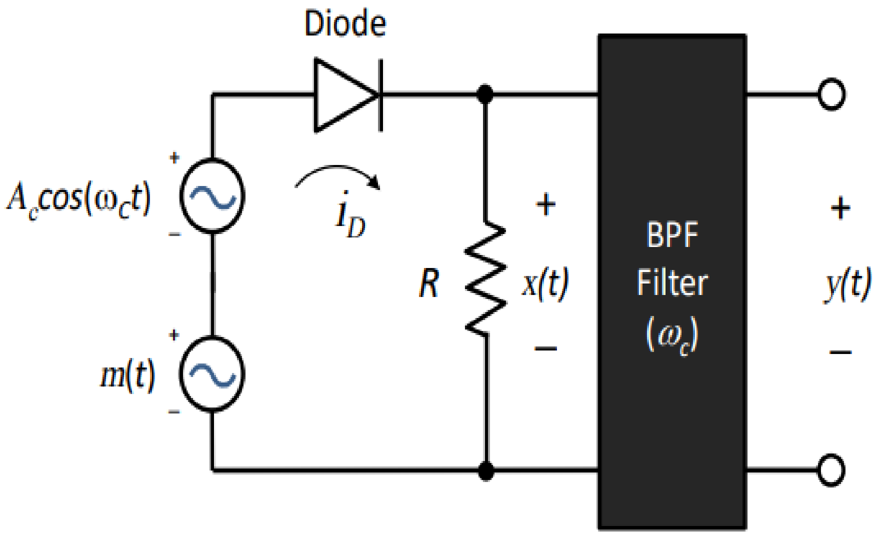
AM(DSB-LC) Modulation

- **Using Nonlinearity for Modulation**



$$x(t) = (m(t) + A_c \cos(w_c\, t))D(t)$$

$$D(t) = \frac{1}{2} + \frac{2}{\pi}\left[\cos(w_c\, t) - \frac{1}{3}\cos(3w_c\, t) + \frac{1}{5}\cos(5w_c\, t) - \cdots\right]$$

$$x(t) = \frac{1}{2}m(t) + \frac{1}{2}A_c\cos(w_c\, t) + \frac{2}{\pi}m(t)\cos(w_c\, t) + \frac{2}{\pi}A_c\cos(w_c\, t)^2 - \ldots.$$

After bandpass filter

$$y(t) = \frac{1}{2}A_c\cos(w_c\, t) + \frac{2}{\pi}m(t)\cos(w_c\, t)$$

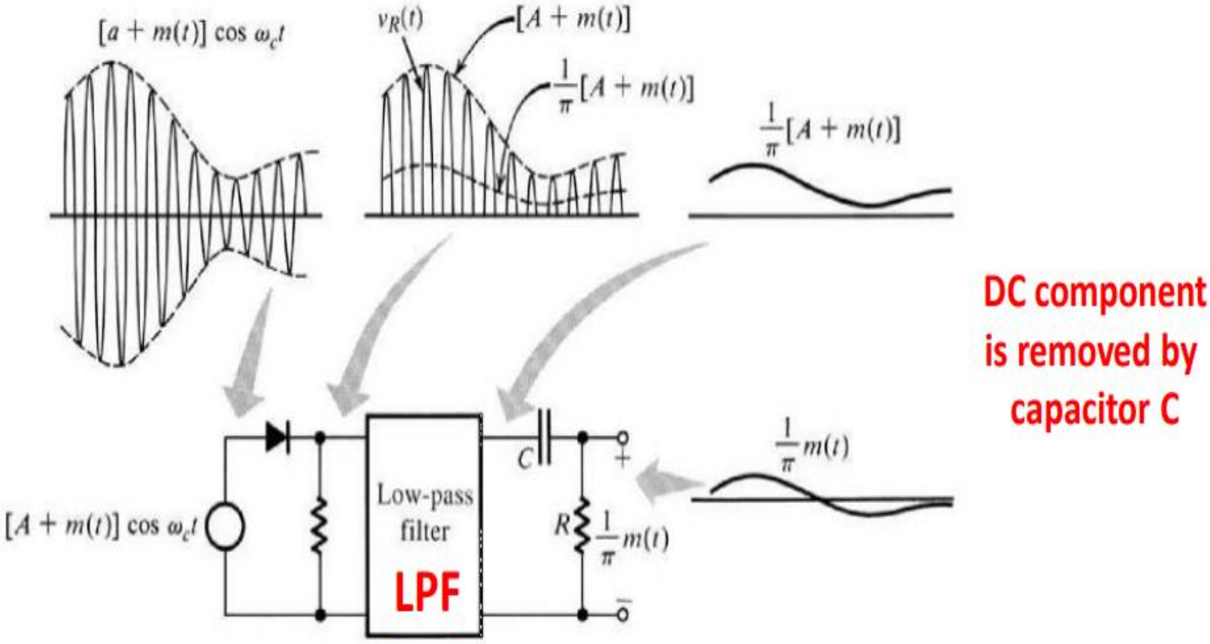
Carrier signal **modulated signal (side band signal)**

