DESIGN AND CONSTRUCTION OF A 94.6 MHZ, 4WATT, FM TRANSMITTER.

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Dedication

This work is dedicated to the Almighty Allah for whose sake I did it, and then to my parents, teachers and well wishers.

Declaration

I, Oyewo Maroof Olayinka, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copy right to the Federal University of Technology, Minna.

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Acknowledgement

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Abstract

Modulation is the process of combining the low – frequency signal with a very high – frequency radio wave called carrier wave (CW). The resultant wave is called modulated carrier wave. This job is done at the transmitting station.

Frequency modulation as the name shows is a modulation where only the frequency of the carrier wave is changed and not its amplitude. The FM signal contains information (or intelligence we wish to convey) in the form of frequency variation.

This signal is produced by superimposing audio signals of varying intensity from the Audio frequency amplifier with a carrier signal having uniform amplitude and frequency from the Radio Frequency Amplifier. The resulting FM signal undergoes further processing such as amplification, filtering and pre-emphasis before it is finally transmitted via the antenna. FM Transmission is used in FM broadcast band (88 – 108MHz), in TV broadcast, mobile or emergency services and also in amateur bands where only voice frequencies are transmitted.

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Chapter One

1.0 Introduction

For a successful transmission of intelligence (Code, Voice, etc) by the use of radio waves, the process called Modulation is essential. Speech and code etc are sent thousands of kilometres away by a radio transmitter. The scene in front of a television camera is also sent many kilometres away to viewers. Similarly a moon probe, checking its environments, sends the information it gathers millions of kilometres through space to receivers on earth. In all these cases, the carrier is the high frequency radio wave. The intelligence i.e sight, sound or other data collected by the transmitting station (radio, T.V or probe), is impressed on the radio wave and is carried along with it to the destination

Modulation therefore, is the process of combining the low –frequency signal with a very high-frequency radio wave called carrier wave. The resultant wave is called modulated carrier wave. This job is done at the transmitting station.[1]. During modulation, some characteristic of the carrier wave is varied in time with the modulating signal and is accomplished by combining the two. The wave form can be varied by any of its following three factors or parameters:

1. **The amplitude:** Here the information or AF signal changes the amplitude of the carrier wave without changing its frequency or phase.
2. **The Frequency**: In this case, the AF signal changes the frequency of the carrier wave without changing its amplitude or phase.
3. **The Phase**: Here, the AF signal changes the phase of the carrier wave without changing its other two parameters.

However, the major concern in this project is the frequency modulation method which is involved in the process of FM transmission.

1.1 Frequency Modulation

As the name shows, in this modulation, it is only the frequency of the carrier which is changed and not its amplitude. The amount of change in frequency is determined by the amplitude of the modulating signal whereas the rate of change is determined by the frequency of the modulating signal. Therefore in an FM carrier, information (intelligence) is carried as variations in its frequency. So frequency of the modulated carrier increases as the signal amplitude increases but decreases as the signal amplitude decreases. It is at its highest frequency when the signal amplitude is at its maximum positive value and at its lowest frequency when signal amplitude is at its maximum negative value. When the signal amplitude is zero, the carrier frequency is at its normal frequency called resting or centre frequency. When the signal is applied, the carrier frequency deviates up and down from its resting value. This change or shift either above or below the resting frequency is called frequency deviation. A maximum frequency deviation of 75 KHz is allowed for commercial FM broadcasting stations in the 88 to 108MHZ VHF band. Hence FM channel width is 2 x 75 = 150KHz. Allowing a 25 KHz guard band on either side, the channel width becomes = 2(75 +25) = 200 KHz. This guard band is meant to prevent interference between adjacent channels.

The FM Transmitter considered in this project operates at a frequency of 94.6MHz (as its resting frequency). The FM Transmitter is made up of the following electronic circuit stages / modules.

1. Input stage
2. Radio Frequency Oscillator stage.
3. Frequency Modulation Stage.
4. Output Stage.

It is the combination of these modules that make up an FM Transmitter.

1.2 Principle of Operation

The design and operation of the FM Transmitter are based upon the application of some engineering principles. These principles are:

1. Signal Transformation
2. Signal (RF) generation
3. Signal modulation and
4. Signal frequency selection

These principles have their application at specific stages in the circuit of the equipment. The signal transformation takes place at the input stage of the device. This involves the transformation of the sound into audio-frequency signals of low amplitude. The signal generation involves the stage of RF Oscillation i.e. generation of RF signals (carrier waves) which are to be properly mixed with the AF signals at the frequency modulation stage hence signal modulation.

The modulated signal produced at the modulator circuit is found to posses many frequencies, which make up the sidebands. Though theoretically their number is infinite, their strength becomes negligible after a few side bands. They lie on both sides of the centre frequency spaced far apart from each other. The (fo + fm) frequency band (an upper side band) and the (fo – fm) frequency, (a lower side band) have been found to carry the same level of perfection concerning the modulated signal, however one of the two will have to be transmitted thus, in order to maximize transmission power, hence the need for signal frequency selection.

1.3. Aims and Objectives

The main aims and objectives behind undertaking the project of designing and constructing an FM transmitter covering the area of Gidan Kwano campus, F.U.T. Minna are stated below:

1. Development of indigenous engineering technology.

2. Ensuring the development of basic project construction skills.

3. Development of learning culture among students on campus through educative and enlightening programs aired out from the transmission room by Professors, Tutors and fellow students substituting the time-wasting musical and immoral programs been aired these days.

4. Helps us appreciate the realities of what we studied during the course of our program.

1.4. Scope of the Project

The scope of this work is limited to a simple non commercial 4W FM transmitter built to cover approximately an area of $100km^2$ which implies a coverage radius of about 6km. This coverage area is about the size of the Federal University of Technology, Gidan Kwano Campus.

