B.SC. T.Y.
UNIT: III

MODULATION

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MODULATION:

Introduction:

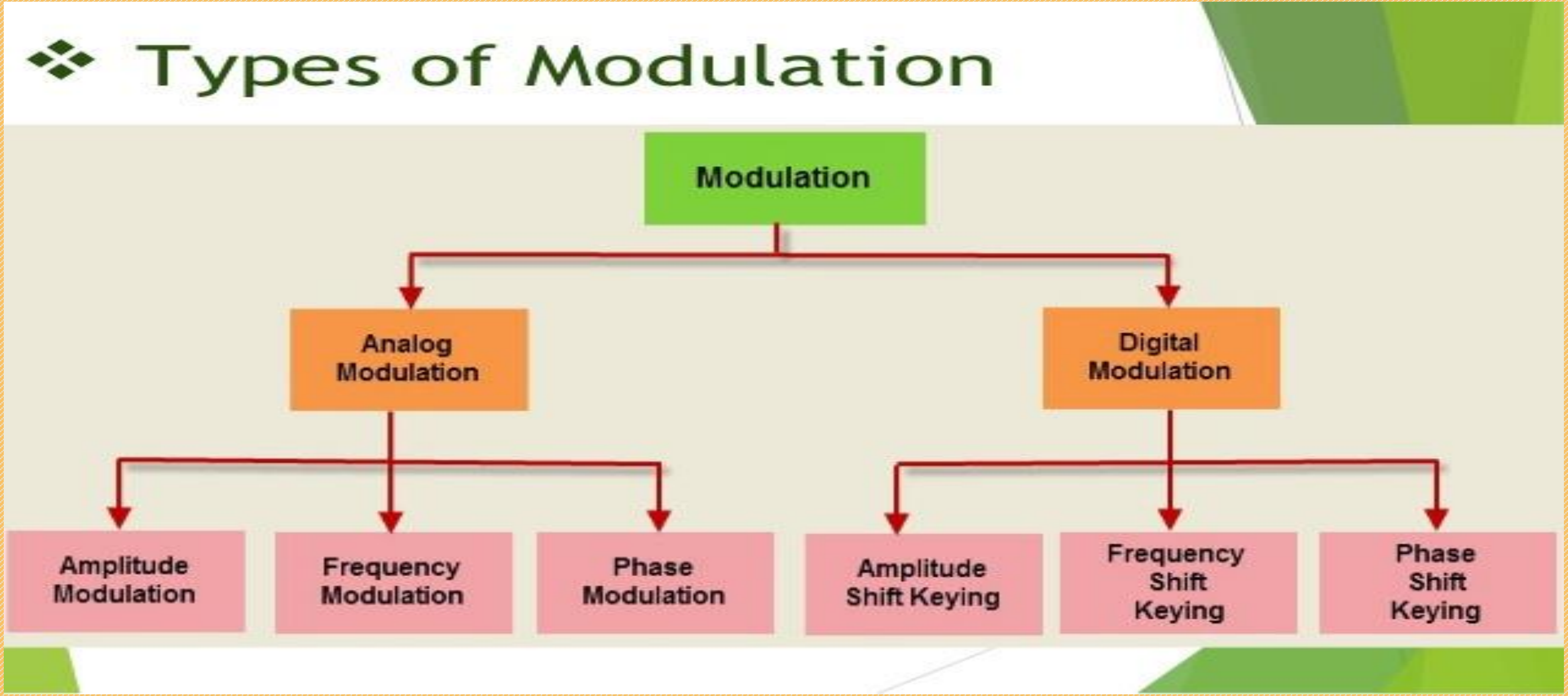
Different types of signals that are generally encountered in communication system.

Many signals have frequency spectra that is not suitable for direct transmission when atmosphere is used

