Final

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Basics of Modulation :

Q: what is Modulation?

⇒ Modulation is a process which are used for changing signal properties.

⇒ Modulation is the process of changing the characteristics of a carrier signal with respect to a message / modulating signal.

$$A \cos(\omega t + \Phi)$$

Amplitude (A), angular frequency (ω), phase (Φ)

Signal properties

[যেকোন signal এ ৩টি properties থাকে]

(i) Amplitude

(ii) Frequency

(iii) Phase

☆ Signals involved in the process of Modulation.

1. Message / Modulating signal:

It is an audio / video signal containing the necessary data or information to be transmitted.

⇒ It is a low frequency signal (20 Hz - 20 kHz)

(ii) Carrier signal :

It is a high frequency signal with frequency range from 10KHz to 30000 MHz whose characteristics such as amplitude, frequency or phase is altered with respect to the message / modulating signal.

* Basically, Message signal rides over carrier signal by the process of modulation.

Types of Modulation :

3 types:

(i) Amplitude Modulation

(ii) Frequency Modulation

(iii) Phase Modulation

Q: Why we need Modulation ?

⇒ There are 4 reasons:

1. Frequency range and energy
2. Antenna length
3. Wireless communication
4. Interference

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* Reasons of modulation:

3. Wireless communication
4. Effects of Interference

3. Wireless communication:

* Audio frequency signals or message signals need material medium for transmission. for this reason their transmission range is low.
[material medium example: twisted cable
copper cable]

* carrier signal or radio frequency signal donot need any material medium for transmission. since carrier signal has high frequency, so they have high energy components. As a result their transmission range is vast.

4. Effects of interference:

expectation → should be low

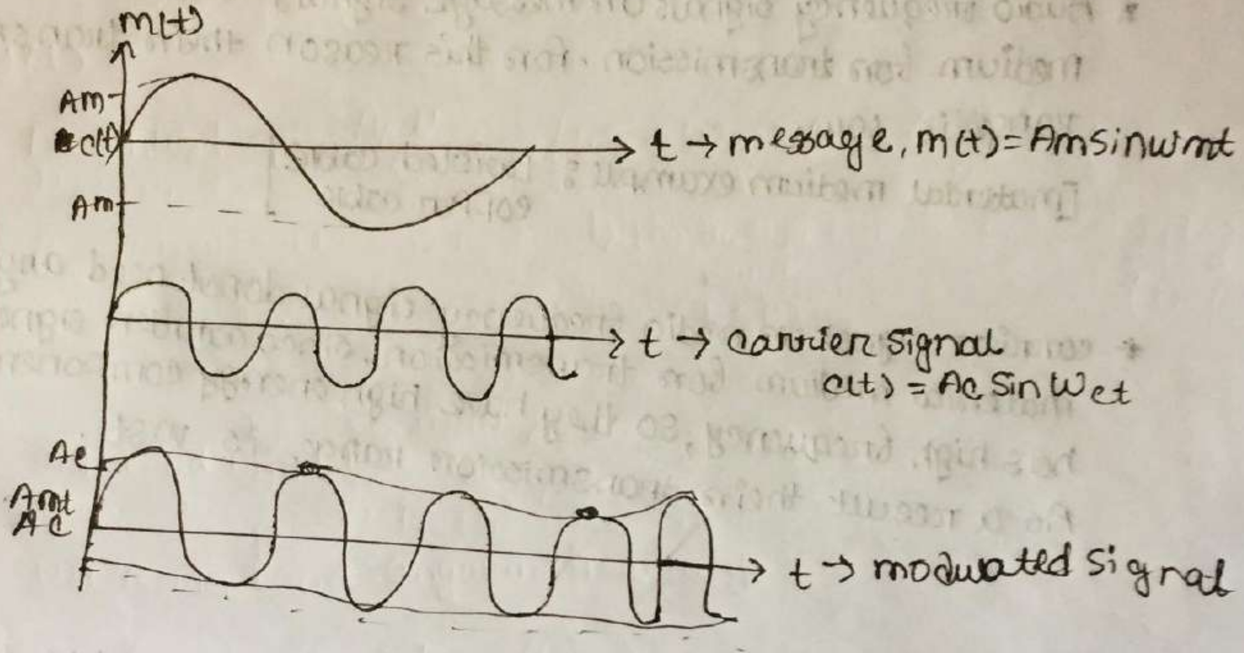
Noise
distortion}

* From electromagnetic wave theory, we can say that - when the frequency of mutual interference is higher when the frequency of a signal is low and mutual interference (MI) is lower when the frequency of a signal is higher.

message signal

solution → Modulation
↳ carrier signal
↳ frequency → high
↳ It will give us low interference
↳ That should be our goal

Amplitude modulation: It is the Process in amplitude of carrier signal changes w.r.t message (modulating) signal.



