# Amplitude Modulation

AM generation involves mixing of a carrier and an information signal. In low level modulation, the message signal and carrier signal are modulated at low power levels and then amplified. The advantage of this technique is that a small audio amplifier is sufficient to amplify the message signal.

The basic theory and equations behind amplitude modulation are relatively straightforward and can be handled using straightforward trigonometric calculations and manipulation. Essentially an amplitude modulated wave consists of a radio frequency carrier - a sine wave at one frequency, typically in the radio frequency portion of the spectrum. A modulating wave, which in theory could be another sine wave, typically at a lower audio frequency is superimposed upon the carrier. The two signals are multiplied together and the theory shows how they interact to create the carrier and two sidebands. The equations for the simple example of a single tone used for modulation can be expanded to show how the signal will appear of a typical sound consisting of many frequencies is used to modulated the carrier.

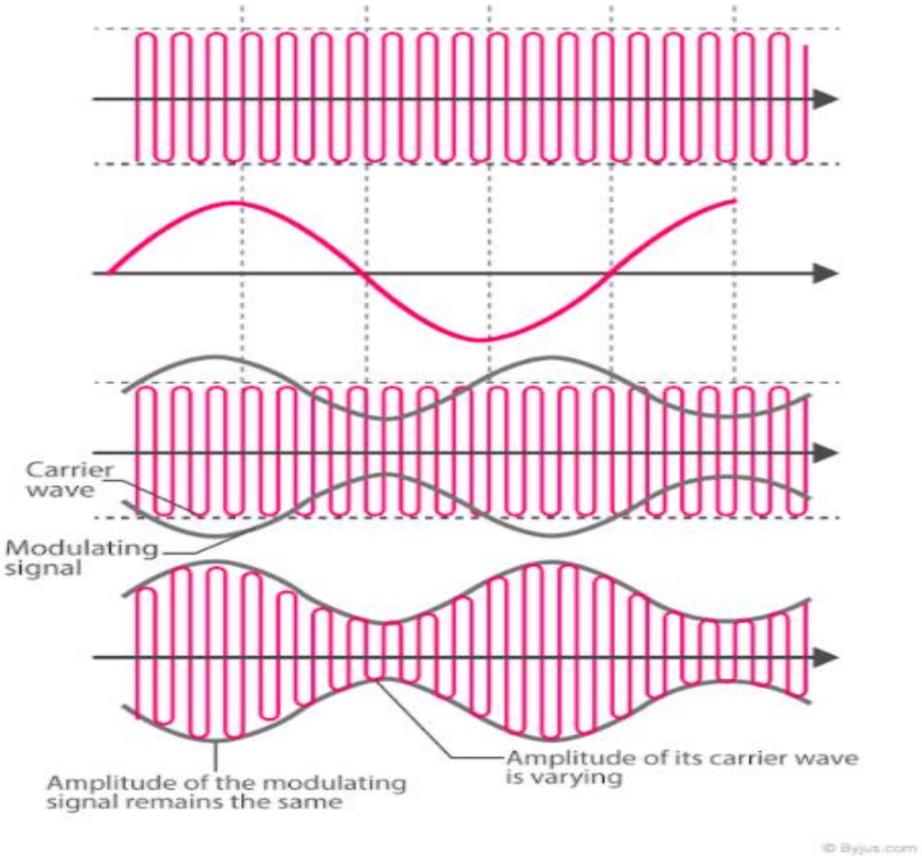



Figure: Double side band with large carrier (Normal AM)

# Types of Amplitude Modulation (AM)

1- **Double Sideband with Large Carrier (we will call it AM) (DSB-LC):** This is the most widely used type of AM modulation. In fact, all radio channels in the AM band use this type of modulation.
2- **Double Sideband Suppressed Carrier (DSB-SC**): This is the same as the AM modulation above but without the carrier.
3- **Single Sideband (SSB):** In this modulation, only half of the signal of the DSB-SC is used.
4- **Vestigial Sideband (VSB):** This is a modification of the SSB to ease the generation and reception of the signal.

# Double Sideband with Large Carrier (DSB-LC)
# (Normal AM)

Consider a sinusoidal carrier wave $\boldsymbol{c(t)}$ defined by

$$\boldsymbol{c(t) = A_c \cos(2\pi f_c t + \theta)}$$

where $\boldsymbol{A_c}$ is the carrier amplitude and $\boldsymbol{f_c}$ is the carrier frequency. The information-bearing signal or message signal is denoted by $\boldsymbol{m(t)}$; the terms “information-bearing signal” and “message signal” are used interchangeably throughout the presentation. To simplify the exposition without affecting the results obtained and conclusions reached, we have assumed that the phase $\boldsymbol{\theta}$ of the carrier wave is **zero**. Amplitude modulation (AM) is formally defined as a process in which the amplitude of the carrier wave $\boldsymbol{c(t)}$ is varied about a mean value, linearly with the message signal $\boldsymbol{m(t)}$. An amplitude-modulated (AM) wave may thus be described as a function of time as follows:

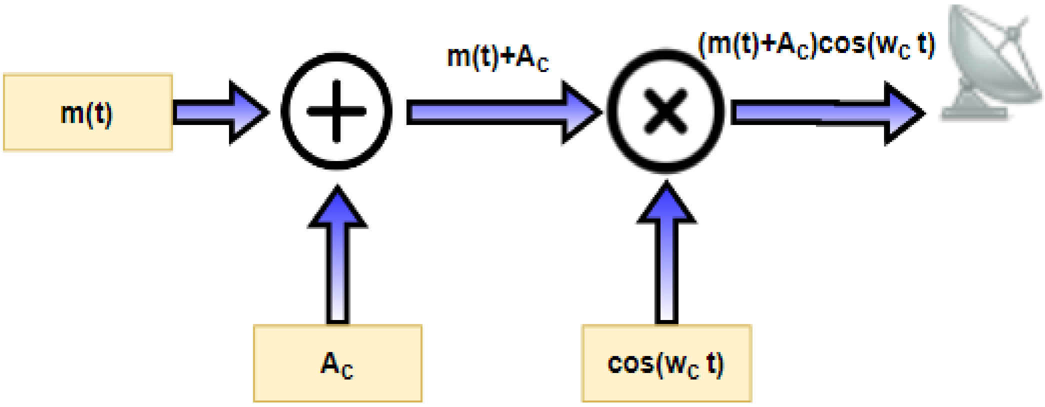



Figure: Block diagram Double Sideband with Large Carrier (DSB-LC)

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

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

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

**Assume have tone modulating signal $m(t) = A_m\cos(w_m\, t)$**

$$x(t) = (A_c + A_m\cos(w_m\, t))\cos(w_c\, t)$$

$$x(t) = A_c\left(1 + \frac{A_m}{A_c}\cos(w_m\, t)\right)\cos(w_c\, t)$$

$$\boldsymbol{k = \frac{A_m}{A_c}}$$

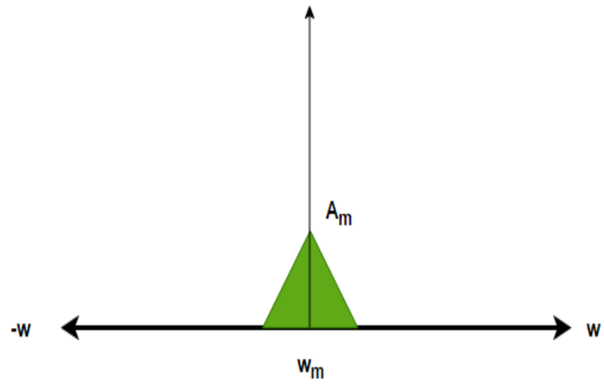
$$\boldsymbol{k = modulation\ index}$$

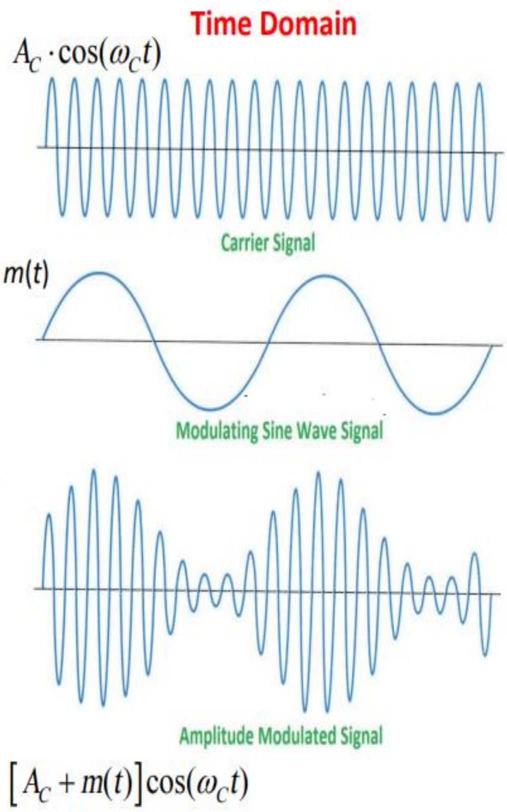
$$x(t) = A_c(1 + k\cos(w_m\, t))\cos(w_c\, t)$$

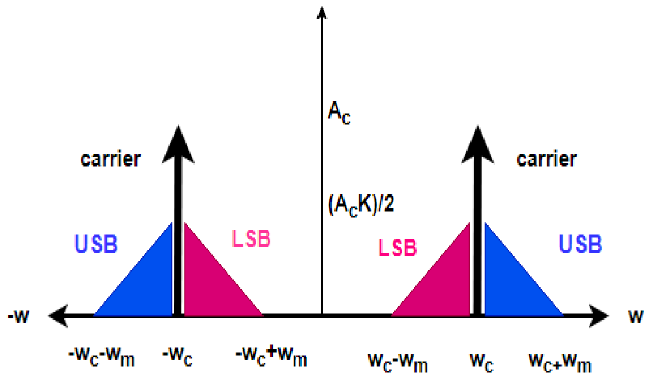
$$x(t) = A_c\cos(w_c\, t) + A_c k\cos(w_m\, t)\cos(w_c\, t)$$

$$\boldsymbol{x(t) = A_c\cos(w_c\, t) + \frac{A_c k}{2}\cos((w_c - w_m)\, t) + \frac{A_c k}{2}\cos((w_c + w_m)\, t)}$$

$$X(w) = A_c\pi[\delta(w - w_c) + \delta(w + w_c)] + \frac{A_c k\pi}{2}[\delta(w - (w_c - w_m)) + \delta(w + (w_c - w_m)) + \delta(w - (w_c + w_m)) + \delta(w + (w_c + w_m))]$$




