DESIGN AND CONSTRUCTION OF A 105 MHz, 1 WATT, FM TRANSMITTER

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IN PARTIAL FUFILLMENT OF THE REQUREMENT FOR THE AWARD OF A BACHELOR OF ENGINNERING (B.ENG) DEGREE

NOVEMBER 2004

DECLARATION

I hereby declare that apart from reference to other peoples work, which have been dully credited, this project was solely and wholly done by me **Agbejule, O.Ayokunle** of Electrical and Computer Engineering Department of Federal University of Technology Minna, under the supervision of **Engr. M.D Abdullahi** of Electrical and Computer Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State, during the 2003/2004 academic session.

Signature O.Agbejule

Date 8/12/2004

CERTIFICATION

This is to certify that this project titled **DESIGN AND CONSTRUCTION OF A 105MHz, 1 WATT FREQUENCY MODULATION TRANSMITTER,** was carried out by **AGBEJULE .O. AYOKUNLE** under the supervision of **ENGR. M. D. ABDULLAHI** and submitted to the department of Electrical and Computer Engineering, Federal University Of Technology Minna in partial fulfilment of the requirement for the award of a Bachelor of Engineering (B. ENG) Degree in Electrical and Computer Engineering

ENGR M. D. ABDULLAHI

Project Supervisor

8/12/2004

Signature and date

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Head of department

8/12/2004

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External supervisor

....

Signature and date

ACKNOWLEDGEMENTS

I would like to thank Almighty **God** for his mercies, guidance and protection. I would also like to thank all those he has used to touch me. Most especially my loving parents **Mr and Mrs T. O. AGBEJULE.** To my brothers and sister for all the invaluable love and support.

To my supervisor **ENGR M. D. ABDULLAHI** for his professional, and fatherly guidance thank you sir. I would like to appreciate my dear friend **VAJIME CARL WANGER** for your immeasurable personal assistance in the actualisation of this project. Also, I want to thank **SANYA, SOLA AND SEYE ALAGBE** and all staff of **REHOBOTH** computers for all their assistance. I also want to appreciate my special friends: **OBI NWEKE** for being a brother, much love to **BUNMI OLATINWO**, you've been like an unconditional lover, thanks for all your encouragement and support, may almighty **ALLAH** grant you your heart desires. To **KABIRU MUSA** and **FEMI OLATINWO** for being reliable friends. To **AMINU WAKILI, HABIBA ALI, BUKEY SULE,AND EWEKA MUDIA** for being wonderful flatmates. To **IDRIS, MIKE, MUNAWAR, BABA, BAMBO, CHIMA,** to all my **UNCLES, AUNTIES** and my **GRANDMOTHER** for their love. To **LATEEFAH, JANE, MATILDA, BILY,YEWANDE, RONKE, SHADE, FISAYO, SHAKIRA, IDIAT, SEYI, AISHA**[milkos]**,FADILA, AMAH,** and all my other friends whom I got to know at the dawn of my study. May **God** bless you all. Finally to **ENGR DIPO ADEEKO,** and to all students and lecturers of Electrical Engineering Department F.U.T Minna, **thank you.**

DEDICATION

This project is dedicated to my parents for sponsoring my education, and for their support and to the memory of my friend and colleague, **MOHAMMED JIBRIL**.

ABSTRACT

Due to man's curiosity for fast information dissemination, science and technology has made it so fast that information can be transmitted and received within seconds by electronic means. Information can be transmitted from one point to another through frequency modulation technique. Transmission of information through this means is so common, that it is found in almost every corner of our planet

Frequency modulation, is a modulation technique generated by varying the frequency of a carrier which is between a frequency range of 88MHz – 108MHz , with and audio frequency which is then transmitted in electromagnetic waves for reception and processing into its original audio form at different locations.

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CHAPTER ONE

1.0 GENERAL INTRODUCTION.

Transmission is an indispensable process in the field of electronics or electrical communication both in the aspect of intercommunication and telecommunication. It is obvious that the use of frequency modulation (FM) is gaining ground in the design of communication systems such as transmitters and receivers. It will be essential at this point to define what modulation is and the various types of modulation.

1.1.1 DEFINITION

Modulation is defined as a process of superimposing a "base-band" frequency signal onto a high frequency carrier wave so that the information may be transmitted over a considerable distance either in a cable or in electromagnetic waves. There are basically two method of Analog modulation. Amplitude modulation (AM) and angle-modulation. Amplitude modulation (AM) involves varying the amplitude of the carrier in sympathy with the instantaneous value of the modulating signal. The angle modulation embraces phase modulation and frequency modulation with a slight difference between them. In phase modulation, the phase angle of the carrier signal is varied linearly with modulating signal while in frequency modulation; the phase angle of the carrier signal is varied linearly with the integral of the modulating signal. The difference between them is the nature of dependency on modulating signal. However, the major concern in this project is the frequency modulation method.

1.1.2 FREQUENCY MODULATION

Frequency modulation involves varying the frequency of the modulating signal. One of the advantages is that FM is less susceptible to interference. It could be achieved using two methods: direct and indirect methods of modulation.

Direct method is by varying the carrier frequency directly with the modulating signal. The result is "The wide Band Frequency Modulation" (WBFM). On the other hand the indirect method, "Narrow band frequency modulation" (NBFM) is obtained and then multiplied by some factors using frequency multipliers to achieve a wide band frequency modulation. Frequency multiplier is a non-linear device designed to multiply the frequency of input signal by a factor.

The FM transmitter may be said to be a single voice-band system. It is not a multi-channel communication system, because only one voice band is allowed or transmitted per time. The flow of information or message exists in only one direction; hence it is uni-directional, in terms of its information or signal flow.

A Transmitter is an electronic device, which processes a signal electronically and transmits it into the atmosphere in form of electromagnetic waves or through wires depending on the type of transmitter. Modulating signal such as speech consists of two components: - Information conveyed by virtue of the frequency of the signal and information conveyed by virtue of the amplitude of the signal. In FM transmitter, the frequency of the carrier conveys the amplitude information while the rate of change of the carrier frequency conveys the frequency information. The FM is considered in this project operates with the frequency of 105MHz with a frequency deviation of $\pm$ 500Hz. This gives the bandwidth of 104.5MHz to 105.5MHz.

The transmitted signal is radiated in to the atmosphere through the antenna in form of electromagnetic waves. These electromagnetic waves abound everywhere in nature and travel with the speed of light. The commercial transmitter has some important considerations in the design procedure, such as the frequency of operation, which falls between 88MHz to 108MHz. where 88MHz is the lower limit and 108MHz is the upper limit. Another thing under consideration is the area under coverage i.e. the radius that virtually depends on the radiated power. It should be borne in mind also that it has to be sensitive enough to be able to respond to the voice signal. From the title of the above named project, the following could be deduced; the type of the signal modulation i.e. frequency modulation. 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 gave birth to what is called FM transmitter.

1.1.3 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

4) Signal frequency selection

These principles have their applications at specific stages in the circuit of the equipment. The signal transformation principle is applied at the input stage. The signal generation principle is applied at the radio-frequency (RF) oscillator stage; the signal 8modulation principle finds its usefulness at the frequency modulation stage and the signal frequency selection principle at the output stage. The input sound transducer (microphone) receives the voice frequency signal from the mouth of the speaker and converts it into audio-frequency signals of low amplitude. The audio frequency signal is applied to the RF oscillator stage via a coupling capacitor where the RF oscillator generates the carrier wave signal. The audio-frequency signal and radio frequency signal are applied to the frequency modulator where the proper blending or mixing of both signals is effected.

The modulated signal produced at the modulator circuit is found to possess three frequencies fo, fc+fm and fc-fm. The fc+fm frequency band and the fc-fm frequency band were discovered to carry the same level of perfection concerning the modulating signal, hence, one of the two will have to be transmitted thus, the need to select the desired frequency band which is to be transmitted via the antenna.

1.1.4 AREA OF APPLICATION

The FM transmitter has many areas of application. Its limit is only a function of the user's imaginative power. Some of the common areas of application are indicated below.

1) Security application

2) Intercom application

3) Talking-piece of a walkie-talkie

4) Public address system (single voice-band PA system)

5) Mimicking a voice-transmitting radio station.

1.1.5 AIMS AND OBJECTIVES

The understated aims and objectives are pivoted to the design and construction of the 105MHz transmitter.

