Chapter 4

Amplitude Modulation

Modulation:

A process by which a property of a signal is varied in proportion to a second signal.

Types of Modulation:

1- Continuous Wave (CW) Modulation:

In which a sinusoidal signal is changed in amplitude, frequency or phase in proportion to a message signal, such as AM, FM and PM.

2- Pulse Modulation:

In which a periodic train pulses is changed in amplitude, position or width in proportion to a message signal. Such as PAM, PPM, PWM, PCM and DM.

Reasons of Modulation:

1- Modulation for frequency location assignment.
2- Modulation for bandwidth alteration.
3- Modulation to increase efficiency of radiation.
4- Modulation to reduce noise and interference.
5- Modulation to overcome equipment limitation.

Amplitude Modulation:

The general sinusoidal signal can be written as:

$$\Phi(t) = a(t)cos[\omega_c t + \gamma(t)]$$

Amplitude Frequency Phase

Angle

In amplitude modulation (AM), $a(t)$ is changed in proportion to the message signal. Frequency is constant, phase $(t) = 0$.

Types of AM:

1- Double-Sideband, suppressed Carrier (AM/DSB-SC).
2- Double-Sideband, Large Carrier (AM/DSB-LC) [AM].
3- Single-sideband, suppressed carrier (AM/SSB-SC) [SSB].
4- Vestigial –sideband (AM/VSB).

1- AM/DSB-SC

The AM/DSB-SC signal, assuming proportionality constant =1, is given by:

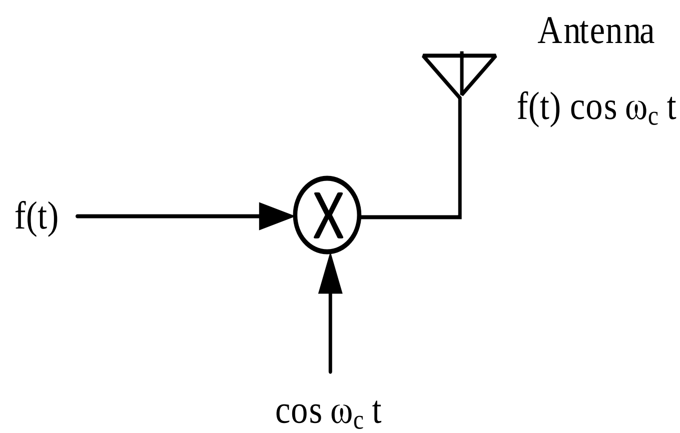
$$\Phi(t)_{DSB/SC} = f(t)cos\omega_c t \quad \text{… (4-1)}$$

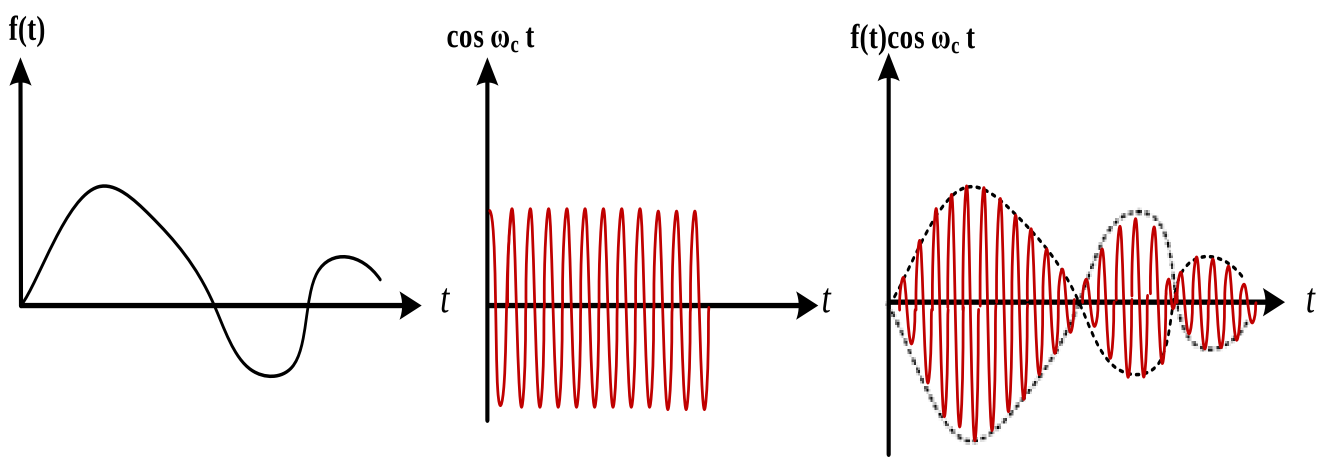
Modulated Signal Modulating Signal Carrier Signal

