DESIGN OF A FM TRANSMITTER AND RECEIVER OPETATES AT 90 MHZ

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ABSTRACT

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Frequency modulation is used for sound broadcasting, mobile and radio relay systems in the VHF, UHF and SHF bands respectively. Efficiency and bandwidth of FM signal depends on maximum modulating frequency and modulation index. FM offers better efficiency in terms of bandwidth and immunity to noise when compared with AM and PM. Though the side-band structure is quite complex but the efficiency is normally enhanced by making the bandwidth larger. A tradeoff is made between efficiency and performance. The modulation index can be varied based on the application. This paper attempts to design a 90 MHz FM transmitter and receiver that can be used for FM radio system.

Key words: frequency modulation, transmitter, receiver, wireless communication

INTRODUCTION

BASIC SYSTEM

Frequency is a technique of representing data onto an AC waveform by changing the instantaneous frequency of the modulating signal.
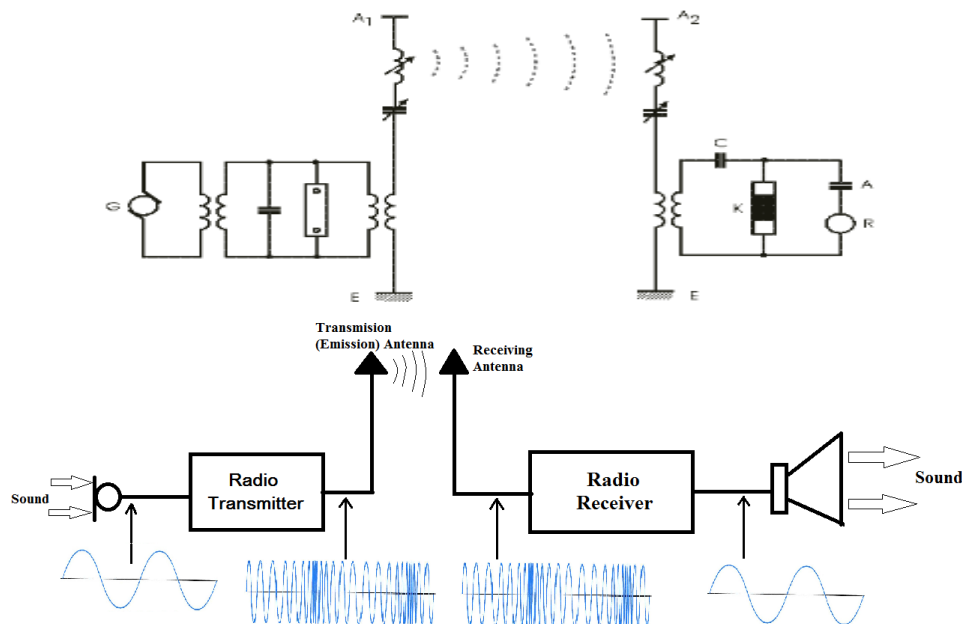

Fig. 1. Basic System of Radio Engineering

Frequency modulator is that particular electronic circuit that generates frequency modulated signal. This device modifies the frequency coming from an oscillator with respect to the information signal's amplitude. Frequency changes proportionally with the change in amplitude if the modulation is linear.

Oscillator operates in higher frequency generally use either inductance-capacitance tuned circuits or piezoelectric crystals to generate carrier. By changing the value of capacitance or inductance frequency can be tuned in accordance with the modulating signal. Typically, varactor diode is utilized to change the frequency in accordance with the information signal.

