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ASSIGNMENT - 5
ELECTRONICS & COMM. ENGINEERING

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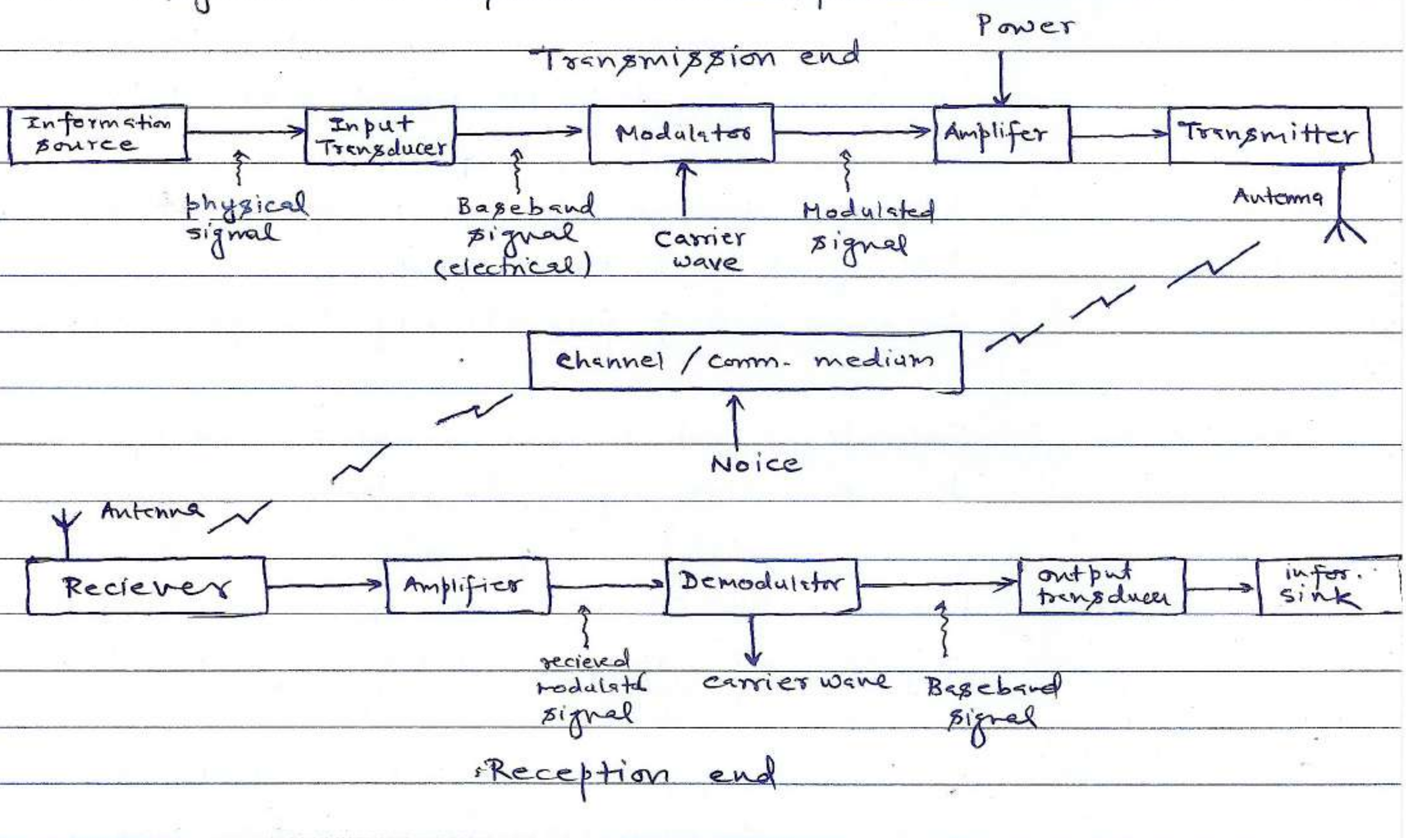
Q1. Draw the block diagram of wireless communication system and explain each component



BLOCK DIAGRAM OF A COMMUNICATION SYS.

