# Modulation

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| **Objectives**<br>After going through this module the learner will be able to<br>• Understand the meaning of modulation<br>• Appreciate the need for modulation<br>• Know about different types of modulation<br>• Describe amplitude modulation<br><br>**Content Outline**<br>• Unit Syllabus<br>• Module Wise Distribution of Syllabus<br>• Words You Must Know<br>• Modulation<br>• Need for Modulation<br>• Types of Modulation<br>• Amplitude Modulation<br>• Summary |

## Unit Syllabus

**Unit 10 Communication Systems**

**Chapter 15 Communication System**

Elements of a communication system (block diagram) bandwidth of signals speech, TV and digital data) bandwidth of transmission medium, propagation of electromagnetic waves in the atmosphere, sky and space wave propagation, satellite communication, need for modulation, types of modulation, amplitude modulation, production of amplitude modulated wave, detection of amplitude modulated wave, Internet and mobile phones

## Module Wise Distribution of Unit Syllabus - 6 Modules

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|---|---|
| Module 1 | • History of communication<br>• Special vocabulary<br>• Signals and band width |

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| Module 2 | • Propagation of electromagnetic wave<br>• Ground wave<br>• Sky wave<br>• Space wave<br>• Satellite communication |
| Module 3 | • Modulation<br>• Need for modulation<br>• Types of modulation<br>• Amplitude modulation AM<br>• Frequency modulation FM<br>• Meaning of tuner frequencies 98.3FM |
| Module 4 | • Amplitude modulation<br>• Modulation index<br>• Production of amplitude modulated wave<br>• Detection of amplitude modulated wave<br>• Applications of amplitude modulation |
| Module 5 | • Short range communications<br>• Increasing the area of influence using antenna<br>• Use in factories, villages, towns for police work<br>• Internet<br>• Internet servers |
| Module 6 | • Mobile phones<br>• Mobile towers<br>• 3G, 4G, 5G<br>• Mobile companies, what do they do? |

## Module 3

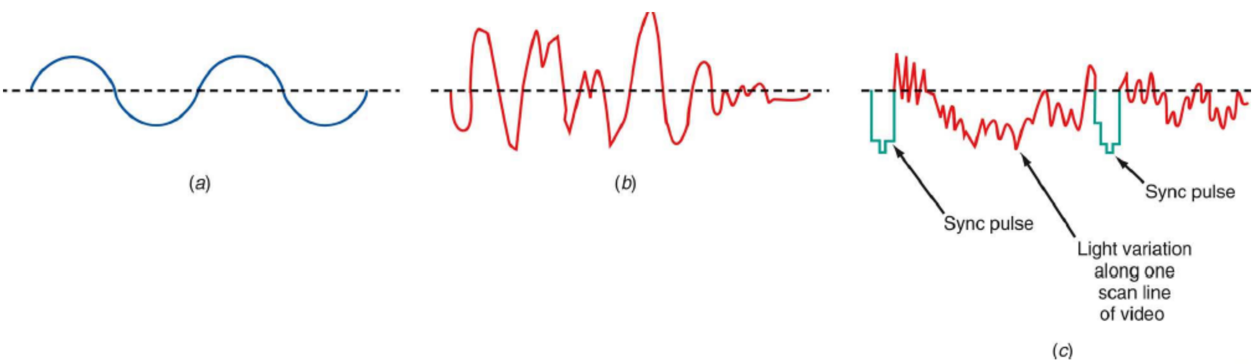
## Words You Should Know

- **Communication:** The process of putting across ideas through words and pictures.
- **Audio Communication:** Communication by means of speech/sound or messages that can be received by our ears.
- **Video Communication:** Communication by means of pictures, still or moving or messages that can be received by our eyes.

- **Audio Video Communication:** Communication by means of speech/sound or messages that can be received by our ears.
- **Device:** an apparatus designed for special functions.
- **Mode of Transfer of Information:** method of transfer of information.
- **Antenna:** a device designed to send out and receive electromagnetic waves.
- **Electromagnetic Waves:** The range of electromagnetic signals encompassing all frequencies is referred to as the electromagnetic spectrum.
- **Frequency:** It is defined as the number of cycles per second or number of waves per second.
- **Wavelength** is the distance occupied by one cycle of a wave and is usually expressed in meters. Wavelength is also the distance traveled by an electromagnetic wave during the time of one cycle. The wavelength of a signal is represented by the Greek letter lambda (λ).
- **Transducer:** An electrical transducer may be defined as a device that converts some physical variable (pressure, displacement, force, temperature, etc.) into corresponding variations in the electrical signal at its output. For example, a microphone converts sound energy into electrical energy.
- **Signal:** Information converted in electrical form and suitable for transmission is called a signal. Signals can be either analog or digital.
- **Analog Signals** are continuous variations of voltage or current. *T*hey are essentially single-valued functions of time. Sine wave is a fundamental analog signal.