To obtain precise control over the carrier frequency, piezoelectric crystals are used in frequency modulator. These crystals are comparable to a series LC tuned circuit with an exceptionally high quality factor. The crystal holder has a small capacitance which is in parallel with the crystal and therefore causes parallel resonance at a slightly higher frequency than the series resonant frequency of the crystal. (Islam *et al*. 2015)
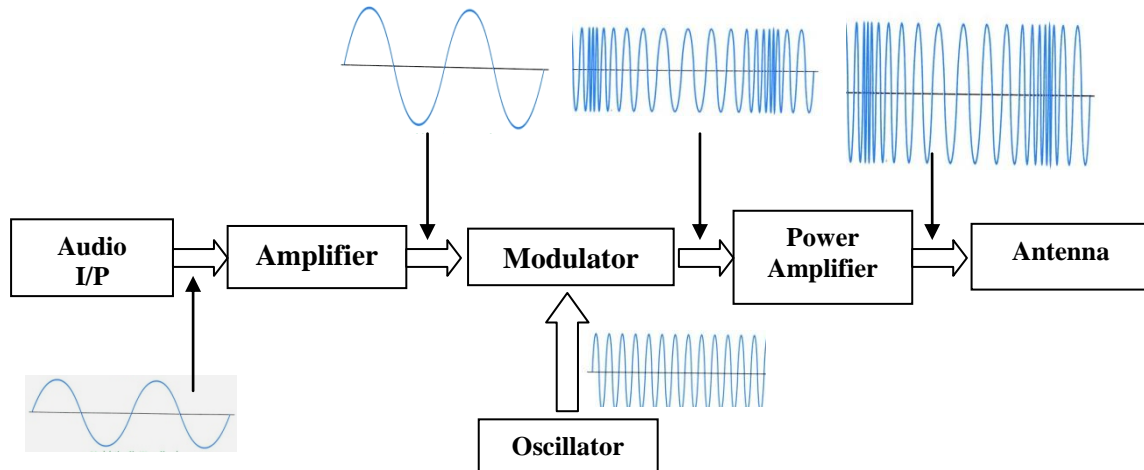
Frequency Modulation Transmitter

Fig. 2. Block diagram of Frequency Modulation

Fundamental components of frequency modulator includes, amplifer, modulator, oscillator, power amplifier and antenna system.
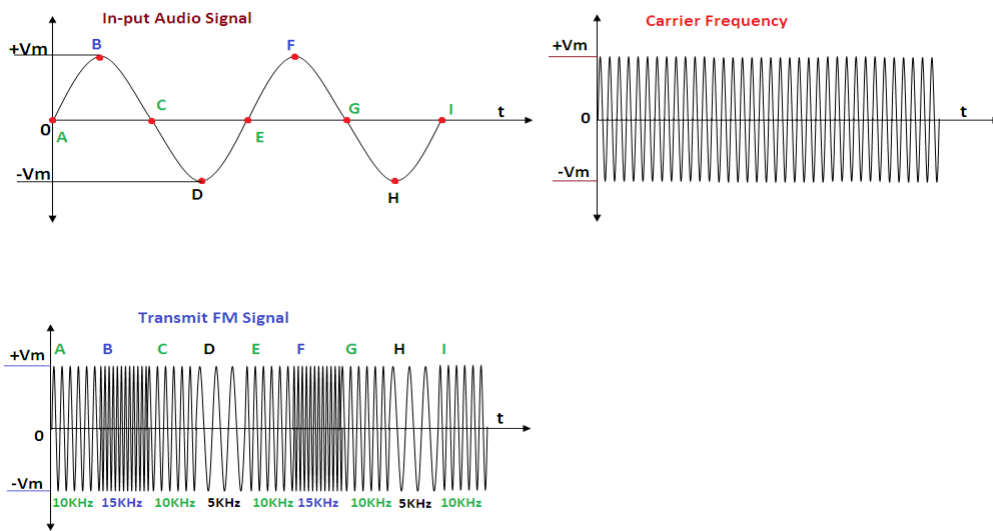
FM Waveforms

Fig. 3. FM Waveforms

MATERIALS AND METHODS

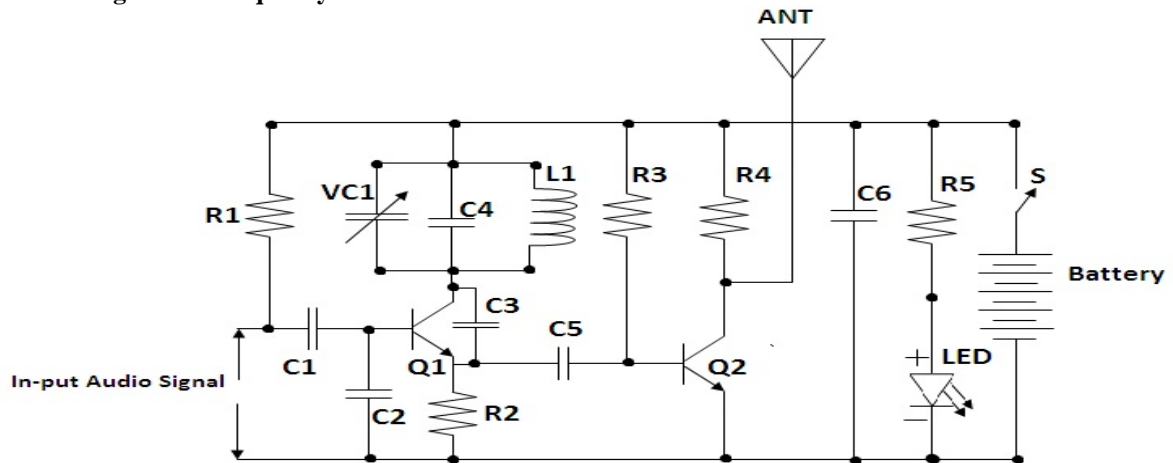**Circuit Diagram of Frequency Modulation Transmitter**

