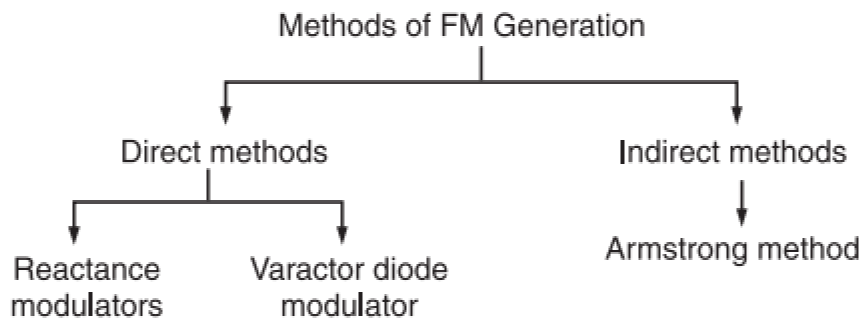
Generation of FM Wave

The FM modulator circuits used for generating FM signals can be divided into two categories such as:

(i) The direct method or parameter variation method

(ii) The Indirect method or the Armstrong method

The classification of FM generation methods is shown below :



The Direct Method or Parameter Variation Method

In direct method or parameter variation method, the baseband or modulating signal directly modulates the carrier. The carrier signal is generated with the help of an oscillator circuit. This oscillator circuit uses a parallel tuned L-C circuit. Thus the frequency of oscillation of the carrier generation is governed by the expression:

$$\omega_c = \frac{1}{\sqrt{LC}} \quad (1)$$

Now, we can make the carrier frequency ωc to vary in accordance with the baseband or modulating signal x(t) if L or C is varied according to x(t). An oscillator circuit whose frequency is controlled by a modulating voltage is called voltage controlled oscillator (VCO). The frequency of VCO is varied according to the modulating signal simply by putting a shunt voltage variable capacitor with its tuned circuit.

This voltage variable capacitor is called varactor or varicap. This type of property is exhibited by reverse biased semiconductor diodes. Also the capacitance of bipolar junction transistors (BJT) and field-effect transistors (FET) is varied by the Miller-effect. This miller capacitance may be utilized for frequency modulation. In addition to this, the electron tubes may also provide variable reactance (either it is inductive or capacitive) which is proportional to modulating or baseband signal. This type of tubes are called reactance tubes and may be used for FM generation. The inductance L of the tuned circuit may also be varied in accordance with the baseband or modulating signal x(t). The FM circuit using such inductors is called saturable reactor modulator.Frequency modulation can also be achieved from voltage controlled devices such as PIN diode, Klystron oscillators and multivibrators.

Reactance Modulator

In direct FM generation shown in figure 2.4.1, the instantaneous frequency of the carrier is changed directly in proportion with the message signal. For this, a device called voltage controlled oscillator (VCO) is used. A VCO can be implemented by using a sinusoidal oscillator with a tuned circuit having a high value of Q.

The frequency of this oscillator is changed by changing the reactive components involved in the tuned circuit. If L or C of a tuned circuit of an oscillator is changed in accordance with the amplitude of modulating signal then FM can be obtained across the tuned circuit as shown in figure 2.4.1 below.

