Poc..unit 1 - Poc material unit 1 r20 jntuk

UNIT- I

Amplitude - Modulation

Introduction :-

The purpose of a communication system is to transmit an information - bearing signal from a source located at one point, to a user or destination, located at another point.

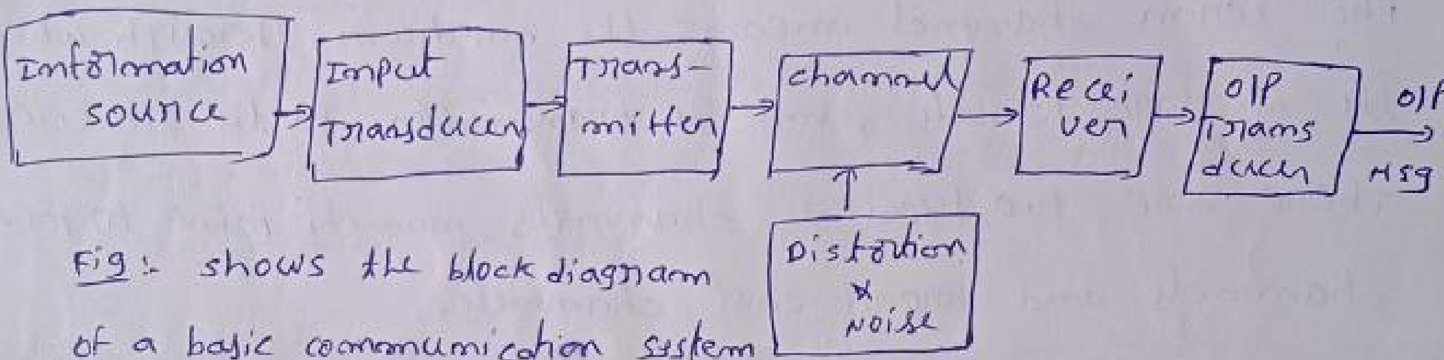


Fig :- shows the block diagram of a basic communication system

→ The essential components of a basic communication system are information source, Transmitter, communication channel and receiver.

Information source - The function of information source is to produce required message which has to be transmitted. The various Message signals are in the form of words, group of words, symbols and sound signals etc.

Transducer : A Transducer is a device which converts one form of energy into another form.

An input transducer is used to convert message signal into an electrical signal. and O/P Transducer for converting Electrical signal into message signal.

Ex:- Microphone.

Transmitter:. The purpose of a transmitter is to modify the message signal in a suitable form for transmission over the communication channel. This can be achieved through a process known as Modulation.

The channel and the noise

The term channel means the medium through whi the message travels from the transmitter to the receive There are two types of channels, namely Point to Poi channels and broad cast channels.

The Point to Point channels are wire lines, microw links and optical fibres

An example of a broadcast channel is a satellite in geo - stationary orbit, which covers about $\frac{1}{3}$ of the earth surface.

-> During the process of transmission and reception signal gets distorted due to noise introduced in the system.

Noise is an unwanted signal which tend to interference with the required signal.

Receiver The main function of the receiver is to reproduce the message in electrical form from the distorted received signal. This reproduction of the original signal is accomplished by a process known as the demodulation or detection.

Destination Destination is the final which is used to convert an electrical message signal into its original form.

Modulation

The purpose of communication system is to transmit a message signal from one place to another place through a communication medium or channel.

Here basically the message signals are low frequency signals which cann't be transmitted effeciently to long distance over the channel directly.

so you can use a carrier signal as high frequency signals which carry the message signal to a long distance for purpose of communicationg.

so the low frequency signals are translated into high frequency signal is known as modulation.

-> Modulation may be defined as the process by which some characteristic parameters of a high frequency signal called carrier signal is varied in accordance with the instanteous value of low freq signal called message signal.

Let a sinusoidal carrier wave in analog modulation is given by $c(t) = A_c \sin(\omega_c t + \theta)$

where A_c = Amplitude of carrier signal

ω_c = Angular freq of " "

θ = phase angle.

Any of these parameters may be varied in accordance with the message signal. Accordingly the modulation process is termed as AM, FM and PM.

The frequency and phase modulation are collectively called as Angle modulation.

Basically modulations are of two types.

1. Continuous wave modulation when the carrier wave is continuous in nature, the modulation process is known as continuous wave modulation or analog modulation.

~~2. pulse modulation~~ Examples of continuous wave modulation are Amplitude modulation and angle modulation.

2. Pulse modulation when the carrier wave is a pulse type waveform, the modulation is known as pulse modulation.

Ex:- pulse amplitude modulation, pulse width modulation, pulse code modulation.

Modulation

- continuous wave Modu
  - Amplitude Modu
    - DSB-SC Modu
    - SSB Modu
  - Angle Modu
    - Freq Mod
    - Phase Modu
- pulse wave Modulation
  - pulse analog
    - PAM
    - PPM
    - PWM
  - pulse digital
    - PCM
    - Delta Mody

Need for Modulation:-

1. To reduce the antenna height
2. To remove interference
3. Reduction of noise.
4. Improves quality of reception.
5. Improve the signal to noise ratio.

Amplitude Modulation:-

Amplitude Modulation is defined as the process in which the amplitude of the carrier wave is varied in accordance with the instantaneous amplitude of message signal (or) Modulating signal.

Expression for Amplitude Modulated wave

Let a carrier and Modulating signals may be represented as $c(t) = A_c \cos(2\pi f_c t + \phi_c)$

Here $\phi_c = 0$ for all Amplitude Modulated Techniques.

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

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

where A_c = Amplitude of the carrier wave

f_c = angular freq " " "

A_m = Amplitude of the message signal.

f_m = Angular freq " " "

According to the defination, The Amplitude modulated signal is $s(t) = m(t) \cdot c(t)$.

$= A_c\, m(t) \cos 2\pi f_c t$ — ①

In order to recover the message signal at the receiving antenna, the carrier signal is added to the product of message signal and carrier signal. Then

$s(t) = A_c \cos 2\pi f_c t + A_c\, m(t) \cos 2\pi f_c t$ — ②

$s(t) = A_c [1 + m(t)] \cos 2\pi f_c t$ (8)

$s(t) = A_c [1 + K_a m(t)] \cos 2\pi f_c t$ — ③

where K_a is constant = Amplitude sensitivity

substitute $m(t) = A_m \cos 2\pi f_m t$ in eq ③, we get

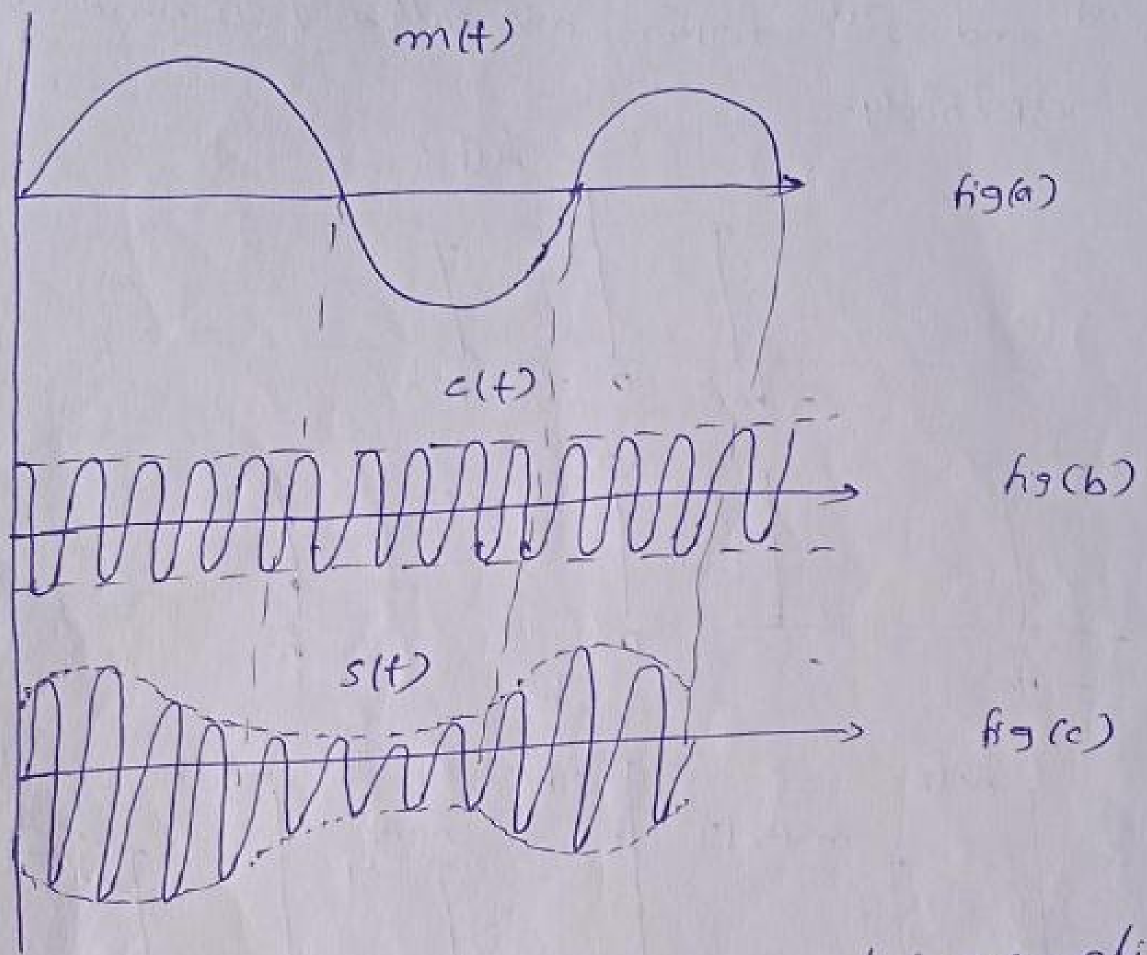
$s(t) = A_c \cos 2\pi f_c t + A_c K_a A_m \cos 2\pi f_m t \cdot \cos 2\pi f_c t$

$K_a A_m = m$ = modulation index.

$$s(t) = A_c \cos 2\pi f_c t + A_c m \cos 2\pi f_m t \cdot \cos 2\pi f_c t.$$

$$\boxed{s(t) = A_c\left[(1 + m \cos 2\pi f_m t) \cos 2\pi f_c t\right]} \quad - (4)$$

This is the expression for AM wave in time domain.



fig(a) message signal (b) carrier signal (c) Amplitude modulated signal.

→ equation (4) can be written as

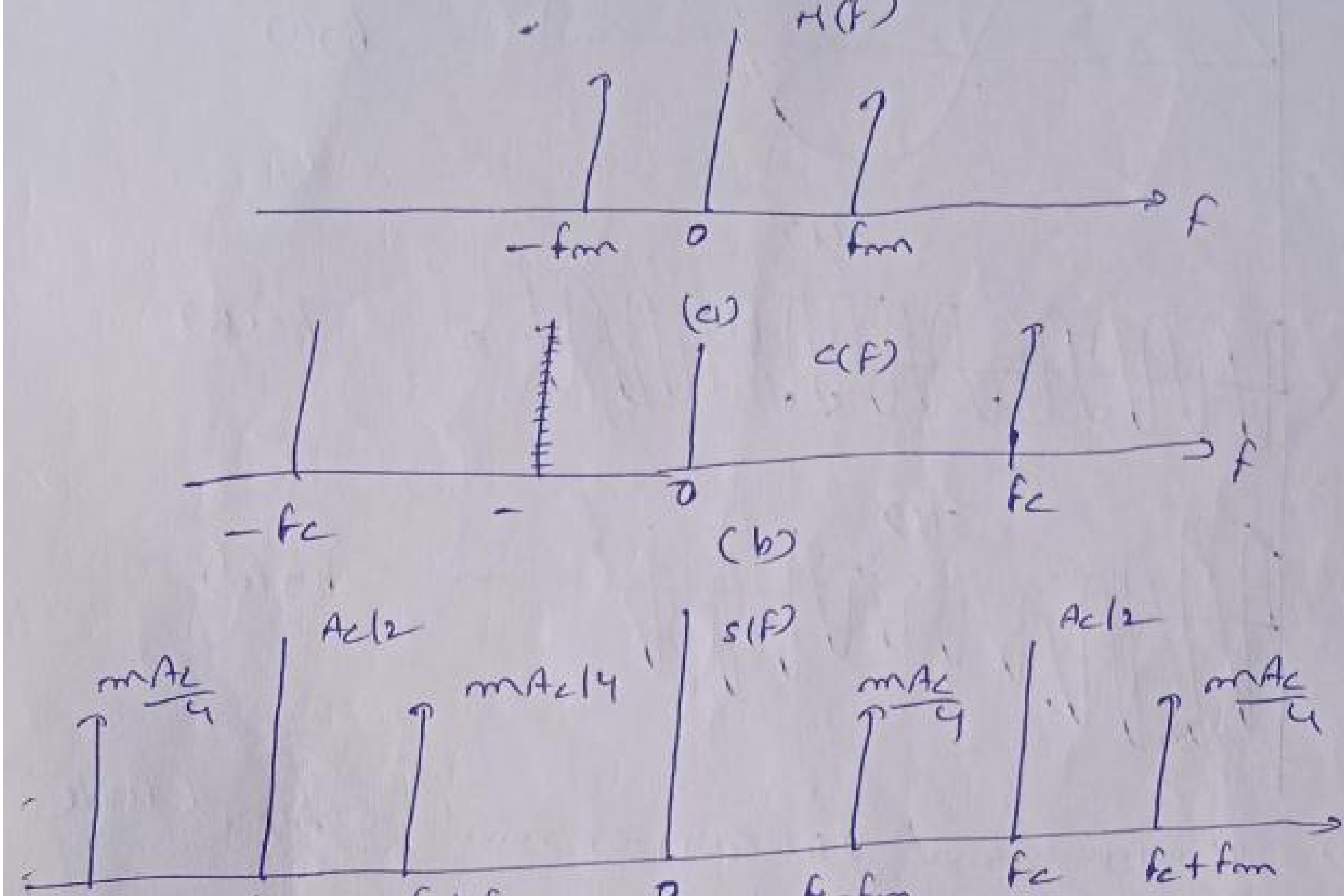
$$s(t) = A_c \cos 2\pi f_c t + m A_c \cos 2\pi f_m t \cdot \cos 2\pi f_c t + \text{---} (5)$$

