# Fundamentals of communication Engineering.

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## Introduction:

communication system means a system for information exchange. In our daily life, we use communication systems in various ways. For example, Telephone, Radio, TV, cell phone etc. are used for information exchange.

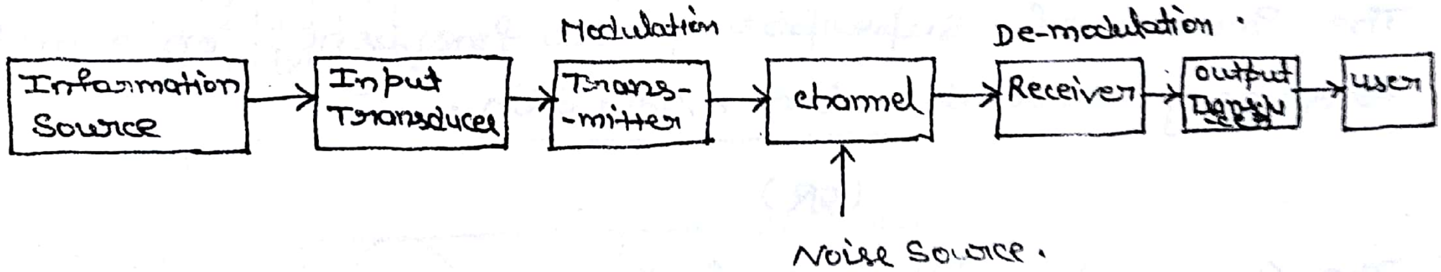
Voice = 300Hz - 3.5KHz

Audio = 20Hz - 20KHz

Video = 0 - 4.5MHz

## Elements of communication system:

Below figure shows the block diagram of communication system.




* The communication system Communicate messages. The messages comes from the information source. The information may be voice, Picture, code, Data, music and their combination. The message produced by information source is not electrical in nature.

* The Input transducer converts one form of energy to other form (electrical) without changing its frequency.

* The most of the transmitter have built in amplifier circuits. In transmitter circuits, signals goes for modulation ...

which helps in faithful reception of the transmitted info at the receiver end.

* channel can be a coaxial cable, two wire line, free space, or an optical fibre, or we can say that it is a link between transmitter and receiver.

* At Receiver, the signal is received by the receiver section which is in electrical in nature, and goes for demodulation process.

* At output Transducer, signal converted to their original form. e.g loud speaker.

* And, then signal reaches to the user or at Destination.

Need For modulation:

(i) For Long Distance communication:

Most of the signals of information have low frequency and they are not able to travel long distance directly in free space, Due to that modulation is Required.

The Process of superposing Low frequency on a high frequency wave is called modulation.

(OR)

The Process in which one of the parameter (Amplitude, Frequency, phase) of the carrier will be varied Linearly in accordance with message signal amplitude variation, called as Modulation.

ii) TO Reduce Antenna Height:

For Faithful transmission of a signal, minimum antenna Height should be $\lambda/4$.

