of insulation. For this design, a 4 turns of coil of diameter 5 mm wound on a 3.5 mm length is used. Care is taken to wound the coil in a clock-wise direction for proper orientation and each end of the coil is terminated on the printed circuit board. The distance of transmission will be affected by the prevailing conditions such as in the open or in a building, the type of aerial used such as a single wire as adopted in this project work or a half wave dipole to enhance the range of transmission.

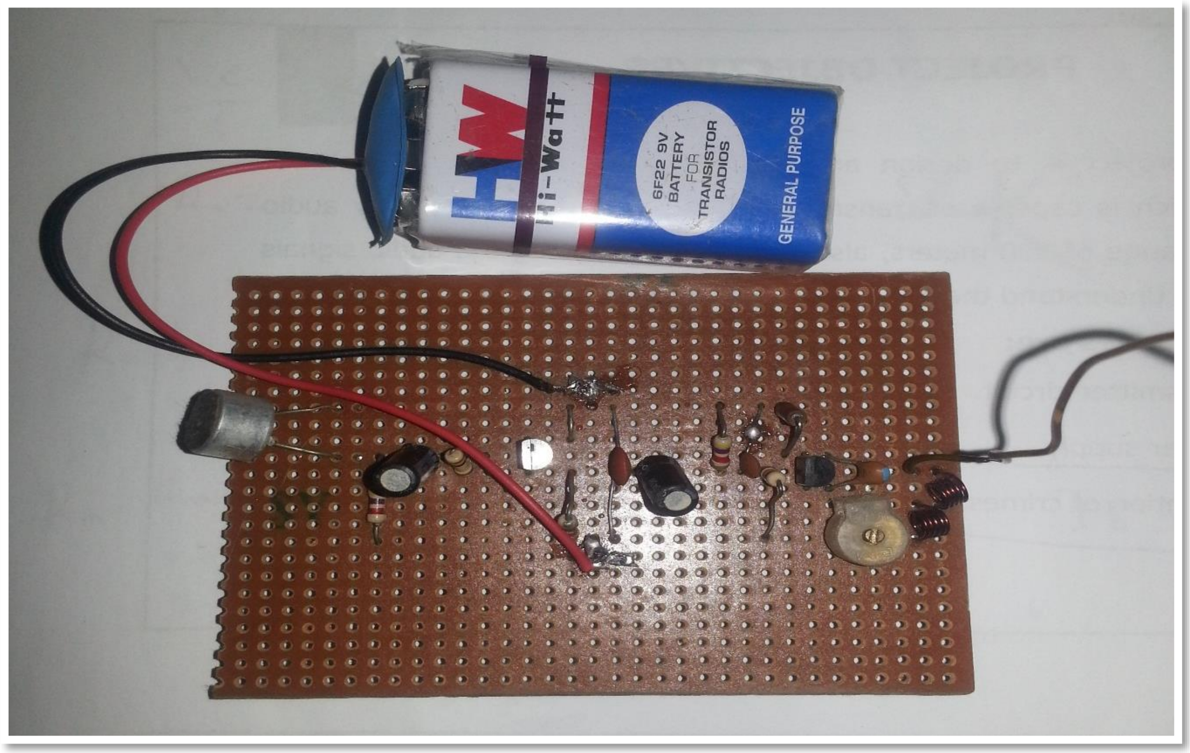


Figure 4: FM Bug Transmitter Circuit Prototype

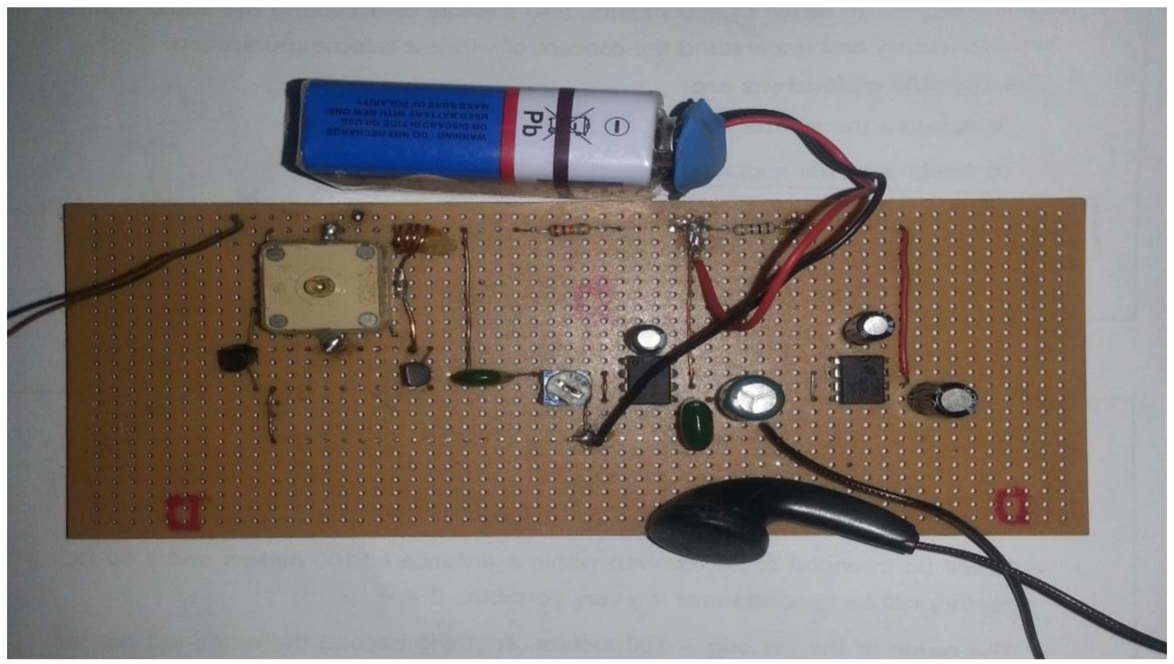


Figure 5: FM Bug Receiver Circuit Prototype

When the receiver is switched on the output will consist of noise. The frequency can now be adjusted using a screw driver. When an FM station is encountered the noise will reduce in volume or disappear altogether. The tuning must be adjusted so that it is just on the edge of the band occupied by the transmitted signal, this requires a little patience, luck, and skill with the screwdriver. Once you have found your favourite station, of course, there is no need to adjust the circuit again.
The sound quality from this simple receiver is admittedly somewhat mediocre, although it is remarkable that it works at all given that only two transistors are used and a better microphone.

To demodulate an FM signal, the tuning must be adjusted so that the centre frequency of the signal is on the edge of the range that will stimulate the oscillator. The whole process can be seen clearly on an oscilloscope.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

In conclusion the FM bug transmitter and receiver circuit with a variable capacitor and inductor coil design was a success. The FM bug transmitter was able to broadcast at frequency 97MHz provided conditions for wireless communication are favourable. Even though much guidance was given from other schematics, it still took some time to complete the final project. Also a better understanding of BJT transistors, amplifiers, resistors, oscillators, capacitors and inductors were developed. In addition, a better understanding of the oscilloscope was also achieved. The mastering of horizontal and vertical position controls to find the output frequency took some patience. In the future, an oscilloscope could be used to find the precise frequency. Also, better components and a higher voltage supply would allow for a larger transmitting distance.