$$\cos 2\pi f_m t \cdot \cos 2\pi f_c t = \frac{\cos(2\pi(f_c + f_m)t + \cos 2\pi(f_c - f_m)t}{2}$$

Then equation (5) can be written as

$$s(t) = A_c \cos 2\pi f_c t + \frac{mA_c}{2}\left[\cos 2\pi(f_c+f_m)t + \cos 2\pi(f_c-f_m)t\right] \quad -(6)$$

The eq (6) of an Amplitude Modulated wave contains 3 terms. The 1st of R.H.S represents the carrier wave, the 2nd and 3rd terms are called LSB and USB respectively.



(a) Message signal (b) carrier signal (c) AM signal.

Frequency of lower side band = $f_c - f_m$ and the frequency of upper sideband = $f_c + f_m$

Bandwidth = $(f_c+f_m) - (f_c-f_m) = 2f_m$.

Thus in AM, BW is equal to twice the frequency of modulating signal.

Frequency domain description of AM signal

The Amplitude modulated wave can be represented in time domain as

$$s(t) = A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t \quad \text{--- (1)}$$

In order to obtain the spectrum of the Amplitude modulated wave $s(t)$, by taking the Fourier Transform of $s(t)$.

Let $C(f)$, $M(f)$, and $S(f)$ be the Fourier Transforms of $c(t)$, $m(t)$, and $s(f)$ respectively.

Taking the F.T on both sides of equation (1), we get

$$\cos 2\pi f_c t \xleftrightarrow{FT} \frac{1}{2}\left[\delta(f+f_c) + \delta(f-f_c)\right]$$

$$m(t) \cos 2\pi f_c t \xleftrightarrow{FT} \frac{1}{2}\left(M(f+f_c) + M(f-f_c)\right]$$

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

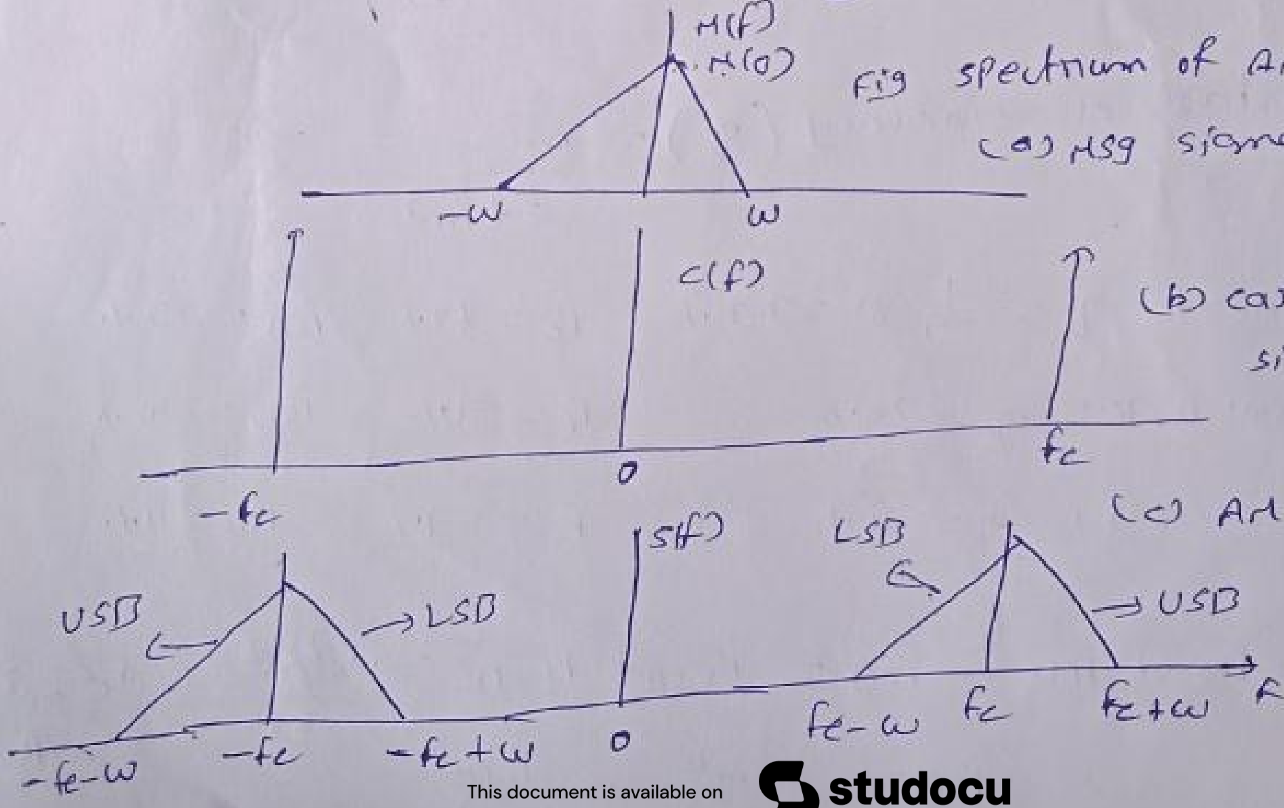


Fig spectrum of AM signal
(a) msg signal
(b) carrier signal
(c) AM signal

Modulation index

Modulation index is defined as the ratio of maximum amplitude of message signal to the maximum amplitude of carrier signal $m = \frac{A_m}{A_c}$.

and also $m = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

The carrier Power $P_c = \frac{A_c^2}{2R}$

upper sideband power P_{USB} = Lower sideband power P_{LSB}

$$P_{USB} = P_{LSB} = \frac{A_c^2 m^2}{8R} = \frac{P_c m^2}{4R}$$

Total power in AM signal $P_T = \frac{A_c^2}{2R}\left(1 + \frac{m^2}{2}\right)$

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

percentage of efficiency $(\eta) = \frac{m^2}{2+m^2}$

If $m=1$, $\eta = \frac{1}{3}$ or 33.3% $P_c = 67\%$, $P_{SB} = 33\%$

If $m = 0.707$, $\eta = 20\%$ $P_c = 80\%$ $P_{SB} = 20\%$

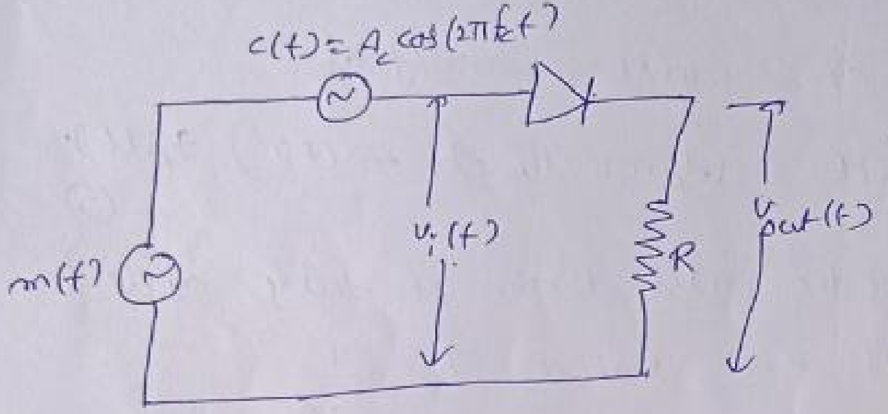
If $m = 0.51$ $\eta = 11\%$ $P_c = 89\%$ $P_{SB} = 11\%$

side band power $P_{SB} = P_{USB} + P_{LSB} = \frac{A_c^2 m^2}{8R} + \frac{A_c^2 m^2}{8R}$

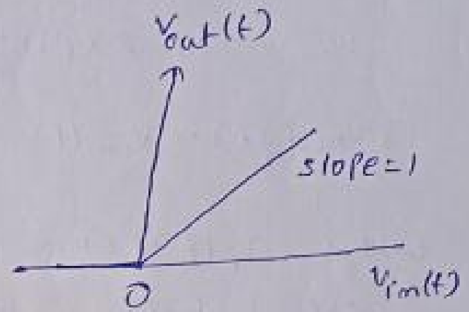
$$P_{SB} = \frac{A_c^2 m^2}{4R} = \frac{P_c m^2}{2}$$

Switching Modulator

Efficient high level modulators are arranged so that undesired modulation products never fully develope and ~~no~~ need not be filtered out. This can be accomplished with the help of a switching device.



fig(a) switching modulator



fig(b) Idealised I/P–O/P ch-ics.

The carrier wave $c(t)$ applied to the diode is large in amplitude, so that it swings right across the ch-ic curve of the diode. We assume that the diode acts as an ideal switch.

→ The diode offers zero resistance in the forward direction $c(t) > 0$, and infinite resistance in the reverse direction ie $c(t) < 0$. The transfer characteristic of the diode-load resistor combination by a piece-wise-linear as shown in fig(b).

The input voltage can be written as

$$v_{in}(t) = c(t) + m(t)$$

$$= A_c \cos(2\pi f_c t) + m(t). \quad -(1)$$

The resulting load voltage $v_{out}(t)$ is

$$v_{out}(t) \approx \begin{cases} v_{in}(t) & c(t) \geq 0 \\ 0 & c(t) < 0 \end{cases} \quad —②$$

∴ The load voltage $v_{out}(t)$ varies periodically between the values of $v_{in}(t)$ and zero at a rate equal to the carrier frequency f_c.