AM(DSB-LC) Demodulation

Coherent (i.e., synchronous) demodulation (or detection) is a method to recover the message signal from the received modulated signal that requires a carrier at the receiver. This carrier signal must match in frequency and phase the received signal.

But . . . Amplitude Modulation has the advantage of not requiring coherent detection methods. Non-coherent methods can be used which are much simpler to implement.

1. AM Rectifier Detector



$$x(t) = [(m(t) + A_c)\cos(w_c\, t)]D(t)$$

$$D(t) = \frac{1}{2} + \frac{2}{\pi}\left[\cos(w_c\, t) - \frac{1}{3}\cos(3w_c\, t) + \frac{1}{5}\cos(5w_c\, t) - \cdots\right]$$

$$x(t) = \frac{1}{2}(m(t) + A_c)\cos(w_c\, t) + \frac{2}{\pi}(m(t) + A_c)\cos(w_c\, t)^2 - \ldots.$$

$$\cos(x)^2 = \frac{1}{2}(1 + \cos(2x))$$

$$x(t) = \frac{1}{2}(m(t) + A_c)\cos(w_c\, t) + \frac{1}{\pi}(m(t) + A_c)(1 + \cos(2w_c\, t)) - \cdots$$

$$x(t) = \frac{1}{2}(m(t) + A_c)\cos(w_c\, t) + \boldsymbol{\frac{1}{\pi}(m(t) + A_c)} + \frac{1}{\pi}(m(t) + A_c)\cos(2w_c\, t) - \cdots$$

After lowpass filter

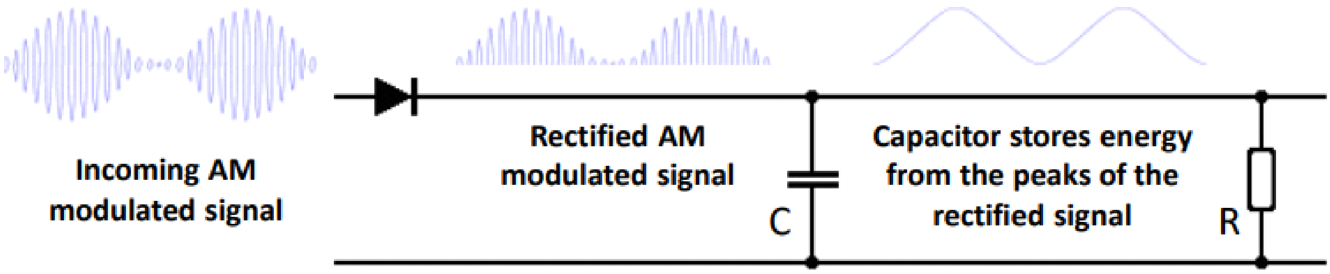
$$y(t) = \boldsymbol{\frac{1}{\pi}m(t) + \frac{1}{\pi}A_c}$$

After DC blocking(capacity)

$$y(t) = \boldsymbol{\frac{1}{\pi}m(t)} \qquad (information\ signal)$$

Explain that mathematically how ***H.W***: can remove $\frac{1}{\pi}A_c$ by using capacity?

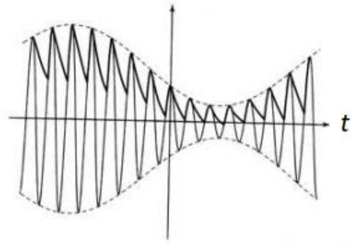
2. AM Envelope Detector



Envelope Detection requires the RC network with time constant **τ = RC**

Choosing the RC Time Constant in Envelope Detector

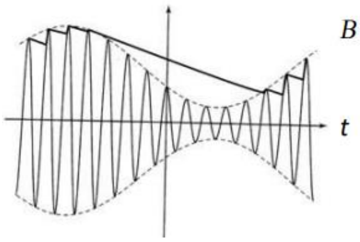
$$W_m \leq \frac{1}{RC} \leq W_c \quad \text{or} \quad \frac{1}{W_c} \leq RC \leq \frac{1}{W_m}$$



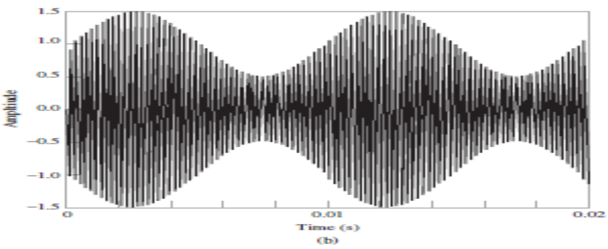
Time constant τ = RC too short.

