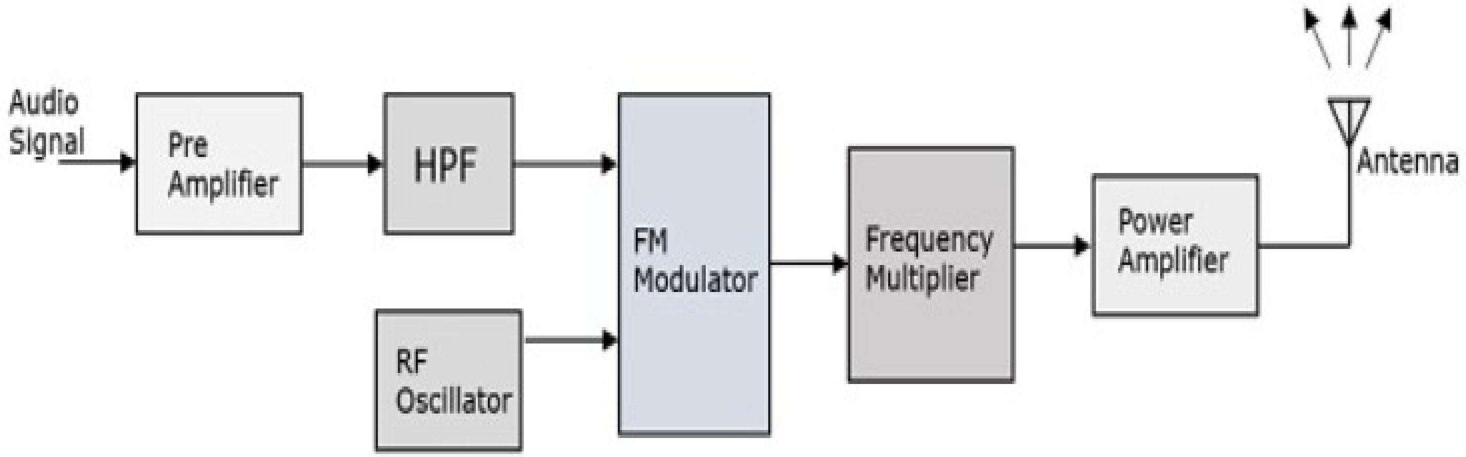
FM TRANSMITTER AND RECEIVER

FM TRANSMITTER

FM transmitter is the whole unit which takes the audio signal as an input and delivers FM modulated waves to the antenna as an output to be transmitted.

FM transmitter consists of 6 main stages



The working of FM transmitter

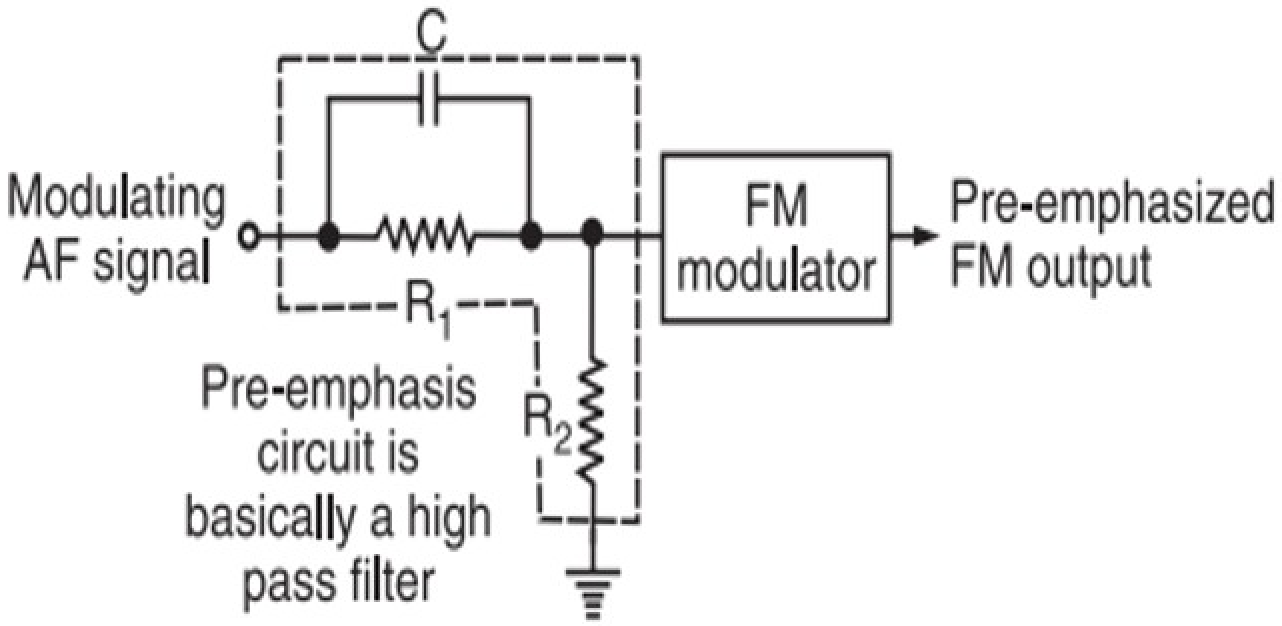
The audio signal from the output of the microphone is given to the pre-amplifier which boosts the level of the modulating signal.

- This signal is then passed to the high pass filter, which acts as a **pre-emphasis** network to filter out the noise and improve the signal to noise ratio.
- This signal is further passed to the FM modulator circuit.
- The oscillator circuit generates a high frequency carrier, which is given to the modulator along with the modulating signal.
- Several stages of frequency multiplier are used to increase the operating frequency. Even then, the power of the signal is not enough to transmit. Hence, a RF power amplifier is used at the end to increase the power of the modulated signal. This FM modulated output is finally passed to the antenna to get transmitted.