We may express eq ② mathematically as

$$v_{out}(t) = v_{in}(t) \cdot g_p(t) = \left(A_c \cos(2\pi f_c t) + m(t)\right) g_p(t) \quad —③$$

where $g_p(t)$ is a periodic pulse train of duty cycle equal to one half and period $T_0 = \frac{1}{f_0}$

∴ $g_p(t)$ can be expressed in Fourier series as

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

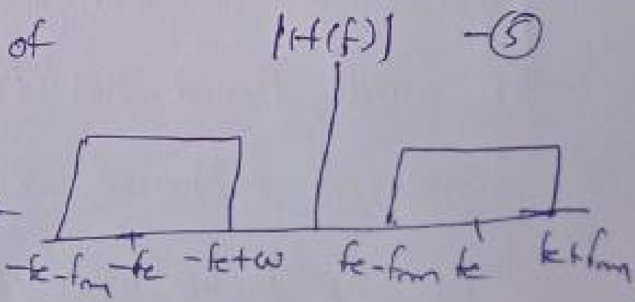
$$g_p(t) = \frac{1}{2} + \frac{2}{\pi}\left(\cos 2\pi f_c t - \frac{1}{3}\cos 6\pi f_c t + \frac{1}{5}\cos 10\pi f_c t\right) \quad —④$$

substitute equation ④ in eq ③ we get

$$v_{out}(t) = \left(m(t) + A_c \cos 2\pi f_c t\right)\left(\frac{1}{2} + \frac{2}{\pi}\left(\cos 2\pi f_c t - \frac{1}{3}\cos 6\pi f_c t\right)\right)$$

$$v_{out}(t) = \frac{m(t)}{2} + \frac{A_c}{2}\cos 2\pi f_c t + \frac{2}{\pi} m(t)\cos 2\pi f_c t + \frac{2A_c}{\pi}\cos^2 2\pi f_c t + \cdots \quad —⑤$$

The BPF is having the passband of $f_c \pm f_m$



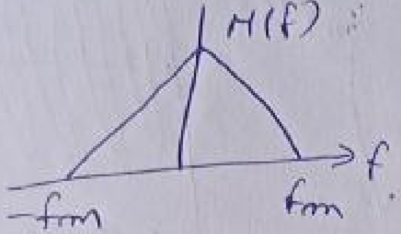
$$v_{out}(t) = \frac{A_c}{2}\cos 2\pi f_c t + \frac{2m(t)}{\pi}\cos 2\pi f_c t$$

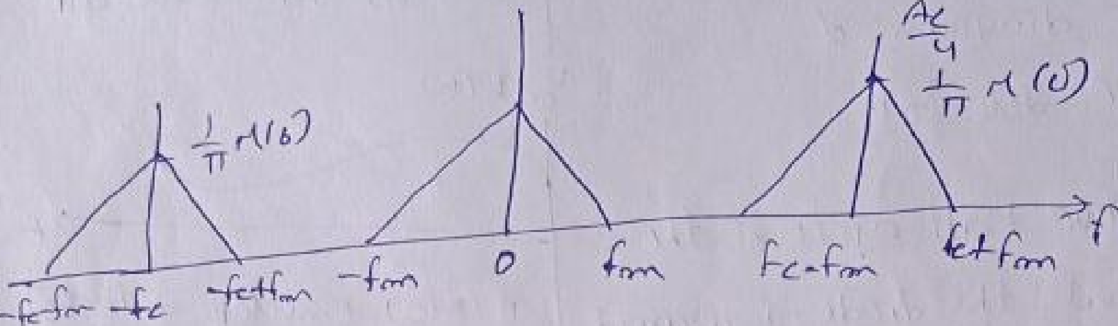
Fig. Ideal BPF

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

where $k_a = \frac{4}{\pi A_c}$

$v_{out}(t) = \frac{A_c}{2}\left[1 + k_a m(t)\right] \cos 2\pi f_c t$





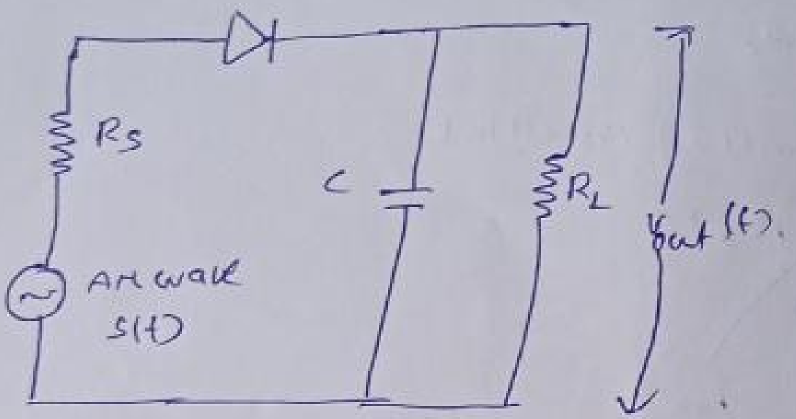
Envelope detector

consider the case of an AM wave in which the carrier freq is much larger than the message bandwidth and percentage modulation is less than 100% such a case shown in below fig.

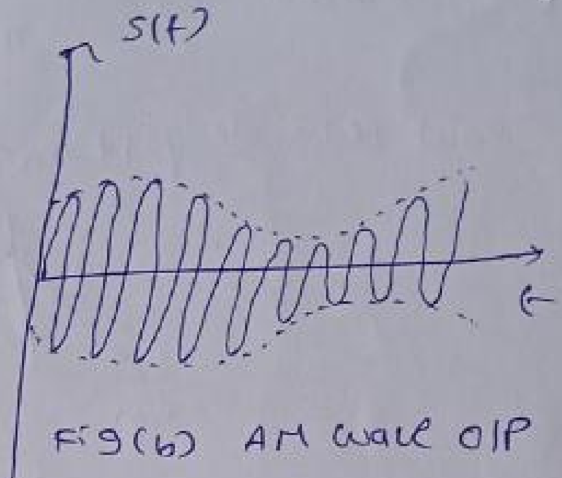
→ The envelope of the AM wave looks like the modulating signal. Thus the desired demodulation can be accomplished by extracting the envelope of the resulting AM wave by using detector known as envelope detector.

→ The envelope detector produces an output signal that follows the envelope of the input signal waveform exactly.

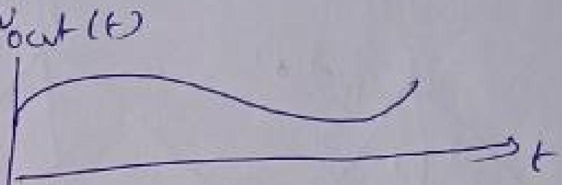
→ The detector consists of a diode and resistor - capacitor filter.



Fig(a) ckT diagram of envelope detector.



Fig(b) AM wave O/P



Fig(c) Envelope detector O/P.

→ on the positive half cycle of the input signal, the diode is forward biased and capacitor "c" charges up rapidly to the peak value of the input signal.

→ when the input signal falls below this value, the diode becomes reverse biased and the capacitor "c" discharges through the load resistor "R_L". The discharging process continuous until the next positive half cycle.

→ when the input signal becomes greater than the voltage across the capacitor, the diode conducts again and the process is repeated.

→ The charging time constant R_sC must be short compared with the carrier time period ie $R_sC \ll \frac{1}{f_c}$.

→ The discharging time constant R_LC must be long enough so that the capacitor discharges slowly through the load resistor R_L ie $\frac{1}{f_c} \ll R_LC$.

In the detector O/P some ripples may be present which may be fined removed by using LPF

Double side band suppressed carrier modulation

(8)

We know the Amplitude modulated wave is given by

$$s(t) = A_c \cos 2\pi f_c t + \frac{mA_c}{2}\left[\cos 2\pi(f_c+f_m)t + \cos 2\pi(f_c-f_m)t\right] \quad -(1)$$

From this equation, it is observed that the carrier component in AM wave remains constant in amplitude and freq. This means that the carrier of amplitude modulated wave does not convey any information.

In 100% modulation, 67% of the total Power is required for transmitting the carrier which does not ~~con~~ contain any information. Hence, if the carrier is suppressed only the side bands remain and save the $\frac{2}{3}$ of Power in 100% modulation. Only the sidebands contain the information.

→ This type of suppressing the carrier from the modulated wave is called Double sideband suppressed carrier modulation

Time domain description of DSB-SC modulation

The DSB-SC modulation is obtained by taking the product of carrier signal $c(t)$ and the message signal $m(t)$ as

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

$$s(t) = A_c\, m(t) \cdot \cos 2\pi f_c t \quad -(1)$$

substitute the $m(t) = A_m \cos 2\pi f_m t$ in equation (1), we get

$$s(t) = A_c A_m \cos 2\pi f_m t \cdot \cos 2\pi f_c t.$$

w.k.T $\cos A \cos B = \frac{\cos(A+B) + \cos(A-B)}{2}$

where $A = 2\pi f_m t$, $B = 2\pi f_c t$

$$\therefore s(t) = \frac{A_m A_c}{2}\left[\cos(2\pi(f_c+f_m)t) + \cos(2\pi(f_c-f_m)t)\right]$$

$$s(t) = \frac{A_m A_c}{2}\cos 2\pi(f_c+f_m)t + \frac{A_m A_c}{2}\cos 2\pi(f_c-f_m)t \quad -(2)$$

equation (2) is called time domain description of DSB-SC wave.

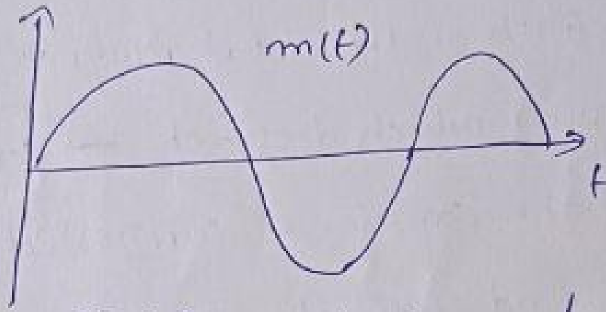


Fig (a) Message signal

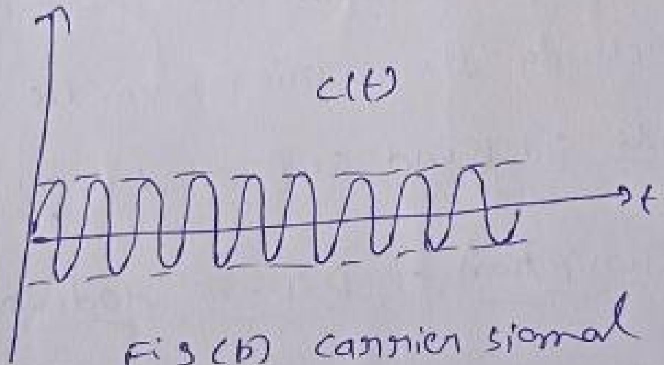


Fig (b) carrier signal

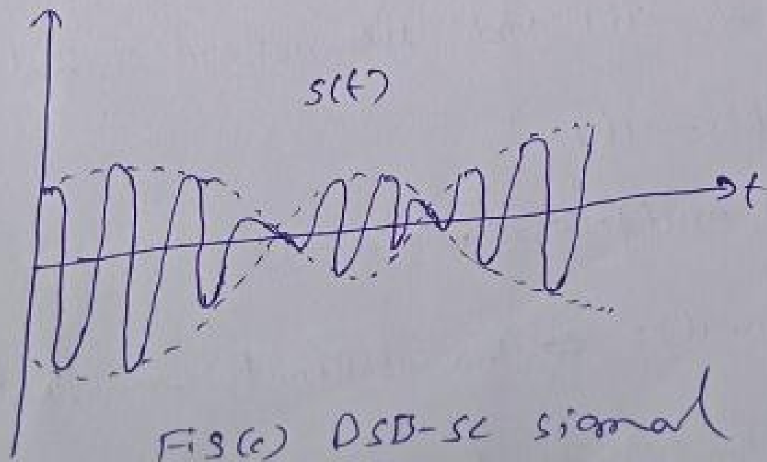


Fig (c) DSB-SC signal

Frequency domain description of DSB-SC signal

W.K.T the DSB-SC signal is given by

$$s(t) = A_c\, m(t) \cos 2\pi f_c t \quad -(1)$$

In order to obtain the spectrum of DSB-SC, by applying the Fourier Transform. Let $c(f)$, $m(f)$ and $s(f)$ be the Fourier Transform of $c(t)$, $m(t)$ and $s(t)$ respectively.