Minimum Antenna Height = $\lambda/4$

$$H_t = \frac{1}{4} * \frac{c}{f}$$

If $f = 15\,KHz$

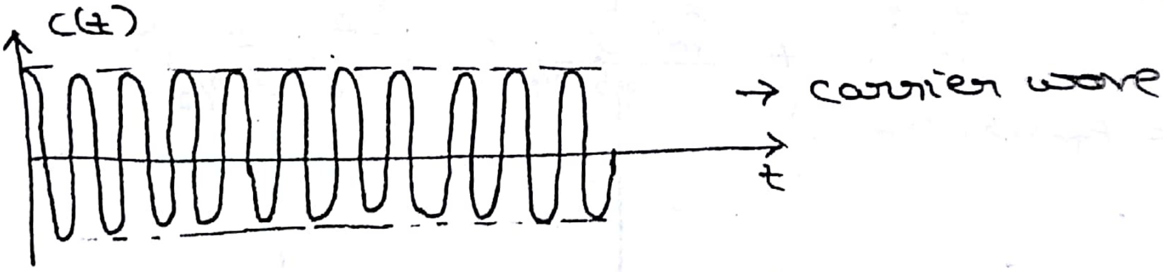
$$H_t = \frac{3 * 10^8}{4 * 15\,KHz}$$

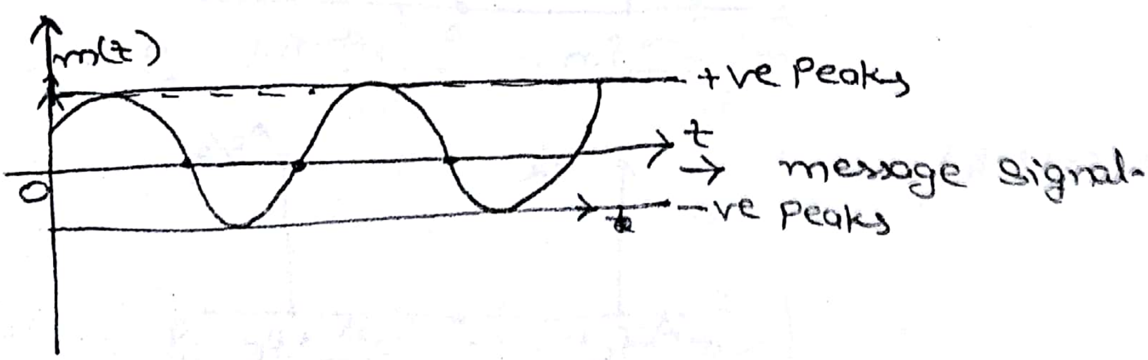
$= 5\,Km.$ (Not Possible)

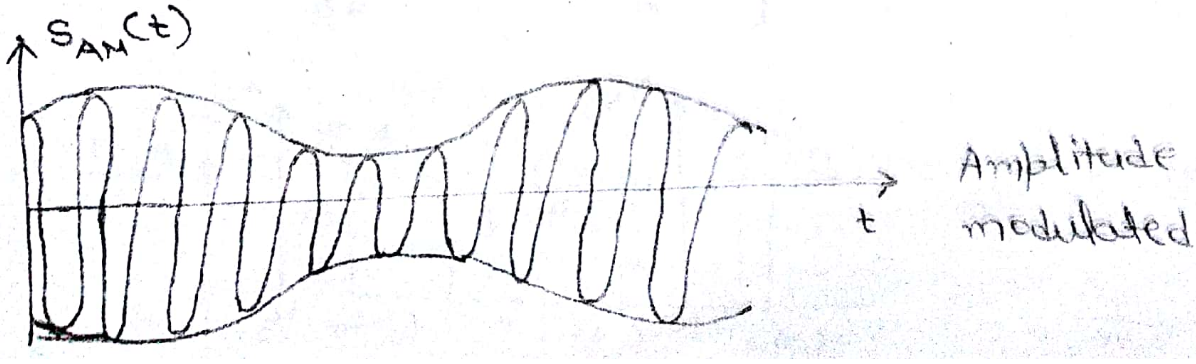
so that, Modulation is the process of increasing the frequency of signal to reduce Antenna height.

## Amplitude modulation:

It is the Process in which Amplitude of the carrier signal will be varied linearly in accordance with message signal Amplitude variation.



