DO - 2
DO - 3
DO - 1

1/8/22

Data rate (R)

18ECE205J - ANALOG AND DIGITAL COMMUNICATION

UNIT-1 : ANALOG MODULATION.

A Signal is measured by amplitude

representation of signal by discrete Voltage levels is called digital → has finite

Analog Signal will have infinite voltage level.

Audio frequency range 300Hz → 3KHz.

Bandwidth is the range of frequency

Bandwidth (W) = USB − LSB.

Wavelength, $\lambda = \frac{c}{f} = \frac{3\times10^{8} m/sec}{1/sec} = m$.

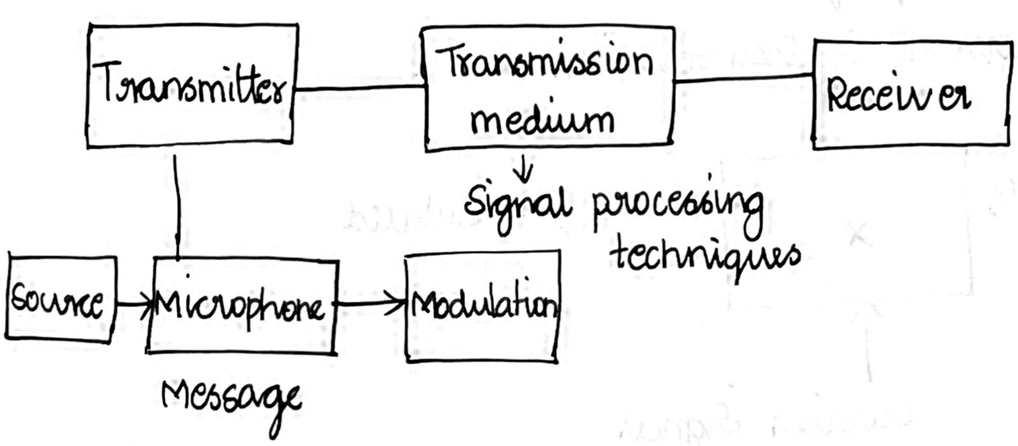
A signal is a physical quantity which has three parameter, Amplitude, timeperiod and frequency.

MODULATION

Information signal is superimposed on a carrier Signal (High frequency) to send the information signal to a longer distance.

20Hz − 20KHz → Audio frequency.

Transducer → Converts energy from one form to another
Ex, microphone (voice to electrical signal)



3 parameters for Signal.

1. Amplitude (voltage)

2. Time period (ms) for getting kHz.

3. Frequency (KHz - Hz)

Carrier Signal.

→ Used to carry information signal.

→ If amplitude of the carrier signal changes in accordance with message signal it is called amplitude modulation (AM)

→ If frequency of carrier signal changes in accordance with message signal is called Frequency Modulation (FM)

→ If the phase of carrier signal changes in accordance with message signal is called Phase Modulation (PM)

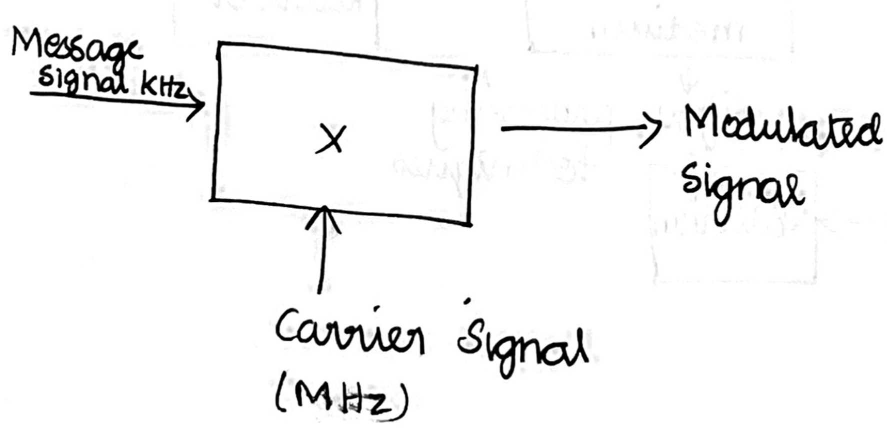
MODULATION.

Modulation is the process of changing one of the characteristics of carrier signal in accordance with message signal

MODULATOR

→ Device that performs modulation.

→ It is present in transmission Block.



Tx'er - Transmitter   Tx'ion - Transmission   Tx' - Transmit

NEED FOR MODULATION.

guard band 0.1 2-1 2-2 2-3
protects overlapping of carrier frequency

1. Long distance transmission
2. Multiplexing (multiple users can transmit in a single cable)
3. Practicability of Antenna height

For any application the antenna hight is half the wavelength, $h = \frac{\lambda}{2}$. $\lambda \rightarrow$ wavelength.

We know, $\lambda = \frac{c}{f}$

$$\lambda = \frac{c}{2f}$$

1. To transmit a 5 kHz signal what should be the height of the antenna.

$$\lambda = \frac{c}{2 \times 5 \times 10^3}$$

$$= \frac{3 \times 10^8 \times 10^{-3}}{10}$$

$$= \frac{3}{10} \times 10^5$$

$$= 0.3 \times 10^5 = 30.0 \times 10^3.$$

$$\lambda = 30\ km$$

If we want to transmit a signal of 10 MHz

$$\lambda = \frac{3 \times 10^8}{2 \times 10 \times 10^6}$$

$$= \frac{3 \times 10^2}{20} = 0.15 \times 10^2$$

$$\lambda = 15\ m$$

VSB - Vestigial Side Band

TYPES OF MODULATION.

DSB - Double Side Band
SC - Suppress Carrier
SSB - Single Side Band

- Continuous wave modulation
  - Amplitude modulation
    - DSB-SC
    - SSB-SC
    - VSB
  - Angle modulation
    - FM
      - narrow band
      - wide band
    - PM
- Pulse wave modulation
  - Pulse analog
    - PAM
    - PWM
    - PPM
  - Pulse digital
    - PCM
    - DPCM
    - DM

PAM - Pulse Amplitude modn
PWM - Pulse width modulation
PPM - Pulse position modulation

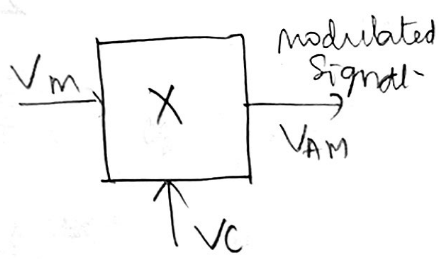
PCM - Pulse Code modulation
DPCM - Differential pulse Code modulation
DM - Delta modulation.

