Date :
Page No. :

UNIT-5

Communication Engineering

Definitions :-

(1) BANDWIDTH :- It is the range of frequencies over which information signal is transmitted.

(2) Channel Bandwidth :- It is defined as the range of frequencies which a channel can pass through without any distortion.

(3) Frequency spectrum :- It is the representation of a signal in freq. domain. It consists of amplitude and phase spectrum of signal.

(4) Base Band Signal :- It is defined as the message signal in the original form. Message signal may be in the form of text, sound, picture etc. Base band signal is also called as Modulating Signal.

Date :
Page No. :

Modulation :- In modulation, some parameters of the carrier wave such as Amplitude, Frequency or phase is Varied in accordance with the modulating signal, is Called as Modulation.

Modulation is done at the transmitter side, and the resultant signal is called as Modulated Signal.

→ Modulated signal is also called as Broad Band Signal.

Date :
Page No. :

IEEE Frequency spectrum / EM spectrum and its Applications :- (RADIO FREQUENCY SPECTRUM) :-

	Frequency Band	Applications
1.	30HZ - 300HZ Extremely Low Freq. (ELF)	In power Transmission
2.	300HZ — 3 KHZ Voice Frequencies (VF)	Audio Applications
3.	3 KHZ — 30 KHZ Very Low Frequencies (VLF)	Navy, Military Applications
4.	30 KHZ — 300 KHZ Low Frequencies (LF)	Aeronautical and Marine Navigation
5.	300 KHZ - 3 MHZ Medium Frequencies (MF)	AM Radio BroadCast
6.	3 MHZ - 30 MHZ High Frequencies (HF)	short Wave transmission
7.	30 MHZ - 300 MHZ Very High Frequencies (VHF)	TV BroadCasting
8.	300 MHZ — 3 GHZ Ultra High Frequencies (UHF)	Cellular phones, Military Applications.

9.	3 GHz - 30 GHz Super High Frequencies (SHF)	Radar And Satellite Communication
10.	30 GHz – 300 GHz Extreme High Frequencies (EHF)	Satellite and specialized Radars.

M. Imp

Need for Modulation :- Modulation is Needed due to Following reasons:-

(1) **To Reduce the height of Anteena :-** For the transmission of radio signals, the Anteena height must be a multiple of $\frac{\lambda}{4}$.

→ Minimum Height of Anteena For $\boxed{F = 10\ KHz}$ is –

$$\frac{\lambda}{4} = \frac{c}{f \times 4} = \frac{3 \times 10^8}{10 \times 10^3\ Hz \times 4} = 75m$$

→ Therefore we can see, As the frequency increases, the height of anteena decreases.

→ Minimum Height of Anteena For $\boxed{F = 1\ MHZ}$ –

$$\frac{\lambda}{4} = \frac{c}{f \times 4} = \frac{3 \times 10^8}{1 \times 10^6 \times 4} = 75m$$

Date :
Page No. :

② Modulation Avoids mixing of signals :- If baseband signals are transmitted by more than 1 transmitter then all the signals will get mixed up due to same bandwidth (0-20 KHz) and Receiver can't separate them from each other.

If each baseband signal is used to modulate a diffrent carrier, they won't get mixed up.

③ Increases the range of Communication :-

The Frequency of baseband signal is low and low Frequency signals can't travel a long distance. They get heavily attenuated.

So by modulation we can increase the range of communication.

④ Makes Multiplexing possible :- Multiplexing is a process in which two or more signals can be transmitted over the same communication channel.

⑤ Improves Quality Reception :- With FM and digital communication techniques, the effect of noise is reduced to a great extent.

Date :
Page No. :

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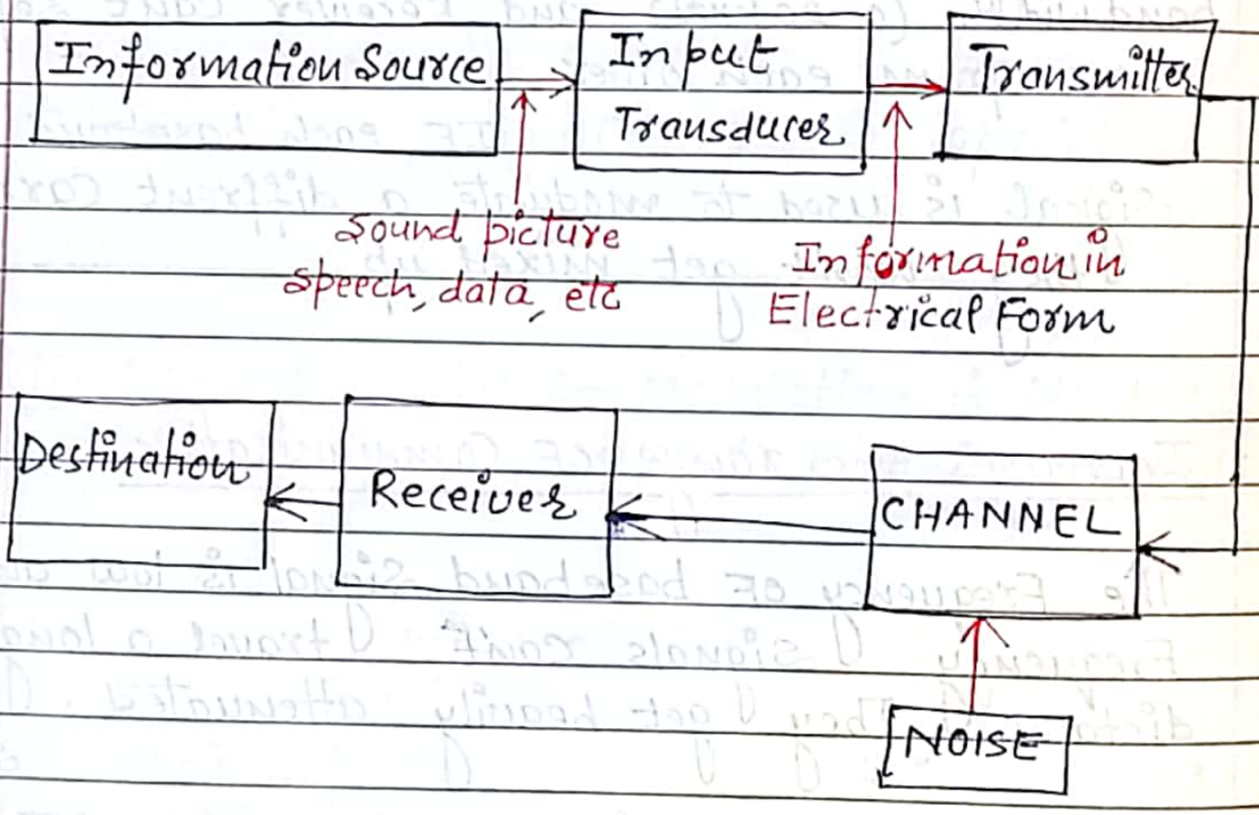
Block Diagram of Communication System :-



