SEMESTER – V

Applications of Electricity & Magnetism

UNIT - IV: Modulation Circuits

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UNIT- IV Modulation circuits

Part-A

* Modulation.

In the process of modulation, characteristics of a (high frequency sine wave (the carrier) is varied in accordance with the instantaneous value of the other (modulating) signal is called Modulation.

Such a sine wave may be represented by the equation.

$$e = E \sin(\omega t + \phi).$$

where

$e \rightarrow$ instantaneous value of the sine wave, called the carrier.

$E \rightarrow$ maximum amplitude.

$\omega \rightarrow$ angular frequency.

$\phi \rightarrow$ phase relation w.r.to some reference.

Any of these E, ω, ϕ of carrier may be varied by the modulating Sinal, giving rise to amplitude, frequency or phase modulation, respectives. Carries frequency is greter than modulation frequency.

* Need for Modulation :

1. To reduce the size of the antenna :

without modulation, antenna size will be very large. with modulation, we can use small antennas.

2. To transmit signals to long distances :

Audio signals cannot travel long distances.

Modulated Signals can travel long distances.

3. To avoid mixing of Signals :

without modulation, many signals mix together. Modulation helps to Separate signals.

4. To improve the quality of transmission :

Modulation reduces noise. Modulation improves clarity.

5. To match with the Communication channel :

Audio signals cannot be directly sent through space. Modulated Signals match with the channel.

* Types of Modulation :

1. Amplitude modulation :

Here the amplitude of high frequency carrier wave is changed in accordance with the intensity of the signal to ~~th~~ be transmitted while there is no change in frequency (or) phase of the carrier wave.

2. Frequency Modulation :

Here the frequency of the carrier wave is changed in accordance with the intensity of the signal while the amplitude & phase of carrier wave remain unchanged.

3. phase modulation :

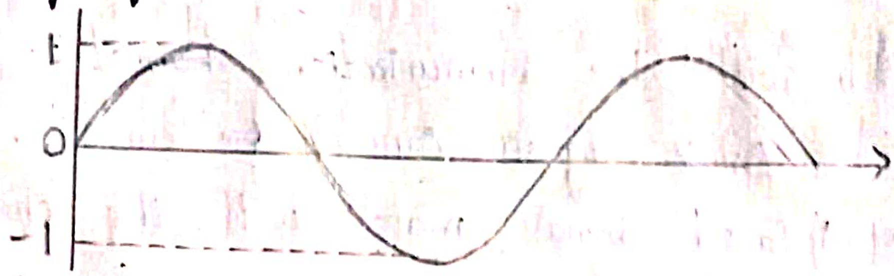
Here the phase of the carrier wave is change while its amplitude & frequency remain unchanged.

* Amplitude Modulation :

Amplitude modulation is the process in which the amplitude of high frequency carrier wave is changed in accordance with the intensity of the signal to be transmitted while there is no change in frequency (or) phase of the carrier wave.

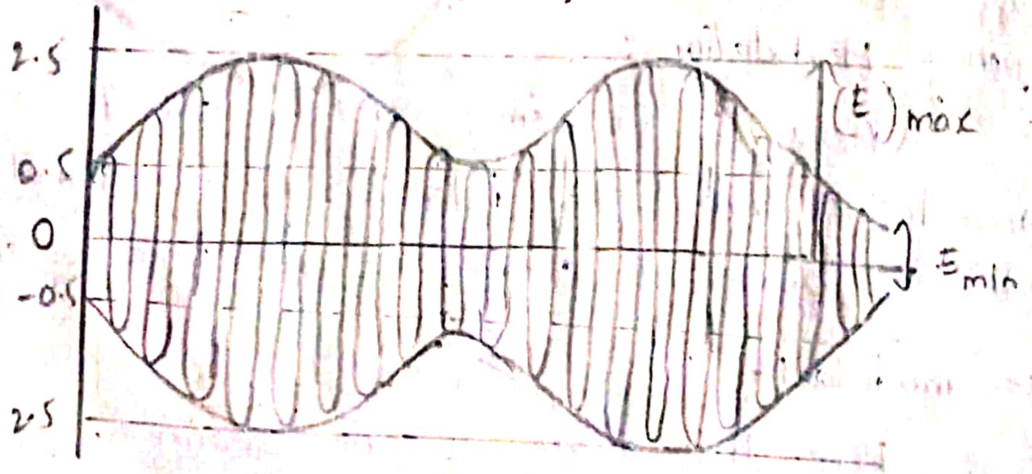
→ Greater the amplitude of audio frequency modulating signal greater are the fluctuating in the amplitude of the modulated carrier wave.

Modulating signal.



(a) Modulating signal.

(b) Carrier wave



(c) Amplitude modulated wave.

