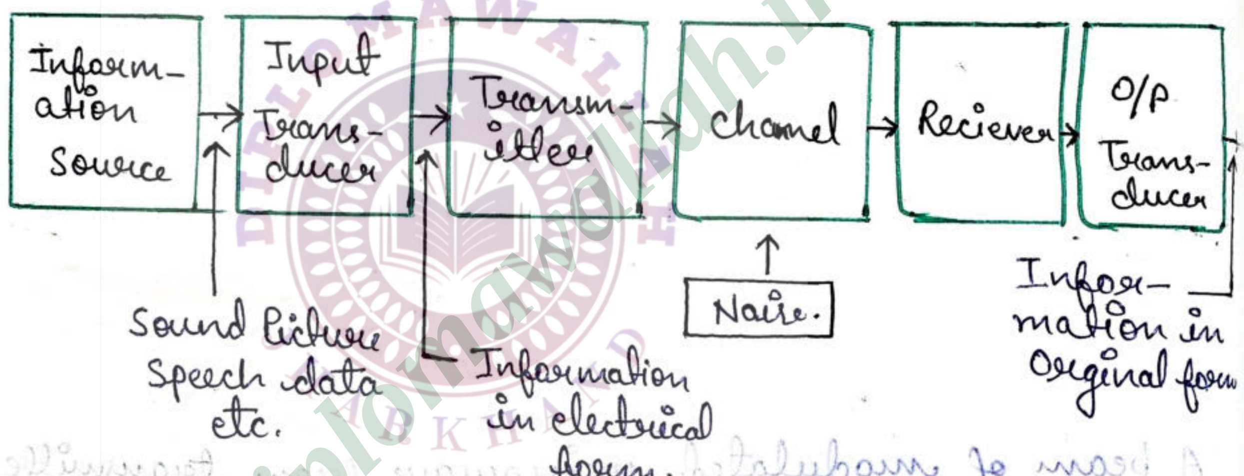
Unit:- 08

Analog Modulation

» Block Diagram of Communication System:-



① Information Source :- The message or information originate in the information source. The message should be in the form of words, group of words, code, symbols, sound signals etc. However out of these messages, only the desired messages selected or communicated.

② Input Transducer :- A transducer is a device which converts one form of energy into another form. When the message produce by the information source ~~who~~ is not electrical in nature, and input transducer is used to convert it into electrical form.

③ Transmitter:- The function of the transmitter is to process the electrical signal from different aspects. Modulation is the main function of the transmitter. In modulation, the message signal or baseband signal supreme-posed upon the high frequency carrier signal.

④ Channel:- The function of the channel is to provide a physical connection between the transmitter and the receiver.

⑤ Receiver:- The main function of the reciever is to praduce the message signal in electrical form from the distorted received signal.

⑥ Output Transducer:- ~~0.~~ It convert the electrical signal in original signal. Demodulation is the main function of output Transducer.

Modulation:-

Modulation may be defined as the process by which some characteristics of a signal called carrier is varied in accordance with the instantenous value of another signal called modulating signal.

→ Need of Modulation:-

i) Reduce the height of antenna:-
For an example the AM broadcast system, the
(Analog Modulation)

maximum audio frequency transmitted for a radio station is 5 KH_2. If this message is to transmit without modulation then the height of antenna will be

$$\boxed{l = \frac{\lambda}{4} = \frac{c}{4f}.}$$

$$l = \frac{3\times10^8}{4\times5\times10^3}$$

$$= 15\ Km.$$

If we use modulation for an example if an audio frequency is translated to radio frequency carrier of 4 MH_2 then the antenna height

$$l = \frac{\lambda}{4} = \frac{c}{4f}.$$

$$l = \frac{3\times10^8}{4\times4\times10^6}$$

$$= \frac{300}{16}$$

$$= 18.75\ m.$$

ii) To remove interference :- Another reason for not radiating modulating signal itself is that the frequency range of audio signal is from 20 H_2 to 20 KH_2. In radio-broadcasting, there are several radio stations, there is no modulation all these stations transmit audio or sound signals in the range of 20 H_2 to 20 KH_2. Due to this transmission over same range, the programmes of different stations will get mixed up.