① **Information Source :-** Information source contains message. This message may be in the form of sound picture, speech, data, text etc.
This information may be or may not be in electrical nature.

② **Input Transducer :-** Transducer is a device which transforms one form of energy into another form.
The input

Date :
Page No. :

transducer is used to Convert the information or message, which is in non-electrical form, into a time varying electrical form.

③ Transmitter :- The transmitter processes the incoming information or message signal so as to make it suitable for transmission. Modulation is done at the transmitter.

④ CHANNEL :- Channel is a medium through which the message travels from the transmitter to the receiver. In other words the Function of channel is to provide a physical Connection between the transmitter and the receiver.

⑤ Noise :- Noise may interfere with signal at any point in the communication system. If noise is present in the channel or at the input of receiver, it harms a lot.

⑥ Receiver :- The Function of receiver is to receive the signal (modulated) and to extract the message, which is in electrical form, from the carrier signal that means De-Modulation is done at the receiver.

Date :

Page No. :

⑥ Destination :- This is the Final stage which is used to Convert an electrical message signal ~~its~~ into its original Form.

For this Inverse transducer is used.

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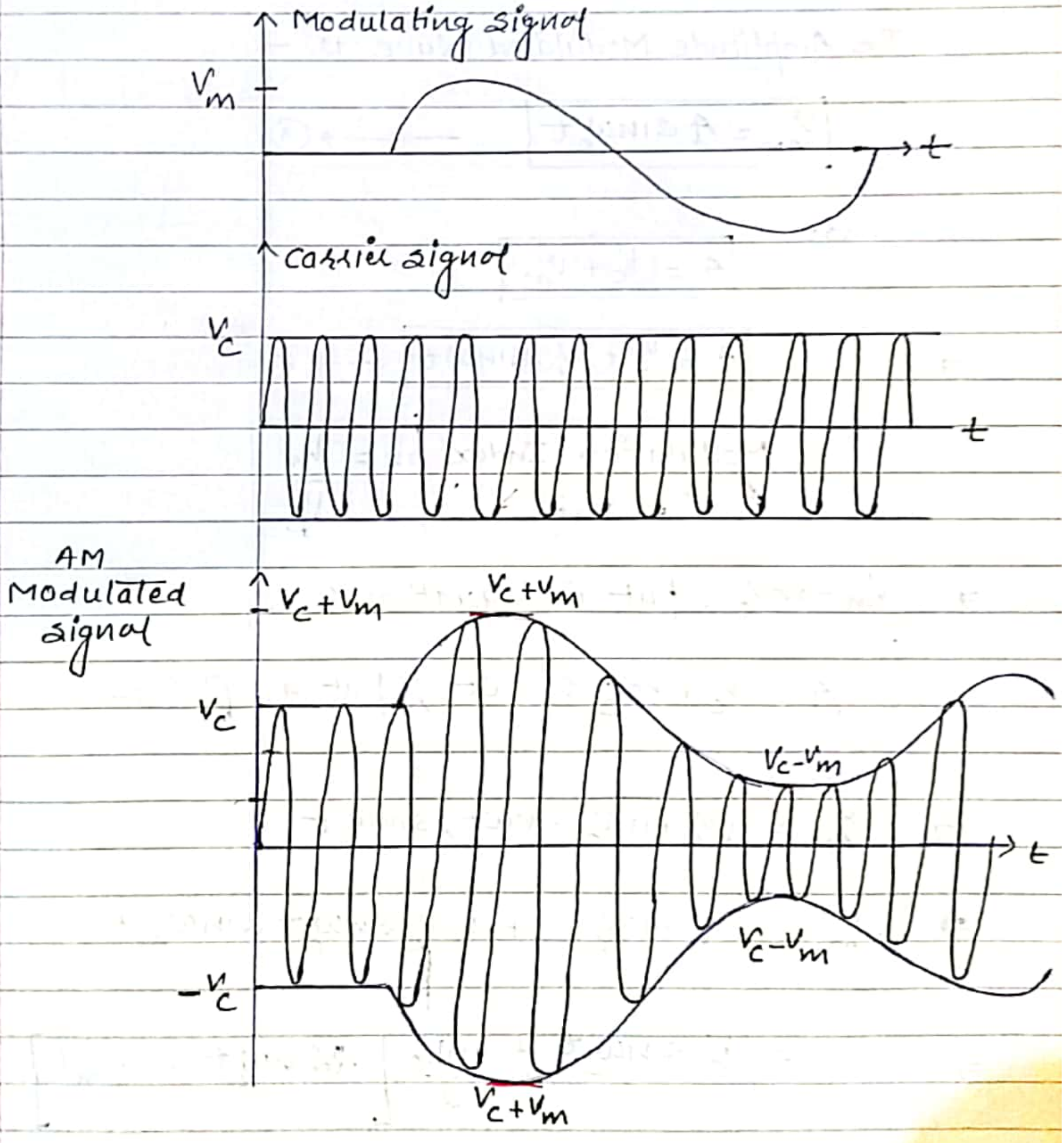
Classification OF Modulation :-