1) Development of indigenous engineering technology

2) Ensuring the development of basic project construction skills

3) Enabling us young engineers to put to practice what we learnt in the classroom

4) Help us appreciate the realities of what we studied during the course of our program

5) Help us student engineer's, perfect basic trouble-shooting techniques.

1.1.6 SCOPE OF THE PROJECT

The scope of the project includes the design and physical construction of a 105MHz FM transmitter.

The project is therefore limited to the design and construction of a 105MHz transmitter whose technology has application in television and radio stations.

CHAPTER TWO

2.1 FREQUENCY MODULATION

Frequency modulation utilizes the audio modulation signal to vary the frequency of the RF carrier. The greater the amplitude of the modulation frequency, the greater the frequency deviation from the central carrier frequency. The rate of the frequency deviation is the direct function of the frequency of the audio modulating signal. In the FM modulation, multiple pairs of sidebands are produced. The actual number of side bands that make up a modulated wave is determined by the modulating index (MI) of the system. The modulation index is a function of frequency of the system and the applied modulating system.

MI = Frequency deviation/ Modulating frequency.

As the MI increases these are more sidebands produced. As the modulating frequency increases for a given maximum deviation, there will be a smaller number of sidebands spaced at wider intervals. Unlike amplitude modulation, which has a percentage of modulation directly proportional to the carrier power; the percentage of modulation in FM is generally referenced to the maximum allowable occupied bandwidth set by regulation. For example, FM broadcast stations are required to restrict frequency deviation of +/- 75KHz from the main carrier. This is referred to as 100% modulation for FM broadcast stations.

To determine the frequency spectrum of the transmitted FM waveform, it is necessary to compute a Fourier series or Fourier expansion to show the actual signal component involved. This work is difficult for a waveform of this type, as the integrals that must be performed in the Fourier expansion or Fourier series are difficult to solve. The actual result is that the integral produces a particular class of solution that is identified as the Bessel Function.

Supporting mathematics will show that an FM signal using the modulation indices that broadcast systems will have a multitude of sidebands. To achieve no distortion, all sidebands would have to be transmitted, received, and demodulated. However, in reality, the +/- 75 KHz maximum deviations, which is used in FM broadcasting, allows the transmission and reception of audio with negligible distortion.

The power transmitted by an FM transmitter is virtually constant, regardless of the modulating signal. Additional noise or distortion of the amplitude of the waveform has virtually no effect on the quantity-received audio. Thus, FM transmitters may utilize class C type amplifiers, which cause distortion and allow greater power to be generated, but are inherently more efficient than the less amplitude distorting class A or class B types of amplifiers. In addition, atmospheric and man-made noise has very little effect, since the receiver clips all the amplitude variation off the signal prior to demodulation. This is why FM allows high fidelity with very low noise.

2.2 FREQUENCY MODULATION (FM) BROADCASTING.

The monophonic system of FM broadcasting was developed to allow sound transmission of voice and music for reception by the general public for audio frequencies from 50 to 15,000 Hz, all to be contained within a +/- 75-KHz RF bandwidth. This technic provided higher fidelity reception than was available with standard broadcast AM along with less received noise and interference. FM broadcasting in the U.S is allocated the 88-108 MHz frequency band.

Pre-emphasis is employed in an FM broadcast transmitter to improve the received signal-to-noise ratio. The pre-emphasis upper-frequency limit is based on a time constraint of 75 μs as required by the FCC for FM broadcast transmitters. Audio frequencies from 50 to 2120Hz are transmitted with normal FM; whereas audio frequencies from 2120Hz to 15KHz are transmitted are emphasized with a larger modulation index. There is a significant signal-to-noise improvement at the receiver, which is equipped with a matching **de-emphasis** circuit.

2.3 FM BROADCAST MODULATION TECHNIQUES

FM stereos was developed in 1961 to provide transmission capability for a left- and right- stereo audio signal. Stereophonic transmission is accomplished by adding left- and right- channel stereo information together in the baseband signal. In addition, a left-minus right is added and frequency multiplexed on a sub carrier of 38-KHz using double sideband suppressed carrier modulation. An unmodulated 19-KHz subcarrier is derived from the 38-KHz subcarrier to provide a synchronous detector at 38-KHz recovers the left-minus right channel information, which is then combined with left-plus right channel information in sum and difference combiners, produce the original left-channel and right-channel signals. The system works and, because the baseband mono signal is a combination of both left and right audio, provides full compatibility with monophonic FM receivers.

2.4 FREQUENCY ALLOCATIONS

The 100 carrier frequencies for FM broadcast range from 88.1 to 107.9 MHz and are equally spaced every 200 KHz. The channels from 88.1 to 91.9 MHz are reserved for education and non-commercial broadcasting, and those form 92.1 to 107.9 MHz for commercial broadcasting. Each channel has a 200-KHz bandwidth. The maximum frequency swing under normal conditions is +/- 75 KHz. Stations operating with SCA may, under certain condition exceed this level, but in no case exceed a frequency swing of +/- 82.5 KHz. The carrier centre frequency is maintained with +/- 2000 Hz. 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.

FM station classifications, powers and Antenna Heights

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

Table 2.1 FM station classifications.

2.5 TRANSMITTERS.

FM broadcast transmitters typically range in power output from 10W to 50W and have performance standards similar to specified above for AM broadcast transmitters Digital technology is being used extensively in the processing and exciter stages, allowing for precision modulation control, whereas solid-state devices are predominately used for RF drivers and amplifiers up to several kilowatts. High-power transmitters still rely on tubes in the final stages for the generation of RF power, but manufacturers are developing new devices and technology that will make high-power solid-state transmitters cost efficient and more reliable.

2.6 ANTENNA SYSTEM

FM broadcast antenna systems are required to have a horizontally polarized component. Most antenna systems, however, are circularly polarized, having both horizontal and vertical components. The antenna system, which usually consist of several individual radiating bays, is fed as a phase array mount-ed on a tower, has a radiation characteristic that concentrates the transmitted energy in the horizontal plane towards the population to be served, minimizing the radiation out into space and down towards the ground. Thus, the ERP towards the horizon is increased with the power gains up to 10-DP. That means that a 5-KW transmitter coupled to an antenna system with a 10-DP gain would have an ERP of 50 KW. The RF power is transferred to the antenna via the transmission line. At FM broadcasting frequencies and powers, coaxial transmission line is used, ranging in the size from 7/8in outside diameters to 3 in. the dielectric (the material between the inner and outer conductors in coaxial transmission lines) is foam or for air types, either dry air or nitrogen. These coax cables are not 100% efficient, and some are lost as heat in the line. The larger diameter air type cables have the least loss. The combination if transmitter power output (TPO), feedline loss, and antenna gain determine the actual ERP of the station. For a given ERP, a station must install a large, multi bay antenna with high gain and relatively low TPO or use a low-gain antenna and a high TPO. The choice is determined by a number of factors, including, service area, terrain in the area and economics.

The radiation pattern of a non-directional FM broadcast antenna system is designed to radiate equally well in all directions. However, when mounted on a tower as a support structure, the structure distorts the uniformity of the pattern, especially on towers with large cross-seminal dimension over 36 in. It is possible to optimise the omnidirectional pattern. The use of such elements allows an international directionalization of the pattern using additional parasitic elements to offset the effects of the tower and achieve a more circular pattern. The use of such elements also allows the intentional directionationalzation of the pattern to avoid interference with other station or to meet spacing requirements. In other to meet with FGC requirements, a directional FM antenna must meet strict standards. Figure 103.8 is a plot of horizontal and vertical components of a typical non-directional circular polarized FM broadcast antenna showing the effect upon the pattern caused by the supporting tower.

