

# UNIT-01

## Amplitude Modulation

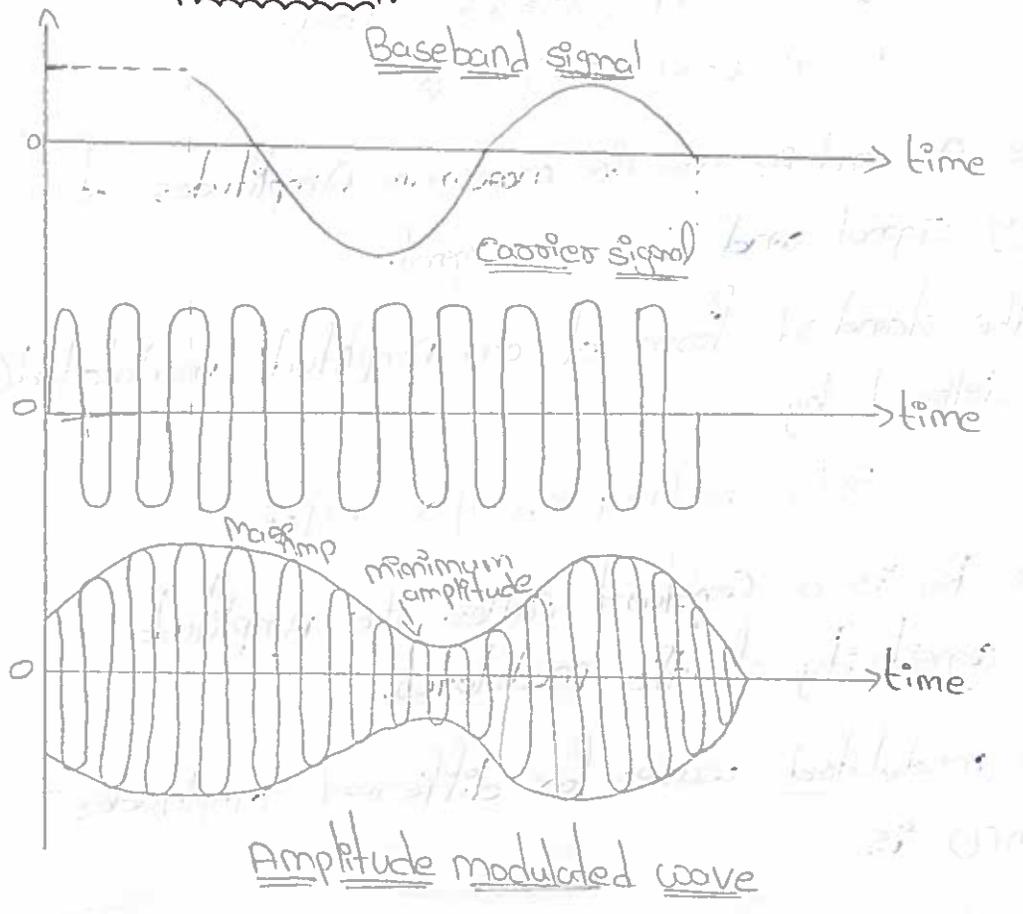
### Need for modulation:-

Message signals or base band signals are not possible for direct transmission over the channel and therefore, we have to use modulation technique for the communication of the baseband signal.

### Advantages of using modulating technique:-

- \* Reduce the height of Antenna.
- \* Avoid mixing of signals.
- \* Increases the Range of Communication.
- \* Allows multiplexing of signals.
- \* Allows adjustment in the bandwidth.
- \* Improve the quality of reception.

### Amplitude modulation:-



Amplitude modulation is defined as system of modulation. In this instantaneous value of the carrier signal Amplitude changes in accordance with the Amplitude of the modulating signal.

Figure gives a single frequency sine wave modulating high frequency carrier signal. The frequency of the carrier signals remains constant during modulation process. But its amplitude varies in accordance with the modulating signal.

Time and Frequency Domain Description:-

Time Domain Description:-

The instantaneous value of modulating signal and carrier signal can be represented as below.

\* Instantaneous value of modulation signal.

$$m(t) = A_m \cos(2\pi f_m t) \quad \text{--- (1)}$$

\* Instantaneous values of carrier signal.

$$c(t) = A_c \cos(2\pi f_c t) \quad \text{--- (2)}$$

where  $A_m$  and  $A_c$  are the maximum Amplitudes of modulating signal and carrier signal.

The standard form of an Amplitude modulated (AM) wave is defined by

$$s(t) = A_c [1 + k_a m(t)] \cos 2\pi f_c t.$$

where  $k_a$  is a constant called the Amplitude sensitivity of the modulator.

Amplitude modulated waves for different amplitudes of  $k_a m(t)$  is

2

$k_a m(t) > 1$  over modulation

$k_a m(t) < 1$  under modulation

$k_a m(t) = 1$  Critical modulation.

Conditions for Amplitude Modulation:-

\* The factor  $k_a m(t)$  must be less than '1'.

\* The message bandwidth ( $\omega$ ) must be small compared to the carrier frequency  $f_c$ .

Percentage modulation (or) modulation factor ( $\mu$ ):-

Substituting value of  $m(t)$  from equation ① in equation ③.

$$\text{we get } s(t) = A_c [1 + k_a A_m \cos(2\pi f_m t)] \cos(2\pi f_c t) \quad \text{--- ④}$$

The equation ④ can be written as

$$s(t) = A_c [1 + \mu \cos(2\pi f_m t)] \cos(2\pi f_c t) \quad \text{--- ⑤}$$

$$\text{where, } \mu = k_a A_m \quad \text{--- ⑥}$$

The ' $\mu$ ' is a dimensionless constant. It is called as modulation factor or modulation index. When it is multiplied by 100, it is expressed as a % modulation.

$$\mu < 1$$

$$\mu > 1$$

$$\mu = 1$$

## Frequency domain Description:-

The modulated carrier has new signals at the different frequencies called side frequencies or side bands occur in the frequency spectrum directly above or below the carrier frequency.

That is, upper side band frequency

$$f_{USB} = f_c + f_m$$

$$f_{LSB} = f_c - f_m$$

The upper side band is called  $f_{USB}$  and lower side band is called  $f_{LSB}$ .

The existence of side band frequencies in the Amplitude modulated wave with mathematical expression.

$$\text{i.e.; } s(t) = A_c [1 + \mu \cos(2\pi f_m t)] \cos(2\pi f_c t)$$

$$s(t) = A_c \cos(2\pi f_c t) + \mu A_c \cos(2\pi f_m t) \cdot \cos(2\pi f_c t) \quad \text{--- (7)}$$

above equation can be expressed by means of the trigonometrical relation.

$$\text{i.e.; } s(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2} \cos 2\pi(f_c - f_m)t + \frac{\mu A_c}{2} \cos 2\pi(f_c + f_m)t \quad \text{--- (8)}$$

In the above equation 1<sup>st</sup> term represents unmodulated carrier and two side bands.

The frequency of the lower sideband (LSB) is  $f_c - f_m$  and the frequency of the upper sideband (USB) is  $f_c + f_m$ .

