UNIT-1 ANALOG COMMUNICATION:

1 AMPLITUDE MODULATION | AM - DOUBLE SIDE BAND - FULL CARRIER (DSB-FC)

1.1 INTRODUCTION:

DEFINITION: Amplitude Modulation is the process by which amplitude of the carrier signal is varied in accordance with the instantaneous value (amplitude) of the modulating signal, but frequency and phase of carrier wave is constant.

Amplitude Modulation can be classified as follows

Amplitude Modulation (DSB-FC)
(Double Side Band - full carrier)

- DSB-SC (Double side band - Suppressed carrier)
- SSB-SC (Single Side band - Suppressed carrier)
- VSB (Vestigial Side Band)

1.1 AM Envelope:

- DSB-FC is also called as Conventional AM and the shape of Modulated waveform is called as Envelope.
- The repetition rate of the Envelope is equal to the frequency of the modulating signal and the envelope shape is identical to the shape of modulating signal which communicates the information through the system.

~~Fig. 1.1.1 Shows Graphical Representation of AM wave.~~

1.1.2 MATHEMATICAL REPRESENTATION OF AM:

Let the modulating Signal $V_m(t) = V_m \sin \omega_m t \longrightarrow (1)$

carrier signal $V_c(t) = V_c \sin \omega_c t \longrightarrow (2)$

where, V_m = amplitude of message signal in Volts

V_c = amplitude of carrier Signal in Volts

According to the definition, the amplitude of the carrier Signal is changed after modulation

$$V_{AM}(t) = V_{AM} \sin \omega_c t$$

$$= V_{AM} \sin 2\pi f_c t$$

$$\boxed{V_{AM}(t) = \left[V_c + V_m(t)\right] \sin 2\pi f_c t} \longrightarrow (3)$$

Sub (1) in (3)

$$V_{AM}(t) = (V_c + V_m \sin 2\pi f_m t) \sin 2\pi f_c t$$

$$V_{AM}(t) = V_c\left(1 + \frac{V_m}{V_c} \sin 2\pi f_m t\right) \sin 2\pi f_c t$$

$$\boxed{V_{AM}(t) = V_c(1 + m_a \sin 2\pi f_m t) \sin 2\pi f_c t} \longrightarrow (4)$$

where $m_a = \frac{V_m}{V_c} \longrightarrow$ Modulation Index of AM.

Modulation Index: DEFINITION

Ratio between Amplitude of message signal to amplitude of carrier signal is called as Modulation Index (or) Modulation factor (or) Depth of Modulation (or) Modulation Co-efficient.

$$\boxed{m_a = \frac{V_m}{V_c}} \longrightarrow (5)$$

Percentage Modulation:

If the Modulation index is expressed in percentage then it is called as percentage Modulation

$$\boxed{\%\ \text{Modulation} = \frac{V_m}{V_c} \times 100} \longrightarrow (6)$$

- It describes the amount of amplitude change present in AM envelope.
- Dimensionless Quantity

Waveform representation of AM

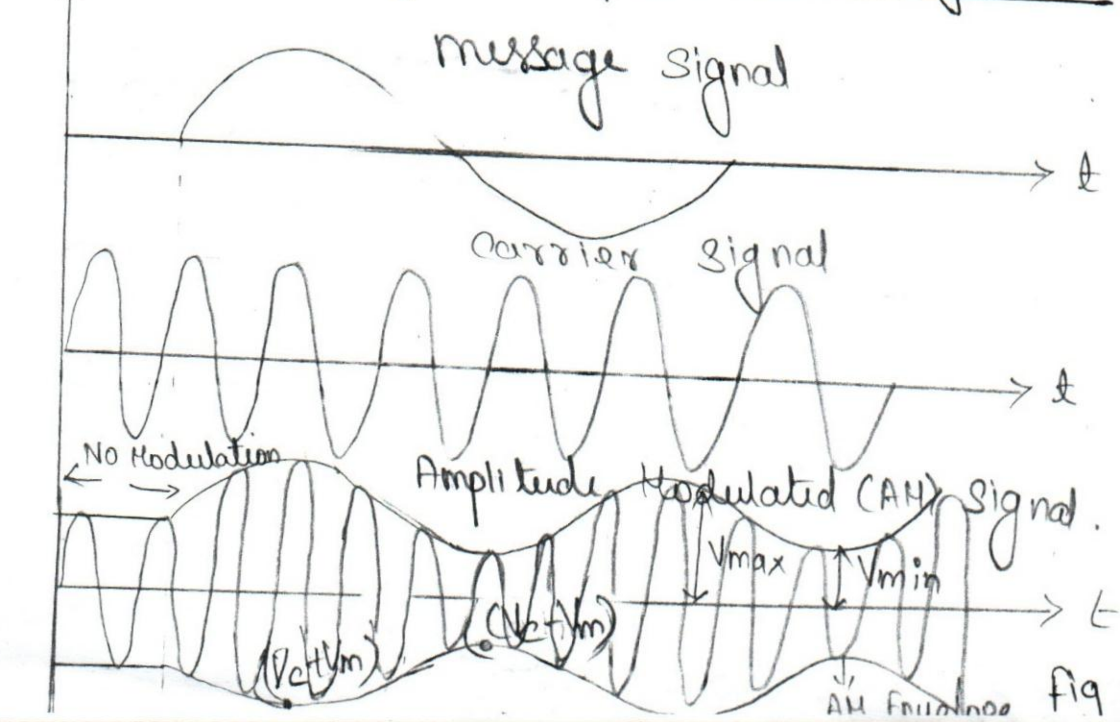


Fig 1 : representation of

1.1.3 FREQUENCY SPECTRUM AND BANDWIDTH OF AM

Mathematical Representation of AM,

$$V_{AM}(t) = V_c(1 + m_a \sin 2\pi f_m t)\sin 2\pi f_c t$$

$$V_{AM}(t) = V_c \sin 2\pi f_c t + V_c m_a \sin 2\pi f_m t \sin 2\pi f_c t$$

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

$$V_{AM}(t) = V_c \sin 2\pi f_c t + \frac{m_a V_c}{2}\left[\cos 2\pi(f_c - f_m)t - \cos 2\pi(f_c + f_m)t\right]$$

$$\boxed{V_{AM}(t) = \underbrace{V_c \sin 2\pi f_c t}_{\text{carrier}} + \underbrace{\frac{m_a V_c}{2}\cos 2\pi(f_c - f_m)t}_{\text{LSB (lower side band)}} - \underbrace{\frac{m_a V_c}{2}\cos 2\pi(f_c + f_m)t}_{\text{USB (upper side band)}}}$$

↳ ~~AM wave consists of carrier, LSB and USB~~.

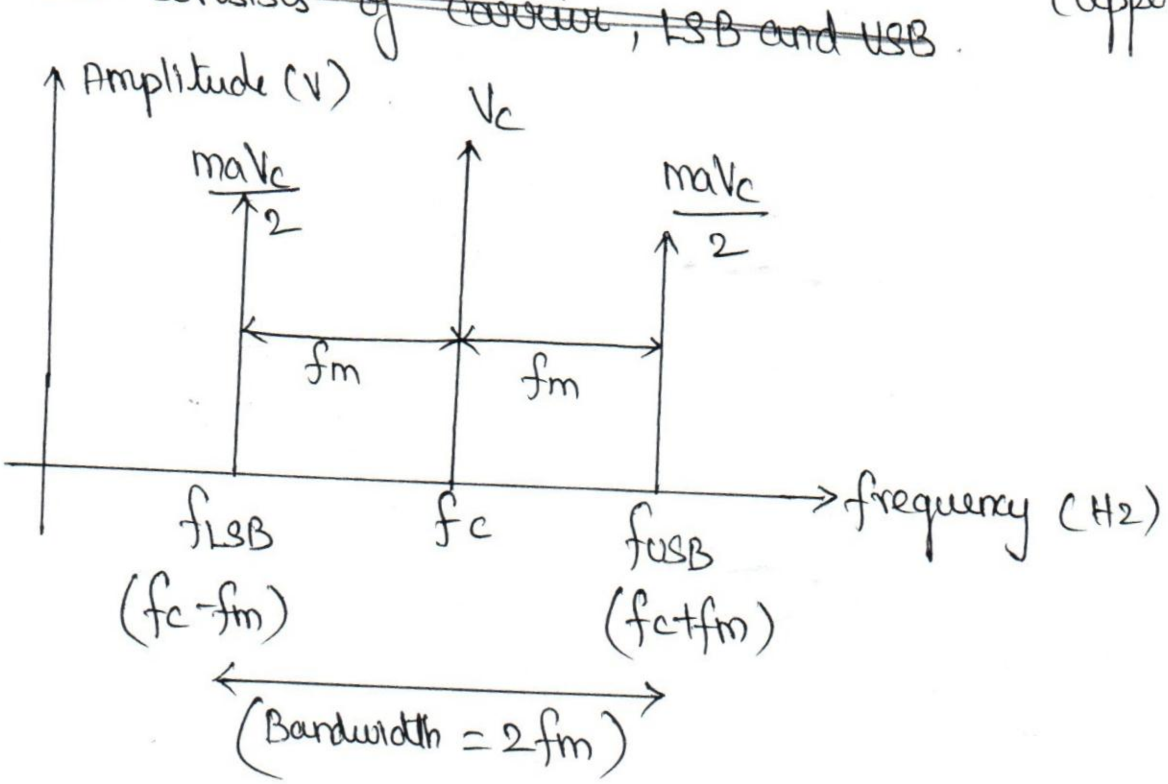


Fig: 2 Frequency spectrum of AM

AM wave contains full carrier, USB (upper Side band and lower Side Band (LSB), hence it is also called as DSB-FC (Double Sideband - full carrier).

BANDWIDTH:

Bandwidth of the signal can be obtained by taking the difference between highest and lowest frequencies.

$$B.W = f_{USB} - f_{LSB}$$

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

$$\boxed{B.W = 2f_m} \longrightarrow (8)$$

∴ Bandwidth of AM signal is twice of the maximum frequency of modulating signal.

SIDEBANS:

- when a carrier is modulated by an information signal, new signals at different frequencies are generated as part of the process. These new frequencies are called Side frequency (or) Side bands.
- Sidebands are occurs in the frequency spectrum directly above and below the carrier frequency.

$$\boxed{\begin{aligned} f_{USB} &= f_c + f_m \\ f_{LSB} &= f_c - f_m \end{aligned}} \longrightarrow (9)$$

1.1.4 PHASOR (or) VECTOR REPRESENTATION OF AM

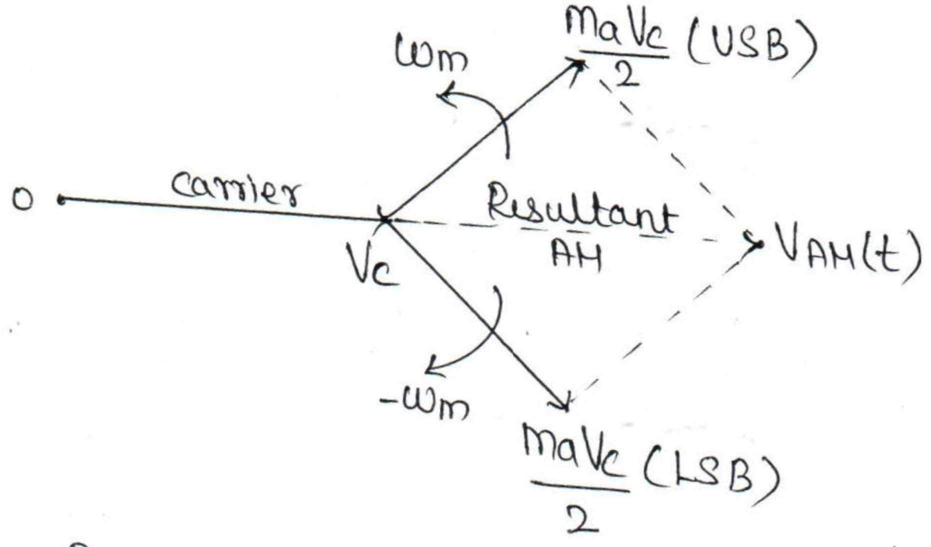


Fig: 3 phasor diagram of AM.

- The phasor for USB rotates in anticlockwise at an angular frequency of ω_m.
- The phasor for LSB rotates in clockwise at the Same angular frequency ω_m.
- The upper Side frequency rotates faster than the carrier ($\omega_m > \omega_c$), and the lower Side frequency rotates Slower ($\omega_m < \omega_c$).
- The resulting amplitude of the modulated wave at any instant is the Vector Sum of the two sideband phasors.
- V_c is carrier wave phasor taken as reference phasor and the resulting phasor is $V_{AM}(t)$.
- The Resultant phasor and carrier phasor are different in amplitude and has Same phase (inphase) with each other.

ALCULATION OF AM MODULATION INDEX FROM AM WAVEFORM.

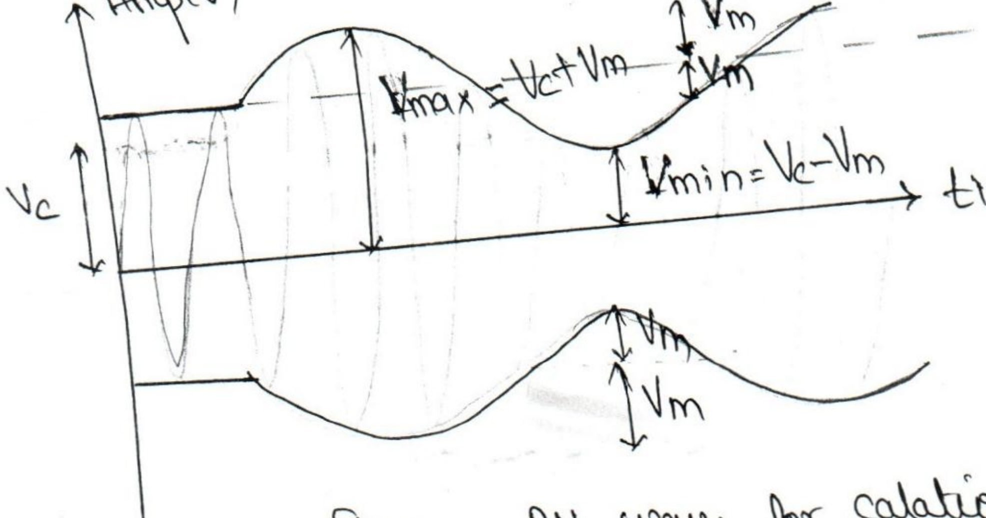


Fig: AM wave for calation of ma (Modulation index)

$$m_a = \frac{\frac{V_m\text{[illegible]}}{2}}{\frac{V_{max}+V_{min}}{2}}$$

$$\boxed{m_a = \frac{V_{max}-V_{min}}{V_{max}+V_{min}}} \longrightarrow (13)$$

where $V_{max} = V_c$ ...

$V_{min} = V_c$ ...

$$\boxed{\%\, m_a = \frac{V_{max}-V_{min}}{V_{max}+V_{min}}} \longrightarrow (14)$$

where, m_a = Modulation Index

$\%\, m_a$ = percentage of Modulation ...

• when ...

1.1.6 DEGREES OF MODULATION

- The Modulating Signals preserved in the Envelope of Amplitude ~~Modulation~~ Modulated signal only if $V_m < V_c$, then $m_a < 1$.
- Depends upon the amplitude of the modulating signal relative to carrier amplitude, degree of Modution is classified into three types.
  (i) under Modulation
  (ii) Critical Modulation
  (iii) Over Modulation

(i) UNDER MODULATION: ($m_a < 1$, $V_m < V_c$)

The envelope of AM signal does not reach the Zero amplitude axis. Therefore the message signal is fully preserved in the AM Envelope. An Envelope detector can recover the message signal without any distortion.

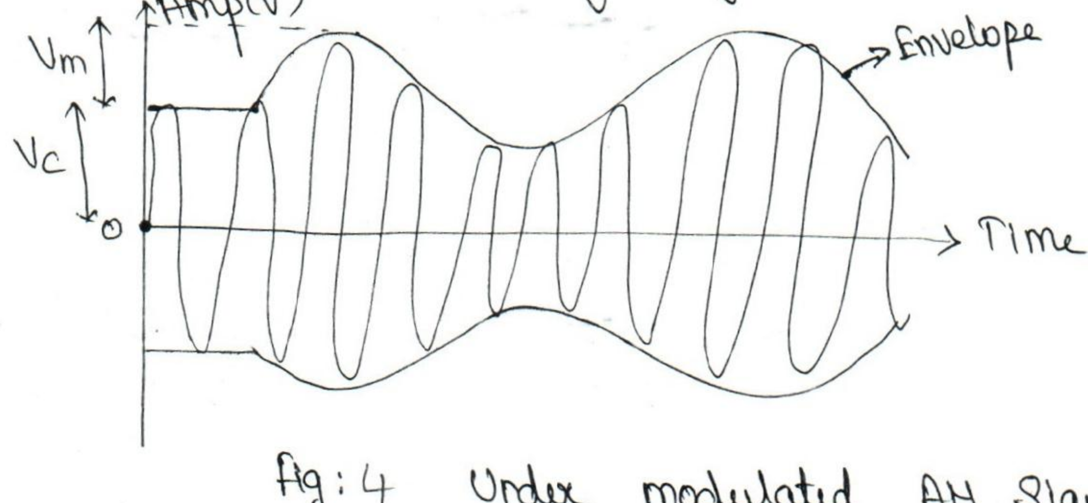


Fig: 4 Under modulated AM Signal.

(ii) CRITICAL MODULATION: ($m_a = 1$, $E_m = E_c$)

When $E_m = E_c$ modulation goes to 100%. this is Known as critical Modulation. The envelope of the modulated signal just reaches the zero amplitude axis.

An envelope detector can recover the message signal without any distortion.

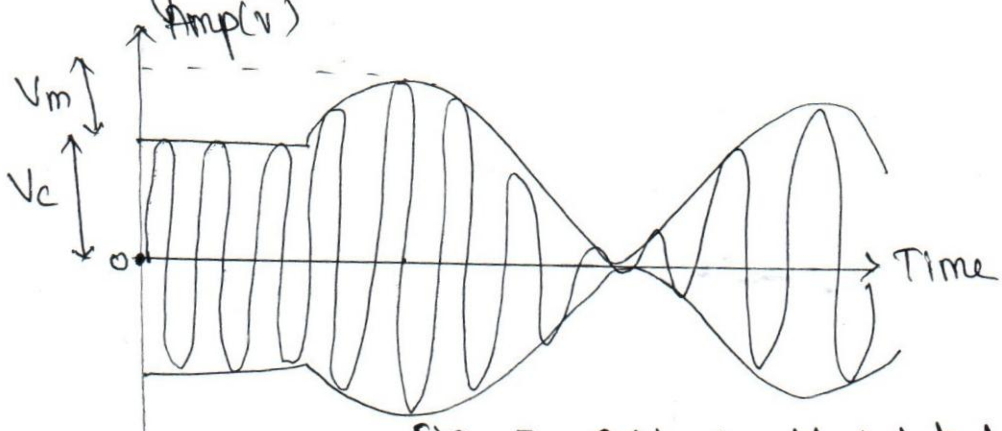


Fig: 5 Critical Modulated AM Signal

(iii) OVER MODULATION: ($m_a > 1$, $E_m > E_c$)

The portion of envelope of the modulated signal crosses the zero amplitude axis, due to this Envelope distortion occurs.

Here Envelope and message signal are not Same.

Both positive and negative extensions of the modulating signals are cancelled (or) clipped out.

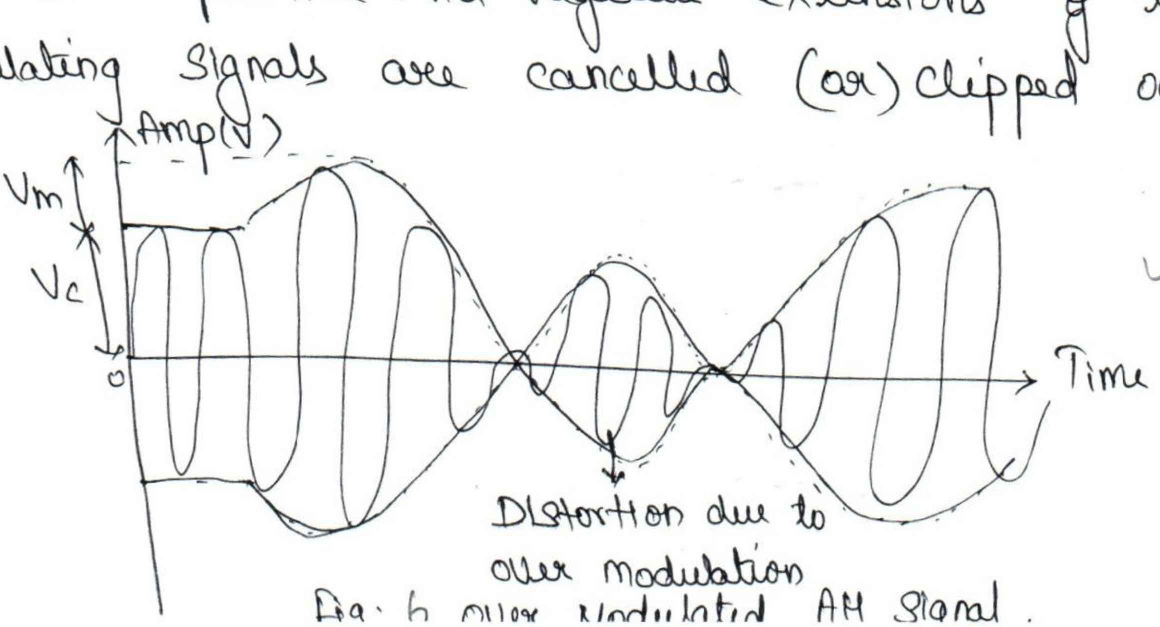


Fig: 6 over Modulated AM Signal.

1.1.7 AM POWER DISTRIBUTION:

we know that AM signal has 3-components: Unmodulated carrier, Lower sideband and Upper sideband Hence Total power of AM wave is the sum of carrier power (P_c) and powers in the two sidebands (P_{USB} and P_{LSB}).

$$\boxed{P_t = P_c + P_{USB} + P_{LSB}} \longrightarrow (17)$$

W.K.T from Equation (7)

$$V_{AM}(t) = V_c \sin 2\pi f_c t + \frac{m_a V_c}{2} \cos 2\pi (f_c - f_m)t - \frac{m_a V_c}{2} \cos 2\pi (f_c + f_m)t$$

~~carrier power (P_c):~~

$$\text{Avg power } (P) = \frac{\text{Rms Voltage}}{\text{Load resistance}}$$

$$= \frac{(V/\sqrt{2})^2}{R}$$

$$\boxed{P = \frac{V^2}{2R}} \longrightarrow (18)$$

for carrier power (P_c):

$$\boxed{P_c = \frac{V_c^2}{2R}} \longrightarrow (19)$$

where
V_c = peak carrier Voltage (volts)
R = Load resistance (ohms)

For SideBand power (P_{SB})

$$P_{USB} = P_{LSB} = \frac{\left(\frac{m_a V_c}{2}\right)^2}{2R} = \frac{(m_a V_c)^2}{8R}$$

$$\boxed{P_{USB} = P_{LSB} = \frac{(m_a V_c)^2}{8R}} \longrightarrow (20)$$

Sub (19) and (20) in eqn (17)

$$P_t = \frac{V_c^2}{2R} + \frac{(V_c m_a)^2}{8R} + \frac{(V_c m_a)^2}{8R}$$

$$= \frac{V_c^2}{2R}\left[1 + \frac{m_a^2}{4} + \frac{m_a^2}{4}\right]$$

$$\boxed{P_t = P_c\left[1 + \frac{m_a^2}{2}\right]} \longrightarrow (21)$$

[if $m_a = 1$]

$$\boxed{P_t = 1.5 P_c}$$

$$\left[m_a = \sqrt{2\left(\frac{P_t}{P_c} - 1\right)}\right] \longrightarrow (21)$$

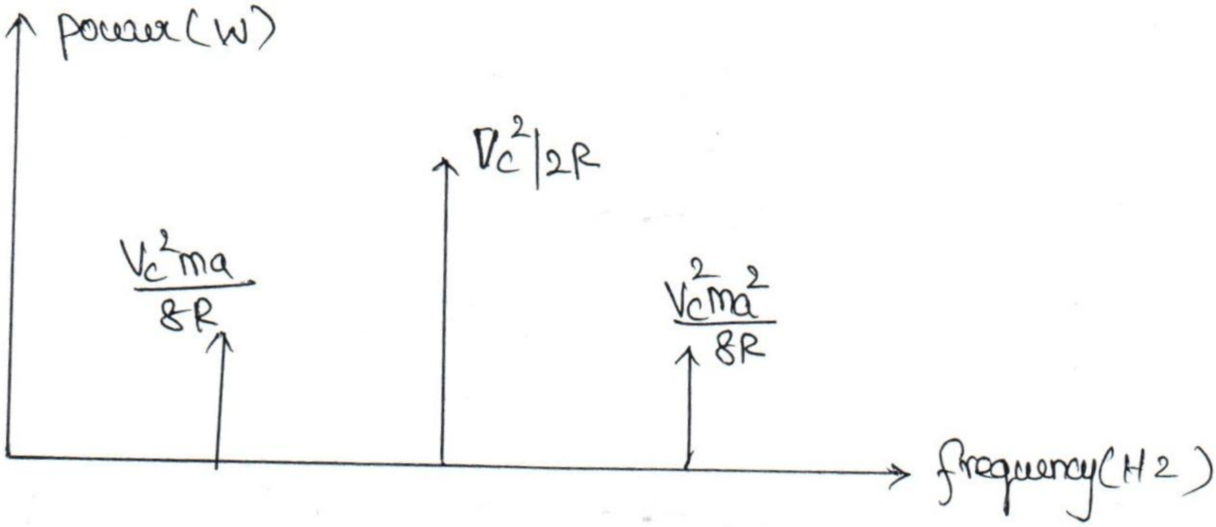


Fig: 7 power Spectra of AM

1.1.8 CURRENT DISTRIBUTION OF AM:

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

$$\left[\because P = I^2R\right]$$

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

$$I_t^2 = I_c^2\left(1+\frac{ma^2}{2}\right)$$

$$\boxed{I_t = \sqrt{I_c\left(1+\frac{ma^2}{2}\right)}} \longrightarrow (22)$$

To find (ma) interms of current:

$$\frac{I_t^2}{I_c^2} = \left(1+\frac{ma^2}{2}\right)$$

$$2\left(\frac{I_t^2}{I_c^2}-1\right) = ma^2$$

$$\boxed{ma = \sqrt{2\left(\frac{I_t^2}{I_c^2}-1\right)}} \longrightarrow (23)$$

To find Transmission Efficiency (η):

(Efficiency) $\eta = \frac{\text{output}}{\text{input}}$

$$\boxed{\eta = \frac{P_{USB}+P_{LSB}}{P_t}}$$

$$\eta = \frac{\frac{ma^2V_c^2}{8R}+\frac{ma^2V_c^2}{8R}}{P_c\left(1+\frac{ma^2}{2}\right)}$$

[DEFINITION: Ratio of power contained in both sidebands to the Total transmitted power]

[The Amount of useful message power present in AM wave is Expressed by a term called transmission Efficiency]

$$= \frac{\frac{E_c^2 ma^2}{4R}}{P_c\left(1+\frac{ma^2}{2}\right)} = \frac{\frac{\cancel{E_c^2}}{\cancel{2R}} \times \frac{ma^2}{2}}{\frac{\cancel{E_c^2}}{\cancel{2R}}\left(1+\frac{ma^2}{2}\right)}$$

$$\boxed{\% \, \eta = \frac{ma^2}{2+ma^2} \times 100} \rightarrow (24)$$

[when $ma = 1$]

$$\eta = \frac{1}{3}$$

$$\boxed{\% \, \eta = 33.33\%}$$

Conclusion:

only 33.33% of power is used for transmission and the remaining power is wasted in the carrier transmission along with the Sidebands.

1.1.9 ADVANTAGES, DISADVANTAGES AND APPLICATIONS OF AM (or) DSB-FC

Advantages:

1) AM wave can travel a long distance
2) Simple Modulators and demodulators
3) AM is Inexpensive
4) It covers larger area than FM.

Disadvantages:

1) wastage of Bandwidth is high
2) poor performance due to Noise
3) Inefficient use of transmitter power.

Applications:

1) Two way mobile Radio communications Such as Citizens band (CB) radio.

2) Aircraft communications in the VHF frequency Range.

3) Low quality form of modulation that is used for commerical broadcasting of both audio and video signals.

1.2 AM MODULATORS:

The device which is used to generate an Amplitude Modulated wave is known as Amplitude Modulator. The methods of AM generation are broadly classified into two types based on its characteristics.

AM MODULATORS

- (i) Low level Modulation (or) Non-linear Modulation
  - a) Square law Modulator
  - b) product Modulator
  - c) Balanced Modulator
- (ii) High level Modulation (or) Linear Modulation
  - a) Transistor Modulator
    - Collector
    - Base
    - Emitter
  - b) Switching Modulator

(i) Low Level Modulator (or) Non-Linear Modulators:

These modulators make use of Non-linear (V-I) characteristics of the devices and are in general suited for use at low voltages.

(ii) High level Modulator (or) Linear Modulators:

In this type of modulators the devices are operated in linear region of its transfer characteristics thus the relation between the amplitude of the modulating signal and the resulting depth of modulation is linear.

1.2.1 COMPARISON OF LOW LEVEL AND HIGH LEVEL MODULATORS

S.NO	PARAMETERS	LOW LEVEL MODULATION	HIGH LEVEL MODULATION
1.	Relation between carrier and modulating Voltage	carrier Voltage is lesser than the modulating Signal Voltage $V_c \ll V_m$	carrier Voltage is greater than the modulating Signal Voltage $V_c \gg V_m$
2.	Filtering	Heavy filtering is required for Extracting the desired Modulated frequency terms	Heavy filtering is not required for Extracting the desired Modulated frequency terms.
3.	power level	Modulation takes place at High power level	Modulation takes place at a low power level
4.	Amplifier Types	Amplifiers like (A, AB(or) B) are used	class-C Amplifiers are used
5.	Devices Used	~~Vacuum tubes~~, Transistors, FET, Op-Amps, Diodes.	Vacuum tubes, Transistors, FET.
6.	Efficiency	Lower than High level modulators	Very High.

7.	Applications	used for wireless intercom, remote control, walkie-talkie, and in TV transmitters	High power transmitters broadcast.

1.2.2 (i) GENERATION OF AM WAVES USING NON-LINEAR MODULATION:-

A Simple diode, or transistor, or FET can be used as a Non-linear Modulator by restricting the operation over Non-linear region of its characteristics. This method is useful only for Small-Signal Amplitude Modulation.

a) SQUARE LAW MODULATOR / POWER-LAW MODULATOR

- Modulation is done at Low power level.
- The devices used in these modulators are operated in Non-linear region of its V-I characteristics

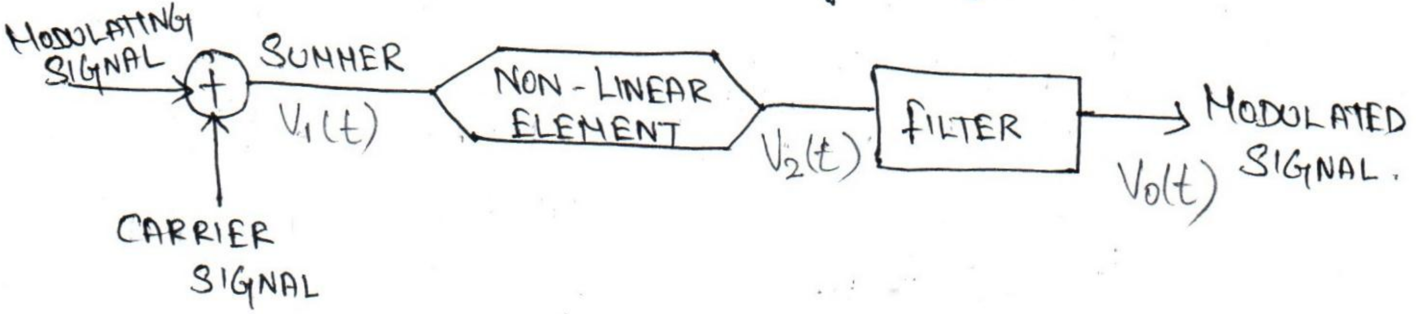


Fig: 8 power-law (or) square law Modulator

- Square law Modulator consists of 3-parts:

(i) • **Summer**: It is used to add both carrier and message Signal

(ii) • **Non-linear device**: It can be used as a active elements like Diode, BJT (Or) FET.

