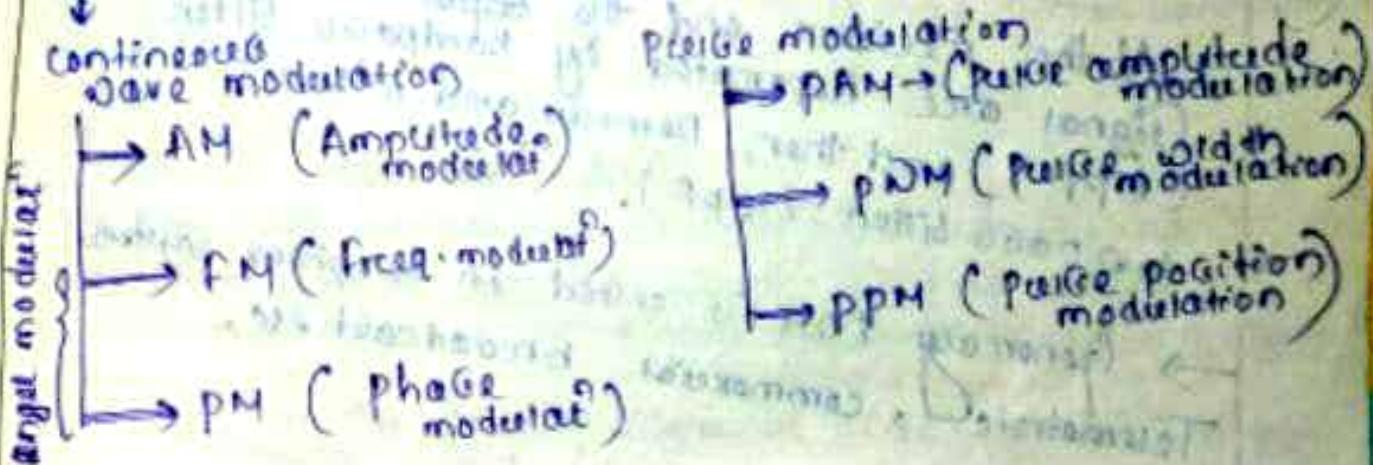


- : Module :- 02 :-

Modulation :-

- Modulation is defined as the process by which the characteristics of a carrier signal is varied according to the instantaneous value of modulating signal or base band signal.
- The characteristics may be amplitude, frequency, phase.
- The carrier frequency is always greater than the modulating frequency.
- The signal which is obtain from the process of modulation is known as modulated signal.

Analog modulation



Continuous :-

Wave Modulation :-

In continuous wave modulation the carrier wave is continuous in nature.

Pulse :-

Modulation :-

In pulse type wave form the carrier is a pulse type.

Multiplexing :-

It is a technique in which several messages are combined into a composite signal for transmission over a common channel.

It is of two types:-

a. Frequency division multiplexing (FDM)

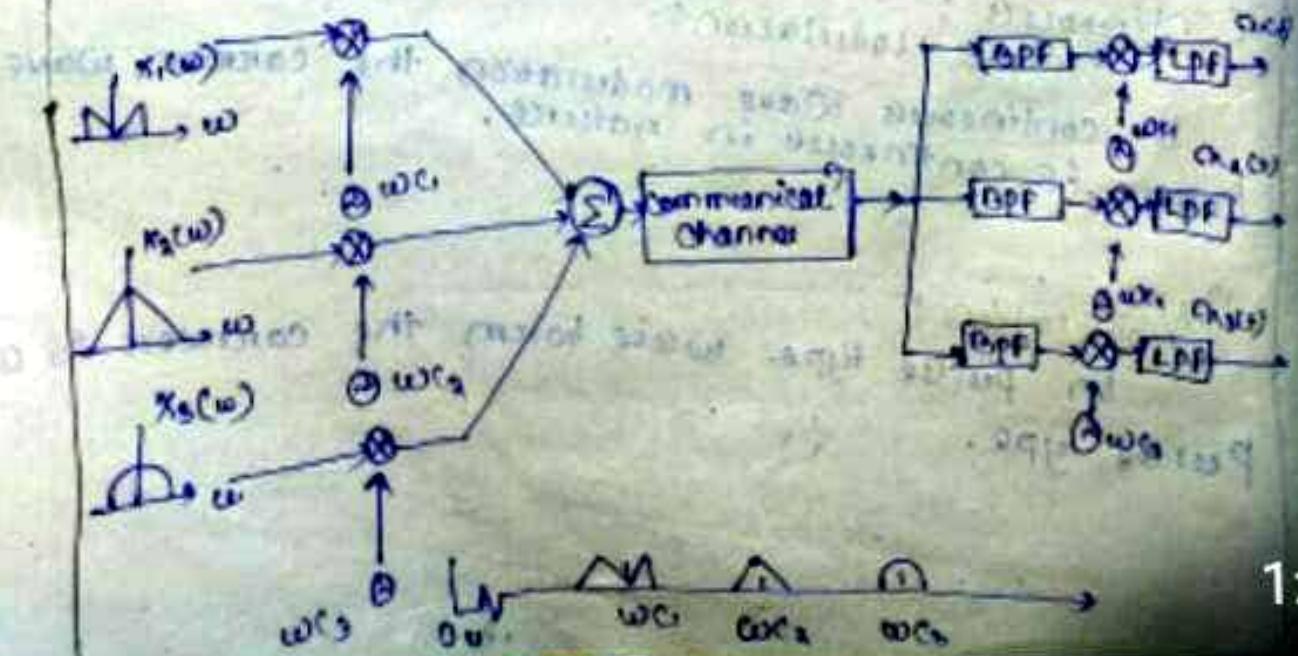
b. Time division multiplexing (TDM)

FDM :-

In FDM different signals of different frequencies are combined at channel. Hence any type of modulation can be used and carrier spacing is sufficient to avoid spectral overlapping.

At the receiver end the input modulated signals are separated by bandpass filters (BPF) and then demodulated with local oscillator (LO) and local pass filters (LPF).

Generally FDM is used in telephone system, television, commercial broadcast etc.



TDM :-

- In TDM the complete channel bandwidth is allotted to one user for a fixed time slot.
- This technique is called bit slot digital signal.
- Hence between the digital signal time spacing is given to avoid intersymbol interference.

Analog Modulation

- It is continuous in nature.
- Signal and noise can not be separated. So repeaters are not required.
- It requires bit coding.
- It has low bandwidth.
- Digital modulation
- It is digital in nature.
- The signal and noise can be separated, repeaters are used.
- It does not require bit coding.
- It has higher bandwidth.

Amplitude modulation (AM) :-

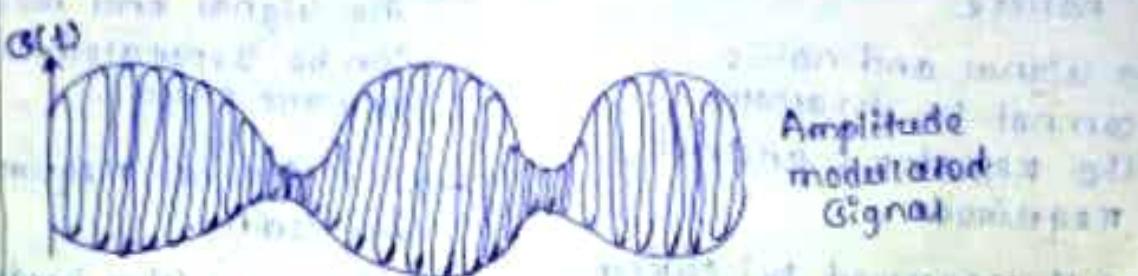
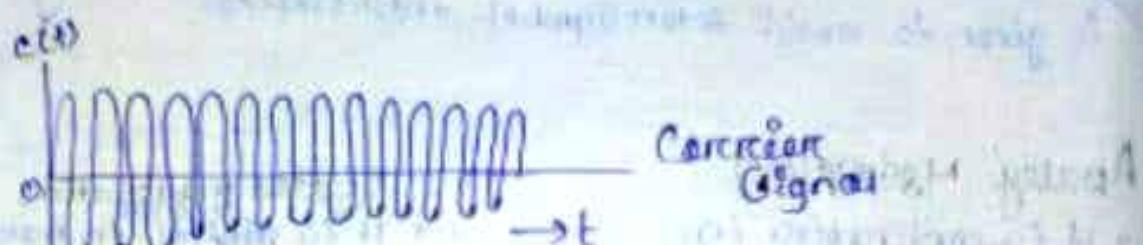
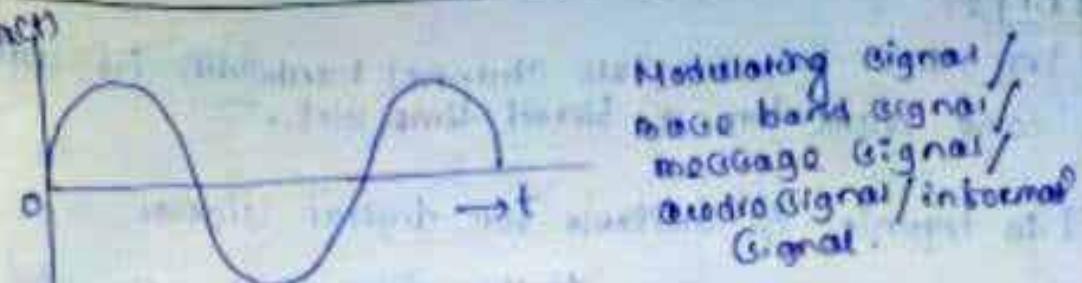
- Amplitude modulation is defined as when the mean amplitude of the carrier signal will be varied in accordance to the other signal known as modulating signal.
- Suppose the carrier signal is $c(t)$. A coswtl and the modulating signal is

$$\alpha(t) = V_m \cos(\omega_m t)$$

When the amplitude modulation will be happen then the amplitude of carrier signal will vary with respect to the modulating signal. The resultant signal will be

$$[c(t), \alpha(t)] \cos(\omega_c t)$$

$$c(t) = [a(t) + A] \cos(\omega_c t) \quad \text{AH}$$



Single tone Amplitude Modulation:

→ Single tone means the signal having one freq.
or constant frequency.

$$a(t) = V_m \cos(\omega_m t)$$

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

$$s(t) = [a(t) + b] \cos(\omega_c t)$$

$$= [A + V_m \cos(\omega_m t)] \cos(\omega_c t)$$

$$= [A \cos(\omega_c t) + V_m \cos(\omega_m t) \cos(\omega_c t)]$$

$$= A \cos(\omega_c t) + \left[1 + \frac{V_m}{A} \right] \cos(\omega_m t) \cos(\omega_c t)$$

$$\therefore A \cos(\omega_c t) + \left[1 + \frac{V_m}{A} \right] \cos(\omega_m t) \cos(\omega_c t)$$

$$M_a = \frac{V_m}{A} = \frac{\text{Amplitude of modulating signal}}{\text{Amplitude of carrier signal}}$$

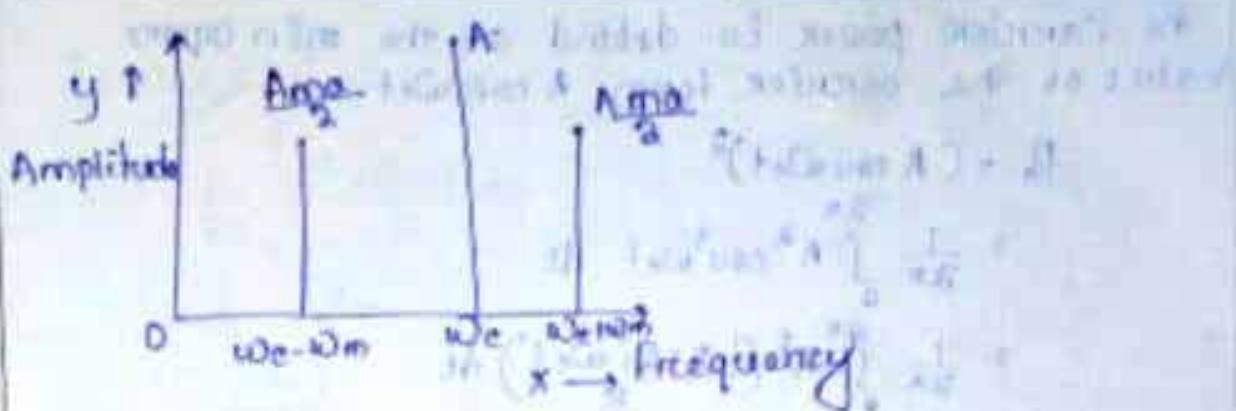
Where $M_a \rightarrow$ Amplitude Modulation Index.

$$\therefore A \cos(\omega_c t) + A M_a \cos(\omega_c t) = A \cos(\omega_c t)$$

$$\therefore A \cos(\omega_c t) + A M_a (\cos(\omega_c t) \cos(\omega_m t))$$

$$\therefore A \cos(\omega_c t) + \frac{A M_a}{2} [\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$$

$A \cos(\omega t + \frac{\pi}{2}) \sin(\omega_c t + \omega_m t) + A \cos(\omega_c t - \omega_m t)$



→ When we represent the expression for single tone amplitude modulation the above frequency shows the details.

→ Here $\omega_c - \omega_m$ is called lower side band (LSB) and $(\omega_c + \omega_m)$ is called upper side band (USB). The bandwidth of amplitude modulation is

$$\begin{aligned}\text{Band width} &= (\omega_c + \omega_m) - (\omega_c - \omega_m) \\ &= \omega_c + \omega_m - \omega_c + \omega_m \\ &= 2\omega_m \\ &= 2\text{ fm}\end{aligned}$$

Power content in AM :-

→ The general expression for AM is

$$S(t) = (A(t)) \cos(\omega t)$$

$= (P_t)(\cos(\omega t) + P_s \cos(\omega_s t))$
So the total power contained in AM is due to the carrier power and Side band power.

$$\text{e.g. } P_t = P_c + P_s$$

Where

P_t = total power.

P_c = carrier power.

P_s = Side band power.

