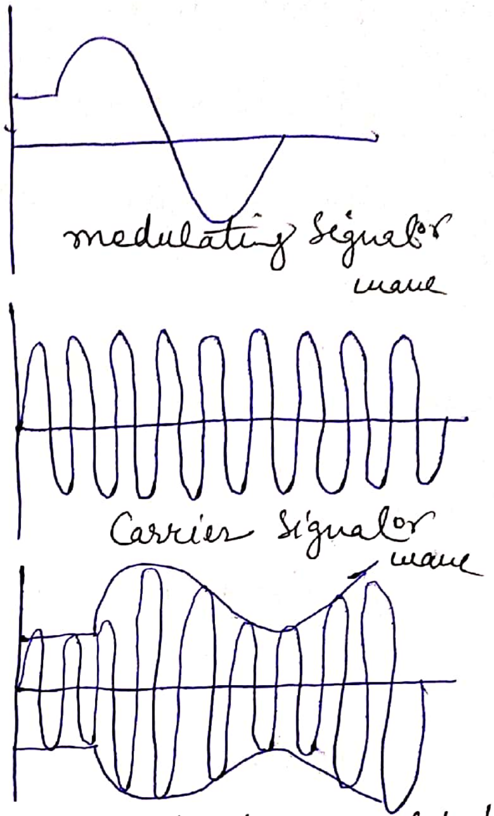
Amplitude Modulation

Let the Carrier & modulating voltage wave be represented as $v_c = V_c \sin w_c t$

$v_m = V_m \sin w_m t$

where v_c, V_c & w_c are the instantaneous value, peak value & angular velocity of the Carrier wave.

& v_m, V_m & w_m are the instantaneous value, peak value & angular velocity of the modulating Signal.



Phase angle has been ignored in both equations as its remains unchanged in amplitude modulation process.

The amplitude of amplitude modulated wave is given as

$$A = V_c + v_m = V_c + V_m \sin w_m t$$

$$= V_c\left[1 + \frac{V_m}{V_c} \sin w_m t\right]$$

$$= V_c\left[1 + m \sin w_m t\right]$$

where m is the ratio of peak value of modulating Signal Carrier wave is known as modulation index. its value is restricted between 0 & unity.

The instantenous value of amplitude modulated wave is given by the following equation.