Assume $m(t) = A_m \cos 2\pi f_m t$

$c(t) = A_c \cos 2\pi f_c t$

* General Expression for AM

$$S_{AM}(t) = A_c \left[1 + K_a m(t)\right] \cos 2\pi f_c t$$

$K_a$ = Amplitude sensitivity factor

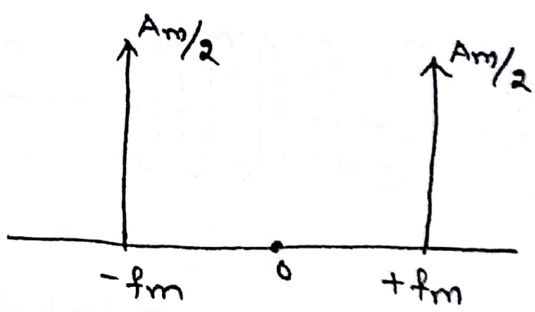
$$S_{AM}(t) = A_c \cos 2\pi f_c t + A_c m(t) \cos 2\pi f_c t \quad \text{if } K_a = 1$$

$$= A_c \cos 2\pi f_c t + A_c A_m \cos 2\pi f_m t \cos 2\pi f_c t$$

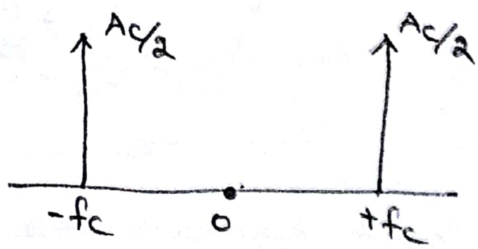
$$S_{AM}(t) = \underbrace{A_c \cos 2\pi f_c t}_{\text{carrier}} + \underbrace{\frac{A_c A_m}{2} \cos 2\pi (f_c + f_m)t}_{\text{USB}} + \underbrace{\frac{A_c A_m}{2} \cos 2\pi (f_c - f_m)t}_{\text{LSB}}$$

Frequency spectrum for AM:

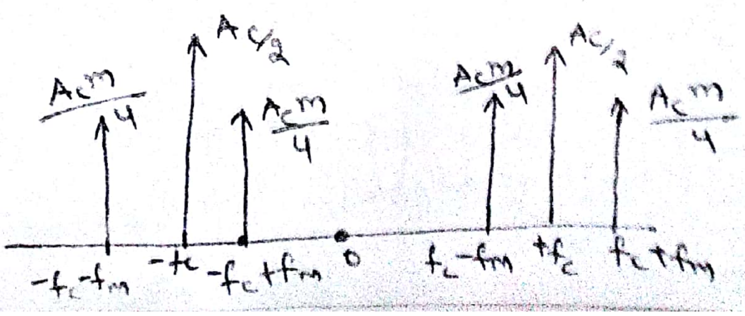
$m(t) = A_m \cos 2\pi f_m t$




$c(t) = A_c \cos 2\pi f_c t$




$S_{AM}(t)$



AM Bandwidth $= (f_c + f_m) - (f_c - f_m)$

$= f_c + f_m - f_c + f_m$

$$\boxed{B.W = 2 f_m}$$ OR $2 *$ msg. signal freq.

## Power calculation For AM :

Total Power For AM is given by

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

$$P_c = \frac{A_c^2}{2R}$$

$$P_{LSB} = P_{USB} = \frac{\frac{A_c^2 A_m^2}{4}}{2R} = \frac{A_c^2 A_m^2}{8R}$$

$$P_t = \underbrace{\frac{A_c^2}{2R}}_{P_c} + \underbrace{\frac{A_c^2 A_m^2}{8R}}_{P_{USB}} + \underbrace{\frac{A_c^2 A_m^2}{8R}}_{P_{LSB}}$$

$$P_t = \underbrace{\frac{A_c^2}{2R}}_{P_c} + \underbrace{\frac{A_c^2 A_m^2}{4R}}_{P_{SB} = P_{USB} + P_{LSB}}$$

$$P_t = \frac{A_c^2}{2R}\left[1 + \frac{A_m^2}{2}\right]$$

(OR)

$$P_t = \frac{A_c^2}{2R}\left[1 + \frac{m^2}{2}\right]$$

$m = A_m$ (if $A_c = 1$)

$m = A_m$ ...

