Vestigial Side band Modulation [VSB]

⇒ The SSB modulation is not appropriate way of modulation when the message signal contains significant components at extremely low frequency.

⇒ Because in such cases the upper and lower sidebands meets at the carrier frequency and it is difficult isolate one side band

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

⇒ In this technique one sideband is passed almost completely whereas just a trace (or) vestige, of the other sideband is retained.

⇒ This is the compromise between SSB modulation and DSBSC modulation.

⇒ The television signals contain significant components at extremely low frequencies and hence vestigial sideband modulation is used in television transmission.

* Frequency Domain Description

⇒ The frequency spectrum of a vestigial sideband (VSB) modulated wave s(t) along with the message signal m(t).

⇒ Here, lower sideband is modified into the vestigial sideband.

⇒ Specifically, the transmitted vestige of the lower sideband components for the amount removed from the upper sideband.

⇒ The transmission bandwidth required by the VSB modulated wave is given by

$BW = W + f_v$

fig:- Spectrum of Message Signal

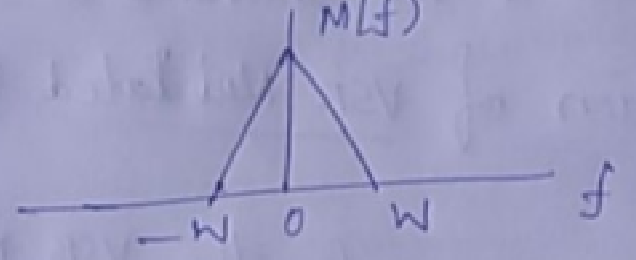
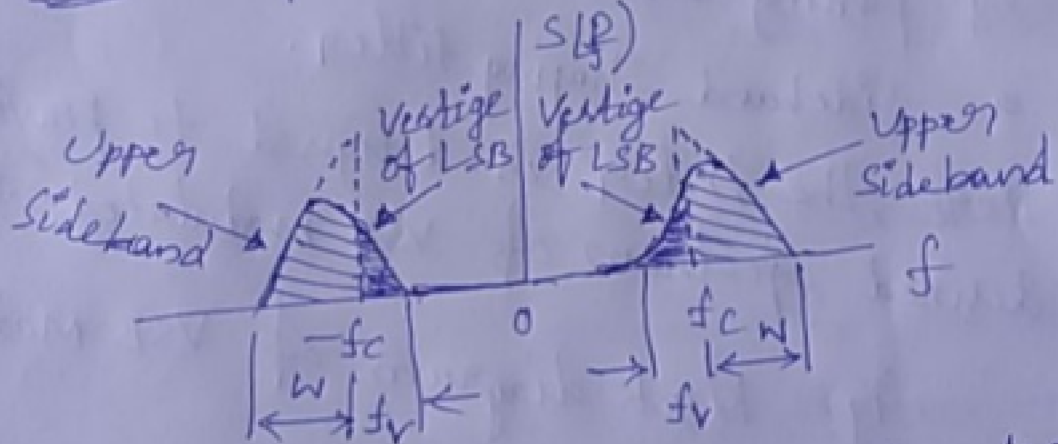


fig:- Spectrum of VSB Modulated wave



⇒ Where "W" is the message bandwidth and f_v is the width of the vestigial sideband.

⇒ When $f_v << W$, the VSB requires the band. width almost equal to SSB transmission, however it retains the excellent low frequency baseband characteristics of DSB Modulation.