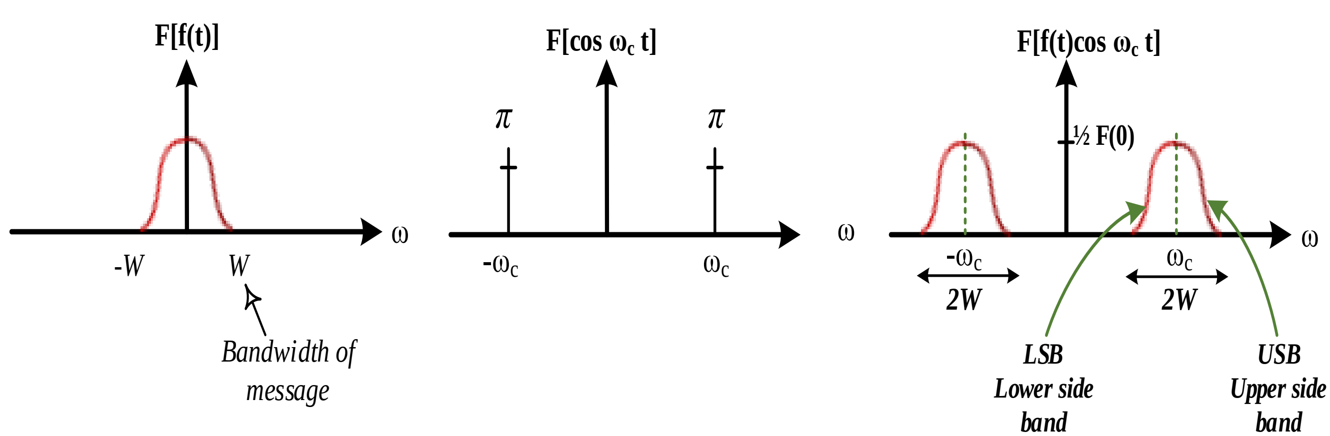
and the spectrum is:

$$\Phi(\omega)_{DSB/SC} = \pi F(\omega - \omega_c) + \pi F(\omega + \omega_c) \quad \text{…(4-2)}$$

DSB-SC Transmitter







Notes:

1- No carrier term is presents (carrier is suppressed)

2- $\text{BW}_{DSB/SC} = 2W$ rad/sec ...(4-3)

Where W is the bandwidth of message (modulating signal) i.e. the bandwidth is doubled.

3- Above process (multiplication) is called "Frequency conversion" or "frequency mixing" or Heterodyning.

DSB-SC Receiver

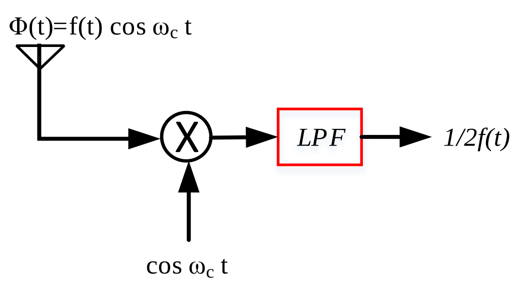
To detect (demodulate) the DSB-SC signal, we multiply it again by $\cos\omega_c t$ as follows:

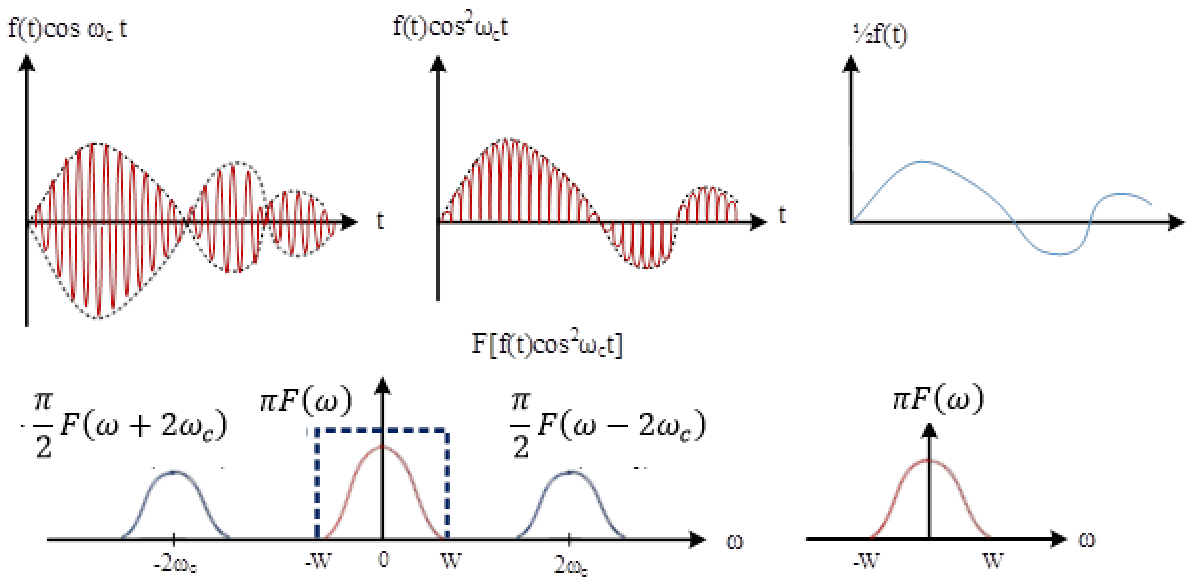
$$\Phi(t)cos\omega_c t = f(t)cos^2\omega_c t$$

