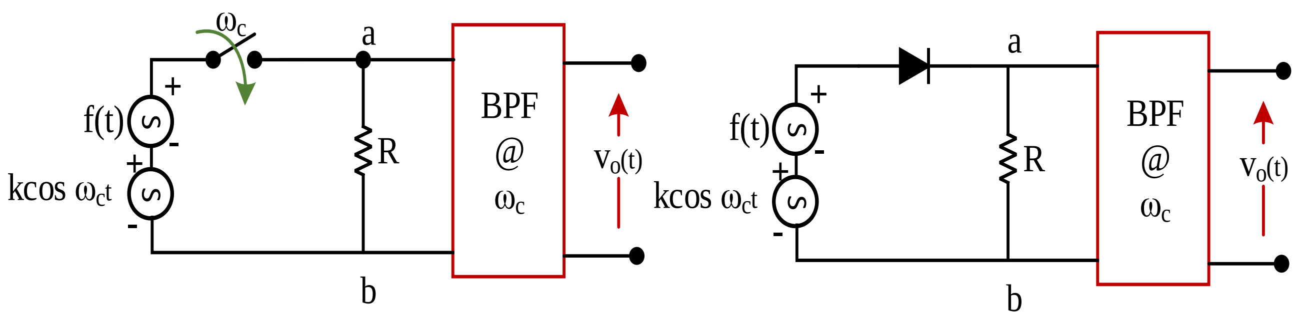
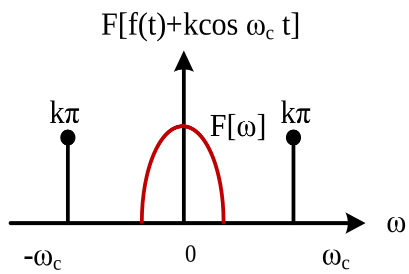
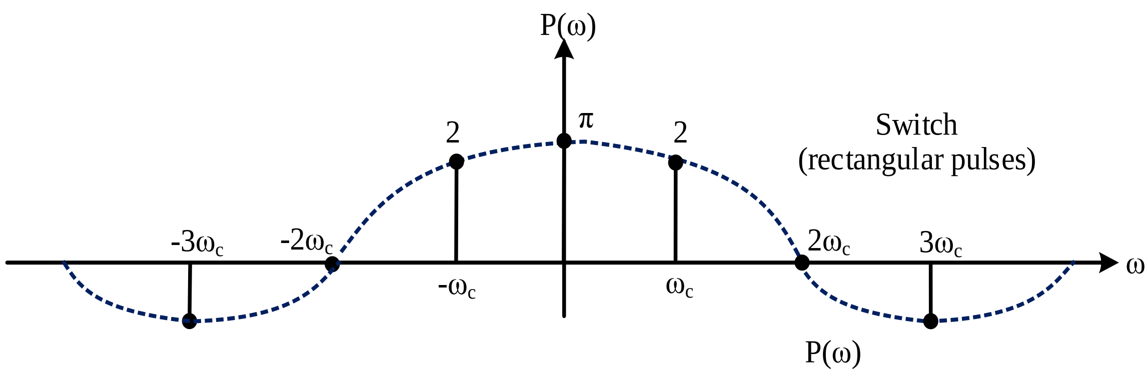
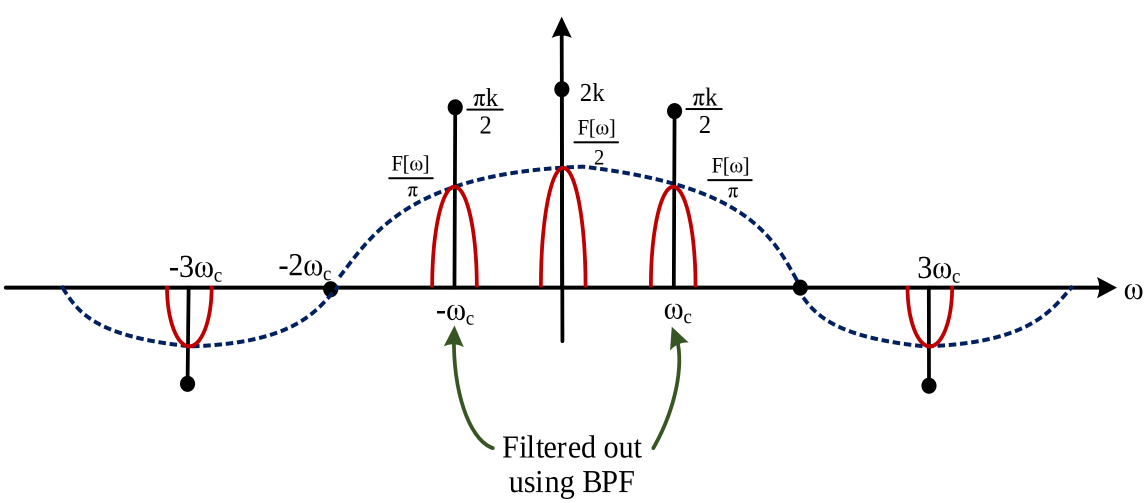
1- Switching (Chopper) modulator [rectifier modulator].