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

m = modulation index

if $m = 0$

$P_t = P_c$

if $m = 1$

$P_t = \frac{3}{2}P_c$ (OR) $P_c = \frac{2}{3}P_t$

$P_t = 1.5P_c$

* As m increases from 0 to 1, Total AM Power is increased by 50%.

But As we seen from $P_c = \frac{2}{3}P_t$, 66.6% of transmitter power is wasted in the form of transmission of additional carrier. This is the biggest drawback of AM.

~~Modula~~

Current Relation for AM :

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

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

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

V.V. Imp.

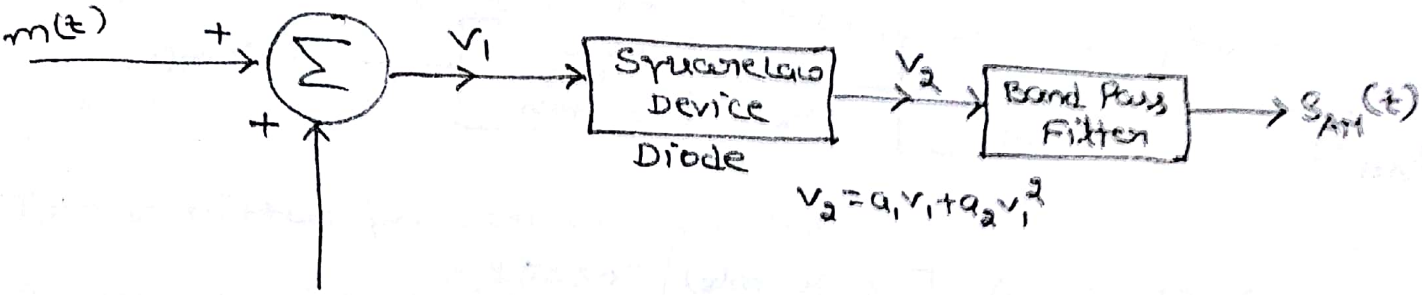
similarly

$$V_t = V_c\sqrt{1+\frac{m^2}{2}}$$

** V. Imp.

## (Mo)dulation Technique for AM:

### (1) Square Law Modulator:




$c(t) = A_c \cos 2\pi f_c t$

$$v_1 = c(t) + m(t)$$

$$v_2 = a_1 v_1 + a_2 v_1^2$$

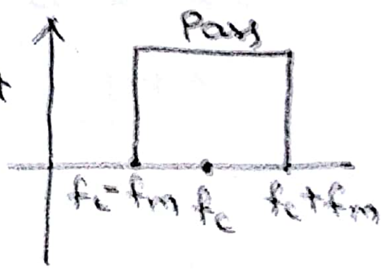
$$v_2 = a_1 \left[m(t) + c(t)\right] + a_2 \left[m(t) + c(t)\right]^2$$

$$= a_1 \left[m(t) + A_c \cos 2\pi f_c t\right] + a_2 \left[m(t) + A_c \cos 2\pi f_c t\right]^2$$

$$= a_1 m(t) + \underbrace{a_1 A_c \cos 2\pi f_c t}_{\text{Pass}} + a_2 m^2(t) + a_2 A_c^2 \cos^2 2\pi f_c t$$

$$+ \underbrace{2 a_2 m(t) A_c \cos 2\pi f_c t}_{\text{Pass}}$$

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




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

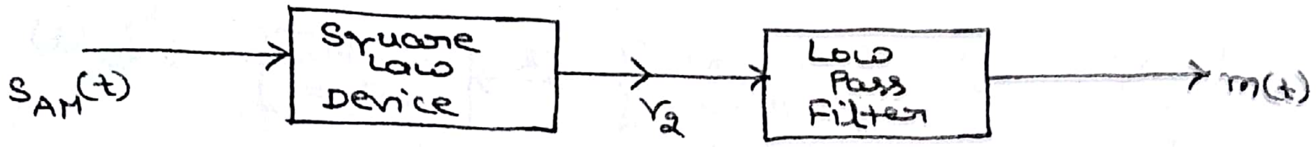
$$\boxed{S_{AM}(t) = A_c' \left[1 + K_a' m(t)\right] \cos 2\pi f_c t}$$