Design criteria is $2\pi B < \frac{1}{RC} << 2\pi f_C$

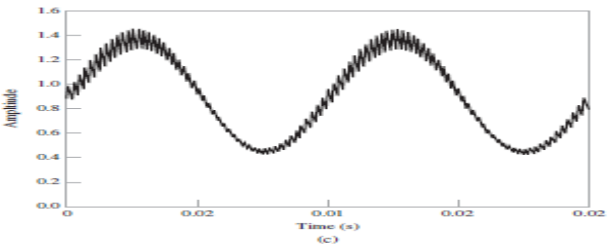
B Hz is bandwidth of message signal.



Time constant τ = RC too long.



using

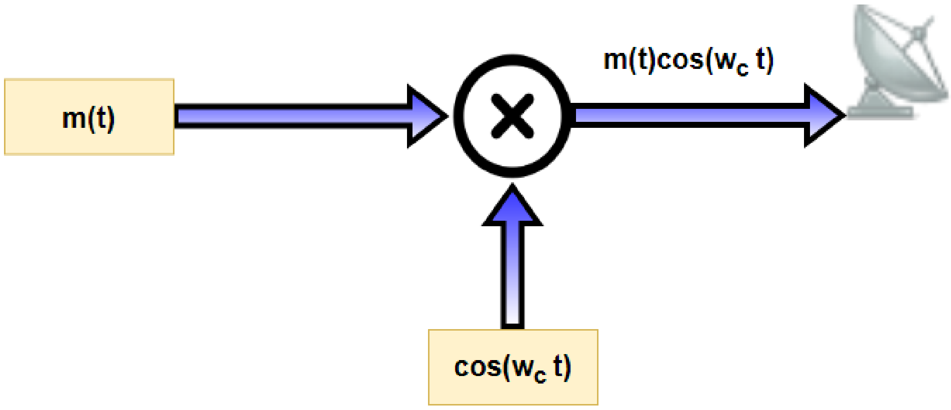


H.W: What is the difference between **AM Rectifier Detector** and **AM Envelope Detector?**

Double-Sideband Suppressed Carrier AM(DSB-SC)

1- Product modulation (Linear Multiplier)

Basically, double sideband-suppressed carrier (DSB-SC) modulation consists of the product of the message signal $m(t)$ and the carrier wave $c(t)$ as shown in the equation.



