Modulation

Modulation is a process that causes a shift in the range of frequencies in a signal.

- Signals that occupy the same range of frequencies can be separated
- Modulation helps in noise immunity, attentuation - depends on the physical medium

Figure 1 shows the different kinds of analog modulation schemes that are available

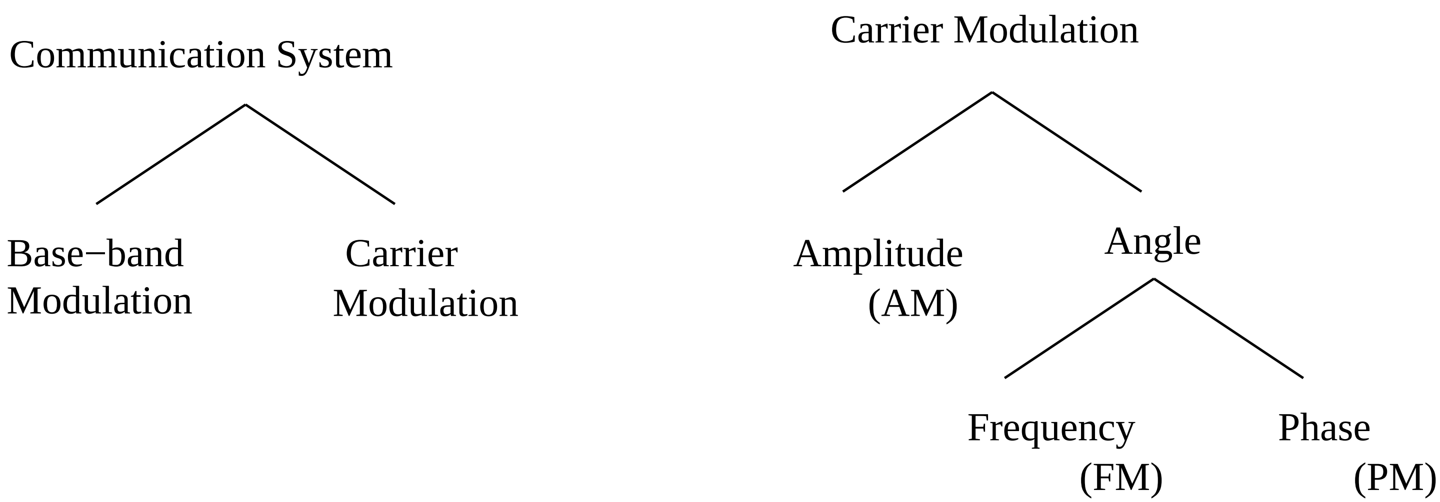

Figure 1: A broad view of communication system

- Amplitude Modulation It is the process where, the amplitude of the carrier is varied proportional to that of the message signal.
  - Amplitude Modulation with carrier
    Let $m(t)$ be the base-band signal, $m(t) \longleftrightarrow M(\omega)$ and $c(t)$ be the carrier, $c(t) = A_c \cos(\omega_c t)$. f_c is chosen such that $f_c >> W$, where W is the maximum frequency component

of $m(t)$.

The amplitude modulated signal is given by

$$s(t) = A_c \left[1 + k_a m(t)\right] \cos(\omega_c t)$$

$$\begin{aligned} S(\omega) &= \pi \frac{A_c}{2} \left(\delta(\omega - \omega_c) + \delta(\omega + \omega_c)\right) + \\ & \frac{k_a A_c}{2} \left(M(\omega - \omega_c) + M(\omega + \omega_c)\right) \end{aligned}$$