For the most part, all of the parts used in this project are discrete and passive, with the exception of the transistors, which are the only real 'active' part of the circuit. The rest are just resistors, capacitors and inductors.

5.2 Recommendation

For efficient operation, the FM transmitter bug must be packaged in dielectric (insulator) material such as wood, plastic and ceramic to enhance the flow of the electromagnetic wave that is constantly being generated. Metal will be hazardous since electromagnetic waves cannot penetrate through metallic substances.

However, one particular factor that could cause the design to fail would be poor soldering. Thus all solder joints should be meticulously cross-checked under good lighting. Also care should be taken to make sure all the components are in their correct positions on the PCB.

In this project, the reception result is distorted due to lack of some suitable devices such as the microphone, antenna e.t.c.

Therefore, these devices can be improved in further work.

Generally this project has been done well.

5.3 Summary

Basically, communication consists of three major parts. Transmitter, Communication channel, Receiver. Frequency modulation is used for sound broadcasting in the VHF bands for VHF and UHF mobile systems and for wide band UHF and SHF radio relay systems. FM transmitters are used to generate high frequency signal. Microphone is a transducer, which converts sound pressure variations in to electrical signals of the same frequency and of amplitudes in the same proportion as a pressure variation. Oscillators are necessary in any low power transmitter because they generate a necessary RF signal.

The purpose of any communication system is to transmit information signals from a source located at one point to the user/destination located at another point. The aim of this project is to transmit a signal at a certain distance wirelessly which is among the main objective of telecommunication engineering.

REFERENCE

Ahmed, M., Menbere, Shitaw and Yewlsew, Mekonen. (June 2012). *Design and implementation of low power FM transmitter.*

Fitzgerald, Dennis G. (Jan 24, 2007). *Informants and Undercover Investigations: Practical Guide to Law, Policy*. CRC Press, page 204.

Louis, E. F. (2008). *Principles of Electronic Communication Systems*.

McSwiggan, Francis. (April 1998). *Design and build a portable, miniaturized, Multichannel fm transmitter in the University of Limerick Ireland.*

Mpilch family. *FM Listening Bug.*

Stephan, J., and Ron, K. (2003). *Introduction to communication Technology.*

Sedra and Smith. (1997). *Microelectronic Circuits,* (fourth edition). Oxford university press.