  **All other analog signals can be fully understood in terms of their sine wave components.**

  Sound and picture signals in TV are analog in nature.



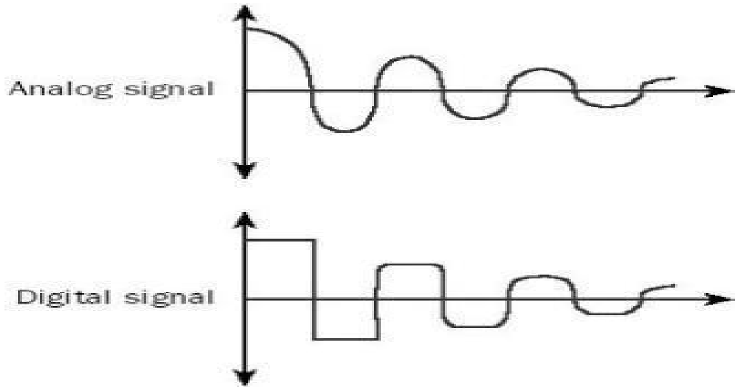

**Analog signals (a) Sine wave “tone.” (b) Voice. (c) Video (TV) signal.**

- **Digital Signals** are those which can take only discrete stepwise values.
- **The Binary System** that is extensively used in digital electronics employs just two levels of a signal. ‘0’ corresponds to a low level and ‘1’ corresponds to a high level of voltage/ current.


**Digital signals (a) Telegraph (Morse code). (b) Continuous-wave (CW) code. (c) Serial binary code**

- **Technically speaking, a signal is a wave, amplitude or frequency of which varies with time and the signal can be analog or digital.**
- **Noise:** These are unwanted signals having the same or similar frequency as that of the required signal. They distort the transmission and receiving process. A virus in a computer is an example of noise. A virus is an unwanted program in the same language in which your required program is, it disrupts your program.
- **Communication Channel:** The communication channel is the medium by which the electronic signal is sent from one place to another. Types of media include electrical conductors, Optical media, Free space, and System-specific media (e.g., water is the medium for sonar).
- **Transmitter:** It is the device that converts the information (message) into a form suitable for transmission. In the above example the online shopping company is the transmitter.
- **Receiver:** It is the device that retrieves the information from received signals. In the shopping example, you are the receiver. A **receiver** is a collection of electronic components and circuits that accepts the transmitted message from the channel and converts it back into a form understandable by humans. Receivers contain **amplifiers, oscillators, mixers, tuned circuits** and **filters**, and a detector that recovers the original intelligence signal from the modulated carrier
- **Transceivers:** A transceiver is an electronic unit that incorporates circuits that both send and receive signals. Examples are: Telephones, Fax machines, radios, Cell, mobile phones, computers.

- **Amplification:** It is the process of increasing the strength of signal. Amplification compensates for attenuation. Amplification is done by an electronic circuit.
- **Attenuation:** It refers to loss in strength of signal while propagating from transmitter to receiver Signal attenuation, or degradation, exists in all media of wireless transmission. It is usually proportional to the square of the distance between the transmitter and receiver




- **Range:** It is the maximum distance that a signal can travel with sufficient strength.
- **Band Width:** It is the frequency range over which a system works. It is calculated as the highest frequency – lowest frequency. For example, the human audio frequency range is 20 Hz to 20,000 Hz, so audio bandwidth = 20,000 – 20 = 19,980 Hz **Bandwidth is** that portion of the electromagnetic spectrum occupied by a signal. **Channel Bandwidth** refers to the range of frequencies required to transmit the desired information.
- **Bandwidth of Transmission Medium** the transmission channels are of three types Wires, free space and optical fiber.
- **Repeater:** repeater station is equipped with Receiver, Amplifier and Transmitter.The mobile phone towers in your area are repeater stations.
- **Communication Satellites** are repeater stations in space. They receive a signal from one ground station, amplify it and transmit it to another ground station.
- **Antenna: It is the** device through which transmission and receiving process are done. The dish connected to your TV set is an antenna in itself.
- **Carrier Wave:** A carrier is a high frequency signal that is modulated by audio, video, or data. A radio-frequency (RF) wave is an electromagnetic signal that is able to travel long distances through space.

