... plate

* Amplitude modulation

Defination → The process by which the amplitude of the carrier signal is changed in accordance with the instantaneous value of the modulating signal is called as amplitud modulation.

- (phase & freq. of the carrier remains constant.)

Let the carrier voltage & modulating voltage v_m and v_c.
& it is represented by,

$$v_m = V_m \sin \omega_m t$$

& carrier signal

$$v_c = V_c \sin \omega_c t$$

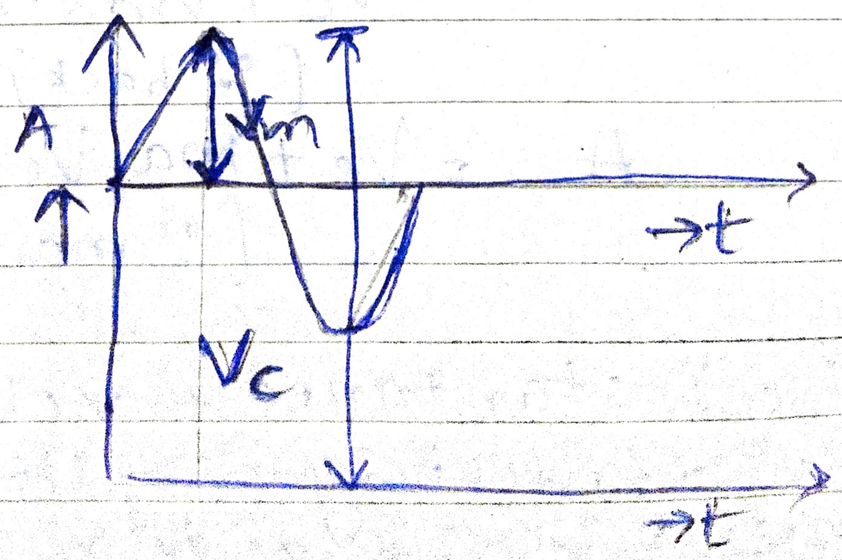
wher

v_m & v_c is the instantaneous value of ~~of~~ the modulating signal & carrier.

and

V_m & V_c is the max. value of modulating signal & carrier respectively.

ω = angular velocity.



V_m & V_c is the amplitude of the modulatigng signal & carrier signal.

The modulation index is defined as the ratio of the max. amplitude of the modulating signal to the max. amplitude of carrier signal.

* Modulation index (m_a)

$$\boxed{m_a = \frac{V_m}{V_c}}$$

The amplitude of modulated voltage, $A = V_c + V_m$

$$= V_c + V_m \sin \omega_m t$$
[$\because$ back]

Derive

$$A = V_c + m_a \cdot V_c \sin \omega_m t$$
[$\because m_a = \frac{V_m}{V_c} \rightarrow V_m = \ldots$]

The instantaneous voltage of the resulting amplitude modulatinged wave is,

$$V = A \cdot \sin \omega_c t$$

$$V = (V_c + m_a V_c \sin \omega_m t) \cdot \sin \omega_c t$$
[∵ value of A]

$$V = V_c \sin \omega_c t + m_a \cdot V_c \sin \omega_c t \cdot \sin \omega_m t$$
[∵ bracket open]

$$\sin x \cdot \sin y = \frac{1}{2}\left[\cos(x-y) - \cos(x+y)\right]$$

$$= V_c \sin \omega_c t + \frac{m_a \cdot V_c}{2}\left[\cos(\omega_c t - \omega_m t) - \cos(\omega_c t + \omega_m t)\right]$$

$$V = \underbrace{V_c \sin \omega_c t}_{\text{carrier signal}} + \underbrace{\frac{m_a \cdot V_c}{2} \cos(\omega_c - \omega_m)t}_{\text{Lower side band freq}} - \underbrace{\frac{m_a \cdot V_c}{2} \cdot \cos(\omega_c + \omega_m)t}_{\text{upper side band freq}}$$

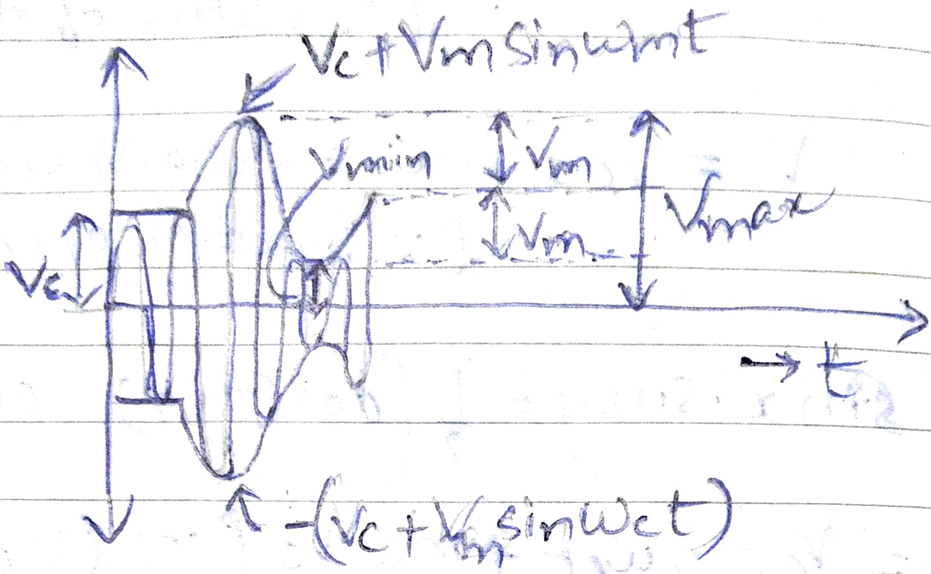
[This is the final value of amplitude modulated signal].

* Amplitude Modulated signal (AM)

Amplitude modulated signal consist of three freq. ie. unmodulated carrier, lower side band freq & upper side band freq. ie represented in above equation.

☆ Representation of AM wave.

Time domain



AM wave consist of three diff. freq. Centre freq. ie carrier & it has highest amplitude then other two freq. [F_{USB}, F_{LSB}]. Symmetrically above it having amplitude which are equal to each other but it can never exceed of the carrier amplitude.

Top envelope of AM wave is given by the relation,

$$A = V_c + V_m \sin \omega_m t$$

The max. -ve amplitude for bottom ~~amp~~ envelope is given by,

$$A = -(V_c + V_m \sin \omega_c t)$$

From fig. ~~you~~ we can write, ~~twice~~

$$2V_m = V_{max} - V_{min}$$

$$V_m = \frac{V_{max} - V_{min}}{2} \rightarrow (1)$$

$$V_c = V_{max} - V_m$$

put the value of V_m.

$$\therefore V_c = V_{max} - \left[\frac{V_{max} - V_{min}}{2}\right]$$

$$\therefore V_c = \frac{2V_{max} - V_{max} + V_{min}}{2}$$

$$\therefore V_c = \frac{V_{max} + V_{min}}{2} \rightarrow (2)$$

But, $m_a = \frac{V_m}{V_c}$

$$\therefore m_a = \frac{\frac{V_{max} - V_{min}}{\cancel{2}}}{\frac{V_{max} + V_{min}}{\cancel{2}}}$$

[$\because$ value of V_c & V_m]

$$\therefore m_a = \boxed{\frac{V_{max} - V_{min}}{V_{max} + V_{min}}} \rightarrow (3)$$

eqn (3) is the standard method to calculate modulation index (m_a).

Modulation index. (ma)

The modulaⁿ index is defined as the max. amplitude of modulating signal to the max. amplitude of the carrier signal.

$$\therefore \boxed{ma = \frac{Vm}{Vc}}$$

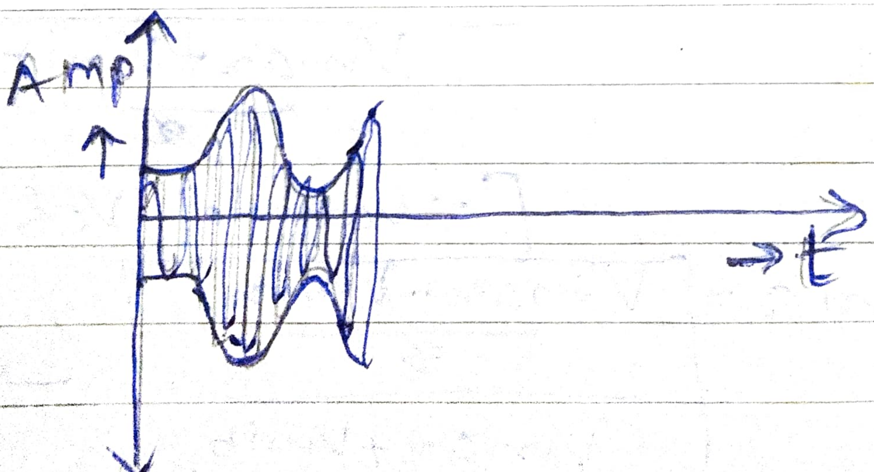
Effect of modulation index.

(1) $ma < 1$ $\left\{ \because ma = \frac{Vm}{Vc} \right\}$

$\therefore Vm < Vc$

[This type of modulaⁿ is known as under modulation].

Under modulation.