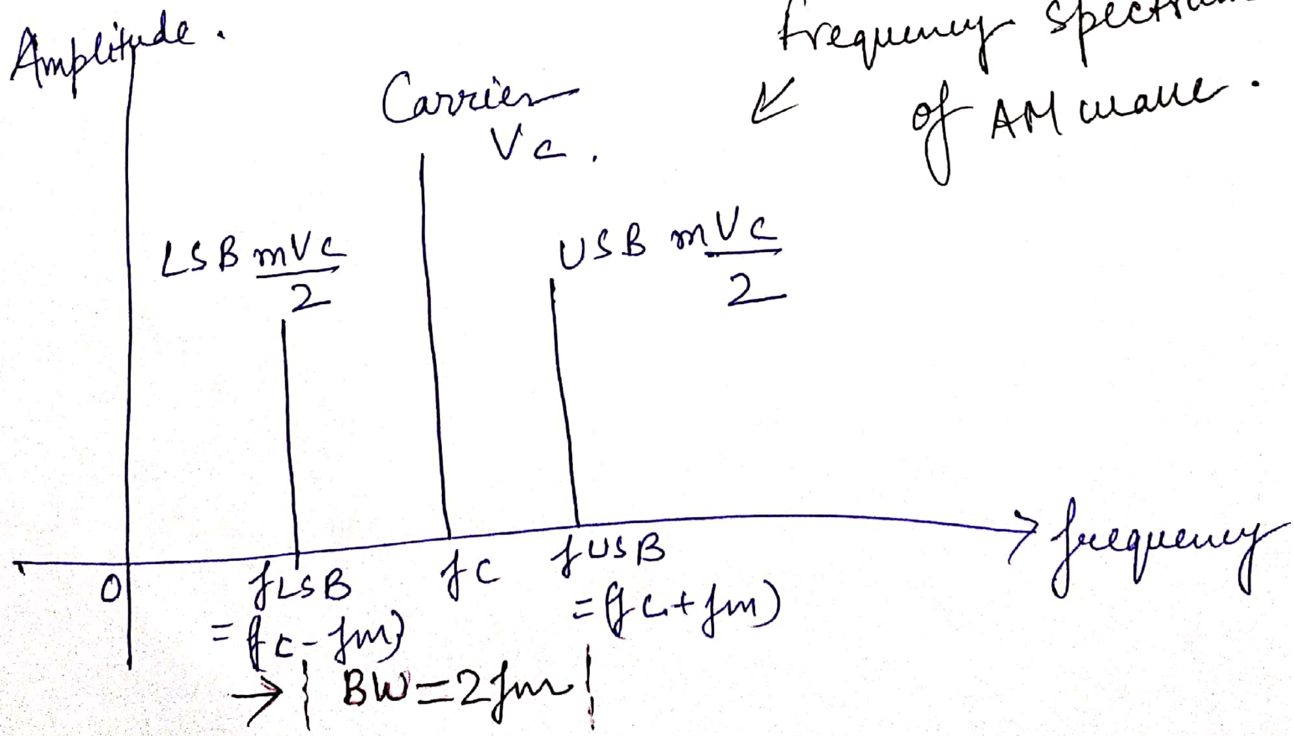
$$v = A \sin \omega_c t$$

$$= V_c [1 + m \sin \omega_m t] \sin \omega_c t.$$

$$= V_c \sin \omega_c t + m V_c (\sin \omega_m t \sin \omega_c t)$$

$$= \underbrace{V_c \sin \omega_c t}_{\text{Carrier signal}} + \underbrace{\frac{mV_c}{2} \cos(\omega_c - \omega_m) t}_{\text{lower side Band } \cancel{\text{frequency}}} - \underbrace{\frac{mV_c}{2} \cos(\omega_c + \omega_m) t}_{\text{upper side Band } \cancel{\text{frequency}}}.$$

from above equation. we can say that first terms represents unmodulated carrier & two additional terms represents two sidebands. The frequency of lower sideband (LSB) is $f_c - f_m$, and frequency of upper sideband (USB) is $f_c + f_m$. the amplitude of both the sidebands is $\frac{mV_c}{2}$.



frequency spectrum of AM wave.

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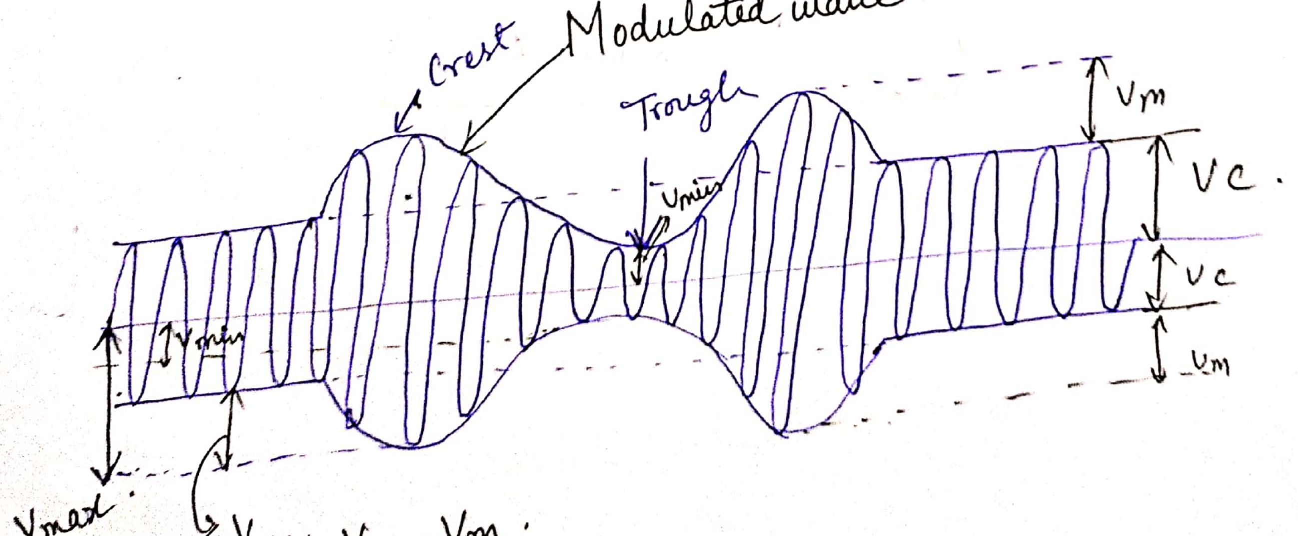
Modulation Index