(iii) • **Filter**: The filter can be BPF (Band pass Filter) used for Extracting desired Modulated Signal.

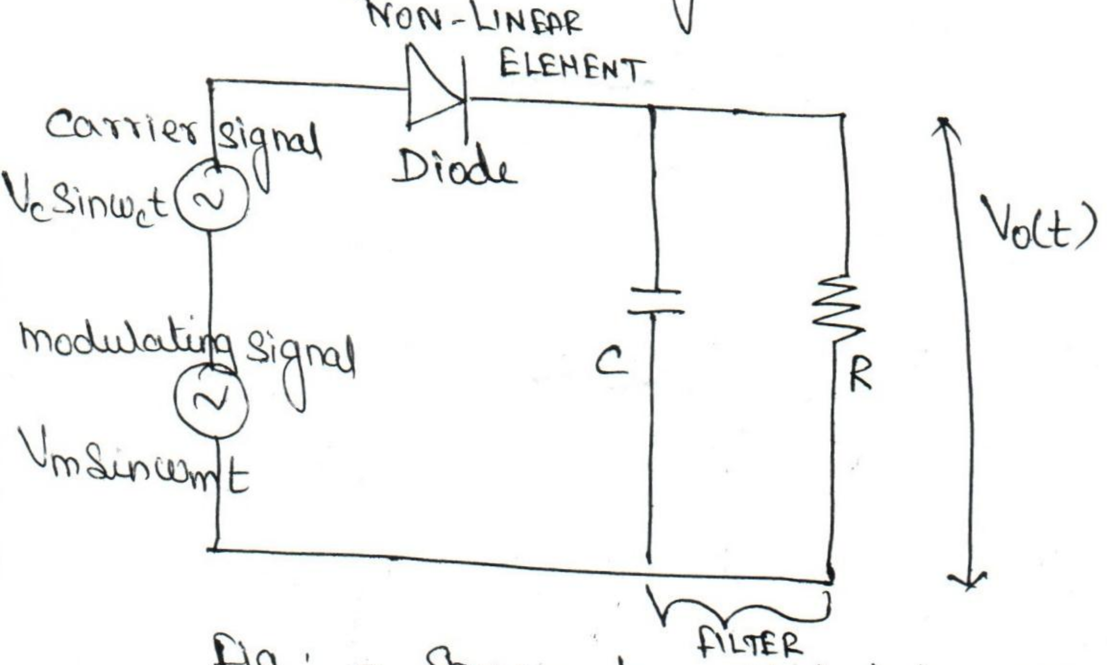


Fig: 9 Square law Modulator using Diode

OPERATION:

- Message Signal (audio frequency) and carrier signal (Radio Frequency) applied at the input are Super imposed each other and makes the diode more forward biased during positive half cycle of input signal and less forward biased during negative half cycle of message signal.

• Thus the magnitude of the carrier component is greater during positive half cycle and lesser during negative half cycle of the modulating Signal.

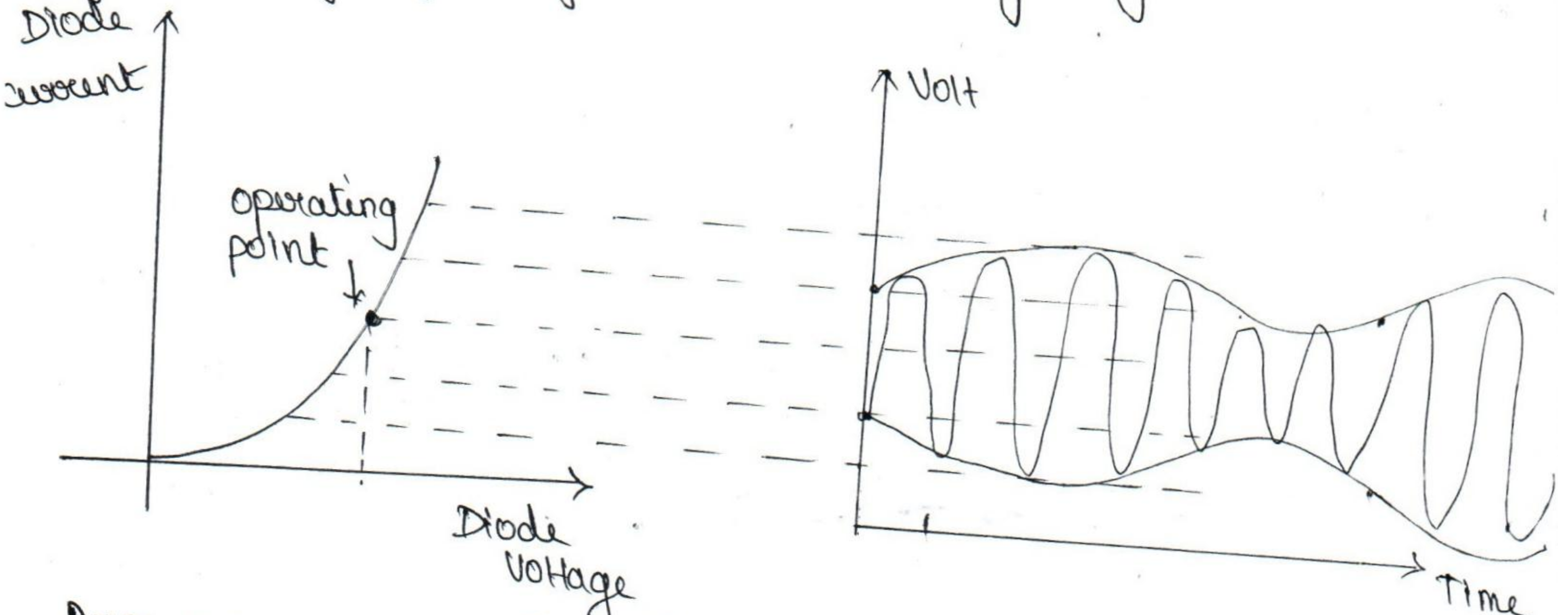


Fig: 10 Modulation waveform

ANALYSIS:

• The modulating and carrier signals are connected in series with each other and their sum $V_1(t)$ is applied at the input of the Non-Linear devices such as diode (or) transistors.

$$V_1(t) = V_m(t) + V_c(t)$$

$$\boxed{V_1(t) = V_m \sin \omega_m t + V_c \sin \omega_c t} \longrightarrow (25)$$

• Input - output relationship for Non-Linear device is

$$\boxed{V_2(t) = a_1 V_1(t) + a_2 V_1^2(t)} \longrightarrow (26)$$

where a_1 and a_2 are constants.

By substituting $V_1(t)$ equation in $V_2(t)$

$$V_2(t) = a_1\left[V_m \sin\omega_m t + V_c \sin\omega_c t\right] + a_2\left[V_m \sin\omega_m t + V_c \sin\omega_c t\right]^2$$

$$= a_1 V_m \sin\omega_m t + a_1 V_c \sin\omega_c t + a_2 V_m^2 \sin^2\omega_m t +$$
$$a_2 V_c^2 \sin^2\omega_c t + 2a_2 V_m V_c \sin\omega_m t \cdot \sin\omega_c t$$

→ By neglating Higher order terms

$$V_2(t) = a_1 V_m \sin\omega_m t + a_1 V_c \sin\omega_c t + 2a_2 V_m V_c \sin\omega_m t \sin\omega_c t$$

$$V_2(t) = a_1 V_m \sin\omega_m t + a_1 V_c \sin\omega_c t +$$
$$\frac{\cancel{2} a_2 V_m V_c}{\cancel{2}}\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]$$

$$\because \sin A \sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$$

$$\boxed{V_2(t) = a_1 V_m \sin\omega_m t + a_1 V_c \sin\omega_c t + a_2 V_m V_c\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]}$$

- when BPF (LC tuned circuit) tuned to carrier frequency, so it allows only High frequencies like ω_c, $(\omega_c - \omega_m)$ and $(\omega_c + \omega_m)$ and Block low frequency like ω_m.

$$\boxed{\therefore V_0(t) = \underbrace{a_1 V_c \sin\omega_c t}_{\text{carrier}} + a_2 V_m V_c\left[\underbrace{\cos(\omega_c - \omega_m)t}_{\text{LSB}} - \underbrace{\cos(\omega_c + \omega_m)t}_{\text{USB}}\right]}$$

Hence AM wave is Generated.

ADVANTAGE:

- Using B.P.F the harmonics are reduced.

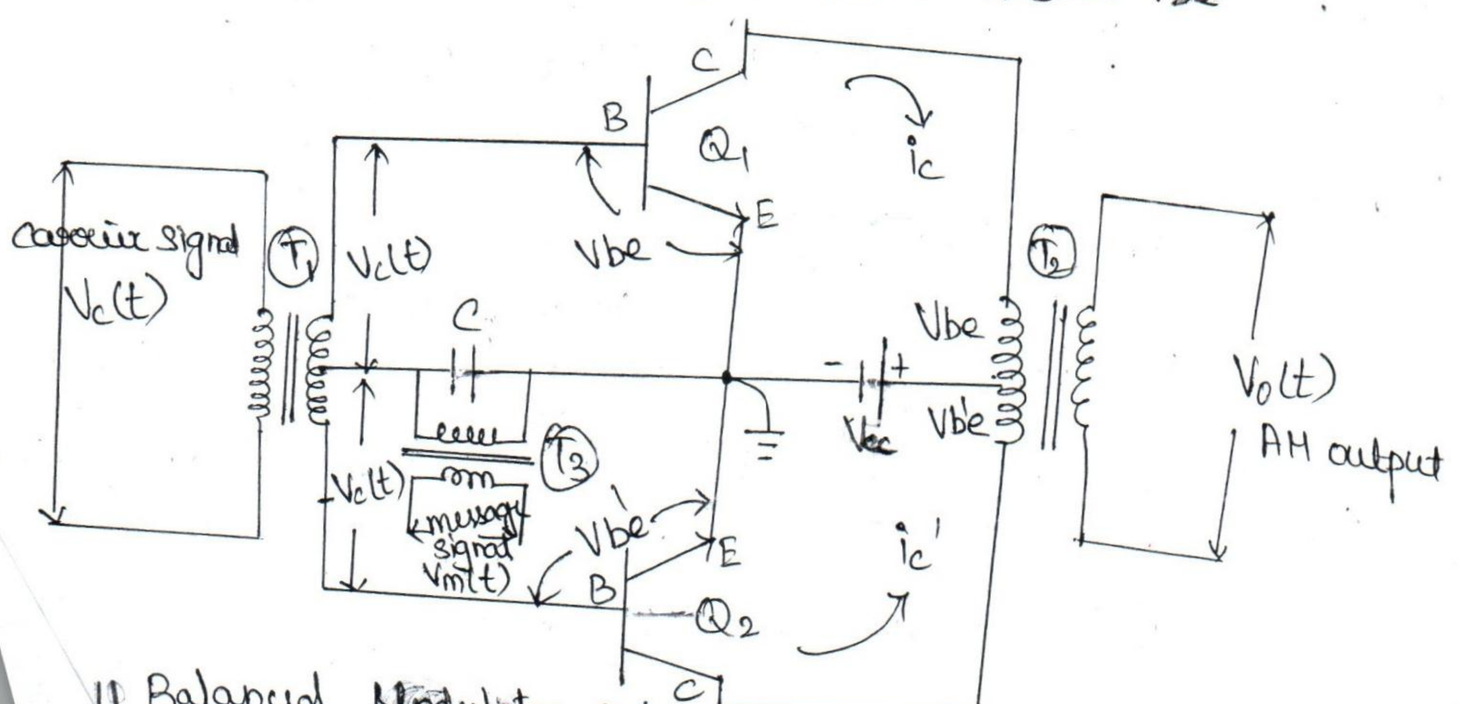
DIS-advantages:

- Diode Modulator does not provide Amplification
- Single diode is unable to Balance out the undesired frequency completely.

These limitations can be eliminated by using Amplifying devices like Transistor, FET in a Balanced Mode.

c) BALANCED MODULATOR

- Two Non-Linear devices are connected in the Balanced Mode.
- Two transistors are identical and circuit is Symmetrical.
- Carrier voltage across upper and Lower part of centre tap transformer are equal and opposite in phase $V_c(t) = -V_c(t)$ (or) $V_{be} = \cancel{V_{be}'}$



// Balanced Modulator circuit

- Balanced Modulator circuit consists of Frequency MIXERS, Modulators and Demodulators.
- operation of the circuit is confined in Non-Linear region of its output characteristics.

ANALYSIS:

- The input Voltage to transistor Q_1 is given by;

$$\boxed{\begin{aligned} V_{be} &= V_c(t) + V_m(t) \\ V_{be} &= V_c \sin\omega_c t + V_m \sin\omega_m t \end{aligned}} \longrightarrow (28)$$

Here both V_c and V_m are inphase

- The input voltage to transistor Q_2 is given by,

$$\boxed{\begin{aligned} V_{be}' &= -V_c(t) + V_m(t) \\ V_{be}' &= -V_c \sin\omega_c t + V_m \sin\omega_m t \end{aligned}} \longrightarrow (29)$$

Here V_c and V_m are in out of phase

- By Non-Linear Relationship (Transistor), output of Q_1 and Q_2 collector currents can be written as

$$i_c = a_1 V_{be} + a_2 V_{be}^2 \longrightarrow$$

$$i_c' = a_1 V_{be}' + a_2 V_{be}'^2 \longrightarrow$$

Hence we obtain

$$i_c = a_1[V_c \sin\omega_c t + V_m \sin\omega_m t] + a_2[V_c \sin\omega_c t + V_m \sin\omega_m t$$

• The output of T_2 is given by,

AM output $V_o(t) = K(i_c - i_c') \longrightarrow$

where K = constant. This is because i_c and i_c' flow in opposite directions in a Tuned circuit, and K depends on impedance of the circuit.

$$i_c = a_1[V_c(t)+V_m(t)] + a_2[V_c(t)+V_m(t)]^2$$

$$i_c = a_1V_c(t) + a_1V_m(t) + a_2V_c^2(t) + a_2V_m^2(t) + 2a_2V_c(t)V_m(t)$$

Illy $i_c' = a_1[-V_c(t)+V_m(t)] + a_2[-V_c(t)+V_m(t)]^2$

$$i_c' = -a_1V_c(t) + a_1V_m(t) + a_2V_c^2(t) + a_2V_m^2(t) - 2a_2V_c(t)V_m(t)$$

Sub i_c and i_c' equation in $V_o(t)$.

$$V_o(t) = K\Big[a_1V_c(t) + a_1\cancel{V_m(t)} + a_2\cancel{V_c^2(t)} + a_2\cancel{V_m^2(t)} + 2a_2V_c(t)V_m(t) + a_1V_c(t) - a_1\cancel{V_m(t)} - a_2\cancel{V_c^2(t)} - a_2\cancel{V_m^2(t)} + 2a_2V_c(t)V_m(t)\Big]$$

$$V_o(t) = K\left[2a_1V_c(t) + 4a_2V_c(t)V_m(t)\right]$$

$$\boxed{V_o(t) = 2Ka_1V_c(t) + 4Ka_2V_c(t)V_m(t)}$$

Sub $V_c(t) = V_c \sin \omega_c t$ and

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

$\therefore V_0(t) = 2Ka_1 V_c \sin w_c t + 4Ka_2 V_c \sin w_c t \, V_m \sin w_m t$

$$V_0(t) = 2Ka_1 V_c \sin w_c t + \frac{4Ka_2}{2} V_m V_c \left[\cos(w_c - w_m)t - \cos(w_c + w_m)t\right]$$

$$\boxed{V_0(t) = \underbrace{2Ka_1 V_c \sin w_c t}_{\text{carrier}} + \underbrace{2Ka_2 V_m V_c \cos(w_c - w_m)t}_{\text{LSB}} - \underbrace{2Ka_2 V_m V_c \cos(w_c + w_m)t}_{\text{USB}}}$$

Hence AM wave is generated.

30

ADVANTAGES :-

- In Simple Non-Linear circuits, the undesired harmonics are eliminated by a Bpf.
- But in the case of Balanced Modulator, the undesired harmonics are automatically Balanced out, So the Filter is not required.

DIS-ADVANTAGES:

- Very low output power Level.

NOTE:

The Same circuit can be used to generate DSB-SC-AM. The main difference between DSB-FC and DSB-SC is, that feeding points of the carrier and Modulating signals are interchanged.

1.2.3 (ii) GENERATION OF AM WAVES USING LINEAR MODULATION

SWITCHING MODULATOR (or) CHOPPER MODULATOR :

- Basically Linear Modulators are arranged so that undesired modulation products never fully develop and need not be filtered out. This is usually accomplished by switching devices like BJT or diode.

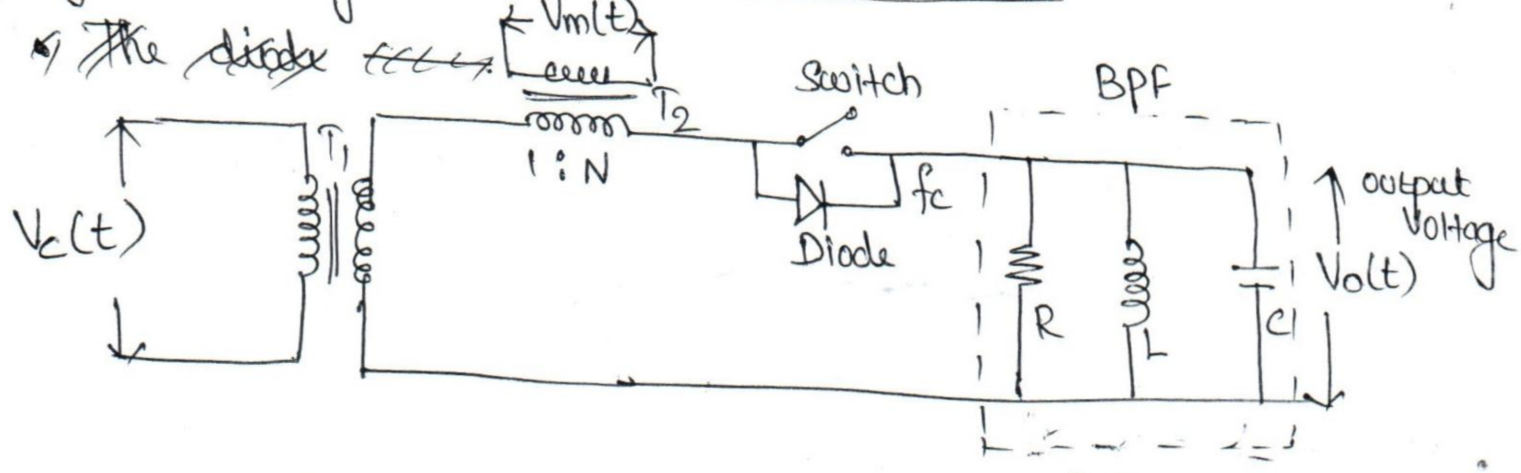


Fig : 12 Switching Modulator using diode

- Here the diode act as a switch, driven at the carrier frequency, closes every $1/f_c$ second. The RLC Load is a tank circuit act as a filter tuned to resonate at f_c so that the switching action causes the tank circuit to ring sinusoidally.

Operation : • Let $V_i(t) = V_c(t) + V_m(t)$

- when diode is forward biased for every positive half cycle of the carrier and behaves like a short circuited switch. Then the signal appears at the input of the BPF.

$$\boxed{V_o(t) = V_i(t)}$$

• For Negative half cycle of the carrier the diode is Reverse biased and behaves like an open switch. The Signal does not reach the Filter and hence no output obtained

$$\boxed{V_o(t) = 0}$$

• Thus Signal is modulated at the rate of carrier frequency.

• The output of BPF tuned to carrier frequency So, it allows ~~all~~ ω_c terms and rejects other frequency terms.

ANALYSIS:

Case: 1 [without message signal $V_m(t)$]

$V_o(t) = V_c(t)$ (only carrier Signal)

$$\boxed{V_o(t) = V_c \sin\omega_c t}$$

case: 2 [with message Signal $V_m(t)$]

• Diode conducts both message and carrier Signal.

$V_o(t) = [V_c + N\, V_m(t)] \sin\omega_c t$

$V_o(t) = V_c \sin\omega_c t + N V_m V_c \sin\omega_c t \sin\omega_m t$ [∵ Transformer T_2 turns ratio = 1 : N]

$$\boxed{V_o(t) = \underbrace{V_c \sin\omega_c t}_{\text{Carrier}} + \frac{N V_m V_c}{2}\left[\underbrace{\cos(\omega_c - \omega_m)t}_{\text{LSB}} - \underbrace{\cos(\omega_c + \omega_m)t}_{\text{USB}}\right]} \rightarrow (31)$$

Hence AM wave obtained.

Advantages:

- High power Modulator
- It doesnot produce undesired frequency components.

1.3 DEMODULATION OF AM SIGNALS

DEFINITION:

It is a process by which modulating signal (or) message signal is recovered from modulated signal.
ie) Reverse process of Modulator.

1.3.1 ENVELOPE DETECTOR (or) SHAPE DETECTOR

- Envelope ~~dector~~ detector produces an output signal that follows the envelope of the input AM.
- It Simply detects The Envelope of AM.

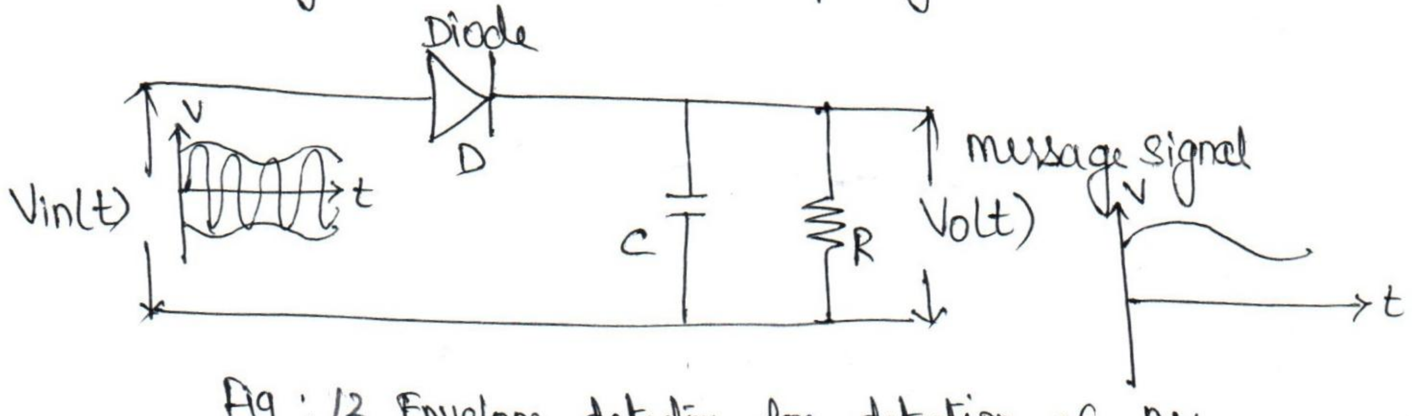


Fig : 1.3 Envelope detector for detection of AM

OPERATION:

- operation takes place over Linear region of characteristics of diode.

- For positive half cycle of ~~carrier~~ input, diode is in F.B (conducts) and it charge the filter capacitor 'C' connected across the load Resistor 'R' to peak value of input voltage.
- once capacitor charges, peak value of the diode stops conducting and starts discharging through 'R'. Thus discharging continues until the next positive half cycle appears.
- when the input signal becomes greater than capacitor voltage diode conducts again and the process repeats.

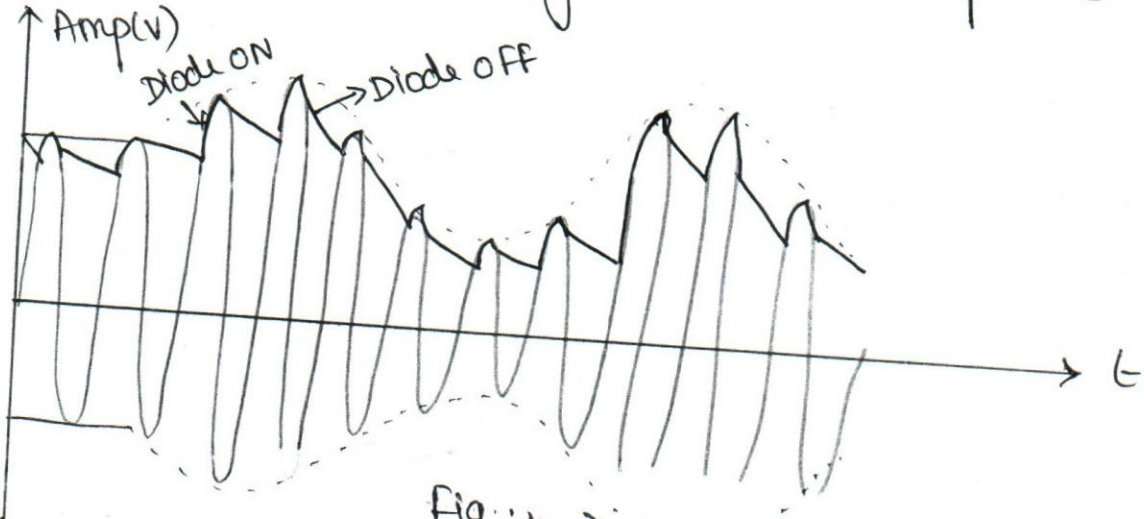


Fig :14a) input of ~~detector~~

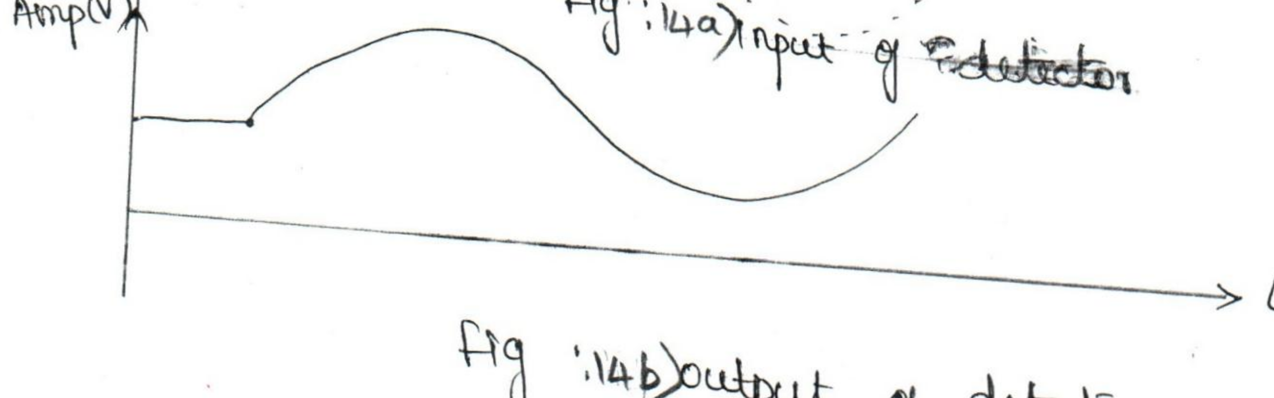


Fig :14b) output of detector

- ~~B~~ Spikes are introduced due to charging and discharging of capacitor

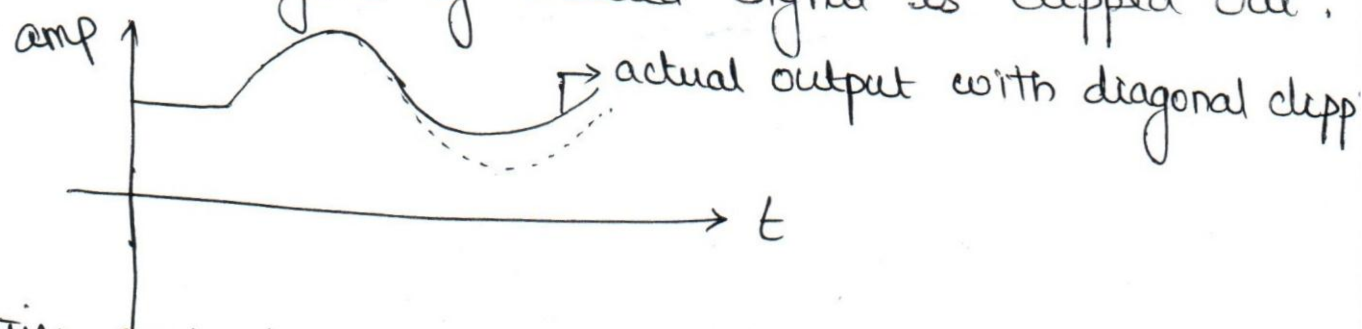
• Discharging Time is controlled by time constant RC.

1.3.2 Distortion in the Envelope detector:

1. Diagonal clipping 2. Negative peak clipping.

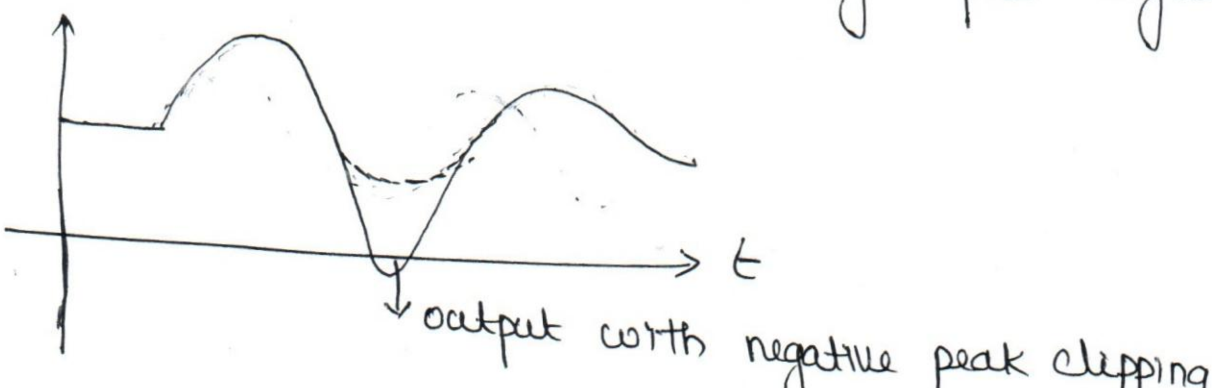
Diagonal clipping:

Distortion occurs when RC time constant of load circuit is too long and it cannot follow the fast changes in the message Envelope. As a result of distortion diagonal of detected signal is clipped out.



Negative peak clipping:

Negative peak clipping occurs when over Modulat occurs ii) Modulation index of detected message signal is greater than Modulation index of input Signal.



