



Double Sideband Suppressed Carrier (DSB-SC)

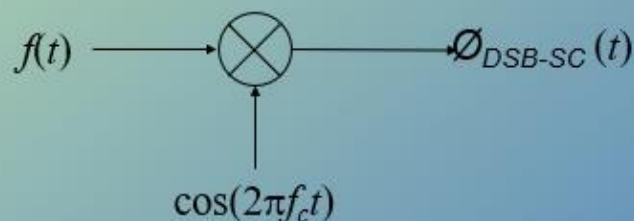
Double-sideband suppressed-carrier transmission (DSB-SC) is transmission in which frequencies produced by amplitude modulation (AM) are symmetrically spaced above and below the carrier frequency and the carrier level is reduced to the lowest practical level, ideally being completely suppressed. The expression of DSB-SC modulation is given by:

Amplitude Modulation :Suppressed Carrier (DSB-SC)

- $\phi_{DSB-SC}(t) = f(t) \cos \omega_c t$

- $\phi_{DSB-SC}(t) = f(t) \cos(2\pi f_c t)$

f_c is the carrier frequency (frequency of radio station)



The term

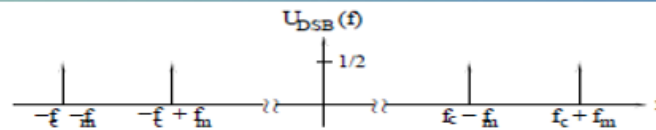
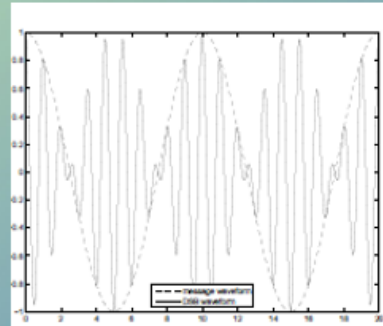
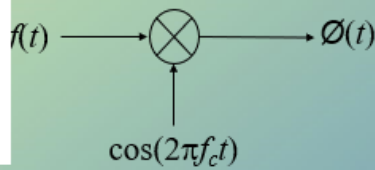
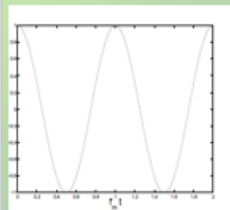
$\cos \omega_c t$ is called the carrier signal

$f(t)$, or $m(t)$ is called the modulating signal

$\phi_{DSB-SC}(t)$ is called the modulated signal



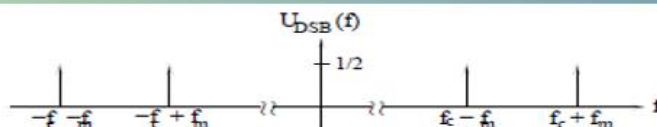
Amplitude Modulation :Suppressed Carrier (DSB-SC)



Amplitude Modulation :Suppressed Carrier

$$m(t) \cos 2\pi f_c t \leftrightarrow \frac{1}{2} (M(f - f_c) + M(f + f_c))$$

$$\Phi_{DSB-SC}(\omega) = \frac{1}{2} F(\omega + \omega_c) + \frac{1}{2} F(\omega - \omega_c)$$





The bandwidth of the modulated waveform is **twice** the information bandwidth:

$$BW = \text{Maximum Freq.} - \text{Minimum Freq.}$$

$$BW = (fc + fm) - (fc - fm)$$

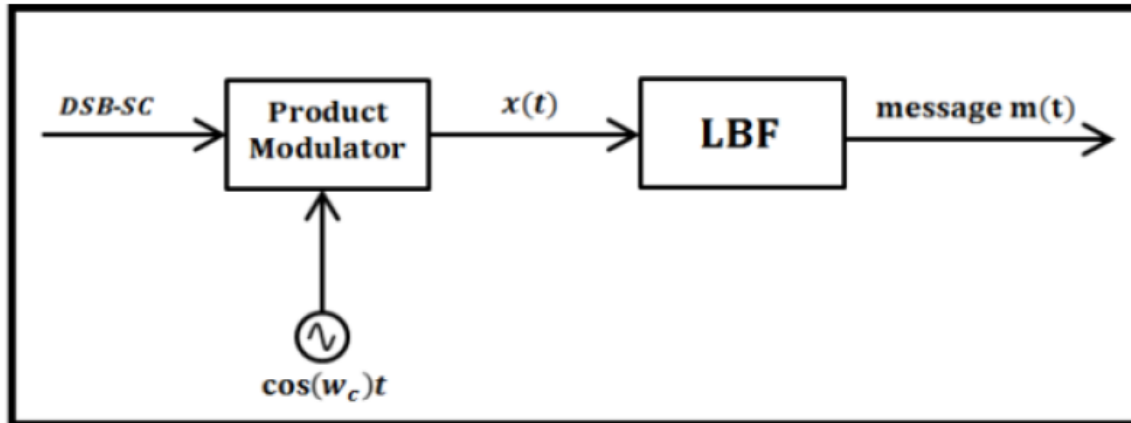
$$BW = 2fm$$

Demodulation of DSB-SC:

In order to demodulate a double-sideband suppressed-carrier (DSB-SC) signal, the signal is first fed into a product modulator. In this modulator, the incoming DSB-SC wave is multiplied by a locally generated carrier signal, represented as $\cos(wct)$. This locally generated carrier must be "coherent," meaning it is perfectly synchronized in both frequency and phase with the original carrier wave used during the generation of the DSB-SC signal.

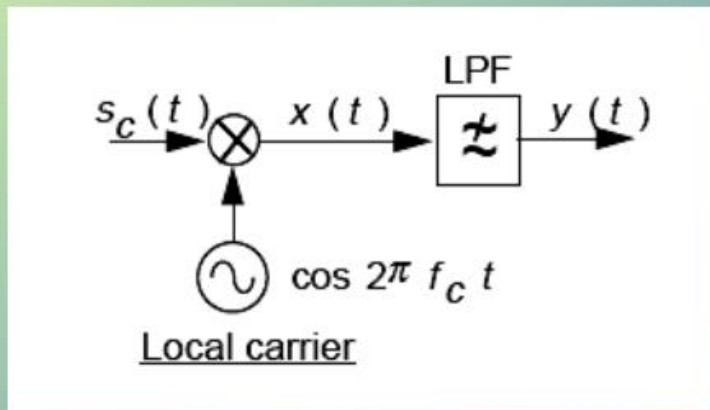
This technique is known as **coherent detection or synchronous detection** because of the precise alignment needed between the locally generated carrier and the original carrier.

After modulation, the output from the product modulator contains both the message signal and various other frequency components. To isolate and retrieve only the message signal, the output is passed through a low-pass filter (LPF). The LPF removes all the unnecessary higher-frequency components, leaving only the original message signal as the final output.



Demodulation of DSB Signals :

Synchronous detector





Demodulation of DSB Signals :

$$\phi_{DSB-SC}(t) = f(t) \cos w_c t$$

$$\phi_{DSB-SC}(t) \cos w_c t$$

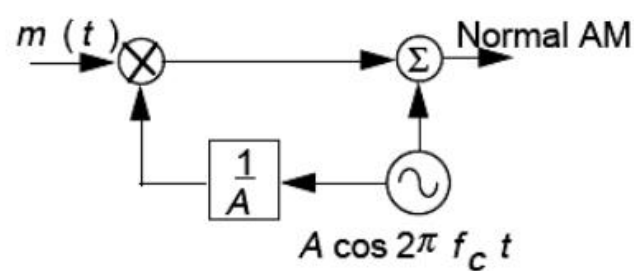
$$\begin{aligned} & f(t) \cos w_c t \cos w_c t \\ & f(t) \cos^2 w_c t \end{aligned}$$