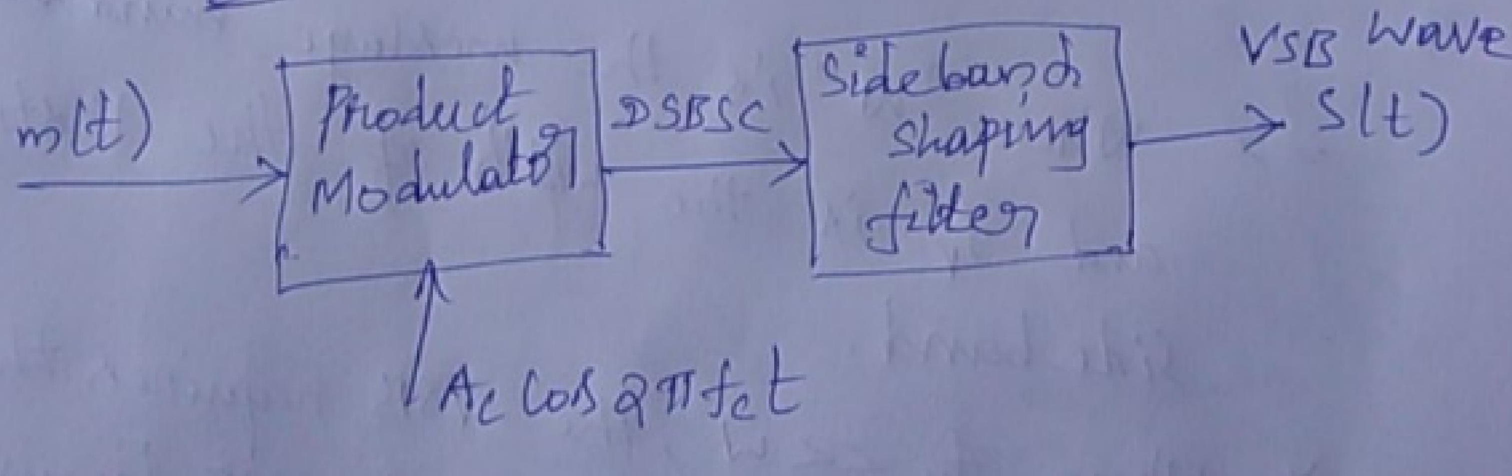
⇒ Therefore, VSB transmission is used where transmission of low frequency component are important are important, but the bandwidth required for double-sideband transmission is unavailable (or) uneconomical.

* Generation of VSB Modulated Wave

⇒ We can generate the VSB modulated wave by passing DSBSC modulated wave through a sideband shaping filter.

⇒ Here, the filter is designed to provide desired spectrum of VSB modulated wave.

fig:- Block diagram of VSB Modulation



⇒ The relation between transfer function $H(f)$ of the filter and the Spectrum $S(f)$ of the VSB modulated wave $s(t)$ is defined by

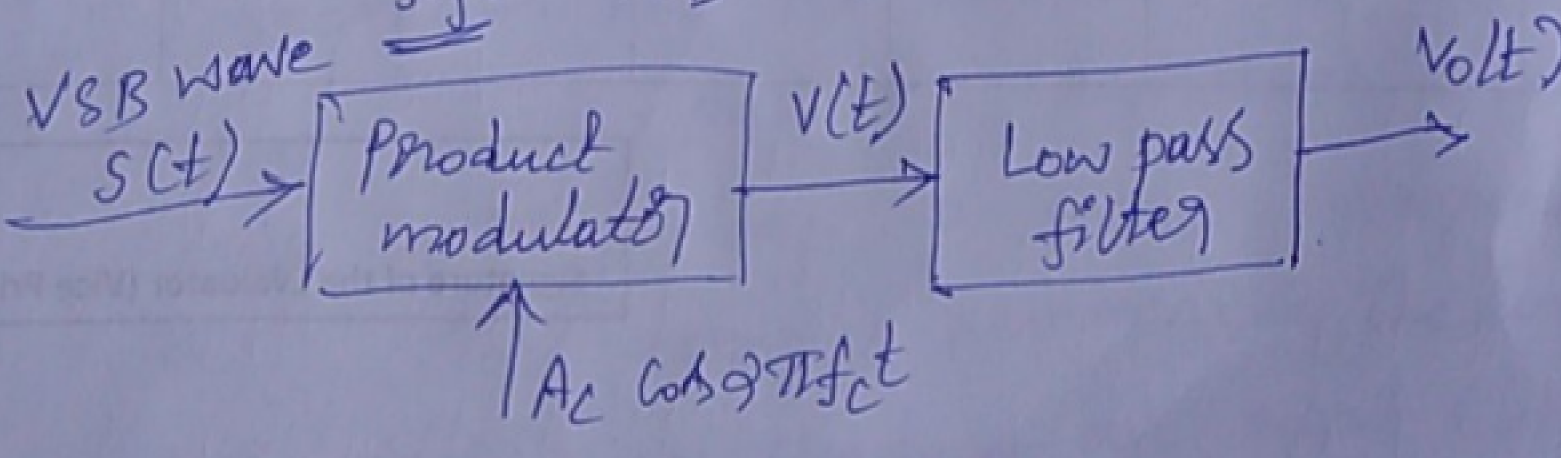
$$S(f) = \frac{A_c}{2}\left[M(f-f_c) + M(f+f_c)\right]H(f)$$