Carrier power :

The carrier power is defined as the mean square value of the carrier term. A carrier with

$$P_c = (A \cos \omega t)^2$$

$$= \frac{1}{2\pi} \int_0^{2\pi} A^2 \cos^2 \omega t dt$$

$$= \frac{1}{2\pi} \int_0^{2\pi} A^2 \left(\frac{1 + \cos 2\omega t}{2} \right) dt$$

$$= \frac{A^2}{4\pi} \int_0^{2\pi} (1 + \cos 2\omega t) dt$$

$$= \frac{A^2}{4\pi} \times 2\pi + \frac{A^2}{4\pi} \left(\frac{\sin 2\omega t}{2\omega} \right)_0^{2\pi}$$

$$= \frac{A^2}{4\pi} [2\pi - 0 + \frac{\sin 2\omega 2\pi - 0}{2\omega}]$$

$$= \frac{A^2}{4\pi} \times 2\pi$$

$$= \frac{A^2}{2}$$

$$\boxed{\Rightarrow P_c = \frac{A^2}{2}}$$

Side Band power :

The side band power is defined as the mean square value of the side band terms

$$P_s = [\alpha \cos(\omega t)]^2$$

$$= \frac{1}{2\pi} \int_0^{2\pi} \alpha^2 \cos^2(\omega t) dt$$

$$= \frac{1}{2\pi} \int_0^{2\pi} \alpha^2 C_1 + \frac{1}{2} [2 \cos^2(\omega t)] dt$$

$$= \frac{1}{4\pi} \int_0^{2\pi} \alpha^2 C_1 (1 + \cos 2\omega t) dt$$

$$= \frac{1}{4\pi} \int_0^{2\pi} \alpha^2 C_1 dt + \frac{1}{4\pi} \int_0^{2\pi} (\cos 2\omega t + \alpha^2 C_1) dt$$

Due to the bandpass filter the carrier frequency
We will be reduced the side bands

$$P_s = \frac{1}{4\pi} \int_0^{2\pi} \alpha^2(t) dt$$

$$= \frac{1}{2\pi} \int_0^{2\pi} \frac{\alpha^2(t)}{2} dt$$

$$= \frac{1}{2} \overline{\alpha^2(t)}$$

$$= \overline{\alpha^2(t)}$$

$$P_s = \frac{\overline{\alpha^2(t)}}{2}$$

$$P_t = P_c + P_s$$

$$= \frac{A^2}{2} + \frac{\overline{\alpha^2(t)}}{2}$$

$$= \frac{1}{2} [A^2 + \overline{\alpha^2(t)}]$$

$$\boxed{P_t = \frac{1}{2} [A^2 + \overline{\alpha^2(t)}]}$$

Transmitter Efficiency for AM:

$$\eta = \frac{P_t}{P_c} \times 100$$

$$= \frac{\frac{1}{2} [A^2 + \overline{\alpha^2(t)}]}{\frac{1}{2} [\overline{\alpha^2(t)}]}$$

$$= \frac{A^2 + \overline{\alpha^2(t)}}{\overline{\alpha^2(t)}}$$

→ The transmission efficiency η for AM is above

Total power content for Single tone AM:

Let the AM having single tone frequency with carrier
Signal A coswt and modulating Signal $\alpha(t) = V_m \cos \omega_m t$

$$\alpha(t) = V_m \cos \omega_m t$$

The carrier power is $P_c = \frac{A^2}{2}$ the side band power is due to the side band frequency. That is zero to oscillations $P_s = \text{The power due to } V_m \cos \omega_m t \text{ coswt}$

$$P_{\text{eff}} = P_e + P_d$$

$$= \frac{A^2}{2} + \frac{1}{2} (m_a^2)$$

$$= \frac{A^2}{2} + \frac{1}{2} (v_m \cos \omega m t)^2$$

$$= \frac{A^2}{2} + \frac{1}{2} \times \frac{V_m^2}{2}$$

$$= \frac{A^2}{2} + \frac{V_m^2}{4}$$

$$= \frac{A^2}{2} \left(1 + \frac{V_m^2}{2 A^2} \right)$$

$$= \frac{A^2}{2} \left(1 + \frac{m_a^2}{2} \right)$$

$$\boxed{P_d = P_e \left(1 + \frac{m_a^2}{2} \right)}$$

$$\frac{P_d}{P_e} = 1 + \frac{m_a^2}{2}$$

$$\Rightarrow \frac{\pi l^2 R}{P_e^2 R} = 1 + \frac{m_a^2}{2}$$

$$\Rightarrow \Omega_e^2 \cdot l^2 \left(1 + \frac{m_a^2}{2} \right)$$

$$\Rightarrow T_e = \sqrt{\Omega_e^2 \left(1 + \frac{m_a^2}{2} \right)}$$

$$\Rightarrow T_e = \Omega_e \sqrt{1 + \frac{m_a^2}{2}}$$

Q1.

Findout the modulation index for carrier signal having power 800 kW with total power of 1200 kW.

Sol

$$P_d = P_e \left(1 + \frac{m_a^2}{2} \right)$$

$$P_d = 1200 \times 10^3$$

$$P_e = 800 \times 10^3$$

$$\Rightarrow 1200 \times 10^3 = 800 \times 10^3 \left(1 + \frac{m_a^2}{2} \right)$$

$$\Rightarrow \frac{1 + m_a^2}{2} = \frac{1200}{800}$$

$$\Rightarrow \frac{m_a^2}{2} = \frac{3}{4} - 1$$

$$\Rightarrow m_a^2 = 1.5 \text{ m.u. (Ans)}$$

For Modulation:

$$P_{t+} = P_0 \left(1 + \frac{m_1^2}{2} + \frac{m_2^2}{2} + \dots \right)$$

$$\Omega_1 = P_0 \sqrt{\left(1 + \frac{m_1^2}{2} + \frac{m_2^2}{2} + \dots \right)}$$

Equivalent Modulation Index:

$$M_e = \sqrt{m_1^2 + m_2^2 + m_3^2 + \dots}$$

Q1

Find out the total power of a modulated signal having modulation index 0.4, 0.5 and 0.6 with a carrier power of 900 W.

Sol

$$P_t = P_0 \left(1 + \frac{m_1^2}{2} + \frac{m_2^2}{2} + \dots \right)$$

$$P_t = 900 \left(1 + \frac{(0.4)^2}{2} + \frac{(0.5)^2}{2} + \frac{(0.6)^2}{2} \right)$$

$$= 900(1.385)$$

$$= 1246.5 \text{ W.}$$

Q2

Find the relation bet' total power and carrier power of a modulating signal with a modulation index of 40%.

Sol

$$P_t = P_0 \left(1 + \frac{m_1^2}{2} \right)$$

$$m_1 = 40\%$$

$$= \frac{40}{100} = 0.4$$

$$\Rightarrow P_t = P_0 \left(1 + \left(\frac{0.4}{2} \right)^2 \right)$$

$$\Rightarrow P_t = P_0 \left(1 + \frac{0.4^2}{2} \right)$$

$$\Rightarrow P_t = P_0 (1.245)$$

$$\Rightarrow P_t = 1.245 P_0 \text{ or } 1.245 \text{ times of } P_0$$

Generation of AM waves:

The circuit that generates the AM waves is called as amplitude modulator. It is of two types

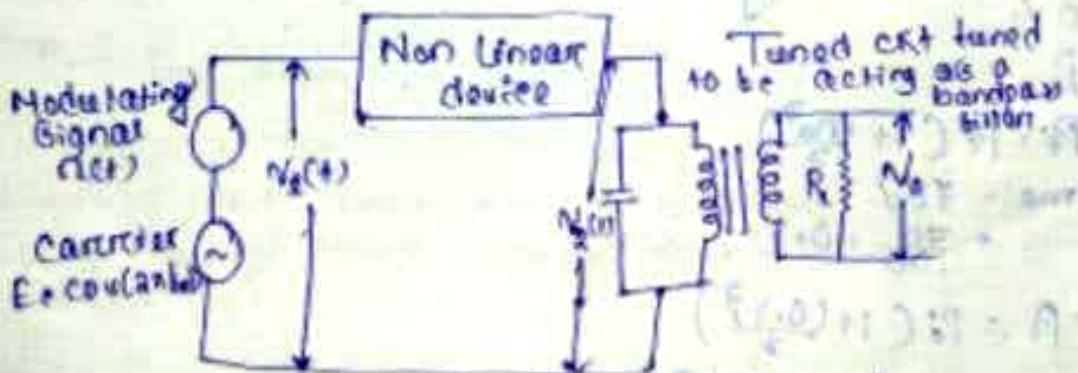
- Square law modulator
- Gating modulator

Both of them use a nonlinear element such as diode for their implementation. A non-linear device is the device with a non-linear relation between its current and voltage. Both these modulators are low power modulators.

i) Square Law Modulator:

It contains following:

- A non-linear device.
- A bandpass filter.
- A constant source and modulating signal.



The modulating signal and carrier are connected in series with each other and their sum $V_s(t)$ is applied at the i/p of the non-linear device such as diode, transistor etc.

$$V_s(t) = \alpha(t) + A \cos(\omega_b t) \quad \text{--- (1)}$$

The o/p r/o related to non-linear device is given by

$$V_o(t) = \alpha V_s(t) + B V_s^2(t) \quad \text{--- (2)}$$

Where a, b are constants. Substituting the expression for $V_s(t)$ we get

$$V_o(t) = a [a \cos(\omega t) + b \sin(\omega t)] + b [a \cos(\omega t) + b \sin(\omega t)]$$

$$V_o(t) = a^2 \cos(\omega t) + b^2 \sin(\omega t) + b[a \cos(\omega t) + b \sin(\omega t)]$$

$$V_o(t) = \underbrace{a^2 \cos(\omega t)}_{\text{DC}} + \underbrace{ab \cos(\omega t)}_{\text{AC}} + \underbrace{b^2 \cos^2(\omega t)}_{\text{AC}} + \underbrace{b^2 \sin^2(\omega t)}_{\text{AC}} + \underbrace{2ab \cos(\omega t) \sin(\omega t)}_{\text{AC}}$$

$a \cos(\omega t) \rightarrow$ Modulating Signal.

$a^2 \cos^2(\omega t) \rightarrow$ Constant

$b^2 \cos^2(\omega t) \rightarrow$ Squared modulating signal.

$2ab \cos(\omega t) \sin(\omega t) \rightarrow$ AM wave with unity sidebands.

$b^2 \cos^2(\omega t) \rightarrow$ Squared constant.

Out of these five terms terms 2 and 4 are useful whereas the remaining terms are not useful.

$$V_o(t) = \underbrace{a^2 \cos^2(\omega t) + b^2 \cos^2(\omega t)}_{\text{constant term}} + \underbrace{2ab \cos(\omega t)}_{\text{AM signal}} + \underbrace{b^2 \cos^2(\omega t)}_{\text{useless term}}$$

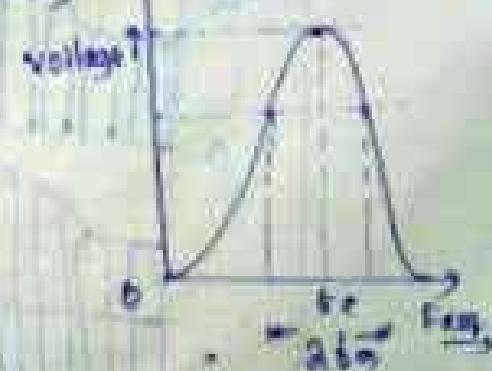
The LC tuned circuit is a bandpass filter. The BPF eliminates the useless terms leaving us w/ $V_o(t)$.

Hence the o/p voltage $V_o(t)$ contains only the useful terms.