2 DOUBLE SIDE BAND - SUPPRESSED CARRIER (DSB-SC)

2.1 INTRODUCTION:

Drawbacks of DSB-FC:

- DSB-Sc has 3-terms like carrier, USB (upper side band), LSB (lower side band), where carrier doesnot convey any information,
- Most of the power is wastated by the carrier information.

→ This problem can be overcome by the Suppression of carrier.

DSB-SC (DEFINITION):

Most of the power is transmitted in the carrier, that is not used for carring information. Hence carrier is Suppressed and only Sidebands are transmitted. Such modulation is called as (DSB-SC) Double Side band - Suppressed Band.

- DSB-SC contain LSB and USB term, resulting that the transmission Bandwidth is twice the frequency of message signal

$$\boxed{B.W = 2f_m}$$

2.1.1 MATHEMATICAL REPRESENTATION OF DSB-SC:

- Message signal $V_m(t) = V_m \sin \omega_m t$
- carrier signal $V_c(t) = V_c \sin \omega_c t$
- Modulated signal $V_{DSB-SC}(t) = V_m(t) \cdot V_c(t)$

$$V_{DSB-SC}(t) = V_m V_c \sin \omega_c t \sin \omega_m t$$

$$\boxed{V_{DSB-SC}(t) = \frac{V_m V_c}{2}\left[\underbrace{\cos(\omega_c - \omega_m)t}_{LSB} - \underbrace{\cos(\omega_c + \omega_m)t}_{USB}\right]} \quad (1)$$

~~Thus & DSB-SC~~

This expression shows only two sidebands and unmodulated carrier signal is removed.

2.1.2 Freq spectrum of DSB-SC:

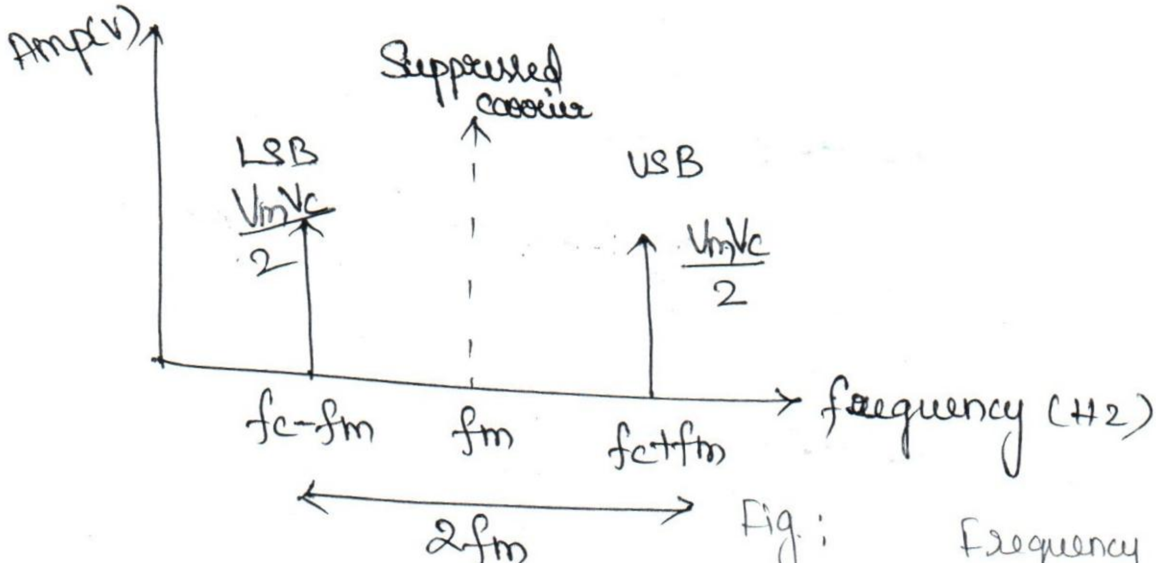


Fig: Frequency spectrum of DSB-SC

$$DSB-SC\ (B.W) = \text{High frequency} - \text{Low frequency}$$
$$= (f_c + f_m) - (f_c - f_m)$$

$$\boxed{B.W = 2f_m}$$

2.1.3 phasor Representation of DSB-SC:

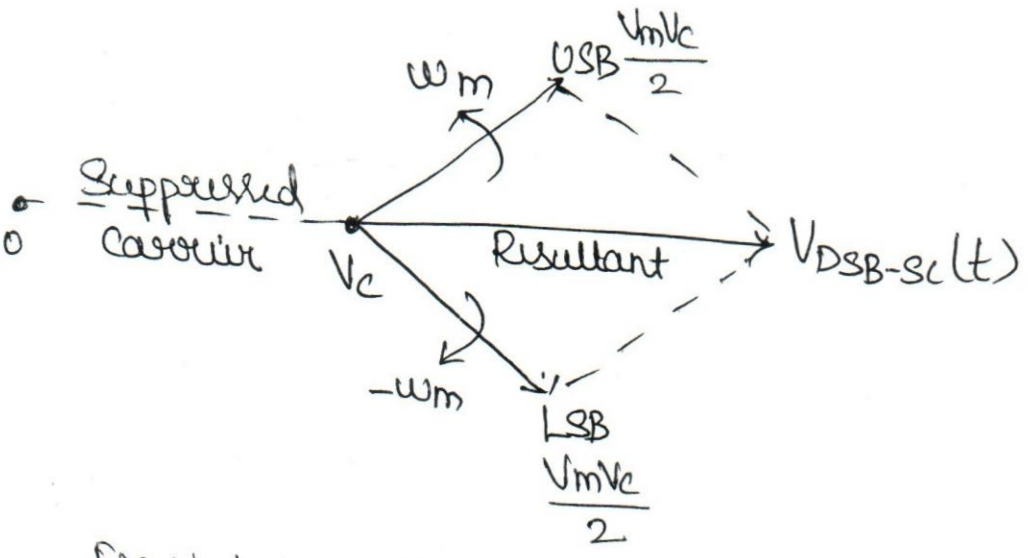


Fig: phasor diagram of DSB-SC

- where USB rotates at an angular frequency of ω_m in anticlockwise direction and LSB rotates at an angular frequency of ω_m in clockwise direction
- The resultant Amplitude of modulated wave is Vector Sum of two Sidebands.

2.1.4 power representation of DSB-SC:

W.K.T AM Total power $\boxed{P_t = P_c\left[1+\frac{m_a^2}{2}\right]} \rightarrow (2)$

- Since carrier power is Suppressed in DSB-SC

DSB-SC Total power $\boxed{P_t' = P_{USB} + P_{LSB}} \rightarrow (3)$

W.K.T $P_{USB} = P_{LSB} = \frac{(m_a V_c)^2}{8R}$

$$P_t' = \frac{(m_a V_c)^2}{8R} + \frac{(m_a V_c)^2}{8R}$$

$$P_t' = \frac{m_a^2 V_c^2}{4R}$$

$$P_t' = \frac{m_a^2}{2}\left(\frac{V_c^2}{2R}\right)$$

$$\boxed{P_t' = \frac{m_a^2}{2} P_c} \rightarrow (4)$$

when $m_a = 1$, then

$$\boxed{P_t' = \frac{P_c}{2}}$$

- **POWER SAVING OF DSB-SC:**

By relating total power of AM & DSB-SC

$$\text{power Saving} = \frac{P_t - P_t'}{P_t}$$

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

$$= \frac{P_c + \cancel{\frac{P_c m_a^2}{2}} - \cancel{\frac{P_c m_a^2}{2}}}{P_c\left[\frac{2 + m_a^2}{2}\right]}$$

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

$$\boxed{\therefore \text{ \% power saving} = \frac{2}{2 + m_a^2} \times 100} \rightarrow (5)$$

- when $m_a = 1$ then 100% modulation

$$\therefore \% \text{ Power}_{DSB-SC} = \frac{2}{3} \times 100$$

$$\boxed{P_{DSB-SC} = 66.7\%} \rightarrow 6$$

Here by suppression of carrier signal in DSB-SC 66.7% of power is saved.

<u>Advantages of DSB-SC</u>

- More efficient in transmitted power i.e) 66.7%
- wastage of power is less compared with DSB-SC.
- SNR (Signal to Noise Ration) is Better.

<u>Dis-advantages of DSB-SC</u>

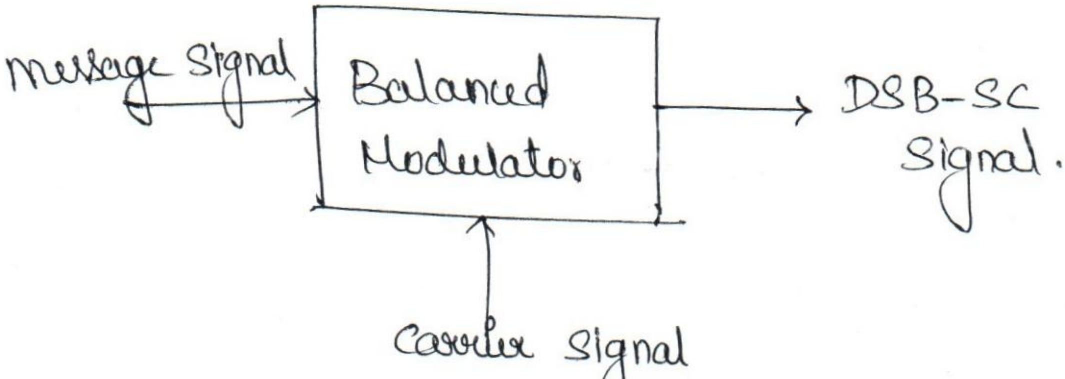
- Bandwidth of DSB-SC is also 2fm as DSB-FC, even carrier is suppressed.
- Receiver is complex and Expensive.

(2.2) GENERATION OF DSB-SC:

Generation of DSB-SC wave:

1. Balanced Modulator 2. Ring Modulator.

2.2.1 (1) BALANCED MODULATOR:



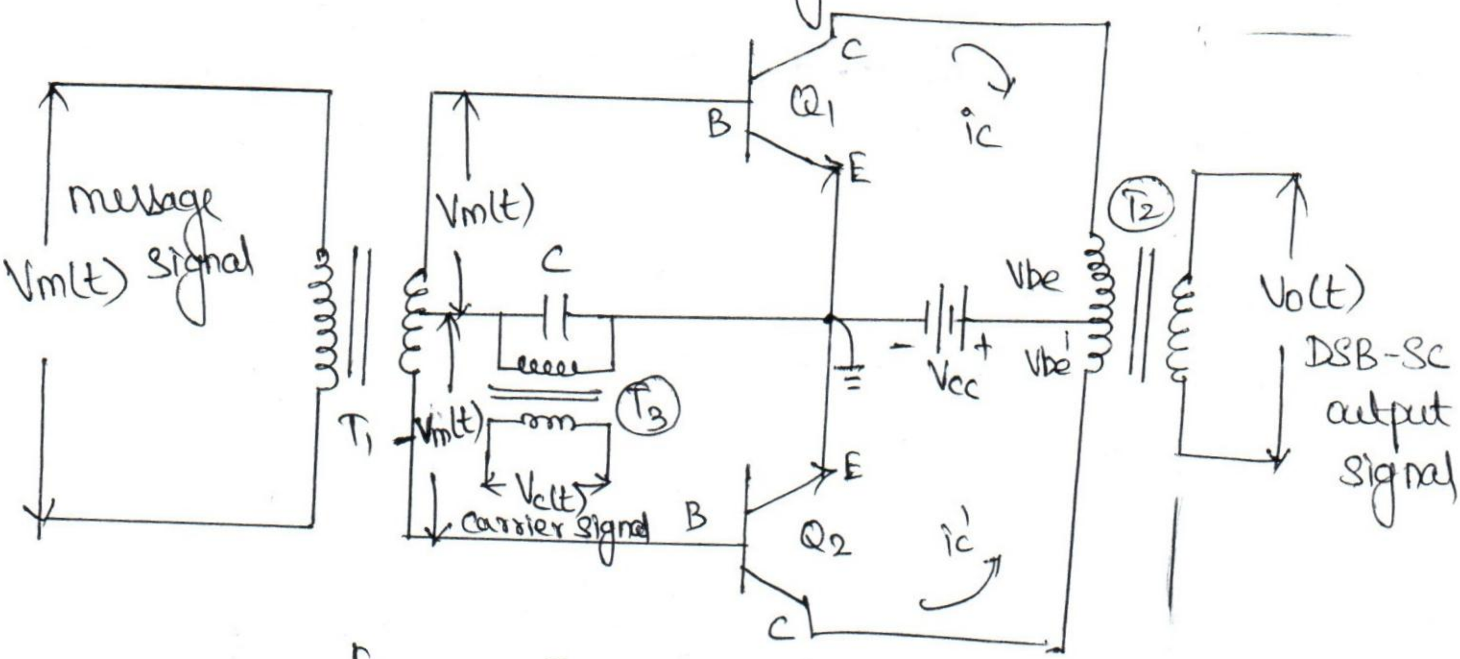


Fig:2 Balanced Modulator

- Two Non-linear devices are connected in Balanced Mode, so that carrier signal is suppressed.
- The circuit that automatically eliminates the unwanted carrier signal.
- It is assumed that the two transistors are

identical & the circuit is symmetrical.

ANALYSIS:

- The input voltage at the base of Q_1 is the sum of two input voltage

$$\boxed{V_{be} = V_c(t) + V_m(t)} \longrightarrow (7)$$

where $V_c(t) = V_c \sin w_c t$ and $V_m(t) = V_m \sin w_m t$

~~Here~~ V_c and V_m are inphase.

- The input voltage at the base of Q_2 is difference of two input voltage

$$\boxed{V_{be}' = V_c(t) - V_m(t)} \longrightarrow (8)$$

V_c and V_m are out of phase.

- By Non-linear (transistor), the collector currents ~~output of transistors~~ Q_1 and Q_2 can be written as,

$$i_c = a_1 V_{be} + a_2 V_{be}^2 \longrightarrow (9)$$

$$i_c' = a_1 V_{be}' + a_2 V_{be}'^2 \longrightarrow (10)$$

- The output of T_2 is given by,

$$\boxed{V_o(t) = K(i_c - i_c')} \longrightarrow (11)$$

where K = constant. This is because i_c and i_c' flows in opposite direction in a Tuned circuit and K depends on impedance of the circuit.

Substitute (3.6) in (3.8) eq

$$i_c = a_1[V_c(t)+V_m(t)] + a_2[V_c(t)+V_m(t)]^2$$

$$i_c = a_1V_c(t) + a_1V_m(t) + a_2V_c^2(t) + a_2V_m^2(t) + 2a_2V_c(t)V_m(t)$$

Illy Substitute (3.7) in (3.9) eq

$$i_c' = a_1[V_c(t)-V_m(t)] + a_2[V_c(t)-V_m(t)]^2$$

$$i_c' = a_1V_c(t) - a_1V_m(t) + a_2V_c^2(t) + a_2V_m^2(t) - 2a_2V_c(t)V_m(t)$$

Substitute i_c and i_c' equation in $V_o(t)$

$$V_o(t) = K\Big[\cancel{a_1V_c(t)} + a_1V_m(t) + \cancel{a_2V_c^2(t)} + \cancel{a_2V_m^2(t)} + 2a_2V_c(t)V_m(t)$$
$$- \cancel{a_1V_c(t)} + a_1V_m(t) - \cancel{a_2V_c^2(t)} - \cancel{a_2V_m^2(t)} + 2a_2V_c(t)V_m(t)$$

$$V_o(t) = K\left[2a_1V_m(t) + 4a_2V_c(t)V_m(t)\right]$$

$$\boxed{V_o(t) = 2Ka_1V_m(t) + 4Ka_2V_c(t)V_m(t)}$$

Now Substitute $V_m(t) = V_m \sin\omega_m t$ and $V_c(t) = V_c \sin\omega_c t$

$$V_o(t) = 2Ka_1V_m\sin\omega_m t + 4Ka_2V_mV_c\sin\omega_c t\cos\omega_c t$$

$$\boxed{V_o(t) = 2Ka_1V_m\sin\omega_m t + 2Ka_2V_mV_c\Big[\underbrace{\cos(\omega_c-\omega_m)t}_{LSB} - \underbrace{\cos(\omega_c+\omega_m)t}_{USB}\Big]}$$

Hence DSB-FC wave obtained.

Conclusion:

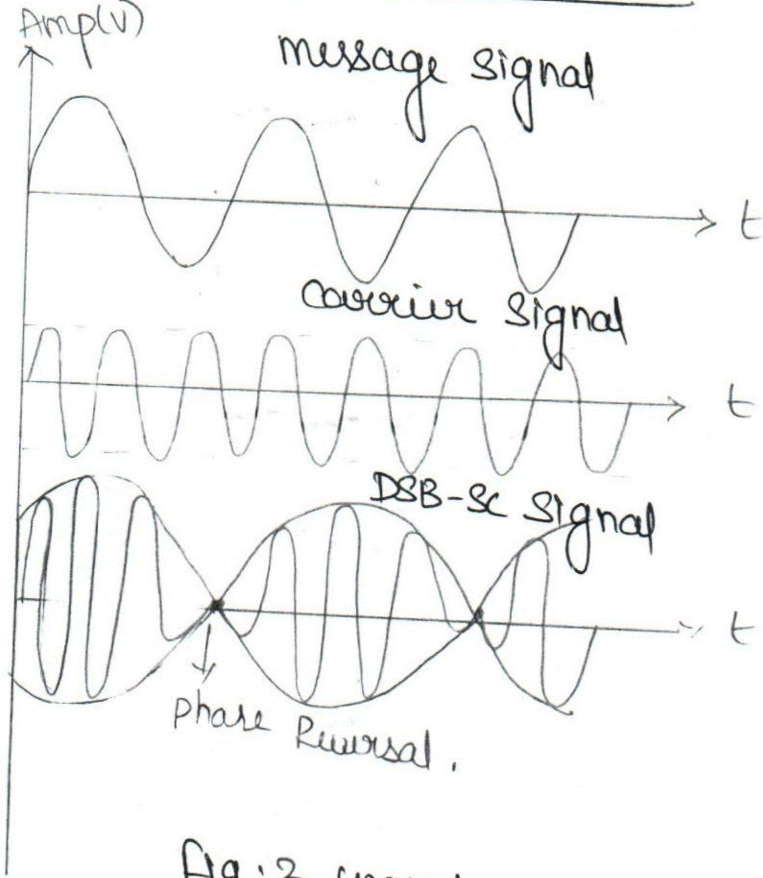
output of the circuit $V_o(t)$ contains only two side bands and carrier is suppressed.

12

Advantages:-

- Large power saved, due to the suppression of carrier
- High Efficiency
- Commonly used in carrier current telephone system.

(2) RING MODULATOR:

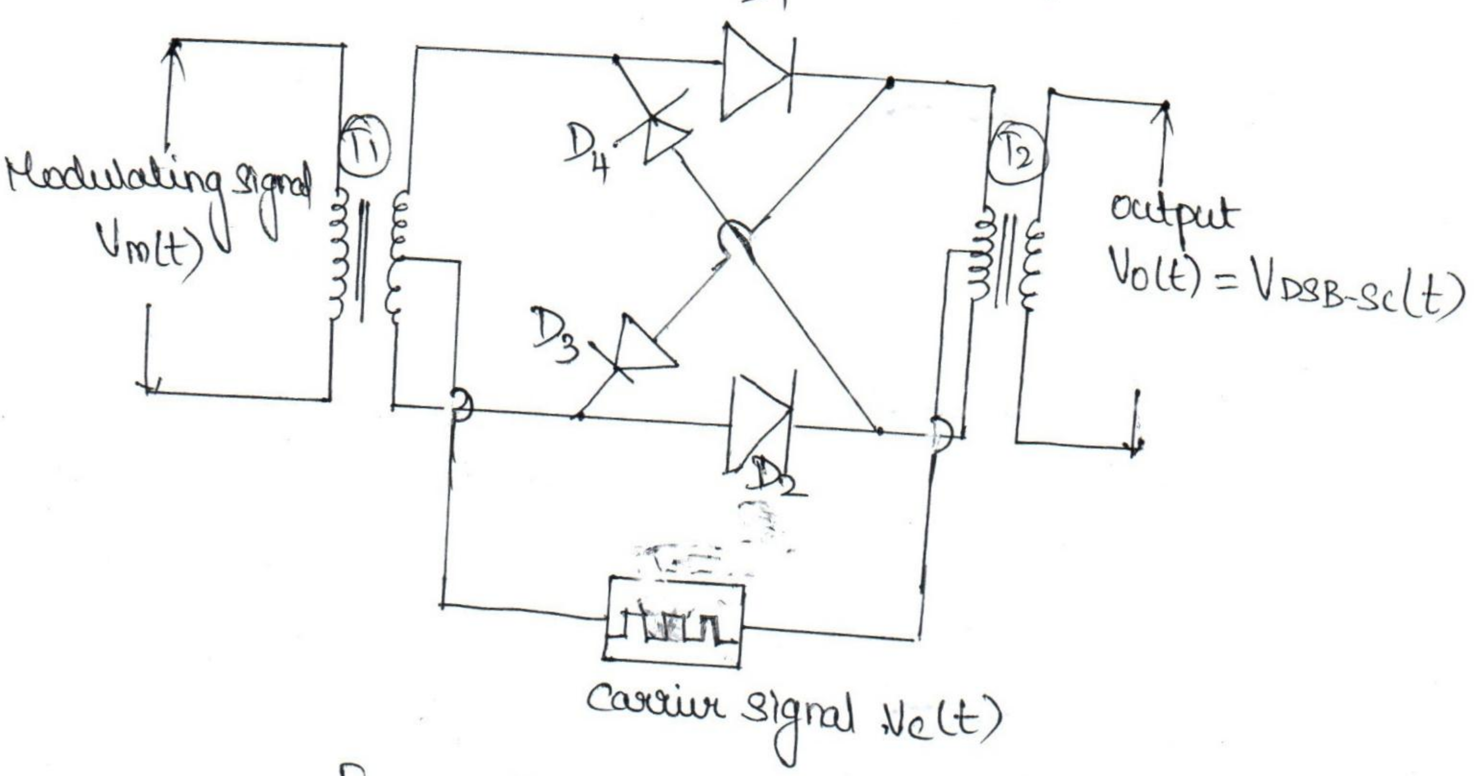


This diagram should come before Analysis

Fig:3 waveforms of DSB-Sc Signal.

2.2.2 (2) RING MODULATOR (or) Balanced Modulator using diode

- Ring Modulator suppresses both unwanted message and carrier signal at the output. So, BPF is not used in Ring Modulator circuit.
- The four diodes are controlled by a carrier wave $V_c(t)$ at a frequency 'ω_c'.
- It is also called as Lattice type Balanced Modulator



Carrier signal $V_c(t)$

Fig: 4 Ring Modulator

operation:

- Consider a carrier signal as a switching signal to alternate the polarity of the modulating signal at carrier frequency 'ω_c'.
- There are two modes of operation in Ring Modulator.

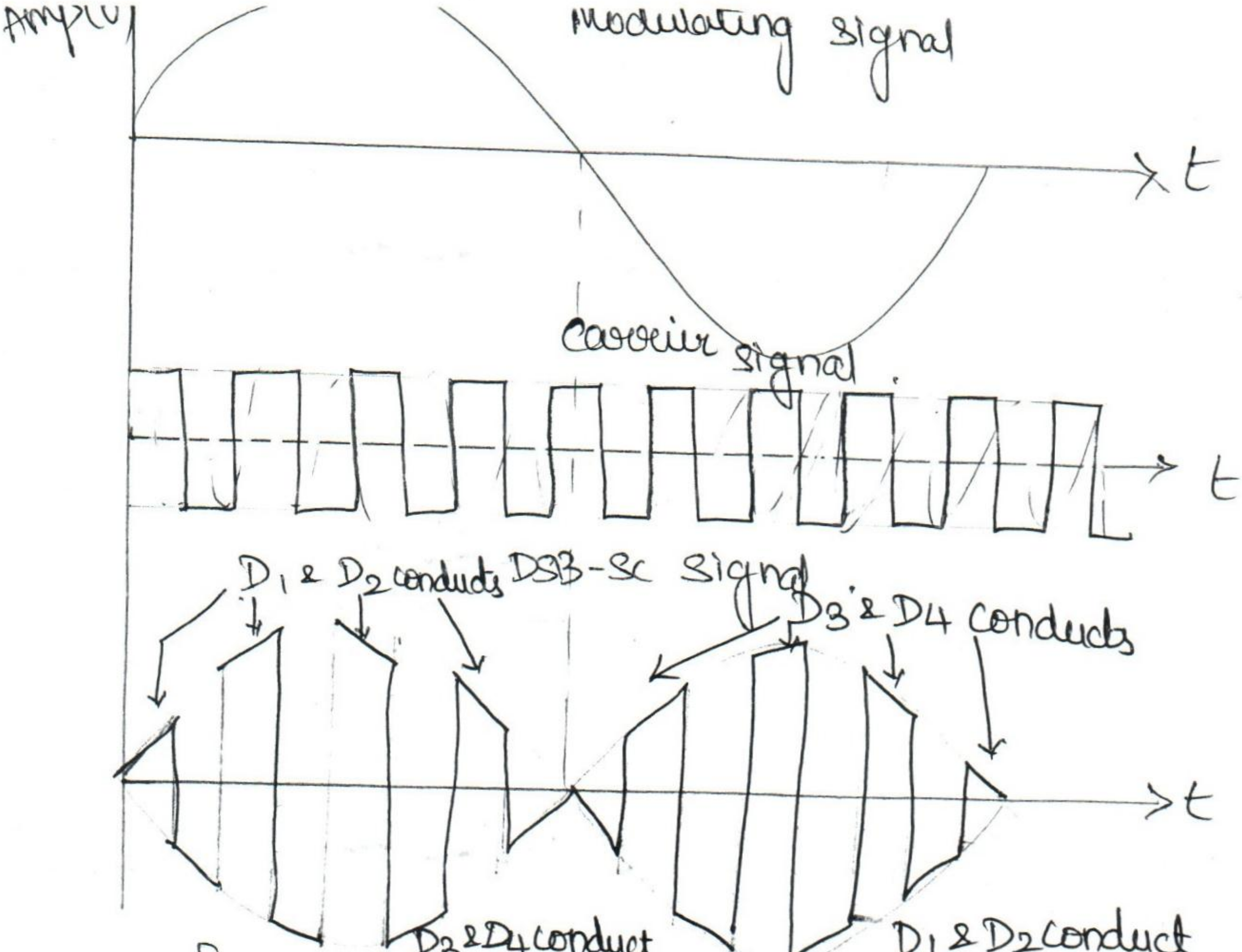


fig: 5 Waveform of DSB-SC signal.

Mode: 1 [when there is no Modulating Signal]

case(i) • On positive half cycle of the carrier, diode D_1 and D_2 ~~are~~ in forward bias (conduct) and D_3 and D_4 are in Reverse bias (open circuit). The current divides equally in the upper and lower portion of 1° of T_2 and produce magnetic field.

• The magnetic field produces at upper and lower part is equal and opposite, cancel each other no output will produced at the 2° of transformer T_2.

$$\boxed{V_0(t) = 0}$$

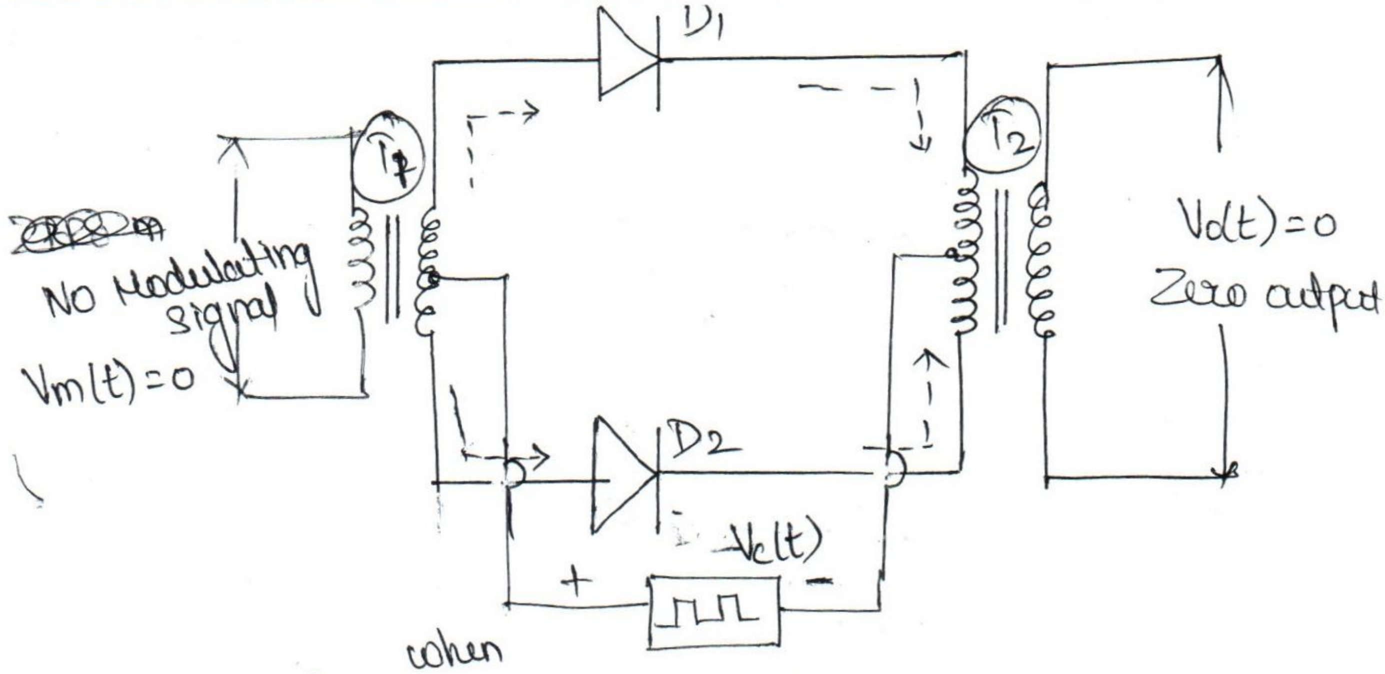


Fig: 6 when Diode $D_1 = D_2 =$ forward bias

Case (ii)

- On negative half cycle of the carrier diode D_3 and D_4 in forward bias (short circuit) will conducts and D_1 and D_2 are in Reverse bias (open circuit). The current divides and produce magnetic field at the upper and lower part of 1^0 of T_2 which cancells and no output at the 2^0 of T_2.

$$\boxed{V_o(t)=0}$$

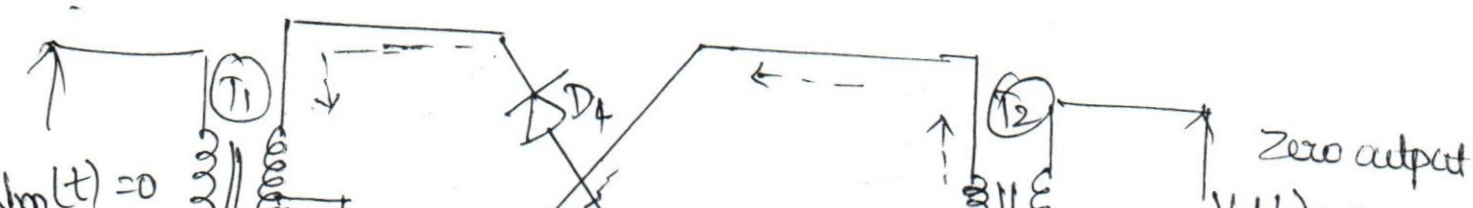


Fig: 7 when Diode $D_3 = D_4 =$ forward bias.

