UNIT-I

Communication:-

Exchange of information from one system to another system.

Modulation:-

Modulation is the process of varing one (or) more properties of a periodic wave form called the carrier signal, with a modulating signal that typically contains information to be transmitted.

It is used in communication process.

Types of Modulation:-

* Amplitude Modulation
* frequency Modulation
* Phase Modulation.

Amplitude Modulation:-

Amplitude Modulation is modulation technique in which the Amplitude of the carrier is changed in accordance with the instantaneous value of Modulated signal in which frequency and Phase of the signal is constant.

Need of Modulation:-

* Reduction in the height of an anttenaa.
* Avoid the mixing of signals.
* Increases the range of communication.

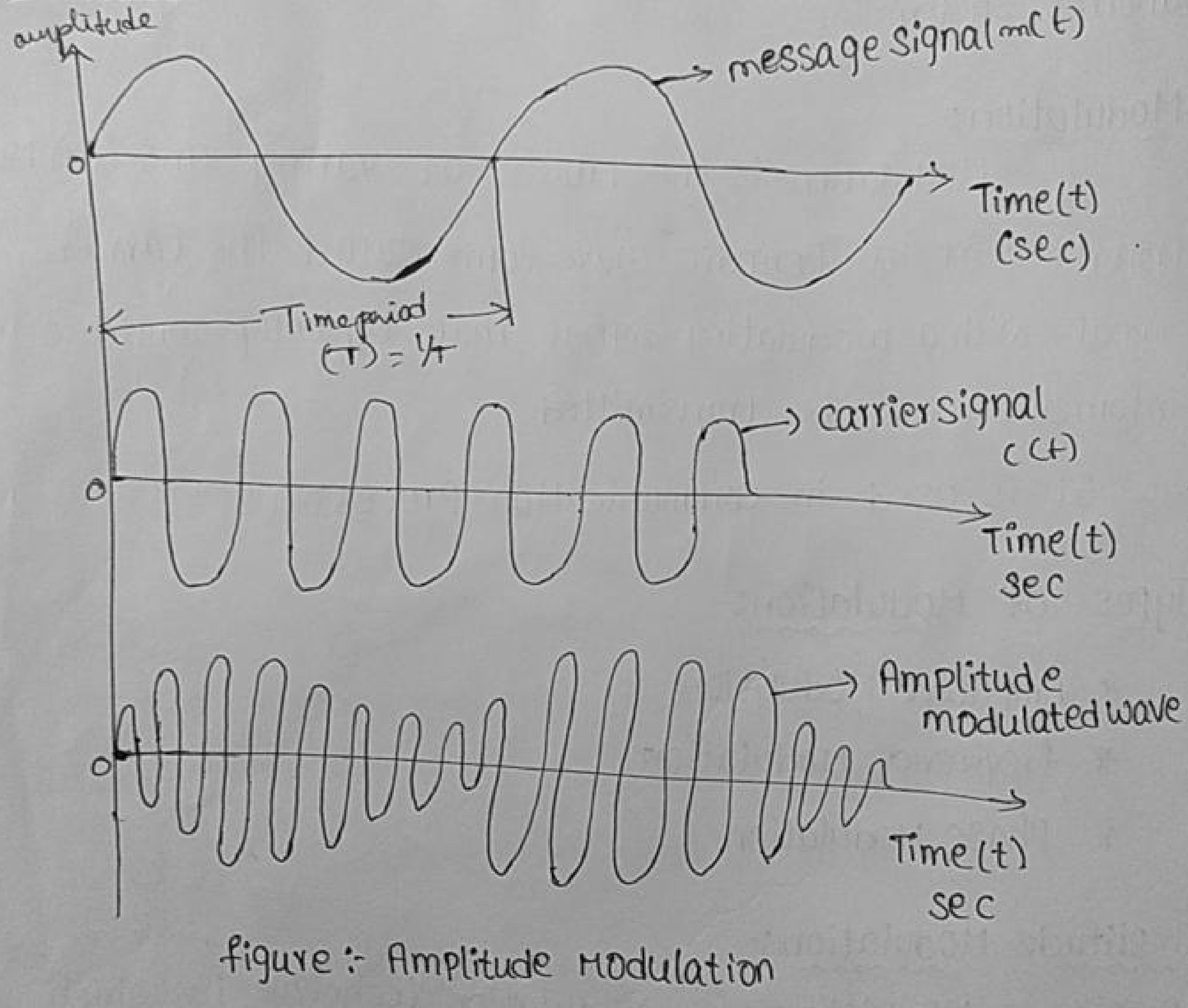

figure :- Amplitude Modulation

Applications :-

* Two way radius
* civil Axiation
* Computers Modems
* wifi rotuers

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frequency Modulation:-

frequency Modulation is a modulation technique in which the frequency of the carrier is changed in accordance with the instantaneous value of Modulated signal in which Amplitude and Phase of signal are constant.

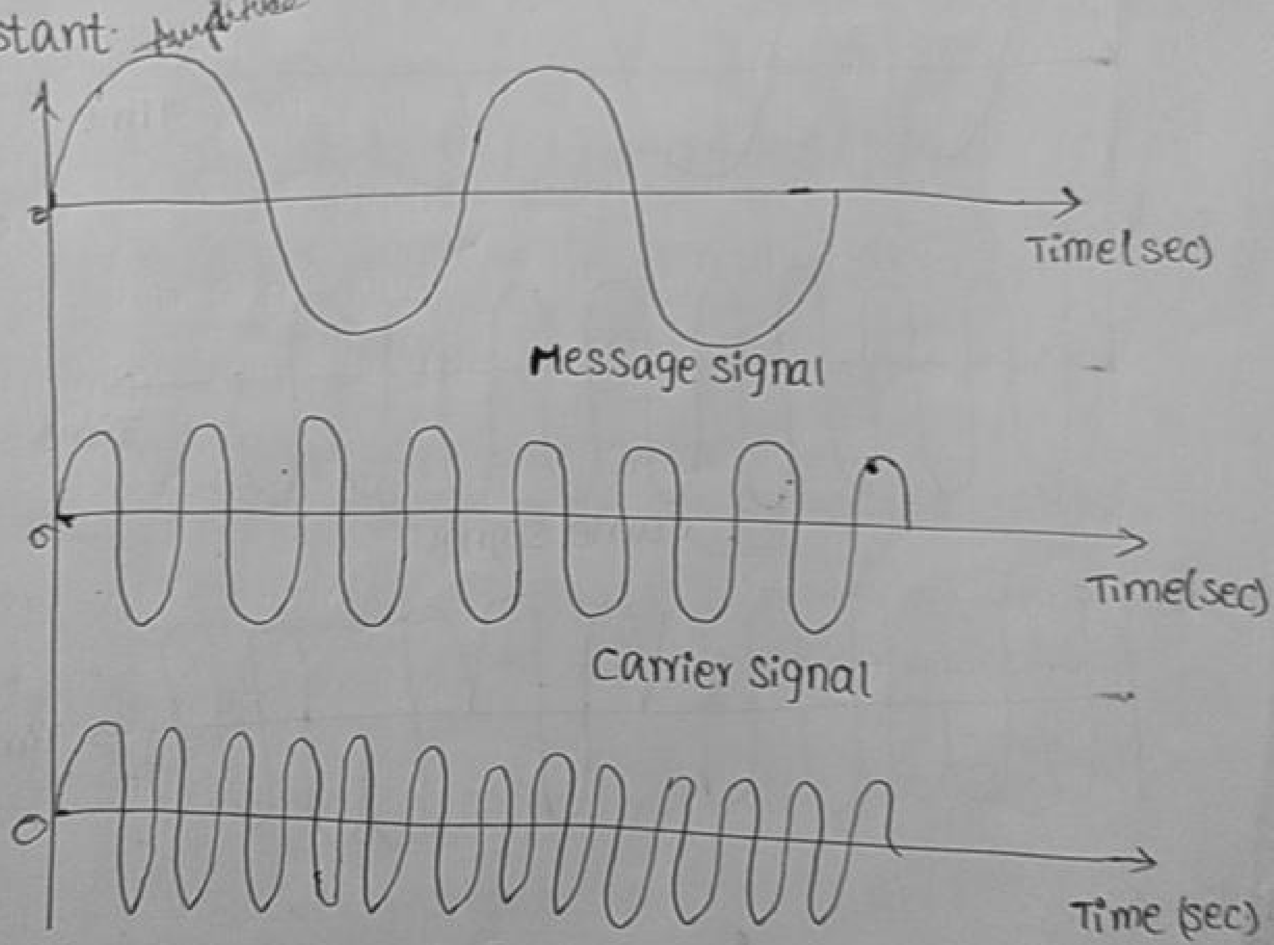


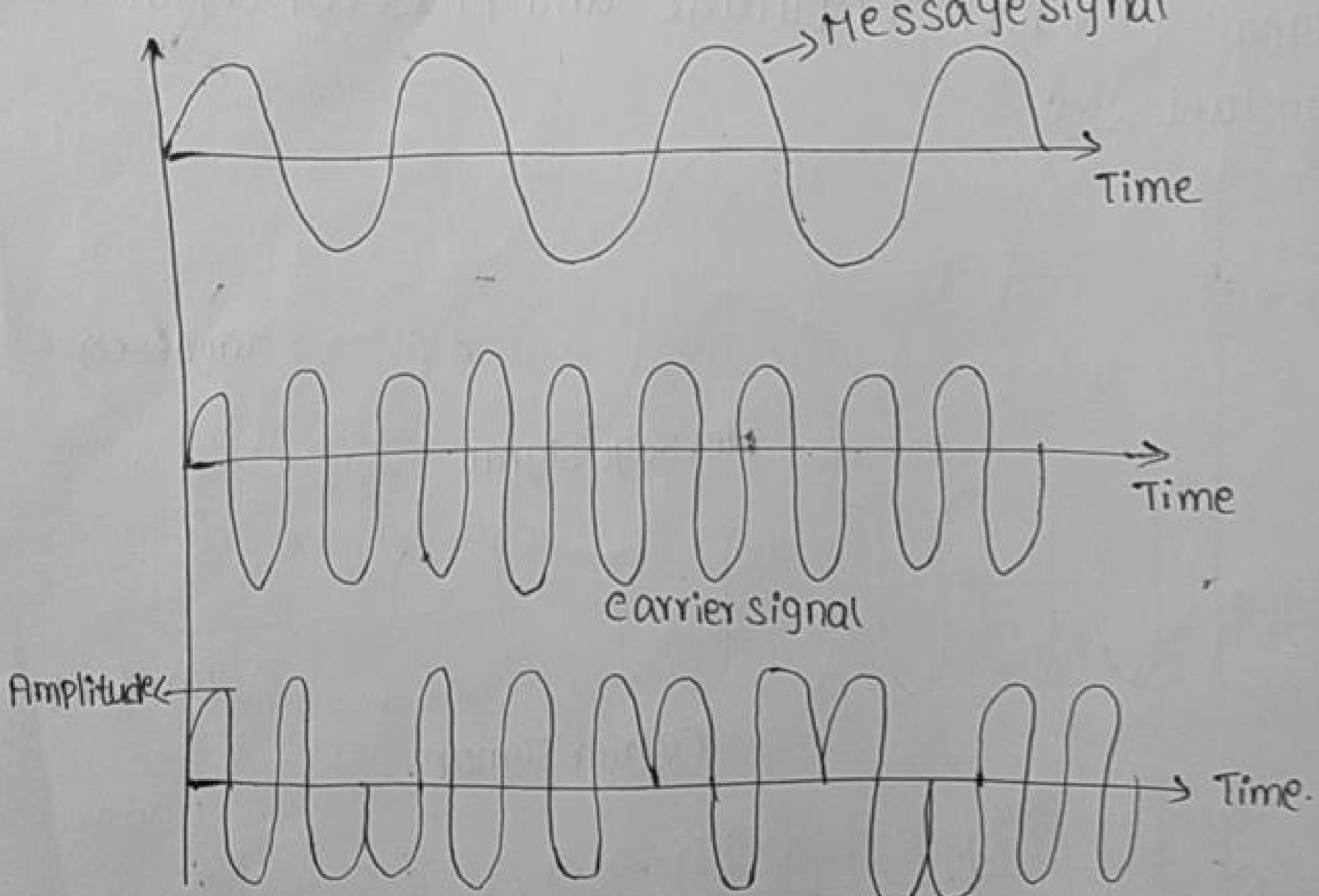
figure :- frequency Modulated signal

Applications :-

* FM radio broad casting
* Radar
* Tape recording systems
* vedio transmission system.