- Modulation
  - Analog Modulation
    - Amplitude Modulation
    - Angle Modulation
      - Frequency Modulation
      - Phase Modulation
    - Pulse Analog Modulation
      - PAM → pulse Amplitude Modulation
      - PWM → Pulse width Modulation
      - PPM → Pulse position modulation
  - Digital Modulation
    - PCM (Pulse coded) Modulation
    - Delta Modulation

Modulation Index :- The modulation index is the ratio of maximum amplitude of message signal to the maximum amplitude of carrier signal ie

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

Amplitude Modulation :- If the amplitude OF Carrier signal is varied in accordance with the instantaneous value OF the modulating signal, is called as Amplitude Modulation.



Let the Carrier wave is $\boxed{v_c = V_c \sin\omega_c t}$ → ①

Let the modulating signal is $\boxed{v_m = V_m \sin\omega_m t}$ → ②

The Amplitude Modulated wave is –

$$\boxed{v_{AM} = A \sin\omega_c t} \longrightarrow ③$$

Where $\boxed{A = V_c + v_m}$

$$\Rightarrow \boxed{A = V_c + V_m \sin\omega t} \longrightarrow ④$$

Modulation Index $\boxed{m = \frac{V_m}{V_c}}$

$\Rightarrow$ $\boxed{V_m = mV_c}$, put in equation ④ :–

$\boxed{A = V_c + mV_c \sin\omega t}$, put in eq^n ③ :–

$$\Rightarrow v_{AM} = (V_c + mV_c \sin\omega t)\sin\omega_c t$$

$$\Rightarrow v_{AM} = V_c \sin\omega_c t + mV_c \sin\omega_c t \sin\omega_m t$$

$$\Rightarrow \quad = V_c \sin\omega_c t + \frac{mV_c}{2}\left[2\sin\omega_c t \sin\omega_m t\right]$$

$$\boxed{v_{AM} = V_c \sin\omega_c t + \frac{mV_c}{2}\left[\cos(\omega_c-\omega_m)t - \cos(\omega_c+\omega_m)t\right]}$$

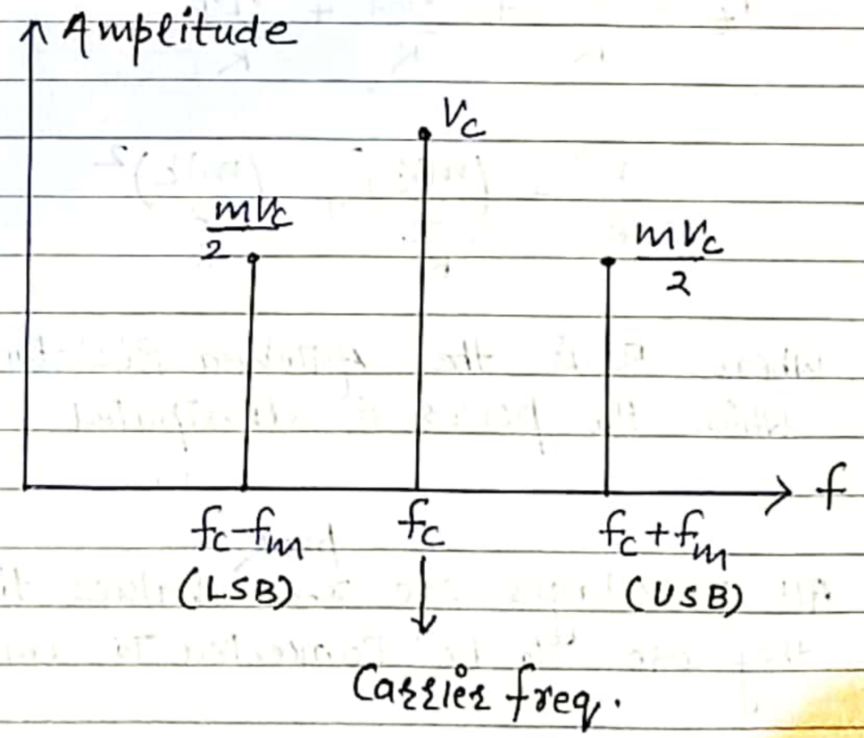
I term $\qquad\qquad$ II term $\qquad\qquad$ III term

<u>I term</u> :- $V_c \sin\omega_c t$ is a unmodulated carrier signal.