$$y(t) = f(t) \left[\frac{1}{2} + \frac{1}{2} \cos 2w_c t \right]$$

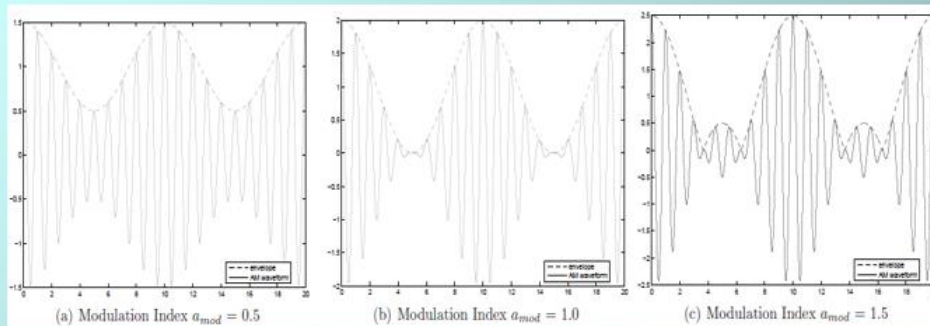
$$y(t) = \frac{1}{2} f(t) + \frac{1}{2} f(t) \cos 2w_c t$$



Generation of Normal AM Signals :



Modulation Index



Under Modulation
 $m < 1$

100% Modulation
 $m = 1$

Over modulation
 $m > 1$



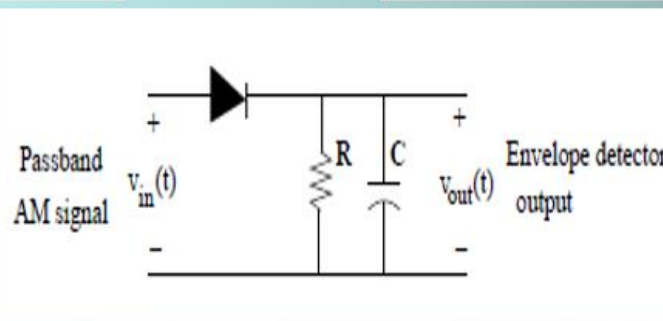
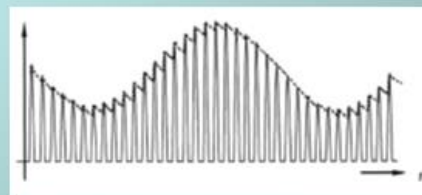
Modulation Index

The mathematical expression for the modulation index of an amplitude modulated wave.

$$m_a = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$$

The Envelope Detector Circuit

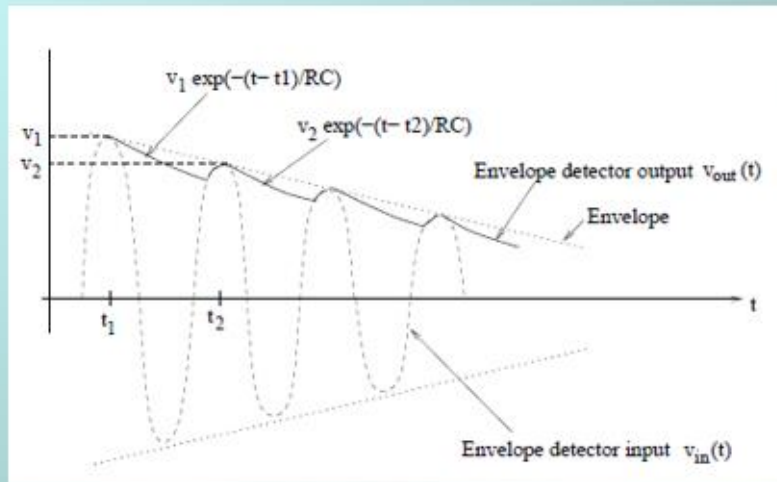
The diode (half-wave) rectifies the AM wave and the RC time-constant (follows) the envelope with a slight ripple.





RC-time

$$\frac{1}{f_c} \ll RC \ll \frac{1}{B}$$





Power Content

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

$$P = \frac{V^2}{R}$$

$$\text{Amplitude of LSB or USB} = \frac{mA}{2}$$

$$P_{LSB} = P_{USB} = \frac{m^2 P_c}{4}$$

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

$$P_T = P_c + \frac{m^2 P_c}{2}$$

$$P_T = P_c \left(1 + \frac{m^2}{2}\right)$$

Efficiency

$$\text{Transmission Efficiency} = \frac{P_s}{P_T} \times 100$$

$$P_s = \frac{m^2 P_c}{2}$$

$$P_T = P_c \left(1 + \frac{m^2}{2}\right)$$

$$\text{Efficiency} = \frac{\frac{m^2 P_c}{2}}{P_c \left(1 + \frac{m^2}{2}\right)} = \frac{m^2}{2 + m^2}$$