∴ apply the Fourier Transform of eq (1) on both sides, we get

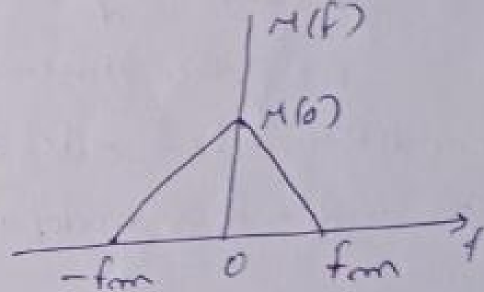
$$F.T[s(t)] = F.T[A_c\, m(t) \cos(2\pi f_c t)] = A_c\, F.T\left[m(t)\left\{\frac{e^{j2\pi f_c t} + e^{-j2\pi f_c t}}{2}\right\}\right]$$

$$s(f) = \frac{A_c}{2}\left\{F.T\left[m(t)\, e^{j2\pi f_c t}\right]\right\} + \frac{A_c}{2}\left\{F.T\left[m(t)\, e^{-j2\pi f_c t}\right]\right\}$$

$$m(t)\, e^{j2\pi f_c t} \xleftrightarrow{FT} M(f-f_c)$$

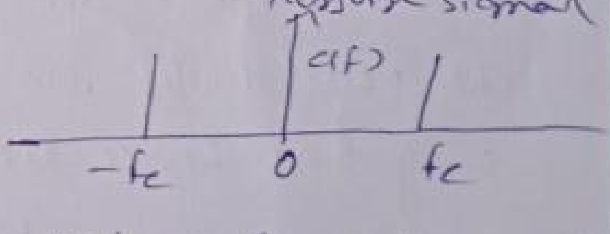
$$m(t)\, e^{-j2\pi f_c t} \xleftrightarrow{FT} M(f+f_c)$$

$$s(f) = \frac{A_c}{2}\left\{M(f-f_c) + M(f+f_c)\right\} \quad -(2)$$



Fig(a) spectrum of message signal

equation (2) is called DSB-SC in frequency domain description.



spectrum of carrier signal

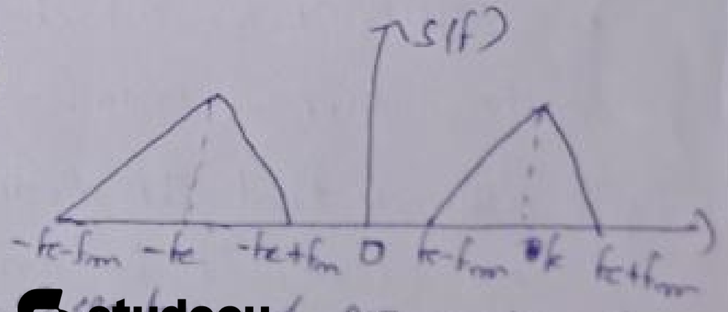
upper sideband freq $= f_c + f_m$

lower sideband freq $= f_c - f_m$

Bandwidth $=$ USB freq $-$ LSB freq

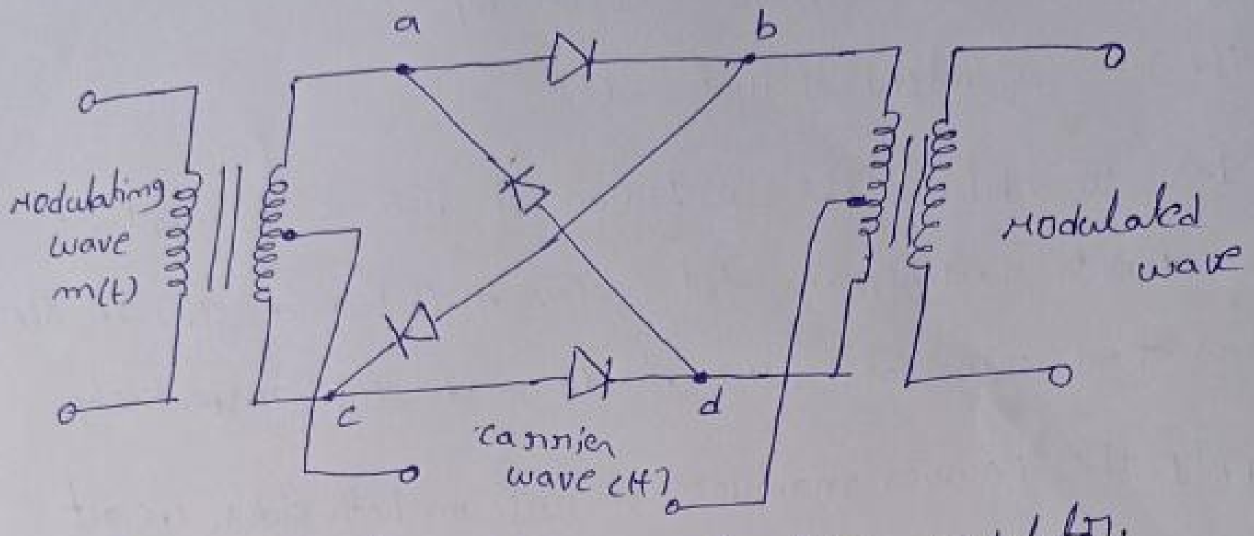
$= (f_c + f_m) - (f_c - f_m)$

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



spectrum of DSB-SC signal

Ring Modulator:



(a) circuit diagram of Ring modulator.

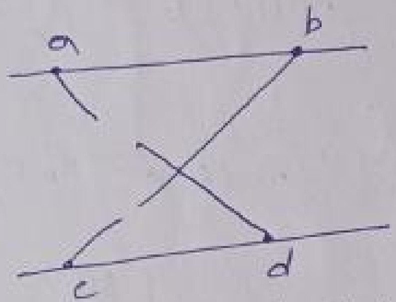


Fig (b) illustrating the condition when outer diodes are on and inner diodes are off.

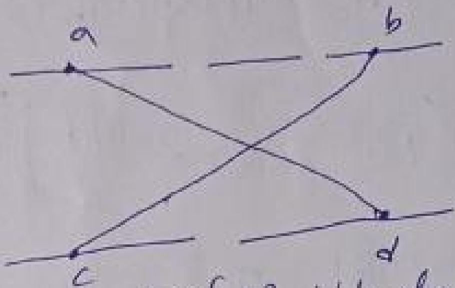


Fig (c) illustrating the condition when outer diodes are on and inner diodes are off.

→ one of the most useful product modulators for generating a DSB-SC wave is the ring modulator shown in fig (a). The Four diodes form a ring in which they all point in the same way hence the name ring modulator.

→ The diodes are controlled by a square wave carrier c(t) of frequency fc, which is applied by means of two center-tapped transformers.

→ we assume that the diodes are ideal and the transformers are perfectly balanced.

→ when the carrier voltage is positive, the outer diodes are switched on and offers zero resistance, whereas the inner diodes are switched off and offers infinite resistance as shown in fig(b). so that the modulator multiplies the message signal by "+1".

→ when the carrier voltage is negative, the situation becomes reversed and the modulator multiplies the message signal by "−1". Thus the ring modulator is a product modulator for a square wave carrier and the message signal as shown in fig2.

The square wave carrier c(t) can be represented by a Fourier series as

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

The ring modulator output is $s(t) = c(t)\, m(t)$.

$$\therefore s(t) = \frac{4}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos 2\pi f_c t(2n-1)\, m(t).$$

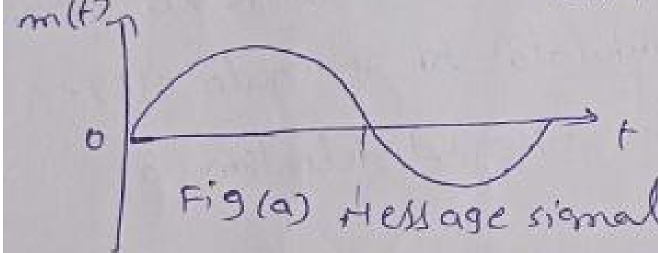
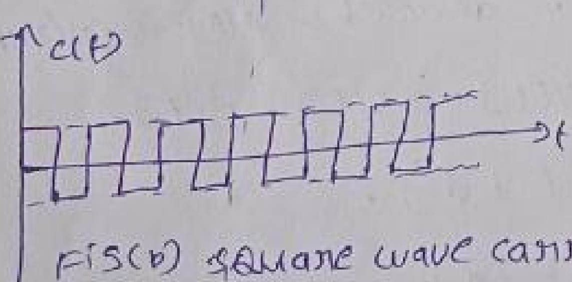


Fig (a) Message signal

there is no output from the modulator at the carrier frequency, ie the modulator output consists of modulation products. Thus the ring modulator is refered to as double balanced modulator.



Fig(b) square wave carrier

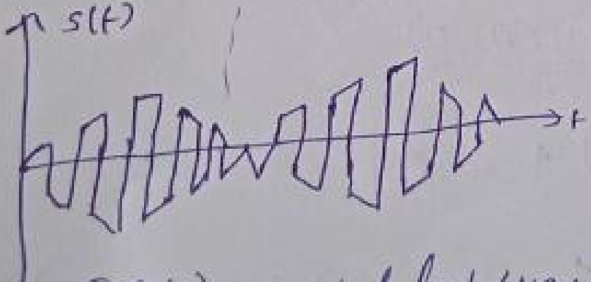


Fig (c) Modulated wave

coherent Detection of DSB-SC Modulation

The process of extracting an original message signal from DSB-SC wave is known as detection or demodulation of DSB-SC

→ The message signal m(t) can be recovered from a DSB-SC wave s(t) by multiplying s(t) with a locally generated sine wave and then low pass filtering the product as shown in fig.

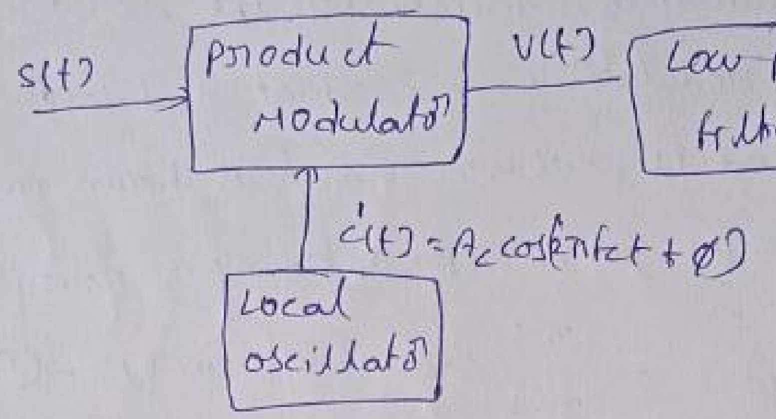


Fig: coherent detection of DSB-SC wave.

→ It is assumed that the locally generated carrier signal is exactly coherent in both frequency and phase with the carrier signal c(t) used in the product modulator to generate s(t).
The method of demodulation is known as coherent detection or synchronous detection.
The locally generated carrier signal is denoted as $c'(t) = A_c \cos(2\pi f_c t + \phi)$

∴ The o/p of the product modulator $v(t) = s(t) \cdot c'(t)$.

$$v(t) = A_c \cdot m(t) \cos 2\pi f_c t \cdot A_c \cos(2\pi f_c t + \phi).$$

$$= A_c^2 \, m(t) \cos 2\pi f_c t \cdot \cos(2\pi f_c t + \phi).$$

w.k.T $\cos A \cos B = \dfrac{\cos(A+B) + \cos(A-B)}{2}$

$$v(t) = \frac{A_c^2}{2} m(t) \left[\cos(4\pi f_c t + \phi) + \cos\phi \right]$$

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

The first term in eq ① represents a DSBSC wave with a carrier frequency $2f_c$, whereas the second term is proportional to the message signal $m(t)$.

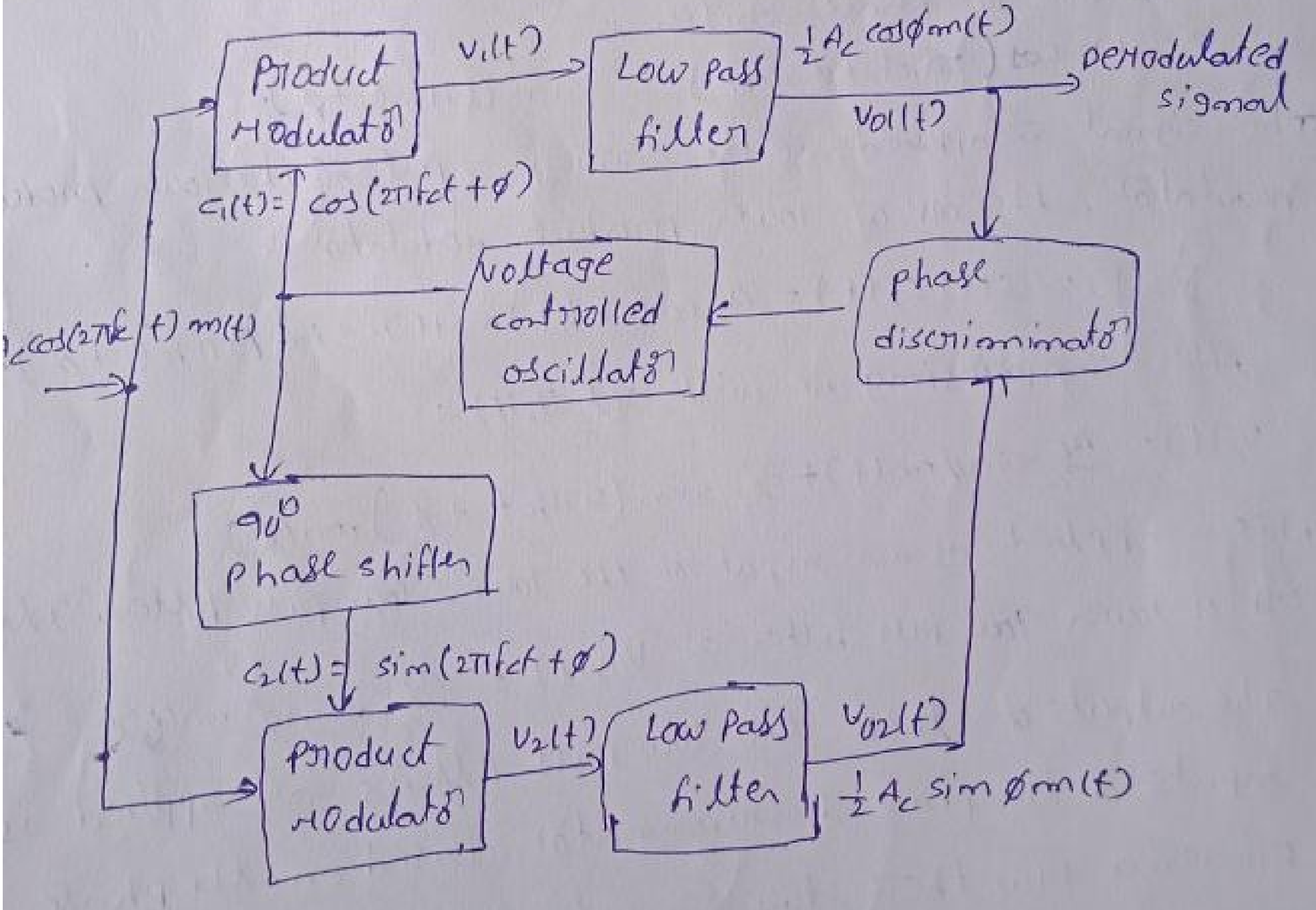
→ The O/P of the product modulator is passed through the LPF.

