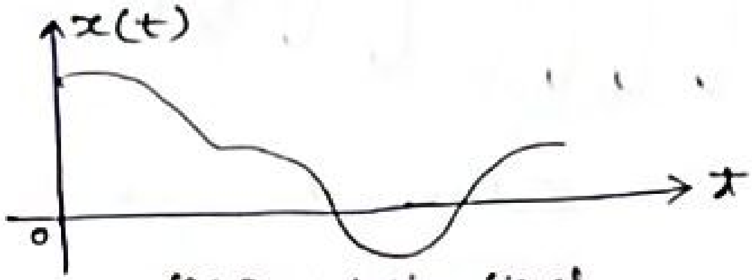
UNIT - 1

AMPLITUDE MODULATION

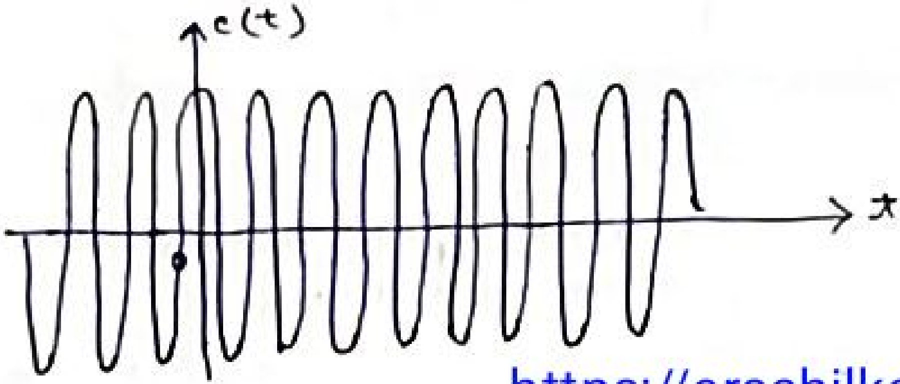
Amplitude Modulation may be defined as a system in which the maximum Amplitude of the carrier wave is made proportional to the Instantenious Value (amplitude) of the modulating or baseband signal.

Let us consider a sinusodial carrier wave $c(t)$

$$c(t) = A \cos \omega_c t \quad \ldots\ldots\ldots (i)$$



(a) Modulating signal



(b) Carrier signal

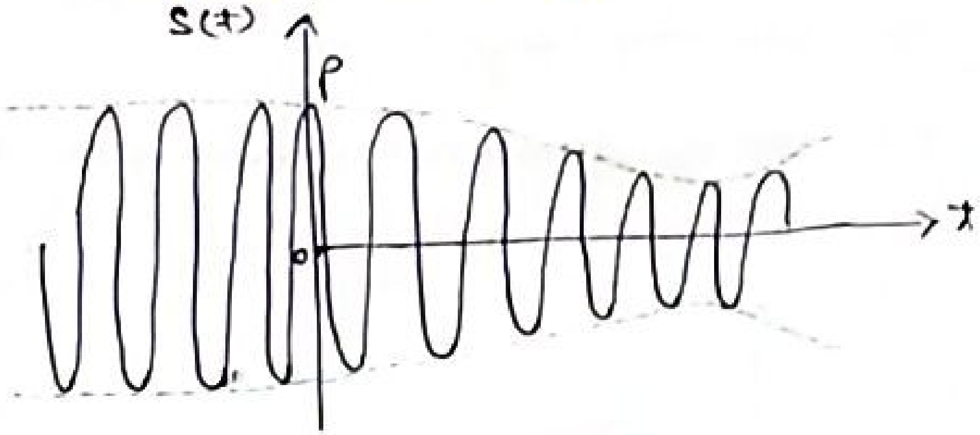
In eq ①, Here A is the maximum Amplitude of the Carrier wave & ω_c is the carrier frequency. for simplicity here we have Assumed that the phase of the carrier wave is zero in Equation (1.)

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

The standard eq. for Amplitude modulated (AM) wave may be Expressed as

$$s(t) = x(t)\cos\omega_c t + A\cos\omega_c t \quad \cdots\cdots (2)$$

or



(C) Modulated Signal

So,

$$\boxed{s(t) = \left[A + x(t)\right]\cos\omega_c t} \quad ------ ③$$

Few Points:-

(i) It may be observed that eq. ② & ③ describes the time domain behaviour of A Modulated signal.

(ii) It may be noted that Carrier signal $[c(t) = A\cos\omega_c t]$ is a fixed frequency signal having freq. ω_c.
The modulateding or baseband signal $x(t)$ contains the information or Intelligence to be transmitted.

(iii) In the process of Amplitude modulation, the frequency & phase of the Carrier Remain constant.

(iv) fig (c) Shows the Process of Amplitude modulation. It may be observed that up to point P modulating signal is not Applied, so there is no modulation & max. Amplitude Remains constant.
Now at Point P, the modulating signal is Applied.

This means that the maximum amplitude A of the carrier now varies in accordance with the instantaneous value of the modulating signal $x(t)$.

(v) The AM wave has a time varying amplitude called as the envelope of the AM wave. fig (c) shows the envelope of AM wave consists of the modulating or baseband signal.

So, this is the unique property of AM that the envelope of the modulated carrier has the same shape as the message signal or base band signal.

from the expression of AM wave

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

or

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

where,

$$E(t) = A + x(t)$$

$E(t)$ is called the Envelope of AM wave. This envelope consists of the baseband signal $x(t)$.

Hence the modulating or baseband signal may be recovered from an AM wave by detecting the envelope.

SPECTRUM of AM wave or frequency domain Representation

If $x(t)$ is a modulating signal & carrier signal is given by;

$$c(t) = A \cos\omega_c t \quad \text{------- (1)}$$

Then the eq. for AM wave will be,

$$s(t) = x(t)\cos\omega_c t + A\cos\omega_c t \quad \text{------- (2)}$$

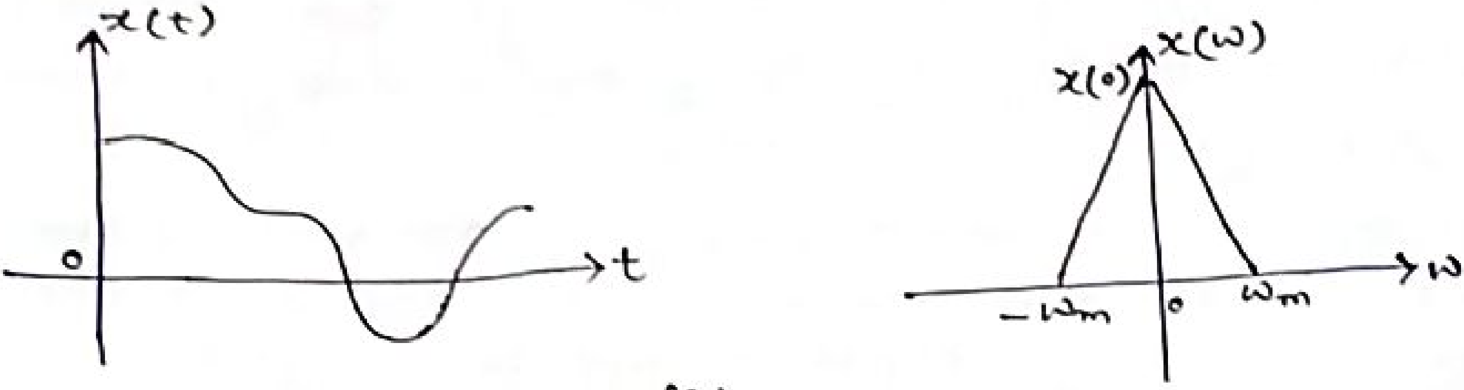
This eq. describes the AM wave in time domain. Now if we want to know the frequency description or freq. present in AM wave, we will have to find the spectrum or freq. domain representation.

for this purpose, first we have to take the fourier Transform of AM. wave.

Let, $S(\omega)$ denotes the $\xleftrightarrow{f.T.}$ $s(t)$

$C(\omega)$ " " " $c(t)$

$X(\omega)$ " " " $x(t)$



(a)

Let the modulating signal or message signal $x(t)$ be band limited to the interval $\underline{-\omega_m \leq \omega \leq \omega_m}$.

This means that the modulating signal does not have any frequency component outside the interval $(-\omega_m, \omega_m)$.

