UNIT1, MODULE3: Amplitude Modulation, Modulation Index and Frequency spectrum.

INTRODUCTION:

Amplitude modulation or AM as it is often called, is a form of modulation used for radio transmissions for broadcasting and two way radio communication applications.

Although one of the earliest used forms of modulation it is still used today, mainly for long, medium and short wave broadcasting and for some aeronautical point to point communications.

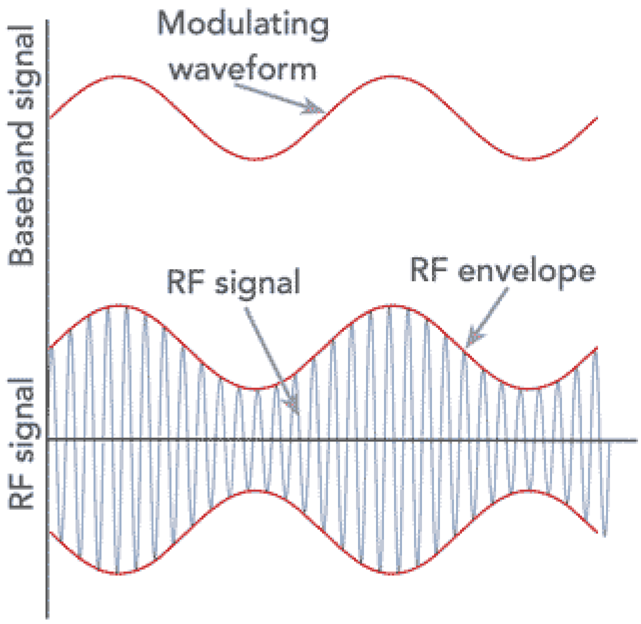
One of the key reasons for the use of amplitude modulation was its ease of use. The system simply required the carrier amplitude to be modulated, but more usefully the detector required in the receiver could be a simple diode based circuit. This meant that AM radios did not need complicated demodulators and costs were reduced - a key requirement for widespread use of radio technology, especially in the early days of radio when ICs were not available.

What is amplitude modulation?

In order that a radio signal can carry audio or other information for broadcasting or for two way radio communication, it must be modulated or changed in some way. Although there are a number of ways in which a radio signal may be modulated, one of the easiest is to change its amplitude in line with variations of the sound.

In this way the amplitude of the radio frequency signal varies in line with the instantaneous value of the intensity of the modulation. This means that the radio frequency signal has a representation of the sound wave superimposed in it.

In view of the way the basic signal "carries" the sound or modulation, the radio frequency signal is often termed the "carrier".



Amplitude Modulation, AM

Advantages

It is simple to implement

it can be demodulated using a circuit consisting of very few components

AM receivers are very cheap as no specialised components are needed.

Disadvantages

It is not efficient in terms of its power usage

It is not efficient in terms of its use of bandwidth, requiring a bandwidth equal to twice that of the highest audio frequency

It is prone to high levels of noise because most noise is amplitude based and obviously AM detectors are sensitive to it.

Although in the current technological climate, AM in its basic form is not nearly as effective as other modes that can be used, it is still retained in many areas like broadcasting, because of the number of users. However, it is likely that with time, its use will decrease still further and ultimately many AM transmissions will cease. However, its derivatives like quadrature amplitude modulation are widely used as they offer a very effective form of modulation, especially for data transmission.