Pre-emphasis

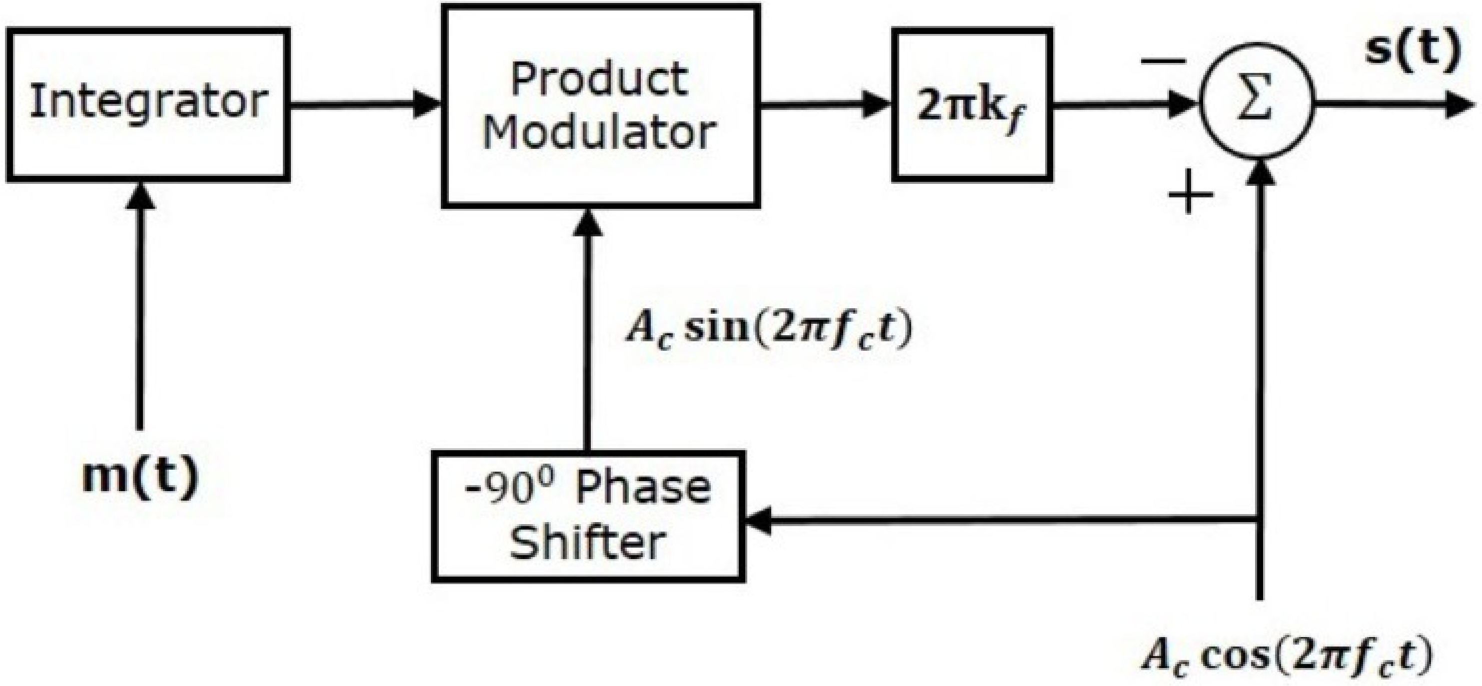
- In FM, the noise has a greater effect on the higher modulating frequencies. This effect can be reduced by increasing the value of modulation index (m_f) for higher modulating frequencies (f_m).
- This can be done by increasing the deviation Δf
- Δf can be increased by increasing the amplitude of modulating signal at higher modulating frequencies.
- Thus, if we boost the amplitude of higher frequency modulating signals artificially, then it will be possible to improve the noise immunity at higher modulating frequencies.

- The artificial boosting of higher modulating frequencies is called as pre-emphasis.
- Boosting of higher frequency modulating signal is achieved by using the pre-emphasis circuit as shown in fig.



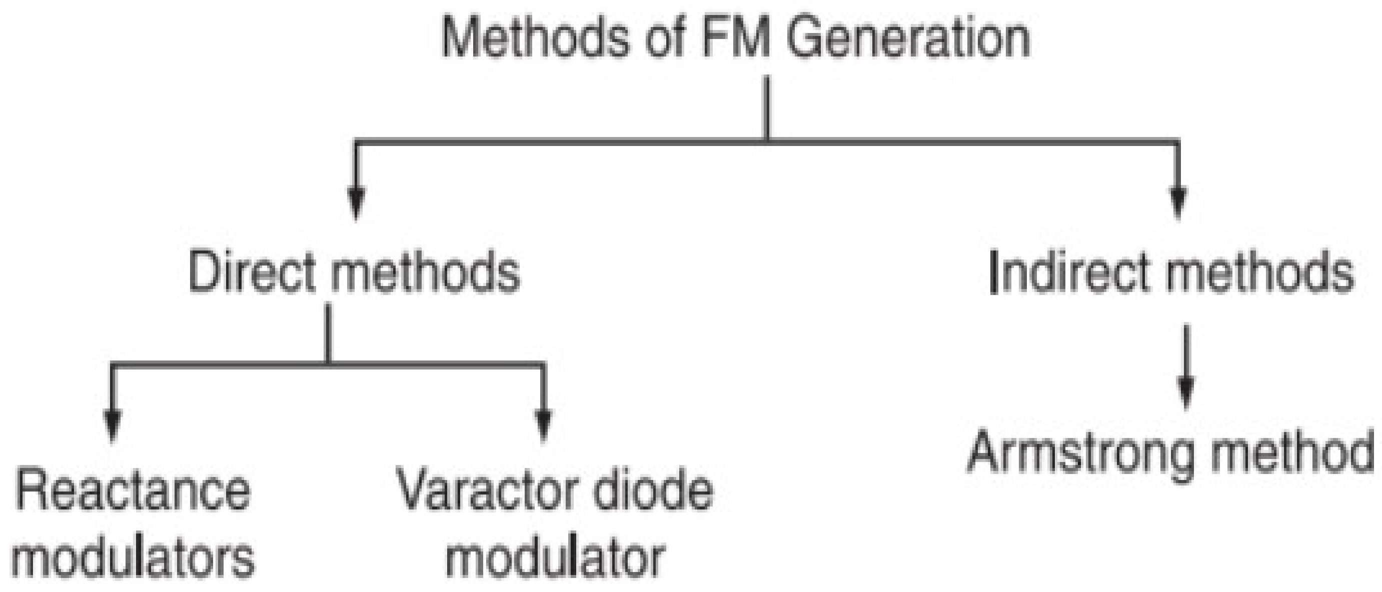
(a) Typical pre-emphasis circuit

NBFM GENERATION (NBFM MODULATOR)