$$= \frac{1}{2}f(t) + \frac{1}{2}f(t)cos2\omega_c t$$

$$F[\Phi(t)cos\omega_c t] = \pi F(\omega) + \frac{\pi}{2}F(\omega - 2\omega_c) + \frac{\pi}{2}F(\omega + 2\omega_c)$$

Then using LPF of bandwidth W **rad/sec** we obtain the original signal.





Notes:

1- For LPF will reject the frequency component at $\pm 2\omega_c$.

2- For correct detection it must that:

a) $\omega_c \gg W$

b) Both the local oscillator (cos ω_ct generators) in Tx and Rx are **synchronized.** (Synchronous detection and coherent detection).

Generation of DSB-SC:

1- Using Switching Modulator:

f(t) is multiplied by a periodic signal given by:

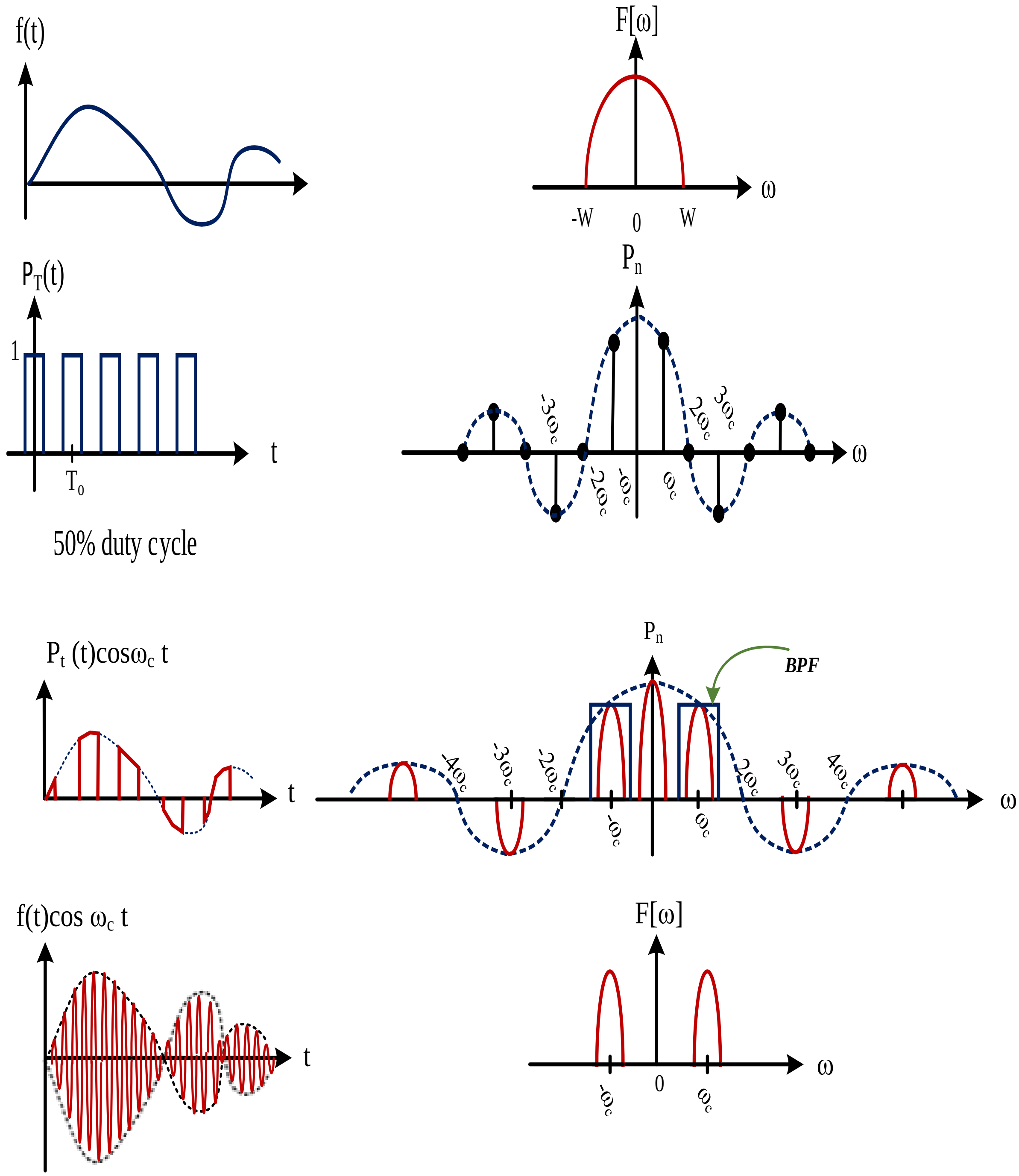
$$P_T = \sum_{n=-\infty}^{\infty} P_n e^{jn\omega_o t} \omega_o = \frac{2\pi}{T_o}$$