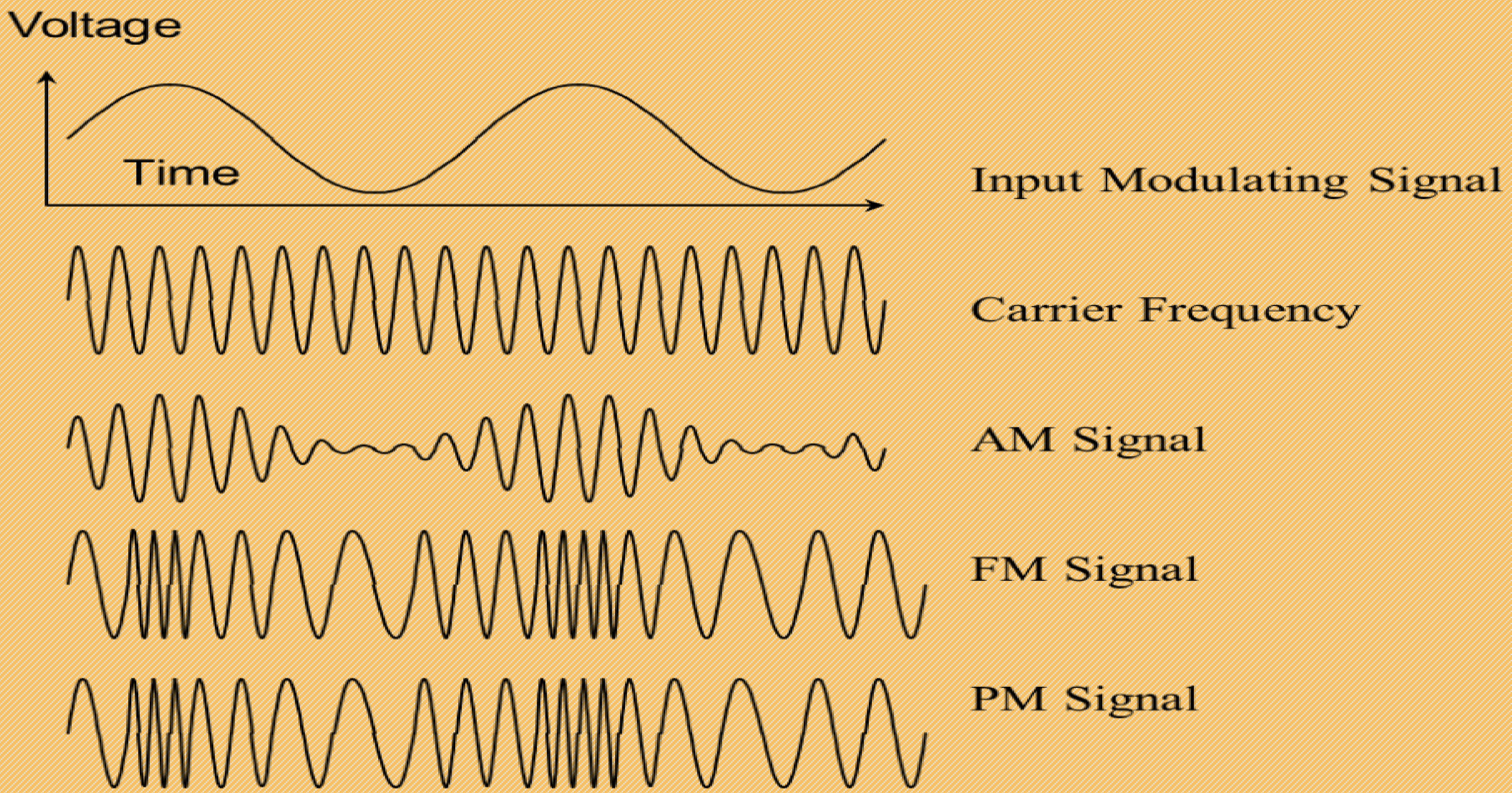
In such a case frequency spectra of signal may transmitted by modulating high frequency carrier wave with signal

Modulation: Process by which some parameters of high frequency signal (termed as carrier) is varied in accordance with signals to be transmitted.

TYPES OF MODULATION:



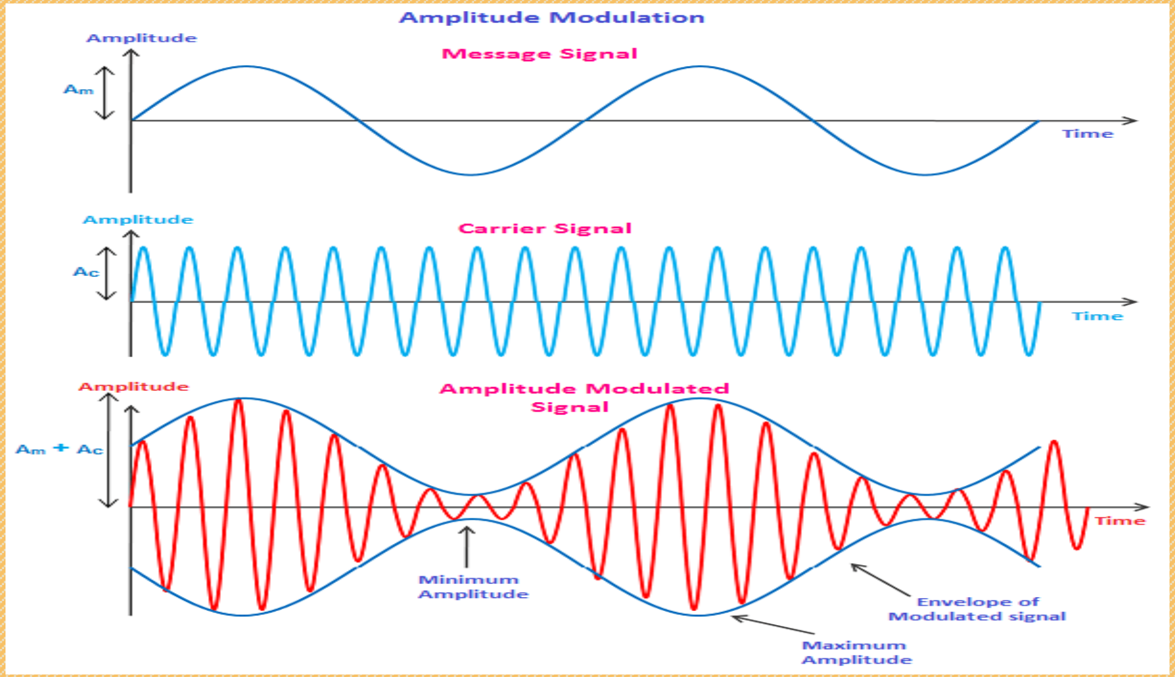
TYPES OF MODULATION:



TYPES OF MODULATION:

Amplitude Modulation (AM) :
Type of modulation in which amplitude of carrier wave is varied in accordance with signal to be transmitted while frequency and phase kept constant.
Frequency modulation (FM) :
Type of modulation in which frequency of carrier wave is varied in accordance with signal to be transmitted while amplitude and phase kept constant.
Phase modulation (PM) :
Type of modulation in which phase carrier wave is varied in accordance with signal to be transmitted while amplitude and frequency kept constant.