Chapter Two

2.0 - Theoretical Background

2.1 - How does the FM Transmitter Work? [2]

The variable capacitor and the inductor which forms the tank circuit in the RF Oscillator stage will vibrate at frequencies in the FM radio band (88 – 108MHz). The electric microphone has a resistance that depends on how loudly you speak into it. This microphone is battery powered and according to the V = IR ohm's law, change in resistance for fixed voltage will result in proportional changes in current. This current feeds into the base of the NPN transistor which is connected to your variable capacitor, inductor and antenna via an Audio Signal amplifier.

2.2 Frequency Modulation

A distinction can be made between the frequency modulation of a carrier derived from

(i) a variable frequency oscillator, and

(ii) a crystal controlled source.

For signals of the first classification, and at carrier frequencies of less than 500MHz, say, LC tuned circuits are invariably used. The modulating signal is made to control the inductance or effective capacitance of the resonant circuit and thereby determine the instantaneous frequency. The generation of FM at higher frequencies can be carried out directly at the carrier frequency by using thermionic devices such as the Klystron [3]. Another method is to generate the signal at a lower frequency, i.e. less than 500MHz, and then adopt a process of frequency translation.

Frequency modulation of a carrier derived from a crystal oscillator can be achieved by an indirect means, since it is not possible to control the frequency of the resonant circuit by direct application of the modulating signal. Nowadays, nearly all communication systems use crystal-controlled sources for generating the carrier. The formation of a FM Signal from a variable frequency oscillator finds application in the field of instrumentation and therefore an account of the basic principle of varying the inductance or capacitance of an oscillator resonant circuit is given below:

2.2.1 – Generation of FM by varying the Inductance or capacitance of an oscillator Resonant circuit.

The Unmodulated resonant frequency fo of a shunt LC circuit is

$$Fo = \frac{1}{2\pi\sqrt{LC}} \text{ -- } (1)$$

If the capacitance is considered to be a variable with a maximum change of ± Δc, then

$$f_{min} = \frac{1}{2\pi\sqrt{L(C+\Delta C)}} \text{ -- } (2)$$

and

$$f_{max} = \frac{1}{2\pi\sqrt{L(C-\Delta C)}} \text{ -- } (3)$$

Where fo – f_{min} and f_{max} – fo corresponds to the peak frequency deviation, Δf.

Rearranging equation (2) gives

$$f_{min} = \frac{1}{2\pi\sqrt{LC}}\left(1+\frac{\Delta c}{c}\right)^{-1/2}$$

and if $\Delta c << c$,

$$f_{min} \approx \frac{1}{2\pi\sqrt{LC}}\left(1-\frac{\Delta c}{2c}\right)$$

$$= f_0\left(1-\frac{\Delta c}{2c}\right)$$

or $$fo - f_{min} \approx fo\frac{\Delta c}{2c} \text{ ------------------------------------- (4)}$$

Similarly, $$f_{max} - f_o \approx fo\frac{\Delta c}{2c} \text{ ------------------------------------- (5)}$$

Therefore the peak frequency deviation, or in general the instantaneous frequency deviation, is directly proportional to the change in capacitance provided that this is small compared with the total capacitance in the resonant circuit. By a similar analysis, but with the inductance being treated as a variable, the peak frequency deviation is given by

$$f_{max} - f_o \approx f_o\frac{\Delta L}{2L} \text{ ------------------------------------- (6)}$$

To generate a frequency modulated signal i.e. a signal whose instantaneous frequency deviation is directly proportional to the instantaneous amplitude of the modulating signal, a variable reactance device exhibiting a linear reactance / applied voltage characteristic is required. Such a device does not exist, but a reasonable approximation can be obtained by using the variable capacitance properties of a varactor diode [4] operated over a restricted portion of its characteristic. The reactance valve [5] provides a method of simulating either a variable capacitor or inductor and has in the past been used with success. Ferrite cored inductors have also been considered [6,7].

2.3 FM Radio Broadcasting

The most commonly used radio broadcasts are the FM radio broadcasts operating at around 88 – 108MHz frequency band. FM broadcasting offers around 50Hz to 15 KHz bandwidth with stereo sound. The deviation used in FM broadcast is 75 KHz (peak deviation). Typical transmitter power for FM station can be from 10w up to 100kw. Those broadcasts were originally mono broadcasts, but were later converted to stereo. The stereo broadcasts use special technique to be compatible with mono receivers.

Modern FM radio stations usually nowadays heavily process the audio before they transmit it. Typical processing is the FM broadcasting following: Audio Amplifier adjusts level of input signals from left and right channels to required intensity. Usually this stage includes nowadays some form of automated signal level control, compression and / or limiting. Stereo coder converts the left and the right channels signals into L +R and L - R elements. It multiplexes them with a synchronising pilot – signal of 19 KHz. It can also combine signals of traffic radio, radio data system, or subsidiary communications Authorisation Channels. Modulator superimposes the signal on the carrier frequency. Synthesizer can set transmitter's Rated frequency in steps (usually 10 KHz steps over the entire range 88 – 108MHz). It synchronizes the signal with Reference Frequency (from stabilized crystal source). Audio amplifier, stereo coder, modulator and synthesizer together make up the exciter portion of an FM transmitter. Power amplifier in takes a weak signal from Exciter and amplifies it to the high power that is sent to the transmitting antenna [8].

2.4 Frequency Allocations

The 100 carrier frequencies for FM Broadcast range from 88.1 to 107. 9MHz and are equally spaced every 200 KHz. The channels from 88.1 to 91.9MHZ are reserved for educational and non-commercial broadcasting. Each channel has a 200 – KHz bandwidth. The maximum frequency swing under normal conditions is +/ - 82.5 KHz. The carrier centre frequency is maintained with +/- 2000Hz. The frequency used for FM broadcasting limit the coverage to essentially line-of-sight distances. As a result, consistent FM coverage is limited for a maximum receivable range of a few hundred kilometres depending on the antenna height above average terrain (HAAT) and effective radiated power (ERP). The actual coverage area for a given station can be reliably predicted after the power and the antenna height are known. Either increasing the power or raising the antenna will increase the coverage area [9].