AMPLITUDE MODULATION (AM)

Message Signal $\rightarrow$ $V_m(t) = V_m \cos(\omega_m t + \theta)$

Amplitude; angular freq of message Signal; Phase angle = 0; Cos wave

$V_m(t) = V_m \cos \omega_m t$



Carrier Signal.

$V_c(t) = V_c \cos \omega t$

$\omega_c = 2\pi f_c$ $\quad$ $f_c \rightarrow$ Carrier frequency

Voltage of Carrier Signal

$V_{AM}(t) = (V_c + V_m(t)) \cos \omega t.$

Voltage of message signal

$V_{AM}(t) \rightarrow$ modulated Signal.

$V_{AM}(t) = (V_c + V_m \cos \omega_m t) \cos \omega_c t$

$= V_c \cos \omega_c t + V_m \cos \omega_m t \cos \omega_c t$

$= V_c \cos \omega_c t + V_m \cos \omega_c t . \cos \omega_m t$

$$2\cos A\cos B = \cos(A+B) + \cos(A-B)$$

$$V_{AM}(t) = V_c\cos\omega_c t + \frac{V_m}{2}\left[\cos(\omega_c+\omega_m)t + \cos(\omega_c-\omega_m)t\right]$$

$$V_{AM}(t) = \underbrace{V_c\cos\omega_c t}_{\text{Carrier Signal}} + \underbrace{\frac{V_m}{2}\cos(\omega_c+\omega_m)t}_{\text{Upper Side band (USB)}} + \underbrace{\frac{V_m}{2}\cos(\omega_c-\omega_m)t}_{\text{Lower Side band (LSB)}}$$

$$= V_c\cos\omega_c t + \underbrace{\frac{V_m}{2V_c}}_{\rightarrow M_a} V_c\cos(\omega_c+\omega_m)t + \frac{V_m}{2V_c}V_c\cos(\omega_c-\omega_m)t$$

$$= V_c\cos\omega_c t + \frac{M_a V_c}{2}\left[\cos(\omega_c+\omega_m)t + \cos(\omega_c-\omega_m)t\right]$$

where M_a, Modulation Index $= \frac{V_m}{V_c}$

Modulation Index or Modulation depth are of three types,

1. Under Modulation $M_a < 1 \rightarrow$ ideal
2. Over Modulation $M_a > 1 \rightarrow$ not accepted
3. Critical Modulation $M_a = 1 \rightarrow$ Accepted as minimum criteria

→ For amplitude modulation, the modulation Index should always be greater than (or) equal to one.

→ For AM M_a should be

Band width of AM

$$\text{Modulation Index} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

$$BW_{AM} = USB - LSB$$

$$= \omega_c + \omega_m - (\omega_c - \omega_m)$$

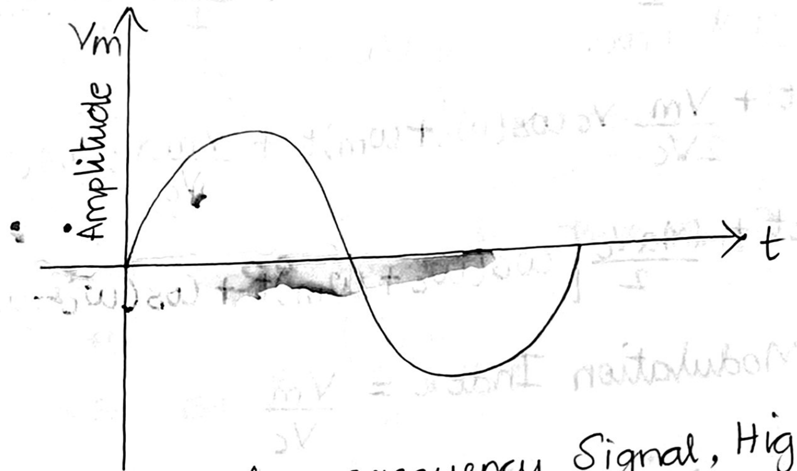
$$= \omega_c + \omega_m - \omega_c + \omega_m$$

$$= \omega_m + \omega_m$$

$$BW_{AM} = 2\omega_m \text{ (or) } 2f_m$$

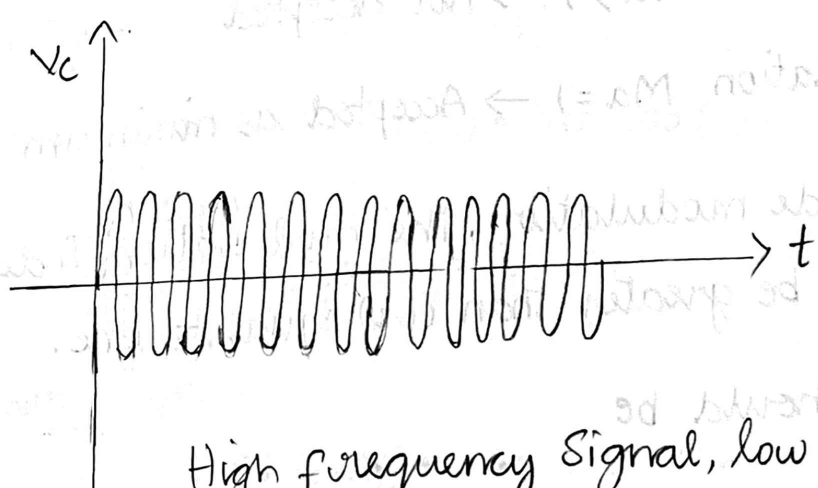
GRAPHICAL REPRESENTED OF AM.

Message Signal (Modulating Signal)



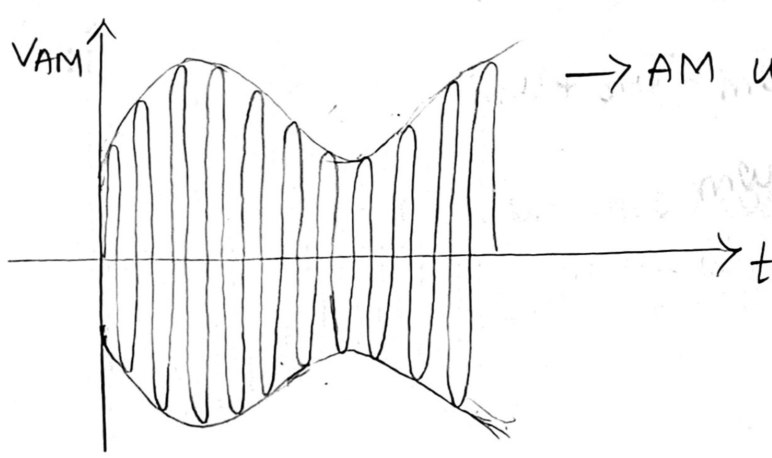
low frequency Signal, High time period

Carrier Signal



High frequency Signal, low time period.