∴ The O/P of the LPF is $v_0(t) = \frac{A_c^2}{2} m(t)\cos\phi$.

→ The Amplitude of demodulated output is maximum and equal to $\frac{A_c^2}{2}$ when $\phi = 0^0$ and the amplitude is zero when $\phi = \pm 90^0$. This effect is called Quadrature null effect.

→ Quadrature means the phase difference of 90^0 or $\pi/2$ radians.

Costas Receiver



Costas receiver consists of two product modulators with common input $s(t)$, which is DSBSC wave. The other input for both product modulators is taken from voltage controlled oscillator (VCO) with -90° phase shift to one of the product modulator as shown in fig.

w.k.T the DSBSC signal is given by $s(t) = A_c \cos(2\pi f_c t)\, m(t)$.

Let the output of VCO be $c_1(t) = \cos(2\pi f_c t + \phi)$.

The o/p of VCO is applied as the carrier input of the upper product modulator, Hence the o/p of the upper product modulator is

$$v_1(t) = s(t)\, c_1(t) = A_c \cos(2\pi f_c t)\, m(t) \cos(2\pi f_c t + \phi)$$

$$\therefore v_1(t) = \frac{A_c}{2} \cos\phi\, m(t) + \frac{A_c}{2} \cos(4\pi f_c t + \phi)\, m(t).$$

This signal is applied as an input of the upper low pass filter. The o/p of this low pass filter is $v_{01}(t) = \frac{A_c}{2} \cos\phi\, m(t)$.

→ The o/p of -90° phase shifter is

$$c_2(t) = \cos(2\pi f_c t + \phi - 90^\circ) = \sin(2\pi f_c t + \phi).$$

This signal is applied as the carrier input of the lower product modulator, the o/p of lower product modulator is

$$v_2(t) = s(t)\, c_2(t) = A_c \cos(2\pi f_c t)\, m(t) \cdot \sin(2\pi f_c t + \phi).$$

After simplifying we will get $v_2(t)$:

$$v_2(t) = \frac{A_c}{2} \sin\phi\, m(t) + \frac{A_c}{2} \sin(4\pi f_c t + \phi) \cdot m(t)$$

This is applied as an input of the lower low pass filter. The o/p of lower low pass filter is $v_{02}(t) = \frac{A_c}{2} \cdot \sin\phi\, m(t)$.

→ The outputs of these two low pass filters are applied as inputs of the phase discriminator. Based on the phase difference b/w these two signals, the phase discriminator produces a DC control signal.

Quadrature - carrier Multiplexing :-

Quadrature carrier multiplexing (or) Quadrature-amplitude modulation (QAM) scheme enables two DSB-SC modulated waves to occupy the same transmission bandwidth, and it allows for the separation of the two message signals at the receiver output.

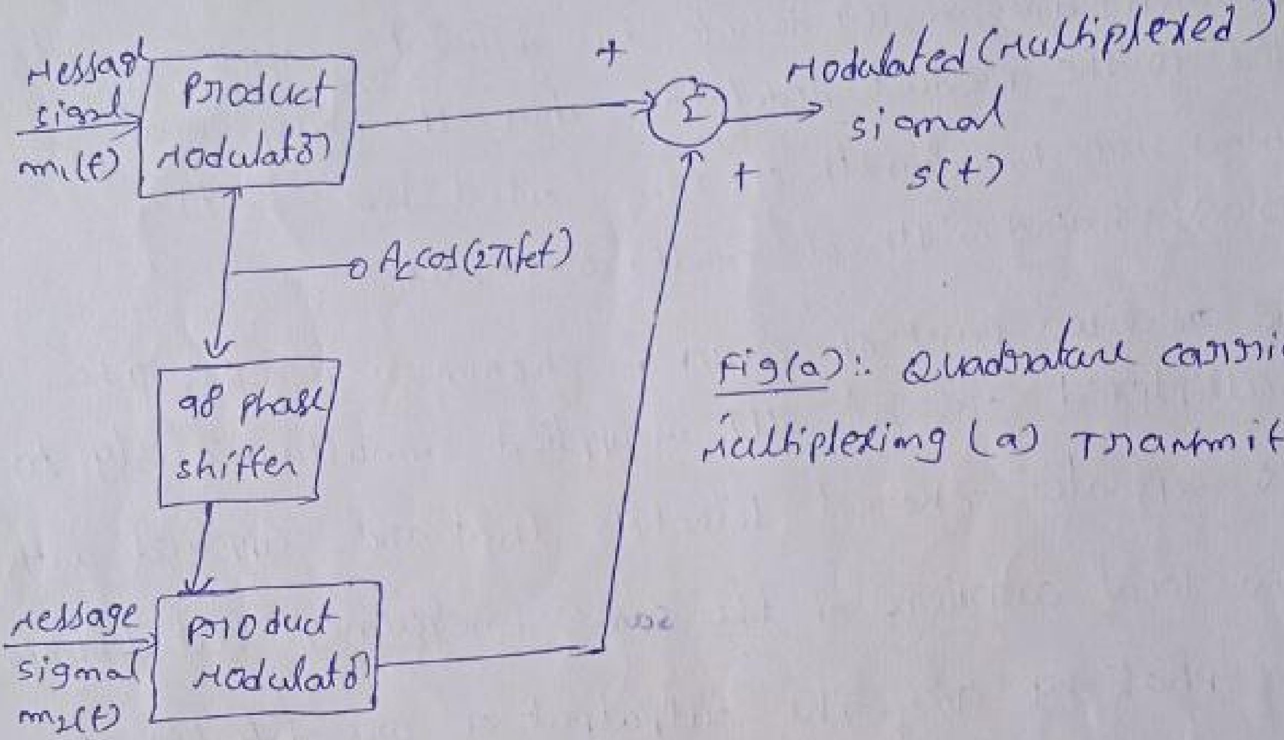


Fig (a) :- Quadrature carrier multiplexing (a) Transmitter.

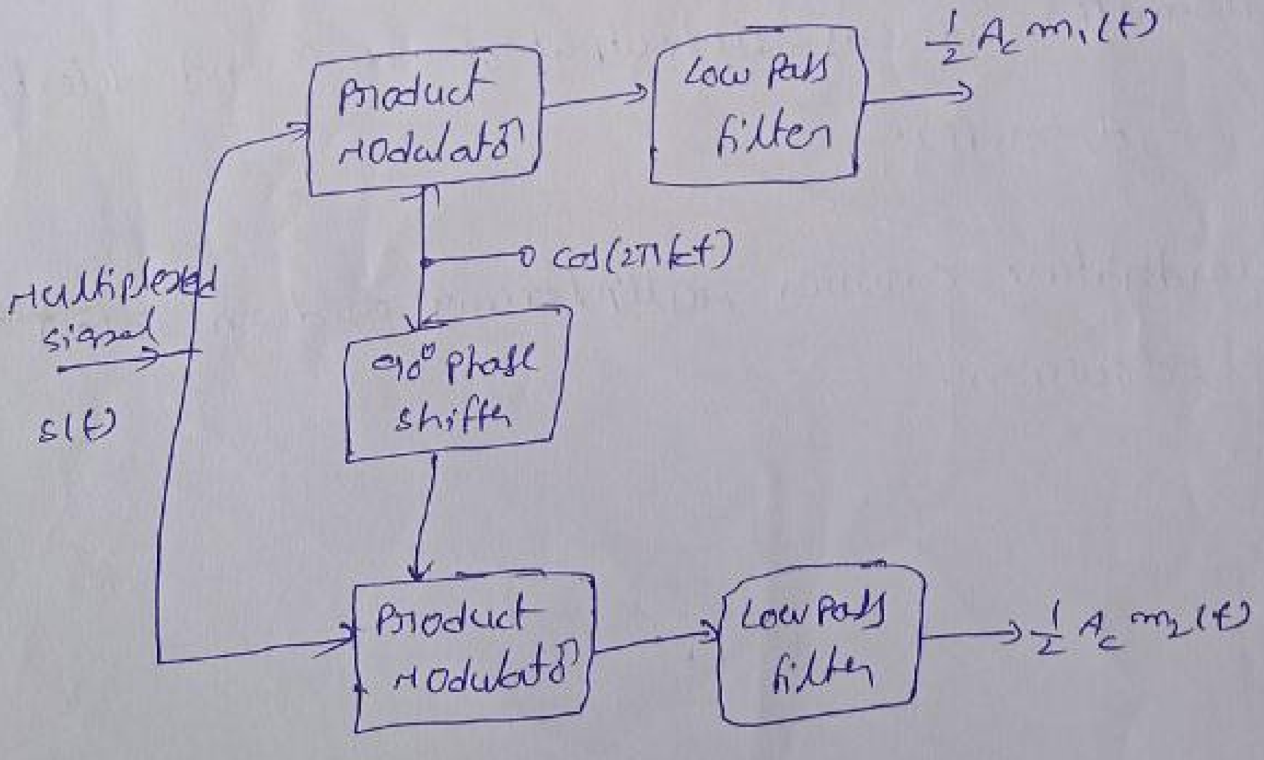


Fig (b) Receiver

→ The transmitter part of QAM shown in fig (a), which use of two separate product modulators that are supplied with two carrier signals of the same frequency but differing in phase by 90°. The transmitted signal $s(t)$ consists of the sum of these two product modulator outputs. Then

$$s(t) = A_c m_1(t) \cos(2\pi f_c t) + A_c m_2(t) \sin(2\pi f_c t) \quad -(1)$$

where $m_1(t)$ and $m_2(t)$ denote two different message signals applied to the product modulators. Thus $s(t)$ occupies a transmission bandwidth of $2f_m$, where f_m " is the message bandwidth of $m_1(t)$ or $m_2(t)$.

→ The receiver part of QAM is shown in fig(b), The multiplexed signal $s(t)$ is applied simultaneously to two separate coherent detectors that are supplied with two local carriers of the same frequency, but differing in phase by 90°. The outputput of one detector is $\frac{1}{2} A_c m_1(t)$ whereas the output of the second detector is $\frac{1}{2} A_c m_2(t)$.

→ Quadrature carrier multiplexing used in color television.

Single sideband Modulation (SSB-SC)

Amplitude Modulation and double sideband suppressed carrier modulation are wasteful of bandwidth because both are required a transmission bandwidth equal to twice the message bandwidth. In either case, one half of the transmission bandwidth is occupied by the upper sideband, whereas the other half occupied by the lower sideband.

→ The upper and lower sidebands are uniquely related to each other by virtue of their symmetry about the carrier. This means that if the amplitude and phase spectra of one is known, other can be uniquely determined.

→ so far as transmission is concerned only one side band is necessary to reproduce the message signal uniquely at the receiver end. Thus in AM, if carrier and one of the sideband is suppressed, no information is lost.

→ so far the advantage is that the transmission bandwidth required for this case is equal to the message bandwidth.

→ when only one sideband is transmitted, the modulation scheme is refered to as a SSB-SC Modulation

→ The advantage of SSB-SC is the elimination of high power carrier and reduced bandwidth requirement.

Time domain description of SSB Modulation

The standard expression for DSB-SC wave in time domain is $s(t) = A_c m(t) \cos 2\pi f_c t$

where $m(t) = A_m \cos 2\pi f_m t$.

$$s(t) = A_c A_m \cos 2\pi f_m t \cdot \cos 2\pi f_c t$$

$$s(t) = \frac{A_c A_m}{2}\left[\cos 2\pi (f_c + f_m)t + \cos 2\pi (f_c - f_m)t\right]$$

$$= \frac{A_c A_m}{2} \cos 2\pi (f_c + f_m)t + \frac{A_c A_m}{2} \cos 2\pi (f_c - f_m)t \quad -①$$

The equation ① can be written as

$$\boxed{s(t) = \frac{A_c A_m}{2} \cos 2\pi (f_c \pm f_m)t}$$

This is the expression for SSB wave in time domain. Here + sign is used for USB and -ve sign is used for LSB.