It includes negative frequency also from $\underline{-\omega_m}$ $\underline{\text{to } 0}$. Practically there is no meaning of negative frequencies. Hence, we can say that modulating signal contains frequency from 0 to ω_m.

fourier Transform of a Cosine signal $\cos\omega_c t$ consists of two impulse at ω_c & $-\omega_c$ as,

$$\cos\omega_c t \longleftrightarrow \pi\left[\delta(\omega+\omega_c) + \delta(\omega-\omega_c)\right] \quad \text{-----(3)}$$

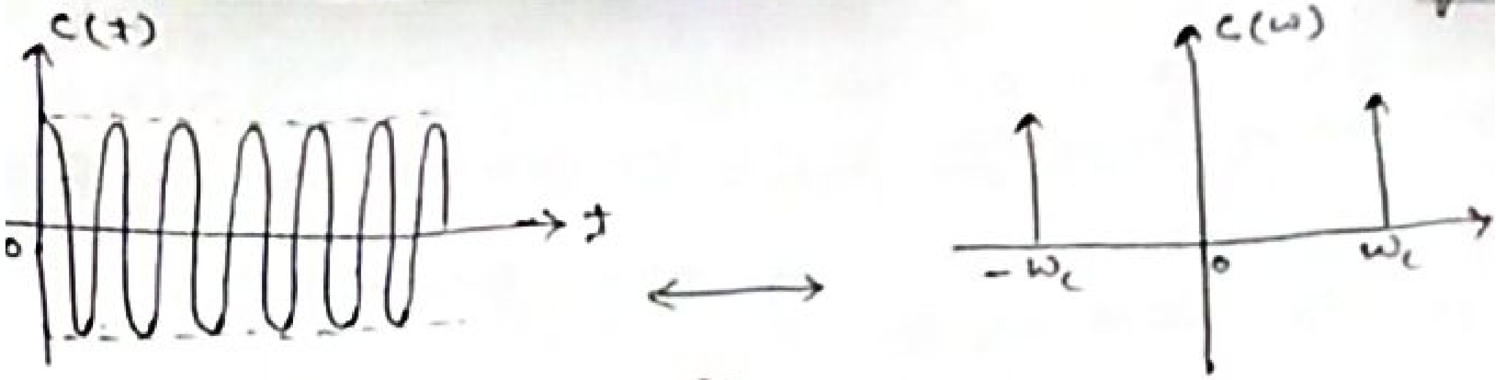
Since, the carrier signal is $c(t) = A\cos\omega_c t$, therefore

$$A\cos\omega_c t \longleftrightarrow \pi A\left[\delta(\omega+\omega_c) + \delta(\omega-\omega_c)\right] \quad \text{-----(4)}$$

Now, the figure (B) shows the carrier signal $A\cos\omega_c t$ & its fourier Transform.

Now the AM wave is given as (There are Two factors)

$$s(t) = \underbrace{x(t)\cos\omega_c t}_{①} + \underbrace{A\cos\omega_c t}_{②}$$



B

To, find the fourier Transform of $x(t)\cos\omega_c t$, we first note the freq. shifting Theorem of fourier transform

$$\text{If } x(t) \longleftrightarrow X(\omega)$$

then,

$$e^{j\omega_c t} x(t) \longleftrightarrow X(\omega-\omega_c) \text{ - - - - - (A)}$$

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 freq. domain is shifted by an Amount ω_c.

Similarly,

$$e^{-j\omega_c t} x(t) \longleftrightarrow X(\omega+\omega_c) \text{ - - - - - (B)}$$

Since $e^{j\omega_c t}$ is not a real function & can not be generated practically. Therfore freq. shifting in practice is Achieved by multiplying $x(t)$ by a sinusoid such as $\cos\omega_c t$.

$\therefore$

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

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

Now, using eq. (A) + (B)

$$\boxed{x(t)\cos\omega_c t \longleftrightarrow \frac{1}{2}\left[X(\omega-\omega_c) + X(\omega+\omega_c)\right]}$$

- - - - - (C)

This means that the multiplication of a signal $x(t)$ by a sinusoid of frequency ω_c shifts the spectrum $X(\omega)$ by $\pm\omega_c$.

The fourier Transform of second factor $A\cos\omega_c t$ will be as in eq. (D)

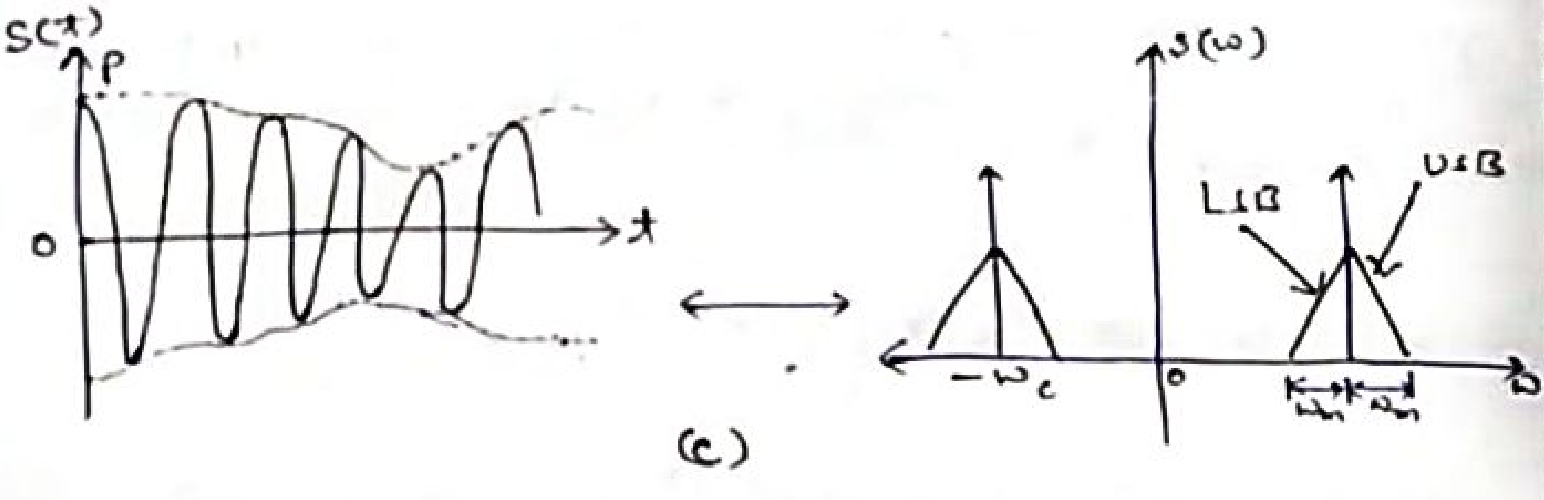
$$A\cos\omega_c t \longleftrightarrow \pi A[\delta(\omega+\omega_c)+\delta(\omega-\omega_c)] \quad \text{.........(D)}$$

∴ The fourier Transform of AM wave will be given by the sum of equations (C) & (D).

$$\boxed{S(\omega)=\frac{1}{2}[X(\omega-\omega_c)+X(\omega+\omega_c)]+\pi A[\delta(\omega+\omega_c)+\delta(\omega-\omega_c)]}$$

The first factor given as $\frac{1}{2}[X(\omega-\omega_c)+X(\omega+\omega_c)]$ represents the spectrum of original signal or baseband signal shifted in the positive as well as in the negative direction by the factor ω_c.

The second factor given as $\pi A[\delta(\omega+\omega_c)+\delta(\omega-\omega_c)]$ represents the presence of carrier signal.



(c)

fig. (C) shows the spectrum of modulated signal containing shifted spectrum of modulating signal & the spectrum of carrier signal.

Few Points

(i) For Positive frequency, a portion of the spectrum of AM wave is lying above the carrier frequency ω_c. This band of frequency lying above ω_c is known as USB, whereas the symmetrical portion below ω_c is known as LSB.

MODULATION INDEX

In AM system the modulation index is defined as the measure of extent of amplitude variations about an unmodulated maximum carrier. It is represented by m_a.

$$\text{Modulation Index } m_a = \frac{|x(t)|_{max}}{\text{Max. Carrier Amplitude}}$$

or

$$\boxed{m_a = \frac{|x(t)|_{max.}}{A}}$$

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

⇒ The absolute value of m_a multiplied by 100 is known as percentage modulation.

OVER MODULATION

We know that modulation Index is given by,

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

A = Amplitude of the carrier signal.

The baseband or modulating signal will be preserved in the envelope of the AM signal only if we have,

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

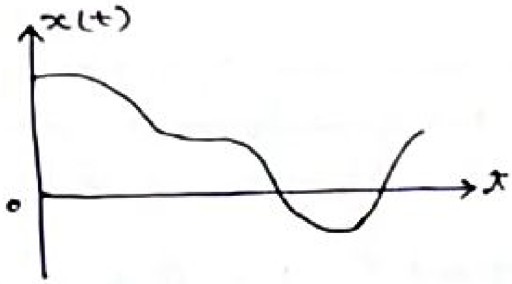
If $m_a > 1$ or the percentage modulation is greater than 100 the baseband signal is not preserved in the envelope.

It means that in this case, the baseband signal recovered from the envelope will be distorted.

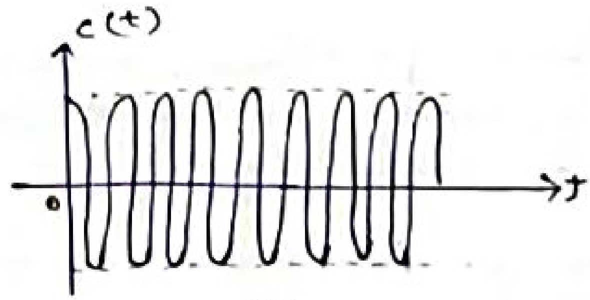
This type of distortion is called envelope distortion & the AM signal with $m_a > 1$ or $m_a > 100\%$ is called over-modulated signal.