Fig. 4. Circuit diagram of Frequency Modulation

Construction and working priciple

➢ R_1 and R_3 are used as base bios resistor and C_1, C_2, C_6 are used as filtering capacitor
➢ L_1 possesses 6 turns of 24 AWG enamel coated magnet wire which is wound with a inside diameter of about 4mm.
➢ Oscillatory circuit is formed with VC_1, C_4 and L_1 that creates the carrier frequency. Tuning operation is performed by VC_1. Whereas C_3 acts as feedback capacitor. This transmitters is designed such that it operates in 90–95 MHz band which is the normal broadcasting frequency.
➢ To perform the function of modulation Q_1 is used whereas Q_2 is used as audio power amplifier transistor.
➢ 20cm long antenna is required for desired operation
➢ Turned ON led indicates the operating state of the circuit.
➢ 9V is used to provide the voltage required for the operation of the circuit (Gordan and King, 1970).
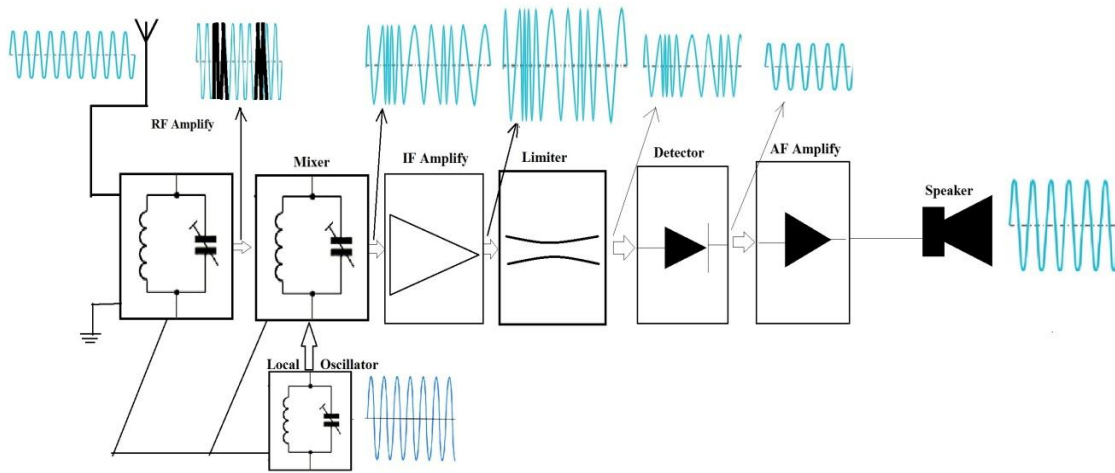
FM Receiver