WBFM GENERATION (WBFM MODULATOR)

1. The Direct Method or Parameter Variation Method
2. The Indirect method or the Armstrong method

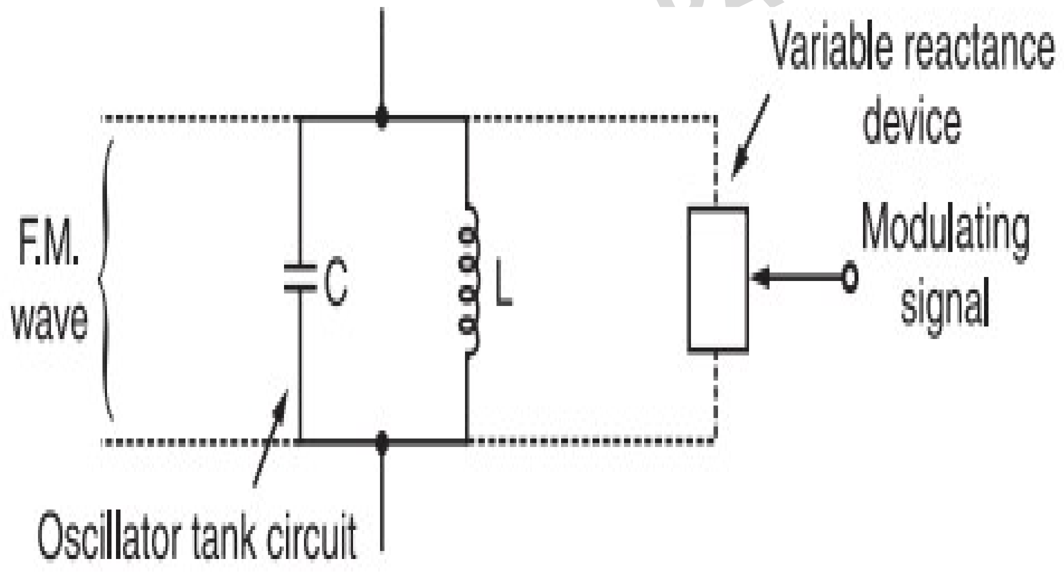


The Direct Method or Parameter Variation Method

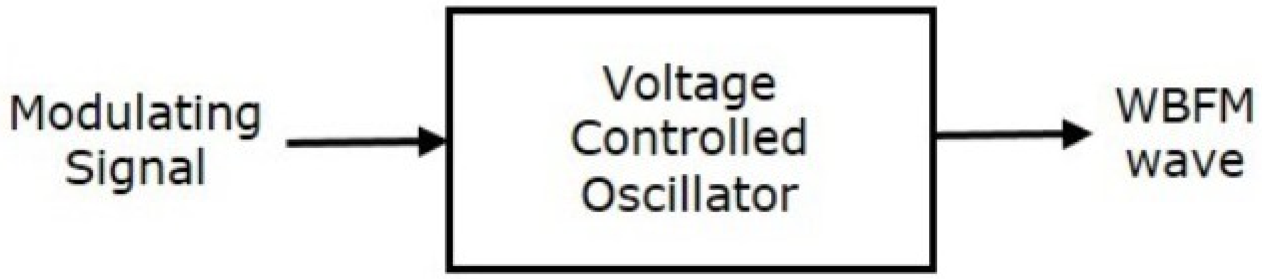
- In this method, the baseband or modulating signal directly modulates the carrier.
- The carrier signal is generated with the help of an oscillator circuit.
- This oscillator circuit uses a parallel tuned L-C circuit.
- Thus the frequency of oscillation of the carrier generation is governed by the expression:

$$\omega_c = \frac{1}{\sqrt{LC}}$$

- Now, we can make the carrier frequency ω_c 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).**



- This method is called as the Direct Method because we are generating a wide band FM wave directly.
- In this method, VCO is used to generate WBFM.
- VCO produces an output signal, whose frequency is proportional to the input signal voltage.
- The block diagram is shown in the figure.



- Here, the modulating signal m(t) is applied as an input of VCO.
- VCO produces an output, which is nothing but the WBFM.

$$f_i \, \alpha \, m(t)$$

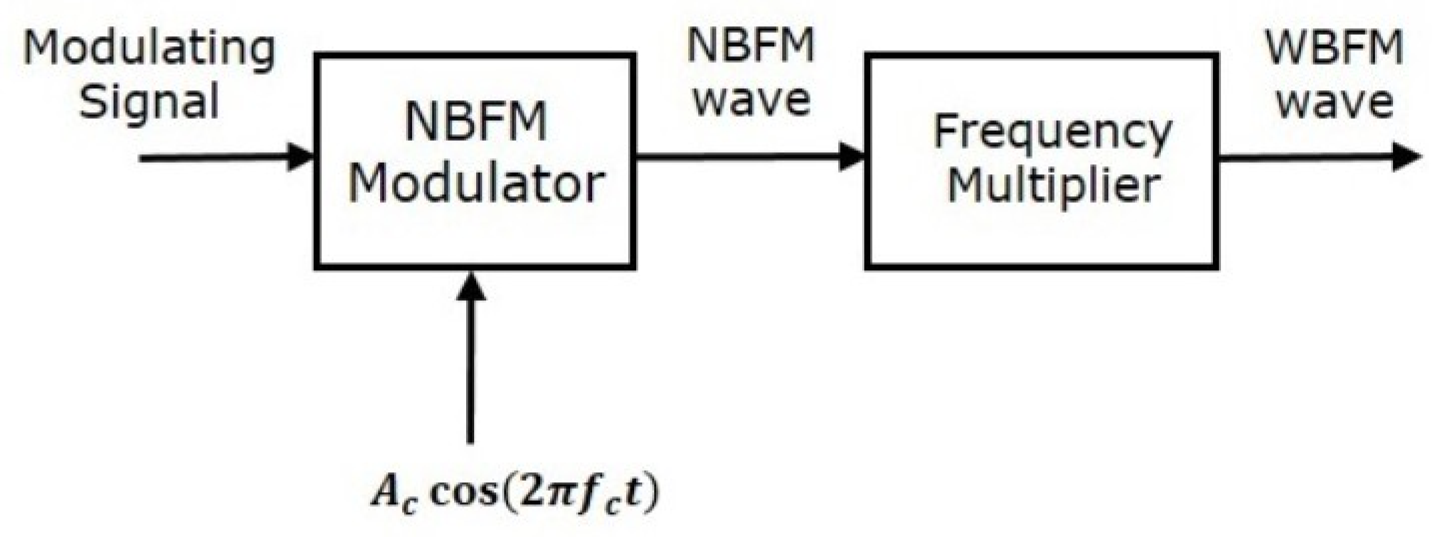
$$\Rightarrow f_i = f_c + k_f m(t)$$

- f_i is the instantaneous frequency of WBFM wave.