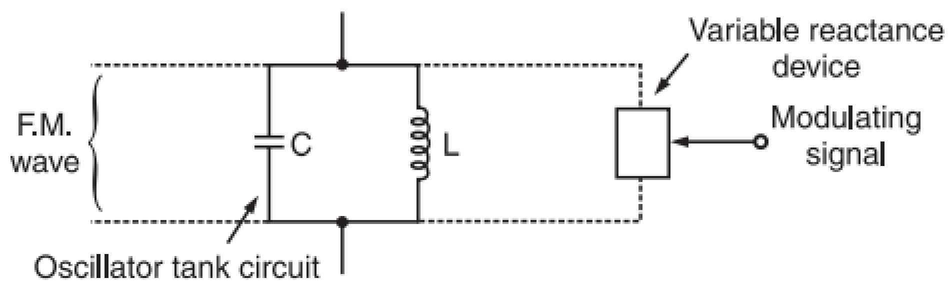


Figure.2.4.1 Principle of Reactance Modulator

Diagram Source Electronics Tutorials

A two or three terminal device is placed across the tuned circuit. The reactance of the device is varied proportional to modulating signal voltage. This will vary the frequency of the oscillator to produce FM. The devices used are FET, transistor or varactor diode. An example of direct FM is shown in figure 1 which uses a Hartley oscillator along with a varactor diode.

The varactor diode is reverse biased. Its capacitance is dependent on the reverse voltage applied across it. This capacitance is shown by the capacitor C(t) in figure 2.4.2

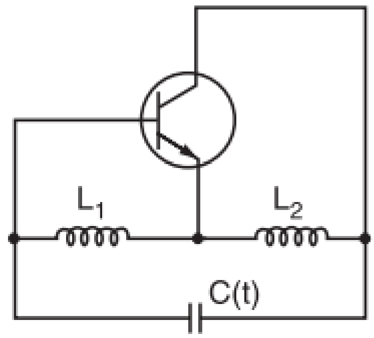


Figure.2.4.2 Hartley Oscillator

Diagram Source Electronics Post

The FM transmitter has three basic sections.

1. The exciter section contains the carrier oscillator, reactance modulator and the buffer amplifier.
2. The frequency multiplier section, which features several frequency multipliers.
3. The power output section, which includes a low- level power amplifier, the final power amplifier, and the impedance matching network to properly load the power section with the antenna impedance.

The essential function of each circuit in the FM transmitter may be described as follows.

The Exciter

1. The function of the carrier oscillator is to generate a stable sine wave signal at the rest frequency, when no modulation is applied. It must be able to linearly change frequency when fully modulated, with no measurable change in amplitude.

2. The buffer amplifier acts as a constant high-impedance load on the oscillator to help stabilize the oscillator frequency. The buffer amplifier may have a small gain.

3. The modulator acts to change the carrier oscillator frequency by application of the message signal. The positive peak of the message signal generally lowers the oscillator's frequency to a point below the rest frequency, and the negative message peak raises the oscillator frequency

to a value above the rest frequency. The greater the peak-to-peak message signal, the larger the oscillator deviation.

