Single Sideband Modulation Technique

As discussed earlier, the DSB-spectrum has two sidebands: the upper sideband (USB) and the lower sideband (LSB), each containing the complete information of the baseband signal $m(t)$. As a result, DSB modulation technique requires two times of the RF bandwidth of $m(t)$ to transmitt. To improve the spectral efficiency, in single sideband modulation (SSB), we remove either the LSB or VSB and uses only bandwidth of B (Hz) for one message signal $m(t)$.

Recall that, in DSB transmission the information stored in the LSB is identical to the information stored in USB. Infact, the two sidebands of AM signal are mirror images of each other. Now if the amplitude and phase spectra of one sideband is known, then the amplitude and phase spectra of the other sideband can also be uniquely determined. This means, no information is lost by suppressing the carrier and one of the two side bands of the AM signal. As both sidebands contains same information, there is no preference of one over the other.

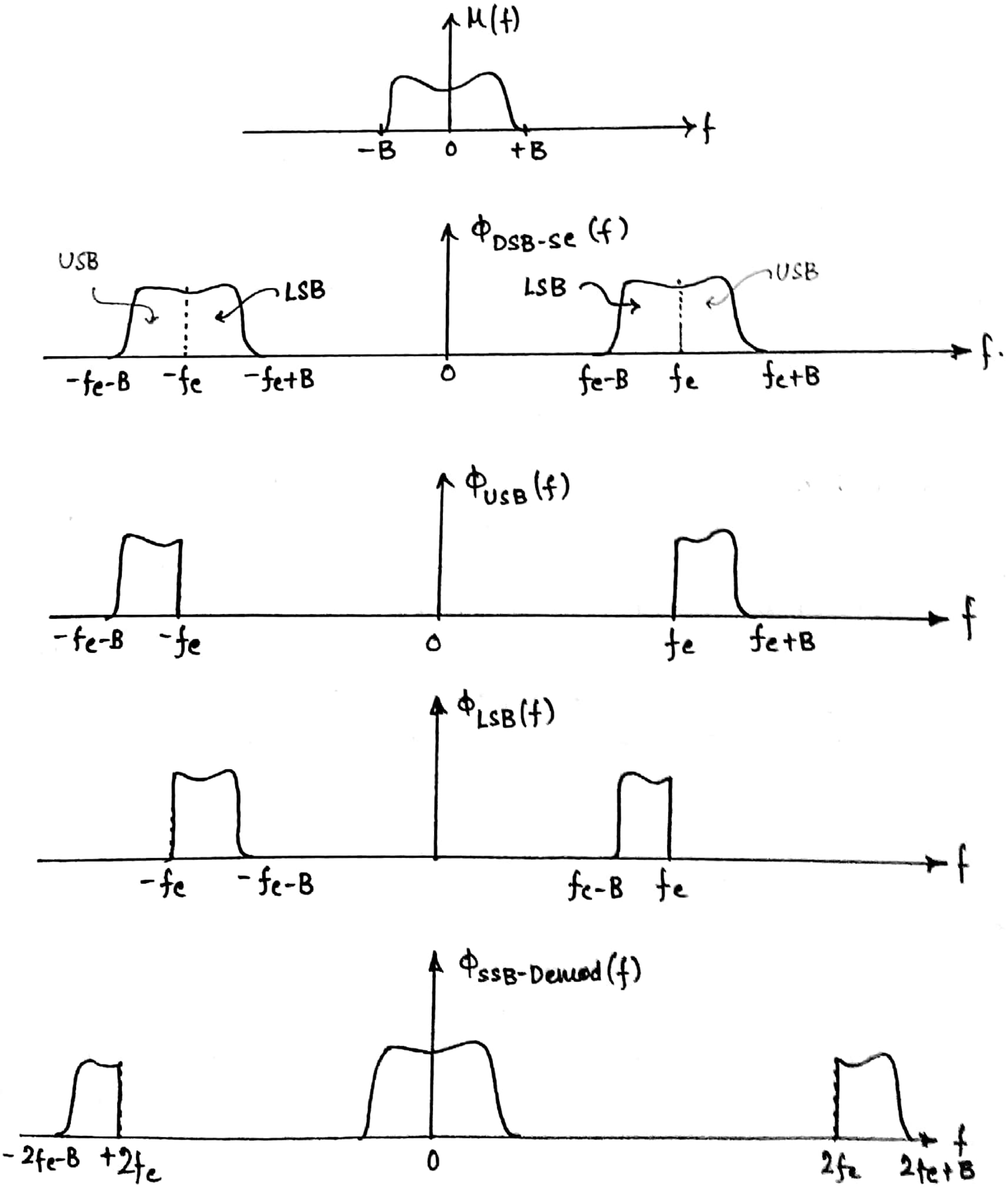
As only one sideband is transmitted in SSB signal, the transmission bandwidth is equal to the maximum frequency of the modulating frequency, i.e.

$$\boxed{B_{SSB} = f_m}$$

In terms of BW, SSB-SC signal requires the BW, half of AM signal or DSB-SC signal i.e.

$$\boxed{B_{SSB} = \frac{B_{AM}}{2} = \frac{B_{DSB\text{-}SC}}{2} = f_m}$$

The spectra of SSB-SC signal are shown below.