Figure 2.1 **Typical non-directional 92.5-MHz FM antenna characteristics showing the effect of the tower structure on the horizontal and vertical radiation patterns.**

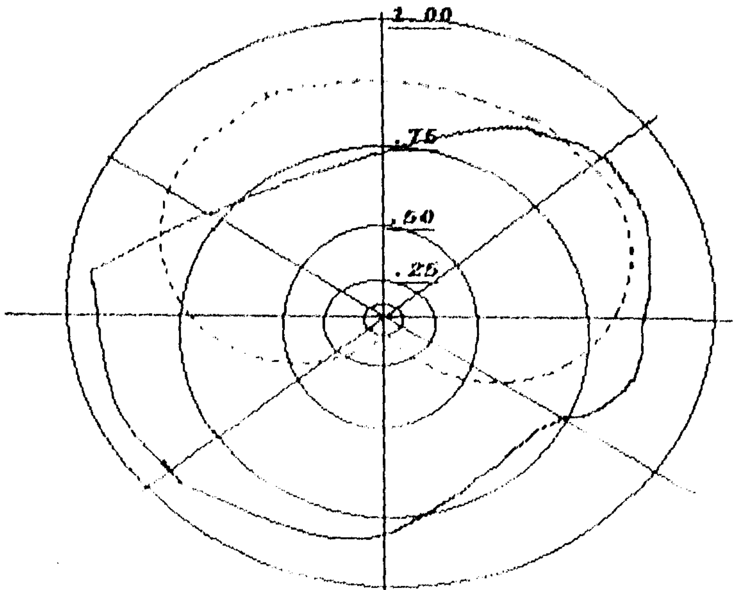


Fig 2.1 Typical non-directional 92.5 MHz FM antenna

Legend:

Horizontal =

Vertical =

CHAPTER THREE

3.0 REVIEW OF FM TRANSMITTER

FM TRANSMITTER DESIGN.

The design of the FM transmitter will be using the block diagram. The voice of a human being produces a signal voltage of the order of a few millivolts {mV} and something needs to it to enable effective communication in the audience of a larger number of people.

The block diagram consists of three basic stages namely; the pre-amplifier, the oscillator and the output power amplifier stage as indicated in fig (3.0)

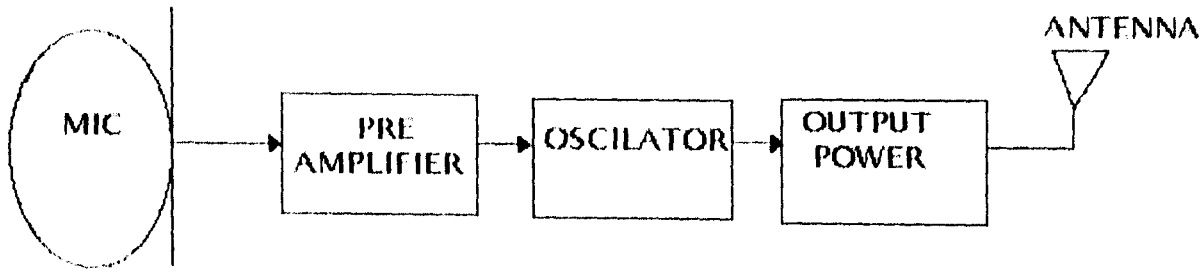


Fig 3.0 BASIC STAGES OF FM TRANSMITTER

3.1.2 INPUT STAGE/SOUND TRANSDUCER

A transducer may be said to be any engineering device that converts energy existing in one particular form to another form. A transducer can also be referred to as an energy converter. Table 3.1 below shows some transducers.

S/N	ENERGY TRANSITION	ENERGY COVERTER
1	SOUND VOLTAGE	MICROPHONE
2	VOLTAGE (electrical) to SOUND	LOUDSPEAKER
3	LIGHT to VOLTAGE	PHOTOCELL
4	LIGHT to RESISTANCE	LIGHT DEPENDENT RESISTOR & PHOTO RESISTOR
5	CHEMICAL to ELECTRICAL	BATTERY
6	MECHANICAL to ELECTRICAL	GENERATOR

TABLE 3.1 TYPES OF TRANSDUCERS

3.1.3 TYPES OF MICROPHONE

1. Dynamic microphone
2. High impedance Microphone
3. Carbon Microphone
4. Capacitor Microphone
6. Condenser microphone

The Microphone is the pickup of the system. As the name implies, it picks up the audio signal and converts it to electrical signal. It could be described as an electrical device whose electrical resistance varies in accordance with the waveform of the sound incident upon it. The input stage is essentially an audio/voltage transducer otherwise categorized as a sound-voltage energy converter as illustrated in the first row of the table (3.1). it converts the input audio frequency signal into electrical impulses, which subsequently is applied to the transmitter electrical board. For this particular project, the microphone shall be used as our input sound transducer. This device receives voice signal input and converts it to alternating voltage signal that is sent at its own frequency of oscillation to the RF oscillation. The electrical signal in the microphone is then coupled to the pre-amplified stage with a coupling capacitor.

The pre-amplifier receives the signal in the order of a few millivolts and amplifies it. The output of the amplifiers is at a higher level of the audio frequency signal level to the modulation. A copulating capacitor is also used in the coupling of the output of the pre-amplifier stage to the stage of modulating input.

The modulator receives the signal from the pre-amplifier stage and modulates by super imposing the audio frequency signal on a high frequency called the carrier frequency. For a signal to be frequently translated to another part of the frequency spectrum, it is necessary for the signal to vary one of the characteristics of a sinusoidal wave, usually known as carrier wave whose frequency occupies the required part of the spectrum. The process by which one of the characteristics of a carrier wave is modified in accordance with the characteristics of a modulating signal is known as modulation. An oscillator generates the modulation frequency. It will then be of importance to know what an oscillator is, and it is defined as follows: an oscillator is an electronic circuit that has been designed to produce an alternating e.m.f of known waveform. It could also be described as an amplifier that provides its input signal, the input signal being derived from the output signal as seen below.

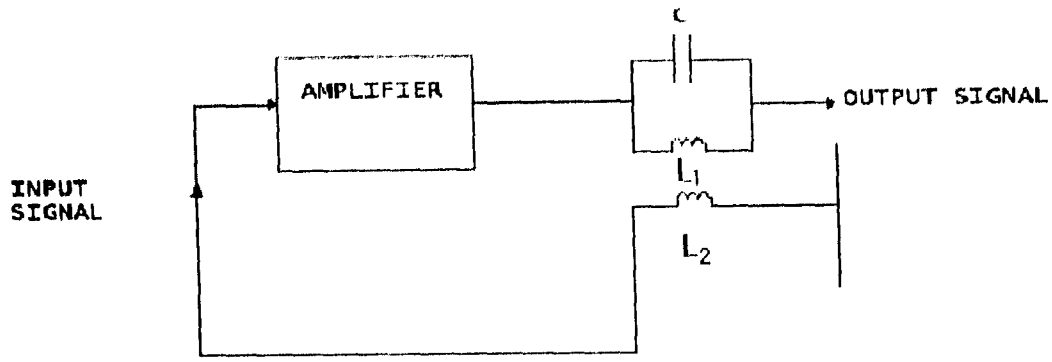


Fig (3.1) THE PRINCIPLE OF AN OSCILATOR

Where c is a capacitor L1 & L2 are inductors

3.1.4 R.F. OSCILLATOR

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.

3.1.5 OSCILLATION

Oscillation is a very important process to the communication engineering industry. The most common method of generating signal is via oscillation circuit.

The need for oscillation is on a very wide spectrum and many electronic equipments/gadgets make use of oscillation in one form or the other.

3.1.6 CHOICE OF OSCILLATORS.

There are many types of oscillators in use. The choice of a particular one is based upon the under listed factors.

1) Purity of output
2) Frequency stability
3) Frequency operation
4) Output Amplitude.

3.1.7 CONDITIONS FOR OSCILLATION

For many oscillators, the under listed conditions must be satisfied other wise 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 input 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.

3.1.8 TYPES OF OSCILLATORS

1. Multi-Vibrator
2. Phase-Shift Oscillator
3. Hartley's Oscillator
4. Crystal Oscillator
5. Transistor Oscillator: One stage R-C coupled Amplifier oscillator.

Collpits Oscillator.

6. Collpits Oscillator

3.1.9 WAVE/SIGNAL PARAMETER THAT CAN BE MODULATED.

1) Amplitude: This may be said to be the maximum displacement of a signal from its zero position on the Cartesian graph.
2) Frequency: This is defined as the number of cycles that the wave/signal can successfully complete in a second. A frequency metre measures it and its standard unit is Hertz (Hz), Kilo Hertz (KHz) Mega Hertz (MHz) and Giga Hertz (GHz) respectively.

   The frequency modulation stage is a very important module because it does the mixing of the RF oscillating signal and incoming oscillating signal. It is at this stage that the actual enveloping of the modulating signal by the carrier signal is effected. Depending on the types of modulation involved, a particular parameter of the carrier wave is varied in accordance with the frequency of the modulating signal, then the frequency modulating technique are at work.