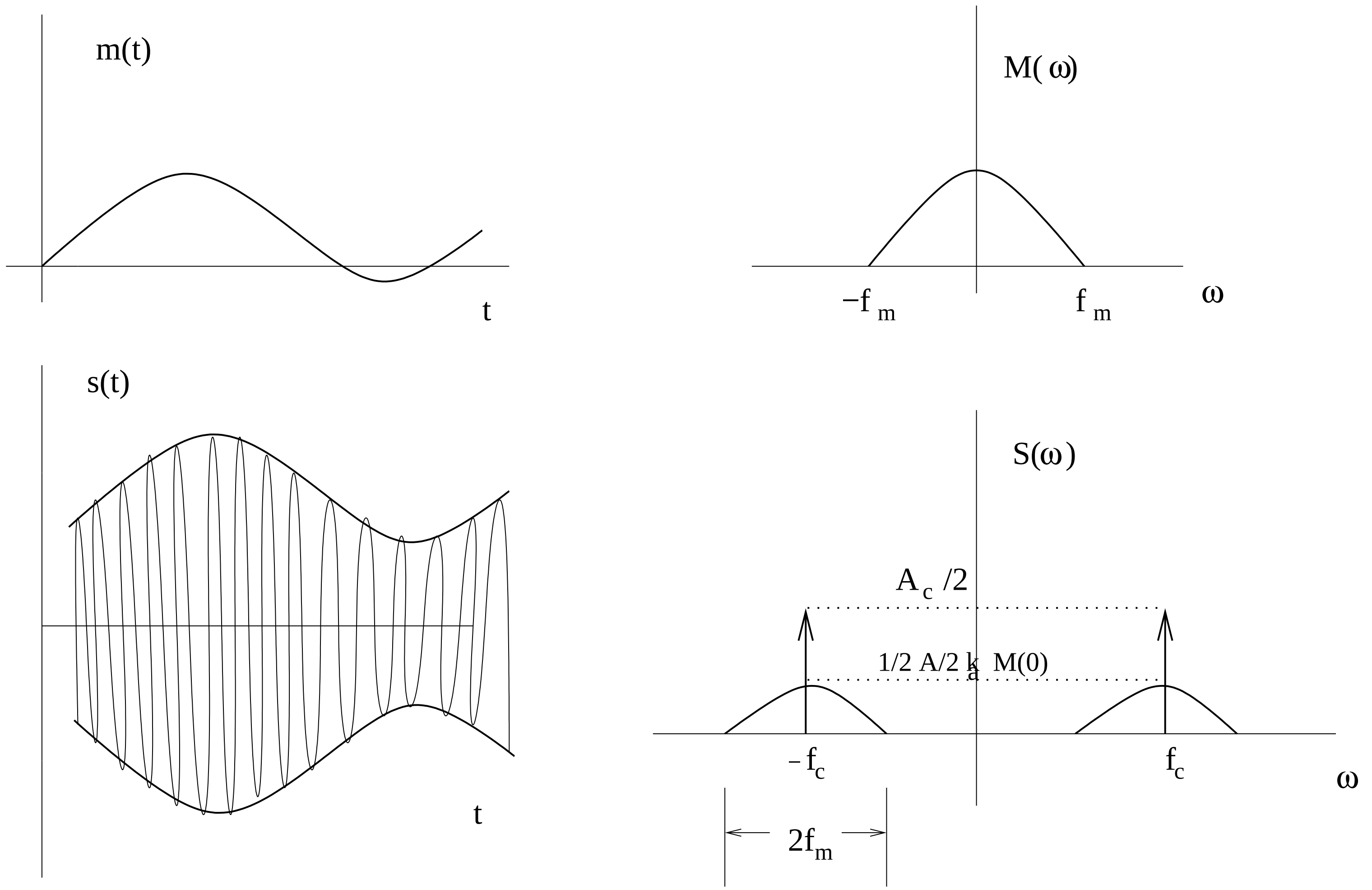

Figure 2: Amplitude modulation

Figure 2 shows the spectrum of the Amplitude Modulated signal.

– k_a is a constant called *amplitude sensitivity*. $k_a m(t) < 1$ and it indicates percentage modulation.

– Modulation in AM: A product modulator is used for generating the modulated signal as shown in Figure 3.