Input Transducer : Converts physical signal (like sound etc) into electrial signal (Baseband signal) which is generelly of low frequency & weak.
Eg. Microphone, camera, scanner

Modulator : Mix baseband signal with carrier wave (high frequency) and creates modulated signal which is feasible to transmit.

Amplifier : Increases the power of modulated signal to transmit it to suitable ranges through channel.

Transmitter : Transmit modulated signal in form of electromagnetic waves that propagate through communication medium to reciever.

Channel : Physical medium between transmission and recieving ends through which em waves pass

Noice & Attenuation : unwanted electrial impulses caught by or induced in the signal over the channel.
Gradual loss of flux intensity through a medium

Reciever & Amplifier : Collects signal from channel and amplify the attenuated signal to suitable strengths.

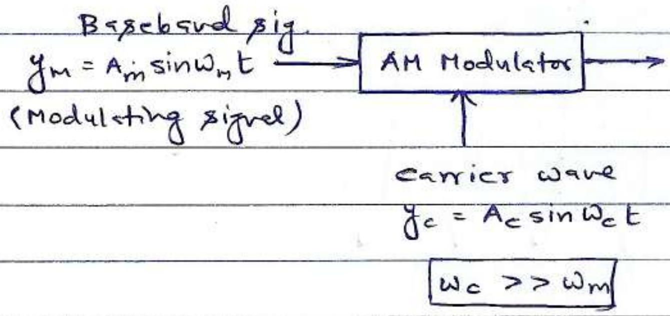
Demodulator : Removes the carrier wave from modulated signal and outputs baseband signal

Output Transducer : Converts recieved baseband signal into physical signal as consumed by information sink.
eg. Speaker, monitor, printer.

Q2. What is amplitude modulation? (Explain with expression and diagram)

Amplitude Modulation (AM)

In AM, the amplitude of carrier wave is varied according to baseband signal.



AM signal

$y_{AM} = R \sin \omega_c t$

where $R = A_c + A_m \sin \omega_m t$.

∴ AM wave is
$$y_{AM} = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$
$$y_{AM} = A_c\left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t$$

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

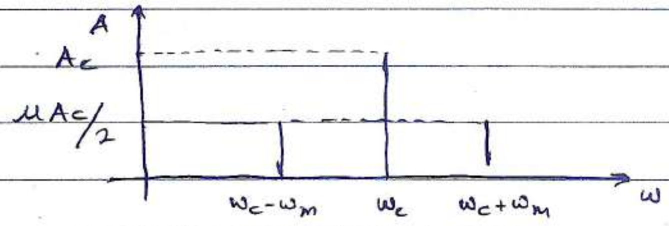
$$y_{AM} = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t$$

