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Design, Construction and Testing of a Low Energy Digital Frequency Modulation (FM) Transmitter

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Abstract---- A rapidly growing demand for the use of Frequency Modulation (FM) transmitter exists within institutions and individuals. The FM transmitters are however a complex equipment demanding high power supply, high voltage system design, critical maintenance and exorbitant price. These problems of the transmitter constitute major impediments to institutions and individuals that may wish to adopt radio broadcast as means of electronic media. This study was therefore carried out to design and construct an FM transmitter that is of low cost, and simple in maintenance, efficient in use and yet operating on low power supply. The FM transmitter is designed to be received at a range of about 100metres in free air. The transmitter has a capacitor microphone which picks up very weak sound signals, a transistor, resistors, inductor, and capacitors. The design procedure involves the modification of an output of the transmitter. Based on the procedures adopted and the tests carried out, the specific findings include a range of 102.2MHz of transmission from a 9V DC battery. The work indicated that the practical frequency modulated (FM) transmitter requiring a low power can be designed and constructed.

Index Terms----Frequency Modulation, FM Transmitter, Radio Broadcast, Antenna.

1.0 INTRODUCTION

In electronics and telecommunication, a transmitter or radio transmitter is an electronic device which with the aid of an antenna produces radio waves. The transmitter itself generates a radio frequency alternating current which is applied to the antenna. When excited by this alternating current, the antenna radiates radio waves. In addition to their use in broadcasting, transmitter are necessary component parts of many electronic devices that communicate by radio, such as cell phones, wireless computer network, Bluetooth enabled device, garage door openers, two-way radios in aircraft, ships, and spacecraft, radar sets, and navigational beacons. The term transmitter is usually limited to equipment that generates radio waves for communication purposes: or radiolocation, such as radar and navigational transmitters. Generators of radio waves for heating or industrial purposes, such as microwave ovens or diathermy equipment, are not usually called transmitter even though they often have similar circuits.

The term is popularly used more specifically to refer to a broadcast transmitter, a transmitter used in broadcasting, as in FM radio transmitter. This usage usually includes the transmitter proper, the antenna, and often the building it is housed in (Chen, 2002).

A transmitter can be separate piece of electronic equipment, or an electrical circuit within another electronic device. A transmitter and receiver combined in one unit are called a transceiver. The term transmitter is often abbreviated ''XMTR'' or ''TX'' in technical documents. The purpose of most transmitters is radio communication of information over a distance. The information is provided to the transmitter in the form of an electronic signal, such as an audio (sound) signal from a microphone. The transmitter combines the information signal to be carried with the radio frequency signal which generates the radio waves, which is often called the carrier. This process is called modulation. The information can be added to the carrier in several different ways, in different types of transmitter.

1. In a frequency modulation (FM) transmitter, it is added by varying the radio signal's frequency slightly. Many other types of modulation are used.
2. The antenna may be enclosed inside the case or attached to the outside of the transmitter, as in portable devices such as cell phones, walkie-talkies, and garage door openers. In more powerful transmitters, the antenna may be located on top of a building or on a separate tower, and connected to the transmitter by a feed line, that is a transmission line (Jerry, 1991).

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2.0 MATERIALS AND METHOD

2.1 Circuit Design

The design consists of the following sections: audio amplifier, oscillator, frequency multiplier, buffer amplifier, filter and drive and power amplifier and filtering. These sections work in perfect synergy to bring about the overall functionality of the device. The block diagram is shown in the Figure.

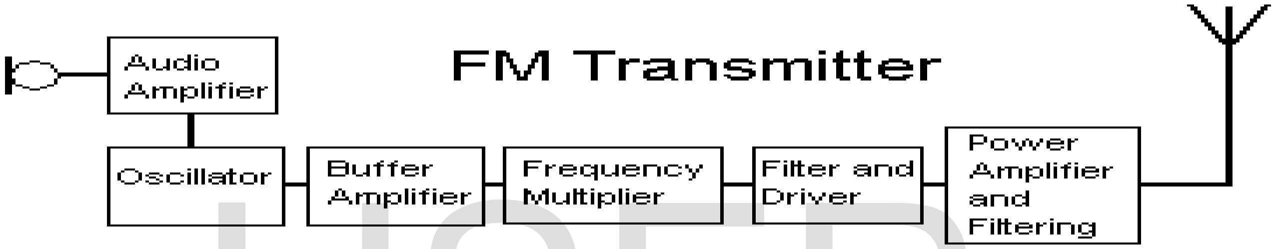

Figure 1: Block diagram of the FM Transmitter

Each of these sections is explained below:

2.2 Audio Amplifier

Any electronic device that increases the power of an electrical signal whose vibrations are confined to the audio frequency range. The range that can be perceived by the human ear is an audio amplifier. All devices that transmit, record, or otherwise electronically process voice signals employ audio amplifiers.

2.3 DC Voltage Source

All components used in this design can be adequately powered using 12 V DC (Direct Current). Therefore, a 9 V, 1.2 Ampere DC (Direct Current) battery was used as the DC source as it can adequately cater for the load and the minimum requirement of 2 V above the regulated voltage requirement.

2.4 Oscillator

An oscillator is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC (Direct Current) source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

2.5 Frequency Multiplier

Frequency multiplier is an electronics circuit that generates an output signal whose output frequency is a harmonic (multiple) of its input frequency. A subsequent bandpass filter selects the desired harmonic frequency and removes the unwanted fundamental and other harmonics from the output.

2.6 Buffer Amplifier

A buffer amplifier (sometimes simply called a buffer) is one that provides electrical impedance transformation from one circuit to another, with the aim of preventing the signal source from being affected by whatever currents (or voltages, for a

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current buffer) that the load may be produced with.

2.7 Filter and Driver

Filter drivers are optional drivers that add value to or modify the behaviour of a device. A filter driver can service one or more devices.

2.8 Construction and Materials Used

The materials used in testing the circuit are:

i. **Project Board:** This is a white electronic kit, which is used to test and construct electronic circuit without soldering the components. It provides room for circuit modification if need be.

ii. **Connecting Wires:** These are tiny pieces of copper wires about $0.2mm^2$ in diameter. They are used to assemble components together on the project board.

iii. **Battery:** The source dc supply is 9volts high watt battery.

iv. **Cutter:** This is to cut connecting wires and components to size.

v. **Digital Multi-meter:** This is a multi-purpose electrical measuring instrument use to test for various parameters in an electrical circuit.