Modulated signal, $y(t) = A' \sin w_c t$

$= (A_c + m_c t) \cdot \sin w_c t$

$= \cancel{A_c(1 + \frac{A}{\ }}$

$M = \frac{A_m}{A_c}$

= Modulating index

$= (A_c + A_m \sin \omega_m t) \cdot \sin \omega_c t$

$= A_c (1 + \frac{A_m}{A_c} \sin \omega_m t) \cdot \sin \omega_c t$

$= A_c (1 + M \sin \omega_m t) \sin \omega_c t$

$= 2 \sin A \sin B$

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

$= A_c \sin \omega_c t + A_c M \sin \omega_c t \sin \omega_m t$

$= A_c \sin \omega_c t + \frac{A_c \mu}{2} \cdot 2 (\sin \omega_c t \cdot \sin \omega_m t)$

$= A_c \sin \omega_c t + \frac{A_c \mu}{2} \{ \cos (\omega_c - \omega_m) t - \cos (\omega_c + \omega_m)$

Sideband

Modulated signal, $y(t) \rightarrow$ having three frequencies, ~~the~~ $\omega_c, \omega_c - \omega_m, \omega_c + \omega_m$

Sideband amplitude,

$$\frac{A_c \mu}{2} = \left(\frac{A_c}{2} \times \frac{A_m}{A_c} \right) = \frac{A_m}{2}$$

$y(t)$
$= \cancel{A_c \sin \omega_c t}$
$\cancel{\frac{A_c \mu}{2} (\cos (\omega_c - \omega_m) t}$ ↳ ~~lower side band~~

* Sideband Amplitude $= \frac{A_c \mu}{2} = \frac{A_m}{2}$

$y(t)$

$$= A_c \sin \omega_c t + \frac{A_c \mu}{2} \cos \underbrace{(\omega_c - \omega_m) t}_{\text{Lower side band (LSB)}} - \frac{A_c \mu}{2} \cos \underbrace{(\omega_c + \omega_m) t}_{\text{upper side band frequency (USB)}}$$

Sideband Amplitude $= \frac{A_c \mu}{2} = \frac{A_m}{2}$

USB = LSB

upper side band angular frequency

$(\omega_c + \omega_m) t$

$\downarrow \quad \downarrow$

$(2\pi f_c + 2\pi f_m) t$

$f_c + f_m \rightarrow$ USB frequency

$f_c - f_m \rightarrow$ LSB frequency

Modulating index / depth of wave / modulation

$m / \mu = \frac{A_m}{A_c} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \rightarrow$ [voltage দেয়া থাকলে এই রুলে]

Modulating signal, $\rightarrow \sin$ [cos ও হতে পারে sin ও হতে পারে]

$m(t) = A_m \cos \omega_m t$

Carrier signal

$c(t) = A_c \overset{\rightarrow \sin}{\cos} \omega_c t$

$\therefore$ $\boxed{f_c \gg f_m}$ $\boxed{A_c \gg A_m}$

$P_c \to$ Power of carrier signal
$P_T \to$ Power of transmission
$I_T \to$ Current transmission
$I_c \to$ modulating current
একোন signal সেন্তে পারি।

$$\mu = 2\left(\frac{P_T}{P_c} - 1\right) \quad [\text{Power এর জন্য}]$$

$$\mu = \cancel{2\left(\frac{P_T}{P_c} - 1\right)} \sqrt{2\left(\frac{I_T}{I_C}\right)^2 - 1} \quad [\text{current এর জন্য}]$$

