Analog and Digital Communication

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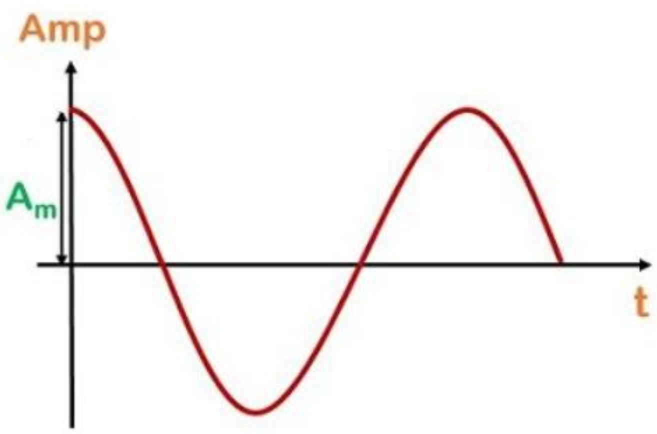
Amplitude Modulation(AM)

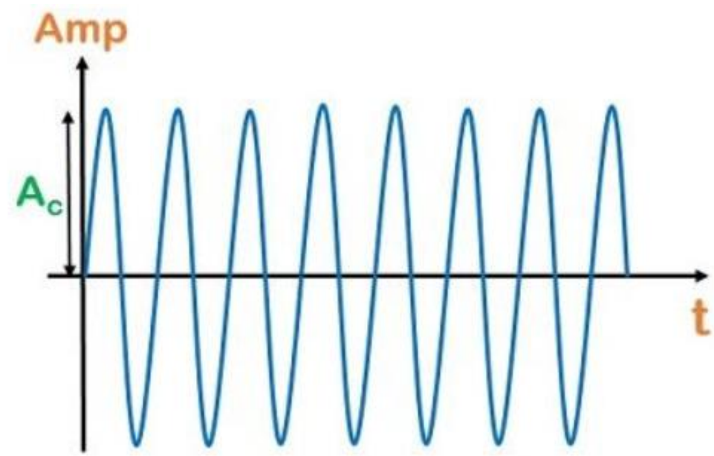
Amplitude Modulation is a technique by which the amplitude of the carrier wave is changed according to the signal wave or modulating signal. Among various modulation schemes, amplitude modulation is the simplest and oldest modulation technique.

Basically, the information that is carried by the low frequency modulating signal is superimposed on the carrier wave of high frequency by varying the amplitude of the carrier. Thus it is termed as amplitude modulation.

Amplitude modulation is the straightforward way to modulate a signal. In which, the amplitude of the informationless carrier wave is changed according to the message signal without changing the other factors associated with the carrier wave such as frequency and phase.

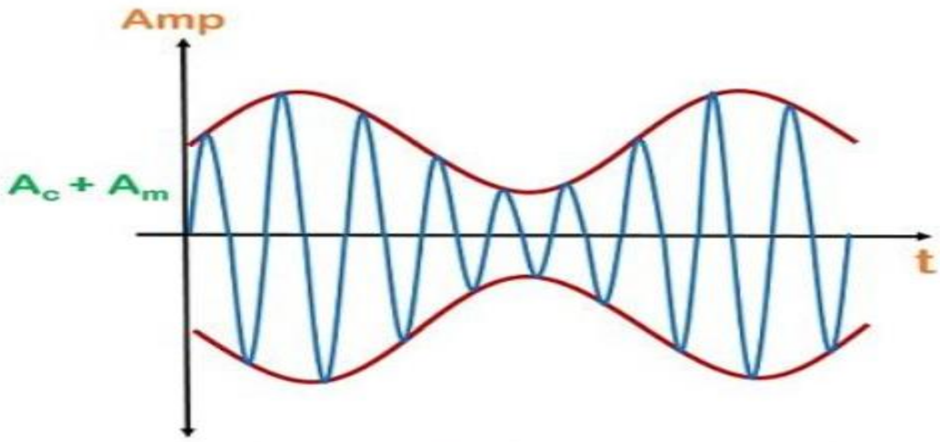


Message signal m(t)