Modulated Signal



→ AM waveform

Amplitude - changed frequency and time period remains constant

$$P = \frac{V_{max}^2}{R} = \frac{\left(\frac{V}{\sqrt{2}}\right)^2}{R}$$

POWER IN AM :-

has no information

$$V_{AM}(t) = V_c \cos \omega_c t + \frac{M_a V_c}{2}\left[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t\right]$$

$$\text{Power of carrier Signal } (P_c) = \frac{\left(\frac{V_c}{\sqrt{2}}\right)^2}{R} = \frac{V_c^2}{2R}.$$

$$\text{Power of USB } (P_{USB}) = \frac{\left(\frac{\frac{m_a V_c}{2}}{\sqrt{2}}\right)^2}{R} = \frac{m_a^2 V_c^2}{8R} = \frac{m_a^2}{4} \cdot \frac{V_c^2}{2R}$$

$$= \frac{m_a^2}{4} \cdot P_c.$$

$$\text{Power of LSB } (P_{LSB}) = \frac{m_a^2}{4} \cdot P_c.$$

$$\frac{M_a^2 P_c}{2}$$

$$P_{tot(AM)} = P_c + P_{USB} + P_{LSB}$$

$$= P_c + \frac{M_a^2 P_c}{4} + \frac{M_a^2 P_c}{4}$$

$$= P_c + \frac{M_a^2 P_c}{2}$$

$$= P_c\left[1 + \frac{M_a^2}{2}\right].$$

$M_a \rightarrow$ modulation index.

$$M_a = \frac{V_m}{V_c}.$$

Assume $M_a = 1$

$$\frac{P_{USB} + P_{LSB}}{tot} = \frac{\frac{m_a^2 P_c}{2}}{P_c\left[1 + \frac{M_a^2}{2}\right]} = \frac{\frac{M_a^2}{2}}{\frac{2 + M_a^2}{2}} = \frac{M_a^2}{2 + M_a^2}$$

Transmission efficiency of AM.

$$\eta = \frac{P_{USB} + P_{LSB}}{P_{tot}} = \frac{\frac{M_a^2 P_c}{2}}{P_c\left[1 + \frac{M_a^2}{2}\right]} = \frac{M_a^2}{2 + M_a^2} \times 100$$

If $M_a = 1$

$$\eta = \frac{1}{3} \times 100 = 33.33\%.$$

Efficiency of AM = 33.33 %.

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DSB-SC (Double Side Band - Suppressed Carrier)

It is an AM scheme where only the side bands are transmitted, carrier is suppressed. As the carrier does not contain any message.

$$P_{tot(AM)} = P_c\left[1 + \frac{M_a^2}{2}\right].$$

POWER IN DSB-SC AM.

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

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

$$= \frac{M_a^2 V_c^2}{4R}.$$

$$P_t' = \frac{M_a^2}{2} P_c.$$

POWER SAVING IN DSB-SC WITH RESPECT TO AM.

$$\%\text{ of Power Saving} = \frac{P_t - P_t'}{P_t} = \frac{P_c\left[1 + \frac{M_a^2}{2}\right] - \frac{M_a^2}{2} P_c}{P_c\left[1 + \frac{M_a^2}{2}\right]}$$

$$= \frac{P_c\left[1 + \frac{M_a^2}{2} - \frac{M_a^2}{2}\right]}{P_c\left[1 + \frac{M_a^2}{2}\right]}$$

$$= \frac{1}{1 + \frac{M_a^2}{2}} = \frac{1}{\frac{2 + M_a^2}{2}} = \frac{2}{2 + M_a^2}$$

$M_a = 1$

$\%$ of power Saving $= \frac{2}{3} \times 100$

$\%$ of power Saving in DSB-SC $= 66.67\%$.

SSB-SC AM.

It is an AM scheme where only one of the Side band is transmitted and the other side band, carrier is suppressed.

The upper side band and the lower side band are symmetric to each other.

POWER IN SSB-SC AM.

$$P_t'' = P_{USB}.$$

$$= \frac{M_a^2 V_c^2}{8R} = \frac{M_a^2 P_c}{4}.$$

POWER SAVING IN SSB-SC AM WITH RESPECT TO AM.

$$\%\text{ of Power Saving} = \frac{P_t - P_t''}{P_t} = \frac{P_c\left[1+\frac{M_a^2}{2}\right] - \frac{M_a^2 P_c}{4}}{P_c\left[1+\frac{M_a^2}{2}\right]}$$

$$= \frac{\left[1+\frac{M_a^2}{2} - \frac{M_a^2}{4}\right]}{\left[1+\frac{M_a^2}{2}\right]}$$

$\frac{4M_a^2 - 2M_a^2}{8}$

$\frac{M_a^2}{4}$

$$= \frac{\left[1+\frac{M_a^2}{4}\right]}{\left[1+\frac{M_a^2}{2}\right]} = \frac{\left[1+\frac{1}{4}\right]}{\left[1+\frac{1}{2}\right]} = \frac{\frac{5}{4}}{\frac{3}{2}}$$

$\frac{5}{\cancel{4}_2} \times \frac{\cancel{2}^1}{3}$

$\frac{5}{6}$

$2\pi f_m n$

$2\pi f_m = 15\pi 10^3$

$f_m = \frac{15\pi 10^3}{2\pi} = 7.5$

$= \frac{5}{6} \times 100$

$= 83.33\ \%$

PROBLEMS.

1. A 400 Watt carrier is modulated to a depth of 75%. find the total power in AM waveform.

→ modulating Index

$$P_{tot} = P_c \left[1 + \frac{Ma^2}{2} \right]$$

$$= 400 \left[1 + \frac{(0.75)^2}{2} \right]$$

$$= 400 \left[1 + 0.28125 \right]$$

$$= 400 \times 1.28125$$

$$P_{tot} = 512.5 \text{ Watt}$$

% of modulation = modulation Index percent

2. A carrier amplitude after AM changes between 4 Volt and 1 volt calculate the modulation Index and % of modulation.

$$\text{modulation Index} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

$$= \frac{4-1}{4+1} = \frac{3}{5} = 0.6$$

$$\%\ \text{of modulation} = 60\ \%.$$

3. A modulating Signal $f(t) = \overset{V_m}{10} \sin 2\pi 10^3 t$ is used to modulate a carrier signal $v(t) = \overset{V_c}{20} \sin 2\pi 10^4 t$

Determine

i) Modulation index.

ii) % of modulation

iii) freq & amplitude of Side band

iv) Bandwidth of modulated Signal

v) Draw its freq Spectrum.