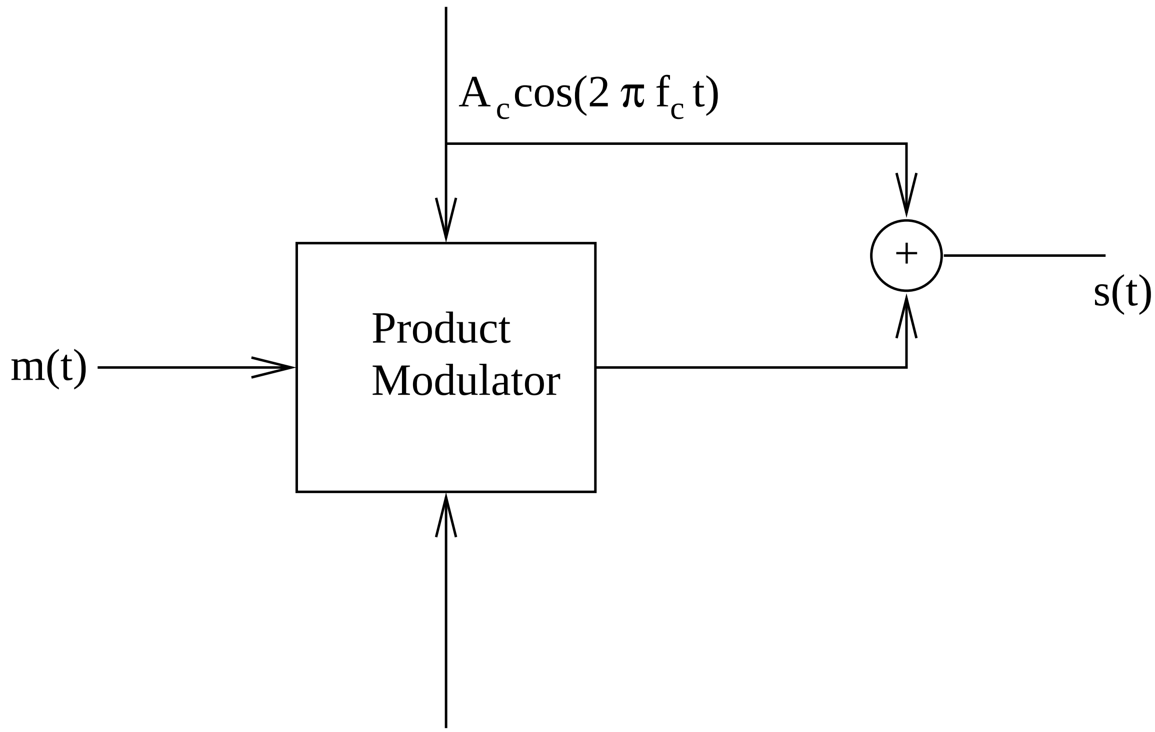

Figure 3: Modulation using product modulator

– Demodulation in AM: An envelope detector is used to get the demodulated signal (see Figure 4).

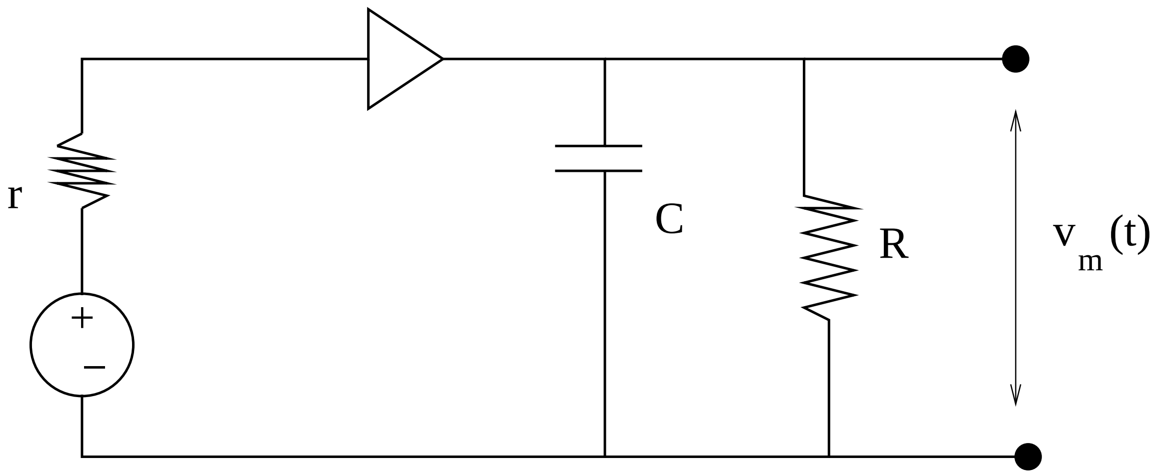

Figure 4: Demodulation using Envelope detector

– The voltage $v_m(t)$ across the resistor R gives the message signal $m(t)$

Double Side Band - Suppressed Carrier (DSB-SC) Modulation

- In AM modulation, transmission of carrier consumes lot of power. Since, only the side bands contain the information about the message, carrier is suppressed. This results in a DSB-SC wave.