Mode : 2 [when Modulating signal and carrier signal present]

Case (i)

- On positive half cycle of the carrier, Diode D_1 and D_2 are in forward bias (short circuit) and D_3 and D_4 are in Reverse bias (open circuit).
- carrier signal voltage is positive, so ~~and connection made~~ it connect the 2° of T_1 to 1° of T_2 ~~carrier signal voltage is positive~~
- Thus message signal at 2° of T_2 is

$$\boxed{V_o(t) = V_m(t)} \quad \because V_c(t) >> 0$$

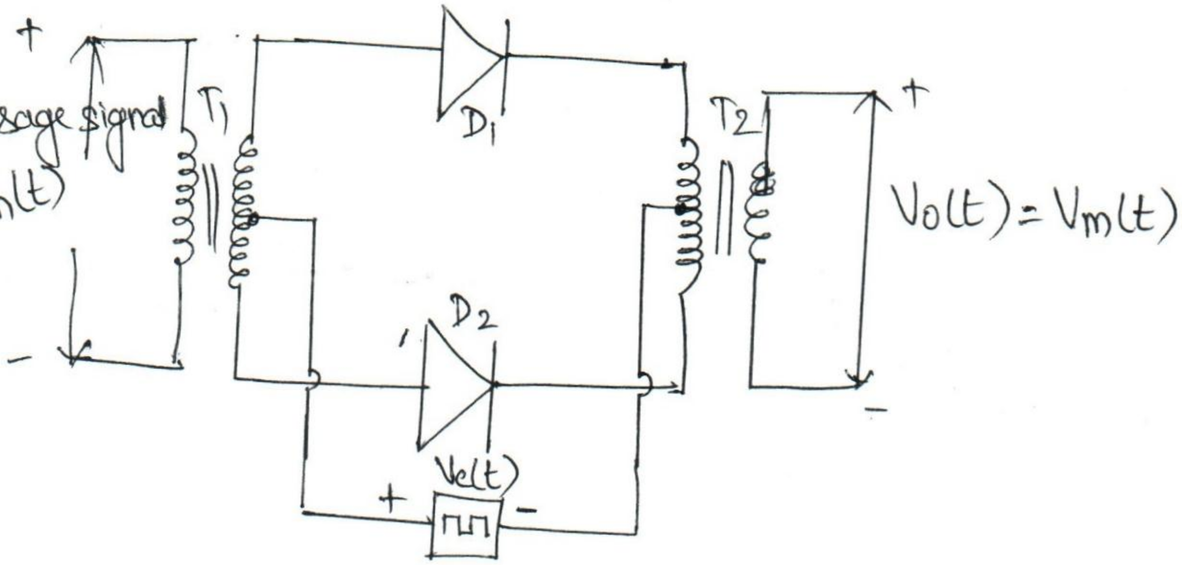


fig: 8 ~~[illegible]~~ +ve half cycle of modulating signal with +ve carrier

Case (ii)

- On negative half cycle of the carrier signal, Diode D_3 and D_4 are in F.B and D_1 and D_2 are in R.B. carrier signal voltage is negative, so it connect the 2° of T_1 to 1° of T_2,
- Thus message signal at 2° of T_2 is

$$\boxed{V_o(t) = -V_m(t)} \quad \because V_c(t) << 0$$

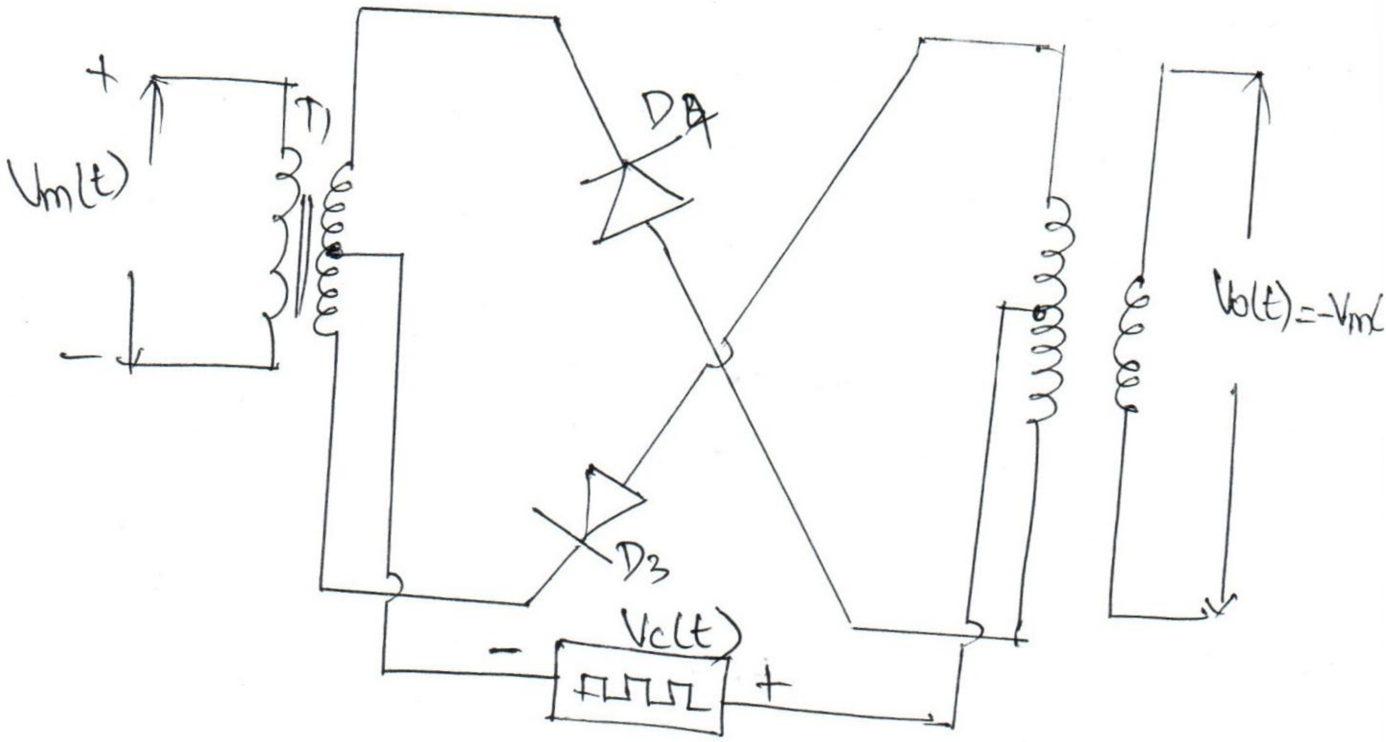


Fig 9 :- -ve half cycle of the ~~___~~ modulating Sig ~~___ carrier ___~~ with -ve carrier.

EXPRESSION:

$V_c(t) = V_m \sin w_m t$

$V_m(t) = V_m \sin w_c t$

The product of two signals

$V_o(t) = V_m V_c \sin w_c t \sin w_m t$

$$\boxed{V_o(t) = \frac{V_m V_c}{2}\left[\underbrace{\cos(\omega_c - \omega_m)t}_{LSB} - \underbrace{\cos(\omega_c + \omega_m)t}_{USB}\right]}$$

Hence DSB-Sc wave obtained.

Advantages:

- Stable output
- External power is not required to activate the diode.
- Longer Life.

2.3 Demodulation of DSB-SC (or) Detection of DSB-SC

Coherent (or) Linear (or) Synchronous detector:

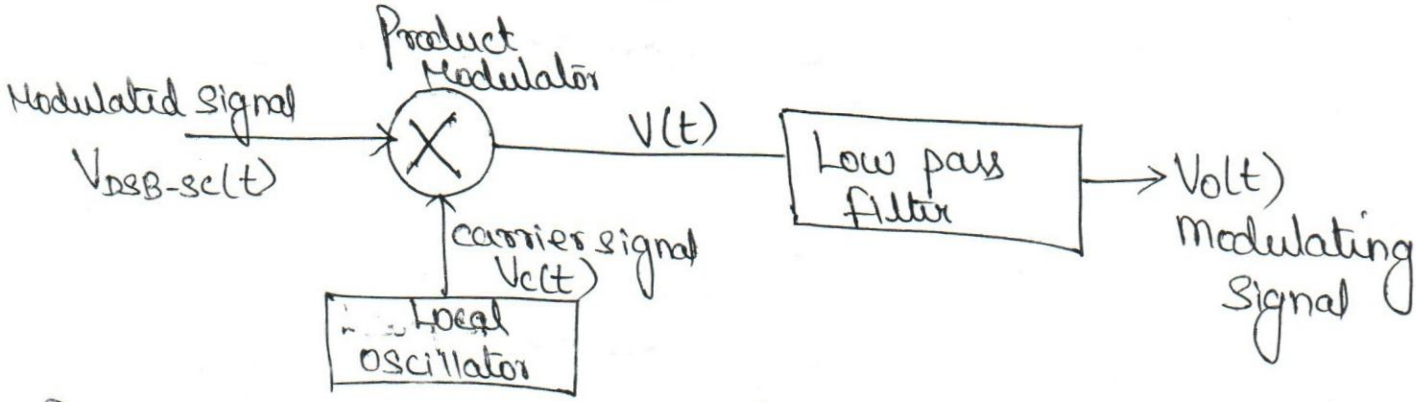


Fig: 10 Demodulation of DSB-SC

Principle:

Signal generated from the Local oscillator is same in frequency and phase as carrier signal for retrieving the message signal from the modulated signal.

Here local oscillator signal is exactly synchronised with carrier in both phase and frequency hence it is called "Synchronous detector"

- By product Modulator

The Modulated signal and carrier signal from the local oscillator are multiplied & procude V(t) output as,

$V_{DSB-SC}(t) = V_m V_c \sin\omega_c t \sin\omega_m t$ → Modulated Signal

$V_c(t) = V_c' \sin\omega_c t$ → Signal from Local oscillator

$V(t) = V_m V_c V_c' \sin^2\omega_c t \sin\omega_m t$

$$\left[\because \sin^2\theta = \frac{1-\cos 2\theta}{2}\right]$$

$$V(t) = V_m V_c V_c' \left[\frac{1-\cos 2\omega_c t}{2}\right] \sin\omega_m t$$

$$\boxed{V(t) = \frac{V_m V_c V_c'}{2}\left[\sin\omega_m t - \sin\omega_m t \cos 2\omega_c t\right]}$$

<u>By Low pass Filter:</u>

After $V(t)$ signal passes through LPF, all high frequencies like carrier term removed.

$$\boxed{\therefore V_o(t) = \frac{V_m V_c V_c'}{2}\sin\omega_m t}$$

The above equation has only $\sin\omega_m t$ term. Thus modulating signal is obtained from coherent detector.

3 SINGLE SIDE BAND - SUPPRESSED CARRIER (SSB-SC)

3.1 INTRODUCTION

- In DSB-SC System both the sidebands are carrying the same information, and the Bandwidth is 2fm.

- One side band is sufficient for transmission and Reception of original modulating signal. Therefore one side band is suppressed in DSB-SC along with carrier. This types of System having only one sideband and suppressed carrier is called as Single-Side band Suppressed carrier.

- In SSB-SC the power and Bandwidth can be saved by using single side band.

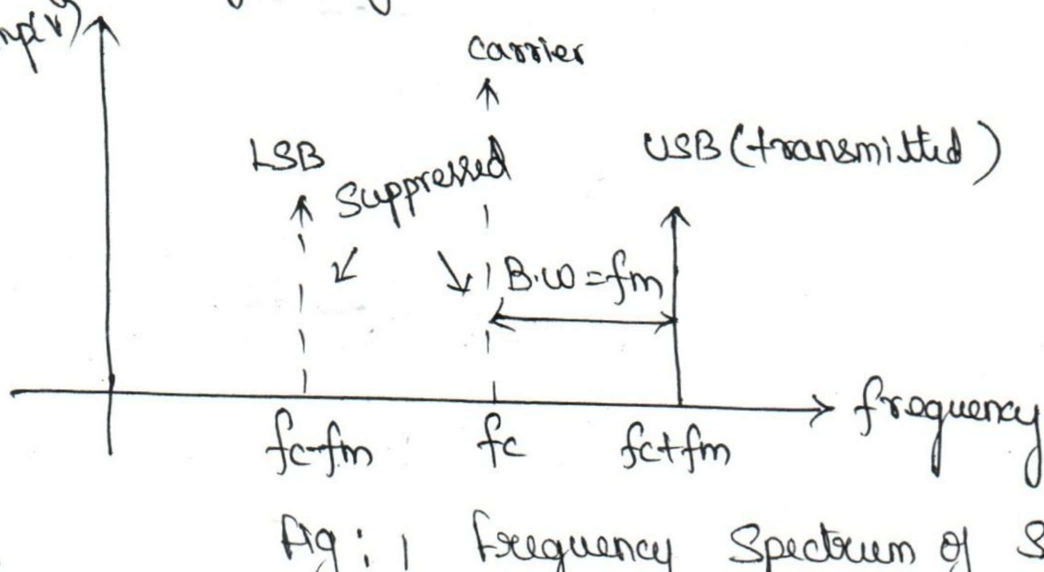


Fig: 1 Frequency Spectrum of SSB-Sc

Bandwidth of SSB-SC is half of the bandwidth of DSB-SC and AM wave.

$$\boxed{B \cdot W = f_m}$$

Here Bandwidth of SSB-SC is equal to the frequency of modulating Signal.

3.1.1 phasor representation of SSB-SC:

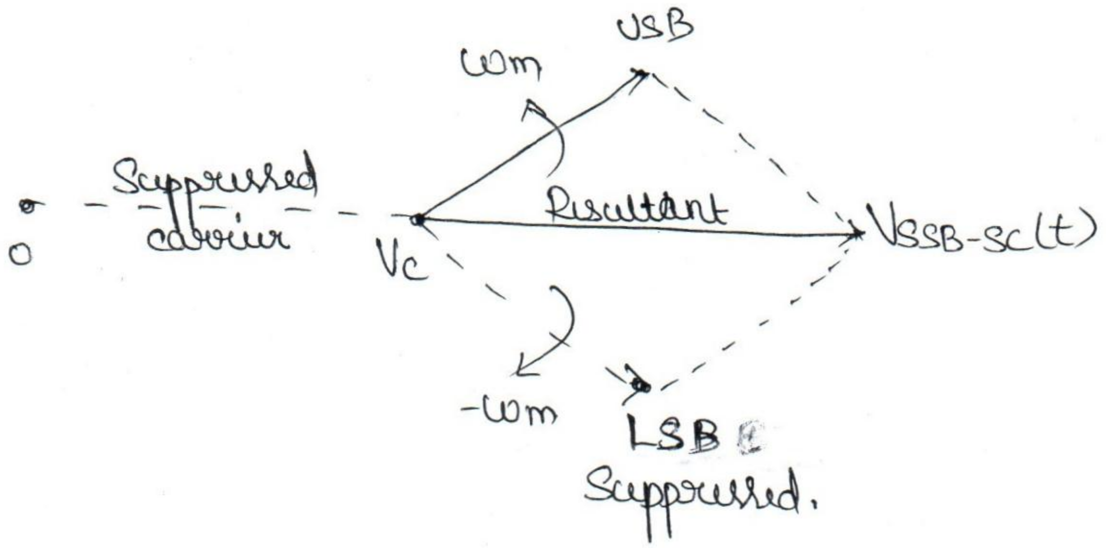


Fig: 2 phasor diagram of SSB-SC

Note:

Side band Suppression in SSB-SC can be either upper Side band (USB) or Lower Side band (LSB).

3.1.2 power Calculation of SSB-SC:

(i) SSB-SC power Saving compared with DSB-FC

W.K.T total power in DSB-FC is,

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

Total power in SSB-SC is

$$P_t'' = P_{USB} \text{ (or) } P_{LSB} = \frac{m_a^2 V_c^2}{8R}$$

$$\boxed{P_t'' = \frac{m_a^2 P_c}{4}} \rightarrow (2) \qquad \because P_c = \frac{V_c^2}{2R}$$

power Saving in SSB-SC:

$$\text{power Saving} = \frac{P_t - P_t''}{P_t}$$

$$= \frac{P_c\left(1+\frac{m_a^2}{2}\right) - \frac{m_a^2 P_c}{4}}{P_c\left(1+\frac{m_a^2}{2}\right)}$$

$$= \frac{P_c + \frac{P_c m_a^2}{2} - \frac{m_a^2 P_c}{4}}{P_c + \frac{P_c m_a^2}{2}}$$

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

$$= \frac{\frac{4+m_a^2}{4}}{\frac{2+m_a^2}{2}} = \frac{4+m_a^2}{2(2+m_a^2)}$$

$$\boxed{\%\ \text{power Saving} = \frac{4+m_a^2}{2(2+m_a^2)} \times 100} \rightarrow (3)$$

when $m_a = 1$ for 100% Modulation

$$\text{power Saving} = \frac{5}{6} \times 100$$

$$\boxed{\text{Power Saving} = 83.33\%} \rightarrow (4)$$

- compared with DSB-FC 83.33% of power is Saved in SSB-SC.

(ii) SSB-SC power saving compared with DSB-SC

w.k.T Total power in DSB-SC

$$\boxed{P_t' = \frac{m_a^2 P_c}{2}} \longrightarrow (5)$$

Total power in SSB-SC

$$\boxed{P_t'' = \frac{m_a^2 P_c}{4}} \longrightarrow (6)$$

$$\text{power saving} = \frac{P_t' - P_t''}{P_t'}$$

$$= \frac{\frac{m_a^2 P_c}{2} - \frac{m_a^2 P_c}{4}}{\frac{m_a^2 P_c}{2}}$$

$$= \frac{1}{2} \times 100\%$$ (when $m_a = 1$)

$$\boxed{\text{power saving} = 50\%} \longrightarrow (7)$$

- Compared with DSB-SC, 50% of power is saved in SSB-SC.

Advantages:

1. Suppressed Side band power is saved.
2) Since only one Sideband is transmitted, the Bandwidth of the System can be improved ($B.W = f_m$)
3) Better Signal to Noise Ratio ie) 9 to 12dB.
4) Fading can be reduced.
5) Less Expensive. 6) Interference with other channels are avoided.

Dis-advantages:

1. Transmission and Reception becomes more Complex.
2. Carrier is Reinserted at the Receiver.
3. complex to design highly Selective filter

Applications:

1. police wireless communication
2. Telegraph System.
3. Radio telephone communication
4. VHF and UHF communication Systems.

3.2 GENERATION (or) MODULATION OF SSB-SC

SSB-SC wave can be generated in two ways:

1. Frequency discrimination (or) Filter method (or) Selective filtering Method.
2. phase discrimination
   - (i) phase Shift Method
   - (ii) Modified phase Shift (or) Weaver's Method.

3.2.1 ① FREQUENCY DISCRIMINATION (or) FILTER METHOD:

(or) SELECTIVE FILTERING METHOD:

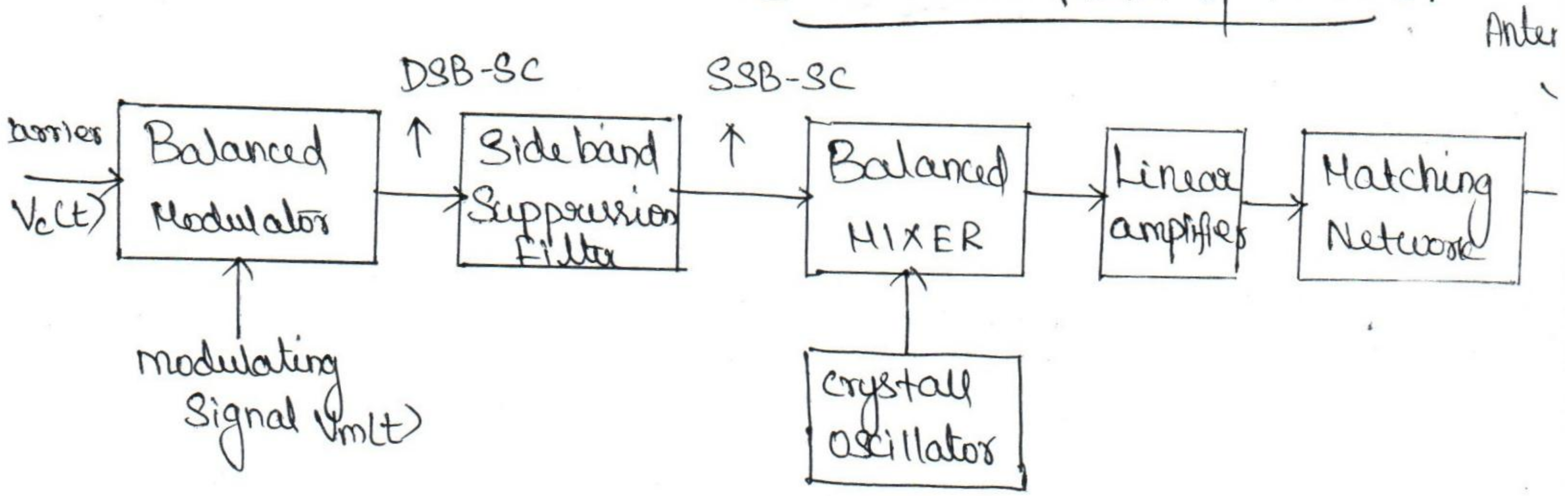


Fig: 3 Block diagram for Generating SSB-SC using filter method.

- This method involves generation of DSB-SC, then extracting only one sideband using appropriate filter to obtain SSB-SC.

STEP: 1

- Modulating signal Vm(t) and carrier signal Vc(t) from low frequency crystal oscillator which provides both USB and LSB given to the Balanced Modulator.
- ~~Here the Balanced Modulator produce DSB-SC signal~~
- Modulation takes place in the Balanced Modulator at a frequency of 100KHZ and produce DSB-SC signal.

STEP: 2

- DSB-SC signal is then given to Sideband

Suppression filter to Suppress one Sidebands and other desired Sideband is Selected by a appropriate filter.

- Generally the Filter Selects high frequency component to get Single sideband (approximately 10MHZ)

Limitation of Sideband Suppression Filter:

- Filter will allow a particular sideband and reject other unwanted Sideband.
- practically it is not possible to design a Suitable filter to extract one Sideband & remove other one.

Design of Filter:

To Suppress a particular side band Filter is designed by

- Stopband and passband
- Desired Sideband Should lies is passband
- Unwanted Suppressing Sideband lies in Stopband.

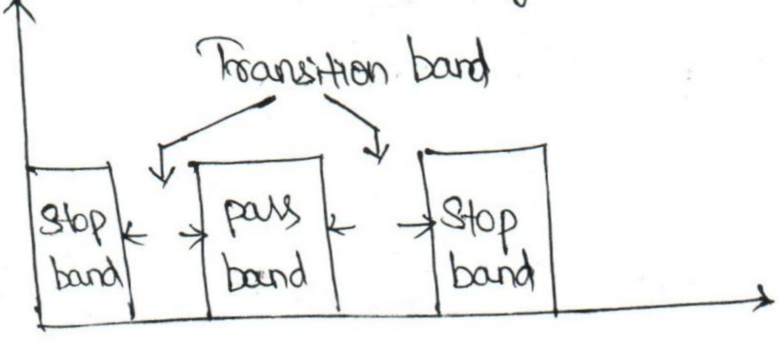


Fig:4 Selective filter

Two Requirements for Filter design:

(i) passband of the filter should be same as that of desired sideband which is going to Extract.

(ii) The seperation region between stopband and passband is transition band. This Transition band should not exceed twice the maximum frequency component present in the bassband.

- Filtering is not possible if transmission of message signal is very high (10MHZ) or low frequency (50HZ).
- To overcome this problem Selective filtering is replaced by Mechanical and crystal filter.
  - → crystal filters are cheaper and more preferable at the frequencies greater than 1MHZ.
  - → Mechanical filters are used only for the following reasons.
    1) Very small in size
    2) Good filter and attenuation characteristics
    3) Adequate upper frequency.
- At the end of step-2 operation one side band is suppressed and hence SSB-SC is obtained.
- If SSB-SC frequency obtained is lesser than Maximum transmitting frequency, then "Frequency-up Conversion" is required.

Step 3:

- ~~Balanced Mixer is used as a frequency upconverter~~
- ~~The Frequency of SSB-Sc is increased by mixing SSB-Sc signal with carrier Signal which is generated from crystal oscillator.~~

⊙ Balanced Mixer is used as a frequency upconverter to increase the frequency of SSB-SC.

⊙ Balanced Mixer adds the low frequency SSB-SC and crystal oscillator carrier frequency. Thus the frequency of SSB-Signal is increased to a desired transmitting frequency.

⊙ ~~MIXER is~~ Followed by a MIXER, Linear power Amplifier is used.

Step 4:

⊙ Linear power amplifier is used to raise the amplitude of SSB Signal without distortion.

⊙ Linear amplifier

class-C → High Efficiency but distorts the Signal.

class-A → Less Efficiency

class-B → More efficiency and it is used as Linear power amplifier

Matching network: It matches the output signal to the antenna and provide proper Impedance matching.

Drawbacks of Filtering Method:

- It is not suitable for high and low frequency.
- Filtering process is very complicated.

3.2.2 (2) phase discrimination METHOD:

This type of Modulation is divided into two types (i) phase shift Method (or) Hartley's method
(ii) Modified phase shift (or) Weaver's method.

(i) phase shift Method (or) Hartley's method.

- The drawbacks of filtering Method can be overcome by using phase shift method of generating SSB-SC.

PRINCIPLE:

- The undesired sideband is suppressed (removed) by generating that same two undesired sideband which are 180° out of phase with each other.
- Two side bands are added and cancel each other, so that one side band is suppressed and other side band transmitted.

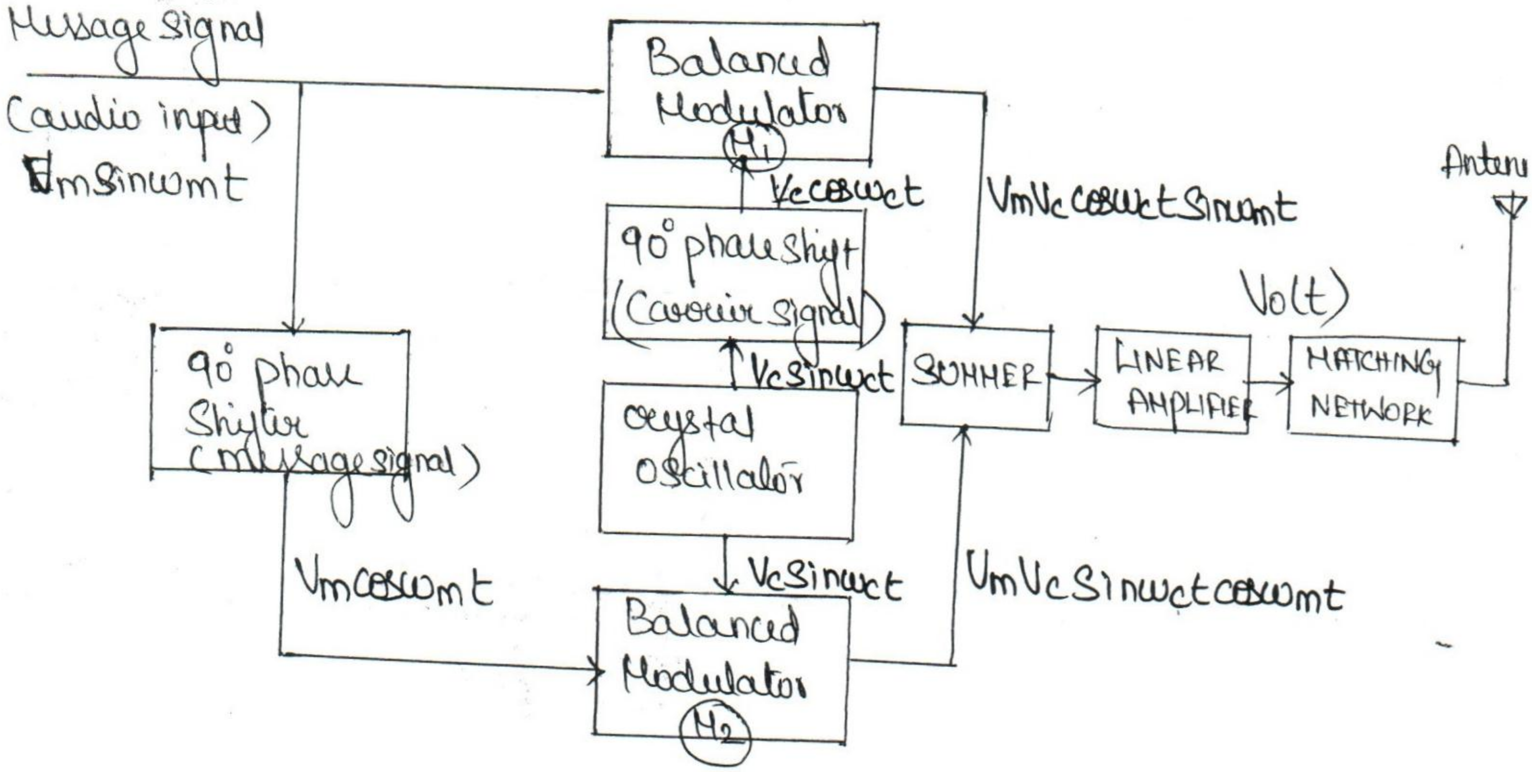


Fig : 5 phase Shift Method to generate SSB Signal.

Balanced Modulator

- Two Balanced Modulators and two phase Shifters are used in the above block diagram.
- Modulator M_1 receives message signal and 90° phase Shift of carrier signal and Modulator M_2 receives 90° phase Shift of message signal and direct carrier Signal. Here two Modulators M_1 and M_2 are constructed so that it should be balanced each other.

Balanced Modulator (M_1):

- upper Balanced Modulator (M_1) generates USB and LSB both are shifted with +90° phase shift. ~~Lower Balanced Modulator (M_2) generates USB with +90° phase Shift and lower side band with -90° phase Shift~~

message → $V_m(t) = V_m \sin\omega_m t$

carrier → $V_c(t) = V_c \sin(\omega_c t + 90^\circ)$

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

output of Balanced modulator M_1:

$$\boxed{V_{BM_1}(t) = V_m \sin\omega_m t \times V_c \sin\omega_c t} \rightarrow (8)$$

Balanced Modulator (M_2):

- Lower Balanced Modulator M_2 generates USB with $+90^\circ$ phase shift and LSB with -90° phase shift.

message → $V_m(t) = V_m \sin(\omega_m t + 90^\circ)$

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

$V_c(t) = V_c \sin\omega_c t$

output of Balanced Modulator M_2:

$$\boxed{V_{BM_2}(t) = V_m \cos\omega_m t \times V_c \sin\omega_c t} \rightarrow (9)$$

SUMMER ~~AND~~ AMPLIFIER NETWORK:

- The output of Balanced Modulators are added by a Summer and amplified by the Linear amplifier
- From both Modulators USB are with $+90^\circ$ phase shift, they are inphase and add each other to produce double amplitude signal. ~~But~~ whereas both Modulators LSB are with $+90^\circ$ and -90° ie)

180° out of phase and hence cancel each other.

(c) Finally output of amplifier network produce only one USB and carrier is already suppressed by Balanced Modulators.

$$V_o(t) = V_{BM_1}(t) + V_{BM_2}(t)$$

$$= \left[V_m V_c \cos\omega_c t \sin\omega_m t\right] + \left[V_m V_c \sin\omega_c t \cos\omega_m t\right]$$

$$= V_m V_c \left[\cos\omega_c t \sin\omega_m t + \sin\omega_c t \cos\omega_m t\right]$$

$$\boxed{V_o(t) = V_m V_c \left[\underbrace{\sin(\omega_c+\omega_m)t}_{\text{only USB}}\right]} \rightarrow (10)$$

Hence SSB-SC signal obtained.

