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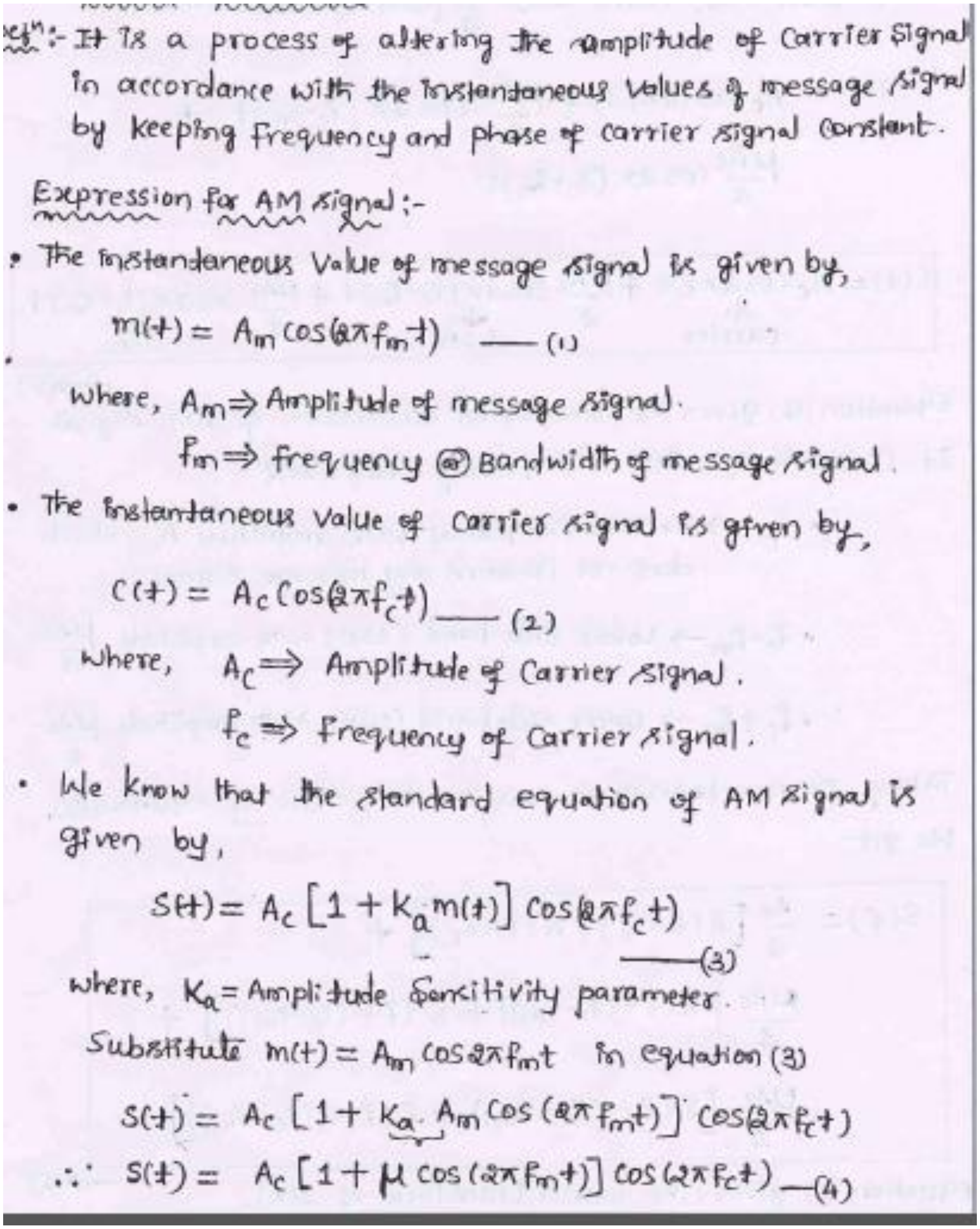
Internal Assesment Test - I

Sub:	Principles of Communication Systems							Code:	18EC53
Date:	November 2021	Duration:	90 mins	Max Marks:	50	Sem:	5th	Branch:	ECE (All sections)
Answer All Questions									

No	Question	Marks	CO	RBT
1	Describe AM. Obtain the expression for the spectrum of single tone and multi tone AM signal. Plot the spectrum in each case.	10	CO1	L2
2	Explain in detail the working of switching modulator with the help of necessary diagrams, waveforms and derivations.	10	CO1	L2
3	With necessary diagrams, waveforms and equations explain the working of Ring modulator	10	CO1	L2
4	An audio frequency signal, $5cos\ (2\pi 10^3 t)$, is used to amplitude modulate a carrier signal$100cos\ (2\pi 10^6 t)$, Assume modulation index of 0.4. Find i) Sideband frequencies ii) Bandwidth required iii) Total transmitted power iv) Efficiency	10	CO1	L3
5	Write short notes on a)QAM b)FDM	10	CO1	L2
6	What is coherent detection? Explain how Costas receiver can be used for demodulating the DSBSC signal.	10	CO1	L2
7	Explain the scheme for generation and detection of VSB modulated wave, with the help of relevant spectrum depictions and mathematical expressions.	10	CO1	L2

IA! Question Paper Solution

1 Single tone and Multitone AM



ef^n:- It is a process of altering the amplitude of carrier signal in accordance with the instantaneous values of message signal by keeping frequency and phase of carrier signal constant.

Expression for AM signal :-

- The instantaneous value of message signal is given by,

$$m(t) = A_m \cos(2\pi f_m t) \quad \text{---- (1)}$$

where, $A_m \Rightarrow$ Amplitude of message signal.

$f_m \Rightarrow$ frequency ⓐ Bandwidth of message signal.

- The instantaneous value of carrier signal is given by,

$$c(t) = A_c \cos(2\pi f_c t) \quad \text{---- (2)}$$

Where, $A_c \Rightarrow$ Amplitude of carrier signal.

$f_c \Rightarrow$ frequency of carrier signal.

- We know that the standard equation of AM signal is given by,

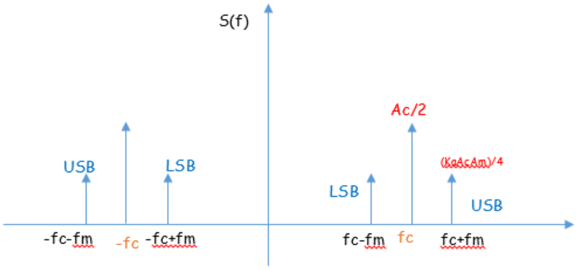
$$s(t) = A_c[1 + K_a m(t)] \cos(2\pi f_c t) \quad \text{---- (3)}$$

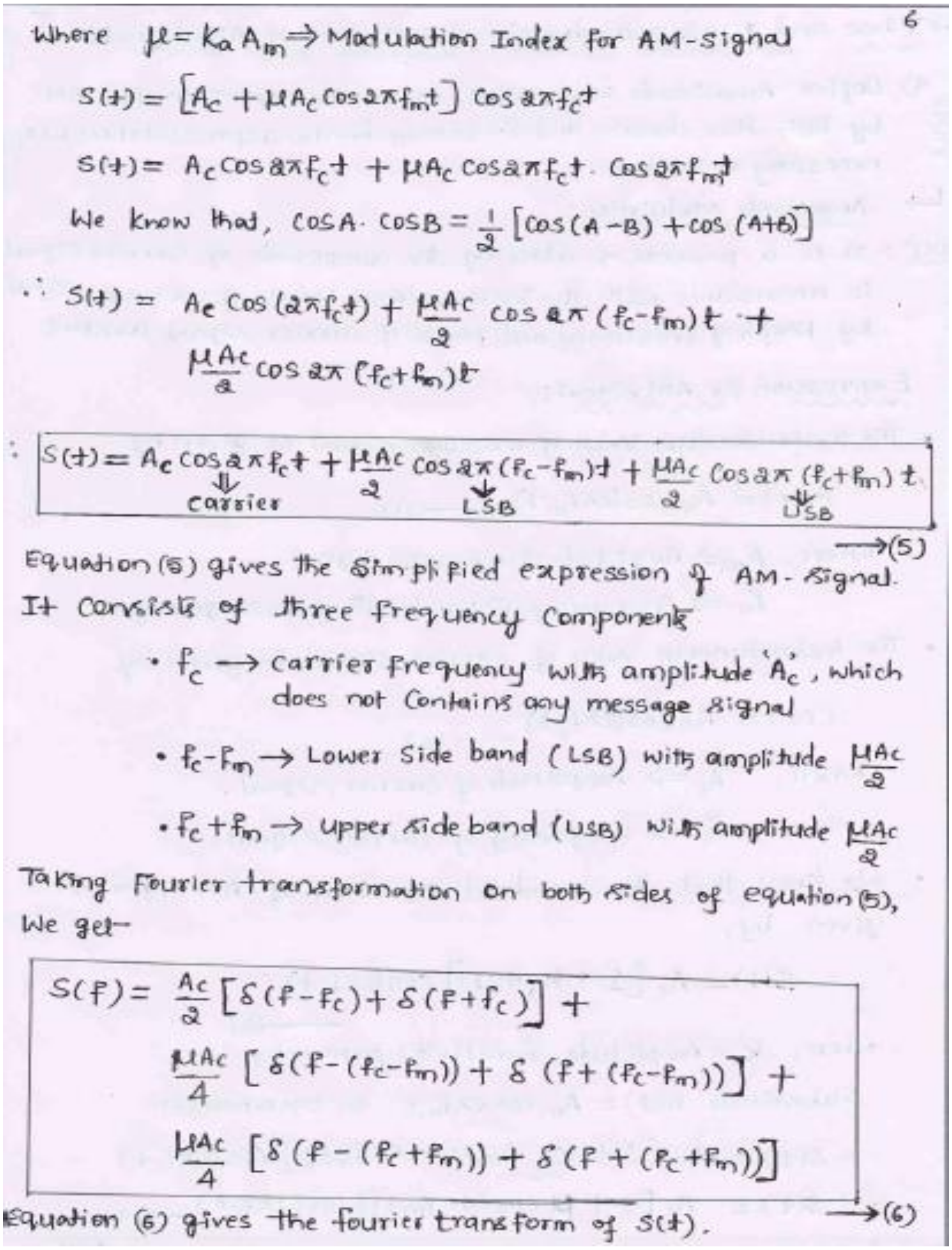
where, K_a = Amplitude sensitivity parameter.