vi. **Insulation Tape**

vii. **Complete Pliers Set**

viii. **Screw driver**

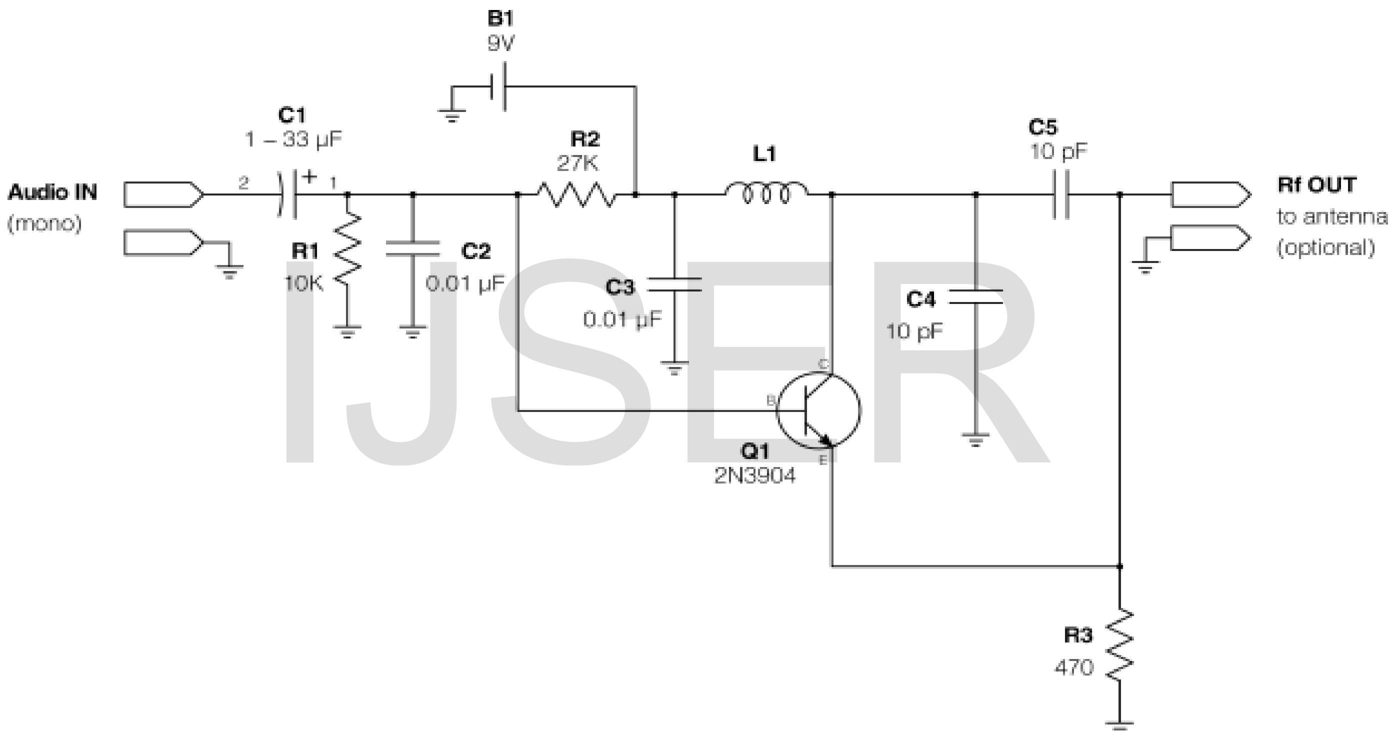

Figure 2: Overall Circuit Diagram

2.9 Design Construction

The actual realization of the design was carried out in adherence to circuit schematics. Assembled first on bread board before transferring to a Copper Clad board (CCB). The choice of electronic materials and components used were done with the objective of achieving low cost.

2.10 Design Procedure

The design procedure for the project hinged on an existing frequency modulation (FM) transmitter circuit. This transmitter circuit, which the researchers constructed and tested, showed some desirable characteristics. Operating efficiently on a low-power 9 V DC (Direct Current) which process minimal safety problem.

However, the transmitter incorporates a low power ($2.52 \times 10^{-5} mw$) output stage using transistor $2N3904$ which produces a range too short for practical application. The design procedure then involved the calculations experiments and exercises required to successfully replace the low output of the existing transmitter with less output stage of useful broadcast value.

2.11 DESIGN CALCULATION

i. Transmitter Distance (d)

From the Global Positioning System (GPS), using the fields Area measurement software, a total distance of 1.375km=1375m was obtained as the total range to be covered by the transmitter.

ii. The required output power P_t of the radio transmitter

Using the formula $P_t = \frac{E^2 \times d^2}{30}$

Where $E = 20\mu v = 20 \times 10^{-6} v$, $d = 1375m$

∴ The distance (d) will be $1375m$

$$P_t = \frac{(20 \times 10^{-6})^2 \times (1375)^2}{30}$$

$$\therefore P_t = 2.52 \times 10^{-5} mw$$

When measuring a transmitter output, the measurements must be made in the far field, the power received per unit area from an isotropic antenna is calculated from the following equation.

$$P_r = \frac{P_t}{(4\pi d^2)}$$

Where P_r = received power

P_t =transmitted power

d=distance from transmitter in meters

$P_t = 2.52 \times 10^{-5} mw$, d=1375m

$$P_r = \frac{2.52 \times 10^{-5}}{(4\pi \times (1375)^2)}$$

$$P_r = \frac{2.52 \times 10^{-5}}{2.375 \times 10^7}$$

$$P_r = 1.06 \times 10^{-12} mw$$

∴ $1.06 \times 10^{-12} mw$ is the received power from the transmitter.