Table 2.4 FM Station Classifications, Powers and Antenna Heights [10].

Station class	Maximum ERP	HAAT, m (ft)	Distance, (km)
A	6KW(7.8dbk)	100 (328)	28
B1	25KW(14.0dbk)	100 (328)	39
B	50KW (17.0dbk)	150 9492)	52
C3	25KW(14.0dbk)	100 (328)	39
C2	50KW (17.0dbk)	150(492)	52
C1	100KW (20.0dbk)	299(981)	72
C	100KW (20.0dbk)	600 (1968)	92

2.5 Transmitters

At the start of the 20th century, RF (radio frequency) energy was created using "Alexanderson alternators which generates frequencies up to 100 KHz through rotation. The 1920s saw radio make the switch to electronic transmitters, apparatuses based on then-current vacuum tube technology. When amplification is combined with the circuit and a portion of the resulting output is fed back into the input of the amplifier, the amplifier oscillates. The transmitter, therefore, is an electronic device, or oscillator, which uses an antenna to propagate a radio signal.

In theory, a basic transmitter can be defined as an oscillator attached to an antenna. Today's technology, of course offers more than this basic assemblage. Normally a transmitter has a power supply, an oscillator, a modulator, and Audio Frequency (AF), intermediate Frequency (IF) and Radio Frequency (RF) amplifiers. Some high-tech machines like mobile phones have both a transmitter and a radio receiver (also known as transceiver). The function of the modulator is to piggy back the signal onto the carrier frequency.

In more complex transmitters, the device's frequency is not produced by the oscillator, but one of its harmonic frequencies are used in frequency multiplier circuits; in such an operation, an oscillator and a chain of its frequency multipliers raise the "fundamental frequency" to create the desired total output. Radio is created by low frequency because it is easier to control the stability necessary for radio output at low frequencies. However, equipment frequencies can produce more than a megawatt of output.

Besides its use in the field of radio, RF transmitters are used in a variety of ways in many industries. They are packaged in a metal rack that can be installed in a cabinet for telecommunications use. RF transmitters are also used in article surveillance systems (or EAs), as seen in retail stores. Inventory management systems frequently use transmitters instead of bar codes [11].

2.6 Antennas

An antenna is an RF component used to transform an RF signal, travelling on a conductor, into an airborne wave and vice-versa. Antennas are passive devices that radiate and pick up radio frequency energy (RF). Antennas are typically designed so that they work with the desired operation frequency, have a wanted radiation pattern and are matched to the cable connected to them (most often 50ohm coaxial cable, can also be 75ohm coax or 240 – 300 ohm flat line.

Antennas do not create RF energy. In transmitting applications, antennas focus the energy in a specific area or direction, which increases the signal strength in that direction or area. This is specified as gain in units of decibels (dBi). An antenna with 0dBi gain is one which radiates in all directions equally. An antenna with 12 dBi gain has a direction in which the signal is 12db stronger than in another direction. In reception the antenna gain helps the antenna to pick up signals from one direction stronger than from other directions. This directivity is very important if you need to receive weak signals in noisy environment.

Every antenna and every antenna feed-line have a characteristic impedance, or opposition to electrical current. In an ideal situation, the impedance of line and antenna match perfectly, and 100percent of electrical energy sent to the antenna is converted to radio energy and radiated with the atmosphere. In a less than ideal case, when the impedances aren't perfectly matched, some of the electrical energy sent to the antenna won't be converted to radio energy, but will be reflected back down the feed-line. The energy reflecting back from the antenna causes standing waves of electrical energy in the feed line.

An ideal antenna solution has an impedance of 50ohm all the way from the transceiver to the antenna, to get the best possible impedance match between transceiver, transmission line and antenna. Since ideal conditions do not exist in reality, the impedance in the antenna interface often must be compensated by means of a matching network i.e. a net built with inductive and / or capacitive components. [12]

Chapter Three

3.0 Transmitter Design And Construction

The FM TRANSMITTER was designed using the Modular technique. The circuit consists of five modules. The power supply stage, three RF stages and one audio preamplifier stage for the modulation. It works off approximately 14 volts.

3.1 Power Supply Stage

The power supply stage comprises of a 240/12v step down a.c transformer whose secondary is directly connected to a full-wave bridge rectifier for converting the transformers a.c output to d.c for the powering of the FM Transmitter.