Xlander, mel. *Fundamental of reliable circuit design.*

European Academic Research. (November 2013), ISSN: 2286-4822, Vol. I. *FM Transmitter Bug for Baby Monitoring.*

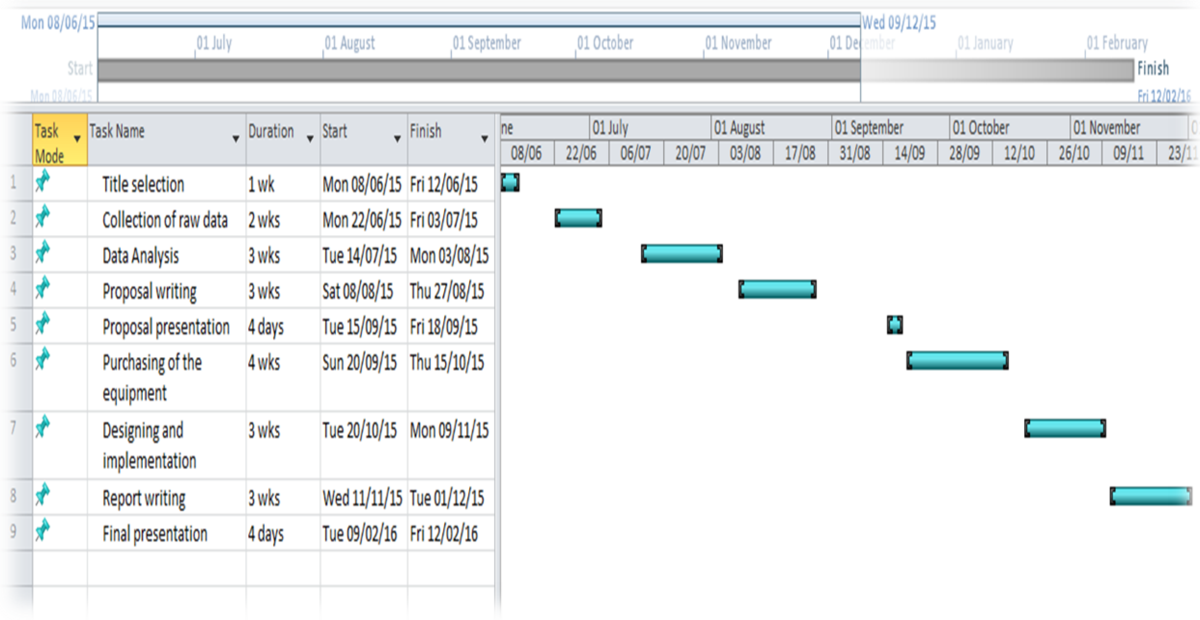
Construction of an FM Transmitter.

Electronics Hub, 2 km FM Transmitter.

Electronics Hub, FM Bugger Circuit.

APPENDIX I: PROJECT SCHEDULE

Table A1: GANTT CHART



	Task Mode	Task Name	Duration	Start	Finish
1		Title selection	1 wk	Mon 08/06/15	Fri 12/06/15
2		Collection of raw data	2 wks	Mon 22/06/15	Fri 03/07/15
3		Data Analysis	3 wks	Tue 14/07/15	Mon 03/08/15
4		Proposal writing	3 wks	Sat 08/08/15	Thu 27/08/15
5		Proposal presentation	4 days	Tue 15/09/15	Fri 18/09/15
6		Purchasing of the equipment	4 wks	Sun 20/09/15	Thu 15/10/15
7		Designing and implementation	3 wks	Tue 20/10/15	Mon 09/11/15
8		Report writing	3 wks	Wed 11/11/15	Tue 01/12/15
9		Final presentation	4 days	Tue 09/02/16	Fri 12/02/16

APPENDIX II: PROJECT MANAGEMENT

Table B2: BUDGET TABLE

Item	Description	Quantity	Unit Price	Amount
1	Resistors	10	500 Ugx	5,000 Ugx
2	Capacitors	10	500 Ugx	5,000 Ugx
3	Transistor 2N2222	3	3,000 Ugx	9,000 Ugx
4	Antenna wire	2	5,000 Ugx	10,000 Ugx
5	Battery 9V	4	4,000 Ugx	16,000 Ugx
6	Microphone	3	5,000 Ugx	15,000 Ugx
7	Jumper wires	2	3,000 Ugx	6,000 Ugx
8	Breadboard	2	15,000 Ugx	30,000 Ugx
9	Switch	2	2,000 Ugx	4,000 Ugx
10	Inductor coil	4	10,000 Ugx	40,000 Ugx
11	BF 499 Transistor	4	5,000 Ugx	20,000 Ugx
12	IC LM386	2	7,000 Ugx	14,000 Ugx
13	Variable Resistor	2	5,000 Ugx	10,000 Ugx
14	Variable Capacitor	3	15,000 Ugx	45,000 Ugx
15	Speaker	2	5,000 Ugx	10,000 Ugx
16	PCB	3	7,000 Ugx	21,000 Ugx
17	Miscellaneous			70,000 Ugx
	TOTAL			333,000 Ugx

APPENDIX III: FM GRAPH

Table C3: OSCILLOSCOPE GRAPH