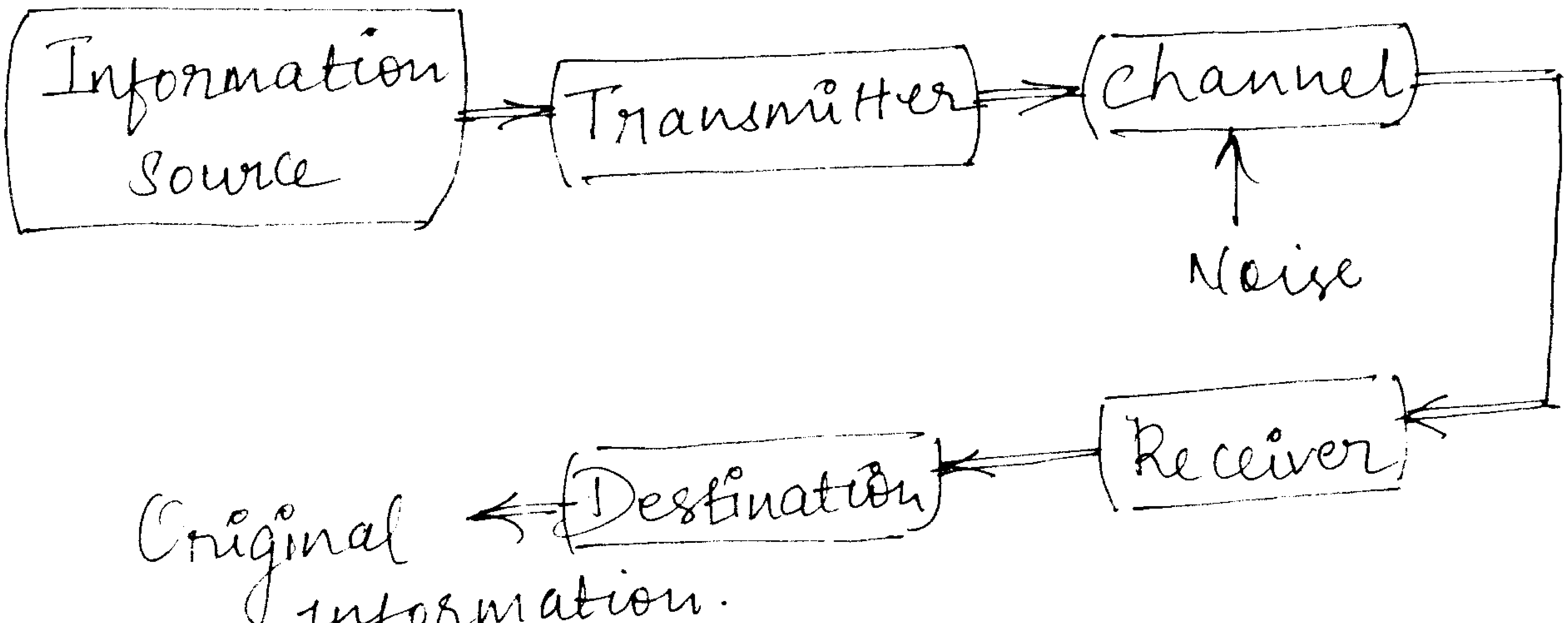
INTRODUCTION:

Communication : It is the process of conveying or transfering message from one point to another. The information may be sound, picture, music, computer data etc.

Various stages of communication Systems:



i) Modulating Signal : The signal containing information or intelligence to be transmitted is known as modulating signal. Otherwise known as message or base band signal.

ii) Carrier Signal : It is the high frequency signal to carry the message signal.

iii) Modulated signal : The signal resulting from the process of modulation.

iv). Demodulated Signal : Signal resulting from the process of demodulation.