Substitute $m(t) = A_m \cos 2\pi f_m t$ in equation (3)

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

$$\therefore \; s(t) = A_c[1 + \mu \cos(2\pi f_m t)] \cos(2\pi f_c t) \quad \text{---- (4)}$$





Where $\mu = K_a A_m \Rightarrow$ Modulation Index for AM-signal

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

$$S(t) = A_c \cos 2\pi f_c t + \mu A_c \cos 2\pi f_c t \cdot \cos 2\pi f_m t$$

We know that, $\cos A \cdot \cos B = \frac{1}{2}[\cos(A-B) + \cos(A+B)]$

$$\therefore S(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2} \cos 2\pi (f_c - f_m) t + \frac{\mu A_c}{2} \cos 2\pi (f_c + f_m) t$$

$$\therefore \boxed{S(t) = \underset{\text{carrier}}{A_c \cos 2\pi f_c t} + \frac{\mu A_c}{2} \underset{\text{LSB}}{\cos 2\pi (f_c - f_m) t} + \frac{\mu A_c}{2} \underset{\text{USB}}{\cos 2\pi (f_c + f_m) t}} \longrightarrow (5)$$

Equation (5) gives the simplified expression of AM-signal. It consists of three frequency components

- $f_c \longrightarrow$ carrier frequency with amplitude 'A_c', which does not contains any message signal
- $f_c - f_m \rightarrow$ Lower side band (LSB) with amplitude $\frac{\mu A_c}{2}$
- $f_c + f_m \rightarrow$ upper side band (USB) with amplitude $\frac{\mu A_c}{2}$

Taking Fourier transformation on both sides of equation (5), we get

$$\boxed{\begin{aligned} S(f) = {} & \frac{A_c}{2}[\delta(f - f_c) + \delta(f + f_c)] + \\ & \frac{\mu A_c}{4}[\delta(f - (f_c - f_m)) + \delta(f + (f_c - f_m))] + \\ & \frac{\mu A_c}{4}[\delta(f - (f_c + f_m)) + \delta(f + (f_c + f_m))] \end{aligned}} \longrightarrow (6)$$

Equation (6) gives the fourier transform of $S(t)$.

* Expression for Multitone Amplitude Modulation:-

Consider two modulating signals

$$m_1(t) = A_{m_1} \cos 2\pi f_{m_1} t \quad \text{——} (1)$$

$$m_2(t) = A_{m_2} \cos 2\pi f_{m_2} t \quad \text{——} (2)$$

W.K.T the standard equation of AM-wave is

$$S(t) = A_c \left[1 + K_a m(t)\right] \cos 2\pi f_c t \quad \text{——} (3)$$

In this case $m(t) = m_1(t) + m_2(t) = A_{m_1} \cos 2\pi f_{m_1} t + A_{m_2} \cos 2\pi f_{m_2} t$

$$\therefore \quad S(t) = A_c \left[1 + K_a \left(A_{m_1} \cos 2\pi f_{m_1} t + A_{m_2} \cos 2\pi f_{m_2} t\right)\right] \cos 2\pi f_c t$$

$$S(t) = A_c \left[1 + \underbrace{K_a A_{m_1}}_{\mu_1} \cos 2\pi f_{m_1} t + \underbrace{K_a A_{m_2}}_{\mu_2} \cos 2\pi f_{m_2} t\right] \cos 2\pi f_c t$$

$$\therefore \boxed{S(t) = A_c \left[1 + \mu_1 \cos 2\pi f_{m_1} t + \mu_2 \cos 2\pi f_{m_2} t\right] \cos 2\pi f_c t} \quad \text{——} (4)$$

$$S(t) = A_c \cos 2\pi f_c t + \mu_1 A_c \cos 2\pi f_c t \cdot \cos 2\pi f_{m_1} t + \mu_2 A_c \cos 2\pi f_c t \cdot \cos 2\pi f_{m_2} t$$

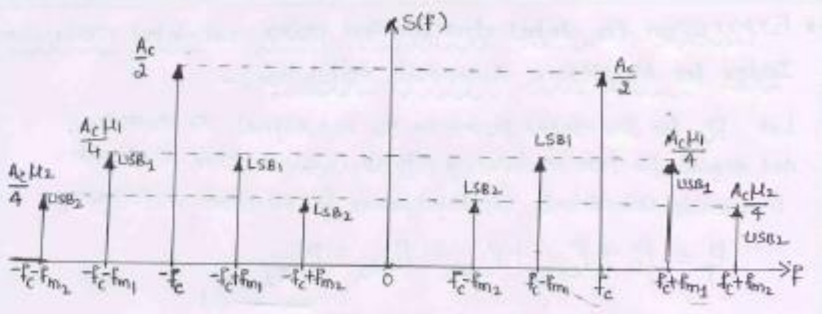
W.K.T $\cos A \cdot \cos B = \frac{1}{2}\{\cos(A-B) + \cos(A+B)\}$

$$\therefore \quad S(t) = A_c \underbrace{\cos 2\pi f_c t}_{\text{carrier}} + \frac{\mu_1 A_c}{2} \cos \underbrace{2\pi (f_c - f_{m_1}) t}_{LSB_1} + \frac{\mu_1 A_c}{2} \cos \underbrace{(2\pi (f_c + f_{m_1}) t)}_{USB_1}$$
$$+ \frac{\mu_2 A_c}{2} \cos \underbrace{2\pi (f_c - f_{m_2}) t}_{LSB_2} + \frac{\mu_2 A_c}{2} \cos \underbrace{2\pi (f_c + f_{m_2}) t}_{USB_2} \quad \text{——} (5)$$

From equation (5), it is clear that, when we have two modulating frequencies (f_{m_1}, f_{m_2}) we get total four side bands. i.e., Two upper sidebands (USB) $f_c + f_{m_1}$, $f_c + f_{m_2}$ & Two Lower Sidebands (LSB) $f_c - f_{m_1}$, $f_c - f_{m_2}$.

\- Applying Fourier transform to equation (5) we get,

$$S(f) = \frac{A_c}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right] + \frac{\mu_1 A_c}{4}\left[\delta(f - [f_c - f_{m_1}]) + \delta(f + [f_c - f_{m_1}])\right]$$
$$+ \frac{\mu_1 A_c}{4}\left[\delta(f - [f_c + f_{m_1}]) + \delta(f + [f_c + f_{m_1}])\right] + \frac{\mu_2 A_c}{4}\left[\delta(f - [f_c - f_{m_2}])\right.$$
$$\left. + \delta(f + [f_c - f_{m_2}])\right] + \frac{\mu_2 A_c}{4}\left[\delta(f - [f_c + f_{m_2}]) + \delta(f + [f_c + f_{m_2}])\right]$$
$$\text{——} (6)$$



—: Spectrum for Multitone Amplitude Modulation :—

2 Switching Modulator

1.3 : SWITCHING MODULATOR :-

It is a Diode circuit used to generate AM-Signal.

Q) Explain the operation of switching Modulator with circuit diagram and waveforms. Dec 2016/Jan 2017

↳ Switching Modulator is used to generate AM Signal.