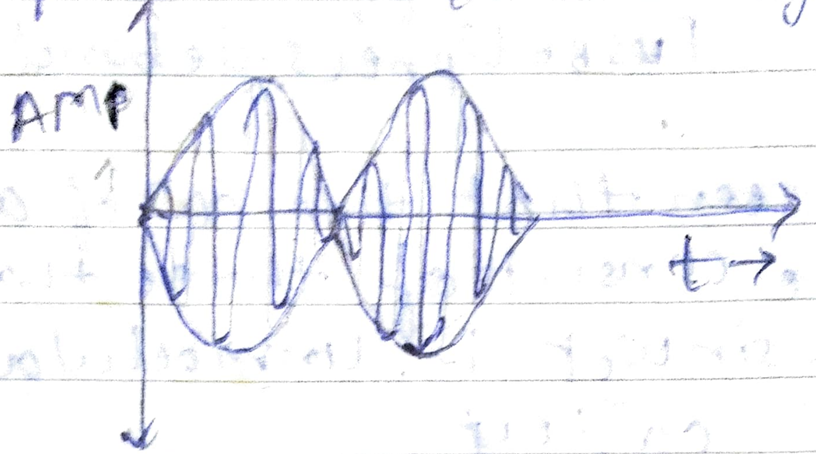


If the modulaⁿ index of Am signal is less then unity ~~is~~ this type of modulaⁿ is known as Under modulaⁿ.

(2) $m_a = 1$

$\therefore V_m = V_c$ [fully modulated or 100% modulated].

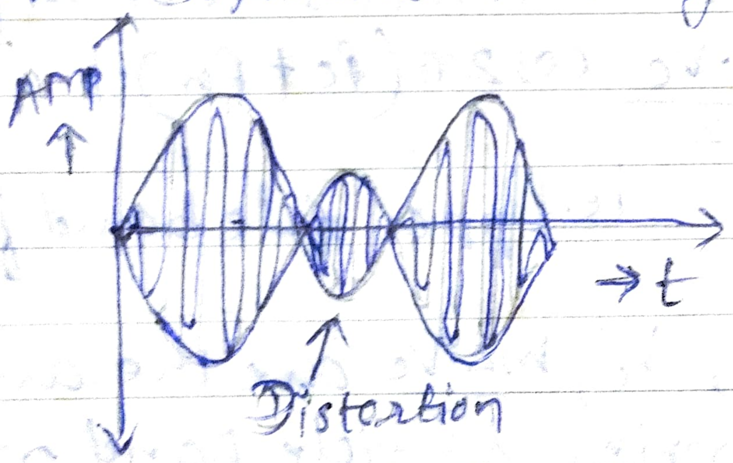
If ...... is equal to unity then ..



(3) $m_a > 1$

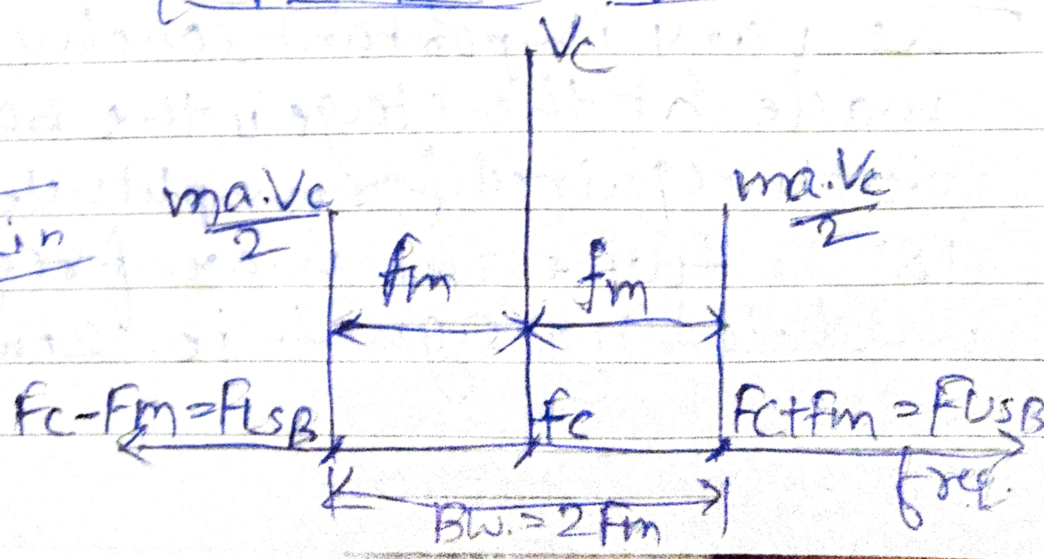
$V_m > V_c$ [Over modulation]

If ..... is greater than unity then ....



☆ Freq. Spectrum of AM. Wave.

freq. domain



where B.W. = Bandwidth
F_c = carrier freq.
F_m = max. modulating freq.
F_{LSB} = ~~Left~~ lower side band freq.
F_{USB} = Upper side band freq.

It is seen that the eqⁿ. of an AM wave consist of three terms,

(1) $V_c \sin \omega_c t$ i.e. unmodulated carrier.

(2) $\frac{m_a . V_c}{2} \cos 2\pi (f_c - f_m).t$

i.e. lower side band freq.

(3) $\frac{m_a . V_c}{2} \cos 2\pi (f_c + f_m).t$

i.e. Upper side band freq.

where, V_c, $\frac{m_a V_c}{2}$ are the amplitude of carrier & side band respectively as shown in the freq. spectrum.
The very important conclusion we made at the stage is the band width required for amplitude modulation is twice the max. freq. of modulating signal. i.e. $2f_m$.

* Power relation in AM wave.

The modulated wave contain extra energy in the two side band component. Therefore the modulated wave contain more power than the carrier ~~at~~ before the modulation takes place.

Since the amplitude of side band depends on the modulation index.

→ The total power in the modulated wave will be,

$$P_t = P_{carrier} + P_{LSB} + P_{USB}.$$

$$= \frac{V^2_{carrier}}{R} + \frac{V^2_{LSB}}{R} + \frac{V^2_{USB}}{R} \text{ (rms)}$$

where, all three voltages is rms value. & R is the antenna resistance in which the power is decipated:

Unmodulated carrier power is given by,

$$P_c = \frac{V^2_{carrier}}{R} = \frac{(V_c/\sqrt{2})^2}{R} = \frac{V_c^2}{2R}$$

similarly, $P_{LSB} = \frac{V^2_{LSB}}{R} = \frac{\left(\frac{m_a \cdot V_c}{2} / \sqrt{2}\right)^2}{R} = \frac{m_a^2 \cdot V_c^2}{8R}$

||ly, $P_{USB} = \frac{V^2_{USB}}{R} = \frac{m_a^2 \cdot V_c^2}{8R}$ (same)

$$P_t = P_{carrier} + P_{LSB} + P_{USB}$$

$$= \frac{V_c^2}{2R} + \frac{m_a^2 \cdot V_c^2}{8R} + \frac{m_a^2 \cdot V_c^2}{8R}$$

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

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

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

$$\boxed{P_t = P_c\left(1 + \frac{m_a^2}{2}\right)} \quad \left[\because P_c = \frac{V_c^2}{2R}\right.$$

★ Problems

(1) If the eq^n of AM wave is given by, $e_{AM} = 180(1 + 0.8 \sin 2\pi \times 10^3 t) \times \sin 2\pi \times 10^6 t$.

complete the AM freq. spectrum & calculate Band width.

→ Given eq^n is, compair with,

& $e_A = V_c(1 + m_a \cdot \sin \omega_m t) \cdot \sin \omega_c t$

$V_c = 180V$, $\omega_m = 2\pi \times 10^3$

$m_a = 0.8$, $\omega_c = 2\pi \times 10^6$

$$\omega = 2\pi f$$

$$\therefore \omega_m = 2\pi f_m$$

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

$$\therefore f_m = \frac{\cancel{2\pi}\times 10^3}{\cancel{2\pi}} = 1000 = 1\,KHz.$$

$$\& \; f_c = \frac{\omega_c}{2\pi}$$

$$= \frac{\cancel{2\pi}\times 10^6}{\cancel{2\pi}} = 1000000 = 1\,MHz.$$

$$F_{LSB} = F_c - F_m$$

$$= 10^6 - 10^3$$

$$= 9,99,000$$

$$= 999\,KHz$$

$$F_{USB} = F_c + F_m$$

$$= 1001\,KHz$$

$$\frac{m_a \cdot V_c}{2}$$

$$= 72\,\cancel{KHz}\,V.$$

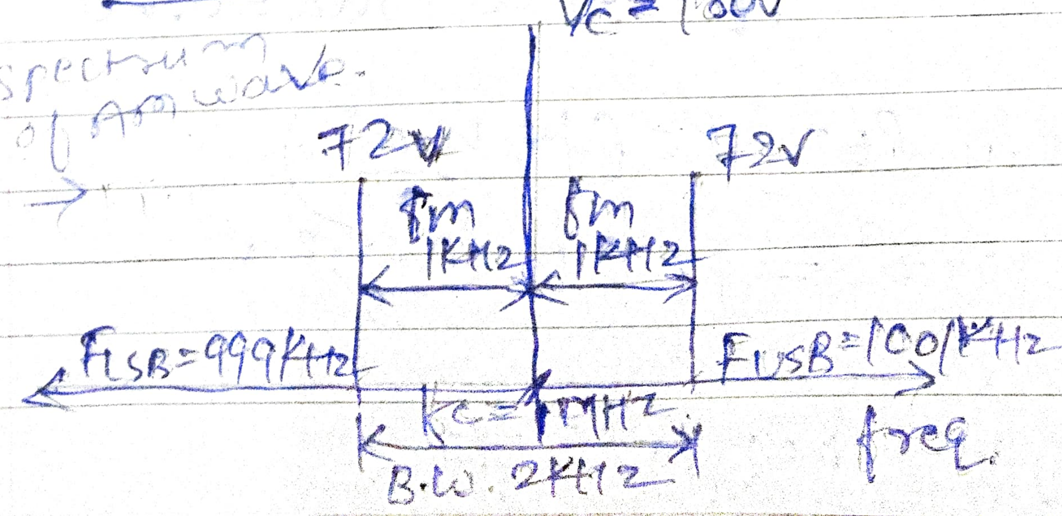
$$B.W. = 2 f_m$$

$$= 2 \times 1\,KHz$$

$$\boxed{B.W. = 2\,KHz}$$

$V_c = 180V$

Freq. spectrum of AM wave.