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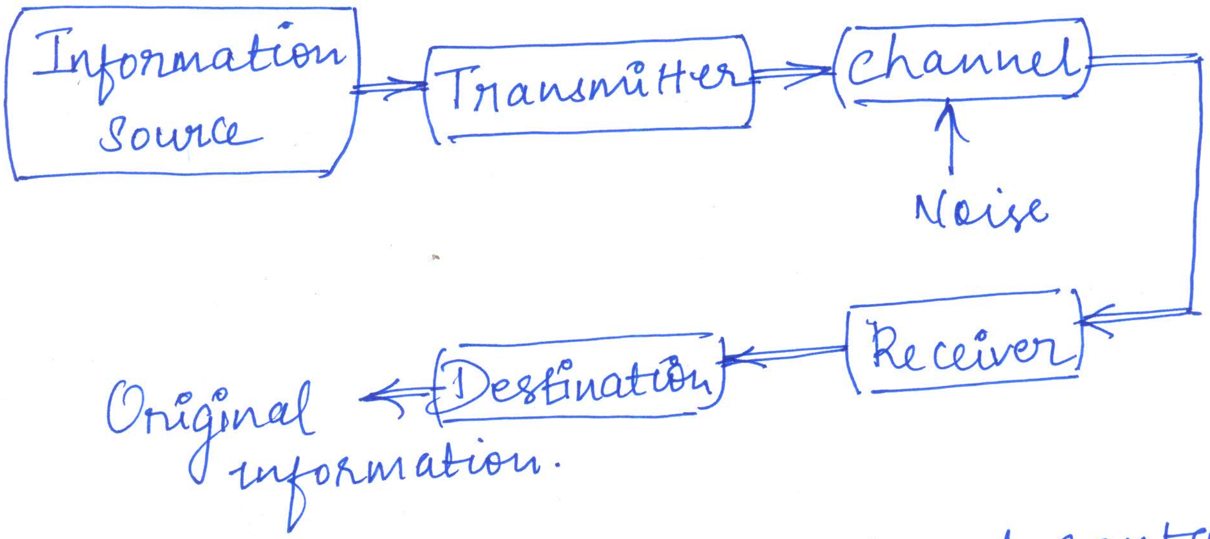

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iii) Modulated signal : The signal resulting from the process of modulation.

iv). Demodulated signal : signal resulting from the process of demodulation.

Modulation: It is the process by which some characteristics of high frequency carrier is varied inaccordance with the instantaneous value of message signal.

Demodulation or Detection:

Reverse process of modulation.

It is the process by which the modulating voltage is recovered from the modulated signal.

Types of Communication Systems (or) types of Modulation Systems:

Modulation or Communication Systems.

- Analog
  - Continuous wave modulation
    - AM
    - FM
    - PM.
  - Pulse modulation.
    - PAM
    - PPM
    - PWM.
- Digital.
  - PCM
  - DM.

CHANNEL BANDWIDTH: It is used to describe the range of frequencies required to transmit the desired information.

Need for Modulation:

Easy transmission
Narrow Banding
Multiplexing
To overcome equipment limitation.
Reduce noise & interference.
Improves quality of reception.

AMPLITUDE MODULATION

Def: It is the process by which the amplitude of the carrier is changed in accordance with the amplitude of the modulating signal. Frequency & phase of the carrier are not varied.

Mathematical Representation:

i) Time domain analysis:

Let the modulating signal be

$$V_m(t) = V_m \sin \omega_m t \quad \text{——} \ (1)$$

Let the carrier signal be

$$V_c(t) = V_c \sin \omega_c t \quad \text{——} \ (2)$$

Where, v_m - Peak amplitude of message,
v_c - " " " carrier,
ω_m - angular frequency of message,
ω_c - " " " carrier.

According to the definition, the amplitude of carrier is changed after modulation,

$$\therefore \quad V_{am} = v_c + v_m(t).$$

$$= v_c + v_m \sin\omega_m t.$$

$$= v_c \left[1 + \frac{v_m}{v_c} \sin\omega_m t\right].$$

$$= v_c \left[1 + m_a \sin\omega_m t\right] \text{ --- } (3)$$

$$\therefore \quad m_a = \frac{v_m}{v_c} \rightarrow$$ Modulation index
or
Depth of modulation.
or
Coefficient of modulation.

Instantaneous amplitude Modulated wave be,

$$V_{AM}(t) = v_{am} \sin\omega_c t.$$

$$= v_c \left[1 + m_a \sin\omega_m t\right] \sin\omega_c t. \text{ --- } (4)$$

ii) Frequency domain Analysis.

Frequency Spectrum is the representation of a signal in the frequency domain. It consists of amplitude and phase spectrums of the signal. i.e. It indicates the amplitude and phase of various frequency components present in the signal.