AMPLITUDE MODULATION:



Amplitude Modulation (AM) :

In AM amplitude of carrier voltage varies in accordance with instantaneous value of modulating voltage

Let modulating voltage

$e_m = E_m \, Cos \, \omega_m t$ ---(1)

Let carrier voltage

$e_c = E_c \, Cos(\omega_c t + \theta)$ ---(2)

In this case phase angle θ does not play any roll

$\therefore e_c = E_c \, Cos \, \omega_c t$ --(3)

AMPLITUDE MODULATION:

On modulation amplitude of carrier varies with time and resulting modulated wave has form

$e = (E_C + KaEmcos\omega_m t)\ Cos\omega_c t$---(4)

Amplitude factor $K_a E_m cos\omega_m t$ express sinusoidal variation for amplitude of wave

K_a is proportionality factor

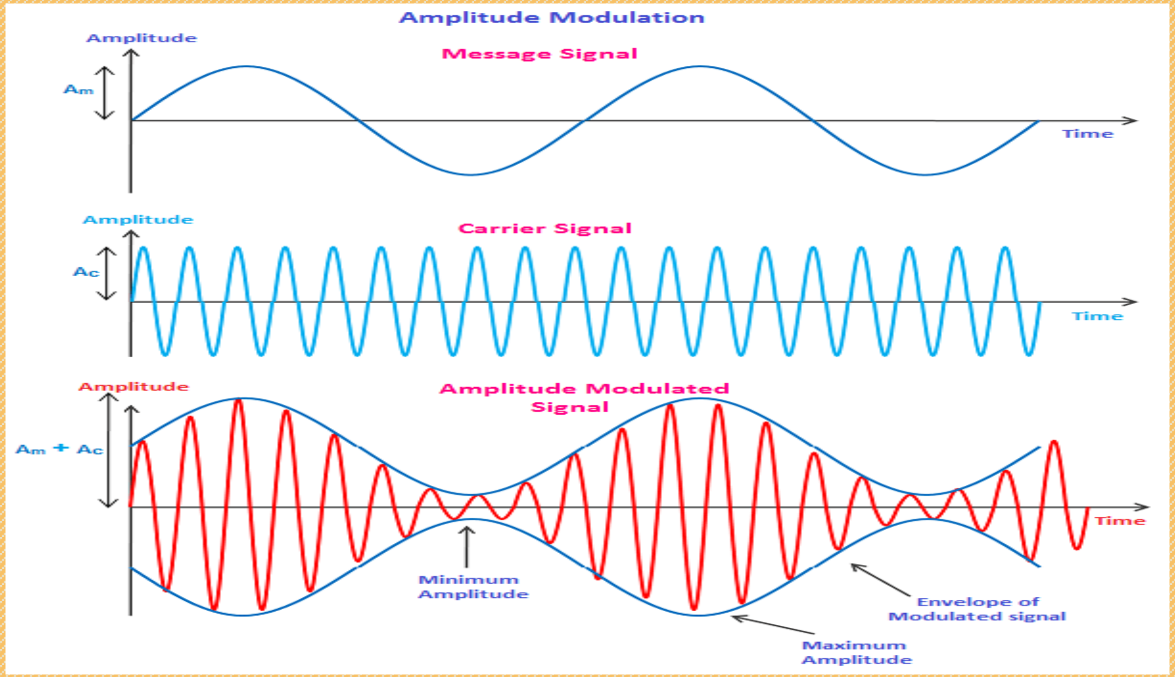
and determines maximum variation in amplitude

Equation 4 can be written as

$$e = Ec\left(1 + Ka.\frac{E_m}{E_c}\cos\omega_m t\right)\cos\omega_c t$$

$$=E_c(1 + m_a\cos\omega_m t)\cos\omega_c t \text{ --(5)}$$

m_a is modulating index or depth of modulation



From fig c frequency of carrier remains unchanged but amplitude variation accordance with modulating voltage e_m

Further seen that

$m_a = \frac{E_{c\ max} - E_c}{E_c}$ ---(6)

Also $m_a = \frac{E_{c - E_{c\ min}}}{E_c}$ --(7)