$$A_c' = a_1 A_c$$

$$K_a' = \frac{2a_2}{\ }$$

## Demodulation of AM:

### (i) Square Law Demodulator:




$$S_{AM}(t) = A_c[1 + K_a m(t)]\cos 2\pi f_c t$$

$$(SLD)_{o/p} = v_2 = a_1 S_{AM}(t) + a_2 S^2_{AM}(t)$$

$$v_2 = a_1\left[A_c \cos 2\pi f_c t + A_c K_a m(t)\cos 2\pi f_c t\right]$$
$$+ a_2\left[A_c^2 \cos^2 2\pi f_c t + A_c^2 K_a^2 m^2(t)\cos^2 2\pi f_c t\right]$$
$$+ \left[2 a_2 A_c^2 K_a m(t)\cos^2 2\pi f_c t\right]$$

$$= a_1 A_c \cos 2\pi f_c t + a_1 A_c K_a m(t)\cos 2\pi f_c t + a_2 A_c^2 \cos^2 2\pi f_c t$$

$$+ \underbrace{a_2 A_c^2 K_a^2 m^2(t)\cos^2 2\pi f_c t}_{a_2 A_c^2 K_a^2 m^2(t)\left[\frac{(1+\cos 4\pi f_c t)}{2}\right]} + \underbrace{2 a_2 A_c^2 K_a m(t)\cos^2 2\pi f_c t}_{2 a_2 A_c^2 K_a m(t)\left[\frac{1+\cos 4\pi f_c t}{2}\right]}$$

$$(LPF)_{o/p} = \underbrace{\frac{a_2 A_c^2 K_a^2 m^2(t)}{2}}_{\text{Noise}} + \underbrace{a_2 A_c^2 K_a m(t)}_{\text{Signal.}}$$

## ...antages of AM :

1. Demodulation is simple.
2. AM is preferred for Long distance Communication.

## Drawbacks :

1. Transmitter power is wasted.
2. It needs High transmission Bandwidth.
3. Effect of Noise is High.

## Application :

1. It is preferred in broad-casting (Point to Multipoint communication).

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## Double Sideband Supressed carrier : DSB-SC :

The advantage of DSB-SC, over AM is, transmitter power will be saved.

Assume message signal $m(t) = A_m \cos 2\pi f_m t$

carrier signal $c(t) = A_c \cos 2\pi f_c t$

General Expression for DSB,

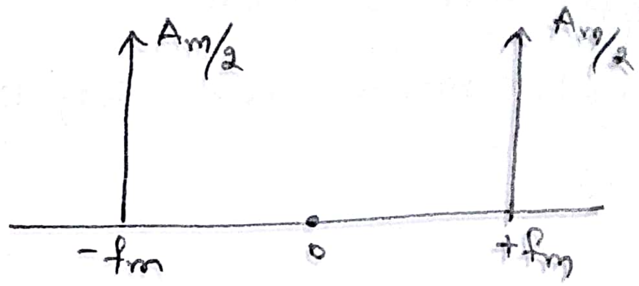
$$S_{DSB}(t) = A_c m(t) \cos 2\pi f_c t$$

$$= A_c A_m \cos 2\pi f_m t \cos 2\pi f_c t$$

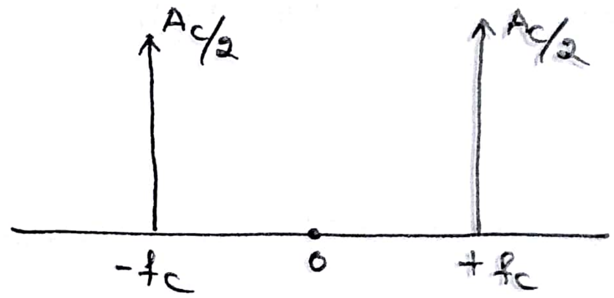
$$S_{DSB}(t) = \underbrace{\frac{A_c A_m}{2} \cos 2\pi (f_c + f_m)t}_{USB} + \underbrace{\frac{A_c A_m}{2} \cos 2\pi (f_c - f_m)t}_{LSB}$$