Where $M(f)$ is the message Spectrum

* Demodulation of VSB Modulated Wave

⇒ The demodulation of VSB modulated wave can be achieving by passed VSB wave $s(t)$ through a coherent detector and then determining the necessary conditions for the detector output to provide an undistorted version of the original message signal $m(t)$

fig:- VSB demodulation



→ Here $s(t)$ signal is multiplied by the locally generated sinewave $\cos(2\pi f_c t)$, which is synchronous with the carrier wave $A_c \cos(2\pi f_c t)$ in both frequency and phase

$$\therefore v(t) = \cos(2\pi f_c t) s(t)$$

By taking the fourier transform we get

$$v(t) = \frac{1}{2}\left[S(f-f_c) + S(f+f_c)\right]$$

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

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

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

The $V(f)$ spectrum and its equation, the second term in the equation represents a VSB wave corresponding to carrier frequency $2f_c$. This term is removed by the low pass filter to produce an output $v_o(t)$

⇒ The Spectrum of $V_0(t)$ is given by

$$V_0(f) = \frac{A_c}{4} M(f)\left[H(f-f_c) + H(f+f_c)\right]$$

⇒ The Spectrum $V_0(f)$. To reproduce distortionless original Message signal $m(t)$ at the coherent detector output, we required $V_0(f)$ to be a scaled version of $M(f)$.

* To fulfill this requirement the transfer function $H(f)$ must satisfied the condition is $H(f-f_c) + H(f+f_c) = 2H(f_c)$

⇒ Where $H(f_c)$ is constant. The normalized response so that $H(f)$ falls to one half at the carrier frequency f_c.

⇒ The cutoff portion of the response around f_c exhibits odd symmetry. This means that inside the transition interval defined by $f_c - f_v \leq f \leq f_c + f_v$.