$$V_o(t) = a^2 \cos^2(\omega t) + b^2 \cos^2(\omega t)$$

$$\text{or } V_o(t) = [a^2 + b^2] \cos^2(\omega t)$$

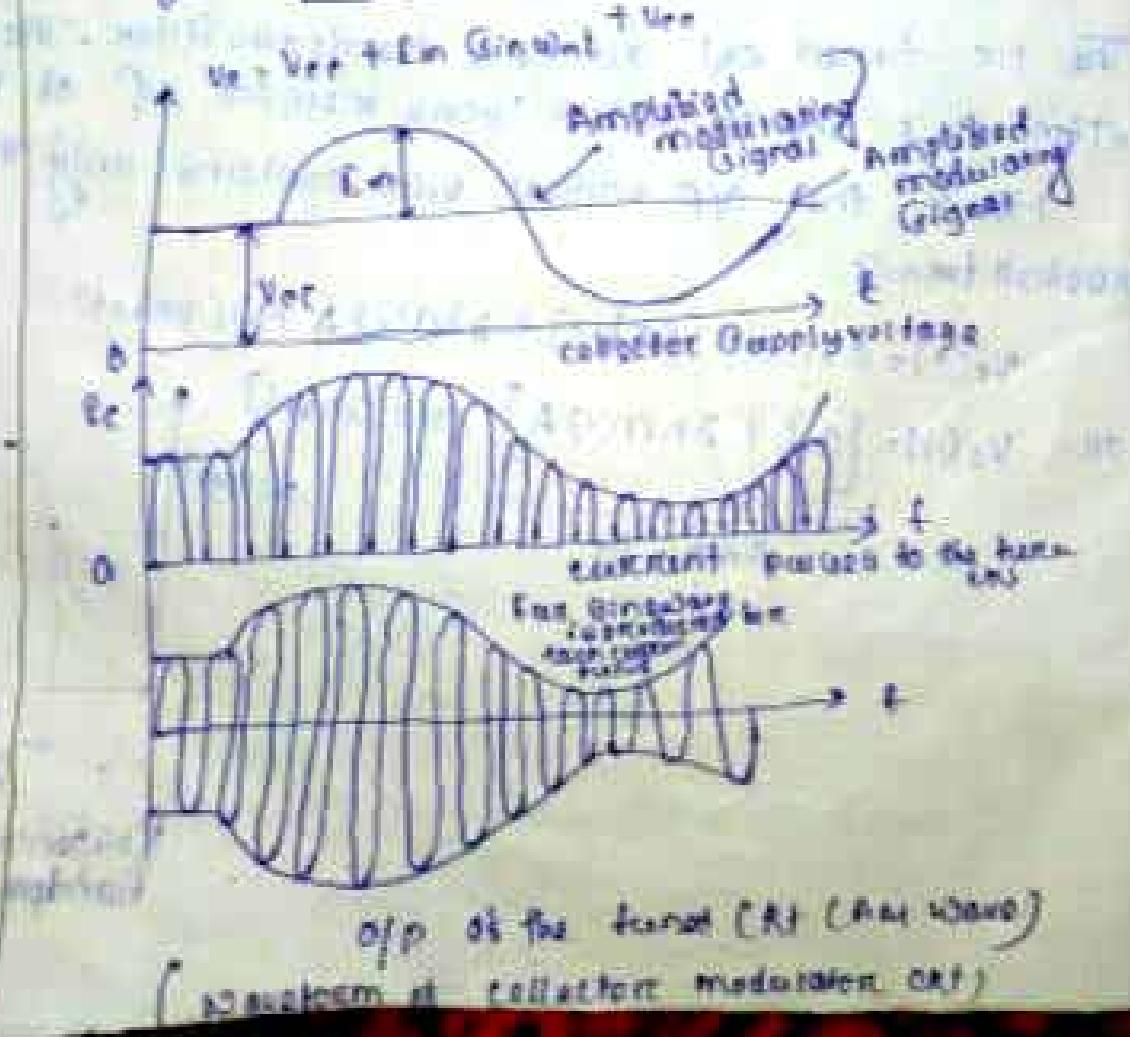
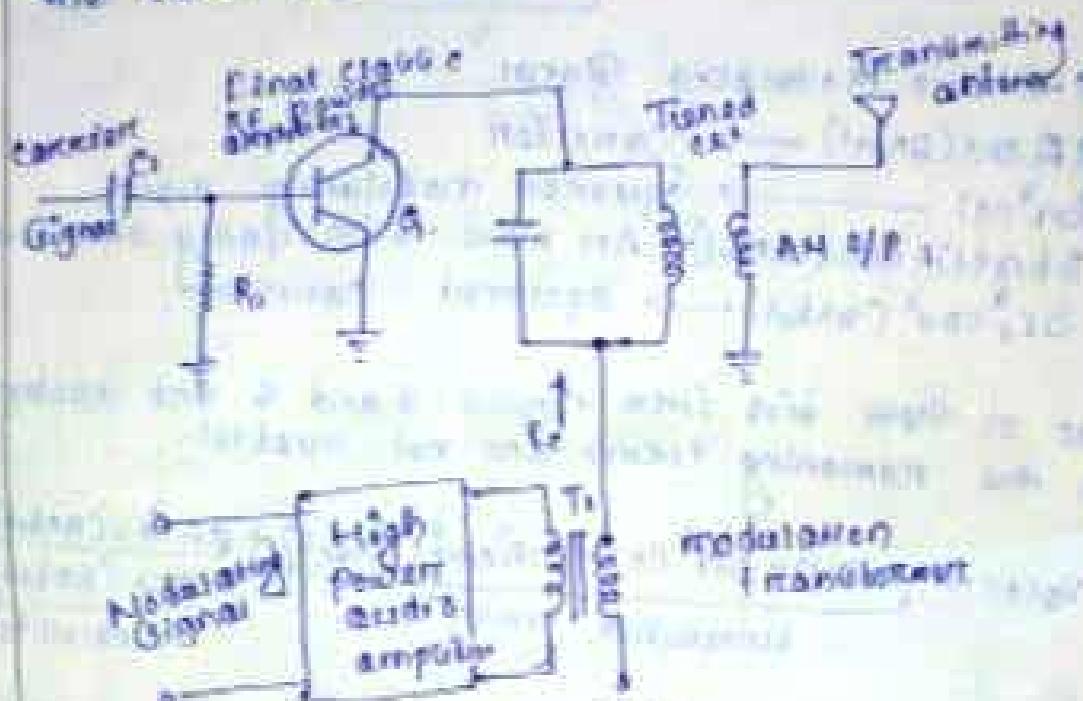
Amp. = $\sqrt{a^2 + b^2}$



Response of the bandpass filter

High level modulator circuit:

This circuit shows the O.P. stage of a transmitter. It is a high power RF (Radio frequency). It can be called 'amplifier'. The class C amplifier conducts for only a portion of the positive half cycle of the carrier signal applied at the base of transistor Q1.



Working operation of the circuit

The transistor Q₁ controls the RF current. It is connected at the base. However the transistor Q₂ controls only half a portion of the positive half cycle of the carrier signal. Thus the alternate current pulses of Q₂ is in the form of current pulses. These current pulses are supplied to the tuned circuit. The high power RF power is fed to the modulating signal to a high power modulator. The secondary winding of the modulating transformer T₁ is connected in series with the dc supply voltage V_c.

The varying supply voltage is then applied to the class C amplifier. Increasing the amplitude of collector current pulses will vary in accordance with the modulating signal. Thus current pulse pass through the tuned circuit. The AM wave is produced in the O/P of the tuned circuit.

Advantage of:

The other type of modulator is base modulator. The collector modulator has the following advantages:

-The collector modulator has the following advantages over base modulator

- (i) More efficiency.
- (ii) Higher efficiency per transistor.
- (iii) Higher O/P power per transistor.

Detection (demodulation) of AM Wave

AM demodulation is the reverse process of AM modulation. A conventional double sideband AM receiver simply converts a received amplitude modulated wave back to the original source information. To do this a receiver must be capable of receiving, amplifying and spectrum to specific desired band of frequencies.

The 'Select' process is called tuning the receiver.

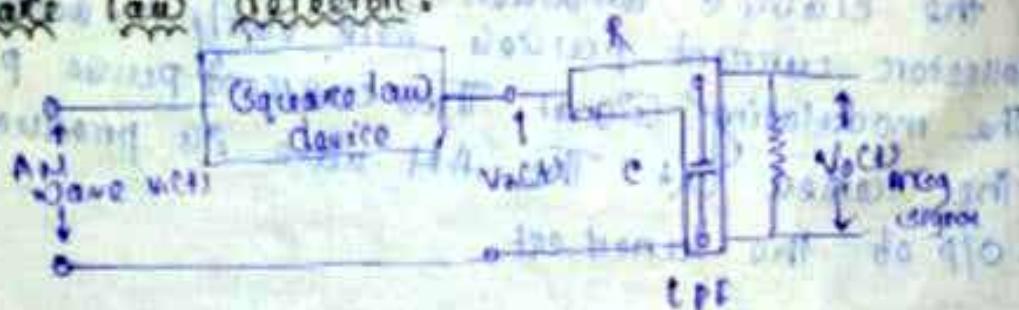
It is of two types AM:

(i) Square law detector

(ii) Envelope detector



Square law detector:



Working operation and analysis:

The T/P O/P characteristics of the transistor characteristics of a square law device are non-linear and it is expressed mathematically

$$V_o(t) = aV_i + bV_i^2 \quad (1)$$

where V_i is RF voltage to the detector - AM wave.

$$V_i(t) = A [1 + m \cos(\omega t)] \cos(\omega t)$$

Putting the $V_i(t)$ value in eq 1

$$V_o(t) = aA [1 + m \cos(\omega t)] \cos(\omega t) + bA^2 [1 + m \cos(\omega t)]^2 \cos^2(\omega t) \quad (2)$$

$$\text{But } \cos^2 \theta = \frac{1}{2} [1 + \cos 2\theta]$$

$$\cos^2(\omega t) = \frac{1}{2} [1 + \cos(2\omega t)]$$

Substituting these values, we get

$$V_{ac}(t) = @ A [\sin(\omega t)] \cos(\omega t) + \frac{bA^2}{2} [1 + \cos(2\omega t)]$$

$$[1 + \cos(2\omega t)] \quad \text{--- (ii)}$$

Out of these terms the only desired term is $bA^2 \cos(\omega t)$ which is due to the b.v. item.
Hence name of this detection is envelope detection.
This desired term is extracted by using a LPF
after the diode as shown in fig. True after the LPF
we get

$$V_{ac}(t) = (bA^2 m) \cos(\omega t) \quad \text{--- (iii)}$$

Degraded O/P:

An other term which passes through the load
passes before to the load resistance $R_L = 6$ ohm and are

$$\frac{1}{2} bA^2 m^2 \sin(2\omega t)$$

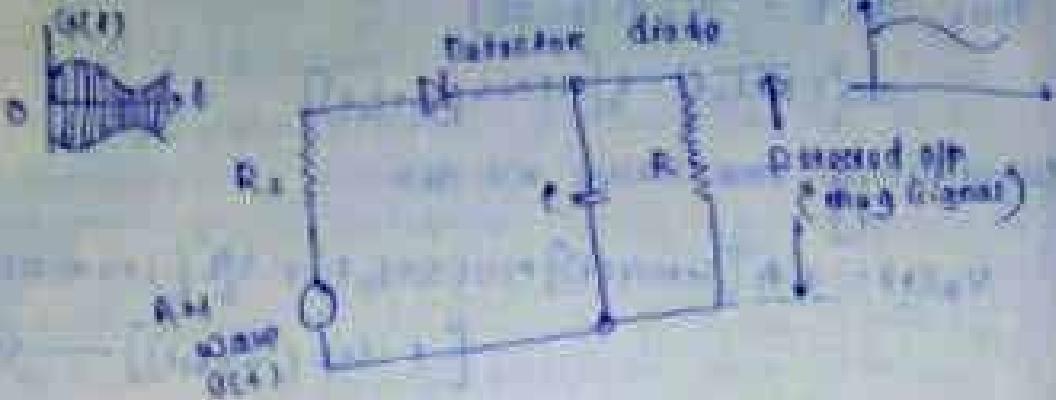
This is an unwanted signal and gives rise to a
signal detected signal to the undetected o/p, is given by

$$\text{Ratio} = \frac{\text{Desired o/p}}{\text{undesired o/p}}$$

$$\frac{bA^2 m \cos(\omega t)}{\frac{1}{2} bA^2 m^2 \sin(2\omega t)} \geq \frac{2}{m \cos(\omega t)} \quad \text{--- (iv)}$$

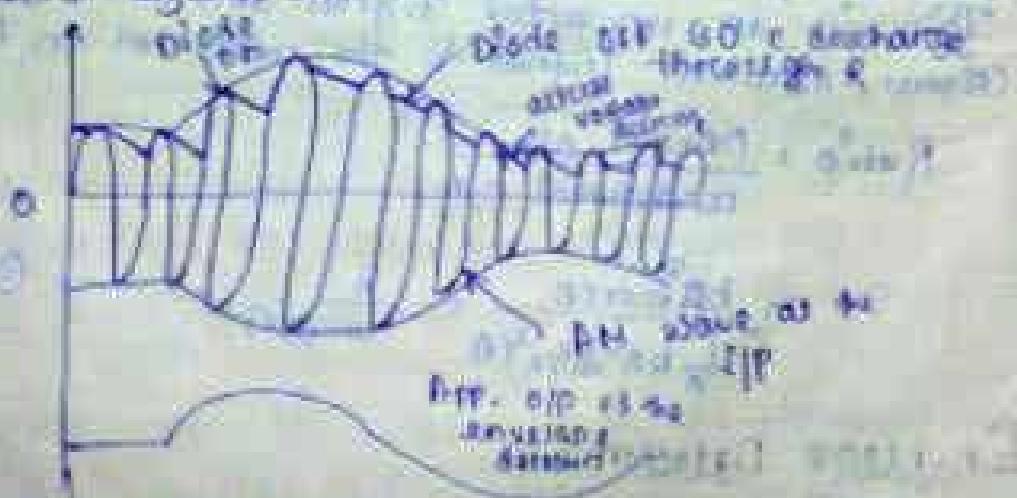
Envelope Detector:

The envelope detector is a simple and very efficient device which is suitable for a narrowband AM signal. A narrow band AM wave is the one in which the carrier freq. is much higher as compared to the bandwidth of the modulating signal.



Working

The Standard AC voltage applied at the ZP of the detector. In every positive half cycle of the ZP the detector diode D1 is forward biased. It will charge the capacitor C connected across it. The load resistance R_L is used to limit the peak value of ZP voltage. As soon as the capacitor charges to the peak value, the diode stops conducting. The capacitor will discharge through R_L for the positive peak value. The discharging process continues until the next positive half cycle. When the ZP signal becomes more greater than the capacitor voltage, the diode conducts again and the process repeats itself.



Ques. Explain that the diode is ideal, which prevents a Zener resistance between the anode and cathode terminals when it is off.

Operation of the R.C. time delayed?

The capacitor charges through D and R₁ when the base is on and it discharged through R when the base is off. The charging is done constant R.

Deficiencies in the Focused electron gun

i) Diagonal clipping

ii) Negative peak clipping

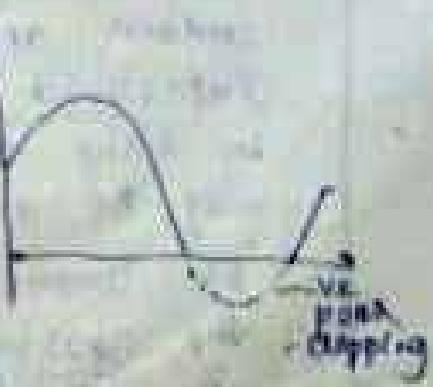
Diagonal clipping:

This occurs when the RF time constant of the load circuit is too long due to this the R.C. gain control loss the bias changes in the modulating envelope.

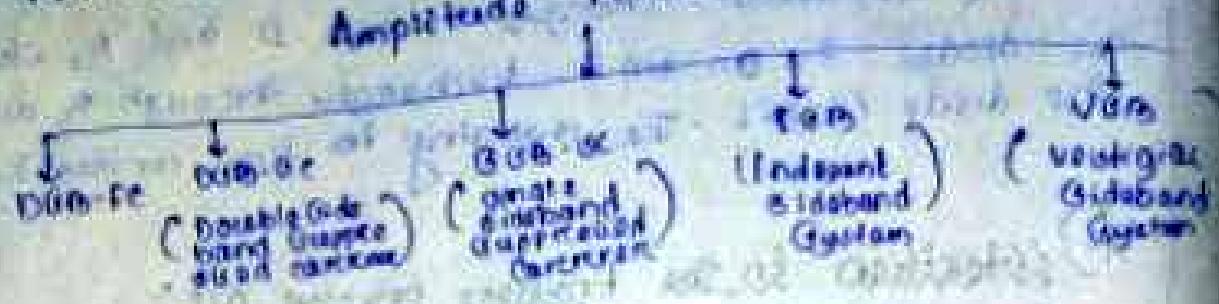


Negative peak clipping:

It occurs due to a fact that the modulating index on the off side of the detector is higher than that on its tip side. Hence at higher depth than that on the tip side. Hence at higher depth of modulator at no transmitted signal, the point of modulation may take place at the off of the modulator. The negative peak clipping will take place due to a result of this discrimination.



Other types of AM :-



Amp

Applications of AM :-

- Radio broadcasting
- Picks transmission in a TV system

DGSC System :-

The equation of AM wave in its simplest form

$$S(t) = A \cos \omega_c t + K \cdot \frac{M}{2} \cos(\omega_c t + \phi) \cos(\omega_m t + \theta)$$

From this eq it is obvious that the carrier component in AM wave remains constant in amplitude and frequency. This means that there are no characteristics of amplitude modulated wave which conveys any information.

