UNIT - II

Till now, we have discussed the amplitude modulation AM. It is also called as the "Double Sideband Full carrier System (DSB-FC). But, this is not the only type of AM. There are some other types of AM as shown.

Amplitude Modulation (AM)

- DSB-FC
- DSB-SC — Double sideband suppressed carrier system
- SSB-SC — Single sideband suppressed carrier system
- ISB — Independent sideband system
- VSB — Vestigial sideband system.

DISADVANTAGES OF DSB-FC

(i) Power wastage takes place in DSB-FC transmission.

(ii) DSB-FC system is bandwidth inefficient system.

(i) Power Wastage in DSB-FC transmission:

The carrier signal in the DSB-FC system does not convey any information. The information is contained in the two sidebands only. But, the sidebands are images of each other and hence both of them contain the same information. Thus, all the information can be conveyed by one sideband.

The total power in AM is given as

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

$$P_t = P_c + \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$$

Out of the three terms in above equation, the carrier component does not contain any information and one sideband is redundant.

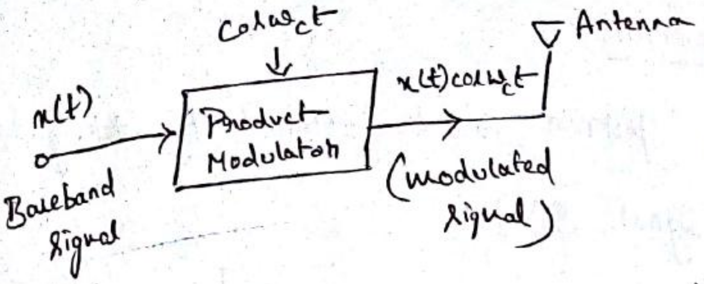
Hence, out of the total power $P_t = \left[1 + \frac{m^2}{2}\right]P_c$ the wasted power is given by:

$$\text{Power Wastage} = P_c + \frac{m^2}{4}P_c$$

Thus for 100% of modulation about 67% of the total power is required for transmitting the carrier which does not contain any information. Hence, if the carrier is suppressed, only the sidebands remain and in this way a saving of two-third power may be achieved at 100% modulat

This type of suppression of carrier does not affect the baseband signal in any way.

→ Therefore, a DSB-SC signal is obtained by simply multiplying modulating signal $x(t)$ with a carrier signal correct. This is achieved by a product modulator. The block diagram is given below.



The expression for DSB-SC signal is given as

$$s(t) = x(t) \cos w_c t$$

where $x(t)$ = Baseband signal

$\cos w_c t$ = Carrier signal.)

SINGLE TONE DSB-SC MODULATION :

In a single tone DSB-SC modulation, the message signal $x(t)$ will be sinusoidal signal and it is represented as

$$x(t) = V_m \cos(2\pi f_m t)$$

V_m = amplitude & f_m = frequency of the modulating signal $x(t)$

TIME-DOMAIN DESCRIPTION :

The DSB-SC modulated wave is given by,

$$s(t) = x(t) \cdot c(t) = V_m \cos(2\pi f_m t) \cdot V_c \cos(2\pi f_c t)$$

$$s(t) = V_m \cdot V_c \cos(2\pi f_c t) \cdot \cos(2\pi f_m t).$$

But $\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$

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

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

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FREQUENCY DOMAIN DESCRIPTION :

The frequency spectrum can be obtained by taking the Fourier transform of signal $s(t)$

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

Taking Fourier transform on both sides

$$S(f) = F\left[\frac{1}{2} V_m V_c \cos 2\pi (f_c + f_m)t \right] + F\left[\frac{1}{2} V_m V_c \cos 2\pi (f_c - f_m)t \right]$$

But, $\cos(2\pi f_x t) \longleftrightarrow \frac{1}{2} \left[\delta(f + f_x) + \delta(f - f_x) \right]$

Therefore, we have.

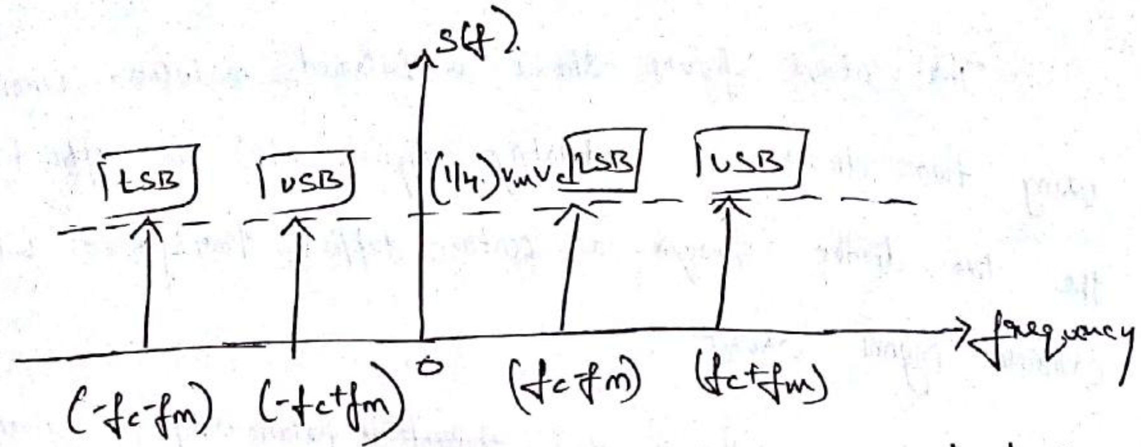
$$S(f) = \frac{1}{4} V_m V_c \left[\delta(f + f_c + f_m) + \delta(f - f_c - f_m) \right]$$
$$+ \frac{1}{4} V_m V_c \left[\delta(f + f_c - f_m) + \delta(f - f_c + f_m) \right]$$

01. So, it is clear that the impulses at $\pm \omega_c$ are missing which means that the carrier term is suppressed in the spectrum and only two sideband term, USB and LSB are left. Therefore, it is called double sideband suppressed carrier.

02. Considering only positive side the upper side band frequency is $\omega_c + \omega_m$, whereas the lower side band frequency is $\omega_c - \omega_m$. The difference of these two is equal to the "transmission Bandwidth".

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

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

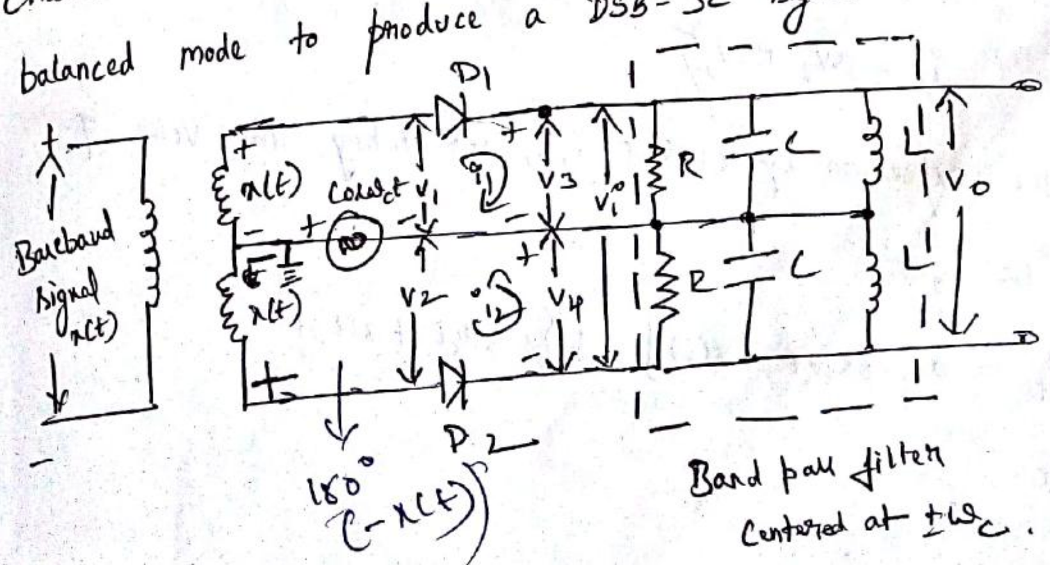


(a) Double sided spectrum of DSB-SC with single tone modulation.

THE BALANCED MODULATOR :

We know that a non-linear device may be used to produce Amplitude Modulation, i.e., one carrier and two sidebands. However, a DSB-SC signal contains only two sidebands. Thus, if two non-linear devices such as diodes, transistors etc are connected in a balanced mode so as to suppress the carriers of each other, then only sidebands are left, i.e. a DSB-SC signal is generated.

Therefore, a balanced modulator may be defined as a circuit in which two non-linear devices are connected in a balanced mode to produce a DSB-SC signal.