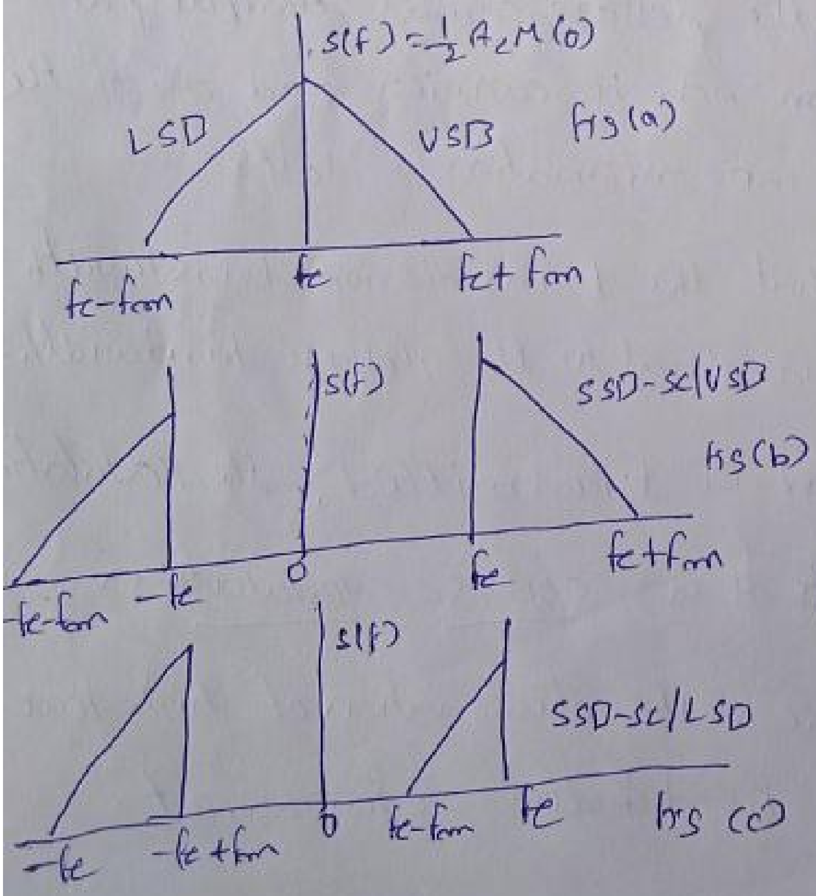


fig (a) spectrum of DSB

fig (b) spectrum of USB

fig (c) spectrum of LSB

Band width of SSB

$= f_c - (f_c - f_m)$

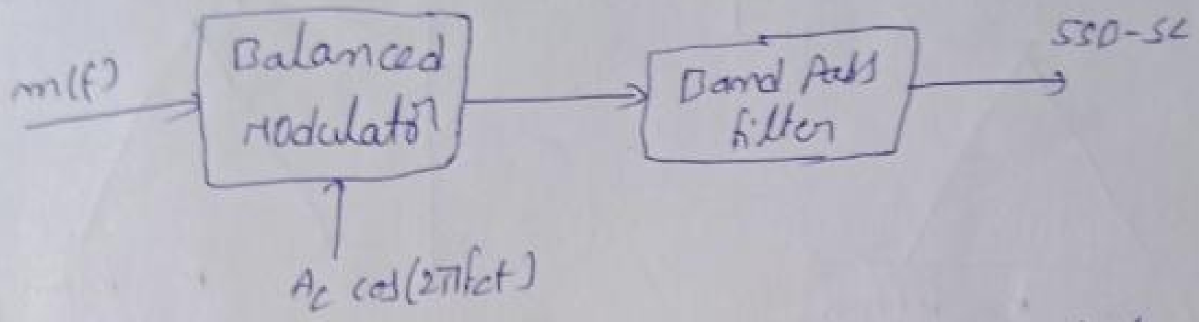
$= \cancel{f_c} - \cancel{f_c} + f_m = f_m$

$\boxed{\text{B.W of SSB} = f_m}$

where f_m is message signal frequency.

Generation of SSB-SC wave

Frequency discrimination Method :-



The frequency discrimination method can be used to generate SSB-SC wave when the message signal is restricted and approximately related to carrier frequency.

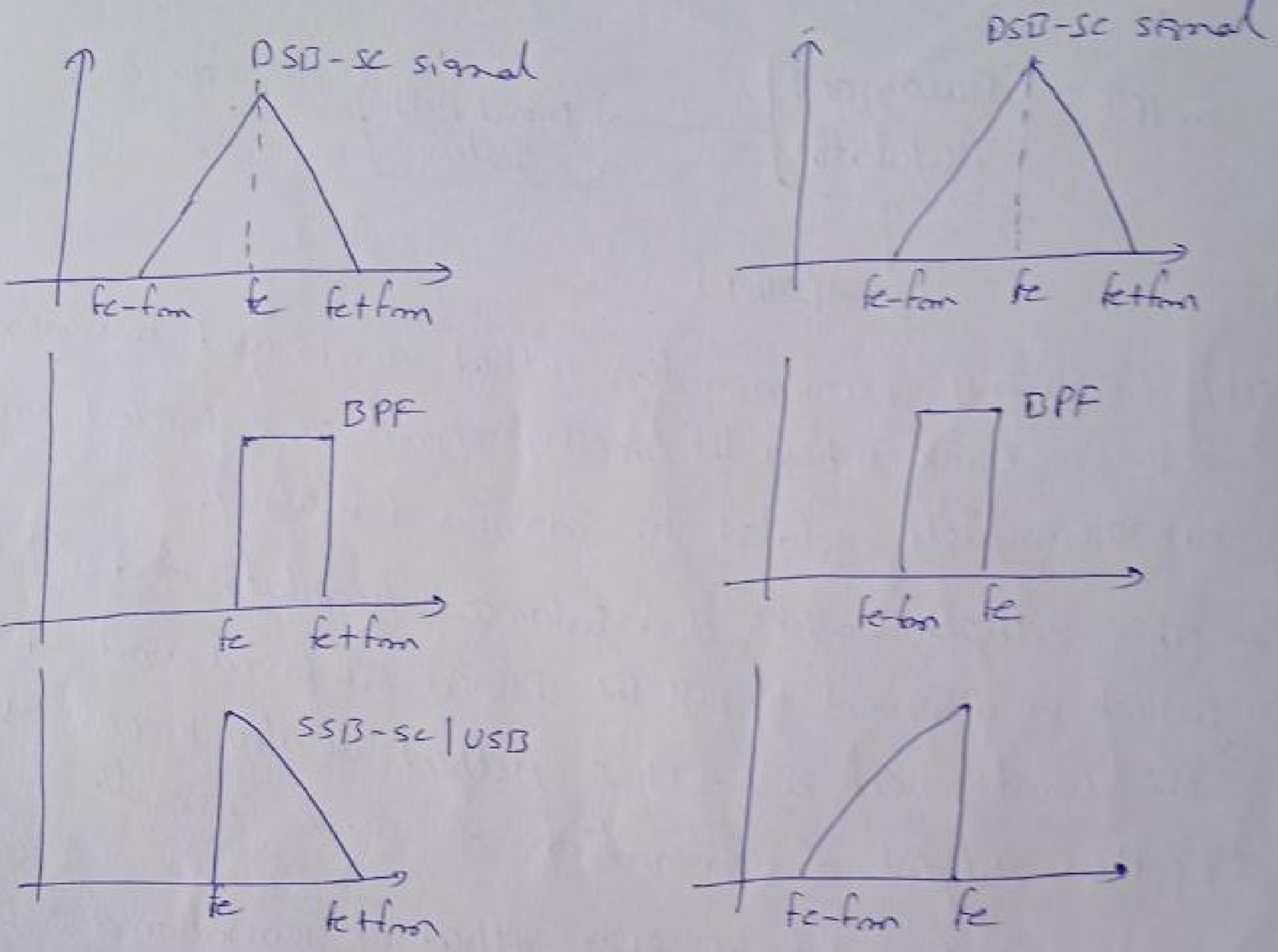
→ This method consists of a balanced modulator and a filter which is designed to pass the desired sideband and supress the undesired one. This method is also known as filter method of generation of SSB-SC signal.

→ The requirement of this method of generation of SSB-SC is the unwanted sideband whose frequency components is suppressed from the desired sideband by twice the lowest frequency component of modulating signal.

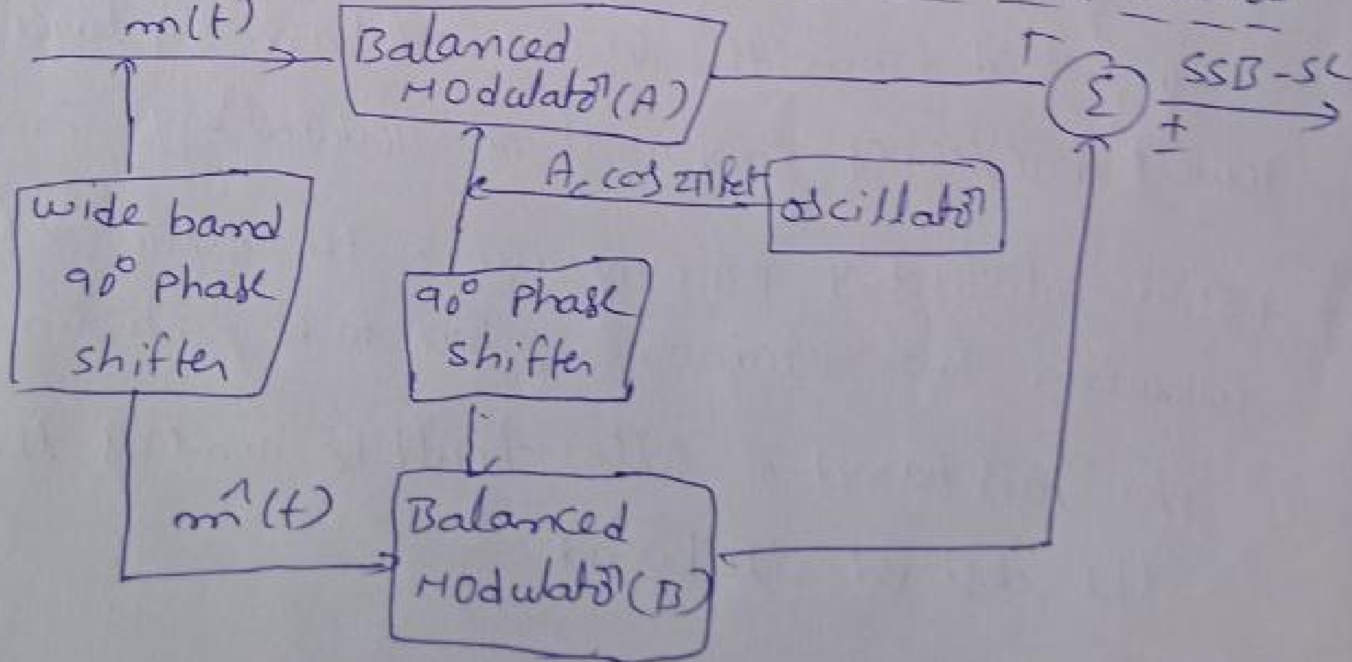
→ For a satisfactory performance of the system the following two requirements have to be satisfied

1) The pass band of filter should be same as that of the desired side band.

2) The transition band of the filter should not exceed twice the minimum frequency component present in the message signal.



Phase discrimination method (or) phase shift method



This method is based on the time domain description of the SSB-SC signal.

→ The SSB-SC signal can be generated by using two separate simultaneous DSB modulation and combining them suitably depending on the desired sideband.

→ It consists of two balanced modulators with carrier wave in phase quadrature to each other.

→ The incoming message signal $m(t)$ is applied to the balanced modulator A, producing a DSB-SC wave that translates the spectrum of $m(t)$ symmetrically spaced above the carrier frequency "f_c".

→ The hilbert transform $\hat{m}(t)$ of $m(t)$ is applied to the balanced modulator B, producing a DSB-SC wave that contains sidebands having identical amplitude spectrum as those of modulator A, but of different relative phase.

→ vector addition or subtraction of the two modulator o/ps in the summing device results in cancellation of one set of sidebands and reinforcement of the other set.