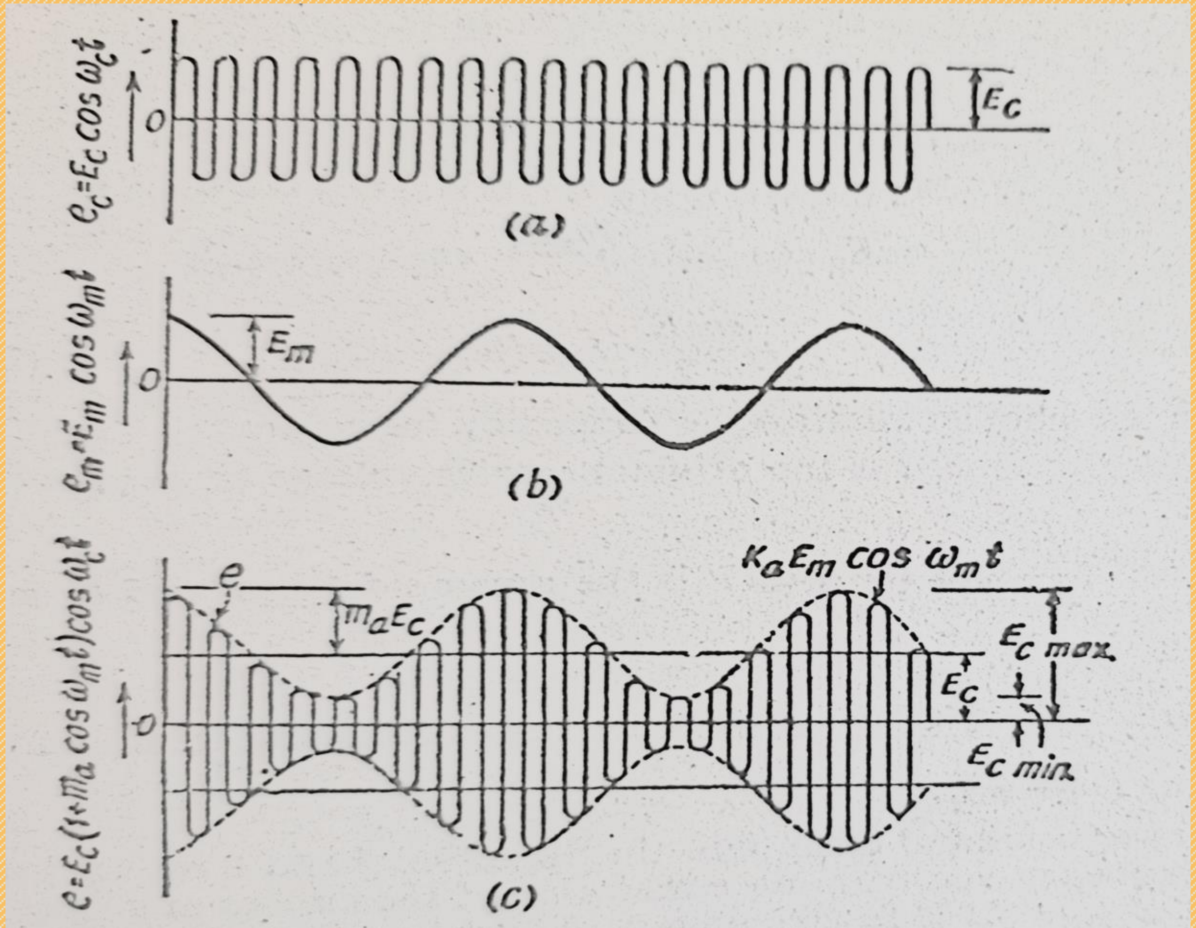
$\therefore E_{c\ max} - E_c = E_{c - E_{c\ min}}$ ---- (8)

OR $E_{c\,max} + E_{c\,min}$=2 Ec ----(9)

Adding 6 and 7

$m_a = \frac{E_{c\,max} - E_{c\,min}}{2E_c}$

$m_a = \frac{E_{c\,max} - E_{c\,min}}{E_{c\,max} + E_{c\,min}}$ ---(10)



(a) Unmodulated carrier voltage.
(b) Modulating voltage.
(c) Amplitude modulated voltage.
Fig. 20-1. Waveform amplitude modulated carrier voltage.

SIDEBAND PRODUCED IN AMPLITUDE MODULATED WAVE:

Expression of AM modulated wave is

$$e = E_c(1 + m_a \cos\omega_m t)\cos\omega_c t$$

$$= E_c cos\omega_c t + \frac{m_a E_c}{2}(2\cos\omega_c t \cos\omega_m t)$$

$$= E_c cos\omega_c t + \frac{m_a E_c}{2}[cos(\omega_c + \omega_m)t + cos(\omega_c - \omega_m)t]$$

$$= E_c cos\omega_c t + \frac{m_a E_c}{2}cos(\omega_c + \omega_m)t + \frac{m_a E_c}{2}cos(\omega_c - \omega_m)t$$