## AM Modulation Index Basics – Definition $(k)$

can be defined as the ratio of the peak $\boldsymbol{k}$ The amplitude modulation $\boldsymbol{A_m}$ modulation index value of the message signal to the amplitude $\boldsymbol{A_c}$ of the carrier signal. When expressed as a percentage it is the same as the depth of modulation. In other words it can be expressed as:

$$\boldsymbol{modulatin\ index\ (k) = \frac{A_m}{A_c}}$$

$$\boldsymbol{V_{max} = A_c + A_m}$$

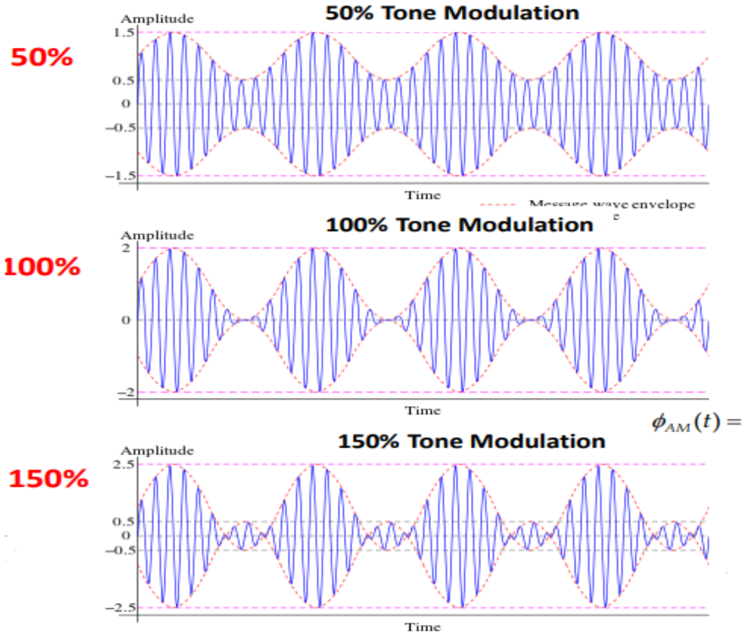
$$\boldsymbol{V_{min} = A_c - A_m}$$

$$\boldsymbol{k = \frac{\frac{V_{max} - V_{min}}{2}}{\frac{V_{max} + V_{min}}{2}} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}}$$

$\boldsymbol{A_c}$ is the carrier signal amplitude.

$\boldsymbol{A_m}$ is the peak modulation amplitude.

❖ To avoiding loss the signal at the receiver the modulation index must be $(\mathbf{0} < \boldsymbol{k} \le \mathbf{1})$ **why??(H.W)**




## Power of Amplitude Modulation

$$P_t = \lim_{T\to\infty} \frac{1}{T}\int_{-T}^{T} x(t)^2$$

$$\boldsymbol{Power\ total(P_t) = \frac{{A_c}^2}{2} + \frac{{A_c}^2 k^2}{8} + \frac{{A_c}^2 k^2}{8}}$$

$$\boldsymbol{Power\ carrier(P_c) = \frac{{A_c}^2}{2}}$$

$$\boldsymbol{P_t = P_c + \frac{k^2}{4}P_c + \frac{k^2}{4}P_c}$$

$$\boldsymbol{P_t = P_c(1 + \frac{k^2}{2})}$$

$$\boldsymbol{Power\ lower\ sideband(P_{LSB}) = \frac{{A_c}^2 k^2}{8}}$$

$$\boldsymbol{Power\ lower\ sideband(P_{USB}) = \frac{{A_c}^2 k^2}{8}}$$

$$\textbf{Power sidebands } \boldsymbol{(P_s) = P_{LSB} + P_{USB} = \frac{{A_c}^2 k^2}{8} + \frac{{A_c}^2 k^2}{8} = \frac{{A_c}^2 k^2}{4} = \frac{k^2}{2}P_c}$$

$$\boldsymbol{P_t = P_c + P_s}$$

$$\boldsymbol{Power\ efficiency(\eta) = \frac{\textbf{Power sidebands(usaful power)}}{Power\ total} = \frac{\frac{k^2}{2}P_c}{P_c\left(1 + \frac{k^2}{2}\right)} = \frac{k^2}{2 + k^2}}$$

$$\boldsymbol{Bandwidth(B.W) = 2f_m}$$