WKT, $V_{AM}(t) = V_c \sin w_c t \, (1 + m_a \sin w_m t)$.

$= V_c \sin w_c t + m_a V_c \sin w_c t \sin w_m t$.

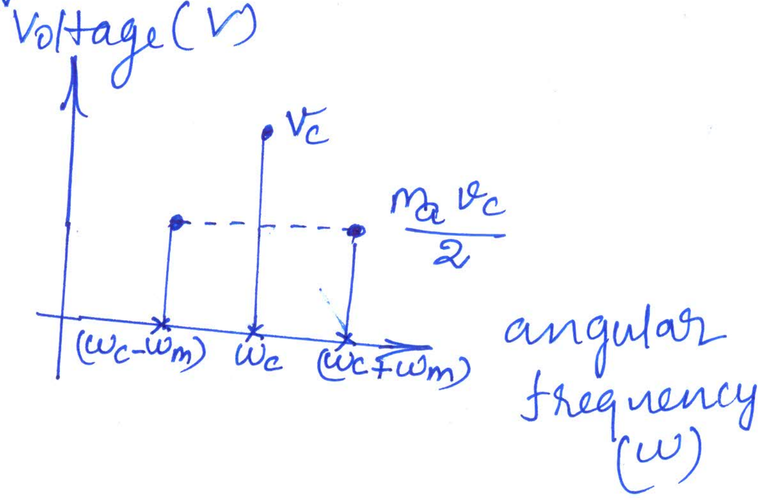
$= V_c \sin w_c t + \frac{m_a V_c}{2} \left[\cos(w_c - w_m)t - \cos(w_c + w_m)t \right]$

$\because \sin A \sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$.

$= \underbrace{V_c \sin w_c t}_{\text{Carrier}} + \underbrace{\frac{m_a V_c}{2} \cos(w_c - w_m)t}_{\text{LSB}} - \underbrace{\frac{m_a V_c}{2} \left[\cos(w_c + w_m) t \right]}_{\text{USB}}$