The above figure shows a balanced modulator circuit using two diodes. A modulating signal $x(t)$ is applied to the two diodes through a centre-tapped transformer with the carrier signal $\cos\omega_c t$.

A non-linear v-i ~~characteristic~~ relationship is given as

$$i = av + bv^2$$

Here, we have neglected the higher power terms

In above expression, 'v' is the input voltage applied across a non-linear device and 'i' is the current through the non-linear device.

The two input voltages v_1 and v_2 across the two diodes as

$$v_1 = \cos\omega_c t + x(t)$$

$$v_2 = \cos\omega_c t - x(t)$$

For diode D_1, the non-linear v-i relationship becomes

$$i_1 = av_1 + bv_1^2$$

Similarly, for diode D_2, the non-linear v-i relationship

$$i_2 = av_2 + bv_2^2$$

In the expression of current i_1, substituting the value of v_1, we get

$$i_1 = a\left[\cos\omega_c t + x(t)\right] + b\left[\cos\omega_c t + x(t)\right]^2$$

&

$i_1 = a\cos\omega_c t + ax(t) + b[\cos^2\omega_c t + x^2(t) + 2x(t)\cos\omega_c t]$

$i_1 = a\cos\omega_c t + ax(t) + b\cos^2\omega_c t + bx^2(t) + 2bx(t)\cos\omega_c t$

Similarly, in the expression of current i_2, substituting the value of V_2, we get

$i_2 = a[\cos\omega_c t - x(t)] + b[\cos\omega_c t - x(t)]^2$

$i_2 = a\cos\omega_c t - ax(t) + b\cos^2\omega_c t + bx^2(t) - 2bx(t)\cos\omega_c t$

Due to currents i_1 and i_2, the net voltage v_i at the input of bandpass filter is expressed as

$v_i = v_3 - v_4$

But from the figure

$v_3 = i_1 R$

$v_4 = i_2 R$

Therefore $v_i = i_1 R - i_2 R$

$v_i = R(i_1 - i_2)$

In above equations, substituting the values of i_1 and i_2

$v_i = R[2ax(t) + 4bx(t)\cos\omega_c t]$

$v_i = 2R[ax(t) + 2bx(t)\cos\omega_c t]$

This voltage v_i is the input to the bandpass filter centered around $\pm\omega_c$.

A bandpass filter is that type of filter which allows to pass a band of frequencies. It will attenuates all other frequencies and preserve the sidebands.

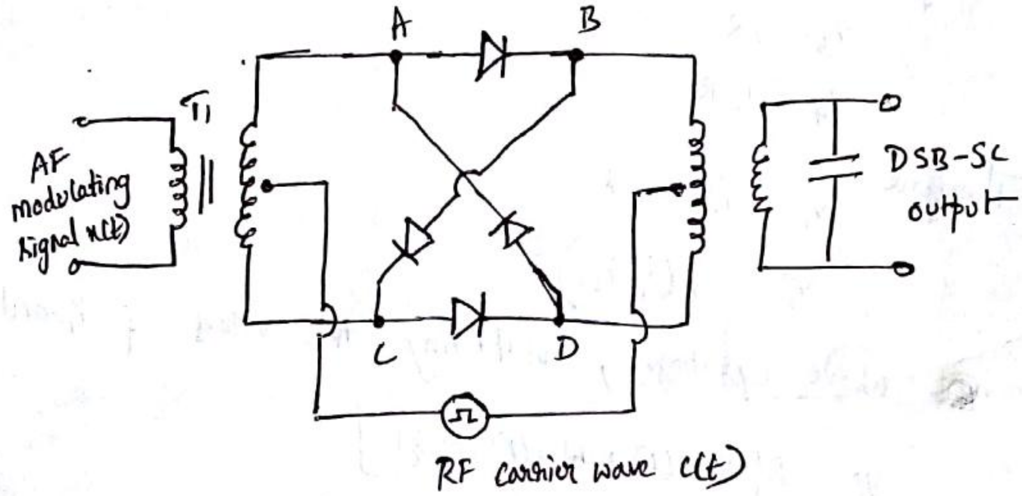
$$\boxed{v_0 = 4aRx(t)\cos\omega_c t}$$

P...

RING MODULATOR (OR) CHOPPER MODULATOR :

Below figure shows the circuit diagram of a diode ring modulator. It consists of four diodes, an audio frequency transformer T_1 and an RF transformer T_2. The carrier signal is assumed to be a square wave with frequency f_c and it is connected between the centre taps of the two transformers.

The DSB-SC output is obtained at the secondary of the RF transformer T_2.



RF carrier wave c(t)

The operation is explained with assumption that the diodes act as perfect switches and that they are switched ON and OFF by the RF carrier signal. The operation can be divided into different modes without the modulating signal and with modulating signal as follows:

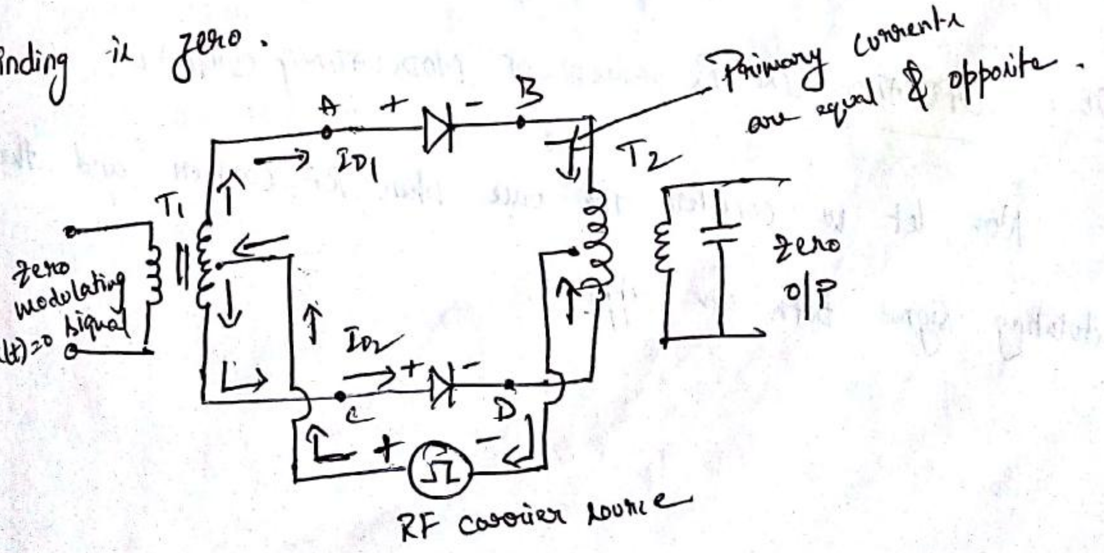
MODE 1: Carrier Suppression.

To understand how carrier suppression takes place, let us assume that the modulating signal is absent and only the carrier signal is applied. Hence, $\boxed{x(t) = 0}$.

(i) Operation in the positive half cycle of the carrier:

In this mode, let us assume that the modulating signal is zero, and only the carrier signal is applied. The equivalent circuit for this mode of operation is shown below. As shown, the diodes D_1 and D_2 are forward biased. Diodes D_3 and D_4 are reverse biased.

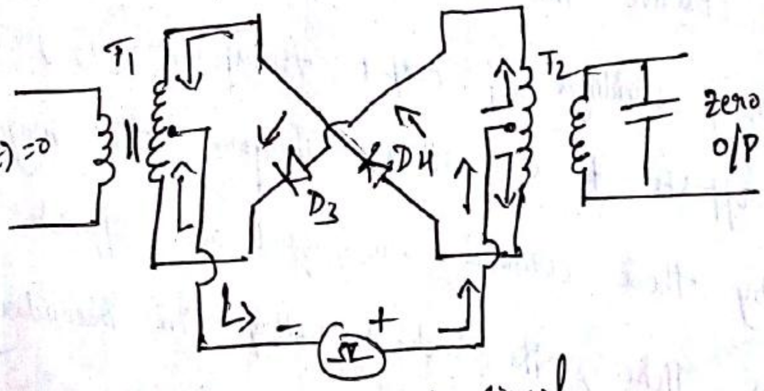
Let us observe the direction of currents flowing through the primary windings of output transformer T_2, they are equal and opposite to each other. Therefore, the magnetic fields produced by these currents are equal and opposite and cancel each other. Hence, the induced voltage in secondary winding is zero.



(ii) Operation in negative half cycle of the carrier :

In this mode also, let us assume that the modulating signal is zero. In the negative half cycle of the carrier, the diodes D_3 and D_4 are forward biased and the diodes D_1 and D_2 are reversed biased.

The currents flowing in the upper and the lower halves of the primary winding of T_2 are again equal and in opposite directions. This is going to cancel the magnetic fields. Thus the output voltage in this mode also is zero. Thus the carrier is suppressed in the negative cycle also.



