

LECTURE NOTES  
ON  
ANALOG & DIGITAL  
COMMUNICATION ENGG.

5th SEM  
ELECTRONICS &  
TELECOMMUNICATION ENGG

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## Elements of Communication System

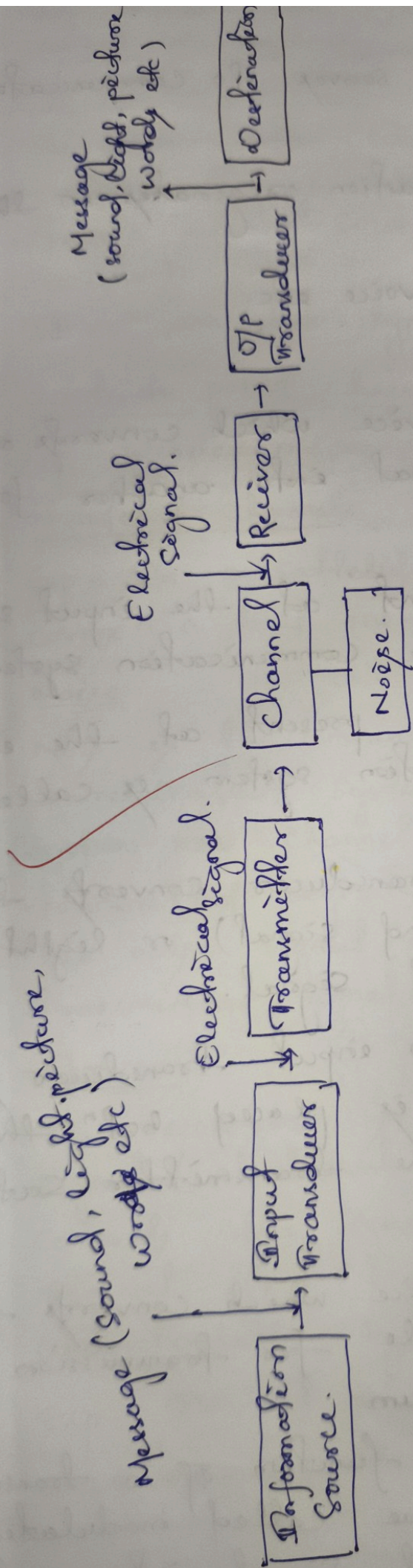
(1.1) Concept of elements of communication system & its block diagram.

- \* Communication means sending, receiving & processing of information bet<sup>n</sup> two or more devices.
- \* A collection of elements (devices) which work together to establish a communication bet<sup>n</sup> the sender & the receiver is called a communication system.
- \* Some examples of communication system include radio broadcasting, television broadcasting, mobile comm<sup>n</sup>, computer comm<sup>n</sup> etc.
- \* Two or more people communication with each other by using sound signals is also called as the communication system.

### Block Diagram of Communication System.

- \* The basic components of a communication system are information source, input transducer, transmitter, communication channel, receiver, output transducer, & destination.





Block Diagram of Communication System.



### (1) Information Source

- \* The communication system serves to communicate a message or information.
- \* The message or information originates in the information source.
- \* Example, picture, data, voice etc.

### (2) Input Transducer

- \* A transducer is a device which converts one form of energy or signal into another form of energy or signal.
- \* The transducer is present at the input side & output side of the communication system.
- \* The transducer that is present at the input side of the communication system is called input transducer.
- \* Generally, the input transducer converts the non electrical signal (sound signal) or light signal into an electrical signal.
- \* The best example of an input transducer is the microphone which is placed bet<sup>n</sup> the information source & the transmitter section.

### (3) Transmitter

- \* The transmitter is a device which converts the signal produced is suitable for transmission over a given channel or medium.
- \* Modulation is the main function of a transmitter.
- \* Transmitters use a technique called modulation to convert the electrical signal into a form



that is suitable for transmission over a given channel or medium.

#### (4) Communication channel

\* The communication channel is a wired or wireless medium through which the signal (information) travels from source (transmitter) to destination (receiver).

\* There are two types of communication channels.

##### (i) point to point channels

\* Ex - wireless, microwave, links & optical fibres.

##### (ii) Broadcast channels

\* Ex - An a satellite in geostationary orbit which covers about one-third of the earth's surface.

#### (5) Noise

\* Noise is the unwanted signal that enters the communication system via the communication ~~system~~ channel & interferes with the transmitted signal.

\* The noise signal (unwanted signal) degrades the transmitted signal (signal containing information).

#### (6) Receiver

\* The receiver is a device that receives the signal (electrical signal) from the channel & converts the signal (electrical signal) back to its original form (light & sound) which is understandable by humans at the destination.

\* Ex - TV set is a good example of a receiver.



## (7) Output Transducer

- \* The transducer that is present at the output side of the communication system is called output transducer.
- \* Generally, the output transducers convert the electrical signal into a non-electrical signal (Sound signal, light signal, or both signals).
- \* Exp - Loudspeakers which is placed bet<sup>n</sup> the receiver section & destination.

## (8) Destination

- \* The destination is the final stage in the comm<sup>n</sup> system which is used to convert an electrical message signal into its original form.
- \* For example - In radio broadcasting, the destination is a loudspeaker which works as a transducer i.e. it converts the electrical signal in the form of original sound signal.

## (1.2) Source of Information

- \* The message or information originates in the information source.
- \* The following four important sources of information.

### (a) Speech

- \* The speech communication process involves the transfer of information from a speaker to a listener.

### (b) Television

TV, refers to the transmission of picture in motion by means of electrical signals.

### (c) Facsimile

- \* Facsimile (Fax) machine, is to transmit still pictures over a communication channel (a telephone channel)



- \* For a signal generation is a facsimile machine is to scan an original document (i.e. picture) & use an image sensor to convert the light to an electrical signal.

#### (d) Personal Computers:

- \* personal computers (PCs) are becoming increasingly an important part of our daily lives.
- \* We use them for electronic mail, exchange of software, & sharing of resources.

#### (1.2) Communication Channel

- \* The communication channel is a wired or wireless medium through which the signal (information) travels from source (transmitter) to destination (receiver).
- \* The following four important of comm<sup>n</sup> channels.

##### (i) Telephone Channels

A one-way or two-way path suitable for the transmission of audio signals bet<sup>n</sup> the two stations.

##### (ii) Optical Fibers

The optical fibers optics, it refers to a medium & technology associated with the transmission of information as light along a glass or plastic wire or fiber.

##### (iii) Mobile radio channels

- \* The mobile radio channel, extends the capability of the public telecommunication network by introducing mobility into the network by virtue of the ability to broadcast.
- \* Therefore, a mobile radio channel as a linear



time varying channel that is statistical nature.

### (1.2) Satellite channel

- \* Satellite channel provides broad-area coverage in a continental as well as inter continental range.
- \* Satellites can provide fixed point-to-point links extending over long distances & into remote areas, communication to mobile platforms (exp - aircrafts, ships), or broadcast capabilities.

### (1.3) Classification of Communication Systems

- \* The model of propagation communication divided into two forms.

#### (a) Line communication

- \* In line comm, the medium of transmission is a pair of conductors called transmission line.
- \* This is also called as wire channel.
- \* This means that in the wire comm the transmitter & the receiver are connected through a wire or line.

#### (b) Wireless or Radio communication

- \* In wireless or radio communication, a message is transmitted through open space by electromagnetic waves called a radio waves.
- \* Radio waves are radiated from the transmitter in open space through a device called antenna.
- \* A receiving antenna intercepts the radio waves at the receiver.
- \* All the radio, TV & satellite broadcasting are wireless or radio communication.

#### Advantages

- \* Cost effectiveness



- \* Long distance communication
- \* Simplicity.

#### (1.4) Modulation Process

- \* The process of changing some characteristics (exp- amplitude, frequency or phase) of a carrier wave in accordance with the intensity of signal is known as modulation.
- \* Modulation means to "change"
- \* In modulation some characteristics of carrier wave is changed in accordance with the intensity (i.e. amplitude) of the signal.
- \* The resultant wave is called modulated wave or radio wave & contains the audio signal.

#### (1.4) Need of Modulation

- \* Modulation is extremely necessary in communication system due to the following reasons:-

##### (i) practical Antenna length

- \* The length of the transmitting antenna should be approximately equal to the wavelength of the wave.

$$\text{Now, Wavelength} = \frac{\text{Velocity}}{\text{frequency.}}$$

$$\text{Wavelength} = \frac{3 \times 10^8}{\text{frequency (Hz)}} \text{ meters.}$$

##### (ii) Operating Range

- \* The energy of a wave depends upon its frequency.



- \* The generator the frequency of the wave
- \* the generator the energy possessed by it.

### (iii) Wireless communication:

- \* In wireless communication, a message is transmitted through open space by electromagnetic waves called as radio waves.
- \* Radio waves are radiated from the transmitter in open space through a device called antenna.

### (1.4) Classification of Modulation process

- \* Modulation is basically of two types

#### (i) Continuous Wave Modulation

- \* When the carrier wave is continuous in nature the modulation process is known as continuous wave (CW) modulation or analog modulation.
- \* Ex<sup>amp</sup> of it is amplitude modulation or ~~angle~~ Angle modulation.
- \* When the amplitude of the carrier is varied in accordance with the message signal, it is known as amplitude modulation (AM)
- \* Also, when the angle of the carrier wave is varied according to the instantaneous value of the modulating signal, it is called angle modulation.
- \* Angle modulation subdivided into 'frequency modulated' (FM) & phase modulation (PM), in which instantaneous frequency ~~modulated~~ & phase of the carrier, respectively are varied in accordance with the message signal.



## (ii) pulse modulation

- \* When the carrier wave is a pulse type waveform the modulation process is known as pulse modulation.
- \* In pulse modulation the carrier consists of a periodic sequence of rectangular pulses.
- \* Pulse modulation can be of an analog or digital type.
- \* In analog pulse modulation the amplitude, duration or position of a pulse is varied in accordance with sample value of the message signal.
- \* The analog pulse modulation following three types:

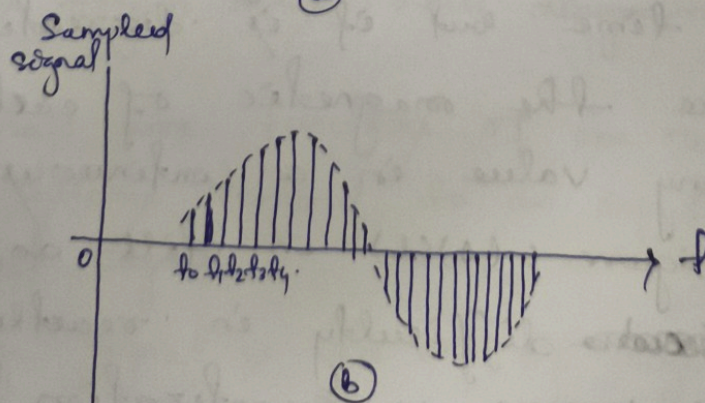
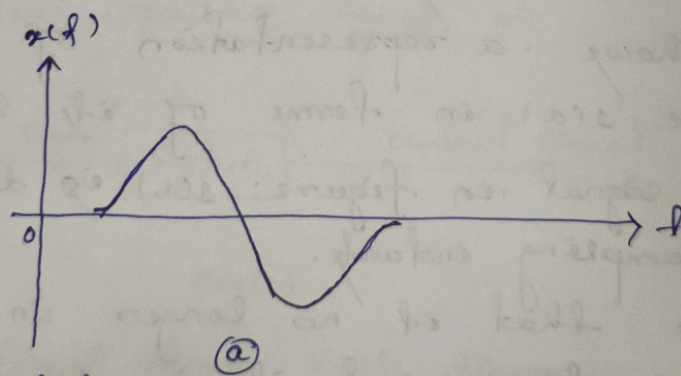
(a) pulse - amplitude modulation (PAM)

(b) pulse - duration modulation (PDM)

(c) pulse - position modulation (PPM)

- \* The digital form of pulse modulation is known as pulse-code modulation.