2- Using Nonlinear Devices:

In the previous figure, if the diode is not operated as an ideal switch, the nonlinearities in the diode characteristics may be given as:

$$i(t) = a_1 e(t) + a_2 e^2(t) + a_3 e^3(t) + \cdots$$

Therefore, from the figure:

$$v_{ab}(t) = a_1 R[f(t) + k\cos\omega_c t] + a_2 R[f(t) + k\cos\omega_c t]^2 + \cdots$$

$$= \boxed{a_1 Rk\cos\omega_c t + 2a_2 Rkf(t)\cos\omega_c t} + \boxed{other terms}$$

AM suppressed by BPF

$$V_o(t) = a_1 Rk\cos\omega_c t + 2a_2 Rkf(t)\cos\omega_c t$$

Ex 4-5:

A carrier signal with frequency of 1 MHz and peak-to-peak amplitude of $10\sqrt{2}v$ is added to a single tone message with frequency of 1 kHz and peak-to-peak amplitude of $4\sqrt{2}v$. Then passed through a diode having the following c/c$_S$:

$i(t) = e(t) + 0.5e^2(t)$, find:

1- Modulation depth of DSB signal.
2- Frequency of each component in the diode current.

Solution:

Carrier: $5\sqrt{2}\cos 2\pi \times 10^6 t\ volt$

S.T message: $2\sqrt{2}\cos 2\pi \times 10^3 t\ volt$

$e(t) = 5\sqrt{2}cos2\pi \times 10^6 t + 2\sqrt{2}cos2\pi \times 10^3 t$

$i(t) = e(t) + 0.5e^2(t)$

$= \left(5\sqrt{2}cos2\pi \times 10^6 t + 2\sqrt{2}cos2\pi \times 10^3 t\right) + 0.5\left(5\sqrt{2}cos2\pi \times 10^6 t + 2\sqrt{2}cos2\pi \times 10^3 t\right)^2$

$= 5\sqrt{2}cos2\pi * 10^6 t + 2\sqrt{2}cos2\pi * 10^3 t + 14.5 + 12.5cos4\pi * 10^6 t + 2cos4\pi * 10^3 t + 10\cos 2\pi(10^6 + 10^3)\, t + 10\cos 2\pi(10^6 + 10^3)\, t$

The frequencies in the diode current are

$1\ MHz, 1\ kHz, 0\ Hz, 2\ MHz, 2\ kHz, 1.001\ MHz\ and\ 0.999\ MHz.$

The AM signal is represented by the terms of frequencies, f_c, $f_c \pm f_m$ (other terms are suppressed by a BPF) i.e

$$\underbrace{5\sqrt{2}}_{A_c}cos\underbrace{2\pi * 10^6}_{\omega_c}t + \underbrace{20}_{A_mA_c}cos\ \underbrace{2\pi * 10^6}_{\omega_c}t\ 20cos\ \underbrace{2\pi * 10^3}_{\omega_m}t$$

$\therefore A_m = 2\sqrt{2}\ volt$ and $A_c = 5\sqrt{2}\ volt$

Therefore $D = \frac{2\sqrt{2}}{5\sqrt{2}} \times 100\% = 40\%$

Demodulation of AM/DSB-LC Signals:

1- Synchronous (coherent) detection:

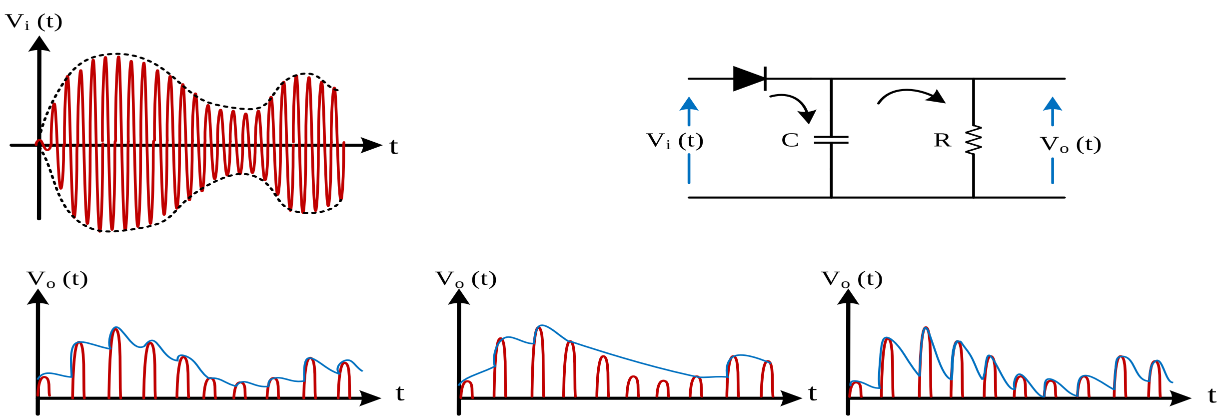
The same as in DSB/SC (i.e direct connection and pilot carrier) [High cost].

2- Asynchronous detection (Noncoherent detection)

It is also called envelope detection since it extracts the message from its envelope. It is low cost and applicable only when $m \leq 1$

Noncoherent detection:

a) Envelope detector:



Correct RC value RC too large RC too small

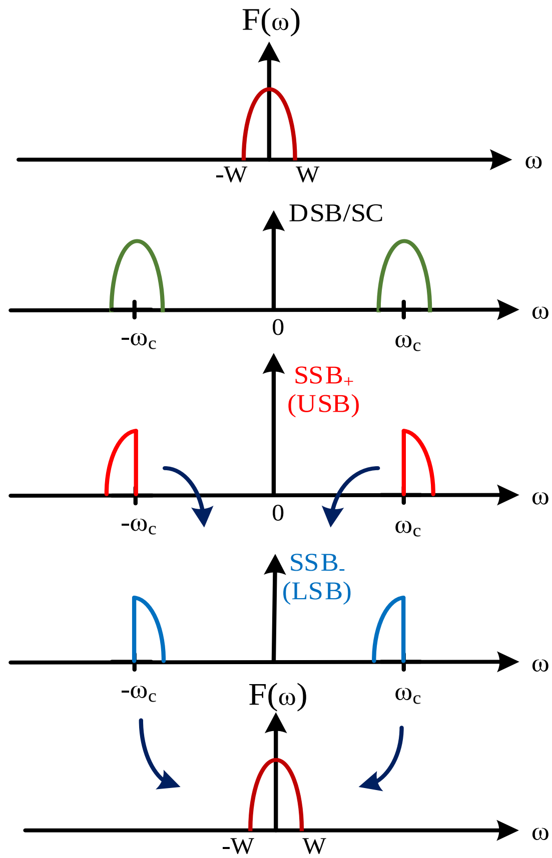
- It is a very simple, efficient, and cheap demodulator
- For correct detection: the charge time should be fast and discharge time [RC] should be slow.
- In P.H.S, C is charged while in N.H.S, C is discharged through R.
- Usually this circuit is followed by LPF to eliminate unwanted harmonic content.