Carrier + LSB − USB

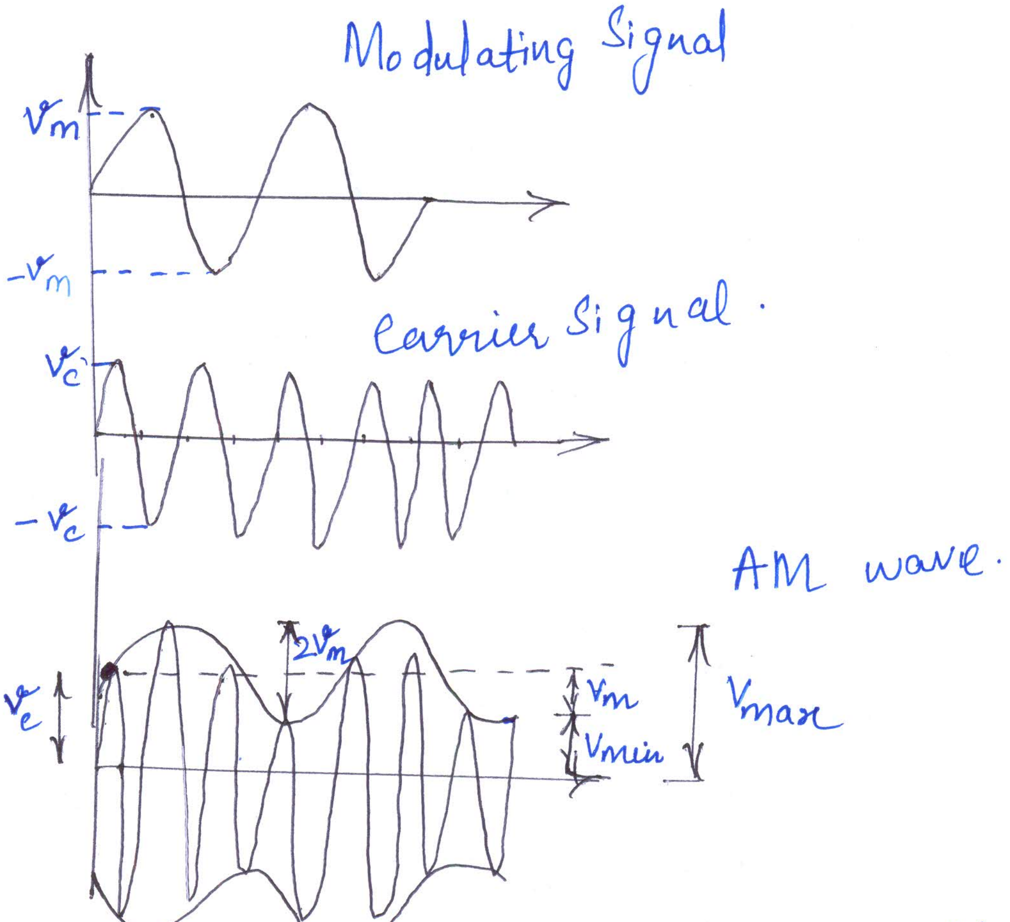
frequency Spectrum:-



Bandwidth: It is defined as the frequency range over which an information signal is transmitted.
∴ It is the difference between the upper and lower frequency limits of the signal.

$$BW = f_H - f_L \quad \text{or} \quad \omega_H - \omega_L.$$
$$= 2f_m \quad \text{or} \quad 2\omega_m.$$

Graphical Representation:



From the diagram, $* \; 2V_m = V_{max} - V_{min}$

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

$$* \; V_c = V_m + V_{min}$$
$$= \frac{V_{max} + V_{min}}{2}$$

$$\boxed{* \; m_a = \frac{V_m}{V_c} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

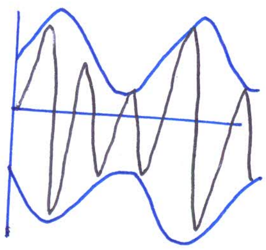
Degrees of modulation :-

Under Modulation

$m_a < 1$

$V_m < V_c$

Envelope of AM wave doesnot reach zero amplitude axis. Hence message is fully preserved.

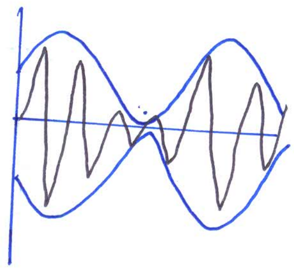


Critical modulation

$m_a = 1$

$V_m = V_c$

Envelope of AM just reaches the zero amp. axis.

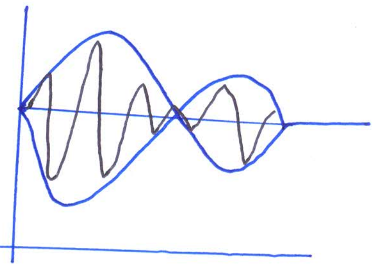


Over modulation

$m_a > 1$

$V_m > V_c$

Envelope of AM ~~jus~~ crosses zero axis. So positive & negative extensions are cancelled.



POWER CALCULATION OF AM :-

* Total Power $P_t = P_c + P_{LSB} + P_{USB}$.

i) $P_c = \dfrac{V_c^2}{2R}$

ii) $P_{LSB} = \dfrac{V_{LSB}^2}{R}$

$= \dfrac{\left(\dfrac{m_a V_c}{2\sqrt{2}}\right)^2}{R} = \dfrac{m_a^2 V_c^2}{8R}$

iii) $P_{USB} = \dfrac{V_{USB}^2}{R} = \dfrac{m_a^2 V_c^2}{8R}$.

$P = \dfrac{V^2}{R}$

$V \rightarrow V/\sqrt{2}$

$P = \dfrac{V^2}{2R}$

$$\therefore P_t = \frac{V_c^2}{2R} + \frac{m_a^2 V_c^2}{8R} + \frac{m_a^2 V_c^2}{8R}.$$

$$= \frac{V_c^2}{2R}\left[1 + \frac{m_a^2}{2}\right]$$

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

For 100% modulation, Put $m_a = 1$

$$\boxed{\therefore P_t = 1.5\, P_c}.$$

CURRENT RELATION:

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

$$I_t^2 \cdot R = I_c^2 \cdot R\left[1 + \frac{m_a^2}{2}\right]$$

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

EFFICIENCY: defined as the ratio of Power in sidebands to total power because sidebands only contain useful information

$$\% \eta = \frac{P_{SB}}{P_t} \times 100$$

$$P_{SB} = P_{LSB} + P_{USB} = \frac{2 m_a^2 V_c^2}{8R} = \frac{m_a^2 V_c^2}{4R}$$

$$= \frac{P_{SB}}{P_t} = \frac{\frac{m_a^2 V_c^2}{4R}}{P_c\left[1+\frac{m_a^2}{2}\right]}$$

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

$$= \frac{m_a^2/2}{(2+m_a^2)/2} = \frac{m_a^2}{2+m_a^2}.$$

Put $m_a = 1$, [illegible] $= \frac{1}{3} \times 100$

$= 33.33\ \%$.