Circuit diagram :-

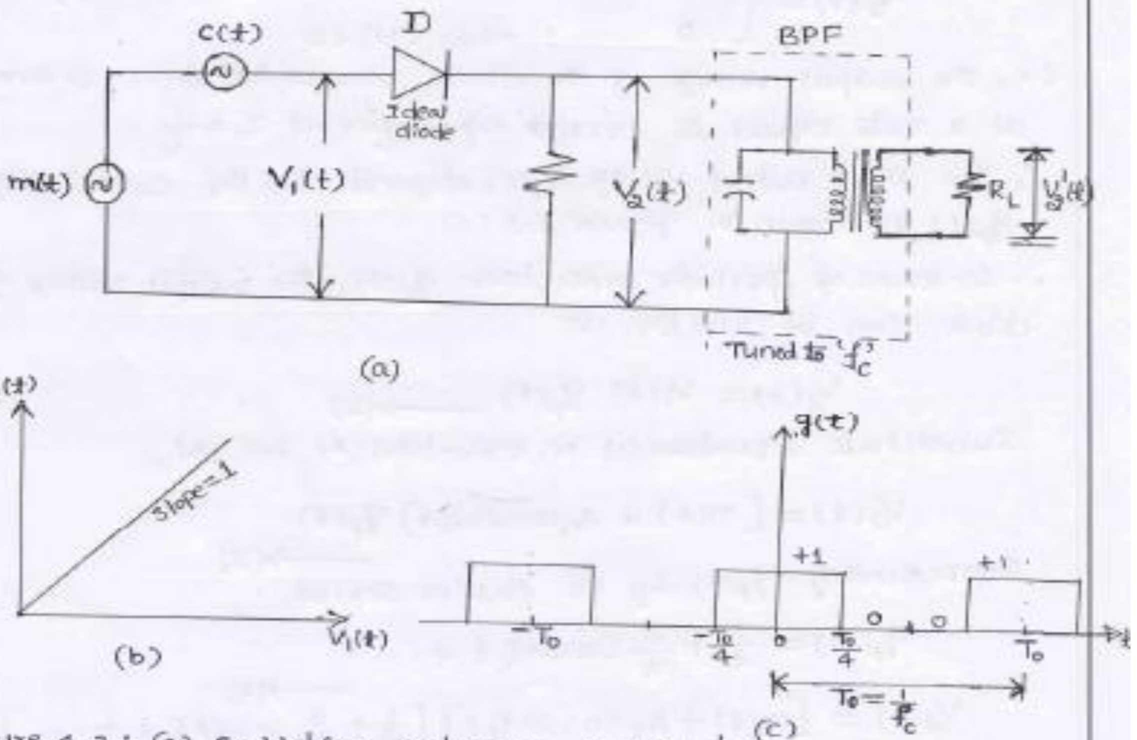


Figure 1.3 : (a) Switching Modulator Circuit diagram
(b) Idealized input ($v_1(t)$) and output $V_2(t)$ relation of Diode
(c) periodic pulse-train of c(t).

Explanation :- switching modulator consists of an Ideal diode which is used as a switch, followed by Band pass Filter (BPF) tuned to frequency 'f_c' as shown in figure 1.3 (a).

↳ Message signal m(t) and Carrier signal c(t) are simultaneously applied as input signal for Ideal diode 'D', as shown in figure 1.3(a).

∴ The total input '$V_1(t)$' to the diode is given by

$$V_1(t) = m(t) + c(t)$$

$$\therefore \boxed{V_1(t) = m(t) + A_c \cos 2\pi f_c t} \longrightarrow (1)$$

It is assumed that $|m(t)| \ll A_c$. Therefore ON & OFF of Diode 'D' is Controlled by $c(t)$.

∴ The output voltage of Diode 'D' is,

$$V_2(t) = \begin{cases} V_1(t) & ;\ \text{when } c(t) > 0 \Longrightarrow \text{shown in figure 1.3(b)} \\ 0 & ;\ \text{when } c(t) < 0 \end{cases}$$

i.e., the output voltage of the diode varies between 0 and $V_1(t)$ at a rate equal to Carrie signal period $T_0 = \frac{1}{f_c}$.

∴ The Diode output voltage $V_2(t)$ depends on the control signal $g_p(t)$ as shown in figure 1.3 (c).

∴ In terms of periodic pulse train $g_p(t)$, the output voltage of the diode can be written as

$$V_2(t) = V_1(t) \cdot g_p(t) \longrightarrow (2)$$

Substitute Equation (1) in equation (2) we get,

$$V_2(t) = \left[m(t) + A_c \cos 2\pi f_c t\right] g_p(t) \longrightarrow (3)$$

Representing $g_p(t)$ by its Fourier Series,

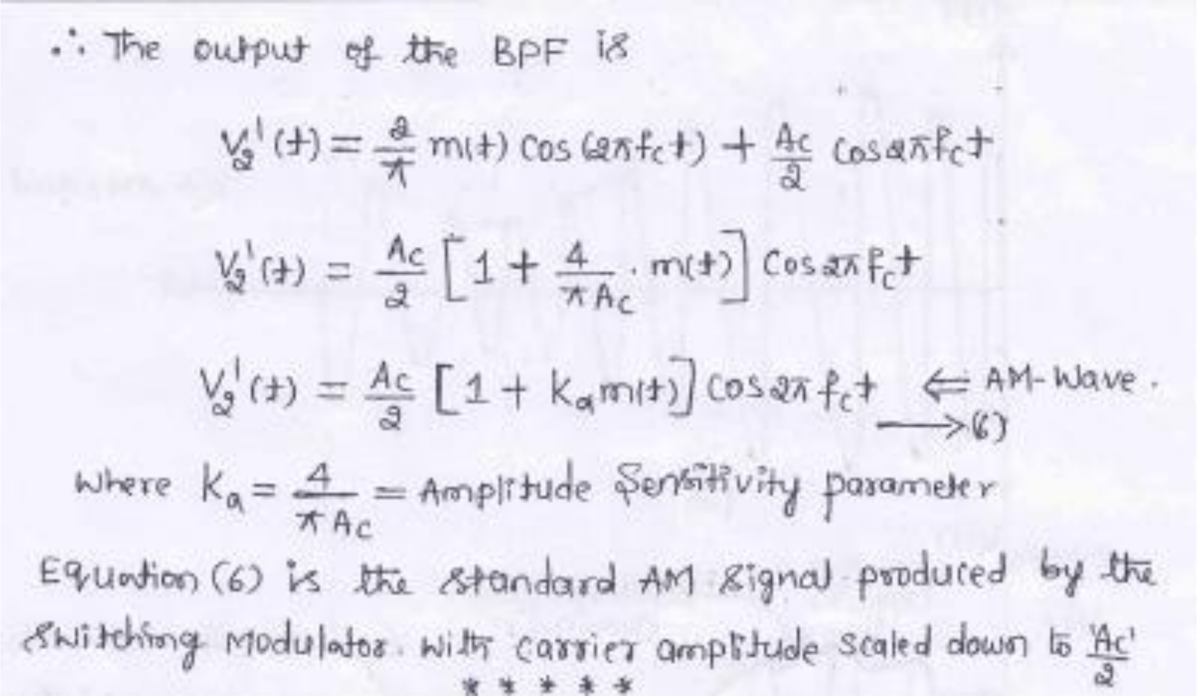
$$g_p(t) = \frac{1}{2} + \frac{2}{\pi} \cos 2\pi f_c t + \cdots \longrightarrow (4)$$

$$\therefore V_2(t) = \left[m(t) + A_c \cos 2\pi f_c t\right]\left[\frac{1}{2} + \frac{2}{\pi}\cos 2\pi f_c t + \cdots\right]$$

$$V_2(t) = \frac{1}{2} m(t) + \frac{2}{\pi} m(t) \cdot \cos 2\pi f_c t + \frac{A_c}{2} \cos 2\pi f_c t + \frac{2A_c}{4}\Big[\underbrace{\cos^2 2\pi f_c t}_{\left(\frac{1+\cos 2\theta}{2}\right)}\Big] + \cdots$$

$$V_2(t) = \frac{1}{2} m(t) + \frac{2}{\pi} m(t) \cos 2\pi f_c t + \frac{A_c}{2} \cos 2\pi f_c t + \underset{(DC)}{\frac{A_c}{4}} + \frac{A_c}{4} \cos 4\pi f_c t + \cdots \longrightarrow (5)$$

The required AM wave Centered at 'f_c' is obtained by passing $V_2(t)$ through an ideal BPF having Center frequency 'f_c' and $BW = 2f_m$ Hz



∴ The output of the BPF is

$$V_2'(t) = \frac{2}{\pi} m(t) \cos(2\pi f_c t) + \frac{A_c}{2} \cos 2\pi f_c t$$

$$V_2'(t) = \frac{A_c}{2}\left[1 + \frac{4}{\pi A_c} \cdot m(t)\right] \cos 2\pi f_c t$$