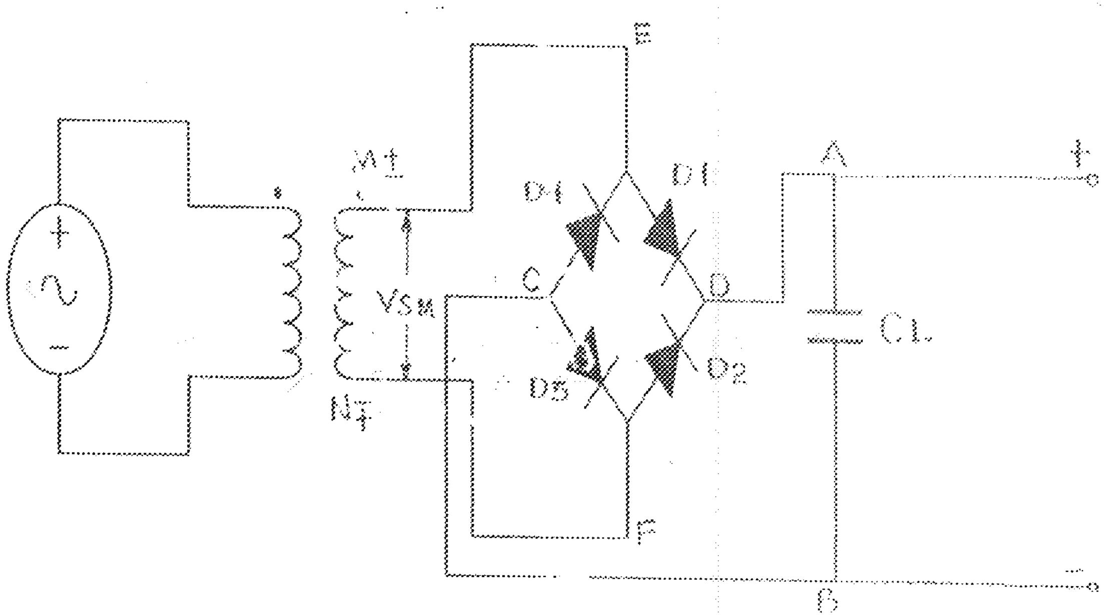


Fig. 3.1 Power Supply Stage

During the positive input half cycle, terminal M of the secondary is positive and N is negative. Diodes D_1 and D_3 become forward – biased (ON) whereas D_2 and D_4 are reversed (OFF). Hence, current flows along MEAECFN producing a drop across capacitor C_L.

During the negative input half cycle, secondary terminal N becomes positive and M negative. Now, D_2 and D_4 are forward biased. Circuit current flows along NFABCEM. Hence we find that current keeps flowing through load resistance R_L in the same direction AB during both half cycles of the a.c supply. Consequently, point A of the bridge rectifier always acts as an anode and point C as cathode. The output voltage across capacitor C_L is as shown in fig. 3.1. Its frequency is twice that of the supply frequency.

3.1.1 D.C Voltage across Load

In order to obtain the d.c voltage across terminals AB in the above figure, we apply the formula:

$$V_L(d.c) = \frac{2Vsm}{\pi}$$

Where: V_L (d.c) is the d.c voltage across the load.

V_{sm} is the transformer secondary voltage.

It may be noted that r.m.s value of a.c voltage across the secondary is 12V.

$$\therefore Vsm = 12\sqrt{2} = 16.97v$$

$$\text{So } V_L(d.c) = \frac{2 \times 16.97}{\pi} = 10.80v$$

Therefore the d.c voltage of the full-wave Bridge rectifier is at an approximate value of 11v.

3.1.2 Shunt Capacitor Filter

In this circuit, a suitable single capacitor C_L is connected across the rectifier and in parallel with the load R_L to achieve filtering action. This type of filter is known as capacitor input filter. The main function of a filter circuit is to minimize the ripple content in the rectifier output.

The value of the capacitor can be derived from the formula:

$$C = \frac{Id.c}{4\sqrt{3}f\gamma V_{ip}}$$

Where: I.d.c ⇒ d. c current across the load

f ⇒ frequency

γ ⇒ Ripple factor for full-wave rectifier

V_{ip} ⇒ Maximum value of load voltage

The value of the capacitor is taken at a maximum of 1000µf

3.2 The Pre-Amplifier / Input Stage

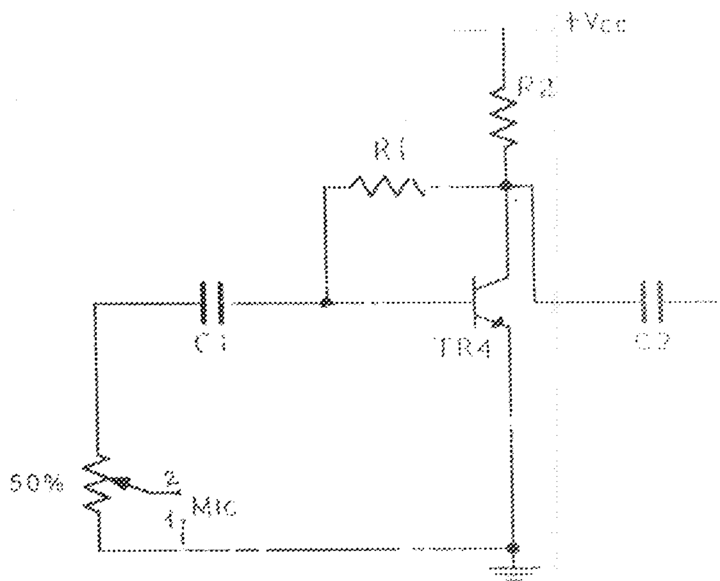


Fig. 3.2 The Pre-Amplifier / Input Stage

The circuit of the pre-amplifier is very simple and is built around TR_4. The input sensitivity of the stage is adjustable in order to make it possible to use the transmitter with different input signals and depends upon the setting of variable Resistor 1 (VR1). As it is, the transmitter can be modulated directly with a piezoelectric microphone, a small cassette recorder etc. It is of course possible to use an audio mixer in the input for more professional results.

The conductivity of semiconductor is temperature dependent and so are the characteristics of a transistor. Maintaining the d.c. operating point, irrespective of rise in ambient temperaure, is called stabilization. The loop equation for an amplifier circuit with poor stabilization gives:

$V_{BE} = V_{CC} - I_B R_B$ where; V_{BE} is the base emitter voltage, V_{CC} is the voltage supply, I_B is the base current, R_B is base resistance.

The Base – Emitter voltage B_{BE} is temperature dependent. For every 10^0c rise in temperature, V_{BE} decreases by about 20mV. Thus rise in temperature, V_{BE}, will cause an increase in I_B since V_{CC} is constant. The collector current ($I_C = IBh_{FE}$) increases to cause further heating of the transistor until it eventually becomes saturated or gets damaged. The effect is called 'thermal runaway'.