Indirect method or Armstrong Method

- In the direct method of FM generation, LC oscillators are to be used. The crystal oscillator cannot be used. The LC oscillators are not stable enough for the communication or broadcast purpose. Thus, the direct methods cannot be used for the broadcast applications.
- The alternative method is to use the indirect method called as the Armstrong method of FM generation.
- In this method, the FM is obtained through phase modulation. A crystal oscillator can be used hence the frequency stability is very high and this method is widely used in practice.

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



- In the first stage, the NBFM wave will be generated using NBFM modulator.
- The modulation index of NBFM wave is < 1. Hence, in order to get the required mod index (>1) 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 (β <1) is applied as the input of frequency multiplier, then the frequency multiplier produces an output signal, whose modulation index is ‘n’ times β and the frequency also ‘n’ times the frequency of NBFM 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.

Frequency Modulation
vs
Phase Modulation

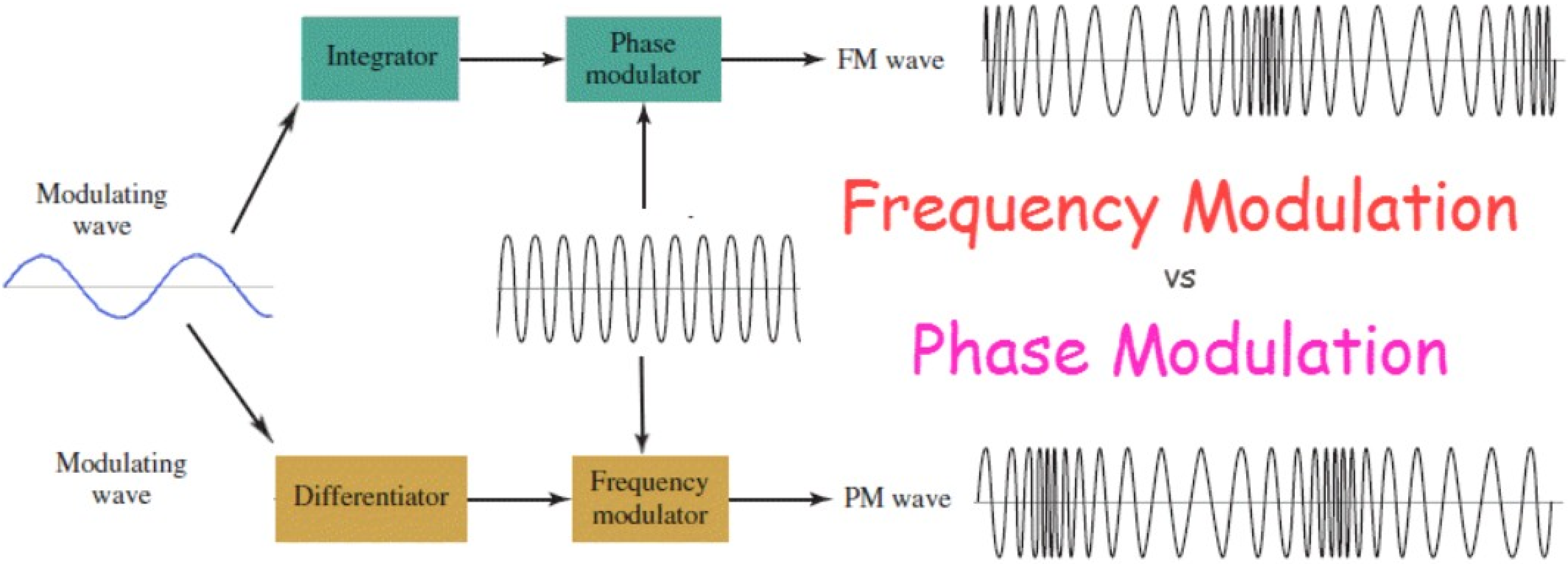
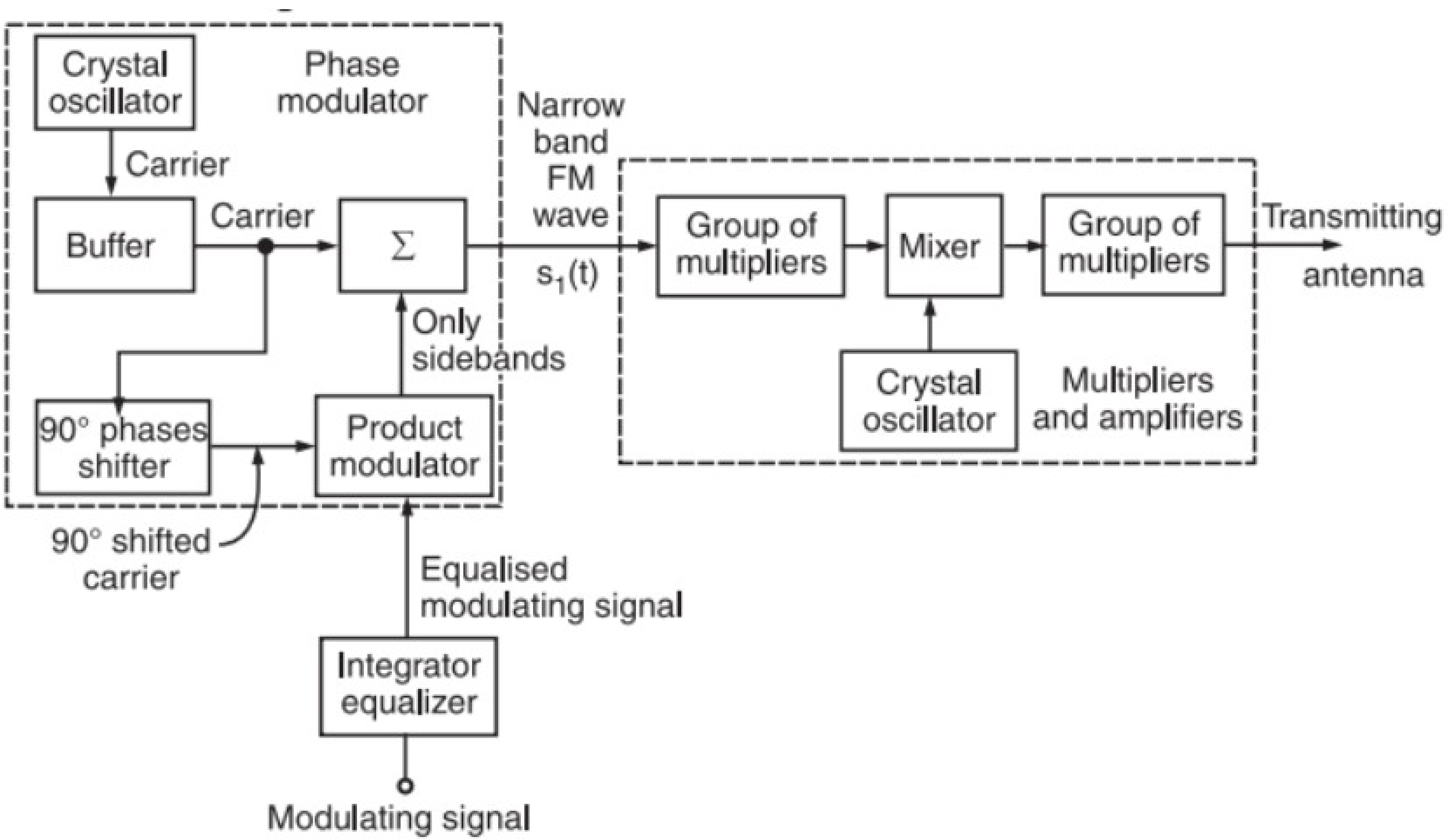