Phase modulation:-

In phase modulation technique in which the phase of the carrier is changed in accordance with the instantaneous value of modulated signal in which Amplitude and frequency are constant



Applications:-

* Transmitting Radio waves
* wifi, Modems and routers.
* GSM
* Signal and wave form synthesizers.
* Long distance communication
* Grand wave communication.

Time Domain Representation of Amplitude Modulation:-

Let us consider the

The Sinusoidal carrier wave $c(t) = A_c \cos(2\pi f_c t)$.

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

→ Amplitude modulated (AM) wave It will be represented in the time as

$$s(t) = A_c[1 + K_a m(t)] \cos(2\pi f_c t)$$

where K_a is the constant It is called sensitivity of due modulator.

Substituting $m(t)$,

$$s(t) = A_c[1 + K_a A_m \cos 2\pi f_m t)] \cos(2\pi f_c t)$$

where μ is modulation index (or) depth of the modulation. $\mu = K_a A_m$.

$$s(t) = A_c \cos(2\pi f_c t) + \mu A_c \cos(2\pi f_m t)] \cos(2\pi f_c t)$$

using: $\cos A \cos B = \frac{1}{2}[\cos(A-B) + \cos(A+B)]$.

→ $s(t) = A_c \cos(2\pi f_c t) + \mu A_c/2 \cos 2\pi(f_c + f_m)t + \mu A_c/2 \cos 2\pi(f_c - f_m)t$.

$A_c \cos(2\pi f_c t)$ ↓ un modulated carrier.

$\mu A_c/2 \cos 2\pi(f_c + f_m)t$ ↓ Upper Side band.

$\mu A_c/2 \cos 2\pi(f_c - f_m)t$ ↓ lower side band.

The 3 components are used in Am.

$$\boxed{S(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t)}$$

* Two Conditions to be satisified are

1. The amplitude $k_a m(t)$ of is always less than unity, that is

$$|k_a m(t)| < 1, \text{ for all}$$

2. The carrier frequency is much greater than the highest frequency component 'ω' of the message signal

$$f_c >> \omega$$

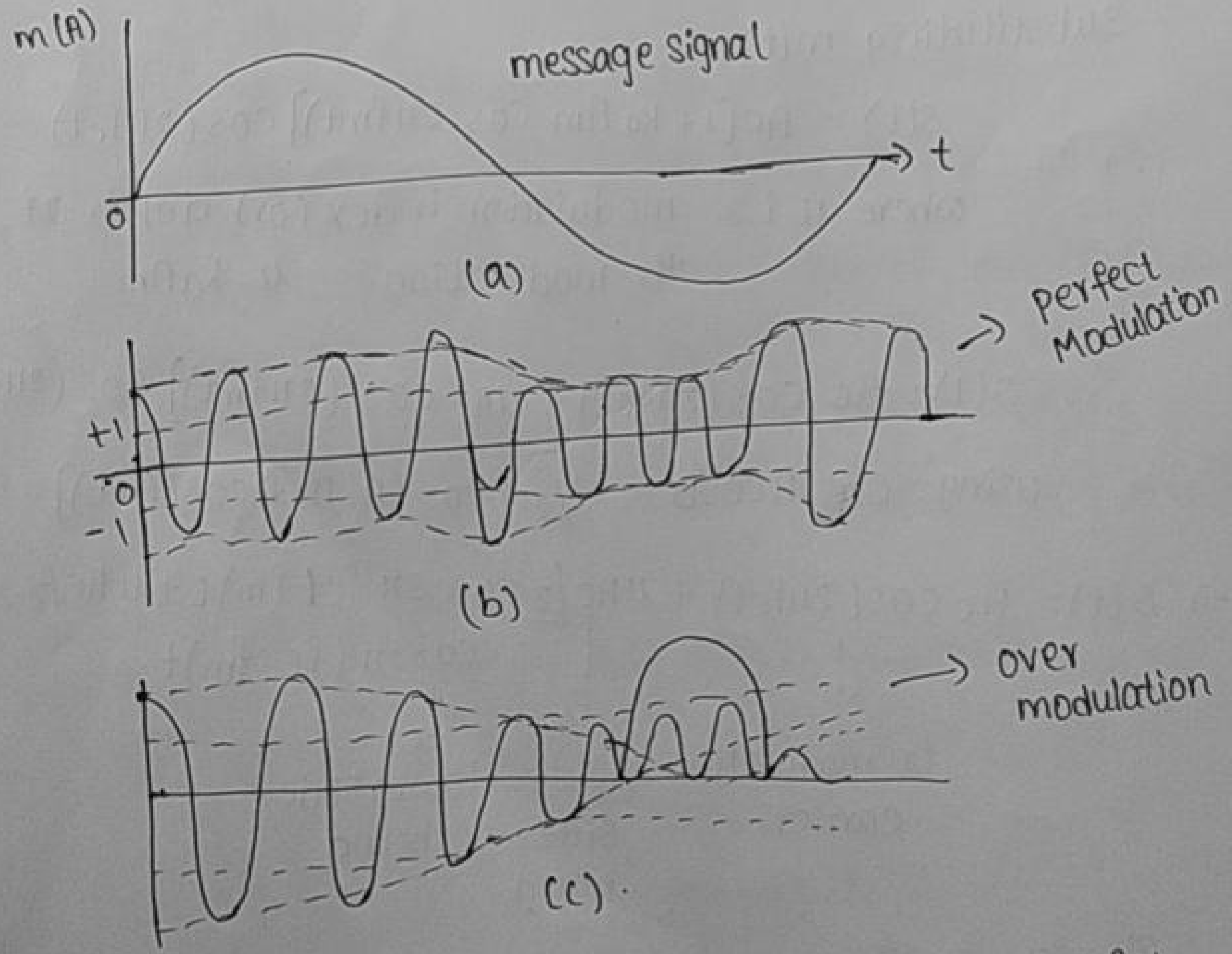


figure: The graphical representation of time domain in AM.

In case

$|K_a m(t)| > 1 \rightarrow$ we usually get due to over modulation

Frequency Domain Representation in Amplitude modulation:-

How to transulate frames time domain into frequency domain we have apply fourier transform for Time domain Equation then we get frequency Domain representation.

let us consider

$$m(t) \rightleftharpoons M(f)$$

Message signal

fourier transform.

where $M(f)$ is called the Message spectrum.

from the Equation $s(t) = A_c[1 + k_a m(t)] \cos 2\pi f_c t$,

due to fourier transform (or) spectrum of due AM wave is given by

$$S(f) = \frac{A_c}{2}[\delta(f - f_c) + \delta(f + f_c)] + \frac{k_a A_c}{2}[M(f - f_c) + M(f + f_c)].$$

we have used the relations:-

$$\cos(2\pi f_c t) = \frac{1}{2}[\exp(j2\pi f_c t) + \exp(-j2\pi f_c t)]$$

$$\exp(j2\pi f_c t) \rightleftharpoons \delta(f - f_c)$$

and

$$M(f) \exp(j2\pi f_c t) \rightleftharpoons M(f - f_c).$$

The graphical representation of frequency Domain in AM is

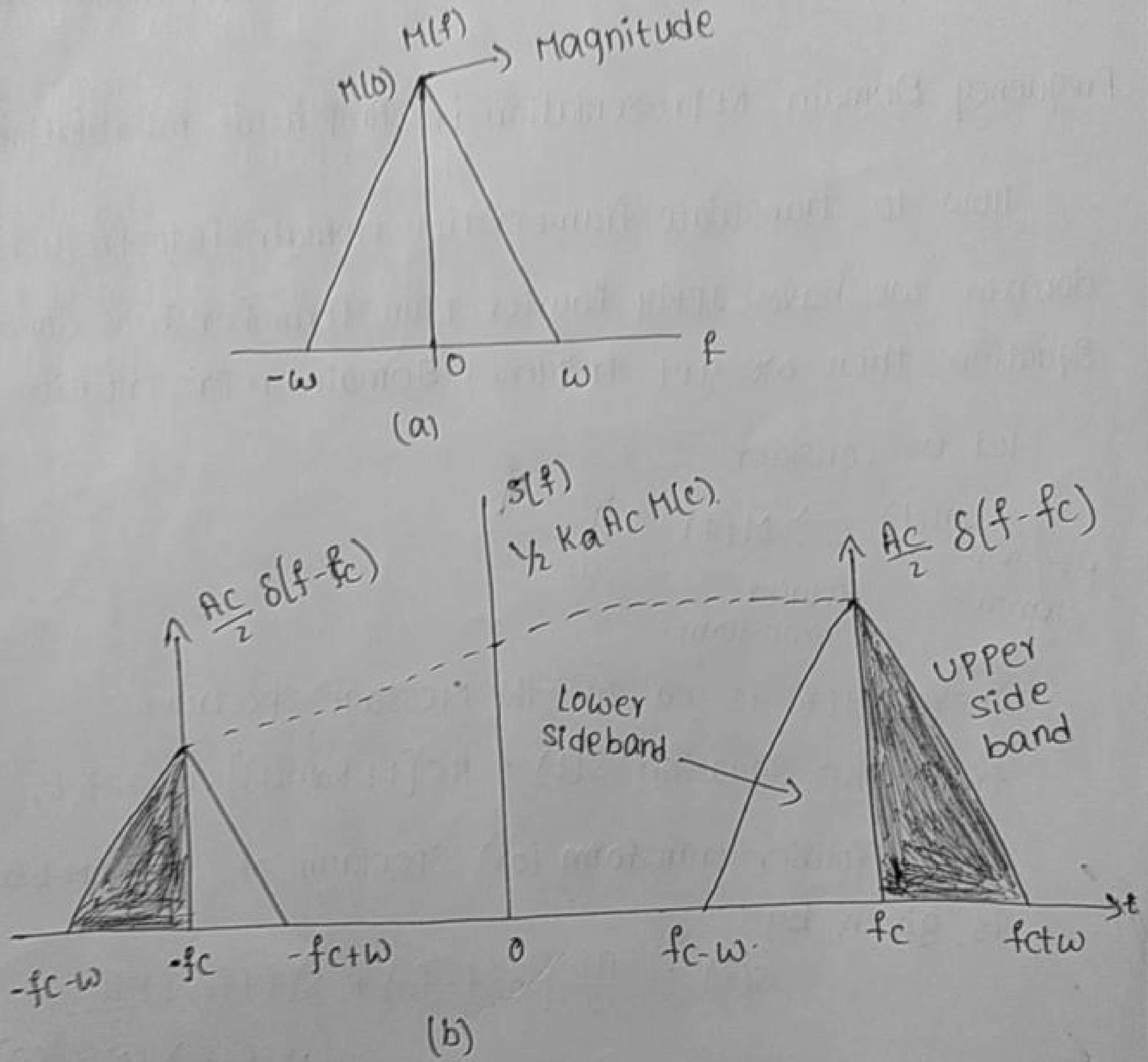
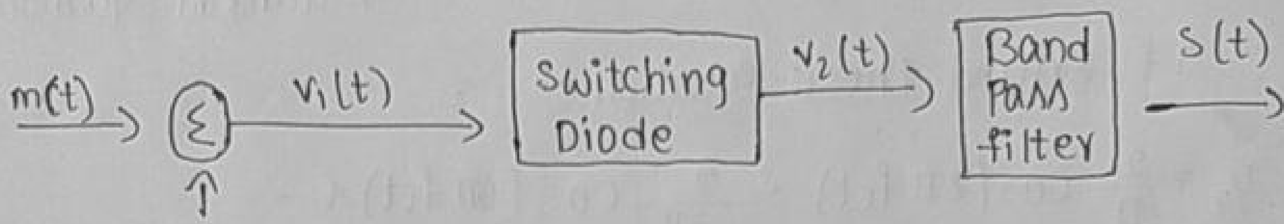


figure (a) spectrum of Message signal m(t) (b)

(b) spectrum of AM Wave s(t).