RF carrier signal.

MODE:2. OPERATION IN PRESENCE OF MODULATING SIGNAL

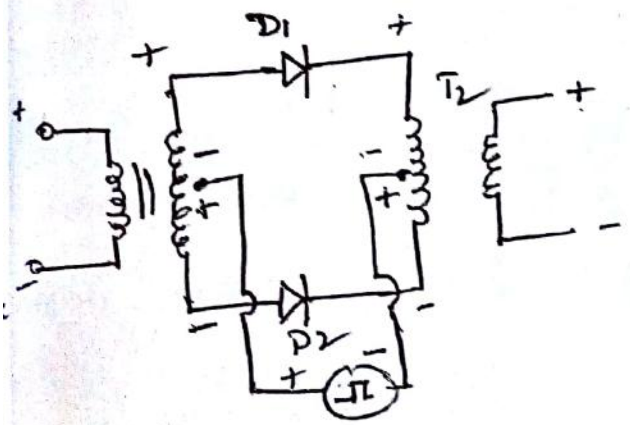
Now, let us consider the case when RF carrier and the modulating signal both are applied.

(ii) Operation in the positive half cycle of modulating signal :

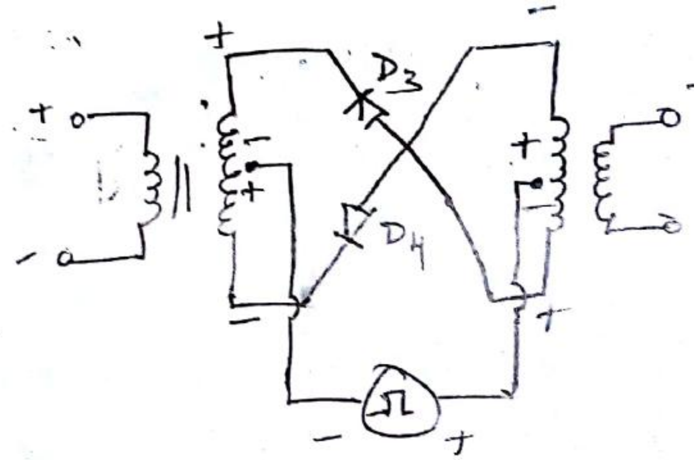
(i) As we apply the low frequency modulating signal through the input audio transformer T_1, there are many cycles of the carrier signal, in the positive half cycle of the modulating signal

(ii) In the positive half cycle of the carrier, D_1 and D_2 are on and secondary of T_1 is applied as it is across the primary of T_2. Hence during the positive half cycle of carrier, the output of T_2 is positive.

(iii) In the negative half cycle of the carrier, D_3 and D_4 are turned on and the secondary of T_1 is applied in a reversed manner across the primary of T_2. Thus, the primary voltage of T_2 is negative and output voltage also becomes negative.



(a) Equivalent circuit in the positive half cycle of modulating signal with carrier positive

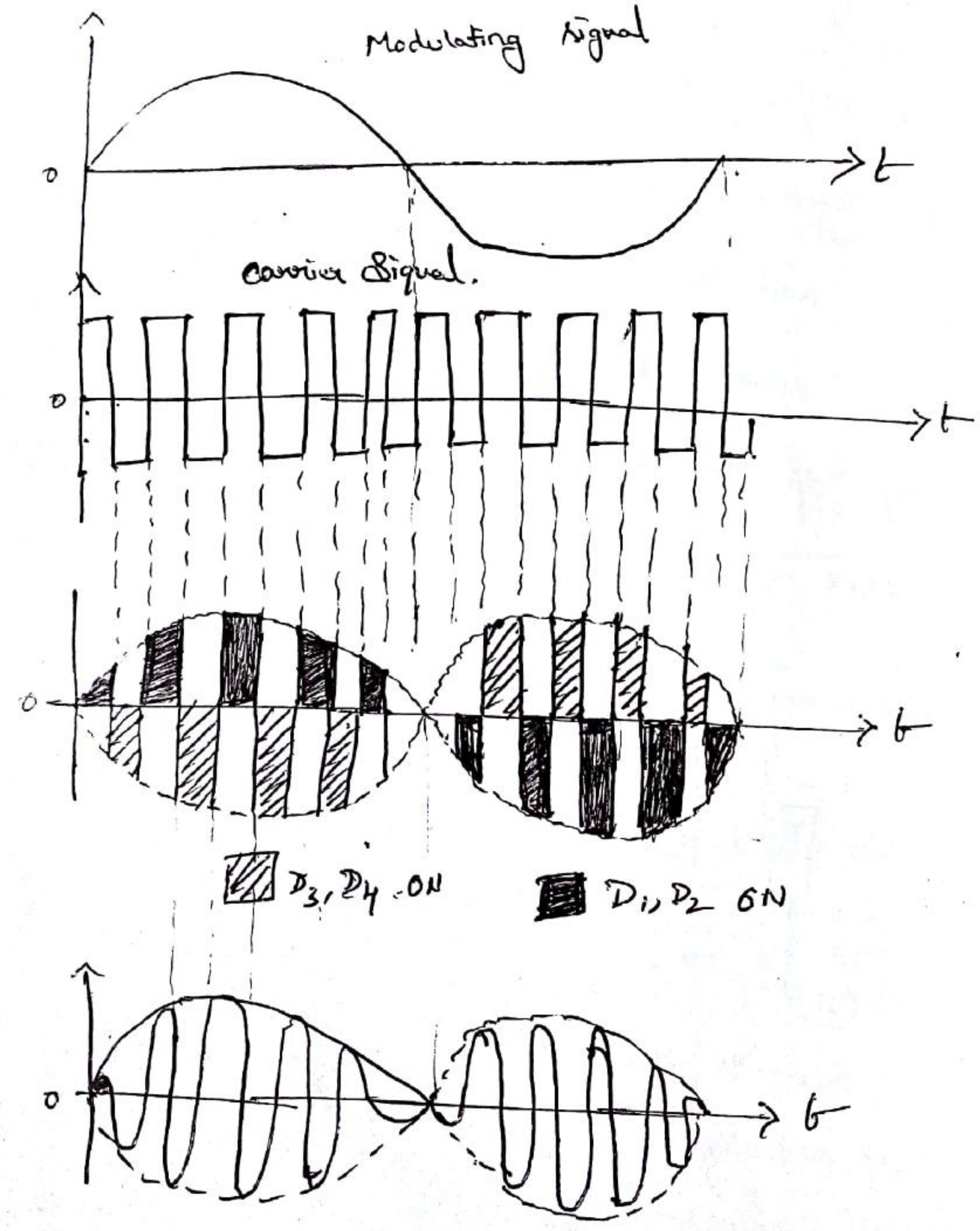


(b) Equivalent circuit in the positive half cycle of modulating signal with carrier negative

(ii) Operation in the negative half cycle of modulating sig

When modulating signal reverses the polarity, operation of the circuit is same as that in the p half cycle. Now, the only difference is that diode p will produce a positive output voltage whereas D_1 D_2 will a negative output voltage.

WAVEFORMS



DEMODULATION (OR) DETECTION OF DSB-SC

The modulated signal is transmitted from the transmitter and it reaches the receiver through a transmission medium.

At the receiver end, the original modulating signal $x(t)$ is recovered from the modulated (DSB-SC) signal. This process is known as Demodulation (or) Detection.

A method of DSB-SC detection is known as Synchronous detection.

Synchronous Detection Method :

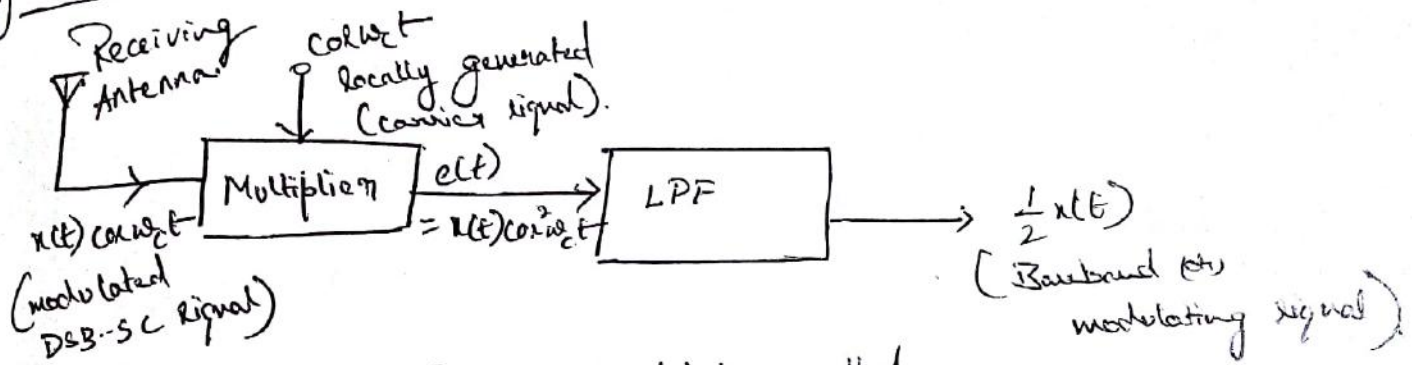


Fig: Synchronous detection method.