→ $s(t)_{SSB-SC} = \frac{A_c}{2} m(t)\cos(2\pi f_c t) \mp \frac{A_c}{2}\hat{m}(t)\sin(2\pi f_c t)$

Here -ve sign for USB, +ve sign for LSB.

This is also called Hartley modulation.

Vestigial sideband Modulation (VSB)

→ A vestigial sideband system is a compramise between DSB-SC and SSB-SC system.

→ It is relatively easier to generate VSB signals and Bandwidth is only slightly higher than SSB signals but cosiderably less than DSB-SC signals.

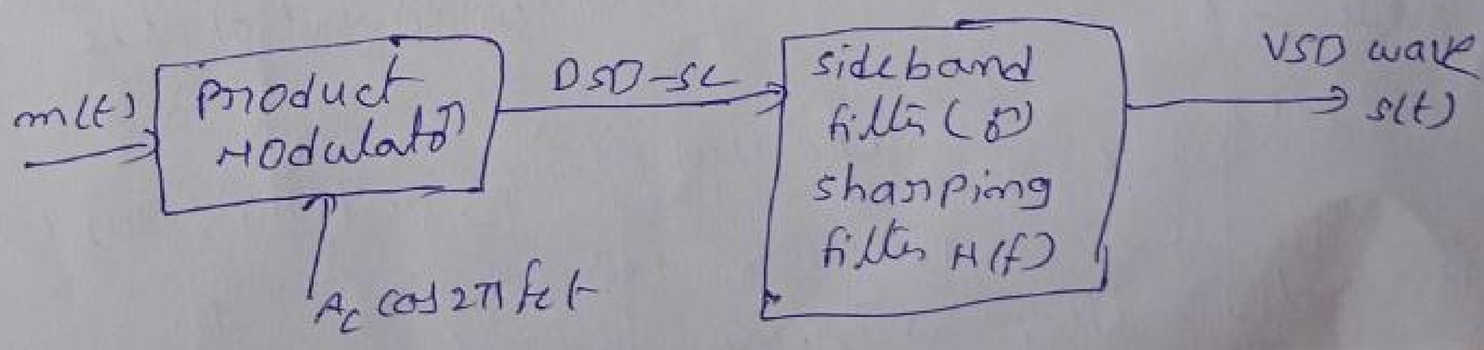
→ ie SSB-SC system is ~~not~~ most suited for transmission of signals which is not very high in low freq components

→ At low frequencies, the upper and lower sidebands of translated signal tend to meet at the carrier freq. under such cases, it becomes very difficult to isolate one sideband from the other.

→ The difficulty has been overcome the new scheme called vestigial side band (VSB), in which instead of one sideband reject completely. we allowed a gradual cut-off that sideband.

→ This gradual cut is compensated by a vestige (or portion) of the other sideband.

Generation of VSB signals



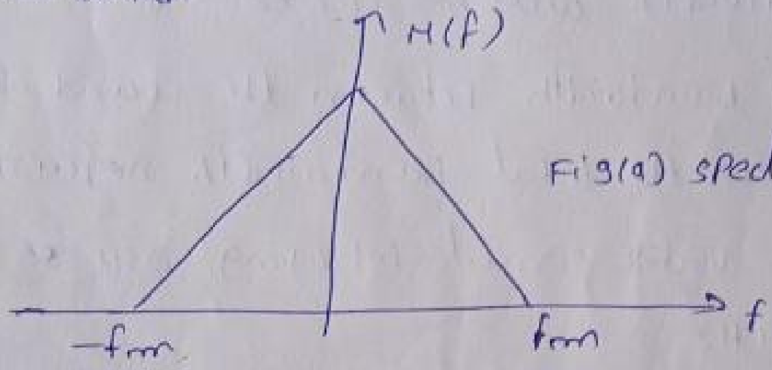
VSB signal can be generated by passing a DSB-SC signal through an appropriate filter of transfer function $H(f)$, as shown in fig.

$$\therefore\ s(t) = (A_c\, m(t) \cos 2\pi f_c t)\ H(f) \quad -(1)$$

The spectrum of VSB signal $s(t)$ is given by

$$S(f) = \frac{A_c}{2}\left[M(f-f_c) + M(f+f_c)\right] H(f) \quad -(2)$$

The function of the sideband filter is to allow the complete one sideband and some part of the other sideband.



Fig(a) spectrum of Message signal

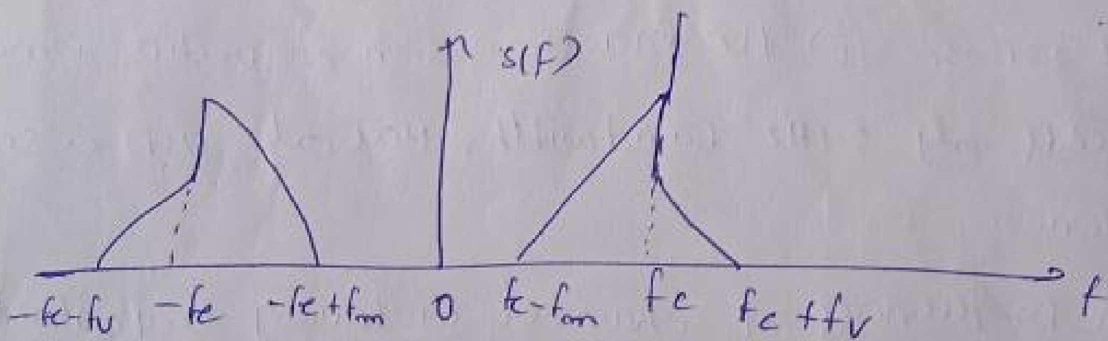


Fig (b) spectrum of VSB signal

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

$= \cancel{f_c}+f_v-\cancel{f_c}+f_m$

$$\boxed{B.W = f_c+f_v}$$

where f_v is the frequency of vestigial sideband

VSB Transmission of analog and Digital Television:

VSB Modulation used for the transmission of television and similar signals, and also good phase characteristics for the transmission of low frequency components.

→ In television. AM is used for vedio and FM is used for sound signals. In television. Audio signal bandwidth is 250KHZ and vedio signal bandwidth is 4.2 MHZ

→ By using DSB-SC, ie AM transmission for the TV signals. the system bandwidth will be $4.2 \times 2 = 8.4$ MHZ.

If we add the guard bandwidth between the sound and picture carriers, then the total bandwidth required for the transmission of vedio signal by using DSB-SC is ~~about~~ above 9 MHZ

→ If we use SSB-SC for the transmission of vedio signal which needs only 5MHZ bandwidth, Here only USB is sent Television.

→ But lower frequencies of channel is having important information of picture.

→ ∴ By using VSB for transmission, the upper side band of vedio signal and picture carrier are transmitted without any suppression, whereas a vestige ie a part of lower sideband is transmitted as shown in fig. and the remaining part is suppressed.

so by using VSB on Television

→ Full USB (5 MHz + 0.5 MHz (Guard band)) = 5.5 MHz) Txed

→ For LSB (0.75 MHz + 0.5 MHz = 1.25 MH) is Transmitted

→ sound is given with bandwidth of 0.25 MHz

→ color is sent along with video signal, and color has maximum bandwidth of 1.5 MHz.

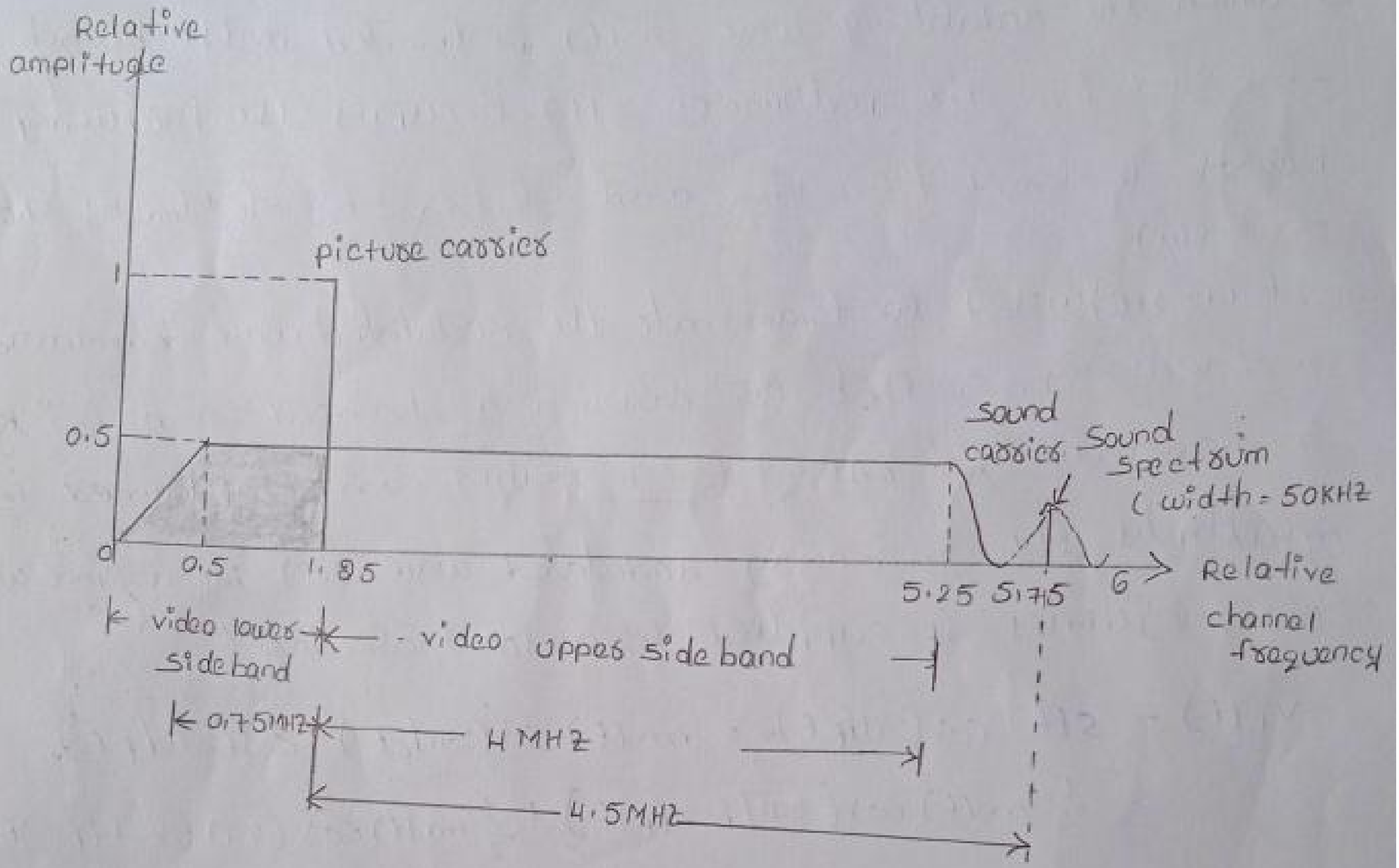


Fig. 3.85 spectrum of transmitted TV signal using VSB Transmission (NTSC).

Frequency Translation :-

The process of converting a band of frequencies to another location on the total frequency spectrum is called frequency Translation.

→ It is necessary to translate the modulated wave upward or downward in frequency, so that it occupies a new frequency band. This frequency translation is obtained by multiplication of the signal by a locally generated sine wave. For example, consider the DSB-SC wave

$$s(t) = m(t)\cos(2\pi f_c t) \quad -① $$

in which the modulating wave $m(t)$ is limited to the band $-f_m \le f \le f_m$. The spectrum of $s(t)$ occupies the frequency bands $f_c - f_m \le f \le f_c + f_m$ and $-f_c - f_m \le f \le -f_c + f_m$ as shown in fig (a).

→ It is required to translate the modulated wave downward in frequency, so that its carrier is changed from "f_c" to a new value "f_e" where $f_e < f_c$. This can be obtained by multiply the incoming modulated wave $s(t)$ by a sine wave of frequency f_t supplied by a local oscillator.

$$v_1(t) = s(t)\cos(2\pi f_t t) = m(t)\cos(2\pi f_c t)\cdot\cos(2\pi f_t t)$$

$$= \frac{1}{2}m(t)\cos(2\pi(f_c - f_t)t) + \frac{1}{2}m(t)\cos(2\pi(f_c + f_t)t)$$

The spectrum of $v_1(t)$ is shown in fig (b).

⇒ The modulated wave translated downward in frequency by passing the multiplier output $v_1(t)$ through a band pass filter of mid-band frequency f_0 and bandwidth $2f_m$.