Bandwidth of AM wave:-

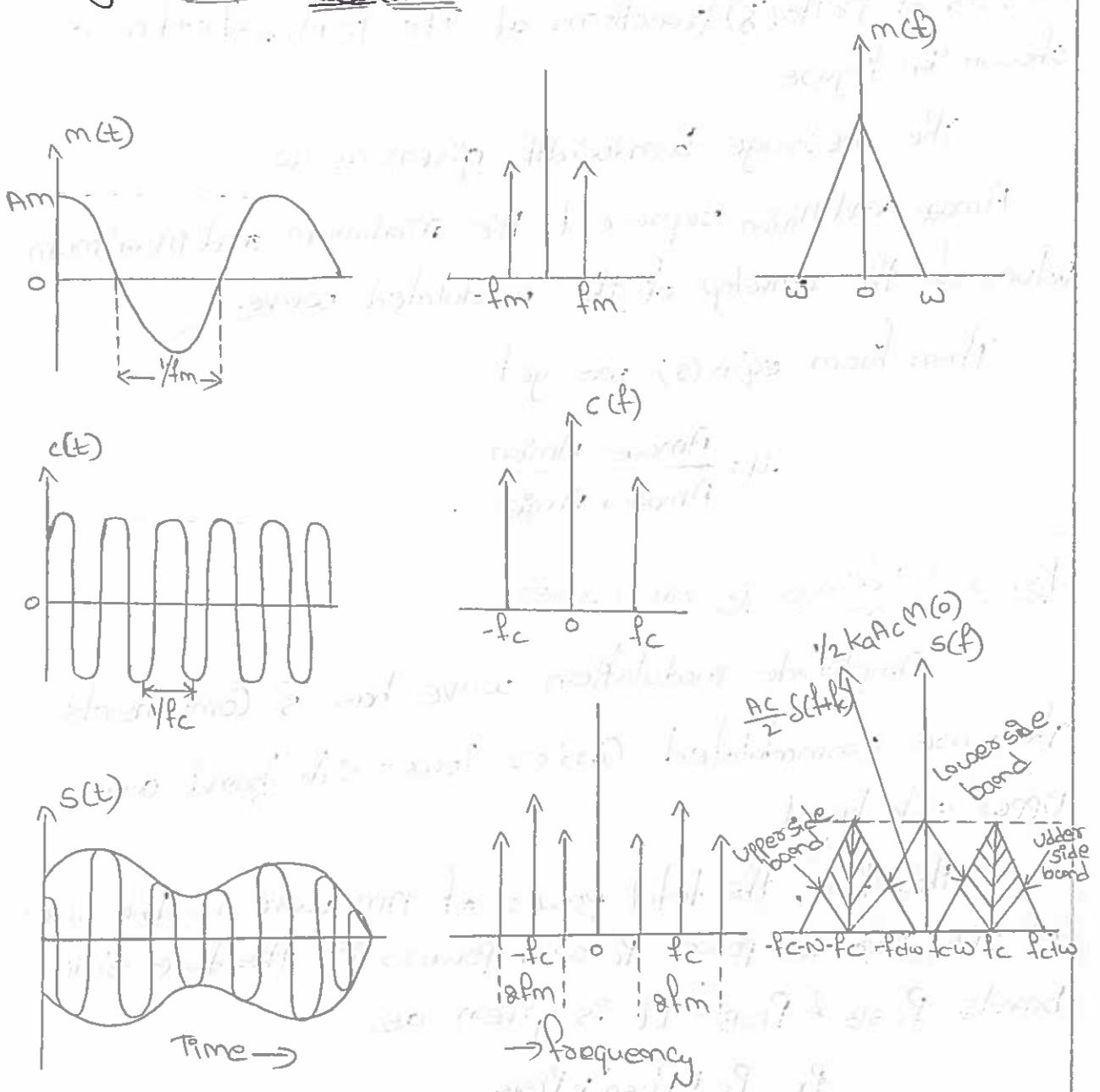
The bandwidth required for the Amplitude modulation is twice the frequency of the message signal or modulating signal.

$$\text{Band width} = f_{USB} - f_{LSB}$$

$$= f_c + f_m - f_c + f_m$$

$$\text{BW} = 2f_m = 2\omega$$

Single tone modulation:-



The time domain and frequency domain characteristics of modulated wave produced by single tone.

We know that,

$$s(t) = A_c \cos 2\pi f_c t + \frac{\mu A_c}{2} \cos 2\pi (f_c - f_m) t + \frac{\mu A_c}{2} \cos 2\pi (f_c + f_m) t$$

The Fourier transform of  $s(t)$  is given as,

$$S(f) = \frac{A_c}{2} [\delta(f - f_c) + \delta(f + f_c)] + \frac{\mu A_c}{4} [\delta(f - f_c + f_m) + \delta(f + f_c - f_m)] + \frac{\mu A_c}{4} [\delta(f - f_c - f_m) + \delta(f + f_c + f_m)]$$

The spectrum of AM wave for the sinusoidal modulation consists of Delta ( $\delta$ ) functions at  $\pm f_c$ ,  $f_c \pm f_m$ ,  $-f_c \pm f_m$  as shown in figure.

The message bandwidth given as 'w'.

$A_{max}$  and  $A_{min}$  represent the minimum and maximum values of the envelop of the modulated wave.

Then from eq'n (5) we get

$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

Power Relations in AM waves:-

Amplitude modulation wave has 3 components they are unmodulated carrier, lower side band and upper side band.

Therefore, the total power of AM wave is the sum of the carrier power  $P_c$  and powers in the two side bands  $P_{USB}$  &  $P_{LSB}$ . It is given as,

$$P_T = P_c + P_{USB} + P_{LSB}$$

The average carrier power,  $P_c = \frac{(\frac{A_c}{\sqrt{2}})^2}{R}$

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

where,  $R$  is the impedance of load.

Similarly average power for two side bands can be given as,

$$P_{USB} = P_{LSB}$$

$$P_{USB} = \left( \frac{\mu A_c}{2} \right)^2 \times \frac{1}{R}$$

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

The Average total power,

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

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

$$= \frac{A_c^2}{2R} \left[ 1 + \frac{\mu^2}{2} \right]$$

$$P_{total} = P_c \left[ 1 + \frac{\mu^2}{2} \right]$$

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

The above equation gives the total power of Amplitude modulated wave with the power unmodulated carrier. The maximum possible value of  $\mu$  (or)  $m$  in the Amplitude modulated wave is '1'.

Therefore from above equation the maximum total Power of Amplitude modulated wave is  $1.5 P_c$ .

$$\begin{aligned} \text{Upper side band power} &= \text{Lower side band power} = \frac{\mu^2 A_c^2}{8R} \\ &= \frac{A_c^2}{2R} \left( \frac{\mu^2}{4} \right) \end{aligned}$$

$$= P_c \left( \frac{\mu^2}{4} \right)$$

modulation index in terms of  $P_{total}$  and  $P_c$ .

$$\mu = \sqrt{2 \left( \frac{P_{total}}{P_c} - 1 \right)}$$

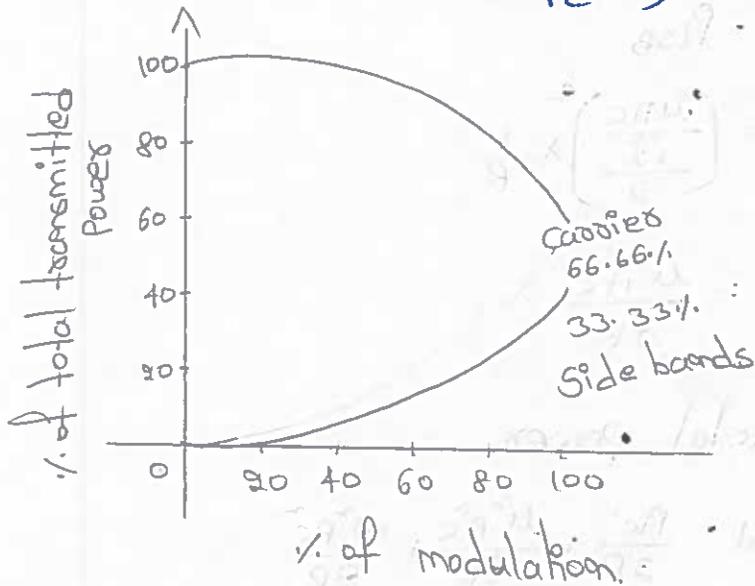


Fig: Variations of Carrier power and total side band power with percentage modulation.

Generation of AM waves:-

The device which is used to generate an Amplitude modulated (AM) wave is known as Amplitude Modulator.

The methods of AM Generation may be broadly classified as follow:

- i) Low-level AM modulation
- ii) High-level AM modulation.

Low Level Amplitude modulation:-

In a low-level amplitude modulation system, the modulation is done at low power level. At low power levels, a very small power is associated with the carrier signal and the modulating signal. Because of this, the output power

of modulation is low. Therefore, the power amplifiers are required to boost the amplitude-modulated signals upto desired output level. From block diagram in figure 3.4, it is clear that modulation is done at low power level. After this the amplitude-modulated signal (i.e. a signal containing a carrier and two sidebands) is applied to a wide band power amplifier. A wide-band power amplifier is used just to preserve the sidebands of the modulated signal. Amplitude modulated systems, employing modulation at low power levels are also called low-level amplitude modulation transmitters.