Fig. 5. Block Diagram of FM Receiver

FM receiver comprises of RF amplifier, mixer, oscillator, IF Amplifier, limiter, detector, AF amplifier and speaker.
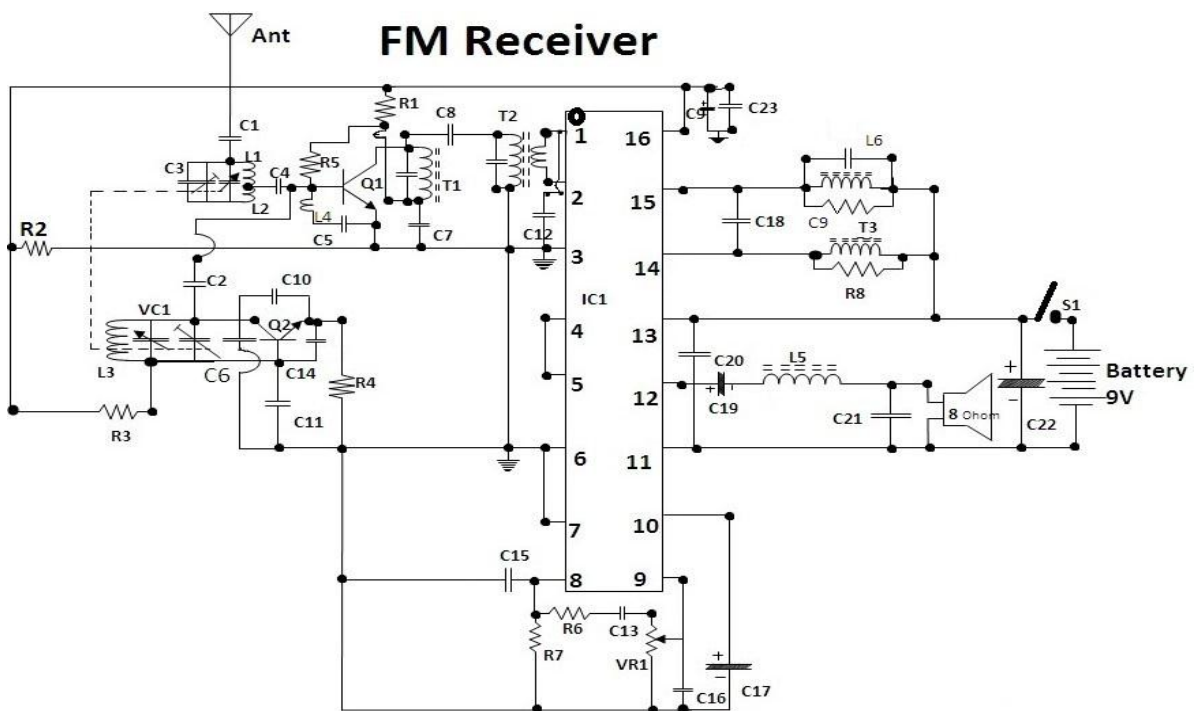

Fig. 6. Schematic diagram of FM receiver
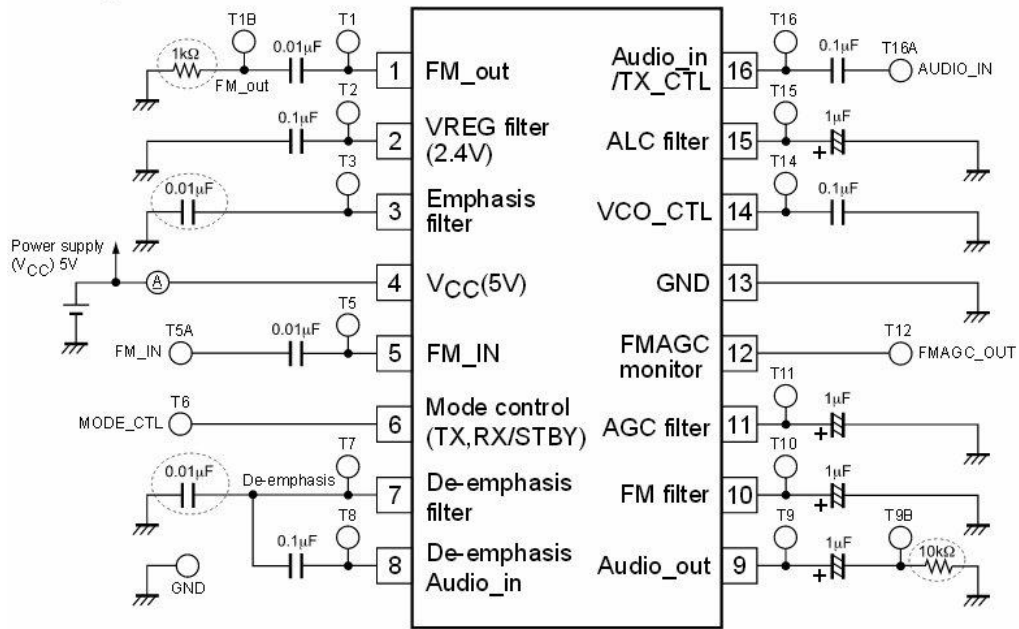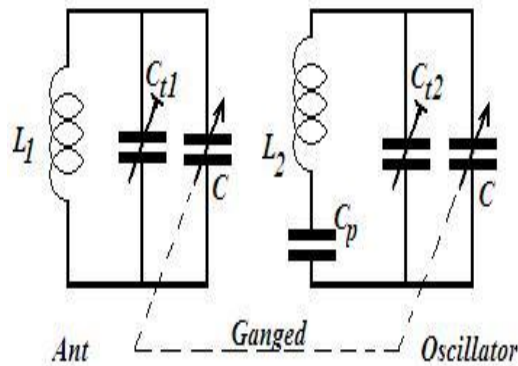
Pinout of IC LA72914V