Working :

01. In synchronous detection method, the received modulated (or) DSB-SC signal is first multiplied with a locally generated carrier signal $\cos\omega_c t$ and then passed through a low pass filter (LPF).
02. At the output of a low pass filter (LPF), the original modulating signal is recovered.

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Mathematically,

$$e(t) = \underbrace{x(t)\cos\omega_c t}_{\text{DSB-SC Signal}} \quad \underbrace{\cos\omega_c t}_{\text{locally generated carrier signal.}}$$

$$e(t) = x(t)\cos^2\omega_c t = \frac{1}{2}x(t)\left[2\cos^2\omega_c t\right]$$

$$e(t) = \frac{1}{2}x(t)\left[1+\cos 2\omega_c t\right]$$

$$= \frac{1}{2}x(t) + \frac{1}{2}x(t)\cos 2\omega_c t$$

Now, it may be observed that when multiplied signal is passed through a LPF, then the term $\frac{1}{2}x(t)\cos 2\omega_c t$, at $\pm 2\omega_c$ is suppressed by LPF and thus at the output of LPF, the original modulating signal $\frac{1}{2}x(t)$ is obtained.

* NOTE :

We have observed that the detection process for DSB-SC requires a local oscillator at the receiver end. The frequency and phase of the locally generated carrier signal and the carrier signal at the transmitter carrier must be identical.

This mean that the local oscillator signal must exactly coherent (or) synchronized with the carrier signal at the transmitter, both in frequency and phase, otherwise the detection signal would get distorted.

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CASTA'S RECEIVER :

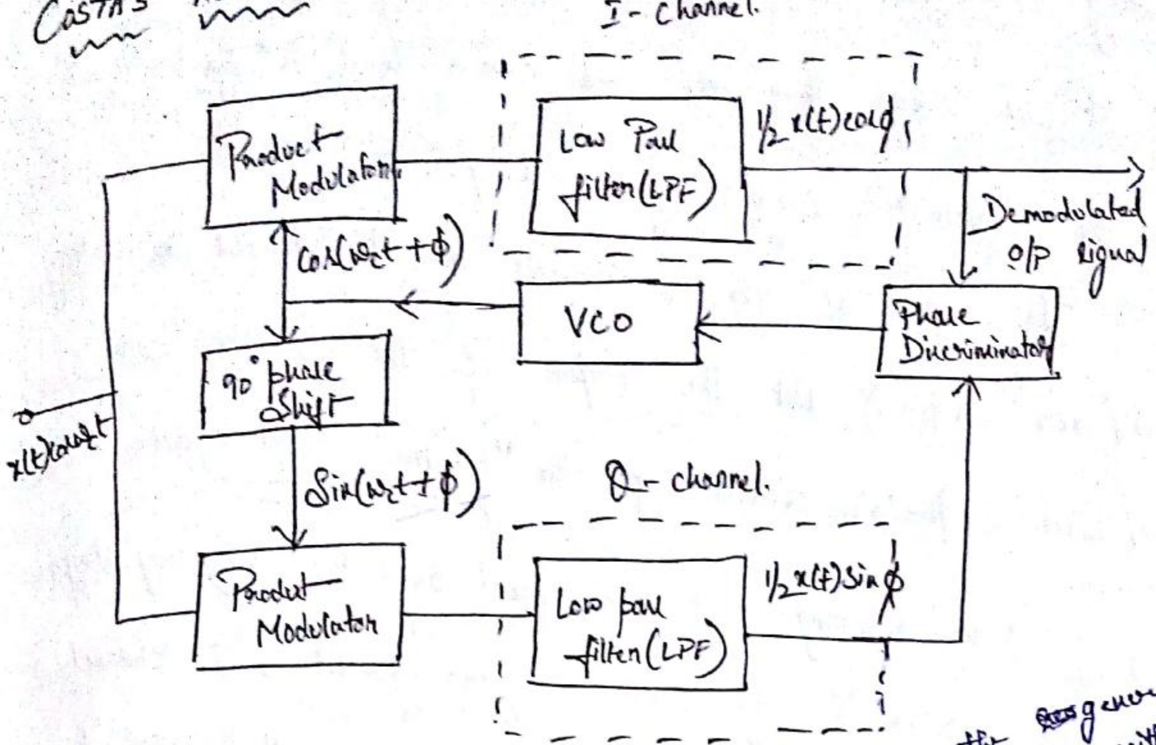


Fig: Casta's Receiver ⇒ It tells if the generated carrier is out of phase with previous then we won't get o/p.

01. This system has two synchronous detectors - one detector is fed with a locally generated carrier signal which is in phase with the transmitted carrier signal. This detector circuit is called inphase coherent detector (OR) I - channel.

02. The other synchronous detector employs a local carrier which is in phase quadrature with the transmitted carrier signal and is called Quadrature phase coherent detector (OR) Q - channel.

03. On combining, the two detectors constitute a negative feedback system which synchronizes the local carrier signal with the transmitted carrier signal.

Operating Principle :

Let us assume that the local carrier signal is synchronized with the transmitted carrier signal and $\phi = 0$.

The output of the I-channel is the desired modulating signal (since $\cos\phi = 1$), but the output of the Q-chanel is zero (since $\sin\phi = 0$). because of the "quadrature null effect".

Now assuming that the local oscillator frequency drifts slightly i.e., ϕ is a very small non-zero quantity, I-channel output will be almost unchanged, but Q-channel output now is not a zero, rather some signal would appear at its output and is proportional to $\sin\phi$. Thus the o/p of the Q-channel,

(i) is proportional to ϕ (since $\sin\phi = \phi$ for small ϕ).

(ii) would have a polarity same as the I-channel for one direction of phase shift in local oscillator, where as, the polarity would be opposite to I-channel for the other direction of phase shift.

The phase discriminator provides a dc control signal which may be used to correct local oscillator phase error. The local oscillator is a voltage controlled oscillator (VCO).

$$v_1 = S_{DSBSC} \cos(2\pi f_c t + \theta).$$

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

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

$$v_0 = \frac{A_c m(t)}{2} \cos\theta$$

if $\theta = 0° = v_0 = \frac{A_c m(t)}{2}$

$\theta = \pi/4$ $v_0 = \frac{A_c m(t)}{2\sqrt{2}}$

("quadrature null effect" — $\theta = 90°$, $v_0 = 0$.

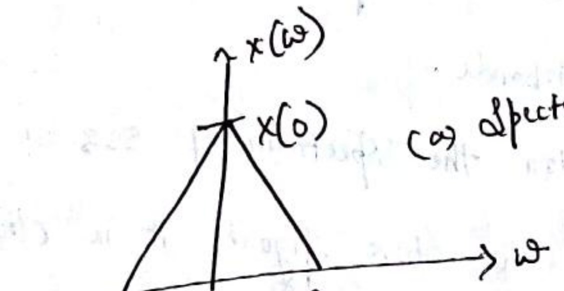
SINGLE SIDEBAND SUPPRESSED- CARRIER MODULATION (SSB-SC):

01. As discussed earlier that amplitude modulation and double side band suppressed - carrier (DSB-SC) modulation are wasteful of bandwidth since they both need a transmission bandwidth equal to twice the message signal bandwidth.

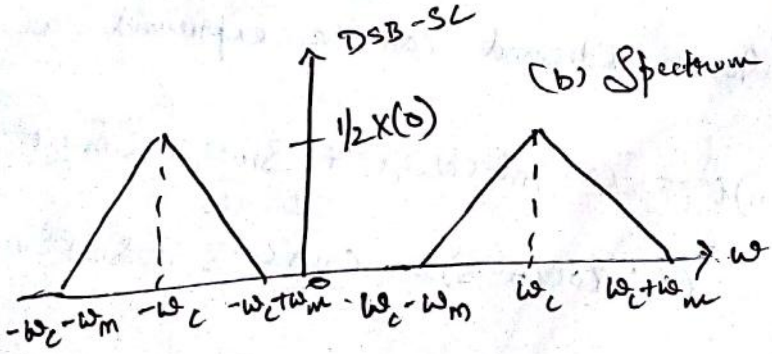
→ So, if the carrier and one of the two sidebands are suppressed at the transmitter, no information is lost. Modulation of this type which provides a single sideband with suppressed carrier is known as (SSB-SC) system.