Therefore special circuits have been designed to prevent 'thermal runaway' by automatically compensating for variation of collector. Hence the transistor pre-amplifier circuit in fig. 3.2. with good stabilization has the following d.c loop equations:

$I_C = (V_{CC} - V_{CE}) / R_L$

$I_B = (V_{CE} - V_{BE}) / R_B$

Where: I_C is the collector current,

V_{CE} is the collector-emitter voltage,

R_L is the load resistance.

If I_C increases due to rise in temperature, V_{CE} decreases since V_{CC} is constant. Decrease in V_{CE} cause I_B to decrease, since V_{BE} remain (compared with V_{CE}) almost constant at about 0.6V. This tends to decrease I_C thereby bringing it to the original value. An increase in I_C causing an effect which will decrease I_C is called negative feedback. The amplifier in Fig. 3.1 will never get saturated. [13]

The capacitor C_1, connected in series with the variable resistor serves to filter the noise from the sound input signal. While C_2 couples the pre-amplifier with the first RF stage which is the RF Oscillator.

3.3 The Rf Oscillator Stage

The input signal generated by the input sound transducer is very small. If it is applied to the transmitting antenna that way, before the signal gets to the receiver, it must have faded-out-totally, hence no work done. In trying to avoid this kind of problem, the radio frequency oscillation stage is included in the design and construction of FM transmitter. The RF oscillation generates a signal at a particular strength and frequency that has the capability of carrying or enveloping the modulating signal or the design signal to its destination without fading –out or losing details. The signal generated by the RF oscillator stage is called carrier signal operating or oscillating at a frequency called Carrier frequency.

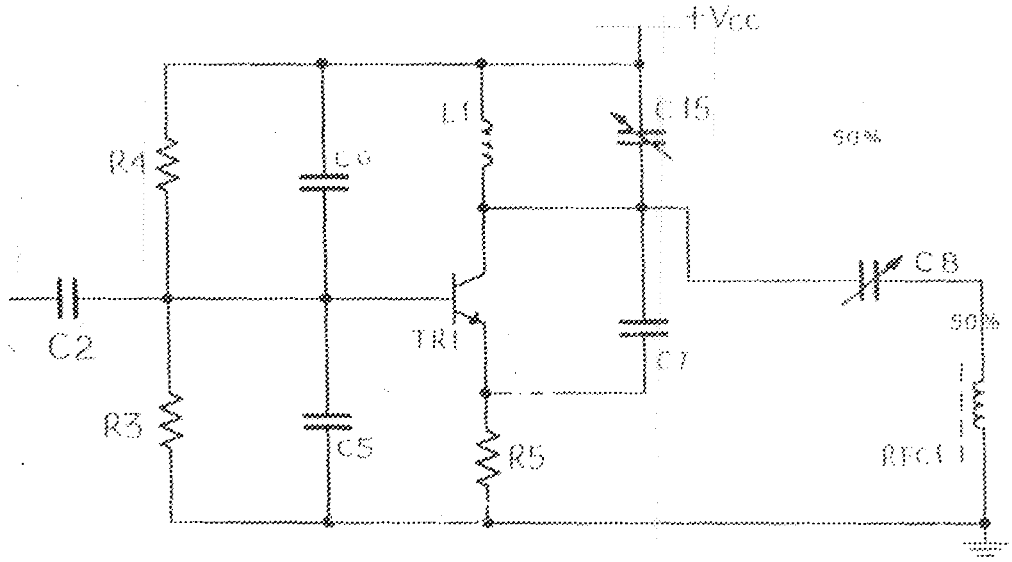


Fig. 3.3 RF Oscillator Stage

3.2.1 Conditions for oscillation

For many oscillators, the under listed conditions must be satisfied otherwise the circuit arranged cannot be called oscillator.

1. There must be a feedback path. This path usually exists between the output and input terminals.

The feedback path takes a portion of the output signal and returns it to the input terminal. It therefore acts as an add-on signal to the input signal.

2. The signal that is fed back into the oscillator must be in phase with the original input signal.

In fig. 3.3 above, C5 and C6 are the d. c. blocking capacitors and act to bypass R_3 and R_4 respectively so that they have no effect on the a. c. operation of the circuit. The parallel LC network, L1 – C15 controls the frequency of the oscillator and forms the frequency determining circuit or the tank circuit. C7 is there to ensure that the circuit continues oscillating and C8 adjusts the coupling between the oscillator and the next RF stage which is an amplifier. The RFC (Radio Frequency Choke) provides d. c. load for the collector and also keeps a.c. currents out of d.c. supply.

3.2.2 - Inductance Of An Air coil

The inductor has a value determined by its radius R, length x, and number of wire turns n.

$$\text{So } L = \frac{n^2 r^2}{9r + 10\chi}[\mu H]$$ [4]

For an inductor of r = 0.3937inches, x = 0.25inches and n = 4turns, it results in

$$L = \frac{4^2 \times (0.3937)^2}{(9 \times 0.3937) + (10 \times 0.25)}$$

$$L = 0.4104\mu H$$

The specified frequency f generated is now determined by the capacitance c and inductance < of the tank circuit measured in Farads and Henry respectively:

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

3.3.3 - Resonant Frequency of a Parallel LC Circuit

FM radio station operates on frequencies between 88 and 108MHz. The variable capacitor and the 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 by an FM receiver.

In tank circuits, the underlying physics is that a capacitor stores electrical energy in the electric field between its places 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 is a kinetic versus potential energy balance that dictate the period (or frequency) of oscillations.

Given the variable capacitor range of 4 – 20pF, the tank circuit will resonate between two extremes determined by the resonating frequency formula given above:

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

Therefore, the minimum frequency $\Rightarrow f_{min} = \frac{1}{2\pi \times \sqrt{0.41\mu Hx20pF}} = 55.5MHz$

and maximum frequency, $f_{max} = \frac{1}{2\pi \times \sqrt{0.41\mu Hx4pF}} = 124MHz$

Which are well within the FM radio range.