Advantages:

- Ability to generate SSB at any range of frequency.
- Heavy filtering is not required.

Dis-advantages:

- Distortion will occur due to 90° phase shifter
- Modulator sensitivity should be equal to baseband signal.

(ii) Modified phase Shift Method (or) Weaver's Method:

To overcome the drawbacks in phase Shift method, the modified phase shift method is introduced by D.K Weavers and was developed during 1950's.

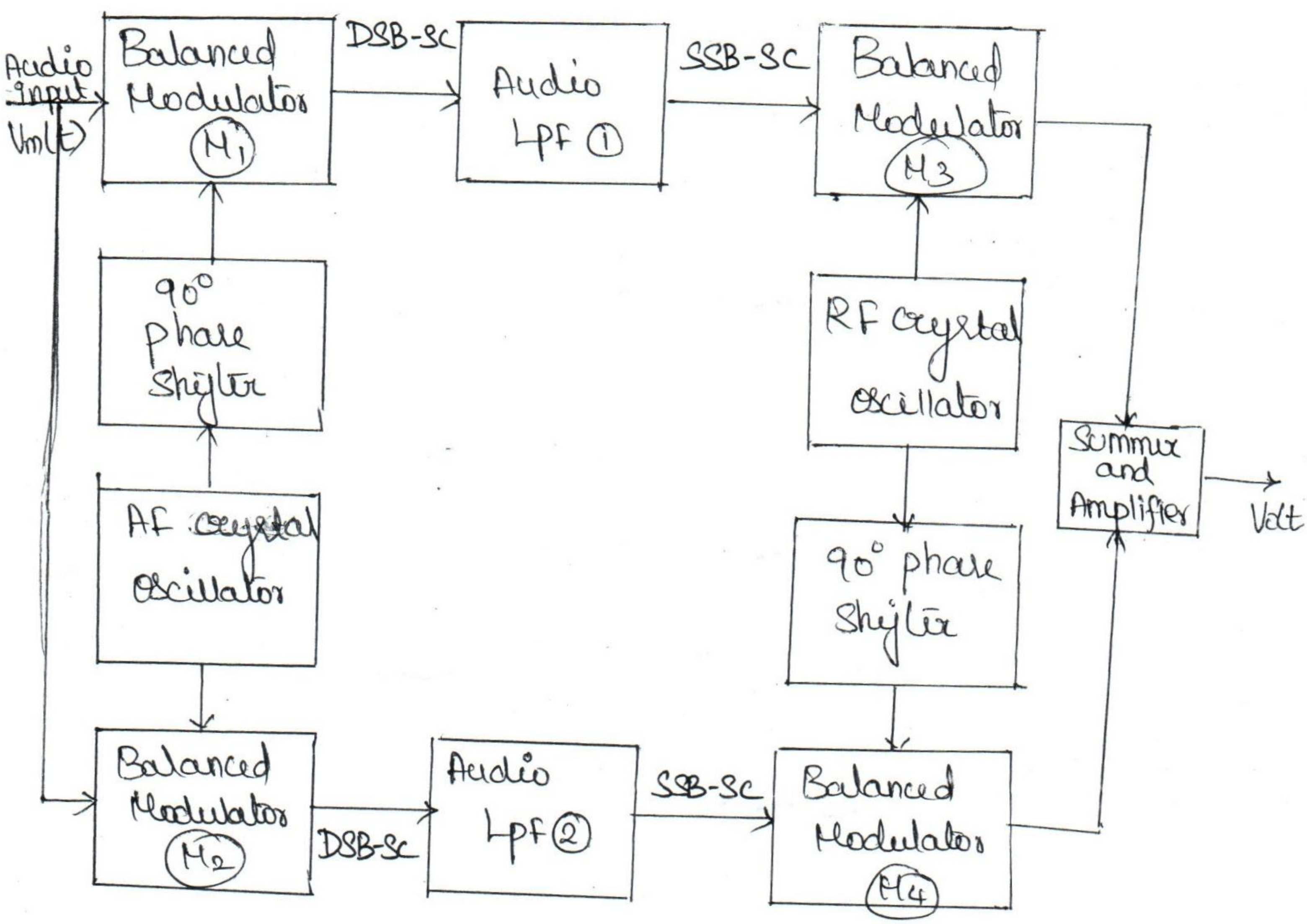


fig: 6 Weaver's method to generate SSB-Sc

~~ASSUMPTION:~~

- ~~Let us assume magnitude of carrier and message signal as Vm~~

- The Audio signal (or) modulating signal,

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

- Audio Frequency (AF) carrier signal,

$$V_o(t) = 2V_o \sin\omega_o t$$
$$V_o(t) = 2\sin\omega_o t$$

- Radio frequency (RF) carrier signal

$$V_c(t) = 2V_c \sin\omega_c t$$
$$V_c(t) = 2\sin\omega_c t$$

where
ω_m = Low frequ
ω_o = medium frequen
ω_c = High frequ

Here assume that the magnitude of the carrier signal is twice than the magnitude of modulating signal.

$\boxed{\text{Assume } V_m = V_o = V_c = 1}$

OPERATION & ANALYSIS:

Balanced Modulator (H1):

- Input to the Balanced Modulator (H1) are modulating signal (audio input) and AF carrier with 90° phase shift.

~~Output of M1 is DSB-SC signal.~~

message $\rightarrow$ $V_m(t) = \sin\omega_m t$

carrier $\rightarrow$ $V_c(t) = 2(\sin\omega_o t + 90°)$

output $\rightarrow$ $V_{BH_1}(t) = 2\sin(\omega_o t + 90°)\sin\omega_m t$

output $V_{B4}(t) = 2\sin(\omega_c t + 90^\circ)\cos(\omega_0 t - \omega_m t)$

$$\boxed{V_{BH4}(t) = \sin(\omega_c t + \omega_0 t - \omega_m t + 90^\circ) + \sin(\omega_c t - \omega_0 t + \omega_m t + 90^\circ)} \rightarrow (16)$$

Summer & Amplifier Network:

output of H_3 and H_4 are added and amplified

$V_0(t) = V_{BH3}(t) + V_{BH4}(t)$

$$V_0(t) = \sin(\omega_c t + \omega_0 t - \omega_m t + 90^\circ) + \sin(\omega_c t - \omega_0 t + \omega_m t + 90^\circ) + \sin(\omega_c t + \omega_0 t - \omega_m t + 90^\circ) + \sin(\omega_c t - \omega_0 t + \omega_m t + 90^\circ)$$

where 2nd term and 4th term are in out of phase. So cancell each other.

$$\boxed{\begin{aligned} V_0(t) &= 2\sin(\omega_c t + \omega_0 t - \omega_m t + 90^\circ) \\ &\text{(or)} \\ V_0(t) &= 2\cos(\omega_c t + \omega_0 t - \omega_m t) \end{aligned}} \rightarrow (17)$$

- Above equation $V_0(t)$ is only LSB, it is SSB-SC.
- Hence Single Sideband Suppressed carrier is obtained by Modified phase Shift method without phase Shifting the audio message signal.

ASSUMPTION:

- ~~Let us assume magnitude of carrier and message signal as, Vm~~

- The Audio signal (or) modulating signal,

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

- Audio Frequency (AF) carrier signal,

$$V_o(t) = 2V_o \sin\omega_o t$$
$$V_o(t) = 2\sin\omega_o t$$

- Radio frequency (RF) carrier signal

$$V_c(t) = 2V_c \sin\omega_c t$$
$$V_c(t) = 2\sin\omega_c t$$

where
ω_m = Low frequency
ω_o = medium frequency
ω_c = High frequency

Here assume that the magnitude of the carrier signal is twice than the magnitude of modulating signal.

$\boxed{\text{Assume } V_m = V_o = V_c = 1}$

OPERATION & ANALYSIS:

Balanced Modulator (H_1):

- Input to the Balanced Modulator (H_1) are modulating signal (audio input) and AF carrier with 90° phase shift.

~~Output of M.P is DSB-SC signal.~~

message → $V_m(t) = \sin\omega_m t$

carrier → $V_c(t) = 2(\sin\omega_o t + 90°)$

output → $V_{BH_1}(t) = 2\sin(\omega_o t + 90°)\sin\omega_m t$

$$V_{BM_1}(t) = \cancel{2}\left[\frac{\cos(\omega_0 t + 90^\circ - \omega_m t) - \cos(\omega_0 t + 90^\circ + \omega_m t)}{\cancel{2}}\right]$$

$$\boxed{V_{BM_1}(t) = \underbrace{\cos(\omega_0 t - \omega_m t + 90^\circ)}_{LSB} - \underbrace{\cos(\omega_0 t + \omega_m t + 90^\circ)}_{USB}} \rightarrow (11)$$

- Output of the BM$_1$ is DSB-SC. Since the above equation contains both LSB and USB without carrier.

Audio LPF (1):

- After passing through Lowpass Filter (1), DSB-SC is converted to SSB-SC. Here LPF cancell all the higher frequencies

$$\boxed{V_{BM_1}(t) = \underbrace{\cos(\omega_0 t - \omega_m t + 90^\circ)}_{LSB}} \rightarrow (12)$$

- Output of LPF (1) is SSB-SC.

Balanced Modulator (M2):

- Input of the M$_2$ are direct ~~audio~~ message signal and audio frequency carrier signal.

message $\rightarrow V_m(t) = \sin\omega_m t$

carrier $\rightarrow V_c(t) = 2\sin\omega_0 t$

output $V_{BM_2}(t) = 2\sin\omega_0 t \sin\omega_m t$

3.3 Demodulation of SSB-SC: (Synchronous detector):

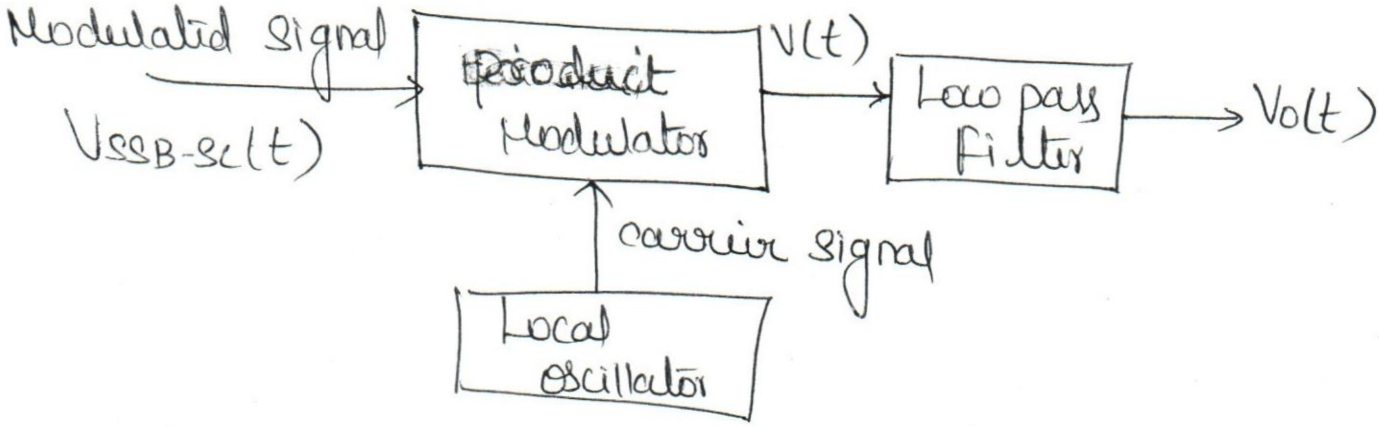


Fig :7 Synchronous detector.

- Product Modulator takes the input of SSB-SC modulated Signal and carrier signal from crystal oscillator.
- Here oscillator carrier Signal is inphase with the Modulated carrier Signal, so this type of detector is called as Synchronous or coherent detector.
- output of the Product Modulator is passed through LPF and so it neglect all higher frequency term. Hence low frequency modulating Signal is obtained at the output of LPF.

4 VESTIGIAL SIDEBAND (VSB)

4.1 INTRODUCTION:

- The main purpose of using SSB-SC is Reduced bandwidth and power Saving as compared with ~~the~~ DSB-SC.
- SSB-SC Signal generation is very difficult in nature due to the Selection of desired Sideband and Suppression of unwanted Sideband using Selective Filters.
- This problem of SSB-SC filtering is overcome by Vestigial Sideband Modulation (VSB).
- Modulating signals of example Video signals, TV signals & high speed data signal ~~of huge~~ Bandwidth having very low frequency and high frequency components, which are very close to the carrier frequency and also Sidebands.
- Low frequency components of Video signals contain most important information of pictures in Lower Sidebands if complete Suppression of LSB results in loss of information and hence produce distortion.
- This problem can be Solved by Vestigial side band Concept.

DEFINITION:

In Vestigial Side band (VSB), the desired Sideband is complitely transmitted and the undesired Sideband (Some portion or trace or Vestige) is transmitted. This Vestige of undesired Side band will compensates the desired Sideband loss of information.

- VSB system is compromise between DSB-SC and SSB-SC.
- VSB is easy to generate, but at the same time their Bandwidth is slightly greater than SSB-SC and lesser than DSB-SC.

$$\boxed{(B.W)_{DSB} > (B.W)_{VSB} > (B.W)_{SSB}}$$

4.1.1 Frequency Spectrum of VSB:

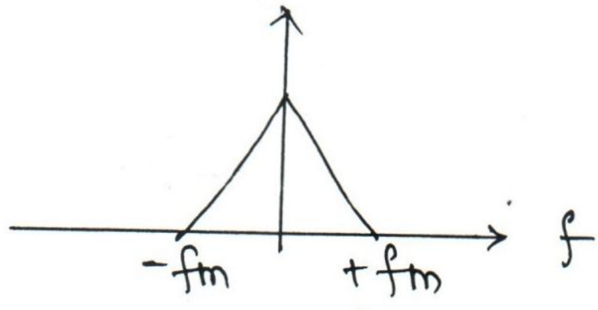
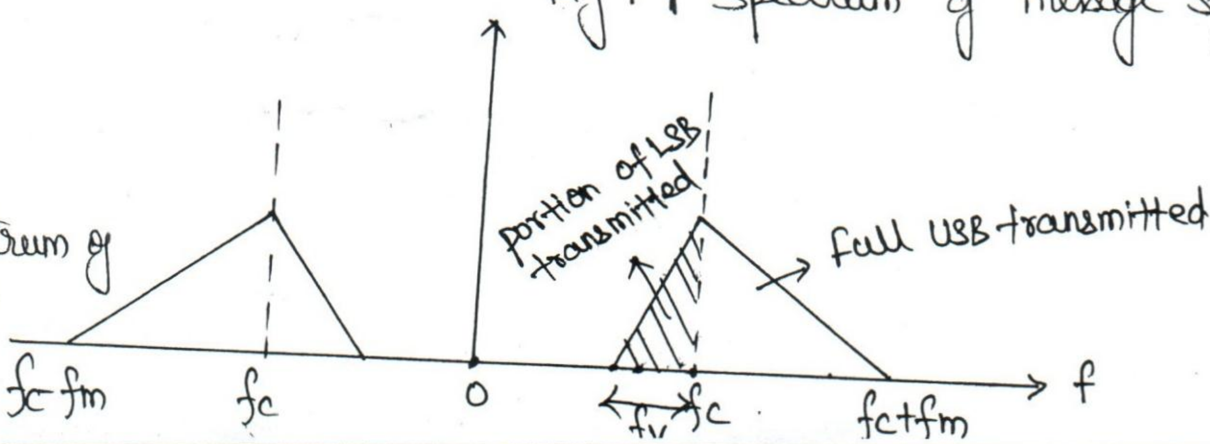


Fig: 1 Spectrum of message signal

Fig: 2 Spectrum of VSB



4.1.2 B Magnitude Response of VSB filter:

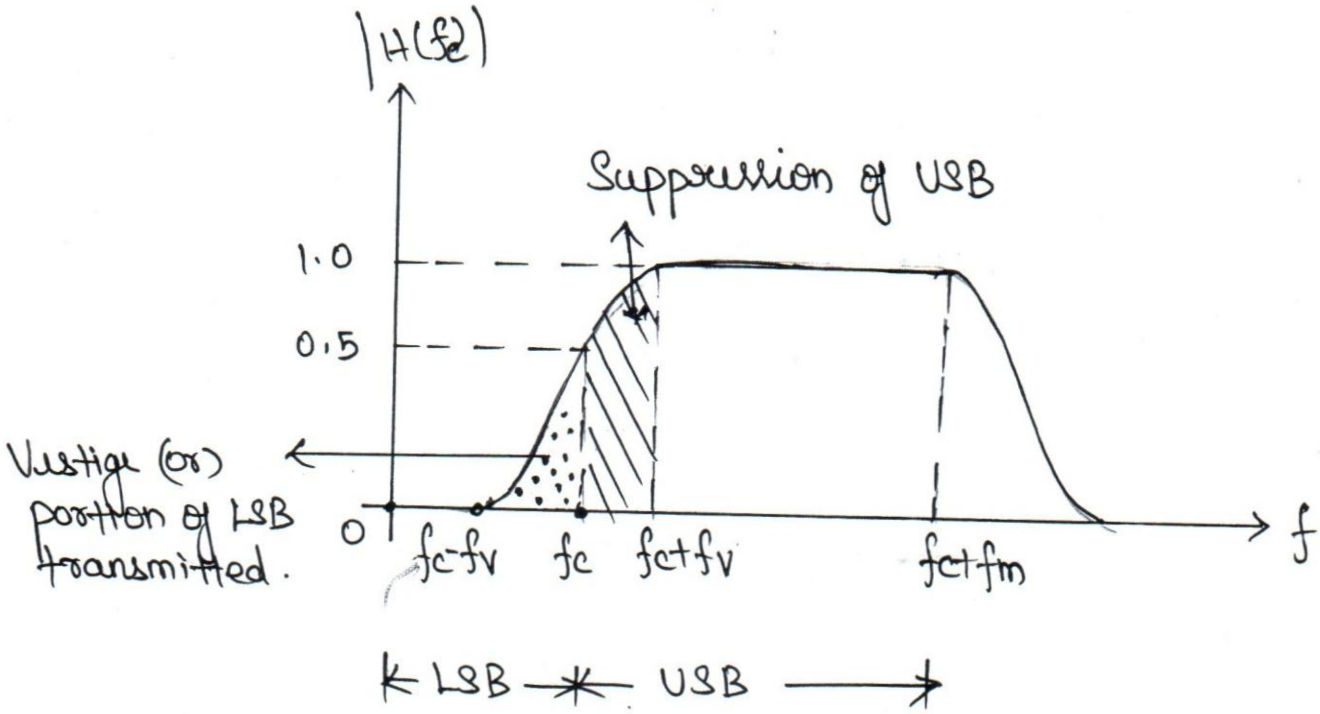


Fig: 3 Magnitude Response of VSB Filter

Bandwidth = [B.w of USB + B.w of LSB]

* Lower side band is from fc to fc-fv and this portion of LSB is transmitted as a vestige.
* Upper side band is from fc to fc+fm, in this suppressed portion of USB is from fc to fc+fv.

Bandwidth:

$$B.w \text{ of } VSB = [f_c-(f_c-f_v)]+[f_c+f_m-f_c]$$

$$\boxed{B.w \text{ of } VSB = f_v+f_m}$$

Bandwidth of VSB = Bandwidth of message signal + Bandwidth of Vestige.

where f_m = frequency of message
f_v = frequency of ~~LSB~~ vestigial side band.
f_c = frequency of carrier

Design (or) Magnitude Response of VSB Filter:

- $|H(f_c)| = \frac{1}{2}$ and the frequency response $f_c - f_v \leq |H(f)| \leq f_c + f_v$ exhibits odd symmetry.
- Sum of any two components in this range is $f_c - f_v \leq f \leq f_c + f_c$ equal to unity.

  $$H(f-f_c) + H(f+f_c) = 1$$

- phase response is Linear.

Advantages of VSB

1) Less Bandwidth compared with DSB
2) Heavy filtering is not required.
3) Low frequencies, are transmitted without any loss.

Applications:

- Used in Television transmission, Since low frequencies represents picture details and they are unaffected due to VSB.

4.2 Generation and Detection of VSB:

4.2.1 Generation of VSB:

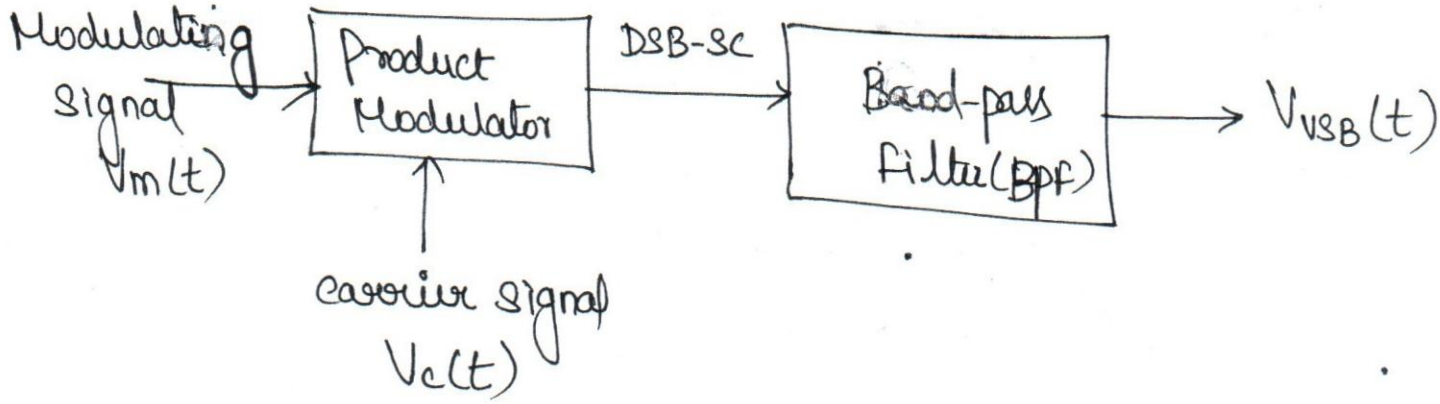


Fig: 4 Generation of VSB Signal.

- Modulating signal and carrier signal are applied as the input of product Modulator. The output of the product Modulator is DSB-SC signal and this signal is passed through Bandpass filter to get Vestigial Side band signal.

$$V_{DSB-SC}(t) = V_m(t) \times V_c(t)$$

$$V_{DSB-SC}(t) = V_m V_c \sin w_c t \sin w_m t$$

- The above equation represents DSB-SC modulated signal. This same signal can be represents in frequency domain by Fourier transform of Modulation Theorem

$$V_{DSB-SC}(f) = \frac{V_c}{2}\left\{ M(f-f_c) + M(f+f_c) \right\}$$

After passing through BPF, the VSB signal represents as

$$V_{VSB}(f) = \frac{V_c}{2}\left\{ M(f-f_c) + M(f+f_c) \right\} H(f) \longrightarrow (1)$$

4.2.2 Demodulation of VSB:

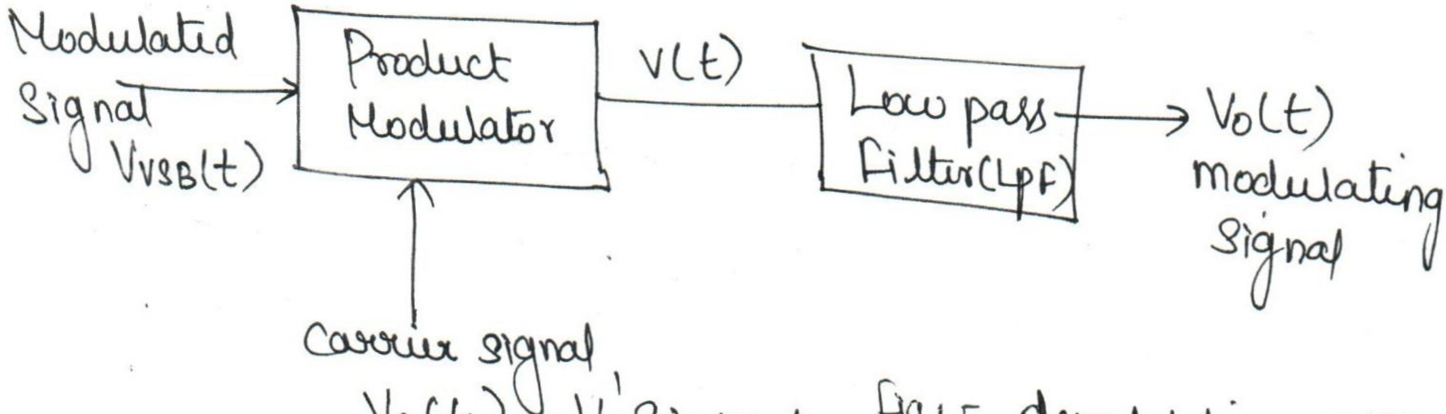


Fig: 5 demodulation of VSB

- The product Modulator multiplies the modulated VSB Signal and carrier Signal and produce the modulating signal after passed through LPF.

$$V(t) = V_{VSB}(t) \times V_c(t)$$

$$V(t) = V_{VSB}(t) \times V_c' \sin \omega_c t$$

Taking Fourier Transform on both side,

$$V(f) = \frac{V_c'}{2}\left\{ V_{VSB}(f-f_c) + V_{VSB}(f+f_c) \right\} \longrightarrow (2)$$

Sub equation (1) in (2)

$$V(f) = \frac{V_c V_c'}{4}\left\{ M(f-f_c-f_c) + M(f-\cancel{f_c}+\cancel{f_c}) \right\} H(f-f_c) +$$

$$\frac{V_c V_c'}{4}\left\{ M(f+\cancel{f_c}-\cancel{f_c}) + M(f+f_c+f_c) \right\} H(f+f_c)$$

$$V(f) = \frac{V_c V_c'}{4}\left\{ H(f-f_c) + H(f+f_c) \right\} M(f) +$$

$$\frac{V_c V_c'}{4}\left\{ M(f-2f_c)\,H(f-f_c) + M(f+2f_c)\,H(f+f_c) \right\}$$

In above equation,

1st term → frequency spectrum of modulating signal

2nd term → Spectrum of VSB with carrier frequency "$2f_c$"

- After LPF → 2nd term high frequency carrier cancel out.

$$\boxed{V_o(f) = \frac{V_c V_c'}{4}\left\{ H(f-f_c) + H(f+f_c) \right\} M(f)}$$

(5) COMPARISION OF VARIOUS AM Systems

Characteristics	AM (or) DSB-FC	DSB-SC	SSB-SC	VSB
Signal Nature	carrier and both USB & LSB	only USB and LSB	only one Side band	One sideba and vestige of other ban
Bandwidth	$2f_m$	$2f_m$	f_m	$f_m < BW < 2f$
power transmitted	$P_t = P_c\left(1+\frac{m_a^2}{2}\right)$	$P_t = \frac{P_c m_a^2}{2}$	$P_t = \frac{P_c m_a^2}{4}$	$P_{tSSB} < P_{tVSB} < P_t$
power saved	33.33 %	50 %	83.3 % ~~[illegible]~~	75 %
Efficiency	33.3 %	100 %	100 %	$33.3 < \eta < 100\%$
Modulation Techniques	~~Easy~~ Simple	~~Easy~~ Simple	complex	complex
Detection Techniques	Simple	Complex	More complex	Complex.
Distortion	High distortion	More distortion than SSB-SC	less distortion	less distortion
Applications	AM Broadcasting	Telephony Short distant communication	wireless Communication specially in audio signal transmision	Television Broadcasting

6 AM TRANSMITTER AND RECEIVER

6.1 AM TRANSMITTER:

- In order to increase the power level of the modulated signal at the transmitter side, the AM transmitters are classified depends on the requirement of power for a particular applications
- AM transmitters are divided into two types. They are,
  (i) Low Level AM Transmitter
  (ii) High level AM Transmitter

6.1.1 (i) Low Level AM Transmitter

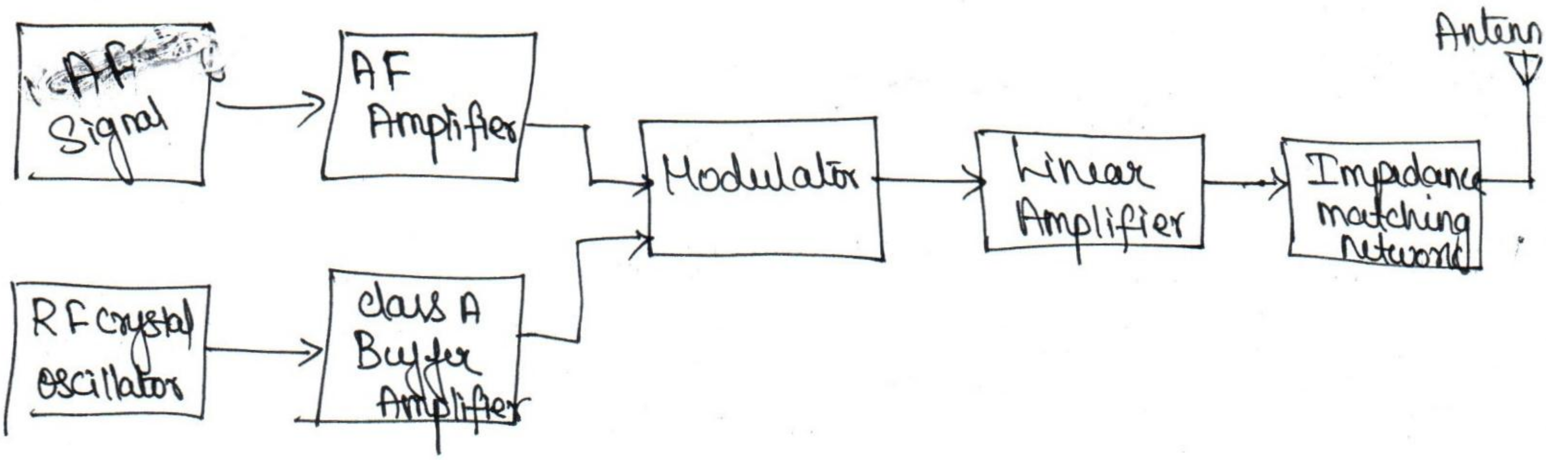


Fig: 1 Low level Transmitter

- Here carrier and Modulating signals are amplified after Modulation.

~~Modulating~~

Af Signal : Audio frequency (AF) Signal is the original modulating Signal going to transmit'

Af Amplifier : Magnitude of the audio Signals are Strengthen by an amplification process

Rf crystal oscillator : Without any trigger of input Signals the crystal oscillator induce a high frequency carrier signal and it is Stabilized inorder to maintain the carrier frequency division within a prescribed Limit.

Buffer amplifier → To avoid Some loading Effect and temperature variation the Rf Signals are buffered and Then ~~amplifier~~ amplified.

Modulator : The modulating Signal & carrier Signal are applied as ~~i/p~~ input for the Modulator. ~~and at~~ The AM Signal is obtained at the output of the Modulator.

Linear Amplifier : This AM Signal is Then amplified by using chain of Linear amplifiers in order to increase the power levels. The amplifier may be any type like class-A (or) class-B (or) class A-B.

Then AM waves are transmitted to the antenna using Impedance matching network.

Advantages → • It does not require Large AF Modulator power

• Designing of transmitter is Easy

Dis-advantage: Due to the use of less efficient Linear amplifier, efficiency of The transmitter is less

Application : Lower power Systems like wireless Intercoms, pagers, walkie-Talkie and in Remote control units.

