4. Amplitude Modulation: Vestigial Side Band (VSB) Modulation

4.1 Introduction: As discussed earlier, it is rather difficult to generate exact SSB signals. They generally require that message signal $m(t)$ have a null around dc. A phase shifter is required in the phase shift method is unrealizable or approximately realizable. The generation of DSB signals is much simpler, but requires twice the signal bandwidth. Vestigial Side Band (VSB) modulation is called the asymmetric sideband system, is a compromise between DSB and SSB. It inherits the advantageous of DSB and SSB but avoids their disadvantageous at the small cost. VSB signals are relatively easy to generate and at the same time their bandwidth is only a little (typically 25%) greater than that of SSB signals.

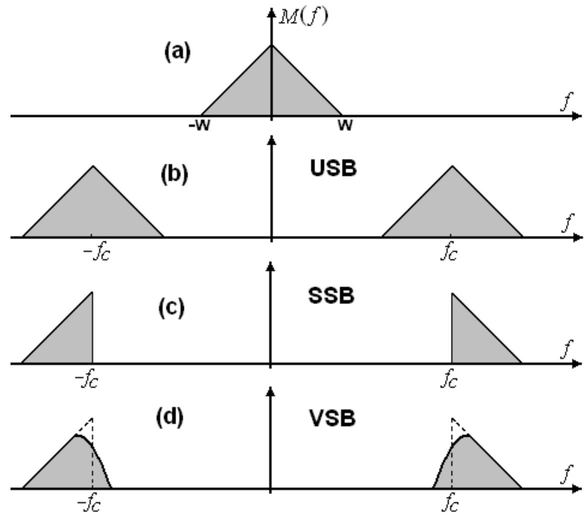

Fig 1. Spectra of modulating signal and corresponding DSB, SSB and VSB

In VSB instead of rejecting one sideband completely (as in SSB), a gradual cutoff one sideband is accepted (Fig.1). The baseband signal can be recovered exactly by a synchronous detector in conjunction with an appropriate equalizer filter $H_o(f)$ at the receiver output (Fig. 3). If a large carrier is transmitted along with the VSB signal, the baseband signal can be recovered by an envelope (or a rectifier) detector.

4.2 VSB wave Generation: The block diagram of VSB modulator is shown in Fig 2. The modulating signal $m(t)$ and the carrier $c(t)$ is applied to the product modulator. The output of the product modulator in time domain is given by

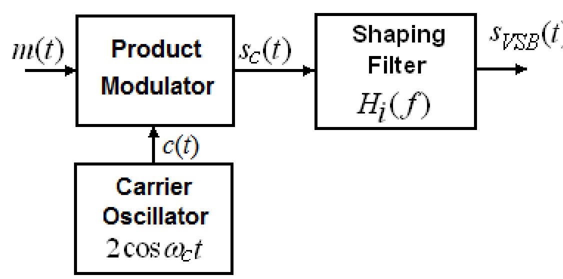

Fig. 2 VSB Modulator

$$s_c(t) = m(t)\, c(t) = 2m(t)\cos\omega_c t \qquad (1)$$

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

VSB modulated signal. This filter will pass the required sideband (usually USB) and the vestige of the other (LSB) sideband.

Let the transfer function of the filter be $H_i(f)$. Then the output of the filter is given by

$$s_{VSB}(t) = s_c(t) * h_i(t) = 2m(t)\cos\omega_c t * h_i(t) \qquad (2)$$

where $h_i(t)$ is the impulse response of the shaping filter. Then the spectrum of VSB modulated signal is given by $S_{VSB}(f) = S_c(f)H_i(f) = \left[M(f+f_c) + M(f-f_c)\right]H_i(f)$ (3)

4.3 Demodulation / Detector of VSB wave: The block diagram of synchronous detector of VSB modulated wave is shown in Fig. 3. The VSB modulated wave is passed through a product modulator, where it is multiplied with the locally generated carrier.

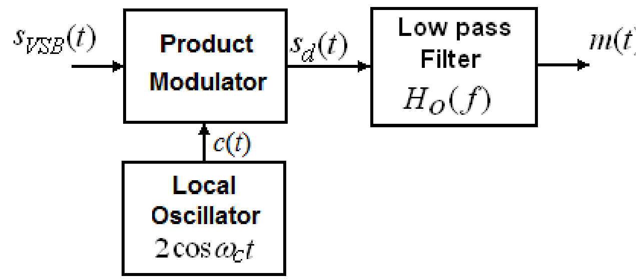

Fig. 3 VSB Demodulator

Then the output of the product modulator is given by

$$s_d(t) = s_{VSB}(t)\,c(t) = 2s_{VSB}(t)\cos\omega_c t \qquad (4)$$

By taking the Fourier transform on both sides this equation, we get

$$S_d(f) = S_{VSB}(f) * C(f) = S_{VSB}(f) * 2\left(\frac{1}{2}\left[\delta(f+f_c) + \delta(f-f_c)\right]\right)$$
$$= \left[S_{VSB}(f+f_c) + S_{VSB}(f-f_c)\right] \qquad (5)$$

The signal $s_d(t)$ is further passed through the low pass equalizer filter of the transfer function $H_o(f)$. The output of the equalizer filter is required to be *m*(*t*). Hence the output signal spectrum is given by

$$M(f) = \left[S_{VSB}(f+f_c) + S_{VSB}(f-f_c)\right]H_o(f) \qquad (6)$$

From equations (2) and (6) and eliminating the spectra at $\pm f_c$ (by suppressed by a LPF $H_o(f)$), we obtain $M(f) = M(f)\left[H_i(f+f_c) + H_i(f-f_c)\right]H_o(f)$ (7)

Hence

$$H_o(f) = \frac{1}{H_i(f+f_c) + H_i(f-f_c)}, \quad |f| \le W \qquad (8)$$

Where '*W*' is message signal bandwidth. It is noted to be that $H_i(f)$ is a band stop filter, the terms $H_i(f \pm f_c)$ contains low-pass components.

4.4 Complementary VSB Filter and Envelope Detection of VSB+C signals:

As a special case of a filter at the VSB modulator, we can choose $H_i(f)$ such that

$$H_i(f+f_c)+H_i(f-f_c)=1, \quad |f|\le W$$

The output filter is just a simple LPF with transfer function $H_o(f)=1, \quad |f|\le W$

The resulting VSB signal plus carrier (VSB+C) can be filtered by envelope detection. Let a new LPF $G(f)=j[1-2H_i(f-f_c)]=-j[1-2H_i(f+f_c)]$.

Defining a new (complex) low-pass signal as $m_v(t)\overset{FT}{\Longleftrightarrow} M_v(f)=G(f)M(f)$

Then we can write the VSB signal as

$$S_{VSB}(f)=\frac{M(f+f_c)+M(f-f_c)}{2}+\frac{M_v(f+f_c)+M_v(f-f_c)}{2j}$$

In time domain $s_{VSB}(t)=m(t)\cos 2\pi f_c t+m_v(t)\sin 2\pi f_c t$.

Main points:

a) VSB modulation is a tradeoff between DSB modulation and SSB modulation.

b) Use more bandwidth than SSB, but simplify the system.

   i) The VSB filter is much easier to implement than the SSB filter, which requires near ideal frequency response at '*0*' or f_c.

   ii) The VSB filter can be implemented at the receiver instead of at the transmitter due to power constraints.

c) Envelope detection is also possible for VSB:

d) Used in Television Transmission system.