Total transmisson power,

1. $$\boxed{P_T = P_c + \underbrace{P_{USB}}_{\text{upper side band}} + \underbrace{P_{LSB}}_{\text{lower side Band}}}$$

$$P_c = \frac{A_c^2}{2R} \quad [\because R = \text{circuit এর resistance (আর্হ)}]$$

$$P_{USB} = P_{LSB} = \frac{\mu^2 A_c^2}{8R}$$

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

$\cancel{\mu = 1}$

$\mu = 1$ হলে

$\boxed{P_T = 1.5 P_c}$ [এই rules apply]

$\therefore$ Transmission efficiency,

$$\eta \% = \frac{\mu^2}{2 + \mu^2} \times 100$$

$$\eta = \frac{P_{LSB} + P_{USB}}{P_T} \times 100$$

Bandwidth,

$$Bw = 2 \times fm$$

Total transmitted current,

$$I_T = I_c \sqrt{1 + \frac{\mu^2}{2}}$$

Problem: 1

A 500 watt carrier is modulated to ~~th~~ a depth of 75 percent, calculate the total power in the moduated wave?

$P_c = 500 \text{watt}$

$\mu = 75\% = 0.75$

$P_T = ?$

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

$$= 500 \left(1 + \frac{(0.75)^2}{2}\right)$$

$$= 640.625 W$$

Prob: 2

A modulating signal $\overbrace{30\sin(2\pi\times10^3)t}^{m(t)}$ is used to modulate a carrier signal $\underbrace{40\sin(2\pi\times10^4)t}_{c(t)}$

(i) Modulating Index → μ

(ii) Percentage of modulation

(iii) frequencies → $f_m, f_c, f_{USB}, f_{LSB}$

(iv) Bandwidth → BW

(v) draw the spectrum of the AM wave (Amplitude modulating)

(vi) transmission efficiency → η

(i) $m(t) = A_m \sin\omega_m t \rightarrow A_m = 30$

$\omega_m = 2\pi f_m$

$2\pi\times10^3 = 2\pi f_m$

$\therefore f_m = 10^3$

$c(t) = A_c \sin\omega_c t \rightarrow A_c = 40$, $f_c = 10^4$

$$\mu = \frac{A_m}{A_c} = \frac{30}{40} = 0.75$$

(ii) percentage of modulation $= 0.75\times100 = 75\%$

(iii) $m(t) = A_m \sin\omega t \longrightarrow A_m = 30$

$\omega_m = 2\pi f_m$

$f_m = \frac{\omega_m}{2\pi} = 10^3$

$c(t) = A_c \sin\omega_c t$

$\rightarrow A_c = 40$

$\omega_c = 2\pi f_c$

$f_c = \frac{\omega_c}{2\pi} = 10^4$

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Problems:

1. A modulating signal of $3\cos 5000t$ is amplitude modulated over a carrier signal of $6\cos 20000t$. Derive the total transmitted power and transmission efficiency.

2. The amplitude modulated wave is with maximum amplitude 12V and the minimum amplitude 8V. Find the modulation index.

3. For the amplitude modulated wave $s(t) = \underbrace{100}_{A_c}(1+\underbrace{0.6}_{\mu}\sin 6280t)$ $\rightarrow$ AM $\sin(2\pi * 10^6 t)$. Determine

(i) frequency of message signal & carrier signal

(ii) Modulation index

(iii) frequency of upper sidbands and lower side bands.

$f_c + f_m$ $f_c - f_m$

1. $m(t) = 3\cos 5000t$ $A_m = 3$

$= A_m \cos \omega_m t$ $\omega_m = 2\pi f_m$

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

1. $m(t) = A_m \cos \omega_m t \Rightarrow A_m = 3 \rightarrow \omega_m = 2\pi f_m \Rightarrow f_m = \frac{\omega_m}{2\pi}$

$= 795.77$

$c(t) = A_c \cos \omega_c t \Rightarrow A_c = 6 \Rightarrow \omega_c = 2\pi f_c \Rightarrow f_c = \frac{\omega_c}{2\pi}$