Fig. 7. IC Pinout of FM Receiver

VC₁ (POLY VARIABLE CONDENSERS)

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}, \omega_0 = \frac{1}{\sqrt{LC}}$$

Fig. 8. Poly Variable Condenser

Basic of FM receiver

Low power received RF signal is boost up through the power amplifier which is an electronic amplifier that drives the antenna of a transmitter. RF amplifier is a tuned amplifier used in radio communications to amplify the signal. Value of inductance and capacitance are changed to obtain the desired frequency at which maximum gain occurs in an RF amplifier. The shunt capacitance allows high gain at radio frequencies because it unfavorably affects the gain of a resistance-capacitance coupled amplifier. There are different types of RF amplifiers and the categories are based on frequency range, supply current, supply voltage, noise figure, gain, output power at 1 dB compression and packaging type. Classification of RF amplifiers includes, Gain Blocks, RF Low Noise Amplifier, RF Low Power Amplifier or RF Power Amplifiers. (John and Rider, 2002).
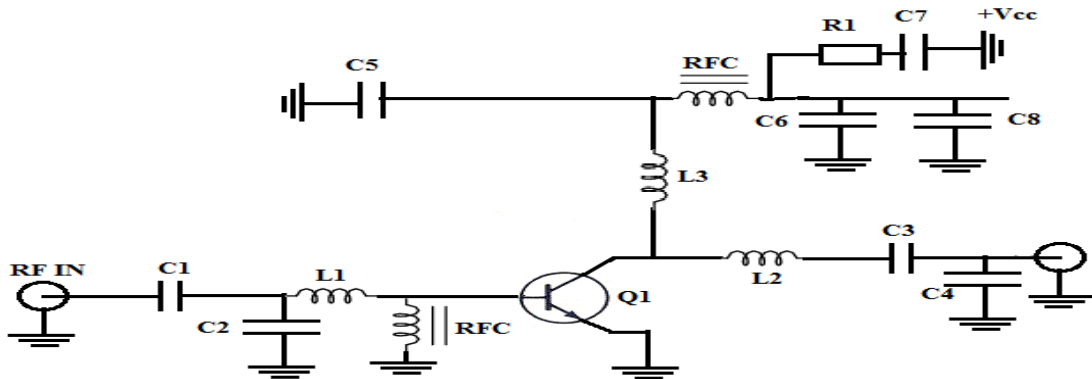
RF Amplifier Circuit

Fig. 9. Schematic diagram of RF Amplifier

RF amplifier is a simple common emitter high frequency amplifier. The circuit comprised of 1 transistor, 8 capacitors, 2 inductors and 2 RFC. C_1 and L_1 are filtering unit and C_2 and RFC_1 are bypass unit. The input BPF is used to pass the 88-108 MHz frequency and it blocks other frequency components.

Frequency Mixer

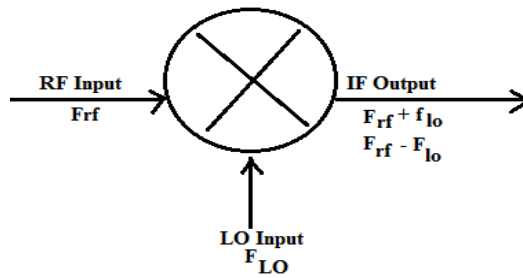A frequency mixer is a type of nonlinear circuit that generates new frequencies from applied two signals.

Fig. 10. Frequency Mixer

An RF mixer is a electronic device that translates a signal from one frequency to another. It can either modulate or demodulate a signal. It got three signal connections, RF input, LO (Local Oscillator) input and the IF (intermediate Frequency) output. A mixer accepts an RF input signal at a frequency f_{RF} then frequency f_{LO} is mixed with it and produces an IF output signal that includes the sum and difference frequencies, $f_{RF} \pm f_{LO}$. The user provides a BPF that follows the mixer and selects the sum ($f_{RF} + f_{LO}$) or difference ($f_{RF} - f_{LO}$) frequency. When the sum frequency is used as the IF, the mixer is named an up converter; when the difference is used the mixer is called a down converter. Up-converter is typically used in a transmit channel, the down converter is used in a receive channel. In a receiver, when the local oscillator frequency is below the RF it is said to be low-side injection and the mixer is called a low-side down converter; when the LO is above the RF, it is named as high-side injection and the mixer a high-side down converter. Different types of mixers are Double balanced RF mixer, BJT or transistor mixer, FET mixer, Gilbert cell mixer or multiplier and Image rejection mixer. (John and Rider, 2002)