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

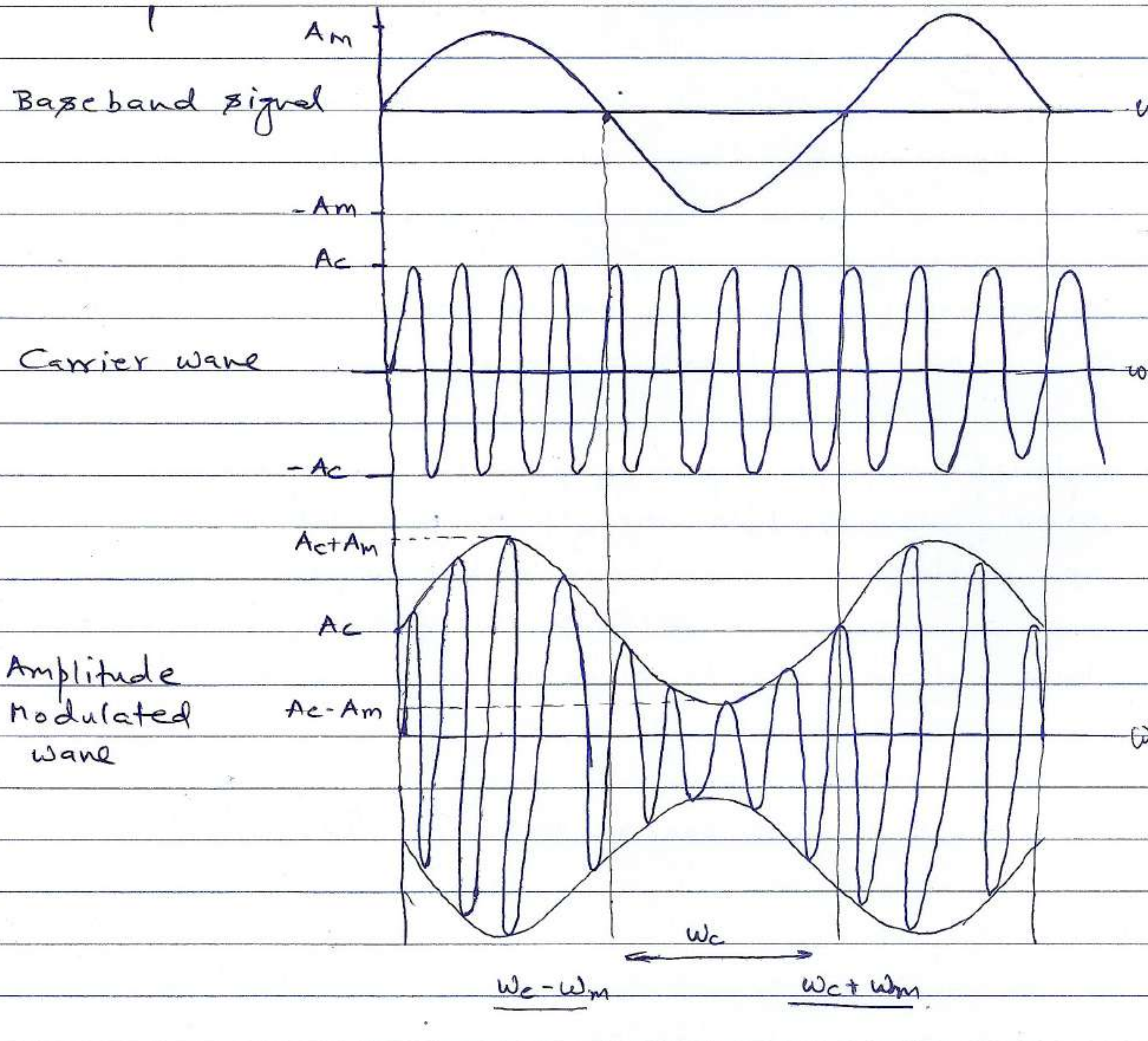
∴ AM signal consist of 3 frequencies ω_c, $\omega_c - \omega_m$, $\omega_c + \omega_m$

- ω_c → carrier frequency
- $\omega_c - \omega_m$ → lowerside frequency
- $\omega_c + \omega_m$ → upperside frequency

Freq. spectrum of AM wave.



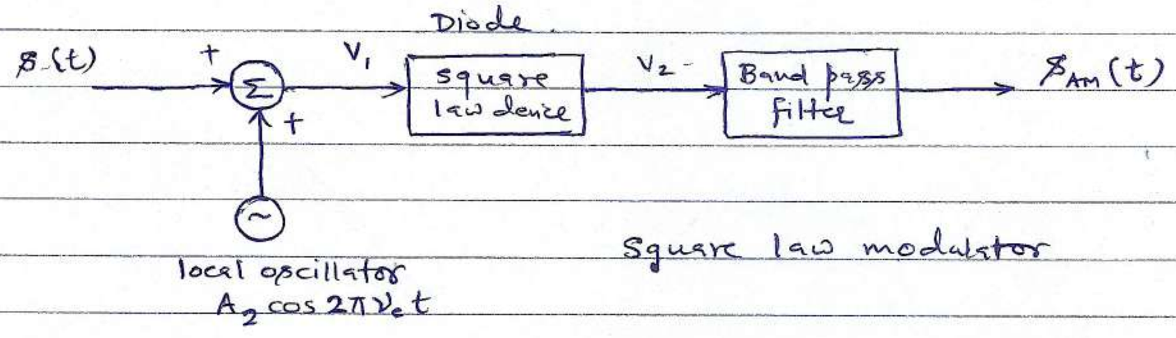
Waveform of AM wave



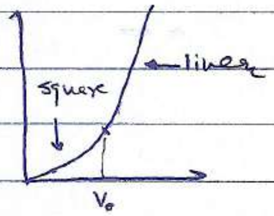
Q3. Explain the generation of amplitude modulated wave using square law modulator.