- **Broadcasting** is the distribution of audio or video content to a dispersed audience via any electronic mass communications medium, but typically one using the electromagnetic spectrum (radio waves), in a one-to-many model.
- **Mode of EM Wave Propagation:** EM waves travel in three ways through the atmosphere, ground wave, sky wave and space wave.

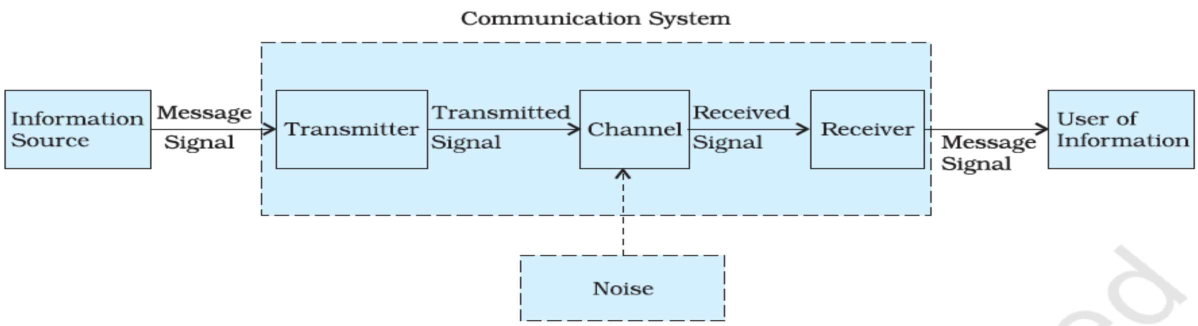
## Introduction

Suppose you're the principal of a school addressing students in assembly or want to make an announcement in the school you would use a microphone and a public address system. .A microphone converts sound energy into electrical energy. You would probably reach out to everyone concerned, but your scope is limited to school.

Now suppose you want to reach out to a friend on mobile phone or send an email, mere conversion of sound /data to electrical signal will not be sufficient hence the need to understand the use of transducers that convert the electrical signal into radio waves, which can travel at the speed of light and through the atmosphere.

What happens at the other end?

The radio waves with the message signal, send flow through the metal antenna and cause electrons to wiggle back and forth. That generates an electric current—a signal that the electronic components inside my radio turn back into sound I can hear.

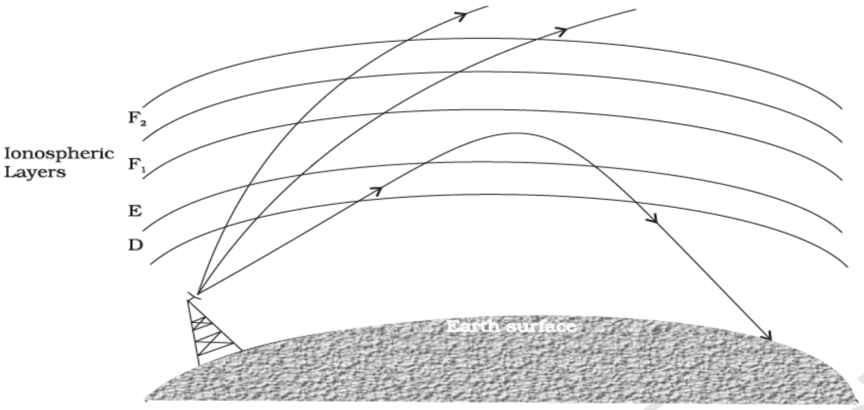



- Electricity flowing into the transmitter antenna produces radio waves.
- The radio waves travel through the air at the speed of light.
- When the waves arrive at the receiver antenna, they are converted into an electric current that recreates the original signal.

Transmitter and receiver antennas are often very similar in design Often, though, transmitters and receivers look very different. TV or radio broadcasting antennas are huge masts sometimes stretching hundreds of meters into the air, because they have to send powerful signals over long distances, say 280 metre. But you don't need anything that big on your TV or radio at home: a much smaller antenna will do the job fine.

Depending on what kinds (frequencies) of waves we want to send, how far we want to send them, and when we want to do it, there are actually three different ways in which the waves can travel:

- **Ground Wave Propagation**
- **Sky Wave Propagation**
- **Space Wave Propagation**




1) As we've already seen, they can go in a straight line, line of sight
2) They can speed round the Earth's curvature, a ground wave. AM (medium-wave) radio tends to travel this way for short-to-moderate distances. This explains why we can hear radio signals beyond the horizon (when the transmitter and receiver are not within sight of each other).
3) They can shoot up to the sky, bounce off the ionosphere (an electrically charged part of Earth's upper atmosphere), and come back down to the ground again. This effect works best at night, which explains why distant (foreign) AM radio stations are much easier to pick up in the evenings. During the daytime, waves shooting off to the sky are absorbed by lower layers of the ionosphere. At night, that doesn't happen. Instead, higher layers of the ionosphere catch the radio waves and send them back to Earth, like total internal reflection, to carry radio waves over very long distances.
4) The very high frequency waves may be made to reach out in space and be reflected by satellites reaching the most obscure parts of the world.