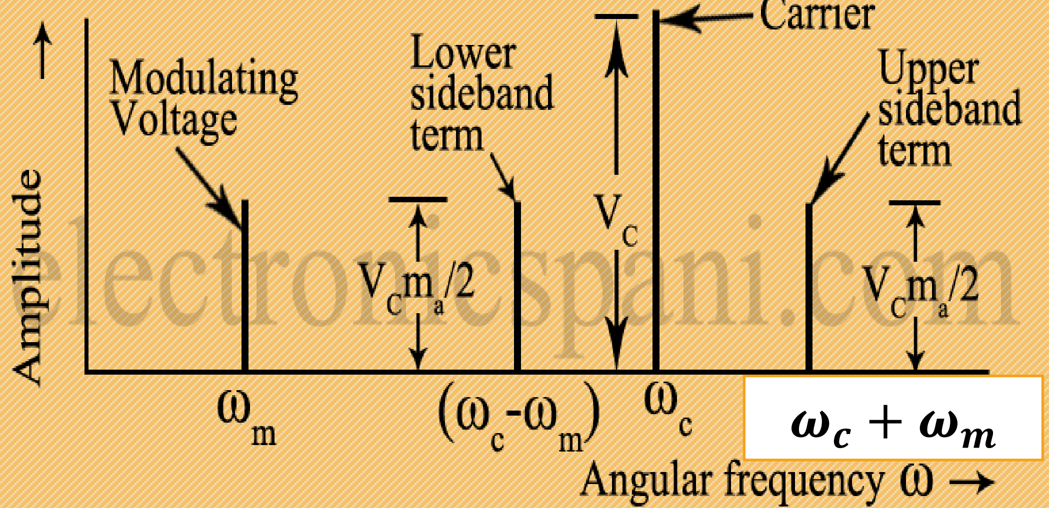


Figure 2: Frequency components in amplitude modulated carrier

SIDEBAND PRODUCED IN AMPLITUDE MODULATED WAVE:

$= E_c cos\omega_c t + \frac{m_a E_c}{2} cos(\omega_c + \omega_m)t + \frac{m_a E_c}{2} cos(\omega_c - \omega_m)t$

The frequency terms are

1 $E_c cos\omega_c t$ –original carrier voltage of angular frequency ω_c

2 $\frac{m_a E_c}{2} cos(\omega_c + \omega_m)t$ –Upper side band of angular frequency $(\omega_c + \omega_m)$

3 $\frac{m_a E_c}{2} cos(\omega_c - \omega_m)t$ – Lower side band of angular frequency $(\omega_c - \omega_m)$

Lower and upper side bands are located on either side of carrier at frequency interval of ω_m

Magnitude of both bands is $\frac{m_a}{2}$ of carrier amplitude E_c

If m_a =1 each sideband is half carrier voltage in amplitude

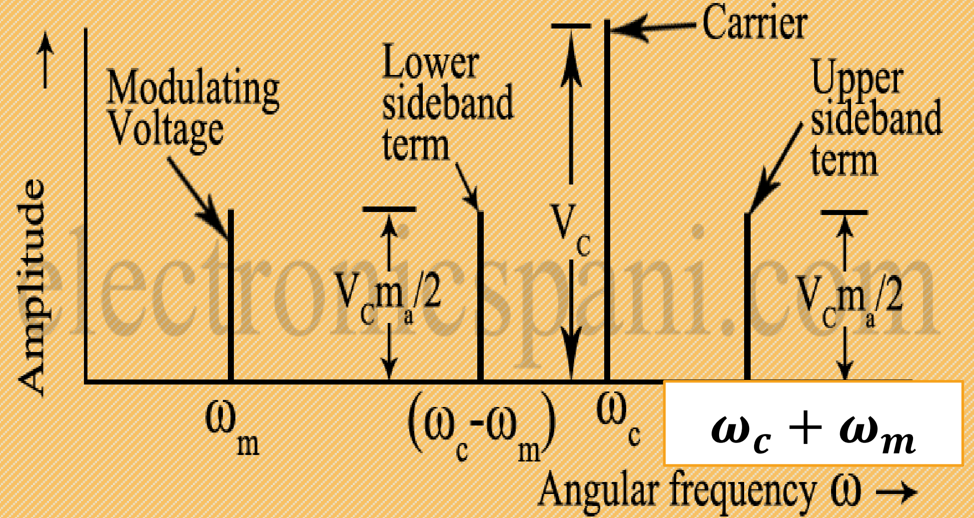


Figure 2: Frequency components in amplitude modulated carrier

MODULATED POWER OUTPUT IN AMPLITUDE MODULATION:

In AM wave total energy obtained by summing energy contains of carrier and sidebands

Three components of modulated wave are

1 Carrier wave $E_c cos\omega_c t$

2 Upper sideband $\frac{m_a E_c}{2} cos(\omega_c + \omega_m)t$

3 Lower sideband $\frac{m_a E_c}{2} cos(\omega_c - \omega_m)t$

Power dissipated by each components through arial or resistive load is directly proportional to square of amplitude(Voltage or current)

Power in carrier $\propto E_c^2 = K E_c^2$

Power in upper sideband $\propto (\frac{m_a E_c}{2})^2 = K \frac{m_a^2 E_c^2}{4}$

Power in lower sideband $\propto (\frac{m_a E_c}{2})^2 = K \frac{m_a^2 E_c^2}{4}$

MODULATED POWER OUTPUT IN AMPLITUDE MODULATION:

Total power $= K\ E_c^2 + K\,\frac{m_a^2 E_c^2}{4} + K\,\frac{m_a^2 E_c^2}{4}$

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

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

If ma=1 then

Total modulated power is

$= carrier\ power\left(1+\frac{1}{2}\right)$

3/2 carrier power

Carrier power = 2/3 of total power

FREQUENCY MODULATION:

Frequency modulation (FM) :

Type of modulation in which frequency of carrier wave is varied in accordance with signal to be transmitted while amplitude and phase kept constant.

Amplitude of carrier voltage remains constant

Advantages:

All natural , man made noises consist of amplitude disturbances.