<u>II term</u> :- It refers to $f_c - f_m$, which is known as Lower side band (LSB)

<u>III term</u> :- It refers to $f_c + f_m$, which is known as upper side band (USB)

FREQUENCY SPECTRUM OF AM Wave :-



Bandwidth of AM Wave = USB - LSB

$$B\cdot Width = (f_c + f_m) - (f_c - f_m)$$

$$\boxed{B\cdot Width \text{ of AM Wave} = 2f_m}$$

Power Relation in AM wave:-

The AM Modulated Wave has total Power P_t or P_{AM} is given by:-

$$\boxed{P_{AM} = P_t = P_C + P_{USB} + P_{LSB}}$$

$$\Rightarrow \quad P_t = \frac{V_c^2}{R} + \frac{V_{USB}^2}{R} + \frac{V_{LSB}^2}{R}$$

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

⇒ Where R is the Antenna Resistance across which the power is dissipated.

⇒ All 3 voltages are ~~rms~~ peak values therefore they are to be converted to rms values.

$$\therefore \quad P_t = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{mV_c}{2\sqrt{2}}\right)^2}{R}$$

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

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

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

Where m = modulation Index

OR

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

Note :- When $\boxed{m = 1}$, the maximum power in AM Wave is $1.5 P_c$, this is the max. power that an amplifier must be capable of handling without distortion.

Current Relation in AM Wave :-

We know

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

$$\frac{P_T}{P_c} = 1+\frac{m^2}{2}$$

$$\frac{I_T^2 R}{I_c^2 R} = 1+\frac{m^2}{2}$$

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

classmate
Date ______
Page ______

Efficiency:- (η)

We know $\eta = \frac{O/P\ Power}{I/P\ Power}$

$$= \frac{P_{SB}}{P_C + P_{SB}}$$

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

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

$$= \frac{\frac{m^2}{2}}{\frac{2+m^2}{2}}$$

$$\boxed{\eta = \frac{m^2}{2+m^2}}$$

Let $\boxed{m=1}$ then $\eta = \frac{1}{2+1} \Rightarrow \boxed{\eta = \frac{1}{3}} \times 100 = 33.33\%$

$\Rightarrow$ Efficiency of AM wave is 33.33 % only. This implies that only one-third of the total power is carried by Sidebands and the rest two-third power is Wastage.

Modulation Index (m) :- (Modulation depth)

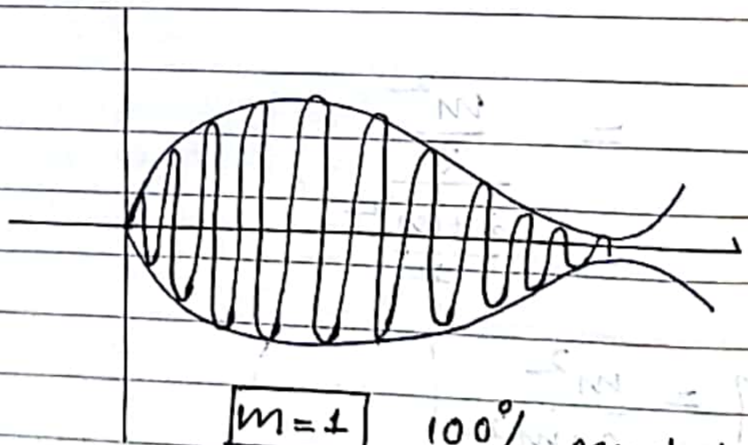
$$\boxed{\text{modulation Index } m = \frac{V_m}{V_c}}$$

It is also called as % modulation.

Case 1 :- if $\boxed{m = 1}$ then -

$$m = \frac{V_m}{V_c} = 1$$

$\boxed{V_m = V_c}$ Which means that the amplitude of the message signal is equal to amplitude of carrier signal.



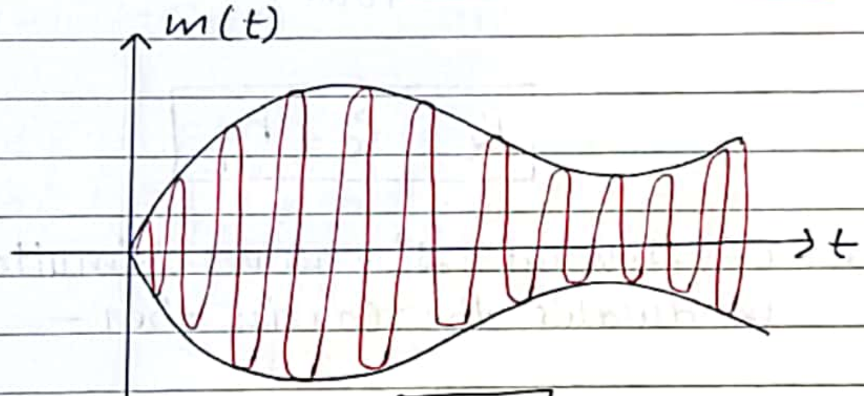
$\boxed{m = 1}$ 100% modulation.

Case 2 :- if $\boxed{m < 1}$ then

$$m = \frac{V_m}{V_c} < 1$$

$$\boxed{V_m < V_c}$$

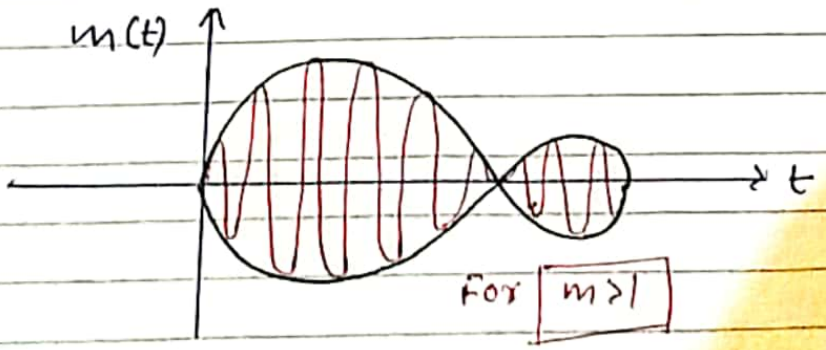
Which means that the amplitude of message signal is less than the amplitude of carrier signal. It means that the baseband signal may be fully recovered from the envelope of AM wave. This phenomenon is known as under modulation.