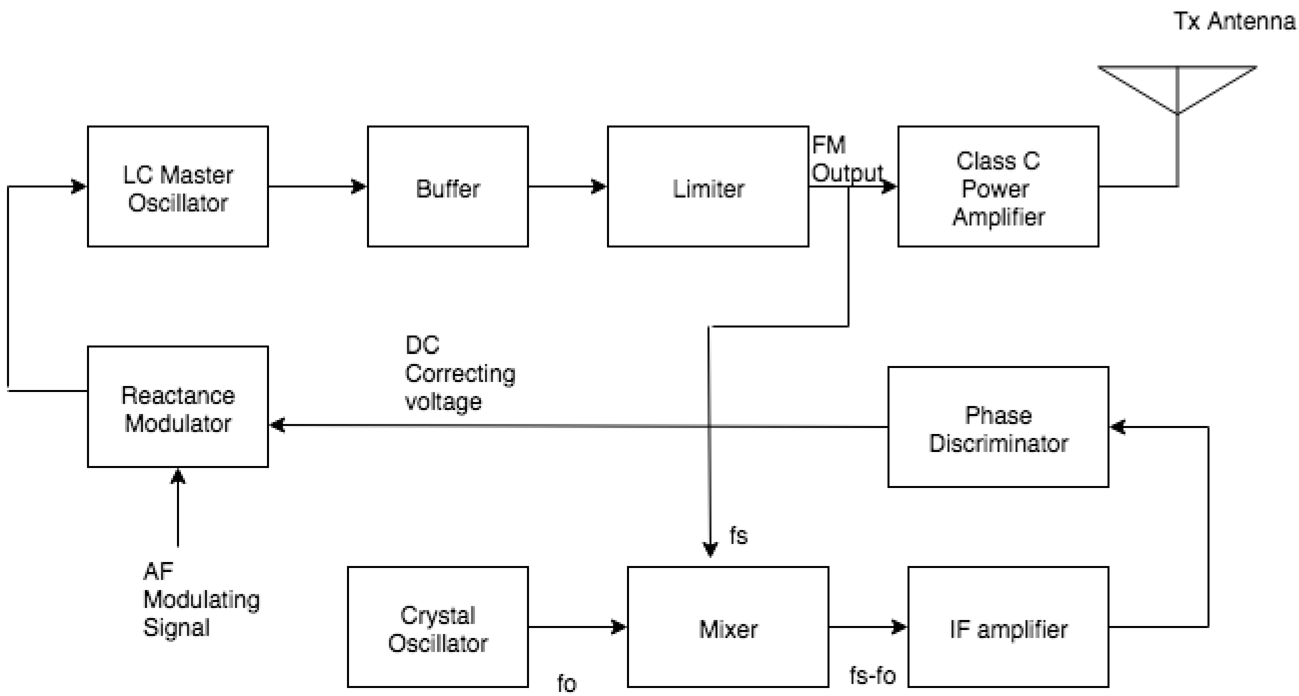


Figure.2.4.3 Reactance Modulator

Diagram Source Electronics Post

Frequency multipliers are tuned-input, tuned-output RF amplifiers in which the output resonant circuit is tuned to a multiple of the input frequency in the above figure 2.4.3. Common frequency multipliers are 2x, 3x and 4x multiplication. A 5x Frequency multiplier is sometimes seen, but its extreme low efficiency forbids widespread usage. Note that multiplication is by whole numbers only. There can not a 1.5x multiplier, for instance. The final power section develops the carrier power, to be transmitted and often has a low-power amplifier driven the final power amplifier. The impedance matching network is the same as for the AM transmitter and matches the antenna impedance to the correct load on the final over amplifier.

Frequency Multiplier

A special form of class C amplifier is the frequency. multiplier. Any class C amplifier is capable of performing frequency multiplication if the tuned circuit in the collector resonates at some integer multiple of the input frequency.

For example a frequency doubler can be constructed by simply connecting a parallel tuned circuit in the collector of a class C amplifier that resonates at twice the input frequency. When the collector current pulse occurs, it excites or rings the tuned circuit at twice the input frequency. A current pulse flows for every other cycle of the input.

A Tripler circuit is constructed in the same way except that the tuned circuit resonates at 3 times the input - frequency. In this way, the tuned circuit receives one input pulse for every three cycles of oscillation it produces Multipliers can be constructed to increase the input frequency by any integer factor up to approximately 10. As' the multiplication factor gets higher, the power output of the multiplier decreases. For most practical applications, the best result is obtained with multipliers of 2 and 3.

Another way to look the operation of class C multipliers is .to .remember that the non-sinusoidal current pulse is rich in harmonics. Each time the pulse occurs, the second, third, fourth, fifth, and higher harmonics are generated. The purpose of the tuned circuit in the collector is to act as a filter to select the desired harmonics.

In many applications a multiplication factor greater than that achievable with a single multiplier stage is required. In such cases two or more multipliers are cascaded to produce an overall multiplication of 6. In the second example, three multipliers provide an overall multiplication of 30. The total multiplication factor is simply the product of individual stage multiplication factors.

