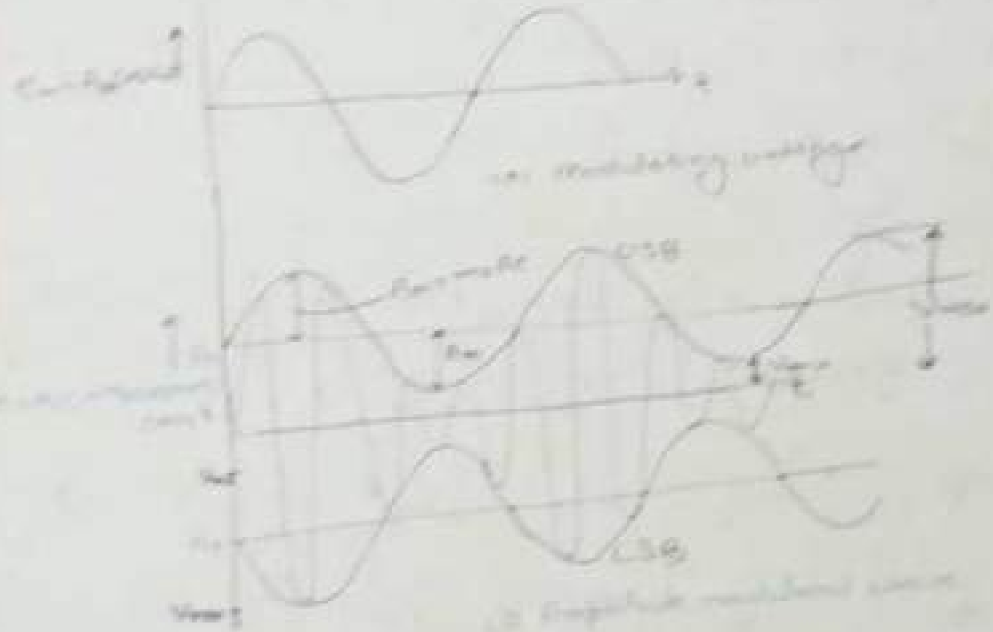
Representation of AM –

Given below fig shows the waveform of the modulating signal and that of modulated wave called the modulation envelope.



modulation index $m_a = k_a \frac{A_m}{A_c}$ where $k_a = 1$ $\boxed{m_a = \frac{A_m}{A_c}}$

hence $m_a = \frac{\text{Amplitude of modulating signal}}{\text{Amplitude of carrier wave}}$

from AM wave fig

$$A_m = \frac{V_{max} - V_{min}}{2} \quad \text{—} (1)$$

also
$$A_c = V_{max} - A_m$$
$$= V_{max} - \frac{V_{max} - V_{min}}{2}$$
$$= \frac{2V_{max} - V_{max} + V_{min}}{2}$$
$$= \frac{V_{max} + V_{min}}{2} \quad \text{—} (2)$$

hence from eq^n (1) and (2)

$$\boxed{m_a = \frac{A_m}{A_c} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

...where for percentage of modulation = m × 100

Power relations :— Since modulated wave contains ... frequency (higher non-recurring) component as it has ... sideband carrier wave. Amplitude of side bands ($m E_c / 2$) depends upon m. So total power in modulated signal depends upon the modulation index.

So total power of the wave

$$P_t (\text{or } P_m) = P_c + P_{USB} + P_{LSB} = \frac{V_{carr}^2}{R} + \frac{V_{USB}^2}{R} + \frac{V_{LSB}^2}{R}$$

where $P_c = \frac{V_{carr}^2}{R}$ where all voltages are rms values

R is the resistance (of antenna) where power is dissipated

$$P_c = \frac{1}{R}\left(\frac{E_c}{\sqrt{2}}\right)^2 = \frac{E_c^2}{2R}$$

Similarly

$$P_{LSB} = P_{USB} = \frac{V_{SB}^2}{R} = \frac{1}{R}\left(\frac{m E_c}{2\sqrt{2}}\right)^2 = \frac{m^2 E_c^2}{8R}$$

So

$$P_t = \frac{E_c^2}{2R} + \frac{m^2 E_c^2}{8R} + \frac{m^2 E_c^2}{8R}$$

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

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

So $\boxed{P_t = P_c\left(1 + \frac{m^2}{2}\right)}$ This eqn also ...

power contained in side bands

$$P_{SB} = P_{USB} + P_{LSB}$$

$$= \frac{m^2 E_c^2}{8R} + \frac{m^2 E_c^2}{8R}$$

$$= \frac{E_c^2}{2R} \cdot \frac{m^2}{2}$$

$$\boxed{P_{SB} = P_c \frac{m^2}{2}}$$

... that $P_{SB}/P_t = \frac{m^2/2}{1 + m^2/2} = \frac{1}{3}$ ... only ... of total ... contained in the ...

