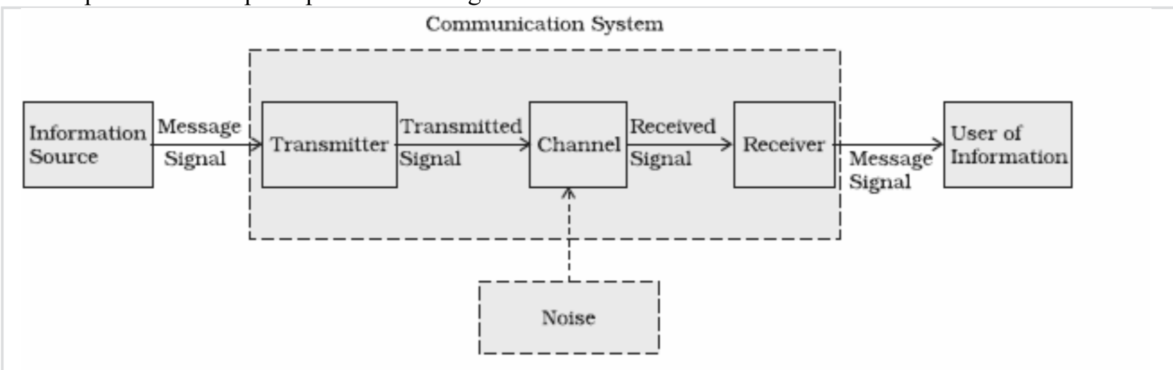
1. ELEMENTS OF COMMUNICATION SYSTEMS

The following are the elements of a communication system:

Transmitter

- Transmitter is a device that transmits a message or signal over the channel to the receiver.
- It is empowered with a transducer and an amplifier.
- The function of transducer is to convert energy in one form to another.
- Amplifier boosts up the power of the signal.



Communication Channel

- The signal from the transmitter is carried to the receiver by the communication channel.
- Signals may be carried to the receiver in two ways:
  - Through wires or cables
  - By electromagnetic waves (wireless medium)

Receiver

- The reconstruction of the original information from the signals fed through the channel is done by the receiver. Then the actual information is delivered to the user.

Note: Noise is any undesirable effect created due to channel imperfection. This causes the signals to get distorted or corrupted.

2. ELECTRONIC COMMUNICATION SYSTEMS

Basic Terminology

Transducer is a device to convert energy in one form to another. An electrical transducer converts some physical variable (pressure, displacement, force, temperature, etc) into corresponding variations in the electrical signal at its output.

Signal is the information converted into electrical form and suitable for transmission. Analog signals are continuous variations of voltage or current. Digital signals are those which can take only discrete stepwise values.

Noise refers to the undesirable effects that tend to disturb the transmission and processing of message signals in a communication system.

A transmitter processes the incoming message signal so as to make it suitable for sending over the channel.

A receiver extracts the desired message signals from the received signals at the channel output.

Attenuation refers to the loss of strength of a signal while propagating through a medium.

Amplification is the process of increasing the amplitude and thereby the strength of a signal using an electronic circuit called the amplifier.

Range is the largest distance between a source and a destination up to which a signal is received with sufficient strength.

Bandwidth refers to the range over which the frequencies of a signal vary.

Modulation is the process of varying of certain characteristic of a periodic wave with external signals. It enables the information bearing signal to be transmitted over long distances. Types of modulation include; amplitude modulation (AM), frequency modulation (FM) and phase modulation (PM).

Demodulation refers to the retrieval of original information from the carrier wave at the receiver.

Repeater: The function of repeaters is to extend the range of a communication system.

A repeater receives the signal from the transmitter, amplifies and retransmits it to the receiver or another repeater. Communication satellites serve as repeaters in space.