The extent to which the amplitude of the carrier wave is varied by modulating signal is called the degree of amplitude modulation or modulating index is represented by m.

$$m = \frac{V_m \text{ (amplitude change of carrier wave)}}{V_c \text{ (amplitude of normal or unmodulated carrier wave)}}.$$

When it is expressed as percentage then it is called % modulation.

$$\%\ \text{modulation} = \frac{V_m}{V_c} \times 100.$$



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

$$m = \frac{V_m}{V_c}$$

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

$$V_m = \frac{V_{max} - V_{min}}{2} \quad \text{—(I)}$$

$$V_{max} - V_{m} = V_c \quad \text{—(ii)}$$

Putting value of V_m from eqn(i) in eqn(ii) we get,

$$V_c = V_{max} - \left(\frac{V_{max} - V_{min}}{2} \right)$$

$$= \frac{V_{max} + V_{min}}{2}. \quad \text{—(iii)}$$

$$m = \frac{V_m}{V_c} \quad \text{—(iv)}$$

Putting the value of V_m & V_c in eqn (iv) we get.

$$\boxed{m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

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Amplitude modulated waves for different values of m.

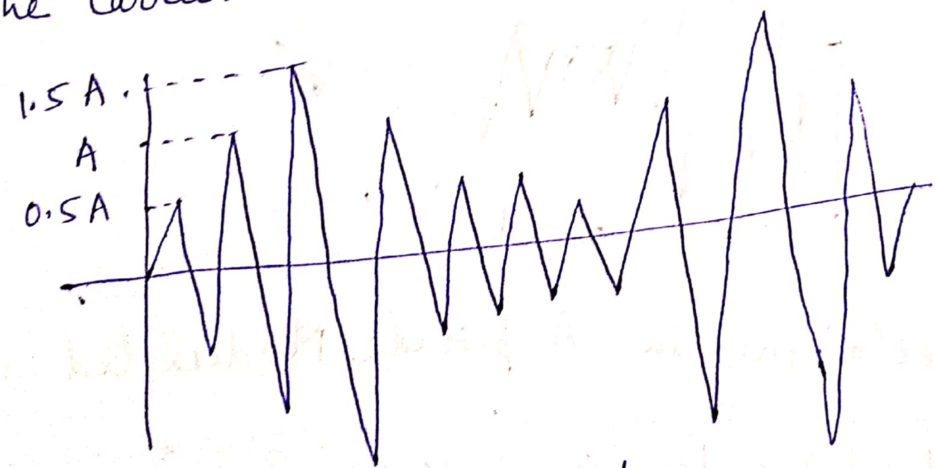
Case(1). Smallest value of m=0 i.e. when amplitude of modulating Signal is zero. it means m = 0 for unmodulated Carrier wave.

Case(2) when Signal amplitude is $\frac{1}{2}$ of the Carrier amplitude. amplitude of Carrier waves varies b/w 1.5 A to 0.5 A where A is amplitude of Carrier.