So there are two cases :-

Let us consider a base band signal $x(t)$ & A carrier signal $A \cos w_c t$.

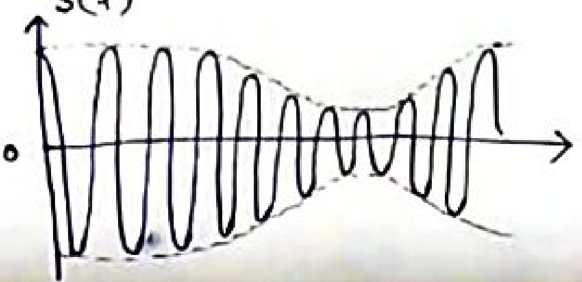


(a)



(b)

(i) Amplitude Modulation with $m_a < 1$



(c)

The waveform of the AM signal is shown in fig (c).
Here the max. Amplitude of baseband signal is less than max. carrier Amplitude A.

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

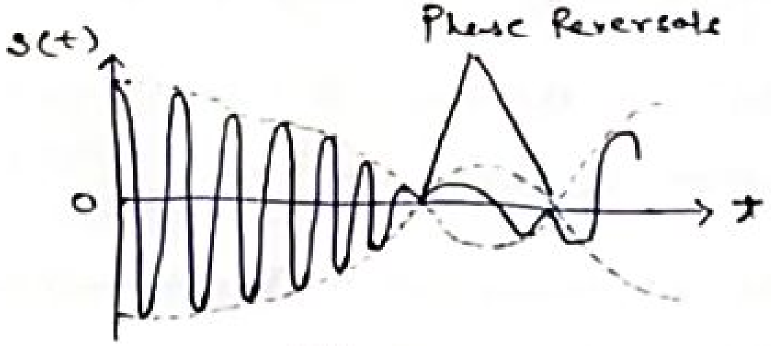
from fig. It may be observed that the

The waveform of the AM signal is shown in fig (c). Here the max. Amplitude of baseband signal is less than max. Carrier Amplitude A.

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

from fig. It may be observed that the envelope is not reaching the zero-Amplitude axis of the AM waveform & so, the baseband signal may be fully recovered from the envelope of AM wave.

(ii) Amplitude Modulation with $m_a > 1$



(d).

Here the Amplitude of the baseband signal Exceeds the Maximum Carrier Amplitude i.e..

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

In this case m_a is more than 1 or 100%.

SINGLE TONE AMPLITUDE MODULATION

Till now, we discussed About Amplitude Modulation in which we assummed that base band or modulating signal is a random signal which consists of a large no. of freq. components.

In this section, we shall discuss Amplitude modulation in which the modulating or baseband signal consists of only one (single freq.) that is modulation is done by single frequency or Tone.

This type of Amplitude modulation is known as Single Tone Amplitude modulation.

Let us consider a single tone modulating signal as

$$x(t) = V_m \cos \omega_m t^{*} \quad \text{------------ (i)}$$

* Signal $x(t)$ may be a voltage signal or a current signal. Here we assummed that $x(t)$ is a voltage signal with maximum Amplitude equal to V_m.

Let the carrier signal be

$$c(t) = A \cos \omega_c t \quad \text{------------ (ii)}$$

we know the general equation for AM signal is

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

or

$$s(t) = A \cos \omega_c t + x(t) \cos \omega_c t \quad \text{-------- (iii)}$$

Putting the value of $x(t)$ we get

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

or

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

or

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

But we know that modulation index m_a is given as

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

where, $|x(t)|_{max}$ denotes the max. Amplitude of modulating signal & A is the max. Amplitude of the carrier signal

In this case we have,

$$|x(t)|_{max} = V_m$$

or

$$m_a = \frac{V_m}{A}$$

Putting the value of m_a in eq. no (iv), we get desired eq. for single tone Amplitude modulation.

$$\boxed{s(t) = A \cos \omega_c t \left[1 + m_a \cos \omega_m t\right]}$$

POWER CONTENT IN AM WAVE :-

It may be observed from the expression of AM wave that the carrier component of the Amplitude modulated wave has the same Amplitude as unmodulated carrier.

In Addition to carrier component, the modulated wave consists of two sideband components.

It means that modulated wave contains more power than the unmodulated carrier. In this section we find the power contents of the carrier & the sidebands.

we know the General expression of AM wave is

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

The total power P of the AM wave is the sum of the carrier power P_c & side band Power P_s.

Carrier Power :-

The carrier Power P is equal to the mean-square (ms) value of the carrier term $A\cos w_c t$

$$P_c = \text{mean Square value of } A\cos w_c t$$

$$P_c = [A\cos w_c t]^2 = \frac{1}{2\pi}\int_0^{2\pi} A^2\cos^2 w_c t \cdot dt^* = \frac{A^2}{2} \text{ ----(i}$$

[* since Period of the signal $A\cos w_c t$ is 2π]

SIDE BAND POWER :-

The side band Power P_s is equal to the mean square value of the side band term $x(t)\cos w_c t$ ... i.e. --

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

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

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

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

In AM Generation, a band pass filter (BPF) or a tuned circuit tuned to carrier frequency ω_c is used to filter out the second integral term.

Therefore,

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

or, P_s = mean square value of $\frac{1}{2}x^2(t) = \frac{1}{2}\overline{x^2(t)}$ ......(iii)

However the total side band power P_s is due to the equal contribution of the upper & lower side bands. Hence the power carried by the upper & lower side-bands will be,

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

∴ The total power P_t of the AM signal is the sum of the carrier power P_c & sideband power P_s.

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

TRANSMISSION EFFICIENCY of Amplitude Modulated Signal

In AM wave the amount of useful message power P_s may be expressed by a term known as Tx efficiency η.

Hence transmission efficiency of AM wave may be defined as the percentage of total power contributed by the side bands.

$$\boxed{\eta = \frac{P_s}{P_t} \times 100}$$

The max. Transmission efficiency of the AM is only 33.33%. This implies that only one third of the total power is carried by the sidebands & the rest two third is wasted.

Power of a Single Tone Amplitude-Modulation (AM Signal)

Let us consider that a carrier signal $A\cos\omega_c t$ is Amplitude modulated by a single tone modulating signal.
$x(t) = V_m \cos\omega_m t$

Then the unmodulated or carrier power

$$P_c = \text{mean square (ms value)}$$
$$P_c = \overline{(A\cos\omega_c t)^2} = \frac{A^2}{2}$$

The Sideband power

$$P_s = \frac{1}{2}\overline{x^2(t)} = \frac{1}{2}\overline{(V_m \cos\omega_m t)^2}$$

$$P_s = \frac{1}{2}\frac{V_m^2}{2} = \frac{1}{4}V_m^2$$

We know that total modulated power P_t is the sum of $P_c + P_s$

$$P_t = P_c + P_s = \frac{A^2}{2} + \frac{1}{4}\cdot V_m^2$$

or

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

But $\dfrac{V_m}{A} = \dfrac{\text{Max. baseband Amplitude}}{\text{Max. Carrier Amplitude}} = m_a$

& m_a = modulation Index for AM

Hence,
$$P_t = \frac{A^2}{2}\left[1 + \frac{1}{2}\cdot m_a^2\right]$$

But
$$\frac{A^2}{2} = P_c = \text{Carrier Power}$$

$$\therefore \boxed{P_t = P_c\left[1+\frac{m_a^2}{2}\right]}$$

Current Calculation for Single Tone AM

Let I_c be the r.m.s. value of the carrier or unmodulated current & I_t be the r.m.s. value of the total or modulated current of an A.M transmitter. Let R be the Antenna Resistance through which these current flows. Now, we know that for a single tone modulation the power relation is expressed as:-

$$P_t = P_c\left[1 + \frac{m_a^2}{2}\right] \quad \text{------- (i)}$$

P_t = Total modulated Power

P_c = Carrier or Unmodulated Power

m_a = Modulation Index

from eq. (1) we may write

$$\frac{P_t}{P_c} = 1 + \frac{m_a^2}{2}$$

or

$$\frac{I_t^2 \cdot R}{I_t^2 \cdot R} = 1 + \frac{m_a^2}{2}$$

or

$$\frac{I_t}{I_c} = \sqrt{1 + \frac{m_a^2}{2}} \quad \text{or} \quad \boxed{I_t = I_c\sqrt{1+\frac{m_a^2}{2}}}$$

Problems:-

Q.① A 400 watts Carrier is modulated to a depth of 75%. find the total Power in the Amplitude modulated wave. Assume the modulating signal to be sinusoidal.

Q.② An AM Broadcast radio transfer radiates 10K watt of power if modulation percentage is 60. Calculate how much of this is the carrier Power.