Example 2.6 :

A 600 watt carrier is modulated to depth 75%. Calculate total power in AM wave.

Solution :

Given :

$$P_c = 600 \text{ watt}$$
$$m = 0.75$$

Total power,

$$P_t = \left(1 + \frac{m^2}{2}\right) P_c$$
$$= \left(1 + \frac{(0.75)^2}{2}\right) \times 600$$
$$\boxed{P_t = 768.75 \text{ Watt}}$$

Example 2.7 :

A 500 watt carrier is modulated to depth of 80%. Calculate -

(i) Total power in AM wave.

(ii) Power in sidebands.

Solution :

Given :

$$P_c = 500 \text{ watt}$$
$$m = 0.8$$

(i) Total Power :

$$P_t = \left(1 + \frac{m^2}{2}\right) P_c$$
$$= \left(1 + \frac{(0.8)^2}{2}\right) \times 500$$
$$\boxed{P_t = 660 \text{ Watt}}$$

(ii) Power in sidebands :

$$P_{USB} = P_{LSB} = \frac{m^2}{4} \times P_c$$
$$= \frac{(0.8)^2}{4} \times 500$$
$$= 80 \text{ Watt}$$
$$\boxed{P_{USB} = P_{LSB} = 80 \text{ Watt}}$$

A modulating signal 20 sin ($2\pi \times 10^3 t$) is used to modulate a carrier signal 40 sin ($2\pi \times 10^4 t$). Find

(a) Modulation index

(b) Percentage modulation

(c) Sideband frequencies and their amplitude

(d) Bandwidth of AM wave

(e) Draw the frequency spectrum.

Solution :

Given : Modulating signal,

$$e_m = 20 \sin (2\pi \times 10^3 t) \quad \ldots (1$$

$$e_m = E_m \sin (2\pi f_m t) \quad \ldots (2$$

$\therefore$ Compare equation (1) and (2), we get

$$E_m = 20 \text{ V}$$

$$f_m = 10^3 \text{ Hz} = 1 \text{ kHz}$$

Similarly, carrier signal

$$e_c = 40 \sin (2\pi \times 10^4 t) \quad \ldots (3$$

$$e_c = E_c \sin (2\pi f_c t) \quad \ldots (4$$

Compare equation (3) and (4), we get,

$$E_c = 40 \text{ v}$$

$$f_c = 10^4 \text{Hz} = 10 \text{ kHz}$$

(a) Modulation Index :

$$m = \frac{E_m}{E_c} = \frac{20}{40} = 0.5$$

$$\boxed{m = 0.5}$$

$$\frac{18}{16} = 1 + \frac{m^2}{2}$$

$$\therefore \quad m^2 = 25$$

$$\therefore \quad m = 0.50$$

(b) Percentage modulation :

$$\% \text{ modulation} = m \times 100$$

$$= 0.5 \times 100$$

$$= 50\%$$

(c) Sideband frequencies and their amplitude :

$$\text{LSB} = F_{LSB} = f_c - f_m$$

$$= 10 \text{ kHz} - 1 \text{ kHz}$$

$$= 9 \text{ kHz}$$

$$\text{USB} = F_{USB} = f_c + f_m$$

$$= 10 \text{ k} + 1 \text{ kHz}$$

$$= 11 \text{ kHz}$$

$$\text{LSB amplitude} = \text{USB amplitude}$$
$$= \frac{mE_c}{2} = 0.5 \times \frac{40}{2}$$
$$= 10 \text{ V}$$

(d) Bandwidth of AM

$$BW = 2 \times f_m$$
$$= 2 \times 1 \text{ kHz}$$
$$\boxed{BW = 2 \text{ kHz}}$$

(e) Frequency spectrum

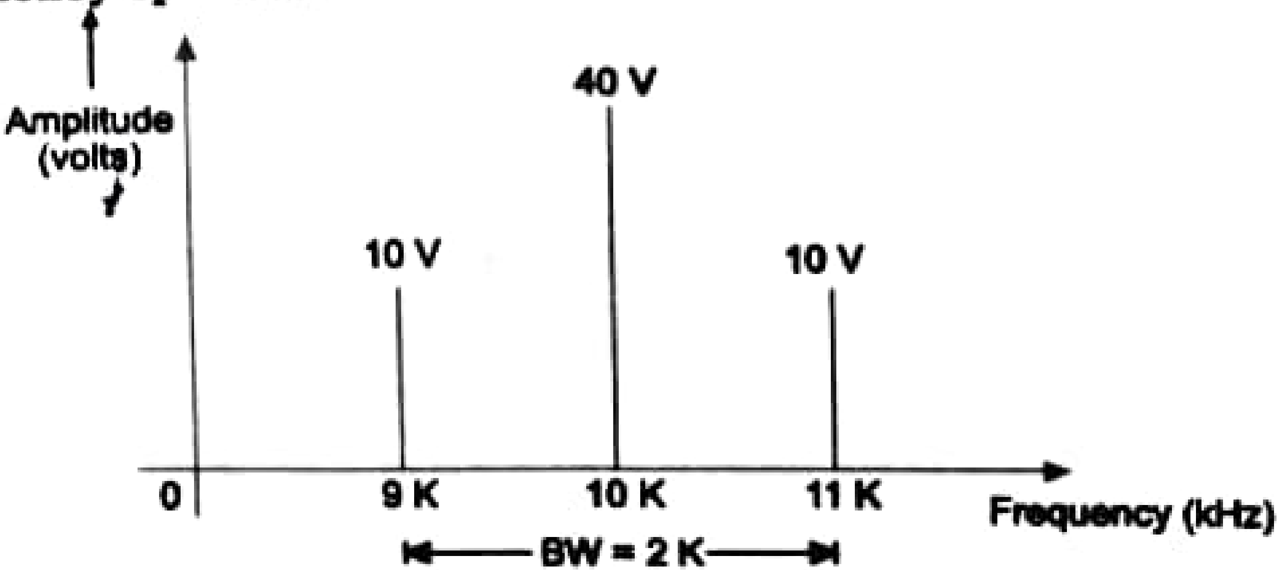


Fig. 2.14

2.7.1 Modulation Index in terms of Power

From equation (2.23),

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

$$\therefore \quad \frac{P_t}{P_c} = 1 + \frac{m^2}{2}$$

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

$$\therefore \quad \boxed{m = \left[2\left(\frac{P_t}{P_c} - 1\right)\right]^{\frac{1}{2}}} \quad \dots ($$

(2) A 400 watt carrier is modulated to a depth of 75% calculate the total power required for modulated.

→ $P_c = 400\,W$

$m_a = 0.75$

$\cancel{P_{USB} = \frac{m_a^2 V_c^2}{8R}}$

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

$$= 400\left(1 + \frac{(0.75)^2}{2}\right)$$

$$\boxed{P_t = 512.5\ \text{watt}}$$

(3) First radio transmitter radiates 10 kW power when modulation power is 60%. Then calculate the power.