Reactance Modulator

The reactance modulator takes its name from the fact that the impedance of the circuit acts as a reactance (capacitive or inductive) that is connected in parallel with the resonant circuit of the Oscillator. The varicap can only appear as a capacitance that becomes part of the frequency determining branch of the oscillator circuit. However, other discrete devices can appear as a capacitor or as an inductor to the oscillator, depending on how the circuit is arranged. A colpitts oscillator uses a capacitive voltage divider as the phase-reversing feedback path and would most likely tapped coil as the phase-reversing element in the feedback loop and most commonly uses a modulator that appears inductive.

Frequency of oscillations of the Hartley oscillator is given by :

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1 + L_2)C(t)}}$$

where C(t) = C + Cvarector

This means that C(t) is the effective capacitance of the fixed tuned circuit capacitance C and the varactor diode capacitance C varector.

Let the relation between the modulating voltage x(t) = 0 and the capacitance C(t) be represented as under:

$$C(t) = C - k_c\, x(t)$$

where C = total capacitance when x(t)

kc is the sensitivity of the varactor capacitance to change in voltage

Substituting expression for C(t) in equation(1) , we get

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1 + L_2)(C - k_c\, x(t))}} = \frac{1}{2\pi\left[\sqrt{(L_1 + L_2)C - (L_1 + L_2)k_c\, x(t)}\right]}$$

or $$f_i(t) = \frac{1}{2\pi\sqrt{(L_1 + L_2)C}\left[1 - \frac{k_c\, x(t)}{C}\right]^{1/2}}$$

But, let

$$\frac{1}{2\pi\sqrt{(L_1 + L_2)C}} = f_0$$

which is the oscillator frequency in absence of the modulating signal [x(t) = 0]. Therefore, we have,

$$f_i(t) = f_0 \left[1 - \frac{k_c}{C} x(t)\right]^{-1/2}$$

If the maximum change in the capacitance corresponding to the modulating wave is assumed to be small as compared to the unmodulated capacitance C then equation (2) for fi (t) can be approximated as under:

$$f_i(t) = f_0 \left[1 + \frac{k_c}{2C} x(t)\right]$$

or

$$f_i(t) = f_0 + \frac{f_0 k_c}{2C} . x(t)$$

Now, let us define

$$\frac{f_0 k_c}{2C} = k_f$$

Therefore, we have

$$f_i(t) = f_0 + k_f x(t)$$

where kf is called as the frequency sensitivity of the modulator.

Varactor Diode Modulator

- Varactor diode modulator is the direct method of FM generation wherein the carrier frequency is directly varied by the modulating signal.
- A varactor diode is a semiconductor diode whose junction capacitance varies linearly with applied voltage when the diode is reverse biased.

- Varactor diodes are used along with reactance modulator to provide automatic frequency correction for an FM transmitter. The varactor diode modulator circuit is shown in Figure5. for generation of FM wave.

The varactor diode FM modulator has been shown below in figure 2.4.4.

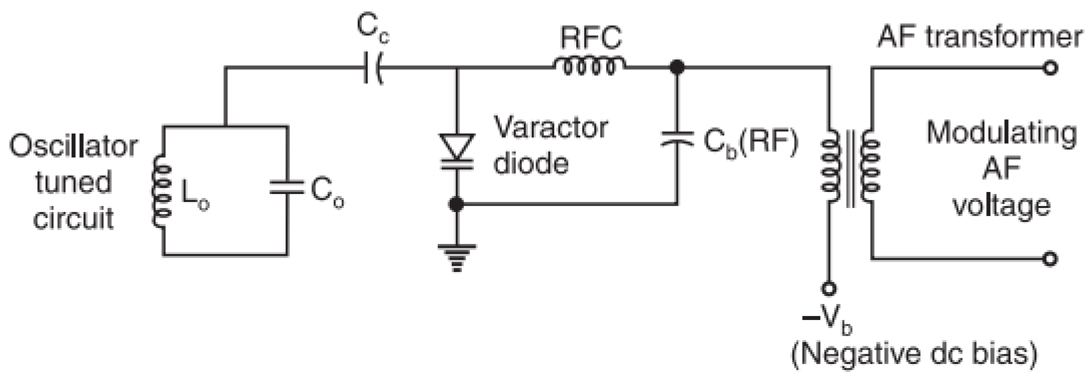


Figure.2.4.4 Varactor Diode Modulator

Diagram Source Electronics Post

A varactor diode is a semiconductor diode whose junction capacitance varies linearly with the applied bias and the varactor diode must be reverse biased.