Carrier wave c(t)

After amplitude modulation, an amplitude modulated wave is achieved, which is shown below:



Amplitude modulated wave y(t)

Mathematical Expression for Amplitude Modulation

Let us consider a modulating signal m(t), which is given by,

$$m(t) = A_m \cos \omega_m t$$

and the carrier signal c(t), given by the expression

$$c(t) = A_c \cos \omega_c t$$

Now, when the amplitude of the carrier is changed according to the message signal, an amplitude modulated wave is generated which is given by

$$y(t) = A_0 \cos \omega_c t$$

Here, $A_0 = A_c + m(t)$

Thus, modulated wave is given as,

$$y(t) = (A_c + A_m \cos \omega_m t) \cos \omega_c t \quad \text{— equation 1}$$

$$y(t) = A_c\left(1 + \frac{A_m}{A_c}\cos\omega_m t\right)\cos\omega_c t \text{ — equation 2}$$

$$: \frac{A_m}{A_c} = \mu$$

which is termed as the modulation index.

Thus, we can say the modulation index is the ratio of the amplitude of the message signal and the carrier signal.

Assume, Amax to be the maximum amplitude of the modulated signal and Amin to be the minimum amplitude of the modulated signal.

Amax is achieved if cos ω_m t = 1

Amax is given as

$$A_{max} = A_c + A_m \quad \text{——— equation 3}$$

Amin is achieved, if cos ωmt = -1

Amin is given as

$$A_{min} = A_c - A_m \quad \text{— equation 4}$$

On summing equation 3 and equation 4,

Amax + Amin = Ac + Am + Ac – Am

Amax + Amin = 2 Ac

$$A_c = \frac{A_{max} + A_{min}}{2} \quad \text{— equation 5}$$

On subtracting equation 4 from equation 3

Amax – Amin = Ac + Am – Ac + Am

Amax – Amin = 2 Am

$$A_m = \frac{A_{max} - A_{min}}{2} \qquad \text{———— equation 6}$$

Dividing equation 6 by equation 5

$$\frac{A_m}{A_c} = \frac{\frac{A_{max} - A_{min}}{2}}{\frac{A_{max} + A_{min}}{2}}$$

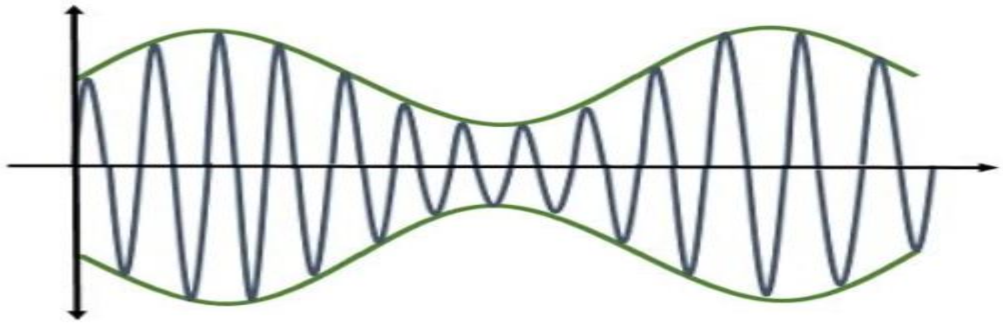
Thus, the modulation index is given as

$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

When the value of μ is 1, then it is said to be an ideal modulation.