## (1.5) Analog & digital signals & its conversion





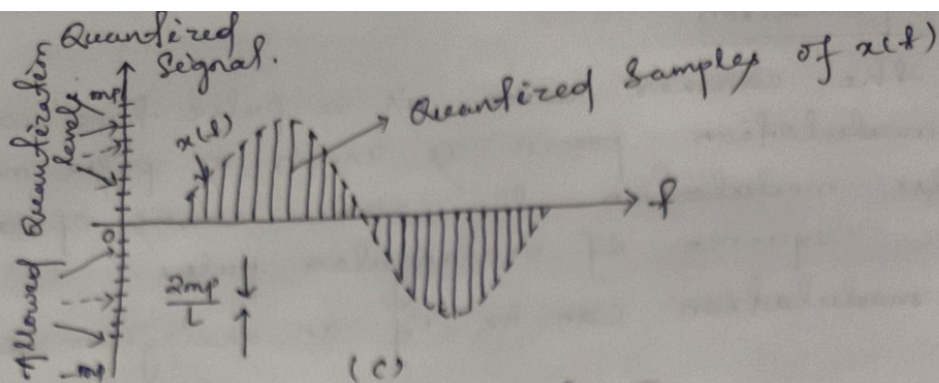


Fig: (a) An analog signal, (b) Samples of analog signal  
(c) Quantization.

- \* To convert an analog signal into digital signal.
- \* This means that to convert a continuous time signal in the form of digits.
- \* A signal can be converted from analog to digital form, let us consider an analog signal as show up in figure:-

(1) First of all, we get sample of this signal according to sampling theorem.

- \* Figure 1(a) For this purpose the time intervals along the time axis.

- \* Fig 1(b) Shows a representation of the signal of figure 1(a) in terms of its samples.

- \* Now the signal in figure:- 1(b) is defined as only at the sampling instants.

- \* This means that it no longer is a continuous function of time but it is discrete-time signal.

- \* However, since the magnitude of each sample can take any value in a continuous range, the signal in figure: (1)(b) is still an analog signal.

This ~~difficulty~~ difficulty is exactly resolved by a process known as quantization.



\* In Quantization, the total amplitude range which the signal is divided into a number of standard levels.

\* As shown in figure (1)(c) amplitude <sup>range</sup> of the signal  $x(t)$  lies in the range  $(-m_p, m_p)$  which is partitioned into 'L' intervals each of magnitude  $\Delta u = \frac{2m_p}{L}$

\* Now, each sample is approximated or rounded off to the nearest quantized level as shown in figure.

\* Since each sample is now approximated to one of the 'L' numbers, therefore the information is digitized.

### (1-6) Basic concept of signal

\* A signal is a physical quantity which varies with respect to time, space, & contains some information from source to destination.

\* The form signal includes audio, video, speech, image communication, radar signals etc.

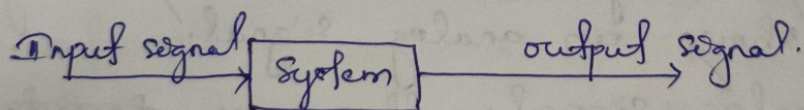


Fig (2)

\* In this fig (2) shows block diagram of a signal & system.

\* The signals are functions of one or more variables & the systems respond to an input signal by producing an output signal.

\* A voltage signal is an exp of signal voltage across



two points varying as a function of time.

- \* Oscilloscope in an exp of system, it takes in a voltage signal, outputs an image characteristic of the voltage signal.

### (1-6) Classification of Analog signal & Digital signal

- \* It is of two types.

#### (i) Analog signals

- \* The analog signal is that type of signal varying smoothly & continuously with time.
- \* This means that analog signals are defined for every value of time & they take on continuous values in a given time interval.

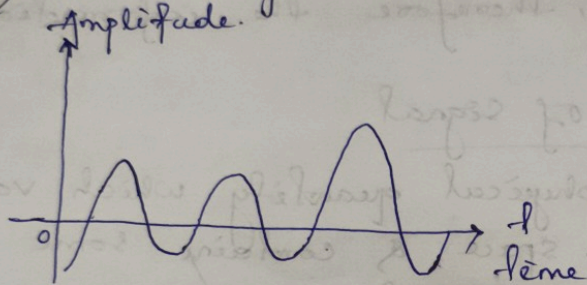


Fig (13) (An Analog signal)

- \* Thus, an analog messages are characterized by data whose values vary over a continuous range.
- \* Figure (3) shows an analog signal.
- \* For an analog signal, the name ~~derives~~ derives from the fact that such a signal is analogous to the physical signal that it represents.
- \* For exp - the temperature or the atmospheric pressure of a certain location vary over a continuous range & assume an infinite number of possible values.
- \* Analog signals can have an infinite number of



values in a range.

- \* In a binary system, each digit in the number takes on one of only two possible values, denoted as '0' & '1'.
- \* Correspondingly, the digital signal in binary systems only two voltage levels which labelled low & high.

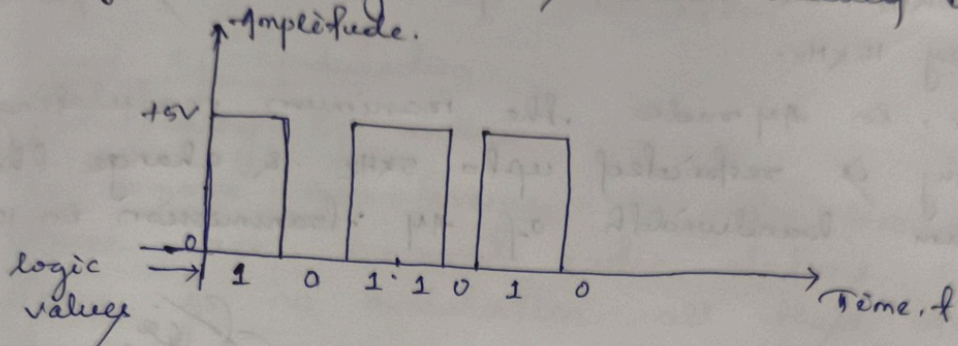


Fig (4) (A Digital signal)

- \* Fig (4) shows a digital signal.
- \* The waveform is a pulse train with or representing a '0' signal or logic '0' & +5V representing logic '1'.
- \* Digital signals can have only a limited number of values.

#### (1.7) Bandwidth Limitation

- \* The bandwidth limitation is another major constraint in a communication system.
- \* The frequency range or the band of frequency needed for a particular given transmission is known as bandwidth.
- \* This band of frequencies required for a particular given transmission is also called channel.
- \* The information theory states that the generator is the transmission bandwidth of a communication system, the more is the information that can be



transmitted.

- \* Let us consider an example.
- \* Suppose one is listening to a music on an AM radio.
- \* The complete amount of information available to the human ear is confined in a frequency range upto 15 kHz, i.e. musical information extends upto a frequency 15 kHz.
- \* However, in AM radio the maximum modulating frequency is restricted upto 5 kHz. & change the maximum bandwidth of AM transmission in 10 kHz.

Unit 2

(2.1)

Modulation

The process of amplifying a signal according to the need.

Need

(i) Power

(ii) Time

from

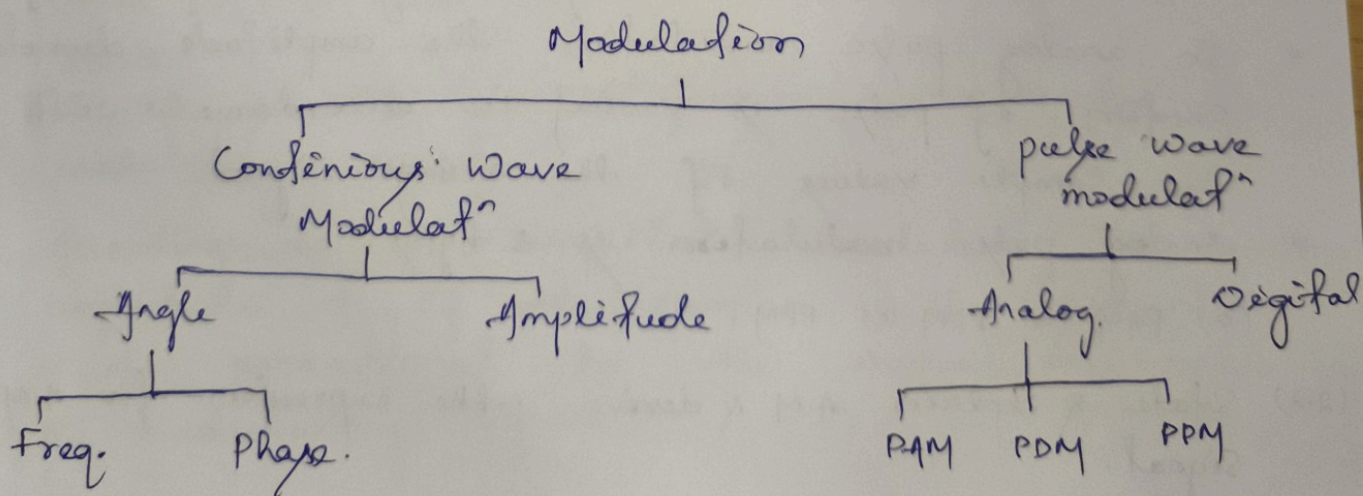


(2.1) Modulation

The process of changing some characteristics (exp- amplitude, freq. & phase) of a carrier wave in accordance with the intensity of the baseband signal is known as modulation.

Need of Modulation

- (i) practically of antenna.
- (ii) To remove interference - In radio broadcasting, there are several radio stations. In case there is no modulation all these stations transmit audio or sound signal in range of 20Hz to 20KHz.
- (iii) Due to this transmission over the same range the program of different stations we will get mixed off.
- (iv) Hence in order to keep the various signal separate it is necessary to translate or shift them to different portion of electromagnetic spectrum. Thus each other is allocated or assigned with a particular band of frequency.

(2.1) Classification of Modulation



PAM - pulse amplitude modulation  
PDM - pulse duration modulation  
PPM - pulse position modulation

### Continuous Wave Modulation

When the carrier is continuous in nature the modulation process is known as continuous wave modulation signal or analog modulation.

Exp - Amplitude, Angle modulation.

#### Amplitude Modulation (A.M)

When the amplitude of the carrier wave is varied according to the instantaneous value of the modulating signal is called angle modulation.

#### Frequency Modulation

When the frequency of the carrier is varied w.r.t the message signal or baseband signal is known as frequency modulation.

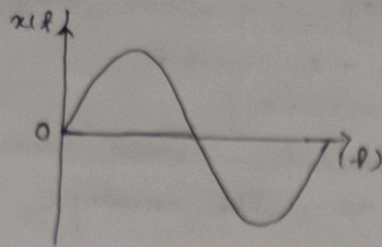
#### Pulse Modulation

- \* When the carrier is pulse type wave from the modulation process is known as pulse modulation.
- \* In pulse modulation the carrier consists of a periodic frequency of rectangular pulse.
- \* Pulse modulation can be of analog or digital type.
- \* In analog pulse modulation the amplitude, duration, position of pulse is varied in accordance with the sample values of the message signal.
- \* Analog pulse modulation is 3 types.

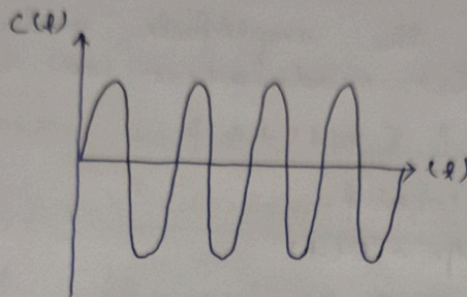
(a) PAM (b) PDM (c) PPM.

(2.2) State & explain A.M & derive the expression for A.M signal.

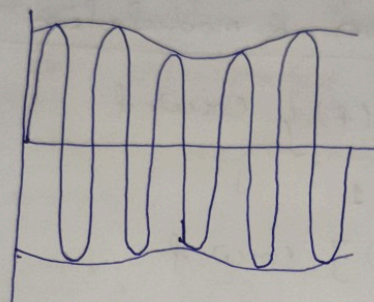




$x(t)$  = Modulating Signal  
 $x(t) = A_m \cos \omega_m t$



$c(t) = A_c \cos \omega_c t$



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

Amplitude modulation may be defined as a system in which the maximum amplitude of the carrier wave is made proportional to the instantaneous value i.e. amplitude of the modulating or baseband carrier wave  $c(t)$  given as

$c(t) = A_c \cos \omega_c t$

where  $A_c$  is the maximum amplitude of the carrier wave.

$\omega_c$  is the carrier frequency  $x(t)$  denotes the modulating signal.

- \* According to the amplitude modulation the maximum amplitude  $A_c$  of the carrier will have to be made proportional to the instantaneous amplitude of modulating signal.



\* The standard eq<sup>n</sup> of AM wave may be expressed as

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

$$= \cos \omega_c t \{ x(t) + A_c \}$$

\* The amplitude modulation wave has a time varying amplitude called as the envelope of the amplitude modulation wave.