For 100% modulation about 87% of the total power is required for transmitting the carrier. The carrier which does not contain any information. If the carrier is suppressed only the sideband remain and in this way a saving of two-third power may be achieved at 100% modulation. This type of suppression of carrier does not affect the sideband signals in any way. The resulting signal obtained by suppression of the carrier from the modulated wave is called DGSC system.

This is a DSB-SC modulation. There are no carrier signals only sidebands are present.

We know that the freq-shifting property of FT is given as

$$x(t) \xrightarrow{\text{FT}} X(\omega)$$

$$e^{j\omega_0 t} x(t) \xrightarrow{\text{FT}} X(\omega - \omega_0) \quad \textcircled{1}$$

This property states that if a signal $x(t)$ is multiplied by $e^{j\omega_0 t}$ in time domain then its spectrum $X(\omega)$ in frequency domain is shifted by an amount ω_0 .

Similarly $e^{-j\omega_0 t} x(t) \xrightarrow{\text{FT}} X(\omega + \omega_0) \quad \textcircled{2}$

But since $e^{\pm j\omega_0 t}$ is not a real function & cannot be generated practically therefore frequency shifting in practice is achieved by multiplying $x(t)$ by a sinusoid such as cosine.

$$x(t) \cos(\omega_0 t) = x(t) \cdot \frac{1}{2} [e^{j\omega_0 t} + e^{-j\omega_0 t}]$$

$$\xrightarrow{\text{FT}} \frac{1}{2} [x(\omega - \omega_0) + x(\omega + \omega_0)] \quad \textcircled{3}$$

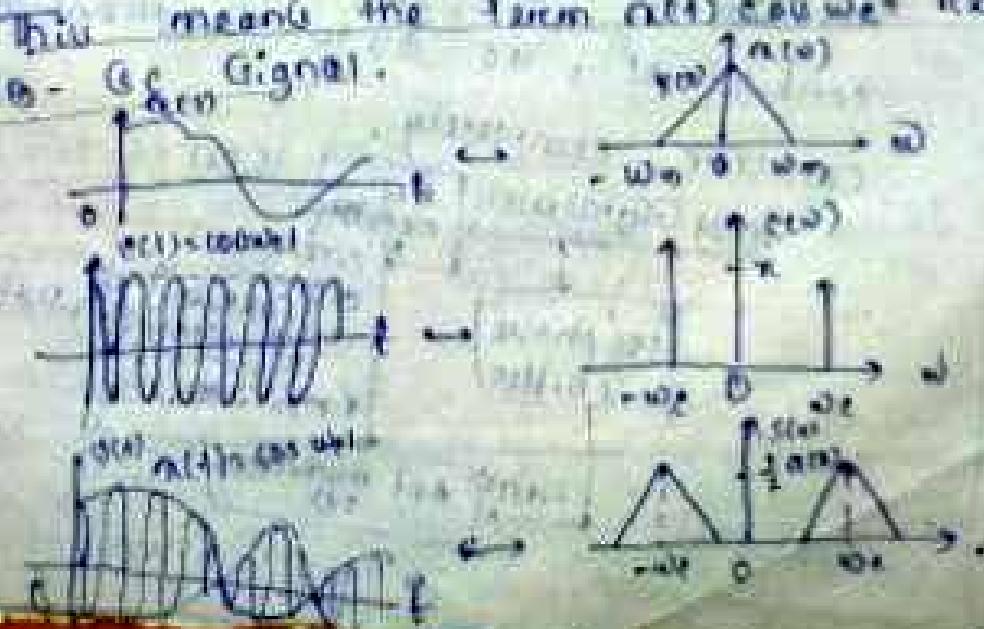
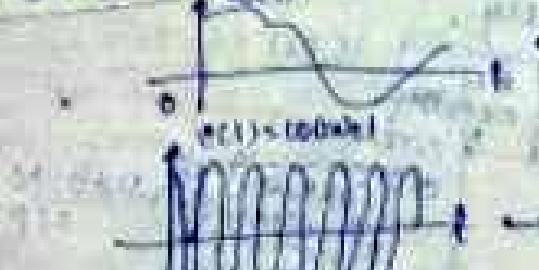
using freq-shifting property in eq³ $\textcircled{3}$

$$x(t) \cos(\omega_0 t) \xrightarrow{\text{FT}} \frac{1}{2} [X(\omega - \omega_0) + X(\omega + \omega_0)]$$

If $a(t)$ is taken as modulating signal or message signal and $\cos(\omega_0 t)$ is taken as carrier signal then $a(t) \cos(\omega_0 t)$ will represent the modulated signal.

This means the sum of two signals representation.

a. DSB-CW Signal.

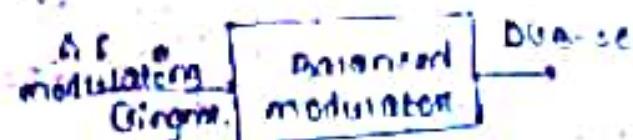


Generation of Double Sideband

To generate the DSB-SC wave we need to take the product of the carrier and modulator. As we need to use a device for this called product modulator for the generation of DSB-SC waves.

Suppression of the sidebands (Balanced Modulation)

The balanced modulators are used to suppress the unwanted carriers in AM. A wave. The carrier and modulating signals are applied to I & Q F/P of the balanced modulator and we get the DSB SC signal with suppressed carrier at the channel. Output of the balanced modulator has only the output content of upper and lower sidebands only.



Balanced Modulator using AM Modulators:

If it consists of two standard amplitude modulators arranged in the balanced configuration, so as to suppress the carrier completely.



Working operation and analysis:-

The carrier signal $a_c(t)$ is connected to both the AM modulators M_1 and M_2 . The msg signal $m(t)$ is applied as if it is to M_1 and its inverted version $-m(t)$ is applied to M_2 . At the o/p of modulators M_1 and M_2 we get the standard AM signal $s_1(t)$ and $s_2(t)$

$$\text{O/P of } M_1 : s_1(t) = A [1 + m(t)] \cos(\omega_b t)$$

$$\text{O/P of } M_2 : s_2(t) = A [1 - m(t)] \cos(\omega_b t)$$

These are then applied to a subtractor and the subtractor produces the desired DSB-SC signal as under.

$$\begin{aligned} \text{Subtractor O/P} &= s_1(t) - s_2(t) = A [1 + m(t)] \\ &\quad \cos(\omega_b t) - A [1 - m(t)] \cos(\omega_b t) \\ &= A \cos(\omega_b t) [1 + m(t) - 1 + m(t)] \\ &= 2m A \cos(t) \cos(\omega_b t) \end{aligned}$$

The R.H.S of this expression consists of product of $m(t)$ and $\cos(\omega_b t)$ i.e. $\cos(\omega_b t)$ It represent DSB-SC signal.

$$\text{DSB Signal} = 2m A \cos(t) \cos(\omega_b t)$$

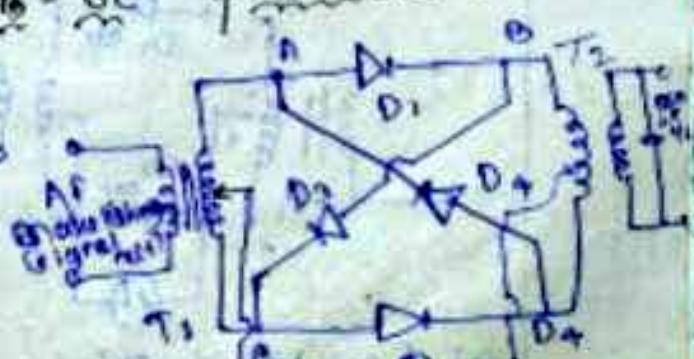
Ring Modulator DSB Chopper Modulator base DSB-SC generation :-

It consist of four diodes and an audio frequency transformer T_2 and an RF transformer T_1 .

RF transformer T_1 -

The carrier signal is

assumed to be a square wave with freq. ω_c and it is connected at the centre tap of the RF transformer. The DSB-SC o/p is obtained at



Secondary of RF transformer T_1

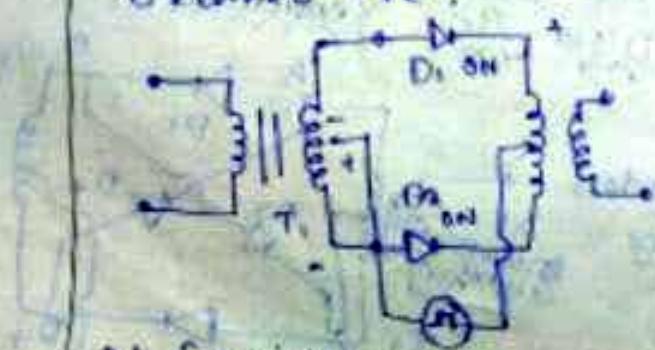
Working operation of RF FET:

The operation is explained with the assumption that the diodes act as perfect switches and that they are switched ON and OFF by the RF carrier signal. This is because the amplitude and freq. of the current is higher than that of the modulating signal.

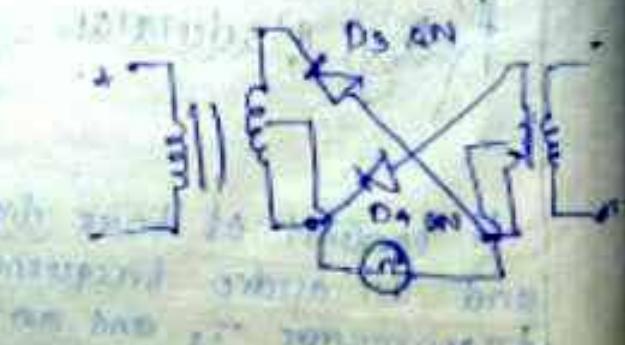
Operation in the two half cycle of modulating signal:-

In the two half cycle of the carrier D_3 and D_4 are on and Secondary of T_1 is applied across it in across the primary of T_2 . During the two half cycle of the carrier the o/p of T_2 is zero.

In the -ve half cycle of the carrier D_3 and D_4 are turned on and the secondary of T_1 is applied in a reversed manner across the primary of T_2 . Thus the primary voltage of T_2 is +ve and o/p voltage also becomes -ve.



a) Equivalent circuit in the two half cycle of modulating signal with carrier.



b) Eq. circuit in the -ve half cycle of modulating signal with carrier -ve.

spaced in the -ve half cycle of modulating signal.

When modulating signal reverses the polarities, the output of the circuit is same as that in the +ve half cycle discussed earlier. The only difference is that the diode pair D₃ D₄ will produce a +ve o/p voltage while as D₁ D₂ will produce -ve o/p voltage.

Single Sideband modulator :-

The information contained in the UGB is exactly identical to the carried by the LGB. So by transmitting both the sidebands we are transmitting the same information twice. We can transmit only one sideband (UGB or LGB) without any loss of information. So it is possible to suppress the carrier and one sideband completely when only one sideband is transmitted. The modulation is referred to as Single Sideband modulator. It is also called UGB or GSC modulator.

Transmission Bandwidth :-

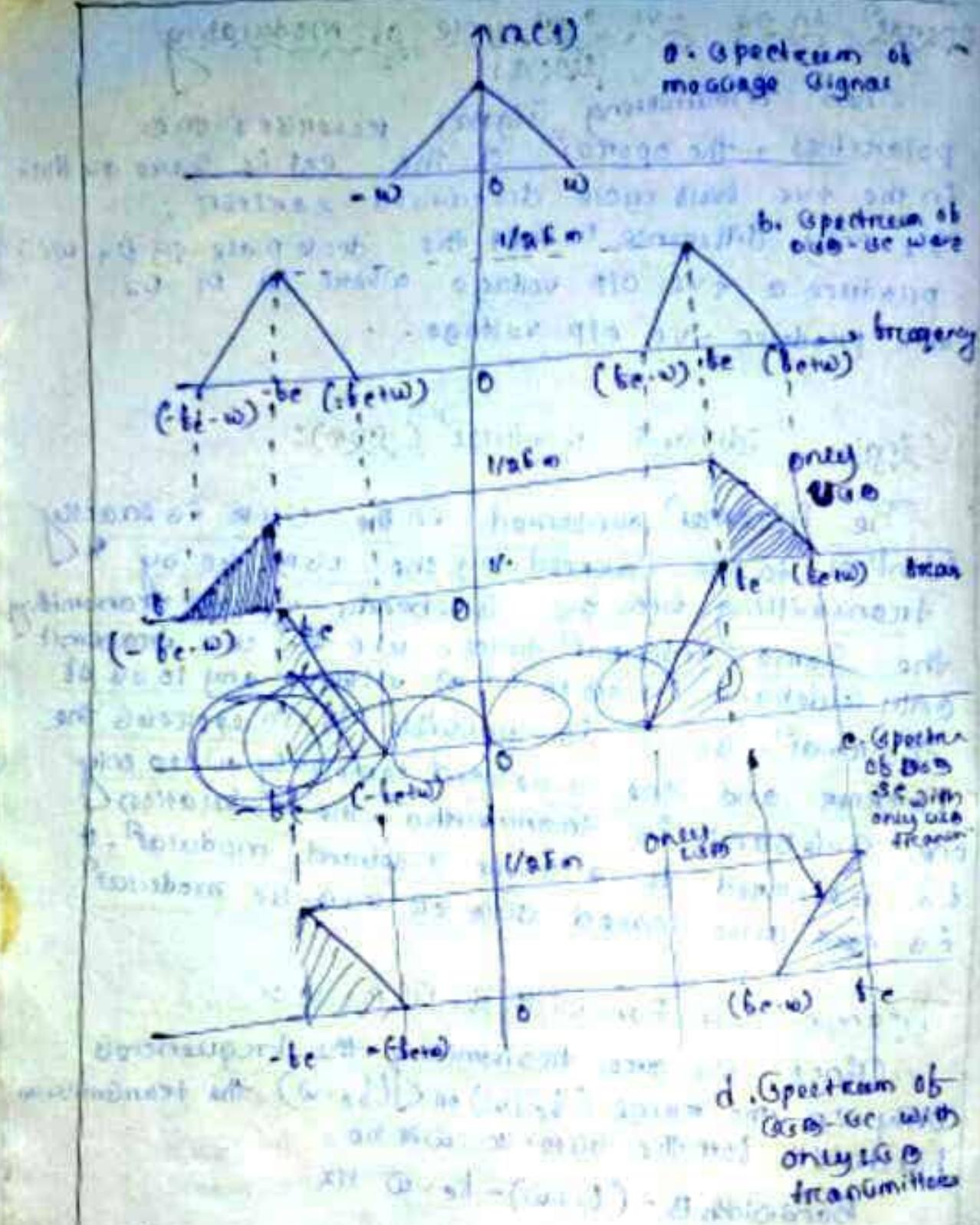
Since we are transmitting the frequencies only in the range ($b+\omega$) to ($b-\omega$) the transmission bandwidth for the UGB-SC will be

$$\text{Bandwidth } B = (b+\omega) - b - \omega \text{ Hz}$$

$$B = f_e - (b - \omega) = \omega \text{ Hz}$$

Advantages of UGB-SC modulator :-

- (i) Reduction in transmission bandwidth
- (ii) Power saving since the high power carrier and one sideband are not being transmitted.