$V_m = 10$

$V_c = 20$. $\frac{M_a V_c}{2}$

i) Modution index $= \frac{10}{20} = 0.5$

$\frac{V_m}{\cancel{V_c}} \times \cancel{V_c} \over 2$

ii) % of modution $= 50\%$.

$\frac{10}{2} = 5$

iii) f_m, modulating frequency $= 10^3$ Hz $= 1$ KHz

f_c, carrier frequency $= 10$ KHz $= 10^4$ Hz

Amplitude of Side band $= \frac{M_a V_c}{2}$

$= \frac{10}{2} = 5$ Volt

iv) Upper Side band, $f_c + f_m = 10 + 1 = 11$ KHz

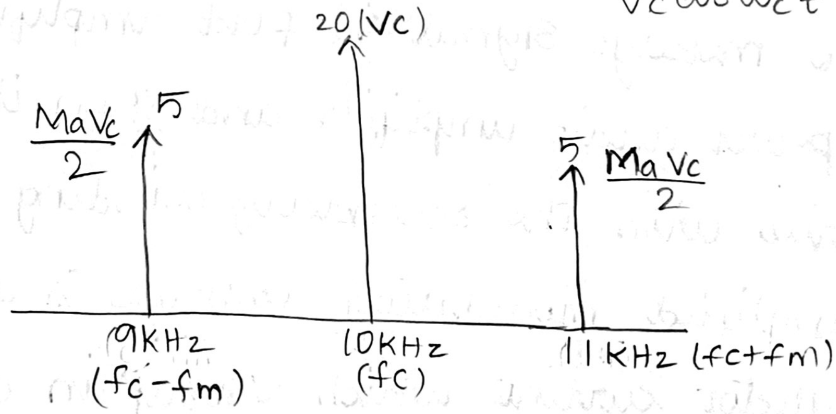
Lower Side band, $f_c - f_m = 10 - 1 = 9$ KHz.

Band width of AM $=$ USB $-$ LSB (or) $2 f_m$

$= 11 - 9 = 2$ KHz.

$V_c \cos \omega_c t$

v)



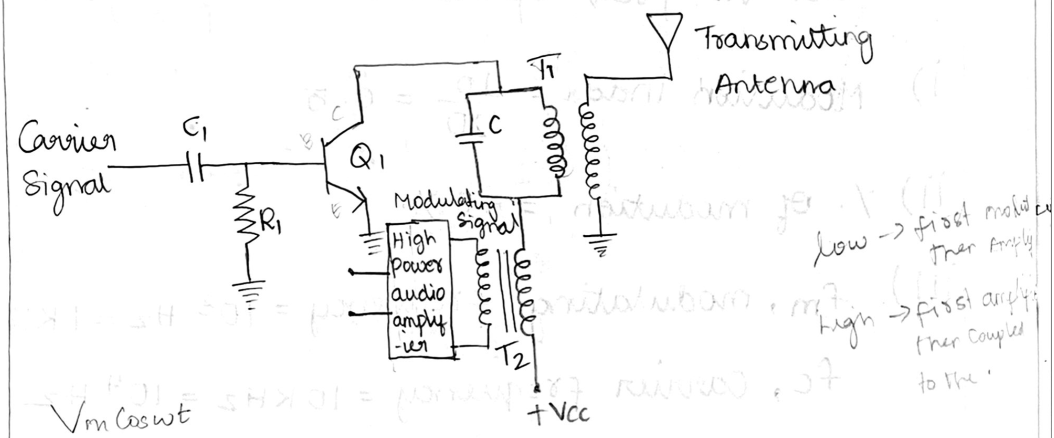
MODULATORS.

Modulator is a device / circuit that performs modulation available at the transmission side.

TYPES OF AM MODULATORS

1. Linear Modulator (Collector Modulator Method) power level High level modulation
2. Non Linear Modulator (Balanced Modulator) low level modulation

COLLECTOR MODULATOR METHOD.



The transistor Q_1 receives the carrier signal at its base. The transistor conducts only for the positive half cycle of the carrier signal, Thus the collector current of Q_1 is the current pulse. This current pulse is supplied to the tunned circuit which is tunned to the carrier signal frequency.

The message signal is first amplified through a high power audio amplifier and then it is connected in series with the secondary winding of T_2 and Vcc The amplified modulating voltage is connected to the collector currents which varry in accordance with

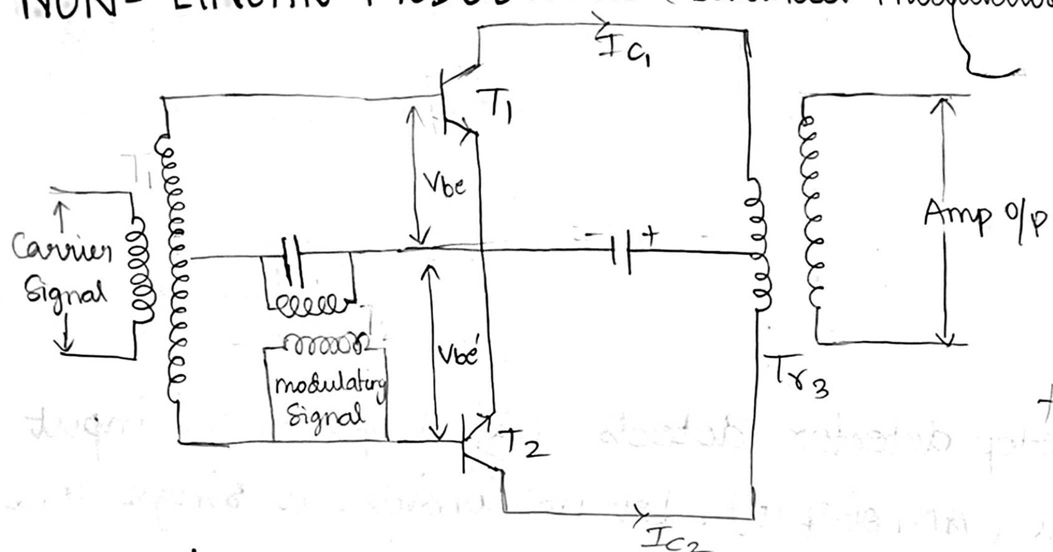
Simon Hacking
5th edition

modulating signal.