3.1.10 ADVANTAGES OF FM OVER AM.

1. FM is used for sound broadcasting in the VHF band
2. FM is used in sound signal 625-line television broadcasting.
3. It is useful in multi-channel telephony system operating in UHF band.
4. It is also useful in mobile communication systems.
5. Suppression of ground noise
6. It has very good modulating index.

Modulating index = Ratio of frequency deviation to Modulation frequency.

Frequency deviation = $\frac{(KF(t))}{2\pi}$

Where F(t) = high frequency signal

K = constant

$\pi = 22/7$.

In summary, modulation may be defined as the process whereby signals which naturally occur in a given frequency band (known as the base band) are translated into another frequency which is characteristic of the transmission machine that is the channel modulation translates signal from there base band into frequency spectrum associated with a carrier frequency.

If the given carrier wave is a sinusoidal waveform of frequency (Fc) and arbitrary phase and amplitude.

The carrier is defined as:

$C(t) = A \cos [2\pi f(c) + \Phi]$.

Where A = signal/carrier Amplitude.

Fc = carrier frequency.

Φ = carrier phase angle.

The oscillator is then coupled to the output power amplifier. The radio frequency (RF) power amplifier processes the signal via a coupling capacitor and amplifies it. Another coupling capacitor couples the radio frequency signal to the antenna where radiation takes place. The signal is radiated into the atmosphere in form of electromagnetic wave. The quality and size of the antenna influences the radiation per antenna.

3.1.11 ANTENNA

An antenna may be defined as a structure usually made from a good conducting material that has been designed to have a shape and size that will radiate electromagnetic power in an efficient manner.

It is a well-established fact that time-varying currents will
radiate electromagnetic waves. Thus, an antenna is a strut on which time-varying currents can be excited with a relatively large amplitude when the antenna is connected to a suitable source usually by means of transmission line or wave guide.

There are almost endless varieties of structural shapes that can be used for an antenna. However, from a practical point of view, those structures that are simple and economical to fabricate are the one most commonly used. In other to radiate effectively, the minimum size of antenna must be comparable to the wavelength. It is apparent from these considerations that the size of radiations required is inversely proportional to the frequency. Every radiator has directional characteristic, as a result of which it send out stronger waves in certain direction than in the other.

3.1.12 SOME BASIC ANTENNA PARAMETERS

1. RADIATION PATTERN: The out word movement of the wave from the source is called Radiation. There are two main types of field.

   I. The induction field: The majority of this field exist mainly near the source.

   II. The radiation field: This exists some distance away from the source i.e. it means that although it stands as minority, its spreads much far away from the source where it is very much a majority.

2. Gain: Antenna gain (G) is defined as the ratio of maximum radiation intensity to max. Radiation intensity from reference antenna with some power inputs.

$G = KD$

Where D = directivity, is defined as the ratio of max. Radiation intensity to the average radiation intensity.

D = max. Radiation intensity ÷ Average radiation intensity.

3.1.13 TYPES OF ANTENNA

1. Low Frequency Antenna: This applies to aerial antenna that operates with systems operating at less than 300 KHz frequency of operation. The aerial / Antenna

system are normally restricted to vertical radiators of relatively simple form supported by two or more wires or mast that are electronically short.

2. Medium Frequency Antenna: These antenna embraces those that are used between 300KHz and about 1MHz. Most medium frequency aerial had been constructed in form of a "T" arrangement of conductors suspended between, but insulated from the towers.

3. Ultra-High Frequency Aerial: Radio transmitters operating at UHF can employ relative small size that produces a small narrow beam of radiation.

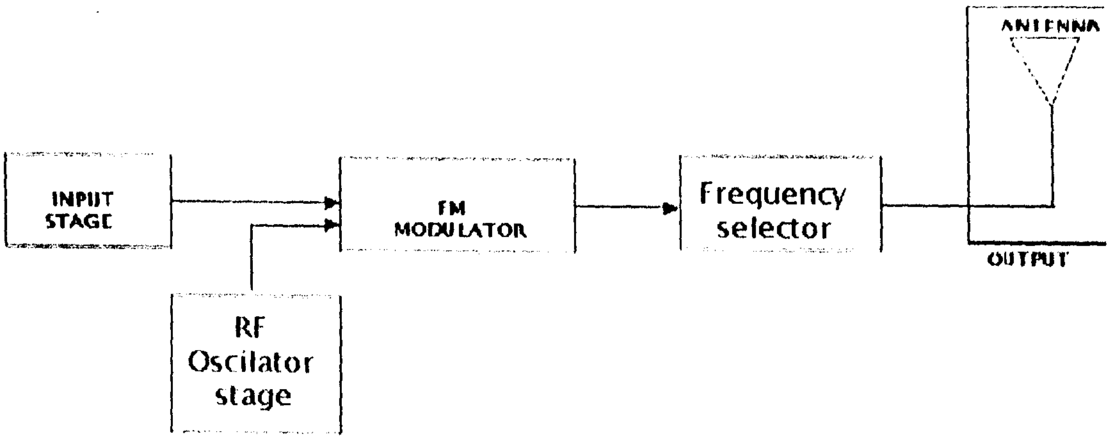


Fig (3.2) Simplified Block diagram of FM Transmitter

CHAPTER FOUR

4.0 ANALYSIS

For the purpose of our design and construction of 105MHz, 1 WATT, 300 METRES range FM transmitter, the block diagram in the fig below is to be used.

4.1.0 BLOCK DIAGRAM OF FM TRANSMITTER

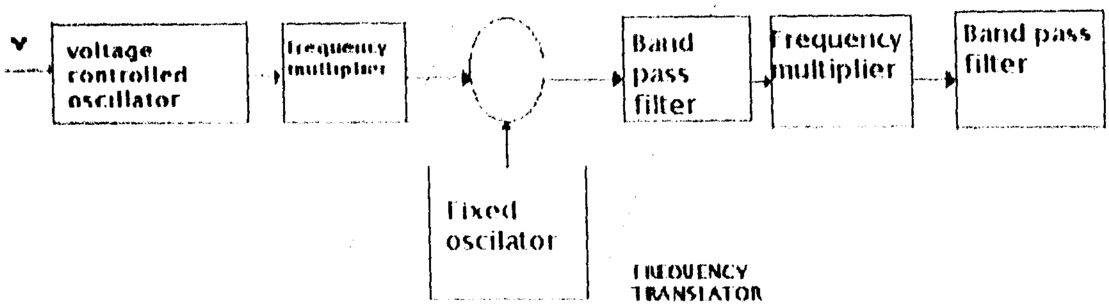


Fig 4.0 BLOCK DIAGRAM OF FM TRANSMITTER

Frequency modulator for communication and telemetry purpose generally fall into the category of what may be termed "hard" oscillator having relatively high-Q frequency-determining networks, or they fall into category of "Soft" oscillator having supply and bias sources as the frequency-determining networks. Examples of each are shown below;

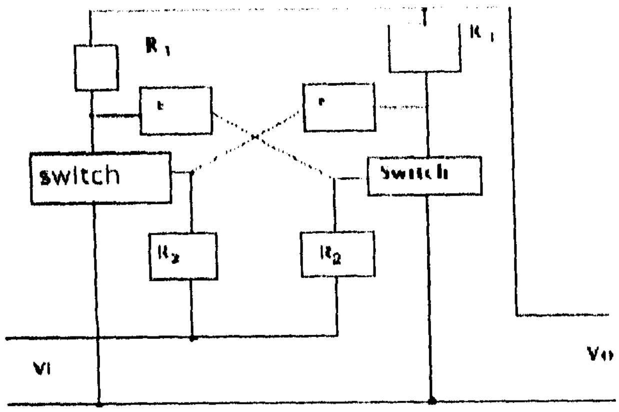


Fig 4.1a[Soft oscillator]

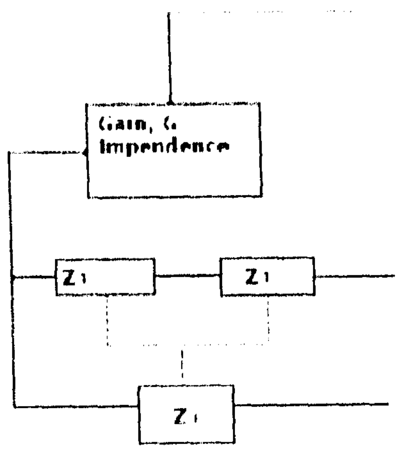


Fig 4.1b [Hard oscillator]

Control of hard oscillator is executed by symmetrical incremental variation of reactive components. For the case of a Hardtley Oscillator, Z1 and Z2 are inductors and Z3 is a capacitor, allowing the use of varicaps paralleling Z3 as the voltage controllable reactance. In such a case,

$$F_o = \frac{1}{2\pi[C_3(L1 + L2)]^{1/2}}$$

Where C_3 is the total capacitance of the variable and fixed capacitor of Z_3.