$\boxed{m<1}$

Case3 :- if $\boxed{m>1}$ then $m = \frac{V_m}{V_c} > 1 \Rightarrow \boxed{V_m > V_c}$

It means that the baseband signal or original signal doesn't recover from the envelope of AM wave. This phenomenon is called over modulation ~~and~~ or envelope distortion.



For $\boxed{m>1}$

Modulation by several sine waves :-

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

$$P_t = \underbrace{P_c}_{\text{Carrier Power}} + \underbrace{P_c\frac{m^2}{2}}_{\text{Power of sidebands}}$$

$$\therefore \boxed{P_t = P_c + P_{SB}}$$

⇒ If several sine waves simultaneously modulates the carrier then –

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

$$\therefore m_t^2 = m_1^2 + m_2^2 + \cdots$$

$$\boxed{m_t = \sqrt{m_1^2 + m_2^2 + \cdots}}$$

Where m_t = Total Modulation index.

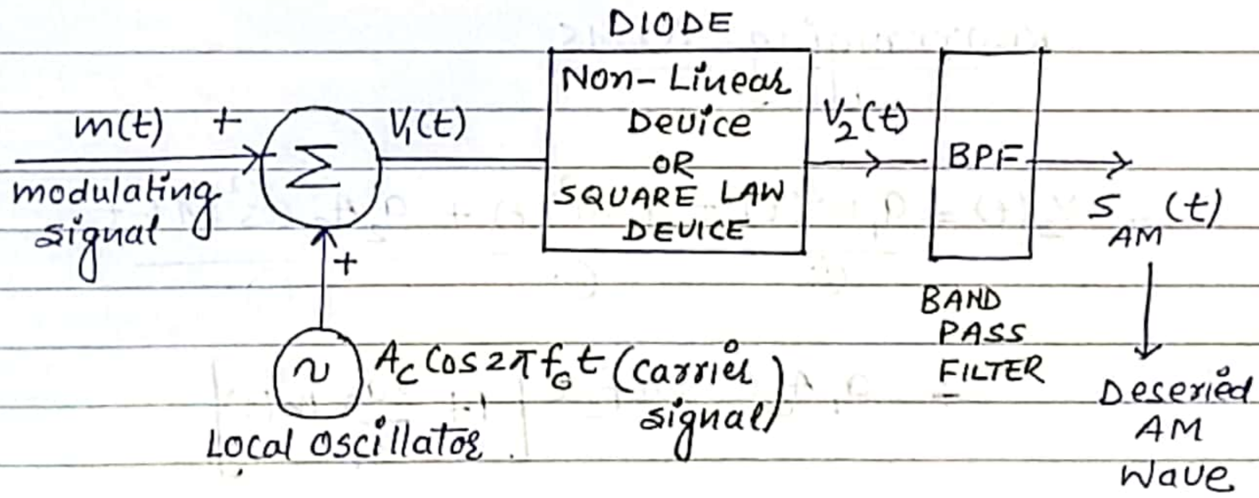
Generation of AM waves | Square Law Modulator :-

Introduction :- AM waves are generated using square Law modulator. It requires 3 Features :-

1) A means of summing Carrier and modulating signal

2) A Non-linear device (diode)

3) A band pass Filter for extracting desired modulated signal.



From the diagram

$$V_1(t) = m(t) + A_c \cos 2\pi f_c t \longrightarrow ①$$

The transfer characteristics of Non-Linear device is given by :-

$$\Rightarrow \quad V_2(t) = a_1 V_1(t) + a_2 V_1^2(t) + a_3 V_1^3(t) + \cdots$$

put the value of $V_1(t)$ in above equation.

$$\Rightarrow \quad V_2(t) = a_1\left[m(t) + A_c \cos 2\pi f_c t\right] + a_2\left[m(t) + A_c \cos 2\pi f_c t\right]^2 + \cdots$$

$$\Rightarrow \quad V_2(t) = a_1 m(t) + a_1 A_c \cos 2\pi f_c t + a_2 m^2(t) + a_2 A_c^2 \cos^2 2\pi f_c t + 2 a_2 A_c m(t) \cos 2\pi f_c t$$

Rearranging terms.

$$\Rightarrow \quad V_2(t) = \underbrace{a_1 m(t)}_{①} + \underbrace{a_2 m^2(t)}_{②} + \underbrace{a_2 A_c^2 \cos^2 2\pi f_c t}_{③}$$

$$+ \underbrace{a_1 A_c \cos 2\pi f_c t\left[1 + \frac{2a_2}{a_1} m(t)\right]}_{④}$$