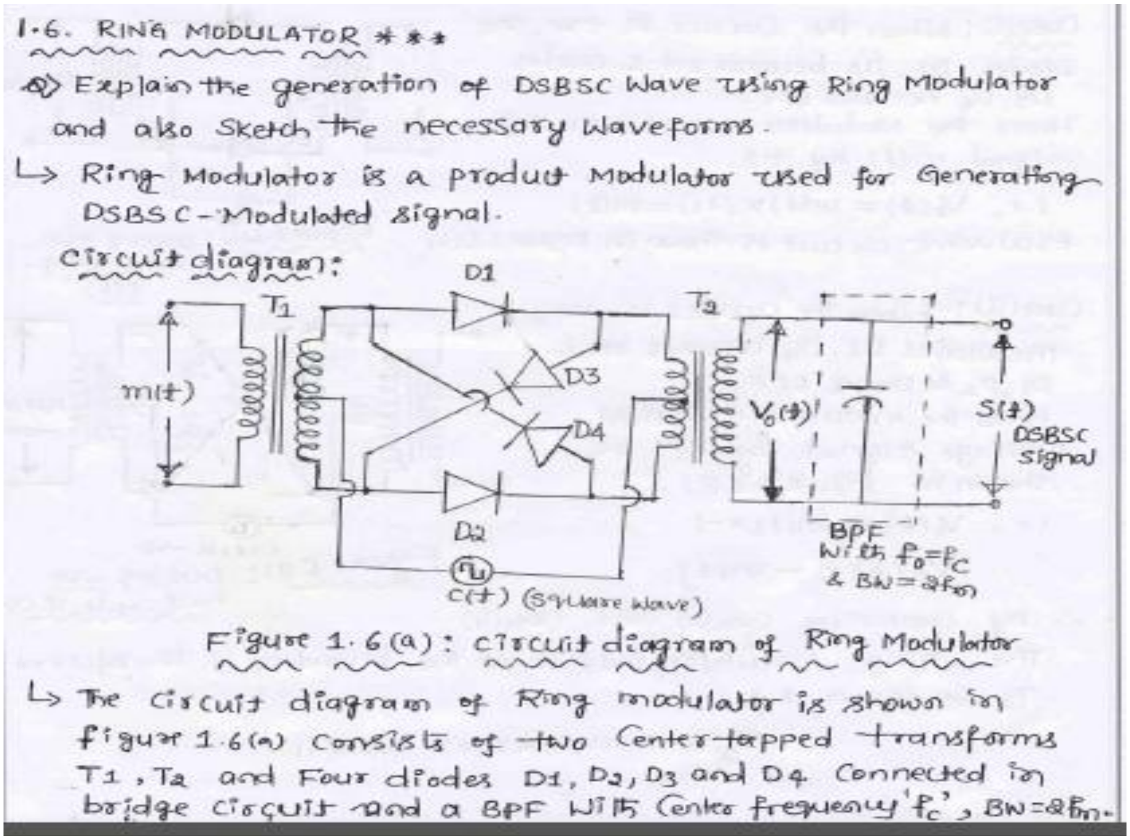
$$V_2'(t) = \frac{A_c}{2}\left[1 + K_a m(t)\right] \cos 2\pi f_c t \Leftarrow \text{AM-Wave.} \longrightarrow (6)$$

Where $K_a = \frac{4}{\pi A_c}$ = Amplitude Sensitivity parameter

Equation (6) is the standard AM signal produced by the switching Modulator. with carrier amplitude scaled down to $\frac{A_c}{2}$

* * * * *

3 Ring Modulator



1.6. RING MODULATOR ***

Q) Explain the generation of DSBSC Wave using Ring Modulator and also Sketch the necessary Waveforms.

↳ Ring Modulator is a product Modulator used for Generating DSBSC-Modulated signal.

Circuit diagram:

Figure 1.6(a): circuit diagram of Ring Modulator

↳ The circuit diagram of Ring modulator is shown in figure 1.6(a) consists of two Center-tapped transforms T1, T2 and Four diodes D1, D2, D3 and D4 Connected in bridge circuit and a BPF With Center frequency 'f_c', BW = $2f_m$.

- The carrier signal is applied to the center taps of the input (T_1) and output (T_2) transformers. Modulating signal is applied to the input transformer T_1.
- The output voltage appears across the secondary of the transformer, T_2 (After passing through BPF).
- The Diodes connected in the bridge circuit (Ring) acts like switches and their switching is controlled by carrier signal (square wave).

Circuit operation :-

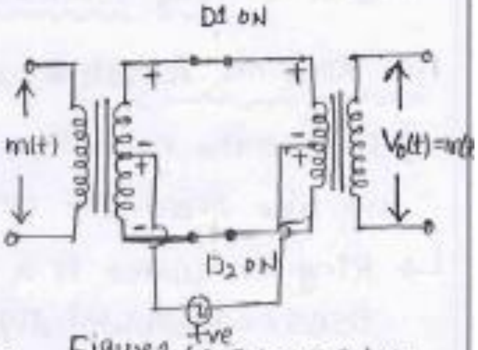


Figure 1.6(b): During +ve half cycle of C(t)

Case(I): When the carrier is +ve, the Diodes D1, D2 becomes ON & Diodes D3, D4 becomes OFF.
Hence the Modulator Multiplies message signal m(t) by +1.

i.e., $V_0(t) = m(t) \times (+1) = m(t)$

Equivalent circuit is shown in Figure 1.6(b)

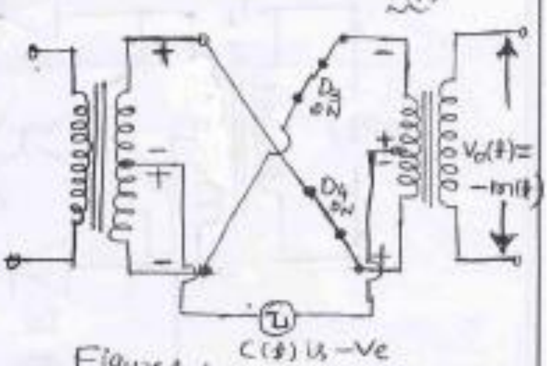


Figure 1.6 (c): During -ve half cycle of C(t)

Case(ii) :- When the carrier is -ve, the Diodes D3, D4 becomes ON & D1, D2 becomes OFF.
Hence the modulator multiplies message signal by "-1" as shown in figure 1.6 (c).

i.e., $V_0(t) = m(t) \times -1$

$$V_0(t) = -m(t)$$

∴ By combining Case(i) and Case(ii)
The Ring Modulator output at the secondary of transformer T_2 is given by

$$V_0(t) = m(t) \times C(t) \quad \text{—(1)}$$

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

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

$$\therefore c(t) = \frac{4}{\pi}\left[\cos 2\pi f_c t - \frac{1}{3}\cos 6\pi f_c t + \cdots\right] \quad \text{—(2)}$$

∴ Substitute equation (2) in $V_o(t)$ equation(1) we get

$$V_o(t) = m(t)\times\frac{4}{\pi}\left[\cos 2\pi f_c t - \frac{1}{3}\cos 6\pi f_c t + \cdots\right] \quad \text{—(3)}$$

When $V_o(t)$ is passed through BPF having center frequency 'f_c' and Bandwidth '$2f_m$' we get DSBSC signal,

$$\boxed{S(t) = \frac{4}{\pi}\, m(t)\cos 2\pi f_c t} \Leftarrow \text{DSBSC Wave generated from RING Modulator}$$