Switching Modulation :-

It is a linear Property.



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

It is much greater than m(t).

$$v_1(t) = m(t) + A_c \cos(2\pi f_c t)$$

$$c(t) >> m(t)$$

→ The diode it acts as switch either ON switch (or) off switch.

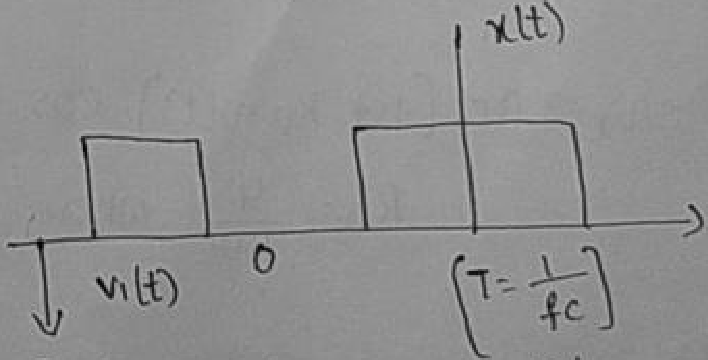
$c(t) > 0$ → The diode forward bias " ON Switch"

$c(t) < 0$ → Diode is in reverse bias " Off Switch".

$$v_2(t) = \begin{cases} v_1(t), & c(t) > 0 \rightarrow \text{Diode is in F.B is ON switch.} \\ 0, & c(t) < 0 \rightarrow \text{Diode is in R.B is Off switch.} \end{cases}$$

$$v_2(t) = v_1(t)\, x(t).$$

x(t) is the perodic pulse Train



It having the Time Period.

To Providing Am. wave form by using the Switching Modulator.

$$v_2(t) = v_1(t)\, x(t)$$

$$x(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos(2\pi(2n-1) f_c t)$$

$\longrightarrow$ standard Equation.

If Expand these Equation

$$= \frac{1}{2} + \frac{2}{\pi} \cos(2\pi f_c t) - \frac{2}{3\pi} \cos(6\pi f_c t) + \cdots$$

$$v_2(t) = [m(t) + A_c \cos(2\pi f_c t)]\left[\frac{1}{2} + \frac{2}{\pi} \cos(2\pi f_c t) - \frac{2}{3\pi} \cos(6\pi f_c t) + \cdots\right]$$

Expanded form of the $v_2(t)$

$$v_2(t) = \frac{A_c}{2}\left(1 + \left(\frac{4}{\pi A_c}\right) m(t)\right) \cos(2\pi f_c t) + \frac{m(t)}{2} + \frac{2A_c}{\pi} \cos^2(2\pi f_c t) - \frac{2m(t)}{3\pi} \cos(6\pi f_c t) - \frac{2A_c}{3\pi} \cos(2\pi f_c t) \cos(6\pi f_c t) + \cdots$$

AM wave Equation.

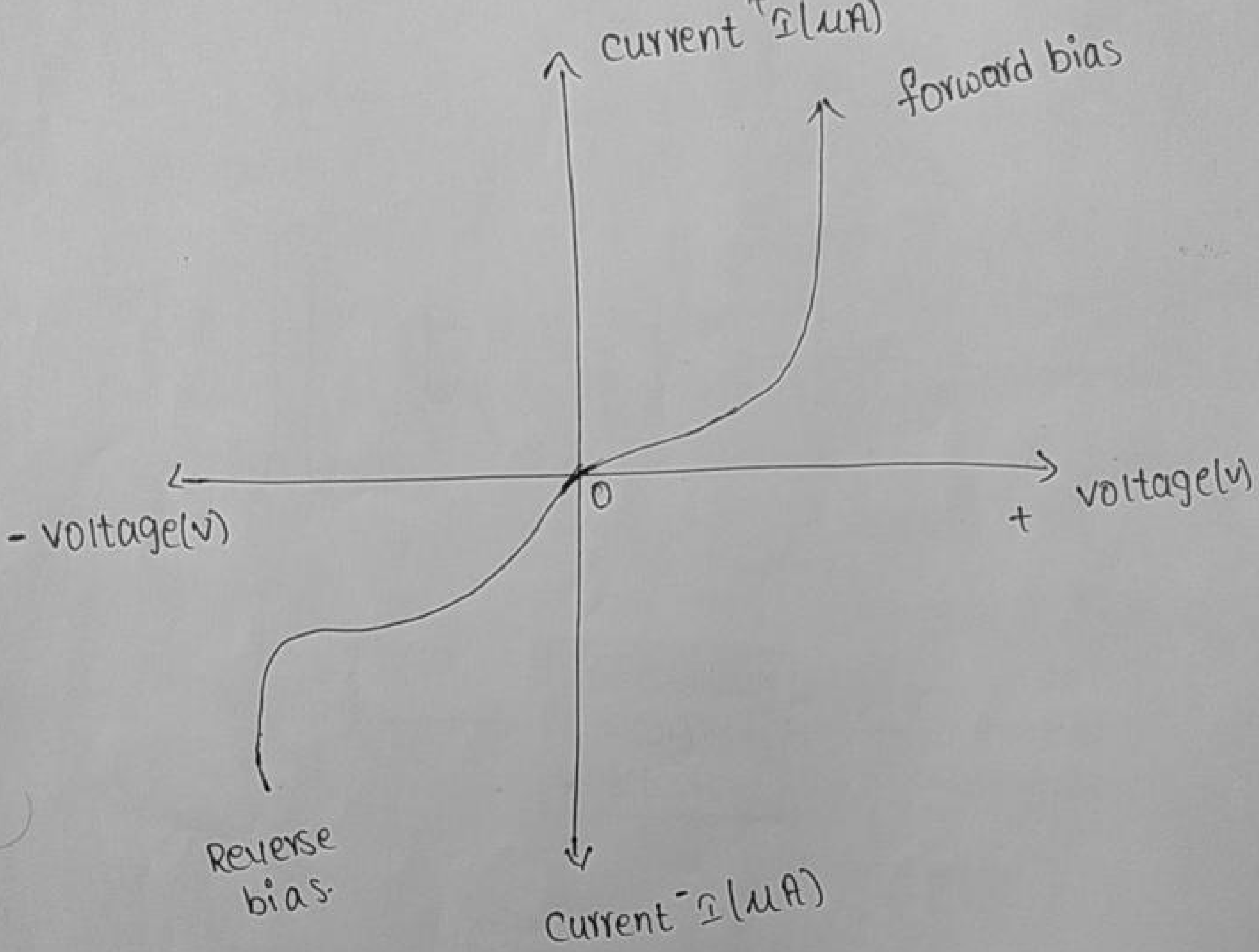
These travels will be cuting by the band Pass filter and give the orginal AM wave

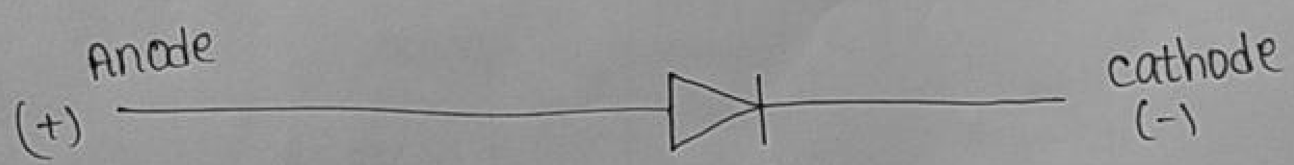
$$s(t) = \frac{A_c}{2}\left(1 + \left(\frac{4}{\pi A_c}\right) m(t)\right) \cos(2\pi f_c t)$$

$$s(t) = A_c [1 + K_a m(t)] \cos(2\pi f_c t)$$

$K_a = \frac{4}{\pi A_c}$ where K_a is amplitude sensitivity.

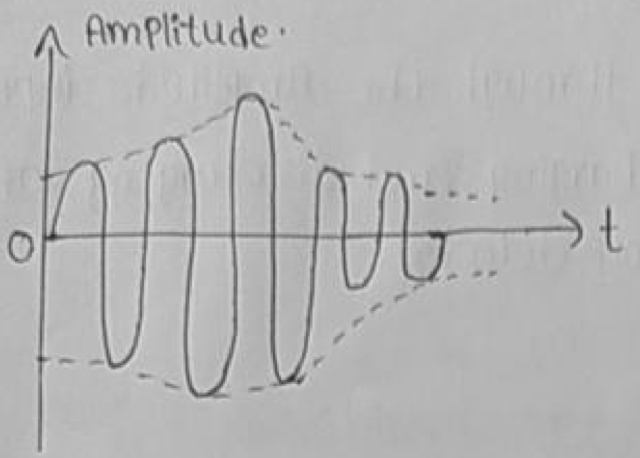
The graphical representation of the Diode.

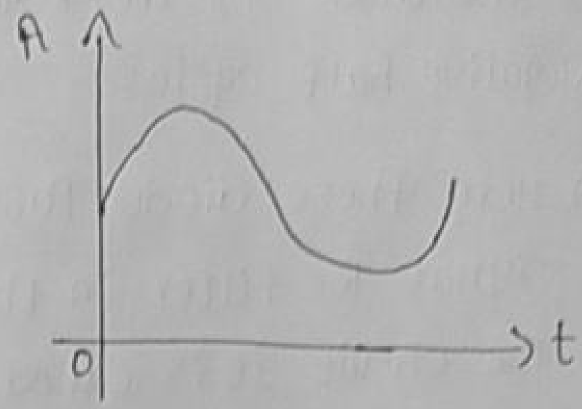


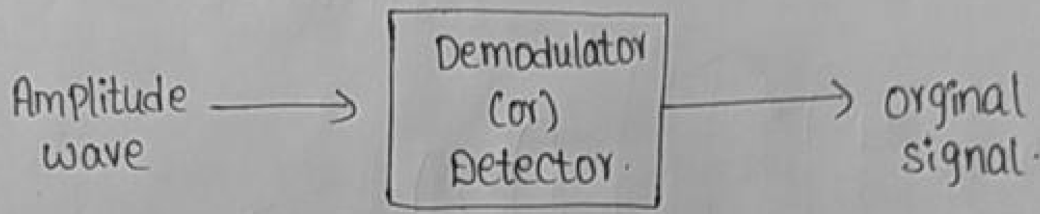


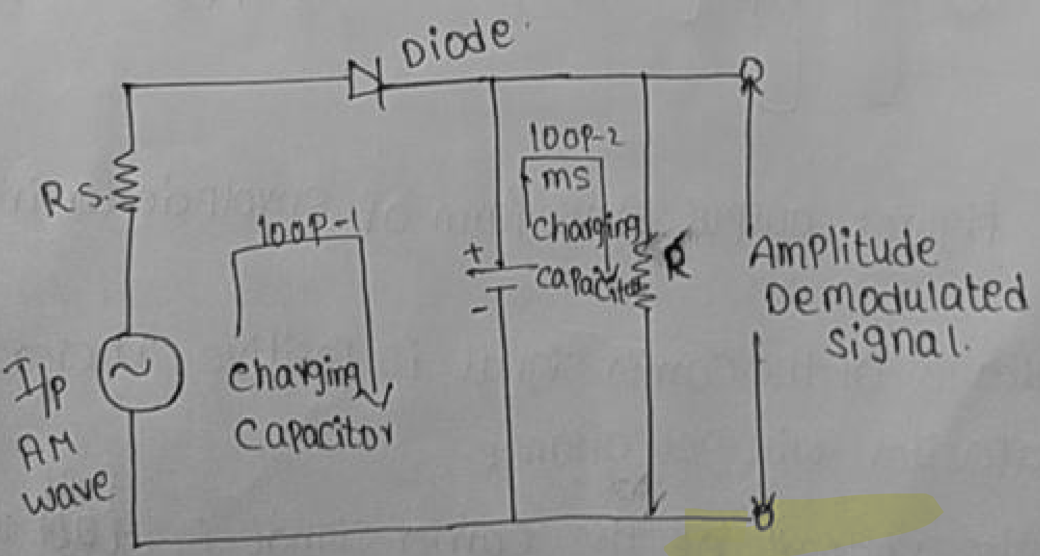
Envolp detector in Amplitude Detection:-

Amplitude Wave









The working Principle of Envolp detector here in this the input signal i.e amplitude modulation wave is given to the diode(D). In this the diode it act as rectify the diode clipping the Negative half cycles in the diode is the forward

Bias Condition. It will be in Positive half cycles.