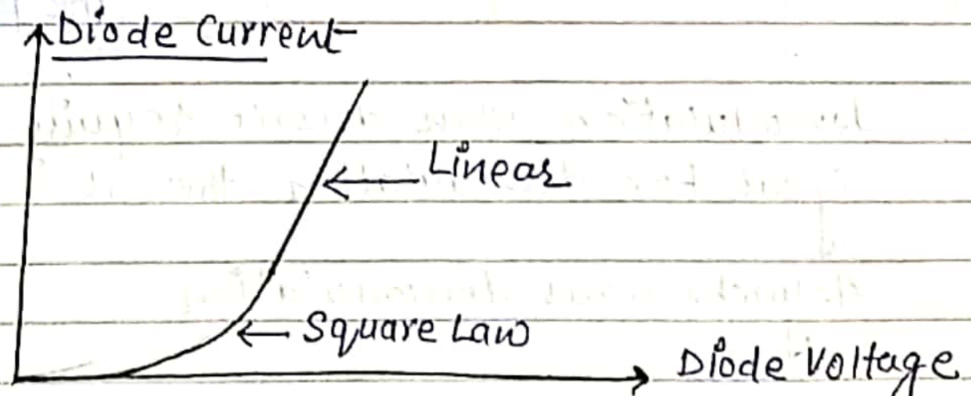
$\Rightarrow$ $a_1 m(t)$ & $a_2 m^2(t)$ will not be selected (Rejected by BPF) b'coz carrier component is absent & modulation will not take place.

$\Rightarrow$ $a_2 A_c^2 \cos^2 2\pi f_c t$ will not be selected because there is no message signal component and contains Harmonics of Carrier signal.

$\Rightarrow$ The term $a_1 A_c \cos 2\pi f_c t\left[1 + \frac{2 a_2}{a_1} m(t)\right]$ will be passed through Bandpass Filter and is the desired AM wave.

$\Rightarrow$ Let $\boxed{\frac{2a_2}{a_1} = k_a}$; Called as Amplitude sensitivity

$$\therefore \boxed{\text{Desired AM wave at the o/p} = a_1 A_c \cos 2\pi f_c t\left[1 + k_a m(t)\right]}$$



Note: At Low voltage $\rightarrow$ Diode Follows square law characteristics
At high voltage $\rightarrow$ It Follows Linear characteristics

De-Modulation OF AM Wave :-

① The process OF extracting modulating signal From modulated signal is Called demodulation.

② Depending upon methodology To detect, the detection process Can be OF 2 Types :-

① Synchronous | Coherent detection

② Asynchronous | Non-Coherent

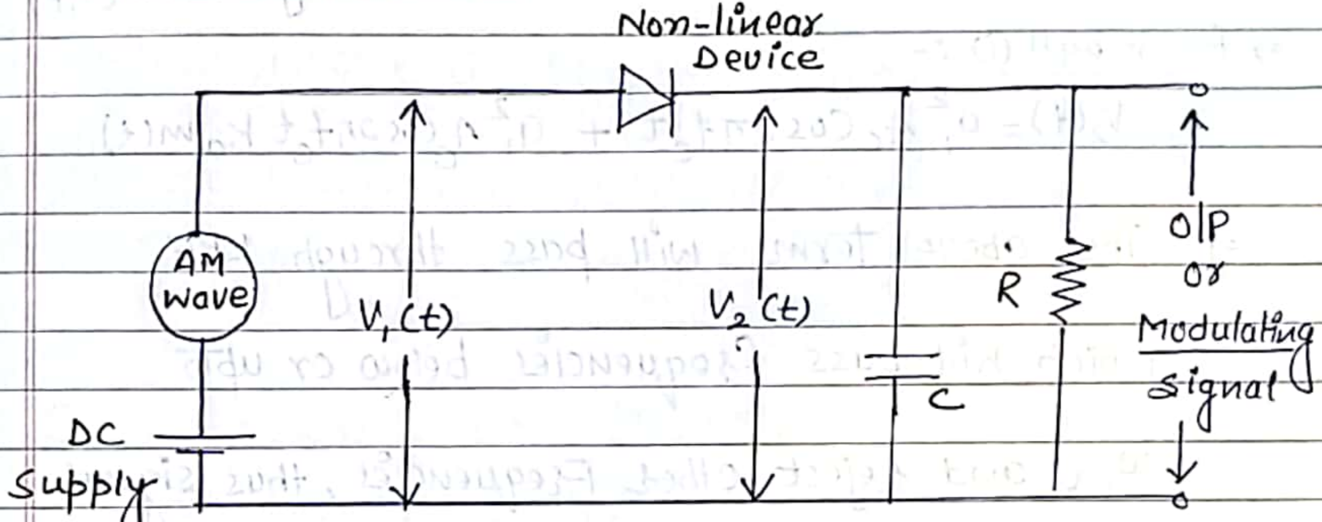
① Synchronous | Coherent :- The process OF demodulation when we require Carrier signal For demodulation, it is Called as Synchronous demodulation.

② Asynchronous | Non-Coherent :- The process OF demodulation when doesn't require Carrier Signal For demodulation then it is Called as Asynchronous demodulation.