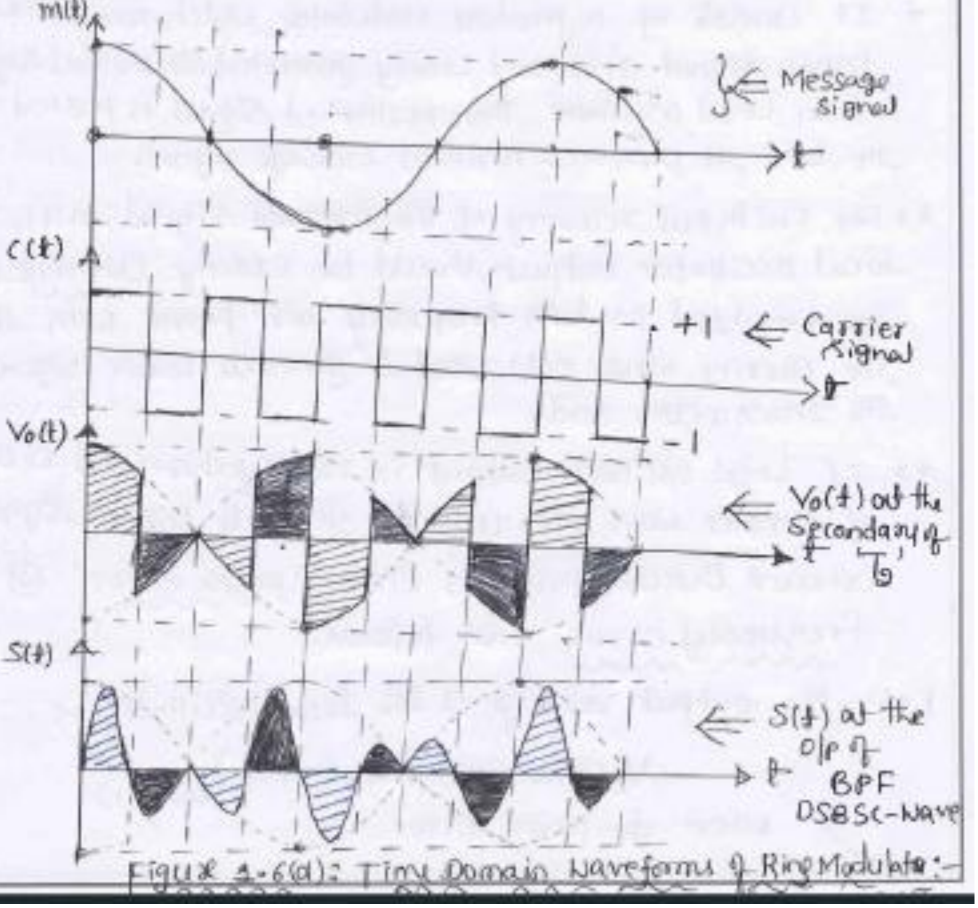


Figure 1.6(d): Time Domain Waveforms of Ring Modulator:-

** Time and Frequency domain description of AM-signal:

VTU Dec

Q> Define Amplitude Modulation. Obtain the Expression for AM by both time domain and frequency domain representation with necessary waveforms.

↳ Amplitude Modulation:-

Def^n:- It is a process of altering the amplitude of Carrier Signal in accordance with the Instantaneous Values of message signal by keeping frequency and phase of carrier signal constant.

Expression for AM signal:-

- The instantaneous Value of message signal is given by,

$$m(t) = A_m \cos(2\pi f_m t) \quad \text{—— (1)}$$

Where, $A_m \Rightarrow$ Amplitude of message signal.

$f_m \Rightarrow$ frequency (or) Bandwidth of message signal.

- The Instantaneous value of carrier signal is given by,

$$C(t) = A_c \cos(2\pi f_c t) \quad \text{—— (2)}$$

Where, $A_c \Rightarrow$ Amplitude of Carrier signal.

$f_c \Rightarrow$ frequency of Carrier signal.

- We know that the standard equation of AM signal is given by,

$$S(t) = A_c \left[1 + K_a m(t)\right] \cos(2\pi f_c t) \quad \text{—— (3)}$$

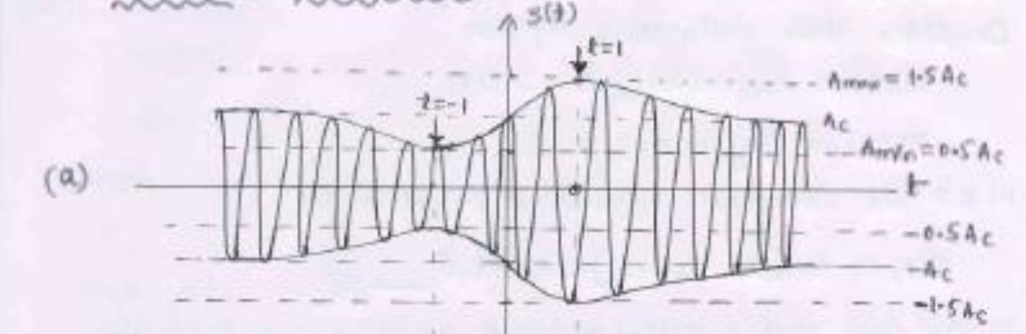
where, K_a = Amplitude Sensitivity parameter.

Substitute $m(t) = A_m \cos 2\pi f_m t$ in equation (3)

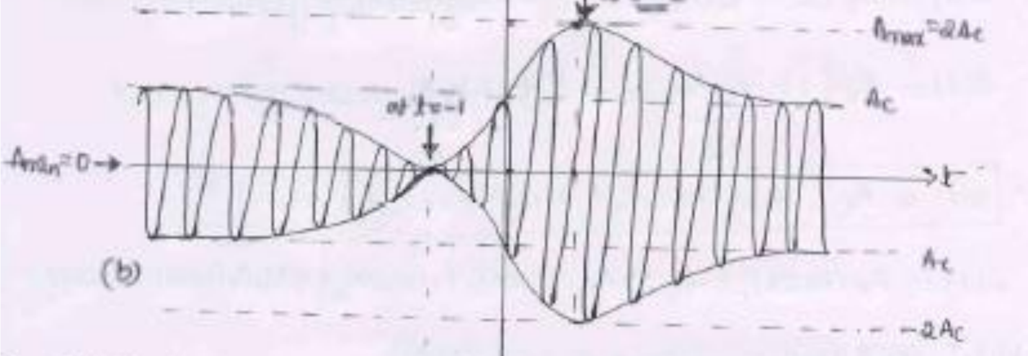
$$S(t) = A_c \left[1 + \underbrace{K_a \cdot A_m}_{} \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$$

$$\therefore S(t) = A_c \left[1 + \mu \cos(2\pi f_m t)\right] \cos(2\pi f_c t) \quad \text{—— (4)}$$

Case(i) : $\mu=50\%$: Under Modulation:-



Case(ii) $\mu=100\%$: Critical Modulation



Case(iii): $\mu=125\%$: Over Modulation:-

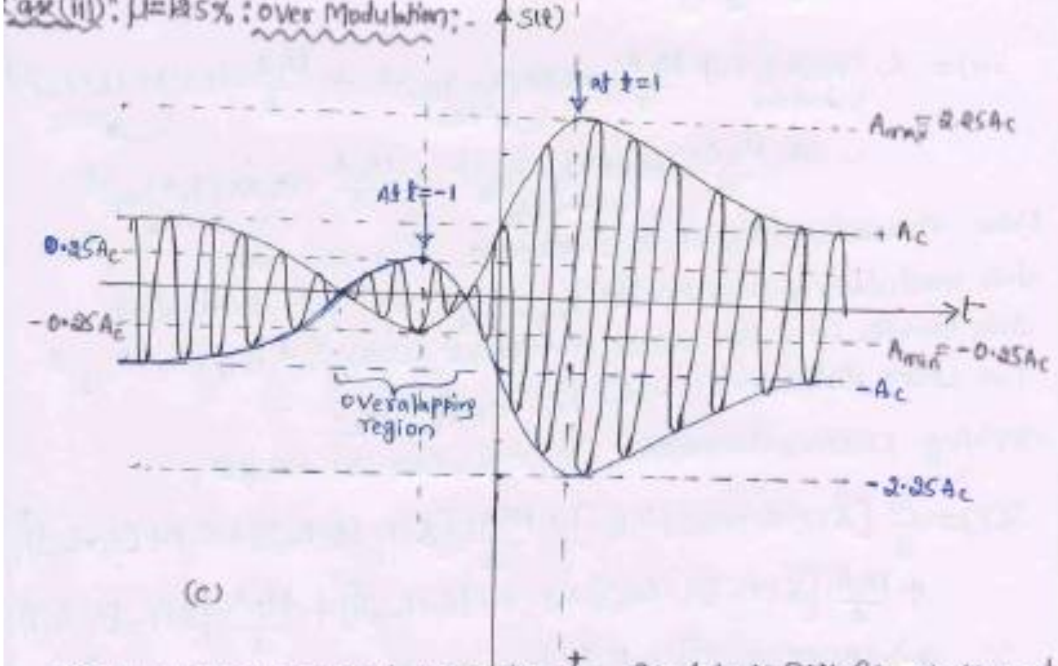


Figure 1.2: AM signal for $m(t)=\frac{t}{1+t^2}$ for (a) $\mu=50\%$ (b) $=100\%$ and (c) $\mu=125\%$

4)

Ac=100, fm=1kHz,fc=1000kHz

a) LSB=> Fc-Fm=999kHz

USB => fc+fm= 1001kHz

b)BW= 2fm=2kHz

c) Power

$P_T = \frac{{A_c}^2}{2R}(1 + \frac{\mu^2}{2})$

Considering R=1 , Ac=100,u=0.4

PT= 5400W

d) Efficiency

% Modulation efficiency $= \frac{\mu^2}{2+\mu^2} * 100\ \%$

Efficiency=7%

5 a)QAM

→ Quadrature Carrier Multiplexing is a technique in which we can transmit more number of signals (DSBSC-wave) within the same channel Bandwidth. this technique is also named as Quadrature-Amplitude Modulation (QAM).