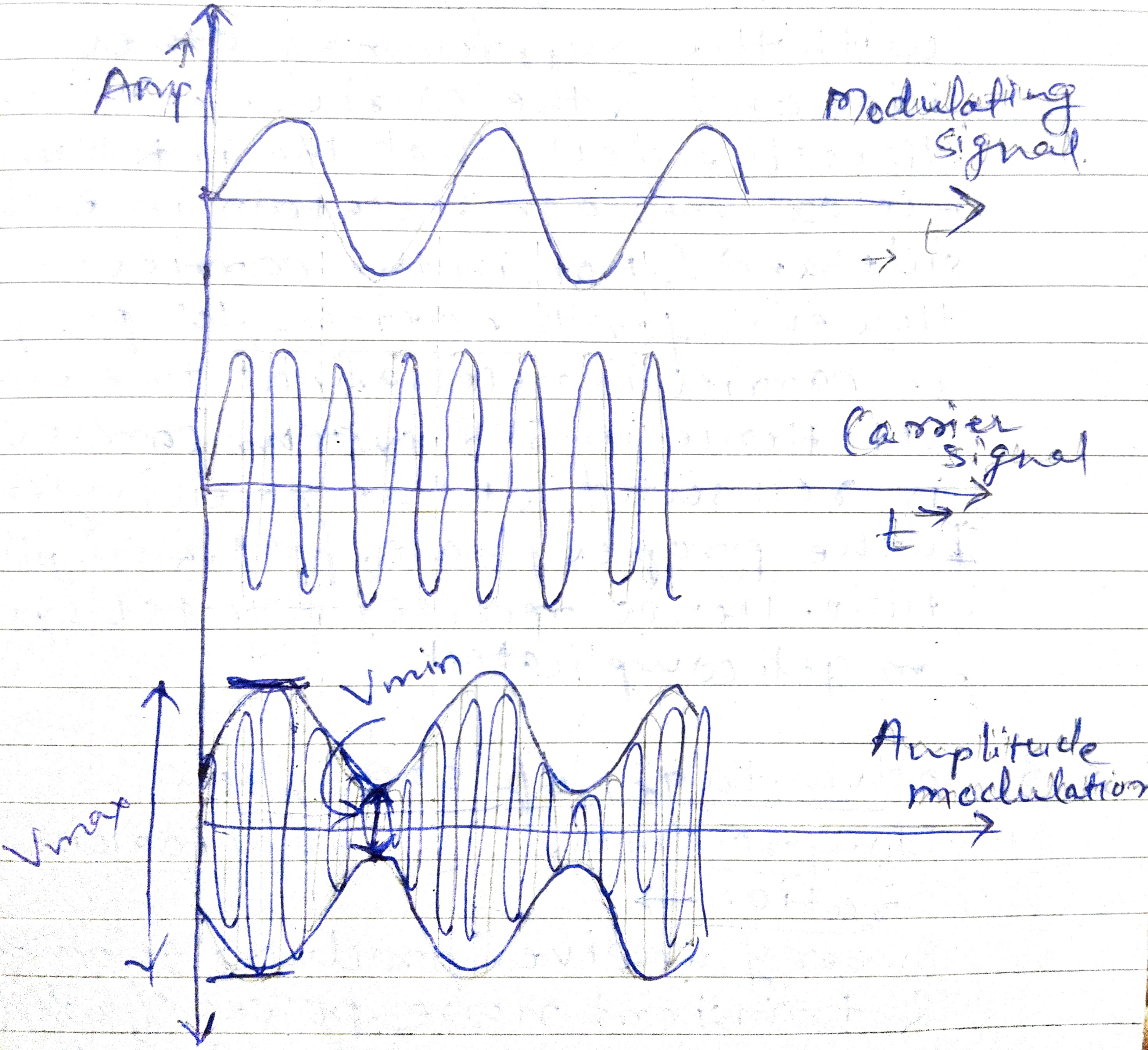
→ $P_t = 10\,kW \quad m_a = 0.60$

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

$$10 \times 10^3 = P_c\left(1 + \frac{(0.60)^2}{2}\right)$$

$$P_c = 8.474\ kW.$$

* AM signal waveform



* Disadv. of DSBFC

→ Power wastage

∵ carrier power is ≈ 66.66%

power saving if 'm' = 1

then, $= \frac{P_c}{\left(1+\frac{m^2}{2}\right)P_c}$ i.e. $\frac{P_c}{P_t}$

∴ power saving = $\frac{1}{1.5} \times 100 = 66.66\%$

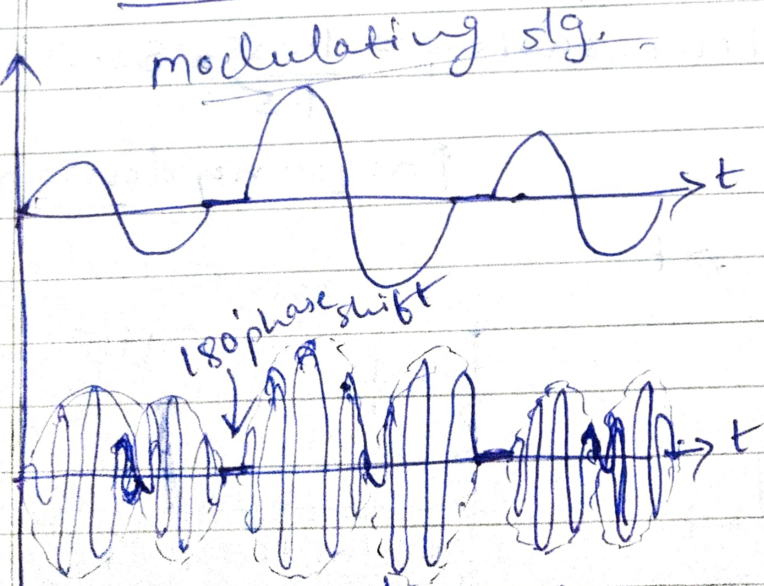
→ Bandwidth inefficient.

∵ 2fm, same info is there in both side band, so one is sufficient.

DSBSC

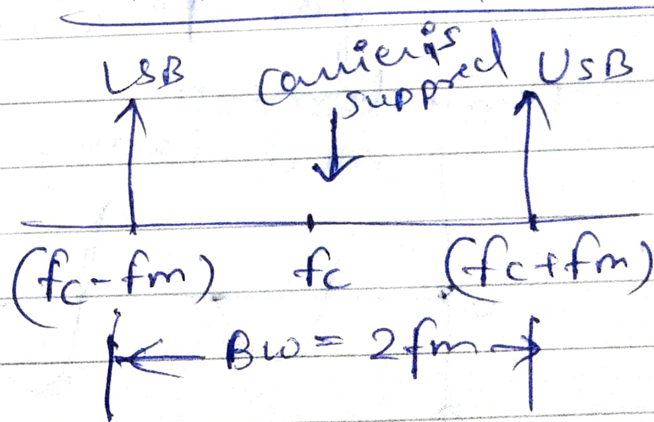
Adv we can save power by suppressing carrier, i.e. we can save 66.66% power of total Power.

In Time domain



Suppressed carrier.

In Frequency domain



Disadv Bandwidth is still 2fm, which is inefficient.

→ Time domain analysis

let $x(t)$ is modulating slg.

$\therefore \; x(t) = V_m \cos(2\pi f_m t)$

$\uparrow$ amplitude $\qquad \uparrow$ freq.

DSBSC modulated wave $= x(t) \cdot c(t)$

$\therefore \downarrow \quad V_c V_m \cos(2\pi f_m t)\cos(2\pi f_c t)$

$\cos A \cdot \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$

$\therefore$ DSBSC modulated wave $\Rightarrow \frac{1}{2} V_m V_c \left[\underbrace{\cos 2\pi (f_c + f_m) t}_{USB} + \underbrace{\cos 2\pi (f_c - f_m) t}_{LSB}\right]$

$\frac{V_m V_c}{2}$ USB $+ \frac{V_m V_c}{2}$ LSB

⊛ SSB-SC

Adv → Power saving is more ie. 83.33%

$\%$ power saving $= \dfrac{P_c\left[1 + \frac{m^2}{4}\right]}{P_c\left[1 + m^2/2\right]} = \dfrac{5/4}{3/2}$

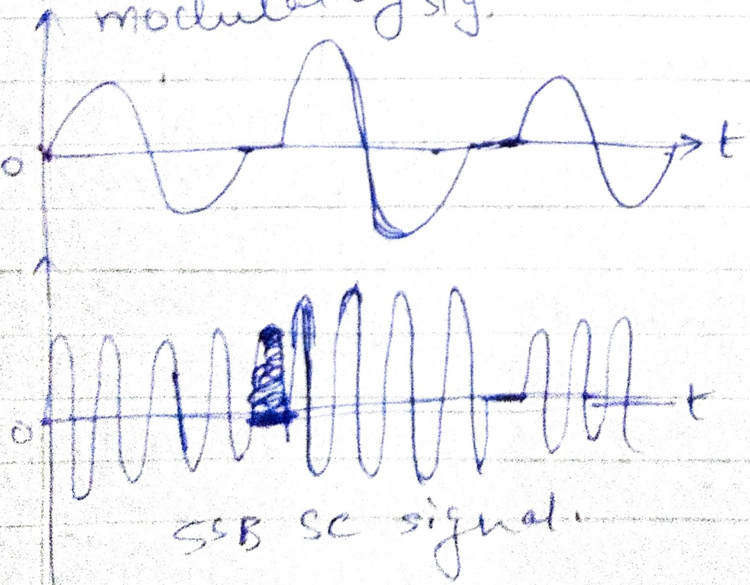
→ B.w. efficient.