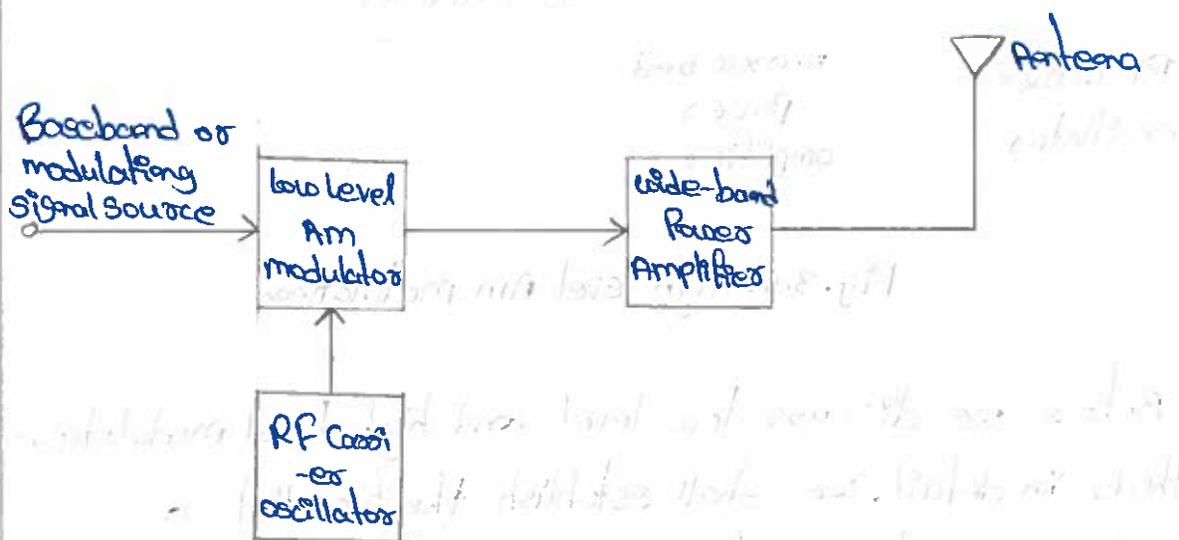


Fig. 3.4. Low level AM modulation

Square-law diode modulation and switching modulation are examples of low-level modulation.

### High level Amplitude modulation :-

In a high-level amplitude modulation system, the modulation is done at high power level. Therefore, to produce amplitude-modulation at these high power levels, the baseband signal and the carrier signal must be at high power levels. In block diagram of figure 3.5, the modulating signal carrier signal are first power amplified and then applied to AM high-level

Modulator. For modulating signal, the wide-band power amplifier is required just to preserve all the frequency components present in modulating signal. On the other hand, for carrier signal, the narrow-band power amplifier is required because it is a fixed-frequency signal. The collector modulation method is the example of high-level modulation.

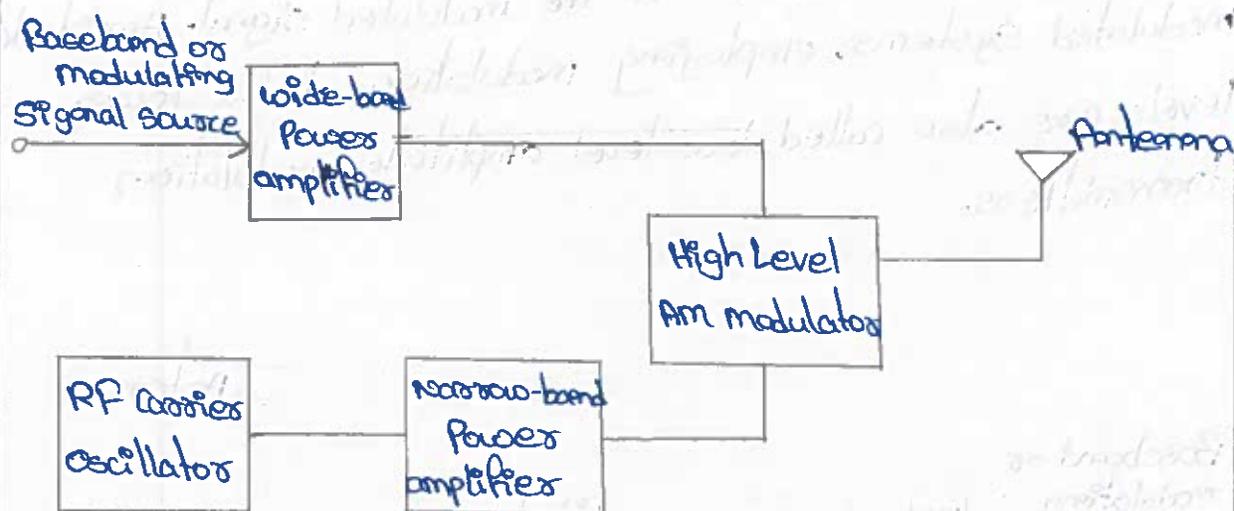


Fig. 3.5. High level AM modulation

Before we discuss low level and high level modulation methods in detail, we shall establish the fact that a non-linear resistance of a non-linear device can be made to produce Amplitude modulation when two different frequencies are passed together through it.

### Switching modulator:-

The carrier wave  $c(t)$  applied to the diode is large in amplitude. So it swings right across the characteristics curve of the diode. We assume that the diode acts as an ideal switch. That it is present zero impedance when it is forward biased corresponding to  $c(t) > 0$ , and infinite impedance when it is

reverse biased corresponding to  $c(t) < 0$ , accordingly  
for an input voltage  $v_1(t)$  given by

$$v_1(t) = m(t) + A_c \cos 2\pi f_c t.$$

$$e(t) = A_c \cos 2\pi f_c t.$$

diode is on and off action is controlled by  $e(t)$  in forward bias.

$$v_2(t) = \begin{cases} v_1(t) & \text{if } c(t) > 0 \\ 0 & \text{if } c(t) < 0 \end{cases}$$

$$v_2(t) = v_1(t) m(t)$$

$m(t)$  periodic pulse train with the period and  $t = 1/f$ ,  
the fourier series representation of this periodic  
pulse train is

$$m(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos 2\pi (2n-1) f_c t$$

$$v_1 = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \cos 2\pi f_c t$$

$$v_2 = \frac{1}{2} + \frac{2}{\pi} \sum_{n=2}^{\infty} \frac{-1}{2n-1} \cos 2\pi (2n-1) f_c t$$

$$v_2 = \frac{1}{2} + \frac{2}{\pi} \left[ -\frac{1}{3} \cos(6\pi) f_c t \right]$$

$$m(t) = \frac{1}{2} + \frac{2}{\pi} \cos 2\pi f_c t - \frac{2}{3\pi} \cos(6\pi) f_c t$$

substitute  $v_1(t)$  and  $e(t)$

$$\text{Then } v_2(t) = [e(t) + A_c \cos(2\pi) f_c t] \left[ \frac{1}{2} + \frac{2}{\pi} \left[ \cos 2\pi f_c t - \frac{2}{3\pi} \cos 6\pi f_c t \right] \right]$$

$$\frac{e(t)}{2} + \frac{A_c}{2} \cos 2\pi f_c t + \frac{2e(t)}{\pi} \cos 2\pi f_c t + \frac{2}{\pi} A_c \cos^2 2\pi f_c t$$

$$- \frac{2}{3\pi} e(t) \cos 6\pi f_c t - \frac{2}{3\pi} A_c \cos 2\pi f_c t \cos 6\pi f_c t$$

$$\text{Then } \frac{A_c}{2} \cos 2\pi f_c t + \left[ 1 + \frac{4}{\pi A_c} e(t) \right]$$

$$\therefore \frac{A_c}{2} \left[ 1 + \frac{4}{\pi A_c} a(t) \cos 2\pi f_c t \right]$$

Which is the desired AM wave with amplitude sensitivity ( $K_A$ )

$$K_A = \frac{4}{\pi A_c}$$

An unwanted component the spectrum of which contains 'g' functions at  $0, \pm 2f_c, \pm 4f_c$  and  $\dots$  and which occupies frequency intervals of width  $2\omega$  centered at  $0, \pm 3f_c, \pm 5f_c, \dots$  where ' $\omega$ ' is the message band width. Here, again the unwanted terms are removed from the load voltage  $v_2(t)$  by means of a bandpass filter with mid band frequency  $f_c$  and band width  $2\omega$  provided  $f_c > 2\omega$ .

### Detection of AM waves:-

Demodulator circuit receives a modulated signal and recovers the original modulating information. These circuits are also known as Detectors (or) Demodulators.

The mostly used amplitude demodulators are

- \* Envelope Detector
- \* Square Law Detector.

#### Envelope Detector:-

Envelope detector is used to detect (de-modulate) high level AM wave.



\* This envelope detector consists of a diode and Low Pass filter.

\* Here, the diode is the main detecting element.