* Analysis :

Consider a carrier wave having a frequency f_c 2 peak amplitude E_c. Then instantaneous voltage of carrier ~~carrier~~ wave is.

$$E_c = E_m \sin \omega t$$

The signal can be represented as,

$$e_m = E_m \sin \omega t$$

where $\omega_c = 2\pi f_c$ $f_c \to$ frequency of carrier wave.

$\omega_m = 2\pi f_m$ $f_m \to$ frequency of Signal.

In AM the amplitude of the carrier wave is varied in accordance with the instantaneous value of the modulating signal. Therefore, the amplitude of the modulated wave is given by.

$$E = E_c + E_m \sin \omega_m t$$

Then, the instantaneous value of the amplitude modulated wave,

$$e = E \sin \omega_m t$$

$$= \left(E_c + E_m \sin \omega_m t\right) \sin \omega_c t$$

$$= E_c \left[1 + \frac{E_m}{E_c} \sin \omega_m t\right] \sin \omega_c t$$

$$= E_c \left[1 + \mu \sin \omega_m t\right] \sin \omega_c t$$

$$= E_c \sin \omega_c t + \mu E_c \sin \omega_m t + \sin \omega_c t$$

$$e = E_c \sin \omega_c t + \frac{\mu E_c}{2}\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]$$

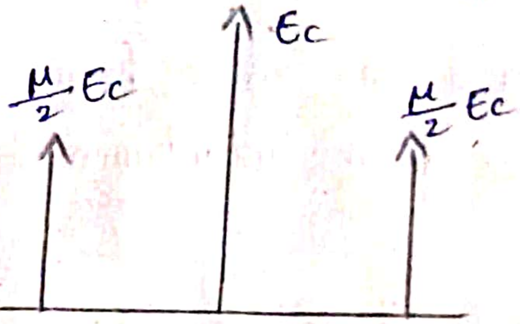
∴ The AM wave is equivalent to the summation of three sinusoidal waves.

$$e = E_c \sin 2\pi f_c t + \frac{\mu E_c}{2}\left[\cos 2\pi (f_c - f_m) t - \cos 2\pi (f_c + f_m) t\right]$$

$f_c \to$ carrier frequency $f_c - f_m \to$ lower side band frequency

$f_c + f_m \to$ uppper side band frequency

Frequency spectrum for A.M wave



i, First having amplitude E & frequency f_c.

ii, Second having amplitude $\frac{\mu}{2} E_c$ & frequency $f_c - f_m$

iii, Third having amplitude $\frac{\mu}{2} E_c$ & frequency $f_c + f_m$.

Modulation Index :

It is defined as the ratio of maximum value of signal wave to the maximum value of carrier wave.

$$\mu = \frac{E_m}{E_c} \qquad \boxed{\mu = \frac{E_m}{E_c}}$$

which is used to indicate the strength & quality of transmitted signal.

$E_{max} = E_c + E_m$

$E_{min} = E_c - E_m$

$$\boxed{\mu = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}} = \frac{E_m}{E_c} = \mu.$$

$$= \frac{E_m}{E_c} = \mu$$

It is easy to Identify the maximum & minimum voltage of modulated wave.

m<1 undermodulated (modulation is not distorted).

m=1 100%. 100% modulation.

m>1 over modulated (distortion in modulated wave).

Power in AM:- If R is the load resistance, then the power in the carrier wave is given by

$$P_c = \frac{A_c^2}{2R}$$

Power in side bands is given by.

$$P_{USB} = P_{LSB} = \frac{\mu^2}{4} P_c$$

Total power in the side band is given by

$$P_{SB} = P_{USB} + P_{LSB} = \frac{\mu^2}{2} P_C$$

Hence total power in AM wave is given by

$$P_t = P_c + P_{SB} = P_c + \frac{\mu^2}{2} P_c = P_c\left(1 + \frac{\mu^2}{2}\right)$$

$$P_t = P_c\left(1 + \frac{\mu^2}{2}\right)$$

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* AM transmitter, AM Receiver.

Modulation is the Process of changing Some property of a carrier wave like amplitude, frequency or phase according to the message signal.

Amplitude Modulation (AM):

In amplitude modulation, the amplitude (or height) of the carrier wave changes, while the frequency and phase remain the same.

→ This type of modulation is more affected by noise during transmission, which can distort the signal quality.

Applications:

→ AM radio.
→ Aircraft communication.
→ walkie-talkies.

AM Transmitter.

→ AM Transmitter is used to combine the message signal with a high-frequency carrier wave to produce an AM Wave that can be sent over long distances using an antenna.

Main parts of an AM Transmitter :

1. Microphone : Converts sound into an electrical signal (message signal).
2. Audio Amplifier : Increases the strength of the message signal.
3. Carrier Oscillator : Generates a high - frequency carrier wave.
4. Modulator : Combines the message signal with the carrier wave to produce the AM signal.
5. RF (Radio Frequency) Amplifier : Boosts the modulated signal to a suitable power level.
6. Antenna : Sends the modulated signal into space.