$$E_{fs} = \frac{\sqrt{(30P_t)}}{d}$$

Where E_{fs} is the field strength in v/m,

P_t is the transmitted power and d is the distance from transmitter in meters.

$$P_t = 2.52 \times 10^{-5} mw, d = 1375m$$

Let E_{fs} be the field strength

$$E_{fs} = \frac{\sqrt{(30 \times 2.52 \times 10^{-5})}}{1375}$$

$$E_{fs} = \frac{\sqrt{7.56 \times 10^{-4}}}{1375}$$

$$E_{fs} = 1.99 \times 10^{-5}\ v/m$$

∴ $1.99 \times 10^{-5}\ v/m$ is the field strength in the transmitter.

The one stage circuit in figure 2 works from a $9V$ battery, its output frequency was measured to be $102.2MHz$. The final common emitter stage of this circuit, develops power in the tank circuit, which is transferred to the antenna, most of the power is developed in the coil, there are three ways to calculate this

$$P = VICos\theta \quad (1)$$

$$P = I^2 V \quad (2)$$

$$P = \frac{V^2}{Z} \quad (3)$$

In the circuit, V_E (voltage emitter) was measured at $2.99V$ across the $470 - ohm$ emitter resistor.

As $I_E = I_C$ then collector current is:

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

Where $V_E = 2.99V$

$$R_E = 470\ ohm\ or\ 0.47k$$

$$I_E = \frac{2.99\ V}{0.47\ K} = 6.362\ mA$$

This value will be substituted for the ac collector current. The impedance of the tank circuit is now found. At resonance the impedance is given by the following equation, where R is the DC (Direct Current) resistance of the coil in the tank circuit. R(resistor) was measured at 0.15μ ohm.

$$Z = \frac{L}{CR}$$

$L = 0.15\mu H = 0.15 \times 10^{-6} H$

$C = 15 \times 10^{-12}$, $R = 0.1$ ohm

$$Z = \frac{0.15 \times 10^{-6}}{15 \times 10^{-12} \times 0.1}$$

$$Z = \frac{0.15 \times 10^{-6}}{1.5 \times 10^{-12}}$$

$$\therefore Z = 100k$$

2.11 Small Signal Analysis

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Output power will be worked out as I^2Z but first the equivalent output circuit for the transmitter must now be drawn to calculate overall impedance. The tank circuit (impedance $100k$) is in parallel with the output impedance h_{oe} of the transistor. h_{oe} varies with collector current, but at $6mA$ is about $27k$.

Looking at the circuit there is a 10pf capacitor across base and emitter in series with a $470 - ohm$ resistor, one end of the resistor is grounded. The power rails are decoupled with a $22pf$ capacitor which is considered a short circuit at RF.

3.0 RESULTS AND ANALYSIS

The outcome of this research gave rise to an FM transmitter equipment with a robust search and discover capabilities in terms of radio transmission. Plate1. Shows the picture of the device.

Figure 3: Designed and Constructed FM Transmitter

In order to assess the functionality of the device, an evaluation test was carried out on the device inside a laboratory.

During the experimental procedure the following test was carried out on the transmitter components using a digital multi-meter.

i. Polarity test
ii. Frequency test
iii. Inductance test

3.1 Polarity test: At every stage of mounting the components especially the ones that have polarity, there comes a need to make use of the digital multi-meter.

3.2 Frequency test: In this experiment the standard frequency test was carried out using a digital multi-meter to note at which frequency the transmitter frequency varies.

3.3 Inductance test: Inductance or mutual inductance refers to when an electrical circuit develops voltage as a result of a change in another circuit. In other form inductance is a ratio of voltage to current and it's measured in a unit called Henry, defined as 1volt-second per ampere.

4.0 CONCLUSION

Conclusively from this research work which is aimed at modulating frequency with the aid of a transmitter, we were able to transmit audio signals from a phone, laptop and also from oral communication, after going through several experiment test. This design and construction were achieved after going through several literature reviews of which the principle of modulation was discussed and the beginning of radio transmission also put into view.

Though transmission was possible after testing but didn't give the desired result of having a crystal reception and longer transmission.

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