Square law modulator

It is a circuit in which a square law device (like diode) is used to filter a second order input coupled with a bandpass filter to create AM signal.



Square law modulator



Diode charecteristics

At low voltages : square law charcteristic

At high voltages : linear charectoristics

- strength of message signal is practically very weak, if a carrier wave with low strength is generated, the diode can be operated in square charecteristic region
- If sum of message signal & carrier wave is func^n V_1 then its peak voltage should be close to knee voltage

$$V_1 = s(t) + c(t)$$
$$= s(t) + A_c \cos 2\pi \nu_c t \quad -(1)$$

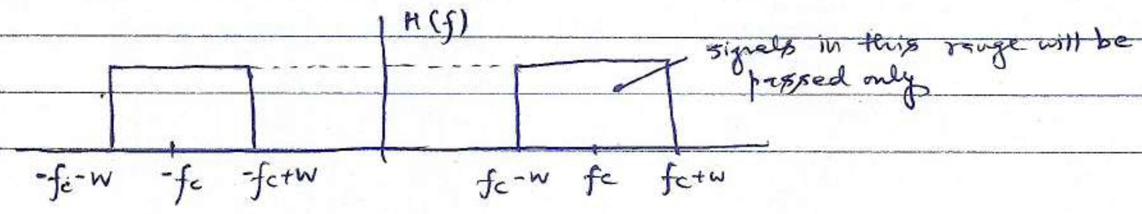
Transfer charecteristics of a non linear device is given by

$$V_2 = a_1 V_1 + a_2 V_1^2 + a_3 V_1^3 + \ldots$$

which for a square law device, become

$$V_2 = a_1 V_1 + a_2 V_1^2$$
$$= a_1 (s(t) + A_c \cos 2\pi \nu_c t) + a_2 (s(t) + A_c \cos 2\pi \nu_c t)^2$$
$$= a_1 (s(t) + A_c \cos 2\pi \nu_c t) + a_2 (s^2(t) + A_c^2 \cos^2 2\pi \nu_c t + 2 s(t) A_c \cos 2\pi \nu_c t)$$

This output of square law device (diode) is fed to Band pass filter whose response should be



Band pass filter output will be the modulated signal $s_{AM}(t)$

Since frequency of $s(t)$ is generally very low, $\cos^2 f_c$ has twice the frequency f_c. Hence V_2 becomes

$$(BPF)_{o/p} = s_{AM}(t) = a_1 A_c \cos 2\pi f_c t + 2a_2 A_c s(t) \cos 2\pi \nu_c t$$

$$s_{AM}(t) = a_1 A_c \left[1 + \frac{2a_2}{a_1} m(t)\right] \cos 2\pi \nu_c t$$

$$\boxed{s_{AM}(t) = A_c' \left[1 + k_a m(t)\right] \cos 2\pi f_c t}$$

where $A_c' = a_1 A_c$

& $k_a = \frac{2a_2}{a_1}$ = Amplitude sensitivity

Q4 Describe DSB-SC and SSB-SC.

DSB-SC (Double side band - suppressed carrier)

→ Need of DSB-SC

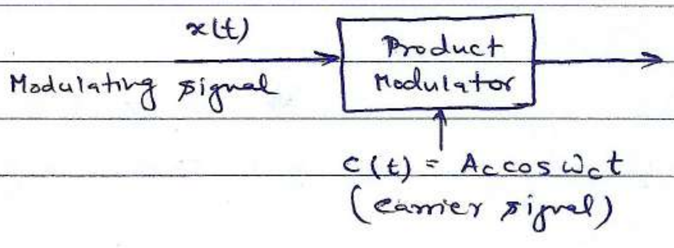
AM signal : $y(t) = A_c \cos \omega_c t + \frac{\mu A_c}{2} \cos(\omega_c + \omega_m)t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t$

(carrier; upperside band; lower side band)

No information is carried by carrier signal, it is carried only by upperside band and Lowerside band. Hence transmission power is wasted in carrier signal in AM, hence in DSB-SC, this carrier signal is suppressed to increase transmission efficiency.