AM Receiver.

→ AM Receiver is used to receive the AM wave and extract the original message signal from it.

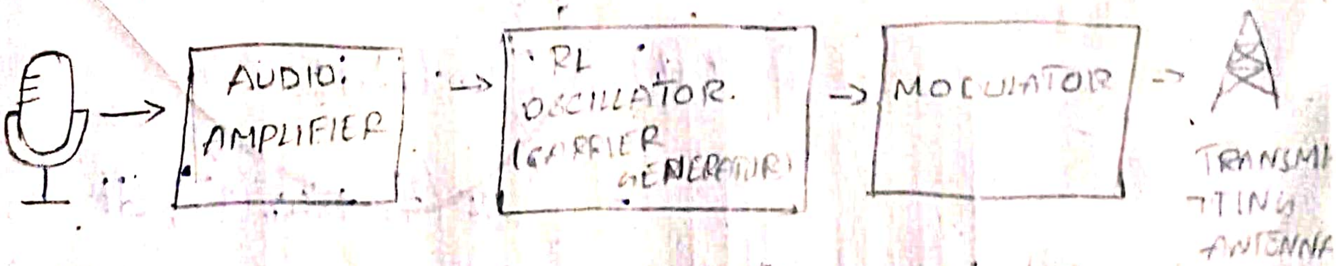
Main parts of an AM Receiver :

1. Antenna : Captures AM radio waves from the air.
2. Tuner : selects the desired frequency from all incoming signals.
3. RF Amplifier : strengthens the received AM signal.
4. Detector (Demodulator) : Separates the message signal from the carrier wave.
5. Audio Amplifier : Increases the strength of the recovered message signal.

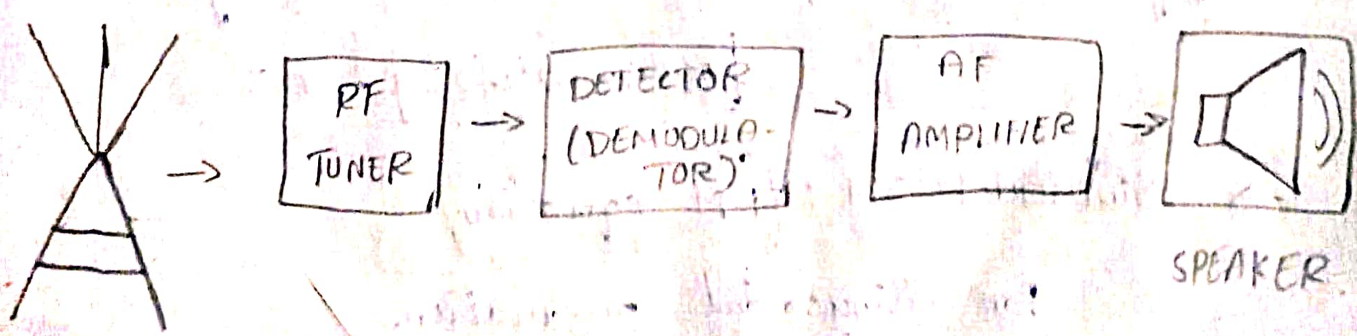
6. Speaker : Converts the electrical message signal back into sound.

AM Transmitter	AM Receiver.
Sends the AM wave.	Receives the AM wave
Performs modulation	Performs demodulation.
Contains modulator and amplifier.	contains detector and amplifier.
Needs more power	Needs less power.
Uses transmitting antenna.	Uses receiving antenna.