Using collector modulator circuit we cannot obtain 100% modulation so we are going for the non linear modulation technique.

Message signal - base band signal

NON-LINEAR MODULATORS (Balanced modulator)



+ve – $I_{C_1} \uparrow$
$T_1 \rightarrow V_c + V_m$
$T_2 \rightarrow -V_c + V_m$
-ve $I_{C_2} \uparrow$
$T_1 = V_m - V_c$
$T_2 = V_c + V_m$
+ve V_{be} becomes $V_c + V_m$

without amplifier

Non-linear modulator is also called as low level modulation because the message signal is modulated first. During the positive half cycle the voltage at the ~~Transformer~~ T_1 is $\overset{V_{be}}{V_c + V_m}$, T_2 will be $\overset{V_{be}'}{-V_c + V_m}$

During the negative half cycle the voltage at T_1 is $\overset{V_{be}}{V_m - V_c}$, voltage at T_2 will be $\overset{V_{be}'}{V_c + V_m}$

Both the transistors conducts for each cycle alternatively

Tr_3 will join both the half cycle.

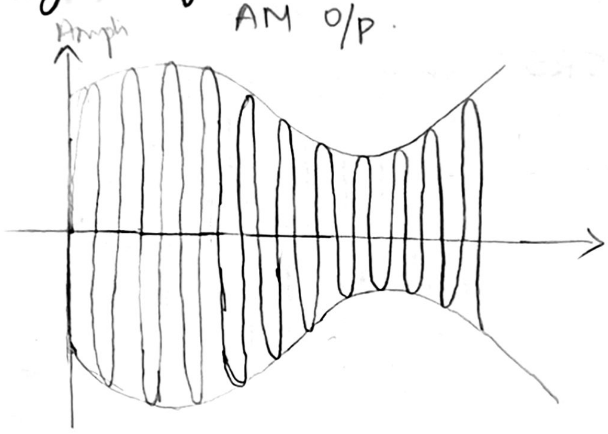
Coherent → carrier signal is again added
same

DEMODULATOR / DETECTOR / DISCRIMINATOR

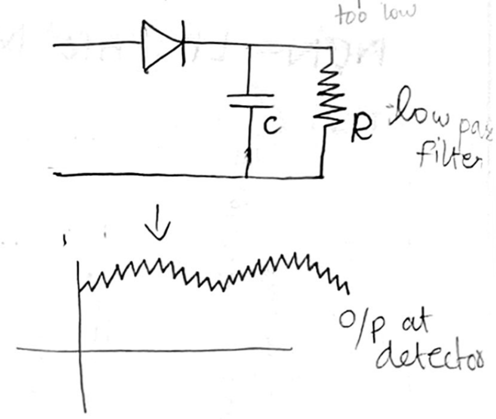
ENVELOP DETECTOR. (non-coherent detector)

trace of carrier signal

Demodulation is the process extracting the original signal from the ~~modulat~~ received modulated signal.

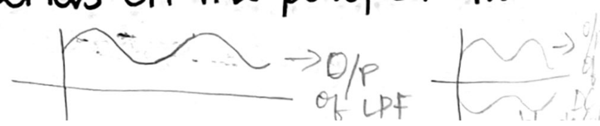


the voltage across capacitor is too low



Envelop detector detects the shape of the input signal (AM ~~output~~ i/p). Let us consider a single tone message signal (f_m) and a single tone carrier signal (f_c) $f_c \ggg f_m$ the i/p to the demodulator is an AM signal. The diode D conducts for the positive half cycle of AM signal. during that time the circuit becomes shortcircuit and the capacitor charges upto the peak voltage of the AM signal. During the negative half cycle, the diode is RB the circuit becomes open circuit during that time the capacitor discharges across R.

The output of the envelop detector is the trace of message signal with ripples using low pass filter the ripples can be removed. Using DC block capacitor, the DC component can be removed. The entire operation of the envelope detector depends on the proper choice of time constant $\tau = RC$.



DERIVATION OF TIME CONSTANT for ENVELOP DETECTOR

$$V_{AM}(t) = V_c \cos w_c t + V_m \cancel{V_c} \cos w_c t \cos w_m t$$

$$= V_c \cos w_c t \left[1 + \frac{V_m}{V_c} \cos w_m t \right]$$

$$= V_c \cos w_c t \left[1 + M_a \cos w_m t \right]$$

$$= \boxed{V_c \left[1 + M_a \cos w_m t \right]} \cos w_c t$$

$V_c[1 + M_a \cos w_m t]$ is the envelop of the AM signal to be traced by the detector

Envelop of the detector, $(e) = V_c[1 + M_a \cos w_m t]$.

Rate of change of envelop $= \frac{de}{dt}$

$$= \frac{d}{dt}[V_c + V_c M_a \cos w_m t].$$

$$\frac{de}{dt} = -V_c M_a w_m \sin w_m t.$$

The negative sign indicates the decay of the voltage.

Magnitude of the envelop across the capacitor is given by,

$$= \frac{V_c[1 + M_a \cos w t]}{RC}$$

To avoid diagonal clipping envelop across the capacitor should be greater than or equal to rate of decay of envelop.

envelop across the capacitor ≥ Rate of decay of envelop

$$\frac{V_c[1+M_a\cos\omega_m t]}{RC} \geq V_c M_a \omega_m \sin\omega_m t$$

$$\frac{1}{RC} \geq \frac{M_a \omega_m \sin\omega_m t}{[1+M_a\cos\omega_m t]}$$

$$RC \leq \frac{[1+M_a \cos\omega_m t]}{M_a \omega_m \sin\omega_m t}$$

→ If RC is too small, the capacitor discharges rapidly and we will have more ripples

→ On the other hand, if RC is too large the capacitor discharges too slowly so it cannot follow the envelop of AM signal.

To have $\frac{1}{RC}$ always greater than or equal to RHS. The condition is taking derivative of RHS and equate to zero.

$$\frac{d}{dt}\left[\frac{M_a \omega_m \sin\omega_m t}{1+M_a\cos\omega_m t}\right] = 0$$

$$\frac{1}{RC} \geq \frac{\omega_m M_a}{\sqrt{1-M_a^2}}$$

1. An amplitude modulated wave $10[1+0.6\cos 2\pi 10^3 t]\cos 2\pi 10^6 t$ is to be detected by a linear diode detector

i) time Constant

ii) the value of R if capacitance 100 pf

$$10[1+0.6\cos 2\pi 10^3 t]\cos 2\pi 10^6 t. \quad \text{—} (1)$$

$$V_c[1+M_a\cos w_m t]\cos w_c t \quad \text{—} (2).$$

Comparing (1) & (2).