$$\text{let } m = 1 \text{ to get maximum Efficiency} = \frac{1}{2 + 1}$$

$$\text{Maximum Efficiency} = 33.33\%$$



Current calculation for single-tone AM

$$P_T = P_c \left(1 + \frac{m^2}{2}\right)$$

$$\frac{P_T}{P_c} = 1 + \frac{m^2}{2}$$

$$P = I^2 R$$

$$\frac{I_T^2}{I_c^2} = 1 + \frac{m^2}{2}$$

$$\frac{I_T}{I_c} = \sqrt{1 + \frac{m^2}{2}}$$

$$I_T = I_c \sqrt{1 + \frac{m^2}{2}}$$

Total or net modulation index for multiple-tone modulation

$$P_T = P_c \left[1 + \frac{m_1^2}{2} + \frac{m_2^2}{2} + \frac{m_3^2}{2} \dots + \frac{m_n^2}{2}\right]$$

$$m_T^2 = m_1^2 + m_2^2 + m_3^2 + \dots + m_n^2$$

$$m_T = \sqrt{m_1^2 + m_2^2 + m_3^2 + \dots + m_n^2}$$



Example:

Determine the power content of each of the sidebands and of the an AM signal that has a percent modulation of 85% and contains 1200 W total power

Solution: Given that $M=85\%$, $m_a=0.85$, $P_T=1200$ W, to find P_C , P_{LSB} , P_{USB}

$$P_T = P_C \left(1 + \frac{m^2}{2}\right), \quad 1200 = P_C \left(1 + \frac{(0.85)^2}{2}\right)$$

$$1200 = P_C (1 + 0.3613), \quad 1200 = 1.3613 P_C$$

$$P_C = \frac{1200}{1.3613}$$

$$P_C = 881.5W$$

$$P_C + P_{SB} = P_T$$

$$881.5 + P_{SB} = 1200$$

$$P_{SB} = 318.5 \text{ watts}$$

$$P_{USB} = P_{LSB}$$

$$= \frac{P_{SB}}{2}$$

$$= 159.25 \text{ watts}$$



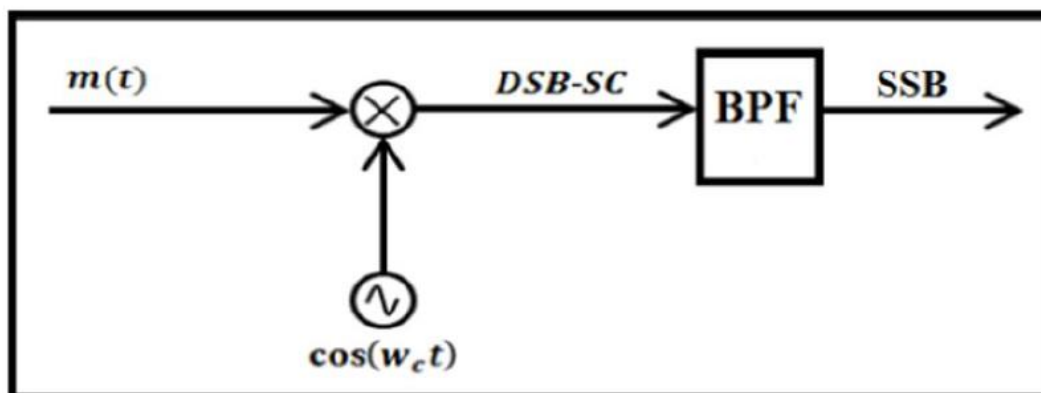
Single Sideband (SSB)

There are two common methods to generate a Single Sideband (SSB) signal.