NOTE: The lower and upper sidebands are uniquely related to each other by virtue of their symmetry. So will ~~oth~~ suppressed one sideband and the carrier.

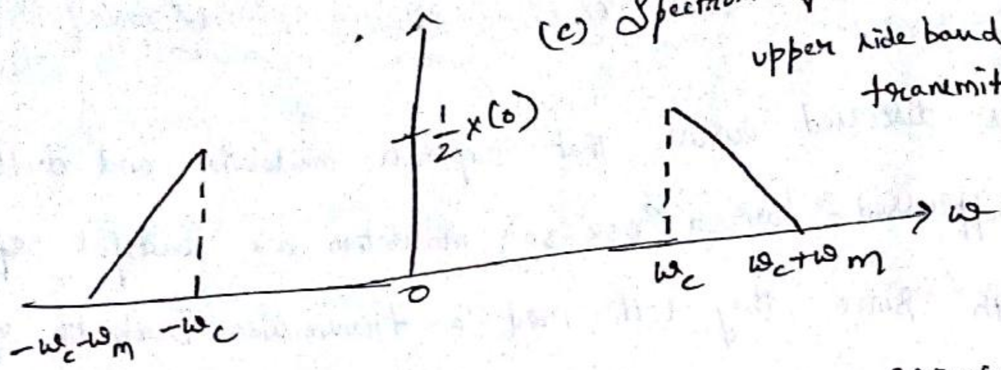
FREQUENCY SPECTRUM:



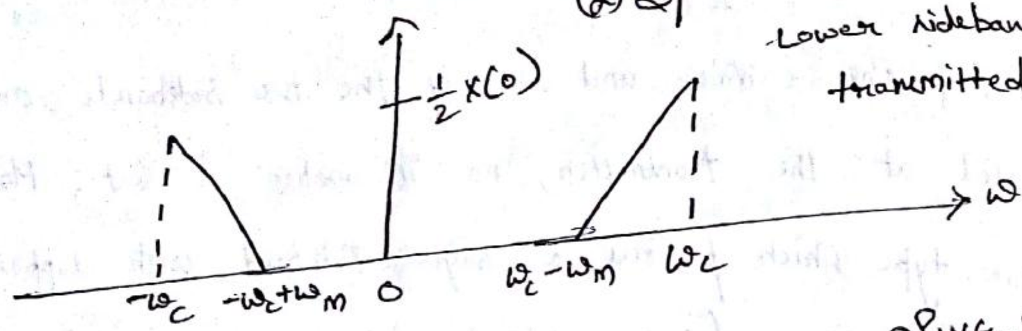
(a) Spectrum of baseband signal



(b) Spectrum of DSB-SC system,



(c) Spectrum of SSB-SC with upper side band transmitted.



(d) Spectrum of SSB-SC with Lower sideband transmitted.

TIME-DOMAIN DESCRIPTION OF SSB-SC WAVE WITH SING-TONE MODULATING SIGNAL:

let us consider a single-tone modulating signal as

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

To get the SSB-SC waveform, we will have to eliminate one of the two sidebands.

let us consider the spectrum of SSB-SC wave with lower sidebands. From the above figure, it is clear that this spectrum corresponds time-domain signal $\cos(\omega_c-\omega_m)t$. The SSB-SC with lower sideband can be expressed as

$$\cos(\omega_c-\omega_m)t = \cos\omega_m t\cos\omega_c t + \sin\omega_m t \sin\omega_c t \quad (1)$$

$$(\because \cos(A-B) = \cos A\cos B + \sin A \sin B).$$

In the same manner, the expression for the single-tone SSB-SC wave with upper sideband may be expressed as

$$\cos(\omega_c + \omega_m)t = \cos\omega_m t \cos\omega_c t - \sin\omega_m t \sin\omega_c t \longrightarrow (2)$$

Both these equations (1) & (2) may be combined as

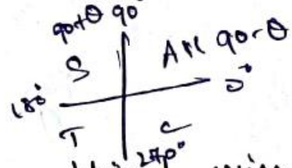
$$s(t)_{SSB} = \cos\omega_m t \cos\omega_c t \pm \sin\omega_m t \sin\omega_c t \longrightarrow (3)$$

Here, the (+) sign represents the lower sideband and (−) sign represents the upper sideband.

We may write the terms $\sin\omega_c t$ and $\sin\omega_m t$ as under:

$$\sin\omega_c t = \cos\left(\omega_c t - \frac{\pi}{2}\right) \Rightarrow \cos\left(-(90 - \omega_c t)\right) \quad \cos(-\theta) = \cos\theta$$

$$\sin\omega_m t = \cos\left(\omega_m t - \frac{\pi}{2}\right)$$



This means that the sine terms may be obtained using the corresponding cosine terms by giving a phase shift of $(-\pi/2)$.

In the above equation (3), the term $\sin\omega_m t$ is obtained by giving a phase shift of $(-\pi/2)$ to the modulating frequency $\cos\omega_m t$.

Similarly, in a general modulating signal $x(t)$, if all the frequency components are shifted by $(-\pi/2)$, it may lead to a general expression of SSB-SC signal.

$$\boxed{s(t)_{SSB} = x(t)\cos\omega_c t \pm x_h(t)\sin\omega_c t}$$

where $x_h(t)$ is a signal obtained by shifting the phase of every component present in $x(t)$ by $(-\pi/2)$.

SSB-SC FOR A GENERAL MODULATING SIGNAL :

STEP-1 : Hilbert Transform.

The function $x_h(t)$ obtained by providing $(-\pi/2)$ phase shift to every frequency component present in $x(t)$.

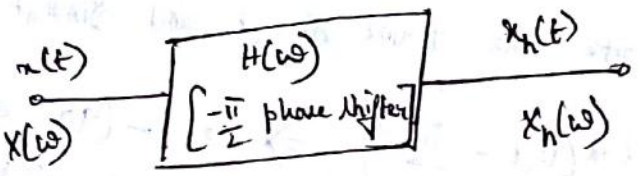


Fig: A phase shifting system.

The given situation may be considered as though the signal $x(t)$ is passed through a phase shifting system having transfer function $H(\omega)$ and the output is $x_h(t)$

The characteristic of this system ~~are~~ is

(i) The magnitude of the frequency components present in $x(t)$ remains unchanged when it is passed through the system. This means that $|H(\omega)| = 1$

The transfer function is

$$H(\omega) = |H(\omega)| e^{j\theta(\omega)}$$

$$H(\omega) = 1 \cdot e^{j\theta(\omega)}$$

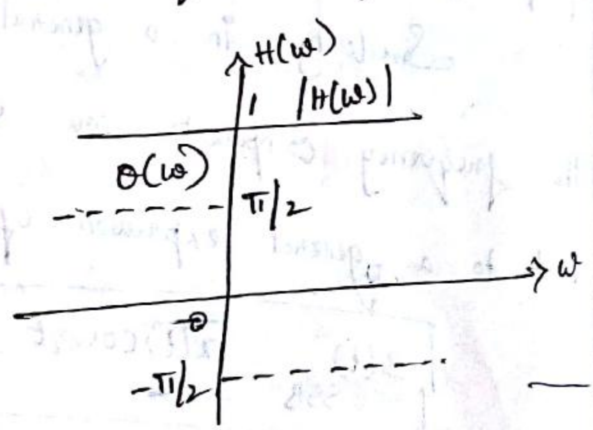


Fig: Transfer function of $-\pi/2$ phase shifter.

From the figure,

$$\theta(\omega) = \begin{cases} +\pi/2 & \text{for } \omega < 0 \text{ (i.e negative frequencies)} \\ -\pi/2 & \text{for } \omega > 0 \text{ (i.e positive frequencies)} \end{cases}$$

Therefore equation may be modified as

$$H(\omega) = \begin{cases} e^{j\pi/2} & \text{for } \omega < 0 \\ e^{-j\pi/2} & \text{for } \omega > 0 \end{cases}$$

WKT

$$e^{j\pi/2} = \cos\frac{\pi}{2} + j\sin\frac{\pi}{2}$$

$$\boxed{e^{j\pi/2} = j}$$

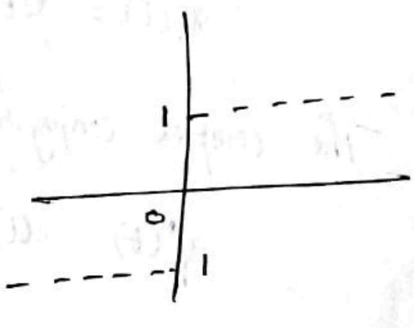
and

$$e^{-j\pi/2} = \cos\left(\frac{-\pi}{2}\right) + j\sin\left(\frac{-\pi}{2}\right)$$

$$\boxed{e^{-j\pi/2} = -j}$$

Thus

$$\frac{H(\omega)}{j} = \begin{cases} 1 & \text{for } \omega < 0 \\ -1 & \text{for } \omega > 0. \end{cases}$$



$$\boxed{\frac{H(\omega)}{j} = -\,\mathrm{Sgn}(\omega).}$$

$$\mathrm{Sgn}(\omega) = \begin{cases} 1 & \text{for } \omega > 0 \\ -1 & \text{for } \omega < 0. \end{cases}$$

$$\boxed{H(\omega) = -j\,\mathrm{Sgn}(\omega)}$$ ⇒ Freq. response of a Hilbert Transform

The response $X_h(\omega)$ of the phase shifting system is related to the input $x(\omega)$

$$\boxed{X_h(\omega) = X(\omega) \cdot H(\omega)}$$

Now substituting the $H(\omega)$ in the above equation

$$\boxed{X_h(\omega) = -j\,X(\omega)\,sgn(\omega)}$$

STEP - II : PRE-ENVELOPE (OR) ANALYTIC SIGNAL :

The concept of pre-envelope, also called as the analytic function is quite useful in deriving the general expression of the SSB-SC signal.