Fig. shows the block diagram of the Armstrong method.



Working Principle

- The Armstrong method uses the phase modulator to generate a frequency modulated wave.
- The working operation of this system can be divided into two parts as follows:

I: Generate a narrow band FM wave using a phase modulator.

II: Use the frequency multipliers and mixer to obtain the required values of frequency deviation, carrier and modulation index.

Generate a narrow band FM using Phase Modulator

- The modulating signal m(t) is passed through an integrator before applying it to the phase modulator as shown in fig.
- Let the narrow band FM wave produced at the output of the phase modulator be represented by $s_1(t)$ i.e.,

$$s_1(t) = A_c \cos[2\pi f_c t + \varnothing_1(t)]$$

- where A_c is the amplitude and f_c is the frequency of the carrier produced by the crystal oscillator.
- Equating to the general exprsn $V_{FM}(t) = A_c \text{Cos}(2\prod f_c t + 2\prod k_f(t)\, dt)$

where m(t) is the modulating s/g

- The phase angle $\Phi_1(t)$ of $s_1(t)$ is related to m(t) as follows:

where k_f represents the frequency sensitivity of the modulator.

- If $\Phi_1(t)$ is very small then,

Cos(1 and sin(

- Hence, the approximate expression for $s_1(t)$ can be obtained as follows:

$s_1(t) = A_c \cos[2\pi f_c t + \varnothing_1(t)]$

$= A_c [\cos(2\pi f_c t) \cos \varnothing_1(t) - \sin(2\pi f_c t) \sin \varnothing_1(t)]$

- After approximation, we get,

$$s_1(t) = A_c\,[\cos(2\pi f_c t) - \sin(2\pi f_c t)\varnothing_1(t)]$$

- Substituting,

$$f_c t) - 2\pi k_f\, A_c \sin(2\pi f_c t)$$

- This expression represents a narrow band FM. Thus, at the output of the phase modulator, we obtain a narrow band FM wave.

Implementation of the Phase Modulator

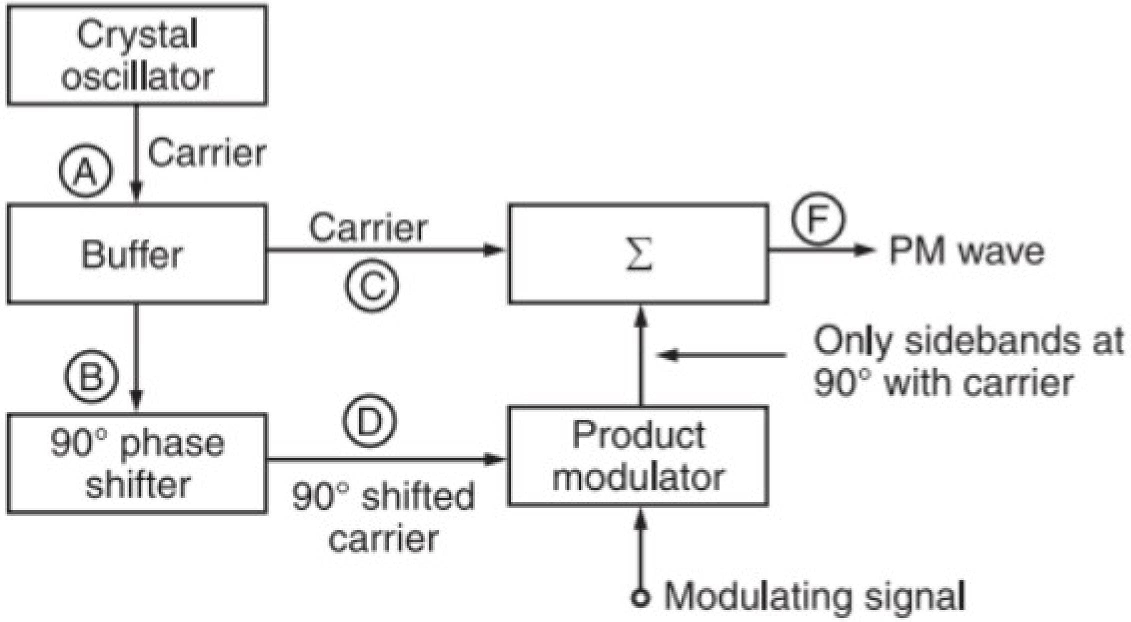


Fig. shows the block diagram of phase modulator circuit.