- A DSB-SC wave $s(t)$ is given by

$$\begin{aligned} s(t) &= m(t) A_c \cos(\omega_c t) \\ S(\omega) &= \pi \frac{A_c}{2} \left(M(\omega - \omega_c) + M(\omega + \omega_c) \right) \end{aligned}$$

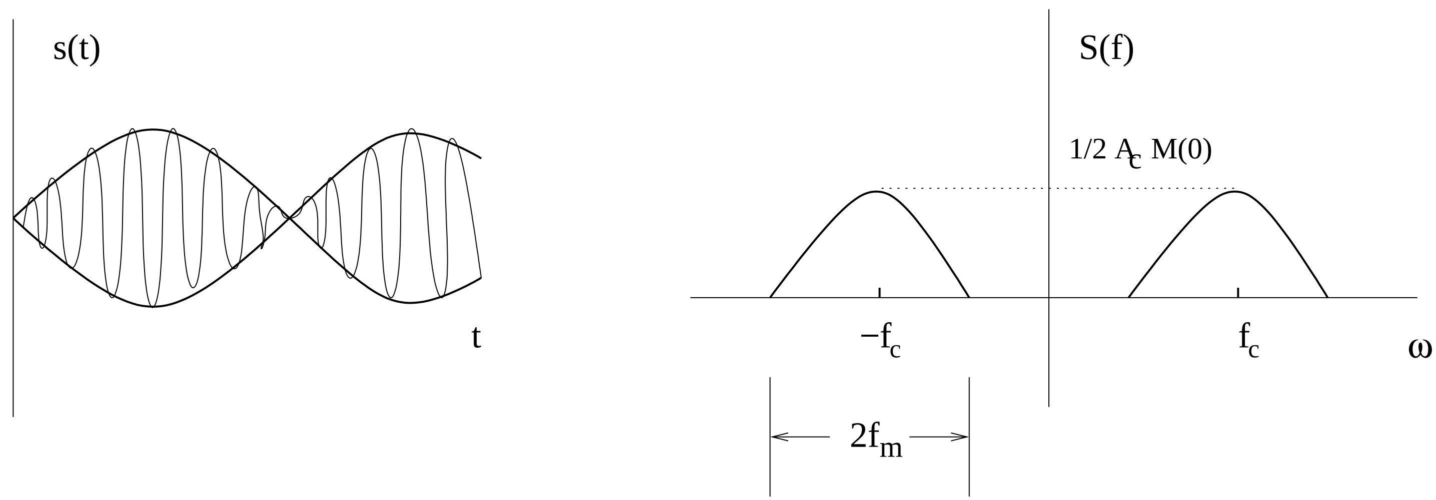

Figure 5: DSB-SC modulation

- Modulation in DSB-SC: Here also product modulator is used as shown in Figure 3, but the carrier is not added. Figure 6 shows the spectrum of the DSB-SC signal.