→ The diode is in Reverised bias Condition. It will be in Negative half cycles.

→ Here these diode Passing through the Amplitude input signal RC filter in the Charging and dis charging of the circuit it is called Envolp detector.

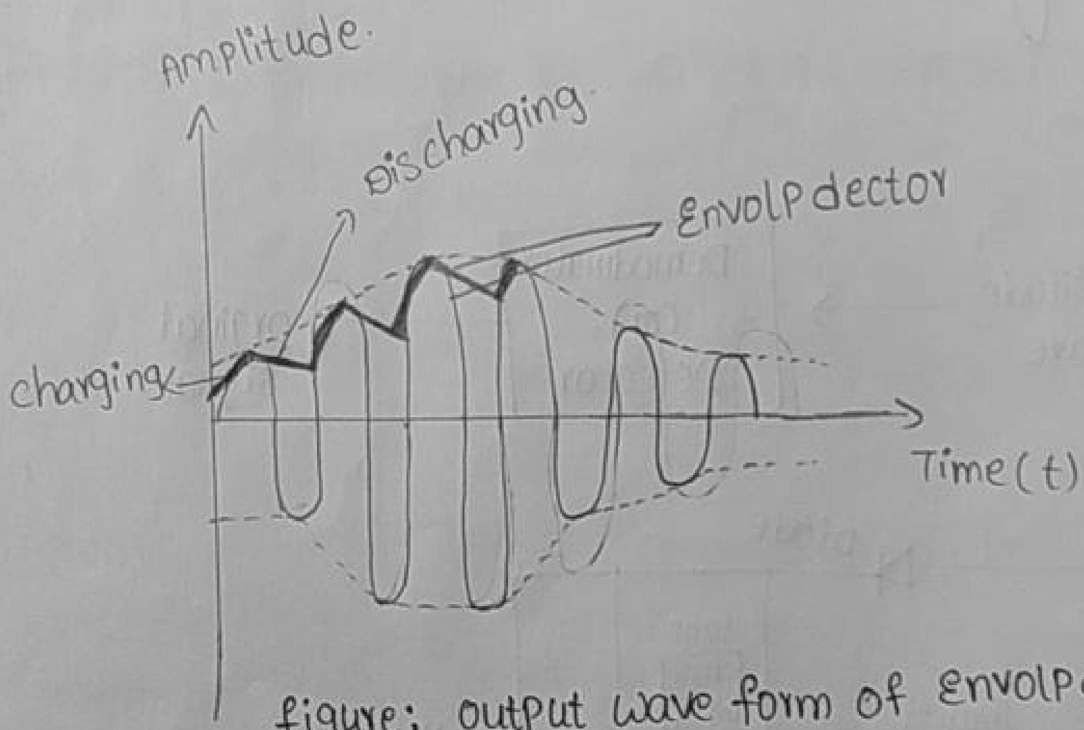


figure: output wave form of Envolp dector in Am.

→ The voltage of the carrier signal is Positive Increasing that capacitor will get change.

→ when the voltage of the carrier signal is ~~fall~~ fall then that capacitor will get discharge.

→ The capacitor will be act as a charging and discharging so it is called as Envolp detector.

→ During Charging and discharging of the capacitor conditions is called as Envolp detector.

→ The following conditions should be satisfied during charging R_SC

$$R_{S}C << \frac{1}{f_c}$$

→ During discharging RC → It is should very large

$$\frac{1}{f_c} << RC$$

maximum modulating frequency.

$$\boxed{RC < \frac{1}{f_m}}$$

Explain Need of Modulation :-

we have seen that baseband signals are incompatible for direct Transmission over the Medium and therefore we have to use modulation Technique for the communication of base band Signal.

* Reduce the height of antenna.
* Avoid of mixing signals.
* Increase the range of Communication.
* Allows multiplexing of Signals.
* Improves quality of reception.

Explain DsbSc ?

* Reduce the height of the antenna.

The height of the antenna required for Transmission and reception of radio waves in radio transmisson of wavelength of the frequency used. The minimum height of the antenna is given as $\lambda/4$

$\lambda = c/f$ Where
c is the velocity of light
f is the frequency.

* Avoid Mixing of Signals :-

All sound signals are concentrated with in the range from 20 Hz to 20 KHz. The transmission is baseband signals from various sources casuses the mixing of signal and it is difficult to seperate at the receiver end.

* Increase the range of Communication :-

At low frequencies radiation is Poor and signal gets highly attenuated. The signals cannot be transmitted directly over long distance. Modulation effectively increases the frequency of the signal increases the distance over which signals can be transmitted faithfully.

* Allows multiplexing of Signals :-

Multiplexing Means Transmission of two or more signals over a same channel. The example of multiplexing are the Number of Television Channels operating simultaneously or Number of radio broad casting the signal in MW and SW band, simultaneously.

* Improve quality of reception :-

The signal communication using Modulation techniques such as frequency and pulse code Modulation reduce the effect of Noise. Reduction in noise improves the quality of reception.

Explain DSbSC ?

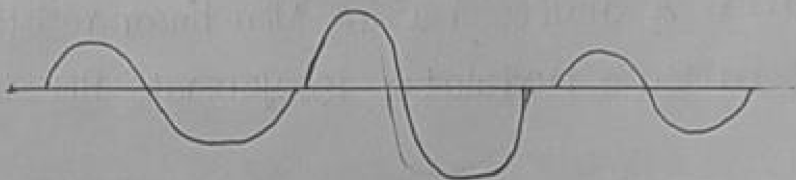
DSbSC Means :- DOuble Sideband Suppressed carrier.

→ In this the carrier is amplitude modulated by a single sine wave, the resulting signal consists of three frequencies i.e.. orginal carrier and two side bands ($f_c \pm f_m$).

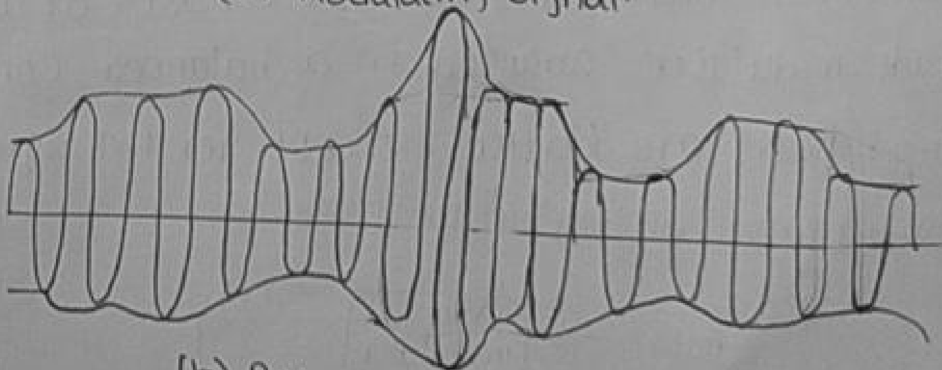
→ In the normal AM systems, both side bands and carrier are transmitted. The carrier system signal doesnot convey any information.

→ When carrier is removed, the remaining signal contains simply upper and lower side bands such as signal is reffered to as a DSBSC signal.

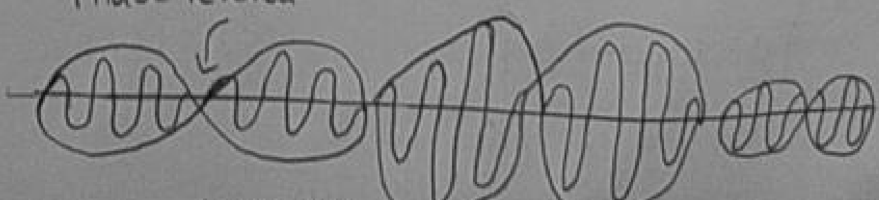
→ This signal No Power is wasted on the carrier and saved Power can be Put into the sidebands for stronger signals over longer distances.



(a) Modulating signal.



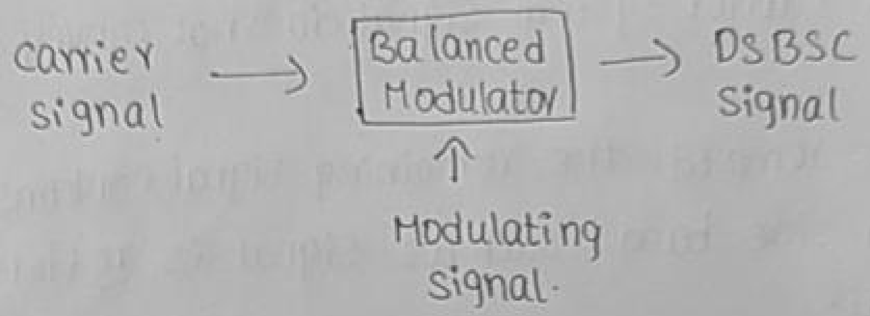
(b) AM wave.



(c) Suppressed - carrier - wave.

Balanced Modulator using Diode (or) ring Modulator:-

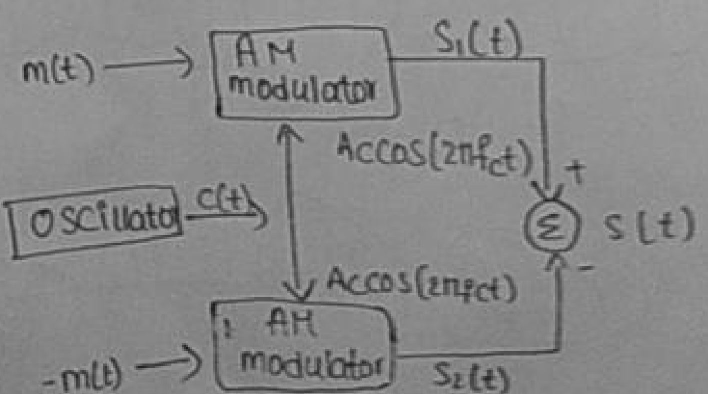
The balanced Modulator circuit is used to suppress the carrier from the AM signal. The inputs to a balanced modulator are the carrier and a Modulating signal. The outputs of a balance modulator are the upper and lower side bands.



Principle used in Balanced Modulator

When two signals at different frequencies are passed through a Non-linear resistance, the AM signal is generated with supressed carrier. A device having Non-linear resistance such as diode used in the balanced Modulator to generate AM signal with suppressed carried.

The balanced modulator circuit. It consists of two standard amplitude modulators arranged in a balanced configuration. The two modulators are identical, except for the sign reversal of the modulating wave applied to the input.



The outputs of the two modulators

$$s_1(t) = A_c[1+k_a m(t)]\cos(2\pi f_c t)$$
$$s_2(t) = A_c[1-k_a m(t)]\cos(2\pi f_c t)$$

$$s(t) = s_1(t) - s_2(t)$$
$$= 2k_a A_c \cos(2\pi f_c t)\, m(t)$$

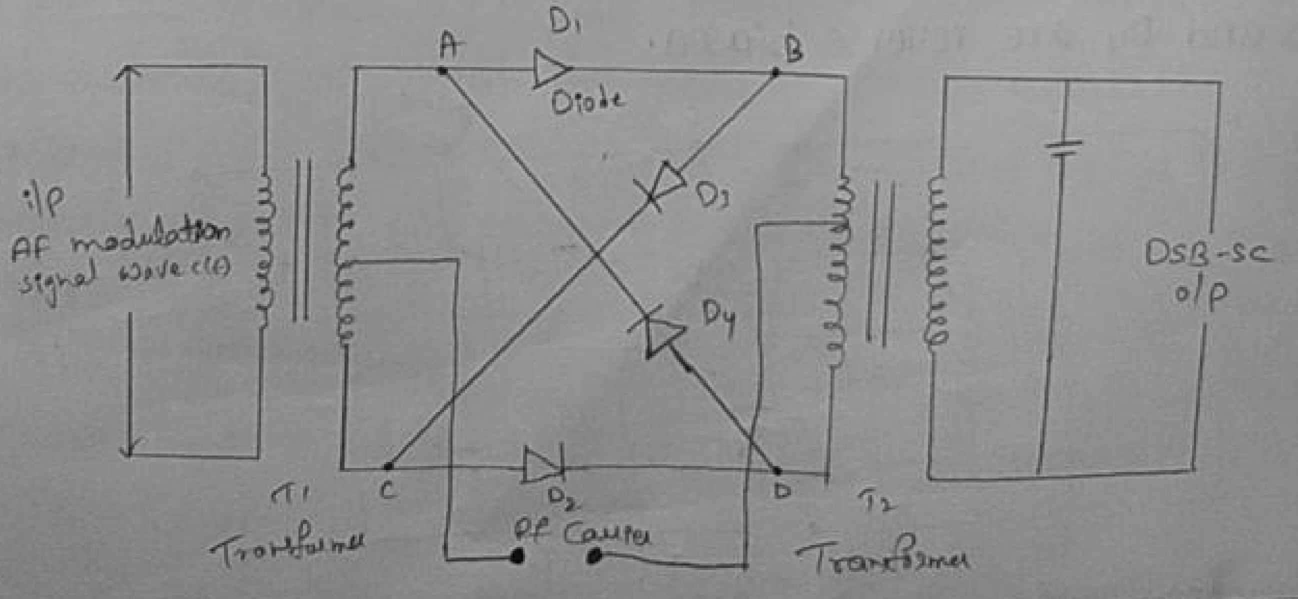
The scaling factor $2k_a$, the balanced modulator output is equal to the product of the modulating and the carrier.