So, change in A of Carrier = 1.5A − A = 0.5A

$$m = \frac{0.5A}{A} = 0.5 \text{ or } 50\%$$

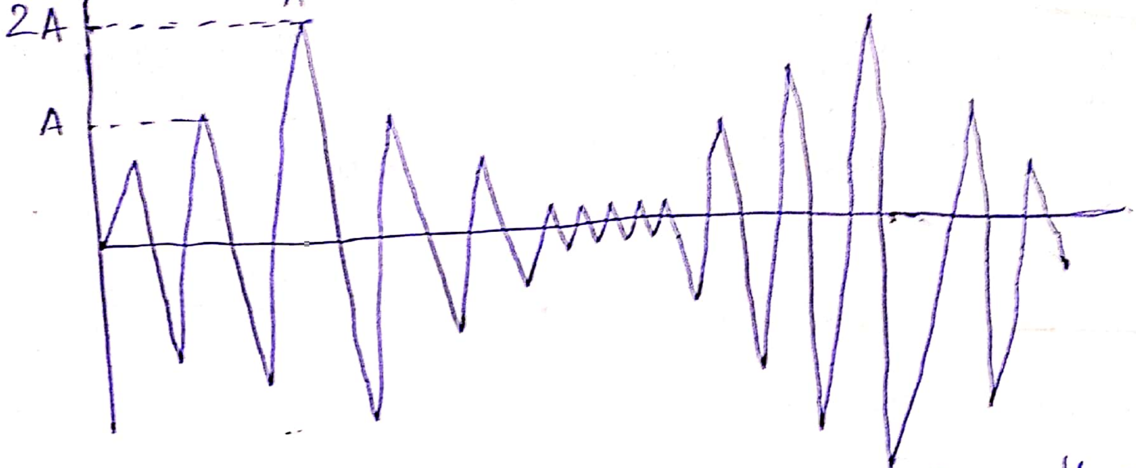
The Carrier is Said to be 50% modulated



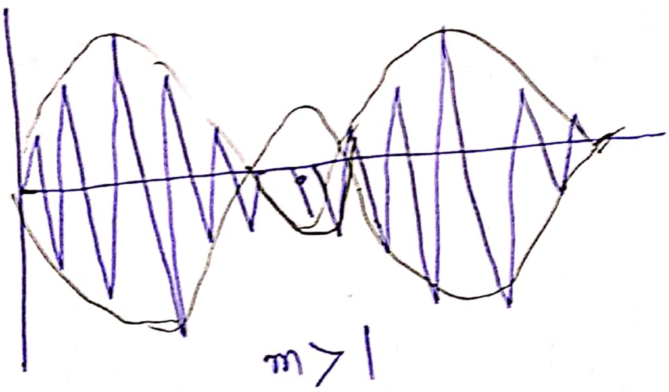
m = 0.5 or 50%.

Case(3) when the Signal amplitude equals the Carrier amplitude.

$m = \frac{A}{A} = 1$ or 100%.



Case(4) when signal amplitude is more than that of the carrier. the modulation is overmodulation. it produces severe distortion & ~~it infor~~ interference. ~~called of~~



$m > 1$

Power relations in Amplitude Modulated wave.

$$\boxed{P_{total} = P_{carrier} + P_{LSB} + P_{USB}}$$

$$P_{carrier} = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{V_c^2}{2R}.$$

Each Sideband has peak value of $\frac{m}{2} V_c$ & rms value of $\frac{m}{2} \frac{V_c}{\sqrt{2}}$

$$P_{LSB} = P_{USB} = \frac{\left(\frac{m}{2} \frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{m^2 V_c^2}{8R}$$

$$= \frac{m^2}{4} \frac{V_c^2}{2R} = \frac{m^2}{4} P_{carrier}.$$

$$P_{total} = \frac{V_c^2}{2R} + \frac{m^2}{4} \frac{V_c^2}{2R} + \frac{m^2}{4} \frac{V_c^2}{2R}$$

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

$$\boxed{P_{total} = P_{carrier} \left(1 + \frac{m^2}{2}\right)}$$

Conclusion

1) $P_{total} = 1.5\, P_{carrier}$ when $m = 1$

2) $$\frac{P_{SB}}{P_{total}} = \frac{\frac{m^2}{4} P_{carrier} + \frac{m^2}{4} P_{carrier}}{P_{carrier}\left(1 + \frac{m^2}{2}\right)} = \frac{\frac{m^2}{2}}{\left(1 + \frac{m^2}{2}\right)}$$

for $m = 1$, $$\frac{P_{SB}}{P_{total}} = \frac{1/2}{3/2} = \frac{1}{3}$$

only $\frac{1}{3}$ of power of modulated ~~carrier~~ wave. is contained in two sidebands & rest of $\frac{2}{3}$ lies in Carrier Component.

3) Several Sinusoidal modulation index.

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

4) $$\frac{P_{total}}{P_{carrier}} = 1 + \frac{m^2}{2}$$

$$\left(\frac{I_t}{I_c}\right)^2 = 1 + \frac{m^2}{2}$$

$$\frac{P_t}{P_c} = \frac{I_t^2 R}{I_c^2 R} = \left(\frac{I_t}{I_c}\right)^2$$

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

Limitations of Amplitude Modulation

1) low efficiency :- In AM, useful power that lies in sidebands is quite small. so. the efficiency of AM system is low.

2) Limited operating range :- Transmitter employing AM have small operating range. this is due to low efficiency. Hence, information can not be transmitted over long distance.

3) Noisy reception ⇒ In AM noise reception is noisy. this is because radioreceiver cannot distinguish the amplitude variation that represent noise & those contain the desired signal.

4) Poor Audio quality ⇒ In order to attain high fidelity reception all audio frequencies up to 15KHz must be produced & this ~~necessi~~ require B.W = 30KHz. while AM broadcasting stations are assinged B.W. of only 10KHz to minimise interference from adjacent broadcasting station.