Q.③ The Antenna current of an AM transmitter is 8A if only the carrier is sent, but it increases to 8.93 A if the carrier is modulated by a single sinusoidal wave. Determine the percentage modulation Also find the Antenna current, if the percent of modulation changes to 0.8.

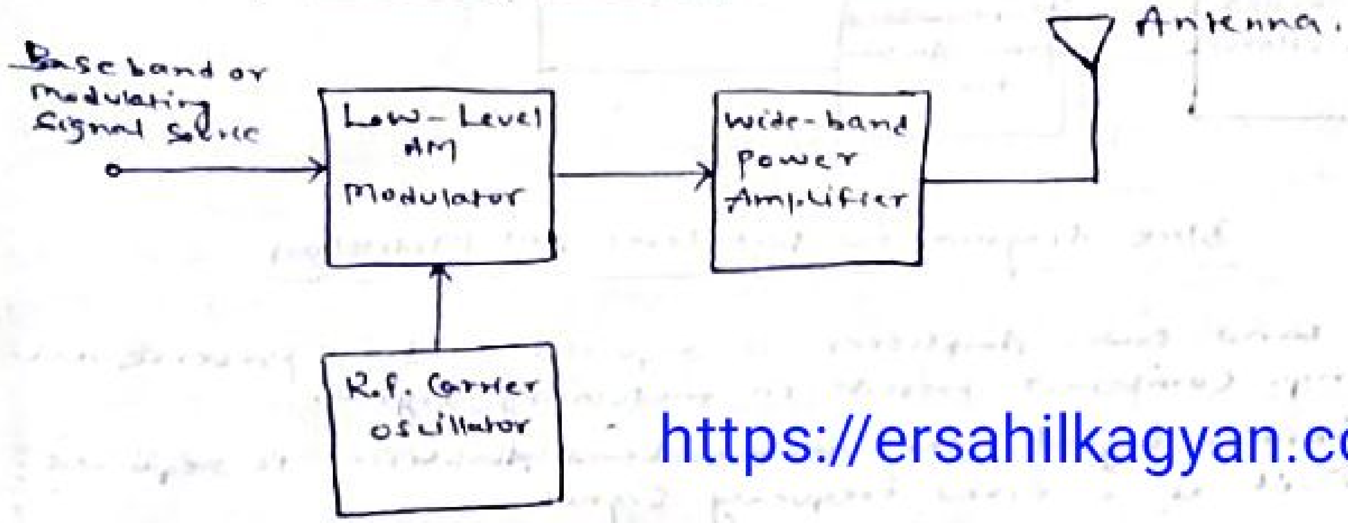
Q.4 A certain Transmitter radiates 10KW with carrier Unmodulated & 12KW, when the carrier is sinusoidally modulated. Calculate the modulation Index.
If another sinewave corresponding to 50% modulation is transmitted simultaneously, determine the total radiated power.

Generation of Amplitude Modulation (AM)

The Methods of AM Generation may be broadly Classified as follow :-

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

(i) Low- level Amplitude Modulation :-



Block diagram for Low level AM modulation

In a low-level AM modulation system the modulation is done at low power level. At low power level a very small power is associated with the carrier signal & the modulating signal. Because of the o/p power of modulation is low. Therefor the power Amplifiers are required to boost the Amplitude modulated signal upto the desired o/p level.

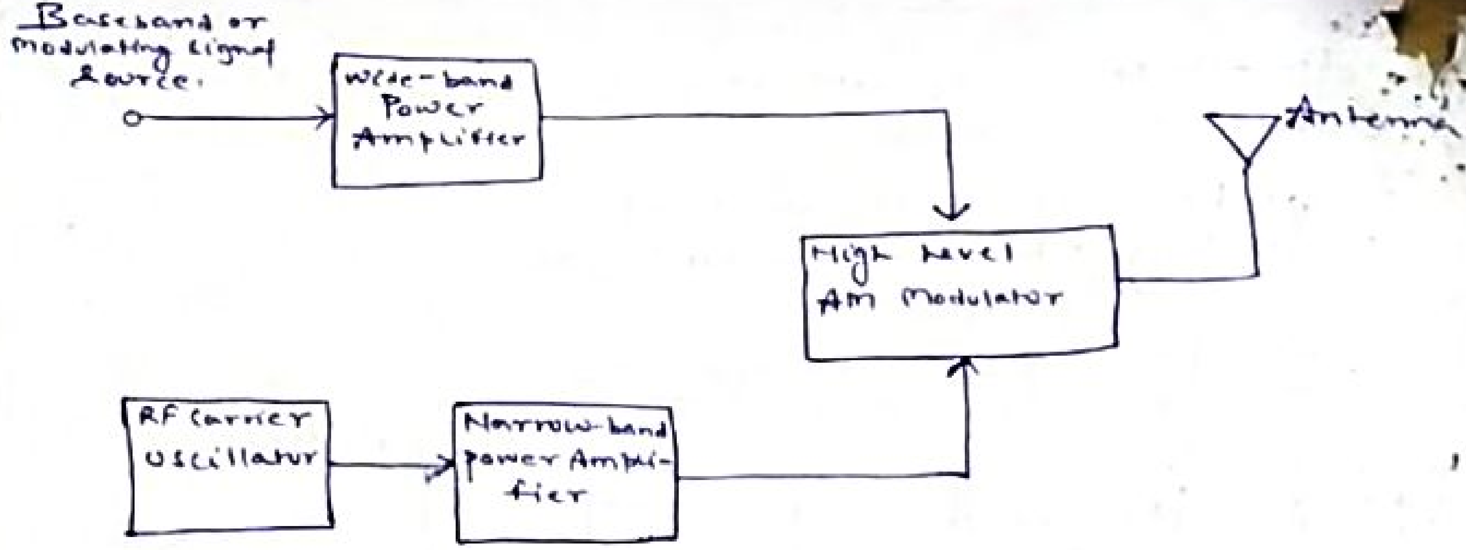
wide band power Amplifier is used to just preserve the side bands of the modulated signal.

This whole process is also called Low- level Amplitude modulation Transmitters.

Square-Law diode Modulation & Switching Modulation are examples of Low- level Modulation.

(ii) High- Level Amplitude Modulation

In a high level Amplitude modulation System, the modulation is done at high Power level.



Block diagram for high level AM Modulation

→ Wide band power Amplifier is required to just preserve all the freq. component present in modulating signal.

→ for carrier signal, the narrow-band Amplifier is required because it is a fixed frequency signal.

→ The collector modulation method is the example of high level Modulation.

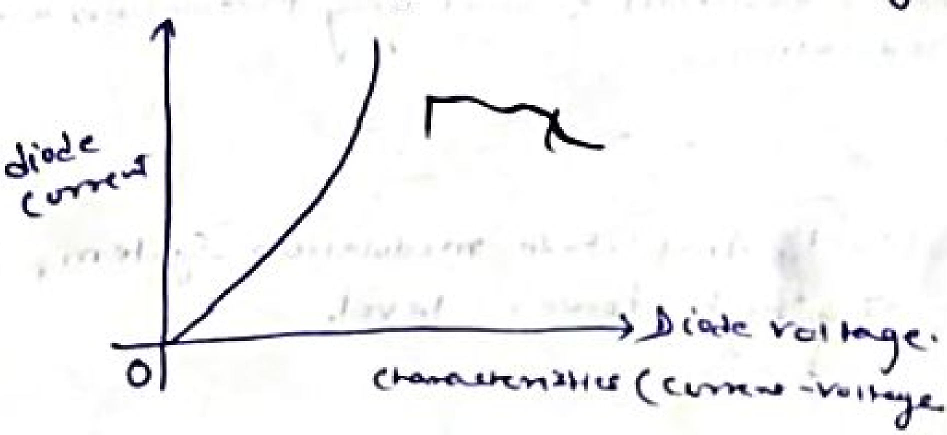
There are two Methods of Generation of AM signal

(i) Square law diode Modulation
(ii) Collector Modulation method

(i) Square Law Diode Modulation :-

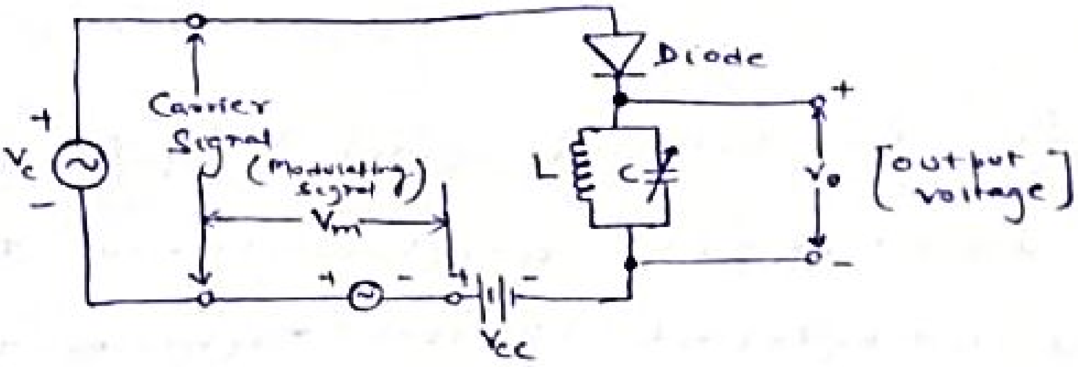
Definition

Square law diode modulation circuit make use of non-linear current-voltage characteristics of diode. This method is suited at low voltage levels because of the fact that current-voltage characteristic of a diode is highly non-linear particularly in the low voltage Region.