QAM transmitter:

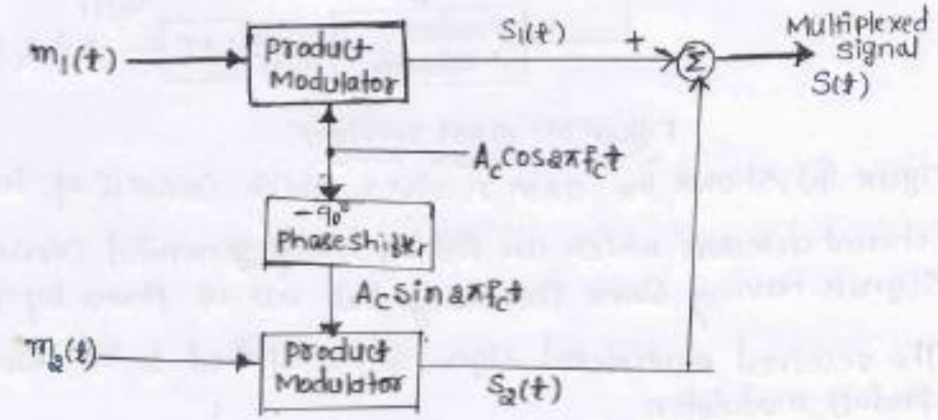


Fig (a) Quadrature Carrier Multiplexing (or) QAM Transmitter

- Figure (a) shows QAM transmitter. It consists of two product modulators that are supplied with carriers which differ in phase by 90° (phase Quadrature)
- The output of the two product modulators are summed to produce multiplexed signal. S(t).

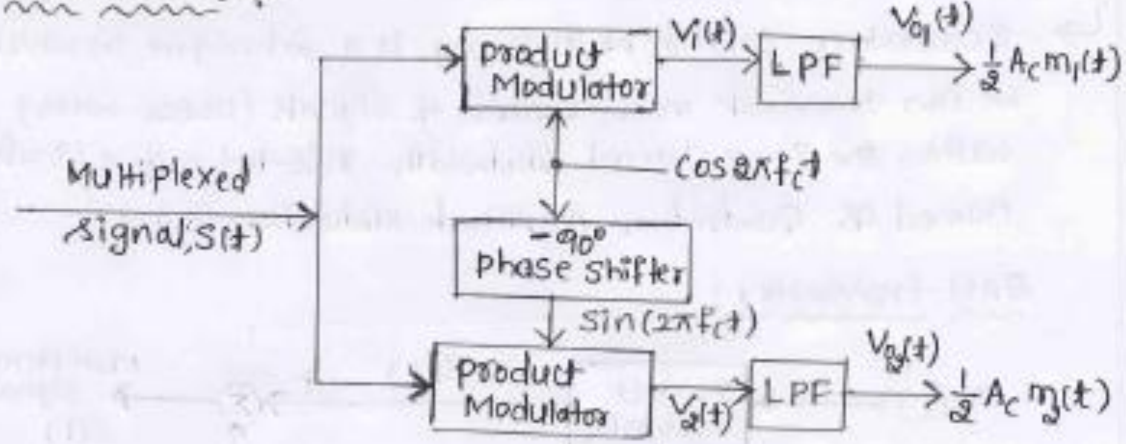
i.e., $S(t) = S_1(t) + S_2(t)$ -

$$S(t) = A_C m_1(t) \cos 2\pi f_c t + A_C m_2(t) \sin 2\pi f_c t$$

∴ QAM-transmitter allows two modulated (DSBSC) waves to occupy the same transmission channel Bandwidth.

∴ The Multiplexed signal s(t), occupies a channel Bandwidth of $BW = 2W$ ∴ $W = \text{Maximum}(f_{m_1}, f_{m_2})$ Centered at the Carrier frequency 'f_c'.

QAM- Receiver:-



Figure(b): QAM receiver

Figure (b) shows the QAM receiver, which consists of two Coherent detectors which are fed by locally generated carrier signals having same frequency but out-of-phase by 90°.

The received multiplexed signal s(t) is applied to the two product modulators.

→ The output of top product Modulator is

$$V_1(t) = s(t) \times \cos 2\pi f_c t.$$

↳ The top LPF removes the high frequency terms and allows only $\frac{A_c}{2} m_1(t)$. ∴ $V_{o_1}(t) = \frac{A_c}{2} \cdot m_1(t)$

Similarly the output of bottom product modulator is

$$V_2(t) = s(t) \times \sin 2\pi f_c t$$

↳ The bottom LPF removes the high frequency terms and allows only $\frac{A_c}{2} \cdot m_2(t)$

$$\therefore V_{o_2}(t) = \frac{A_c}{2} m_2(t)$$

Application: used in color TV

5 b)FDM

* Frequency Division Multiplexing <FDM>

↳ Multiplexing is a process of combining N-independent message signals into a composite signal suitable for transmission over a common channel

↳ Multiplexing is accomplished by seperating the signals either in frequency (or) time.

↳ The technique of separating the signals in frequency domain is referred to as " Frequency Division Multiplexing".

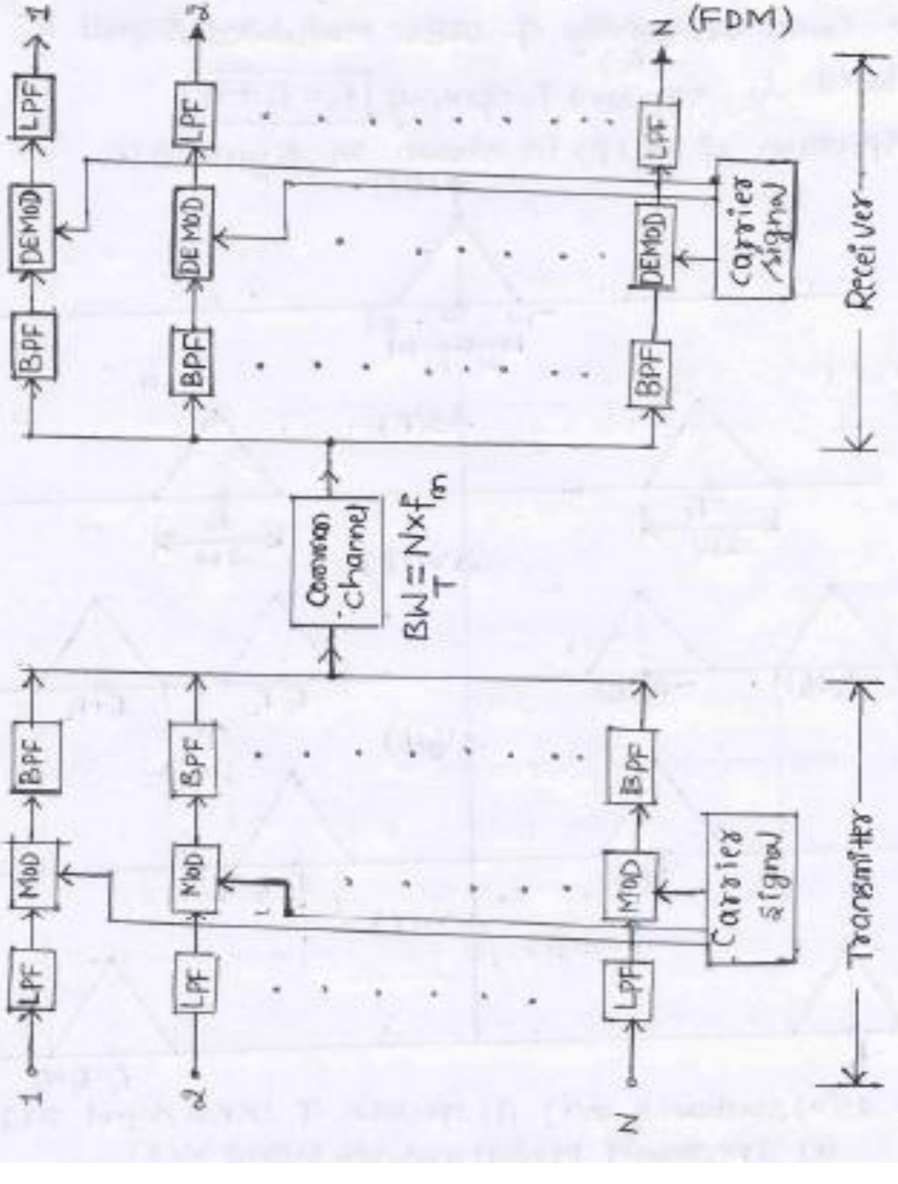


Figure 1: Block diagram of FDM System

The block diagram of FDM-system is shown in figure1.

↳ N-Incoming independent message signals are modulated by mutually Exclusive carriers supplied from carrier source at each modulator. The Modulated signals are passed through the BPF to select any one side band. Therefore BPF's produces SSB-signals and are separated in frequency and combined into a composite signal. and this process is called Frequency division multiplexing.

↳ Multiplexed signal is transmitted over the communication channel.

↳ Total Bandwidth required to N-SSB Modulated signals without any Guard band is

$$BW_T = N \times f_m \; ; \; N = \text{number of Input signals}$$

↳ At the receiver side N-independent message signals are recovered by passing the composite signal through the BPF followed by Demodulator and LPF.