Working Principle

- The crystal oscillator produces a stable unmodulated carrier which is applied to the 90° phase shifter as well as the combining network through a buffer.
- The 90° phase shifter produces a 90° phase shifted carrier. It is applied to the balanced modulator along with the modulating signal.
- Thus, the carrier used for modulation is 90° shifted with respect to the original carrier.
- At the output of the product modulator, we get DSB SC signal i.e., AM signal without carrier.
- This signal consists of only two sidebands with their resultant in phase with the 90° shifted carrier .

- The two sidebands and the original carrier without any phase shift are applied to a combining network (∑). At the output of the combining network, we get the resultant of vector addition of the carrier and two sidebands.
- Now, as the modulation index is increased, the amplitude of sidebands will also increase. Hence, the amplitude of their resultant increases. This will increase the angle Φ made by the resultant with unmodulated carrier.
- The angle Φ decreases with reduction in modulation index.
- Thus, the resultant at the output of the combining network is phase modulated. Hence, this block diagram operates as a phase modulator.

Use of Frequency Multipliers, Mixer & Amplifier

- The FM signal produced at the output of phase modulator has a low carrier frequency and low modulation index. They are increased to an adequately high value with the help of frequency multipliers and mixer.

FM RECEIVER

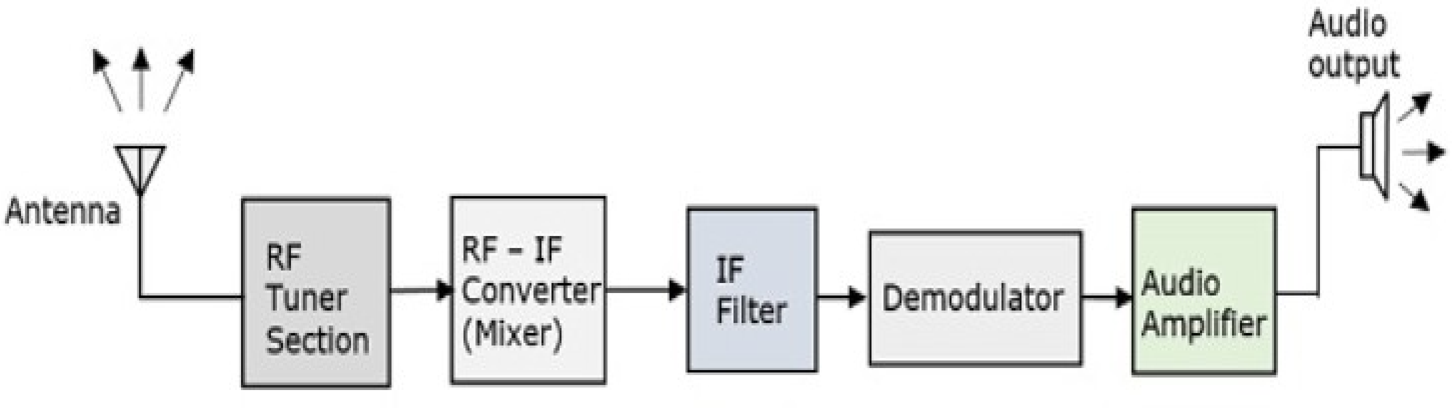
Requirements of a Receiver

- A radio receiver is used to receive both AM band and FM band signals. The detection of AM is done by the method called as Envelope Detection and the detection of FM is done by the method called as Frequency Discrimination.

Such a radio receiver has the following requirements.

- It should be cost effective.
- It should receive both AM and FM signals.
- The receiver should be able to tune and amplify the desired station.
- It should have an ability to reject the unwanted stations.
- Demodulation has to be done to all the station signals, whatever the carrier frequency is.
- For these requirements to get fulfilled, the tuner circuit and the mixer circuit should be very effective.

Superheterodyne FM Receiver



Super Heterodyne Radio Receiver

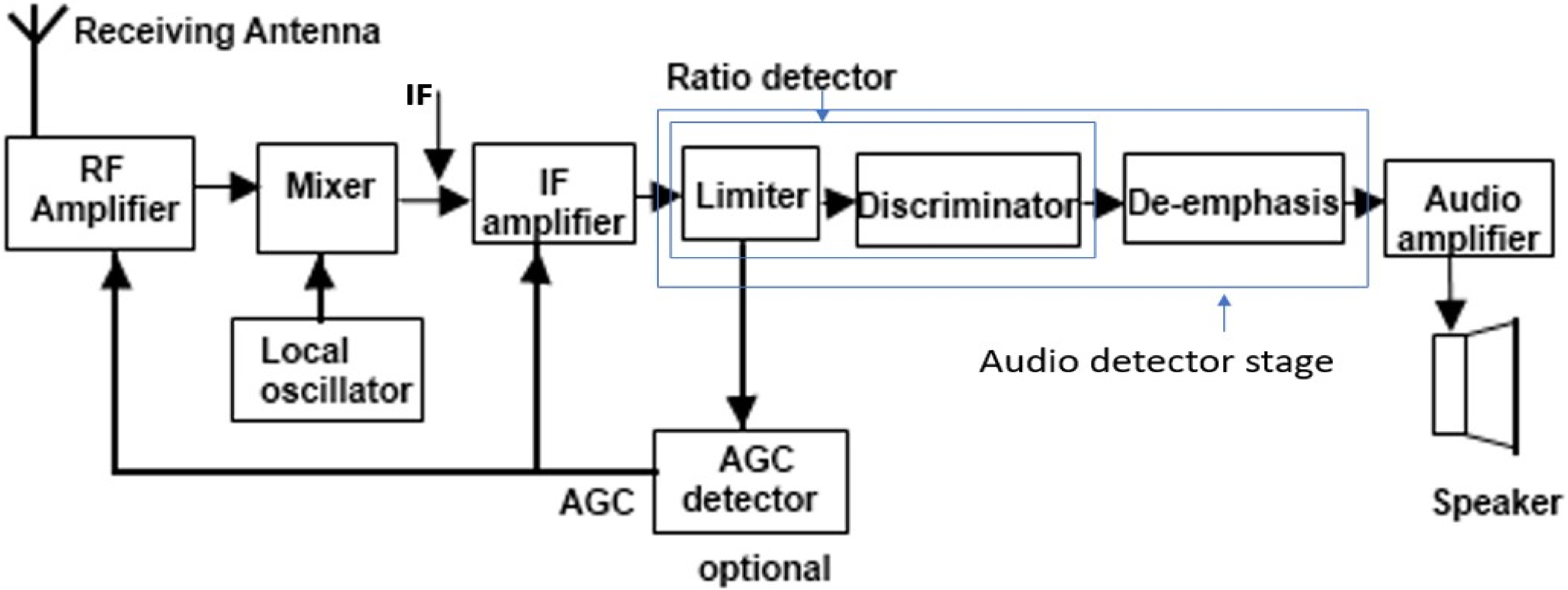
The FM receiver is the whole unit which takes the modulated signal as input and produces the original audio signal as an output.