Characteristics (current-voltage of diode)

Circuit Diagram:-



Working operation:

Carrier & modulating signals are Applied Accross the diode. A d.c. battery is connected Accross the diode to get a fixed operating point.
When two different frequencies are passed through a non-linear device, the process of Amplitude modulation takes place.
Hence when carrier & modulating frequencies are Applied Accross the input of the diode, then different frequency term Appear at o/p of diode.
These different frequency term Applied Accross a tuned ckt, which is tuned to the carrier freq. & has a narrow bandwidth Just to pass two sidebands Along with the carrier & Reject other freq. Hence at the output of tuned ckt. carrier & two side bands are obtained i.e... AM wave is produced.

Mathematical Analysis:-

Let us consider that carrier voltage is expressed as

$$V_c = V_c \cos \omega_c t \quad \text{------ (i)}$$

ω_c = carrier freq.

Let the Modulating voltage be

$$V_m = V_m \cos \omega_m t \quad \text{------ (ii)}$$

ω_m = modulating freq.

The total a.c. voltage Across the diode is given as

$$V_s = V_c + V_m \quad \text{------ (iii)}$$

$$V_s = V_c \cos \omega_c t + V_m \cos \omega_m t \quad \text{--- (iv)}$$

The non-linear relationship between voltage & current for a diode is expressed as

$$i = a + bV_s + cV_s^2 \quad \text{------ (v)}$$

where a, b, c are constants.

i = current through diode

v_s = voltage across diode

Put the value of eq. (iv) in eq. (v).

$$i = a + bv_s + cv_s^2 = a + b(V_c\cos w_c t + V_m\cos W_m t) + c(V_c\cos w_c t + V_m\cos W_m t)^2$$

or, ~~$i = a + bV_c\cos w_c t + bV_m\cos W_m t + c(V_c\cos w_c t + V_m\cos W_m t)^2$~~

or

$$i = a + bV_c\cos w_c t + bV_m\cos W_m t + c(V_c^2\cos^2 w_c t + V_m^2\cos^2 W_m t + 2V_cV_m \cos w_c t\cos W_m t)$$

or

$$i = a + bV_c\cos w_c t + bV_m\cos W_m t + cV_c^2\cos^2 w_c t + cV_m^2\cos^2 W_m t + 2cV_cV_m \cos w_c t\cos W_m t$$

or

$$i = a + bV_c\cos w_c t + bV_m\cos W_m t + \frac{1}{2}cV_c^2(2\cos^2 w_c t) + \frac{1}{2}cV_m^2(2\cos^2 W_m t) + cV_cV_m(2\cos w_c t\cos W_m t)$$

or

$$i = a + bV_c\cos w_c t + bV_m\cos W_m t + \frac{1}{2}cV_c^2(1+\cos 2w_c t) + \frac{1}{2}cV_m^2(1+\cos 2W_m t) + cV_cV_m[\cos(w_c+W_m)t + \cos(w_c-W_m)t]$$

or

$$i = \underbrace{\left[a + \frac{1}{2}cV_c^2 + \frac{1}{2}cV_m^2\right]}_{(1)} + \underbrace{bV_c\cos w_c t}_{(2)} + \underbrace{bV_m\cos W_m t}_{(3)} + \left[\underbrace{\frac{1}{2}cV_c^2\cos 2w_c t}_{(4)} + \underbrace{\frac{1}{2}cV_m^2\cos 2W_m t}_{(5)}\right] + cV_cV_m\cos(w_c+W_m)t + \underbrace{cV_cV_m\cos(w_c-W_m)t}_{(6)} \quad \text{------ (vi)}$$

eq. (6) consists of six terms in all as follows.

(1) is d.c. term. (3) Modulating signal (5) Represents upper side band

(2) carrier signal (4) consists of harmonics of carrier & modulating signal (6) Represents lower side band

in diode modulation ckt. the load impedance is a tuned ckt, which is tuned to the carrier freq. w_c.

thus the freq. component which are actually developed in the output are terms of freq. w_c (w_c+w_m) & (w_c-w_m)

the rest of freq. components are rejected by tuned ckt.

Required expression is :-

$$i_0 = bV_c \cos w_c t + cV_c V_m \cos(w_c+w_m)t + cV_c V_m \cos(w_c-w_m)t$$

$$\text{or } i_0 = bV_c \cos w_c t + cV_c \cdot V_m[\cos(w_c+w_m)t + \cos(w_c-w_m)t]$$

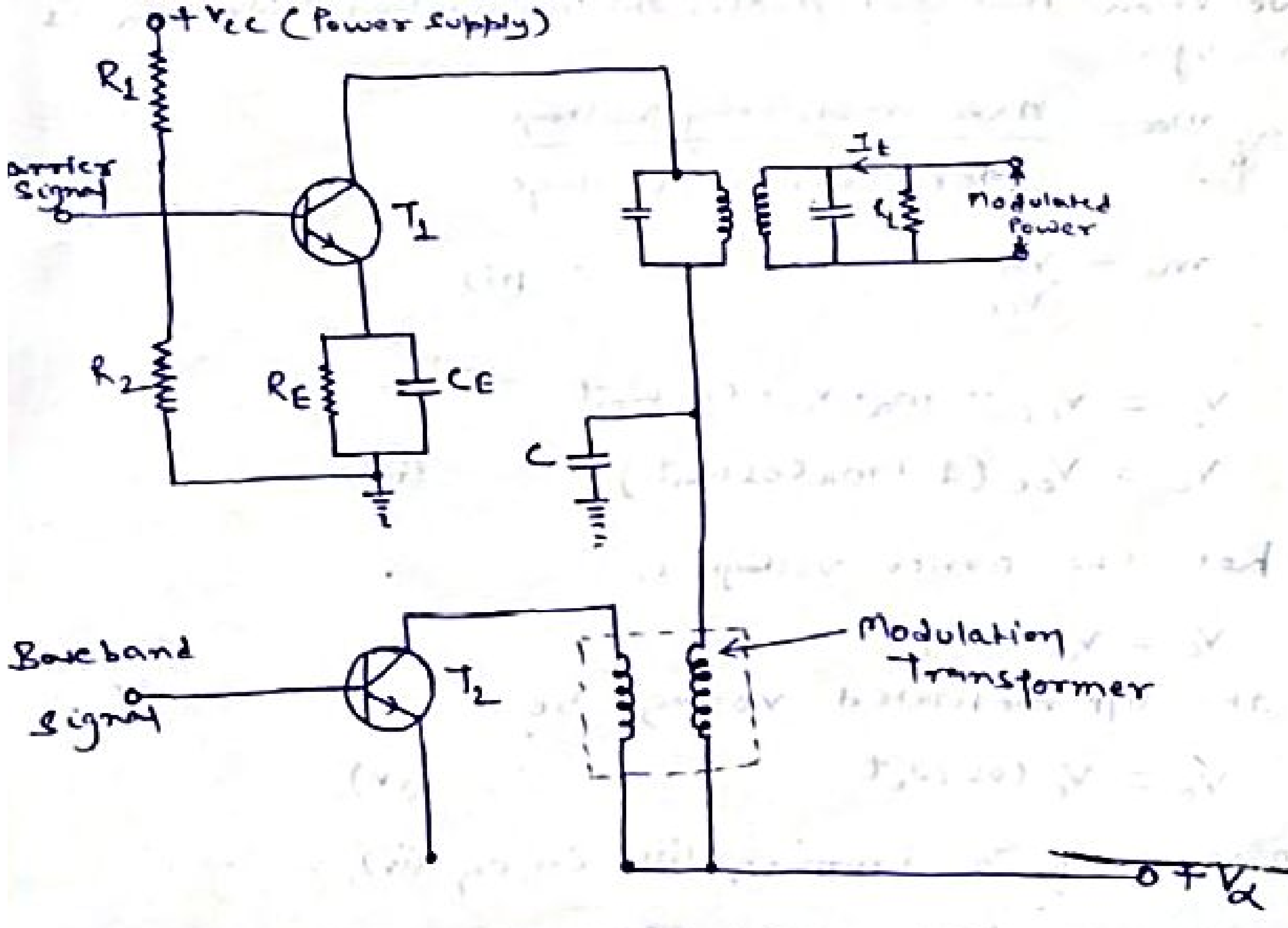
$$\text{or } i_0 = bV_c \cos w_c t + 2cV_c V_m \cos w_c t \cos w_m t$$

$$\text{or } i_0 = bV_c\left[1 + \frac{2cV_m}{b}\cos w_m t\right]\cos w_c t \quad \text{-----} \quad \left[m_a = \frac{2cV_m}{b}\right]$$

$$\text{or } \boxed{i_0 = bV_c(1 + m_a \cos w_m t)\cos w_c t} \quad \text{------} \quad (vii)$$

↳ Req. eq. for A.M. current.