BASIC BLOCK DIAGRAM OF AM TRANSMITTER

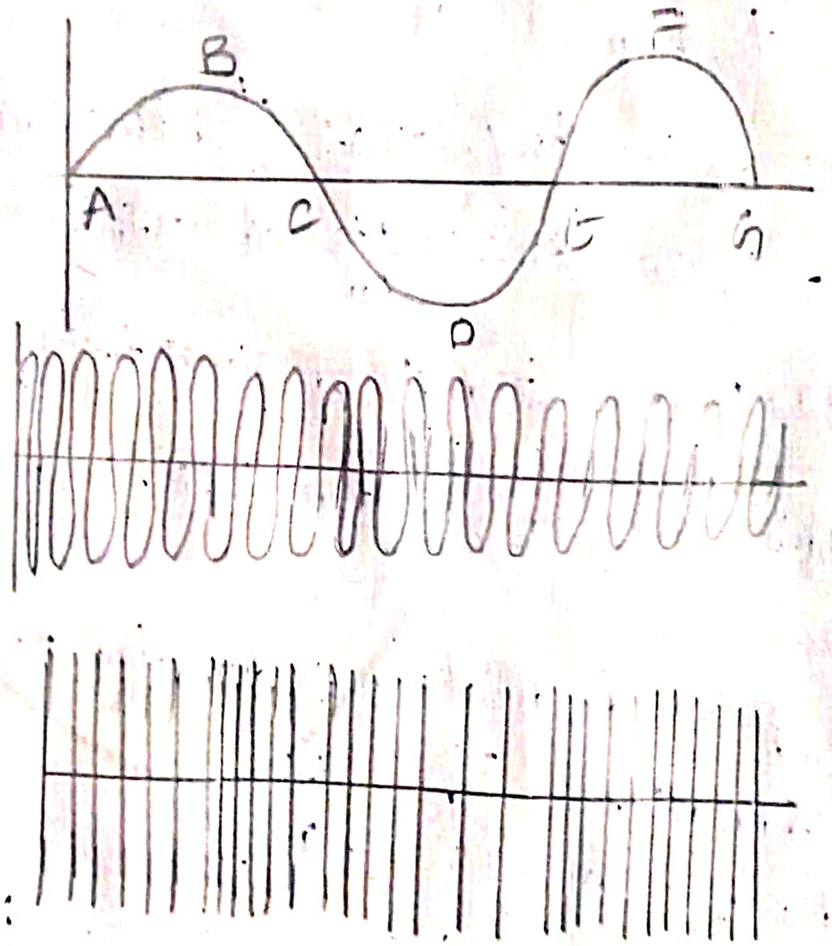


AM RECEVIER



Frequency Modulation :

The frequency of carrier wave is varied inaccordance with the instantaneous amplitude of the modulating signal is called " Frequency Modulation". while the amplitude of carrier wave remains constant.



Analysis :

modulating signal

$e_m = E_m \cos \omega_m t \rightarrow (1)$

Carrier wave $e_c = E_c \cos \omega_c t \rightarrow (2)$

FM modulated wave $e = E_c \cos \omega t \rightarrow (3)$

let, $e = E_c \cos 2\pi f t$

$f = f_c + k e_m(t)$

$$f = f_c + kE_m \cos \omega_m t \rightarrow (4)$$

$$\omega = \frac{d\phi_i}{dt}$$

$$\phi = \int \omega dt$$

$$= 2\pi \int f dt$$

$$= 2\pi \int (f_c + kE_m \cos \omega_m t) dt \quad [\because \text{from } (4)]$$

$$= 2\pi f_c t + 2\pi kE_m \int \cos \omega_m t$$

$$= 2\pi f_c t + 2\pi kE_m \frac{\sin \omega_m t}{\omega_m}$$

$$\phi = 2\pi f_c t + \frac{2\pi kE_m}{2\pi f_m} \sin \omega_m t \quad [\because \omega_m = 2\pi f_m]$$

$$\phi = 2\pi f_c t + \frac{kE_m}{f_m} \sin \omega_m t$$

$$\phi = 2\pi f_c t + \frac{\Delta f}{f_m} \sin \omega_m t \quad (\because kE_m = \Delta f)$$

$$\phi = 2\pi f_c t + \beta \sin \omega_m t \quad (\because \beta = \frac{\Delta f}{f_m})$$

$$e = E_c \cos [2\pi f_c t + \beta \sin \omega_m t]$$

$$\boxed{e = E_c \cos [\omega_c t + \beta \sin \omega_m t]}$$

This is frequency modulated (FM) carrier wave

from (4) $f_c + kE_m \cos \omega_m t$.

Frequency modulation index (m_f)