The pre-envelope of a real-valued signal $x(t)$ is

$$x_p(t) = x(t) + j x_h(t)$$

The complex conjugate of the pre-envelope denoted as

$$x_p^*(t) = x(t) - j x_h(t)$$

The fourier transform of $x_p(t)$ is

$$F[x_p(t)] = F[x(t)] + jF[x_h(t)]$$

$$X_p(\omega) = X(\omega) + j[-j\,X(\omega)\,sgn(\omega)]$$

$$X_p(\omega) = X(\omega) + X(\omega)\,sgn(\omega)$$

Therefore WKT $sgn(\omega) = \begin{cases} 1 & \text{for } \omega > 0 \\ -1 & \text{for } \omega < 0 \end{cases}$

Therefore, we have

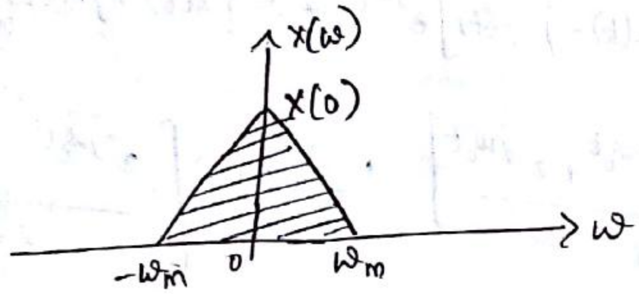
$$X_p(\omega) = \begin{cases} 2X(\omega) & \text{for } \omega > 0 \\ 0 & \text{for } \omega < 0 \end{cases}$$

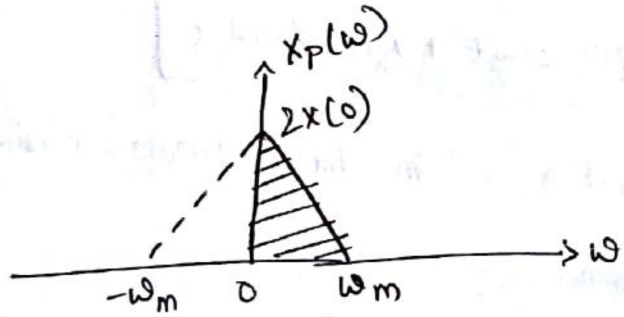
Similarly, the fourier transform of $x_p^*(t)$ is

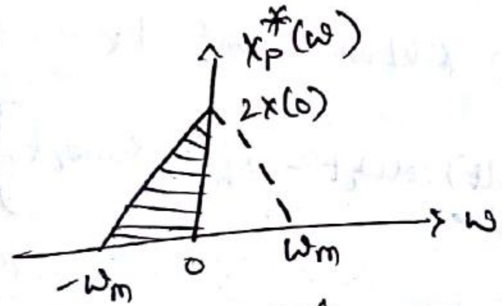
$$X_p^*(\omega) = X(\omega) - j\left[-j \cdot X(\omega)\,\text{sgn}(\omega)\right]$$

$$X_p^*(\omega) = X(\omega) - X(\omega)\,\text{sgn}(\omega)$$

$$X_p^*(\omega) = \begin{cases} 0 & \text{for } \omega > 0 \\ 2X(\omega) & \text{for } \omega < 0 \end{cases}$$







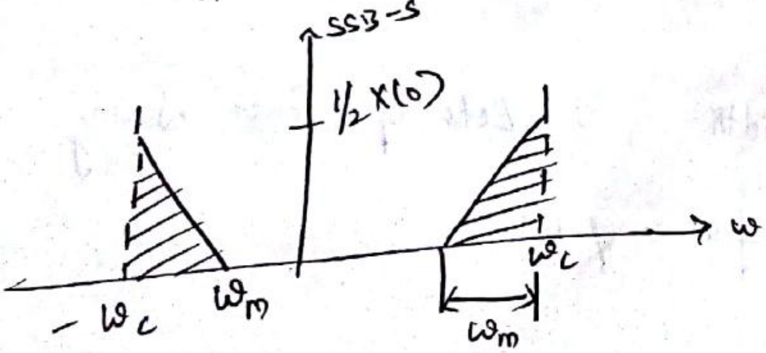


Fig: LSB

Scanned by CamScanner

(i) The right-hand portion of the figure represents a spectrum of $\frac{1}{4} x_p^*(t) e^{j\omega_c t}$

(ii) Similarly, the left-hand portion of figure represents the spectrum of $\frac{1}{4} x_p(t) e^{-j\omega_c t}$

The representation of SSB-SC

$$s(t)_{SSB} = \frac{1}{4}\left[x_p^*(t) e^{j\omega_c t} + x_p(t) e^{-j\omega_c t}\right]$$

Substituting interms of hilbert transform

$$s(t)_{SSB} = \frac{1}{4}\left[x(t) - jx_p(t)\right] e^{j\omega_c t} + \frac{1}{4}\left[x(t) + jx_h(t)\right] e^{-j\omega_c t}$$

$$s(t)_{SSB} = \frac{1}{2} x(t)\left[\frac{e^{j\omega_c t} + e^{-j\omega_c t}}{2}\right] + \frac{j}{2} x_h(t)\left[\frac{e^{-j\omega_c t} - e^{j\omega_c t}}{2}\right]$$

$$s(t)_{SSB} = \frac{1}{2}\left[x(t)\cos\omega_c t + x_h(t)\sin\omega_c t\right]$$

The above equation is in time-domain consisting of only the lower sidebands.

Similarly, the upper sidebands will be

$$s(t)_{SSB} = \frac{1}{2}\left[x(t)\cos\omega_c t - x_h(t)\sin\omega_c t\right]$$

ADVANTAGES

01. Less Bandwidth 02. Lots of Power Saving

03. Reduced Interference of noise.

GENERATION OF SSB-SC SIGNAL :

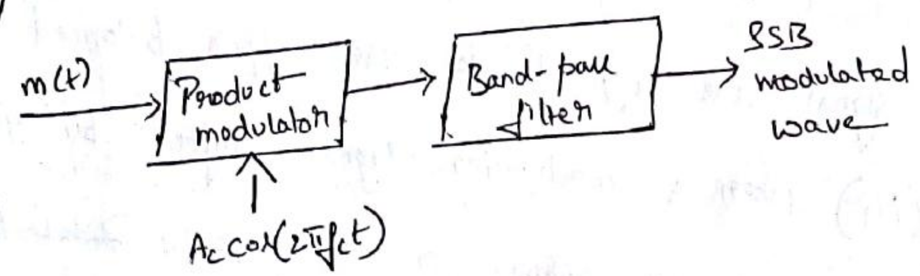
(i) Frequency Discrimination Method (or) Filter Method.

(ii) Phase Discrimination Method (or) Phase-shift Method.

FREQUENCY DISCRIMINATION METHOD :

In a frequency discrimination method, firstly, a DSB-SC signal is generated simply by using an ordinary product modulator (or) balanced modulator. After the balanced modulator, the filter is used to remove unwanted sideband.

The filter must have a flat passband and extremely high attenuation outside the passband. In order to have above response the Q-factor of the tuned circuit must be very high.