Only 33.33% of energy is used, remaining Power is wasted by carrier transmission along with sidebands.

Modulation by Several Sine Waves:

Let $V_1, V_2, V_3 \ldots$ be modulating voltages, then total modulating voltage be equal to square root of sum of square of individual voltages.

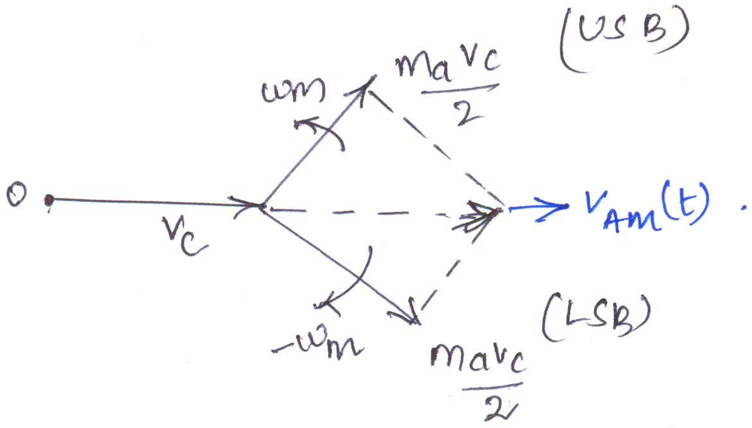
$$V_t = \sqrt{V_1^2 + V_2^2 + V_3^2 + \ldots}$$

$$\div V_c, \quad \frac{V_t}{V_c} = \sqrt{\frac{V_1^2}{V_c^2} + \frac{V_2^2}{V_c^2} + \frac{V_3^2}{V_c^2} + \ldots}$$

$$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + \ldots}$$

AM Envelope: The shape of the modulated signal is defined as AM envelope, because it contains all frequencies that make up the AM signal and is used to communicate the information through the system.

Phasor Representation of AM.



It is the way of representation of AM where v_c is the carrier wave phasor taken as reference phasor. Two sidebands are represented by two phasors rotating in opposite direction. $(\omega_c + \omega m)$ & $(\omega_c - \omega m)$.

DOUBLE SIDEBAND SUPPRESSED CARRIER AM:-
(DSB-SC-AM).

In order to save the power in AM, the carrier may be suppressed. → DSB-SC-AM.

∴ Let the modulating signal be

$$V_m(t) = V_m \sin \omega_m t \quad —①$$

Let the carrier signal be

$$V_c(t) = V_c \sin \omega_c t \quad —②.$$

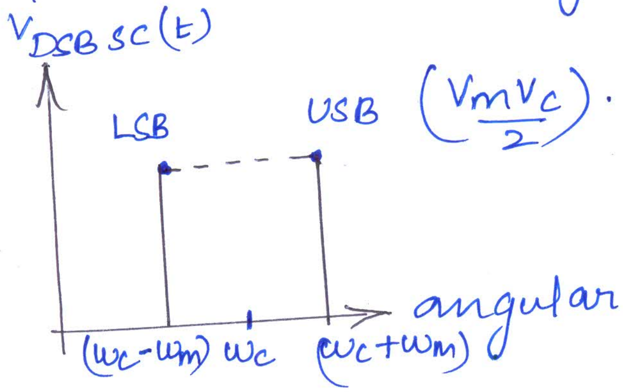
When multiplying ① & ②, the resultant signal is DSB-SC-AM.