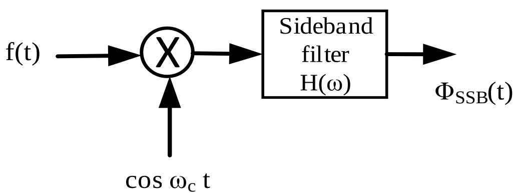
3-AM/SSB:

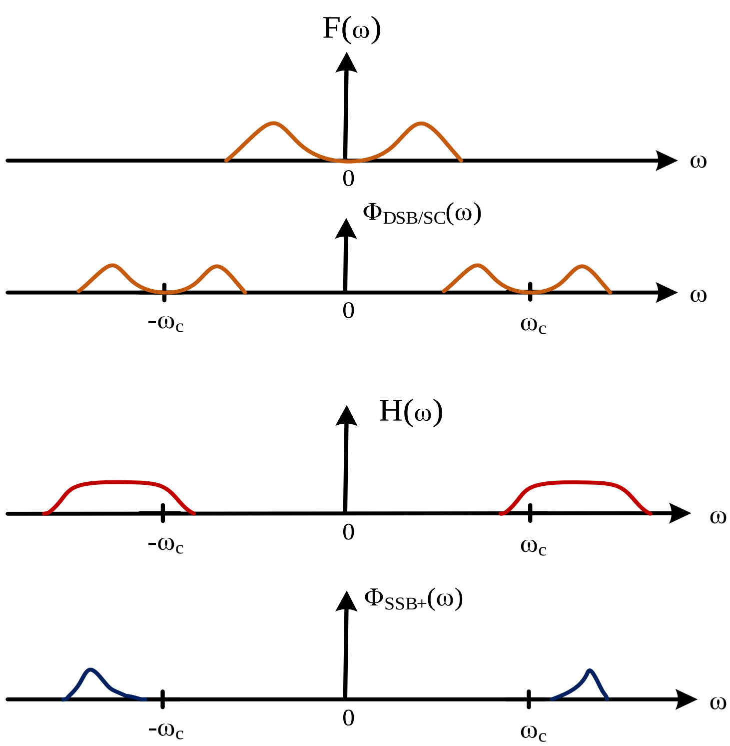
Since either LSB and USB in DSB modulation contains the complete information of the baseband signal. It is more efficient to transmit only one sideband [LSB (-ve) or USB (+ve)] to reduce the required signal bandwidth.

Generation of SSB Signals:

1- Modulation and filtering method:







The filter used should be as sharp as possible (for speech signal,
transmission bandwidth
$\approx$ 600Hz,
stop band attenuation
$\approx$ 40 dB

2- Phase Shift Method:

Using a complex valued carrier signal having one-side spectral density and when taking its real part would have two-sided spectral density

Let $f(t) = e^{j\omega_m t}$

$\therefore$ Upon modulation $f(t)e^{j\omega_c t} = e^{j\omega_m t}e^{j\omega_c t}$

$$Re\{e^{j\omega_m t}e^{j\omega_c t}\} = Re\{e^{j\omega_m t}\}Re\{e^{j\omega_c t}\} - Im\{e^{j\omega_m t}\}Im\{e^{j\omega_c t}\}$$

$$= cos\omega_m t cos\omega_c t - sin\omega_m t sin\omega_c t$$

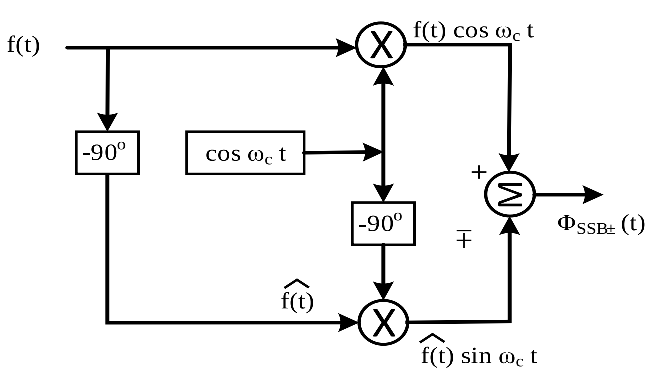
if $f(t) = e^{j\omega_m t} \Longrightarrow \emptyset_{SSB_+} = cos\omega_m t cos\omega_c t - sin\omega_m t sin\omega_c t$