The purpose of a communication system is to transmit information or message signals. Message signals are also called **baseband signals,** which essentially designate the band of frequencies representing the original signal, as delivered by the source of information.

No signal, in general, is a single frequency sinusoid, but it spreads over a range of frequencies called the signal **bandwidth.**

In this module, we will see the data signal which may be.

## Modulation

**A direct transmission of the audio frequency signal is not possible as the associated wavelengths are very large.**

Suppose we wish to transmit an electronic signal in the audio frequency (AF) range (baseband signal frequency less than 20 kHz) over a long distance directly. **Why is this not possible?** Basic reason is that the signal energy would fade; the antenna will need a certain height so as to overcome the attenuation.

For example, an electromagnetic wave of frequency of 10 kHz has a wavelength of about 30 km; transmission of such a signal would require an antenna having a linear dimension of a few kilometres .therefore a communication system must couple with a carrier frequency to ride appropriately without loss of energy covering a larger distance.

The nature of the carrier depends on the application. Both carrier wave frequency and channel are important for efficient transfer of audio video signals.

A continuous sine or a digital signal conveys information but to carry it or transmit the same, it is necessary to vary the characteristics of the wave in some way this variation is called **modulation**.

The audio video signal is superimposed over a suitable carrier wave to facilitate the communication process at the speed of electromagnetic waves.

**Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted**.

In general telecommunications, modulation is a process of modifying the message signal coupling the same with carrier frequency. For example, a digital bit stream or audio signal, inside another signal that can be physically transmitted.

## Need of Modulation

Let us consider the following

- **Size of the Antenna or Aerial**

  For transmitting a signal, we need an antenna or an aerial. This antenna should have a size comparable to the wavelength of the signal (at least λ/4 in dimension) so that the antenna properly senses the time variation of the signal.

  For an electromagnetic wave of frequency 20 kHz, the wavelength λ is 15 km.

  Obviously, such a long antenna is not possible to construct and operate. Hence direct transmission of such baseband signals is not practical.

  **We can obtain transmission with reasonable antenna lengths if transmission frequency is high (for example, if ν is 1 MHz, then λ is 300 m).**

  Therefore, there is a need of translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.

- **Effective Power Radiated by an Antenna**

  A theoretical study of radiation from a linear antenna (length l) shows that the power radiated is proportional to $\left(\frac{l}{\lambda}\right)^2$.This implies that for the same antenna length, the power radiated increases with decreasing λ, i.e., increasing frequency.

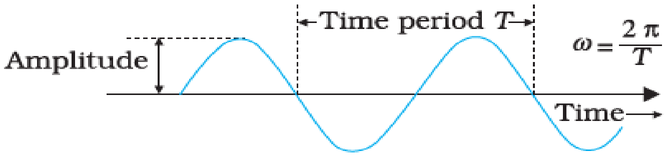
  Hence, the effective power radiated by a long wavelength baseband signal would be small. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

- **Mixing up of Signals from Different Transmitters**

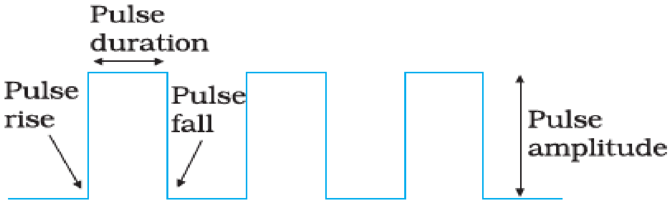
  Another important argument against transmitting baseband signals directly is more practical in nature. Suppose many people are talking at the same time or many transmitters are transmitting baseband information signals simultaneously.

  All these signals will get mixed up and there is no simple way to distinguish between them. This points towards a possible solution by using communication at high frequencies and allotting a band of frequencies to each message signal for its transmission.In doing so, we have to take the help of a high frequency signal, which we call the carrier wave, and a process known as modulation which attaches information to it.