For AM, the demodulators or detectors are of 2 types :-

① Square Law detector ② Envelope detector

Square Law detector :-



$$\Rightarrow \quad V_1(t) = a_1 A_c \cos 2\pi f_c t \left[1 + k_a m(t) \right]$$

⇒ We know, the O/P eqn of a non-linear device is —

$$V_2(t) = a_1 V_1(t) + a_2 V_1^2(t) + \text{-----}$$

Where a_1, a_2, a_3 --- are Constants

$$\Rightarrow \quad V_2(t) = a_1 \Big[\underbrace{a_1 A_c \cos 2\pi f_c t \left[1 + k_a m(t) \right]}_{①} \Big] + a_2 \underbrace{\left[a_1 A_c \cos 2\pi f_c t \left(1 + k_a m(t) \right) \right]^2}_{②} + \text{----} \longrightarrow ①$$

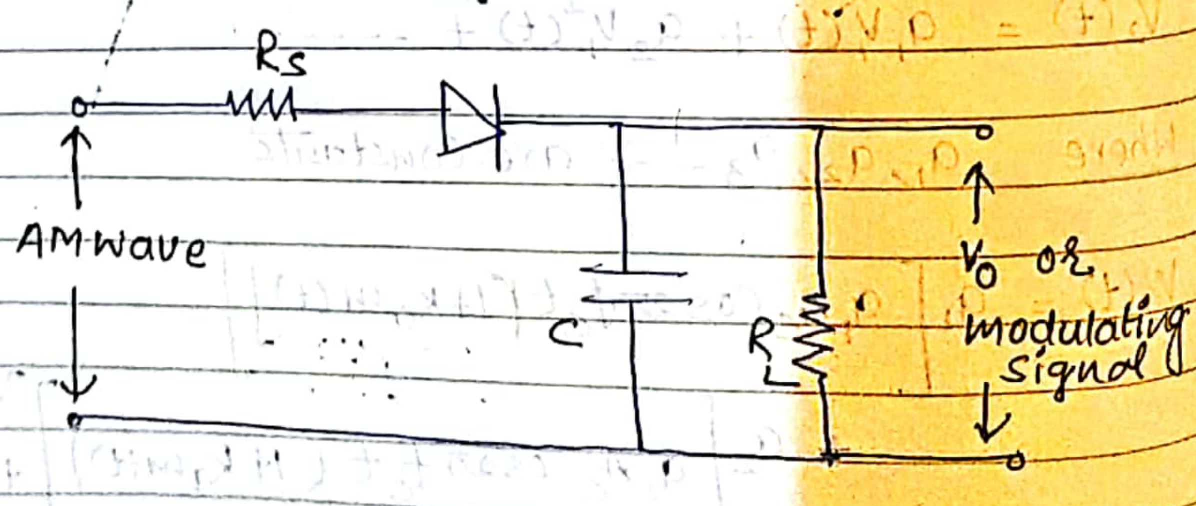
⇒ The 2^{nd} term $a_2\left[a_1 A_c \cos 2\pi f_c t \,(1+k_a m(t))\right]^2$ will produce high Freq Carrier components (harmonics), which will be rejected by LPF (RC ckt)

⇒ From eq^n ① :-

$$\therefore V_2(t) = a_1^2 A_c \cos 2\pi f_c t + a_1^2 A_c \cos 2\pi f_c t \, k_a m(t)$$

⇒ The above terms will pass through LPF which will pass frequencies below or upto ω_m and reject other Frequencies, thus signal (modulating) is detected at the O/P OF LPF.

Envelope Detector | Linear Diode :-



1) Envelope detector is used for demodulation OF AM signals.

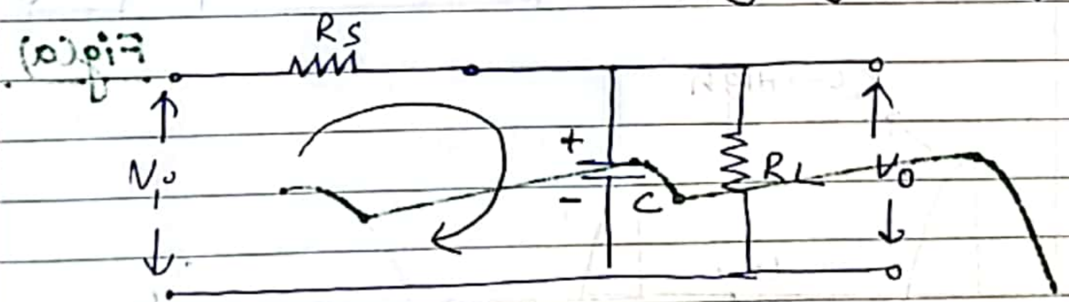
2) Envelope detector extracts the (+ve) envelope OF the applied signal (AM wave) and produces at the O/P.

3) Envelope detector Can be used For $\boxed{m \leq 1}$

Assume input to envelope detector is a Sinusoidal wave as shown in Fig (2).

Case 1 :- $\boxed{\text{When } t = 0^+}$ (Greater than zero)

Diode ⟶ Forward biased and act as short ckt and Capacitor starts charging through Rs.



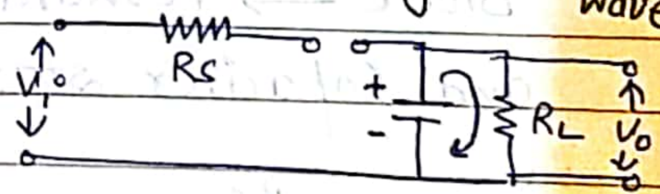
⇒ Charging Time Constant $\boxed{\tau_1 = R_s C}$ is very less b'coz R_s is less

Case 2:- $\boxed{\text{When } t = t_1^+}$ diode will be Reverse biased and behave as open ckt.