$\therefore$ B.W. $= f_m$

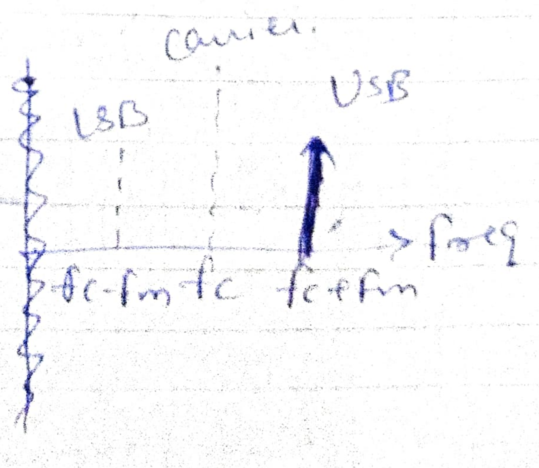
for 100% modulation $m = 1$

$\therefore$ Power saving $= \frac{1.25}{1.5} \times 100 = 83.33\%$

Time domain



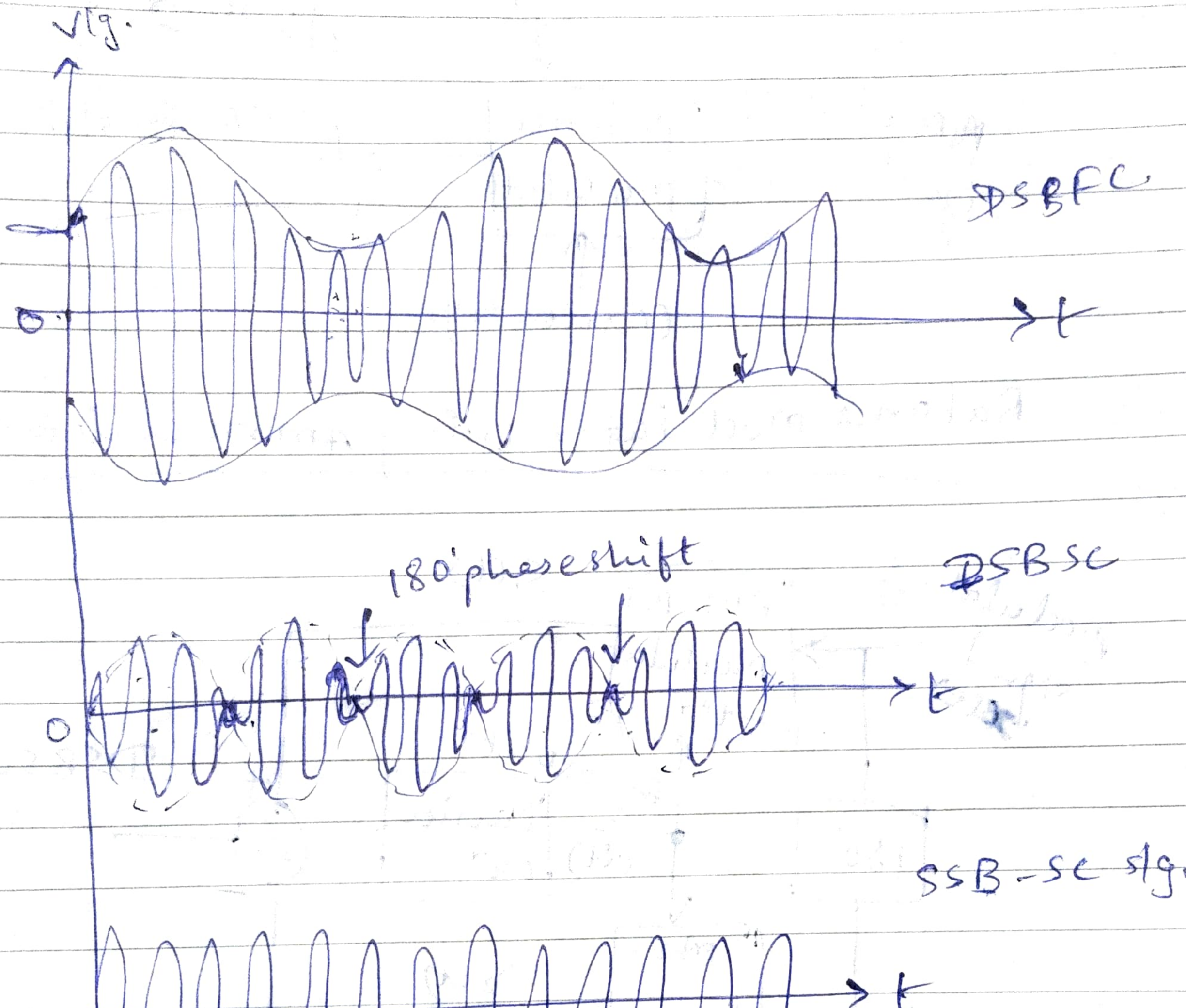
Frequency domain

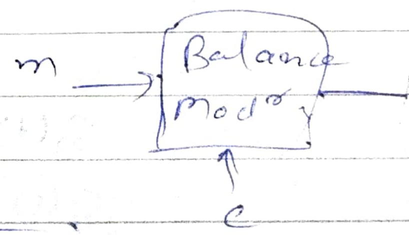


$\cos A \cdot \cos B = \frac{1}{2}\left(\cos(A+B) + \cos(A-B)\right)$

$AM = V_c \cos \omega_c t + \frac{mV_c}{2}\cos(\omega_c+\omega_m)t + \frac{mV_c}{2}\cos(\omega_c-\omega_m)t$

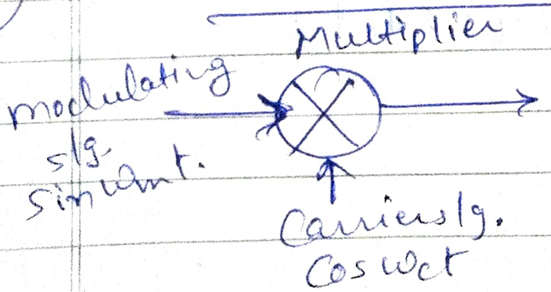
SSB SC signal expression $= \cos(\omega_c \pm \omega_m)t$





★ Generation of DSB-SC signal.

1) → Multiplier Modulator

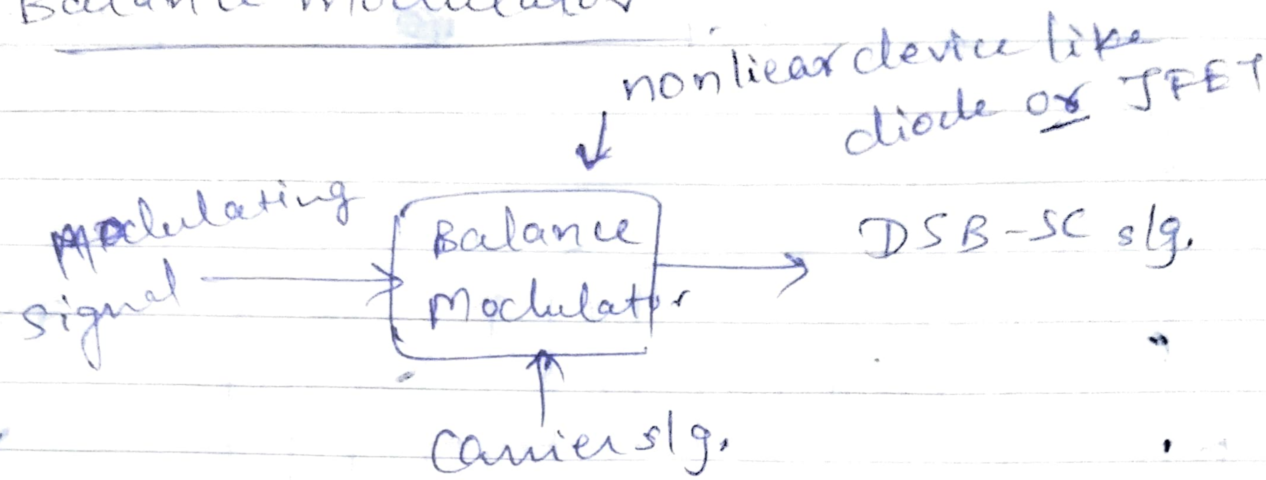


multiplier o/p $= \sin \omega_m t \cdot \cos \omega_c t$.

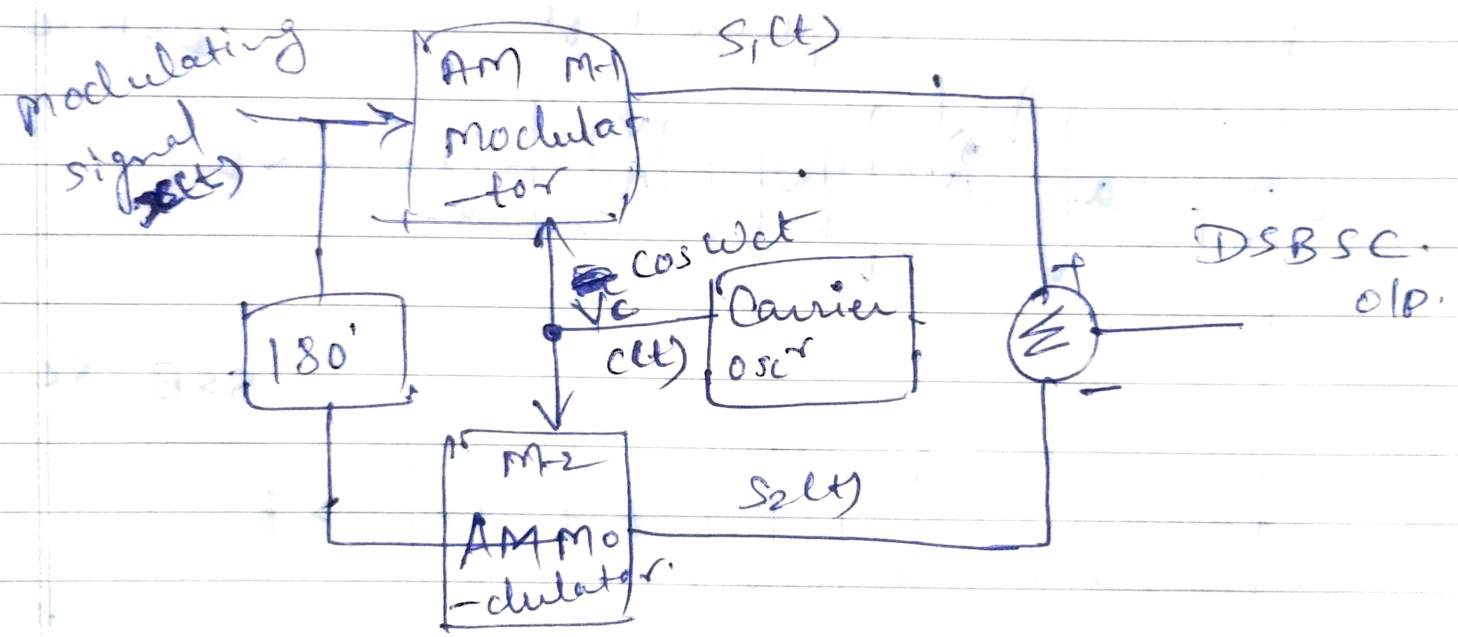
$2\cos A \sin B = \sin(A+B) - \sin(A-B)$