Hence, in order to keep the various signals separate, it is necessary to translate or shift them to different portions of the electromagnetic spectrum.

iii) Reduction of noise :- Noise is the major limitation of any communication. Although noise can not be eliminated completely, but with the help of several modulation schemes, the effect of noise can be minimized.

Types of Modulation:-

Modulation is basically of two types :-

i) Continous Wave Modulation :- When the carrier wave is continous in nature, the modulation process is known as continous wave (CW) modulation or analog modulation.

Example of continous wave modulation are Amplitude Modulation and Angle Modulation.

ii) Pulse Modulation :- When the carrier wave is a pulse - type waveform, the modulation process is a known as pulse modulation.

In analog pulse modulation, the amplitude, duration or position of a pulse is varied in accordance with sample values of the message signal. The analog pulse modulation may be of following three types:-

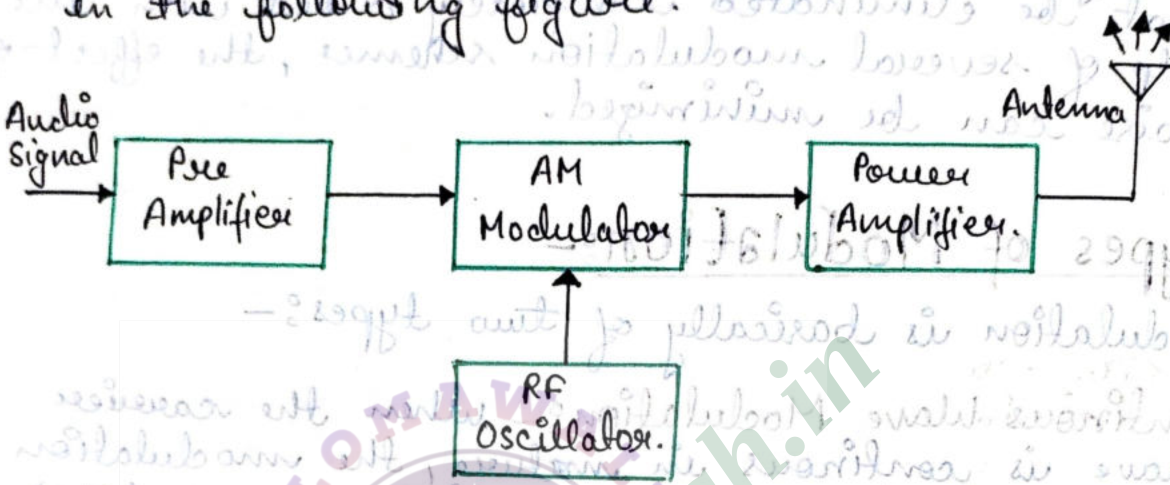
i) pulse - amplitude modulation (PAM)

ii) pulse - duration modulation (PDM)

iii) pulse - position modulation (PPM)

» AM Transmitter ...

AM transmitter takes the audio signal as an input and delivers amplitude modulated wave to the antenna as an output to be transmitted. The block diagram of AM transmitter is shown in the following figure.



The working of AM transmitter can be explained as follows:

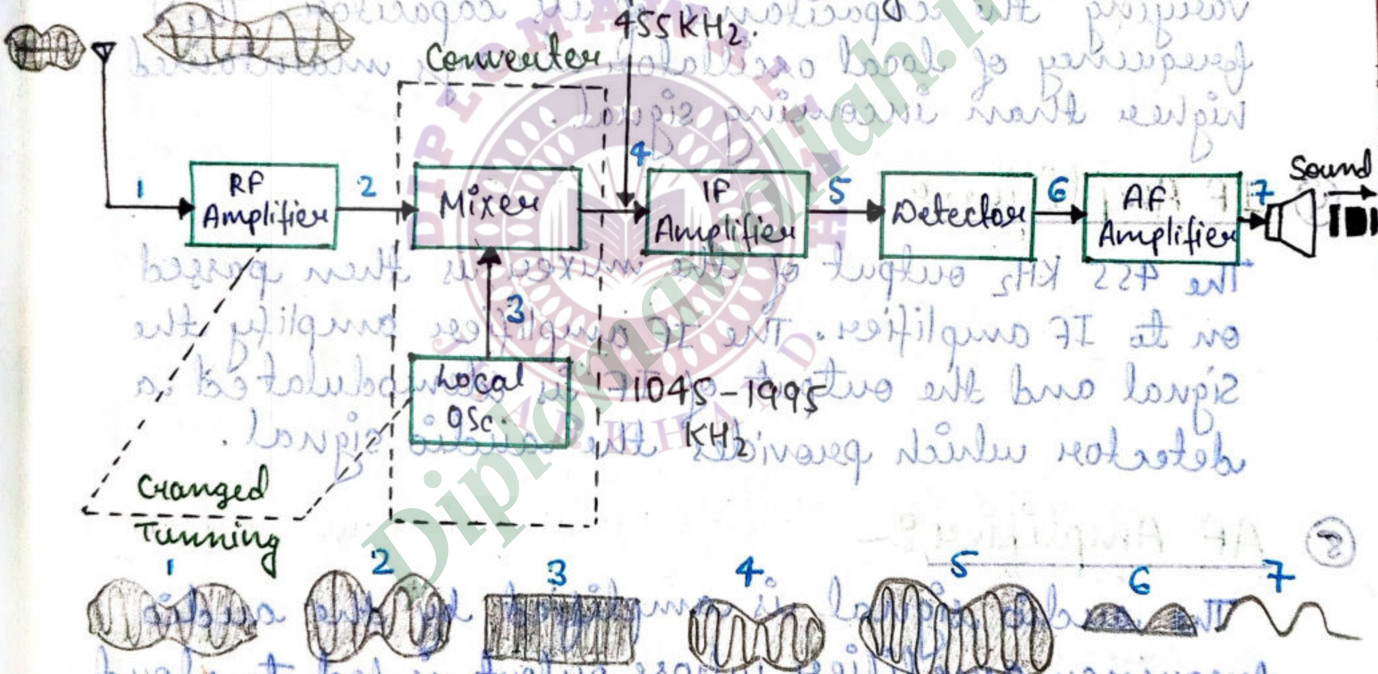
- The audio signal from the output of the microphone is sent to the pre-amplifier, which boosts the level of the modulating signal.
- The RF oscillator generates the carrier signal.
- Both the modulating and the carrier signal is sent to AM modulator.
- Power amplifier is used to increase the power levels of AM wave. This wave is finally passed to the antenna to be transmitted.

Super Heterodyne Receivers:

It is difficult to design amplifiers which give uniform high gain over a wide range of radio frequencies. However it is possible to design amplifiers which can provide high gain and uniform amplification over a narrow band of lower frequencies called intermidate frequencies.

Hence it is necessary to convert the modulated RF signal into modulated IF signal by using a frequency converter. For this we use super hetrodyne receiver.

The word hetrodyne stands for mixing. Here we have mixed the incoming signal frequency with the local oscillator frequency. Therefore this receiver is called super hetrodyne receiver.



① RF Amplifier:

RF low noise amplifiers are designed to increase the desired RF signal amplitude without adding distortion or noise.

② Mixer: —

Mixer circuit is designed to combine two radio frequencies. It has two input from RF amplifier and other from local oscillator.

when mixer combined the two signal we get, $f_o + f_s$ (Sum) and $f_o - f_s$ (Difference). The sum frequency is removed by band pass filtering. The difference frequency given to the input of IF amplifier.

The difference frequency is always maintained at 455 KHz.

③ Local Oscillator :-

The local oscillator is an RF oscillator whose frequency of oscillation can be controlled by varying the capacitance of its capacitor. The frequency of local oscillator always maintained higher than incoming signal.

④ IF Amplifier :-

The 455 KHz output of the mixer is then passed on to IF amplifier. The IF amplifier amplify the signal and the output of IF is demodulated a detector which provides the audio signal.

⑧ AF Amplifier :-

The audio signal is amplified by the audio frequency amplifier whose output is fed to loud speaker which reproduces the original signal.

Ganged Tuning :-

If the incoming signal changes then the local oscillator frequency also changes to maintain the difference frequency. For this purpose the tuning capacitor of the oscillator ganged with the capacitor of the ~~output~~ input circuit i.e. RF amplifier. So that the difference in the frequency of the incoming

signal and oscillator frequency is always cons
i.e 455 KHz.

Example - if the $f_s = 1500$ KHz

$f_o = 1955$ KHz.