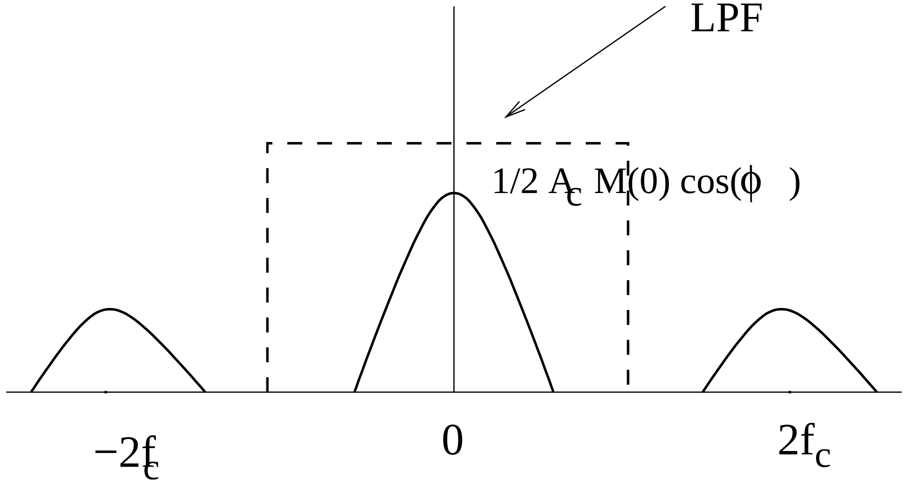

Figure 6: Spectrum of Demodulated DSB-SC signal

- Demodulation in DSB-SC: A coherent demodulator is used. The local oscillator present in the demodulator generates a carrier which has same frequency and phase(i.e. $\phi = 0$ in Figure 7) [a] as that of the carrier in the modulated signal (see Figure 7)

[a] Clearly the design of the demodulator for DSB-SC is more complex than that vanilla AM

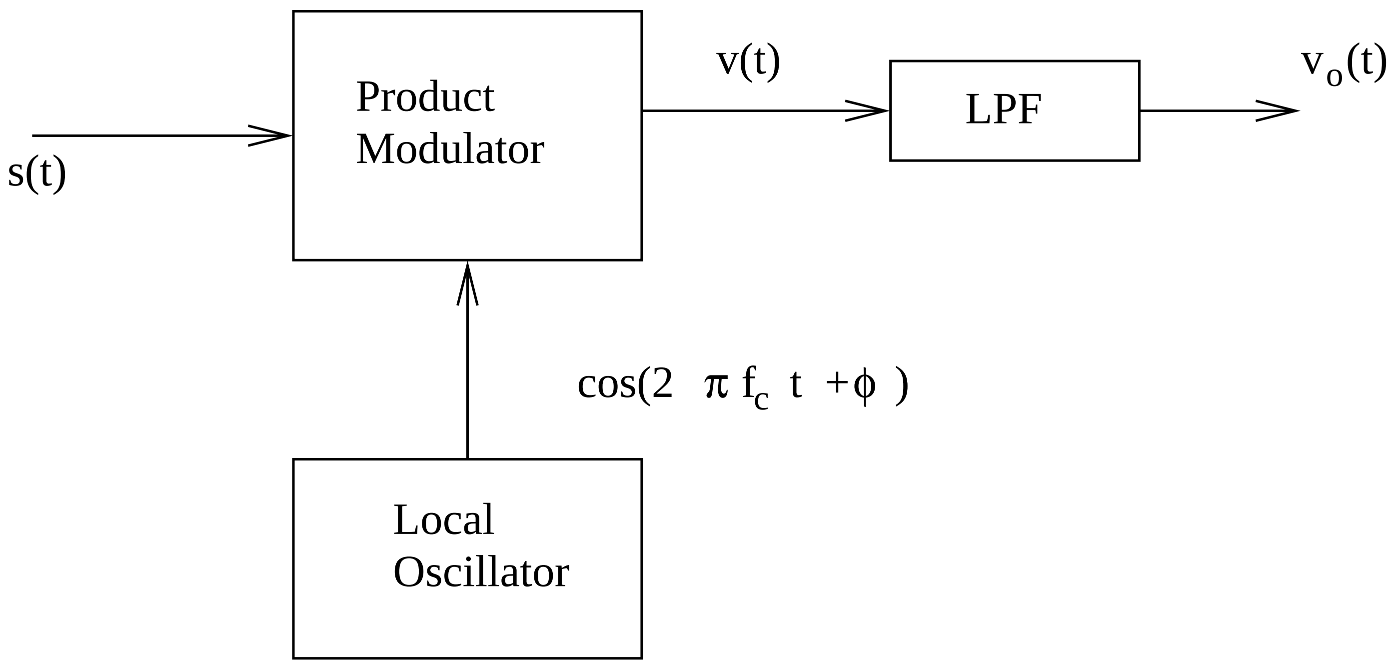

Figure 7: Coherent detector

$$
\begin{aligned}
v(t) &= s(t).\cos(\omega_c t + \phi) \\
&= m(t)A_c \cos(\omega_c t)\cos(\omega_c t + \phi) \\
&= \frac{m(t)}{2} A_c \left[\cos(2\omega_c t + \phi) + \cos(\phi)\right]
\end{aligned}
$$

- If, the demodulator (Figure 7) has constant phase, the original signal is reconstructed by passing $v(t)$ through an LPF.