$\therefore$ multiplier o/p $= \frac{1}{2}\left[\sin(\omega_c+\omega_m)t - \sin(\omega_c-\omega_m)t\right]$

(2) Balance modulator



(3) Balance modulator using Am modulator



$$s_1(t) = V_c\,[1 + m\,x(t)]\cdot\cos(2\pi f_c t)$$

$$s_2(t) = V_c\,[1 - m\,x(t)]\cos(2\pi f_c t)$$

$$\text{Subtractor o/p.} = s_1(t) - s_2(t)$$

$$= 2 m V_c\, x(t) \cos(2\pi f_c t)$$

SSBSC

1 Filter method

Advantage

→ Simpler method compared to other.
→ Suppresses the carrier & one of the sideband.

Disadvantages

→ For Generation of SSB at high freq., up conversion is required.
→ Low audio freq. can't be used because filter becomes bulky.

2 Phase shift method

Advantages

→ Generate SSB at any freq. ∴ up conversion is not req.
→ low audio freq. can be used.
→ Easily switched from one sideband to other.

Disadvantages

→ 90° phase shifting of signal is practically difficult to achieve 90° phase shift.

3 Third Method

Advantage → All advantages of phase shift method.

Disadvantage → Complex & not used commercially.

Using a Nonlinear Resistance Device The relationship between voltage and current in a lnear resistance is given by

$$i = bv \tag{3.67}$$

where b is some constant of proportionality. If the above equation refers to a resistor, then b is obviously its conductance.

In a nonlinear resistance, the current is still to a certain extent proportional to the applied voltage, but no longer directly as before. If the curve of current versus voltage is plotted, as in Fig. 3.13, it is found that there is now some curvature in it. The previous linear relation seems to apply to certain point, after which current increases more (or less) rapidly with voltage. Whether the increase is more or less rapid depends on whether the device begins to saturate, or else some sort of avalanche current multiplication takes place. Current now becomes proportional not only to voltage but also to the square, cube and higher powers of voltage. This nonlinear relation is most conveniently expressed as

$$i = a + bv + cv^2 + dv^3 + higherpowers \tag{3.68}$$

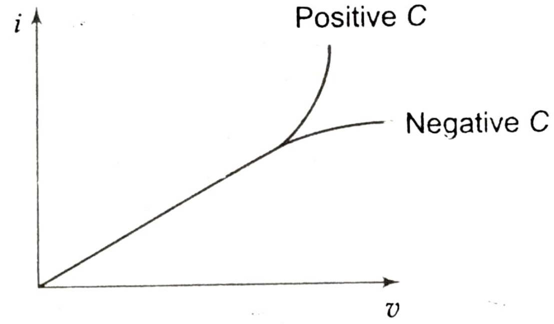


Fig. 3.13 *Nonlinear resistance characteristics.*

The reason that the initial portion of the graph is linear is simply that the coefficient c is much smaller than b. A typical numerical equation might well be something like $i = 5 + 15v + 0.2v^2$, in which case curvature is insignificant until v equals at least 3. Therefore, c in practical nonlinear resistances is much greater than d, which is in turn larger than the constants preceding the higher-power terms. Only the square term is large enough to be taken into consideration for most applications, so that we are left with

$$i = a + bv + cv^2 \tag{3.69}$$

where a represents some dc component, b represents conductance and c is the coefficient of nonlinearity. Since Equation (3.69) is generally adequate in relating the output current to the input voltage of a nonlinear resistance, it can be used for studying the AM signal generation process by a device that exhibit nonlinear resistance. The devices like diodes, transistors and field effect transistors (FET) can be biased with suitable voltage to constrain them to exhibit the negative resistance property.

Figure 3.14 shows the circuit in which modulating voltage v_m and carrier voltage v_c are applied in series at the input of the diode. The output of the diode is collected via a tuned circuit tuned to the carrier frequency with bandwidth of twice the message bandwidth.

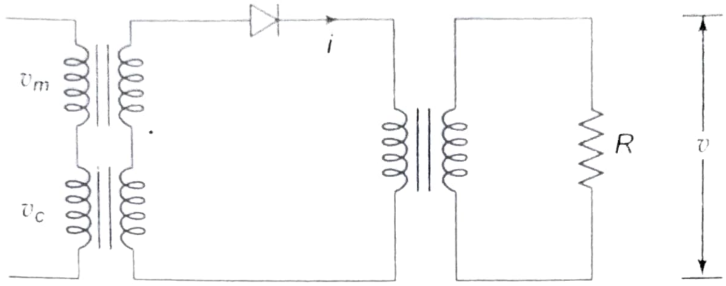


Fig. 3.14 *Generation of AM signal using nonlinear resistance characteristics of diode.*

The diode is biased such that it exhibits the negative resistance property. Under this condition, its output current is given by

$$i = a + b(v_m + v_c) + c(v_m + v_c)^2 = a + b(v_m + v_c) + c(v^2_m + v_c^2 + 2v_m v_c) \tag{3.70}$$

Substituting for $v_m = V_m \sin \omega_m t$ and $v_c = V_c \sin \omega_c t$ we get,

$$i = a + b(V_m \sin \omega_m t + V_c \sin \omega_c t) + c(V_m^2 \sin^2 \omega_m t + V_c^2 \sin^2 \omega_c t + 2V_m V_c \sin \omega_m t \sin \omega_c t) \tag{3.71}$$

Using the trignometric expressions, $\sin x \sin y = 1/2\, [\cos (x - y) - \cos(x + y)]$ and $\sin^2 x = 1/2(1 - \cos 2x)$ we get,

$$i = a + b(V_m \sin\omega_m t + V_c \sin\omega_c t) + c(V_m^2/2(1 - \cos2\omega_m t) + V_c^2/2(1 - \cos2\omega_c t)$$
$$+ V_m V_c(\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m))t \tag{3.72}$$

$$i = (a + cV_m^2/2 + cV_c^2/2) + bV_m \sin \omega_m t + bV_c \sin\omega_c t - (1/2\, cV_m^2 \cos 2\omega_m t$$
$$+ 1/2cV_c^2 \cos 2\omega_c t) + cV_m V_c \cos(\omega_c - \omega_m)t + cV_m V_c \cos(\omega_c + \omega_m)t \tag{3.73}$$

In the above equation the first term is the dc component, second term is message, third term is carrier, fourth term contains the harmonics of message and carrier, fifth term represents the lower sideband and sixth term represents the upper sideband. The requisite AM components can be selected by using the tuning circuit that resonates at the carrier frequency with a bandwidth equal to twice the message bandwidth. At the output of the tuning circuit the current will be

$$i = bV_c \sin \omega_c t + cV_m V_c \cos(\omega_c - \omega_m)t - cV_m V_c \cos(\omega_c + \omega_m)t \tag{3.74}$$

If R is the load resistance, then the amplitude modulated voltage is given by

$$v = iR = V_c \sin\omega_c t + cRV_c \frac{mV_c}{2} \cos(\omega_c - \omega_m)t - cRV_c \frac{mV_c}{2} \cos(\omega_c + \omega_m)t \tag{3.75}$$

$$v = iR = V_c \sin\omega_c t + c' \frac{mV_c}{2} \cos(\omega_c - \omega_m)t - c' \frac{mV_c}{2} \cos(\omega_c + \omega_m)t \tag{3.76}$$

nonlinear resistance property.

3.3.2 Generation of DSBSC Signal

Using Analog Multiplier The conceptual way to realize the generation of DSBSC signal is with the help of an analog multiplier as shown in Fig. 3.15.

The output of the analog multiplier is given by

$$v = v_m v_c = V_m \sin\omega_m t \, V_c \sin\omega_c t = \frac{mV_c}{2}\cos(\omega_c - \omega_m)t - \frac{mV_c}{2}\cos(\omega_c + \omega_m)t \tag{3.77}$$

Thus at the output of the analog multiplier we have the DSBSC signal.

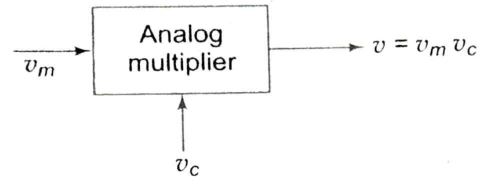


Fig. 3.15 *Block diagram representation of generation of DSBSC signal using analog multiplier.*

Using a Balanced Modulator A **balanced modulator** can be constructed using the non-linear devices like diodes and transistors. The balanced modulator using the diodes is given in Fig. 3.16. The diodes use the nonlinear resistance property for generating modulated signals. Both the diodes receive the carrier voltage in phase; whereas the modulating voltage appears 180° out of phase at the input of diodes, since they are at the opposite ends of a center-tapped transformer. The modulated output currents of the two diodes are combined in the center-tapped primary of the output transformer. They therefore subtract, as indicated by the direction of the arrows in the Fig. 3.16. If this system is made completely symmetrical, the carrier frequency will be completely canceled. No system can of course be perfectly symmetrical in practice, so that the carrier will be heavily supressed rather than completely removed. The output of the balanced modulator contains the two sidebands and some of the miscellaneous components which are taken care of by tuning the output tranformer's secondary winding. The final output consists only of sidebands.