Then $f_o - f_s = 455$ KHz

Or if the $f_s = 1345$ KHz.

$f_o = 1800$ KHz.

Then $f_o - f_s = 455$ KHz.

» AMPLITUDE MODULATION :-

Amplitude Modulation may be defined as a system in which the maximum amplitude of the carrier wave is made proportional to the instantaneous value (amplitude) of the modulating or baseband signal.

Sinusoidal carrier wave $c(t)$ given as

$$c(t) = A \cos \omega_c t$$ → Carrier frequency

Here A is the maximum ~~ap~~ amplitude of the carrier wave and ω_c is the carrier frequency.

Let $x(t)$ denotes the modulating or baseband signal, then according to amplitude modulation, the maximum amplitude A of the carrier will have to be made proportional to the instantaneous amplitude of modulating signal $x(t)$.

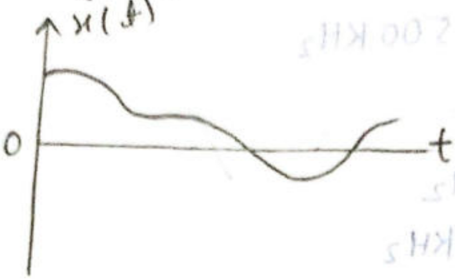
The standard equation for amplitude modulated (AM) wave may be expressed as

$$s(t) = x(t) \cos \omega_c t + A \cos \omega_c t$$

$$s(t) = [A + x(t)] \cos \omega_c t.$$

Maximum carrier amplitude.

(a) Modulating Signal



(b) Carrier Signal

(c) Modulated Signal

» MODULATION INDEX (AMPLITUDE SENSITIVITY) (AM)

In AM system the modulation index is defined as the measure of extent of amplitude variation about an unmodulated maxium carrier

$$\text{Modulation Index } [m_a =] \frac{|x(t)|_{max}}{\text{Maximum carrier amplitude}}$$

or Modulation Index $m_a = \frac{|x(t)|_{max}}{A}$

where $|x(t)|_{max}$ represents the maximum amplitude of modulating signal and A represents the maximum amplitude of carrier signal.

The modulation index is also known as depth of modulation, degree of modulation or modulation factor.

» Frequency Modulation :- (FM)

Definition :-

Frequency modulation is that type of angle modulation in which the instantaneous frequency ω_i is varied linearly with a message or baseband signal $x(t)$ about an unmodulated carrier frequency ω_c.

Mathematical Representation

We know that the instantaneous frequency is given by

$$\omega_i = \omega_c + k_f \cdot x(t)$$

– where k is proportionally constant and is known as the frequency sensitivity of the modulator.

→ The expression for unmodulated carrier single be

$$c(t) = A \cos(\omega_c t + \theta_0)$$

$$c(t) = A \cos\phi$$

where $\phi = \omega_c t + \phi_0$

→ The equation for unbonded carrier is

$$c(t) = A \cos\phi.$$

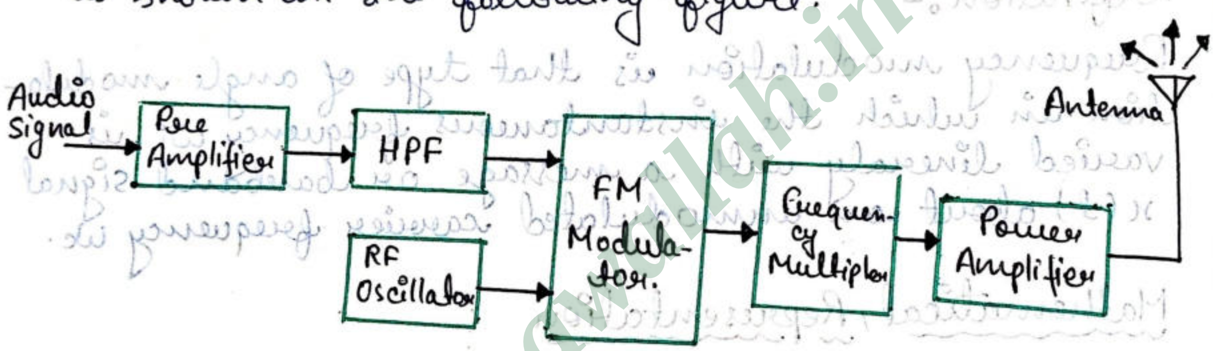
Hence, the expression for frequency modulated wave will be

$$S_{FM}(t) = A \cos \phi_i$$

where ϕ_i = instantaneous phase angle.