$= 3183.09$

$f_{USB} = f_c + f_m$

$= 3.97\ KHZ$

$f_{LSB} = f_c - f_m$

$= 2.38\ KHZ$

(ii) maximum apitude, $A_c + A_m = 12\ V$

minimum " , $A_c - A_m = 8\ V$

$2A_c = 20\ V$

$\Rightarrow A_c = 10$

$\Rightarrow A_m = 2\ V$

$\mu = \frac{A_m}{A_c}$

$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

[voltage দিলে না Amplitude দিলে তাই A]

3. $m(t) = A_m \sin W_m t$

$c(t) = A_c \sin W_c t$

$A_c + A_m$
কারেন্ট high
পাওয়া যাবে

$s(t) = A_c (1 + \mu\, m(t) \cdot c(t))$

$= A_c (1 + \mu \cdot \sin W_m t) \sin W_c t$

$A_c = 100$

$\mu = 0.6$

$w_m = 6280$

$w_c = 2\pi \times 10^6$

frequency of message signal,

$w_m = 2\pi f_m$

$f_m = \frac{w_m}{2\pi}$

$= 999.49$

$= 1KHZ$

and carrier signal $w_c = 2\pi f_c$

$f_c = \frac{w_c}{2\pi}$

$= \frac{\cancel{2\pi} \times 10^6}{\cancel{2\pi}}$

$= 10^6$

$= 1MHZ$

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Frequency modulation: In frequency modulation, the frequency of the carrier signal changes with respect to the message signal.

Let, modulating signal $m(t)$.

Let, $c(t) = A_c \cos(\omega_c t + \phi)$

$= A_c \cos(2\pi f_c t + \phi) \rightarrow f(i) = F(m(t))$

in terms of angle,

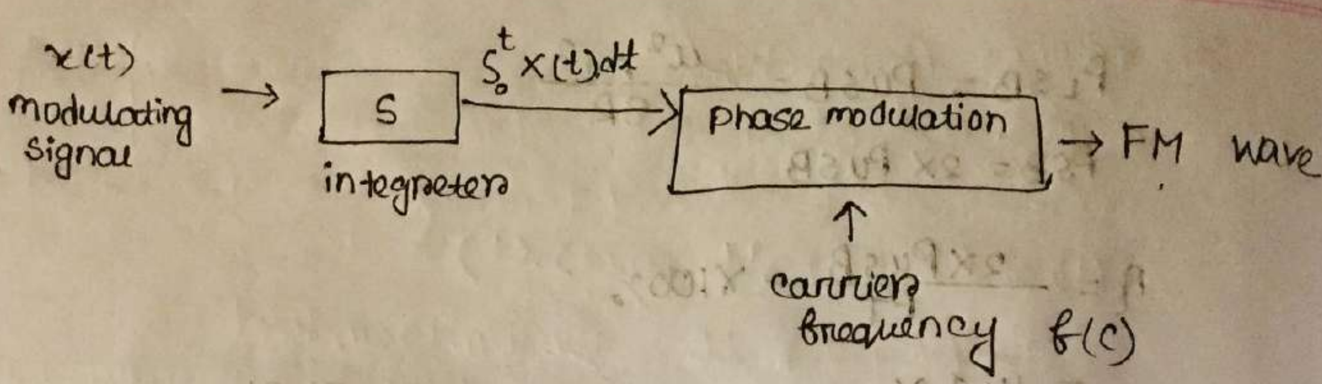
$A_c \cos \theta(t)$

in frequency modulation

$$\underbrace{\theta(t)}_{\substack{\text{daviation} \\ \text{(মান কতটা বিচ্যুতি ঘটেছে)}}} = 2\pi f_c t + \underbrace{2\pi f_K}_{\text{frequency sensitivity}} \int_0^t \underbrace{x(t)}_{\text{message signal}} \, dt$$