Characteristics of superheterodyne receiver

1. Sensitivity
2. Selectivity
3. Fidelity
4. Double Spotting
5. Tracking

- **Sensitivity of Receiver:** ability to amplify weak s/gs.
- **Selectivity of Receiver:** ability to reject unwanted s/gs.
- **Fidelity in Communication:** ability to reproduce all modulating freqs equally
- **Double Spotting:** it is a condition where the same desired signal is detected at two nearby points on the receiver tuning dial.
- **Tracking or Tunning of a Receiver:** There are diff tuned circuits in receiver such as RF tuned ckt, mixer tuned ckt and local oscillator tuned ckt. All these circuits must be tuned to get proper RF input and to get IF frequency at the output of mixer. The process of tuning circuits to get desired output is called tracking.

Superheterodyne FM Receiver Block Diagram



- The RF amplifier amplifies the received signal intercepted by the antenna.
- The amplified signal is then applied to the mixer stage.
- In a superheterodyne receiver, the incoming RF signal frequency is combined with the local oscillator signal frequency through a mixer and is converted into a signal of a lower fixed frequency. This lower fixed frequency is known as an **intermediate frequency (I.F.).**
- The IF signal contains the same modulation as the original signal. This IF s/g is now amplified and demodulated to reproduce the original signal.
- The word heterodyne stands for mixing. Here we have mixed the incoming signal frequency with the local oscillator frequency. Therefore this receiver is called the superheterodyne receiver.

- The o/p of IF ampr is applied to the limiter circuit. The limiter removes the noise in the received signal & gives a constant amplitude signal. This circuit is required when a phase discriminator is used to demodulate an FM signal.
- The output of the limiter is now applied to the FM discriminator (FM demodulator), which recovers the modulating signal. It converts frequency variation into corresponding voltage variation and produces the modulating signal. However, this signal is still not the original modulating signal.
- Before applying it to the audio amplifier stages, it is de-emphasized. De-emphasizing attenuates the higher frequencies to bring them back to their original amplitudes as these are boosted or emphasized before transmission.
- The output of the de-emphasized stage is the audio signal, which is then applied to the audio stages and finally to the speaker.

- The audio signal is amplified by an audio amplifier to get a particular voltage level.
- This amplified audio signal is further amplified by a power amplifier to get a specified power level so that it may activate the loudspeaker.
- The loudspeaker is a transducer that converts this audio electrical signal into an audio sound signal and thus the original signal is reproduced i.e. the original transmission is received.
- Automatic Gain Control, AGC: AGC is incorporated into most superheterodyne radio block diagrams. The function of this circuit block is to reduce the gain for strong signals so that the audio level is maintained for amplitude sensitive forms of modulation, and also to prevent overloading.

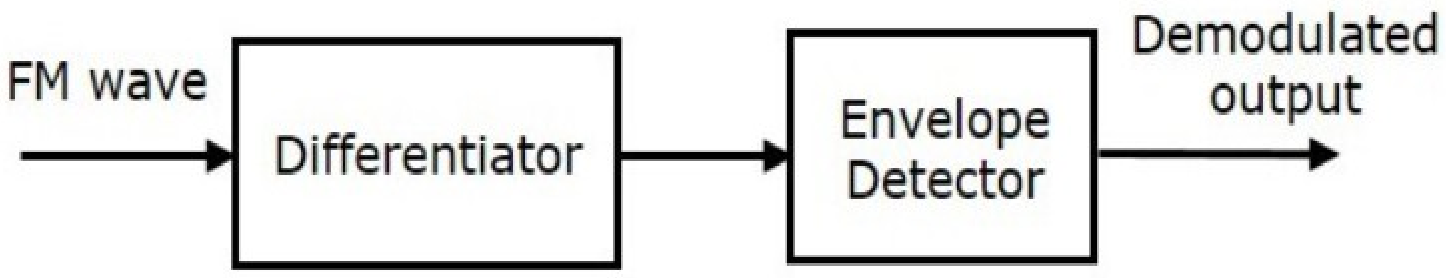
- The AGC circuit prevents the receiver's output level from fluctuating too much by detecting the overall strength of the signal and automatically adjusting the gain of the receiver to maintain the output level within an acceptable range.

FM demodulation methods

The following two methods demodulate FM wave.