$$V(t)_{DSB\text{-}SC} = V_m(t) \cdot V_c(t).$$

$$= V_m V_c \sin \omega_m t \cdot \sin \omega_c t.$$

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

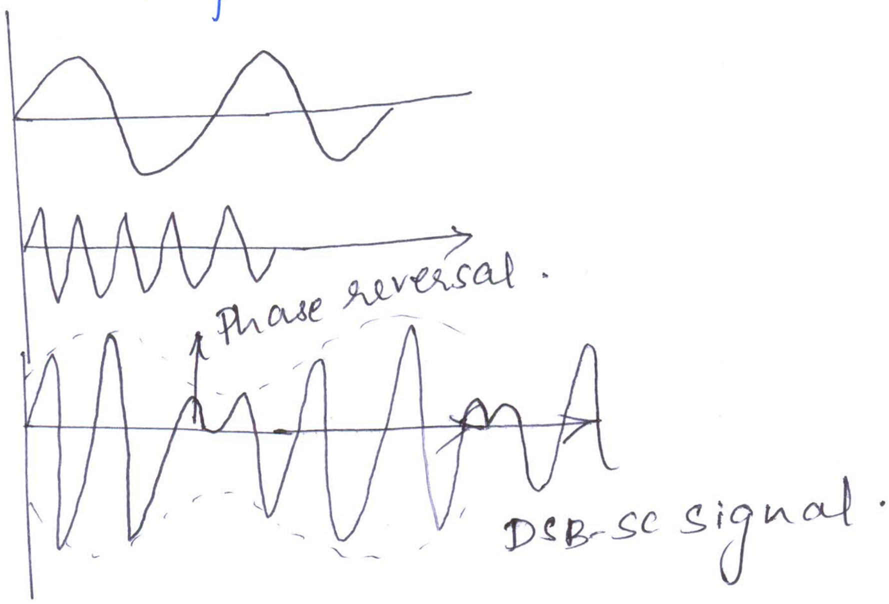
∴ The product of $V_m(t)$ & $V_c(t)$ produces the DSB-SC-AM signal thus, we require product modulator to generate this signal.



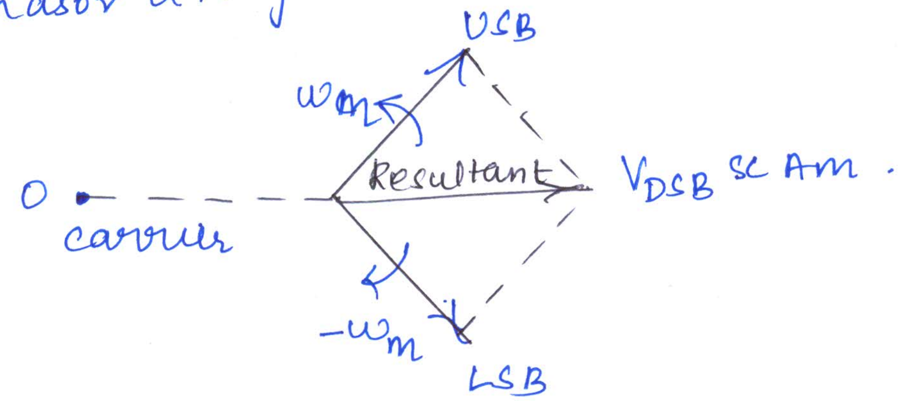
<u>Freq Spectrum</u>

$BW = 2\omega_m$.
or
$2f_m$.

Graphical Representation.



Phasor diagram.



Power Calculation:

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

Where $P_t' \rightarrow$ total power transmitted of DSB-SC wave,

$$P_t' = \frac{m_a^2}{2}\left[\frac{V_c^2}{2R}\right] = \frac{m_a^2 P_c}{2}$$

$$\text{Power Saving} = \frac{P_t - P_t'}{P_t}$$

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

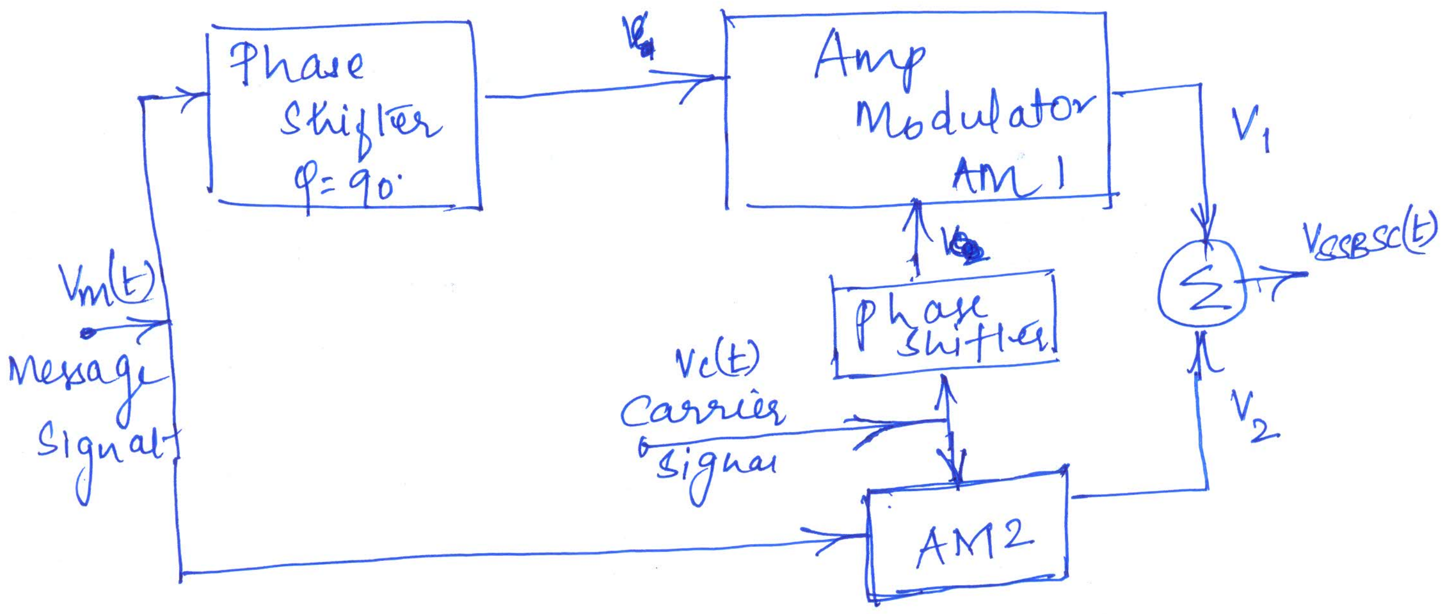
$$= \frac{2}{2+m_a^2}, \text{ put } m_a = 1,$$

$$PS = \frac{2}{3} \times 100 = 66.7\%.$$

Due to the suppression of the carrier wave, the power saving is increasing from 33.3% to 66.7%.

SINGLE SIDE BAND SUPPRESSED CARRIER AM (SSB-SC-AM)

Further increase in the saving of power is possible by eliminating one side band in addition to the carrier component, because USB, LSB are uniquely related by symmetry about the carrier frequency. Transmission bandwidth can be cut into half, if one side band is suppressed along with the carrier.



AM 1 → Product modulator.

$$V_1 = V_m \sin(\omega_m t + 90^\circ) \cdot V_c \sin(\omega_c t + 90^\circ)$$

$$= V_m \cos \omega_m t \cdot V_c \cos \omega_c t \quad \text{— (1)}$$

AM 2

$$V_2 = V_m \sin \omega_m t \cdot V_c \sin \omega_c t \quad \text{— (2)}$$

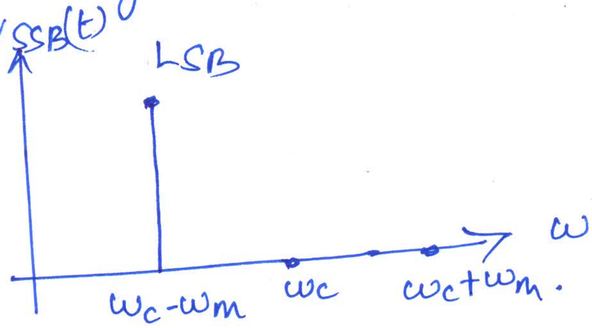
$$V_{SSB}(t) = V_1 + V_2 = V_m \cos \omega_m t \, V_c \cos \omega_c t + V_m \sin \omega_m t \sin \omega_c t$$

$$= V_m V_c \left[\sin \omega_c t \sin \omega_m t + \cos \omega_c t \cos \omega_m t \right]$$