It is the ratio of the maximum frequency deviation to the modulating frequency

$$m_f = \frac{\text{frequency deviation}}{\text{modulating frequency}}$$

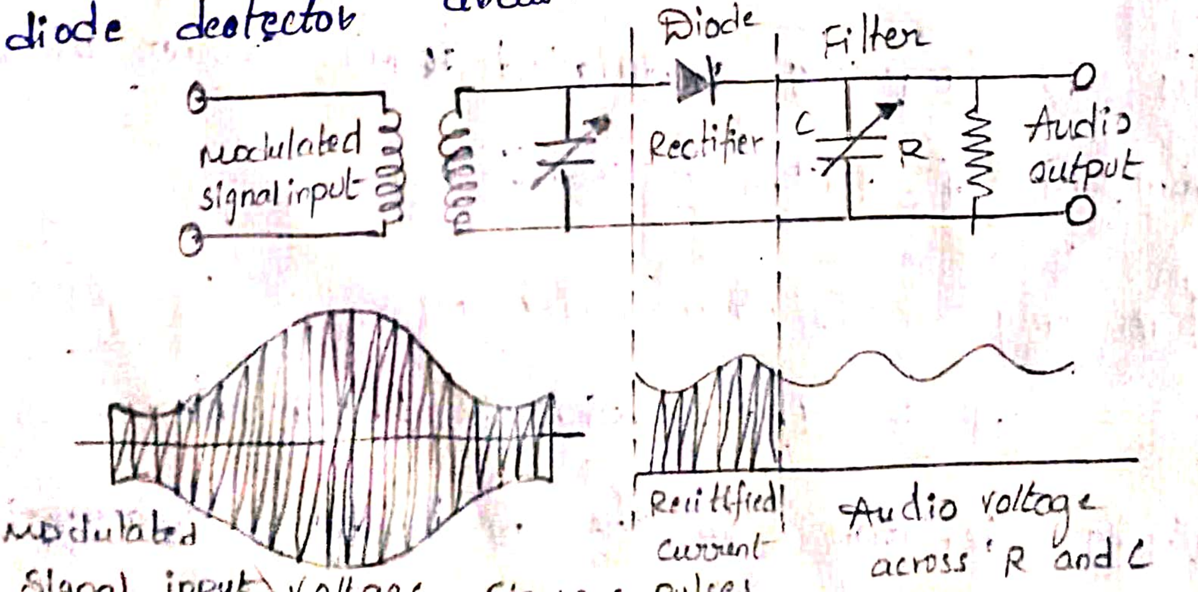
$$\boxed{m_f = \frac{\Delta f}{f_m}}$$

* Demodulation or Detection (Linear Diode Detector)

Demodulation is the process of recovering the audio signal from the modulated wave. The process of detecting an AM carrier wave consists of two steps:

step 1: The negative half-cycles of the modulated carrier wave have to be removed by rectification.

step 2: The carrier frequency must be moved by using suitable filters, Fig. 40.6 illustrates the process of detecting an AM carrier wave. Fig. 40.7 shows the circuit details of diode detector circuit.



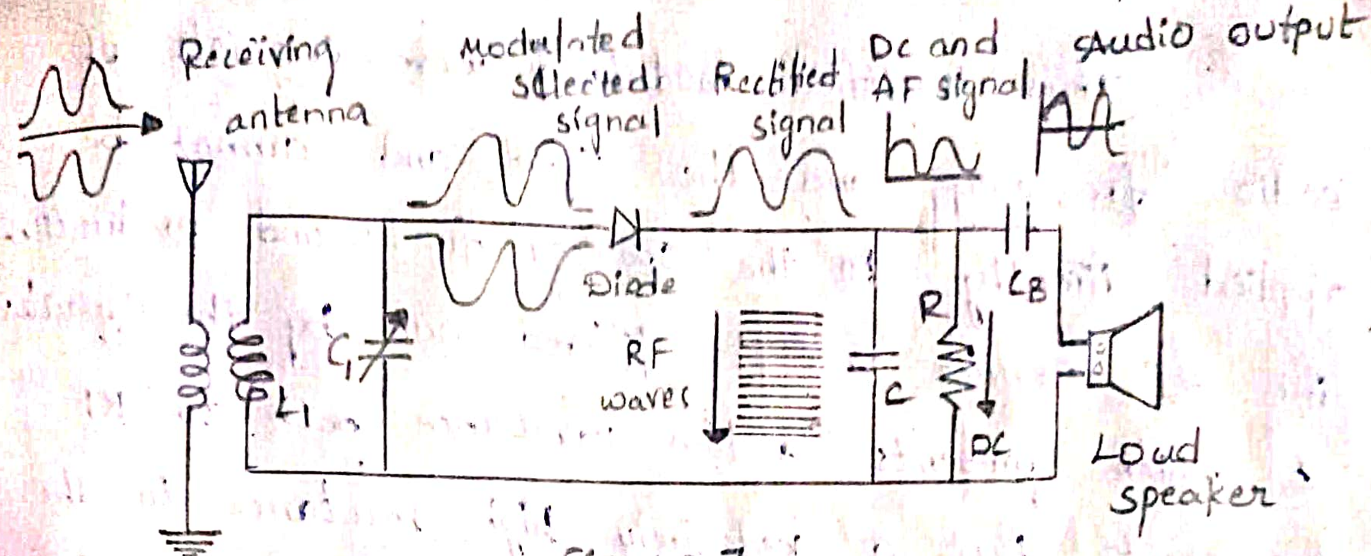


Fig. 40.7

The input to the detector is an amplitude modulated carrier voltage. Tuned circuit $L_1 C_1$ selects the modulated wave of desired frequency. Capacitor C offers a low impedance to the carrier while R is a relatively high resistance. C_B is a blocking capacitor which can pass low frequency AF signals only, but blocks DC from appearing in the output.

circuit operation. By varying the capacitor C_1, the resonant frequency of tuned circuit $L_1 C_1$ can be varied and RF signal of any desired frequency can be tuned in. Thus the modulated wave of desired frequency is selected by the parallel tuned circuit $L_1 C_1$ and is applied to the p-n junction diode. During the positive half cycle of modulated wave, the diode conducts but not during negative half cycles. As a result of this rectifying action, we get only the positive half cycles of the modulated wave in the output of diode.