fig:- Spectrum of $V(f)$

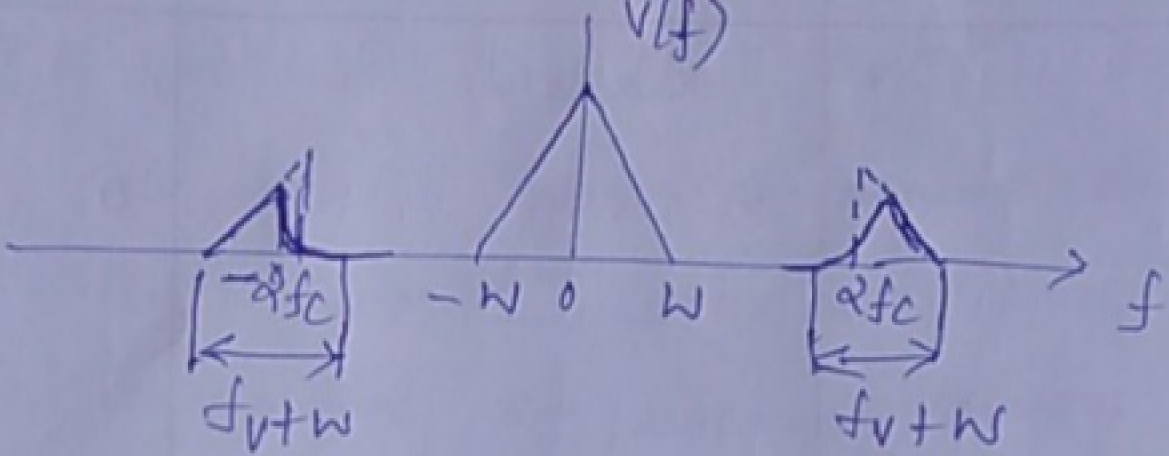


fig:- Spectrum of $V_0(f)$

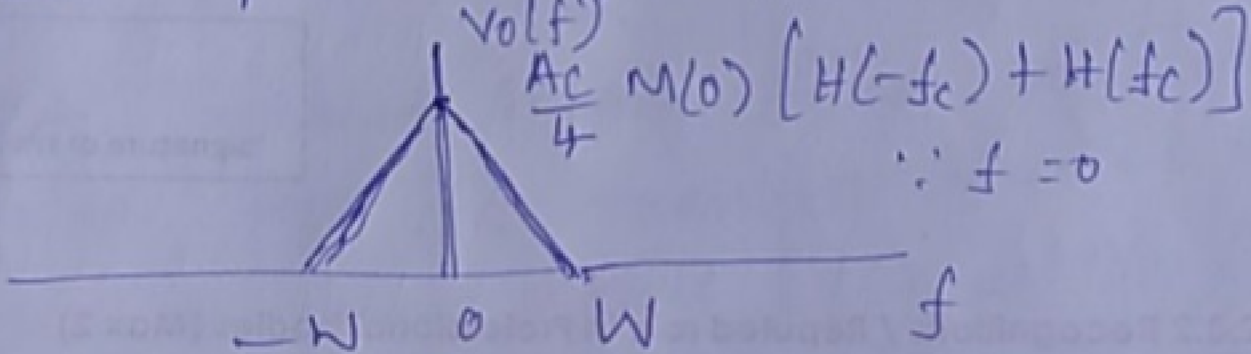
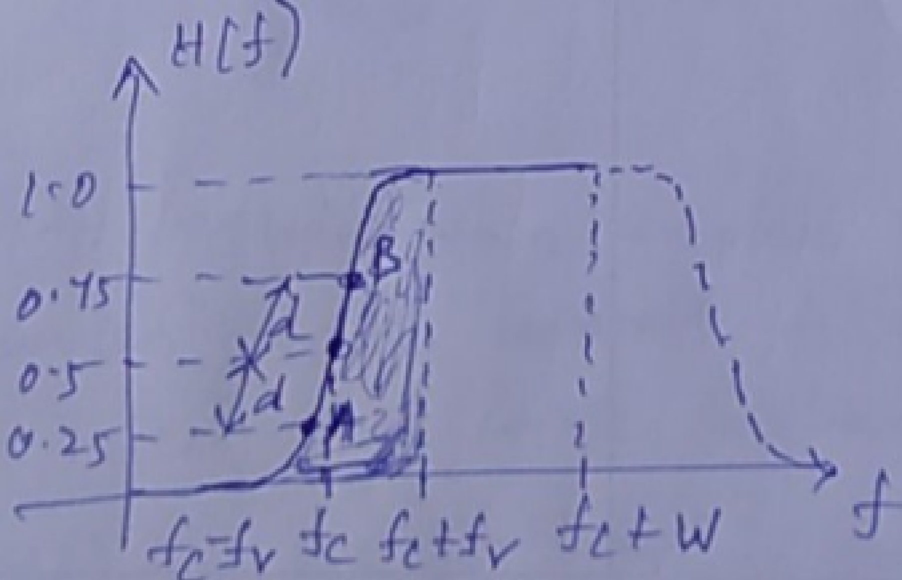


fig:- Frequency response of Sideband shaping filter



* Time Domain Description

→ Let us consider that $s(t)$ as VSB modulated wave containing a vestige of the lower sideband and it is viewed as an output of sideband shaping filter in response to the input, DSBSC modulated wave.

→ The sideband shaping filter can be represented by its transfer function $H(f)$ and we may express $\tilde{H}(f)$ as the difference between two components $\tilde{H}_u(f)$ and $\tilde{H}_v(f)$

$$\tilde{H}(f) = \tilde{H}_u(f) - \tilde{H}_v(f)$$

Where

1. $\tilde{H}(f)$ pertains to a complex lowpass filter equivalent to a bandpass filter designed to reject the lower sideband completely
2. $\tilde{H}_v(f)$ accounts for both the generation of a vestige of the lower sideband and removal of a corresponding portion from the upper sideband.

We have $\tilde{H}_u(f) = \begin{cases} \frac{1}{q}[1+\text{Sgn}(f)], & 0 < f < W \\ 0, & \text{otherwise} \end{cases}$

Substituting in $\tilde{H}(f) = \tilde{H}_u(f) - \tilde{H}_v(f)$

$$\tilde{H}(f) = \begin{cases} \frac{1}{q}\left[1+\text{Sgn}(f) - q\tilde{H}_v(f)\right] & -f_v < f < W \\ 0 & \text{otherwise} \end{cases}$$

$\Rightarrow$ The signum function $\text{sgn}(f)$ and the transfer function $\tilde{H}_v(f)$ are both odd functions of frequency f.

$\Rightarrow$ Hence, they both have purely imaginary inverse Fourier transform.

It produce new transfer function

$$H_Q(f) = \frac{1}{j}\left[\text{Sgn}(t) - q\tilde{H}_v(t)\right]$$

$\Rightarrow$ We denote $h_Q(t)$ as a purely real inverse fourier transform of $H_Q(f)$ as

$$h_Q(t) \rightleftharpoons H_Q(f)$$

fig (a) Frequency response of low-pass filter same as frequency response of the sideband shaping filter