As indicated, the input voltage will be $(v_c + v_m)$ at the input of diode D_1 and $(v_c - v_m)$ at the input of diode D_2. If perfect symmetry is assumed, the proportionality constants will be the same for

Using

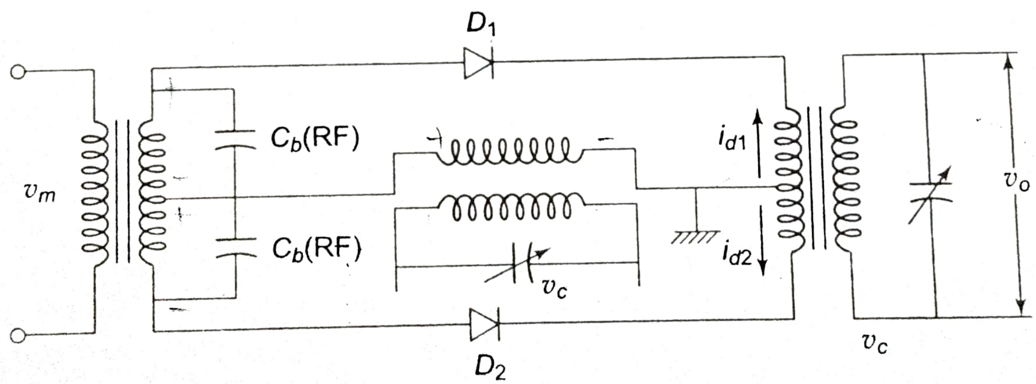


Fig. 3.16 *Generation of DSBSC signal using balanced modulator based on nonlinear resistance characteristics of diode.*

both diodes and may be called a, b, and c as before. The two diode output currents will be

$$i_{d1} = a + b(v_c + v_m) + c(v_c + v_m)^2 \tag{3.78}$$

$$i_{d1} = a + bv_c + bv_m + cv_c^2 + cv_m^2 + 2cv_mv_c \tag{3.79}$$

$$i_{d2} = a + b(v_c - v_m) + c(v_c - v_m)^2 \tag{3.80}$$

$$i_{d2} = a + bv_c - bv_m + cv_c^2 + cv_m^2 - 2cv_mv_c \tag{3.81}$$

As previously indicated, the primary current is given by the difference between the individual diode output currents. Thus

$$i_1 = i_{d1} - i_{d2} = 2bv_m + 4cv_mv_c \tag{3.82}$$

Substituting for v_m and v_c and simplifying we get

$$i_1 = 2bV_m\sin\omega_m t + 4c\frac{mV_c}{2}\cos(\omega_c - \omega_m)t - 4c\frac{mV_c}{2}\cos(\omega_c + \omega_m)t \tag{3.83}$$

The output voltage v_0 is proportional to this primary current. Let the constant of proportionality be α then

$$v_0 = \alpha i_1 = 2b\alpha V_m\sin\omega_m t + 4\alpha c\frac{mV_c}{2}\cos(\omega_c - \omega_m)t - 4\alpha c\frac{mV_c}{2}\cos(\omega_c + \omega_m)t \tag{3.84}$$

Let $P = 2\alpha bV_m$ and $Q = 2\alpha c\frac{mV_c}{2}$. Then

$$v_0 = P\sin\omega_m t + 2Q\cos(\omega_c - \omega_m)t - 2Q\cos(\omega_c + \omega_m)t \tag{3.85}$$

This equation shows that the carrier has been canceled out, leaving only the two sidebands and the modulating frequencies. The tuning of the output transformer will remove the modulating frequencies from the output.

$$v_0 = 2Q\cos(\omega_c - \omega_m)t - 2Q\cos(\omega_c + \omega_m)t \tag{3.86}$$

3.3.3 Generation of SSB Signal

Using Analog Multiplier The conceptual way to realize the generation of SSB signal is with the help of an analog multiplier followed by a bandpass filter as shown in Fig. 3.17.

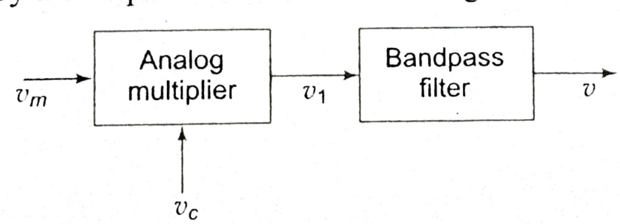


Fig. 3.17 *Block-diagram representation of generation of SSB signal using analog multiplier.*

The output of the analog multiplier is given by

$$v_1' = v_mv_c = V_m\sin\omega_m tV_c\sin\omega_c t = \frac{mV_c}{2}\cos(\omega_c - \omega_m)t - \frac{mV_c}{2}\cos(\omega_c + \omega_m)t \tag{3.87}$$

Thus at the output of the analog multiplier we have the DSBSC signal. This signal is passed through a bandpass filter which, depending on the cut-off frequencies, will attenuate one sideband and allows the other to pass through. If the lower sideband is passed out then the output of the bandpass filter will be

$$v = \frac{mV_c}{2}\cos(\omega_c - \omega_m)t. \tag{3.88}$$

Alternatively, if upper sideband is passed out, then the output of the bandpass filter will be

$$v = -\frac{mV_c}{2}\cos(\omega_c + \omega_m)t. \tag{3.89}$$

This results in the generation of SSB signal.

Using the Filter Method The basis for the filter method is that after the balanced modulator the unwanted sideband is removed by a filter. The block diagram for the filter method of SSB generation is given in Fig. 3.18. The balanced modulator generates the DSBSC signal and the sideband suppression filter supresses the unwanted sideband and allows the wanted sideband.

As derived in the previous section, the output of the balanced modulator is

$$v_1' = 2\alpha cV_m V_c(\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t) \tag{3.90}$$

The sideband suppression filter is basically a bandpass filter that has a flat bandpass and extremely high attenuation outside the bandpass. Depending on the cut-off frequency values we can represent the output of the filter as

$$v = 2\alpha cV_m V_c \cos(\omega_c - \omega_m)t \tag{3.91}$$

or

$$v = -2\alpha cV_m V_c \cos(\omega_c + \omega_m)t \tag{3.92}$$

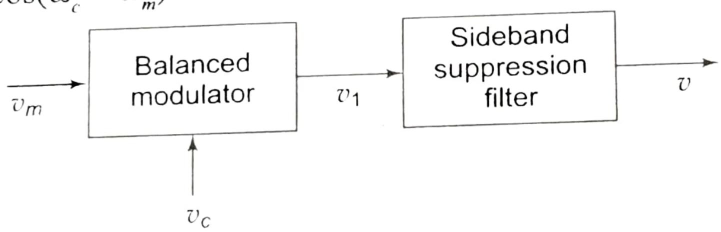


Fig. 3.18 *Block diagram representation of generation of SSB signal using filter method.*

In this way SSB is generated in case of filter method.

Using the Phase Shift Method The phase shift method avoids filters and some of their inherent disadvantages, and instead makes use of two balanced modulators and two phase shifting networks, as shown in Fig. 3.19. One of the balanced modulators, M_1, receives the 90° phase shifted carrier and in phase message signal, whereas the other, M_2, is fed with the 90° phase shifted message and in phase carrier signal. Both the modulators produce the two sidebands. One of the sidebands, namely, the upper sideband will be in phase in both the modulators, whereas, the lower sideband will be out of phase. Thus by suitable polarity for M_2 output and adding with M_1 output results in suppressing one of the sidebands.

Let $v_m = V_m \sin \omega_m t$ be the message and $v_c = V_c \sin \omega_c t$ be the carrier. The 90° phase shifted versions of them are $V_m \cos \omega_m t$ and $V_c \cos \omega_c t$, respectively.