Advantages of FDM:-

1. A Large Number of signals can be transmitted simultaneously.
2. FDM does not requires synchronization between Transmitter & receiver.
3. Demodulation of FDM is easy

Dis advantages of FDM:-

1. Communication channel must have Large Bandwidth
   i.e., $BW_T = N \times fm$
2. Large Numbers of Modulators & Filters are required.
3. cross talk occurs in FDM

6) Costa Receiver

↳

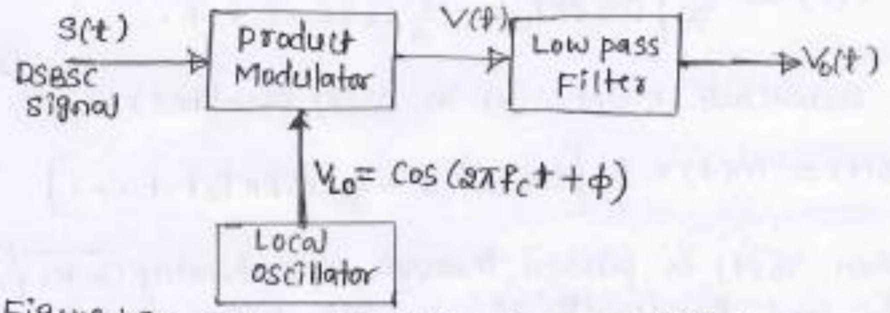


Figure 1.7: Coherent Detector for DSBSC Signal

* The Modulating signal m(t) is recovered from a DSBSC Wave S(t) by using Coherent Detector shown in figure 1.7.

* It Consists of a product Modulator, which multiplies DSBSC signal s(t) and Locally generated sinusoidal signal from Local oscillator. Then Multiplied signal is passed through the LPF, it produces required message signal.

** For Faithful recovery of the message signal m(t), the local oscillator output should be exactly Coherent (or) Synchronized in both frequency and phase with that of the Carrier wave c(t) used to generate DSBSC signal at the transmitter end.

↳ The Costas receiver is a practical synchronous receiver system, suitable for demodulating DSBSC-waves. It is also named as Costas loop @ practical synchronous receiving system.

Block diagram:-

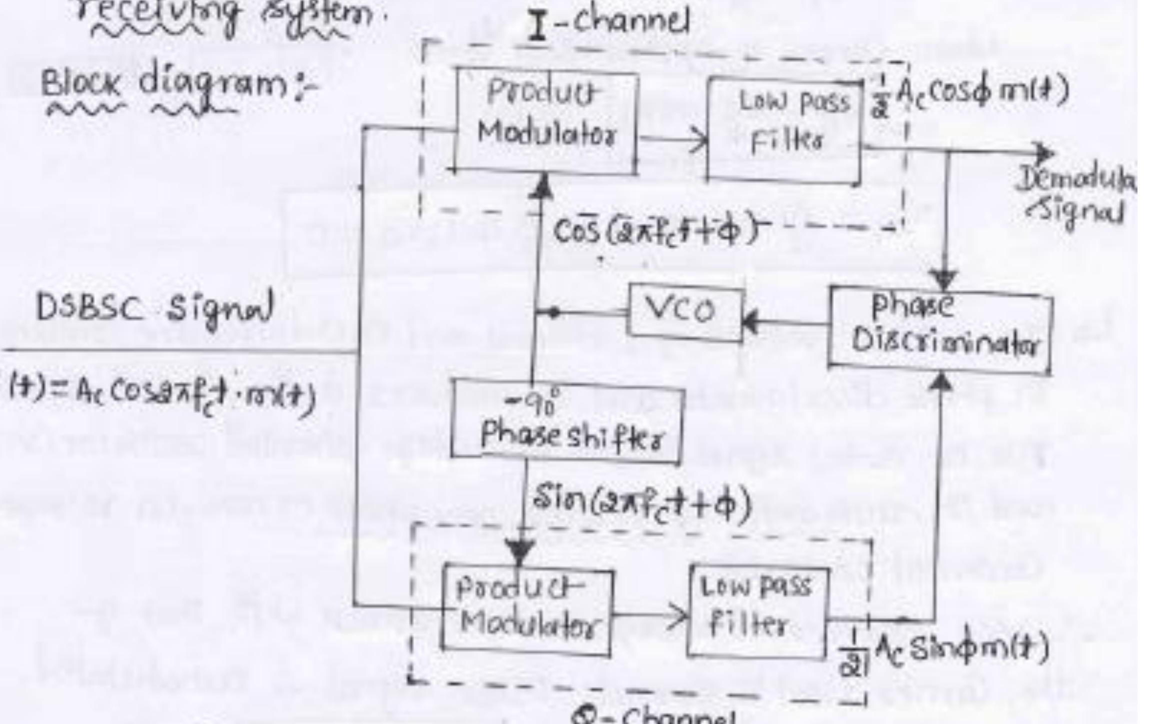
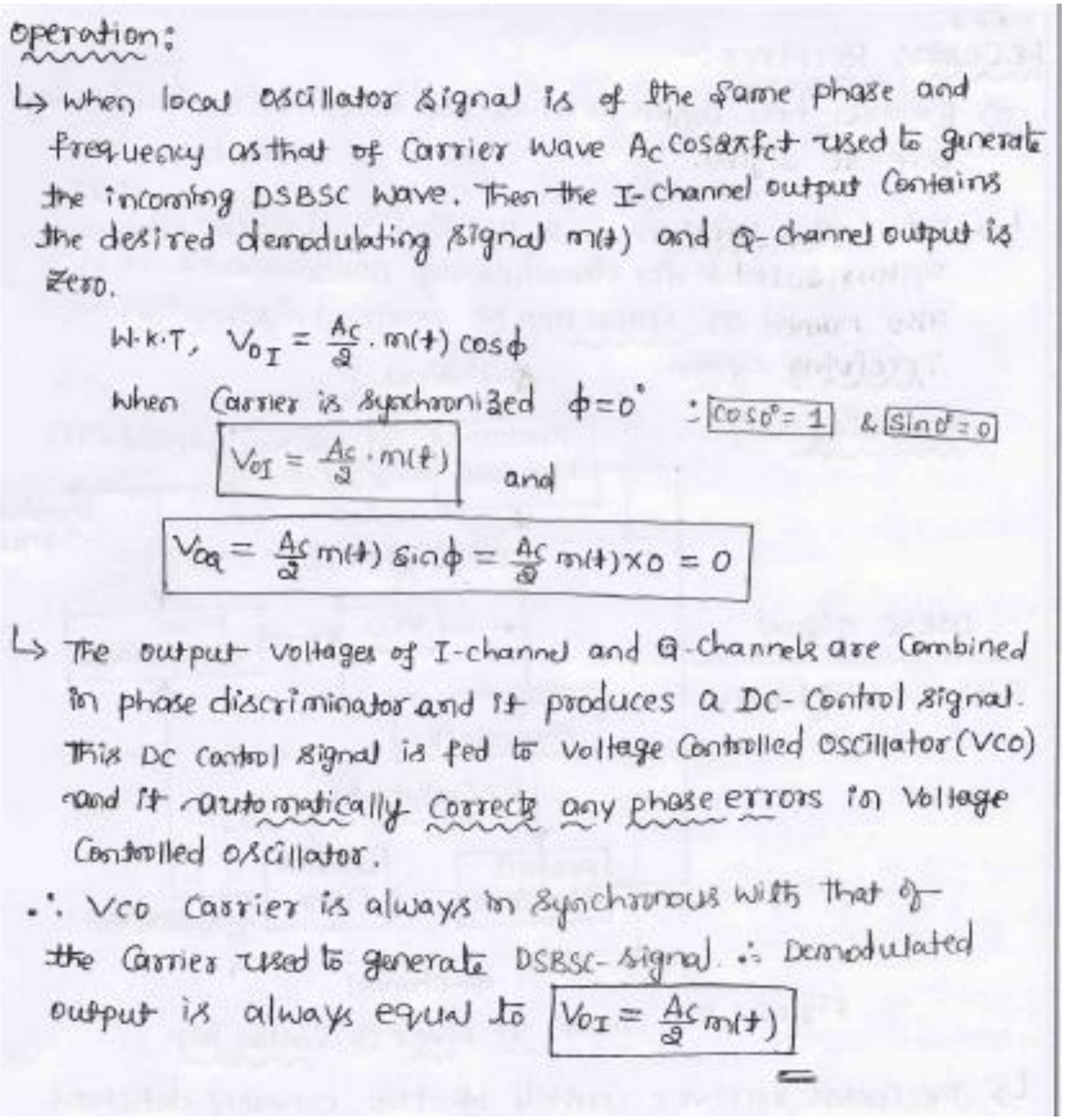


Figure 1.8: Costas receiver @ Costas loop

↳ The Costas receiver consists of two coherent detectors supplied with same input signal (DSBSC-wave $s(t)$) but with individual local oscillator signals that are phase Quadrature with respect to each other. (i.e., the local oscillator signals supplied to the product modulators are 90° out of phase).