($P_t = P_{carrier} + P_{sideband}$)

→ Block diagram.

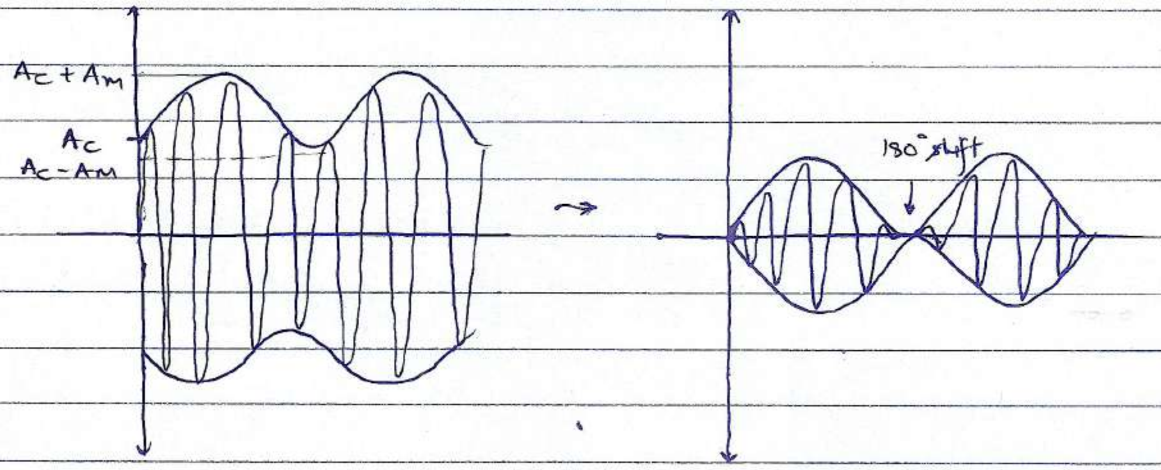


$y(t) = A_c x(t) \cos \omega_c t$

instead of

$y(t) = A_c (1 + \mu x(t)) \cos \omega_c t$.

→ Waveform

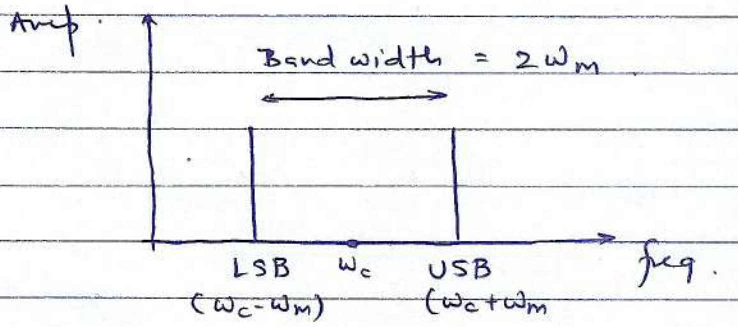


AM DSB - SC

In DSB - SC

- Carrier signal is not produced only sideband signals (LSB & USB) are trasmitted.
- It has 180° phase reversal at zero crossing of modulating signal

→ frequency response



∴ No change in Bandwidth from AM

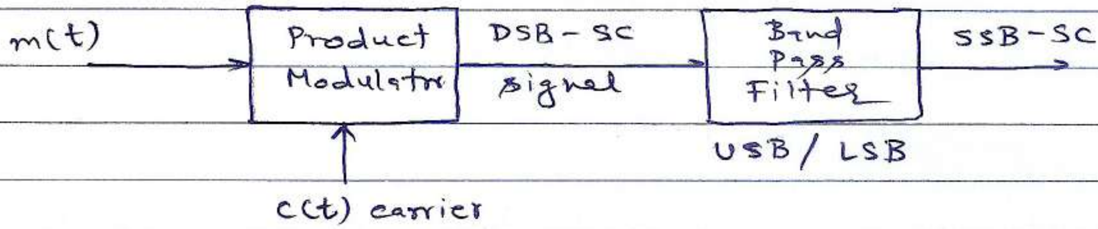
SSB - SC (single side band - suppressed carrier)