Collector Modulation Method :-



The Transistor T_1 makes a radio frequency (RF) class-C Amp. At the base of T_1 the carrier signal is Applied. V_{cc} makes the collector supply used for biasing purpose. Also the transistor T_2 makes a class B Amplifier which is used to Amplify the Audio or Modulating signal.

The base band or modulating signal Appears Accross the modulation transformer After Amplification.

The function of the Capacitor C is to offer low impedance path for high-freq. carrier signal & hence the carrier signal is prevented from flowing through the modulation transformer.

Operating Principle:- (self)

Mathematical Analysis:-

The slowly changing carrier supply voltage V_c may be expressed as:-

$$V_c = V_{cc} + V_m$$

or,

$$V_c = V_{cc} + V_m \cos w_m t \quad \text{------} \quad (i)$$

But we know that for A.M., the modulation Index ma is given by

$$m_a = \frac{\text{Max. modulating Voltage}}{\text{Max. Carrier Voltage}}$$

$$m_a = \frac{V_m}{V_{cc}} \quad \text{------} \quad (ii)$$

$$\therefore \quad V_c = V_{cc} + m_a \cdot V_{cc} \cdot \cos w_m t$$

$$V_c = V_{cc}(1 + m_a \cos w_m t) \quad \text{----} \quad (iii)$$

Let the carrier voltage be

$$V_c = V_{cc} \cos \omega_c t$$

Then the o/p modulated voltage be -

$$V_o \pm V_c \cos \omega_c t \quad \text{------} \quad (iv)$$

Put the value of V_c from eq. (iii) in eq. (iv), we get.

$$\boxed{V_o = V_{cc}(1 + m_a \cos w_m t) \cos w_c t} \quad \text{—} \quad (v)$$

Required eq. for AM wave.

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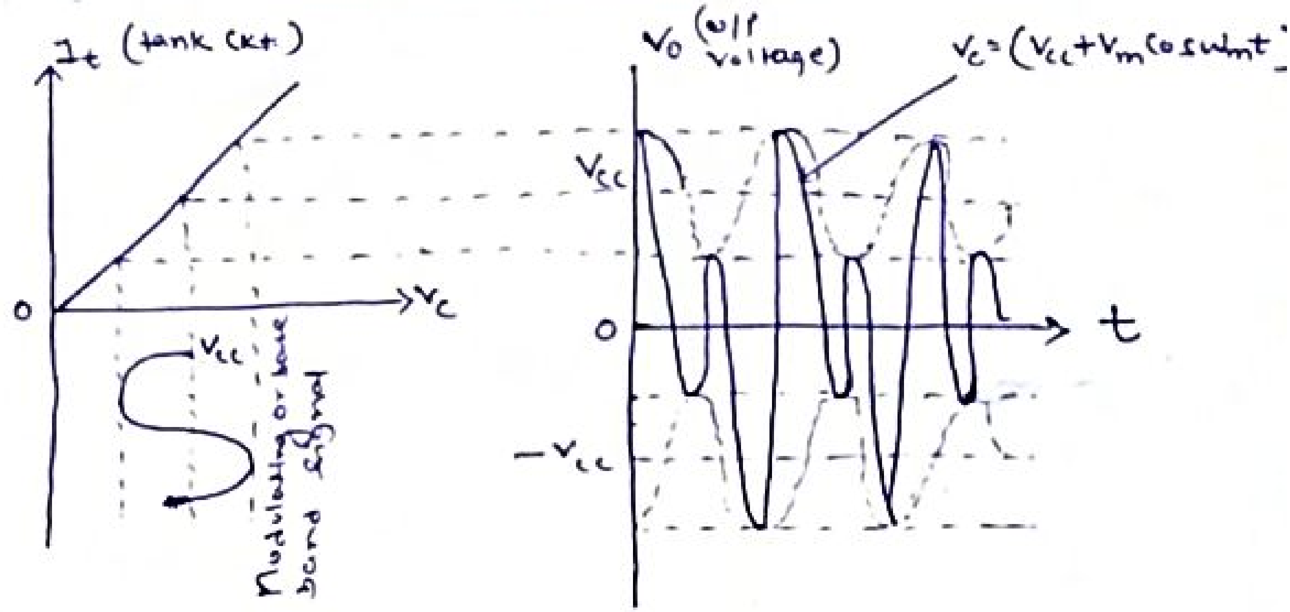
Operating Principle of Collector Modulation Method.



In class C Amplifier, the magnitude of the output voltage is a definite fraction of or at the must equal to the supply volt V_{cc}. A linear Relationship exist between the o/p tank Current I_t & the varriable supply voltage V_c.

This means that in class C- Amplifier, the o/p voltage is an exact Replica of the input voltage waveform & the magnitude of the output voltage will be approx. equal to the carr supply voltage V_{cc}. Now if R is the Resistance of the o/p tank circuit at resonance, then the magnitude of the o/p voltage is given as

$$RI_t \cong V_{cc}$$

The unmodulated carrier is Amplified by class-C modulated Amplifier using transistor T_1 & its magnitude will remain constant at V_{cc} & no voltage Appears Accross the modulating Transformer in the Absence of base band or modulating voltage. But now if a base band or modulating voltage $V_m = V_m \cos w_m t$ Appears Accross the ~~modulating~~ Transformer, this signal be Added to the carrier supply voltage V_{cc}. This Results in a Quite slow variation in carrier supply voltage V_{cc}. This type of slow varriation is carrier supply voltage changes the magnitude of the carrier signal voltage. at the output the modulated class-C Amplifier.

Questions:-

Q. The Antenna current of an AM transmitter is 8A if only the carrier is sent but it increases to 8.93 A. If the carrier is modulated by a single sinusodial wave. Determine the percentage modulation. Also find the Antenna current if the percent of modulation changes to 0.8.

(i) $I_t = I_c\sqrt{1+\frac{m_a^2}{2}}$ $\Rightarrow$ $\left(\frac{I_t}{I_c}\right)^2 = 1+\frac{m_a^2}{2}$ $\Rightarrow$ $\frac{m_a^2}{2} = \left[\left(\frac{I_t}{I_c}\right)-1\right]$ $\Rightarrow$ $m_a^2 = 2\left[\left(\frac{I_t}{I_c}\right)^2-1\right]$

$m_a = \sqrt{2\left[\left(\frac{I_t}{I_c}\right)^2-1\right]}$

$= \sqrt{2\left(\frac{8.93}{8}\right)-1} = 70.1$

DEMODULATION OF AM WAVES:-

The Process of extracting a modulating or baseband signal from the modulated signal is called demodulation or detection.

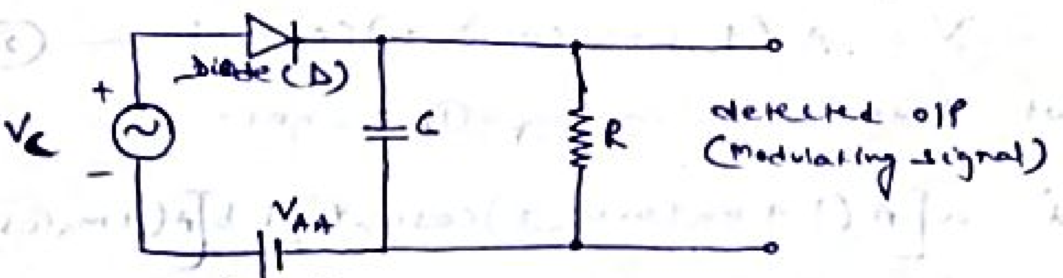
Types:- for A.M, there are two types:-

(i) Square - Law detectors. (for low level Amplitude modulated signal)

(ii) envelope detectors. (for large carriers)