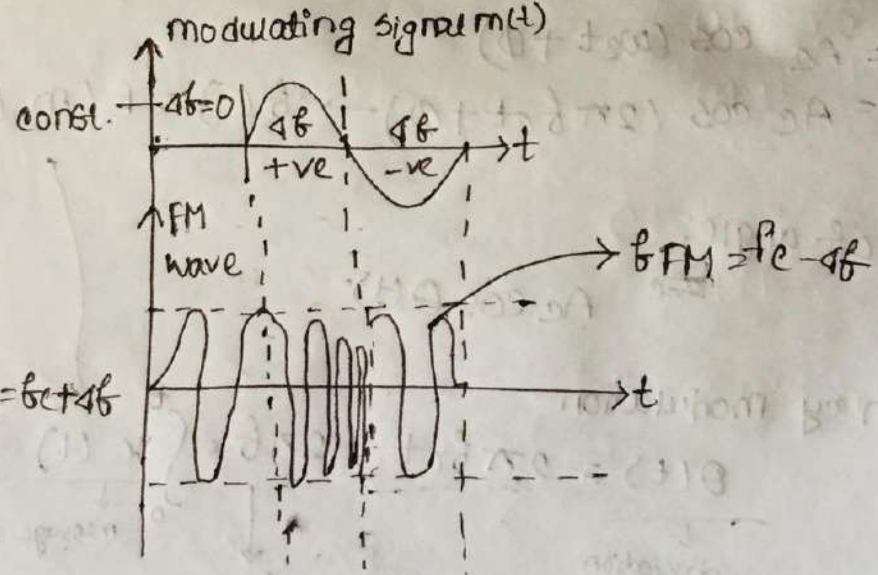
Modulated signal,

$$\boxed{y_{fm}(t) = A \cos\left(2\pi f_c t + 2\pi f_K \int_0^t x(t) \cdot dt\right)}$$



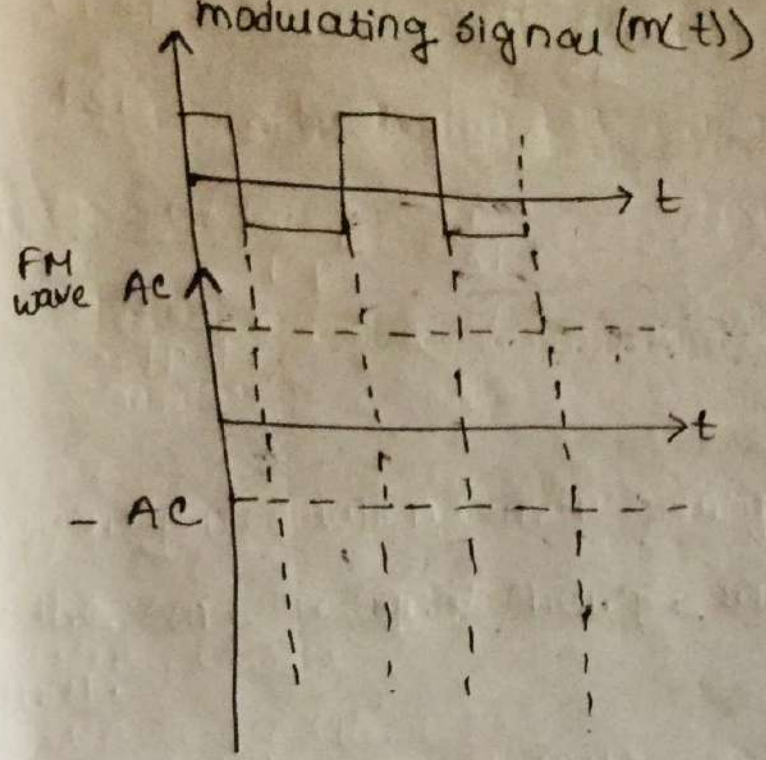
$$\cos\left(2\pi f_c t + 2\pi f_k \int_0^t x(t)\cdot dt\right)$$

frequency modulation wave



$$y_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi f_k \int_0^t x(t).\, dt\right)$$

deviation of frequency (Δf)


modulating signal (m(t))
t
FM wave
AC
t
- AC

Phase modulation

* The phase of carrier signal changes with respect to the modulating signal.

Let a carrier signal,

$$c(t) = A_c \cos(\underbrace{\omega_c t}_{\text{angular frequency}} + \phi)$$

$$= A_c \cos(2\pi f_c t + \phi)$$

$$= A_c \cos\theta(t)$$

Let a modulating signal, $m(t)$

For phase modulation,

$$\theta(t) = 2\pi f_c t + K_p \underbrace{x(t)}_{\text{message signal}}$$

PM wave,

$$y_{PM}(t) = A_c \cos(2\pi f_c t + K_p x(t))$$

↳ Phase sensitivity (rad/volt)

* The higher the value of K_p - The higher the value of phase deviation

phase deviation

$K_p \rightarrow + \Rightarrow x(t) \rightarrow$ Amplitude $\rightarrow +$

→ The carrier signal will lag w.r.t the modulating signal.