Radio receiver can not distinguish noise and desired sound

AM is noisy

EXPRESSION FOR FREQUENCY MODULATED VOLTAGE:

Modulating voltage be given by

$e_m = E_m\, Cos\, \omega_m t$ ---(1)

Carrier voltage is given by

$e_c = E_c\, Sin(\omega_c t + \theta)$ ---(2)

Let $\phi = \omega_c t + \theta$ ---(3)

Total instantaneous phase angle of carrier voltage is

$e_c = E_c\, Sin\phi$ ---(4)

Angular frequency ω_c and instantaneous phase angle ϕ are related as

$\omega_c = \frac{d\phi}{dt}$ -----(5)

After FM frequency varies with instantaneous value of modulating voltage

Frequency of carrier after frequency modulation

$\omega = \omega_c + K_f e_m$

$\omega = \omega_c + K_f E_m\, Cos\, \omega_m t$ -----(6)

EXPRESSION FOR FREQUENCY MODULATED VOLTAGE:

Integrating eq 6 gives phase angle of modulated carrier voltage is

$$\phi = \int \omega \, dt$$

$$\phi = \int \left[\omega_c + K_f E_m \, Cos \, \omega_m t\right] dt$$

$$\phi = \omega_c t + K_f . E_m \frac{1}{\omega_m} \sin \omega_m t + \theta_1$$

θ_1 is constant of integration represents constant phase angle and plays no roll here

Frequency modulated carrier voltage is

$$e = E_m sin \left[\omega_c t + K_f . E_m \frac{1}{\omega_m} \sin \omega_m t\right] \text{--------(7)}$$

EXPRESSION FOR FREQUENCY MODULATED VOLTAGE:

$$e = E_m sin\left[\omega_c t + K_f . E_m \frac{1}{\omega_m} \sin \omega_m t\right] \text{--------(7)}$$

From eq 6 instantaneous frequency of frequency modulated carrier voltage in Hz is

$$f = \frac{\omega}{2\pi} = f_c + K_f \frac{E_m}{2\pi} cos\omega_m t \qquad \text{--(8)}$$

Maximum value of frequency is

$$f_{max} = f_c + K_f \frac{E_m}{2\pi} \qquad \text{-----(9)}$$

Minimum value of frequency is

$$f_{max} = f_c - K_f \frac{E_m}{2\pi}$$

Frequency deviation or maximum variation in frequency from mean value is

$$f_d = f_{max} - f_c$$

$$f_d = f_c - f_{min}$$

$$= K_f \frac{E_m}{2\pi}$$

EXPRESSION FOR FREQUENCY MODULATED VOLTAGE:

$Modulating\ index\ is\ defined\ as\ ratio\ of\ frequency\ deviation\ to\ carreier\ frequency$

$$m_f = \frac{f_d}{f_c}$$

$$= \frac{K_f \frac{E_m}{2\pi}}{f_c} \quad = \frac{K_{fEm}}{\omega_c}$$ ---(10)

Deviation ratio is ratio of frequency deviation to modulating frequency

$$\delta = \frac{f_d}{f_m} \quad = \frac{K_{fEm}}{\omega_m}$$

FM expression in terms of deviation ratio

$$e = E_c\, Sin(\omega_c t + \delta \sin \omega_m t)$$

DEMODULATION:

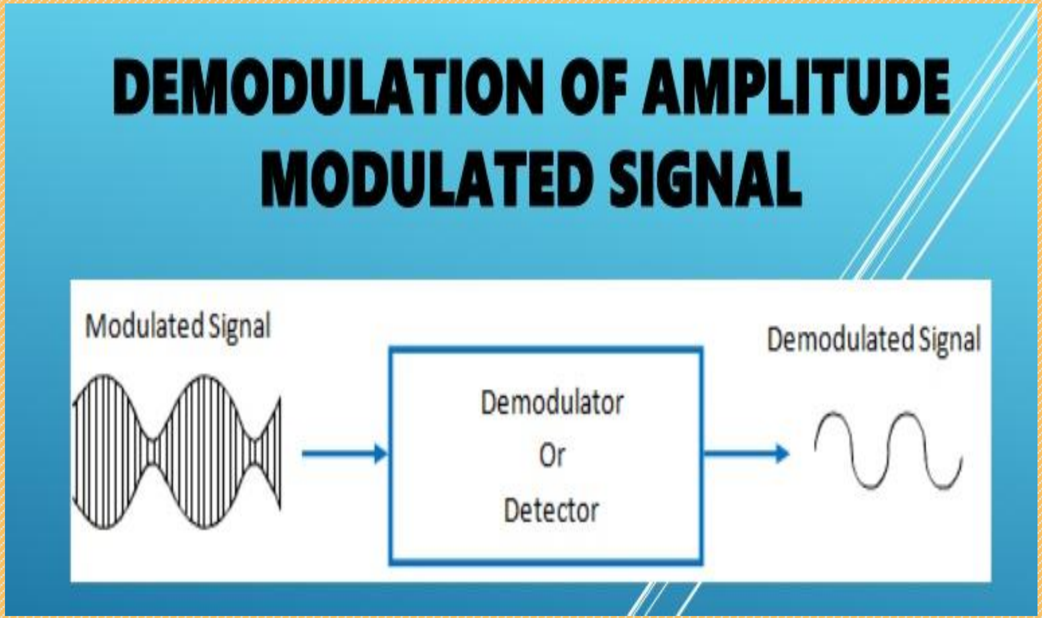
Demodulation : The process by which the original modulating signal , or intelligence is recovered in the receiving equipment called detection or demodulation