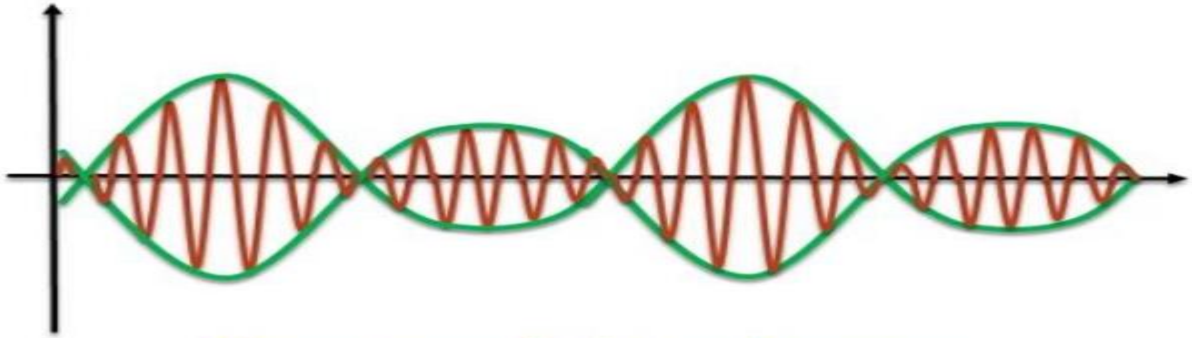
Concept of Linear and Overmodulation

Linear modulation: When the value of the modulation index is less than 1 then it is said to be a linear or under-modulated wave. The figure below shows the linear modulation of amplitude modulated wave.



Linear modulation or under modulated wave

Overmodulation: When the value of the modulation index exceeds more than 1, then over modulation takes place.



Over modulated wave

Types of Amplitude Modulation

1) Double sideband-suppressed carrier (DSB-SC) modulation

- The transmitted wave consists of only the upper and lower sidebands
- But the channel bandwidth requirement is the same as before.

2) Single sideband (SSB) modulation

- The modulation wave consists only of the upper sideband or the lower sideband.
- To translate the spectrum of the modulating signal to a new location in the frequency domain.

3) Vestigial sideband (VSB) modulation

- One sideband is passed almost completely and just a trace of the other sideband is retained.
- The required channel bandwidth is slightly in excess of the message bandwidth by an amount equal to the width of the vestigial sideband.

Advantages of amplitude modulation

- It is the simplest modulation technique.
- Demodulating the modulated wave is easy.
- It is a Low cost technique.

Disadvantages of amplitude modulation

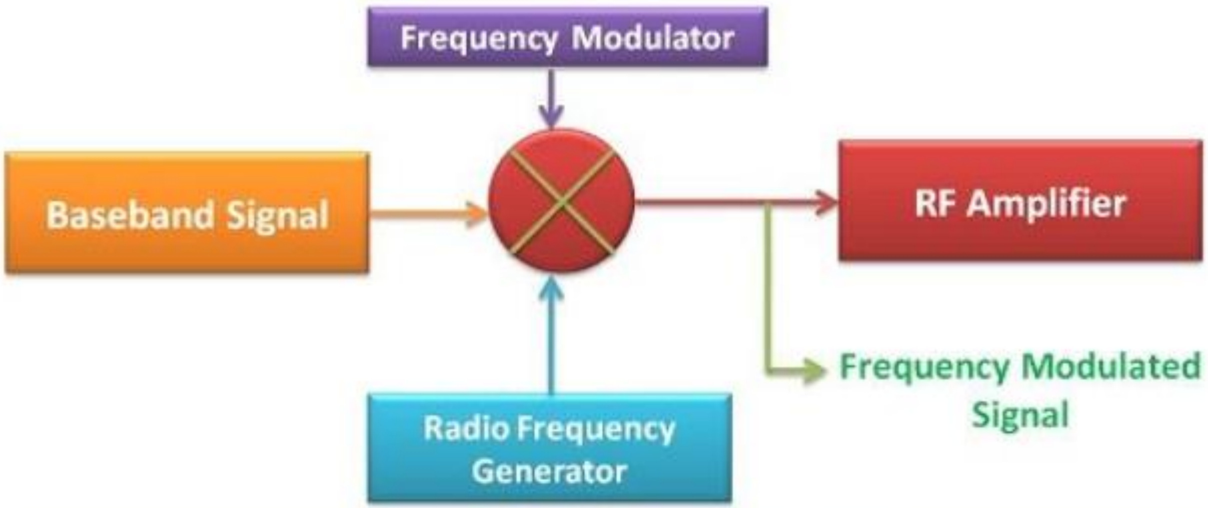
- High signal attenuation due to noise.
- It provides low efficiency.