6.1.2 (ii) High Level AM Transmitters

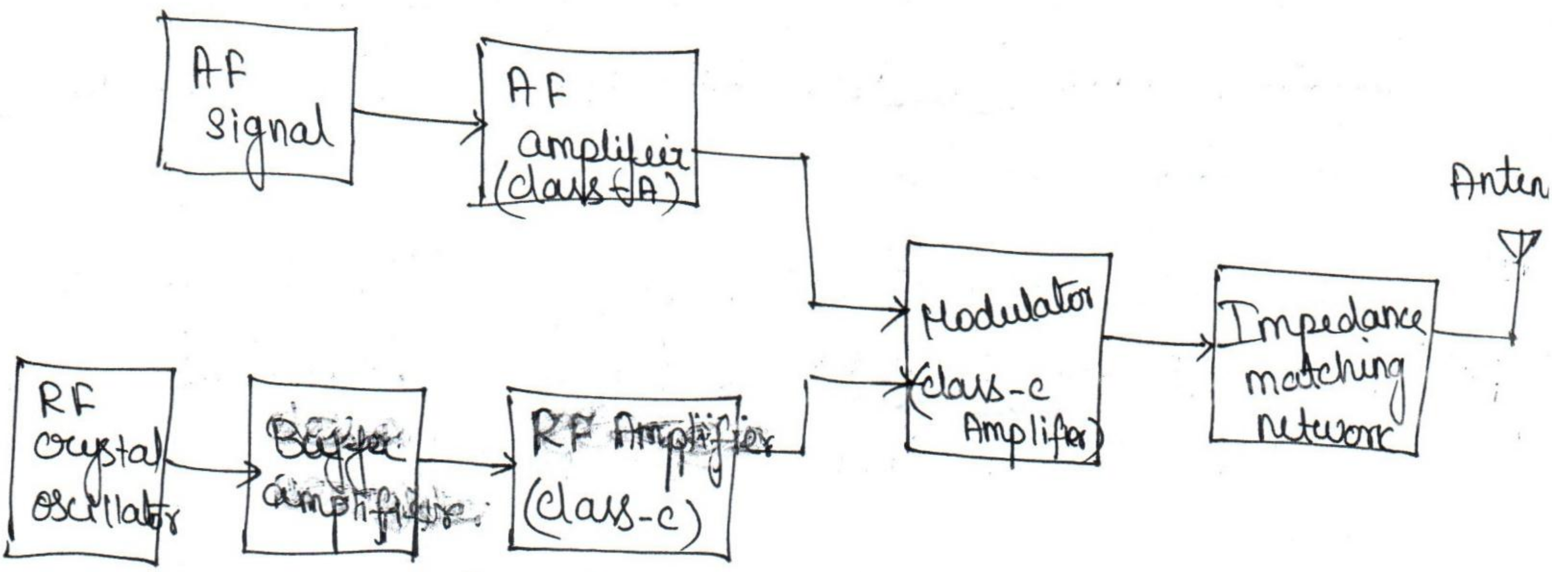


fig: 2 High level transmitter

AF amplifier : It amplifies and raise the ~~signal~~ power level of input audio message Signal.

RF crystal oscillator : It Generates carrier signal.

Buffer Amplifier : It isolates crystal oscillator and driver RF amplifier to avoid Loading Effect &

Temperature Variations

RF Amplifiers: It raise the amplitude level of the carrier signal. Here class-c amplifier type is used to achieve 100% efficiency.

Modulator (class-c): carrier signal drived and message signals are modulated and produce a AM signal as output.

The output of AM signal is transmitted to the antenna by using proper Impedance matching network.

6.1.3 Comparison of low level and High level Modulator

Low-level ~~transmitter~~ transmitter	High level transmitter
Modulated signals are further amplified after Modulation to raise the power level	carrier and message signals are amplified before modulation and hence no amplification is required after modulation
Depth of modulation is less ~~[illegible]~~ than 100%	Depth of modulation is maximum i.e 100%
Low Gain and Efficiency	High gain and efficiency
Applications: Remote control, Walkie-Talkie	Applications: Radio and TV Signal transmission.

6.2 FM RECEIVER

6.2.1 INTRODUCTION:

Radio Receiver is an Electronic Equipment which picks up any desired Radio frequency (RF) signal (modulated signal) and recovers origional message signal from it.

The functions of the Radio Receivers are,

1. Tuning : To select the desired signal.
2. Filtering : To seperate the original modulating signal from all other unwanted signal
3. Amplification : To improve the signal strength and to compensate the loss of information due to distortion during transmission.

6.2.2 RECEIVER PARAMETERS:

The radio receivers performance is measured on the basis of its Selectivity, Sensitivity, Fidelity.

(i) SELECTIVITY:

- The ability of the Receiver to select the desired frequency by rejecting all other frequencies.
- Selectivity of the Receiver can be acheived pratically by RF amplifier.
- Selectivity depends on Tuned LC circuits.

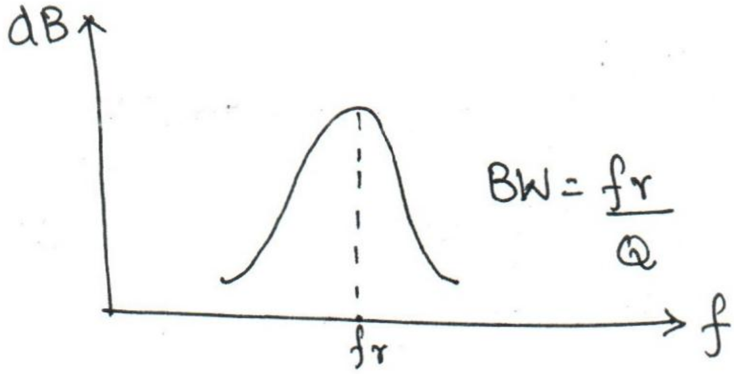


Fig: 3 Selectivity curve

(ii) SENSITIVITY:

- Ability of the Receiver to pick up weakest signal and amplify them.
- Sensitivity of the Receiver can be improved by reducing the Noise Level
- The measurement of the sensitivity is expressed in Microvolts or in decibels.

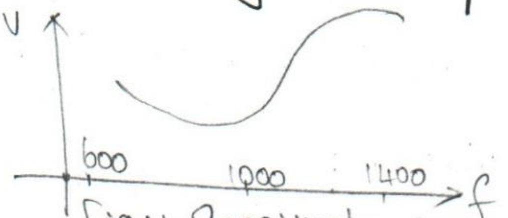
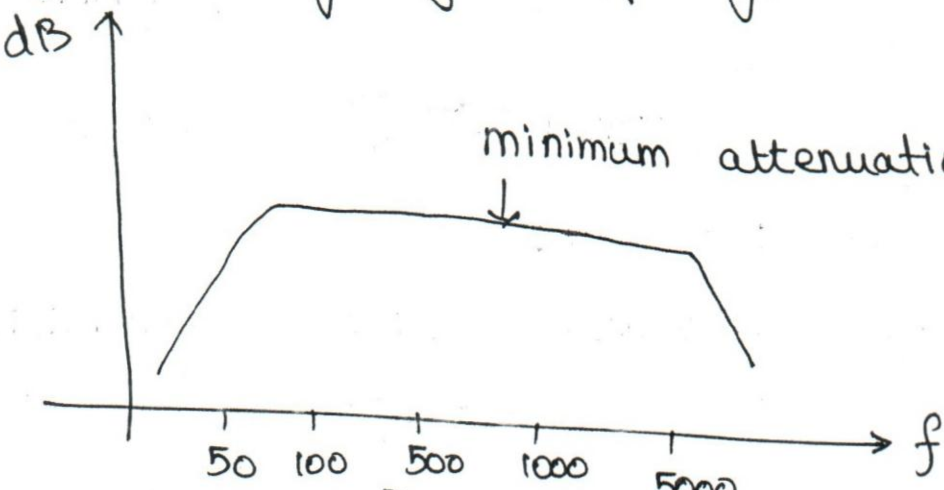


Fig:4 Sensitivity curve

(iii) FIDELITY:

- Ability of the receiver to reproduce all the range of modulating signal equally.



~~Fig: 5 Fidelity curve~~

Fig: 5 Fidelity Response

- For Good Fidelity more bandwidth of RF and IF stages required

6.2.3 TYPES OF AM RECEIVER:

Based on the operation of the AM Receiver. They are classified into two type

(i) Tuned Radio frequency (TRF) Receiver

(ii) Super heterodyne Receiver

6.2.3.1 TUNED RADIO FREQUENCY (TRF) RECEIVER

- TRF receiver is a simple straight receiver and it is used only as Fixed frequency Receiver.
- when this receiver was introduced it was a great improvement over other type of Receivers such as crystal, regenerative Receivers and Super regenerative receivers.

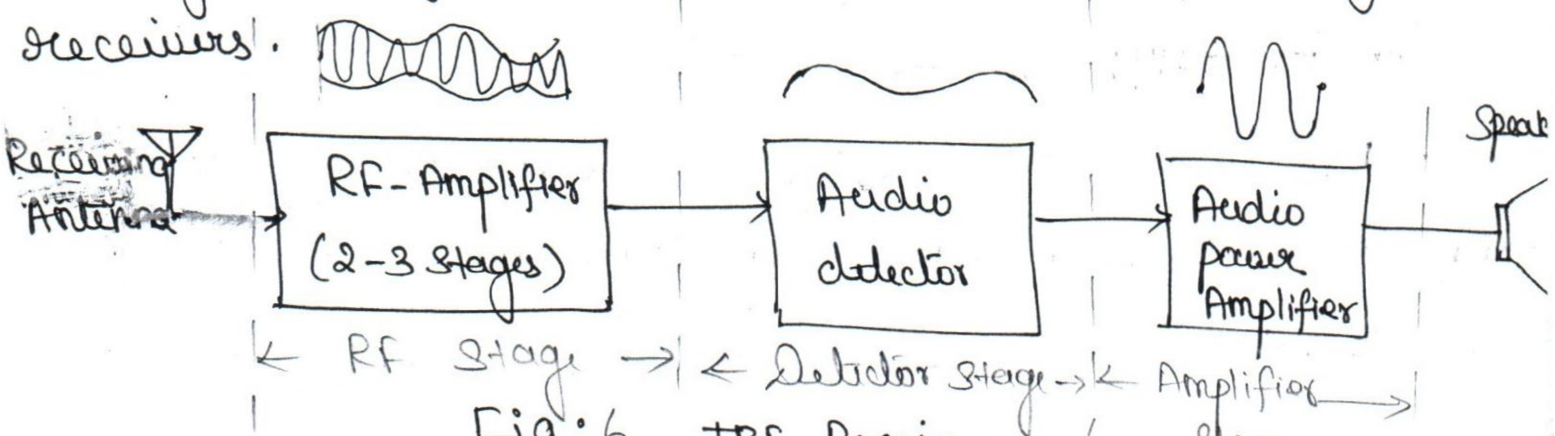


Fig: 6 TRF Receiver

TRF Receiver has 3-Stages:

1. RF Stage 2. Detector Stage 3. Amplifier Stag

1. RF Stage:

- In RF Stage, two or more RF amplifiers are used to tuned together for Selecting a desired

Signal and amplifying Them.

Gang Tuning → Tuning process in Rf Stage is called Gang Tuning.

Gang Tuning is All Rf Stage Amplifiers are tuned Simultaneously in order to tune a desired Signal. In which all the capacitors are connected (ganged) together and operated by one control point. The tuned circuit used in Gang tuning is LC tuned circuit, and that capacitor (c) is called as Gang capacitor.

2: Detector Stage:

After amplication process, the amplified signal is transmitted to a demodulator block.

Here the original modulating signal is recovered by using suitable demodulation technique like product Modulator.

3. Audio Amplifier Stage:

The detected original signal is amplified by a audio amplifier to improve its power level and Then drives by a loudspeaker

Advantages:

(i) Less ~~cost~~ Expensive

(ii) Simple to implement

(iii) High sensitivity.

iv) Easy to design at low frequency (535 to 1640 KHz

DIS- advantages:

(i) used for only single channel with Low frequency applications

(ii) Variation in Gain and Bandwidth

(iii) Unstablity condition due to large number of Rf stages used.

(iv) Simutaneous Tuning of tuned circuit is not possible.

6.3.2.2 SUPERHETERODYNE RECEIVER

PRINCIPLE:

⊙ Superheterodyne Receiver converts all the RF frequencies to a fixed low frequency is called as Intermediate Frequency (IF).

⊙ This IF frequency is then amplified and detected to get original message Signal.

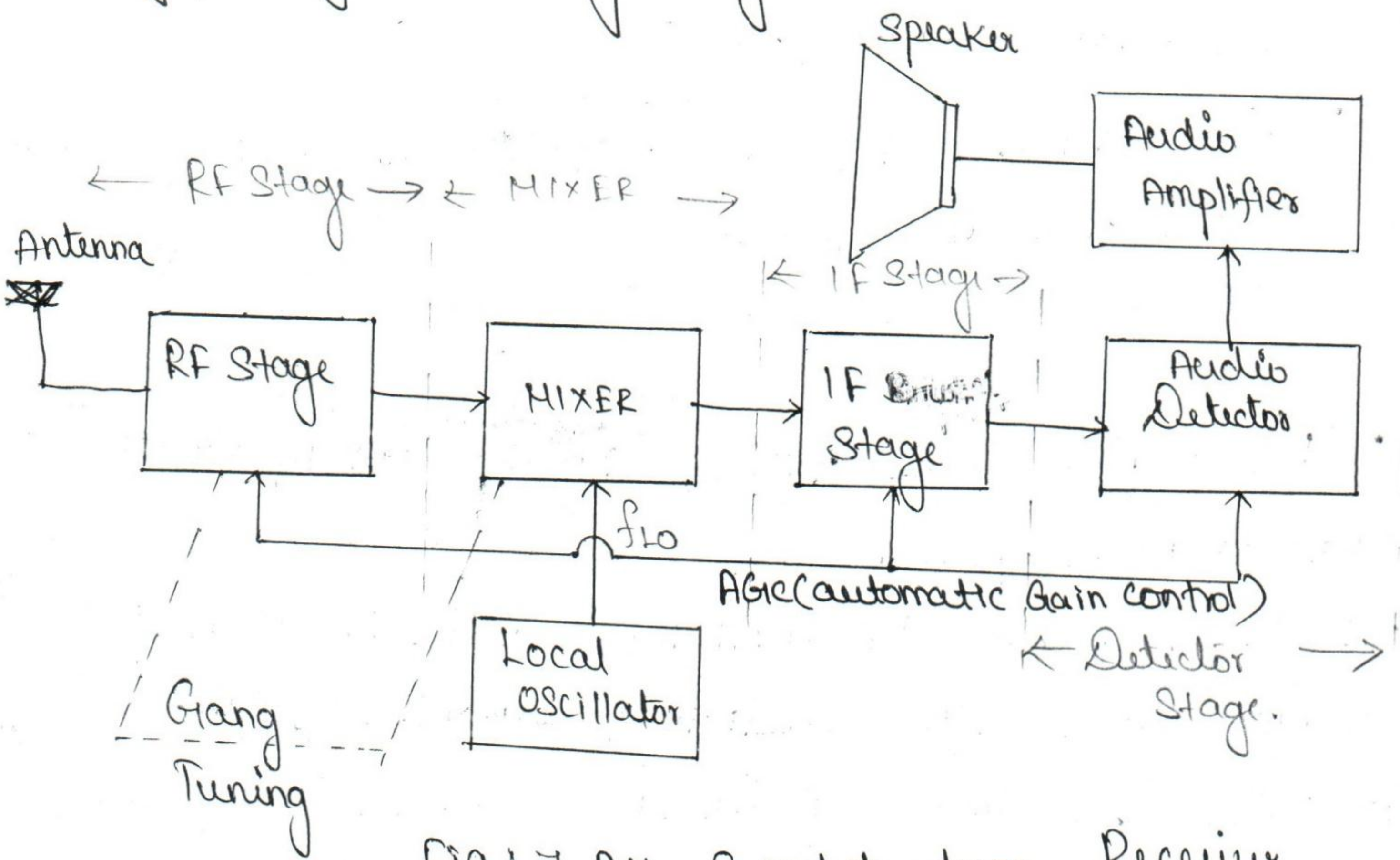


Fig: 7 AM Superheterodyne Receiver

- Superheterodyne Receiver has 3- Blocks.

1) RF Stage 2) MIXER 3) IF Stage

4) Audio detector Stage

1) <u>RF Stage:</u>

The RF Stage has two blocks (i) preselector (ii) RF amplifier.

<u>(i) preselector:</u> ⊙ Modulated signal is received by the Receiver antenna and transmitted to the RF Stage.

⊙ Preselector is Bandpass filter (BPF) which tuned to a desired frequency and reject unwanted frequency called as "<u>image frequency</u>".

⊙ It reduces Noise level of the signal and hence better SNR ~~is~~ obtained.

<u>(ii) RF Amplifier:-</u>

⊙ It amplifies the filtered signal from preselector to get adequate power level.

⊙ More number of RF amplifier can be included, as a result Gain, SNR, Selectivity, Sensitivity and better image frequency rejection ratio can be achieved.

<u>2) MIXER:</u>

⊙ It mix the incoming signal (f_s) and local oscillator signal (f_{LO}) to produce intermediate frequency (f_{IF}).

$$\boxed{f_{IF} = f_{LO} - f_s}$$

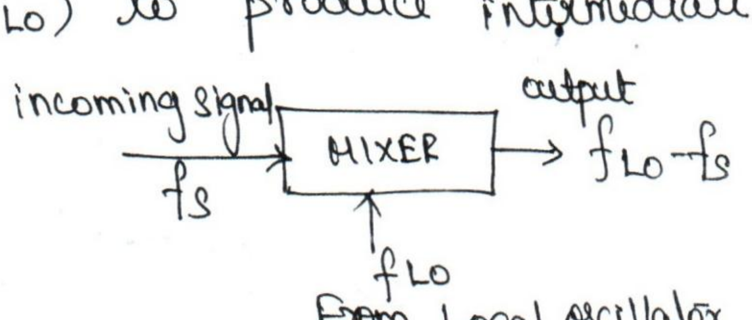


Fig: 8 MIXER

- Intermediate frequency (f_{IF}) is lower than ~~Radio~~ carrier frequency and higher than incoming frequency.
- Most common Intermediate frequency in AM Receiver is 455KHZ.
- Local oscillator frequency $(f_{LO}) = f_S + f_{IF} \longrightarrow (1)$
- Intermediate frequency $(f_{IF}) = f_{LO} - f_S \longrightarrow (2)$
- incoming frequency $(f_S) = f_{LO} - f_{IF} \longrightarrow (3)$
- Image frequency $(f_{si}) = f_{LO} + f_{IF} \longrightarrow (4)$

Sub equation (1) in (4)

$$f_{si} = f_S + f_{IF} + f_{IF}$$

$$\boxed{f_{si} = f_S + 2f_{IF}} \longrightarrow (5)$$

This unwanted signal at frequency is "called image frequency" (f_{si}).

- Image Frequency Rejection Ratio (IFRR):

→ Ability of the preselector to reject the unwanted image frequency is called Image frequency Rejection Radio (IFRR). This image rejection depends on Selectivity of the receiver.

→ IFRR is defined as the ratio of gain at the Signal frequency to the gain at image frequency.

$$IFRR\ (\alpha) = \frac{\text{Gain at the Signal frequency}}{\text{Gain at the image frequency}}$$

$$\boxed{\alpha = \sqrt{1+Q^2\rho^2}}$$

where $\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$

Q = Quality factor of preselector.

- Inorder to get quality of signal detection, the IFRR should be as high as possible.

3) IF Stage:

- IF ~~amplifier~~ stage consists of series of one or more IF amplifier
- Better Gain and Selectivity is provided by IF amplifier.
- The signal is amplified and moved to the detector stage.

4) Detector Stage:

- It consists of two blocks (i) audio detector (ii) audio amplifier
- output of IF stage is applied to a detector which recovers the original message signal and delivered by the Loudspeaker.

Automatic Gain Control (AGC):

- The part of output is taken from the detector and applied to the RF Stage, MIXER and IF Stage in order to acheive a controlled Gain.
- This process will maintains the constant output voltage level over a wide range of RF Signal frequency.

Advantages of Super heterodyne Receiver:

1) Stability and Gain Improved
2) High Sensitivity and Selectivity
3) Bandwidth remains constant for entire operation.
4) Design of IF amplifier is simple.

7 ANGLE MODULATION

7.1 INTRODUCTION:

DEFINITION.

- The angle (frequency or phase) of the carrier signal is varied according to the base band (modulating signal), then it is called as Angle Modulation.

- In angle Modulation amplitude and frequency should remains constant.

- Advantages of this Angle Modulation is it provide Improved Immunity against Noise and distortion

⊙ Angle Modulation is classified into two types.

Angle Modulation

→ Phase Modulation

→ Frequency Modulation

General Representation:

carrier signal → $\boxed{V_c(t) = V_c \cos \omega_c t = V_c \cos 2\pi f_c t}$ → ①

where ω_c = angular carrier frequency

$\boxed{V(t) = V_c \cos Q(t)}$ → ②

where $2\pi f_c = Q(t)$

⊙ The term 2π is phase denoted by $Qi(t)$ and the term f_c is frequency denoted by $fi(t)$

Equation ② can be written as,

Phase Modulation: $V_{PM}(t) = V_c \cos Q_i(t)$, where $Q_i(t)$ = phase of the carrier → ③

Frequency Modulation: $V_{FM}(t) = V_c \cos f_i(t)$, where $f_i(t)$ = frequency of the carrier → ④

7.2 PHASE MODULATION

DEFINITION:

⊙ The phase of the carrier signal is changed in accordance with the modulating signal is called as phase modulation

REPRESENTATION OF PM:

$$Q_i(t) = \omega_c t + K_p V_m(t) \longrightarrow ⑤$$

where K_p = phase sensitivity deviation

unit = radians / Volt.

Substitute equation ⑤ in ③

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

$$\boxed{V_{PM}(t) = V_c \cos\left[\omega_c t + K_p V_m \cos\omega_m t\right]} \rightarrow \text{PM wave}$$

Modulation index of PM:

$m_p \propto V_m$

$\boxed{m_p = K_p V_m}$ radians

where m_p = modulation index of PM signal

K_p = phase sensitivity deviation.

V_m = ~~Mod~~ Amplitude of modulating signal.

Phase modulation of modulation Index (m_p) is defined as a product of phase deviation and amplitude of modulation

Phase deviation (K_p):

⊙ phase angle of the carrier Varies from its unmodulated carrier during modulation process is Known as phase deviation.

$$\boxed{K_p = \frac{m_p}{V_m}} \text{ radians/volt}$$

Generation of PM wave:

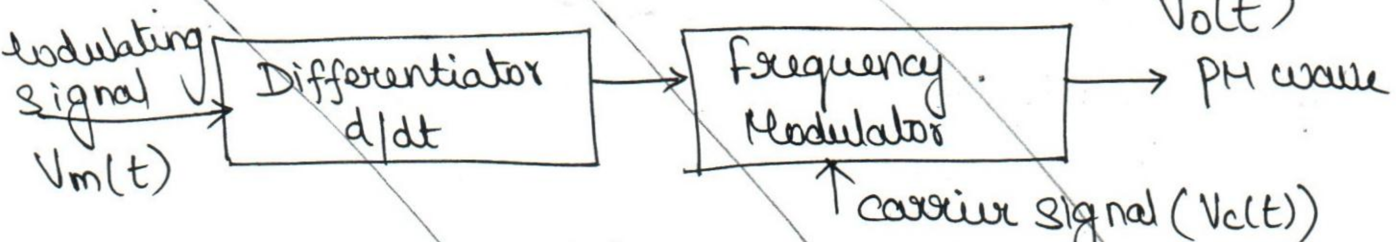


fig: PM wave generation using FM

7.3 FREQUENCY MODULATION:

Definition:

⊙ The frequency of the carrier signal is changed in accordance with the modulating signal remains other as constant ~~frequen~~ phase and Amplitude maintained is called as Frequency Modulation

Representation of FM:

$$f_i(t) = \omega_c t + \int_0^t K_f V_m(t) \longrightarrow (6)$$

where K_f = frequency sensitive deviation

unit → Hertz/volt

W.K.T from equation (4)

$$V_{FM}(t) = V_c \cos \phi_i(t)$$

Substitute equation (4) in (6)

$$V_{FM}(t) = V_c \cos\left[\omega_c t + \int_0^t K_f V_m \cos\omega_m t\right]$$

$$\boxed{V_{FM}(t) = V_c \cos\left[\omega_c t + \frac{K_f V_m}{\omega_m} \sin\omega_m t\right]} \rightarrow \text{FM wave}$$

where K_f = deviation Sensitivity

Modulation index of FM:

$$m_f \text{ (or) } \beta = \frac{K_f V_m}{\omega_m}$$

$$\boxed{m_f = \frac{K_f V_m}{2\pi f_m}}$$

Frequency deviation $\Delta f = \frac{K_f V_m}{2\pi}$

$$\boxed{m_f = \frac{\Delta f}{f_m} = \frac{\text{maximum frequency deviation (Hz)}}{\text{modulating frequency (Hz)}}}$$

Modulation index of FM $m_f \gg 1$.

Frequency deviation (Δf):

- Δf is defined as change in the frequency of carrier with respect to unmodulated value after frequency modulation

$$\boxed{\Delta f \propto V_m}$$

- magnitude of the frequency deviation is proportional to the magnitude of message signal.

Percentage Modulation of FM:

Percentage Modulation is defined as the ratio of actual Frequency deviation produced by the message Signal to the maximum allowable frequency deviation. interms of percentage.

$$\% \text{ Modulation} = \frac{\text{Actual frequency deviation}}{\text{Maximum allowable frequency deviation}} \times 100$$

$$\boxed{\% \text{ Modulation} = \frac{\Delta f(\text{actual})}{\Delta f_{max}} \times 100}$$

Deviation Ratio (DR):

Deviation ratio (DR) is a ratio of maximum peak frequency deviation to the maximum modulating signal frequency.

$$\boxed{\text{Deviation Ratio (DR)} = \frac{\Delta f(max)}{f_m(max)}}$$

where,

$\Delta f(max)$ = Max peak frequency deviation in Hz.

$f_m(max)$ = Max modulating signal frequency in HZ.

7.4 Generation of PM and FM wave:

7.4.1 Generation of PM from Frequency Modulation (FM)

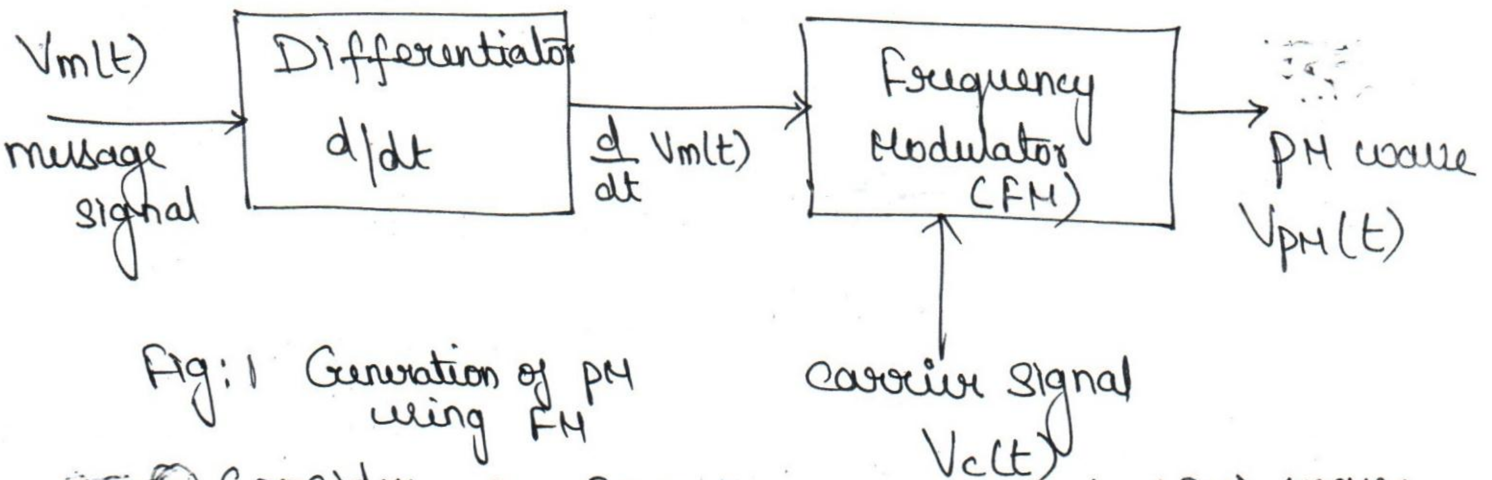


Fig: 1 Generation of PM using FM

- Consider a Frequency Modulated (FM) wave from which the PM waves are generated

W.K.T FM wave →

$$\boxed{V_{FM}(t) = V_c \cos\left[\omega_c t + \frac{K_f V_m}{\omega_m} \sin\omega_m t\right]} \rightarrow (7)$$

- When message signal passes through a differentiator circuit, then the message signal gets differentiated as,

$$= V_c \cos\left[\omega_c t + \frac{K_f}{\omega_m} \frac{d}{dt}\left[V_m \sin\omega_m t\right]\right]$$

$$= V_c \cos\left[\omega_c t + \frac{K_f V_m}{\cancel{\omega_m}} \times \cos\omega_m t \cdot \cancel{\omega_m}\right]$$

$$\boxed{V_{PM}(t) = V_c \cos\left[\omega_c t + K_f V_m \cos\omega_m t\right]} \rightarrow (8)$$

Hence PM wave obtained from FM wave.

7.4.2 Generation of FM wave from phase Modulator (PM)

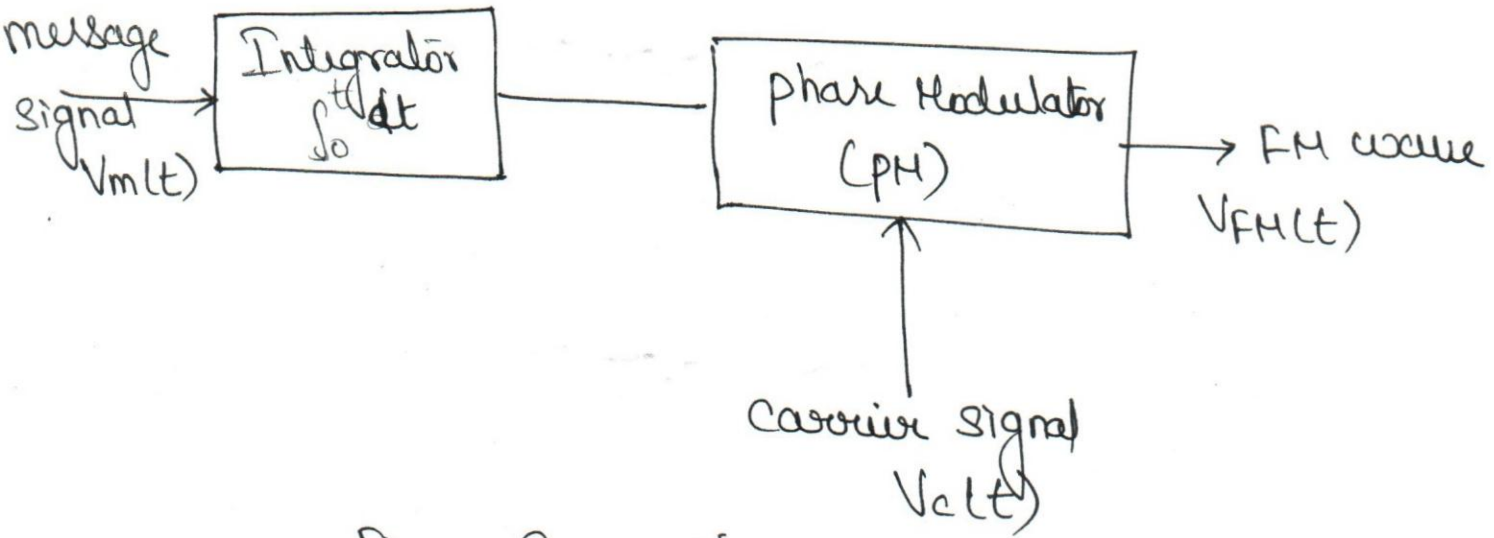


Fig: 2 Generation of FM using PM

- consider a PM wave from which the FM waves are generated

w.k.t PM waves $\boxed{V_{PM}(t) = V_c \cos\left[\omega_c t + K_p V_m \cos\omega_m t\right]}$ → (9)

- message signal gets integrated after passing Through a Integrator with respect to a time interval of (0 to t).

$$= V_c \cos\left[\omega_c t + K_p \int_0^t V_m \cos\omega_m t\right]$$

$$\boxed{V_{FM}(t) = V_c \cos\left[\omega_c t + \frac{K_p V_m}{\omega_m} \sin\omega_m t\right]} \rightarrow (10)$$

Hence FM wave obtained from PM wave.