$$x(t) = m(t)c(t)$$

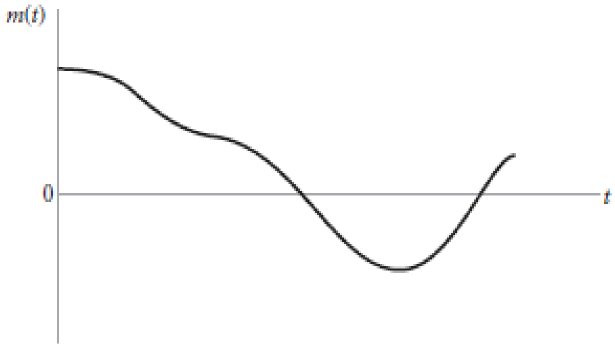
$$m(t) \rightleftharpoons M(w)$$

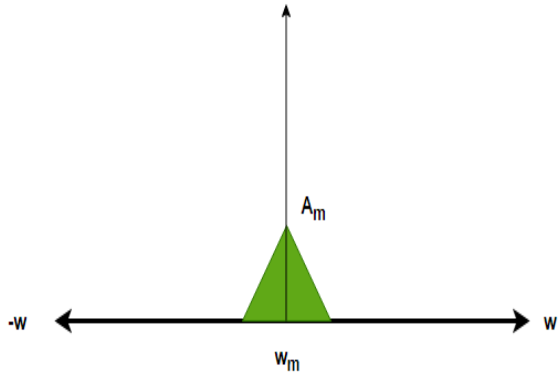
$$x(t) = m(t)\cos(w_c t)$$

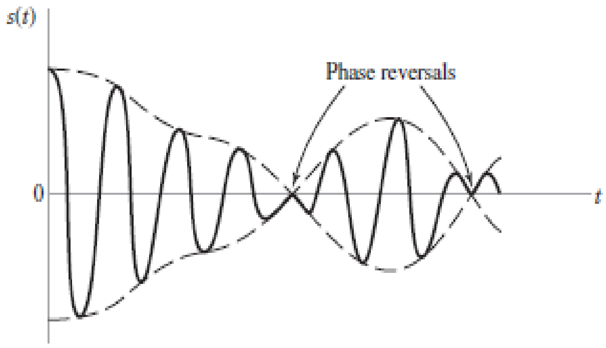
$$x(t) = m(t)\frac{1}{2}[e^{jw_c t} + e^{-jw_c t}]$$

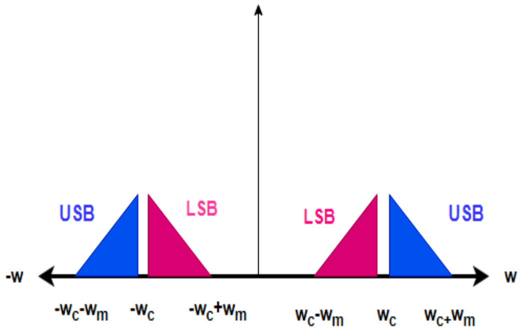
$$X(w) = \frac{1}{2}[M(w - w_c) + M(w + w_c)]$$

Accordingly, the device used to generate the DSB-SC modulated wave is referred to as a ***product modulator***. From equation above we also note that unlike amplitude modulation, DSB-SC modulation is reduced to zero whenever the message signal is switched off. In short, insofar as bandwidth occupancy is concerned, DSB-SC offers no advantage over AM. Its only advantage lies in saving transmitted power, which is important enough when the available transmitted power is at a premium.









$$\boldsymbol{Power\ total} = \textbf{Power sidebands} = \frac{A_c{}^2 k^2}{8} + \frac{A_c{}^2 k^2}{8}$$

$$\boldsymbol{Power\ efficiency(\eta)} = \frac{\textbf{Power sidebands}}{\boldsymbol{power\ total}} = \mathbf{100\%}$$

$$\boldsymbol{B.W = (f_c + f_m) - (f_c - f_m) = 2f_m}$$

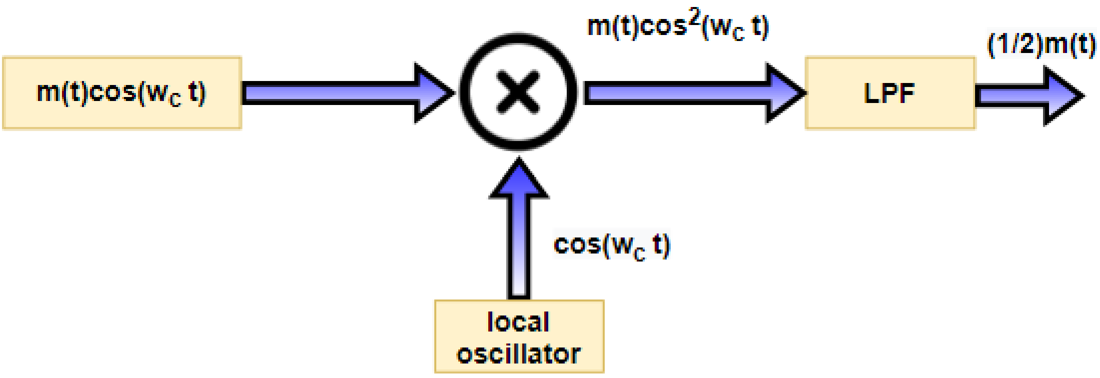
Demodulation:

Coherent Detection (Synchronous Demodulation)

Since the envelope of the DSB-SC modulated wave $\boldsymbol{x(t)}$ is different from the message signal $\boldsymbol{m(t)}$ we have to find some other means for recovering $\boldsymbol{m(t)}$ from $\boldsymbol{x(t)}$. To this end, we recognize that $\cos^2(x)$ contains a constant term, as shown by the trigonometric identity

$$\cos^2(x) = \frac{1}{2}(1 + \cos(2x))$$

In light of this relation rewritten for $\mathbf{x = w_c t}$ that the recovery of the message signal can be accomplished by first multiplying with a locally generated sinusoidal wave and then low-pass filtering the product. It is assumed that the local oscillator signal is exactly coherent or synchronized, in both frequency and phase, with the carrier wave used in the product modulator to generate This method of demodulation is known as **coherent detection or synchronous demodulation**