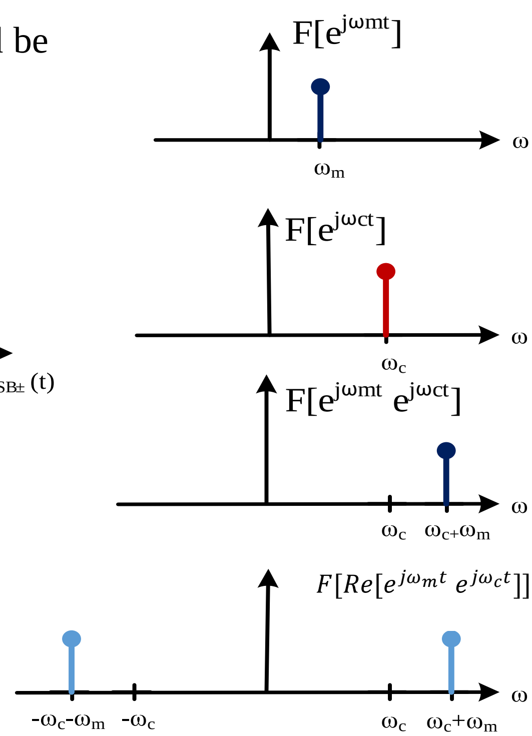
if $f(t) = e^{j\omega_m t} \Longrightarrow \emptyset_{SSB_-} = cos\omega_m t cos\omega_c t + sin\omega_m t sin\omega_c t$

in general:

$$\emptyset_{SSB_\mp} = f(t)cos\omega_c t \pm \widehat{f(t)}sin\omega_c t \quad \text{...(4-25)a}$$

The block diagram of the modulator would be





The major problem in this method is the realization of -90° phase shift for all frequency comonent

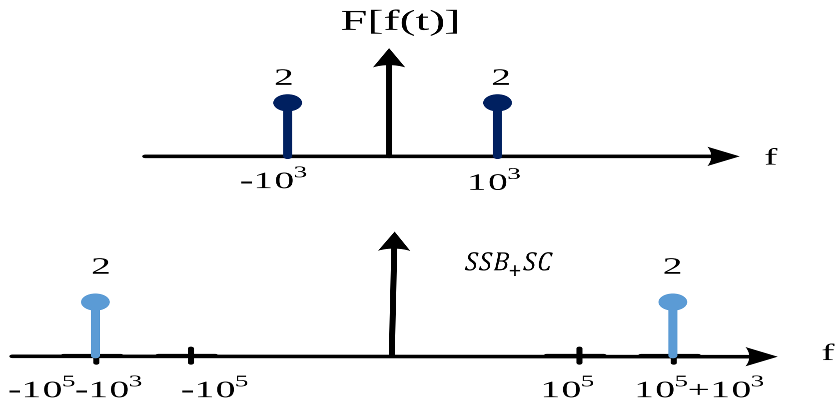
Ex 4-7:

A carrier signal given by $\cos(2\pi \times 10^5 t)\ volt$ is AM/SSB+SC modulated by the message signal given by $4\cos(2\pi \times 10^3 t)\ volt$:

1- Sketch the spectrum of modulated wave
2- Calculate the sideband power and transmission efficiency
3- Calculate the transmission bandwidth

Solution:

1)



2) $\emptyset_{SSB_+} = f(t)cos\omega_c t - f\widehat{(t)}sin\omega_c t$

$P_{SB} = \frac{\overline{f^2(t)}}{2} + \frac{\overline{f^2\widehat{(t)}}}{2}$, since $\overline{f^2\widehat{(t)}} = \overline{f^2(t)}$

$$\therefore P_{SB} = \overline{f^2(t)}$$

For $f(t) = 4\cos 2\pi * 10^3\ t \Longrightarrow P_{SB} = \frac{4^2}{2} = 8\ volt = 8\ watt\ (for\ R = 1\Omega)$

$P_c = 0$ Since suppressed carrier modulation

$\therefore P_T = P_{SSB}$ and $\eta = 100\%$

3) $BW_{tr} = BW_{infor.} = 1\ kHz = f_m$