7.4.3 Waveform of PM and FM:

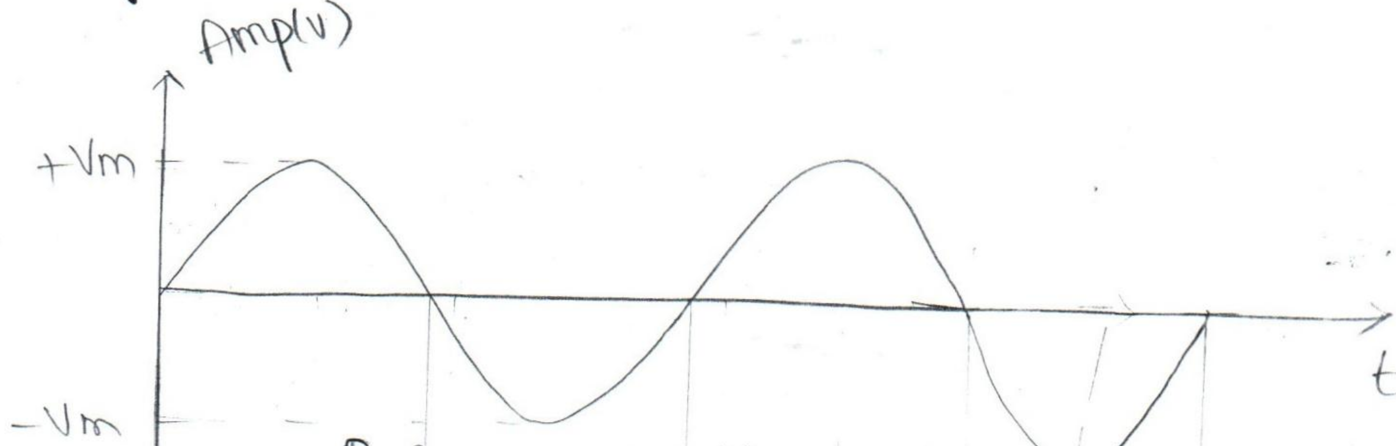


Fig3a: modulating signal

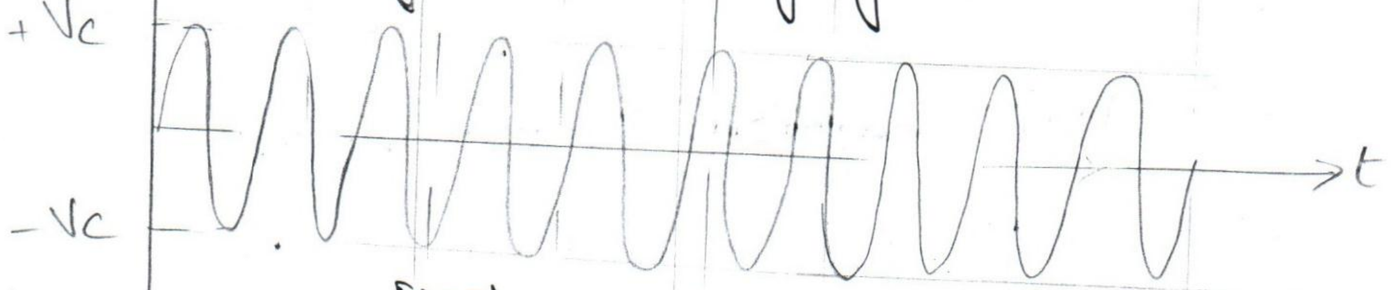


Fig3b: carrier signal

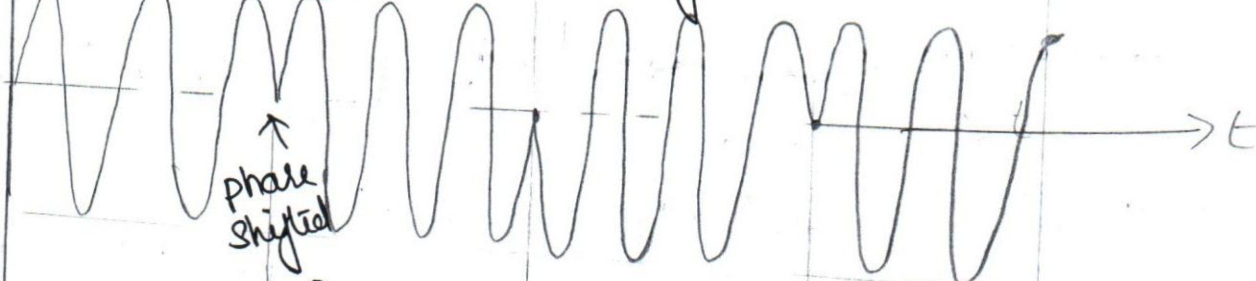


Fig3c: ~~phase~~ Modulation (PM wave)

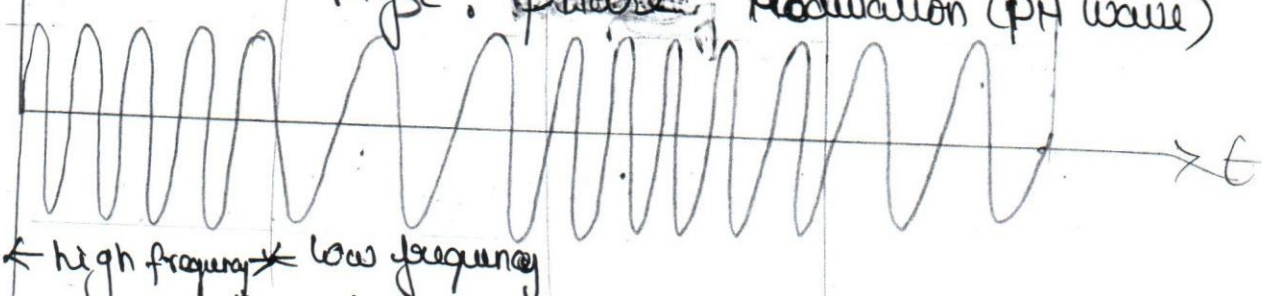


Fig3d: frequency Modulation (FM wave)

7.5.3 Comparision of FM and PM.

S.NO	FM	PM
1.	Frequency deviation is proportional to modulating Voltage	phase deviation is proportion to modulating Voltage
2.	Frequency of the carrier is modulated w.r.t message Signal	phase of the carrier signal is modulated w.r.t message signal.
3.	modulation index is increased as modulation frequency reduced. $\boxed{m_f = \frac{\Delta f}{f_m}}$	Modulation index remains same if the modulating frequency is changed. $\boxed{m_p = K_p V_m}$
4.	Better SNR	Less SNR
5.	Noise Immunity is better than AM	Noise immunity is worst than FM.
6.	FM is used widely in all application	PM is used in some Mobile system.

7.5.4 TYPES OF FREQUENCY MODULATION:

- Dependes on B.W of FM Signal, the modulation index (mf) values Varies.
- If $m_f \uparrow es \iff B.W \downarrow es$
- FM types are classified according to the Values of modulation index (m_f).

Frequency Modulation (FM)

1) Narrow band FM (NBFM)
   - when modulation index $[m_f$ or $\beta << 1]$

2) Wide band FM (WBFM)
   - when modulation index $[m_f$ or $\beta >> 1$

7.5.4.1 Narrow Band FM (NBFM):

- In NBFM bandwidth is Narrow and it is also called as Low-index FM
- Modulation index $\beta << 1$
- $B.W = 2f_m$ (Same as AM signal), all NBFM signal has carrier and two sidebands. So NBFM Signal is Double sideband - full carrier (DSB-FC).

- W.K.T FM wave is

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

$$V_{FM}(t) = V_c \cos\left[\omega_c t + \beta \sin\omega_m t\right]$$

$$\left[\cos(A+B) = \cos A \cos B - \sin A \sin B\right]$$

$$V_{FM}(t) = V_c\left[\cos\omega_c t \cos(\beta \sin\omega_m t) - \sin\omega_c t \sin(\beta \sin\omega_m t)\right] \rightarrow (13)$$

- In NBFM, modulation index ($\beta << 1$) and the Value of approximation is given by,

$$\cos(\beta \sin\omega_m t) \approx \cos 0 \approx 1$$

$$\sin(\beta \sin\omega_m t) \approx \beta \sin\omega_m t \quad \left[\because \sin x \approx x \text{ when } x = \text{small Value}\right]$$

- Substitute the above approximation equation to the equation (13).

$$V_{FM}(t) = V_c\left[\cos\omega_c t - \beta \sin\omega_m t \sin\omega_c t\right]$$

$$\boxed{V_{FM}(t) = \underbrace{V_c \cos\omega_c t}_{\text{carrier}} - \underbrace{\frac{V_c\beta}{2}\cos(\omega_c - \omega_m)t}_{\text{LSB}} + \underbrace{\frac{V_c\beta}{2}\cos(\omega_c + \omega_m)t}_{\text{USB}}}$$

- Hence NBFM wave obtained. This wave is Same like DSB-FC and so bandwidth is also Same as '$2f_m$'.

$$\boxed{V_{FM}(t) = V_{DSB\text{-}FC}(t)}$$

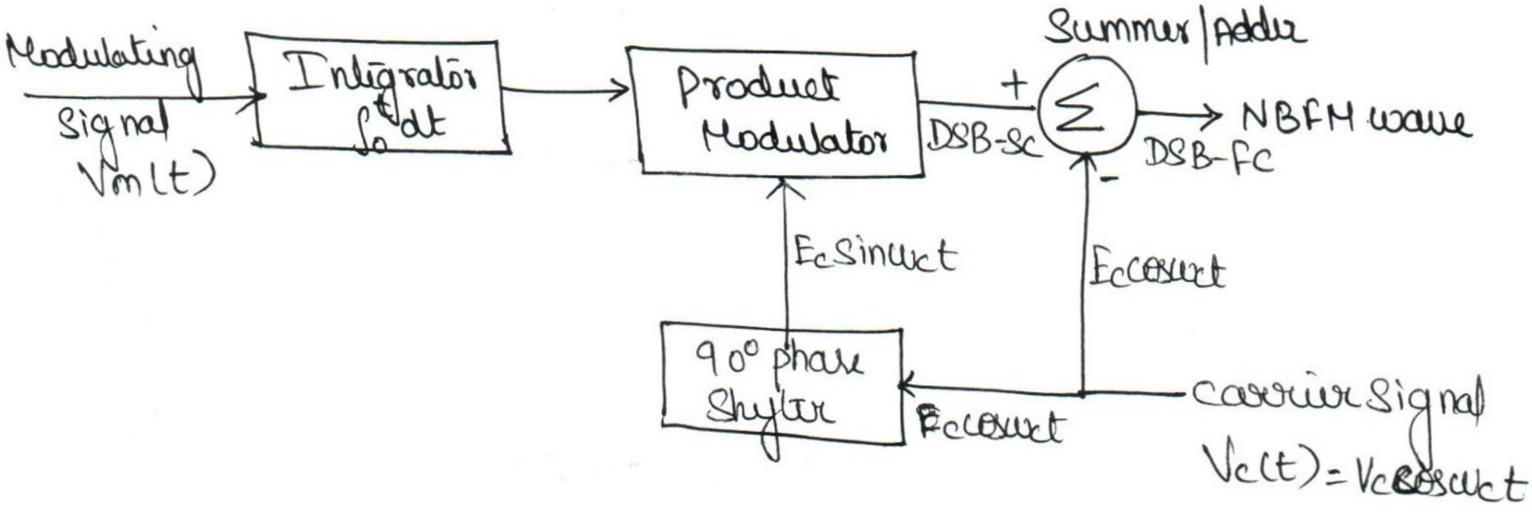


Fig: 4 Generation of NBFM.

- Moduting Signal is integrated over 0 to t time period and multiplied with the 90° phase Shifted carrier Signal by using product Modulator.
- The output of product modulator is Double Side band - Suppressed carrier (DSB-SC) and the narrow band FM Signal is obtained by passing that DSB-SC Signal and direct carrier signal to Summer network.
- The Summer network takes difference between carrier and DSB-SC Signal and produce a narrow band FM Signal with bandwidth twice that of modulating frequency.

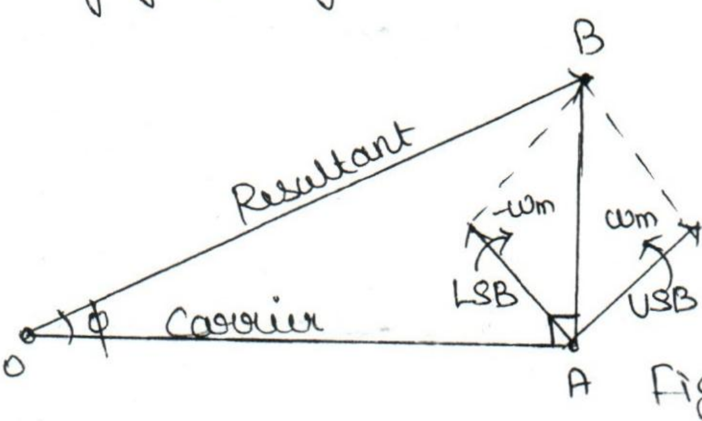


Fig: 5 phasor diagram of NBFM

(i) Figure (5) represents resultant of two side frequencies phasor is always right angles to the carrier phasor.

- Resultant Narrow band FM and carrier has same amplitude value and opposite in phase (out of phase) with each other. Whereas in AM; Resultant and carrier has different amplitude and same phase (in phase) with each other.

7.5.4.2 WIDE BAND FM (WBFM)

- Modulation index $\beta >> 1$, so called high index FM.
- WBFM has ~~Infinite~~ bandwidth
- Having carrier signal and infinite number of Sidebands

- Consider a FM signal as,

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

$$V_{FM}(t) = V_c \cos\left[\omega_c t + \beta \sin\omega_m t\right] \longrightarrow (1)$$

W.K.T $e^{j\theta} = \cos\theta + j\sin\theta$

$$\cos\theta = Re\left[e^{j\theta}\right] \text{ and } \sin\theta = img\left[e^{j\theta}\right]$$

- FM signal represented in Real part of Exponential term as,

$$V_{FM}(t) = Re\left[V_c\, e^{j(\omega_c t + \beta \sin\omega_m t)}\right]$$

$$V_{FM}(t) = Re\left[V_c \cdot e^{j\omega_c t} \cdot e^{j\beta \sin \omega_m t}\right] \rightarrow (2)$$

- The envelope of FM signal $V_{FM}(t)$ can be expressed as,

$$\boxed{V(t) = V_c\, e^{j\beta \sin \omega_m t}} \rightarrow (3)$$

Here $V(t)$ is periodic in nature w.r.t time.

- ~~Taking~~ Sub equation (3) in (2)

$$V_{FM}(t) = Re\left[V(t)\, e^{j\omega_c t}\right] \rightarrow (4)$$

- Taking Fourier Series of $V(t)$ as,

$$V(t) = \sum_{n=-\infty}^{\infty} C_n\, e^{jn\omega_m t} \rightarrow (5)$$

where
$$\boxed{\begin{array}{l} C_n = \text{complex fourier coefficient} \\ C_n = f_m \int_{-1/2f_m}^{1/2f_m} V(t)\, e^{-jn\omega_m t}\, dt \end{array}} \rightarrow (6)$$

Substituting equation (3) in (6)

$$C_n = f_m \int_{-1/2f_m}^{1/2f_m} V_c\, e^{j\beta \sin \omega_m t} \cdot e^{-jn\omega_m t}\, dt$$

$$C_n = V_c f_m \int_{-1/2f_m}^{1/2f_m} e^{j(\beta \sin \omega t - n\omega_m t)}\, dt \rightarrow (7)$$

- Consider $x = \omega m t = 2\pi f m t$

  differentiate 'x' w.r.t 't'

  $$\frac{dx}{dt} = 2\pi f m dt$$

  $$\boxed{dt = \frac{dx}{2\pi f m}}$$

- ~~Calculating the limits as,~~ $\therefore$ ~~$x = 2\pi f m t$~~

Since $x = 2\pi f m t$ ~~$x = 2\pi f m\left(\frac{1}{2 f m}\right)$~~

Substitute lower limit $\left(t = -\frac{1}{2fm}\right)$ ~~$= \pi$~~ | Illy $\boxed{x = -\pi}$

$\boxed{x = -\pi}$

Substitute upper limit $\left(t = \frac{1}{2fm}\right)$

$\boxed{x = +\pi}$

$\therefore$ limits changes from $-\pi$ to $+\pi$

- By Substituting all above assumption in the equation (7)

$$C_n = V_c \cancel{f_m} \int_{-\pi}^{+\pi} e^{j(\beta \sin x - nx)} \cdot \frac{dx}{2\pi \cancel{f_m}}$$

$$C_n = \frac{V_c}{2\pi} \int_{-\pi}^{\pi} e^{j(\beta \sin x - nx)} dx \longrightarrow (8)$$

- Bessel function equation can be written as $J_n(\beta) = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{j(\beta \sin x - nx)} dx \longrightarrow (9)$

where $J_n(\beta)$ = Bessel function of n^{th} order.

Equation (8) can be reduced by,

$$\boxed{C_n = V_c \, J_n(\beta)} \longrightarrow (10)$$

Sub equation (10) in (5)

$$V(t) = \sum_{n=-\infty}^{\infty} V_c J_n(\beta) e^{jn\omega_m t} \longrightarrow (11)$$

Sub equation (11) in (4)

$$V_{FM}(t) = Re\left[\sum_{n=-\infty}^{\infty} V_c J_n(\beta) e^{jn\omega_m t} \cdot e^{j\omega_c t} \right]$$

$$V_{FM}(t) = Re\left[\sum_{n=-\infty}^{\infty} V_c J_n(\beta) e^{j(n\omega_m t + \omega_c t)} \right]$$

$$V_{FM}(t) = \sum_{n=-\infty}^{\infty} V_c J_n(\beta) \cos(\omega_c t + n\omega_m t)$$

$$\boxed{V_{FM}(t) = V_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos(\omega_c t + n\omega_m t).} \longrightarrow (12)$$

Hence WBFM signal obtained.

Representating WBFM signal with Bessel function as,

- Take Fourier Transform of equation (12)

$$V_{FM}(f) = V_c \sum_{n=-\infty}^{\infty} J_n(\beta) \left[\delta(f - f_c - nf_m) + \delta(f + f_c + nf_m) \right]$$

when $n = 0 \rightarrow$ represents carrier

$$V_{FM}(f) = V_c J_0(\beta) \left[\delta(f - f_c) + \delta(f + f_c) \right]$$

when $n=0, n=1 \rightarrow$ represents carrier and Sideband

$$V_{FM}(f) = V_c J_0(\beta)\left[\delta(f-f_c)+\delta(f+f_c)\right] +$$
$$V_c J_1(\beta)\left[\delta(f-f_c-f_m)+\delta(f+f_c+f_m)\right]$$

Similarlly n- no. of Side bands can be derive. Hence WBFM Bandwidth is infinite.

7.5.5 Comparision of Narrow band and wideband f

S.NO	NBFM	WBFM
1)	Modulation index $\beta << 1$	Modulation index $\beta >> 1$
2.	Spectrum has carrier and Two Side bands	Spectrum has carrier and infinite no. of Side bands
3.	$B.W = 2f_m$	$B.W = 2(\Delta f + f_m)$
4.	Modulating frequency range (30HZ to 3KHZ)	Modulating frequency range (30HZ to 15KHZ)
5)	Less Suppression of Noise	More Suppression of Noise
6)	Max frequency deviation is 5KHZ	Max frequency deviation is 75KHZ.
7)	Applications: Mobile communication	Application: Entertainment and Broadcasting

7.5.6 BANDWIDTH OF FM:

Case (i) Depending on frequency deviation:

- ~~when~~ Bandwidth of NBFM:

when $m_f << 1 \rightarrow$ carrier + Side bands

$$\boxed{BW = 2f_m} \text{ Hertz}$$

- Bandwidth of WBFM:

when $m_f >> 1 \rightarrow$ carrier + Infinite Sideband

$$\boxed{B.W = 2(f_m \times n)} \text{ Hertz}$$

where, n = No. of side bands

f_m = Modulating Signal frequency.

- Approximate Bandwidth of Angle Modulation is expressed by an CARSON'S RULE.

CARSON'S RULE:

$$\boxed{B.W = 2(\Delta f + f_m)} \text{ Hertz.}$$

It states that bandwidth of FM signal is equal to twice the sum of frequency deviation and maximum modulating frequency. This rule is called as "Carson's Rule"

Case (ii) Depending on Amplitude:

• The transmission Bandwidth of FM is defined as Separation between two frequencies, beyond which non of the side frequencies are greater than 1% of unmodulated carrier.

$$\boxed{B.W = 2\eta_{max} f_m}$$

where η_{max} = maximum number of Sidebands with more than 1% of V_c

m_f	η_{max}
0	0
0.1	1
0.5	2
1	3

TAble: 2 Modulation index Vs η_{max}

when modulation index $(m_f) = 1$ the corresponding Value of maximum sidebands having more than 1% of carrier amplitude is 3. ie) $m_f = 1$; $\eta_{max} = 3$

$$B.W = 2(3) \times f_m$$

$$\boxed{B.W = 6 f_m}$$

7.5.7 GENERATION OF FM:

- The carrier frequency is required for the modulation of any system. Thus the carrier frequency is generated by LC oscillators.
- The frequency of the carrier signal depends on inductance or capacitance of the LC tank circuit.
- The devices like FET, BJT and Varactor diode whose reactance can be varied when voltage across them changes. Such devices can be used with tank circuits to vary the overall reactance. The change in reactance changes the frequency of the oscillator. The reactance may be inductance or capacitive.

Types of FM Modulators:

- Direct Method FM
  - Reactance Modulator
  - Varactor diode
- Indirect Method FM
  - Armstrong Method.

7.5.7.1 Direct FM Modulators:

In this method, the frequency of the carrier is varied directly by the modulating signal. The frequency deviation is directly proportional to the amplitude of the modulating.

Based on the principle of direct method of generating FM two types are available

(i) Varactor diode Modulator (ii) Reactance Modulato

(i) FET REACTANCE MODULATOR:

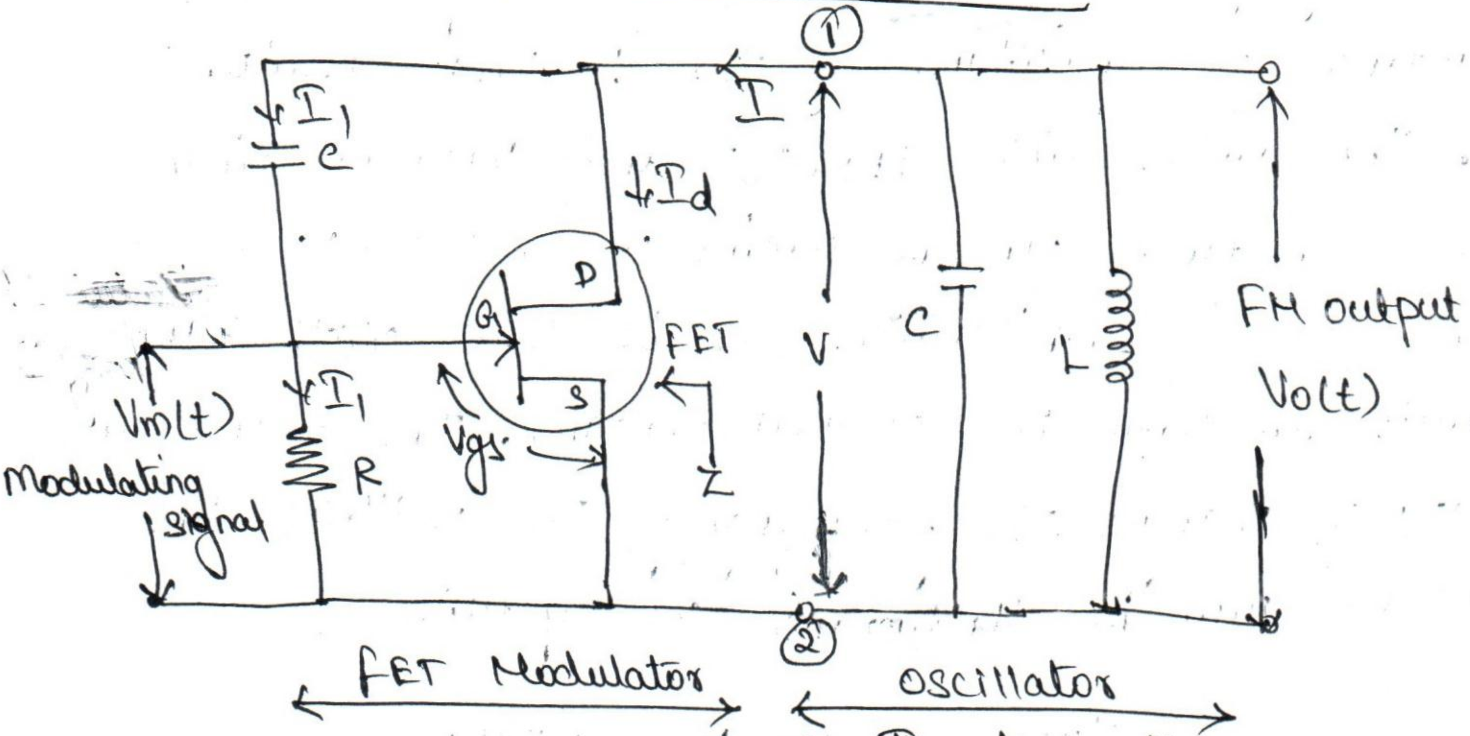


Fig: 6 FM Modulator using FET.

- Here FET act as a reactance.
- Modulating signal is applied to the FET Modulator and this reactance is proportional to the applied modulating signal Vm(t), which controlls the tuned oscillator circuit frequency.
- when the voltage Vm(t) changes, then FET reactance will change and this reactance may be Inductive (or) capacitive.

- Here LC circuit is tuned circuit, where the carrier signal is applied.

ANALYSIS:

⊙ Assume that the gate current is neglected, Then current through c and R is I_1. At carrier frequency, the reactang of c is greater than R ($X_C > R$)

⊙ current I_1 is written as,

$$I_1 = \frac{V}{R + \frac{1}{j\omega c}}$$

$$I_1 = \frac{V}{1/j\omega c} \qquad \because j\omega c >> R$$

$$\boxed{I_1 = j\omega c V} \longrightarrow (1)$$

→ Gate Voltage $V_g = I_1 R \longrightarrow (2)$

Substitute equation (1) in (2)

$$\boxed{V_g = j\omega c V R} \longrightarrow (3)$$

→ Gate current $I_d = g_m V_{gs}$ $\qquad [\because V_g = V_{gs}]$

$$I_d = g_m V_g$$

Sub equation (3)

$$\boxed{I_d = j\omega c R g_m V} \longrightarrow (4)$$

→ Impedence of FET $Z = \frac{V}{I_d}$

Substitute equation (4)

$$Z = \frac{\cancel{V}}{j\omega g_m C R \cancel{V}} = \frac{1}{j\omega (g_m C R)}$$

$$\boxed{Z = \frac{1}{j\omega C_{equ}}} \rightarrow (5)$$

Here $C_{equ} = g_m C R$

∴ Impedance of FET is purely capacitive reactance

<u>CONCLUSION:</u>

⊙ By varing modulating voltage across FET, conductance (g_m) can be varied this varies C_{equ} value. Thus change in capacitive 'c' value will change the frequency of oscillator by,

$$\boxed{f_c = \frac{1}{2\pi\sqrt{LC}}}$$

Advantages:

1) Less Expensive.

2) circuit is simple to design.

dis-advantages:

1) LC oscillator frequency is not stable

2) Distortion is high.

(ii) VARACTOR DIODE FM MODULATOR:

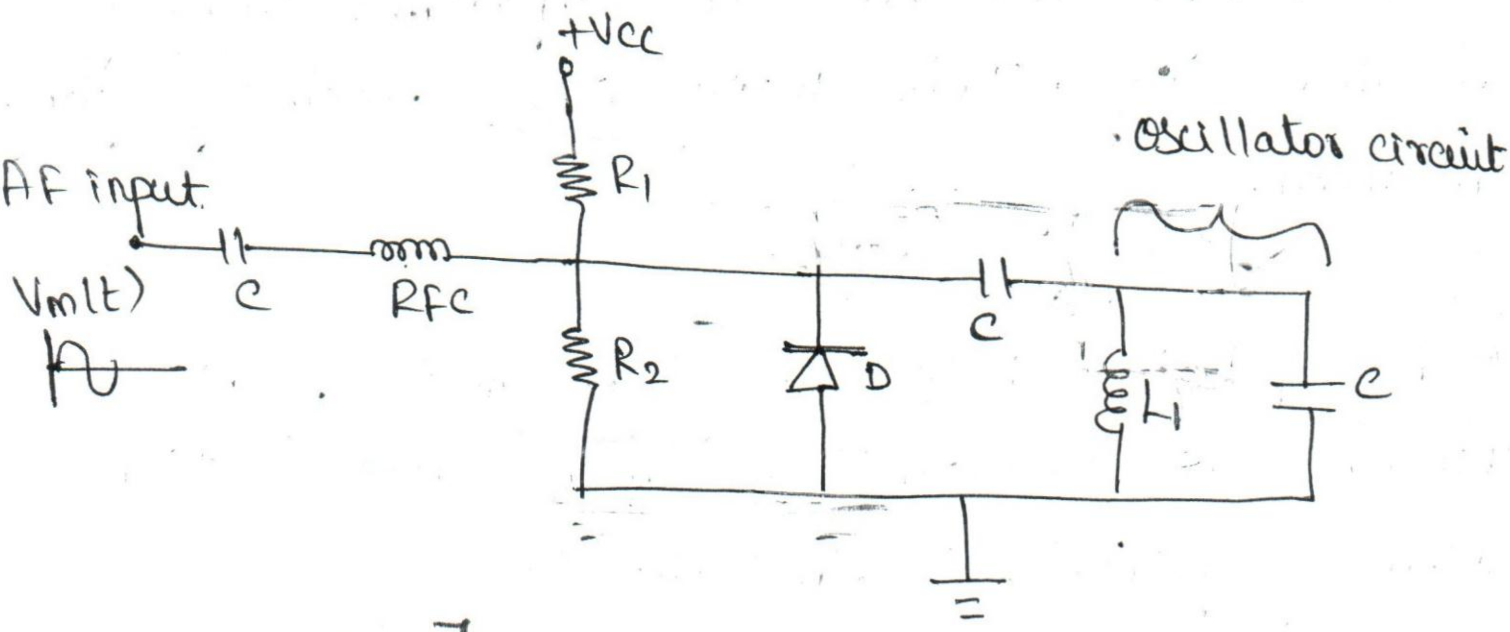


Fig: 7 FM Modulator using Varactor diode.