» FM Transmitter...

FM transmitter is the whole unit, which takes the audio signals as an input and delivers FM wave to the antenna as an output to be transmitted. The block diagram of FM transmitter is shown in the following figure.



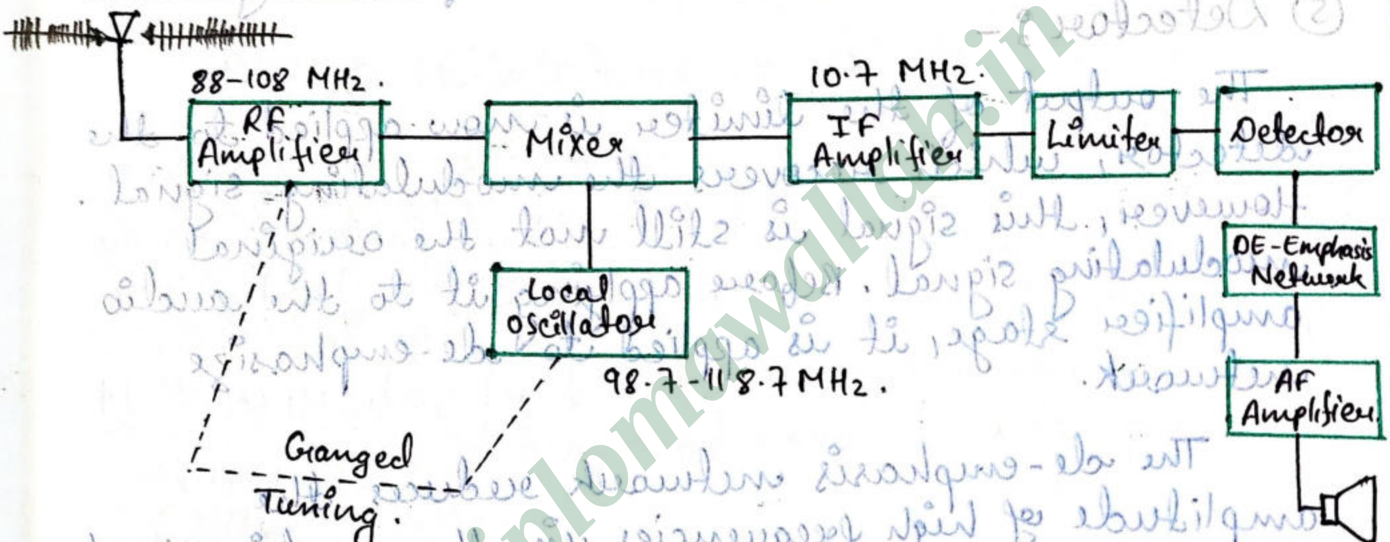
The working of FM transmitter can be explained as follows.

- The audio signal from the output of the microphone is sent to the pre-amplifier, which boosts the level of the modulating signal.
- This signal is then passed to high pass filter, which acts as a pre-emphasis network to filter out the noise and improve the signal to noise ratio.
- The signal is further passed to the FM modulator circuit.

- The oscillator circuit generates a high frequency carrier, which is sent to the modulator along with the modulating signal.

- Several stages of frequency multiplier are used to increase. 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 be transmitted.

FM Receiver :-



① RF Amplifier :-

The RF amplifier amplifies the received intercepted by the antenna. The amplifier is a low noise amplifier.

② Mixer :-

The amplified signal is then applied to the mixer stage. The second input of the mixer comes from the local oscillators.

③ IF Amplifier :-

The output of the mixer is a difference signal of incoming signal and carrier signal i.e, known as intermidate frequency of 10.7 MHz. This signal is then amplified by IF amplifier.

④ Limiter :-

The output of the IF amplifier is applied to the limiter circuit. The limiter removes the noise in the received signal and gives a constant amplitude signal.

This is very important in FM receivers because at amplitude variation in the received signal will result in unfaithful reproduction of the audio signals. Limiter is a sort of clipping circuit.