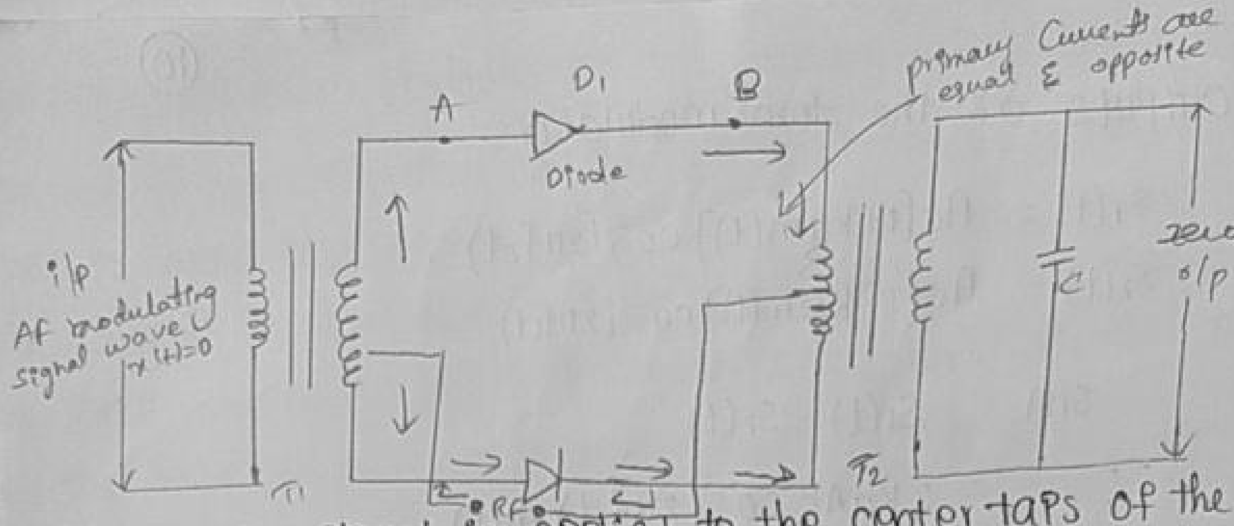
The methods used for suppression of carrier can be classified as.

* using diode, ring or lattice modulator
* using JFET modulator.

Balanced Modulator using diodes or Ring Modulator

The widely used balanced Modulator, diode ring or lattice modulator It consists of an input transformer T_1, an output Transformer T_2 and four diodes are connected in a bridge circuit.



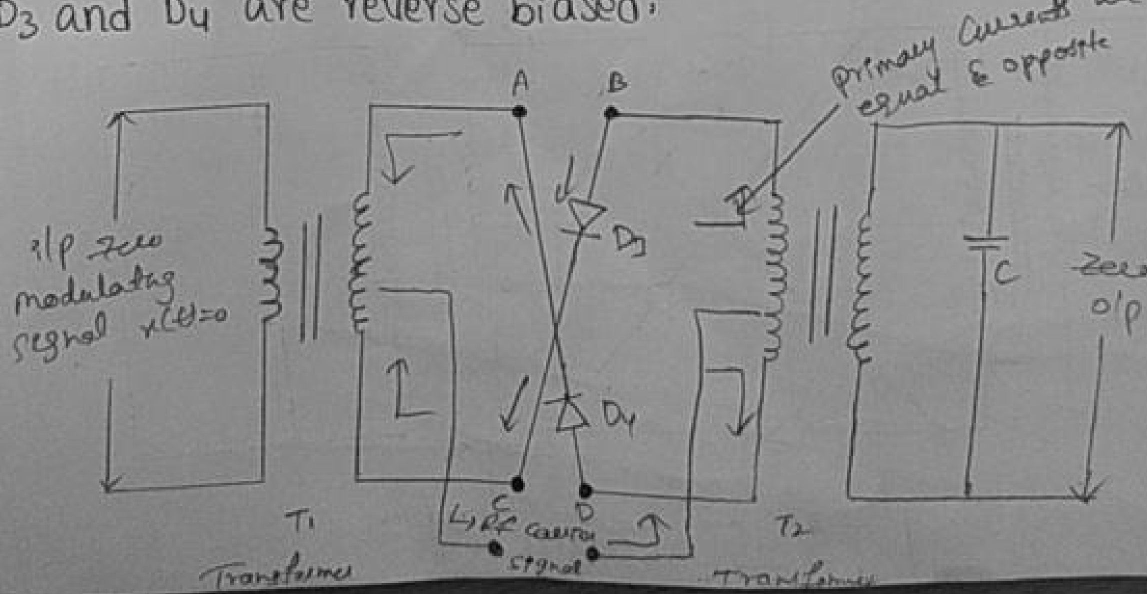


The carrier signal is applied to the center-taps of the input and output Transformers and modulating signal is applied to the input transformer T_1. The output appears across the secondary of the transformer.

The diodes connected in the bridge is like switches, and their switching is controlled by the carrier signal as it is used in higher in frequency and amplitude than modulating signal.

Positive half cycle of carrier signal :-

The working of the circuit we first assume that the modulating input is zero. In the positive half cycles of the carrier signal diodes D_1 and D_2 are forward biased and diodes D_3 and D_4 are reverse biased.



The upper and lower Portions of the Primary winding of T_2. The current in the upper Part of the winding Produces a Magnetic field that is equal and opposite to the Magnetic field Produced by the current in the lower half of the secondary. The Magnetic fields are equal and opposite, they cancel each other, Producing no output at the secondary of T_2. The carrier is suppressed.

Negative half of carrier signal:-

In negative half cycle diodes D_1 and D_2 are reverse biased and diodes D_3 and D_4 are forward biased. To positive half cycles here also magnetic fields in the Primary winding of T_2 are equal and opposite canceling each other.

The suppression of the carrier in both the half cycles depends on the matching of diode characteristcs and precision of center tap of the Transformers to give exactly equal upper and lower currents and Magnetic fields.

With Modulating signal

The low frequency sine wave is applied to the Primary of T_1 as the modulating signal The signal will apprear across the T_1 secondary. The Positive half cycles diodes D_1 and D_2 are forward biased and they will connect the secondary of T_1 to the Primary of T_2

The ring Modulator is more ideal when carrier is a square wave In case of square wave carrier is represented by a fourier series as.

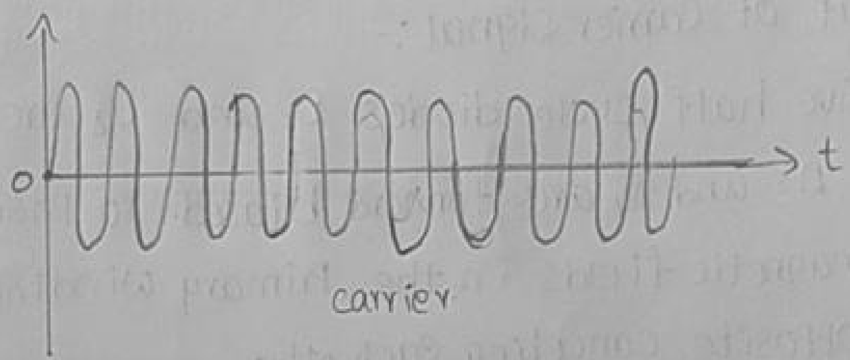
$$c(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos\left[2\pi f_c t (2n-1)\right]$$

W.K.T for DSBSC

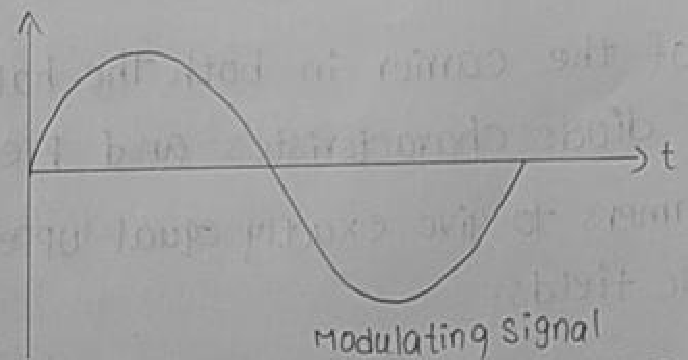
$$s(t) = c(t)\, m(t)$$

Substituting value of $c(t)$ we get

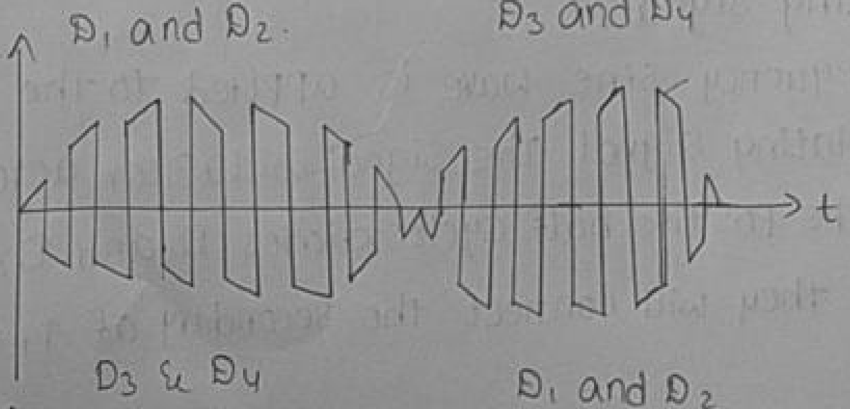
$$s(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos\left[2\pi f_c t (2n-1)\right] m(t).$$