\* The envelope of the amplitude modulation wave consists of the modulation or baseband signal.

$$s(t) = \cos \omega_c t \{ x(t) + A_c \}$$

$$= E(t) \cos \omega_c t.$$

Where  $x(t) + A_c = E(t)$

$E(t)$  is called envelope.

Amplitude modulation & modulation index.

$$\{ A_c + K x(t) \} \cos \omega_c t$$

For  $K=1$

$$[A_c + x(t)] \cos \omega_c t$$

$$= [A_c + A_m \cos \omega_m t] \cos \omega_c t$$

$$= A_c \left[ 1 + \frac{A_m}{A_c} \cos \omega_m t \right] \cos \omega_c t$$

Here  $\frac{A_m}{A_c} = \mu$  is known as modulation index.

The value of  $\mu$  is known as modulation index.

$$0 < \mu < 1$$

Again,  $[A_c + A_m \cos \omega_m t] \cos \omega_c t.$

$$= A_c \cos \omega_c t + A_m \cos \omega_m t + \cos \omega_c t$$

$$= A_c \cos \omega_c t + \mu A_c \cos \omega_m t + \cos \omega_c t \left( \because \frac{A_m}{A_c} = \mu \right)$$

$$= A_c \cos \omega_c t + \frac{\mu A_c}{2} \cdot 2 \cos \omega_m t + \cos \omega_c t.$$

$$[2 \cos A \cdot \cos B = \cos (A-B) + \cos (A+B)]$$



$$= A_c \cos \omega_c t + \frac{A_c}{2} [\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t]$$

### (8.1) power relation of AM wave

- \* power of AM wave is equal to the sum of powers of carrier, upper side band <sup>frequency</sup> and lower side band components.

$$P_T = P_c + P_{USB} + P_{LSB} \quad \text{--- (1)}$$

Total power in one modulated wave,

$$P_T = \frac{V_c^2}{R} + \frac{P_{LSB}^2}{R} + \frac{P_{USB}^2}{R} \quad \text{--- (2)}$$

- \* Where all those voltages are rms values & 'R' is the antenna resistance in which one power is 'dissipated'.
- \* The first term represents the power of modulated carrier,

$$P_c = \frac{V_{c, \text{rms}}^2}{R} = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{V_c^2}{2R} \quad \text{--- (3)}$$

Similarly, one lower side band is given by

$$P_{LSB} = \frac{\left(m \frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{m^2 V_c^2}{8R} \quad \text{--- (4)}$$

- \* Similarly, one upper side band power same as that of one lower side band power.

$$P_{USB} = \frac{\left(m \frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{m^2 V_c^2}{8R} \quad \text{--- (5)}$$

Now, add these three power,

$$P_T = \frac{V_c^2}{2R} + \frac{m^2 V_c^2}{8R} + \frac{m^2 V_c^2}{8R}$$

$$\Rightarrow P_T = \frac{V_c^2}{2R} \left(1 + \frac{m^2}{4} + \frac{m^2}{4}\right)$$

$$\Rightarrow P_T = \frac{V_c^2}{R} \left(1 + \frac{m^2}{2}\right)$$



$$P_t = P_c \left(1 + \frac{m^2}{2}\right) \quad \text{--- (6)}$$

\* When modulation is 100%, i.e.  $m=1$ , The maximum power in the AM wave is  $P_t = 1.5 P_c$  --- (7)

(2.2) power relation

We know that  $\cos \theta = \frac{e^{j\theta} + e^{-j\theta}}{2}$

$$\text{For } A_c \cos \omega_c t = \frac{A_c}{2} [e^{j\omega_c t} + e^{-j\omega_c t}]$$

$$= \frac{A_c}{2} [e^{j2\pi f_c t} + e^{-j2\pi f_c t}]$$

$$A_c \cos \omega_c t$$

$$\text{Power} = \frac{(\text{rms})^2}{R}$$

But for normalized case  $R = 1 \Omega$

$$\text{power} = (\text{rms})^2$$

$$\text{rms} = \frac{\text{Peak}}{\sqrt{2}}$$

$$A_c \cos \omega_c t$$

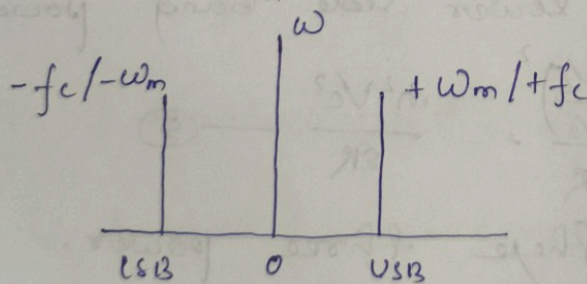
Here peak  $A_c$

$$\text{rms} = \frac{A_c}{\sqrt{2}}$$

$$\text{power} = (\text{rms})^2 = \left(\frac{A_c}{\sqrt{2}}\right)^2$$

$$\text{power} = \frac{A_c^2}{2}$$

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





LSB (Lower side band)

$$\frac{\mu A_c}{2} \cos(\omega_c - \omega_m) t$$

$$\text{power} = (r_{ms})^2$$

$$r_{ms} = \frac{\text{Peak}}{\sqrt{2}}$$

$$= \frac{\frac{\mu A_c}{2}}{\sqrt{2}} = \frac{\mu A_c}{2\sqrt{2}}$$

$$\text{power} = (r_{ms})^2$$

$$= \left( \frac{\mu A_c}{2\sqrt{2}} \right)^2 = \frac{(\mu A_c)^2}{8}$$

$$P_{LSB} = \frac{\mu^2 A_c^2}{8}$$

$$\text{USB} = \frac{\mu A_c}{2} \cos(\omega_c + \omega_m) t$$

$$\text{power} = (r_{ms})^2$$

$$r_{ms} = \frac{\text{Peak}}{\sqrt{2}}$$

$$= \frac{\frac{\mu A_c}{2}}{\sqrt{2}} = \frac{\mu A_c}{2\sqrt{2}}$$

$$\text{power} = \frac{\mu^2 A_c^2}{8}$$

$$P_{LSB} = P_{USB} = \frac{\mu^2 A_c^2}{8}$$

$$\text{Total side band power} = P_{LSB} + P_{USB}$$

$$= \frac{\mu^2 A_c^2}{8} + \frac{\mu^2 A_c^2}{8}$$

$$= \frac{\mu^2 A_c^2}{4}$$

Total transmitted power

$$\frac{A_c^2}{2} + \frac{\mu^2 A_c^2}{4}$$

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

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

$$\left( \because \frac{A_c^2}{2} = P_c \right)$$



### Efficiency ( $\eta$ )

$$\eta = \frac{P_{AB}}{P_T}$$

$$= \frac{\left(\frac{4^2 A_c^2}{4}\right)}{\left(\frac{A_c^2}{2} + \frac{4^2 A_c^2}{4}\right)}$$

$$= \frac{\frac{4^2 A_c^2}{4}}{\frac{2 A_c^2 + 4 A_c^2}{4}}$$

$$\eta = \frac{4^2 A_c^2}{4 A_c^2 (2 + 4)} = \frac{4^2}{(2 + 4^2)}$$

$$\mu = \frac{A_m}{A_c}$$

$$\text{if } A_m = A_c$$

$$\text{Then } \mu = 1$$

$$\text{Now } \eta = \frac{\mu^2}{(2 + \mu^2)}$$

$$\eta = \frac{1}{2 + 1} = \frac{1}{3}$$

$$\boxed{\% \eta = 33.33\%}$$

### (2.2) Generation of Amplitude Modulation

- \* The device which is used to generate an amplitude modulation wave is known as amplitude modulation.
- \* The method of generating AM wave may be classified as two types:-
  - (i) Low level A.M
  - (ii) High level A.M



### Low Level AM

In a low level AM system the modulation is done at low power level. A very small power is associated with the carrier signal & modulating signal. Because of this the o/p power of modulator is low. Therefore the power amplifiers are required to boost the AM signal upto a desired o/p level.

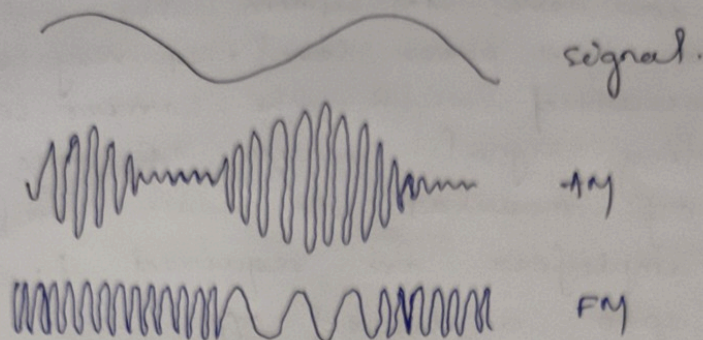
### High Level AM

In a high level AM system the modulation is done at high power level. A very small power is associated with the carrier signal & modulating signal. Because of this the o/p power of modulator is low. Therefore the power amplifiers are required to boost the AM signal upto a desired o/p level.

### Amplitude Modulation (AM)

AM is a signal modulation technique used in electronic communication, most commonly for transmitting messages with a radio wave. In amplitude modulation, the instantaneous amplitude of the wave is varied in proportion to that of the message signal, such as an audio signal. This technique contrasts with angle modulation, in which either the frequency of the carrier wave is varied, as in frequency modulation or its phase, as in phase modulation.





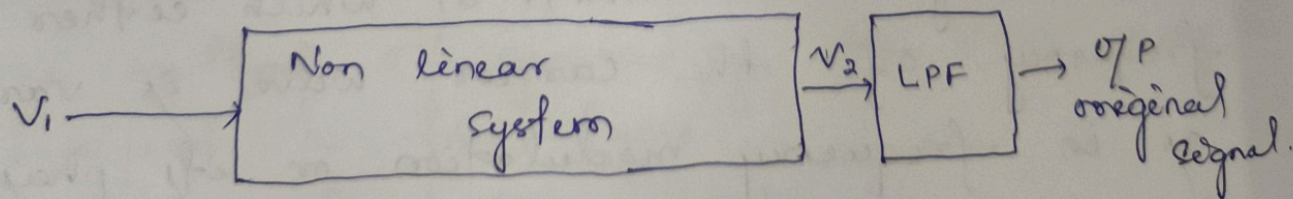
AM was the earliest modulation method used for transmitting audio in radio broadcasting.

### 2.3 Demodulation of AM Waves →

- \* The process of extracting a baseband signal or original signal from the modulated signal is called demodulation.
- \* The device that is used for demodulation is called demodulator.
- \* For AM the demodulators are three types -
  - (i) Square law demodulation.
  - (ii) Envelope detector / linear diode detector.
  - (iii) Synchronous detector (PLL) phase locked loop.

#### Square Law Demodulation

$$V_i = A_c \cos \omega_c t + A_c m(t) \cos \omega_c t$$



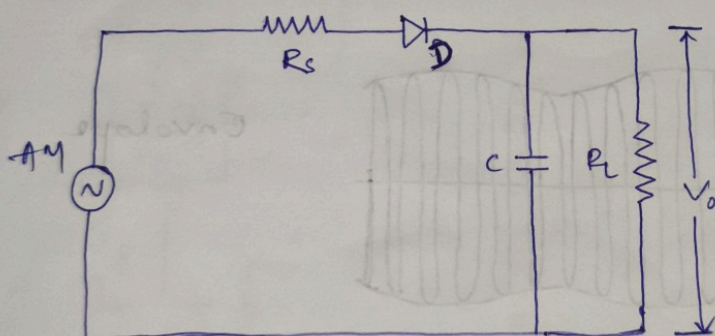


$$\begin{aligned}
 V_2 &= aV_1 + bV_1^2 \\
 &= a[\eta_c \cos \omega_c t + \eta_c m(t) \cos \omega_c t] \\
 &\quad + b[\eta_c \cos \omega_c t + \eta_c m(t) \cos \omega_c t]^2 \\
 &= a\eta_c \cos \omega_c t + a\eta_c m(t) \cos \omega_c t + b\eta_c^2 \cos^2 \omega_c t + b\eta_c^2 m(t)^2 \cos^2 \omega_c t \\
 &\quad + 2b\eta_c \cos \omega_c t \cdot \eta_c m(t) \cos \omega_c t \\
 &= a\eta_c \cos \omega_c t + a\eta_c m(t) \cos \omega_c t + b\eta_c^2 \cos^2 \omega_c t + b\eta_c^2 m(t)^2 \cos^2 \omega_c t \\
 &\quad + 2b\eta_c^2 m(t) \cos^2 \omega_c t.
 \end{aligned}$$

Only the term  $2b\eta_c^2 m(t) \cos^2 \omega_c t$  will pass through the LPF & other high frequency terms are blocked. Again we know that  $\cos^2 \theta = \frac{1}{2} (1 + \cos 2\theta)$

$$\begin{aligned}
 &= 2b\eta_c^2 m(t) \frac{1}{2} (1 + \cos 2\theta) \\
 &= b\eta_c^2 m(t) + b\eta_c^2 m(t) \cos 2\omega_c t
 \end{aligned}$$

Envelope detector - (Linear diode detector)



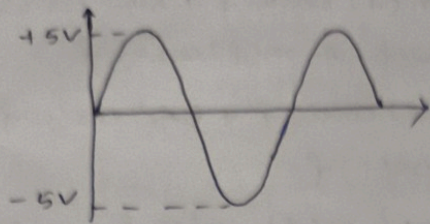
The envelope of the carrier before modulation is constant & after modulation is also constant & is same as the message signal. So the peak amplitude of the AM signal represents the message signal.