$$\boxed{\sin A \sin B + \cos A \cos B = \frac{\cos(A-B)}{2}}$$

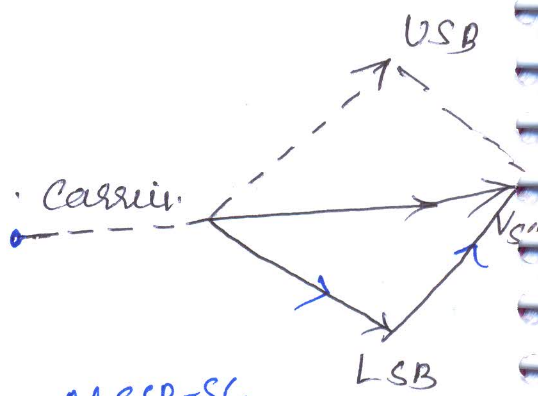
$$\therefore V_{SSB}(t) = \frac{V_m V_c}{2} \cos(\omega_c - \omega_m)t \quad \rightarrow \text{only LSB.}$$

frequency Spectrum:

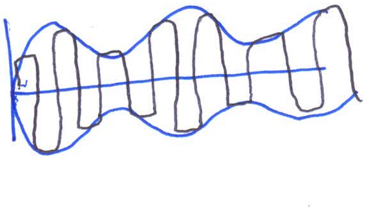


$$\boxed{BW = \omega_m}$$

Phasor diagram



waveform of SSB-SC



Power Calculation:

$$P_t'' = P_{LSB} = \frac{m_a^2 V_c^2}{8R}.$$

$$= \frac{m_a^2 P_c}{4}.$$

Power saving w.r. to AM with carrier,

$$P.S = \frac{P_t - P_t''}{P_t}$$

$$= \frac{4 + m_a^2}{4 + 2m_a^2} = \frac{5}{6} = 83.3\%$$

$(\because m_a = 1).$

Power Saving w.r. to DSB-SC-AM,

$$P_S = \frac{P_t' - P_t''}{P_t'}$$

$$= \frac{m_a^2 P_c/4}{m_a^2 P_c/2}$$

$$= 1/2 \times 100$$

$$= 50\%$$

VESTIGIAL SIDE BAND AM (VSB-AM)

To suppress only the part of the lower side band, thus radiated signal consists of full USB, together with carrier and vestige of the LSB. This type of modulation is known as VSB modulation.

ANGLE MODULATION (FM & PM)

or

EXPONENTIAL MODULATION.

It is the process by which angle of the carrier signal is changed inaccordance with the instantaneous amplitude of the message. Amplitude remains constant.

FREQUENCY MODULATION:

It can be defined as the process by which the frequency of the carrier is altered inaccordance with the inst. amplitude of the message.

Let the message be $v_m(t) = v_m \cos \omega_m t$ — ①

" " carrier " $v_c(t) = v_c \sin(\omega_c t + \theta)$

$\varphi = \omega_c t + \theta$

↳ phase. $v_c(t) = v_c \sin \varphi$ — ②

$\therefore \dfrac{d\varphi}{dt} = \omega_c$ — (3)

According to def, the frequency of the carrier is changed w.r.to amplitude,

After modulation,

frequency of signal be

$$\omega_i = \omega_c + kV_m(t)$$

$$= \omega_c + \underbrace{kV_m}_{\text{freq. deviation}} \cos\omega_m t$$

$$\varphi_i = \int \omega_i \, dt$$

$$= \int (\omega_c + kV_m \cos\omega_m t)\, dt$$

$$= \omega_c t + \frac{kV_m}{\omega_m} \sin\omega_m t \quad \text{— (4)}$$

$\therefore$ Instantaneous frequency Modulated wave be represented as,

$$V_{FM}(t) = v_c \sin\varphi_i$$

$$= v_c \sin\left(\omega_c t + \frac{kV_m}{\omega_m} \sin\omega_m t\right) \quad \text{— (5)}$$

$m_f \rightarrow$ modulation index for FM,

$$\therefore m_f = \frac{kV_m}{\omega_m} = \frac{\delta}{\omega_m} = \frac{\Delta\omega}{\omega_m} = \frac{\omega_d}{\omega_m}$$

$$\boxed{\omega_d = kV_m}$$