$$y(t) = x(t)c(t)$$

$$y(t) = m(t)\cos(w_c t)\cos(w_c t)$$

$$y(t) = m(t)\cos^2(w_c t)$$

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

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

$$Y(w) = \frac{M(w)}{2} + \frac{1}{4}[M(w - 2w_c) + M(w + 2w_c)]$$

After lowpass filter

$$y(t) = \frac{m(t)}{2}$$

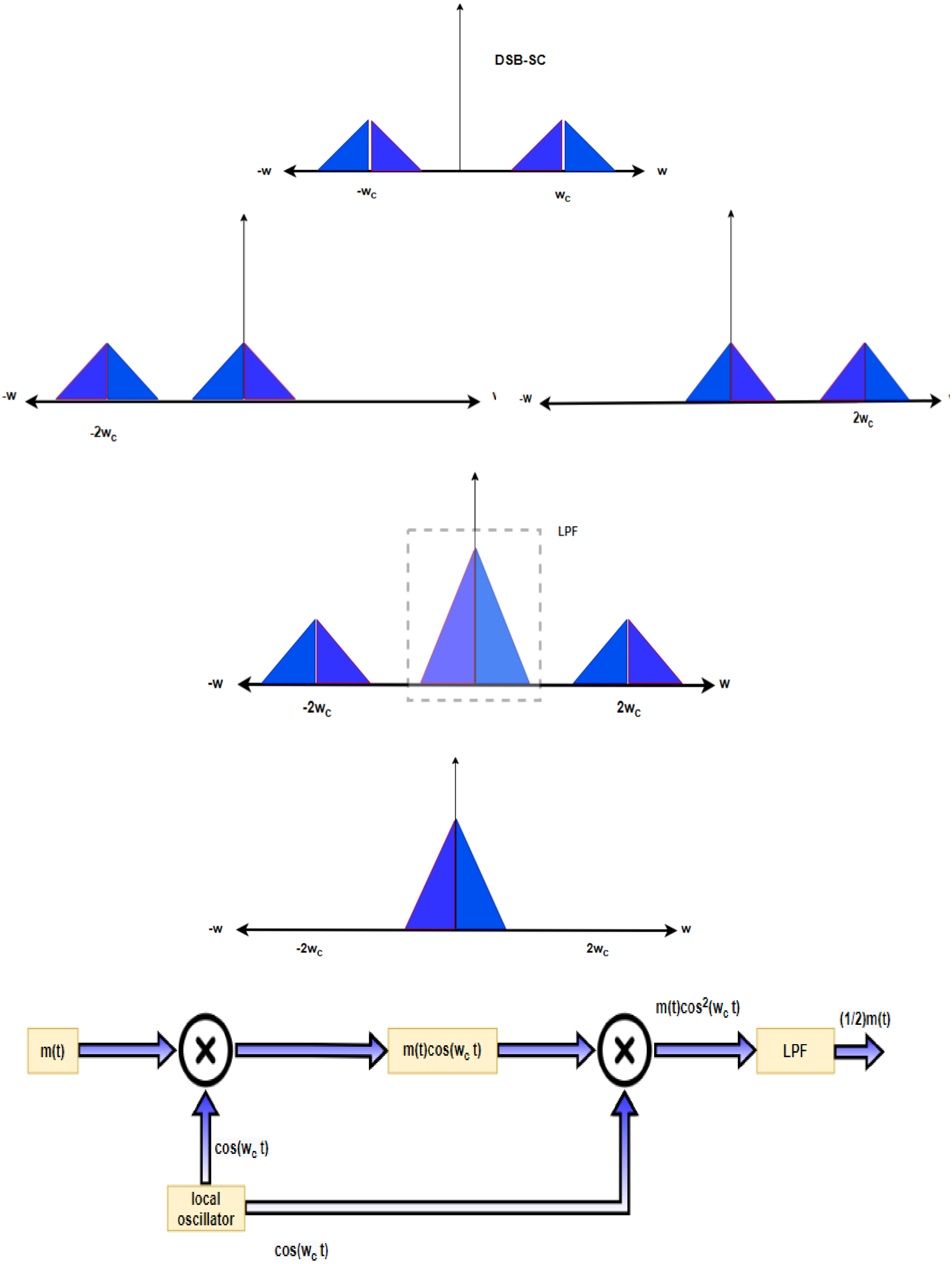


Fig:-Block Diagram Modulation and Demodulaton DSB-SC