\* Hence, the envelope detector is also called as the Diode detector.

\* The lowpass filter contains a parallel combination of the resistor and the capacitor.

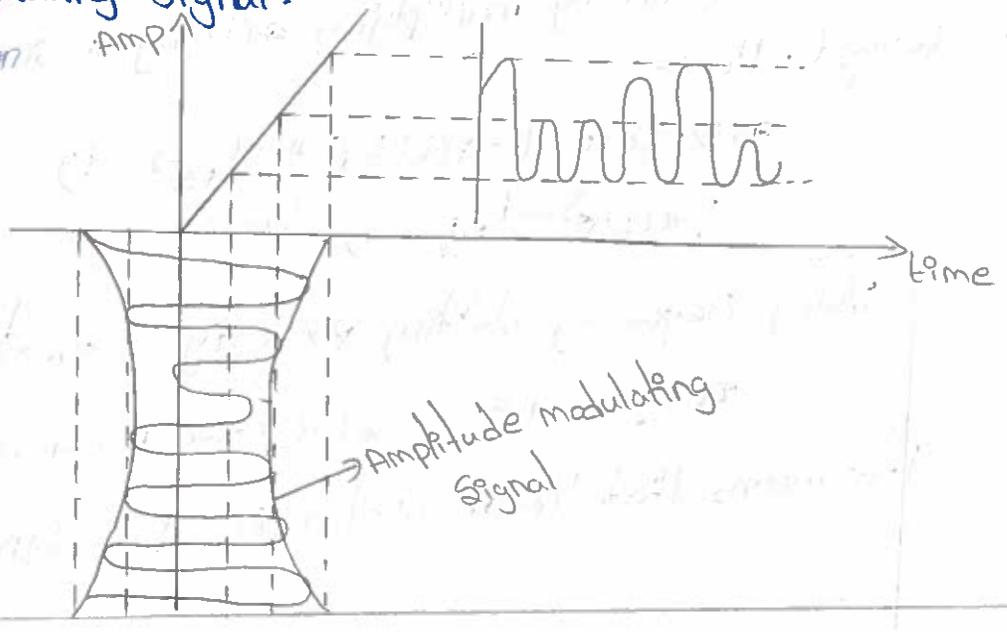
\* The AM wave  $s(t)$  is applied as an Input to this detector.

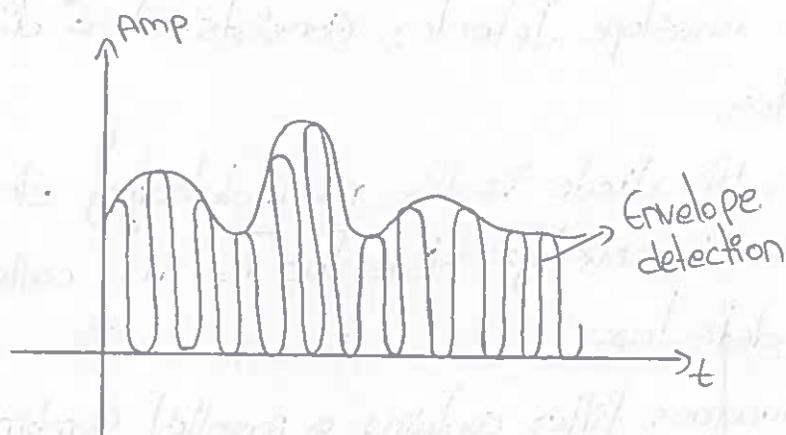
\* We know that, standard form of AM wave is

$$s(t) = A(1 + k_a m(t)) \cos \omega_c t$$

\* In the positive half cycle of AM wave the diode charges the peak value of AM wave is less than this value the diode will be reverse biased. Thus the capacitor will discharge through resistor R. Till the next half cycle of AM wave.

\* When the value of AM wave is Greater than the capacitor voltage. The diode conducts and the process will be repeated. It should select the component values in such a way that the capacitor charges very quickly and discharge very slowly. as a result we will get the capacitor wave form same as that of the envelope of AM wave. which is almost similar to the modulating signal.





### DSB-SC modulation (Double side band Suppressed carrier System):-

In DSB-SC modulation there is no carrier signal only side bands are present. we know that the frequency shifting property of Fourier transform is given as if

$$x(t) \cdot e^{j\omega_c t} = x(\omega - \omega_c)$$

$$e^{j\omega_c t} x(t) = x(\omega - \omega_c)$$

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

$$\text{Similarly } x(t) \cdot e^{-j\omega_c t} = x(\omega + \omega_c)$$

But, since  $e^{j\omega_c t}$  is not a real function and cannot be generated practically. Therefore frequency shifting in practice is achieved by multiplying  $x(t)$  by a sinusoid such as  $\cos \omega_c t$ . Hence,

$$\begin{aligned} x(t) \cos \omega_c t &= x(t) \cdot \frac{1}{2} (e^{j\omega_c t} + e^{-j\omega_c t}) \\ &= \frac{1}{2} x(t) e^{j\omega_c t} + \frac{1}{2} x(t) e^{-j\omega_c t} \end{aligned}$$

Using frequency shifting property in equation

$$x(t) \cos \omega_c t \longleftrightarrow \frac{1}{2} (x(\omega - \omega_c) + x(\omega + \omega_c))$$

This means that the multiplication of a signal  $x(t)$  by

by a sinusoid of frequency  $\omega_c$  shifts the spectrum

$$\frac{x(\omega)}{\pm \omega_c}$$

now, if  $x(t)$  is taken as modulating or base band signal and  $\cos \omega_c t$  is taken as carrier signal. Then  $x(t) \cos \omega_c t$  represents the modulated signal. Further the Fourier transform of this modulated signal is given equation.

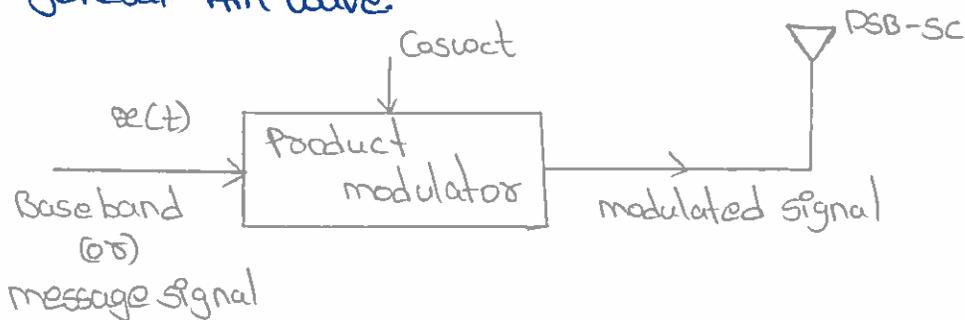
This equation shows that the spectrum of modulated signal contains only shifted spectrum of signal and there is no carrier components. But we know that the modulated signal which contains no carrier but 2 side bands is called DSB-SC modulation. This means that the term  $x(t) \cos \omega_c t$  represents a DSB-SC signal.