→ Need of SSB - SC

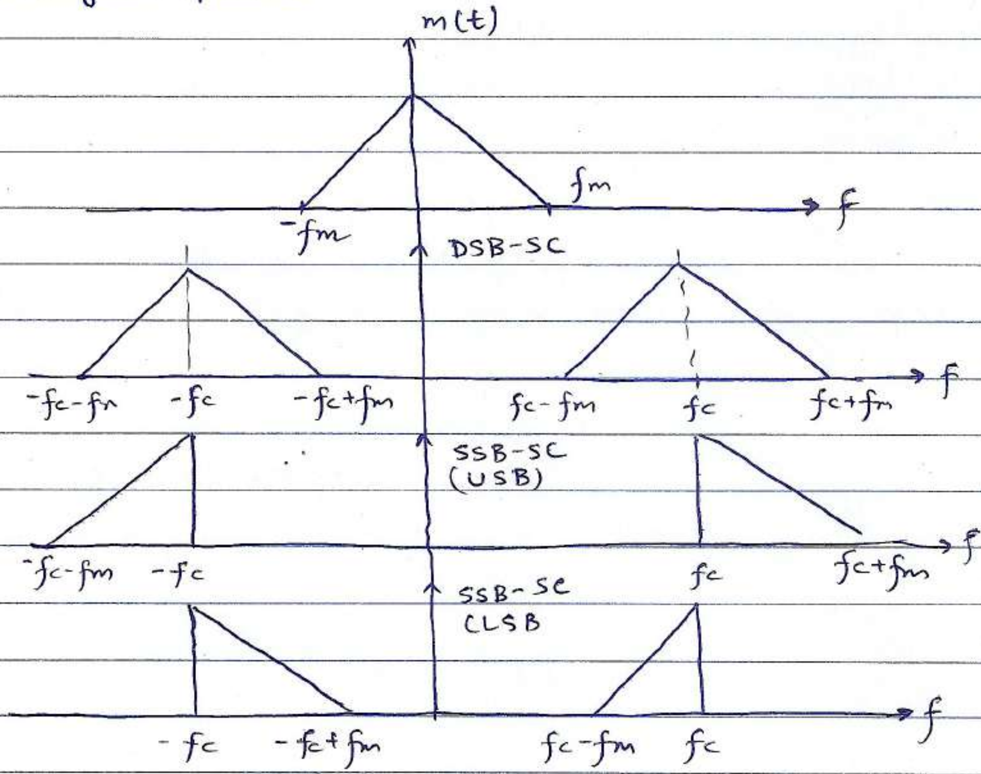
In AM signal & DSB - SC, upper side band and lower side band, charecteristic is symmetric wrt. carrier signal.

However, with only one of either LSB or USB the information can be extracted. Thus bandwidth wastage can be reduced by half compared to AM in SSB SC by cutting either USB or LSB. This reduces power wastage even more than DSB-SC.

→ Block diagram



→ Frequency response



	AM	DSB-SC	SSB-SC
	$y(t) = A_c \cos \omega_c t + \frac{\mu A_c}{2}\cos(\omega_c+\omega_m)t + \frac{\mu A_c}{2}\cos(\omega-\omega_m)t$	$y(t) = \frac{\mu A_c}{2}\cos(\omega_m+\omega_c)t + \frac{\mu A_c}{2}\cos(\omega_m-\omega_c)t$	$y(t) = \frac{\mu A_c}{2}\cos(\omega_m+\omega_c)t$ or $y(t) = \frac{\mu A_c}{2}\cos(\omega_m-\omega_c)t$
Power	$P_{carrier} + P_{sideband}$ $P_c + \frac{\mu^2}{2}P_c$	$P_{sideband} = P_{USB} + P_{LSB}$ $= \frac{\mu^2}{4}P_c + \frac{\mu^2}{4}P_c$	P_{USB} or P_{LSB} $\frac{\mu^2}{4}P_c$.
Bandwidth	$2\omega_m$	$2\omega_m$	ω_m

Q5 What is frequency modulation? (Explain with expression and diagram).

Frequency modulation (FM)

In FM, frequency of carrier wave is varied according to baseband signal.