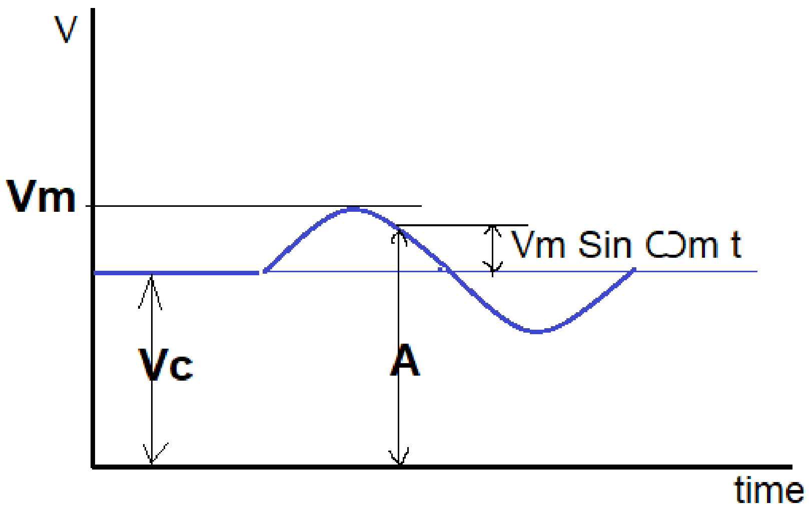
Mathematical representation of Amplitude Modulation

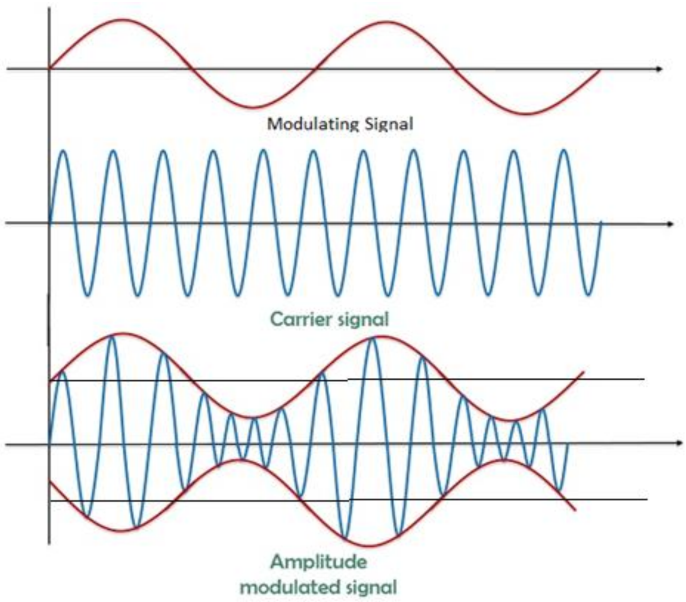
Let the modulating signal be: $v_m = Vm \sin \omega m\ t$

And the carrier signal be: $v_c = Vc \sin \omega c\ t$

Vm and Vc are the amplitude of the modulating signal and the carrier signal respectively.

ωm and ωc are the angular frequency of the modulating signal and the carrier signal respectively.





The amplitude 'A' of the AM wave can be written as

$A = V_c + v_m$

$= V_c + V_m \sin \omega_m t$

$= V_c + mV_c \sin \omega_m t$

$= V_c (1 + m\sin \omega_m t)$

The instantaneous voltage of the resulting amplitude modulated wave is therefore

$v = A \sin \theta$

$= A \sin \omega_c t$

$= V_c (1 + m\sin \omega_m t) \sin \omega_c t$

$= V_c \sin \omega_c t + m V_c \sin \omega_m t \sin \omega_c t$

Thus, the equation of Amplitude Modulated wave will be

$$= V_c \sin \omega_c t + \frac{mV_c}{2} \cos(\omega_c - \omega_m) t - \frac{mV_c}{2} \cos(\omega_c + \omega_m) t$$

Modulation Index of AM wave

A carrier wave, after being modulated, if the modulated level is calculated, then such an attempt is called as Modulation Index or Modulation Depth. It states the level of modulation that a carrier wave undergoes.

Let the carrier signal and the modulating signal be represented by

$v_c = V_c \sin \omega_c t$

$v_m = V_m \sin \omega_m t$

Vm and Vc are the amplitude of the modulating signal and the carrier signal respectively.