Note that the frequency-depending impedances of the network determine the bandwidth of the modulator, i.e. the overall Q and centre frequency. In view of the need of certain minimum bandwidth requirements, and the need for oscillator stability, the total frequency deviation required is sometimes obtained by following the oscillator with a series of frequency multipliers and frequency translator as shown in the block diagram. This configuration permits the attainment of good oscillator stability, constant proportionality between output frequency change and input voltage, and the necessary modulation bandwidth to achieve a wide band FM.

Control for the soft oscillator is introduced as a change in the switching level of active device switches. The frequency of transistor version of the oscillator is, roughly,

$$F = \frac{1}{2R1C \ln[1 + V1/V2]}$$

Since this type of oscillators is a relaxation oscillator, the rate at which the frequency of the oscillation can be changed is limited only by the rate at which the switching points can be altered by voltage control. Modulators of this kind can be designed with bandwidth greater than the frequency of oscillation. The disadvantage of such network is the relatively poor frequency stability compared with the high-Q hard oscillators.

For the purpose of this project, we shall be using "Hard Oscillators".

4.1.1 FUNCTION OF THE RESPECTIVE BLOCKS

In practice, Vi is the input signal (i.e. voice) and might need to be amplified depending on the requirements of the design. For simplicity, one might work on the Vi without amplification first, but the signal level when viewed through an oscilloscope will determine whether such amplification is necessary or not. Based on the requirements of this project, in the terms of power output (i.e. 1 Watt). The amplitude of the signal from the microphone is about 10-50mV.

1. THE VOLTAGE CONTROLLED OSCILLATOR (VCO)

This is an oscillator whose output frequency is a function of the input voltage. It could be linear or non-linear as the case may be.

2. FREQU8ENCY MULTIPLIER

This is a circuit having a non-linear device designed to multiply the frequencies of the input signal by a given factor. For the purpose of this project, we shall employ a simple one-stage transistor circuit, biased in class C to function both voltage controlled oscillator and frequency multiplier as well.

3. THE FIXED OSCILLATOR.

This is a circuit that changes its state at regular intervals or a circuit that oscillates at a fixed or constant frequency

4. THE MIXER

This is a circuit or device that combines two or more range of frequencies to give a common range of frequency. In this particular case, it combines the output frequencies of the fixed oscillator with that of the frequency multiplier to produce lower and higher frequencies.

5. BANDPASS FILTER

This is a device or circuit that allows or passes a particular range of frequencies and blocks or alternates the rest frequencies.

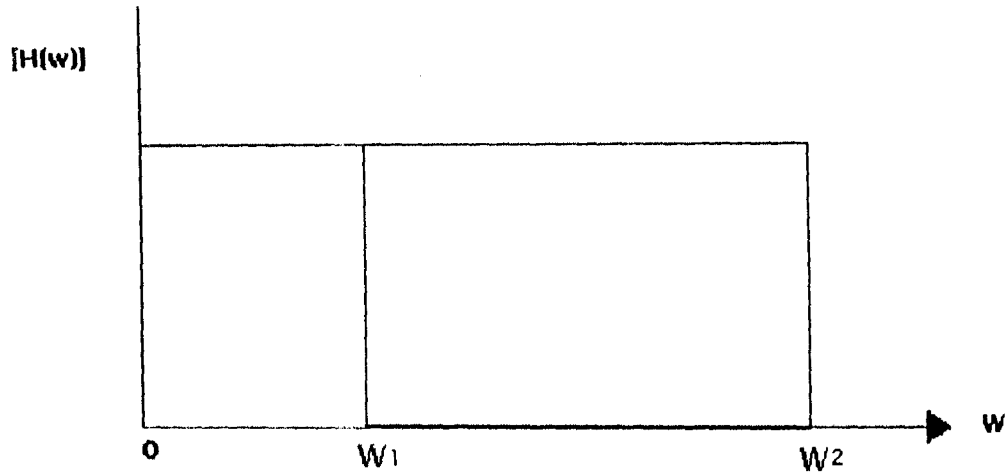


Fig 4.2 BAND PASS FILTER (IDEAL CASE)

The combination of mixer, fixed frequency oscillator and the band pass filter as arranged in the block diagram function as a frequency translator.

For the purpose of this project, portability, simplicity and clarity of the received transmitted signal is of primary concern. So, a single stage transistor circuit will be used to execute the function of voltage-controlled oscillator and the first frequency multiplier. Another single transistor circuit will be used to do the work of the second frequency multiplier while a passive band pass filter will be used at the output.

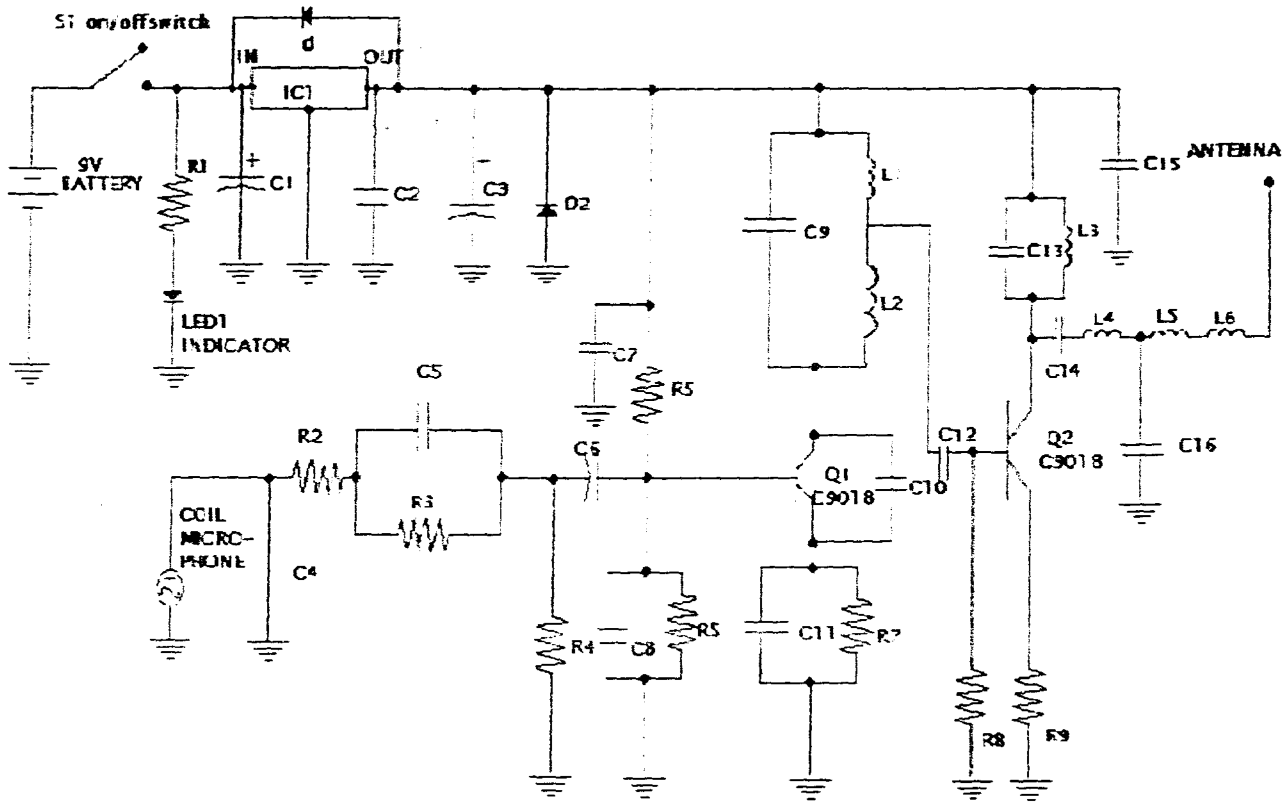


Fig 4.3 COMPLETE CIRCUIT DIAGRAM OF AN FM TRANSMITTER.