When the diode is forward biased it can be represented by short circuit & the capacitor charges. When the diode is open circuit the capacitor

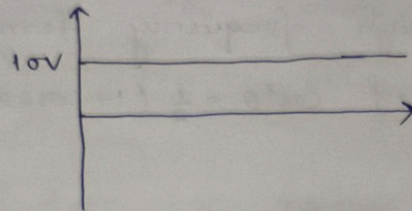


become discharges. The charging time depends on  $RC$ . When the time constant  $RC$  is very high the capacitor gradually discharges

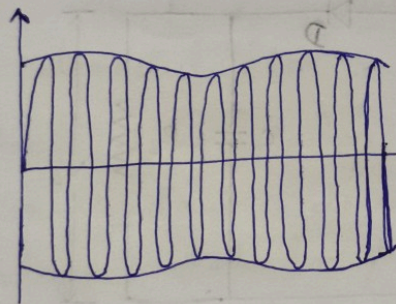
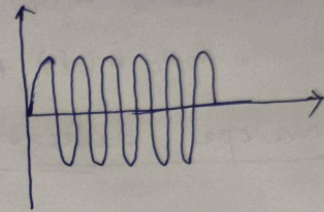
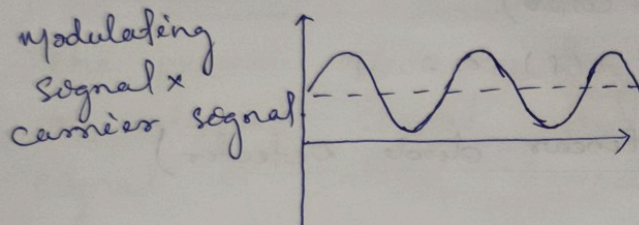
2.2 Phase



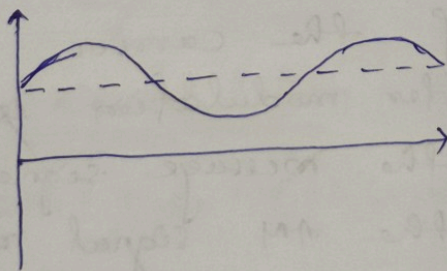
original signal.



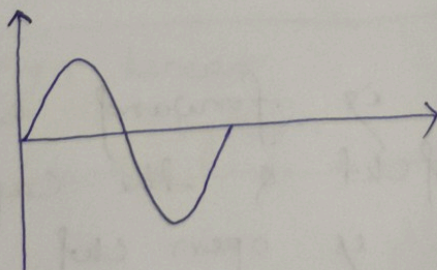
Add 10V dc



Envelope



By using capacitor it will block 10V dc.



original signal



depends  
ex  
charges

## 2.2 Phase Locked Loop (PLL)

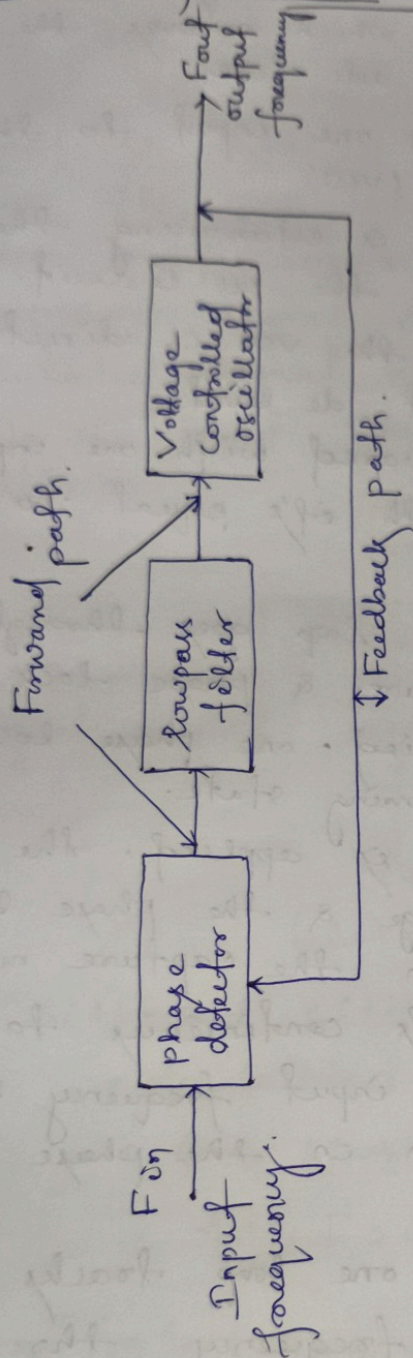


Fig (11) (Block diagram of phase locked loop)

- \* The phase detector or comparator compares one input frequency  $F_{in}$  with the feedback frequency  $F_{out}$ .
- \* One output of the phase detector is proportional to one phase difference bet<sup>n</sup>  $F_{in}$  &  $F_{out}$ .
- \* The output of phase voltage of a phase detector is a 'dc' voltage & therefore is often referred to as the error voltage.



- \* The output of the phase detector is then applied to the low pass filter, which removes the high frequency noise & produces a dc level.
- \* This dc level, in turn, is one input to the Voltage Controlled Oscillator (VCO).
- \* The filter also helps in establishing the dynamic characteristics of the PLL circuit.
- \* The output frequency of the VCO is directly proportional to the input dc level.
- \* The VCO frequency is compared with one input frequency & adjusted with it's equal to the input frequency.
- \* In short, one phase locked loop goes through three states: free running, capture & phase lock.
- \* Before the input is applied, one phase locked loop is in the free running state.
- \* Once one input frequency is applied, the VCO frequency starts to change & the phase locked loop is said to be in the capture mode.
- \* The VCO frequency until it's continuous to change until it's equal to the input frequency & the phase locked loop is then in the phase locked state.
- \* When the phase locked, one loop tracks any changes in one input frequency through it's repetitive action.

#### (2.4) State & explain DSB-SC signal.

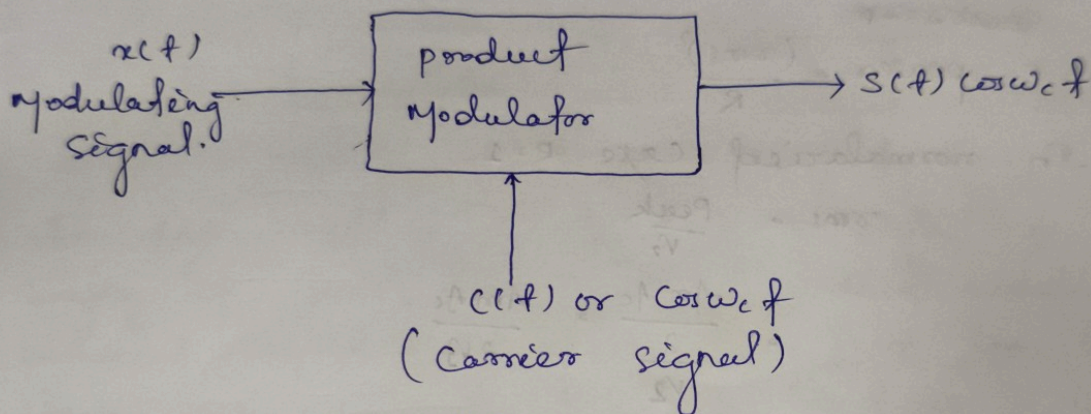
- \* For 100% modulation about 67% of the total power is required for transmitting the carrier which doesn't contain any information.
- \* Hence if the carrier is suppressed only the side band remain. In this way a saving of  $\frac{2}{3}$ rd



plied  
high

power may be achieved at 100% modulation.

- \* This type of suppression of carrier doesn't affect the baseband signal & the resulting signal is obtained by suppressing the carrier from the modulated wave is called double side band suppressed carrier.
- \* A DSB-SC signal is obtained by simply multiplying modulated signal  $x(t)$  with the carrier signal  $c(t)$  or  $\cos \omega_c t$ . This is achieved by a product modulator.



$$S(t) = x(t) \cdot c(t)$$

$$= A_m \cos \omega_m t \cdot A_c \cos \omega_c t$$

$$= A_m A_c \cos \omega_m t \cdot \cos \omega_c t$$

$$= \frac{A_m A_c}{2} [2 \cos \omega_m t \cos \omega_c t]$$

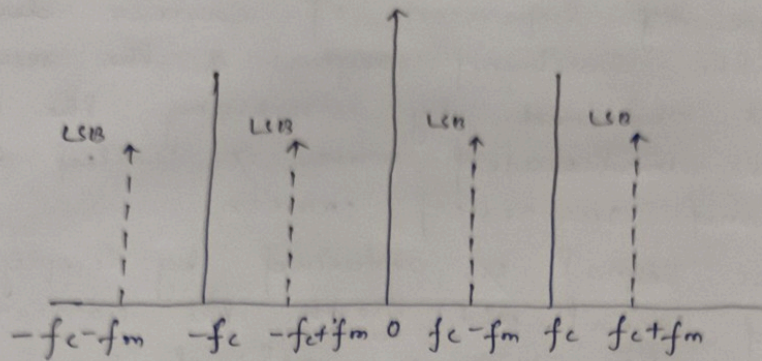
$$= \frac{A_m A_c}{2} [\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t]$$

$$\left\{ \because 2 \cos A \cdot \cos B = \cos(A-B) + \cos(A+B) \right\}$$

$$= \frac{A_m A_c}{2} [\cos(\omega_c - \omega_m)t + \frac{A_m A_c}{2} \cos(\omega_c + \omega_m)t]$$



## Time domain representation of DSB-SC signal



$$\text{Band width} = F_c + F_m - F_c + F_m \\ = 2 F_m$$

~~Power~~

$$L_{SB} = \text{power} = \frac{(\text{rms})^2}{R}$$

In normalized case  $R=1$

$$\text{rms} = \frac{\text{Peak}}{\sqrt{2}} \\ = \frac{A_m A_c}{\sqrt{2}} = \frac{A_m A_c}{2\sqrt{2}}$$

$$\text{power} = \left( \frac{A_m A_c}{2\sqrt{2}} \right)^2$$

$$\text{power} = \frac{A_m^2 A_c^2}{8}$$

$$P_{LSB} = P_{USB} = \frac{A_m^2 A_c^2}{8}$$

$$\text{Total side band power} = P_{LSB} + P_{USB}$$

$$= \frac{A_m^2 A_c^2}{8} + \frac{A_m^2 A_c^2}{8}$$

$$= \frac{A_m^2 A_c^2}{4}$$

Efficiency

(2.5) General

(i) Freq.

$x(t)$

In  
Simple  
bal  
sign  
by  
The

(i) The  
red  
upe

(ii) A  
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P



### Efficiency

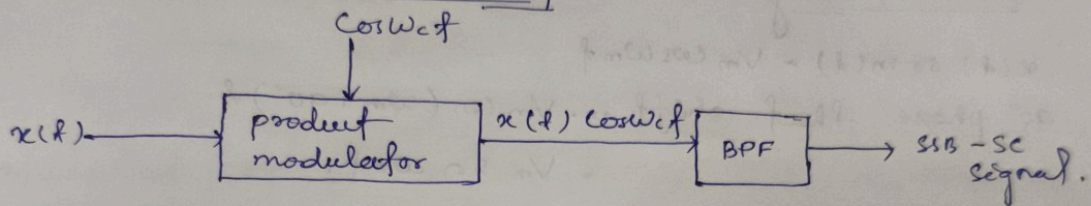
$$\eta = \frac{P_{SB}}{P_T}$$
$$= \frac{\frac{A_m^2 A_c^2}{4}}{\frac{A_m^2 A_c^2}{4}} = 1$$

$$\eta\% = 1 \times 100 = 100\%$$

### (2.5) Generation of SSB-SC signal

SSB-SC signals may be generated by two methods.