Double balanced RF mixer

Double balanced mixers are capable of providing very high levels of performance for many RF design and radio communications applications.
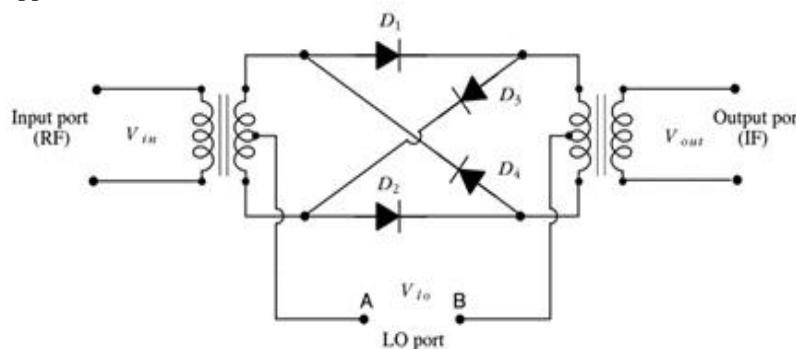

Fig. 11. Double Balance Mixer (DBM)

It comprises of four diodes coupling two transformers. There are three ports by which signals can get into or get out of the double balanced mixer. These input and output ports are *RF*, *LO* and *IF* ports since double balanced RF mixer are used as mixers in heterodyne systems. Connecting the LO ports will allow us to apply a voltage between point A and B.
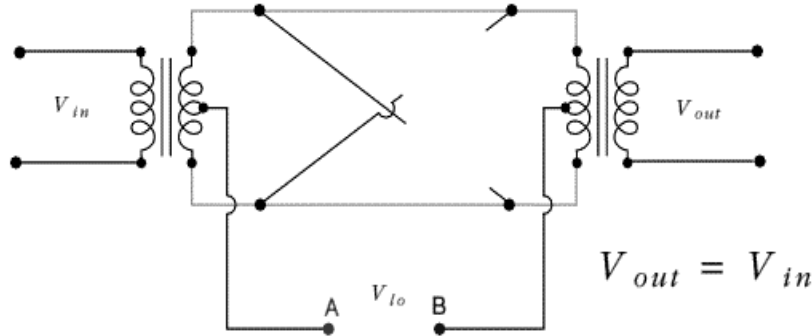

Fig. 12. A +(positive) compared to B

When we apply a voltage, A+ with respect to B (which we'll assume occurs when $V_{lo} > 0$) the diodes, D_1, D_2 will conduct and D_3, D_4 will not conduct. This means that D_1 and D_2 will show a very low resistance to any signals and D_3 and D_4 will exhibit a very high resistance. The diodes connect the transformers directly. $V_{out} = V_{in}$ when we are using 1:1 transformers and low-loss diodes and when V_{lo} is positive.
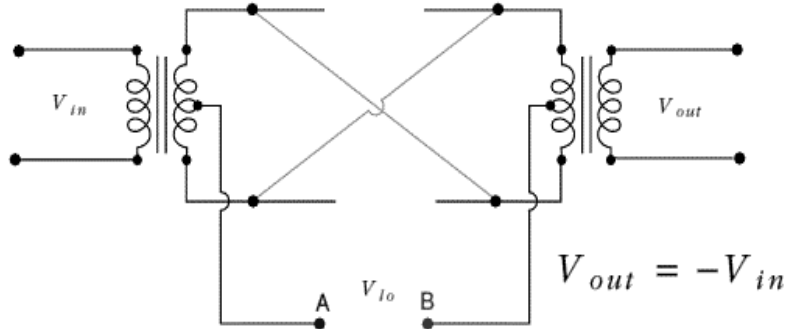
Fig. 13. A– (negative) compared to B

$V_{out} = - V_{in}$ when V_{lo} is negative. Particularly, a real double balance mixer requires a given minimum amplitude of local oscillator voltage to make certain that the diodes have 'turned on/off' correctly. This type of double balance mixer is used for frequency from below 1 MHz to tens of GHz. (Pawar and Chaskar, 2014) FM Based Electronic Digital System Using DSP, IEEE Conferenece Publications)

The Phase Lock Loop (PLL)

In a PLL, the double balanced mixer is used with a LPF as a phase detector.