(a) If $m_a = 1$ then $P_t = P_c(1+\frac{1}{2}) = 1.5 P_c$. So the max. power in AM wave is 1.5 time carrier Power. It is max power that relevant amplifier must be capable of handling without distortion.

Current calculation - Let I_c be unmodulated current and I_t the total (or modulated current) of an AM transmitter. If R is the resistance in which both currents flow, then

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

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

Note - modulation index = depth of modulation

Modulation by several sine wave -

(I) Let V_1, V_2, V_3 etc be the simultaneous modulation voltage. Then the total modulating voltage V_t is -

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

Dividing both sides by V_c we get

$$\frac{V_t}{V_c} = \sqrt{V_1^2 + V_2^2 + \cdots} \,/ V_c$$

$$= \sqrt{\left(\frac{V_1}{V_c}\right)^2 + \left(\frac{V_2}{V_c}\right)^2 + \cdots}$$

i.e. $$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + \cdots}$$

where m_t is the over all modulation index. So over all AM wave is

$$e = A_c\,(1 + m_1 \cos\omega_1 t + m_2 \cos\omega_2 t + m_3 \cos\omega_3 t \cdots) \cos\omega_c t$$

(II) from eqn -

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

where P_{SB} is the total side band Power and is given by

$$P_{SB} = P_c \frac{m_t^2}{2}$$ where m_t = total modulation index ~~(or m_a for general)~~

~~Sine waves modulate the carrier~~

If several sine wave simultaneously modulate the carrier. So carrier power is unaffected and P_{SB} is sum of the individual P_{SB}s. Hence we have

$P_{SBT} = P_{SB_1} + P_{SB_2} + P_{SB_3} + \cdots$

In this case

$P_t = P_c + P_c\frac{m_1^2}{2} + P_c\frac{m_2^2}{2} + \cdots$

$= P_c\left(1 + \frac{m_1^2}{2} + \frac{m_2^2}{2} + \frac{m_3^2}{2} + \cdots\right)$

$= P_c\left(1 + \frac{(m_1^2 + m_2^2 + m_3^2 + \cdots)}{2}\right)$

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

then

$P_{SBT} = P_c\frac{m_t^2}{2}$

$= P_{SB_1} + P_{SB_2} + P_{SB_3} + \cdots$

Q) A certain transmitter radiates 9 kW with the carrier unmodulated and 10.125 kW when the carrier is sinusoidally modulated. Calculate the modulation index. If another sine wave corresponding to 40% modulation is transmitted simultaneously, determine the total radiated power.

Solⁿ

$\frac{m_a^2}{2} = \frac{P_t}{P_c} - 1 = \frac{10.125}{9} - 1 = .125$

$m_a^2 = 2 \times .125 \Rightarrow m_a = .50 = m_1$

for second part

$m_t = \sqrt{m_1^2 + m_2^2} = \sqrt{(.5)^2 + (.4)^2} = .64$

$P_t = P_c\left(1 + \frac{m_t^2}{2}\right) = 9\left(1 + \frac{.64^2}{2}\right) = 9(1 + 0.205)$

$= 10.84$ kW

Q) The antenna current of an AM transmitter is modulated to a depth of 40% by an audio sine wave. It increases to 12 A as a result of simultaneous modulation by another audio sine wave. What is the modulation index due to this second wave?

Solⁿ

$I_c = \frac{I_t}{\sqrt{1 + m^2/2}} = \frac{11}{\sqrt{1 + .4^2/2}} = 10.58$

When $I_t = 12A$ then

$m_t = \sqrt{2\left[\frac{I_t^2}{I_c^2} - 1\right]} = \sqrt{2\left[\left(\frac{12}{10.58}\right)^2 - 1\right]} = .757$

$m_2 = \sqrt{m_t^2 - m_1^2}$

$= \sqrt{(.757)^2 - (.4)^2} = .645 = 64.7\%$

GENERATION OF AM

There are two main methods are

[illegible] — Here the relation between modulating signal A_m and modulation index m is linear. In this method linear portion of transfer characteristic is used. i.e. collector current is proportional to the base voltage

$$\boxed{i_c \propto e_b}$$

[illegible] — Relation between A_m and m follows the square law. In this case curved portion (non-linear) of the transfer characteristics is used. i.e