The output of the balanced modulator M_1 is given by

$$v_1 = V_m V_c \sin\omega_m t \cos\omega_c t = \frac{V_m V_c}{2} (\sin(\omega_c + \omega_m)t + \sin(\omega_c - \omega_m)t)$$

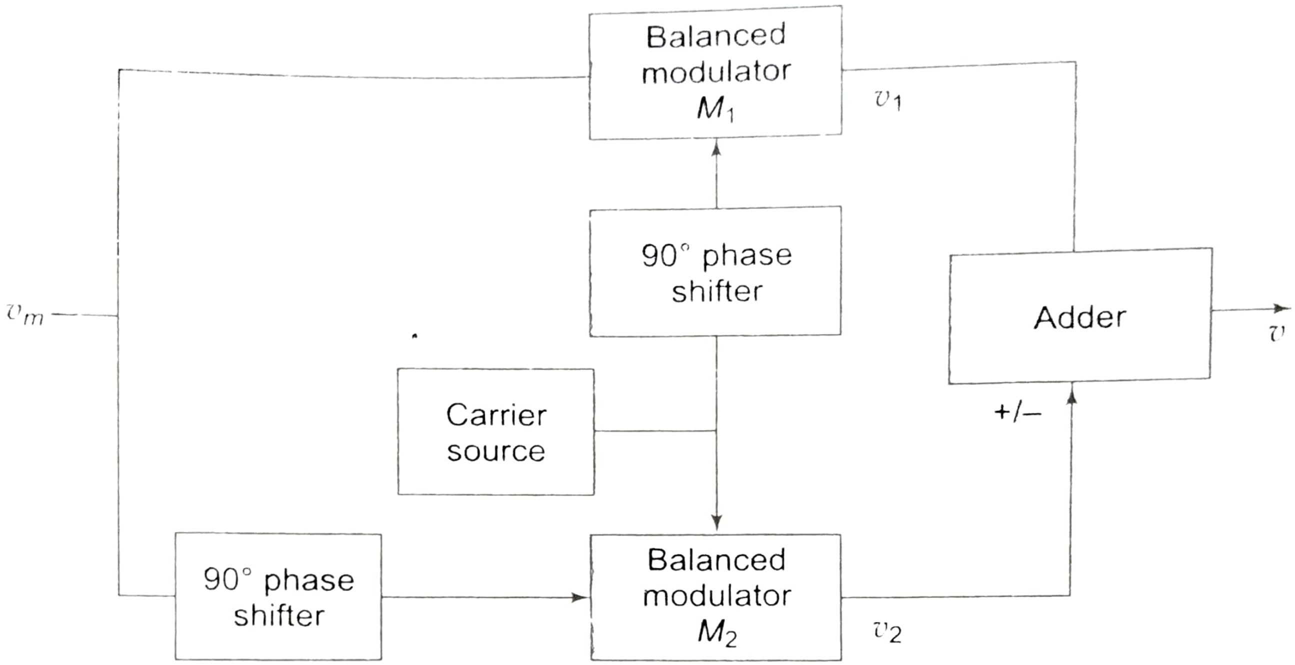


Fig. 3.19 *Block diagram representation of generation of SSB signal using phase shift method.*

The output of the balanced modulator M_2 is given by

$$v_2 = V_m V_c \cos\omega_m t \sin\omega_c t = \frac{V_m V_c}{2} (\sin(\omega_c + \omega_m)t - \sin(\omega_c - \omega_m)t)$$

The output of the adder is

$$v = v_1 \pm v_2$$

In one case we have

$$v = V_m V_c \sin(\omega_c + \omega_m)t$$

In the othercase we have

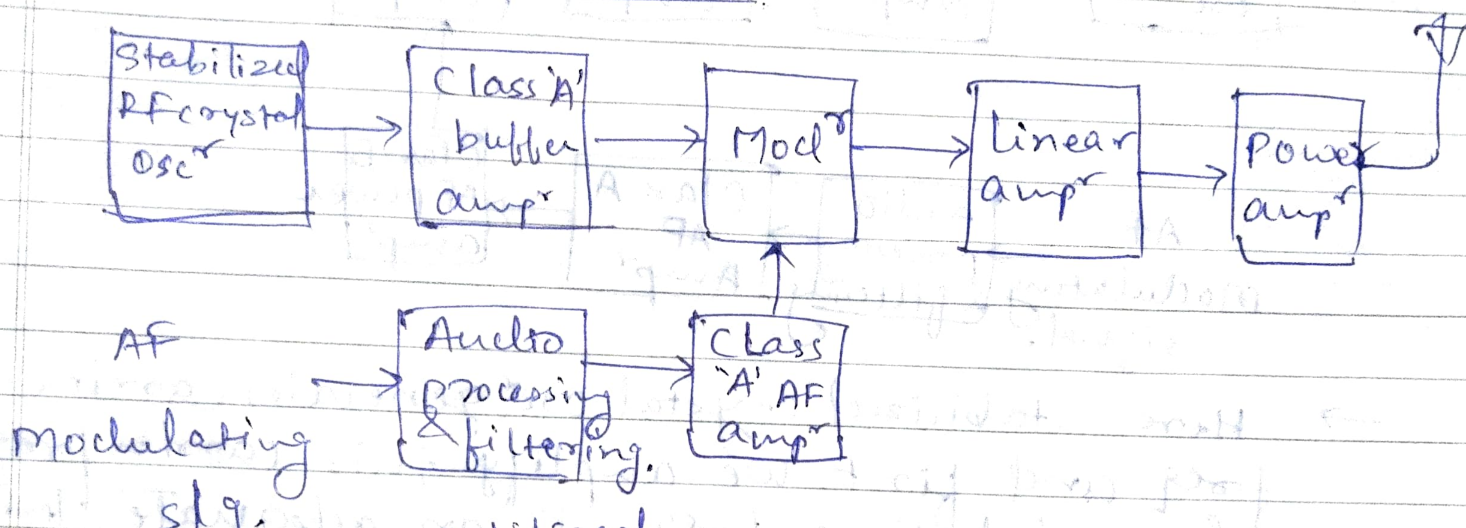
$$v = V_m V_c \sin(\omega_c - \omega_m)t$$

Thus resulting in the generation of SSB signal.

AM Transmitters

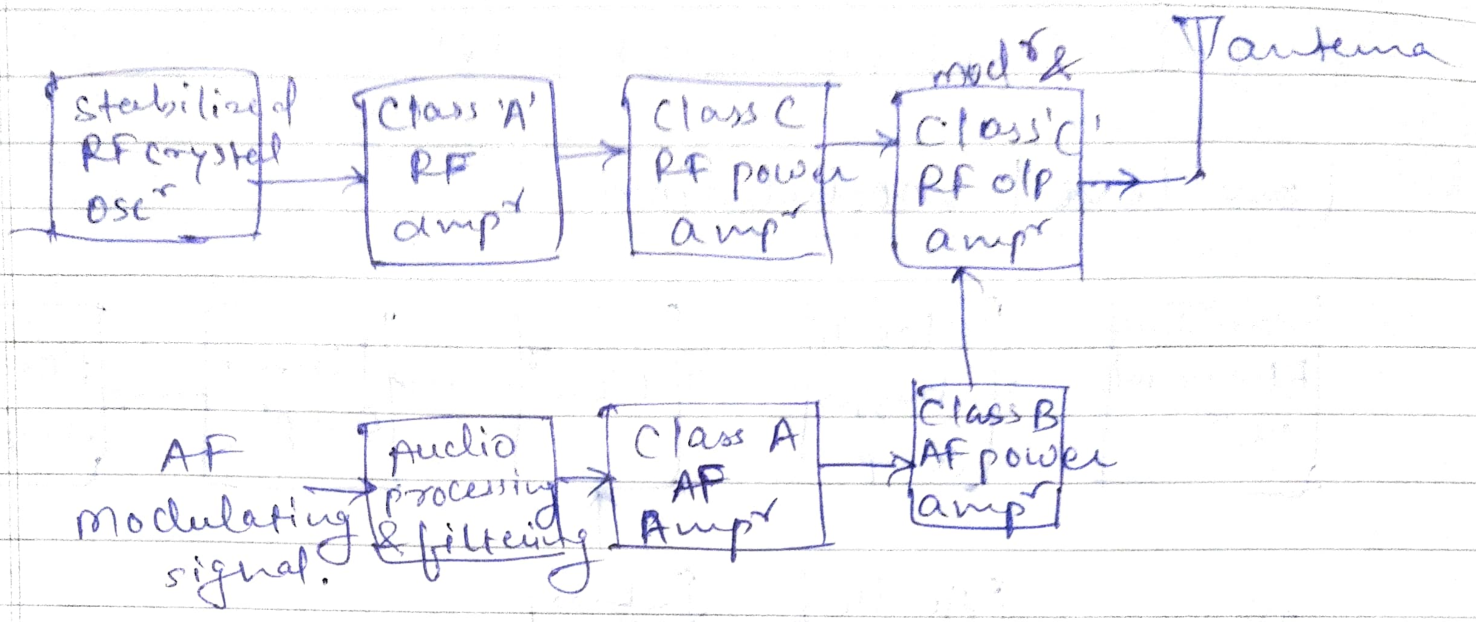
→ High level modulated T_x^r
→ Low level modulated T_x^r

(1) Low level modulation



→ RF oscr produces stabilized carrier signal in order to maintain carrier frequency deviation within prescribed limit. Carrier freq. is same as Transmitting freq.
→ Amplified modulating signal is applied to modulator along with carrier. At the o/p we get AM wave.
→ This AM slg is amplified using chain of linear amplifier to increase its power level. It can be of class A, B or AB. Linear amplifiers are used in order to avoid waveform distortion in AM wave.
→ This AM slg is then transmitted using T_x^r antenna
→ Transistorized modulator ckts are generally used for low level modulator ~~due to~~ it can handle low power.
→ Designing is simple but efficiency is less.

(A) High level modulation



→ Here stabilized crystal osc^{r} generates carrier freq and first we amplify this carrier freq & modulating freq. to an adequate level using class 'C' & class 'B' power amplifiers respectively.

→ If we want 100% modulation then modulating s/g must be 33% of total power.

→ Modulation takes place in last class 'C' RF amplifier. At o/p of this modulator we are getting AM wave.

→ Here we use collector modulated transistorized ckt or plate modulated vaccume tube as as modulator.

→ ~~Eff~~ Efficiency is high because of class 'C' amp^{r} & power level is also high.