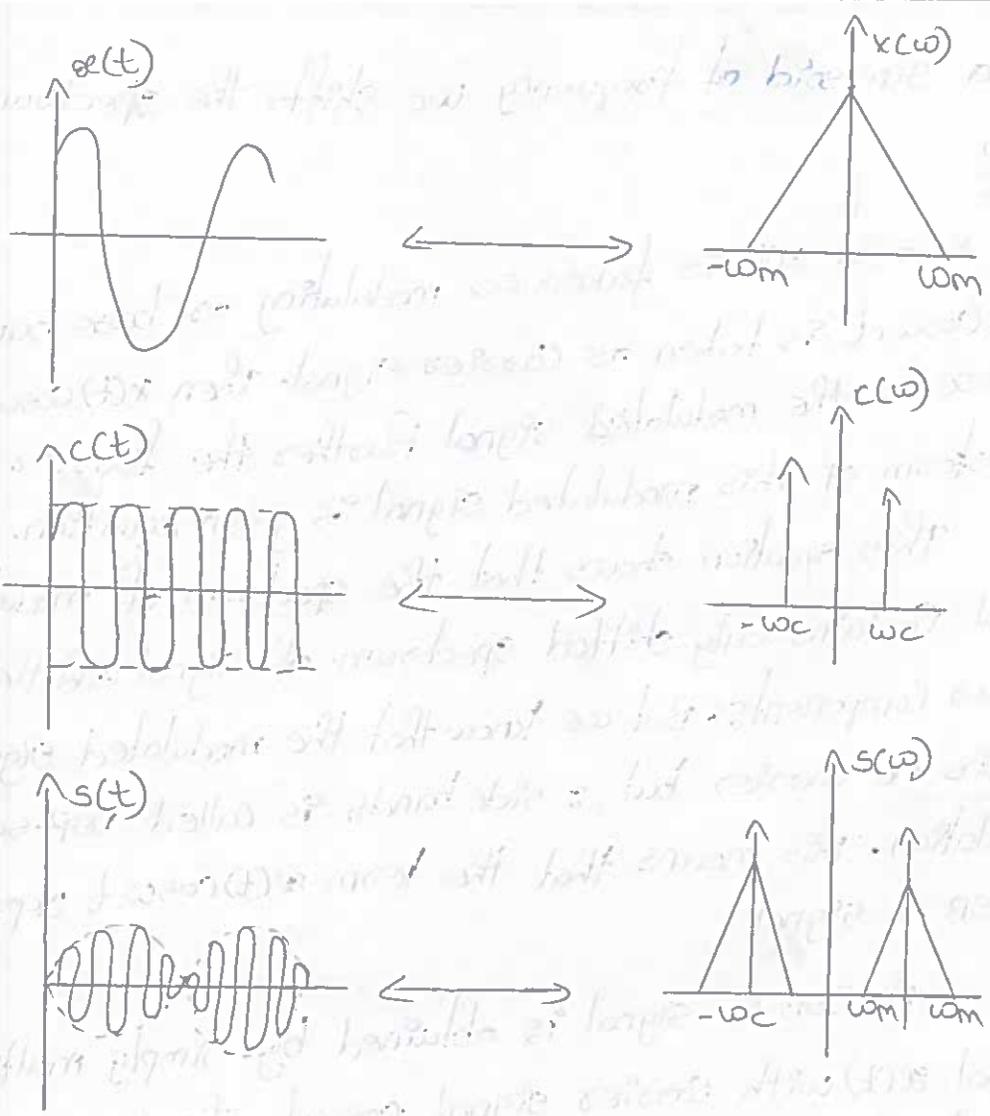
$\therefore$  A DSB-SC signal is obtained by simply multiplying signal  $x(t)$  with carrier signal  $\cos \omega_c t$ . The DSB-SC signal exhibits phase reverse at zero crossing from figure it is clear that the impulses that  $\pm \omega_c$  are missing which means that the carrier term is suppressed in the spectrum in the only two side bands term USB and LSB are left. Corresponding only positive side the USB frequency is  $(\omega_c + \omega_m)$  where, as LSB frequency is  $(\omega_c - \omega_m)$ .

The difference of these two signals is equal to the transmission bandwidth of DSB-SC signal.

$$\therefore \text{Band width} = (\omega_c - \omega_m) \text{ then } B_w = 2\omega_m.$$

The bw of DSB-SC modulation is same as that of general AM wave.





Time domain description:-

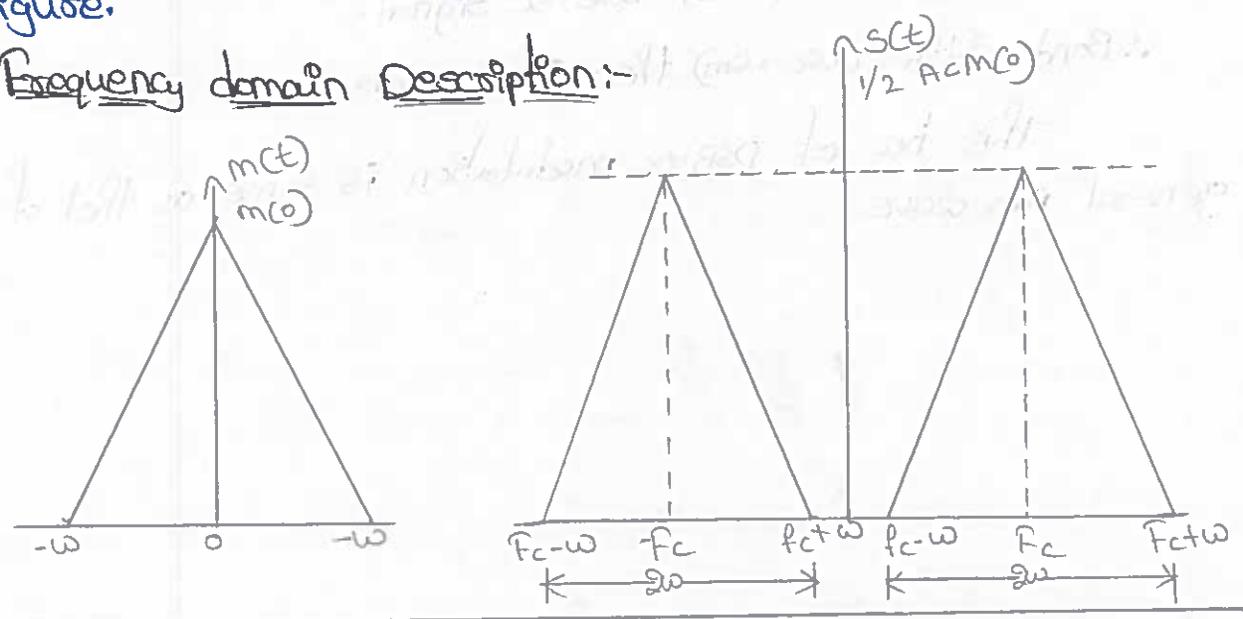
The equation for DSB-SC AM signal is given as

$$s(t) = c(t)m(t)$$

$$= A_c \cos(2\pi f_c t) m(t) \quad \text{--- (1)}$$

This modulated wave undergoes a phase reverse whenever the modulating signal crosses '0' as shown figure.

Frequency domain Description:-



A frequency domain display of DSB signal shown in Figure 1b'. Here dotted line indicated that the carrier is suppressed.

The suppression of the carrier from the modulated wave of equation (1) can be written as by using its Fourier transform.

$$S(f) = \frac{1}{2} A_c [m(f - f_c) + (f + f_c)]$$

### Generation of DSB-SC wave:-

By using Balanced modulator or product modulator we are generating the DSB-SC waves.

The expression for DSB-SC signal is given as

$$s(t) = e(t) \cos \omega_c t$$

where,  $e(t)$  = Baseband signal

$\cos \omega_c t$  = Carrier signal

From this expression a DSB-SC signal is basically the product of the modulating or baseband signal. A single electronic device cannot generate a DSB-SC signal. A circuit to achieve the generation of a DSB-SC signal is called a product modulator namely the balanced modulator (or) Product modulator.

### Balanced modulator:-

A non-linear resistance (or) non-linear device may be used to produce, Amplitude modulation. i.e; one carrier and two side bands. However a DSB-SC signal contains only two side bands. Does if two non-linear device such as diodes, transistors etc. are connected in a balanced mode. So as to suppress the carrier of each other. Then only side bands are left. That is a DSB-SC signal is

generated. A balanced modulator defined as a circuit in which, two non-linear devices are connected in a balanced mode to produce a DSB-SC signal.

The figure shows a balanced modulated circuit using two diodes a modulating signal  $m(t)$  is applied to the two diodes to a center-tape transformer with the carrier signal  $\cos \omega_c t$ .

A non-linear voltage current  $v-i$  is given as

$$I = av + bv^2.$$

Here  $v$  is the input voltage applied across non-linear device and  $I$  is the current to the non-linear device.