⑤ Detector :-

The output of the limiter is now applied to the detector, which recovers the modulating signal. However, this signal is still not the original modulating signal. Before applying it to the audio amplifier stage, it is applied to de-emphasize network.

The de-emphasis network reduces the amplitude of high frequencies in the audio signal to bring them back to their original amplitude as these are increased by the pre-emphasis network at the transmitting station.

⑥ AF Amplifier :-

The output of the de-emphasized stage is the audio signal, which is then applied to the audio amplifier stages and finally to the speaker.

→ For FM, the modulation index is defined as the ratio of frequency deviation to the modulating frequency.

Mathematically,

$$\text{Modulation index, } m_f = \frac{\text{Frequency deviation}}{\text{Modulation Frequency}}$$

or $m_f = \dfrac{\Delta\omega}{\omega_m}$

→ This modulation index may be greater than unity.

$$\text{Percent Modulation } M = \frac{\Delta f\ \text{actual}}{\Delta f_{max}} \times 100$$

$$\boxed{|x(t)|_{max} \le A}$$

→ modulation index m_a is less than or equal to unity.

* If $m_a > 1$ or the percentage modulation is greater than 100. the baseband signal is not preserved in the envelope.
* This type of distortion is called envelope distortion and the AM signal with $m_a > 1$ or $m_a > 100\%$ is called overmodulated signal.

i) Amplitude Modulation with $m_a < 1$

Here the maximum amplitude of baseband signal is less than maximum carrier amplitude.

$$\boxed{|x(t)|_{max} < A}$$

ii) Amplitude Modulation with $m_a > 1$.

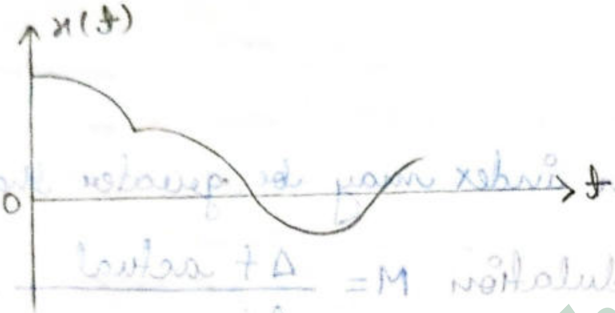
In this case, the waveform of AM signal is shown in figure.

Here, the amplitude of a baseband signal exceeds maximum carrier amplitude.

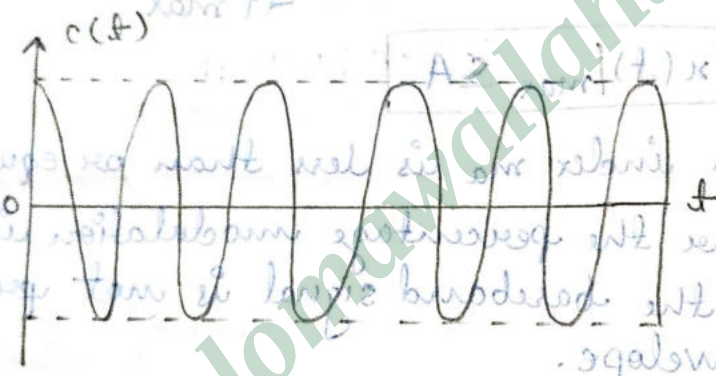
$$\boxed{|x(t)|_{max} > A}$$

In this case, the modulation index m_a is more than 1 or 100%.

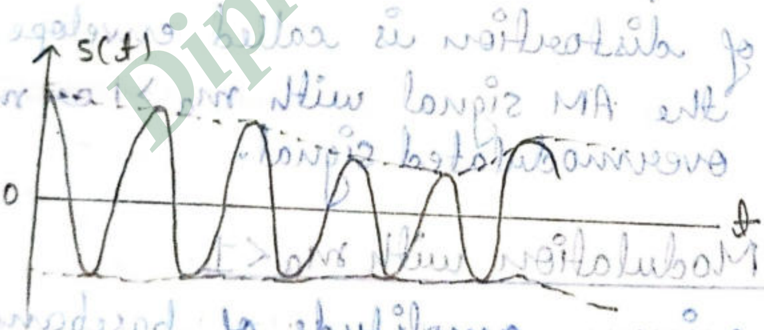
(a)