  The carrier wave may be continuous (sinusoidal) or in the form of pulses as shown




(a)




(b)

**(a) Sinusoidal**

**(b) Pulse Shaped Signals**

A sinusoidal carrier wave can be represented as

$c(t) = A_c \sin sin \left(\omega_c t + \theta\right)$

Where,

- $c(t)$ is the signal strength (voltage or current),
- $A_c$ is the amplitude,
- $\omega_c$ ( = 2πfc) is the angular frequency

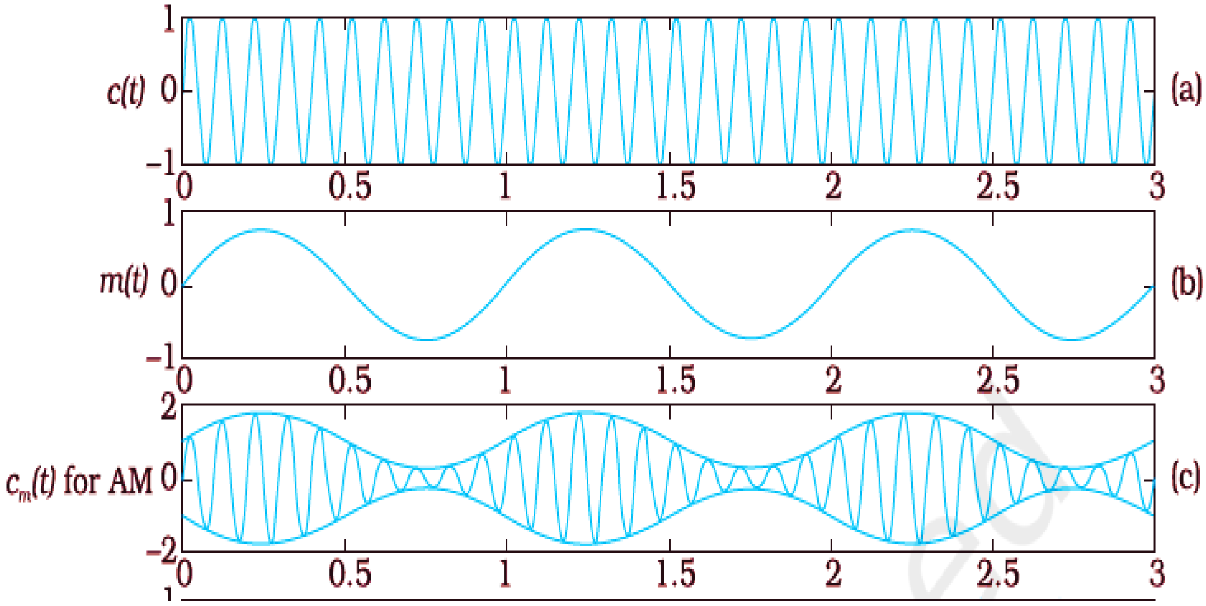
  and
- θ is the initial phase of the carrier wave.

During the process of modulation, any of the three parameters,

*Viz* **$A_c$, $\omega_c$ and θ**, of the carrier wave can be controlled by the message or information signal.

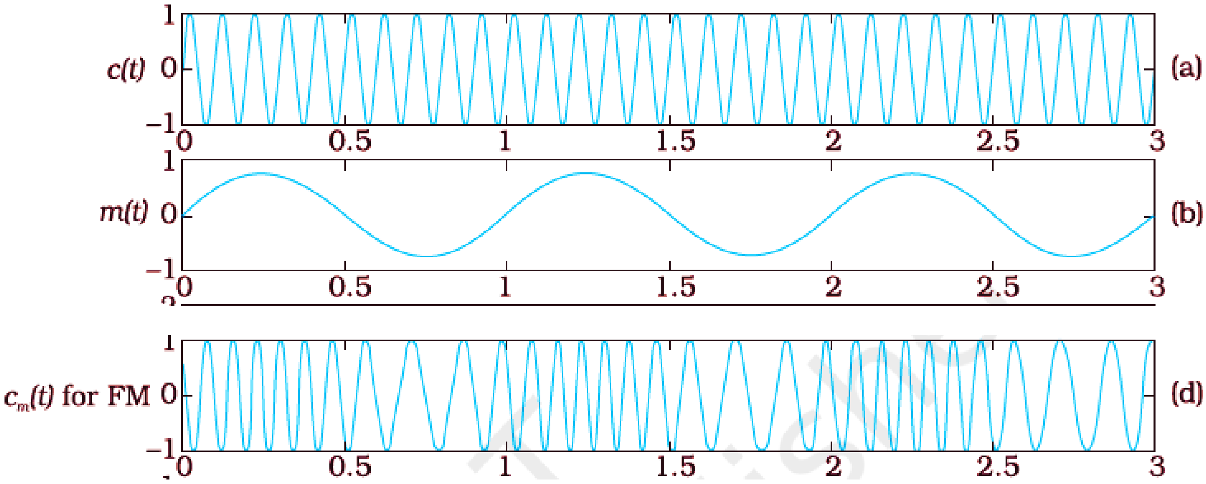
**This Results in Three Types of Modulation**