The frequency translation circuit (i.e. mixer, fixed oscillator and first band pass filter) may not be employed in this circuit for simplicity and economical purposes but rather good stability will be achieved by careful selection of components and its arrangements on the circuit board as well as stable and regulated power supply.

4.1.2 POWER SUPPLY ANALYSIS

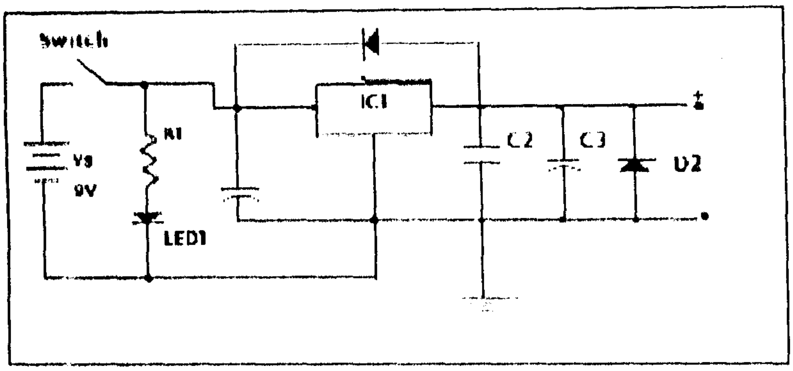


Figure 4.4 Power supply unit

The transmitter power output is 1 Watt. The power supply provides a +5Volts at 400mA, which gives a power output of 2-Watts such that there is always excess (1 Watt) power for transmitter circuit. IC_1 = 78M05, C2 cancels the effect of inductance in the leads stability, C2 = 0.01μF (ceramic type). C3 removes ripples from the DC output current (i.e. filters the output) and stores the current in the form of charge such that the circuit will not be starved of adequate current when it needs it most and consequently reduces variation of the output current.

C3 is chosen to be 10μF/10v.

C1 is taken to be 100μF/16v, which serves as a reservoir for the regulator (i.e. IC1).

D1 and D2 send DC transient or oscillations whose amplitude are greater than the input voltage back to the input terminal thereby protecting IC1 from being damaged and biased the opposite polarity. The power dissipation ($P_{dissipation}$) of the IC is given by

$$(P_{dissipation}) = (Vin-Vo)*I_{L}$$

$$= (9-5)*400*10 \text{ Watts}$$

$$= 1.6W$$

Therefore IC1 will need a heat sink for cooling. LED1 is used as the ON/OFF INDICATOR".

R1 limits the current flowing into LED1.

From the specification of LED1, maximum forward current I_F of LED1 = 35mA. Therefore let normal forward current of LED1 = 10MA.For the worst case, the internal resistance of LED1 = 0Ω. Therefore using ohm's law,

$$R_1 = \frac{V_S - V_F}{\text{Normal forward current of LED1}}$$

But V_S = 9v (battery powered), for simplicity and portability V_F is approximately equals 2.0v-2.5v. Normal forward current of LED1 = 10mA

⇨ $$R1 = \frac{9-2}{10*10^{-3}} \ (\Omega)$$

R1 = 700Ω. Therefore R1 = 680Ω (preferred value)

Power dissipation on R1 will be $P_{R1} = \frac{(V_S - V1)^2}{R1}$ (watt)

$$\frac{(9-2)^2}{700} = 0.07 \text{ Watt}$$

Therefore, R1 = 680Ω, 0.25 Watt Carbon resistor. SI is used as ON/OFF switch that switches the circuit ON and OFF and saves the current form the battery from running down when the transmitter is not in use.

B1 is a 9v battery (type 6F22)

4.1.3 OSCILLATION FREQUENCY COMPUTATION

Q2 has a resonant tank circuit whose frequency is given by

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

$$F = \frac{1}{2\pi\sqrt{L3C13}}$$

$$F = \frac{1}{4\pi^2 C13F^2}$$

Let C13 = 10PF, f = 105MHz,

$L_3 = 0.229\mu H$

$L_3 = 0.229\mu H$ is an adjustable air core inductor. C15 removes the inductance form the leads (cable) by balancing it's effect. C15 is chosen to be 0.01M(Ceramic capacitor). For good output frequency stability, the oscillator frequency of the voltage-controlled oscillator (Vco) built with Q1 should be (1/3), one third of the output frequency.

Output frequency = 105MHz

Therefore, Vco frequency = 105/3 = 35 MHz.

Let L1 + L2 (Series connection) = L

$$F_{vco} = \frac{1}{2\pi\sqrt{LC9}}$$

But Fvco = 35MHz, let C9 = 18pf

$$L = \frac{1}{4\pi^2 C9 F^2}$$

L = 1.14876μH.

L1 and L2 form basically AC voltage divider, preventing excess AC signal from getting into Q2 there causing hums when there is no signal coming from the microphone.

Let L1 & L2 divide the AC voltage into the ratio 1:3. The excess of it, if any could be compensated by proper selection of C_{12}.

$$\frac{L1}{L1+L2} = \frac{1}{3},$$

L1 + L2 = L

Therefore,

$$L = \frac{1.1487}{3}\ \mu H$$

1.1487H = L

L1 = 0.382922 μH

$$L_2 = L - L_1$$

$$= 1.14876 - 0.0389922\,H$$

$$= 0.765838\,\mu H.$$

C10 forms a feedback that feeds some of the energy in the output back to the input to compensate for the energy lost as heat, by so doing, the oscillation is sustained.

Making the C10 too small does not sustain the oscillation while making it too big sustains the oscillation but reduces the signal level of the Vco output since most of the energy is fed back to the circuit thereby causing unacceptable distortion in the output. C10 is chosen to be 18pF, C10= 18PF

4.1.4 MICROPHONE INPUT STAGE

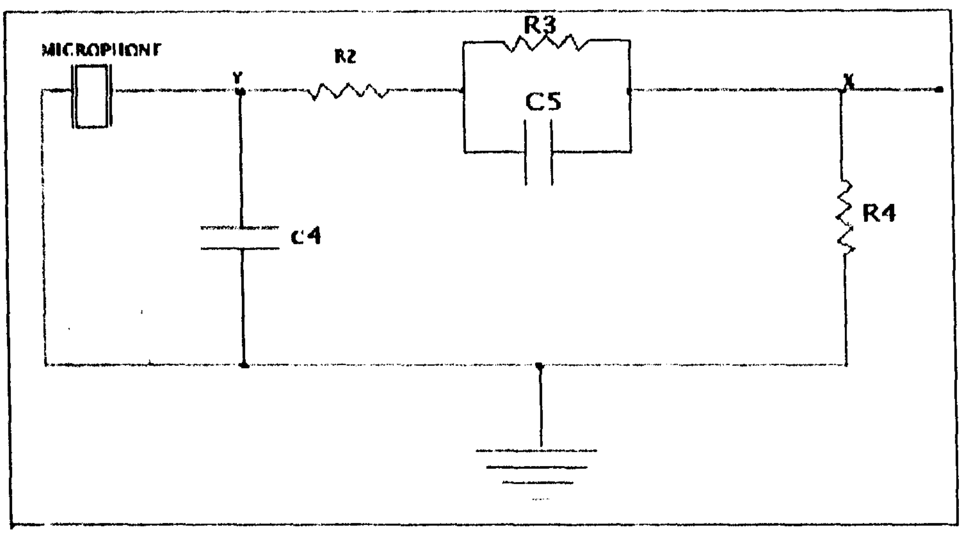


FIG 4.5 Microphone input stage Note; coil microphone impendence is 600Ω

It is desired that the microphone input sub-circuit allows frequency in the range 1.2KHz to 6.2KHz to pass through the reach of the Vco. This range of frequencies has been proved to give good speech quality.

The parallel combination of R3 and C5 forms a low pass filter (LPF) whose cut-off frequency is set to 1.2KHz. This attenuates the input signal by 20Db.

$F_{L1} = 1/2\ R_3C_5$, $F_{L1} = 1.2KHz$

Let $C_5 = 0.0047\mu F$

This implies, $R_3 = 1/2\lambda F_{L1}C_5$

$= 28.218K\Omega$.

$R_3 = 27\ K\Omega$. (Preferred value).