3.4 The First Rf - Amplifier Stage

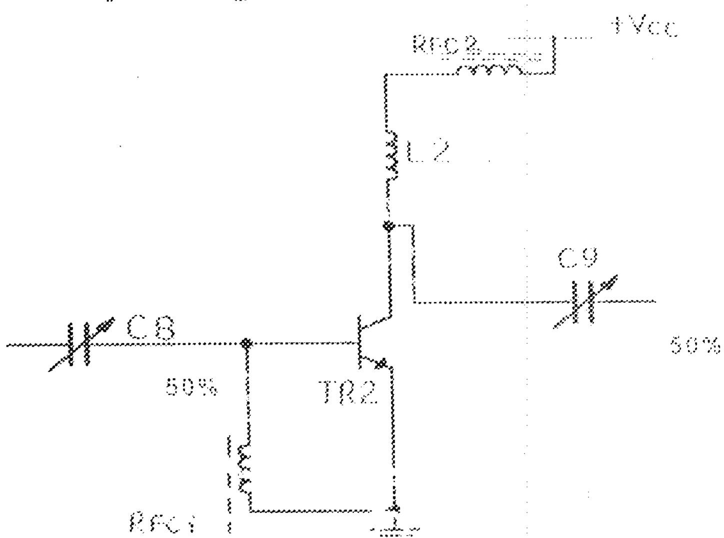


Fig. 3.4 The first Rf amplifier stage

The first RF amplifier stage is built around transistor TR_2 which operates in class C and is tuned by means of L2 and C9. This stage is designed to amplify the modulated signal from the second stage, the RF oscillator. The class c operation of the transistor TR_2 is well suited for this.

3.4.1 Class – C Amplifier

In such amplifiers, the active device i.e. the transistor is biased much beyond cut-off. Hence,

1. Output current flows only during a part of the positive half –cycle of the input signal,
2. There is no output during any part of the negative half – cycle of the input signal.
3. Output signal has hardly any resemblance with the input signal. It consists of short pulse only.
4. Class – C amplifiers have high circuit efficiency of about 85 to 90%.

Because of this distortion, class – C amplifiers are not used for audio-frequency work. They are used for high – power output at radio frequencies (i.e. RF amplifiers) where harmonic distortion can be removed by simple circuits. In reality, they are used as high – frequency power switchers in radio transmitters rather than as amplifiers.

3.4.2 Tuned amplifier

The gain of a transistor amplifier depends on the value of its load impedance. Such high impedance can be obtained by using a high – Q tuned or resonant LC circuit as load (fig. 3.4). The frequency response curve of the amplifier assumes the same shape as the resonance curve of the turned circuit. Obviously, only a narrow band of frequencies around the resonant frequency f_0 would be amplified well whereas other frequencies would be discriminated against. [15]

Non – linear distortion is eliminated because of high selectivity of the load impedance. Hence, output is nearly sinusoidal. With the removal of distortion, high amplifier efficiency can be achieved by operating the transistor in its non-linear region.

3.5 The Second Rf Amplifier Stage

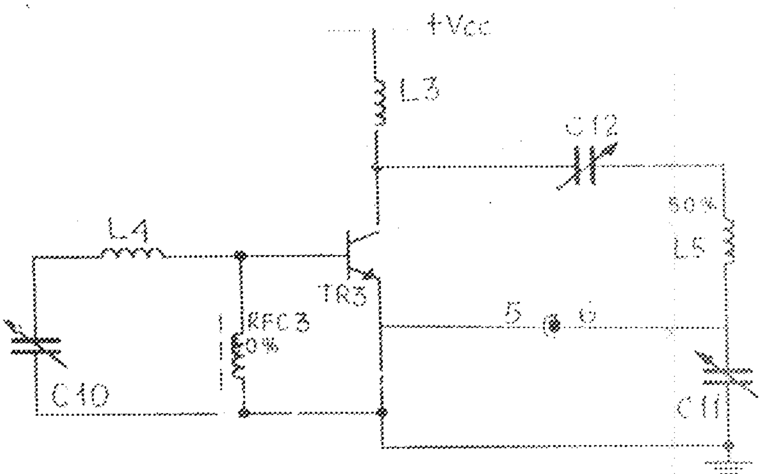


Fig. 3.5 The second Rf amplifier stage

The second or last RF stage is also an amplifier built around TR3 which operates in class C, the input of which is tuned by means of a high load impedance obtained by using the resonant LC circuit, C10 and L4 as load. This stage re-amplifies the modulated signal to give it a higher gain. From the output of this last stage which is tuned by means of L3 – C12 is taken the output signal which through the tuned circuit L5 – C11 goes to the Arial at terminals 5 and 6

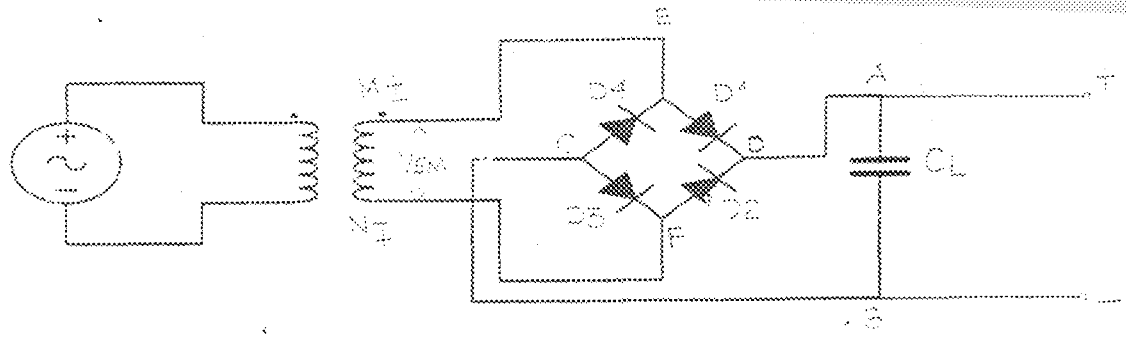
3.5.1 Antenna Length

The antenna length should be approximately ¼ the FM wavelength making reference to the fact that multiplying frequency and wavelength equals the speed of light. The Transmitter is operating with a frequency of 94.6 MHz, as such:

Speed of light = frequency x wavelength = 300,000Km/ sec.

$$\Rightarrow \text{Wavelength} = \frac{300{,}000\text{km/s}}{94.6\text{MHz}} = 3.17\text{meters}$$

∴ Antenna length = 0.25x 3.17 = 0.79meters



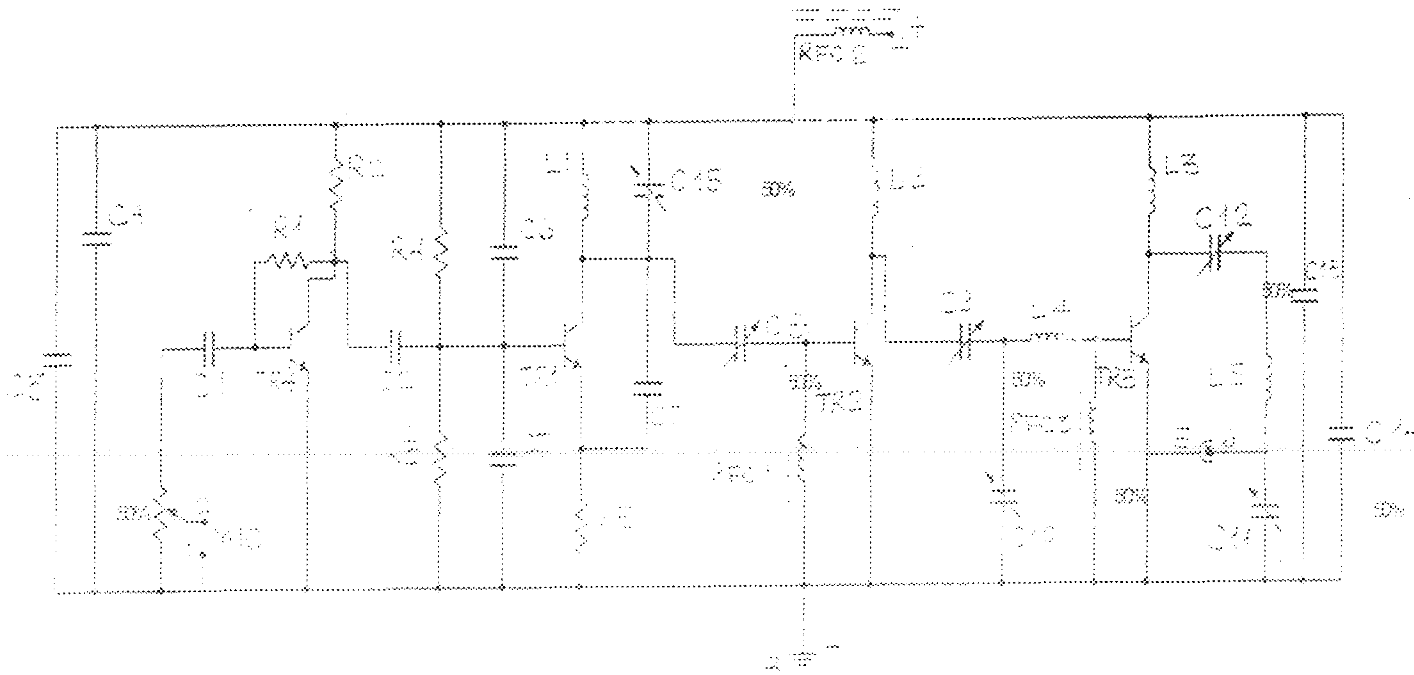


Fig. 3.6 Complete circuit diagram of the FM transmitter

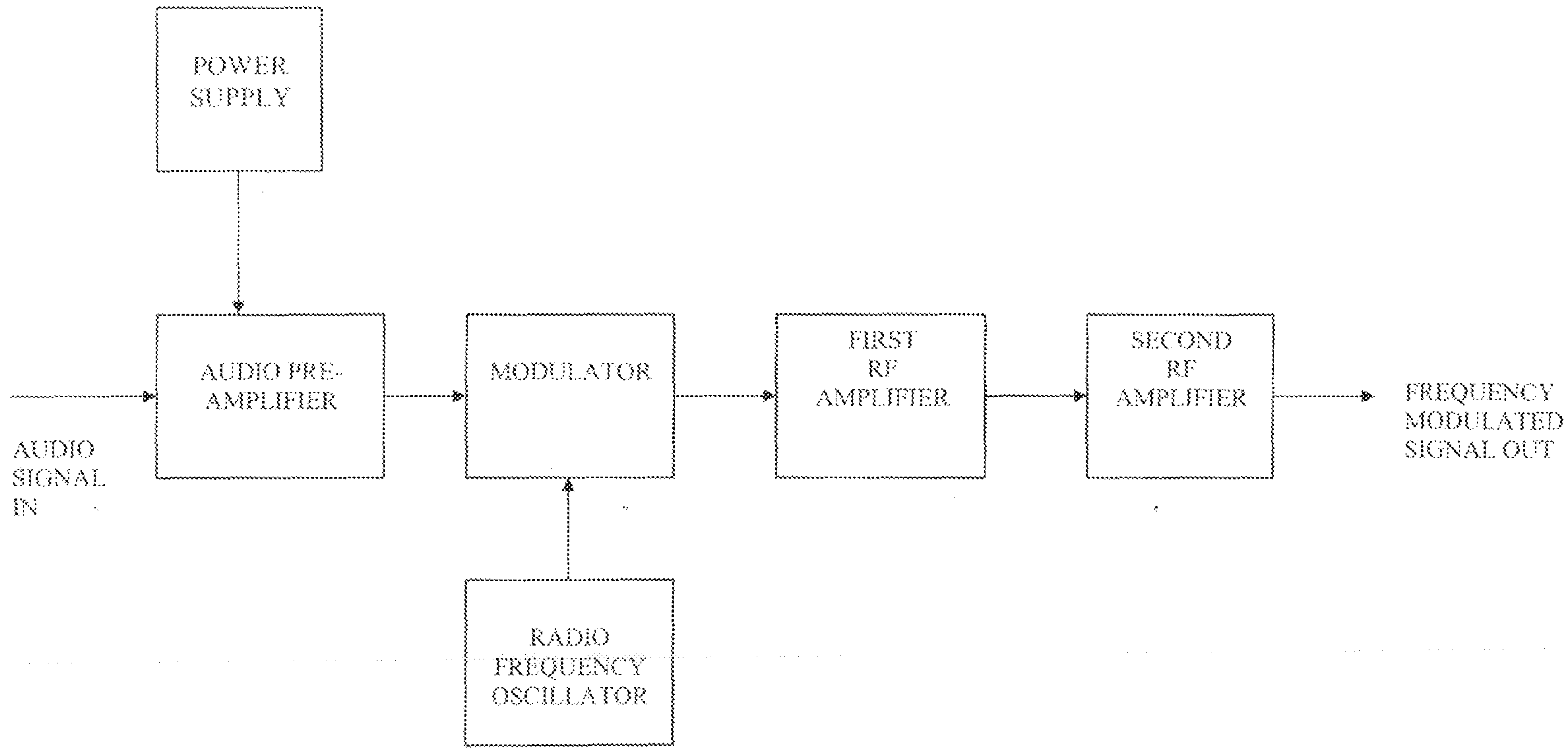


Fig. 3.7 Block Diagram of an FM Transmitter

Chapter Four

4.0 Tests and Results

4.1 Operation of FM Transmitter

First, a battery – powered pocket radio is used as a receiver. A. C. powered boom boxes and home stereos (110 and 220v) are not recommended. Battery powdered radios are much better at receiving transmissions than A. C. powered units.

1. The radio was tuned to dead air, i.e. frequencies within the FM radio band that are silent or only have some hiss. Frequencies near 108MHz are typically dead air.

2. The FM transmitter was turned ON and allowed to warm up. Then the antenna was extended and the transmitter kept at some couple of feet away from the radio. A cassette player was played via the earphone plug while slowly adjusting C15 to the desired frequency and the variable capacitors (trimmers), C8, C9, C10 C12 and C11 slowly until the sound of the cassette player was heard over the FM radio (receiver). In order to achieve this, despite frustratingly tedious, a series of stages of test are to be made. The results shown below could be obtained for an FM Transmitter test.

Table 4.1 Stages of adjustment of trimmers

STAGE	I	II	III	IV
C8[PF]	3	4.5	6.9	9
C9 [PF]	7	12	21	30
C10[PF]	10	10	30	60
C11[PF]	10	22	30	60
C12[PF]	7	14	20	34

Loudness and clarity was most likely found between stages III and IV with the best at stage III. The final construction was done by soldering the components neatly on the circuit board accordingly and carefully housed in a wooden casing, with the following dimensions: length = 33cm, height = 10cm and width = 25cm. The completed FM Transmitter was able to produce the desired signal.