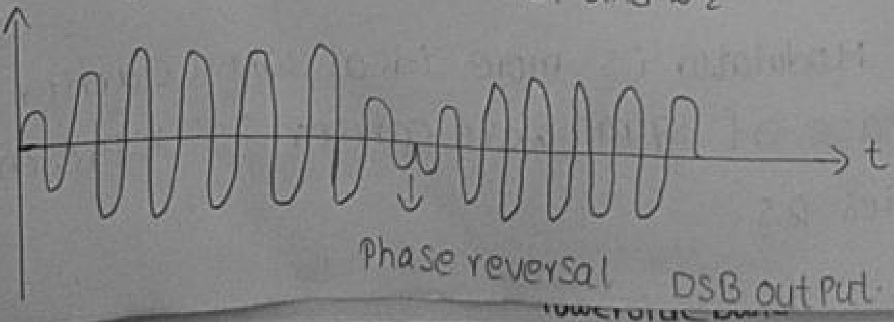


carrier



Modulating signal

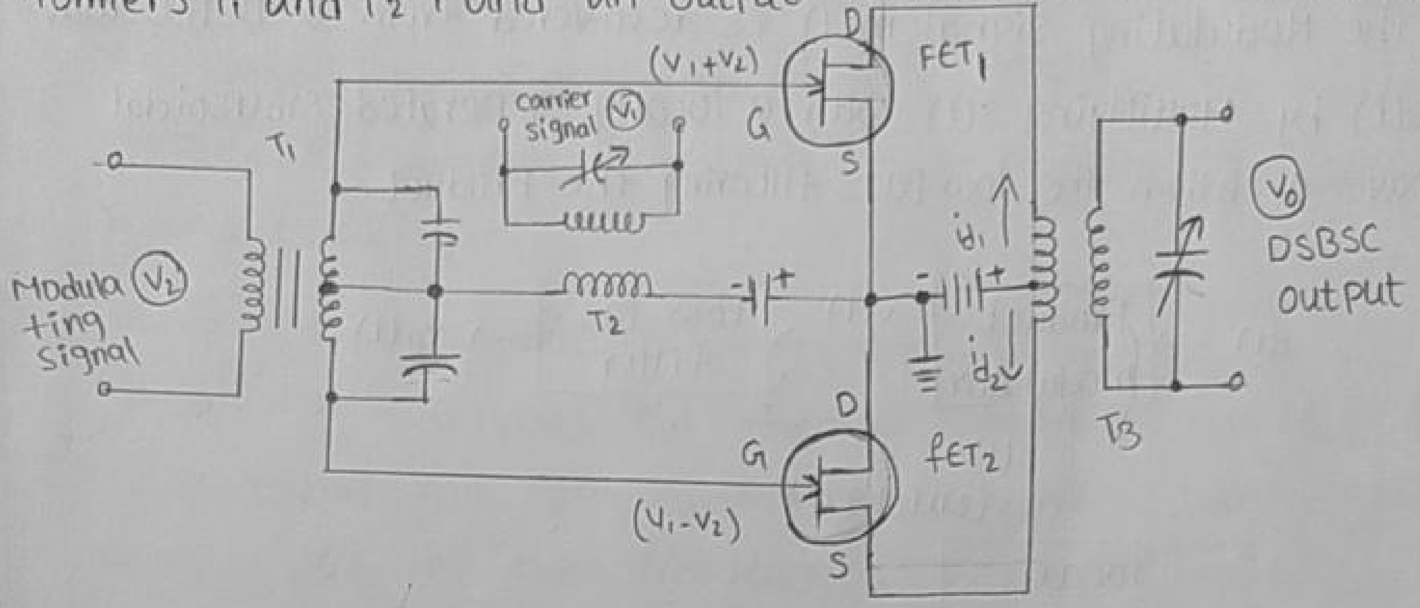




DSB out Put.

Balanced Modulator using fets

The balanced modulator circuit. It consists of an input trans formers T_1 and T_2, and an output transformer T_3, and two fets



Balanced Modulator using FET.

The carrier Signal is applied to the center taps of the input(T_1) and output (T_3) transformers through the transformer T_2. The modulating signal is applied to the input Transformer T_1. The carrier voltage is applied to the two gates in phase; whereas the modulating voltage appears 180° out of phase at the gates, since these are at opposite ends of a center Tapped transformer. The carrier signal are Equal in amplitude but opposite in the directions.

Mathematical Analysis of Balanced Modulator

$$i_d = I_0 + a v_{gs} + b v_{gs}^2$$

$$i_{d_1} = I_0 + a v_{gs_1} + b v_{gs_1}^2$$

$$i_{d_2} = I_0 + a v_{gs_2} + b v_{gs_2}^2$$

$$v_{gs_1} = V_1 + V_2$$

$$v_{gs_2} = V_1 - V_2$$

Modulation frequency

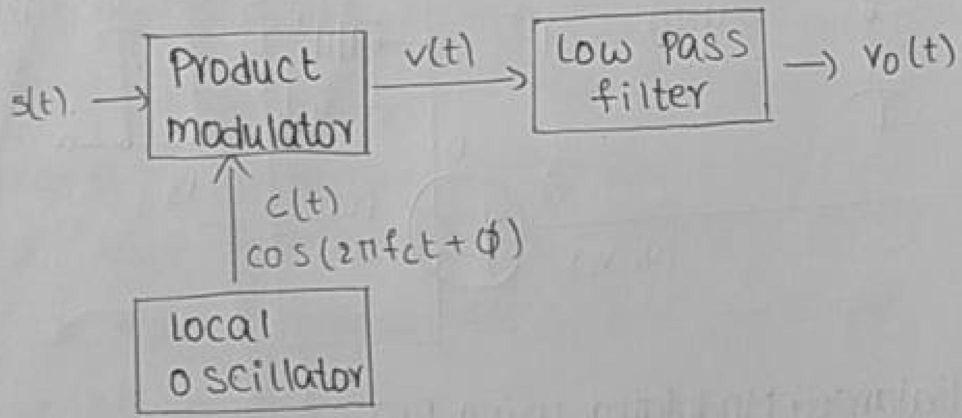
upper side band.

$$V_0 = P\sin\omega_m t + Q\cos(\omega_c - \omega_m)t - Q\cos(\omega_c + \omega_m)t$$

lower side band

Coherent Detector :-

The Modulating signal m(t) is recovered from a DSBsc wave s(t) by Multiplying s(t) with a locally generated Sinusoidal wave and then the low pass filtering the Product.



$$v(t) = \frac{1}{2} A_c \cos\phi \, m(t) + \frac{1}{2} A_c \cos(4\pi f_c t + \phi) m(t)$$

The output consists of two terms: scaled version of message signal and unwanted term. The unwanted term is removed with the help of low-pass filter. The overall output Vo(t) is therefore

$$V_o(t) = \frac{1}{2} A_c \cos\phi \, m(t).$$

When Phase error ϕ is constant, the demodulated Signal Vo(t) is Proportional to m(t). is maximum when $\phi = 0$ and when $\phi = \pm \pi/2$. The zero demodulated signal, which occurs for $\phi = \pm \pi/2$, represents the quadrature null effect of the coherent detector.

Therefore, it is necessary to provide additional circuitry to maintain the local oscillator in Perfect synchronism, in both frequency and Phase, with the carrier wave is used to generate the DSBSC modulated wave in the Transmitter.

SSB Modulation :-

When the carrier is amplitude modulated by a single sine wave, the resulting signal consists of three frequencies i.e original carrier and two side bands ($f_c \pm f_m$). In the normal AM system, both sidebands and carrier are transmitted. The system is commonly known as Double sideband full carrier system (DSBFC).

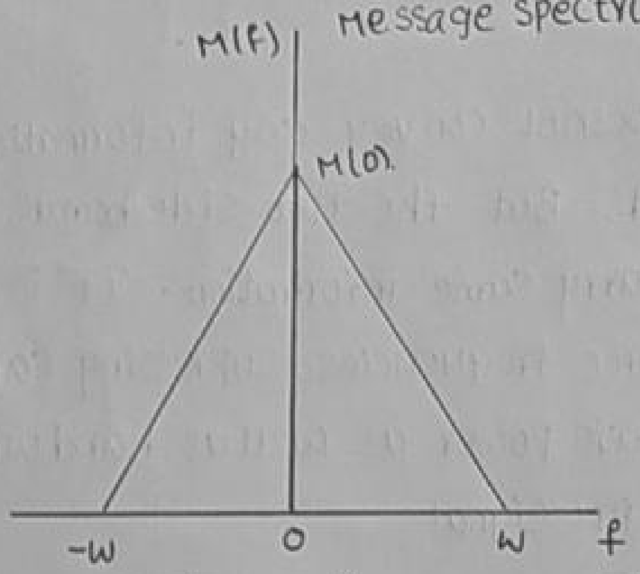
The carrier signal doesnot convey any information. The information carried by sidebands. But the two side bands are the images of eachother and carry same information. It is not necessary to transmit all the three frequencies. Supressing carrier or any one side band we can save power as wellas bandwidth required for Transmission of the AM signal

AM more efficient we can simply no reason why it has to be Transmitted. with the signal no power is wasted on the carrier and the saved power can be put into the sidebands for stronger signals and over long distances.

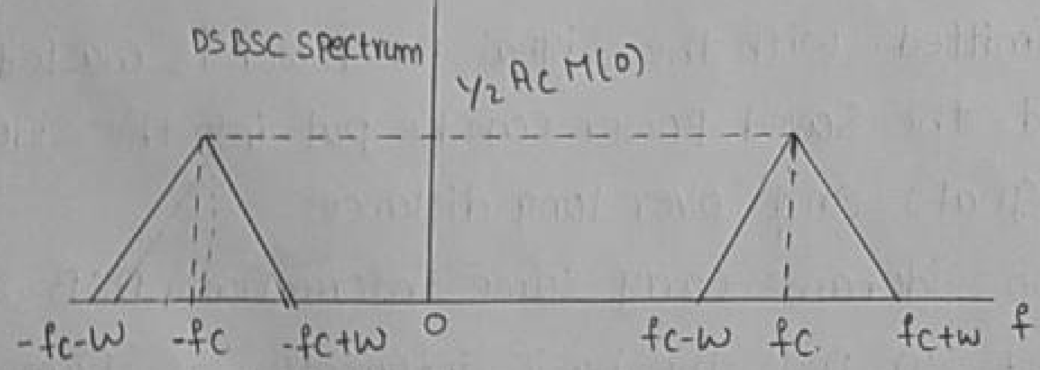
The two sidebands carry same information, DSB signal is redundant. In DSB the basic information is transimitted twice in each side band, there is absolutely no reason to transmit both side bands in order to convey the information. One side band may be suppressed. The resulting signal is side band commonly reffered to as single side band suppressed carrier (SSBSC) signal.

Frequency Domain Description in SSB :-

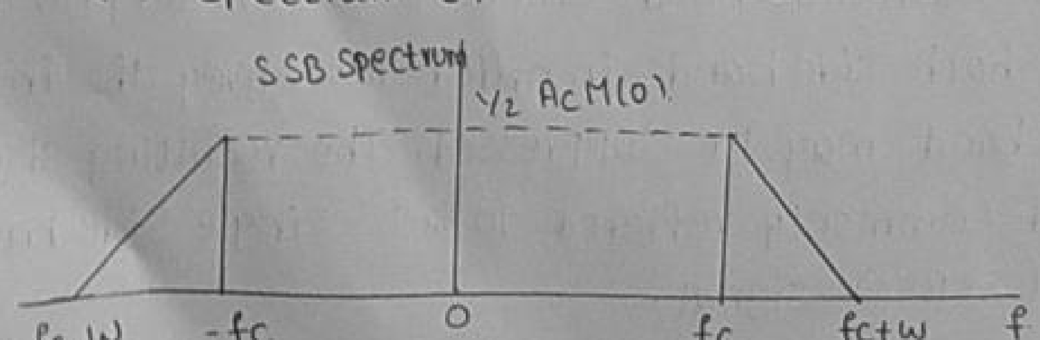
The frequency - domain display of a Single - Side band (SSB) modulated wave depends on which Side band is Transmitted. Spectrum $M(f)$ of the modulating signal. The Spectrum is limited to the band $-W \leq f \leq W$.



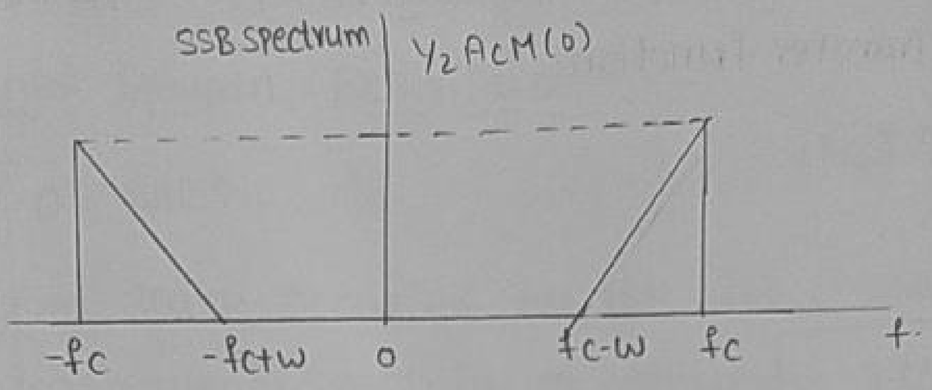
Spectrum of message signal



(b) Spectrum of DSBSC modulated wave.