Transmission efficiency is the ratio of power for the transmission of the message signal to the total power transmitted.

As we know that the transmitted signal is a modulated one, which contains both message signal along with the carrier wave. This carrier wave is of no use after the signal has reached its destination and must be separated from the message signal.

Frequency Modulation(FM)

The frequency modulation is the technique of modulation in which the frequency of the carrier signal is varied in accordance with the frequency of the information or baseband signal keeping the amplitude of carrier signal constant.



Block Diagram of Frequency Modulation

The main advantage of using the frequency modulation technique for transmission is that quality of the transmitted signal does not deteriorate. But the frequency modulation system is complex to design thus, the cost of such system are quite high.

The frequency modulation system is immune to noise distortion.

The FM equation include the following

$v = A \sin [w_c t + (\Delta f / f_m) \sin w_m t]$

$= A \sin [w_c t + m_f \sin w_m t]$

A = Amplitude of the FM signal. Δf = Frequency deviation

m_f = Modulation Index of FM

$m_f = \Delta f / f_m$

m_f is called the modulation index of frequency modulation.

$w_m = 2\pi f_m$ $w_c = 2\pi f_c$

The modulation index of FM is defined as the ratio of the frequency deviation of the carrier to the frequency of the modulating signal

AM	FM
In AM, the radio signal is known as a carrier signal & both the phase & frequency remain the same	In FM, the radio signal is known as a carrier signal, however, the amplitude, as well as phase, remain the same
More liable to noise	Less liable to noise
The sound clarity of AM is poor, however, can transmit long distances	FM has high BW including good sound quality
The AM frequency ranges from 535 kHz – 1705 kHz	The FM frequency ranges from 88 MHz – 108 MHz in the higher spectrum
The modulation index of AM ranges from 0 to 1	The modulation index of FM is higher than 1
AM operates in the MF (medium frequency) & HF(high frequency).	FM works with very high frequency