Using the frequency shifting property and Hilbert transform the two side bands can be mathematically represented as,

$$\varphi_{USB}(t) = m(t)\cos w_c t - m_h(t)\sin w_c t$$

$$\varphi_{LSB}(t) = m(t)\cos w_c t + m_h(t)\sin w_c t$$

Hence, the general SSB signal can be expressed as,

$$\boxed{\varphi_{SSB}(t) = m(t)\cos w_c t \mp m_h(t)\sin w_c t}$$

Demodulation of SSB Signal

For the demodulation of SSB-SC signal, coherent demodulation technique can be estimated. Mathematically,

$$\varphi_{out}(t) = \varphi_{SSB}(t)\cos w_c t$$

$$= [m(t)\cos w_c t \mp m_h(t)\sin w_c t]\cos w_c t$$

$$= m(t)\cos^2 w_c t \mp m_h(t)\sin w_c t \cos w_c t$$

$$= \frac{m(t)}{2}[1+\cos 2w_c t] \mp \frac{1}{2} m_h(t)\cos 2w_c t$$

$$= \frac{m(t)}{2} + \frac{m(t)}{2}\cos 2w_c t \mp \frac{1}{2} m_h(t)\cos 2w_c t$$

$$= \frac{m(t)}{2} + \text{SSB-SC signal at } 2w_c.$$

A low pass filter (LPF) will suppress the unwanted terms at $2w_c$ and only the base band signal will be allowed to pass through. Hence, coherent demodulation can demodulate SSB-SC signal.

Generation of SSB Signal

(i) Selective Filtering Method

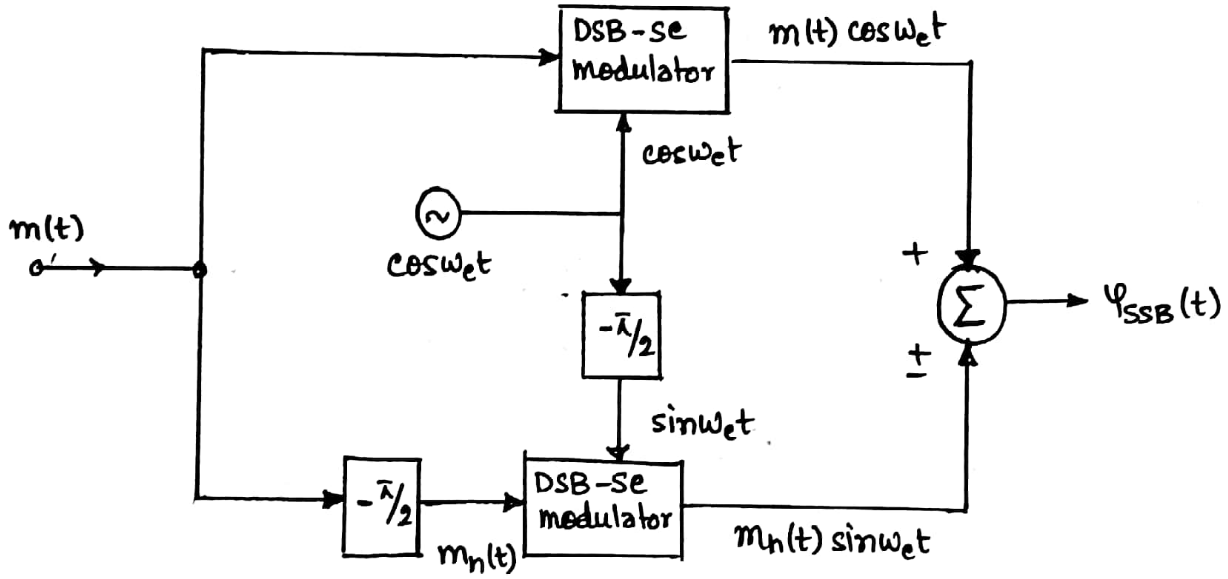
The most commonly used method of generating SSB signal is to pass a DSB signal through a sharp cut-off filter to eliminate the undesired band. For selecting USB, the cut-off filter should pass all components above f_c, unattenuated and completely cut down or suppress all components below f_c. However such a filter is very tough to realize. Hence, we go for an alternative technique of generating SSB-SC signal, such as phase shift method.

(ii) Phase Shift Method

In this method, we directly utilize the generalized expression of SSB-signal, i.e.

$$\varphi_{SSB}(t) = m(t)\cos\omega_c t \mp m_h(t)\sin\omega_c t$$

The following figure depicts the implementation. The $-\pi/2$ phase shifter, delays the phase of every positive spectral component by $\pi/2$. Hence it may be referred to as a Hilbert transformer.



Power gain/improvement in SSB signal

SSB signal requires considerably less power for transmitting the modulating signal. Mathematically,

$$P_{SSB} = P_{SB} = P_c\frac{\mu^2}{4} = \frac{1}{2}P_{DSB\text{-}se}$$

For $\mu = 1$; $P_{SSB} = \frac{P_c}{4} = \frac{1}{6}P_{AM}$.

Hence, power improvement in SSB-se signal compared to AM signal is, $10\log_{10}(6) \simeq 7.8\,dB$ and $10\log_{10}(2) = 3\,dB$ compared to DSB-se signal.

Pros of SSB Modulation:

(i) Due to transmission of only one side band with suppressed carrier in SSB-transmission, much less transmitted power is necessary to produce the same quality signal in the receiver as that of with AM transmission.

(ii) SSB transmission requires half of the BW as compared to the AM transmission and thus conserves the RF spectrum.

(iii) The overall SNR or signal to noise ratio improvement in SSB signal is approximately 7·8 dB compared to standard AM signal.

(iv) Due to half BW utilization, SSB signal will have the reduced effect of thermal noise and thus more robust compared to AM signal.

(v) Due to reduced sideband transmission, effect of distortion in SSB-SC signal is low compared to AM and DSB signal.

Cons of SSB Transmission:

i) SSB receivers require more accurate, complex and expensive tuning circuits.

ii) SSB receivers require a carrier recovery and synchronization circuit. thus SSB receivers are more complex and expensive receivers than conventional AM systems.