## Frequency Spectrum for DSB:

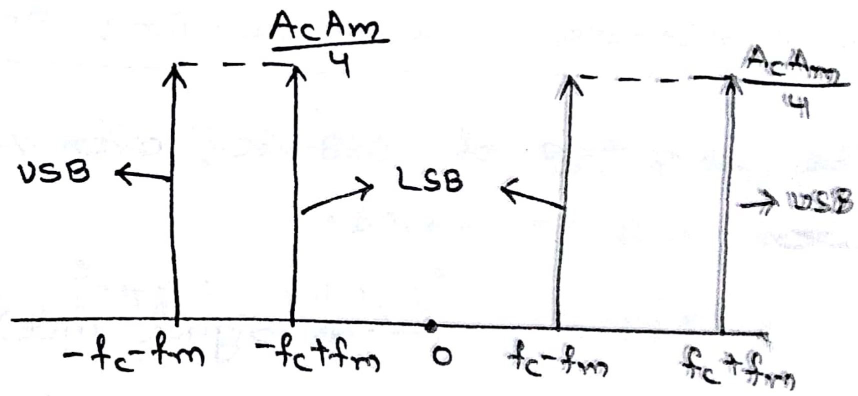
$m(t) = A_m \cos 2\pi f_m t$




$c(t) = A_c \cos 2\pi f_c t$




$S_{DSB}(t)$




## Power of DSB:

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

$$P_{USB} = \frac{\left(\frac{A_c A_m}{2}\right)^2}{2R} = \frac{A_c^2 A_m^2}{8R}$$

$$P_{LSB} = \frac{\left(\frac{A_c A_m}{2}\right)^2}{2R} = \frac{A_c^2 A_m^2}{8R}$$

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$$P_t = \underbrace{\underbrace{\frac{A_c^2 A_m^2}{8R}}_{P_{USB}} + \underbrace{\frac{A_c^2 A_m^2}{8R}}_{P_{LSB}}}_{P_{SB}}$$

$$\boxed{P_t = \frac{A_c^2 A_m^2}{4R}}$$

If $R = 1\Omega$

** V. Imp.

then $$\boxed{P_t = \frac{A_c^2 A_m^2}{4}}$$

## modulation Efficiency :

$$\eta = \frac{P_{SB}}{P_t}$$

$$\eta = \frac{\frac{A_c^2 A_m^2}{4}}{\frac{A_c^2 A_m^2}{4}} = 1$$

$\eta = 1$ 100% Efficient.

## Advantage of DSB :

1. Transmitter Power is saved.
2. Also used For Long Distance communication.

## Drawbacks :

1. Demodulation is complex.
2. It needs High transmission Bandwidth.

## Single side-band suppressed carrier SSB-SC:

The advantage of SSB-SC over AM and DSB, both transmitter Power and channel B.W will be saved.

