Vestigial Sideband Modulation

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In case of single sideband modulation, it was required that there is no DC or low freq^n component in the message signal.

→ so, that there is a guard-band between the two sidebands and it is possible to suppress one band using real filters. (using filter method)

→ which is only possible for speech signals.

→ Moreover, using phase-shift method, it is impossible to build ideal Hilbert' transform block. only approximation is possible. And such approximation works only for speech signals where there is no DC component in the message signal.

→ Moreover, it is difficult to provide $(-\pi/2)$ phase-shift when the message signal has large bandwidth.

→ For signals, which has very low freq^n component, it is rather difficult to generate SSB signal. (e.g video-signal)

→ Generation of DSB-SC signal is relatively easy but it requires twice the signal bandwidth.

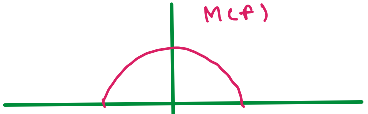
→ Vestigial sideband (VSB) modulation is a compromise between DSB and SSB.

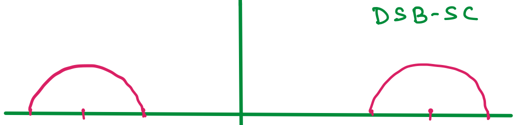
→ It is relatively easy to generate the VSB signal and at the same time, the required bandwidth is 25 to 30% more than SSB signals.

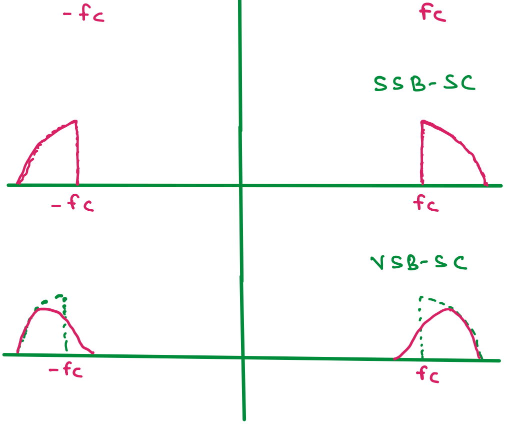
→ In VSB, a small amount or vestige of the unwanted band also appears in the output spectrum.

→ In VSB, instead of completely rejecting the one sideband, it is suppressed using the filter with gradual roll-off.

→ In this process, some portion of the desired band also gets filtered out.



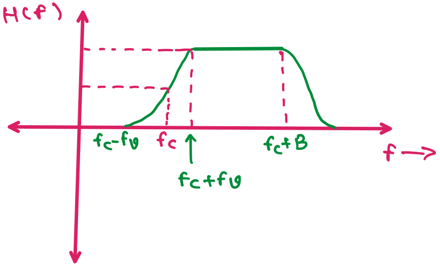




→ In VSB modulation, the filter design is relatively simple and can be used for signals with low freq^n components. (e.g video signals)

→ By passing the DSB-SC signal through VSB filter $H_i(f)$, it is possible to generate VSB signal.

* The response of $H_i(f)$ (for positive freq^n)



→ The filter has flat response from f_c+f_v to f_c+B.

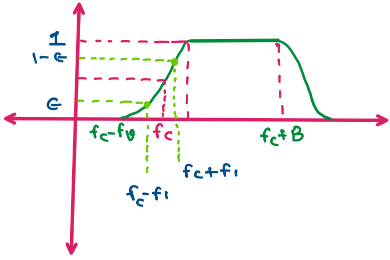
→ There is a gradual roll-off from f_c+f_v to f_c-f_v

→ The one desired side-band is from f_c to f_c+B. Therefore, some portion of the required side band will also get filtered out.

→ While from f_c to f_c-f_v, some portion of the unwanted band will also appear in the output.