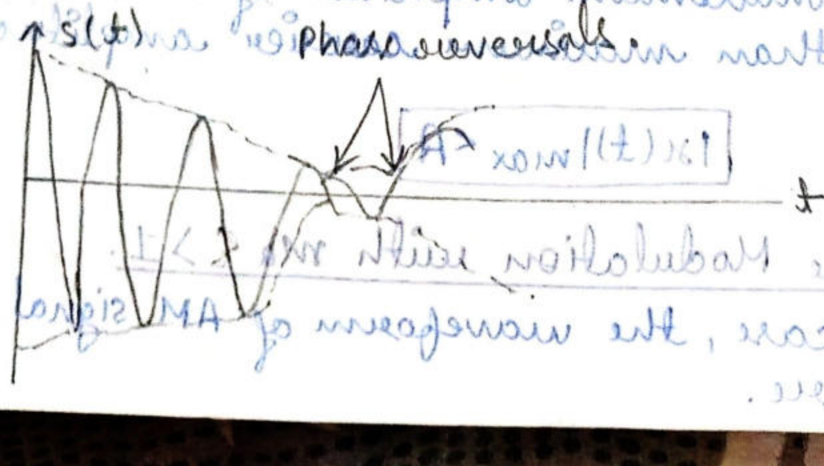
(b)



(c)



(d)



» Power Content IN AM WAVE :-

We know that the general expression of AM wave is given as,

$$s(t) = A \cos \omega_c t + x(t) \cos \omega_c t$$

The total power P of AM wave is the sum of the carrier power P_c and sideband power P_s.

* Carrier Power :-

The carrier power P_c is equal to the mean square value (ms) of the carrier term.

$$P_c = \text{mean square value of } A \cos \omega_c t.$$

$$P_c = [A \cos \omega_c t]^2 = \frac{1}{2\pi} \int_0^{2\pi} A^2 \cos^2 \omega_c t \, dt^* = \frac{A^2}{2}.$$

→ carrier frequency

* Side band power :-

The sideband power P_s is equal to the mean square value of the sideband term $x(t) \cos \omega_c t$,

$$P_s = \text{mean square value of } x(t) \cos \omega_c t$$

$$P_s = [x(t) \cos \omega_c t]^2 = \frac{1}{2\pi} \int_0^{2\pi} x^2(t) \cos^2 \omega_c t \, dt.$$

$$P_s = \frac{1}{2\pi} \int_0^{2\pi} \frac{1}{2} [2 \cos^2 \omega_c t] x^2(t) \, dt.$$

$$P_s = \frac{1}{2\pi} \int_0^{2\pi} \frac{1}{2} x^2(t) \, dt + \frac{1}{2\pi} \int_0^{2\pi} x^2(t) \cos 2\omega_c t \, dt.$$

(Band Pass Filter)

→ BPF tuned to carrier frequency ω_c is used to filter out the second intergal term.

$$P_s = \frac{1}{2\pi} \int_0^{2\pi} \left[\frac{1}{2} x^2(t)\right] dt$$

$$P_s = \text{mean square (ms) value of } \frac{1}{2} x^2(t) = \frac{1}{2} \overline{x^2(t)}$$

→ The power carried by the upper and lower sidebands will be

$$P_{s}(LSB) = P_s(USB) = \frac{P_s}{2} = \frac{1}{4} \overline{x^2(t)}$$

Therefore, the total power P_t of the AM signal is the sum of the carrier power P_t and side band power P_s.

$$P_t = P_c + P_s = \frac{1}{2}A^2 + \frac{1}{2}\overline{x^2(t)}$$

$$P_t = \frac{1}{2}\left[A^2 + \overline{x^2(t)}\right]$$

Frequency Deviation :-

We know that the instantaneous frequency of FM wave is given as

$$\boxed{\omega_i = \omega_c + K_f \cdot x(t)}$$

The instantaneous frequency of FM signal varies with time around the carrier frequency ω_c. This means that the instantaneous frequency of FM signal varies according to the modulating signal.

* The maximum change in instantaneous frequency from the average frequency ω_c is called frequency deviation.

* Maximum frequency deviation is generally denoted by $\Delta\omega$.

Therefore,

Frequency deviation $\Delta\omega = |K_f \cdot x(t)|_{max}$