#### (i) Freq. Discrimination Method.



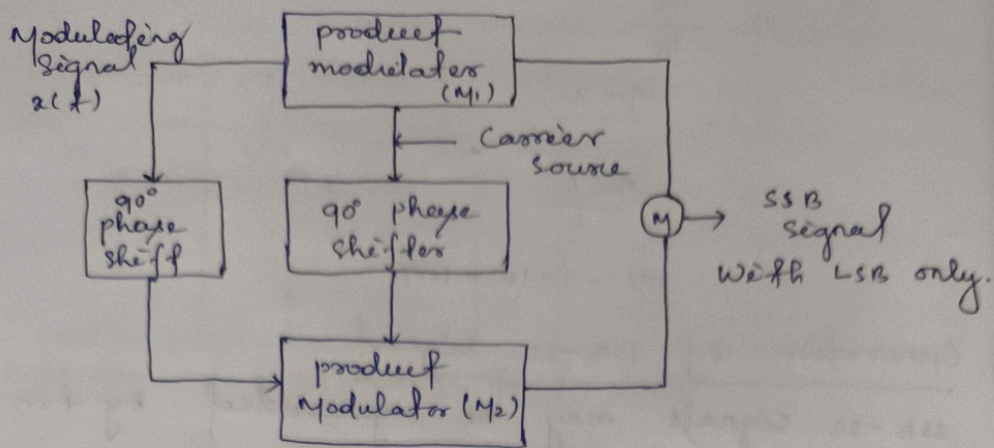
A DSB-SC signal.

In this method firstly USB-SC signal is generated simply of using an ordinary product modulator or balanced modulator after this from the DSB-SC signal one of the two side band is filter out by using a suitable band pass filter.

The limitation for FDM are-

- (i) The FDM is useful only if the baseband signal is restricted at its lower edge due to which the upper & lower side bands are non overlapping.
  - (ii) Another restriction is that the baseband signal must be appropriately related to the carrier freq.
- Phase Discrimination method or phase shift method





Mathematically

$$x(t) \text{ or } m(t) = V_m \cos \omega_m t$$

$$90^\circ \text{ phase shift} \Rightarrow V_m \cos(\omega_m + 90^\circ) t \\ = V_m \sin \omega_m t$$

$$c(t) = V_c \cos \omega_c t$$

$$90^\circ \text{ phase shift} = V_c \sin \omega_c t$$

$$\text{SSBSC} = V_m \cos \omega_m t \cdot V_c \cos \omega_c t \pm V_m \sin \omega_m t \cdot V_c \sin \omega_c t$$

$$= V_m V_c \cos \omega_m t \cdot \cos \omega_c t \pm V_m V_c \sin \omega_m t \cdot \sin \omega_c t$$

$$= V_m V_c [\cos \omega_m t \cdot \cos \omega_c t \pm \sin \omega_m t \cdot \sin \omega_c t]$$

$$= V_m V_c \cos(\omega_c \pm \omega_m) t$$

Advantages of PSM

The advantages are

- (i) It can generate the SSB signal of any frequency so the frequency of converter is not required.
- (ii) It can use the two audio frequency as modulating signal.
- (iii) It is easy to switch from one side band to the other.



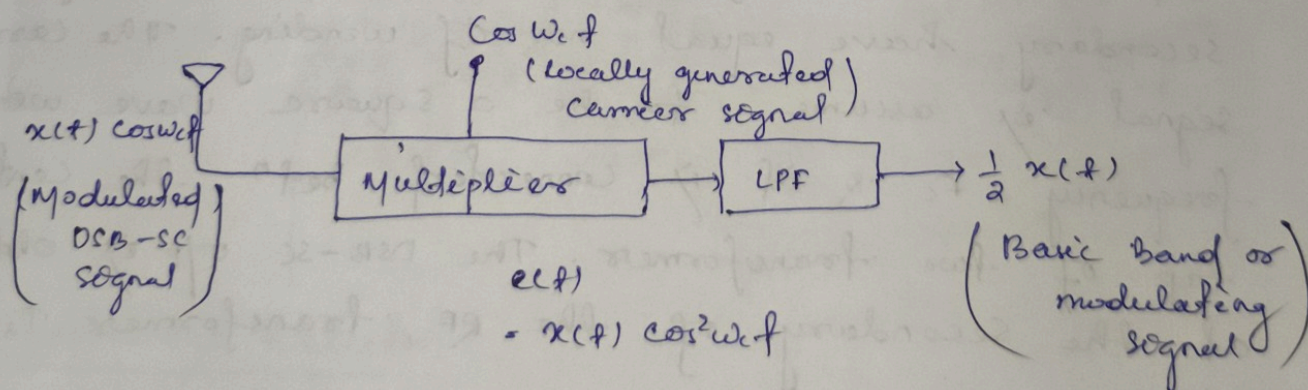
### Disadvantages

- (i) The design of the  $90^\circ$  phase shifting network for the modulating signal is extremely critical.
  - (ii) This network has to provide a correct phase shift of  $90^\circ$  at all the modulating frequencies which is practically difficult to achieve.
- (2.6) Demodulation or detection of DSB-SC signal

The DSB-SC signal may be demodulated by following two methods.

- (i) Synchronous detection method.
- (ii) Using envelope detector.

In synchronous detection method the received modulated or DSB-SC signal is 1st multiplied with a locally generated carrier signal  $\cos \omega_c t$  & then passed through a LPF. At the o/p of the LPF the original modulating signal is recovered from the modulated DSB-SC signal. This can be achieved by simply retranslating the baseband or modulating signal from a higher spectrum. This process of retranslation is called "demodulation" or detection.



$$\Rightarrow e(t) = x(t) \cos^2 \omega_c t$$

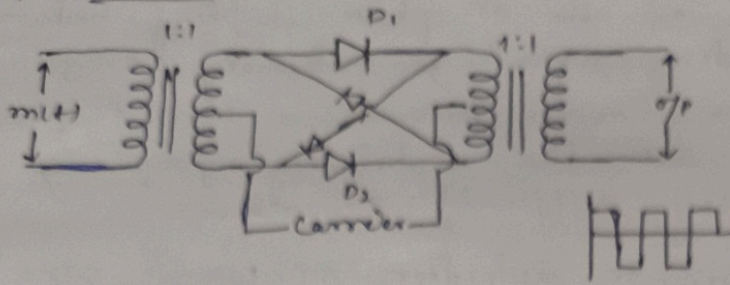
$$= \frac{1}{2} x(t) 2 \cos^2 \omega_c t$$

$$\Rightarrow e(t) = \frac{1}{2} x(t) [1 + \cos 2\omega_c t]$$

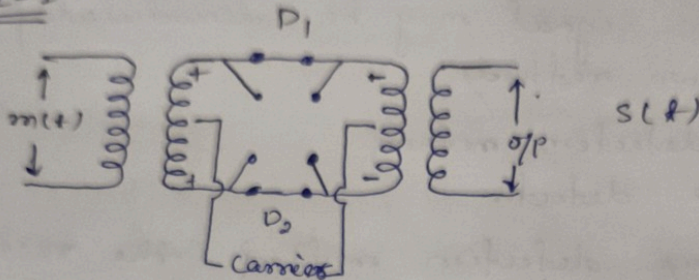
$$\Rightarrow e(t) = \frac{1}{2} x(t) + \frac{1}{2} x(t) \cos 2\omega_c t$$



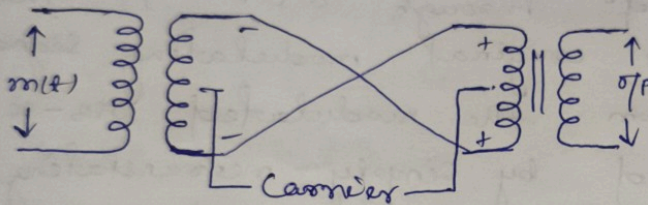
## (24) Ring Modulator



Case-1



Case-2



Ring modulator consists of 4 diodes an audio frequency transformer  $T_1$  & an RF transformer both are 1:1 transformer that means primary & secondary have equal no. of winding. The carrier signal is assume to be a square wave with frequency  $f_c$  & it is connected bet<sup>n</sup> the centre tap of two transformer. The DSB-SC o/p is obtained at the secondary of the RF transformer  $T_2$ .

Case-1

In Case 1  $D_1$  &  $D_2$  are forward biased &  $D_3$  &  $D_4$  are reverse biased then o/p equals to  $s(t)$ .

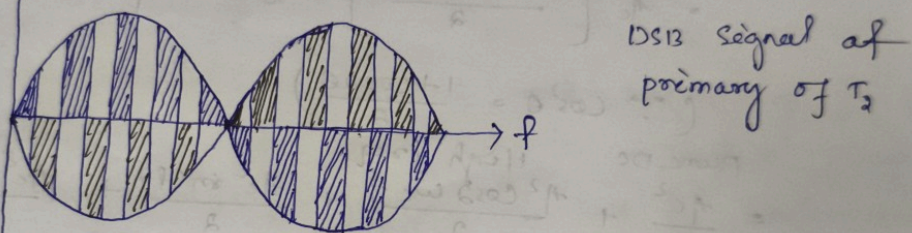
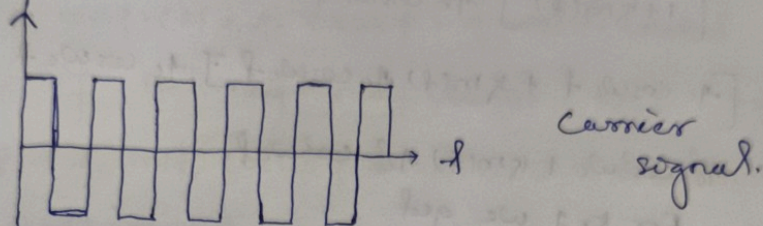
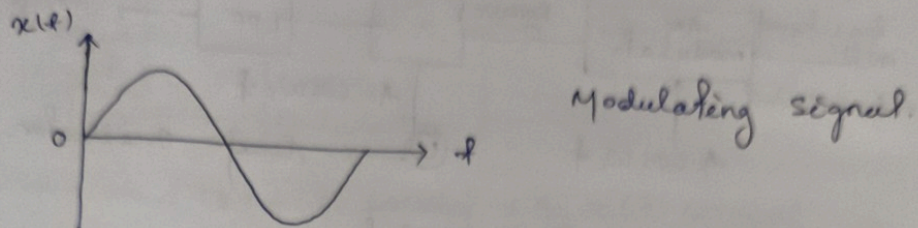
Case-2  
In  
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(25)

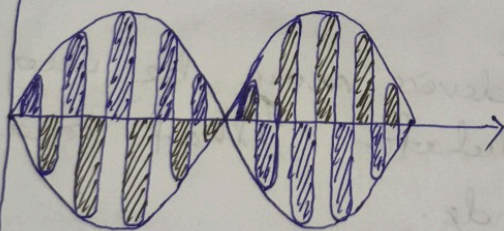


Case-2

In case-2  $D_1$  &  $D_2$  are reverse biased &  $D_3$  &  $D_4$  are forward biased. Due to reversal polarity o/p equals to  $x(t)$ .