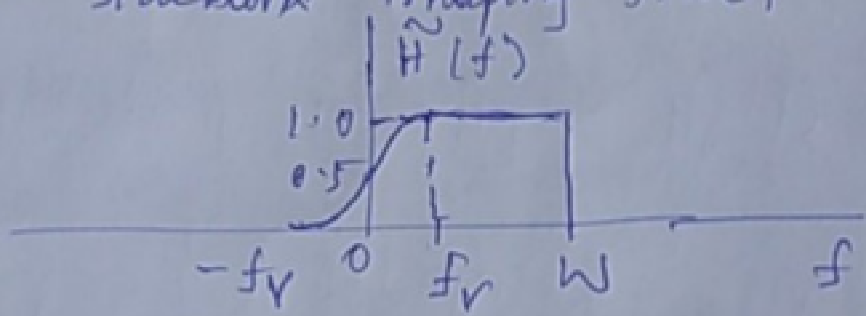


fig (b) : First component of $\tilde{H}(f)$

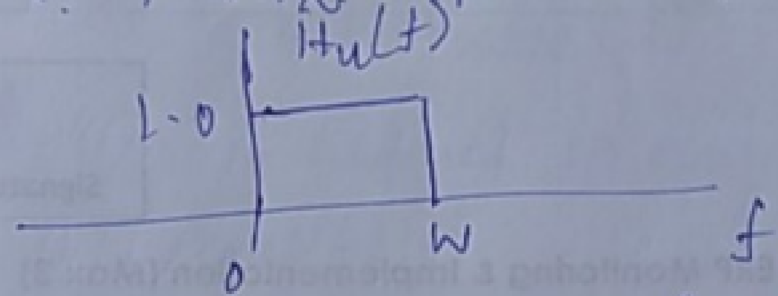


fig (c) : Second component of $\tilde{H}(f)$

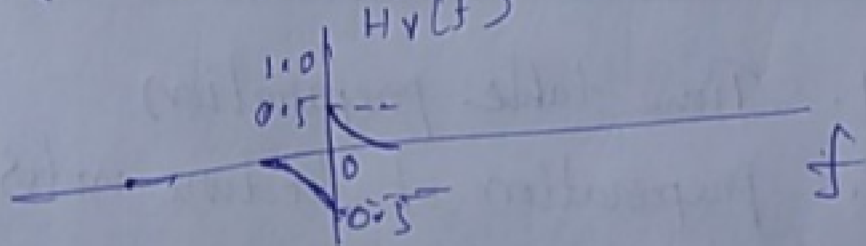
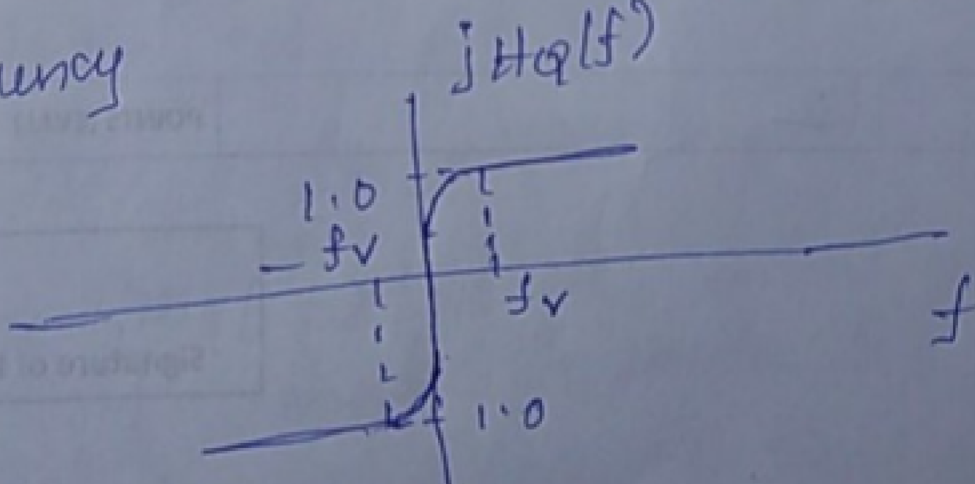


fig (d) : plot of $jH_Q(f)$ as a function of frequency



$$\tilde{H}(f) = \begin{cases} \frac{1}{2}\left[1+jH_Q(f), \right. & -f_v < f < W \\ 0 & \text{otherwise} \end{cases}$$