This rectified modulated wave consists of radio frequency and the signal and cannot be applied directly to the speaker for sound production. The RF carrier wave is filtered out by the capacitor C which presents a low reactance path to RF components but a relatively high reactance to the audio signals. The DC component of the remaining signal can not pass through blocking capacitor C_B.

* FM Transmitter.

→ The carrier frequencies of the radio FM transmitters (that emit the program for "broad audience") are placed in waveband from 88 MHz to 108 MHz.

→ The maximum ~~frequencies~~ frequency shift of the transmitter (during the modulation) is ± 75 kHz.

Block diagram. Fig. 40.10 shows the block the diagram of an Armstrong FM transmitter. It is the most frequently used one.

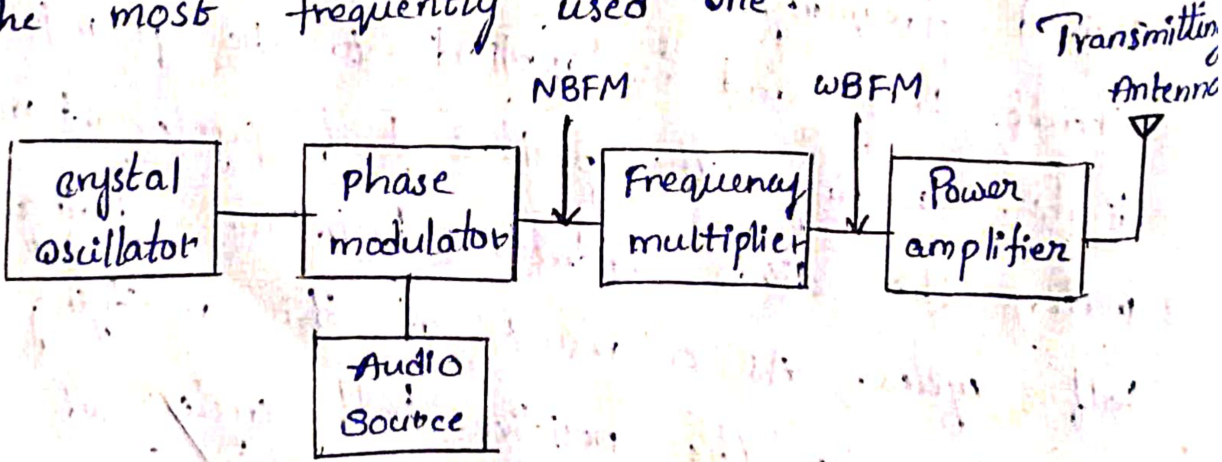
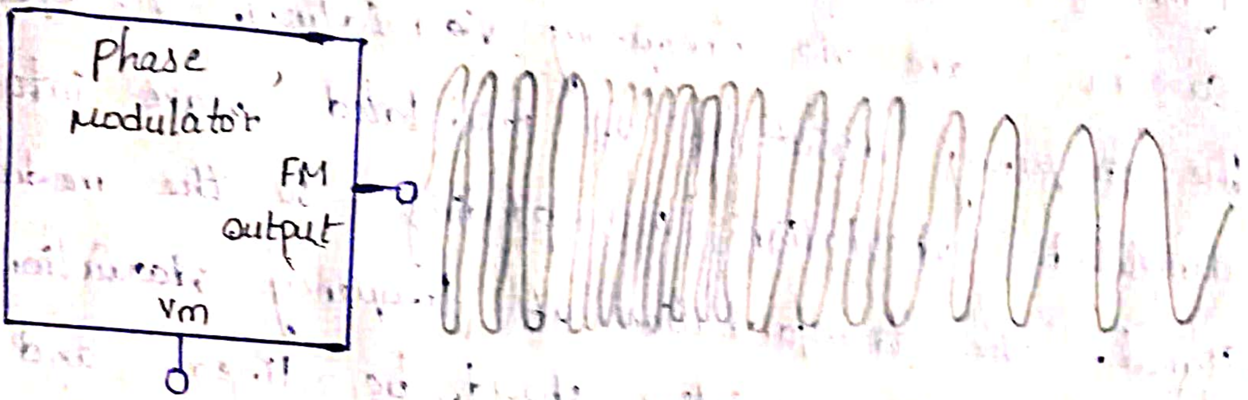


Fig. 40.10

Working of the different stages.