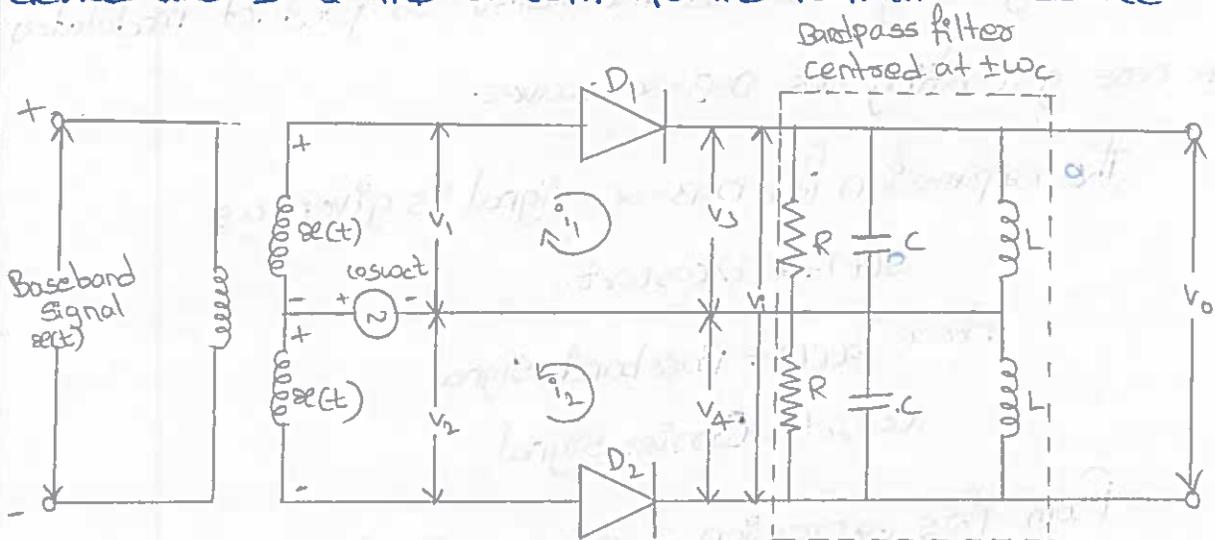


Fig. 3.19. Balanced modulator Using Diodes

From figure the two input voltages  $v_1$  and  $v_2$  across the two diodes

$$v_1 = \cos \omega_c t + m(t)$$

$$v_2 = \cos \omega_c t - m(t)$$

For Diode  $D_1$ , the non-linear  $v-i$  relation becomes

$$I_1 = av_1 + bv_1^2$$

$$I_2 = av_2 + bv_2^2$$

In the expression of current  $I_1$ , substituting the values of  $v_1$ , we get  $I_1 = a(\cos \omega_c t + m(t)) + b(\cos \omega_c t + m(t))^2$

$$\Rightarrow a(\cos \omega_c t + m(t)) + b(\cos^2 \omega_c t + m^2(t) + 2\cos \omega_c t m(t))$$

$$\Rightarrow A \cos \omega_c t + A \varphi(t) + b \cos^2 \omega_c t + b \varphi^2(t) + 2ab \cos \omega_c t + \varphi(t)$$

$$I_2 = aV_2 + bV_2^2$$

$$I_2 = a(\cos \omega_c t + \varphi(t) + b(\cos^2 \omega_c t + \varphi^2(t)))^2$$

$$= a(\cos \omega_c t + \varphi(t) + b(\cos^2 \omega_c t + \varphi^2(t)) - 2ab \cos \omega_c t \varphi(t))$$

$$I_2 = a \cos \omega_c t + A \varphi(t) + B \cos^2 \omega_c t + B \varphi^2(t) - 2ab \cos \omega_c t \varphi(t)$$

Due to currents  $I_1$  and  $I_2$  the net voltage  $v_I$  at the input of the bandpass filter is expressed as

$$v_I = v_3 - v_4$$

$$\text{In the above equation } v_3 = I_1 R$$

$$v_4 = I_2 R \text{ then}$$

$$v_I = R(I_1 - I_2)$$

The above equation substituting the values of  $I_1$  and  $I_2$

$$\begin{aligned} v_I &= R(A \cos \omega_c t + A \varphi(t) + b \cos^2 \omega_c t + B \varphi^2(t) + 2ab \cos \omega_c t + \varphi(t) \\ &\quad - (a \cos \omega_c t + A \varphi(t) + B \cos^2 \omega_c t + B \varphi^2(t) - 2ab \cos \omega_c t \varphi(t)) \\ &= R(\cancel{A \cos \omega_c t} + A \varphi(t) + \cancel{b \cos^2 \omega_c t} + \cancel{B \varphi^2(t)} + 2ab \cos \omega_c t + \varphi(t) - \cancel{a \cos \omega_c t} \\ &\quad + A \varphi(t) - \cancel{B \cos^2 \omega_c t} - \cancel{B \varphi^2(t)} + 2ab \cos \omega_c t \varphi(t)) \end{aligned}$$

$$\Rightarrow 2A \varphi(t) + 2ab \cos \omega_c t + \varphi(t)$$

This voltage  $v_I$  is the input to the band pass filter centered around  $\pm \omega_c$ . A bandpass filter is that type of filter which allows to pass a frequencies. Here, since the bandpass filter is centered around  $\pm \omega_c$  in it will pass a narrow band frequency centered at  $\pm \omega_c$  with a small band width of  $2\omega_m$  to preserve the side bands.

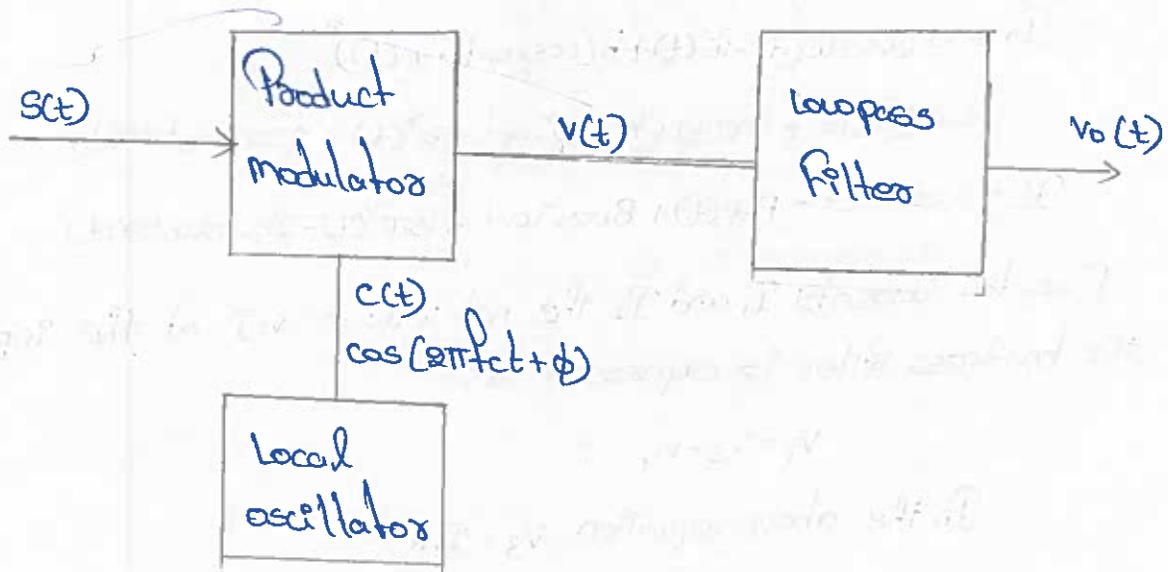
$\therefore$  The output at bandpass filter centered around  $\pm \omega_c$  is given by

$$v_o = 4bR(\varphi(t) \cos \omega_c t)$$

$$v_o = k(\varphi(t) \cos \omega_c t)$$

which is the expression for a DSBSC signal.

## Coherent Detection of DSB-SC modulated waves:-



The modulating signal  $m(t)$  is recovered from a DSB-SC wave  $s(t)$  by first multiplying  $s(t)$  with a locally generated carrier wave and then the lowpass filtering the product as shown in figure.

For faithful recovery of modulating signal  $m(t)$ , the local oscillator output should be exactly coherent or synchronized in both frequency and phase with the carrier wave  $c(t)$  used in the product modulator to generate  $s(t)$ . This method of demodulation is called coherent detection (or) Synchronous Detection.