Similarly, let the series combination of R_2, R_3 AND R_4 be R. The parallel combination of C_4 and R attenuates the signal at 6.2KHz frequency by 20dB, thereby making it difficult for signals above 6.2 KHz to reach the Vco.

$$F_{L2} = \frac{1}{2\pi RC_4}$$

$$C_4 = \frac{1}{2\pi FL_2R}$$

$= 3.29*10^{-10}$

C4 approximated $0.00033\mu f$.

Also C4 increases the input impedance as seen by the Vco. Taking a typical speech signal to be in the neighbourhood of 1.2KHz, the parallel combination of R3 and C5 has an impedance of

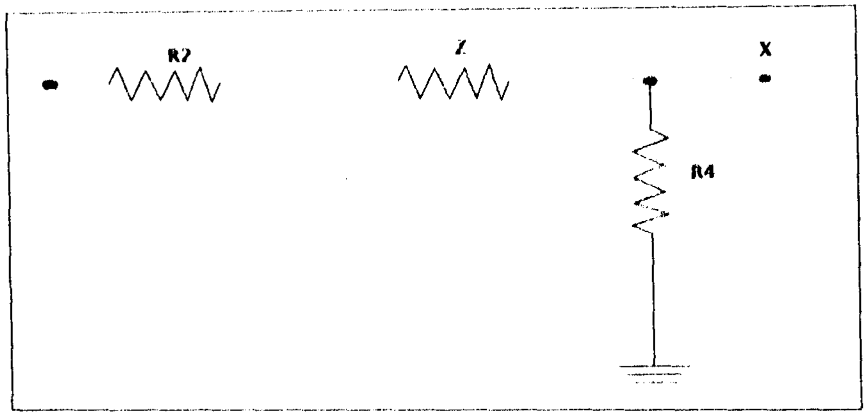
$$R3 \parallel XC5 = \frac{R3.XC5}{R3+XC5}$$

$$XC5 = \frac{1}{2\pi FC}$$

R3//XC5 = R(1/2πFC5)/(R3+1/2πFC5)=R3/(1+2πFC5R3)=2.8*10⁴ Ω

R2, ZR3 $\parallel$ C5 and R4 form a voltage divider. This shows that basically, R2 and R4 is what determine the voltage applied to the Vco.

Let Z1 = R3 $\parallel$ XC5 = 2.8*10⁴ Ω.



$$\frac{Vx}{Vy} = \left[\frac{R}{R2+Z1+R4}\right]$$

Let 95% of the voltage Vy at point y reach X.

$$\frac{Vx}{Vy} = 0.05 = \left[\frac{R}{R2+Z1+R4}\right]$$

$$R4 = 0.05R2 + 0.05Z1 + 0.05R4$$

$$R4\,[1-0.05] = 0.005R2 + 0.05Z4.$$

$$0.9R4 = 0.05R2 + 1400.$$

$$R4 = 0.023R2 + 1473.7.$$

Let R2 = 3.3kΩ. (Not too big to attenuate the speech signal).

$$R4 = (0.023 * 3300) + 1473.7$$

R4 = 1.5KΩ. (Preferred)

4.1.5 DC ANALYSIS OF Vco

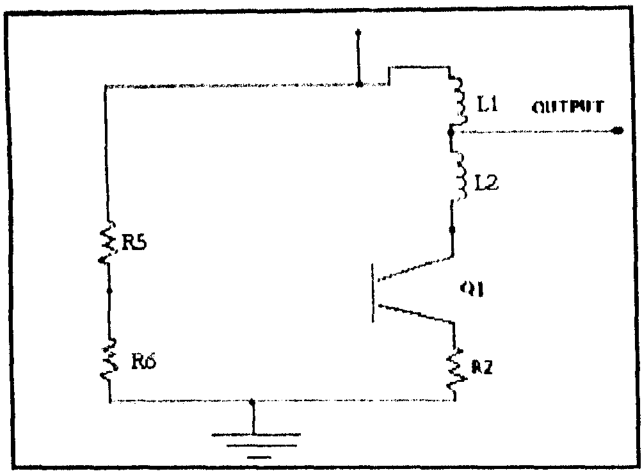


Fig 4.6 Analysis of Vco

Let V_{BE} (ON) of Q1 (silicon transistor) = 0.06V

Because resistance of L1, L2 approximates 0Ω at dc, $V_c = V_{cc} = 5V$

$V_{CE} = 4.67V$

$V_{cc} = 5.00V$

$V_E = I_E R_7 = V_{cc} - V_{CE}$

$= 5.00 - 4.67$

Therefore $V_E = 0.33V$

$V_B = V_{BE}(ON) + V_E$

$= 0.6 + 0.33$

$= 0.93V$.

But $V_E = I_E R_7 = 0.33V$

Let $R_7 = 120\Omega$.

This implies, $I_E = 0.33/120 = 2.75mA$

$I_C + I_B = I_E$ and $I_C = h_{FE} I_B$

This implies $h_{FE} I_B + I_B = I_E = I_B (h_{FE} + 1)$

$I_B = I_E / (h_{FE} + 1)$

$I_B = 2.75 * 10^{-3} / (200 + 1)$, therefore $I_B = 0.01368mA$

Also, $V_B = IR_6$

$IR_6 = 0.93V$.

Let R6 47KΩ

This implies $I = 0.93/47000$

$I = 0.01979mA$.

$V_{CC} - V_B = R_5 (I_B + I)$

$5 - 0.93 = R_5 [(0.0197 * 10^{-3}) + (0.01368 * 10^{-3})]$

$4.07 = 0.03347 * 10^{-3} R_5$

$R5 = 4.07/0.03347 * 10^{-3}$

$= 121.6K\Omega$, approximately 120Ω (preferred value)

Let F_L set by R_7 and C_{11} be half the Vco output.

This implies $F_L = 35$ MHz/2 = 17.5MHz.

$F_L = 1 / 2\Pi C11R7$

$R7 = 120\Omega$, $F_L = 17.5MHz$

$$C11 = \frac{1}{2\pi F_L R7}$$

$= 75.78PF$. C11 = 82pF (preferred value).

C_7 cancels the effect of inductance in the power supply leads. C7 is chosen to be 0.01F (ceramic type). C_6 together with the parallel combination of R_5 and R_6 forms a high pass filter whose cut-off frequency (FC) is set by the value of C_6, R_5 and R_6 respectively (ignoring the high-input impendence of transistor).

$$R6 \| R5 = 47K\Omega \| 47K\Omega.$$

$$= \frac{(47000)(47000)}{(47000) + (47000)}$$

$= 23.5K\Omega$

Let Fc = 10Hz so that every frequency that comes out of the microphone input circuit will reach the Vco.

This implies that, $Fc = \frac{1}{2\pi Fc[R5 \| R6]}$

$$C6 = \frac{1}{2\pi Fc[R5 \| R6]}$$

$$= \frac{1}{2\pi * 10 * 2.35 * 10}$$

$= 0.67726\mu F$

$= 0.68\mu F$

Therefore, $C6 = 1\mu F$

4.1.6 DC ANALYSIS OF FREQUENCY MULTIPLIER

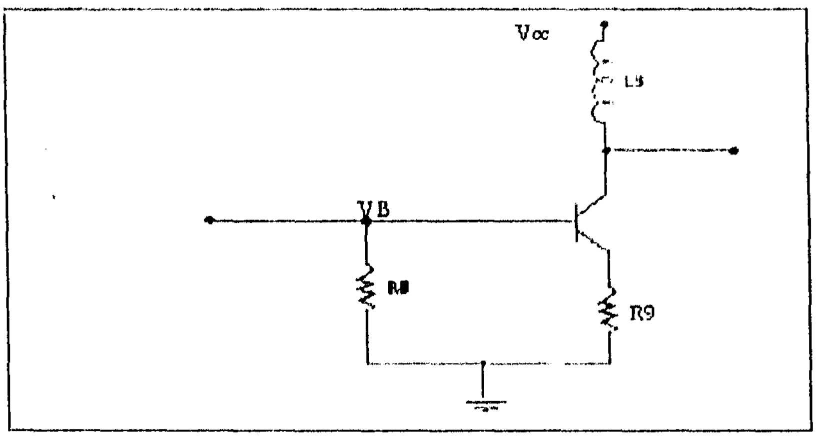


Fig 4.7 DC analysis of frequency multiplier

Q2 is biased by Vcc at cut-off.