Crystal modulator: The crystal oscillator generates the stable carrier signal.

Phase modulator: The modulating signal and the carrier signal are applied to the phase modulator operating in the low power level to generate a narrowband FM wave (Fig. 40.11).



Information being transferred, i.e., the modulating signal, is signal from some LF Source.

Frequency multiplier: The narrowband FM wave is then passed through several stages of frequency multipliers to increase the frequency deviation and also carrier signal frequency to the required level. The several stages of frequency multiplication helps in choosing a suitable Combination of achieving the required level of multiplication factors needed for deviation and carrier signal frequency.

Power amplifier: The output of the frequency multipliers stage will be a wideband FM, but at the low power levels. The WBFM is then passed through one or more stages of power amplifiers to add required power levels. The WBFM with high power is then finally transmitted via the antenna towards the receiver.

* DETECTION OF FM WAVE.

Principle : We detect the modulated signal on the carrier wave via frequency variations. It changes the frequency deviations of modulated wave into amplitude variation corresponding to the modulating signal. The transformation of frequency variation into amplitude variation should be linear and efficient.

Methods : There are several methods for demodulating an FM signal. These include slope detection, phase-shift discrimination, ratio detection, quadrature detection and phase-locked loop demodulation. We discuss PLL demodulation.

Phase - locked loop (PLL) demodulation

Basic concept : The phase-locked loop (PLL) is a feedback circuit consisting of a phase detector, a low pass filter, and voltage controlled oscillator (VCO).

PLL block diagram. Fig 40.12 shows PLL block digram.

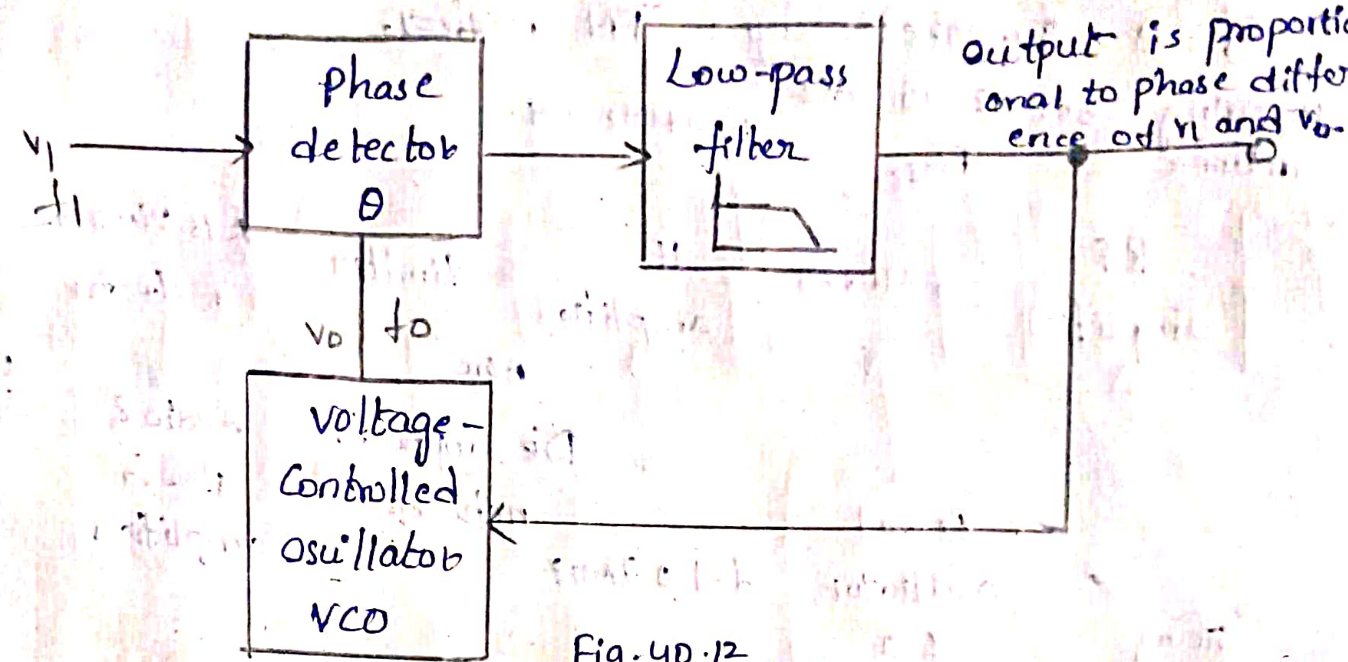


Fig. 40.12

Operation : The phase dector compares the phase difference between the incoming signal, vp and the VCO signal, v_o. when the frequency of the incoming signal, fp is different from that of the VCO frequency, fo, the phase angle between the two signals is also different. At this point, the PLL is locked onto the incoming frequency. If f_i changes, the phase difference also changes, forcing the VCO to track the incoming frequency.