(c) Spectrum of SSB Modulated wave with upper Side band Transmitted.



Time Domain Description in SSB Modulation:-

The SSB signal may be generated by passing a DSBSC modulated wave through band-pass filter of Transfer function $H_u(f)$

The DSBSC modulated wave is defined Mathematically as,

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

$m(t)$ = Message Signal

$A_c \cos(2\pi f_c t)$ = Carrier wave.

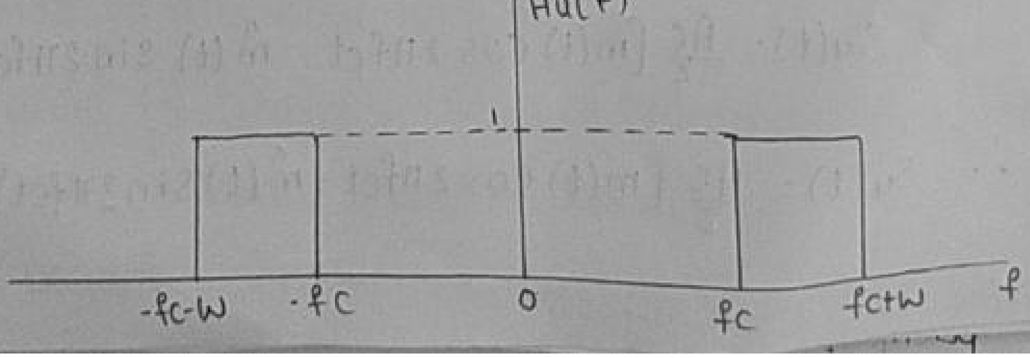
$$\tilde{S}_{DSBSC}(t) = A_c\, m(t)$$

The $S_u(t)$ can be expressed in terms of Complex envelope

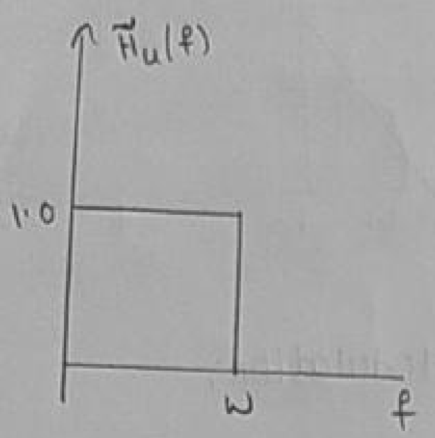
$$S_u(t) = \mathrm{Re}\left[\tilde{S}_u(t) \exp(j 2\pi f_c t)\right]$$

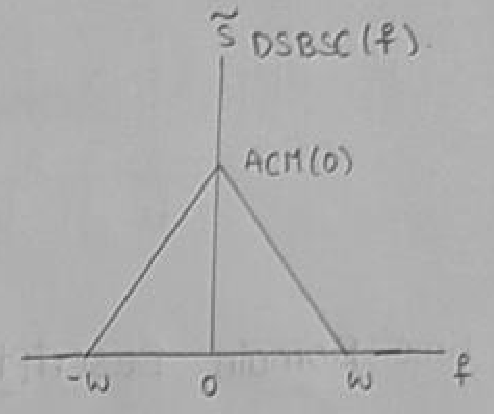
$$= \mathrm{Re}\left[\tilde{S}_u(t)\, e^{(j2\pi f_c t)}\right].$$

The frequency response of ideal band pass filter is



Replace the Transfer function $H_u(f)$ by an equivalent low-pass filter Transfer function.





Mathematically it can be expressed as.

$$\left.\begin{aligned} \tilde{H}_u(f) &= \tfrac{1}{2}\,[1+\mathrm{sgn}(f)], \quad 0<f<W \\ &= 0 \quad , \quad \text{otherwise} \end{aligned}\right\}$$

$\mathrm{sgn}(f)$ = signum function.

DSBSC modulated wave can be obtained as

$$\tilde{S}_{DSBSC}(f) = A_c M(f).$$

$$\tilde{H}_u(f)\,\tilde{S}_{DSBSC}(f) = \frac{A_c}{2}\,[1+\mathrm{sgn}(f)]\,M(f)$$

The inverse of fourier transform

$$\tilde{S}_u(t) = \frac{A_c}{2}\,[m(t) + j\,\hat{m}(t)].$$

$$S_u(t) = \frac{A_c}{2}\,[m(t)\cos 2\pi f_c t - \hat{m}(t)\sin 2\pi f_c t).$$

$$\therefore\ S_u(t) = \frac{A_c}{2}\,[m(t)\cos 2\pi f_c t - \hat{m}(t)\sin 2\pi f_c t)\cdot$$

Advantages and DisAdvantages and Applications in SSB frequency Domain Description.

Advantages of SSB :-

The spectrum space occupied by the SSB signal. The reduction in frequency spectrum or bandwidth allows more signals to transmit.

The spectum space occupied by the SSB signal. The frequency spectrum or bandwidth have the same frequency range without interfering each other.

Due to the suppression of carrier and one side band power is saved to produce a stronger signal and it received at greater distances.

when bandwidth is less, the receives circuits can be made with a narrow bandwidth, filtering out most of the noise. there will be less noise of it.

The carrier and sideband signals have different frequencies, which are effected by the ionosphere in different ways.

DisAdvantages :-

The generation and reception of SSB signal is a complex process. It is discussed later on.

The carrier is absent, the SSB transmitter and receiver need to have an excellent frequency stability.

It is usually used for Transmission of speech signals.

Applications of SSB:-

SSB is used to save Power in applications where such a Power saving is required. In Mobile systems single-side band modulation is also used in applications.
In which band width requirements are low at Point-to-Point Communications, land, air in maritime mobile communications, television, telemetry, military communications.
And in radio navigation and amateur radio are the greatest users of SSB in one form or another.

Vestigial Sideband Modulation [VSM]

The SSB Modulation is not appropriate way of modulation when the Message signal contains significant components at extremely low frequencies.
Because in such cases the upper and lower Sidebands meet at the carrier frequency and it is difficult to isolate one side band.
To over come this difficulty the modulation technique known as vestigial side band Modulation.
In this technique one side band is passed almost just a trace, or vestige, of the other side band is retained.

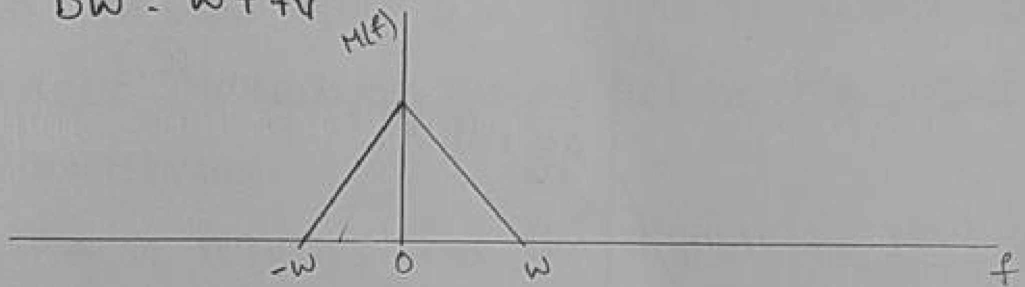
This is the compromise between SSB Modulation and DSBSC Modulation. The signals components at extremely low frequencies and hence vestigal sideband Modulation is used in Television Transmission.

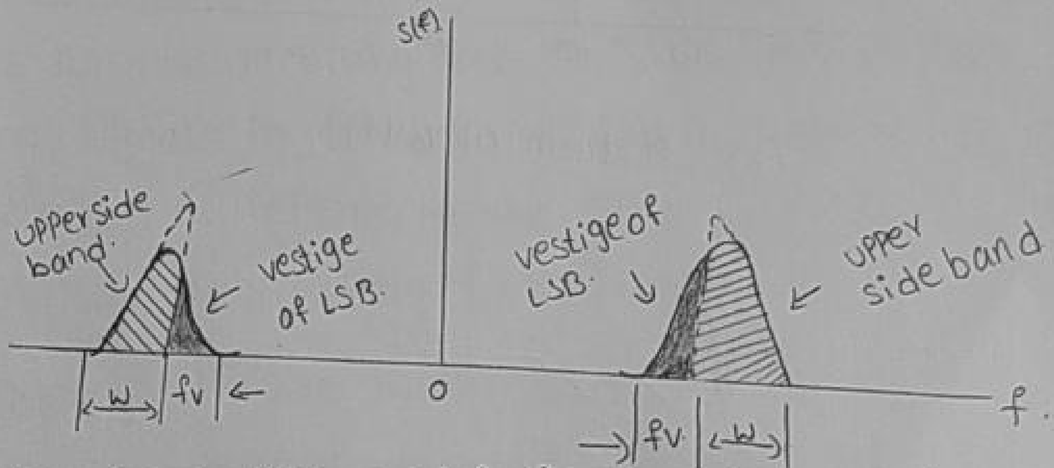
Frequency Domain Description:-

The spectrum of a vestigial side band (VSB) Modulation wave signal along with the message signal the lower Sideband is modified into the vestigial side band. Specifically, the transmitted vestige of lower Sideband Compensates for the amount removed from the upper Side band.

The Transmission bandwidth required by the VSB modulated wave is given by

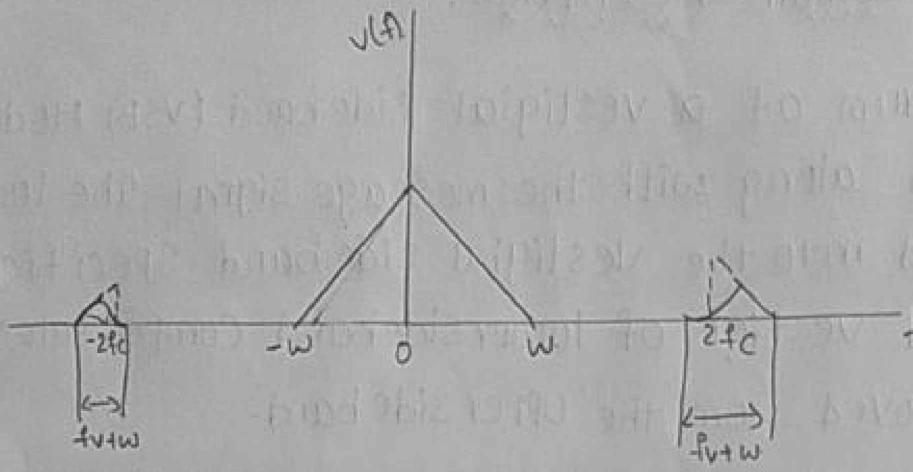
$$BW = W + f_v$$



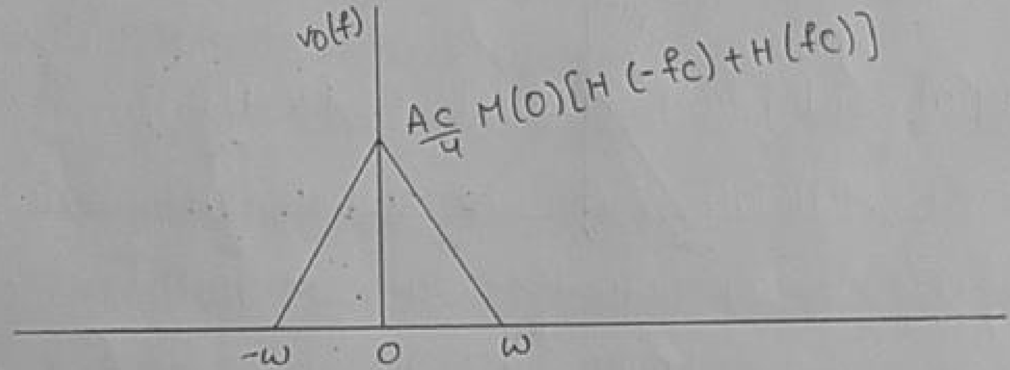


The Message bandwidth and f_v is the width of the vestigial side band. Since $f_v \ll W$, the VSB requires band width almost Equal to SSB Transmission;