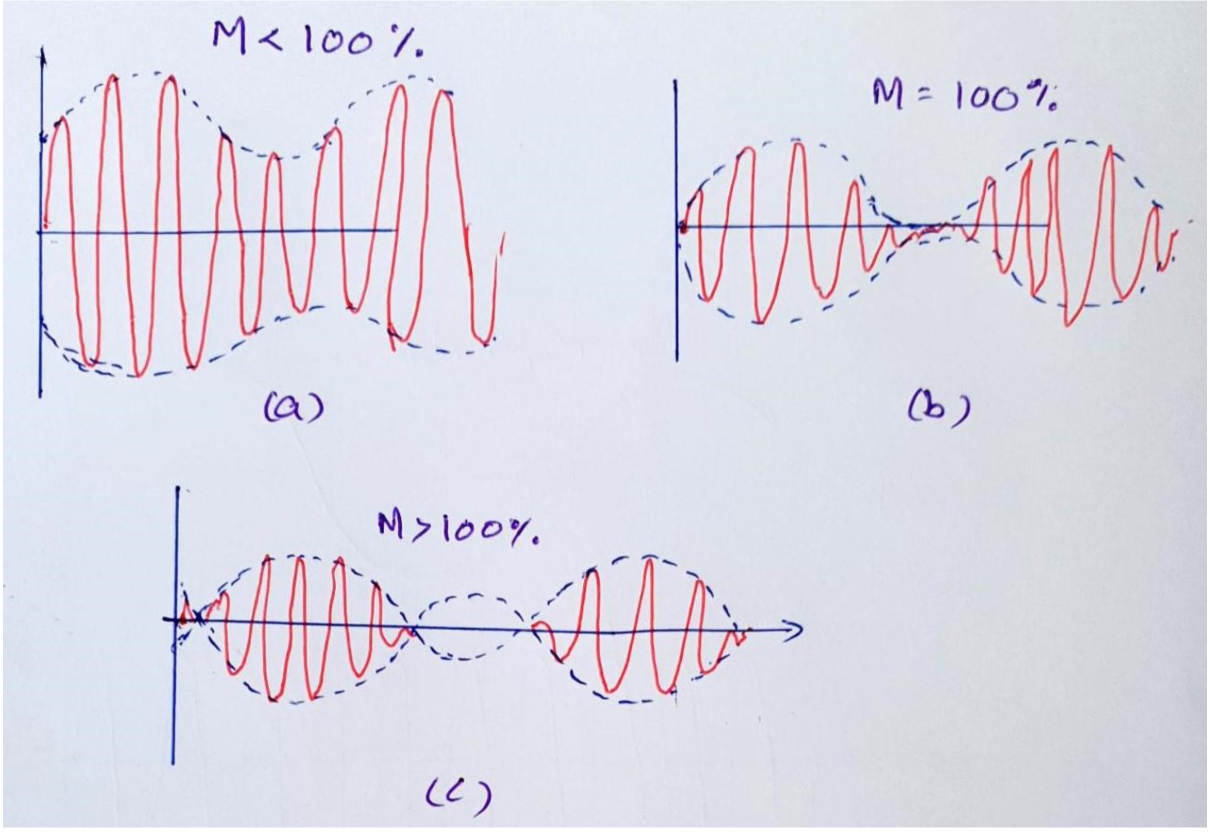
Modulation Index is defined as the ratio Vm/Vc

$$m = \frac{V_m}{V_c}$$

The modulation index is a number lying between 0 and 1, and it is often expressed as a percentage called the percentage modulation.