- The filter output is

$$v_2(t) = \frac{1}{2} m(t) \cos(2\pi(f_c - f_t)t)$$
$$= \frac{1}{2} m(t) \cos(2\pi f_0 t) \quad \text{where } f_c - f_t = f_0.$$

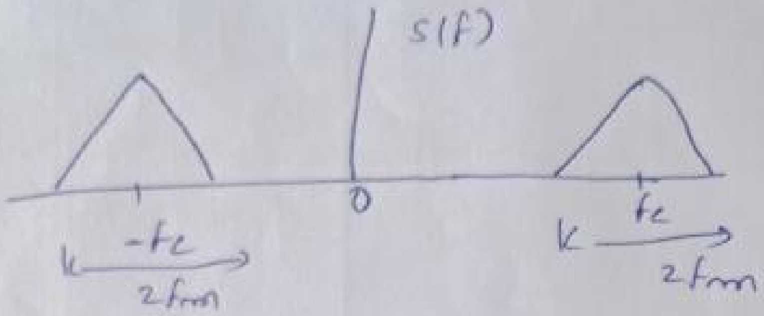
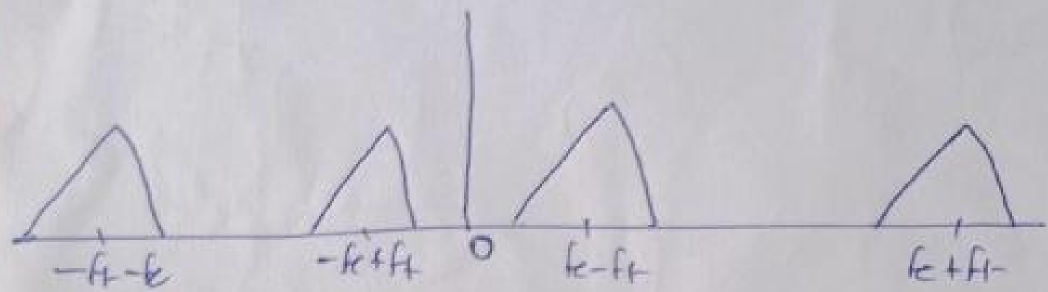
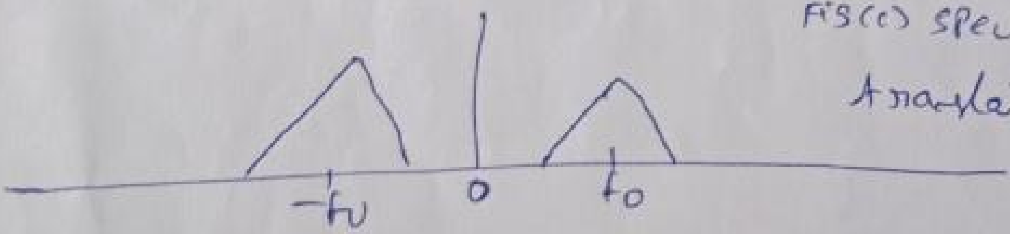


Fig: illustrating the frequency translation process
(a) spectrum of DSB-SC



Fig(b) spectrum of signal by multiplying DSB-SC wave with a local carrier.



Fig(c) spectrum of DSB-SC wave translated downward in freq

→ A device that carries out the freq translation of a modulated wave is called mixer. The operation is called mixing or heterodying. It consists a multiplier and BPF. The multiplier is constructed by using non-linear or switching device. Mixing is a linear operation it completely preserves the relation of the sidebands of the incoming modulated wave to the carrier.

Fig Block diagram of mixer.

Frequency - Division multiplexing (FDM)

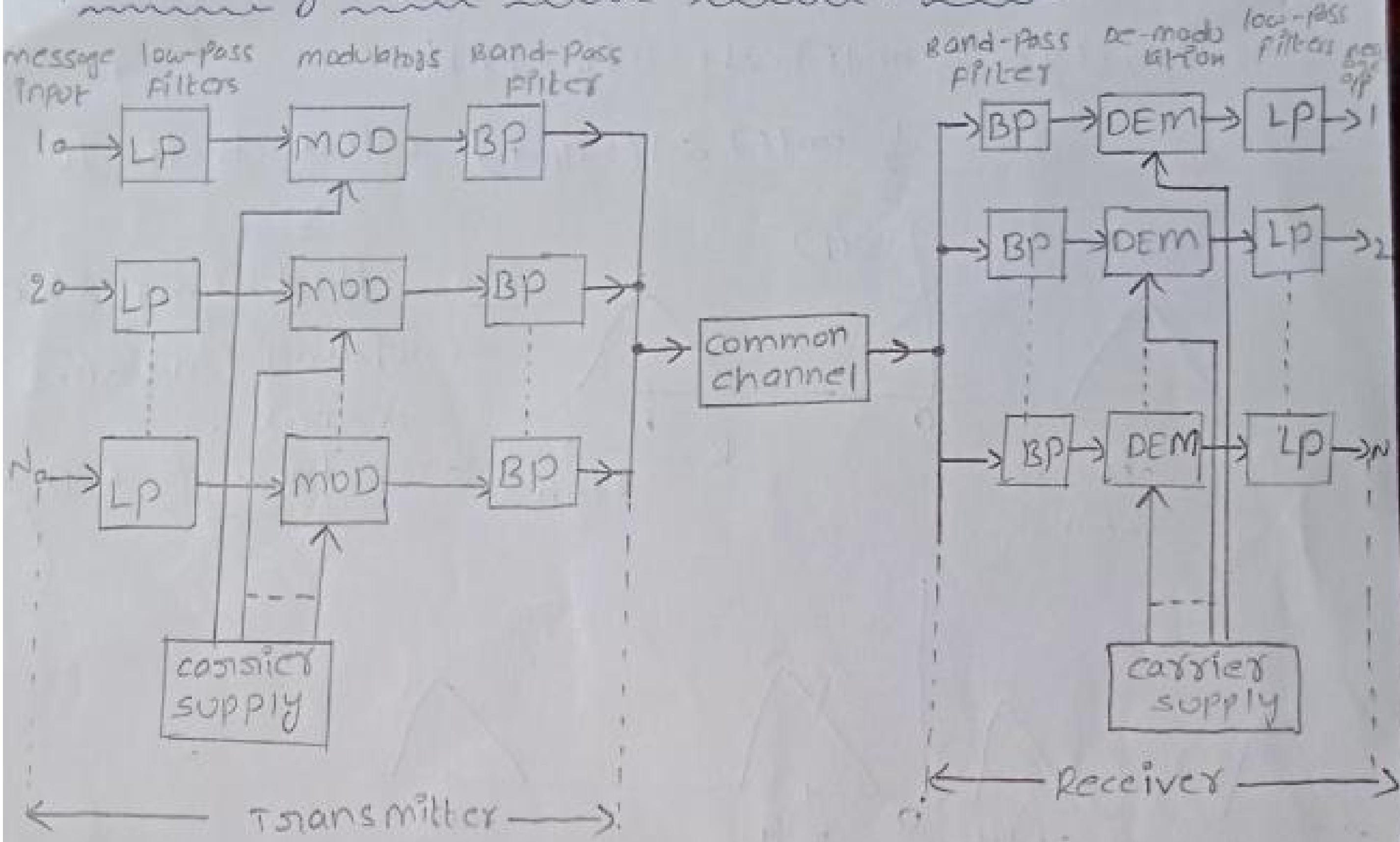


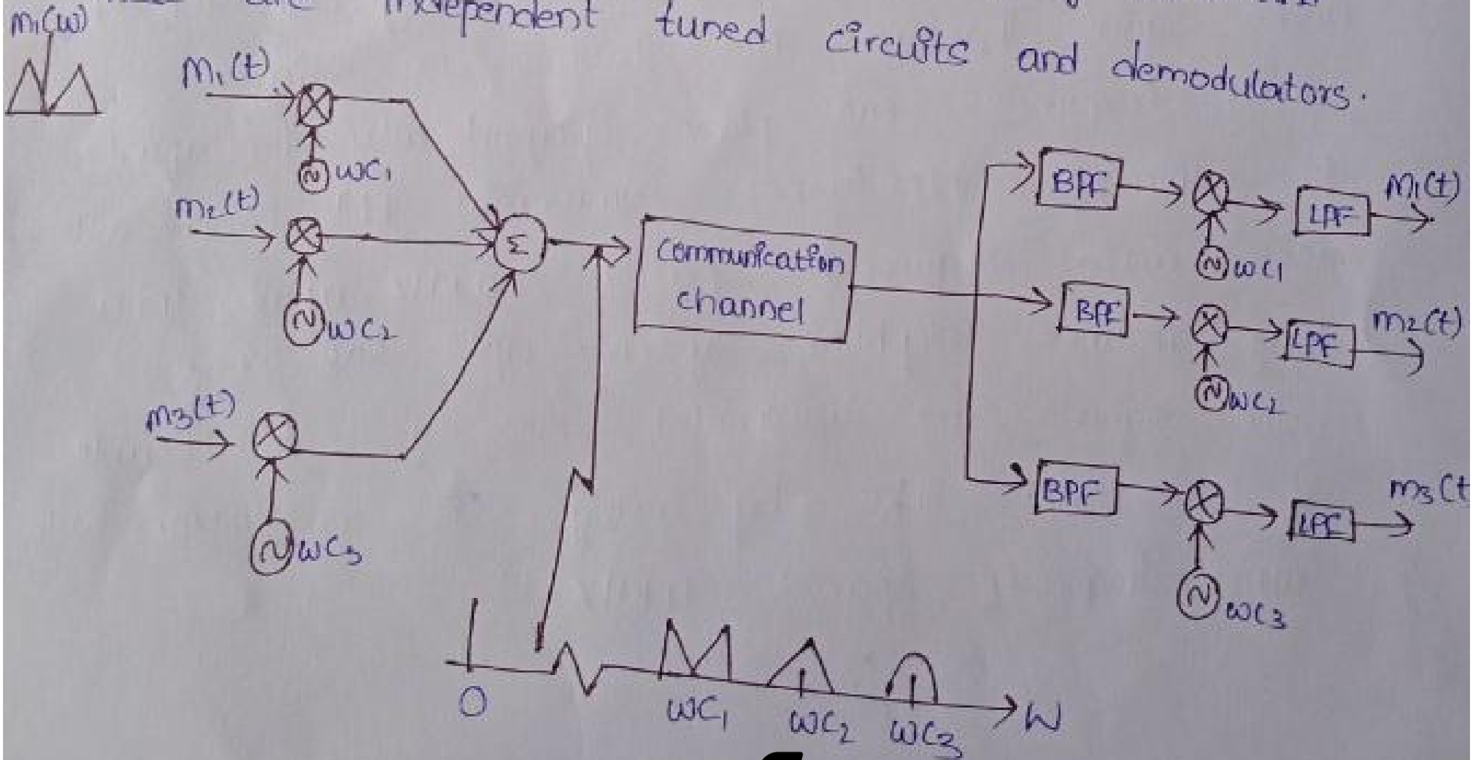
Fig:- Block diagram of FDM system

Frequency division Multiplexing (FDM):

This technique permits a fixed frequency band to every user in the complete channel band width. Such frequency slot its allotted continuosly to that user.

→ As an example consider that the channel band width is 1MHz, let there be 10 users, each requiring upto 100KHz band width. Then the example channel band width of 1MHz can be divided into 10 frequency bands. (i.e) each of 100KHZ and every user can be allotted one independent frequency band. This technique is known as "frequency Divison Multiplexing".

→ It is mainly used for modulated signal. This is due to the fact that a modulated signal can be placed in any frequency band by just changing the carrier frequency. However, at the receiver, these frequency multiplexed signals can be separated by the use of tuned circuits of their respective frequency band and these are independent tuned circuits and demodulators.



→ The FDM scheme is shown in figure with the simultaneous (8)
transmission of three message signals. The spectra of the message signals. The spectra of the message signals and the sum of the modulated carriers are indicated in the figure.

→ Any type of modulation can be used in FDM as long as the carrier spacing is sufficient to avoid spectral overlap. However the most widely user method of modulation is SSB modulation.

→ At the receiving end of the channel the three modulated signals are separated by bandpass filters and then demodulated.

→ FDM is used in telephone system, elementary, commercial broad cost, television and communication networks.

→ Commercial AM broadcast stations use carrier frequency Spaced 10KHZ apart in the frequency range of 540 to 1600 KHZ. This separation is not sufficient to avoid spectral overlap for AM with a reasonably high fidelity audio signal. Therefore AM stations on adjacent carrier frequencies are place geographically for apart to minimize inter-ference. commercial FM broadcost uses carrier frequencies spaced 200 KHZ apart. In a long distance telephone system. upto 600 or more voice signals are transmitted over a co-axial cable or microwave links by using SSB modulation with carrier frequency spaced 4 KHZ.