**(i) Amplitude Modulation (AM)**



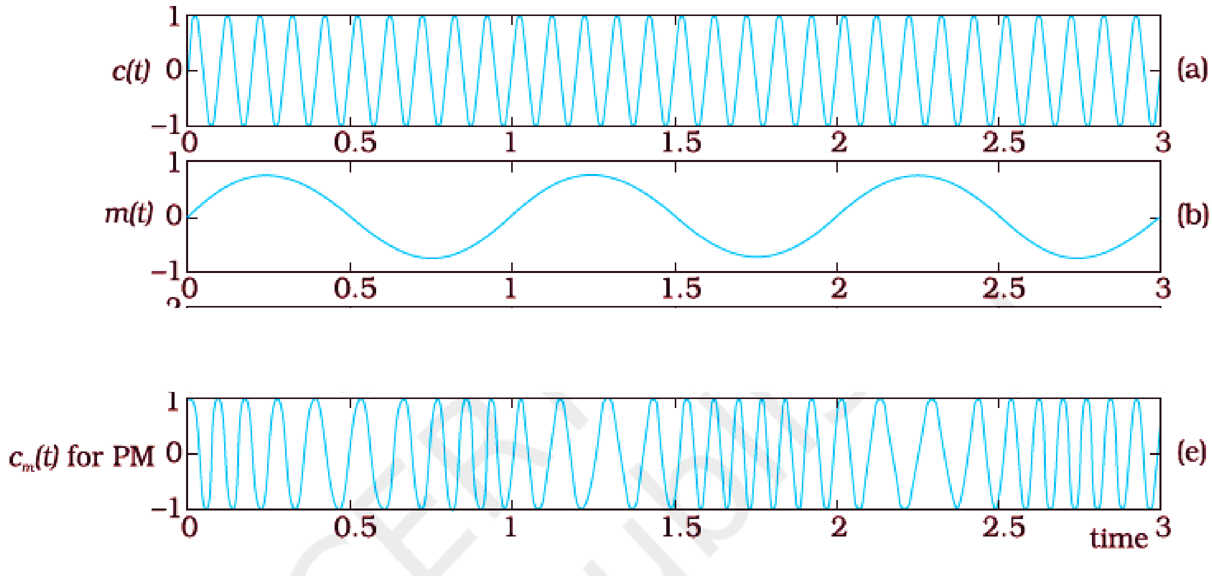

**Notice** the combined waveforms the amplitude modulated wave has the carrier wave amplitude varying with time.

**(ii) Frequency Modulation (FM)**




**Notice** the combined waveforms the frequency modulated wave has the carrier wave frequency varying with time.