$V_B = V_{BE} + V_E$

$I_B R_8 = V_{BE} + I_E R_9.$

$V_{BE} = I_B R_8 - I_E R_9..$

But $I_B + I_C = Ie = I_B h_{fe}$

This implies, $V_{BE} = I_B R_8 - R_9 (Ib + I_B h_{fe})$

$= I_B [R_8 - R_9 (1 + h_{fe})]$

$\frac{VBE}{I_B} = R_8 - R_9 (1 + h_{fe})$

Let Vbe = 0.6V, and Ib = 13.0mA[Big enough to send adequate collector current to give an output power of 1 Watt minimum].

$R_8 - R_9 (1 + h_{fe}) = \frac{0.6V}{13.0 * 10^{-6} A}$

$R8 - R9 (1 + h_{fe}) = 46153.85$

Q2 = C9018

This implies, $h_{fe} = 200$ typical

R8 – R9 (1 + 200) 46153.85

R8   201R9 = 46153.85

Let R8 = 47000Ω,(i.e. 47KΩ)

47000 – 201R9 = 46153.85

201R9 = 47000 – 46153.85

$$R9 = \frac{846.454}{201}$$

= 4.209720647

= 4.2Ω

Since

$$F1 = \frac{1}{2\pi C12R8}$$

Let F1 be 1/500 part of the output frequency [ratio of the output frequency to F1 should be in this range].

R8 = 47KΩ(already computed)

This implies that $C_{12} = \frac{1}{2\pi F1.R8}$

= 2π *210 10³ *47000

= 16.125 *10⁻¹² F

Therefore C12 = 20pF(Large enough to base Q2 to operate as class C amplifiers

4.1.7 ANTENNA MATCHING CIRCUIT/ OUTPUT FILTERING CIRCUIT

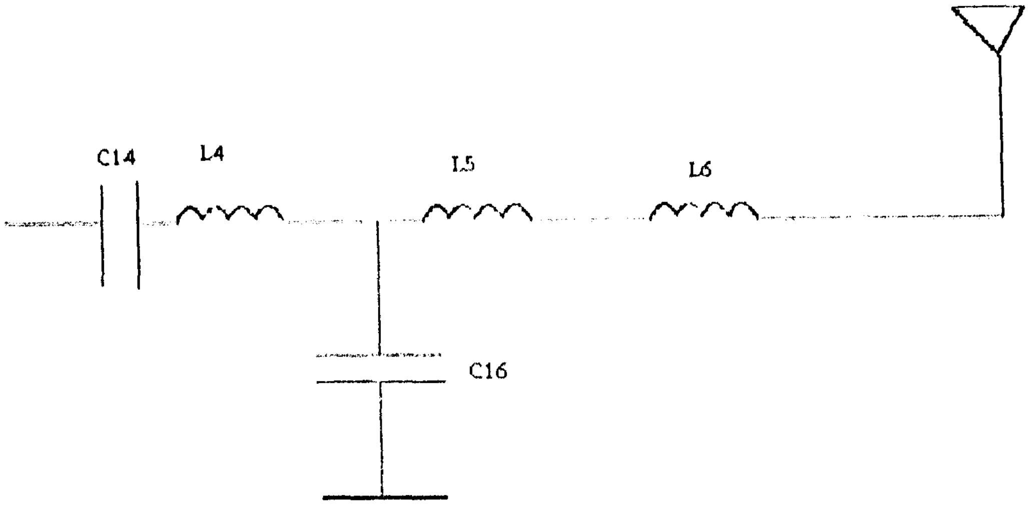


Fig 4.8 Antenna Matching circuit

Let L5 and L6 = L

L augments the impedance of the antenna used as seen by the frequency multiplier circuit. Let the impedance presented to the circuit multiplier circuit be 300Ω. The Antenna to be used is a straight pole of about 20cm in length whose impedance is 2Ω. Even if the impedance of the antenna used falls to zero Ohms (worst case), Let L has an impedance of 300Ω.

$X_L = 2\pi FL$

$L = X_L / 2\pi F$

$= 300/2\pi * 105 * 10$

$= 0.45\mu H.$

$L5 + L6 = 0.455\mu H$

Let L5 = 0.196μH

L6 = L – L5

⇒ = 0.455 – 0.196(μH)

L6 = 0.259 μH.

The number of turns of wire used, diameter and length of the turns; C_{14}, L_4 and C_{16} combination forms a filter that alternates the output signal, thereby restricting the output signal from exceeding the specified range given (i.e. 300m in this case). The values of the C_{14}, L_4 and C_{16} are determined experimentally using an FM receiver positioned at 300m distance while monitoring the clarity of the received signal as well as the loudness.

C14 = 5pF

C16 = 30pF

L4 = 0.131μH.

CHAPTER FIVE

5.0 RESULTS PROBLEMS AND CONCLUSION

5.1.1 RESULTS

The testing circuit was built on a breadboard. The power supply unit with a power source of 9V battery {type 6F22} was built. IC1 {78M05} was to regulate a voltage of 5V. The voltage controlled oscillator was then added and the Vbe {ON} 0.6V and 4.67V respectively.

Frequency multiplier stage was built and the voltage across the terminal of the transistor Q2 was also taken as V_{BE} {ON} 0.6V. The antenna stage was added and placing an FM receiver at a 300m position monitored the clarity and loudness of the received signal. Signal strength was not measured due to non-availability of Field strength meter which measures the signal strength in millivolts Per meter. To achieve the specified area of coverage, an FM receiver was positioned at 300m distance while the values of the capacitors {C14},{C16} and inductor {L4} were varied by removing and replacing with new values while monitoring the clarity and loudness of received signal. These components as shown in fig.4.8 attenuate the output signal by restricting it from exceeding the specified range {300m}. The result obtained is shown in table 5.1.

Stage	I	II	III	IV
C14 {pF}	3	4	5	6
C16 {pf}	20	30	30	36

L4 {μH}	0.12	0.13	0.13	0.13
Observation	Not clear	Clear	Very clear	Clear

Fig 5.1 Test for clarity and loudness

Loudness and clarity was obtained between stage II, III and IV with the best at stage III. The distance was measured with measuring tape in meters. The final construction was done by transferring the components from the breadboard unto a Vero board and soldered neatly and carefully it was housed in a wooden casing with the following dimension: length =12.5cm, height=4.5cm, and width=9cm.The completed FM radio transmitter was able to produce the desired signal. The range of frequency of transmission was also achieved at 104.85MHz to 105.25MHz within the specified area of coverage.

5.1.2 PROBLEMS AND SOLUTIONS.

At the initial stage of building the circuit, there was no result due to contact and when reconstructed by cleaning the tips of all wires used, there was continuity.

During the course of carrying out this project some other problems encountered include: -

1. Suitability of the components: - This was due to the fact that some components had to be changed several times for the signal to be well received.

2. Cost: - The cost of realizing the design of this radio transmitter can be analysed not only in terms of the funds spent, but also on the time and labour involved in the procedure.

5.1.3 CONCLUSION AND SUGGESTION FOR IMPROVEMENT.

In fact, the aim of this project has to design a 105MHz FM Transmitter capable of converting 300 meters with power of 1 Watt.

From the designed specification, the band at which the FM transmitter is between 104.7- 105.2 MHz range with the best at 104.8 MHz.

However, there is need for improvement in the area of the signal clarity at the receiver-end; and the distance covered i.e. the diameter or radius of coverage, for any one intending to work on this or similar project.

The transmitter can be operated using dry leclanché cells (Direct current), which enables the radio to be used in local areas, where an A.C. mains is not available.

LIST OF COMPONENTS

IC1 – 78m05

Capacitors

C_1- 100µf/16v

C_2- 103pf

C_3- 10µf/10v

C_4- 331 pf

C_5- 0.0017µf

C_6-1µf

C_7-103 pf

C_8-102 pf

C_9-47 pf

C_{10}-39 pf

C_{11}-8.2 pf

C_{12}-20 pf

C_{13}-10pf

C_{14}-5pf

C_{15}-103pf

C_{16}-30pf

RESISTORS

R_1 680Ω

R_2 3.3KΩ

R_3 27KΩ

R_4 1.5KΩ

R_5 120KΩ

R_6 47KΩ

R_7 120KΩ

R_8 47KΩ

R_9 4.7KΩ

INDUCTORS

l_1 0.38μH

l_2 0.766μH

l_3 0.229μH

l_4 0.134μH

l_5 0.196μH

l_6 0.289μH

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