Method of Generation of G.M. Modulated Wave:

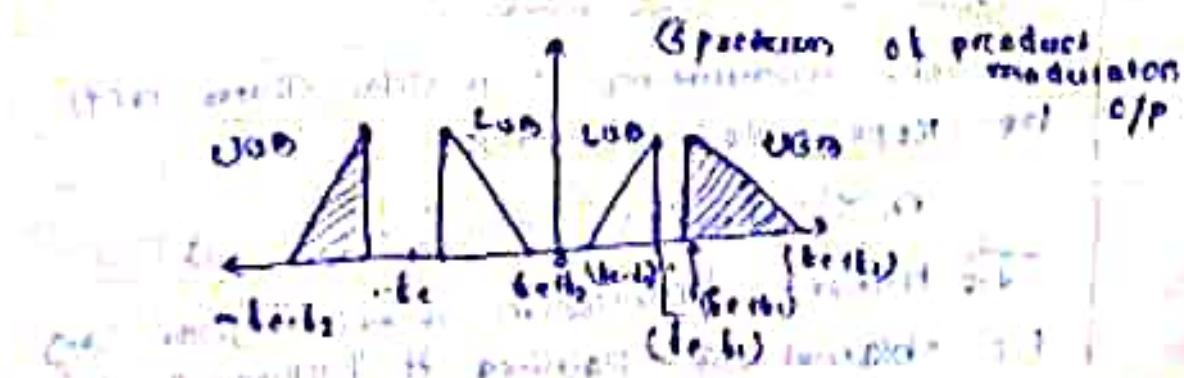
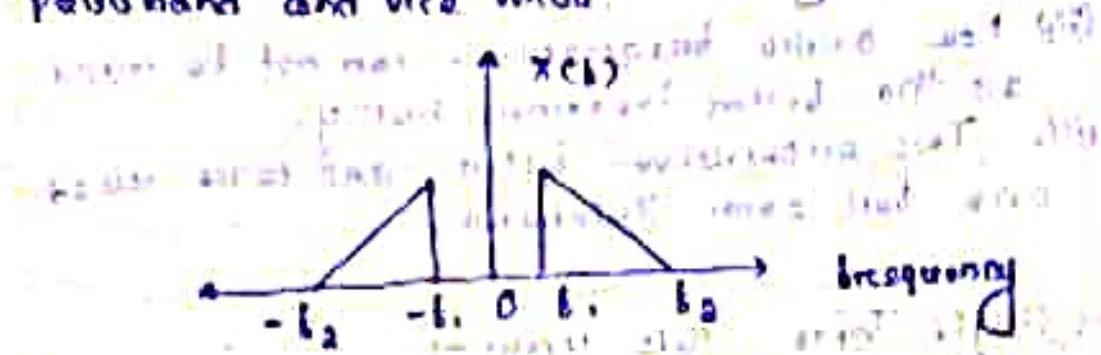
The message signal should not have any low frequency content. The telephone signals will have a frequency range extending from 300 Hz to 3.4 kHz. The freq. in the range 0-300 Hz are absent. The highest freq. in the spectrum of the msg. signal, i.e. ω_M should be much smaller than carrier freq. i.e.



This modulator consists of a product modulator, carrier oscillator and BPF designed to pass the deviated fm side band. GMSK modulated wave which consists of the two sidebands only. The bandpass filter will pass only one of those sidebands and produce the GMSK modulated wave at its O/P.

Demod:

The frequency difference between the highest base, in LFO and the lowest base, in LFO is too small. Designing design of the BPF extremely difficult because the frequency response needs to have very sharp change over from "onward" to "passband" and vice versa.



Design of BPF:

1. passband of bandpass filter must be based on specifying frequency range of that occupied by the spectrum of the desired GMSK modulated wave.

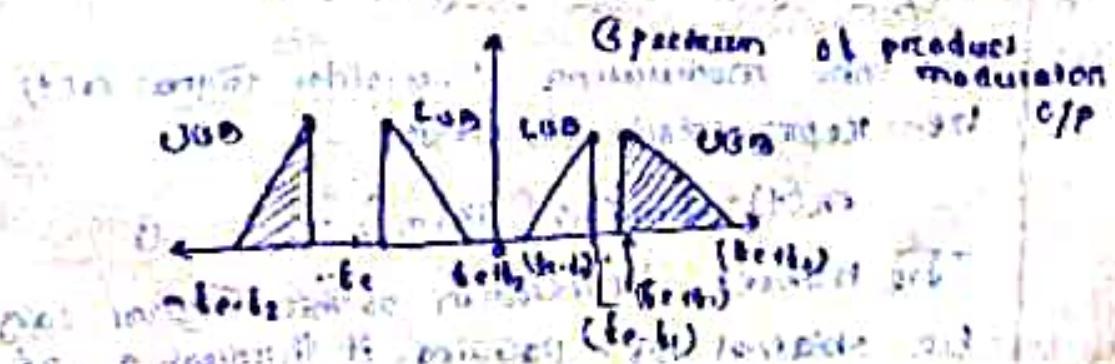
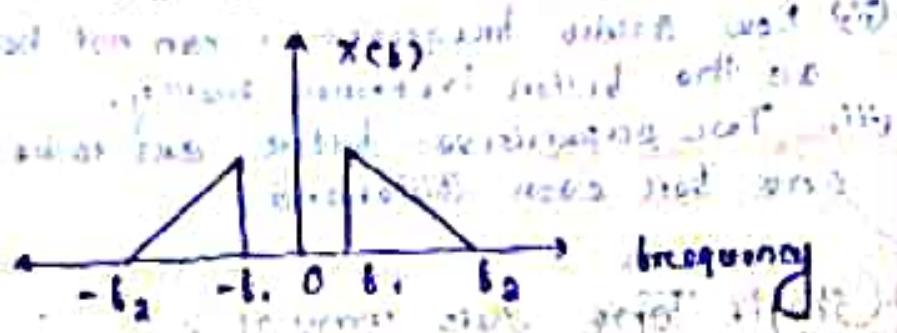
Should occupy the same



This modulator consists of a product modulator, carrier oscillator and BPF designed to pass the desired band side band. DSB-SC modulated wave which consists of the two sidebands only. The bandpass filter will pass only one of these sidebands and produce the DGM modulated wave at its O/P.

Demerit:

The frequency difference between the highest band and the lowest band is very large. This makes design of the BPF extremely difficult because the frequency range it occupies needs to have very sharp change over between all bands to passband and vice versa.



Design of BPF:

- Passband of bandpass filter must be based on carrying frequency range occupied by the spectrum of the deModulated DGM modulated wave.

- A. The width of the guard band which optimizes the produced from. It helps to lower the lowest frequency component of the modulated signal.

Advantages of frequency division method (cont.)

- i. This method gives the adequate sideband suppression. The filter also helps to attenuate the carrier.
- ii. The bandwidth is sufficiently flat and wide.

Disadvantages :-

- i. Due to the inability of the system to generate GMSK at high radio frequencies, the frequency upconversion is necessary.
- ii. Low radio frequencies can not be used as the filter becomes bulky.
- iii. Two separate filters are to be used one for each sideband.

Single Tone GMSK modulation:

Let the modulating sinusoidal signal $m(t)$ be represented as under

$$m(t) = E_m \cos(\omega_m t) - 0$$

The Hilbert transform of this signal can be obtained by passing it through a -90° phase shifter. Hence the Hilbert transform is given by

$$\alpha(t) = E_m \cos(\omega_m t - 90^\circ)$$

$$\begin{aligned} &= E_m [\cos(\omega_m t) \cos(-90^\circ) + \sin(\omega_m t) \sin(-90^\circ)] \\ &= E_m \sin(\omega_m t) - 0 \quad (1) \end{aligned}$$

But the QSB were with only QSB. It is given by

$$QSB(t) = \frac{1}{2} [E_m \cos(\omega_b t) \cos(\omega_a t) - E_m \sin(\omega_b t) \sin(\omega_a t)]$$

Substituting the expression for $\alpha(t)$ and $\beta(t)$ we obtain

$$QSB(t) = \frac{P_m}{2} [E_m \cos(\omega_b t) \cos(\omega_a t) - E_m \sin(\omega_b t) \sin(\omega_a t)]$$

$$QSB(t) = \frac{E_m P_m}{2} [\cos(\omega_a t) \cos(\omega_b t) - \sin(\omega_a t) \sin(\omega_b t)]$$

But $\cos A \cos B - \sin A \sin B = \cos(A+B)$

$$\text{Therefore, } QSB(t) = \frac{E_m P_m}{2} \cos(\omega_a + \omega_b)t$$

Advantages of QSB over DSB:-

- Leads bandwidth requirement of QSB requires a BW of b_m . This will allow more no. of signals to be transmitted in the same freq. range.
- Less power saving : This is due to the transmission of only one sideband component. At 100% modulation the percent power saving is 33.33%.

Disadvantages of QSB :-

- The generation and reception of QSB signals is complicated as discussed latter on.
- The QSB transmitter and receiver need to have an excellent frequency stability. A slight change in freq. will hamper the quality of transmitted and received signals. Therefore, QSB is not generally used for the transmission of good quality music. It is used for speech transmission.

Application of QSB :-

- QSB transmission is used in the applications where the power saving and low bandwidth requirement are important.
- The applications areas are land and sea mobile communications, telemetry, military communications, navigation and amateur radio. Many of those applications are point-to-point communication applications.

Phase Shift Method for the GMSK generation:

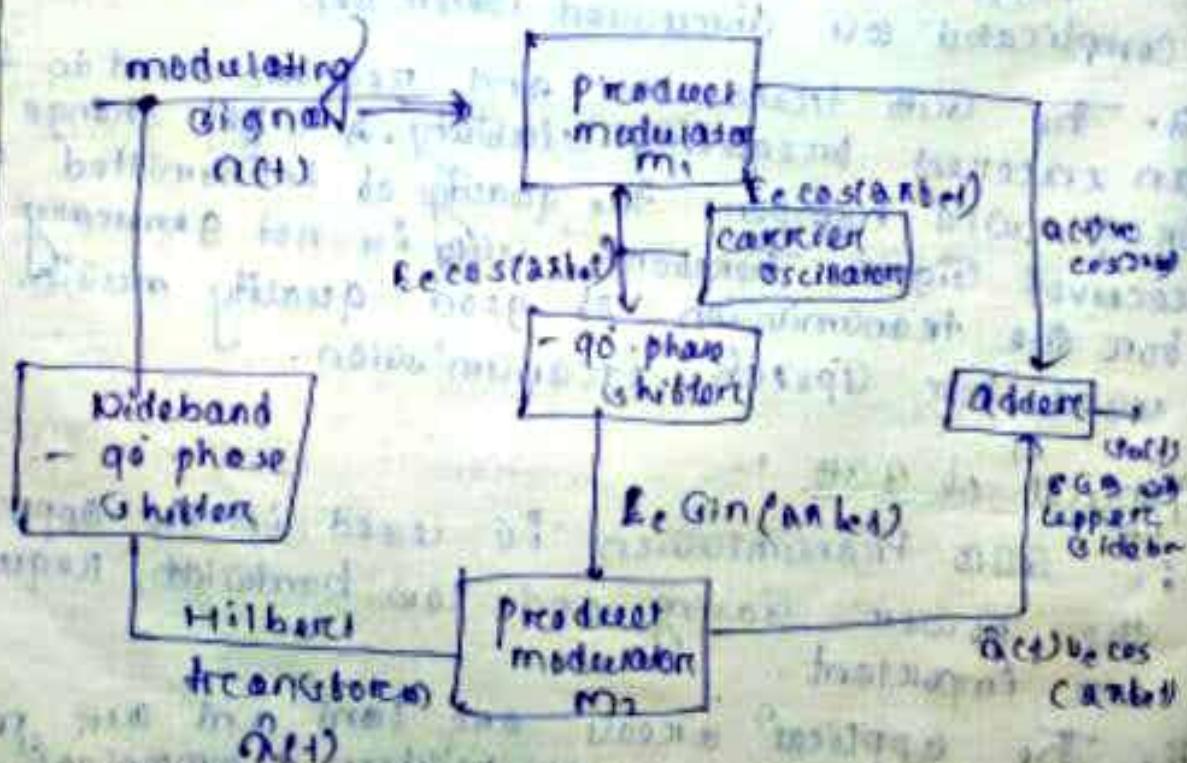
The system is used for the generation of lower sideband. This system uses two balanced modulators M_1 and M_2 and two 90° phase shifting network.

Working:-

The msg signal $a(t)$ is applied directly to the product modulator M_1 and through a -90° phase shifter to the product modulator M_2 . Hence, we get the Hilbert transform $\hat{a}(t)$ at the o/p. of the wideband -90° phase shifter. The o/p of carrier oscillator is applied as it is to modulator M_1 whereas as it is passed through a -90° phase shifter and applied to the modulator M_2 .

$$O/P \text{ of } M_1 = a(t) \cdot E_c \cos(\omega_c t)$$

$$O/P \text{ of } M_2 = \hat{a}(t) \cdot E_c \sin(\omega_c t)$$



The outputs m_1 and m_2 are applied to an adder.
Note the (-) sign before the quadrature path.

$$\text{Adder output} = m_1 \cos(\omega t) + m_2 \sin(\omega t) + m_3 \cos(2\omega t) + m_4 \sin(2\omega t)$$

This expression represents the LSSM signal with only USB. i.e. it includes the USB only.
Conjugated side will not participate.

Advantages of Phase Discriminal method :-

1. It can generate the GMSK signal at any freq.
(So the freq. up converter stage is not required.)
2. It can use the low audio frequencies as modulating signals.
3. It is easy to switch between the Sideband to the other.