Working Operation

Varactor diode is arranged in reverse bias to offer junction capacitance effect. The modulating voltage which is in series with the varactor diode will vary the bias and hence the junction capacitance, resulting the oscillator frequency to change accordingly.The external modulating AF voltage adds to and subtracts from the dc bias, which changes the capacitance of the diode and thus the frequency of oscillation. Positive alternations of the modulating signal increase the reverse bias on the varactor diode, which decreases its capacitance and increases the frequency of oscillation.

Conversely, negative alternations of the modulating signal decrease the frequency of oscillation. The RFC and capacitor C b act as a filter which transmits only the AF variations to the varactor diode and blocks high frequency RF voltage from reaching the AF stage. The varactor diode FM modulators are widely accepted because they are simple to use, reliable and have the stability of a crystal oscillator. This method of FM generation is direct because the oscillator frequency is varied directly by the modulating signal, and the magnitude of frequency change is proportional to the amplitude of the modulating signal voltage.

Varactor diode modulator is used for automatic frequency control and remote tuning. The drawback of varactor diode modulator is that since it uses a crystal, the peak frequency deviation is limited to relatively small values. Thus they are used mostly for low index applications such as two way mobile radio. Also since they are a two terminal device, the applications are quite limited. The varactor diode is reverse biased by the negative dc source –Vb.

The modulating AF voltage appears in series with the negative supply voltage. Hence, the voltage applied across the varactor diode varies in proportion with the modulating voltage .This will vary the junction capacitance of the varactor diode. The varactor diode appears in parallel with the oscillator tuned circuit. Hence the oscillator frequency will change with change in varactor diode capacitance and FM wave is produced. The RFC will connect the dc and modulating signal to the varactor diode but it offers a very high impedance at high oscillator frequency. Therefore, the oscillator circuit is isolated from the dc bias and modulating signal.

Indirect Method of WBFM Generation

This method is called as Indirect Method because we are generating a wide band FM wave indirectly. This means, first we will generate NBFM wave and then with the help of frequency multipliers we will get WBFM wave. The block diagram of generation of WBFM wave is shown in the following figure.

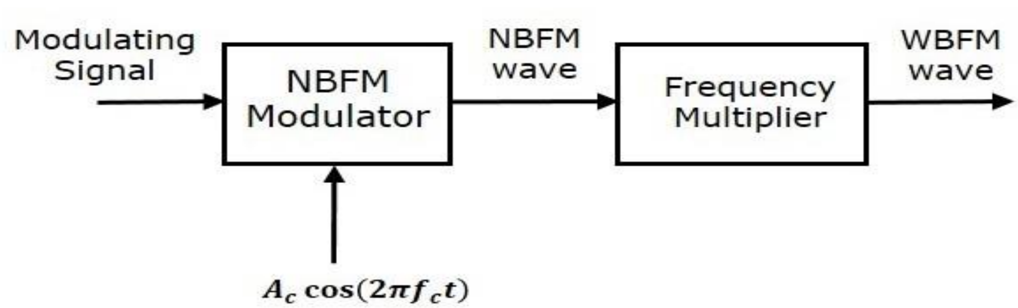


Figure.2.4.5 Varactor Diode Modulator

Diagram Source Electronics Post

This block diagram shown in figure 2.4.5 contains mainly two stages. In the first stage, the NBFM wave will be generated using NBFM modulator. We have seen the block diagram of NBFM modulator at the beginning of this chapter. We know that the modulation index of NBFM wave is less than one. Hence, in order to get the required modulation index (greater than one) of FM wave, choose the frequency multiplier value properly. Frequency multiplier is a non-linear device, which produces an output signal whose frequency is 'n' times the input signal frequency. Where, 'n' is the multiplication factor. If NBFM wave whose modulation index ββ is less than 1 is applied as the input of frequency multiplier, then the frequency multiplier produces an output signal, whose modulation index is 'n' times ββ and the frequency also 'n' times the frequency of WBFM wave.Sometimes, we may require multiple stages of frequency multiplier and mixers in order to increase the frequency deviation and modulation index of FM wave.