Fig. 14. DMO as a phase detector

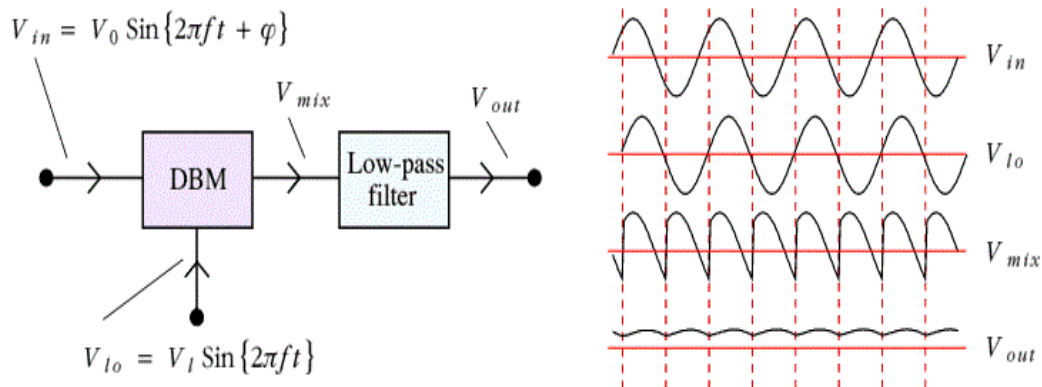Here an input signal $V_{in} = V_0 Sin\{2\pi ft + \varphi\}$ ....(1.1)

is mixed with an LO of $V_{IO} = V_1 Sin\{2\pi ft\}$ ....(1.2)

These produce an output –

$$V_{mix} = V_0 Sin\{2\pi ft + \varphi\} \ when \ V_{lo} > 0$$
$$= -V_0 Sin\{2\pi ft + \varphi\} \ when \ V_{l0} < 0 \quad \text{.................(1.3)}$$

The output LPF flats over a number of cycles to produce an output whose average level can be worked out by integrating over one cycle and dividing by the cycle period.

$$V_{out} = \frac{1}{T}[\int_0^{\frac{T}{2}} V_0 \ Sin\{2\pi ft + \varphi\} - \int_{\frac{T}{2}}^{T} V_0 \ Sin\{2\pi ft + \varphi\}] \text{....(1.4)}$$

which produces the simple result $V_{out} = V_0 Cos\{\varphi\}$ ....(1.5)

By the use of instantaneous level of one signal affecting the level of the other at the output, RF mixing is done. This process involves the two signal levels multiplying together at any given instant in time and the output is a complex waveform comprising of the product of the two input signals. When two signals enter an RF mixer and are mixed together, new signals are generated that are the sum and difference of the two input signals, i.e. if the two input frequencies are f1 and f2, then new signals are seen at frequencies of (f1+f2) and (f1-f2). To take an example, if two signals, one at a frequency of 5 MHz and another at a frequency of 6 MHz are mixed together then new signals at frequencies of 11 MHz and 1 MHz are generated. (Daniel and Talbot, 2010)

Local Oscillator or Tune Circuit

An oscillator creates a periodic, oscillating electronic signal, for example, a sine wave or a square wave. Oscillators convert direct current (DC) from a power supply to an alternating current. Oscillator plays an important role in the super heterodyne receiver system. In our design, the FM broadcast band is 88-108 MHz, in order to mix down to the IF frequency (10.7 MHz), the frequency tuning range in our design is from 98.7 MHz to 118.7 MHz. Here the oscillator is divided into two blocks. One amplifier which is considered to be wideband and one feedback network that is usually frequency selective.