Drawbacks :-

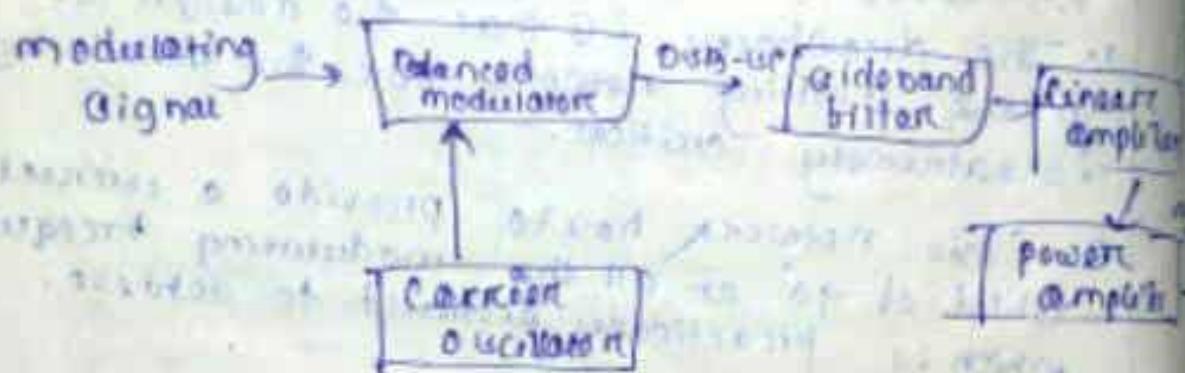
1. The drawback is that the design of the 90° phase shifting network for the modulating signal is extremely critical.
2. This network has to provide a correct phase shift of 90° at all the modulating frequencies which is practically difficult to achieve.

Vestigial Sideband Transmission (VSB) :-

An vestigial sideband is a form of amplitude modulation in which the carrier and one complete sideband are transmitted, but only part of the second sideband is transmitted. The carrier is transmitted at full power. In VSB the lower modulating signal frequencies are transmitted as sideband and the higher modulating signal frequencies are transmitted as single sideband.

The lower frequencies can appreciate the benefit of 100% modulation whereas at the higher frequencies cannot achieve more than the effect of 50% modulation. As a result the lower frequency modulating signal can approach and produce large amplitude signals in the demodulator than the high frequencies.

The stringent freq.-response requirement on the sideband filter in VSB system can be relax by allowing a part of unwanted sideband (called as Vcfigo) to appear in the o/p of the modulator. Due to this the design of the sideband filter is simplified to a great extent. But the bandwidth of the system is increased slightly. To generate a VSB signal use →



Transmission Bandwidth

The "band" of the transmitted VSB modulated wave is given by $B = (b_m + b_s) \text{ Hz}$.

b_m msg bandwidth

b_s width of the vestigial sideband

Advantages of VSB:

- Reductⁿ of Bandwidth. It almost as efficient as the QPSK.
- Due to allowance of transmitting apart of lower Sideband, the constraint on the filter have been relaxed. So practically easy to design filter can be used.
- It possess good phase characteristics and makes the transmission of low frequency component possible.

Applicatⁿ:

QPSK modulator has become standard for the transmission of TV Signals. Because the video Signals need a large transmission BW to be transmitted using DSB-SC or DSB-SC techniques.

G No	Parameter of comparison	QPSK		DPSK	QAM	PSK
		DPSK	QPSK			
1.	Carrier Suppression	N.A	N.A	Fully	fully	N.A
2.	Sideband Suppression	N.A	N.A	N.A	80%	one way partial
3.	Bandwidth	abm	abm	abm	full	large
4.	Transmission Efficiency	min ^m	moderate	moderate	max ^m	moderate
5.	No. of modulating I/P	1	1	1	1	2
6.	Applicat ⁿ	Radio broadcast	Radio broadcast	Point to point mobile teles munic car	TV	

Concept of angle modulation:

It may be defined as the process by 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 const.

Let us consider that an unmodulated carrier signal be expressed as

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

A = amplitude of carrier.

We = carrier freq.

$$\begin{aligned} e(t) &= A \cos(\omega t + \theta_0) \\ \text{Let } \theta_0 &= \text{some phase angle} \\ \text{Rotating vector } A \cos(\omega t + \theta_0) &= A \cos(\theta_0) \cos(\omega t) - A \sin(\theta_0) \sin(\omega t) \\ &= A \cos(\theta_0) \cos(\omega t) - A \sin(\theta_0) \sin(\omega t) \end{aligned}$$

Now we can take $\theta_0 = \omega_0 t$ as per
the rotating phasor method. Let us denote this
rotating phasor by e so that

$$e = A \cos(\theta_0) \cos(\omega t) - A \sin(\theta_0) \sin(\omega t)$$

$$e = A \cos(\theta_0) \cos(\omega t) - A \sin(\theta_0) \sin(\omega t)$$

$$e = A \cos(\theta_0) \cos(\omega t) - A \sin(\theta_0) \sin(\omega t)$$

This phasor e rotates at a const. angular
velocity ω . Clearly θ_0 is the phase angle
of the unmodulated carrier at $t=0$.

From eq (1) the const. angular velocity ω
of the phasor e is related to its total phase
angle ϕ as

$$\phi = \omega t + \theta_0$$

Differentiating both sides of this eq w.r.t.
to t , we have

W.E. 11

Time dependent angular velocity ω is given by
freq. ω_0 known as instantaneous angular velocity
or instantaneous angular frequency is denoted by ω :

$$\frac{d\phi}{dt} = \omega, \quad \text{W.E. 11}$$

where angular freq. ω is \rightarrow time dependent
from eq. 11 we get

$$\phi = \int \omega dt \quad \text{W.E. 11}$$

Again writing eq. 11 of unmodulated carrier as

$$C(t) = A \cos(\omega_0 t + \theta_0)$$

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

where ϕ is the total phase angle of the unmodulated carrier expressed as

$$\phi = \omega_0 t + \theta_0$$

Now if this angle ϕ is varied according to the instantaneous value of message or modulation signal the carrier signal is then said to be angle modulated.

We can vary this phase angle ϕ in two ways and thus there are two types angle modulation as under

i. phase modulation (PM)

ii. freq. modulation (FM)

Phase Modulation (PM)

PM is that type of angle modulation in which the phase angle ϕ is varied linearly with a baseband or modulating signal $m(t)$ about a carrier phase $(\omega_0 t + \theta_0)$. This means that in phase modulation, the instantaneous value of the phase angle is equal to the phase

angle at the unmodulated carrier ($\omega_0 t + \theta_0$) plus a time varying component which is proportional to modulating signal $a(t)$.

We know that the unmodulated carrier signal is expressed as

$$c(t) = A \cos(\omega_0 t + \theta_0)$$

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

$$\phi = \omega_0 t + \theta_0$$

where neglecting θ_0 we get

total phase angle of unmodulated carrier is

$$\phi = \omega_0 t$$

according to phase modulation, this phase angle ϕ is varied linearly with a lowband or modulating signal $a(t)$.

Let the instantaneous value of a phase angle be denoted by ϕ :

Therefore

$$\phi = \omega_0 t + K_p a(t) \quad \text{--- (1)}$$

where K_p is the proportionality constant and is known as phase sensitivity of modulator.

Expression for unmodulated carrier wave is

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

Expression for phase modulated wave will be

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

Putting the value of ϕ in eq (2), we get

$$c(t) = A \cos [\omega_0 t + K_p a(t)] \quad \text{--- (3)}$$

Frequency Modulation:-

Frequency modulation is that type of modulation in which the mod or baseband signal $a(t)$ varies linearly with a carrier frequency ω_c . This means the instantaneous value of the angular frequency ω will be equal to the carrier freq ω_c plus a time varying component proportional to the baseband signal $a(t)$.

$$\text{Instantaneous freq. } \omega = \omega_c + K_f \cdot a(t) \quad (1)$$

where K_f is proportionality const and is known as the freq. Sensitivity of the modulator.

The expression for unmodulated carrier signal be

$$e(t) = A_0 \cos(\omega_c t + \phi_i) \quad (2)$$

$$e(t) = A_0 \cos \phi \quad (3)$$

$$\phi = \omega_c t + \phi_i \quad (4)$$

ϕ is the total phase angle of the unmodulated carrier.

Let ϕ_m be the instantaneous phase angle of the modulated Signal.

From eq (4) the ϕ_m of unmodulate carrier is

$$e(t) = A_0 \cos \phi_m$$

On frequency modulation amplitude A remain constant and only angle will change.

Hence the expression for frequency modulated wave will be

$$e(t) = A_0 \cos \phi_m \quad (5)$$

Where ϕ_m = instantaneous phase angle

from eq (4)

$$\phi_m = \omega_c t + \phi_i$$

$$\phi_m = \omega_c t + \phi_i$$

on differentiation we get

$$\frac{d\phi}{dt} = \omega_c$$

$$\Rightarrow \phi_m = \int \omega_c dt \quad (6)$$

Based on eq (ii) we may write expression for instantaneous phase angle ϕ as

$$\phi = \omega_0 t + \int \omega_m \sin \omega_m t dt \quad \text{--- (VII)}$$

Where ω_0 = instantaneous freq. of wave. due to modulation
wave putting the value of ω_0 in eq (ii) from
eq (i) we get,

$$\phi_1 = \int [\omega_0 + K_F \sin \omega_m t] dt$$

$$\phi_1 = \omega_0 t + K_F \int \sin \omega_m t dt \quad \text{--- (VIII)}$$

Putting this value of ϕ_1 in eq (i) we get the expression for modulated wave

$$S(t) = A \cos [\omega_0 t + K_F \int \sin \omega_m t dt] \quad \text{--- (ix)}$$

If the phase angle of the unmodulated carrier is taken at $t=0$, then the limit of integration in eq (ix) will be 0 to t .

In this case the expression for FM wave will be

$$S(t) = A \cos \left[\omega_0 t + K_F \int_0^t \sin \omega_m t dt \right] - FM$$

Frequency Deviation :-

Instantaneous freq. of FM wave is given by

$$\omega_i = \omega_0 + K_F \sin \omega_m t$$

The instantaneous frequency of FM signal varies with time around the carrier freq. ω_0 . i.e. the instantaneous freq. of FM signal varies according to modulating signal.

The max change in instantaneous freq. the average freq. ω_0 is called freq. deviat.

frequency deviation $\Delta f = k_m \cdot \text{modulation signal}$

Relationship between phase modulation and frequency modulation :-

We know that an angle modulated wave is given by

$$s(t) = A \cos \phi_t \quad \text{--- (1)}$$

A - amplitude

ϕ_t - instantaneous total phase of the angle modulated wave

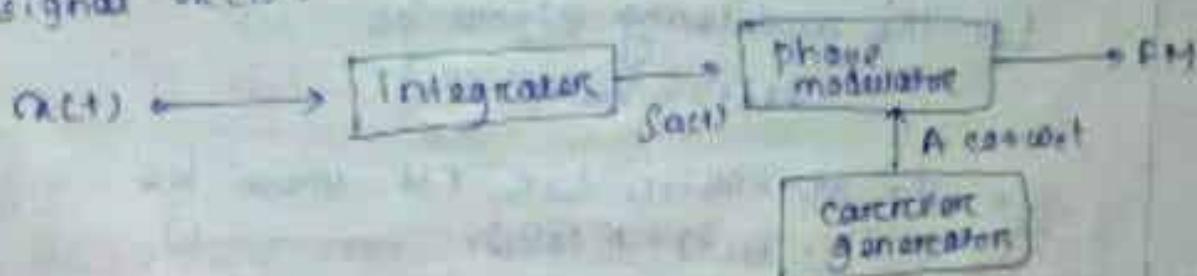
The expression for phase modulated (PM) wave is

$$s(t) = A \cos [w_0 t + K_m \alpha(t)] \quad \text{--- (2)}$$

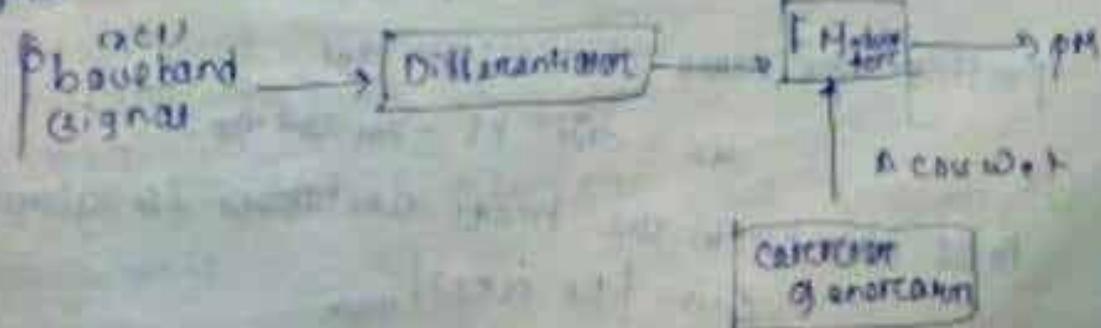
Similarly the expression for freq-modulated (FM) wave

$$s(t) = A \left[\cos w_0 t + K_f \int \alpha(t) dt \right] \quad \text{--- (3)}$$

In PM the phase angle varies linearly with baseband signal $\alpha(t)$ whereas as in case of FM, The phase angle varies linearly with the integral of baseband signal $\alpha(t)$.



Similarly PM waves may be generated by using FM by just differentiating modulation off baseband signal $\alpha(t)$ then apply to the FM.



Single tone freq. modulation :-

General expression of FM

$$x(t) = A \cos [\omega_0 t + k_t \int a(t) dt]$$

FM wave $x(t)$ is a nonlinear function of the base band orc modulating signal $a(t)$. This means that FM is a nonlinear modulation process.

Simplest case of FM wave known as Single tone freq. modulat.