⇒ Let us now determine the VSB modulated wave $s(t)$. It is given by

$$s(t) = R_e\left[\tilde{s}(t)\exp(j2\pi f_c t)\right]$$

Where $\tilde{S}(f) = \tilde{H}(f)\,\tilde{S}_{DSBSC}(f)$

→ Where $\tilde{S}_{DSBSC}$ is defined in equ $s_{DSBSC}(t) = A_c m(t)$

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

$$\tilde{S}(f) = \tilde{H}(f)\,A_c M(f)$$

$$\because \tilde{H}(f) = \frac{1}{2}\left(1+jH_Q(f)\right]$$

$$\therefore \tilde{S}(f) = \frac{A_c}{2}\left[1+jH_Q(f)\right]M(f)$$

By taking inverse Fourier transform of $\tilde{S}(f)$ we get

$$\tilde{s}(f) = \frac{A_c}{2}\left[m(t)+jm_Q(t)\right]$$

⇒ Where $m_Q(f)$ is the output of a low pass filter of impulse response $h_Q(t)$ when filter is the message signal input to lowpass filter is the message signal $m(t)$.

$$\therefore s(t) = \frac{A_c}{2}m(t)\cos(2\pi f_c t) - \frac{A_c}{2}m_Q(t)\sin 2\pi f_c t$$

∴ S(t) is called VSB modulated wave

$$S(t) = \frac{A_c}{2} m(t) \cos(2\pi f_c t) - \frac{A_c}{2} m_Q(t) \sin(2\pi f_c t)$$

(i.e VSB - LSB)

⇒ Where $\frac{A_c}{2}$ is called inphase component and $\frac{1}{2} A_c m_Q(t)$ represents the quadrature component of VSB modulated wave.

⇒ Similarly $S(t) = \frac{A_c}{2} m(t) \cos(2\pi f_c t) + \frac{A_c}{2} m_Q(t) \sin(2\pi f_c t)$

i.e VSB - USB.

Advantages of VSB

1) Low frequencies, near f_c are transmitted without any attenuation

2) Bandwidth is reduced compared to SSB

3) VSB signals are relatively easy to generate

4) VSB inherits the advantages of DSB and SSB but avoids their disadvantages at a small cost.

Applications of VSB

⇒ VSB mainly used for TV transmission.

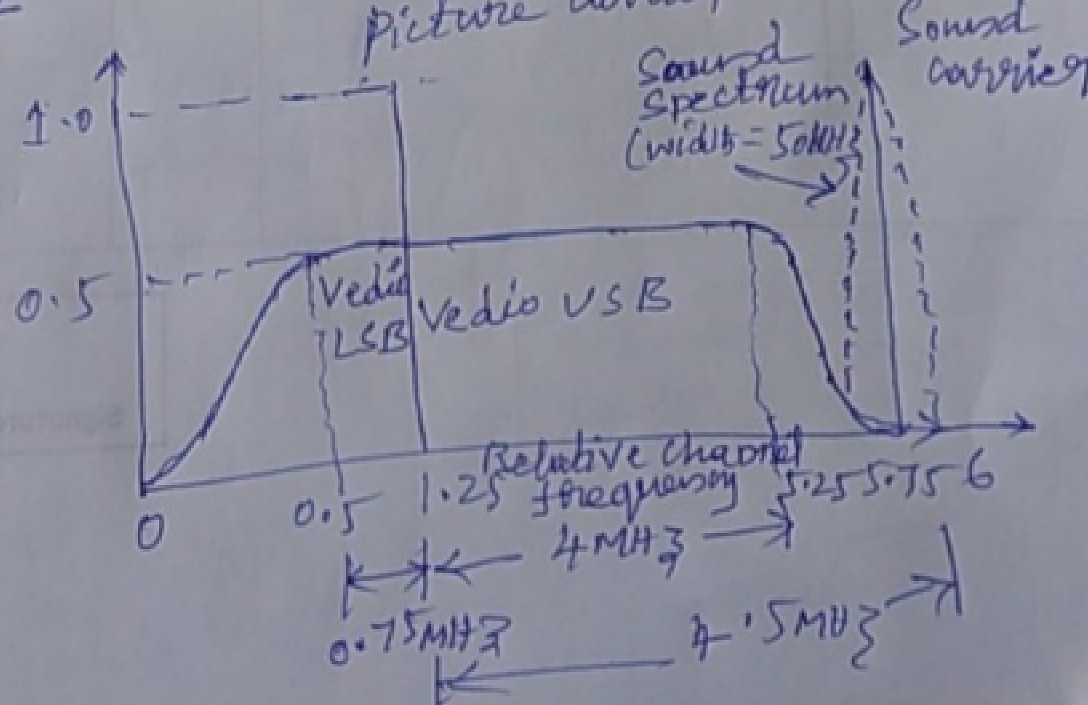
⇒ A TV signal consists of the picture signal (i.e vedio) and the audio signal both having different carrier frequencys.

⇒ The audio carrier is frequency modulated whereas the picture carrier is amplitude modulated.