The product modulator output is given as,

$$v(t) = s(t) \cos(2\pi f_c t + \phi)$$

$$v(t) = A_c \cos(2\pi f_c t) \cos(2\pi f_c t + \phi) m(t)$$

$$= \frac{A_c}{2} [\cos(2\pi f_c t + 2\pi f_c t + \phi) + \cos(2\pi f_c t - 2\pi f_c t - \phi)] m(t)$$

$$= \frac{A_c}{2} [\cos(4\pi f_c t + \phi) + \cos \phi] m(t)$$

$$= \frac{A_c}{2} \cos(4\pi f_c t + \phi) m(t) + \frac{A_c}{2} \cos \phi m(t)$$

unwanted terms

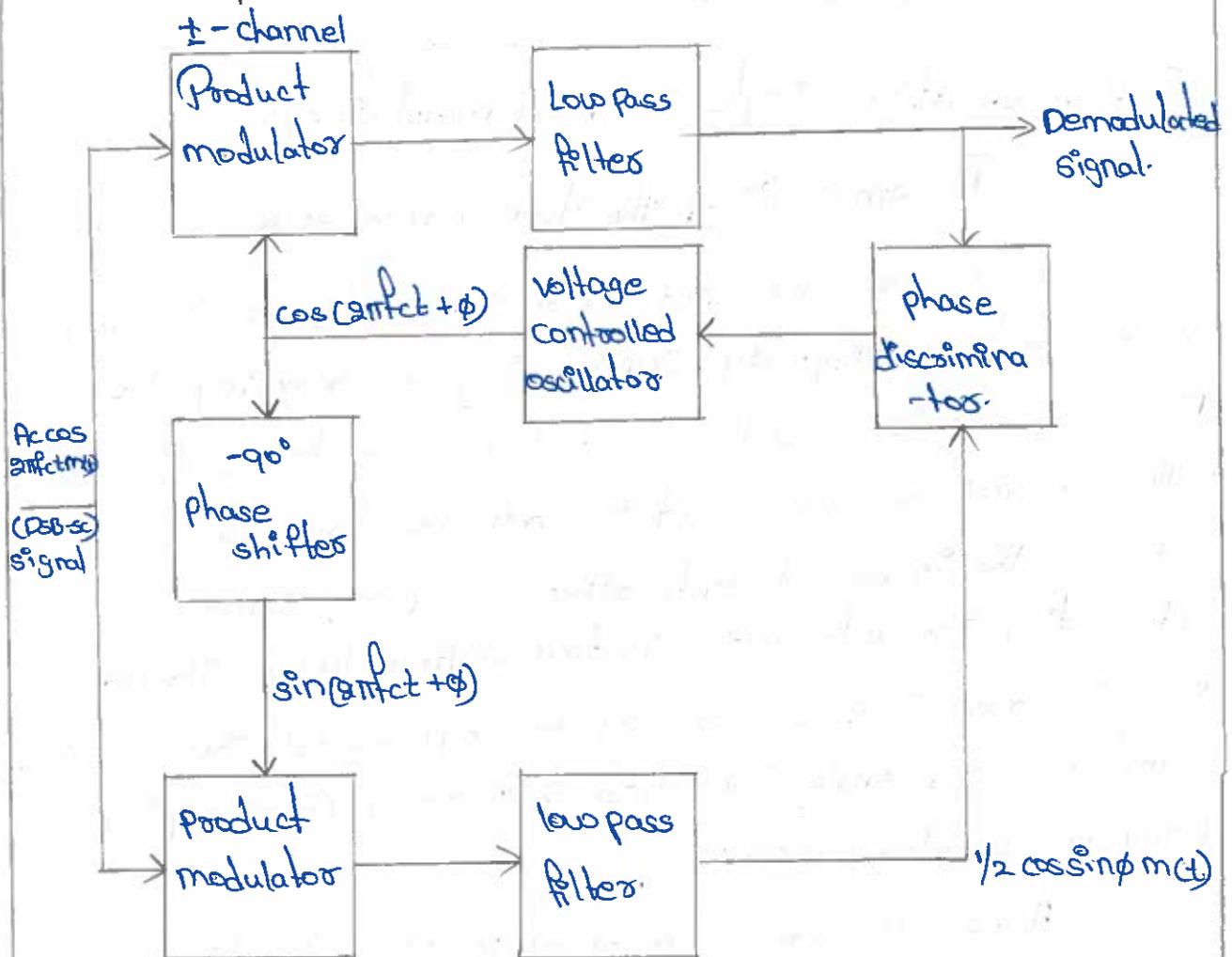
scaled version message.

Unwanted term is removed with the help of lowpass filter. The overall output  $v_o(t)$  is given as

$$v_o(t) = \frac{1}{2} A_c \cos \phi m(t)$$

When phase error  $\phi$  is constant, the demodulated signal  $v_o(t) \propto m(t)$ . It is maximum when  $\phi = 0$  and minimum (0), when  $\phi = \pm \pi/2$ .

### Costas Loop:-



The Costas loop is a method of obtaining a practical synchronous receiving system. In this type receiver consists of two coherent product modulators supplied with the same input signal (DSB-SC modulated wave).

The local oscillator signal supplied to the product modulators are  $90^\circ$  out of phase. The frequency of the local oscillator is adjusted to be the same as the carrier frequency  $f_c$ .

The product modulator in the upper path is called as inphase coherent detector or  $\Phi$ -channel. where as the product modulator in the lower path is called as quadrature phase detector or  $\Psi$ -channel. The outputs of this 2 channels are given to the phase discriminator.

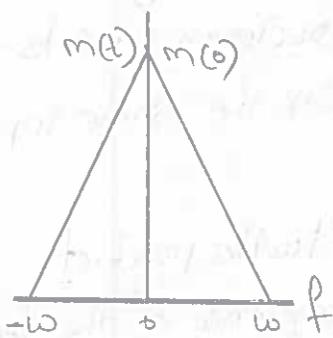
The phase discriminator consists of a multiplier followed by a loop filter produces a DC control signal. Proportional to the phase error  $\theta$ . This DC control signal is used to correct the phase error in the local oscillator.

### SSB modulation (Single side band modulation):-

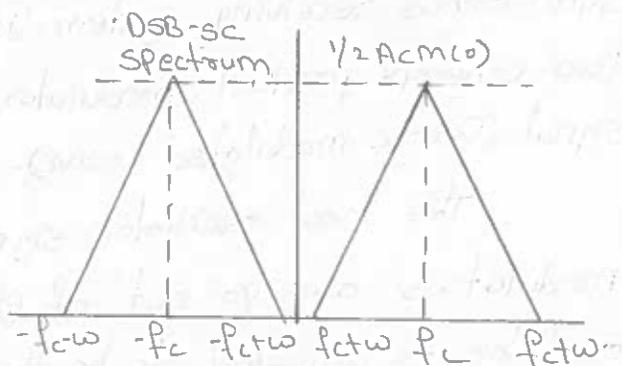
In AM  $(2/3)^{rd}$  of the transmitted power is wasted and Carrier wave does not carry information is carried by 2 side bands only. By suppressing (or) removing the modulated carrier and the 2 side bands are transmitted is called as DSB-SC signals. but the both side bands i.e, LSB or USB are the images of each other and carry same information. The information is transmitted twice. Therefore one side band (LSB or USB) may be suppressed the resulting signal is called single side band suppressed carrier (LSB or USB) are resulting signal.

Hence, in SSB-SC a lot of power and half of the band width can be save compared to AM and DSB-SC.

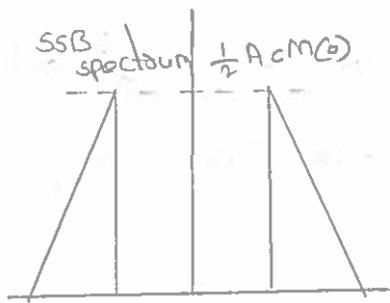
message spectrum



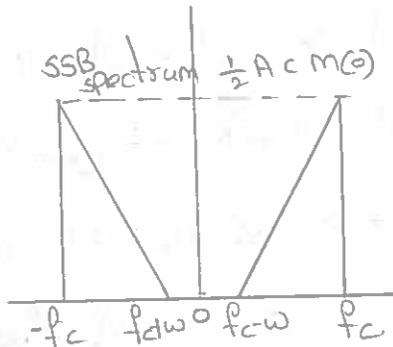
a) spectrum of message signal



b) spectrum of DSB-SC modulator



c) spectrum of sbs modulated.