$V_c = 10$, $M_a = 0.6$, $w_m = 2\pi 10^3$, $w_c = 2\pi 10^6$

$$\frac{1}{RC} \geq \frac{M_a w_m \sin w_m t}{[1+M_a\cos w_m t]}$$

$$\frac{1}{RC} \geq \frac{w_m M_a}{\sqrt{1-M_a^2}}$$

$$\geq \frac{2\pi \times 10^3 \times 0.6}{\sqrt{1-(0.6)^2}}$$

$$\geq \frac{3.768 \times 10^3}{\sqrt{1-0.36}}$$

$$\geq \frac{3.768\times 10^3}{\sqrt{0.64}} \geq \frac{3.768 \times 10^3}{0.8}$$

$$\frac{1}{RC} \geq 4.71 \times 10^3.$$

$$T. = RC \geq 0.212 \times 10^{-3} = 0.212\ ms. = 212\ \mu s$$

ii) $C = 100 \times 10^{-12}\ F$

$T = RC = 212 \times 10^{-6}\ s$

$$R = \frac{212 \times 10^{-6}}{100 \times 10^{-12}} = \frac{212 \times 10^{-6}}{10^{-10}} = 212 \times 10^{4} = 2.12 \times 10^{6}\ \Omega$$

$R = 2.12\ M\Omega.$

ANGLE MODULATION

Frequency modulation (Amp Const / only freq Changes)

Phase modulation

FREQUENCY MODULATION. & Phase Modulation

mathematical expression of carrier Signal.

$$V_c(t) = \overset{\rightarrow \text{Amplitude}}{V_c} \cos(\omega_c t + \theta) \quad — ①$$

$$V_c(t) = V_c \cos\phi \quad — ②.$$

$$\phi = \omega_c t + \theta . \quad — ③.$$

differentiate ③ w r to t

$$\frac{d\phi}{dt} = \omega_c . \rightarrow \text{derivative of } \phi \text{ w r to time} \Rightarrow \omega_i$$

$$\phi_c = \int \omega_i . dt$$

$\left(\frac{d\phi}{dt}\right)$ derivative of phase gives angular freq. (ω_i) or instantaneous

Integration of angular or instantaneous phase is instantaneous phase.

∴ FM can be generated by PM and vise versa

$f = f_c \pm \Delta f$ $f_1 = f_c + \Delta f$

$f_2 = f_c - \Delta f$

FREQUENCY MODULATION (F.M)

In FM ω_i (instataneous angular freq) changes with respect to instantaneous value of message signal. around ω_c

$$\omega_i = \omega_c + K_f V_m(t)$$

where $K_f \rightarrow$ frequency sensitivity $\left(\frac{Hz}{Volt}\right)$

The FM modulated wave is given by $\phi_{FM}(t)$

$$\phi_{FM}(t) = V_c \cos\phi_i \quad — ④$$

$$\phi_i = \int \omega_i . dt$$

$$= \int (\omega_c + K_f V_m(t)).dt$$

$$\phi_{FM}(t) = \int \omega_c . dt + K_f V_m(t).dt$$

$$= \omega_c t + K_f \int V_m \cos \omega_m t . dt.$$

$$= \omega_c t + K_f V_m \frac{\sin \omega_m t}{\omega_m}$$

$$\phi_i = \omega_c t + \frac{K_f V_m}{\omega_m} \sin \omega_m t \quad \text{--- (5)}$$

Sub (5) in (4) $\cos(a+b)$

$$\phi_{FM}(t) = V_c \cos\left[\omega_c t + \frac{K_f V_m}{\omega_m} \sin \omega_m t\right]$$

$\cos a \cos$

Let $K_f V_m = \Delta\omega$

$$\phi_{FM}(t) = V_c \cos\left[\omega_c t + \frac{\Delta\omega}{\omega_m} \sin \omega_m t\right]$$

$$M_f = \frac{\Delta\omega}{\omega_m}$$

where $M_f \rightarrow$ modulation index of FM.

PHASE MODULATION (PM).

$$V_c(t) = V_c \cos(\omega_c t + \theta)$$

$$V_c(t) = V_c \cos \phi_i.$$

$$\phi_i = \omega_c t + \theta$$

$$\theta \propto V_m(t)$$

$$\theta = K_p V_m(t).$$

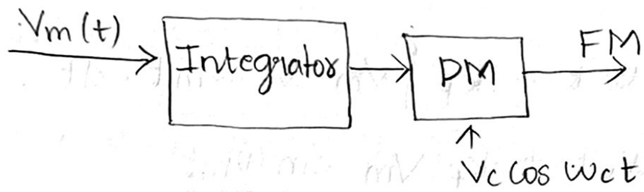
$K_p \rightarrow$ phase sensitivity $\left(\frac{\text{radians}}{\text{Volt}}\right)$.

The PM wave is given by $\phi_{PM}(t)$

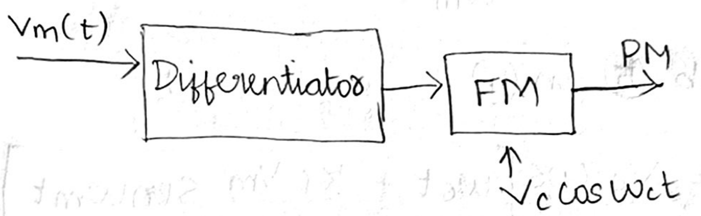
$$\phi_{PM}(t) = V_c \cos\left[\omega_c t + K_p V_m(t)\right]$$

RELATIONSHIP BETWEEN FM & PM.

FM generation using Phase Modulation.



PM generation using frequency Modulation.



BANDWIDTH OF FM.

Bandwidth = $2n\omega_m$

$n \rightarrow$ no of bands freq component present in FM output

n is directly depends on modulation index.

Bandwidth = $2 M_f \omega_m$.

$M_f \omega_m = \Delta\omega$

$= 2\Delta\omega$

$= 2\Delta f$.

Based on K_f (frequency sensitivity) FM is further classified into NBFM, WBFM.

Types of FM

→ Narrow Band FM → K_f is low

→ Wide Band FM → K_f is high.

CARSON'S RULE.