⇒ The vedio information typically contains frequencies as high as 4.2 MHz.

* A fully amplitude modulated television signal would then occupy $4.2 \times 2 = 8.4$ MHz.

fig:- shows Vestigial Sideband signal

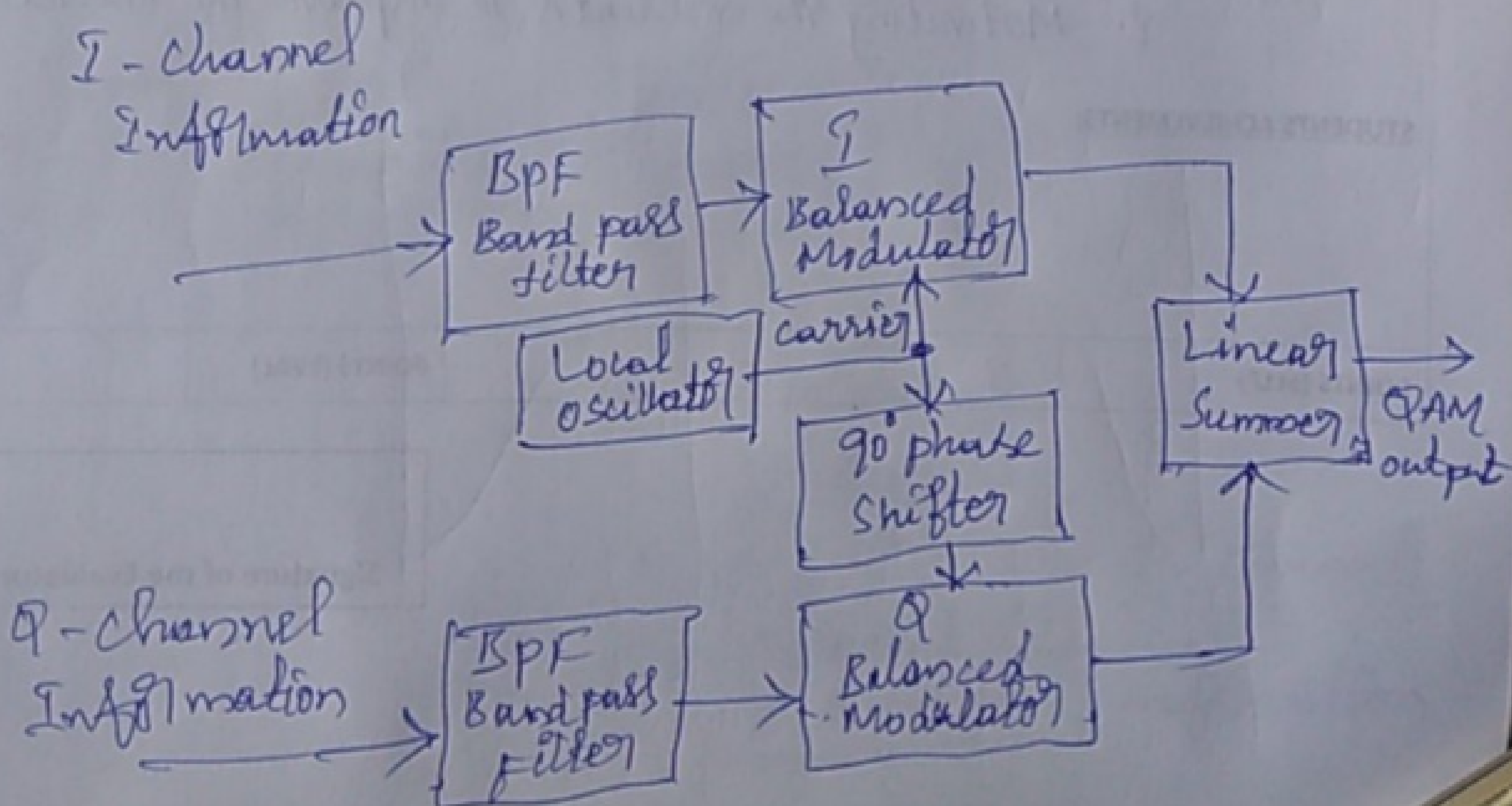


Quadrature Amplitude Modulation (QAM)

⇒ In QAM Signals from two seperate information channels (Sources) modulate the Same carrier frequency simultaneously without inteferring with each other.