Type of Oscillations

Damped and undammed oscillations are the two types of oscillation,

Damped Oscillations

For dampled oscillations, during each oscillation, some energy is lost because of electrical losses (I^2R). The amplitude of the oscillation will be reduced to zero as no balancing arrangement for the electrical losses is present.
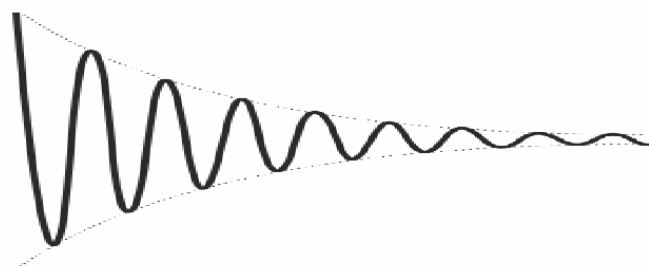

Fig. 15. Damped oscillation

Undammed Oscillations

The oscillation having constant amplitude of oscillation is called undammed oscillation. In the harmonic oscillation equation, the exponential factor $e^{-Rt/2L}$ must become unity. The value of the debauchery component in the circuit which is R should be zero. If its value is negative, the amplitude goes on rising with time t. The amplitude decreases with time t if its value is positive.
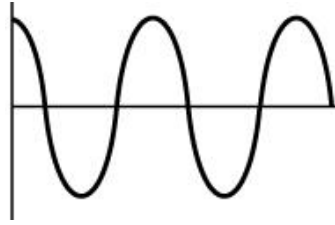
Fig. 16. Undammed Oscillation
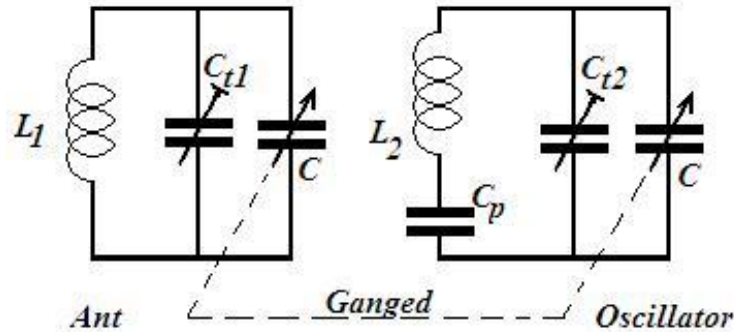
Oscillator or Tune Circuit

Fig. 17. Schematic diagram of Oscillator or Tune Circuit

Signal frequency $f = \dfrac{1}{2\pi\sqrt{L1(C + Ct1)}}$

This gives us two unknowns, namely L_1 and C_{t1} and since we know the upper and lower frequency limits, we have two equations, which immediately create the value.

We require to know the frequency so that we can work backwards to calculate a median value for capacitance called C_{med}. Conventionally, this is the square root of the product of the upper and lower frequency bounds. (Winder and Carr, 2002)

Oscillator circuit

The frequency of the oscillator circuit is determined by the inductance of the oscillator coil L_2 and the combination of C, C_{t2} and Cp. This is given by:

$$ f = \dfrac{1}{2\pi\sqrt{\dfrac{L2Cp(C + Ct2)}{(C + Cp + Ct2)}}} $$

RESULT AND DISCUSSION

The main outcome of this paper is the modeling and successful simulation of FM Transmitter and receiver. Based on the concept of FM transmitter and receiver as shown in Figure 2 and 5, schematic diagram of FM Transmitter and FM Receiver of Figure 4 and Figure 6 respectively were designed. 90 MHz band FM Tx-Rx module was selected because it can be used in ITU Region 1, Region 2 and OIRT. With the use of 50 kHz channel spacing, co-channel interference can be reduced by taking advantage of FM's capture effect and receiver selectivity. (Bakshi and Godse, 2008). The performance of a FM transmitter depends on how we tune our circuit to the desired frequency. Even a small change in the coil condition or small change in the value of variable capacitor can shift the harmonic frequency instead of the 88-108 MHz of FM band and length of the antenna used to transmit the frequency. The important parameters for the optimum performance of an FM transmitter are transmitter frequency, output power and range of transmission, antenna length and coil diameter, length, number of turns and gauge of the wire used for coil winding. Main contribution of our paper is the proposal of the design of small range FM transmitter considering the performance parameters. Our designed frequency modulation (FM) transmitter was able to broadcast at frequency of the range 88 to 94 MHz. The advantage of this circuit is that the implementation is cost effective and we can get the output in a reliable way. The design of Frequency Modulation transmitter can be further modified to get better performance. It's bandwidth and coverage area is satisfactory and it can be tuned by any receiver like mobile phone, FM radio, etc. Furthermore, its internal oscillating circuit can generate signal without distortion.

CONCLUSION

Based on the findings described in the result and discussion section of the paper, it may be concluded that the simulated 90 MHz FM transmitter-receiver module provides reliable output in a cost effective manner for moderate dynamic range and effective for the use in ITU region and OIRT (International Radio and Television Organization) region.

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