  $D_3$  &  $D_4$  ON  
  $D_1$  &  $D_2$  ON

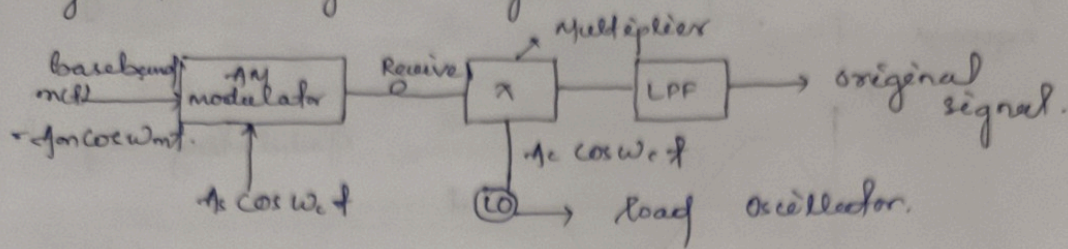


### (22) Synchronous Detector

It is used to demodulate wave modulated AM signal. In this detection method o/p of the AM modulator is multiplied with a carrier



Signal generated by a local oscillator. Again that signal was passed through LPF hence we get the original signal.



$$[1 + K m(t)] A_c \cos \omega_c t$$

$$= [A_c \cos \omega_c t + K m(t) A_c \cos \omega_c t] A_c \cos \omega_c t$$

$$= A_c^2 \cos^2 \omega_c t + K m(t) A_c^2 \cos^2 \omega_c t$$

For  $K=1$  we get.

$$= A_c^2 \cos^2 \omega_c t + m(t) A_c^2 \cos^2 \omega_c t$$

$$= A_c^2 \left[ \frac{1 + \cos 2\omega_c t}{2} \right] + A_c^2 m(t) \left[ \frac{1 + \cos 2\omega_c t}{2} \right]$$

$$\left( \because \cos^2 \theta = \frac{1 + \cos 2\theta}{2} \right)$$

$$= \underbrace{\frac{A_c^2}{2}}_{\text{Pure DC}} + \underbrace{\frac{A_c^2 \cos 2\omega_c t}{2}}_{\text{High freq}} + \underbrace{\frac{A_c^2 m(t)}{2}}_{\text{High freq}} + \underbrace{\frac{A_c^2 m(t) \cos 2\omega_c t}{2}}_{\text{High freq}}$$

$$= \frac{A_c^2 m(t)}{2}$$

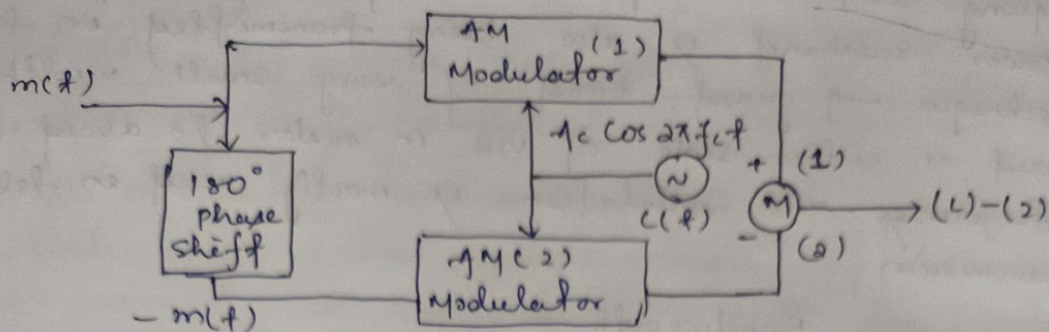
### (2.7) Balance Modulator

\* A non-linear device may be used to produce amplitude modulators that receive one carrier & two side bands.

\* How ever a DSB-SC signal contains only two side bands.

\* There if two non-linear devices are connected in a balanced mode so as to suppress the carriers of each other. There only side bands are connected in a balanced mode to produce a DSB-SC signal.





$$\text{o/p of AM mod. (1)} = A_c \cos \omega_c t + A_c m(t) \cos \omega_c t$$

$$\text{o/p of AM mod. (2)} = A_c \cos \omega_c t - A_c m(t) \cos \omega_c t$$

Then o/p of balanced modulator will be (1)-(2)

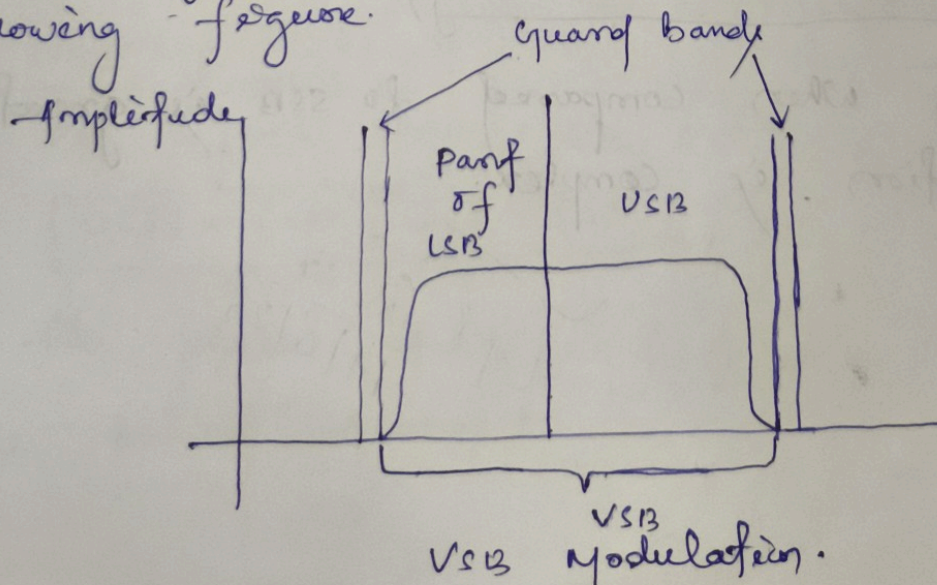
$$= A_c \cos \omega_c t + A_c m(t) \cos \omega_c t - A_c \cos \omega_c t + A_c m(t) \cos \omega_c t$$

$$= 2A_c m(t) \cos \omega_c t$$

$$= 2m(t) \cdot c(t)$$

### (Q.8) Vestigial Sideband

- \* Both of the sidebands are not required for the transmission, as it is a waste. But a single band if transmitted, leads to loss of information hence, this technique has evolved.
- \* Vestigial sideband modulation or VSB modulation is the process where a part of the signal called as vestige is modulated, along with one sideband. A VSB signal can be plotted as shown in the following figure.





Along with the upper sideband, a part of the lower sideband is also being transmitted in this technique. A guard band of very small width is laid on either side of  $VS_{12}$  in order to avoid the interference.  $VS_{12}$  modulation is mostly used in television transmission.

### Transmission Bandwidth

The transmission bandwidth of  $VS_{12}$  modulated wave is represented as -

$$B = (f_m + f_v) \text{ Hz}$$

Where  $f_m$  = Message bandwidth.

$f_v$  = Width of the vestigial sideband.

### $VS_{12}$ Modulation Advantages

Following are the advantages of  $VS_{12}$  -

- \* Highly efficient
- \* Reduction in bandwidth.
- \* Filter design is easy as high accuracy is not needed.
- \* The transmission of low frequency components is possible, without difficulty.
- \* possesses good phase characteristics.

### $VS_{12}$ Modulation Disadvantages

- \* Bandwidth when compared to  $SSB$  is greater.
- \* Demodulation is complex.



chap<sup>3</sup>

## Analog Modulation Systems

### (3.1) Concept of angle modulation & its types (PM & FM)

#### concept of angle modulation:-

- \* Angle modulation be defined as the process in which the total phase angle of carrier wave is varied in accordance with the instantaneous value of the modulating or message signal while keeping the amplitude of the carrier constant.

- \* Mathematical Representation:-

$$C(t) = A \cos(\omega_c t + \theta_0) \quad \text{--- (1)}$$

Where  $A$  = amplitude of carrier

$\omega_c$  = carrier frequency

$\theta_0$  = Some phase angle.

Substituting  $\omega_c t + \theta_0 = \phi$

$$C(t) = A \cos \phi \quad \text{--- (2)}$$

Where

$$\phi = \omega_c t + \theta_0 \quad \text{--- (3)}$$

- \* It is the total phase angle of the carrier signal.

#### Types of Angle Modulation

- \* There are two types of angle modulation as:-

##### (a) Frequency Modulation

- \* The FM signal have the form

$$V(t) = A \cos[\omega_c t + \phi(t)] \quad \text{--- (1)}$$

- \* As the phasor  $A \cos[\omega_c t + \phi(t)]$  runs ahead or falls behind  $A \cos \omega_c t$ .



- \* It must be rotating at a higher or lower angular velocity than  $\omega_c$ .
- \* The radical frequency at any instant will be

$$\omega = \frac{d}{dt} [\omega_c t + \phi(t)]$$

$$\omega = \omega_c + \frac{d}{dt} \phi(t) \quad \text{--- (i)}$$

- \* The corresponding frequency,

$$\omega = 2\pi f$$

$$f = \frac{\omega}{2\pi}$$

$$\Rightarrow f = \frac{1}{2\pi} [\omega_c + \frac{d}{dt} \phi(t)]$$

$$\Rightarrow f = \frac{\omega_c}{2\pi} + \frac{1}{2\pi} \cdot \frac{d}{dt} \phi(t)$$

$$\Rightarrow f - f_c = \frac{1}{2\pi} \frac{d}{dt} \phi(t)$$

$$\Rightarrow \frac{1}{2\pi} \cdot \frac{d}{dt} \phi(t) = f - f_c$$

$$\Rightarrow \boxed{\frac{d}{dt} \phi(t) = 2\pi (f - f_c)} \quad \text{--- (ii)}$$

- \* This shows that the frequency is modulated by the factor  $\frac{1}{2\pi} \cdot \frac{d}{dt} \phi(t)$ .

- \* So, the modulation can be designed in two ways.

\* (1) By making signal  $m(t)$  is proportional to  $\phi(t)$

\* (2) By making signal  $m(t)$  is proportional to  $\frac{d}{dt} \phi(t) = 2\pi (f - f_c)$

\* By making signal  $m(t)$  is proportional to



derivative of instantaneous frequency from carrier frequency.

(3.2) Basic principle of FM & frequency spectrum of FM signal.

The frequency spectrum of FM signal.

\* The modulating waveform is written as the

$$g(t) = \frac{\Delta\omega}{\omega_c} \cos \omega_m t \quad \text{--- (1)}$$

Where  $\Delta\omega$  = is the desired peak frequency change.  
&  $\omega_m$  = is the modulating frequency.

\* The frequency varies in proportion to the message signal  $g(t)$ .

$$\phi(t) = \int_0^t \cos(\cdot) dt$$

$$\text{or, } \phi(t) = \int_0^t \omega_c [1 + g(t)] dt$$

$$\text{or, } \phi(t) = \int_0^t \omega_c dt + \int_0^t \omega_c g(t) dt$$

$$\text{or, } \phi(t) = \omega_c t + \omega_c \int_0^t \frac{\Delta\omega}{\omega_c} \cos \omega_m t dt.$$

$$\text{or, } \phi(t) = \omega_c t + \omega_c \cdot \frac{\Delta\omega}{\omega_c} \cdot \frac{\sin \omega_m t}{\omega_m} + \phi$$

$$\text{or, } \phi(t) = \omega_c t + \frac{\Delta\omega}{\omega_m} \sin \omega_m t + \phi \quad \text{--- (2)}$$

\* The constant of integration is the phase constant ' $\phi$ '

\* The peak phase deviation is given by

$$\frac{\Delta\omega}{\omega_m}, \text{ or } \frac{\Delta f}{f_m}$$



- \* This quantity is usually referred to the modulation index.

$$\left[ \text{i.e. } m_f = \frac{\Delta \omega}{\omega_m} = \frac{\Delta f}{f_m} \right] \quad (2)$$

- \* The frequency modulated wave,

$$e_{FM}(t) = E_c \cos \left[ \omega_c t + \omega_c \int_0^t g(t) dt \right]$$

$$\text{or, } e_{FM}(t) = E_c \cos \left[ \omega_c t + \omega_c \int_0^t \frac{\Delta \omega}{\omega_c} \cos \omega_m t dt \right]$$

$$\text{or, } e_{FM}(t) = E_c \cos \left[ \omega_c t + \omega_c \frac{\Delta \omega}{\omega_c} \cdot \frac{\sin \omega_m t}{\omega_m} \right]$$

$$\text{or, } e_{FM}(t) = E_c \cos \left[ \omega_c t + \frac{\Delta \omega}{\omega_m} \cdot \sin \omega_m t \right]$$

$$\text{or, } \boxed{e_{FM}(t) = E_c \cos \left[ \omega_c t + m_f \sin \omega_m t \right]} \quad (4)$$

- \* The spectrum of the modulated wave  $e_c(t)$ , by expanding equation (4), using familiar trigonometric identity  $\cos(A+B)$

$$\boxed{e_{FM}(t) = E_c \cos \omega_c t \cdot \cos(m_f \sin \omega_m t) - E_c \sin \omega_c t \cdot \sin(m_f \sin \omega_m t)} \quad (5)$$

- \* From equation (4) & equation (5),

It is significant that modulation index for FM is dependent on the ratio of two distinct & independent component,

- \* The derivation ' $\Delta f$ ' would be defined any particular broadcasting system.



(3.3) Expression for FM signal & modulation index & sideband of FM signal.

expression for FM signal.

\* Let the signal have the form.

$$e_c(t) = E_c \cos \phi(t) \quad \text{--- (1)}$$

\* Where  $E_c$  = is peak amplitude of the signal.

$\phi(t)$  = is the phase of  $E_c(t)$

$\omega_c(t)$  = is the frequency of  $e_c(t)$  is the time derivative of  $\phi(t)$ .