For a FM output having more number of frequency components, it is very difficult to find the highest and lowest frequency in such case we use Carson's rule. for Wide Band FM is

$$\text{Bandwidth of FM} = 2(\Delta f + f_m)$$
$$= 2(\Delta\omega + \omega_m)$$

BANDWIDTH OF PM.

$$\text{Bandwidth} = 2 M_p \omega_m$$

where $M_p = k_p V_m$.

INTERNATIONAL REGULATION FOR FM

→ CCIR (Consultative Rommitee for International Radio) for commercial FM broadcast suggest the following

- $\Delta f = \pm 75\,KHz$.
- Allowed Bandwidth = 200 KHz
- Power content no restriction. $A^2/2$
- frequency ~~mode~~ Stability = ±2 KHz

1. A Single tone modulating Signal frequency modulates a Carrier of 10MHz and produces a frequency deviation of 75KHz. Find

i) Modulation index

ii) Phase deviation produced in FM.

iii) If another modulating Signal produces a modulation index of 100 while maintaing the same frequency deviation then find the amplitude and frequency of message signal Assume $K_f = 15KHz/Volt$, $f_m = 7.5KHz$.

i) Modulation index $= \frac{\Delta\omega}{\Delta\omega_m} = \frac{\Delta f}{f_m}$.

$$M_f = \frac{75 \times 10^3}{7.5 \times 10^3} = 10.$$

ii) $\Delta\theta$ in FM $= M_f = 10$ rad.

iii) $M_f = 100$. $\Delta f = 75KHz$.

$$M_f = \frac{\Delta f}{f_m}.$$

$$100 = \frac{75 \times 10^3}{f_m}$$

$$f_m = \frac{75 \times 10^3}{100} = 750\ Hz.$$

$$K_f V_m = \Delta f$$

$$V_m = \frac{75 \times 10^3}{15 \times 10^3} = 5\ Volts.$$

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2. The maximum deviation allowed in a FM System is 75 KHz. If the modulating signal is the single tone sinusoidal signal of 10 KHz. Find the bandwidth of FM Signal. What will be the change in the Bandwidth if the modulation frequency is doubled. Determine the BW when the ~~modulating~~ amplitude is doubled.

i) Bandwidth $= 2(\Delta f + f_m)$

$= 2(75 + 10)10^3$

$= 2(85) \times 10^3$

$= 170$ KHz.

ii) Bandwidth $= 2(\Delta f + 2f_m)$

$= 2(75 + 20) \times 10^3$.

$= 2(95) \times 10^3$.

$= 190$ KHz.

iii) We know $V_m = \dfrac{\Delta f}{K_m}$.

if V_m is doubled Δf is also doubled.

$BW = 2((2 \times 75) + 20) \times 10^3$

$= 340$ KHZ.

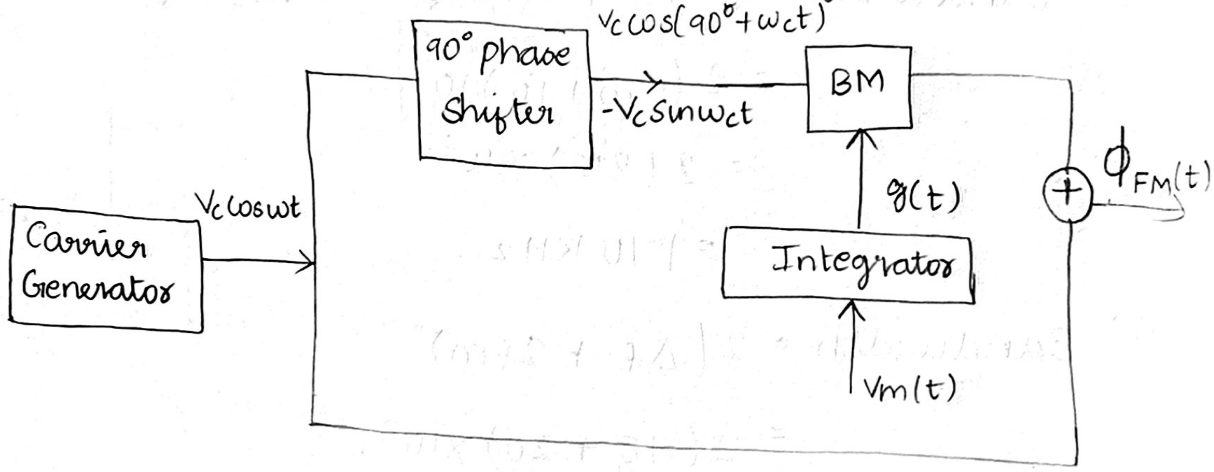
FM GENERATION

$$\phi_{FM}(t) = V_c \cos\left[\omega_c t + \frac{k_f V_m}{\omega_m} \sin \omega_m t\right]$$

$$\phi_{FM}(t) = V_c \cos \omega_c t + V_c \cos \frac{k_f V_m}{\omega_n} \sin \omega_m t.$$

$$g(t) = \int v_m(t)\,dt = \int V_m \cos \omega_m t\,dt = \frac{V_m \sin \omega_m}{\omega_m}$$

BALANCED MODULATOR. (indirect way of FM generation) NB FM



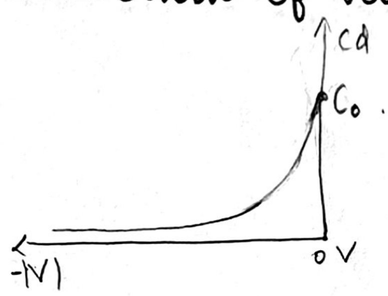
$$BM \cdot o/p = -\left[V_c \sin \omega_c t * \frac{V_m}{\omega_m} \sin \omega_m t\right]$$

$$\phi_{FM}(t) = \left[V_c \cos \omega_c t - V_c \sin \omega_c t \frac{V_m}{\omega_m} \sin \omega_m t\right]$$