Letting $\omega_o = \omega_c$ [speed of switching] the result would be

$$f(t)P_T(t) = \sum_{n=-\infty}^{\infty} f(t) P_n e^{jn\omega_c t}$$

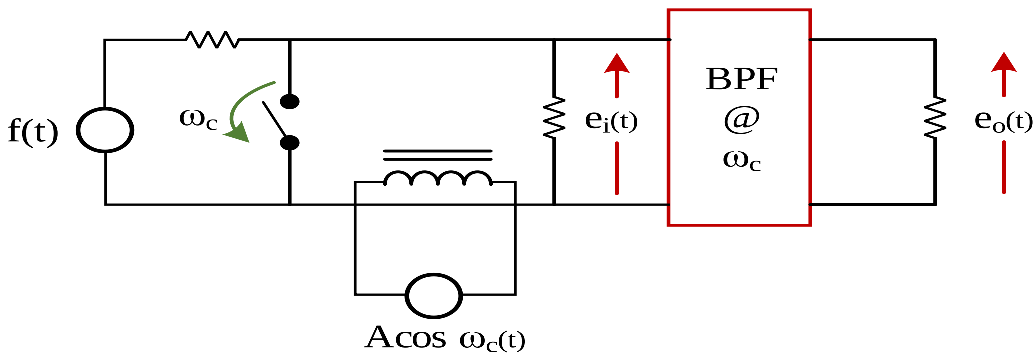
$$F[f(t)P_T(t)] = \sum_{n=-\infty}^{\infty} P_n F(\omega - n\omega_c)$$

The desired result at n=1

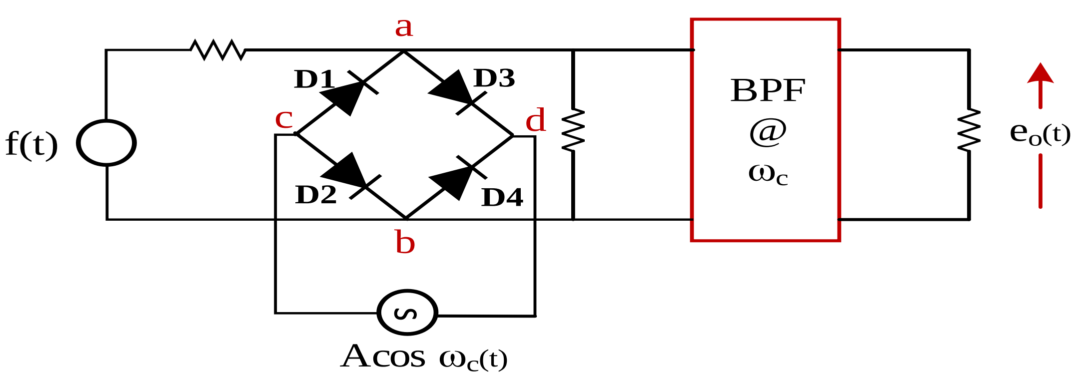


Modulator Implementation:

a) Using Electromechanical Switch:



b) Using Diodes and Switches:



2- Using Nonlinear Devices:

A non-liner device such as diode could be used as a balanced modulator. The nonlinearity between voltage and current approximately is given by:

$$i(t) = a_1 e(t) + a_2 e^2(t) + a_3 e^3(t) + \cdots \qquad \ldots(4\text{-}4)$$