Modulation index, $m_t = \frac{\text{freq. deviat.}}{\text{modulat freq.}}$

$$\text{orc m}_t = \frac{\Delta \omega}{\omega_m}$$

Mathematical Expressions for Single tone freq. modulation :-

Let the expression for carrier signal be
 $c(t) = A \cos \omega_c t$

Let the modulating signal be

$$a(t) = V_m \sin \omega_m t$$

Let the expression for FM wave be

$$x(t) = A \cos (\phi) \quad \text{--- (1)}$$

ϕ = instantaneous freq. of the modulated wave is given by

$$\phi = \omega_c t + k_t a(t) \quad \text{--- (2)}$$

Putting the value of $\phi(t)$ we get

$$\omega_i = \omega_c t + k_t a(t) \omega_m$$

But we know the freq. deviation is given as

$$\Delta \omega = |k_t a(t)|_{\text{max}}$$

$$= k_t |a(t)|_{\text{max}}$$

$$\Delta \omega = k_t V_m$$

The total phase angle ϕ_t of the modulated wave is given by

$$\omega_t = \omega_0 + \Delta\omega \sin \omega_m t \quad (7)$$

The total phase angle ϕ_t of the modulated wave is given by

$$\phi_t = \int \omega_t dt$$

Putting the values of ω_t from eq (7) we get

$$\phi_t = \int [\omega_0 + \Delta\omega \sin \omega_m t] dt$$

$$\phi_t = \omega_0 t + \frac{\Delta\omega}{\omega_m} \sin \omega_m t \quad (8)$$

Peak modulation index mt is given as

$$mt = \frac{\text{max deviation}}{\text{modulating freq.}}$$

$$\text{or } mt = \frac{\Delta\omega}{\omega_m}$$

Putting the value of mt in eq (8) we obtain

$$\phi_t = \omega_0 t + mt \sin \omega_m t$$

Substituting this value of ϕ_t in eq (7) we get the expression for single tone FM wave.

$$v(t) = A \cos \phi_t$$

$$v(t) = A \cos [\omega_0 t + mt \sin \omega_m t]$$

Ex:-

A Single Tone FM is represented by voltage of

$$v(t) = 12 \cos [8 \times 10^6 t + 5 \sin \pi 500 t]$$

Determine the following

- i. Carrier freq.
- ii. Modulating freq.
- iii. Modulation index
- iv. maximum devial?
- v. what power will this FM wave dissipate in 10Ω resistor?

$$\text{Given} \rightarrow \text{Net current} = I_0 \cos(\omega_0 t + \pi/2) \quad \text{.....(1)}$$

$$\text{Net current} = 12.5 \cos(6 \times 10^6 t + \pi/2) \quad \text{.....(2)}$$

Comparing eq (1) & (2) we get

i. carrier frequency

$$\omega_0 = 6 \times 10^6 \text{ rad/sec} \quad (\omega = 2\pi f)$$

$$f_c = \frac{\omega_0}{2\pi}$$

$$f_c \approx 95.5 \text{ MHz}$$

ii. modulating freq.

$$\omega_m = 12.50 \text{ rad/sec}$$

$$f_m = \frac{\omega_m}{2\pi}$$

$$f_m \approx 199 \text{ Hz}$$

$$mt = 5$$

$$iii. mt = 5$$

iv. mean freq. deviation is given by

$$mt = \frac{\Delta \omega}{\omega_m} = \frac{\Delta f}{f_m}$$

$$\Delta f = mt \cdot f_m$$

$$\Delta f = 5 \times 199 = 995 \text{ Hz}$$

v. The power dissipated is

$$P = \frac{U_{rms}^2}{R}$$

$$\approx \frac{(12/V)^2}{10} = \frac{144}{10} = 14.4 \text{ Watts}$$

Narrow Band FM :-

In this case K_b is small and hence the bw of FM is narrow.

Wideband FM :-

In this case K_b is large and hence the FM signal has a wide bandwidth.

FM Generation :-

- i) Direct method or parameter variation method
- ii) The indirect method or the modulating method.

The direct Method :-

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

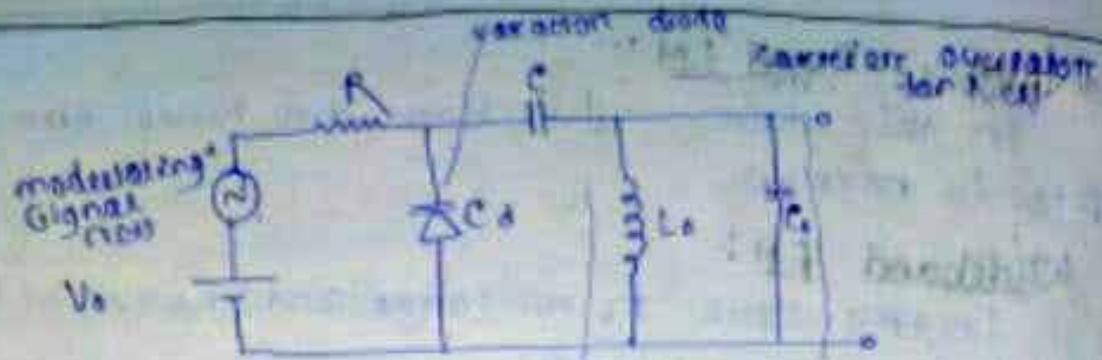
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Now we can make the carrier freq. ω_0 to vary in accordance with baseband or modulating signal and if L or C is varied according to (i) (ii).

Varactor diode method for FM generation :-

The varactor diode is a semiconductor diode whose bias junction capacitance changes with A.C. bias voltage. This varactor diode is connected in shunt with the tuned circuit of the oscillator system.

In varactor diode FM generation arrangement the capacitor C is made much smaller than the varactor diode capacitance so that the radio freq. voltage from oscillator across the diode is small as compared to reverse bias dc voltage across the varactor diode.



Mathematical analysis:-

The capacitance C_d of the varactor diode is expressed as

$$C_d = \frac{K}{\sqrt{V_o}}$$

$$C_d = K(V_o)^{-1/2} \quad \text{--- (i)}$$

Here V_o is the total instantaneous voltage across the varactor diode and is given by

$$V_o = V_0 + \alpha e^t \quad \text{--- (ii)}$$

And K is a const. of proportionality.

The oscillation freq. ω is given as

$$\omega = \frac{1}{\sqrt{L_o C}} \quad \text{--- (iii)}$$

The total capacitance of the oscillator tank circuit will be C_{tot} and thus the instantaneous freq., oscillator ω is expressed as

$$\omega = \frac{1}{\sqrt{L_o(C_{tot} + C_d)}} \quad \text{--- (iv)}$$

In above eq. substituting the value of C_d from eq. we have

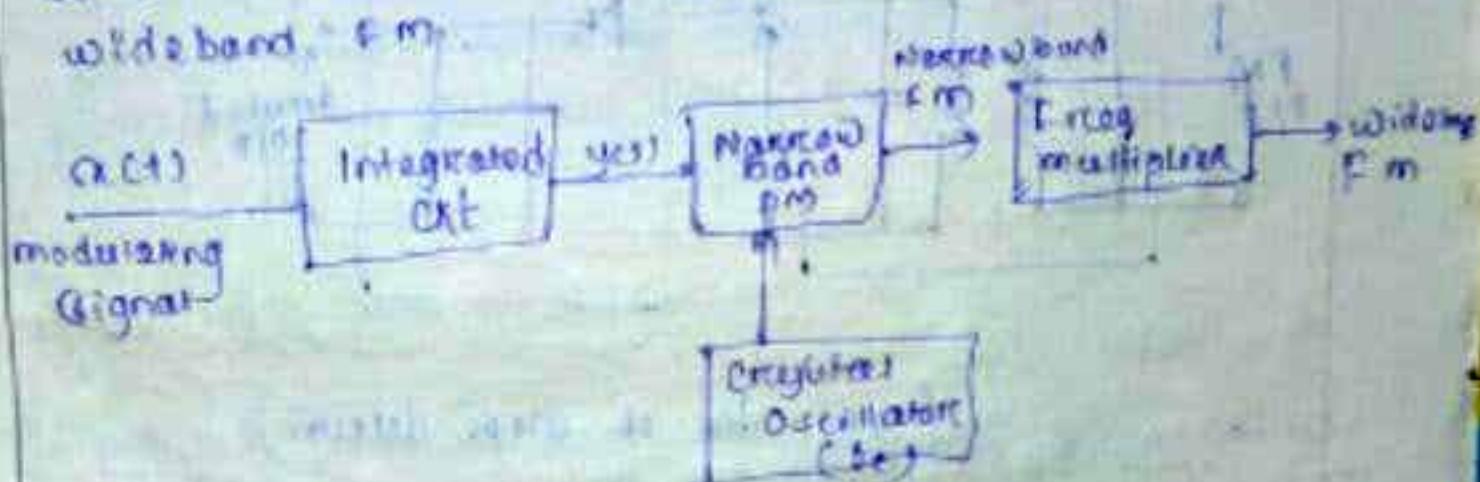
$$\omega = \frac{1}{\sqrt{L_o(C_{tot} + K(V_o)^{-1/2})}}$$

The instantaneous freq. ω of FM signal depends upon V_o which in turn depends upon the value of the modulating signal (V_m) .

Indirect FM Generation Method of FM generation :-

We can get very high frequency stability since in this case the crystal oscillator may be used as a carrier freq. generator. To generate a narrowband FM (NBFM) indirectly by utilizing the phase-modulation technique and then changing this narrowband FM into a wideband FM.

The modulating index is small. Therefore the distortion is very low in narrowband FM. The modulating C.R.T. arises from multiplying the carrier freq. and increasing the frequency deviation and hence the narrow band FM - small frequency deviation is converted into wideband FM.



(A working method for FM generation)

Types of AM Demodulators:

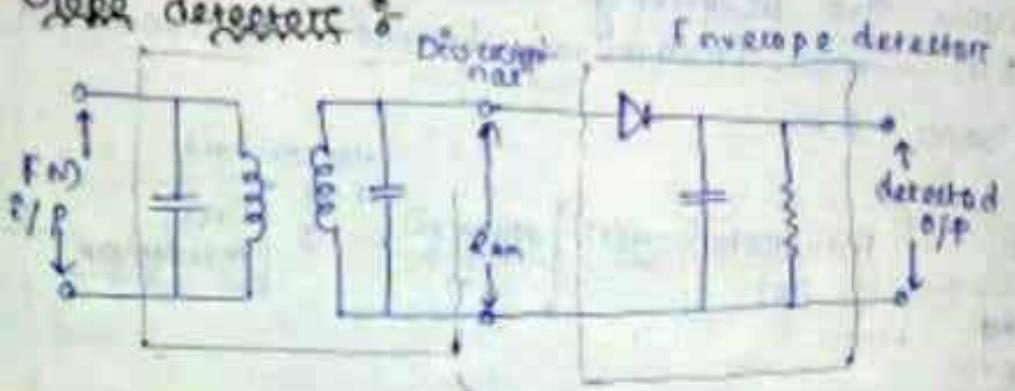
1. Slope detectors

- i. Gengro - tuned detector CRT or simple slope detector.
- ii. Unilaggar - tuned detector CRT or balanced slope detection.

2. Phase difference detector

- i. Foster- Seeley detector.
- ii. Ratio detector.

Slope detector &



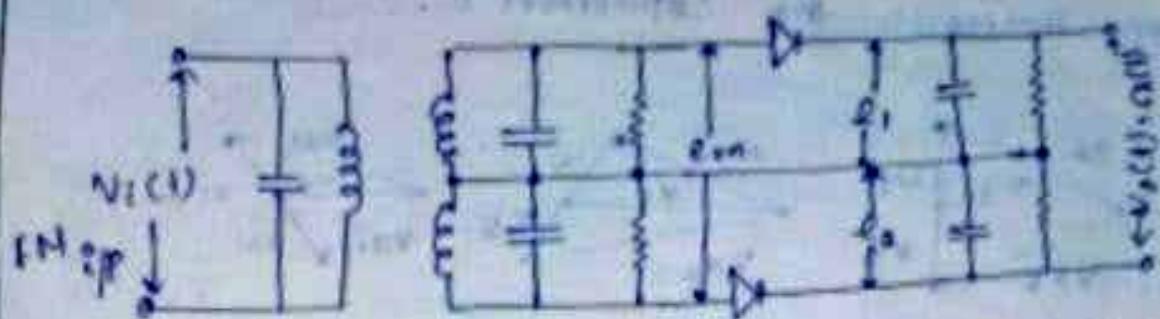
(ext. dis. of slope detector)

The CRT consists of a tuned CRT which is slightly detuned from the carrier freq. i.e. In other words the CRT consists two tuned CRT which are tuned to two different frequencies. First one is tuned to the incoming FM carrier freq. i.e. whereas as the 2nd one is tuned to a freq. slightly different from the carrier freq. i.e. Therefore the two portion of the CRT which contains two tuned CRT is tuned to different frequencies is called discriminators.

This CRT converts the FM signal into AM signal. The another part of the CRT is envelope detector. The AM signal from the CRT of discriminator is applied at the I/p of envelope detector.

Balanced Glimp detector :-

It is an improvement over the Glimp detector. The circuit is consists of two L.C.T.



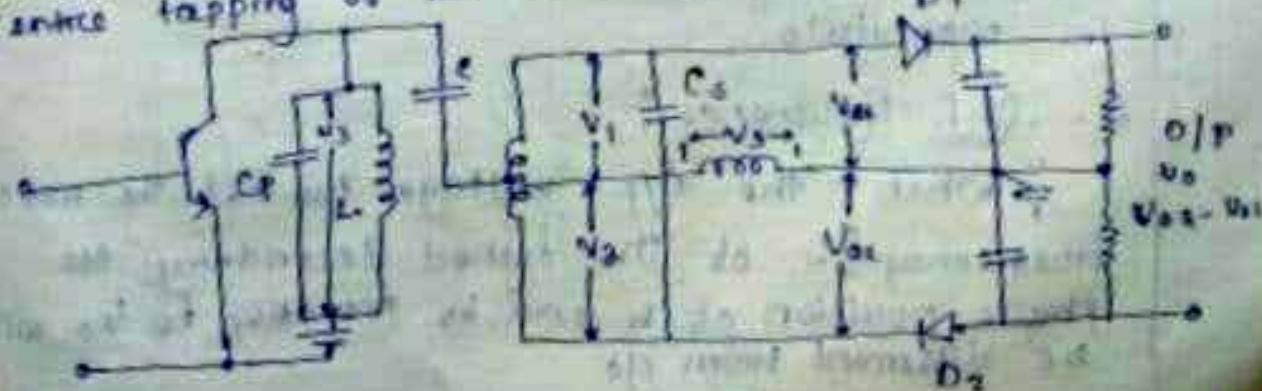
In this circuit, the two tuned circuit are used in the stagger-tuned mode, i.e. one tuned circuit is tuned above the carrier by ω_c and another tuned circuit is tuned below ω_c . The resultant curves (or V_o) is linear as depicted by dotted line in fig.