Advantages of filter method :

01. The filter method gives sideband suppression upto 50 dB which is quite adequate.

02. The sideband filters also helps to attenuate carrier if present in the output of balanced modulator.

03. Bandwidth is sufficiently flat and wide.

Disadvantages of filter method :

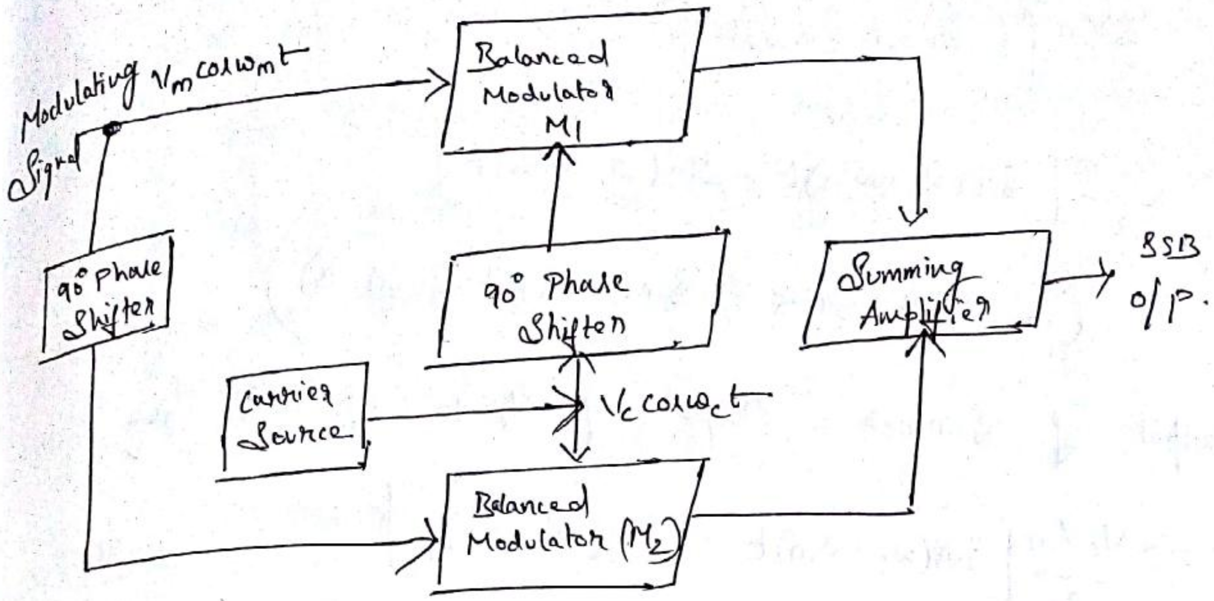
01. They are bulky
02. At lower audio frequencies expensive filters are required.

PHASE DISCRIMINATION METHOD :

The phase-shift method of SSB generation uses a
phase-shift technique that causes one of the sidebands to
be cancelled out.

Below figure shows the block diagram of phase-
shift SSB generator. It consists of two balanced modulators
instead of one and two phase shifting networks,

The carrier signal shifted by 90° and the
modulating signal are applied to the upper balanced
modulator (M_1) whereas modulating signal shifted by 90° and
the carrier signal are applied to the lower ~~sideband~~ balanced
Modulator (M_2). Both modulators produce an output consisting
only of sidebands. Therefore, when the outputs of the
two balanced modulators are added algebraically we get
upper sideband signal.



Mathematically,.

Frequency inputs for balanced Modulator (M_1) are;

$V_m \cos w_m t$ and $V_c \cos(w_c t + 90°)$.

i.e $V_m \cos w_m t$ and $V_c \sin w_c t$

Frequency inputs for balanced Modulator (M_2) are:

$V_m \cos(w_m t + 90°)$ and $V_c \cos(w_c t)$

i.e $V_m \sin w_m t$ and $V_c \cos w_c t$.

Output of $M_1 = V_m \cos w_m t \; V_c \sin w_c t$

$$= \frac{V_m V_c}{2}\left[2 \sin w_c t \cos w_m t\right]$$

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

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

Output of $M_2 = V_c \cos w_c t \times V_m \sin w_m t$

$$= \frac{V_c V_m}{2}\left[2\cos\omega_c t \sin\omega_m t\right]$$

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

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

Output of Summer = Output of M_1 + Output of M_2

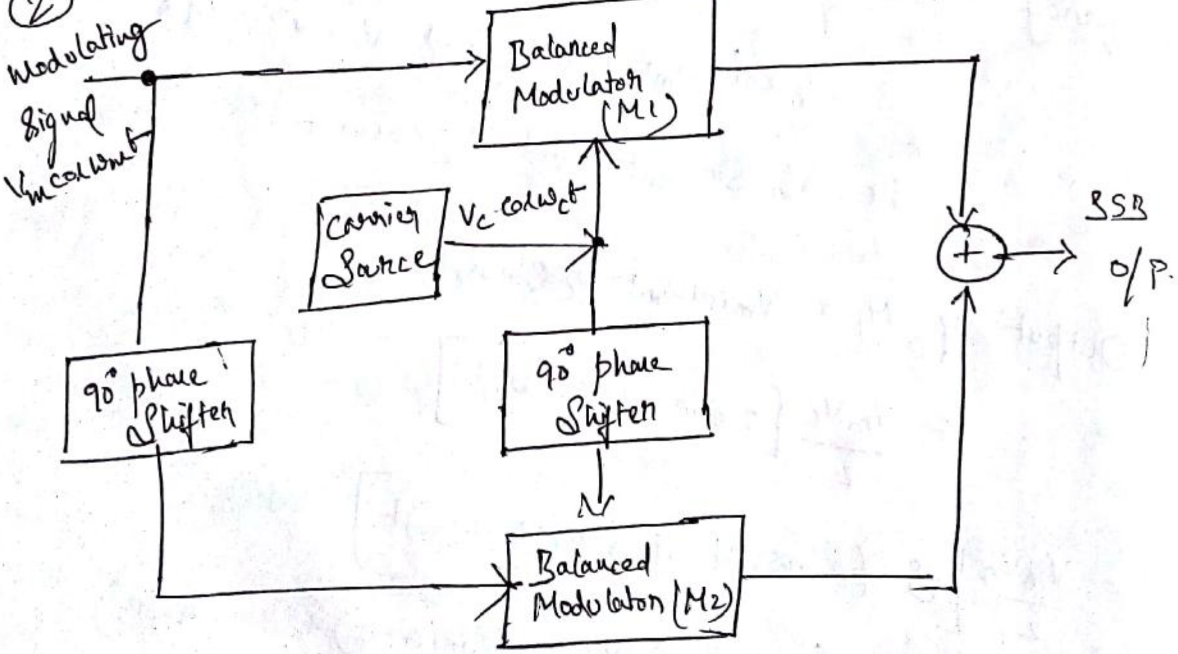
$$\Rightarrow \frac{V_c V_m}{2}\left[\sin(\omega_c+\omega_m)t + \sin(\omega_c-\omega_m)t\right] +$$

$$\frac{V_c V_m}{2}\left[\sin(\omega_c+\omega_m)t - \sin(\omega_c-\omega_m)t\right]$$

$$\Rightarrow V_m V_c \sin(\omega_c+\omega_m)t$$

Thus the lower sidebands in the summer are cancelled.

(2)

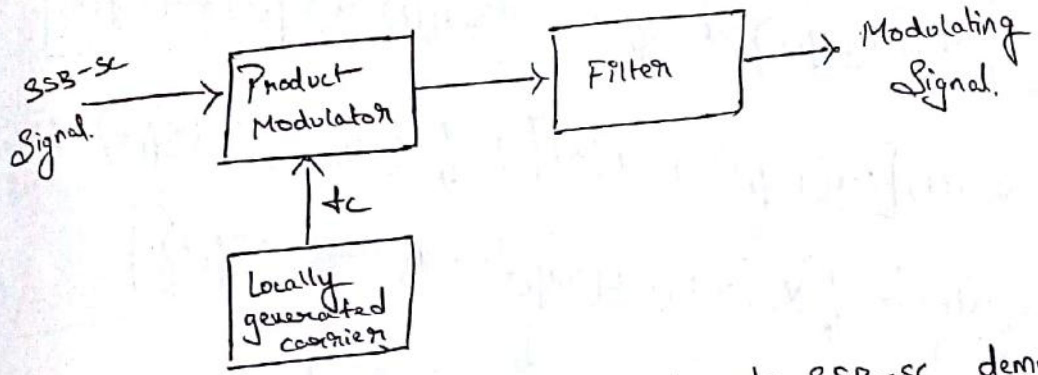


In the above circuit we have seen that the lower sideband is suppressed. To suppress upper sideband the phase shifter connections are slightly different.

Here the modulating signal and the carrier signal both are applied directly to the upper ~~sideband~~ balanced modulator. These signals are phase shifted by 90° and then applied to the lower balanced modulator.

DEMODULATION OF SSB WAVES :

1. COHERENT SSB DEMODULATION :



The block diagram of the coherent SSB-SC demodulator is as shown in figure. The received SSB signal is first multiplied with a locally generated carrier signal.

The locally generated carrier should have exactly the same frequency as that of the suppressed carrier.

The product modulator multiplies the two signals at its input and the product signal is passed through a low pass filter with a bandwidth equal to fm.