→ Total Bandwidth of VSB signal

$\boxed{B.W = B + f_v}$ where, $\underline{f_v < B}$

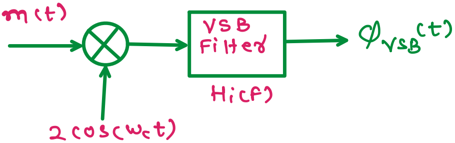


→ The second requirement for the filter is,

the sum of values of magnitude response $|H(f)|$ at any two freq^n equally displaced above and below is unity.

i.e $|H(f_c+f_1)| + |H(f_c-f_1)| = 1$

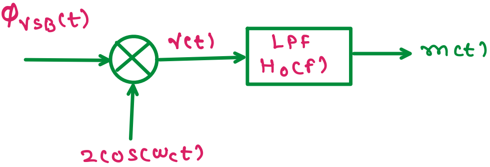
- → with the help of VSB filter and balanced modulator, VSB signal can be generated.



Mathematically,

$$\phi_{VSB}(f) = [M(f-f_c) + M(f+f_c)] H_i(f) \quad -(1)$$

- → At the receiver, using synchronous demodulation and using proper low pass filter, the message signal can be recovered.



Let's say the output after demodulator is , $v(t)$

$$v(f) = [\phi_{VSB}(f-f_c) + \phi_{VSB}(f+f_c)]$$

Substituting the $\phi_{VSB}(f)$ from eq (1)

$$v(f) = [M(f-2f_c) + M(f)]\, H_i(f-f_c)$$

$$+ [M(f) + M(f+2f_c)]\, H_i(f+f_c)$$

$$= M(f)\,[H_i(f-f_c) + H_i(f+f_c)]$$

$$+ \underbrace{[M(f-2f_c)\, H_i(f-f_c) + M(f+2f_c)\, H_i(f+f_c)]}_{\text{Higher order term}}$$

After Low-pass filter, the spectrum will be

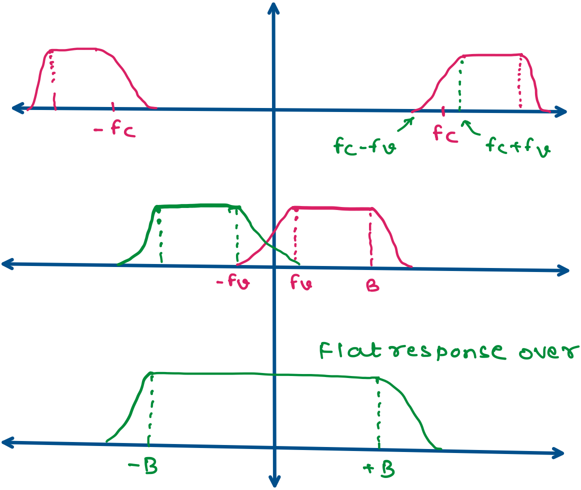
$$M(f)\,[H_i(f-f_c) + H_i(f+f_c)]$$

→ If $\{H_i(f-f_c) + H_i(f+f_c)] = \text{constant}, |f| \leq B$ then output after low pass filter is $kM(f)$.

where k is some constant.

If $k=1$, then after the low-pass filter

$$\Rightarrow v(f)\, H_0(f) = M(f)$$



→ If $[H_i(f-f_c) + H_i(f+f_c)] = \text{constant}$ for $|f| \le B$

at the receiver, we need simple low-pass filter with flat response over $|f| \le B$.

→ But if it is not possible to design such VSB filter then

In general, to get flat response over $|f| \le B$,

$$\Rightarrow \left[H_i(f-f_c) + H_i(f+f_c)\right] = \frac{1}{H_0(f)}$$

$$\Rightarrow \boxed{H_0(f) = \frac{1}{H_i(f-f_c) + H_i(f+f_c)}} \quad |f| \le B$$

→ so, that we get message signal $M(f)$ after output filter $H_0(f)$.

* Vestigial sideband was used for transmission of TV signals. (since they require a large bandwidth and contains low-freq^n components)

→ Since, TV signals are broadcast signals, to keep the receiver design simple, carrier signal was also transmitted along with VSB signal.

→ so, that at the receiver, the demodulation can be carried out using envelope detector.