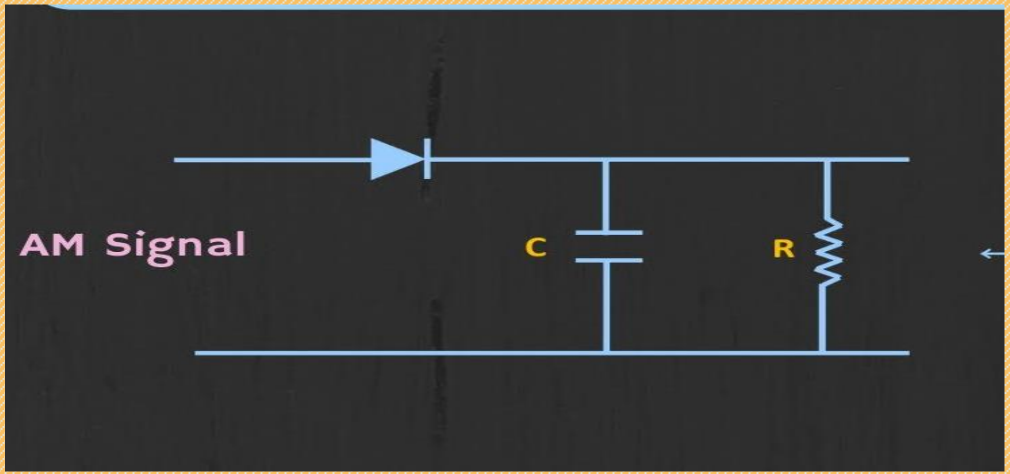
AM consists of carrier and sidebands frequencies and not modulating frequencies

The modulating signals must be reproduced in receiver

Receiver must include detector

Modulating frequency is difference between sideband and carrier frequency ,non-linear device is needed



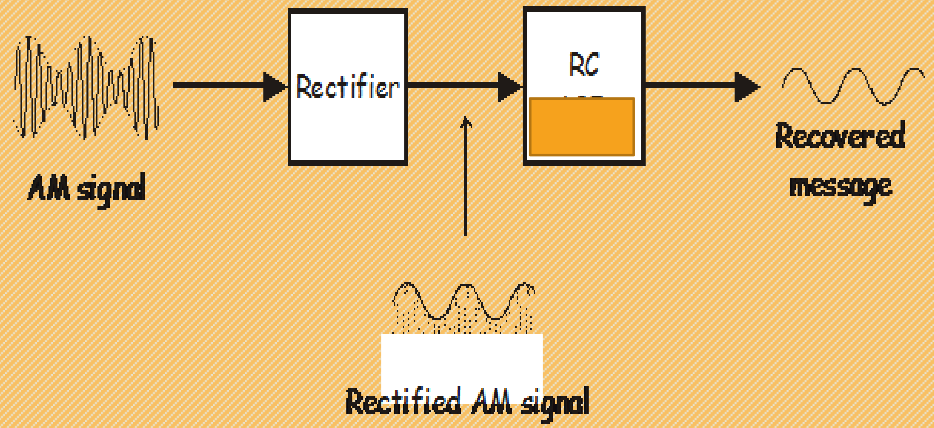


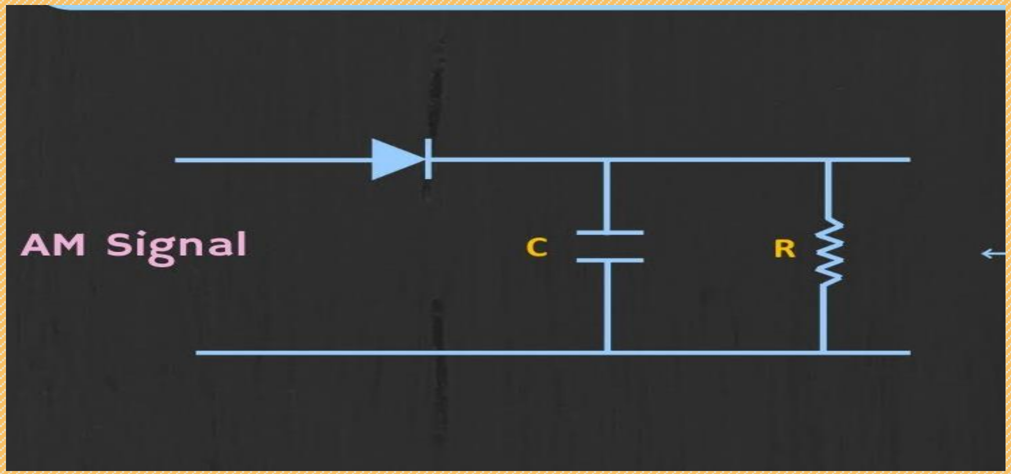
DEMODULATION:

Transistor is square law detector and non-linear device when used in cut off

Detector eliminates one half of modulated wave

Detector acts as rectifier





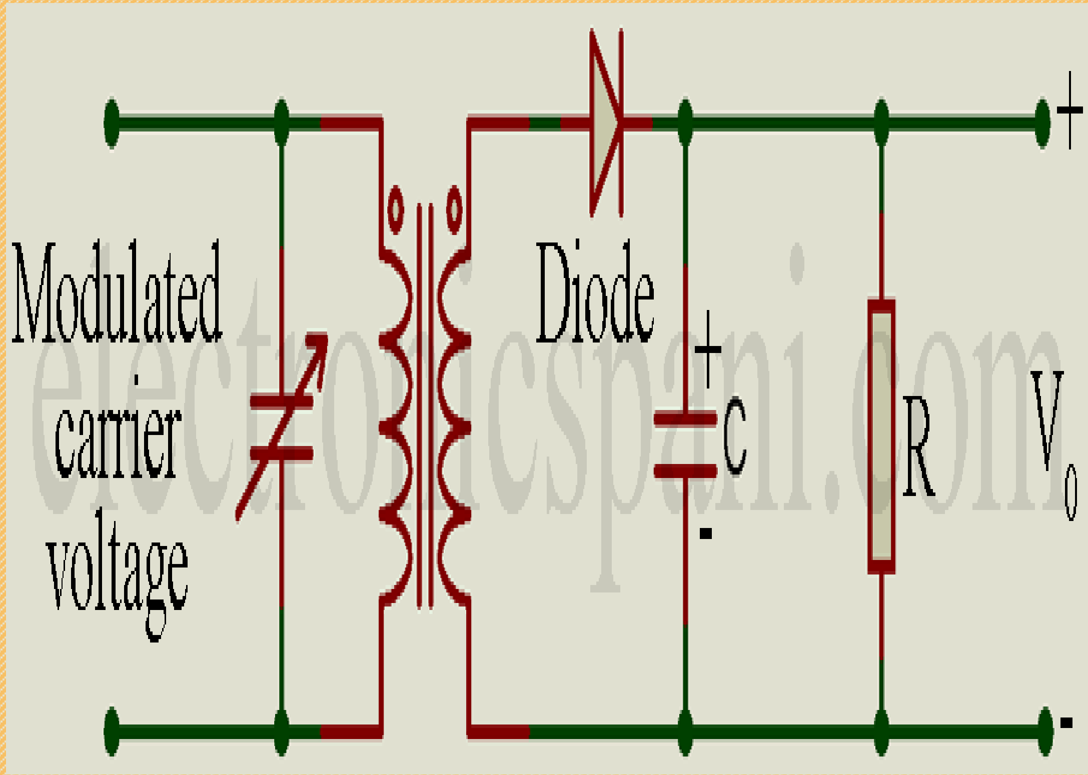
LINEAR DIODE DETECTOR OF AM SIGNALS:

To recover useful sideband information from AM wave diode demodulator or detector is used

Similar to diode rectifier with capacitor filter

C is chosen so that RC time constant is long wrt carrier frequency but short wrt modulating frequency

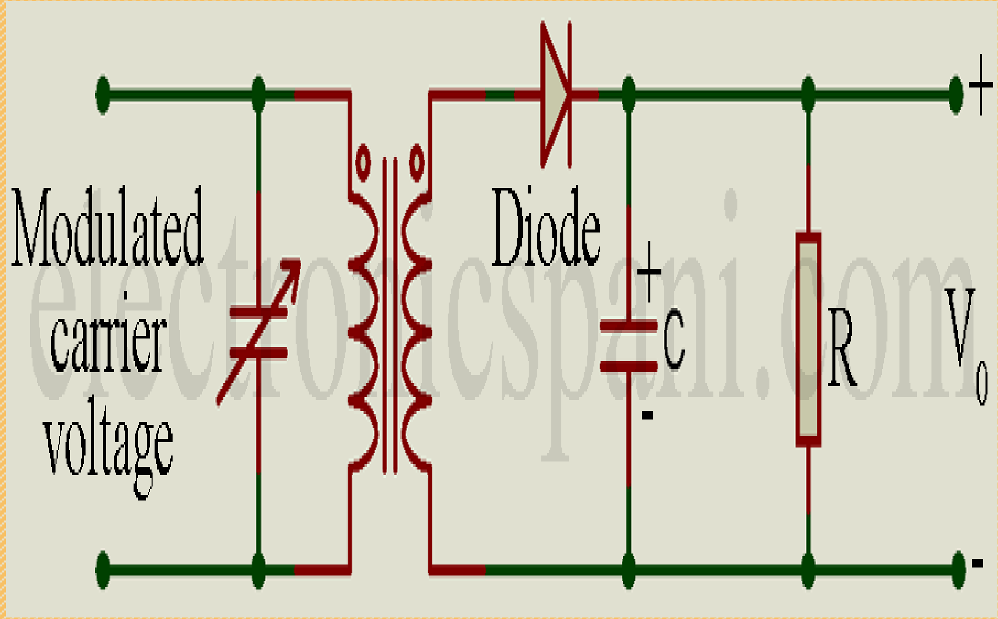
C charges to peak during positive half cycle and small current passes through diode



LINEAR DIODE DETECTOR OF AM SIGNALS:

C can discharge through R during negative half cycle but with long RC time constant discharge covers no. of carrier cycles and V_0 changes at only modulating rate

V0 have recovered original modulation amplitude and frequency.



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