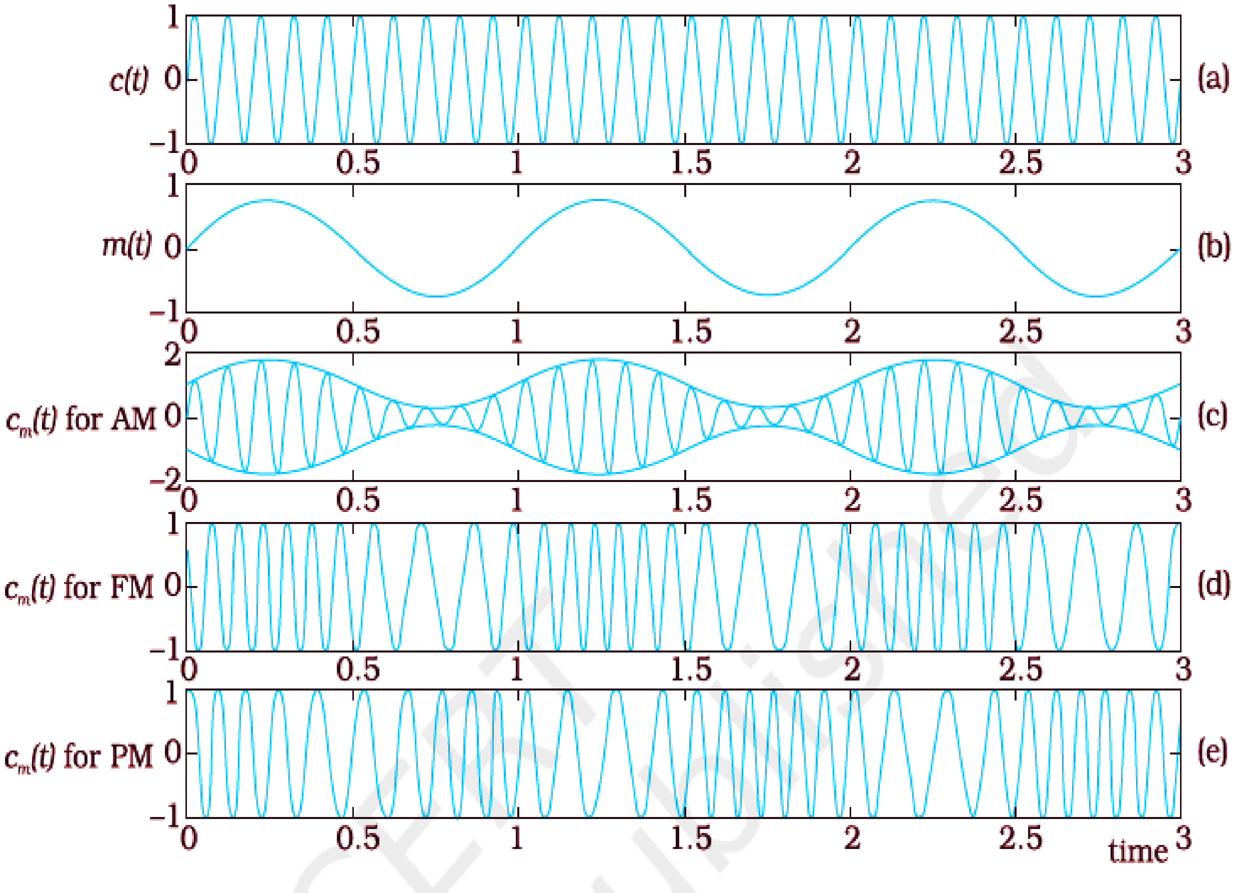
**(iii) Phase Modulation (PM)**




**Notice** the combined waveforms the phase modulated wave has the carrier wave phase varying with time.

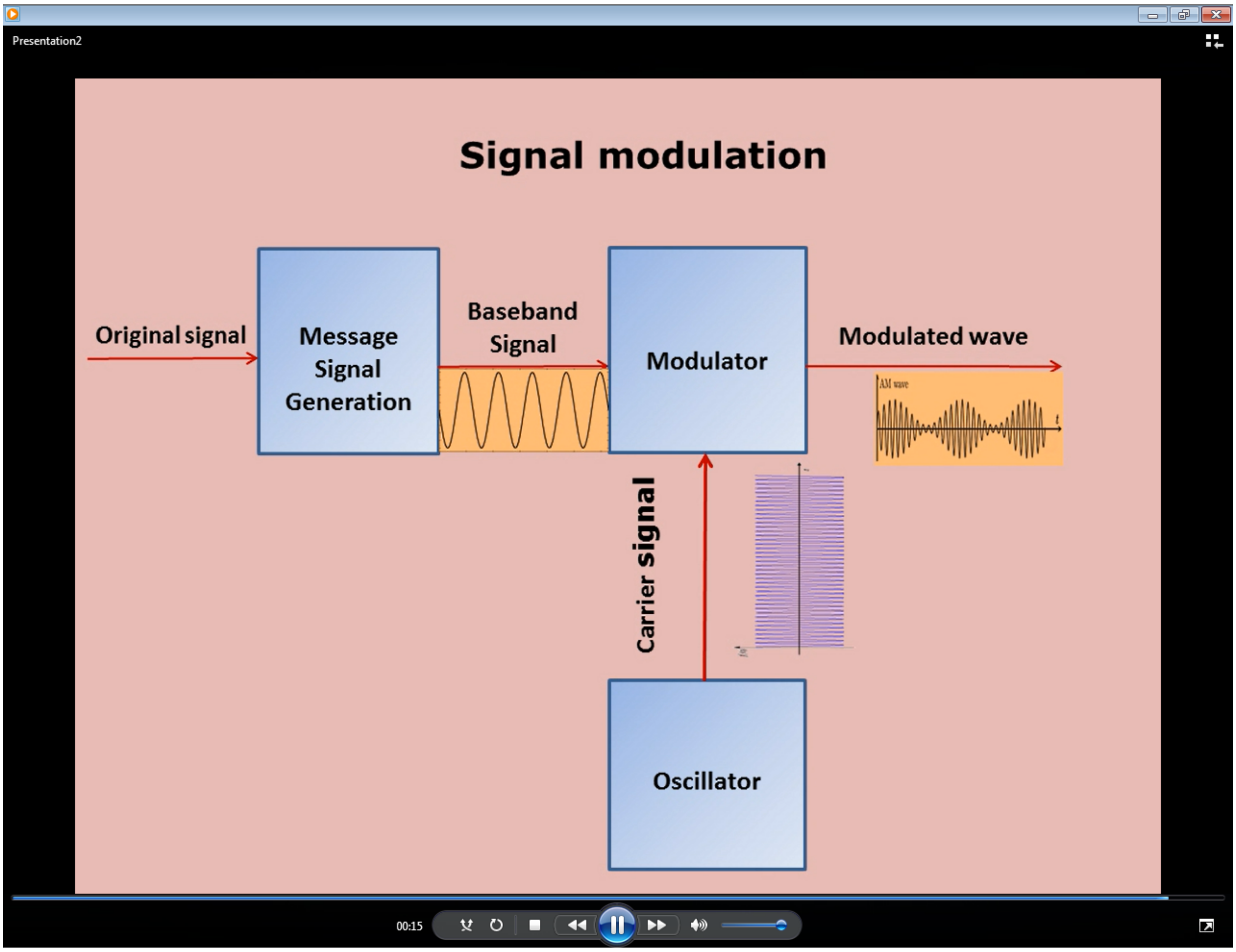
**We can show these together graphically**