Percentage modulation, %m = m*100 = V_m/V_c * 100

Degrees of modulation

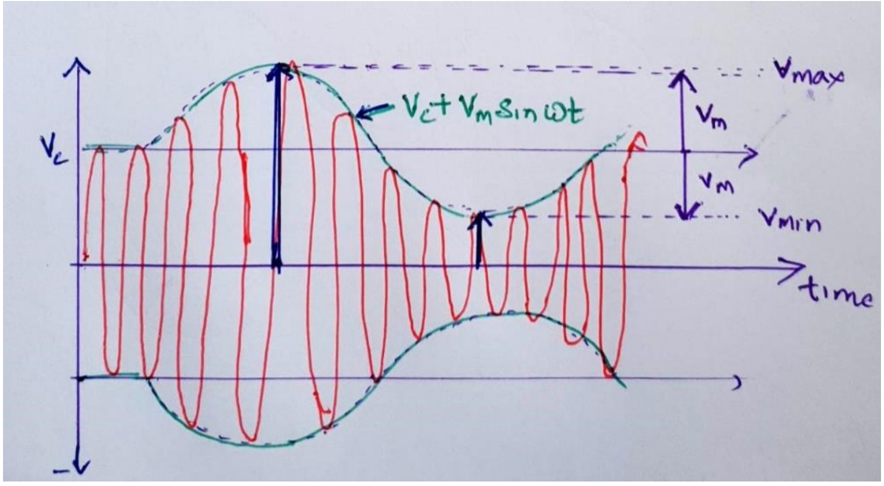


(a) Undermodulation

(b) 100% Modulation

(c) Overmodulation

Another way of expressing the ***modulation index*** is in terms of the maximum and minimum values of the amplitude of the modulated carrier wave. This is shown in the figure below.



$2\ V_m = V_{max} – V_{min}$

$V_m = (V_{max} – V_{min})/2$

$V_c = V_{max} – V_m$

$= V_{max} – (V_{max}-V_{min})/2$

$= (V_{max} + V_{min})/2$

Substituting the values of

Vm and Vc in the equation

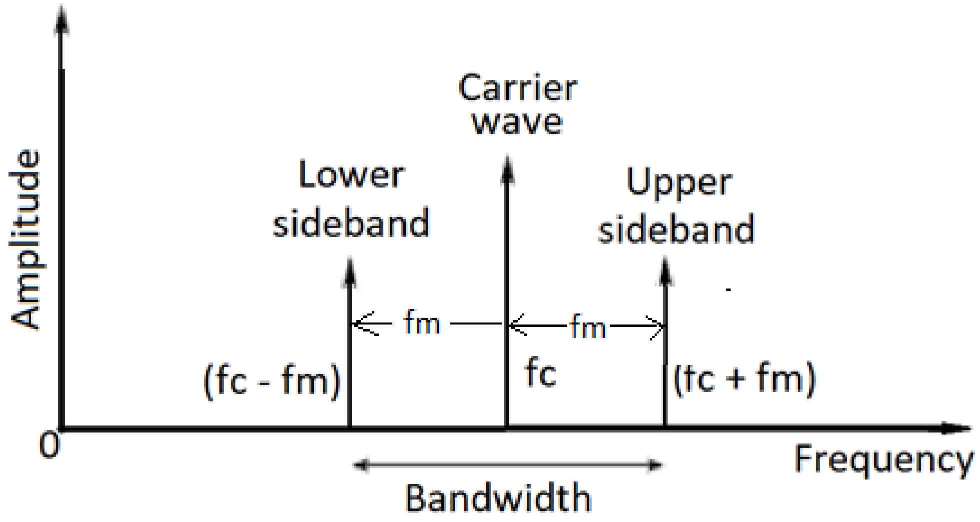
M = Vm/Vc , we get

$$\mathbf{M = \frac{V_{max} – V_{min}}{V_{max} + V_{min}}}$$

FREQUENCY SPECTRUM of AM Wave

The equation of Amplitude Modulated wave is

$$= V_c \sin \omega_c t + \frac{mV_c}{2} \cos(\omega_c - \omega_m)\, t – \frac{mV_c}{2} \cos(\omega_c + \omega_m)\, t$$



The above equation represents the AM wave. It consists of three terms viz the the carrier frequency fc, the lower sideband (LSB) fc – fm and the upper side band (USB) fc + fm

From the above we arrive at the conclusion that the bandwidth required for amplitude modulation is twice the frequency of modulating signal.

Also in modulation by several sine waves simultaneously, as in AM broadcast service, the bandwidth required is twice the highest modulating frequency.