Phase difference detector :-

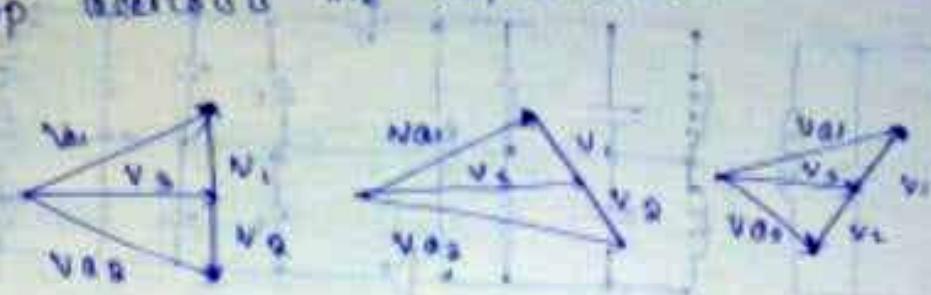
Foster-Seeley detector :-

The circuit consists of an inductively coupled double tuned circuit in which both primary and secondary coils are tuned to the same freq. The centre of the secondary coil is connected to the top of the primary through a capacitor C_p . This capacitor performs the following function:

1. It blocks the d.c. from primary to secondary.
2. It couples the signal freq. from primary to centre tapping of the secondary.



The primary voltage V_p will appear across the inductor. Nearly entire voltage V_p appears V_2 across the inductor L except a small drop across the capacitor C .



The centre-tapping of the Secondary coil has an equal and opposite voltage across each half winding. Hence V_1 and V_2 are equal in magnitude but opposite in phase. The radio freq. voltages V_{2a} and V_{2b} applied to the diodes D_1 and D_2 are反相的 (opposite).

$$V_{2a} = V_2 + V_1$$

$$V_{2b} = V_2 - V_1$$

Voltages V_{2a} and V_{2b} depends upon the phasor relations betw. V_1 , V_2 and V_p .

i. At Resonance:

When an e/p voltage has a freq. equal to the resonant frequency f_r of the tuned Secondary, V_{2a} is in phase quadrature with V_1 and V_2 . This has been shown in last phasor diagram. The resonant voltages V_{2a} and V_{2b} are equal in magnitude.

ii. Off Resonance:

When the e/p voltage is at the resonant frequency f_r of the tuned Secondary, the phase position of V_1 and V_2 relative to V_p will be different from 90°.

The RF voltage V_{RF} and V_{AF} are separately rectified by the rect diode D_1 and D_2 respectively to produce voltage V_{D1} and V_{D2} . The RF components are bypassed by the capacitors leaving only modulating freq. component and a d.c. term. The voltage V_{D1} and V_{D2} then represent the amplitude variations of V_{RF} and V_{AF} respectively. The diodes are arranged so that the O/P voltage V_o is equal to the difference of these.

$$|V_{D2}| - |V_{D1}| \propto e$$

$$V_o = |V_{D2}| - |V_{D1}|$$

Ratio detector :-

Ratio detector is an improvement over the Foster-Geely discriminator and is most widely used. It does not respond to amplitude variation. The circuit is similar to the circuit of Foster-Geely discriminator except the following:

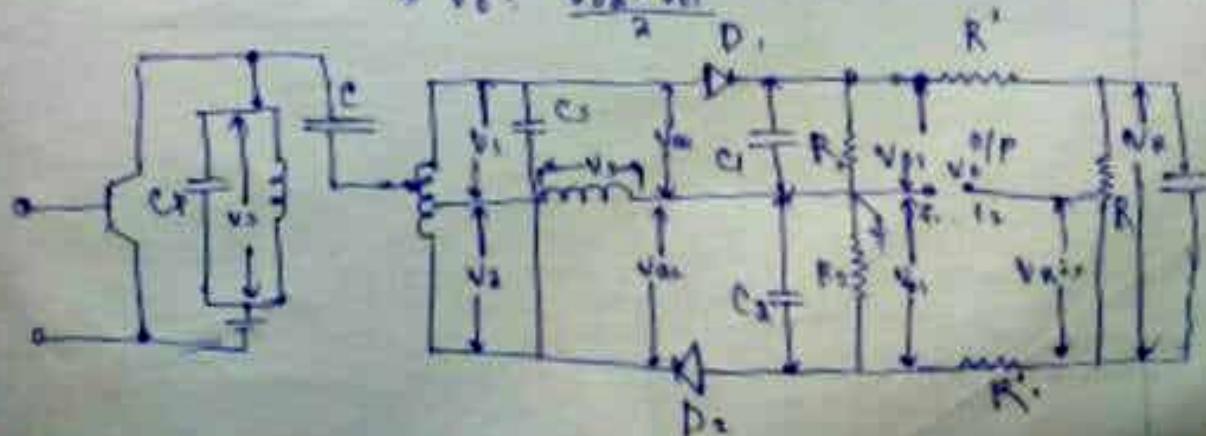
i. Polarity of diode D_2 has been reversed.

ii. The o/p V_o is taken from the centre tap of a resistor R which bears the load impedance of two diodes. The o/p voltage varies with the r.f. signal frequency (F.M.).

The voltage V_{D1} and V_{D2} have the same magnitude as in the case of a Foster-Geely discriminator, but V_{D2} is now reversed in polarity.

$$V_R = |V_{D1}| + |V_{D2}|$$

$$\therefore V_o = \frac{V_{D2} - V_{D1}}{2}$$



Comparison b/w wideband FM and narrowband FM.

S.NO	Parameter/ Characteristics	Wideband FM	Narrow band FM
01	Modulation Index	Greater than 3	Less than or equals greater than 1
02	Minimum deviation	75 KHz	5 KHz
03	Range of modulating frequency	30MHz to 15 KHz	30 Hz to 30KHz
04	Maximum modulation index	5 to 2500	(slightly greater than 1)
05	Bandwidth	Large about 15 times higher than BW of narrowband FM	Same. Apparatus same as that of AM
06	Applications	Entertainment, broadcasting	FM mobile communication, police wire, 1200, amateur etc.
07	Pre-Emphasis and De-emphasis	Needed	Needed

Comparison between FM and PM:

Ques No.	FM	PM
01	$\Delta f = V_m C_{eq} (\omega_0 t + \theta_m \sin \omega_m t)$	$\Delta \phi = V_m C_{eq} [\omega_0 t + \theta_m \sin \omega_m t]$
02	frequency deviation is proportional to modulating voltage.	phase deviation is proportional to the modulating voltage.
03	Associated with the change in frequency there is some phase change.	Associated with the change in phase there is some change in frequency.
04	f_m is proportional to the modulating voltage as well as the modulating frequency.	f_m is proportional to the modulating voltage as well as the modulating frequency.
05	It is possible to receive FM on a PM receiver.	It is possible to receive PM on a FM receiver.
06	Noise immunity is better than AM and PM.	Noise immunity is better than AM but worse than FM.
07	Amplitude of the FM wave is constant.	Amplitude of the PM wave is constant.
08	Signal to noise ratio is better than that of PM.	Signal to noise ratio is inferior to that in PM.
09	FM is widely used.	PM is used for some mobile systems.
10	In FM the frequency deviation is proportional to the modulating voltage only.	In PM the frequency deviation is proportional to both the modulating voltage and modulating frequency.

Probability, Random Signals and Random Variation

- The deterministic Signals have fixed mathematical equations by using Fourier transform to analyze them.
- But Some Signals are there which are uncertain in nature. To predict their properties probability method is used.
- Thus the behaviour of Signal which can not be predicted is known as Random Signals.
example:- The noise interference in communication Signals - Thermal noise generated due to the random motion of electrons

Probability :-

$P(A) = \frac{\text{no. of favorable outcomes}}{\text{Total no. of outcomes}}$.

where A : event

- Properties:
- The probability of an event is unity i.e.
 $P(A) = 1$
 - The probability of an event is always $0 \leq P(A) \leq 1$
 i.e. $P(A) \leq 1$ and non-negative which are mutually exclusive.
 - If A and B are two events then $P(A+B) = P(A) + P(B)$
 - If A is an event then the probability of not happening is $P(\bar{A}) = 1 - P(A)$
 A = complement of A
 - If A & B are two events which are not necessarily exclusive then $P(A \cup B) = P(A) + P(B) - P(A \cap B)$
 Where $P(A \cap B)$ = joint probability.

Conditional Probability

Conditional " of event is given that event A has already happened than

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

$$\text{or } P(A|B) = \frac{P(A \cap B)}{P(A)}$$

Random Variable :-

It is of two types -

a. Discrete Random variable.

b. Continuous Random variable.

a. Discrete Random variable :-

If the Sample Space 'S' contains a countable no. of Sample points then $X(S)$ will be discrete random variable.

b. Continuous Random variable :-

This variable is not restricted to a finite no. of distinct values because it can have any value within a certain range.

Probability density function (p.d.f.)

Generally it is used to describe continuous random variable.

The pdf $f_X(x)$ is defined as

$$P(a \leq X \leq b) = \int_a^b f_X(x) dx$$

Properties :-

→ pdf is non-negative at values of x .

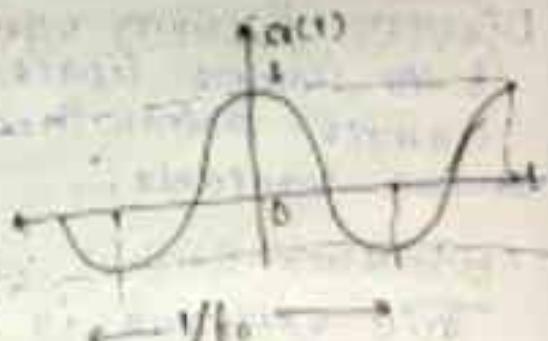
→ $f_X(x) \geq 0$

→ The area under pdf curve in $p.d.f.$ equal to unity

$$\int_{-\infty}^{\infty} f_X(x) dx = 1$$

Ques - 1

Obtain the FT form of a cosine wave having a freq. b_0 and peak amplitude of unity and plot the spectrum.



Ans

A cosine wave

can be mathematically represented as under

$$x(t) = A \cos(\omega_0 t)$$

$$\text{thus } A = 1$$

$$\text{Therefore } x(t) = \cos(\omega_0 t) = 0 \quad \text{--- (1)}$$

By Fourier identifying we can write

$$x(t) = \cos 2\pi b_0 t$$

$$x(t) = \frac{e^{j2\pi b_0 t} + e^{-j2\pi b_0 t}}{2} \quad \text{--- (2)}$$

We know that the FT of $x(t)$ is given by

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-j2\pi f t} dt$$

$$X(f) = \frac{1}{2} \left[\int_{-\infty}^{\infty} e^{j2\pi b_0 t} e^{-j2\pi f t} dt + \int_{-\infty}^{\infty} e^{-j2\pi b_0 t} e^{-j2\pi f t} dt \right]$$

$$X(f) = \frac{1}{2} \left[\int_{-\infty}^{\infty} e^{j2\pi(b_0-f)t} dt + \int_{-\infty}^{\infty} e^{-j2\pi(b_0+f)t} dt \right]$$

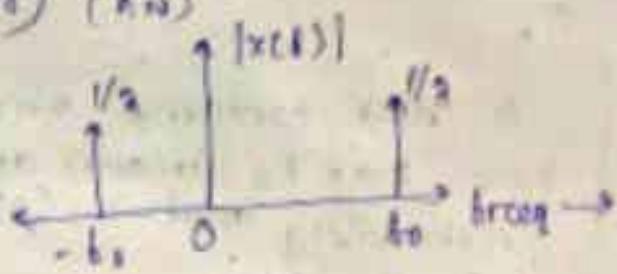
$$X(f) = \frac{1}{2} \left[\int_{-\infty}^{\infty} e^{j2\pi(t-b_0)} dt + \int_{-\infty}^{\infty} e^{-j2\pi(t+b_0)} dt \right]$$

We have already found the FT of a de signal, we have proved that

$$\int e^{j2\pi f t} dt = G(f) \quad \text{--- (3)}$$

using this property from the above eq (3) we get

$$x(t) = \frac{1}{3} b(b-t) + \frac{1}{3} b(t-a) \quad (\text{for } t > a)$$



Q.

The p.d.f. of a random variable

$$b_{x(n)} = \begin{cases} k, & \text{a.s.o.s.s} \\ 0, & \text{otherwise} \end{cases}$$

i. Determine the value of k .

ii. Let $a = -1$ and $b = 2$. Calculate $P(X \in [-1/2, 1/2])$

(SOL)

Therefore $\int_{-\infty}^{\infty} b_{x(n)} dx = 1$

$$\int_a^b k dx = 1$$

$$k(b-a) = 1$$

$$k = \frac{1}{(b-a)}$$

$$b_{x(n)} = \begin{cases} \frac{1}{(b-a)}, & \text{b.o.s.s.s} \\ 0, & \text{o.u.e.} \end{cases}$$

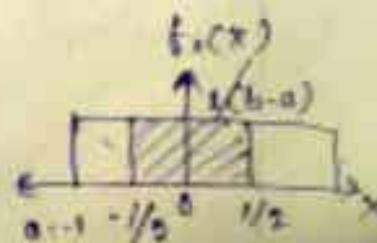
$$P(\max X \leq a_n) = \int_{-\infty}^{a_n} b_{x(n)} dx$$

$$P(-1/2 \leq X \leq 1/2) = \int_{-1/2}^{1/2} \frac{1}{b-a} dx$$

$$P(-1/2 \leq X \leq 1/2) = \int_{-1/2}^{1/2} (1/3) dx$$

$$= \frac{1}{3} (1/2 + 1/2)$$

$$= \frac{1}{3}$$



Q. 8.

A box contains 3 red, 4 white and 5 black balls. One ball is drawn at random. Find the probability that it is (a) red (b) not black (c) black or white.

a. $P(R)$ = Number of choosing red balls
Total no. of ways of choosing
all ball.

$$P(R) = \frac{3}{3+4+5} = \frac{3}{12} = \frac{1}{4} \text{ (Ans)}$$

b. $P(\bar{R}) = 1 - P(R)$

$$P(\bar{R}) = \frac{5}{3+4+5} = \frac{5}{12}$$

$$P(\bar{R}) = 1 - \frac{3}{12} = \frac{7}{12}$$

c. $P(\text{white}) = P(W) + P(\bar{W})$

$$P(W) = \frac{4}{12} + \frac{9}{12}$$

$$P(W) = \frac{9}{12} = \frac{3}{4} \text{ (Ans)}$$