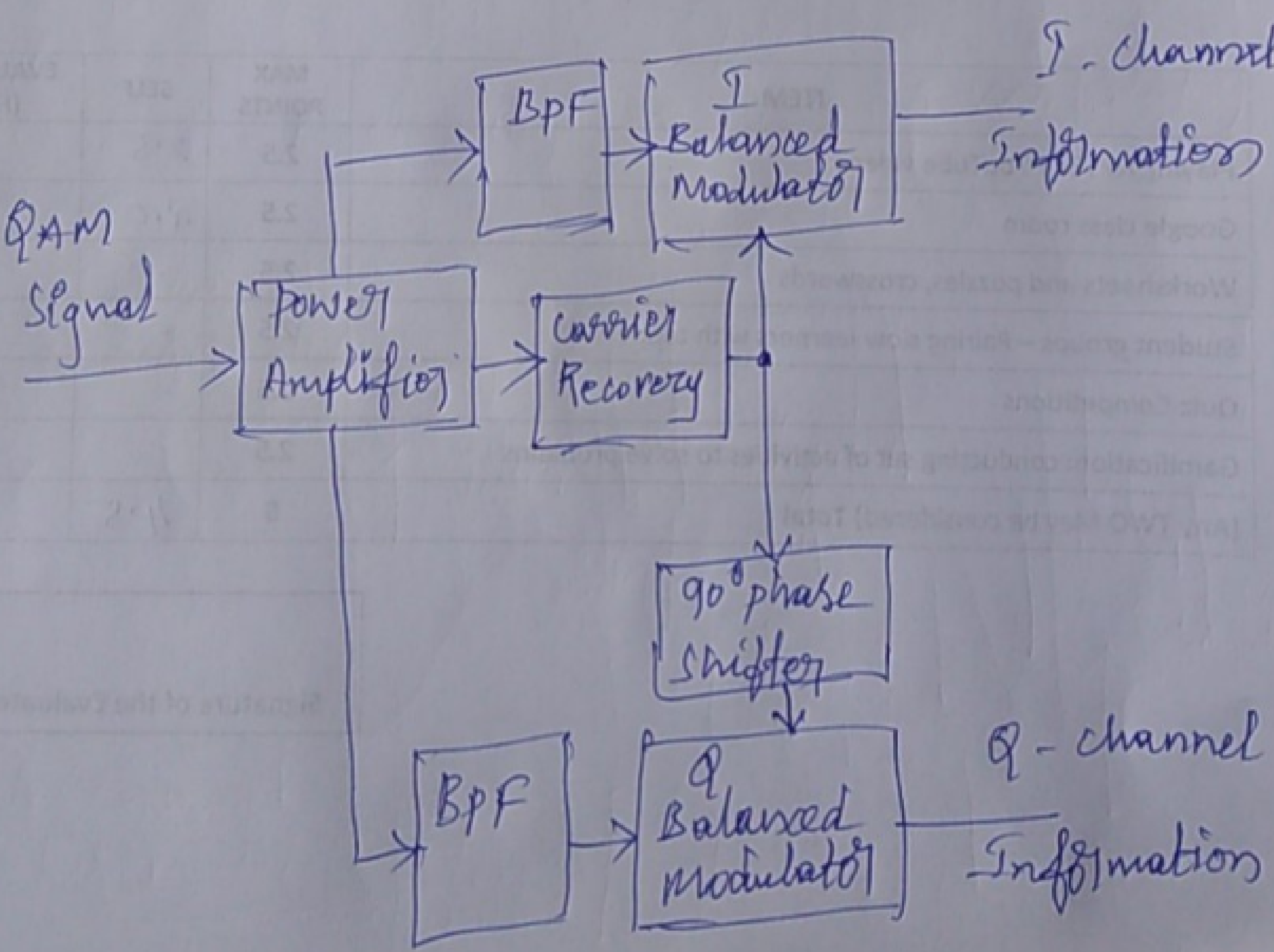
⇒ The carrier signal is seperated into two carrier signals that are 90° out of phase to each other and then modulation is done. This technique is called QAM.

Fig:- Block diagram of QAM modulator



→ The simplified block diagram of QAM modulator. The local oscillator generates carrier signal which is fed to the I - modulator and then the carrier signal is 90° phase shifted and then fed to the Q - modulator undergoes linear summation before its frequency up-conversion and power amplification.

Fig:- Block diagram of QAM demodulator



⇒ The block diagram of QAM demodulator consists of carrier recovery block to recover the original carrier frequency and phase, two balanced modulator for demodulation purpose. The technique of demodulation of the signal is known as Synchronous detection.

→ But this type of process makes the demodulation of QAM expensive than the conventional AM demodulation circuit