https://github.com/PetarV-/TikZ/tree/master/Amplitude%20modulation




**Modulation of a carrier wave: (a) a sinusoidal carrier wave;(b) a modulating signal; (c) amplitude modulation; (d) frequency modulation; and (e) phase modulation**

**The type of modulation selected for any baseband signal depends upon individual requirements for its transmission.**




**See animation to understand it better**

## Advantages of Modulation

- Reduction in the height of antenna
- Avoids mixing of signals
- Increases the range of communication
- Multiplexing is possible
- Improves quality of reception

## Example

Calculate the minimum antenna height required to transmit

a. a baseband signal of $f = 10$ kHz

b. a modulated signal with a carrier wave $f = 1$ MHz

**Solution**

a. For the transmission of radio signals, the antenna height must be multiple of λ/4, where λ is the wavelength. $\lambda = c/f$

   Where, c is the velocity of light

   f is the frequency of the signal to be transmitted

   The minimum antenna height required to transmit a baseband signal of f = 10 kHz is calculated as follows :

   Minimum antenna height$=\frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^{8}}{4\times10\times10^{3}} = 7500m = 7.5km$

   The antenna of this height is practically impossible to install.

b. Now, let us consider a modulated signal at f = 1 MHz . The minimum antenna height is given by,

   Minimum antenna height

   $= \frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^{8}}{4\times10\times10^{6}} = 75m$

   This antenna can be easily installed practically.

   **Thus, modulation reduces the height of the antenna.**

**Try These**

- **How does modulation reduce mixing of signals?**

  If the baseband sound signals are transmitted without using the modulation by more than one transmitter, then all the signals will be in the same frequency range i.e. 0 to 20 kHz. Therefore, all the signals get mixed together and a receiver cannot separate them from each other.

  Hence, if each baseband sound signal is used to modulate a different carrier then they will occupy different slots in the frequency domain (different channels). Thus, modulation avoids mixing of signals.

- **How does modulation increase the Range of Communication?**

  The frequency of baseband signals is low, and the low frequency signals cannot travel long distances when they are transmitted. They get heavily attenuated.

  The attenuation reduces with increase in frequency of the transmitted signal, and they travel longer distances.

  The modulation process increases the frequency of the signal to be transmitted . Therefore, it increases the range of communication.

- **What is multiplexing? How does modulation help in multiplexing?**

Multiplexing is a process in which two or more signals can be transmitted over the same communication channel simultaneously.This is possible only with modulation.

The multiplexing allows the same channel to be used by many signals. Hence, many TV channels can use the same frequency range, without getting mixed with each other or different frequency signals can be transmitted at the same time.

- **How does modulation improve the quality of reception?**

  With frequency modulation (FM) and digital communication techniques such as PCM, the effect of noise is reduced to a great extent. This improves the quality of reception.

## Summary

- Communication of audio video data signals need special circuits.
- Transmitter and receiver make communication over long distances possible.
- Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted.
- There are three types of modulations: amplitude modulation, frequency modulation and phase modulation
- Modulation is necessary as it Reduction in the height of antenna, Avoids mixing of signals, Increases the range of communication, Multiplexing is possible, Improves quality of reception