- Here the varactor diode is a variable diode, works under Reverse bias condition. The capacitance of the varactor diode depends on the fixed bias by R_1, R_2 and audio frequency (AF) modulating signal.
- RFC (Radio frequency choke) is used to prevent the carrier signal from getting into the modulating signal circuit.
- The capacitance of the varactor diode is given by $C \propto \frac{1}{\sqrt{V}}$, where V = Reverse bias voltage

Fig: 8 Transfer characteristics of Varactor diode.

- when $V_m(t)$ changes, Reverse bias of Varactor diode changes and hence the capacitance value of the diode changes. This makes the carrier frequency to vary.

$$\boxed{f_c = \frac{1}{2\pi\sqrt{LC}}}$$

- For positive half cycle of ~~the~~ $V_m(t)$, R.B increases and capacitance of diode decreases, then carrier frequency (f_c) increases.
- For negative half cycle of $V_m(t)$, R.B decreases and capacitance increases, then carrier frequency (f_c) decreases.
- This variation of frequency of carrier represents FM wave.

~~INDIRECT METHOD~~

~~In this method~~

Advantages of Direct method:

1) Less Epensive
2) Circuit is very Simple to design.

Disadvantages of Direct Method:

1) LC oscillator frequency is not Stable
2) Very high distortion
3) Not Suitable for broadcasting and communication

7.5.7.2 Indirect Method:

- In this method, the frequency of carrier signal is varied Indirectly by the use of modulating signal.
- Frequency deviation can be adjusted by the use of Frequency Multiplier.

Armstrong Method of Generating FM wave

There are two steps involved in the generation of FM wave in Armstrong Method

(i) Generating NBFM using PM

(ii) Generating WBFM using Mixer and Frequency Multiplier.

(i) Generating NBFM using PM:

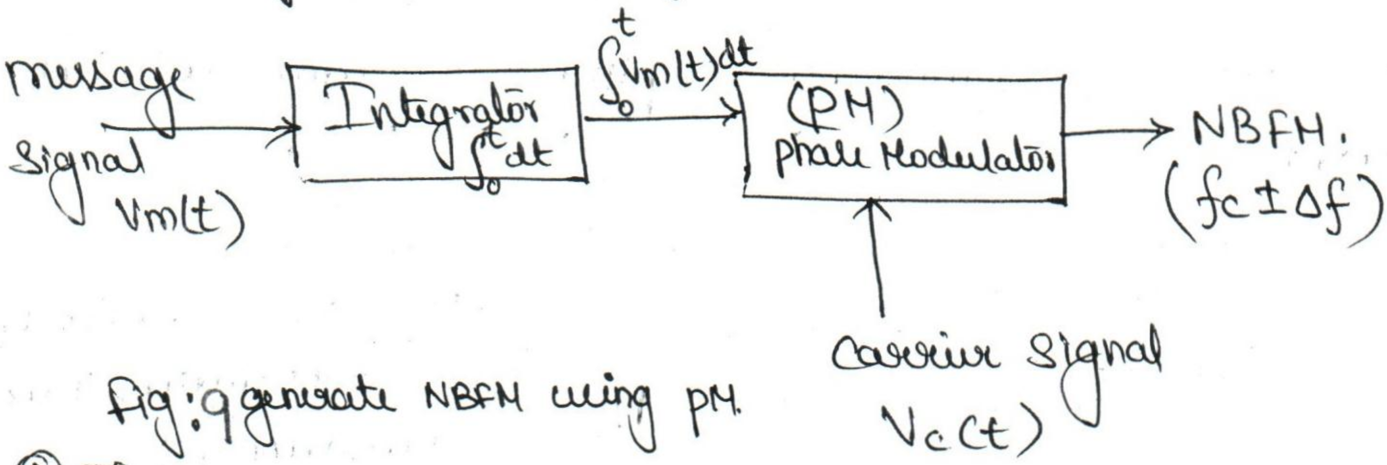


Fig: 9 generate NBFM using PM.

- The message signal is integrator and given to the phase Modulator, which produce a Narrow band FM signal.
- The modulation index is kept very low in order

to maintain less Bandwidth to give only carrier & side bands.

(ii) Generating WBFM using Mixer & frequency Multiplier:

⊙ The block diagram consists of Mixer circuit and frequency multiplier.

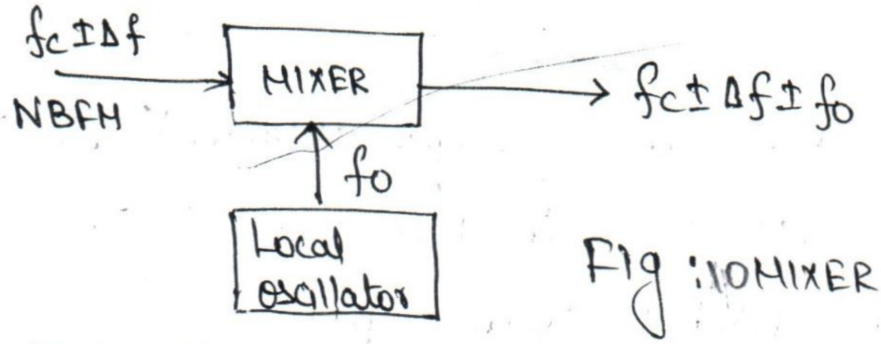


Fig: 10 MIXER diagram

⊙ Mixing NBFM signal with local oscillator frequency f_o to produce frequency components interms of sum and difference as $f_c + \Delta f + f_o$ and $f_c - \Delta f - f_o$ respectively.

⊙ This Mixer is used to increase or decrease the centre carrier frequency, by keeping frequency deviation as constant

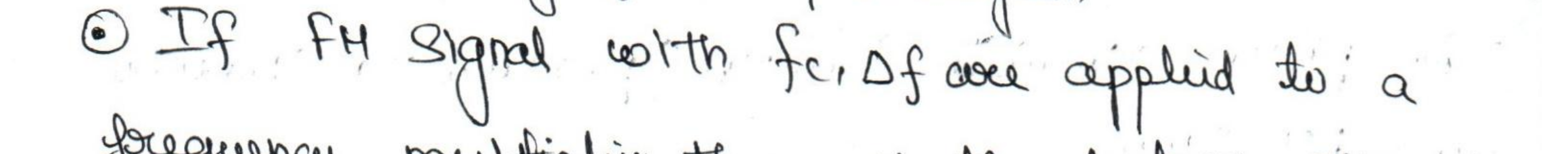


Fig: 5 Multiplier diagram

⊙ If FM signal with f_c, Δf are applied to a frequency multiplier then all the factors are multiplied.

- By using mixers and multipliers number of sidebands increased so that NBFM is converted to a WBFM.

Advantages of Indirect Method;

1) Modulation takes place at low carrier frequency.
2) FM is generated from PM indirectly.

7.5.8 COMPARISION OF Direct & Indirect FM

S.NO	Direct Method	Indirect FM
1.	Frequency of carrier signal is directly varied with message signal.	Frequency of carrier signal is indirectly varied with message signal.
2.	Used in low-capacitance application Example: Remote control	Radio and TV Broadcasting.

7.5.9 Comparision of FM and AM

S.NO	Frequency Modulation	Amplitude Modulation
1.	Frequency of the carrier is Varied accordance with modulating signal.	Amplitude of the carrier is Varied accordance with modulating signal.
2.	Less Noise and Interference	More Noise and Interference
3.	All power is used for transmission	carrier power and one Sideband power is useless
4.	Bandwidth is Large $\boxed{B.W = 2(\Delta f + f_m)}$	Narrow Bandwidth $\boxed{B.W = 2f_m}$
5.	FM transmission and reception equipment are more complex	AM equipment is less complex.

7.5.10 FM DEMODULATOR:

- Demodulators are used to recover the orginal Signal back.
- Fig: 6 Shows the block diagram of PLL FM demodulator.

⊙ The output of voltage controlled oscillator (VCO) is carrier signal and FM modulated signal is given to the phase detector.

7.5.10 **Demodulation of FM Signal**

There are four types of demodulation
① Balanced Slope / frequency discriminator / Round Travis.
② Foster - Seeley Discriminator / phase descriminator
③ Ratio Detector ④ PLL FM detector.

Foster - Seeley discriminator (phase discriminator)

principle: At centre carrier frequency the 1° voltage leads the 2° voltage by 90° and as the input frequency decreases the phase shift increases. This discriminator is also known as center tuned discriminator.

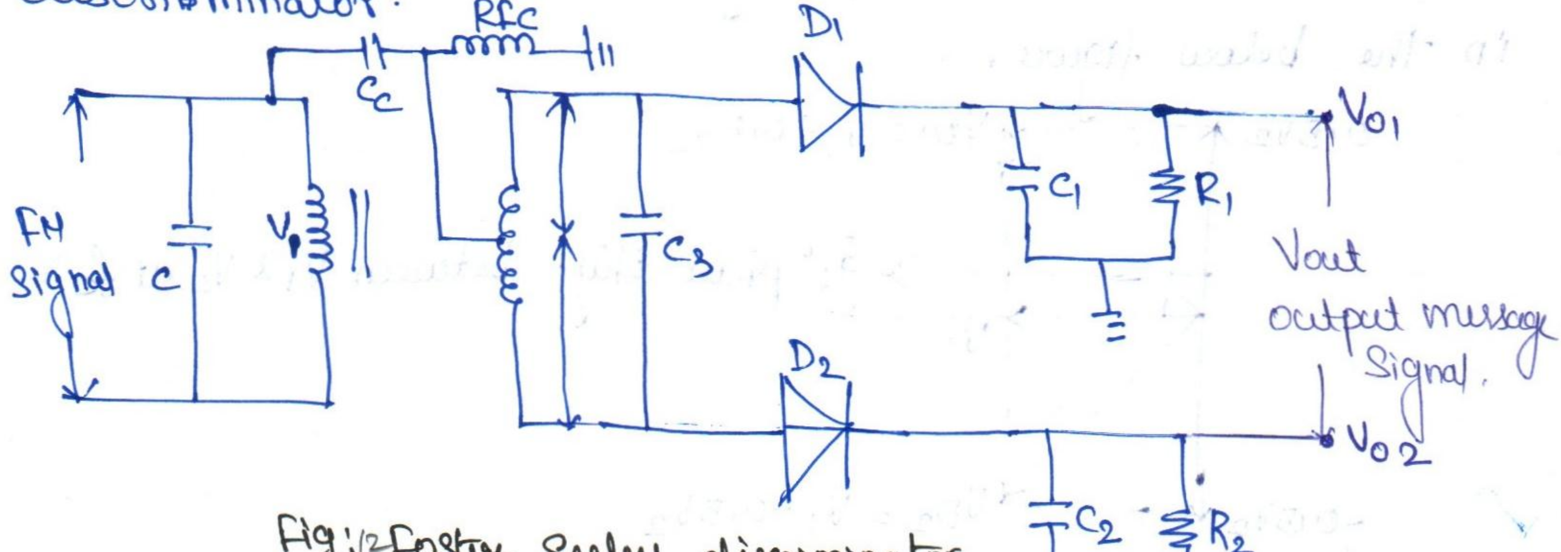


Fig: 1.2 Foster Seeley discriminator for FM demodulation

1° voltage is coupled to 2° winding of the transformer by using coupling capacitor and RFC (Radio frequency choke). The Voltage of 2° is V_2 which is equally divided across upper & lower half of the Secondary coil.

- Voltage across diode D_1 is $V_{D1} = V_1 + 0.5V_2$.
- Voltage across diode D_2 is $V_{D2} = V_1 - 0.5V_2$
- Voltage at the output terminals are

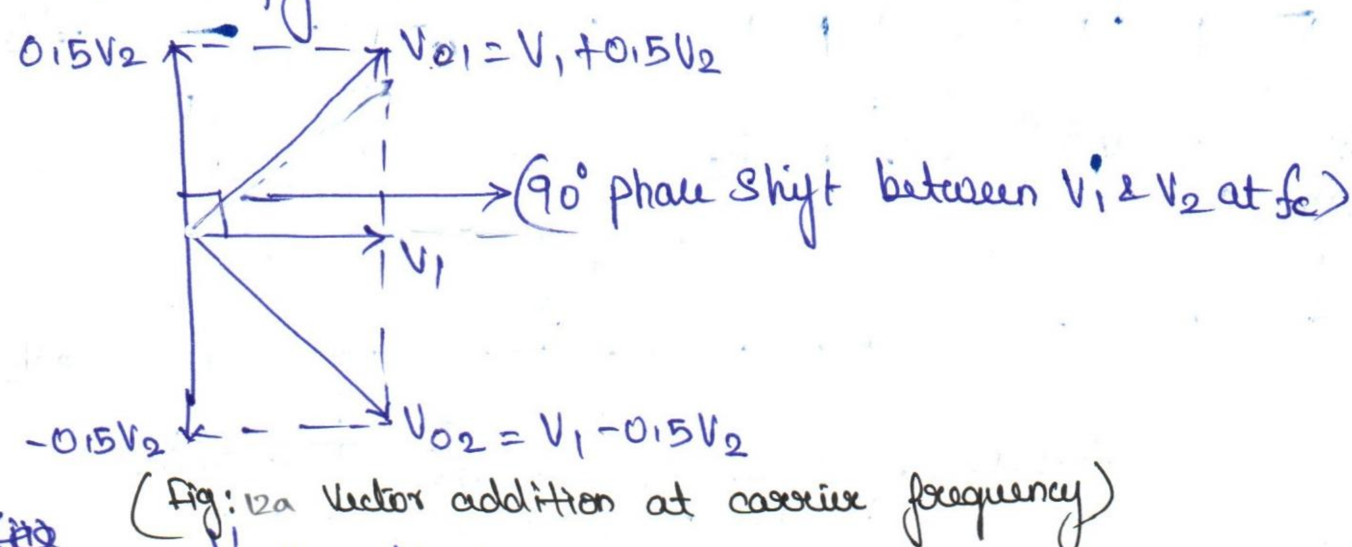
$$V_{01} = V_{D1}$$
$$V_{02} = V_{D2}$$

- output Voltage $(V_0) = |V_{01}| - |V_{02}|$

OPERATION:

case (i) $f_{in} = f_c$ (at resonance)

- Voltage across V_{D1} and V_{D2} will be equal as V_2 will have $90°$ phase shift with V_2. Hence output is zero. The Vector addition of V_{D1} and V_{D2} is shown in the below figure.



(Fig: 12a Vector addition at carrier frequency)

$$V_{out} = V_{01} - V_{02}$$

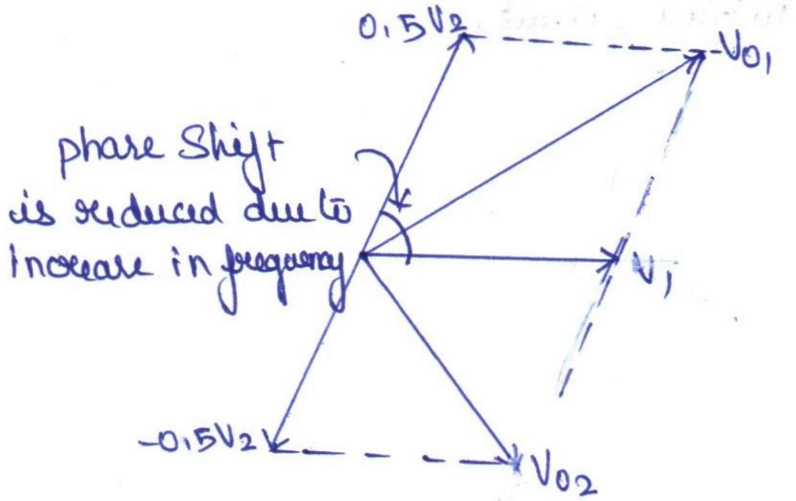
$\boxed{V_{out} = 0}$ Hence net output is zero.

Case(ii) $f_{in} > f_c$ (Above resonance)

$$V_{out} = V_{01} - V_{02}$$

$$= (V_1 + 0.5V_2) - (V_1 - 0.5V_2)$$

$\boxed{V_{out} = V_2}$ Hence net output is positive



~~Here V01 > V02 Since V2 lead V1 less than 90° and V2 lag V1 more than 90°~~

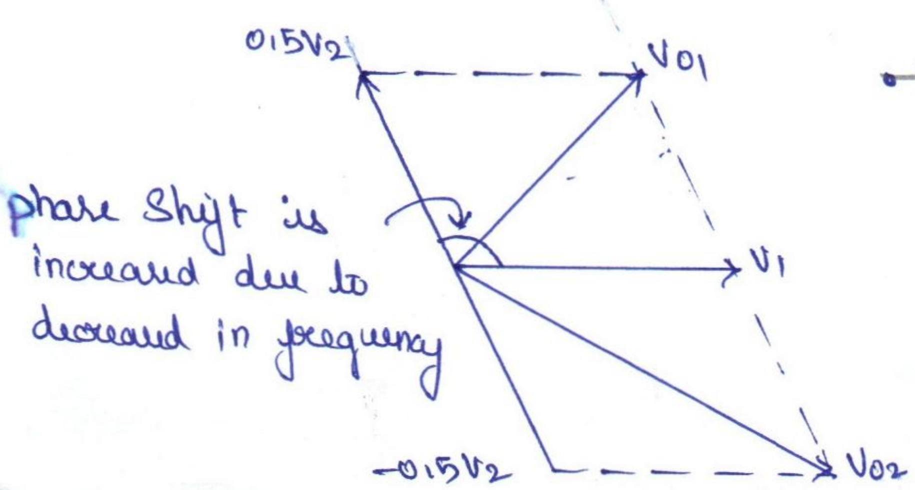
Fig: 12b Vector addition at FM frequency greater than carrier frequency.

Case(iii) $f_{in} < f_c$ (Below Resonance)

$$V_{out} = V_{01} - V_{02}$$

$$= (V_1 - 0.5V_2) - (V_1 + 0.5V_2)$$

$\boxed{V_{out} = -V_2}$ Hence net output is negative.



~~Here V01 < V02, Since~~

Fig: 12c Vector addition at FM frequency less than carrier frequency

Advantages:

1) Better Linearity

2) Easy to allign

3) only 2-tuned circuits needed

Dis-advantage:

Need seperate amplitude limiting circuit.

⊙ output of the detector is diffrence of FM signal and VCO output. This voltage is filtered and then amplified to get a desired modulating signal.

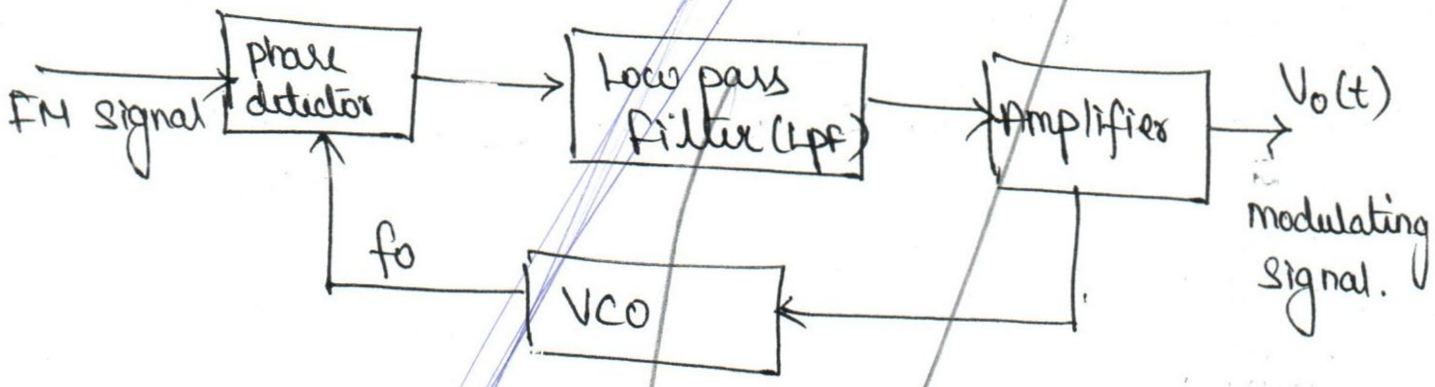


Fig: 6 Block diagram of PLL FM detector.

UNIVERSITY SOLVED PROBLEMS:-

Problem 1: Carrier wave of frequency 10MHZ and peak value of 10V is Amplitude Modulated by 5KHZ sine wave of amplitude 6V. Determine the modulation index, percent modulation, lower side frequency, upper side frequency and draw the frequency spectrum of the modulated signal.

Solution:

Given data: $f_c = 10MHZ$, $V_c = 10V$, $f_m = 5KHZ$, $V_m = 6V$.

(i) Modulation Index:

$$m_a = \frac{V_m}{V_c} = \frac{6}{10} = 0.6$$

$$\boxed{m_a = 60\%}$$

(ii) Lower Side Frequency:

$$LSF = f_c - f_m$$

$$= 10MHZ - 5KHZ$$

$$\boxed{LSF = 9.995MHZ}$$

(iii) Upper Side Frequency:

$$USF = f_c + f_m$$

$$= 10MHZ + 5KHZ$$

$$\boxed{USF = 10.005MHZ}$$

(iv) Frequency spectrum of AM

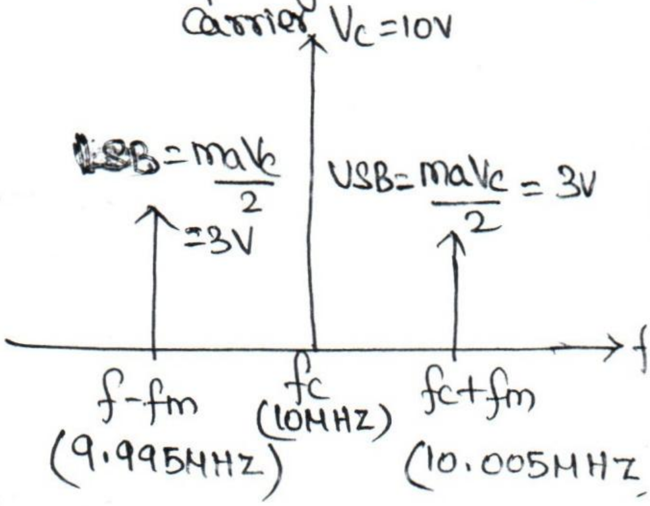


Fig: 1 Spectrum of AM.

problem 2: How may AM broadcast Station can be occommodated in 10KHZ bandwidth if the highest frequency modulating a carrier is 5KHZ?

Given data:

Bandwidth = 100KHZ

f_m = 5KHZ.

Solution:

$$\text{Number of Stations accommodated} = \frac{\text{Total Bandwidth}}{\text{Bandwidth per Station}}$$

$$= \frac{100KHZ}{5KHZ}$$

Total Number of stations accommodated = 10 Stations

Problem 3: Certain transmitter radiates 9KW with carrier unmodulated and 10.125 KW, when the carrier is Sinusoidally modulated. Calculate the modulation index. If another Sine wave, corresponding to 40% modulation is transmitted Simultaneously. Determine the total power.

Given data:

P_t = 9 KW

P_c = 10.125KW

m_a = 40% or 0.4

Solution:

(1) Total power)

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

$$m_a^2 = 2\left(\frac{P_t}{P_c} - 1\right)$$

$$= 2\left(\frac{9k}{10.125k} - 1\right)$$

$$\boxed{m_a = 0.5}$$

(ii) If two signals are simultaniously modulated,

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

$$m_t = \sqrt{0.5^2 + 0.4^2} = 0.64$$

(iii) Total power $P_t = P_c\left(1 + \frac{m_t^2}{2}\right)$

$$P_t = 9 \times 10^3 (1 + 0.205)$$

$$\boxed{P_t = 10.84 \, KW}$$

Problem 4: A message signal $m(t) = (2\cos 100\pi t + 3\sin 24\pi$ this message modulates a carrier of frequency 12MHZ and amplitude of 10V. Determine
(i) Time domain representation of AM wave
(ii) Determine Total Modulation Index (iii) Total transmi power. (iv) plot Spectrum of AM wave (v) find total power of load resistance across 100Ω.

Given: $m(t) = 2\cos 100\pi t + 3\sin 24\pi t$

$f_c = 12\,MHZ$, $V_c = 10V$

(i) Time Domain Representation

AM wave represents as

$$V_{AM}(t) = [V_c + V_m \sin 2\pi f_m t] \sin 2\pi f_c t$$

$$\boxed{V_{AM}(t) = [10 + 2\cos 100\pi t + 3\sin 24\pi t] \sin 2\pi f_c t}$$

(ii) Total modulation index

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

$$m_1 = \frac{V_{m1}}{V_c} = \frac{2}{10} = 0.2, \quad m_2 = \frac{V_{m2}}{V_c} = \frac{3}{10} = 0.3$$

$$m_t = \sqrt{(0.2)^2 + (0.3)^2}$$

$$\boxed{m_t = 0.36}$$

(iii) Total Transmitted power

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

$$P_c = \frac{V_c^2}{2R} = \frac{(10)^2}{2 \times 100} = 0.5W$$

$$\boxed{P_c = 0.5W}$$

$$P_t = 0.5\left(1 + \frac{0.36^2}{2}\right)$$

$$\boxed{P_t = 0.532W}$$

(iv) Frequency Spectrum

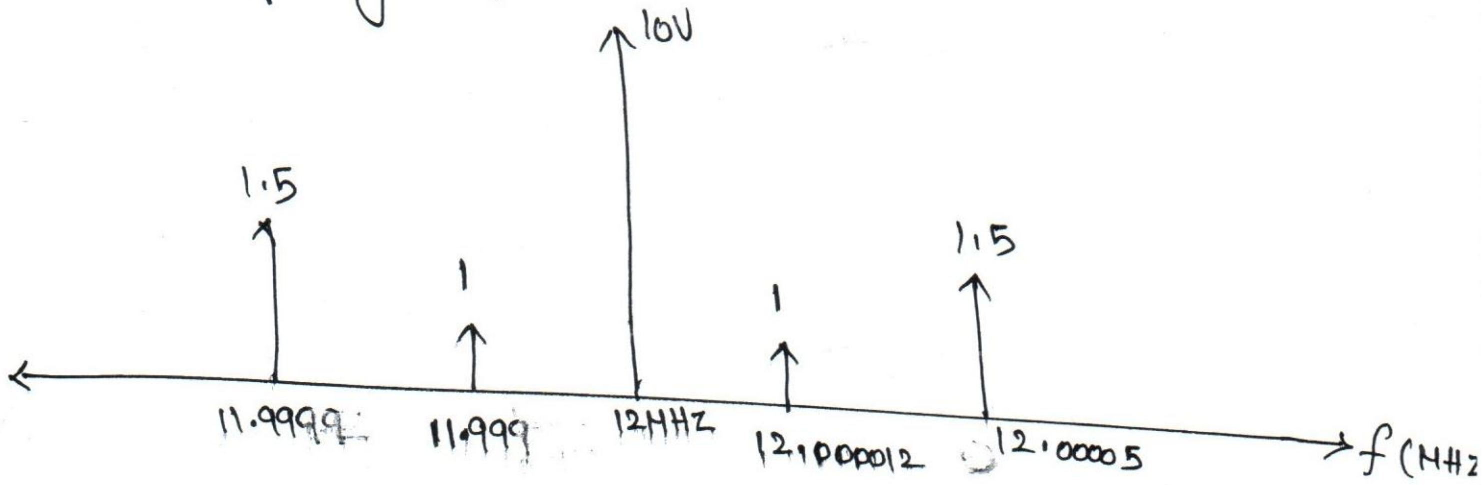


Fig: 2 Spectrum of AM

Problem 5: A DSB-SC signal with $f_c = 1000\,KHZ$ and $f_m = 10\,KHZ$. What is the bandwidth of the signal?

Given data: $f_c = 1000\,KHZ$

$f_m = 10\,KHZ$

Solution: B.W of DSB-SC $= 2f_m$

$= 2 \times 10\,KHZ$

$$\boxed{(B.W)_{DSB-SC} = 20\,KHZ}$$

Problem 6: An angle modulated wave is described by the equation $V(t) = 10\cos(2\times10^6\pi t + 10\cos 2000\pi t)$. Find (i) power of the modulated signal (ii) maximum frequency deviation (iii) Bandwidth of the modulated signal.

Given data: $V_c = 10$

Solution :

FM wave is $V_{FM}(t) = V_c \cos\left[2\pi f_c t + m_f \cos 2\pi f_m t\right]$

and $V(t) = 10\cos(2\times10^6\pi t + 10\cos 2000\pi t)$

compare both equation, $V_c = 10$, $m_f = 10$, $2\pi f_m = 2000\pi$

$f_m = 1KHZ$.

(i) power of the modulated signal is carrier.

$$P_c = \frac{V_c^2}{2R} = \frac{10^2}{2\times1}$$

$$\boxed{P_c = 50W}$$

(ii) Maximum frequency deviation

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

$$\Delta f = m_f \times f_m$$

$$\Delta f = 10 \times 1000HZ$$

$$\boxed{\Delta f = 10KHZ}$$

(iii) Bandwidth

$$B.W = 2(\Delta f + f_m)$$

$$= 2\left[10\times10^3 + 1\times10^3\right]$$

$$\boxed{B.W = 22KHZ}$$

Problem 6: For an AM broadcast-band superheterodyne receiver with IF, RF and local oscillator frequencies of 455KHZ, 600 KHZ and 1055 KHZ respectively. Determine a) Image frequency b) IFRR for pre-selector Q of 100

Given data: $f_{RF} = 60KHZ$, $f_{IF} = 455KHZ$, $Q = 100$, $f_{LO} = 1055KHZ$.

Solution:

a) Image frequency

$$f_{IM} = f_{LO} + f_{IF}$$

$$f_{IM} = f_{RF} + f_{IF} + f_{IF}$$

$$f_{IM} = f_{RF} + 2f_{IF}$$

$$f_{IM} = 1055\,KHZ + (455\,KHZ)2$$

$$\boxed{f_{IM} = 1510\,KHZ}$$

b) $IFRR = \sqrt{1 + Q^2 p^2}$

$$p = \left(\frac{f_{IM}}{f_{RF}}\right) - \left(\frac{f_{RF}}{f_{IM}}\right)$$

$$(p = 2.113)$$

$$IFRR = \sqrt{1 + 100^2 (2.113)^2}$$

$$\boxed{IFRR = 212.15}$$

$$(IFRR)_{dB} = 10 \log IFRR$$

$$\boxed{(IFRR)_{dB} = 23.25\,dB}$$

Problem: 7 The carrier 2KHZ is frequency modulated by ~~Sinusoidal Signal of~~ resulting has a frequency deviation of 5KHZ. calculate modulation Index

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

$$m_f = \frac{5 KHZ}{2 KHZ}$$

$$\boxed{m_f = 2.5}$$

~~Problem: for a FM Modulator with a peak frequency deviation $\Delta f = 20KHZ$, a modulating Signal frequency $f_m = 10KHZ$,~~

Problem: 8 FM modulator Signal $V_{FM}(t) = 12 \sin(6\times10^8 t + 2.5 \sin 1250t)$. Find (i) power of the modulated Signal (ii) max frequency deviation (iii) Bandwidth of the modulated Signal (iv) Spectrum of frequency ~~(v) Bandwidth of the modulated Signal.~~

Given data: $V_{FM}(t) = 12 \sin(6\times10^8 t + 2.5 \sin 1250t)$

Solution: General equation $V_{FM}(t) = V_c \sin(2\pi f_c t + m_f \sin 2\pi f_m t)$

$V_c = 12V$, $m_f = 2.5$, $2\pi f_c = 6\times10^8$, $2\pi f_m = 1250$

$f_m = 199.04$ HZ.