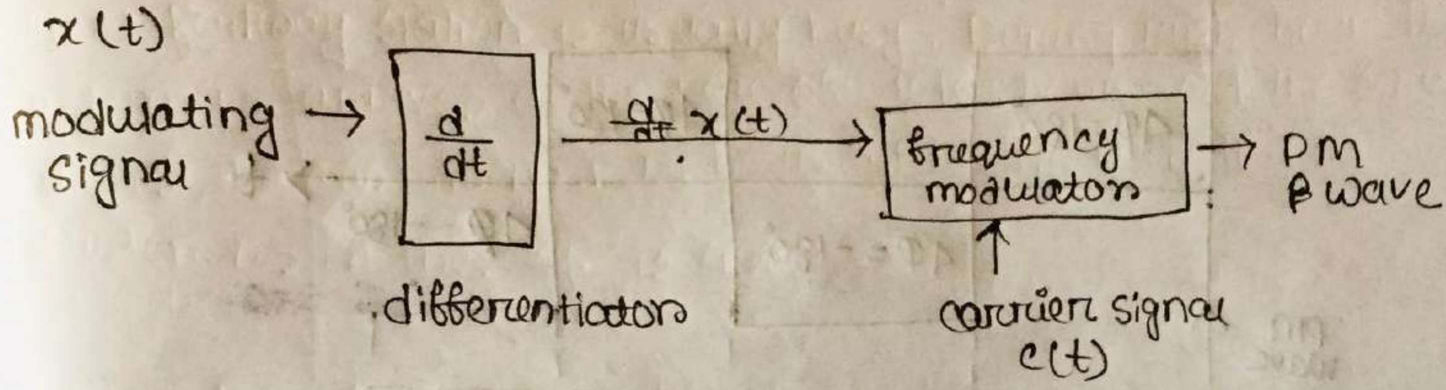
$K_p \rightarrow - \Rightarrow x(t) \rightarrow$ Amplitude $\rightarrow -$

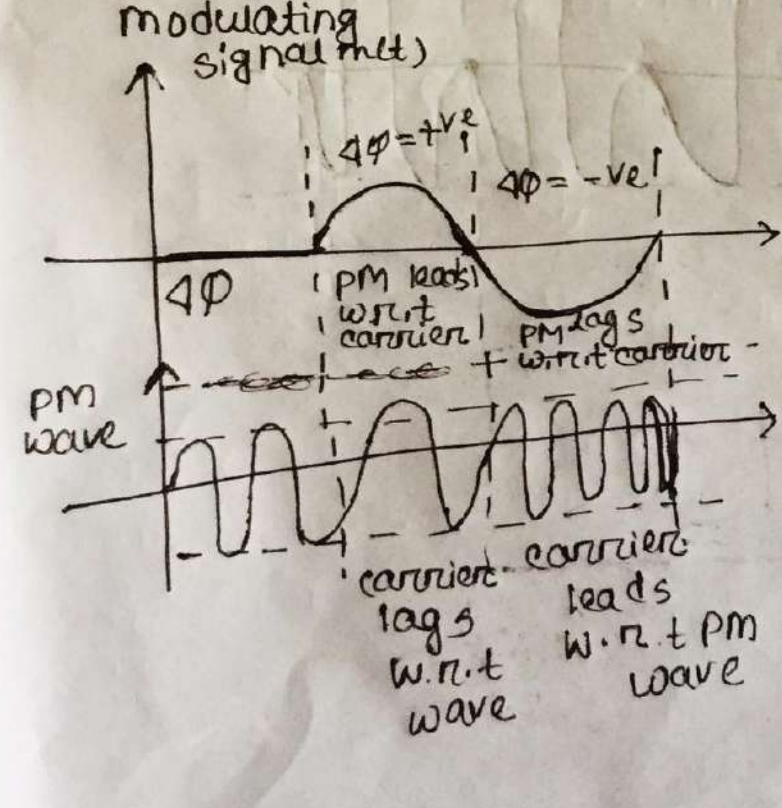
↳ phase deviation is also (-) ve

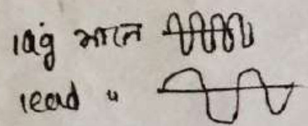
⇒ The carrier signal will lead w.r.t the modulating signal