\* i.e.,  $\omega(t) = \frac{d}{dt} \phi(t) \quad \text{--- (2)}$

Where  $\phi(t) = \omega_c t + \phi$

\* The angle ' $\phi$ ' is the initial phase angle & is the phase of the signal at  $t=0$ .

\* The frequency of the modulated signal is given by:-

$$\omega(t) = \frac{d}{dt} (\omega_c t + \phi) \quad \text{--- (3)}$$

$$\omega(t) = \omega_c$$

\* That is, the frequency varies in proportional to the message signal  $g(t)$  & it is desired that the instantaneous frequency ' $\omega(t)$ ' be.

$$\omega(t) = \omega_c [1 + g(t)] \quad \text{--- (4)}$$

\* That is, the frequency varies in proportional to the message signal  $g(t)$ .

\* From equation (2)

$$\phi(t) = \int_0^t \omega(t) dt = \int_0^t \omega_c [1 + g(t)] dt \quad \text{--- (5)}$$
$$= \omega_c t + \omega_c \int_0^t g(t) dt$$



- \* An inspection of eq<sup>n</sup> (5), reveals that angle varies is proportional to the integral of the message signal.
- \* Substituting eq<sup>n</sup> (5) into equation: (4) results in the following form for the frequency modulated wave,

$$e_{FM} = E_c \cos \left[ \omega_c t + \omega_c \int_0^t q(t) dt \right] \quad \text{--- (6)}$$

### Modulation Index

- \* We know,

$$S(t) = A_c \cos \left[ \omega_c t + K_f \int x(t) dt \right]$$

$$\Rightarrow S(t) = A_c \cos \left[ 2\pi f_c t + 2\pi K_f \int x(t) dt \right]$$

If  $x(t)$  or  $m(t) = A_m \cos 2\pi f_m(t)$

then  $S(t) = A_c \cos \left[ 2\pi f_c t + 2\pi K_f \int A_m \cos 2\pi f_m(t) dt \right]$

$$\Rightarrow S(t) = A_c \cos \left[ 2\pi f_c t + 2\pi K_f A_m \cdot \frac{\sin 2\pi f_m(t)}{2\pi f_m} \right]$$

$$\Rightarrow S(t) = A_c \cos \left[ 2\pi f_c t + K_f \cdot \frac{A_m}{f_m} \cdot \sin 2\pi f_m(t) \right]$$

$$\Rightarrow S(t) = A_c \cos \left[ 2\pi f_c t + \beta \cdot \sin 2\pi f_m(t) \right]$$

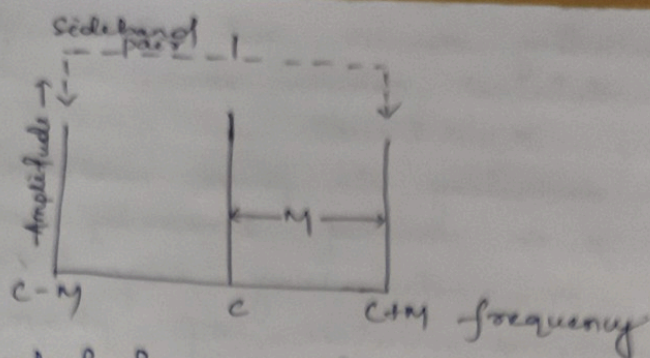
Where  $\beta = \frac{K_f A_m}{f_m}$

Where ' $\beta$ ' is known as modulation index.

### Sideband of FM Signal

- \* A frequency component in a spectrum produced by a modulation of the original signal.
- \* In the case of amplitude & frequency modulation, sidebands occur in pairs on either side of the carrier frequency at a distance equal to the modulating frequency.





- \* Amplitude modulation spectrum of two side waves carrier 'c' & modulator m.
- \* Showing the addition of a pair of sidebands  $c+m$  &  $c-m$ , around the carrier.

### 5.4) Phase Modulation

It is the type of angle modulation in which the phase angle  $\phi$  is varied linearly with a baseband or modulating signal  $x(t)$  about an unmodulated phase angle  $(\omega_c t + \theta_0)$ .

This means that in phase modulation the instantaneous value of the phase angle is equal to the phase angle of the unmodulated carrier  $\omega_c t + \theta_0$  + a time varying component which is proportional to modulating signal  $x(t)$ .

### Mathematical representation

We know that an unmodulated carrier signal is expressed as.

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

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

$$where\ \phi = \omega_c t + \theta_0$$



Neglecting  $\theta_0$  we get total phase angle of  
on modulated carrier is.

$$\phi = \omega_c t \quad \text{--- (1)}$$

Now according to phase modulation this phase angle  $\phi$  is varied linearly with a base band or modulating signal  $x(t)$ . Let the instantaneous value of phase angle be denoted by  $\phi_i$ . Therefore

$$\phi_i = \omega_c t + K_p x(t) \quad \text{--- (2)}$$

Where  $K_p$  = proportionality constant. & is known as phase sensitivity of the modulator.

This is expressed in radians per volt since the expression for unmodulated carrier wave is

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

Therefore the expression for phase modulated will be  $s(t) = A \cos \phi$ ; --- (3)

Now putting the value of  $\phi_i$  in eq<sup>n</sup> (3) from eq<sup>n</sup> (2) we get.

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

Which is the required mathematical expression for phase modulated wave.

### (3.5) Reference comparison bet<sup>n</sup> frequency modulation & Amplitude modulation

- (i) FM receiver may be fitted with amplitude limiter to remove the amplitude variation caused by noise. This makes FM reception very good deal more immune to noise than AM reception.



(ii) It is possible to reduce noise level for the by increasing the frequency deviation. This is a feature which AM doesn't have because it is not possible to exceed 100% modulation without causing severe distortion.

(iii) FM broadcast operates in the upper VHF & UHF frequency range in which there happens to be less noise than in the M.F & H.F ranges occupied by AM modulation depth broadcast.

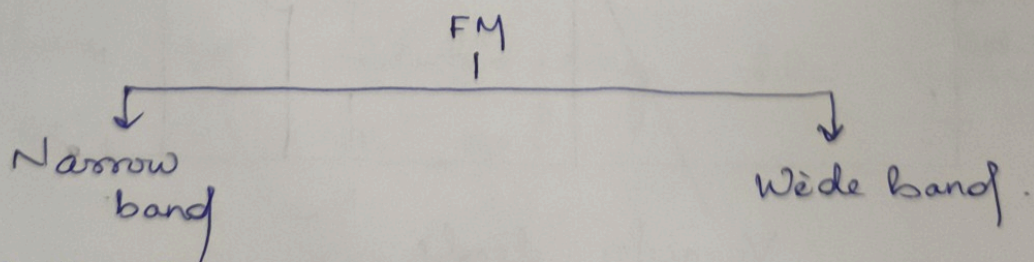
(iv) The amplitude of the FM wave is constant it is thus independent of the modulation depth whereas as in AM modulation depth depends on the transmitted power.

(v) standard frequency allocation provides a guard band bet<sup>n</sup> commercial FM station. Due to this there is less channel interference than in A.M.

### Disadvantages of FM over A.M

(i) A much wider channel typically 200KHz is required in F.M as against only 10KHz in AM broadcast.

(ii) FM transmitting & receiving equipments particularly used for modulation & demodulation tends to be more complex & hence more costly.  
FM signal divided in to two types



### Narrow band

When  $\beta < 1$  the bandwidth of FM is narrow.



## Wideband

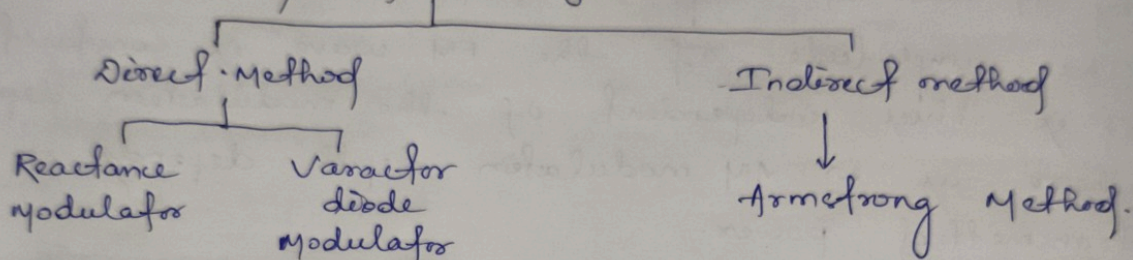
When  $\beta > 1$  the FM signal has a wide-bandwidth.

### (3-6) Generation of FM signal

The method of generation of FM signal may be categorized as under.

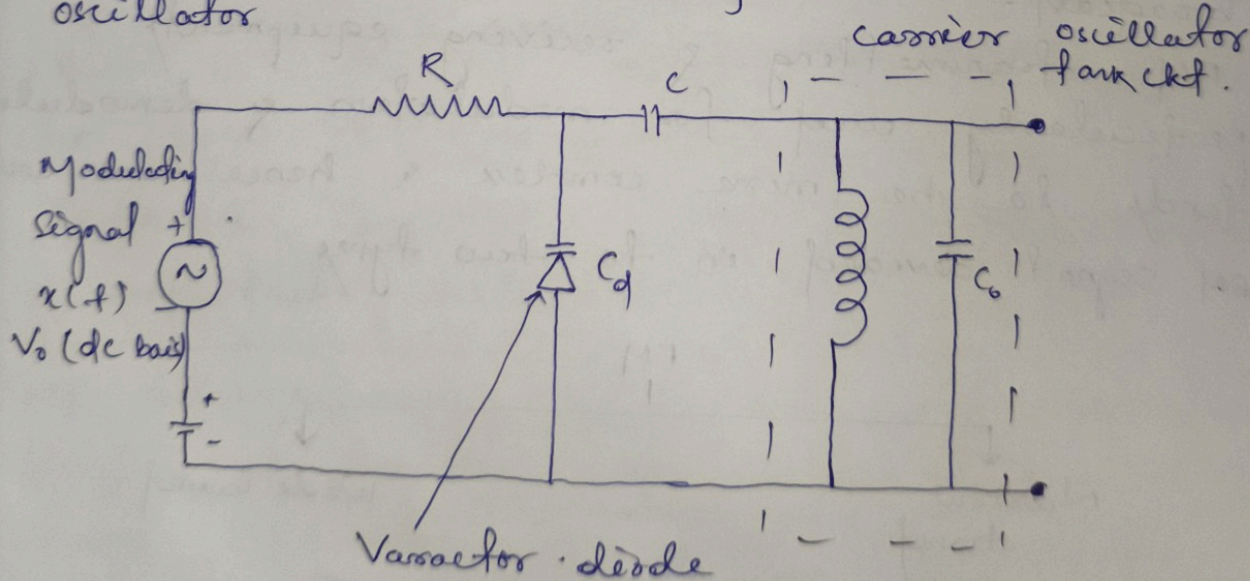
- (i) The direct method / parameter variation method.
- (ii) The indirect method / Armstrong method.

#### Methods of FM generation



#### Direct Method

- \* The varactor diode is a semiconductor diode whose junction capacitance changes with dc bias voltage.
- \* This varactor diode is connected in shunt with the tune ckt of the carrier oscillator.



$m(t) \rightarrow \boxed{VCO} \rightarrow \text{F.M signal.}$



\* The reactance of the capacitance  $C$  at the highest modulating frequency is made large enough compared to resistor  $R$  so that the shunting of the modulating signal through the tune cut may be checked by mathematical analysis:-

The capacitance  $C_d$  of the varactor diode is expressed as

$$C_d = \frac{K}{\sqrt{V_0}} = K V_0^{-1/2} \quad \text{--- (1)}$$

Here  $V_0$  is the total instantaneous voltage across the varactor diode & is given by

$$V_0 = V_0 + x(t) \quad \text{--- (2)}$$

In the above eqn (1)  $K$  is the proportionality constant.