$$m(t) = A_m \cos 2\pi f_m t$$

$$c(t) = A_c \cos 2\pi f_c t$$

$$S_{SSB}(t) = \frac{A_c A_m}{2} \cos 2\pi (f_c \pm f_m) t$$

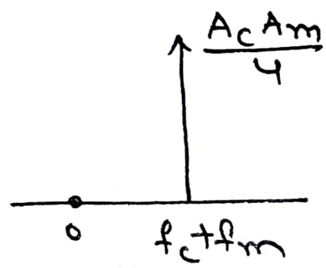
$+ \rightarrow$ USB

$- \rightarrow$ LSB

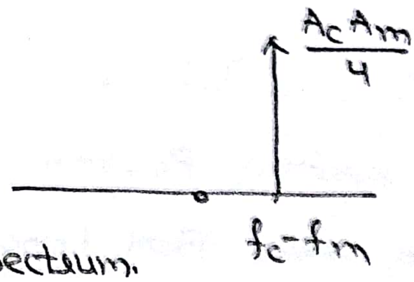
$$= \frac{A_c A_m}{2} \cos 2\pi f_c t \cos 2\pi f_m t \mp \frac{A_c A_m}{2} \sin 2\pi f_m t \sin 2\pi f_c t$$

$$\boxed{S_{SSB}(t) = \frac{A_c m(t)}{2} \cos 2\pi f_c t \mp \frac{A_c \hat{m}(t)}{2} \sin 2\pi f_c t}$$

90° Phase Shift of $m(t) = A_m \sin 2\pi f_m t = \hat{m}(t)$




OR




Frequency Spectrum.

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## Angle Modulation:

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

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

where $\theta(t) = (2\pi f_c t + \phi)$

* In Angle modulation, total Angle of the carrier will be varied in accordance with message signal variation.

* If Angle modulation occurs due to dependence of $f_c$ on $m(t)$, then it is called as frequency modulation.

* If Angle modulation occurs due to dependence of $\phi$ on $m(t)$, then it is called as Phase modulation.

## Frequency Modulation:

Frequency of the carrier before modulation = $f_c$

frequency of the carrier after freq. mod. = $f_i$

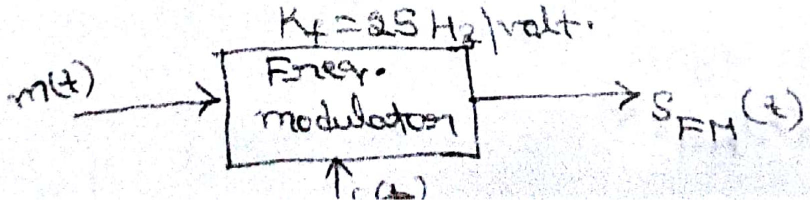
$$f_i = f_c + K_f\, m(t)$$

$K_f$ = freq. sensitivity (Hz/volt)

$f_i$ = Instantaneous freq. (Hz)

$f_c$ = carrier freq. (Hz)

If $m(t) = 0$, No modulation.