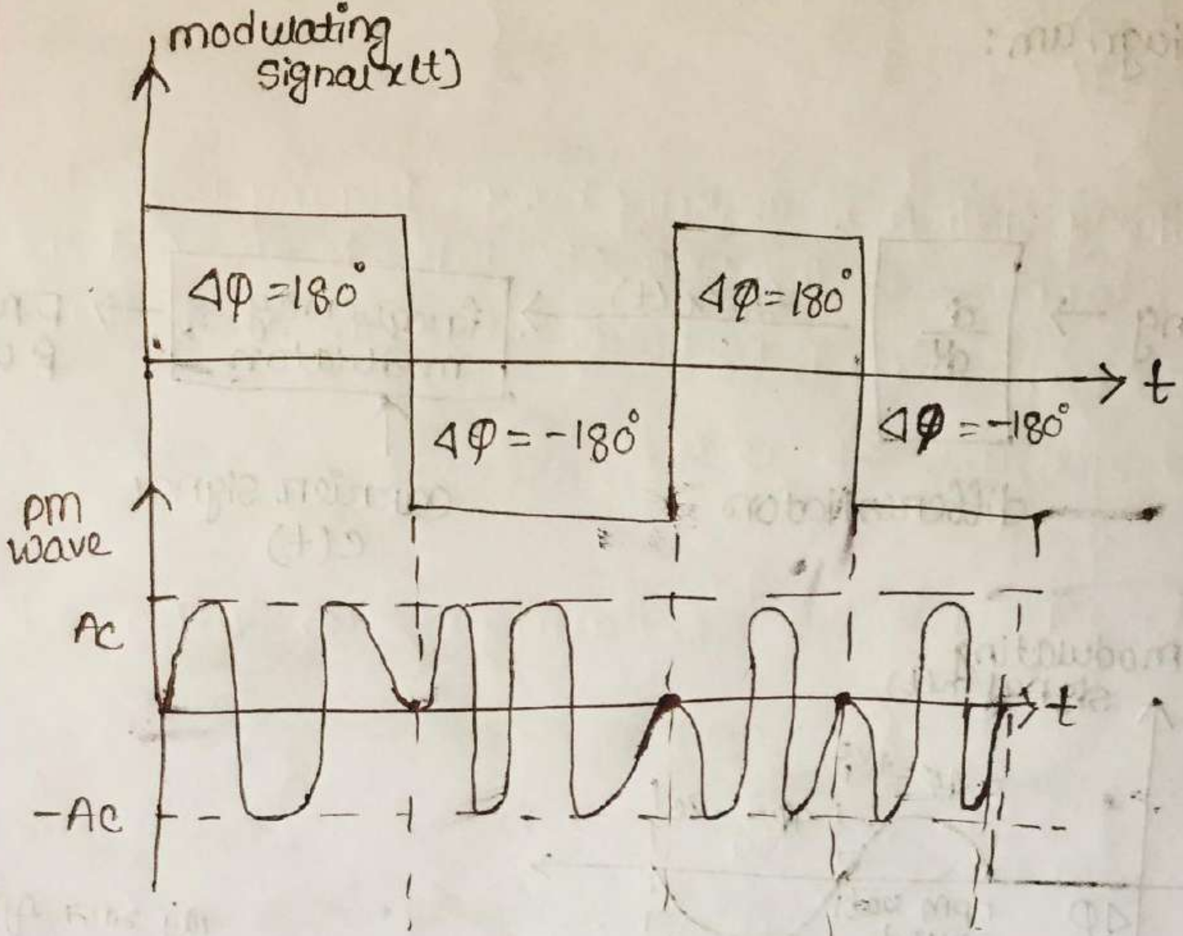
* $y_{pm}(t) = A_c \cos(2\pi f_c t + k_p x(t))$

Block diagram:









modulating signal x(t)
Δφ = 180°
Δφ = -180°
Δφ = 180°
Δφ = -180°
t
pm wave
Ac
-Ac
t