Now Capacitor starts discharging through R_L (Fig(a))

⇒ Discharging time constant $\boxed{\tau_2 = R_L C}$ should be high so that capacitor ~~starts~~ discharges slowly. ($R_L >> R_S$)

⇒ IF capacitor discharges slowly, the o/p signal can follow the envelope OF i/p signal (AM) wave



Fig(a)

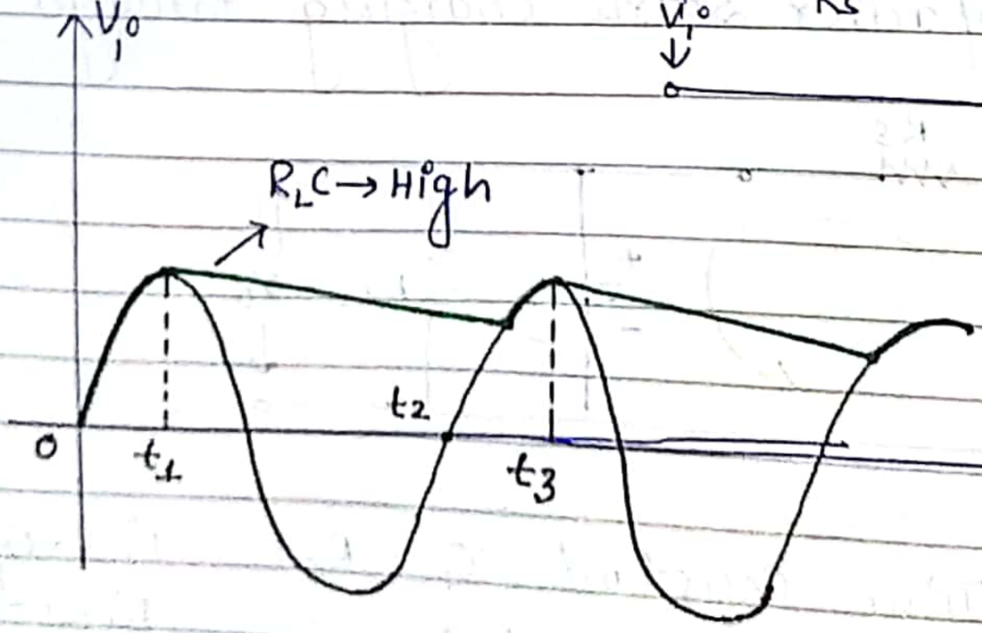
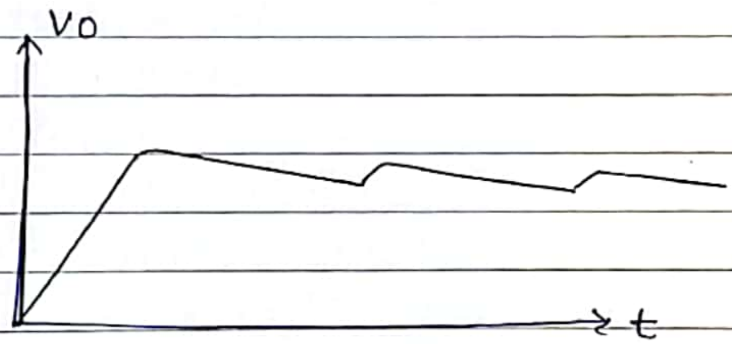


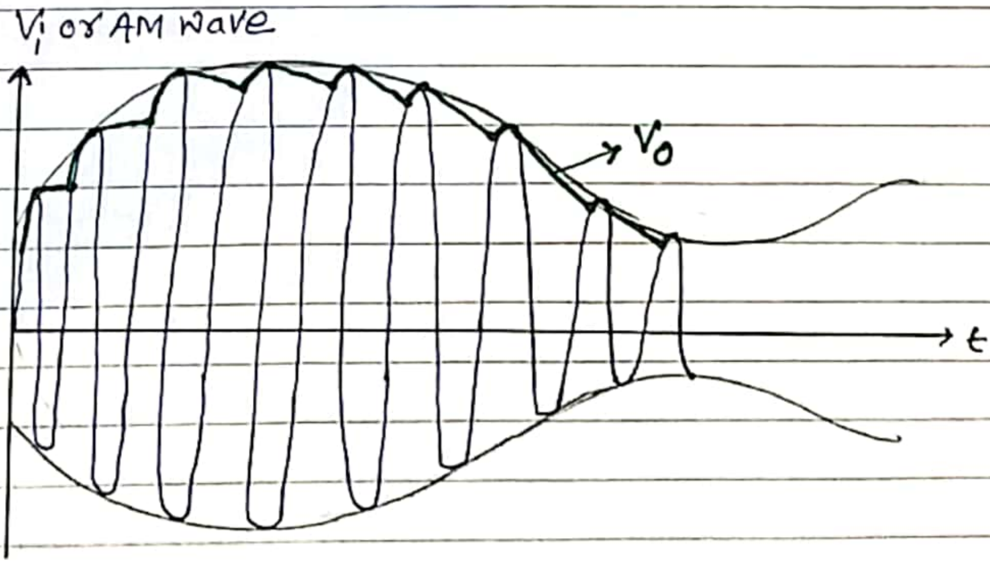
Fig (2)

Case 3 :- When $\boxed{t = t_2^+ \text{ to } t_3}$ at this point again

Diode will be Forward biased and will behave like short ckt and capacitor starts charging through R_S.

Case 4 :- $\boxed{\text{When } t = t_3}$, diode will be Reverse biased and will behave as open ckt and capacitor starts discharging through R_L.





Note :- 1) For proper Envelope detection, $R_S C$ should be small and $R_L C$ should be High.

classmate

Date
Page

Disadvantage of AM with Carrier :-

1. Power Wastage
2. Band width efficient
3. Gets affected due to noise

Features | Advantages

1. Less complex
2. Receivers are simple and detection is easy.
3. Cost efficient

Applications :-

1. Radio Broad Casting
2. Picture transmission in TV system