Analysis of the coherent detector :

let the SSB wave at the input be given by

$$S(t) = \frac{1}{2} V_c \left[x(t) \cos(2\pi f_c t) \pm x_h(t) \sin(2\pi f_c t) \right]$$

The locally generated carrier is $\cos(2\pi f_c t)$

$\therefore$ output of the product modulator is given by,

$$v(t) = S(t) \cdot \cos(2\pi f_c t)$$

$$v(t) = \frac{1}{2} V_c \cos(2\pi f_c t) \cdot \left[x(t) \cos(2\pi f_c t) \pm x_h(t) \sin(2\pi f_c t) \right]$$

$$v(t) = \frac{1}{2} V_c x(t) \cos(2\pi f_c t) \cos(2\pi f_c t) \pm \frac{V_c}{2} x_h(t) \cos(2\pi f_c t) \sin(2\pi f_c t)$$

$$v(t) = \frac{1}{4} V_c x(t) \left[\cos(4\pi f_c t) + \cos(0) \right] \pm \frac{1}{4} V_c x_h(t) \left[\sin(4\pi f_c t) - \sin(0) \right]$$

$$v(t) = \underbrace{\frac{1}{4} V_c \cdot x(t)}_{\text{Message Signal}} + \underbrace{\frac{1}{4} V_c \left[x(t) \cos(4\pi f_c t) \pm x_h(t) \sin(4\pi f_c t) \right]}_{\text{Unwanted Signal.}}$$

When $v(t)$ is passed through the filter, it will allow only the first terms to pass through and will reject all other unwanted terms.

$$\boxed{V_o(t) = \frac{1}{4} V_c x(t)}$$

Phase Error and Frequency Error in Coherent Detection :

The coherent detection explained in the previous section, assumed the ideal operating conditions in which the locally generated carrier is in the perfect synchronization.

But, in practice, a phase error ϕ may arise in the locally generated carrier wave. The detector output will get modified due to phase error.

$$v_0(t) = \frac{1}{4} V_c x(t) \cos\phi \pm \frac{1}{4} V_c x_h(t) \sin\phi$$

In the above expression, the plus sign corresponds to the SSB input signal with only USB whereas the negative sign corresponds to SSB i/p with only LSB.

VESTIGIAL SIDEBAND TRANSMISSION (VSB).

01. The SSB modulation is not appropriate way of modulation when the message signal contains significant components at extremely low frequencies. In such cases the upper and lower sidebands meet at the carrier frequency and it is difficult to isolate one sideband.

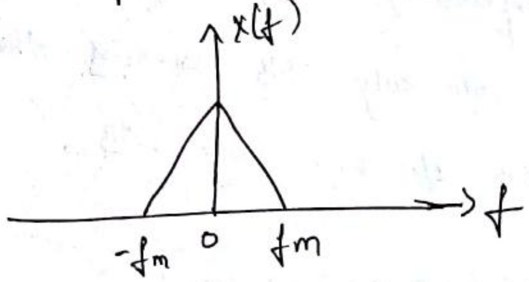
02. To overcome this difficulty the modulation technique known as VSB is used.

03. In this technique one sideband is passed almost completely whereas just a trace of other sideband is retained.

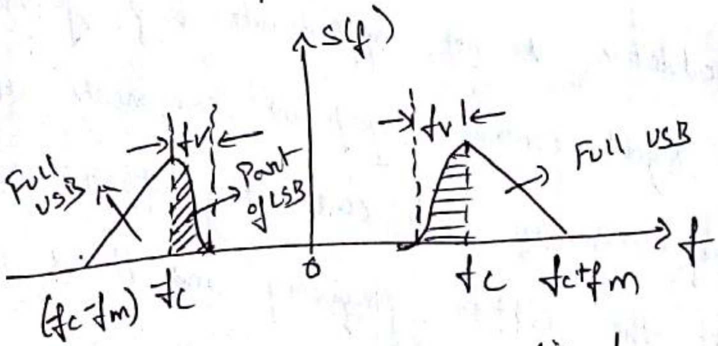
04. The television signals contains significant components at low frequencies and hence VSB modulation is used in television transmission.

Frequency Domain Description:

In the frequency spectrum, it is assumed that the uppersideband is transmitted as it is and the lower sideband is modified into vestigial sideband.

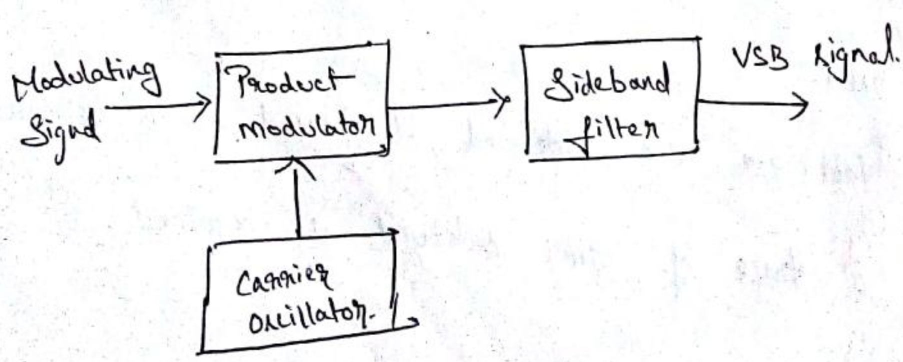


(a) Spectrum of a message signal.



(b) Spectrum of VSB signal.

GENERATION OF VSB MODULATED WAVE:



The output of product modulator is given by

$$m(t) = x(t) \cdot c(t) = x(t) \cdot V_c \cos(2\pi f_c t)$$

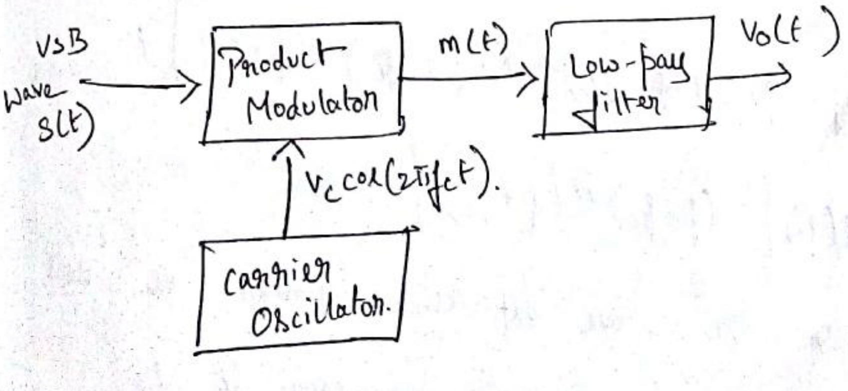
This represents a DSB-SC modulated wave. This DSB-SC signal is then applied to a sideband shaping filter. The design of this filter depends on the desired spectrum of the VSB modulated signal.

This filter will pass the wanted sideband as it is and the vestige of the unwanted sideband. Let the transfer function of the filter be $H(f)$. Hence, the spectrum of the VSB modulated signal is given by,

$$S(f) = \frac{V_c}{2}\left[X(f-f_c) + X(f+f_c)\right] H(f)$$

DEMODULATION (OR) DETECTION OF VSB WAVE:

The synchronous detector for the detection of VSB modulated wave is shown in fig.



Working Operation :

The VSB modulated wave is passed through a product modulator where it is multiplied with a locally generated synchronous carrier.

Hence, the output of the product modulator is given by

$$m(t) = s(t) \times c(t) = s(t)\cos(2\pi f_c t)$$

Taking the Fourier transform on both sides, we get

$$M(f) = S(f) * \left[\frac{1}{2}\delta(f+f_c) + \frac{1}{2}\delta(f-f_c)\right]$$

$$= \frac{1}{2}S(f+f_c) + \frac{1}{2}S(f-f_c)$$

But $S(f) = \frac{V_c}{2}\left[X(f-f_c) + X(f+f_c)\right]H(f)$

$$S(f+f_c) = \frac{V_c}{2}\left[X(f-f_c+f_c) + X(f+f_c+f_c)\right]H(f+f_c)$$

$$= \frac{V_c}{2}\left[X(f) + X(f+2f_c)\right]H(f+f_c)$$

$$S(f-f_c) = \frac{V_c}{2}\left[X(f-2f_c) + X(f)\right]H(f-f_c)$$

Hence

$$M(f) = \frac{V_c}{4}\left[X(f-2f_c)H(f-f_c) + X(f+2f_c)H(f+f_c)\right] +$$

$$\frac{V_c}{4}X(f)\left[H(f-f_c)H(f+f_c)\right]$$

The first term in the above expression represents the VSB modulated wave, corresponding to a carrier frequency of $2f_c$. This term will be eliminated by the filter. The second term will be the o/p.