$f_i = f_c + K_f m(t)$

$m(t) = 0$

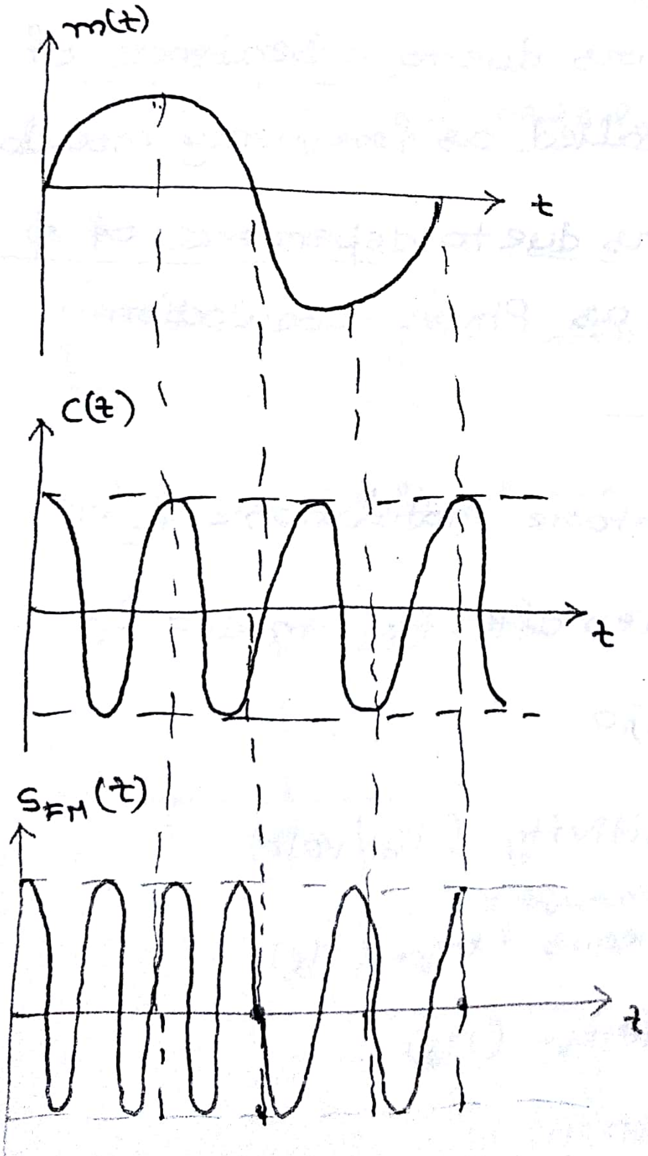
$f_i = f_c$ ⎫ $f_i = f_c$

when $m(t) > 0$ $(+5V)$

$f_i = f_c + 125\ KHz$ ⎫ $f_i > f_c$

when $m(t) < 0$ $(-5V)$

$f_i = f_c - 125\ KHz$ ⎫ $f_i < f_c$




**General Expression for FM signal:**

Carrier before modulation $c(t) = A_c \cos(2\pi f_c t + \phi)$

where $\theta(t) = 2\pi f_c t + \phi$

$$\frac{d\theta(t)}{dt} = 2\pi f_c$$

carrier after freq. modulation

$$S_{FM}(t) = A_c \cos[\theta_i(t)] \quad \text{--- (i)}$$

$$\frac{d\theta_i(t)}{dt} = 2\pi f_i$$

$$f_i = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt}$$

$\theta_i(t)$ = Instantaneous Angle

$$\theta_i(t) = 2\pi \int f_i \, dt$$

$$= 2\pi \int (f_c + K_f m(t))\, dt$$

$$\theta_i(t) = 2\pi f_c t + 2\pi K_f \int m(t)\, dt$$

From equation (i)

$$S_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi K_f \int m(t)\, dt\right)$$

Assume $m(t) = A_m \cos 2\pi f_m t$

$$S_{FM}(t) = A_c \cos\left[2\pi f_c t + \frac{2\pi K_f A_m}{2\pi f_m} \cdot \sin 2\pi f_m t\right]$$

$$= A_c \cos\left[2\pi f_c t + \frac{K_f A_m}{f_m} \sin 2\pi f_m t\right]$$

$$\frac{K_f A_m}{f_m} = \frac{\Delta f}{f_m} = \beta$$

$\beta$ = mod. index

$\Delta f = K_f A_m$ = freq. deviation

$$S_{FM}(t) = A_c \cos(2\pi f_c t + \beta \sin 2\pi f_m t)$$

Power for FM:

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

Bandwidth for FM:

$$B.W = 2(\beta+1) f_m$$

$$\beta = \frac{\Delta f}{f_m}$$

$$\Delta f = K_f A_m$$

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Phase modulation:

Carrier before Phase modulation: $c(t) = A_c \cos 2\pi f_c t$

Carrier after phase modulation

$$S_{PM}(t) = A_c \cos\left[2\pi f_c t + \phi(t)\right]$$

$$\phi(t) = K_p m(t)$$

$K_p$ = Phase sensitivity (Rad./volt)

$$S_{PM}(t) = A_c \cos\left(2\pi f_c t + K_p m(t)\right)$$

$$\Delta\phi = \max.\left[\phi(t)\right] = \max.\left[K_p m(t)\right]$$

$$\Delta\phi = K_p A_m$$

$$B.W = 2(\beta+1) f_m$$

$$\beta = \Delta\phi = K_p A_m$$