The oscillat<sup>n</sup> frequency is given by

$$\omega_c = \frac{1}{\sqrt{LC}} \quad \text{--- (3)}$$

Now the total capacitance of the oscillator tank cut will be  $C_0 + C_d$  & thus the instantaneous frequency of oscillation  $\omega_i$  is expressed as

$$\omega_i = \frac{1}{\sqrt{L_0 (C_0 + C_d)}} \quad \text{--- (4)}$$

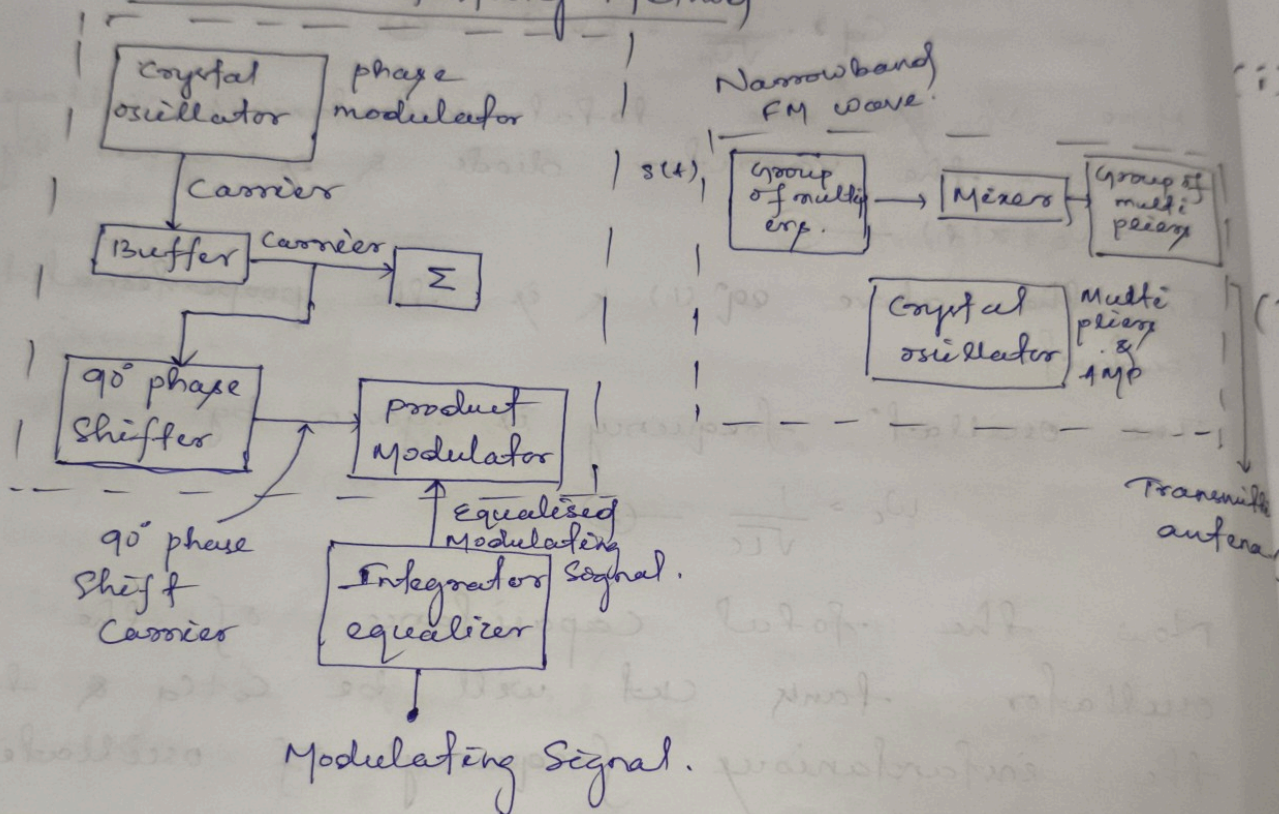
In above eqn substituting the value of  $C_d$  from eqn (1) we get

$$\omega_i = \frac{1}{\sqrt{L_0 (C_0 + K V_0^{-1/2})}}$$



Here we compute that the instantaneous frequency  $\omega_i$  of F.M signal depends upon  $V_e$  which in turn depends upon the value of the modulating signal  $x(t)$ . Thus the instantaneous oscillator frequency,  $\omega_i$  also depends upon the baseband or modulating signal  $x(t)$ . & hence frequency modulation, is generated.

### (3.6) Indirect or Armstrong Method



In case of direct method narrow band FM is generated which is nearly equals to AM to avoid this and to final wide band F.M we use Armstrong method.

The working operation of this system can be understood by dividing it in two parts as follows.



### part-1

To generate a narrow band FM wave using a phase modulator.

### part-2

Use the frequency multiplier & mixer to obtain the required value of frequency deviation, carrier & modulation index.

### Operation of the Armstrong method

- (i) The crystal oscillator generates the carrier at low frequency typically at 1 MHz. This is applied to the combining network at a  $90^\circ$  phase shifter.
- (ii) The modulating signal is passed through an integrator to boost the low modulating frequency. The modulating signal is then applied to a product modulator.
- (iii) The product modulator produces two sidebands which are added in a combining network. That resultant is  $90^\circ$  phase shifted w.r.t the unmodulated carrier.
- (iv) The unmodulated carrier and  $90^\circ$  shifted sidebands are added in a combining network.
- (v) At the output of the combining network we get FM wave. This FM wave has a low carrier frequency  $f_c$  & low value of modulation index  $m_f$ . The carrier frequency & the modulation index are then raised by passing the FM wave through the 1st group of multipliers.



(vi) The carrier frequency is then raised by using a mixer & then the  $f_c$  &  $m_f$  are raised to required high values using the second group of multipliers, mixers & amplifiers.

### Use of frequency multipliers, mixer & amplifiers

The FM signal produced at the o/p of the carrier phase modulator has a low carrier frequency & modulation index. In order to achieve high value of frequency mixers, multipliers & amplifiers are used.

### (3.7) FM Demodulation

The demodulation process of FM waves is exactly opposite to that of frequency modulator. After demodulation we get the original modulating signal at the demodulator o/p.

The i/p to demodulator is FM wave but FM demodulator is basically a frequency to amplitude converter.

### Requirement of F.M demodulation

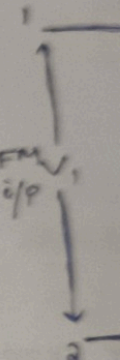
- \* It must convert the frequency variation into amplitude variation.
- \* This conversion must be linear & efficient.
- \* The demodulator cut should be insensitive to amplitude changes. It should be response only to the frequency changes.
- \* It should not be too critical in the

adjustment  
classified

Direct

Freq.  
Discrimin

Forster



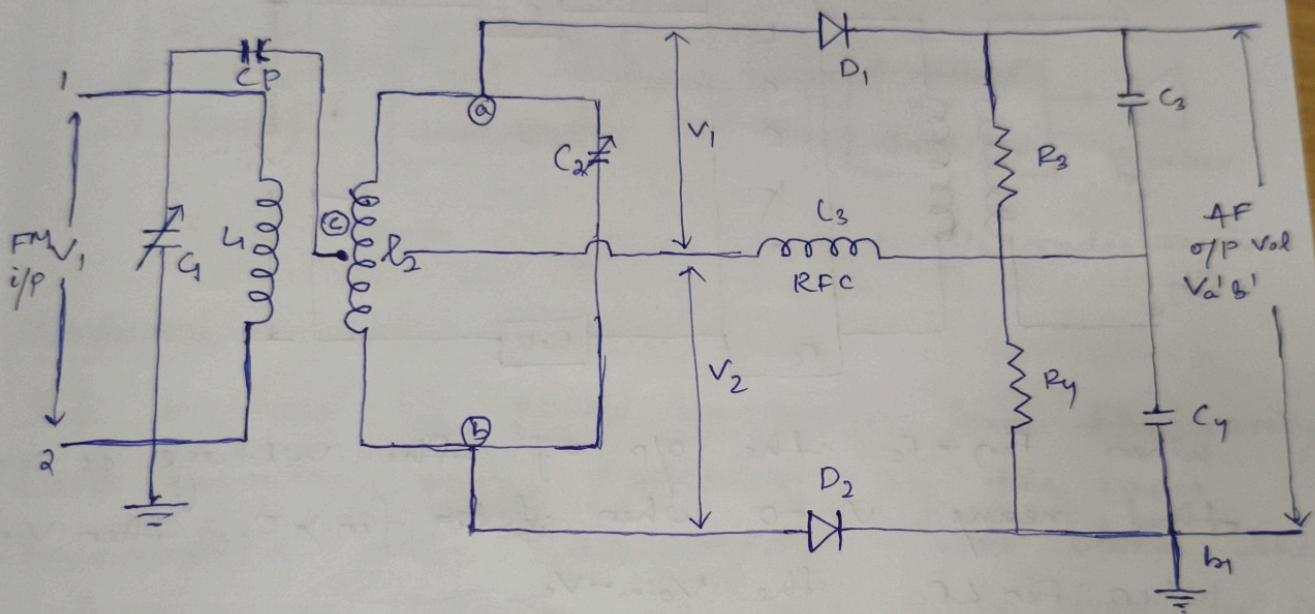
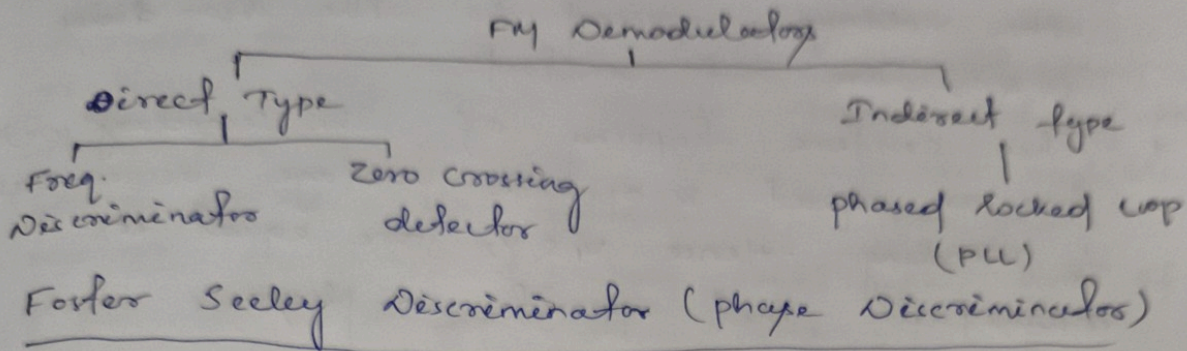
(i)

(ii)



adjustment & operation.

## Classification of FM demodulators



Both the primary & Secondary windings both are tuned to the same center frequency  $f_c$  of the incoming signal.

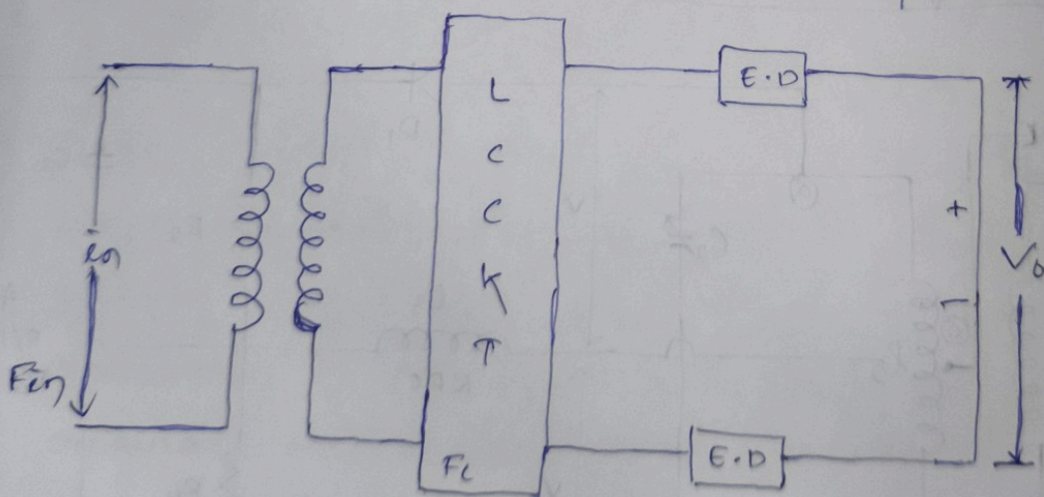
\* The center of the secondary coil is connected to the top of the primary through a capacitor  $C$ . This capacitor  $C$  performs the following function -

- i) It blocks DC from primary to secondary.
- ii) It couples the signal frequency from primary to center tap of the secondary.



Thus the primary voltage across inductor  $L$ .

- \* Even though the primary & secondary tuned ckt are tuned to the same centre frequency the voltage applied to the two diodes  $D_1$  &  $D_2$  are not constant.
- \* Then centre tapping of the secondary will has an equal & opposite voltage across each  $\frac{1}{2}$  winding. Hence  $V_1$  &  $V_2$  are equal in magnitude but opposite in phase.



When  $f_{in} = f_c$  the o/p of the voltage is zero  
 that means  $V_o = 0$  when  $f_{in} > f_c$  then  $V_o = +V_e$   
 When  $f_{in} < f_c$  the  $V_o = -V_e$