* The Superheterodyne FM Receiver.

Principle : It uses superhetrodyne principle.

* The FM broadcast signals lie in the frequency range between 88 MHz and 108 MHz.
* The IF (intermediate frequency) of an FM receiver is 10.7 MHz.

Block diagram: Fig. 40.13 shows the block diagram of a superheterodyne FM receiver.

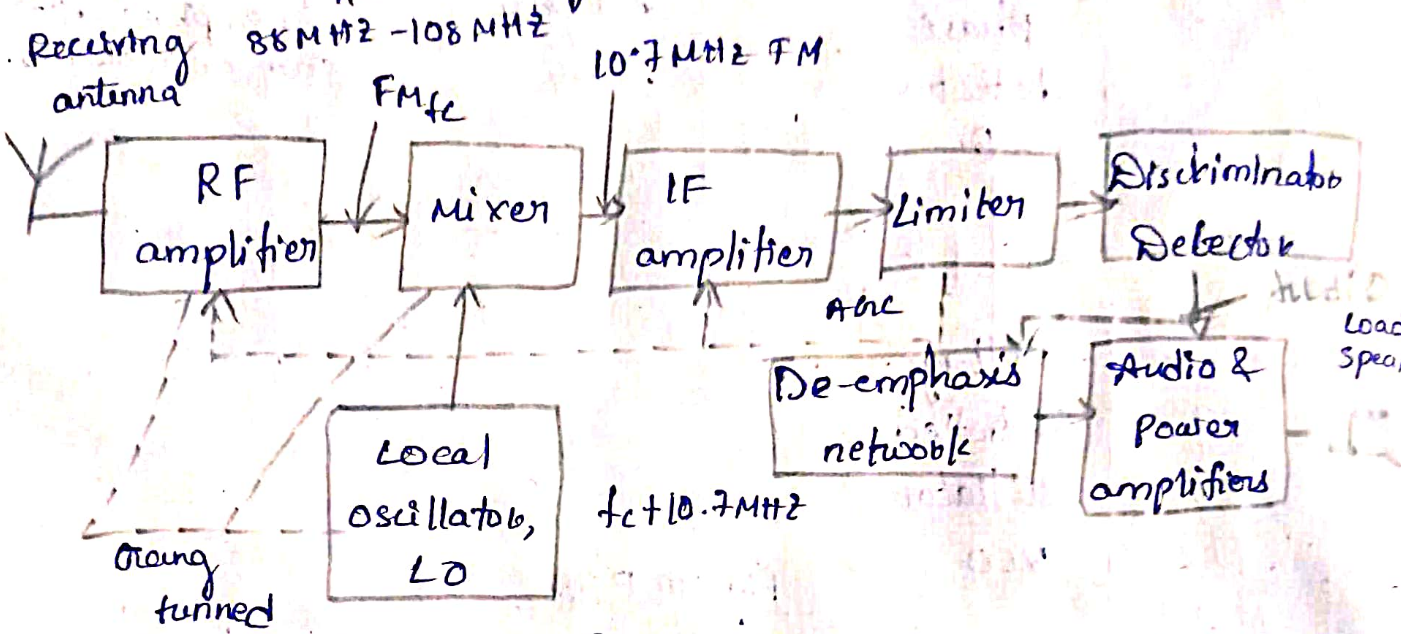


Fig. 40.13

The functions of various stages are as follows:

Receiving antenna: It is used to receive a portion of the transmitted waves.

RF amplifier: This circuit must be capable of amplifying any frequency between 88 MHz and 108 MHz. It is highly selective so that it passes only the selected carrier frequency and significant side-band frequencies that contain the audio.

Local oscillator: The circuit produces a sine wave at a frequency 10.7 MHz above the selected RF frequency.

Mixer: The output from the RF amplifier is fed to the mixer stage where it is combined with the output signal from a local oscillator.

The two frequencies beat together and produce an intermediate frequency (IF). The intermediate frequency (IF) is equal to the difference between oscillator frequency and the RF frequency.

* The output of the mixer is a 10.7 MHz FM signal regardles of the RF carrier frequency.

IF Amplifier : The circuit amplifies the 10.7 MHz FM Signal.

Limiter: Limiter keeps the amplitude variation of Signal under control. The limiter produces a Constant amplitude. FM output at the 10.7 MHz intermediate frequency.

Discriminator : The descriminator recovers the audio from the FM Signal.

* It extracts the intelligence modulated on to the carrier via frequency variations.

De-emphasis network : The higher modulating frequencies are amplified more than the lower frequencies at the transmitting and of an FM system by a process called preemphasis.

Audio and power amplifiers : This circuit amplifiers the detected audio signal and drives the loud speaker to produce sound.