DIRECT METHOD OF FM GENERATION USING VARACTOR DIODE

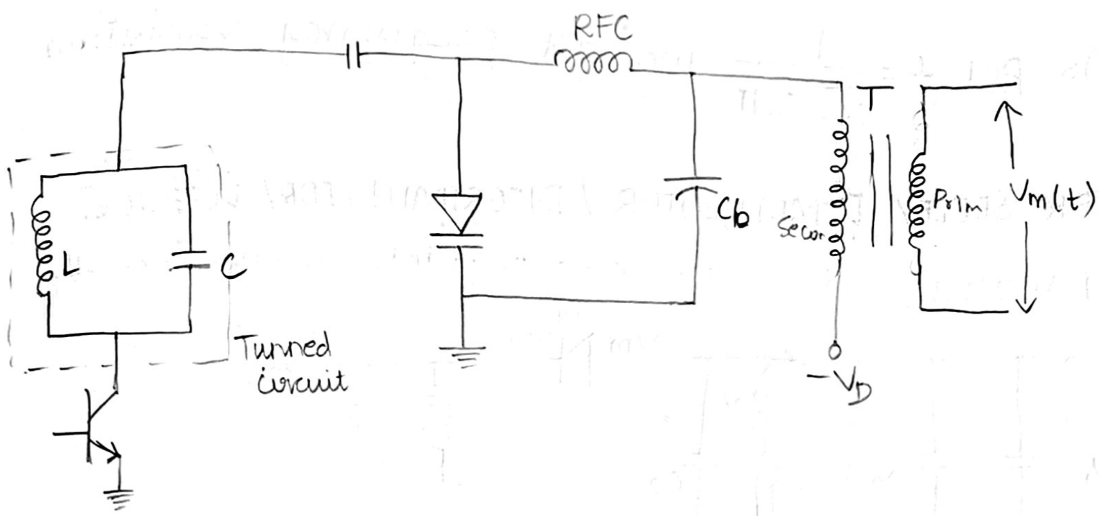
Varactor diode — $C_d \rightarrow$ diode capacitance

Characteristic of varactor diode.



When RB↑ capacitance↓

FM GENERATION USING VARACTOR DIODE.



The Varactor diode is connected in parallel with the tunned circuit of the oscillator. Varactor diode is going to vary its capacitance with respect to instantaneous change in voltage of modulating signal. The modulating signal is fed to the transformer. The secondary winding of the transformer is provided with bias voltage responsible for reverse biasing the varactor diode. RFC (Radio frequency choke) and the capacitance Cb is responsible for preventing the high frequency carrier signal reaching the transformer

WORKING PRINCIPLE.

$V_m(t) \Rightarrow +ve \rightarrow RB\uparrow \rightarrow C\downarrow \rightarrow$ frequency $\uparrow$ $\quad f = \frac{1}{2\pi\sqrt{LC}}$.

$V_m(t) \Rightarrow -ve \rightarrow RB\downarrow \rightarrow C\uparrow \rightarrow$ frequency $\downarrow$

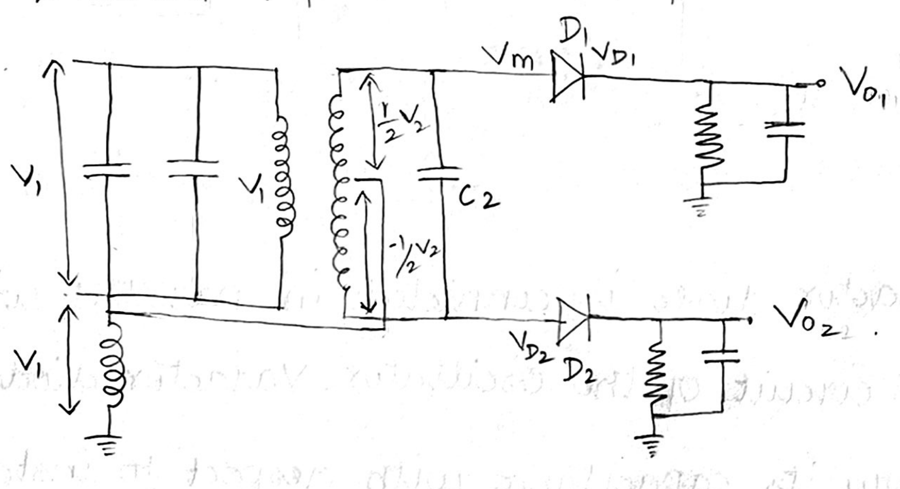
Modulating voltage adds up to the negative bias voltage V_D which varies the reverse bias voltage across the varactor diode.

Since the varactor diode is connected IIel to the capacitance C of the ~~va~~ tunned circuit, the total capacitance of the tuned circuit changes.

As per $f = \frac{1}{\sqrt{LC}\ 2\pi}$ we get frequency variation.

FOSTER SEELEY DEMODULATOR / DISCRIMINATOR / DETECTOR.

freq. variation → phase variation → Amplitude variation → envelop detector → o/p

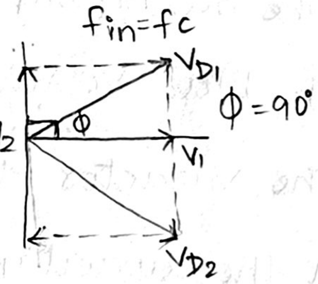


$V_{D_1} = V_1 + \frac{1}{2}V_2$

$V_{D_2} = V_1 - \frac{1}{2}V_2$

$V_o = V_{o_1} - V_{o_2}$

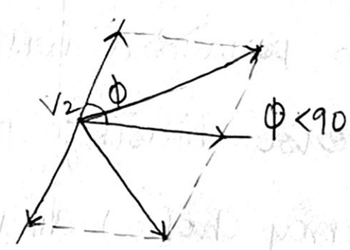
$f_{in} = f_c$



$V_{D1} = V_{D2}$

$V_o = 0$

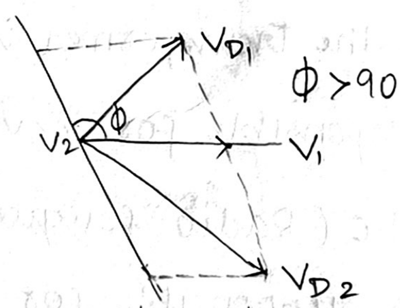
$f_{in} > f_c$



$V_{D1} > V_{D2}$

$V_o = +ve$

$f_{in} < f_c$



$V_{D_1} < V_{o_2}$

$V_o = -ve$

The phase diff btwn V_1 & V_2 decides the diode voltage V_{D_1} & V_{D_2}. If input signal frequency is equal to f_c then the phase difference btwn V_1 & V_2 is exactly 90°.

Case 1

$f_{in} = f_c$

The phase diff btwn V_1 & V_2 is 90°

$V_{D_1} \simeq V_{D_2}$

$V_o = 0$.

Case 2

$f_{in} > f_c$

The phase diff btwn V_1 & V_2 is < 90°

$V_{D_1} > V_{D_2}$

$V_o = +ve$

Case 3

$f_{in} < f_c$

The phase diff btwn V_1 & V_2 is > 90°

$V_{D_1} < V_{D_2}$

$V_o = -ve$