~~Low freq. baseband signal : $y_m = A_m \sin \omega_m t$~~
~~high freq. carrier wave : $y_c = A_c \sin \omega_c t$~~
~~$= A_c \sin 2\pi f_c t$~~

~~$\therefore y_{FM} = A_c \sin [2\pi [f_c + k_f A_m \sin \omega_m t] t]$~~
~~frequency Modulation index~~

Hence, $f_{fm} = f_c + k_f y_m$ Δf : freq. deviation.

$\therefore$ Max. possible frequency of FM sig. $= f_c + k_f A_m$ (Δf).
Min. " " " $= f_c - k_f A_m$ (Δf)

f_t Total frequency swing $= 2 k_f A_m = 2\Delta f$

for y_m to be any general function, the general expression of FM can be written as,

$$y_{FM}(t) = A_c \sin\left[\omega_c t + 2\pi k_f \int y_m(t)\,dt\right]$$

(if $y_m = A_m \sin \omega_m t$)

$$= A_c \sin\left[\omega_c t + 2\pi k_f \int A_m \sin(\omega_m t)\,dt\right]$$

$$= A_c \sin\left[\omega_c t - \frac{2\pi k_f A_m}{2\pi f_m} \cos(\omega_m t)\right]$$

$$\beta = k_f \frac{A_m}{f_m} \quad \text{(Modulation index)}.$$

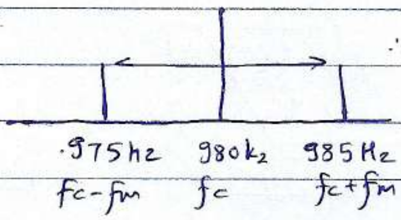
$$\boxed{y_{FM}(t) = A_c \sin\left[\omega_c t - \beta \cos(\omega_m t)\right]}$$

NUMERICALS

Q1. A standard AM broadcast station can transmit modulating frequencies upto 5 kHz. If the AM station is transmitting on a frequency of 980 kHz, what is the total bandwidth occupied by the AM station.

freq. of upper side band $= f_c + f_m = 980 + 5$ kHz $= 985$ kHz

" lower side band $= f_c - f_m = 980 - 5$ kHz $= 975$ kHz



$\therefore$ Bandwidth $= 985 - 975$

$= \boxed{10 \text{ kHz}}$

Q2. An unmodulated AM transmitter power is given by 400W. Find AM transmitter power with 90% Modulation.

$P_c = 400\,W \;;\; \mu = 0.9$

$$P_t = P_c + \frac{\mu^2}{2} P_c = P_c + \frac{(0.9)^2}{2} P_c$$

$$= P_c + \frac{0.81}{2} P_c = (1 + 0.405) P_c$$

$$= 1.405 \times 400\,W = \boxed{562\,W}$$

Q3. For AM, total sideband power is 100W with modulation index as 0.6. Find total AM transmitted power

$$P_s = \frac{\mu^2}{2} P_c \rightarrow P_c = \frac{2P_s}{\mu^2}$$

$$\therefore P_t = P_c + P_s = \frac{2P_s}{\mu^2} + P_s.$$

$$= \left(\frac{2}{0.6^2} + 1\right) P_s.$$

$$\simeq 6.56 \times 100 = \boxed{656W}$$

Q4. An AM transmitter current is given by 10A. Find AM transmitter current with modulation index equal to 0.5.

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

$$= 10 \sqrt{1 + \frac{(0.5)^2}{2}}$$

~~$\neq 10\sqrt{1.03125}$~~ $= 10\sqrt{1.125}$

~~$= 10 \times 1.0155$~~ $\approx 10 \times 1.061$

~~$\simeq \boxed{10.155A}$~~ $= \boxed{10.61A}$

Q5. For a FM signal, minimum possible freq. is given by 1.5 Mhz with total freq of 600 kHz. Find Δf, f_c & f_{max}.

$$f_t = 2\Delta f \rightarrow \Delta f = f_t/2 = 600/2 = \boxed{300 khz}$$

$$f_c = f_{min} + \Delta f = 1500 + 300 = \boxed{1800 kHz}$$

$$f_{max} = f_c + \Delta f = 1800 + 300 = \boxed{2100 kHz}$$

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