(i) Square - Law - detector:-

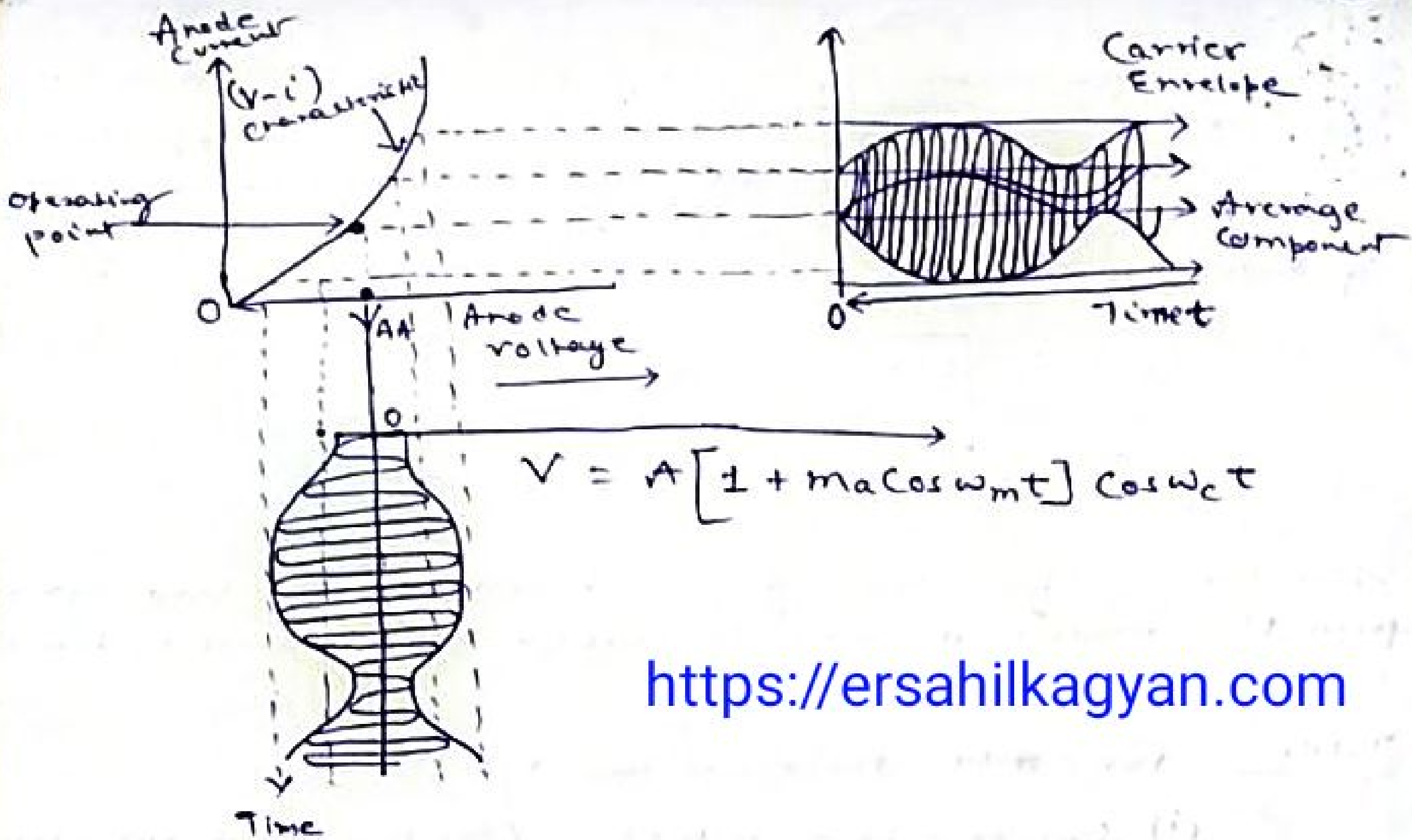
used for detecting modulated signal of small magnitude (below 1 volt.)



Basic ckt. of Square law diode detector

This ckt. is very similar to the square - Law - ~~detector~~ modulator. The only difference lies in the filter ckt. In a square law modulator, the filter used is band pass filter, where as in detector a low pass filter is used.

In ckt the d.c. supply voltage V_{AA} is used to get fixed operating point in the non-linear portion of the diode V-I characteristics. since the operation is limited to the non-linear region of the diode characteristics, the lower half portion of the modulated waveform is compressed.



The distorted o/p diode current is expressed by the non-linear V-I relationship as,

$$i = av + bv^2 \quad \text{——— (i)}$$

Here v is the input modulated voltage.

AM is expressed as.

$$V = A(1 + m_a \cos \omega_m t)\cos \omega_c t \quad \text{—— (2)},$$

Put this value in eq. (1), we get.

$$i = a\left[A(1 + m_a \cos \omega_m t)\cos \omega_c t\right] + b\left[A(1 + m_a \cos \omega_m t)\cos \omega_c t\right]$$

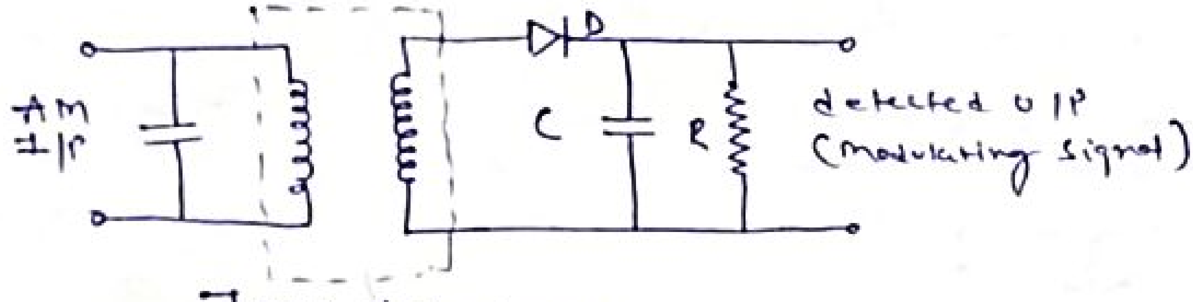
By expanding above expression, we may observe —— (3) presence of terms of frequencies like, $2\omega_c$, ω_m, $2\omega_m$, $2(\omega_c \pm \omega_m)$ etc.

Hence this diode current i containing all these freq. terms is passed through a low pass filter, which allows to pass below or up to modulating freq. ω_m & reject the other higher freq. components & hence modulating or baseband signal ω_m is recovered from modulated signal.

(ii) Linear Diode or Envelope detector

A diode operating in a linear Region of its V-I characteristics can extract the envelope of an AM wave. This type of detector is known as envelope detector or a linear detector.

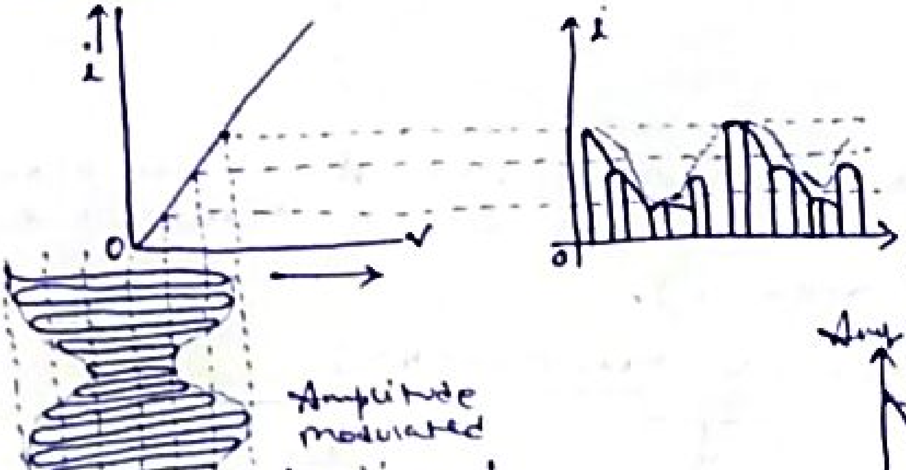
- most popular
- very simple
- less expensive



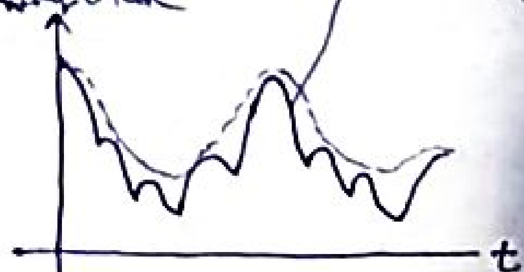
Tuned Transformer

In the input portion of the circuit, the tuned transformed provides perfect tuning at the desired carrier frequency. R-C network is the time constant network. If the magnitude of the modulating signal at the input of the detector is 1 volt or more, the operation takes place in the linear portion of the V-I characteristics of diode.

Waveforms



(b) Characteristics of linear diode detector.



(B) detected output

Operating Principle:-

first of All let us Assume that the capacitor is absent in the ckt. In this case the detector ckt. will work as half-wave rectifier. therefor the output waveform would be a half rectified modulated signal.

Let us now consider that the capacitor is introduced in the ckt. for the positive half cycle, the diode conducts & the capacitor is charged to the peak value of the carrier voltage. for a negative half cycle, the diode is reverse biased & does not conducts.

This means that the input carrier voltage is disconnected from the R-C circuit therefore the capacitor starts discharging through the Resistance R with a time constant $\tau = RC$.

If the time constant $\tau = RC$ suitably chosen, the voltage Across the capacitor C will not fall Appreciably during the small period of negative half-cycle & by that time the next positive cycle Appears.

This positive cycle Again charges the capacitor C to the peak value of the carrier voltage & thus this process repeats Again & Again.

* Spikes. (due to charging & discharging of C)
(Voltage Across C is a spiky modulated or sawtooth

OTHER TYPES OF AM

Till Now we have discussed the Amplitude Modulation AM. It is Also called as the Double sideband full carrier system (DSB-FC).