↳ The coherent detector in the upper path is referred to as the In-phase detector [@ I-channel] and that in the lower path is referred to as Quadrature-phase Detector [@ Q-channel] as shown in figure 1.8.



operation:

↳ when local oscillator signal is of the same phase and frequency as that of carrier wave $A_c \cos 2\pi f_c t$ used to generate the incoming DSBSC wave. Then the I-channel output contains the desired demodulating signal m(t) and Q-channel output is zero.

W.K.T, $V_{0I} = \frac{A_c}{2} \cdot m(t) \cos\phi$

when carrier is synchronized $\phi = 0^\circ$ ∴ $\boxed{\cos 0^\circ = 1}$ & $\boxed{\sin 0^\circ = 0}$

$$\boxed{V_{0I} = \frac{A_c}{2} \cdot m(t)}$$

and

$$\boxed{V_{0Q} = \frac{A_c}{2} m(t) \sin\phi = \frac{A_c}{2} m(t) \times 0 = 0}$$

↳ The output voltages of I-channel and Q-channels are combined in phase discriminator and it produces a DC-control signal. This DC control signal is fed to voltage controlled oscillator (VCO) and it automatically corrects any phase errors in voltage controlled oscillator.

∴ VCO carrier is always in synchronous with that of the carrier used to generate DSBSC-signal. ∴ Demodulated output is always equal to $\boxed{V_{0I} = \frac{A_c}{2} m(t)}$

7) VSB

VESTIGIAL SIDEBAND MODULATION (VSB) :-

Necessity (or) Need for VSB-Modulation:

↳ The SSB modulation is not appropriate way of modulation. Because the upper side band and lower side band meet at the Carrier frequency 'f_c' and it is very difficult to isolate one side band. Therefore generating SSB-signal is challenging.

↳ To overcome this difficulty, the modulation technique known as "Vestigial side Band (VSB) - Modulation" is used.

↳ Vestigial sideband Modulated signal (VSB-signal) consists of

- Almost one complete side band and
- Vestige (or Trace (or) part) of the other side band.

* Generation of VSB Modulated Wave:

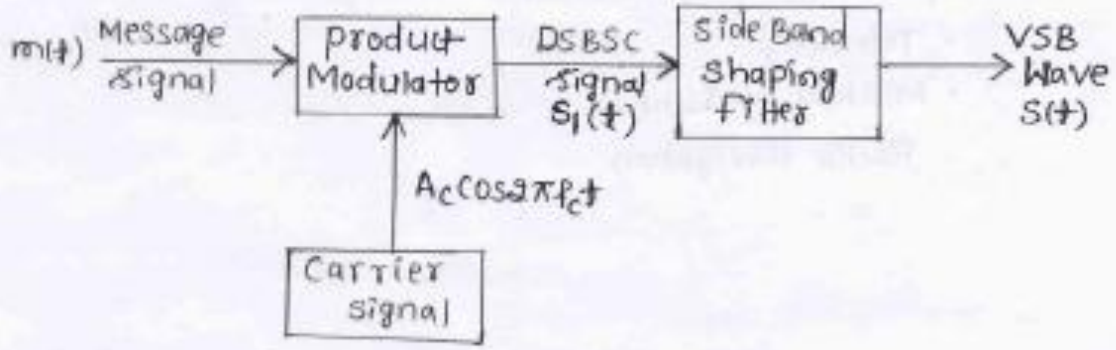


Figure 1: VSB Generator

- VSB signal generator consists of a product Modulator and a sideband shaping filter as shown in figure 1.
- product Modulator generates a DSBSC signal and then pass it through a side band shaping filter.
- Let H(f) be the transfer function of side band shaping filter. This filter will pass one complete sideband along with a vestige (or) trace (or) a part of unwanted (other) side band.

↳ The relation between the transfer function $H(f)$ of the filter and the spectrum $S(f)$ of the VSB-Modulated wave $s(t)$ is defined by, $S(f) = S_1(f) \times H(f)$.

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

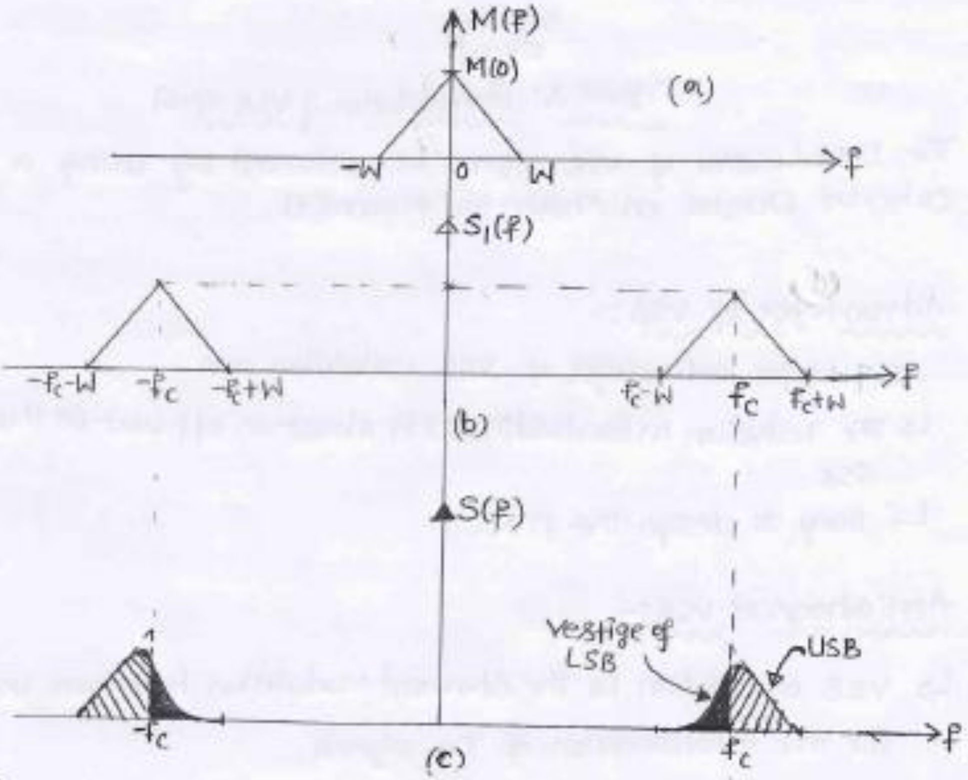


Figure 2: (a) Spectrum of $m(t)$ (b) Spectrum of DSBSC Signal $S_1(t)$
(c) Spectrum of VSB-Modulated Signal $S(t)$

Frequency domain description of VSB modulated wave is shown in figure 2. Figure 2(b) is the Spectrum of DSBSC Signal produced at the output of product Modulator. Figure 2(c) Shows the Spectrum of VSB-modulated Signal $s(t)$.

From figure 2(c) it is evident that the Total transmission Bandwidth of VSB-Modulated signal is higher than that of SSB and Lower than that of DSBSC-signal.

i.e., $W < BW_{T(VSB)} < 2W$

* Demodulation of VSB-Modulated Wave:-

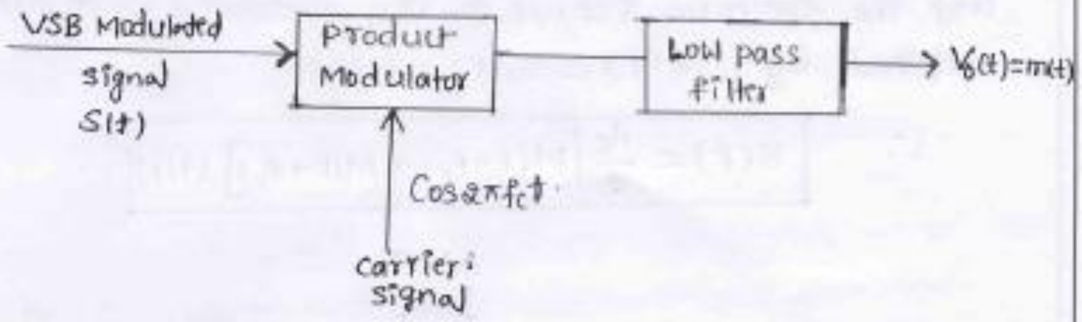


Figure 3: Demodulation of VSB signal

The Demodulation of VSB-signal is achieved by using a coherent Detector as shown in figure(3).

Advantages of VSB:-

The Major advantages of VSB Modulation are

- The reduction in Bandwidth. It is almost as efficient as that of SSB.
- Easy to design the filter.

Applications of VSB:-

- VSB modulation is the standard Modulation technique used for the transmission of TV-signals.