From the test above, the desired value of the variable capacitor C15 in the tank circuit, was obtained as 6.896pF ≈ 7pF

$$f_o = \frac{1}{2\pi\sqrt{0.4104\mu H \times 6.896pF}}$$

$$\Rightarrow f_o = 94.6MHz$$

4.2 Problems and Solutions

During the course of carrying out this project, some of the problems encountered were:

1. Unavailability of some components which prompted quick substitution with some other components of close value.

2. Erratic power supply made testing of the FM transmitter difficult and tedious. This problem can be overcome by having alternative main power supply e.g. D.C supply.

Chapter Five

5.0 Conclusion and Recommendations

This project, which is the design of a 4watt, 94.6MHz FM Transmitter capable of covering about 6km, is a successful improvement of past works on this topic with respect to the coverage area.

However, there is need for improvement in the area of signal clarity at the receiving end perhaps by improvement on value of circuit components for any one intending to work on this or similar project.

List of Components

R1 = 220K ohms

R2 = 4.7k ohms

R3 = R4 = 10k ohms

R5 = 82ohms

VR1 = 22kohms trimmer

C1 = C2 = 4.7μ, 25V electrolytic.

C3 = C13 = 4.7nf ceramic

C4 = C14 = 1n F ceramic

C5 = C6 = 470pF ceramic

C7 = 11pF ceramic.

C8 = 3 – 10pF trimmer

C9 = C12 = 7 – 35pF trimmer

C10 = C11 = 10.60 pF trimmer

C15 = 4 – 20pF trimmer

L1 = 4 turns of copper wire at 5.5mm diameter

L2	=	6 turns of copper wire at 5.5mm diameter
L3	=	3turns of copper wire at 5.5mm diameter
L4	=	Printed on PCB.
L5	=	5 turns of copper wire at 7.5mm diameter
RFC 1 =		RFC 2 = RFC 3 = VK200 RFC
TR1	=	TR2 = 2N 2219NPN.
TR3	=	2N3553 NPN
TR4	=	BC 547 / BC 548 NPN.

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