Amplitude Modulation (AM)

- DSB-FC
- DSB-SC
- SSB-SC
- ISB (Independent Side band System)
- VSB

Disadvantages of DSB-FC (Standard AM)

(i) Power wastage takes place in DSB-FC transmission.
(ii) DSB-FC system is bandwidth inefficient system.
(iii) AM gets Affected due to Noise.

INTRODUCTION TO DOUBLE SIDEBAND SUPPRESSED CARRIER (DSB-SC) SYSTEM

Definition & Mathematical Expression:-

The equation of AM wave in its simplest form is

$$s(t) = A\cos\omega_c t + A\cdot\frac{m_a}{2}\cos(\omega_c+\omega_m)t + A\cdot\frac{m_a}{2}\cos(\omega_c-\omega_m)t. \quad \text{------(i)}$$

from Above equation, it is obvious that the carrier component in AM wave remains constant in Amplitude frequency. This means that the carrier of Amplitude Modulated wave does not convey any information.

In power calculation of AM signal, it has been observed that for single-tone sinusodial modulation, the ratio of the total power to the carrier power is $\left[1+\frac{m_a^2}{2}\right]$, m_a being the modulation index.

Thus for 100 % modulation About 67% of the total power is required for transmitting the carrier which does not contain any information.

Hence ~~the carrier~~ if the carrier is suppressed, only the sidebands remains and in this way a saving of two ~~third~~ third power may be achieved at 100% modulation. This type of Suppression of carrier does not affect the baseband signal in any way. The resulting signal obtained by suppressing the carrier from the modulated wave is called Double Sideband Suppressed Carrier (DSB-SC) system.

So in double side band suppressed carrier modulation, there is no carrier signal only sidebands are present.

from frequency-shifting property of ~~of~~ fourier Transform

If $x(t) \longleftrightarrow X(\omega)$

$$e^{j\omega_c t} x(t) \longleftrightarrow X(\omega - \omega_c) \quad \text{———} \quad (2)$$

Similarly

$$e^{-j\omega_c t} x(t) \longleftrightarrow X(\omega + \omega_c)$$

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

Hence,

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

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

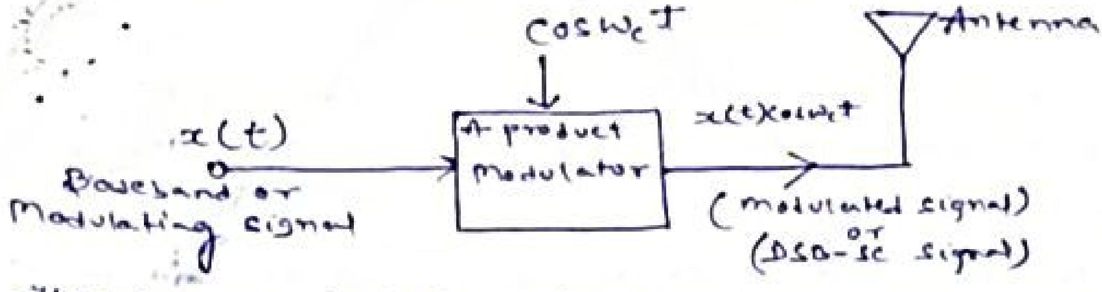
This means that the multiplication of a signal $x(t)$ by a sinusoid of frequency ω_c shifts the spectrum by $\pm \omega_c$. Now, if $x(t)$ is taken as modulating or baseband signal & $\cos \omega_c t$ is taken as carrier signal then $x(t) \cos \omega_c t$ represent the modulated signal, further the fourier transform of this modulated signal is given by the equation ~~eq~~ (2).

This equation shows that the spectrum of modulated signal contain only shifted spectrum of signal & there is no carrier component.

This means that the term

$x(t) \cos \omega_c t$ represent a DSB-SC signal.

Block diagram



Therefore a DSB-SC signal is obtained by simply multiplying modulating signal $x(t)$ with carrier signal $\cos w_c t$. This is achieved by a product modulator.

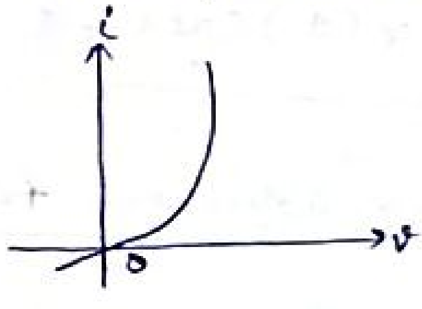
Generation of DSB-SC Signal

Two types of Modulator are there:-

1. Balanced Modulator.
2. Ring modulator

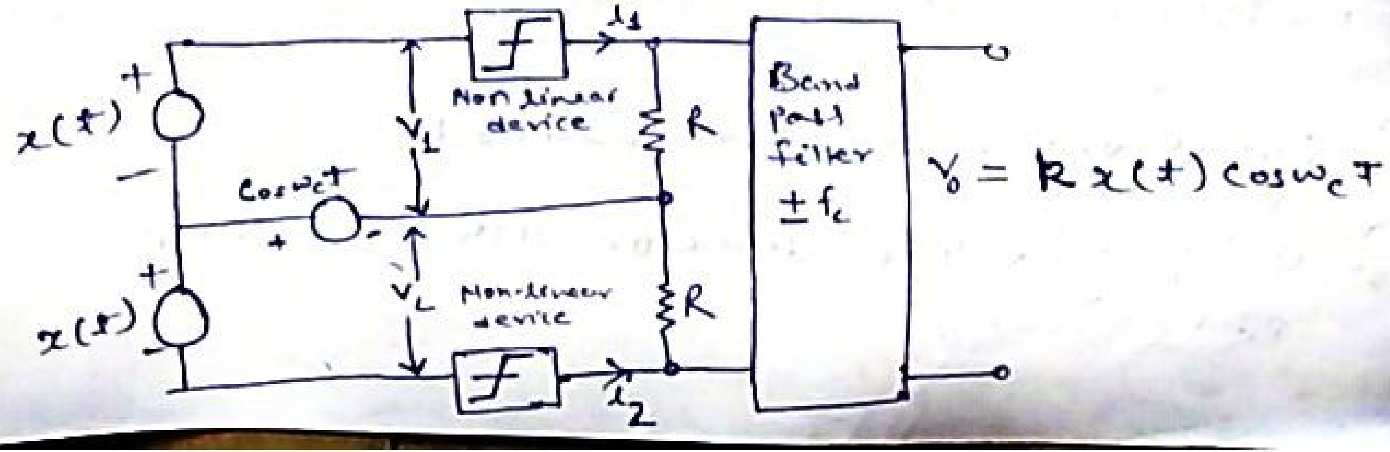
(1) Balanced Modulator (Using Non-linear devices)

The modulation can also be achieved by using the non-linear devices. A semiconductor diode is a good Example of a non-linear device, ~~characteristics~~



$$i = av + bv^2$$

a & b are constants.



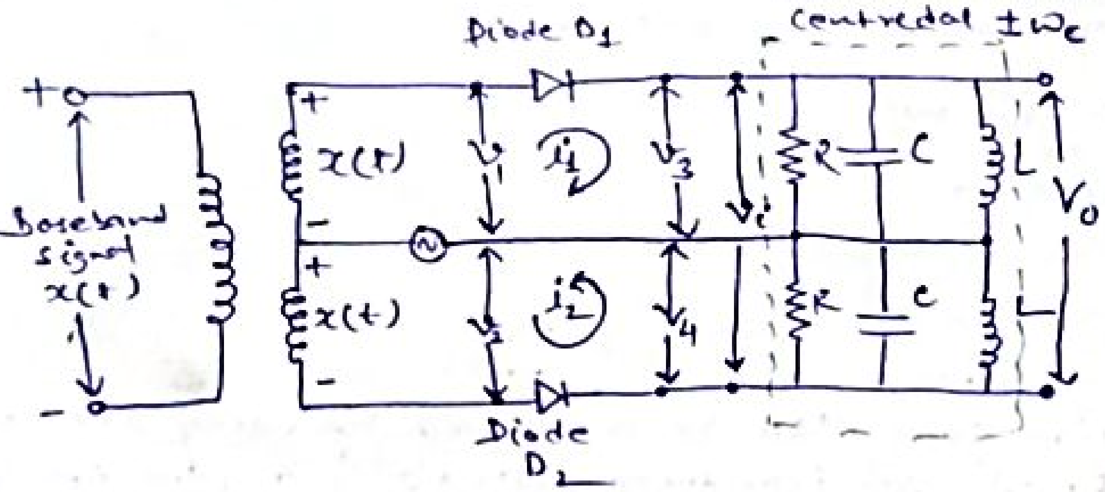
Such arrangement is called as balanced modulator. (44)

The Balanced Modulator using Diodes:-

A Non-linear resistance or a non-linear device may used to produce Amplitude modulation i.e. one carrier & two sidebands.

However a DSB-SC signal contains only two sidebands.

If two non-linear devices such as diodes, transistors etc. are connected in a balanced mode so as to suppress the carriers of each other, then only sidebands are left. & that is DSB-SC signal.



$$\boxed{V_0 = K x(t) \cos \omega_c t}$$

Required Expression for DSB-SC