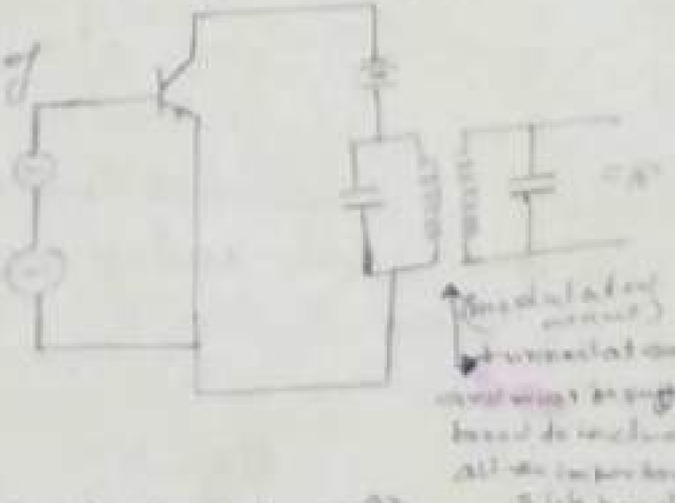
$$i_c = a_0 + a_1 e_b + a_2 e_b^2 + a_3 e_b^3 \ldots$$

For square law modulation, $i_c = a_0 + a_1 e_b + a_2 e_b^2$

Collector modulation — In square law modulation it is supposed that the transfer curve is parabolic over the range of operation as,

$$i_c = a_0 + a_1 e_b + a_2 e_b^2$$

AM is produced by impressing two two sinusoidal potential, carrier and modulating signals of different frequencies on a non linear circuit.



(modulated output)

modulation circuit ... to include all the components ...

Then excitation potential

$$e_b = e_c + e_m$$
$$= A_c \cos\omega_c t + A_m \cos\omega_m t \quad \text{—(1)}$$

Then we can analyzed

$$i_c = a_0 + a_1 e_b + a_2 e_b^2 \quad \text{—(2)}$$
$$= a_0 + a_1(e_m + e_c) + a_2(e_m + e_c)^2$$
$$= a_0 + a_1(A_m\cos\omega_m t + A_c\cos\omega_c t) + a_2(A_m\cos\omega_m t + A_c \ldots$$
$$= a_0 + a_1 A_m\cos\omega_m t + a_1 A_c\cos\omega_c t + a_2 A_m^2\cos^2\omega_m t + a_2 A_c^2\cos^2\omega_c t$$
$$+ 2a_2 A_m A_c \cos\omega_m t\cos\omega_c t$$

$$i_c = a_0 + a_1 A_m \cos\omega_m t + a_1 A_c \cos\omega_c t + \frac{a_2 A_m^2}{2}(1+\cos 2\omega_m t) + \frac{a_2 A_c^2}{2}(1+\cos 2\omega_c t)$$

$$+ a_2 A_m A_c \left[\cos(\omega_c+\omega_m)t + \cos(\omega_c-\omega_m)t\right]$$

$$= a_0 + a_1 A_m \cos\omega_m t + a_1 A_c \cos\omega_c t + \frac{a_2 A_m^2}{2}\cos 2\omega_m t + \frac{a_2 A_c^2}{2}\cos 2\omega_c t$$

$$+ a_2 A_m A_c \left[\cos(\omega_c+\omega_m)t + \cos(\omega_c-\omega_m)t\right] + \frac{a_2 A_m^2}{2} + \frac{a_2 A_c^2}{2}$$

(terms $\frac{a_2 A_m^2}{2}$ and $\frac{a_2 A_c^2}{2}$ is d.c. part which also comes in an analysis)

Assuming that $\omega_c >> \omega_m$ frequency which are not nbd of ω_c are eliminated by using tuned circuit. So that ckt tuned at ω_c, responds only to the terms of frequency ω_c, $(\omega_c+\omega_m)$, $(\omega_c-\omega_m)$. Rest term of above eqn do not produce appreciable voltage across tuned ckt and the output current is given by —

$$i_c = a_1 A_c \cos\omega_c t + a_2 A_m A_c\left[\cos(\omega_c+\omega_m)t + \cos(\omega_c-\omega_m)t\right]$$

$$\Rightarrow \boxed{i_c = a_1 A_c\left(1 + \frac{2a_2 A_m}{a_1}\cos\omega_m t\right)\cos\omega_c t} \quad \text{— ①}$$

From this it is seen that modulation index is given by

$$\boxed{m_a = \frac{2a_2 A_m}{a_1}}$$

So this method can be use to measure m_a.

Here amount of available o/p is not good so efficiency is low. ~~So available o/p is~~

Note :- ① In this ckt input is not exceed 1V. So this is also called small signal modulation.

② In this ckt available output

$$e_0 = A_c(1 + m_a \cos\omega_m t)\cos\omega_c t$$

o/p is tuned at ω_c, so d.c. part and ω_m, $2\omega_m$, $2\omega_c$ part not present in o/p

$$P_t = A_c^2\left(1 + \frac{m_a^2}{2}\right) \qquad \left(P_c = \frac{A_c^2}{2R} \because 2R \text{ is fixed hence} \Rightarrow P_c = A_c^2\right)$$

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

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

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

Since carrier does not carry any information so P_c (or A_c^2 or $\frac{A_c^2}{2R}$) is the wastage of power.