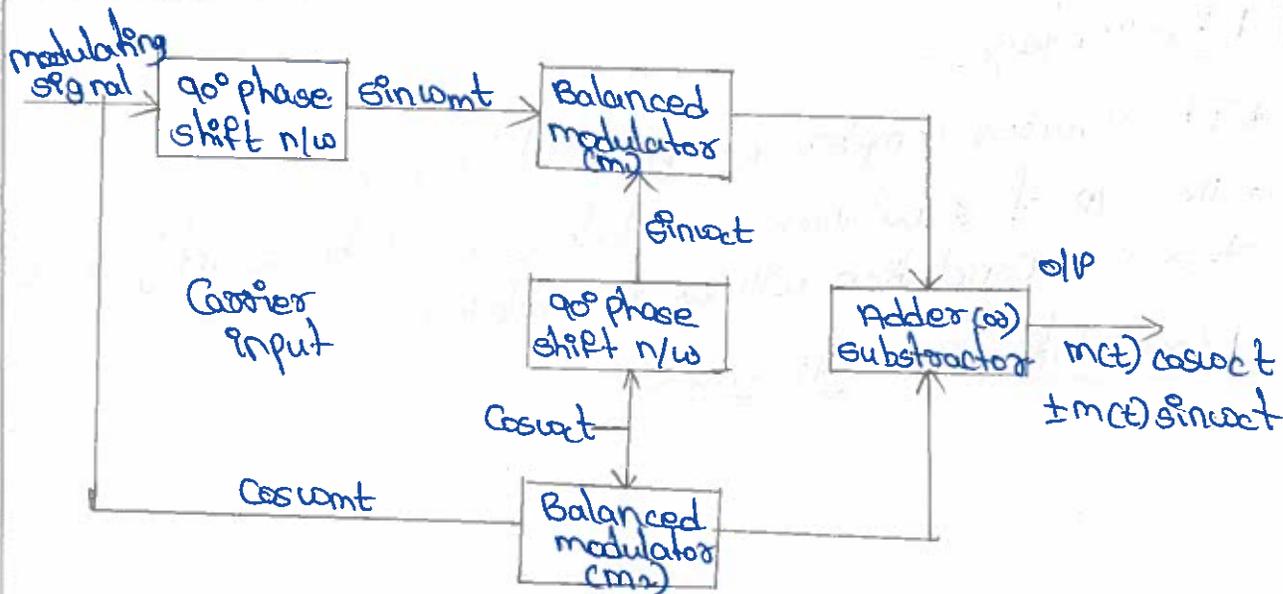


d) spectrum of sbs modulated wave with the lower side band transmitted.

Generation of sbs waves:-

1. Phaseshift method
2. Frequency Discrimination method.

i) Phaseshift Discrimination:-



The phase shift method of sbs Generation uses a Phaseshift technique that causes one of the side bands to be canceled out. It consists of 2 balanced modulators instead of one and 2 phase shifting n/w's. Here, the sinusoidal modulating signal comes out the input of the modulator  $m_1$  as  $\sin \omega t$  and to the modulator  $m_2$  as  $\cos \omega t$ . The carrier signal to the modulator  $m_1$  is  $\sin \omega t$  and to the modulator  $m_2$  is  $\cos \omega t$ .

The o/p's of balanced modulators are

$$\cos \omega_c t \cdot \cos \omega_m t = \frac{1}{2} [\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t] \quad \text{--- (1)}$$

$$\sin \omega_c t \cdot \sin \omega_m t = \frac{1}{2} [\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t] \quad \text{--- (2)}$$

Addition of (1) & (2) gives

$\cos(\omega_c - \omega_m)t$  that is LSB

Subtraction of (1) & (2) gives

$\cos(\omega_c + \omega_m)t$  that is USB

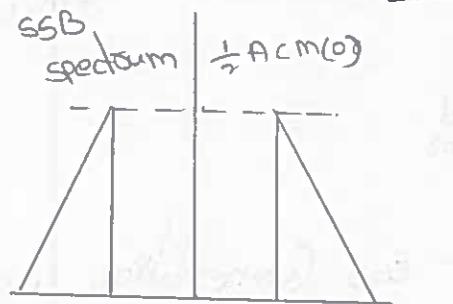
### Advantages:-

- \* Bulky filters are replaced by small filters.
- \* Low audio frequencies may be used for modulation.
- \* It can generate USB and any frequency
- \* Easy switching from one side band to other side band.

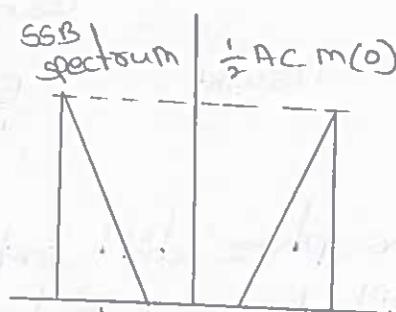
### Disadvantages:-

- \* It requires complex AF phase shift n/w.
- \* The op of 2 balanced modulators must be exactly same otherwise cancellation will be incomplete.

### Demodulation of SSB waves:-



spectrum of SSB modulated wave with the upper side band transmitted.



spectrum of SSB modulated wave with the lower side band transmitted.

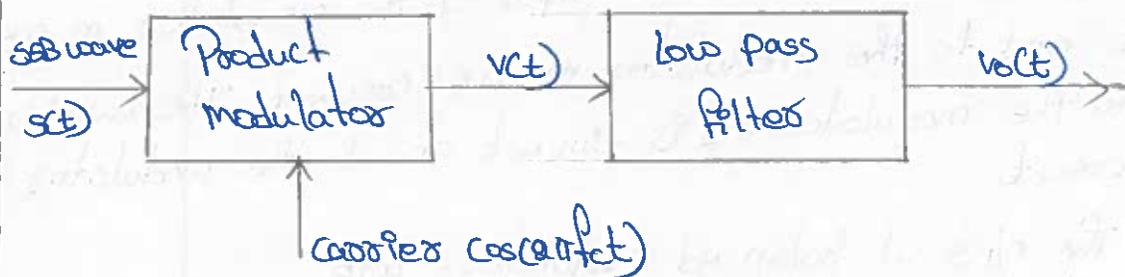


Fig: Demodulation of SSB-wave - coherent detection

This method following procedure.

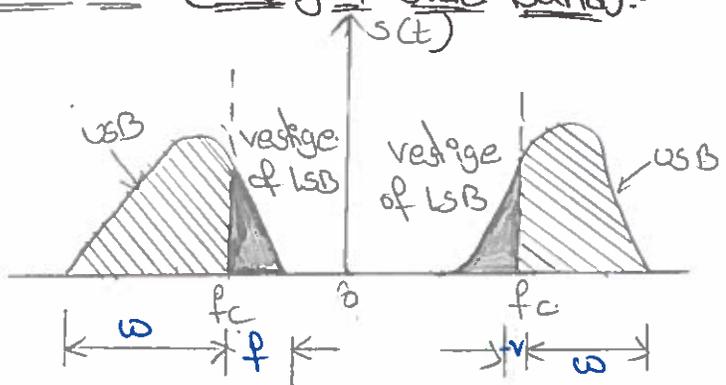
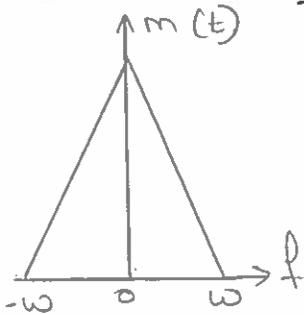
- \* It is having either  $S(t)$  or  $s(t)$
- \* Apply it to a product modulator.
- \* Apply the locally generated carrier wave  $\cos(2\pi f_c t)$  as a 2<sup>nd</sup> input to the product modulator.
- \* Apply the output of modulator to a low pass filter. The output of low pass filter is the recovered signal  $m(t)$ .

Expression for the o/p of Product modulator:-

$$\begin{aligned}
 V(t) &= S(t) \cdot \cos(2\pi f_c t) \\
 &= \cos(2\pi f_c t) (m(t) \cos \omega_c t \pm \hat{m}(t) \sin \omega_c t) \\
 &= \cos(2\pi f_c t) (m(t) \cos 2\pi f_c t \pm \hat{m}(t) \sin 2\pi f_c t) \\
 &= m(t) \cdot \cos^2 2\pi f_c t \pm \hat{m}(t) \cos 2\pi f_c t \sin 2\pi f_c t \\
 &= m(t) \cdot \frac{1 + \cos 4\pi f_c t}{2} \pm \hat{m}(t) \frac{1}{2} [\sin 4\pi f_c t] \\
 &= \frac{m(t)}{2} + \frac{\cos 4\pi f_c t}{2} m(t) \pm \frac{\hat{m}(t) \sin 4\pi f_c t}{2}
 \end{aligned}$$

$$V(t) = \underbrace{\frac{m(t)}{2}}_{\text{wanted term}} + \underbrace{\frac{1}{2} [m(t) \cos 4\pi f_c t \pm \hat{m}(t) \sin 4\pi f_c t]}_{\text{unwanted terms}}$$

Principle of VSB modulation:- (Vestigial side Band):-



spectrum of vsb modulated wave.

In this technique one side band is passed almost completely whereas just a trace or vestige of other side band is retained. This is the compromise b/w SSB modulation and DSB modulation. The Television signals contain significant components of extremely low freq. and hence VSB modulation is used in television transmission.