Advantages of Frequency Modulation

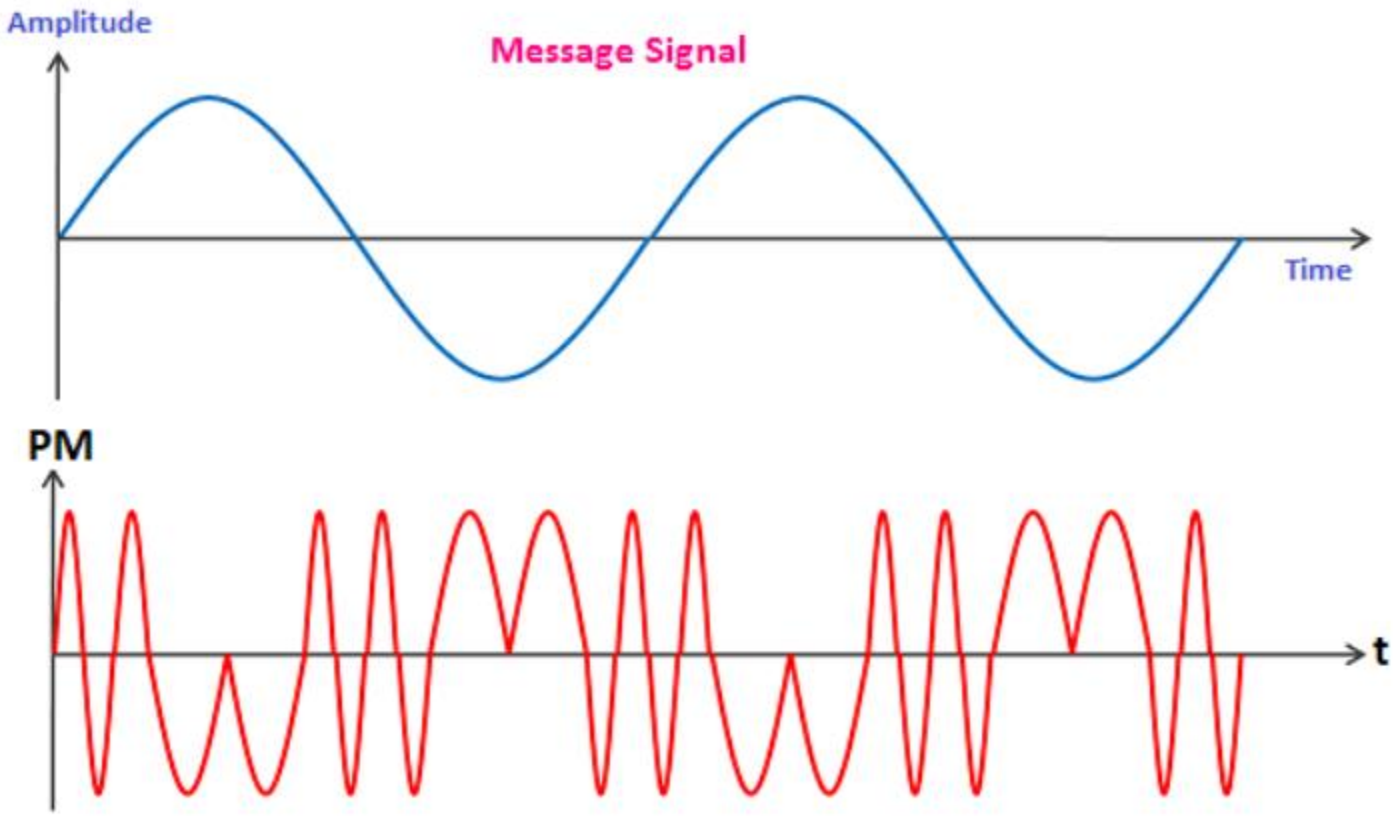
- Less noise and interference
- Service areas are well defined for specified transmitter power.
- As compared to amplitude modulation, FM includes low power consumption.
- The radiated power is less.

Disadvantages of Frequency Modulation

- High equipment cost is high
- High bandwidth
- The receiving area of the FM signal is small.
- The antennas for FM systems should be kept close for better communication
- Much more Bandwidth (as much as 20 times as much).
- More complicated receiver and transmitter.
- Sidebands expand to infinity any side

Phase Modulation

Phase modulation is defined as the process of varying the phase of the carrier signal linearly with the instantaneous value of the message signal. The waveforms of a message signal and the phase-modulated signal are shown below:



The equation of a PM signal is represented by:

$V(t) = A \cos [\omega ct + \phi (t)]$

The applications of Phase Modulation are listed as follows:

- Sound Synthesis
  PM is less susceptible to noise interference and popping sounds than AM. Hence, it is suitable for sound broadcasting, commonly referred to as sound synthesis.

- Digital Synthesizers
  PM is used in digital synthesizers for the generation of signals and waveform.

- Telephone communication
  PM is widely used in telephone communication due to its high-speed transmission

Advantages of Phase Modulation

- High speed

Phase modulation is considered as one the fastest modulation technique. It is due to the pulse generation at high speed.

- Low signal power consumption

PM requires low signal power consumption due to its better efficiency and fast speed.

- Simple circuit design

The components required in the phase modulated circuit are less as compared to FM. Hence, it has a simple circuit design.

- Easy modulation and demodulation

Phase modulation and demodulation is easy as compared to PM due to its simple circuit design.

Disadvantages of Phase Modulation

- Low noise immunity
- Complex circuitry during conversion from FM to PM
- Low signal to noise ratio