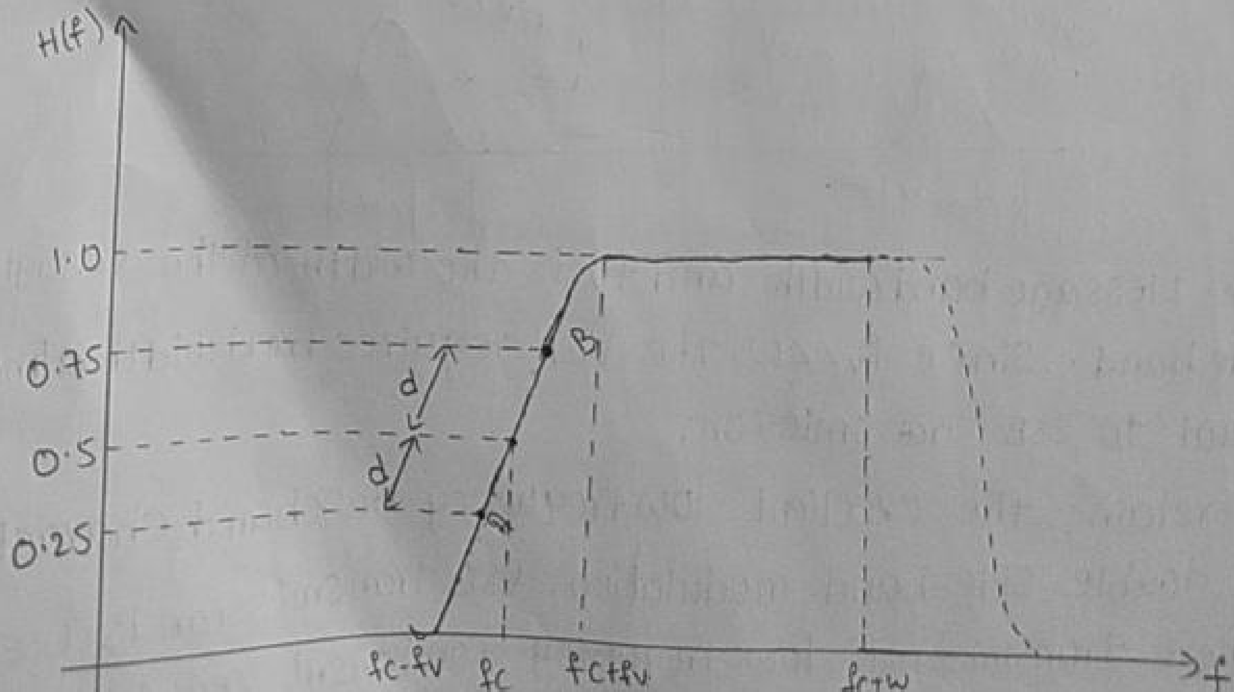
It retains the excellent low frequency baseband Characteristics of double side-band modulation. VSB transmission is used where transmission low frequency component are important, but the band width required for double side band Transmission.



(a) Spectrum of v(f)



(b) Spectrum. of $v_0(f)$

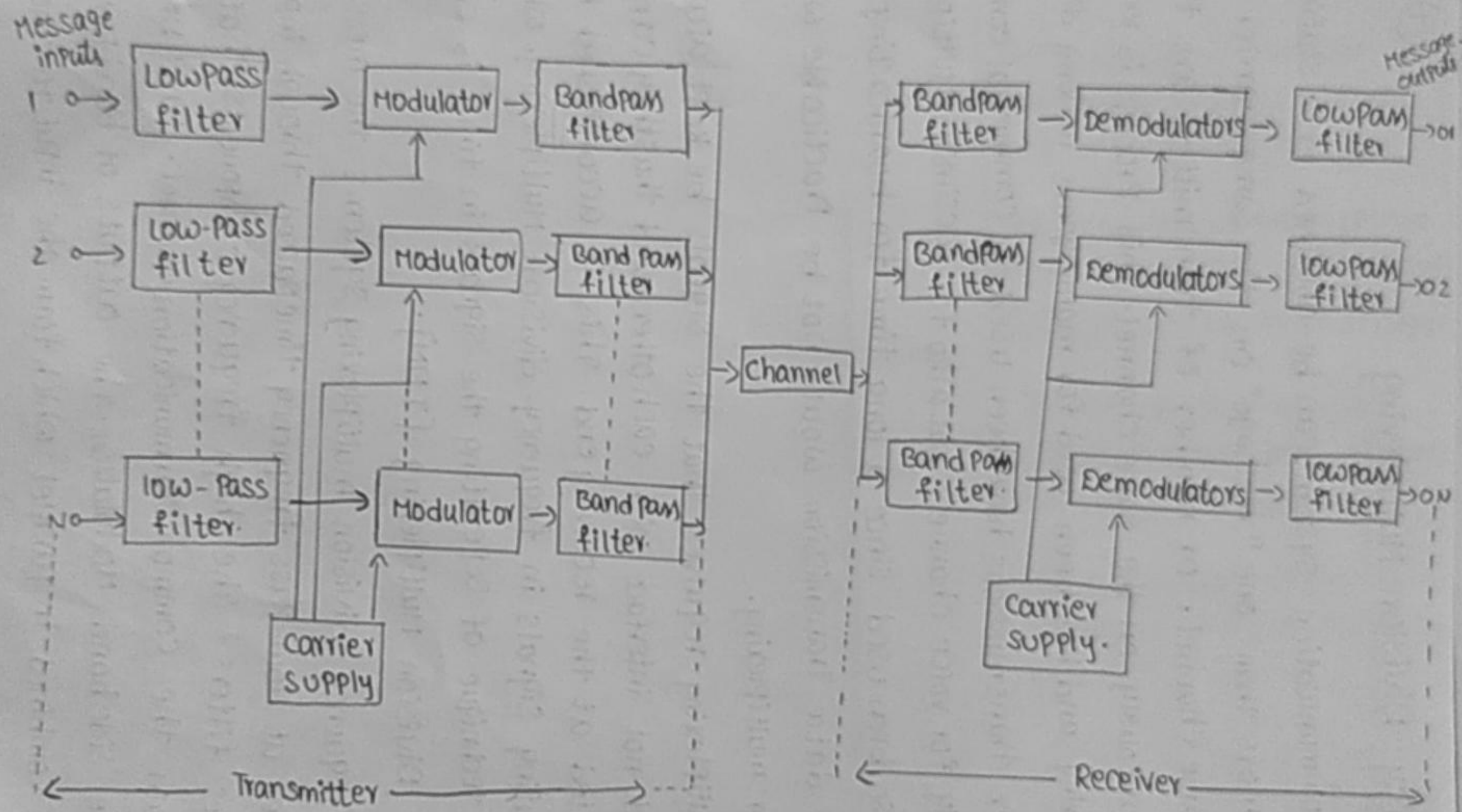


Frequency Division Multiplexing

The communication system can be obtained if a station transmits more than one "message" on the same carrier and on the same channel, or number of transmitters are transmitting simultaneously on the same channel. This process is known as Multiplexing and has been used for many years in long distance. Multiplex transmissions have been used in commerical communications not only for voice channels, but also for facsimile. Multiplexing has also been used since a long time for boardcasting. Remote data Transmission would not be Practicable were it not for multiplexing.

In Multiplexing requires that the signals be kept apart so that they do not interface with each other, and thus they can be seperated at the receiving end. This is accomplished by seperating signals in frequency-division Multiplexing, whereas the technique of seperating the signals in time is called a Time Division Multiplexing [TDM].

In frequency division multiplexing systems the message signals to be at low-pass frequency time passed through input low-passes filters. The high frequency components that do not contain the common communication channel. In FDM is a. Single Side band Modulation. The outputs of band pass filters are combined in parallel which form the input to the common channel.



Block Diagram of FDM System

Comprasion of FM and AM :-

S.No	frequency modulation	Amplitude modulation
1.	The Equation for FM wave is $v = A\sin[\omega_c t + m_f \sin\omega_m t]$	The Equation for AM wave is $v = E_c[1 + m\sin\omega_m t]\sin\omega_c t$
2.	The modulation index can have value either less than one or more than one.	The value of modulation index is always between zero and one
3.	The modulation index determines the Number of significant pairs of side bands in FM signal	In an AM signal, only two side bands are produced, for any value of modulation index.
4.	The carrier or sideband amplitudes are zero at some modulation indices.	The sideband amplitude is never zero for any value of modulation index greater than zero.
5.	The bandwidth of an FM signal is proportional to the modulation index.	The band width of an AM signal is twice the highest modulating frequency.
6.	The main Advantage of FM over AM is the noise immunity, as limiter stage in FM receiver clips off noise signals.	The AM system is more susceptible to noise and more affected by noise than FM.
7.	In FM, greater transmitter efficiency can be relized using class-C amplifiers as amplitude of FM signal is	The efficiency of AM is less than that of FM due to use of class-B amplifer.

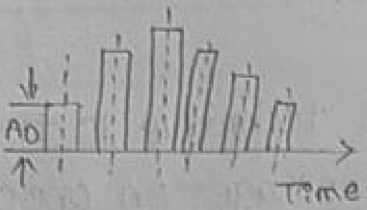
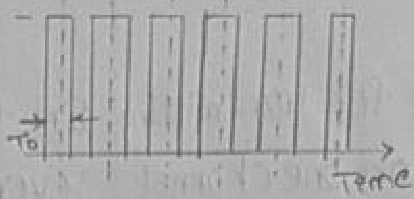
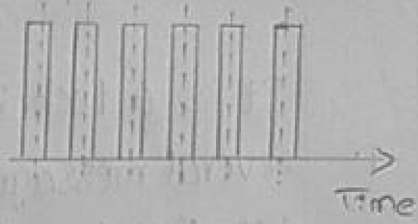
Comparison of FM and PM Systems

S.No	Frequency modulation	Phase modulation
1.	The equation of FM wave is $s(t) = A_c \cos[\omega_c t + 2\pi k_f m(t)]$	The Equation for PM wave is $s(t) = A_c \cos[\omega_c t + k_p m(t)]$.
2.	Frequency modulation is direct method of Producing FM signal	Phase modulation is indirect method of Producing FM.
3.	The modulation index of an FM signal is the ratio of the frequency deviation to the modulating frequency.	The modulation index is Proportional to the maximum amplitude of the modulating signal.
4.	Amplitude of FM wave is constant.	Amplitude of PM wave is constant.
5.	Noise is better suppressed in FM systems as compared to PM system.	Noise immunity is inferior is that of FM.
6.	FM is Mainly used for FM broad casting used for entertainment Purposes	PM used in mobile communication system.

omparison of TDM and FDM

S.NO	TDM	FDM
1.	It is a technique for Transmitting several messages on one channel by dividing time domain slots. one slot for each message	In this technique to transmit several messages on one channel message signals are distributed in frequency spectrum such that they donot overlap.
2.	It requires commutator at the transmitting end and a distributor, working in perfect synchronization with commutator at the receiving end.	FDM requires modulator, filters and demodulators.
3.	Perfect synchronization between Transmitter and receiver is required.	synchronization between transmitter and receiver is not required
4.	cross talk problem is not severe in TDM.	FDM suffers from crosstalk Problem due to imperfect band Pass filter.
5.	It is usually preffered for digital signal transmission	It is usually preferred for analog signal transmission.
6.	It does not require very complex circuitry.	It requires complex circuitry at transmitter and receiver

Comparison of PAM, PWM and PPM systems

Sr No	Pulse amplitude modulation	Pulse width modulation	Pulse position modulation.
1.			
2.	Amplitude of the pulse is proportional to amplitude of modulating signal	width of the pulse is proportional to amplitude of modulating signal	The relative position of the pulse is proportional to the amplitude of modulating signal.
3	The bandwidth of the transmission channel depends on width of the pulse	Bandwidth of transmission channel depends on rise time of the pulse	Band width of transmission channel depends on rising time of the pulse
4.	The instantaneous power of the transmitter varies with amplitude of pulses	The instantaneous power of the transmitter varies with amplitude of pulse with width of pulses.	The instantaneous power of the transmitter remains constant with width of pulses.
5	Noise interference is high	Noise interference is minimum	Noise interference is minimum.
6.	System is complex	Simple to implement	simple to implement
7.	similar to amplitude modulation	Similar to frequency modulation	similar to phase modulation.