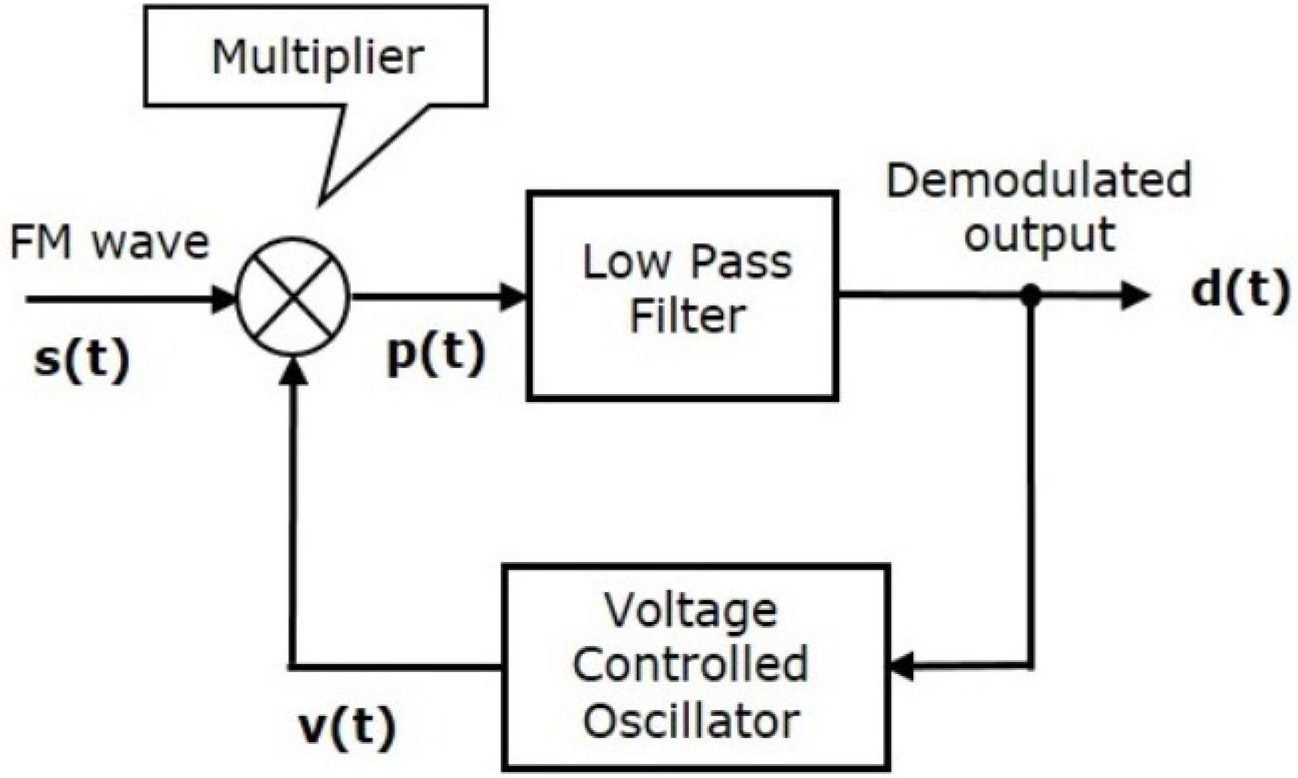
- Frequency discrimination method
- Phase discrimination method

Frequency discrimination method.



- Differentiator is used to convert the FM wave into a combination of AM wave and FM wave.
- This means, it converts the frequency variations of FM wave into the corresponding voltage (amplitude) variations of AM wave.
- Envelope detector produces the demodulated output of AM wave, which is nothing but the modulating signal.

Phase Discrimination Method



- This block diagram consists of the multiplier, LPF and VCO.

- VCO produces an output signal v(t), whose frequency is proportional to the input signal voltage d(t). Initially, when the signal d(t)is zero, adjust the VCO to produce an output signal v(t), having a carrier frequency and -90 deg phase shift with respect to the carrier signal.

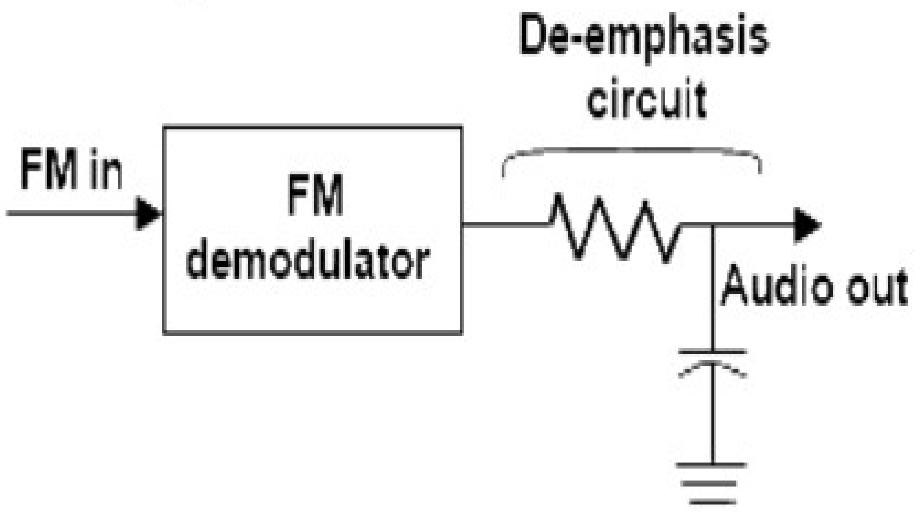
- FM wave s(t) and the VCO output v(t)are applied as inputs of the multiplier. The multiplier produces an output, having a high frequency component and a low frequency component. Low pass filter eliminates the high frequency component and produces only the low frequency component as its output.

- This low frequency component contains only the term-related phase difference. Hence, we get the modulating signal m(t) from this output of the low pass filter.

De-emphasis Circuit

To return the frequency response to its average level, a de-emphasis circuit is used at the receiver. This is a simple low-pass filter.

- The artificial boosting of higher modulating frequencies in the process of pre-emphasis is nullified at receiver by process called de-emphasis.
- The combined effect of pre-emphasis and de-emphasis is to increase the high-frequency components during transmission so that they will be stronger and not masked by noise.



Pre-Emphasis:

Advantages:

- **Improves signal-to-noise ratio** - Boosts high frequencies before transmission which are more susceptible to noise
- **Increases transmission range** - Pre-emphasis provides 6-10 dB gain allowing greater transmission distance
- **Compatible with transmitter characteristics**
- **Reduces channel crosstalk** - Attenuates lower frequencies to prevent crosstalk between channels

Disadvantages:

- **Increases transmit power** - Requires more transmitter power to accommodate pre-emphasis
- **Susceptible to non-linearity** - Can introduce distortion if pre-emphasis is applied incorrectly

De-Emphasis:

Advantages:

- **Restores original frequency response**
- **Reduces noise** - Attenuates amplified high frequencies and the noise introduced during transmission
- **Improves overall SNR** - Combined pre-emphasis and de-emphasis give better SNR
- **Prevents adjacent channel interference** - Reduces high frequencies that may cause interference

Disadvantages:

- **Requires complex circuitry** - Needs tuned circuits or active filters to provide specific de-emphasis
- **Risk of incorrect de-emphasis** - Can further distort signal if de-emphasis doesn't match pre-emphasis