1. Filtering Method

2. Phasing Method

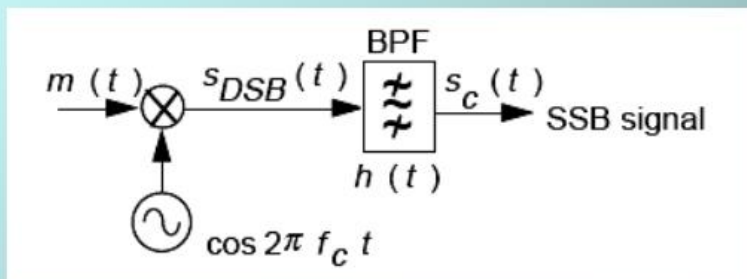
1. **Filtering Method:** One common technique for generating a Single Sideband (SSB) signal is by using a band-pass filter (BPF) to remove one of the sidebands. This filtering process eliminates either the upper sideband (USB), which contains the higher frequency components, or the lower sideband (LSB), which contains the lower frequency components, leaving only one sideband to be transmitted. In SSB transmission, the carrier signal is often reduced or completely suppressed to further save bandwidth and power. This is known as Single Sideband Suppressed Carrier (SSBSC) modulation. By suppressing the carrier and transmitting only one sideband, SSBSC efficiently transmits the essential message information using minimal bandwidth. Figure illustrates the process of generating an SSB signal using this filter-based method





Generation of SSB Signals :

1- Filter Method :

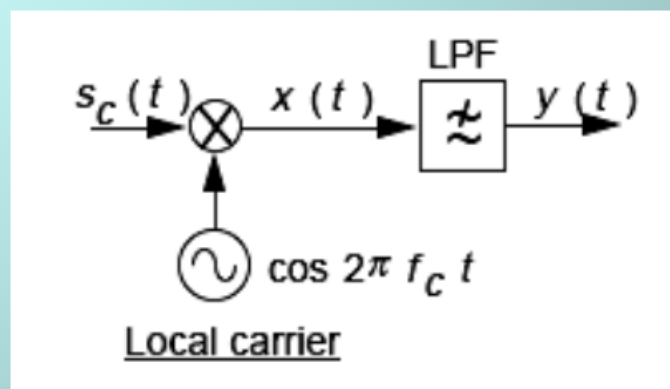


Demodulation of SSB:

Demodulation of SSB signals can be accomplished by using a synchronous detector as used in the demodulation of DSB-SC.

Demodulation of SSB Signals :

Synchronous detector





Bandwidth of AM-DSB-LC, AM-DSB-SC, and SSB

$$\begin{aligned} BW_{AM - DSB - LC} &= f_{USB} - f_{LSB} \\ &= (f_c + f_m) - (f_c - f_m) = 2 f_m \end{aligned}$$

$$\begin{aligned} BW_{AM - DSB - SC} &= f_{USB} - f_{LSB} \\ &= (f_c + f_m) - (f_c - f_m) = 2 f_m \end{aligned}$$

$$\begin{aligned} BW_{SSB} &= f_{USB} - f_c \\ &= (f_c + f_m) - (f_c) = f_m \end{aligned}$$



Power Content of AM-DSB-LC, AM-DSB-SC, and SSB

AM - DSB - LC

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

$$P_{AM - DSB - LC} = P_c \left(1 + \frac{m^2}{2}\right)$$

AM - DSB - SC

$$P_{DSB - SC} = P_{LSB} + P_{USB}$$

$$= \frac{m^2 P_c}{2}$$

$$SSB \quad P_{SSB} = \frac{m^2 P_c}{4}$$



Example:

Calculate the percent power saving for the SSB signal if AM wave modulated to a depth (a)100% (b) 50%

Solution: Power Saving in SSB: Carrier and one sideband are suppressed. Therefore only one sideband is transmitted

$$\% \text{ power saving} = \frac{\text{Power in carrier} + \text{Power in one sideband}}{\text{Total Power}}$$

$$\text{or } \% \text{ power saving} = \frac{P_c \left[1 + \frac{m^2}{4}\right]}{P_c \left[1 + \frac{m^2}{2}\right]} = \frac{\left[1 + \frac{m^2}{4}\right]}{\left[1 + \frac{m^2}{2}\right]}$$

Example:

At 100% modulation, $m=1$

$$\% \text{ power saving} = \frac{1.25}{1.5} = 83.33 \%$$

At 50% modulation, $m=0.5$

$$\% \text{ power saving} = \frac{1.0625}{1.125} = 94.44 \%$$