The part of the Armstrong FM transmitter (Armstrong phase modulator) which is expressed in dotted lines describes the principle of operation of an Armstrong phase modulator. It should be noted, first that the output signal from the carrier oscillator is supplied to circuits that perform the task of modulating the carrier signal. The oscillator does not change frequency, as is the case of direct FM. These points out the major advantage of phase modulation (PM), or indirect FM, over direct FM. That is the phase modulator is crystal controlled for frequency.

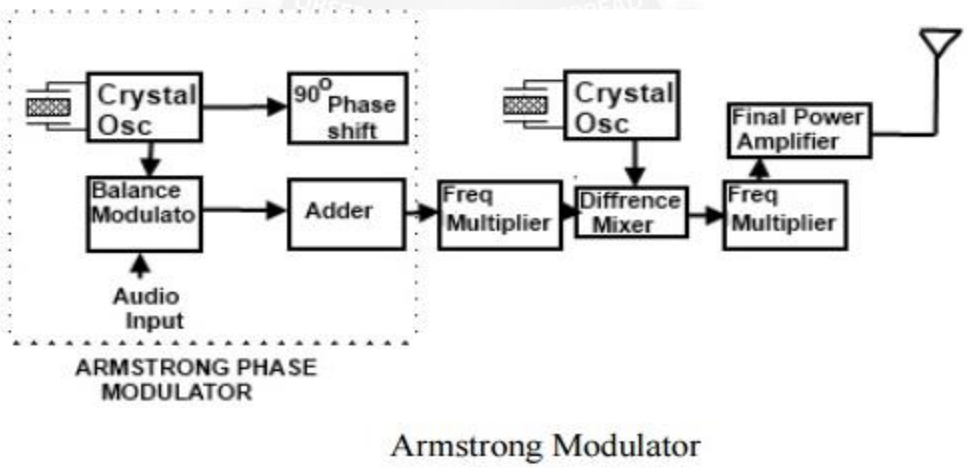


Figure.2.4.6 Armstrong Modulator

Diagram Source Electronics Post

The crystal-controlled carrier oscillator signal is directed to two circuits in parallel. This signal (usually a sine wave) is established as the reference past carrier signal and is assigned a value 0°.The balanced modulator is an amplitude modulator used to form an envelope of double side-bands and to suppress the carrier signal (DSSC). This requires two input signals, the carrier signal and the modulating message signal shown in te figure 2.4.6. The output of the modulator is connected to the adder circuit; here the 90° phase-delayed carriers signal will be added back to replace the suppressed carrier. The act of delaying the carrier phase by 90° does not change the carrier frequency or its wave-shape. This signal identified as the 90° carrier signal.

The carrier frequency change at the adder output is a function of the output phase shift and is found by. fc = Δθfs (in hertz) .When θ is the phase change in radians and fs is the lowest audio modulating frequency. In most FM radio bands, the lowest audio frequency is 50Hz. Therefore, the carrier frequency change at the adder output is 0.6125 x 50Hz = ± 30Hz since 10% AM represents the upper limit of carrier voltage change, then ± 30Hz is the maximum deviation from the modulator for PM. The 90° phase shift network does not change the signal frequency because the components and resulting phase change are constant with time. However, the phase of the adder output voltage is in a continual state of change brought about by the cyclical variations of the message signal, and during the time of a phase change, there will also be a frequency change.