3. BANDWIDTH OF SIGNALS AND TRANSMISSION MEDIUM

Bandwidth of Signals

- ♦ The range over which the frequencies in a signal vary is called its bandwidth.
- ♦ Voice, music, picture or computer data is sent using the communication systems.
- ♦ Each of the above signals has different range of frequencies.
- ♦ The type of communication system needed for a given signal depends on the band of its frequencies
- ♦ Bandwidth of certain signals are given below.
  - Audio signals - approximately 20 kHz (from 20 Hz to 20 kHz)
  - Speech signals used in telephonic communication - 2800 Hz (from 300 Hz to 3100 Hz)
  - Video signals for transmission of pictures - 4.2 MHz
  - TV signals for both voice and picture – 6 MHz

Bandwidth of Transmission Medium

Different types of transmission media offer different bandwidths.

- ♦ Coaxial cables offer a bandwidth of 750 MHz.
- ♦ Communication through free space using radio waves accommodates a very wide range of frequencies, which is subdivided for specific purposes as given in the table below.

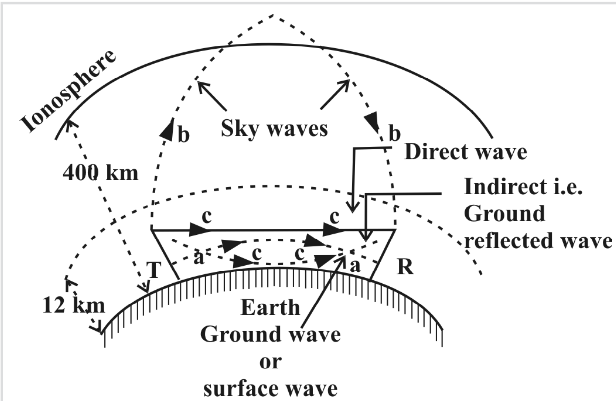
Service	Frequency bands	Comments
Standard AM broadcast	540-1600 kHz	
FM broadcast	88-108 MHz	
Television	54-72 MHz 76-88 MHz 174-216 MHz 420-890 MHz	VHF (very high frequencies) TV UHF (ultra high frequencies) TV
Cellular Mobile Radio	896-901 MHz 840-935 MHz	Mobile to base station Base station to mobile
Satellite Communication	5.925-6.425 GHz 3.7-4.2 GHz	Uplink Downlink

- ♦ An optical fiber can offer a transmission bandwidth in excess of 100 GHz.
- ♦ Usually, optical communication using fibers is performed in the frequency range of 1 THz to 1000 THz (microwaves to ultraviolet).

4. PROPAGATION OF ELECTROMAGNETIC WAVES

Ground wave propagation or surface wave propagation

- Ground waves or surface waves are the radiowaves that travel through the atmosphere following the surface of the earth and the propagation using such waves is called ground wave propagation or surface wave propagation.
- They can travel around the curvature of the earth. Bending of these waves around the corners of obstacles leads to their attenuation and so, they cannot cover large distances.
- It is optimum for local broadcasting using low and medium frequency range up to 2 MHz. Hence, it is also called medium wave propagation.
- The maximum range of ground wave propagation depends on the frequency of the radiowaves and the power of the transmitter.



Sky Wave Propagation

- Sky waves are radiowaves with frequency between 2 MHz and 30 MHz.
- Propagation of communication using sky waves is called sky wave propagation.
- They reach the receiving antenna after getting reflected in the ionosphere. Therefore, it is also termed ionosphere propagation. (See path *b* in the figure given under the previous subheading)
- Radiowaves can cover a distance of 4,000 km in a single reflection from the ionosphere.
- This makes sky waves at medium and high frequencies significant in very long distance radio communication.
- Critical frequency is that maximum frequency of radiowaves, which when sent normally towards the ionosphere, is reflected back to the earth.
- Radiowaves having frequency greater than the critical frequency will penetrate through the atmosphere and escape.

Space Wave Propagation

- Space waves are very high frequency radiowaves (30 MHz to 300 MHz).
- They can travel through the atmosphere from the transmitter antenna to the receiver antenna either directly or after getting reflected from the ground or in the troposphere.
- Propagation of such waves is called space wave propagation or tropospherical propagation. (See path *c* in the figure given under the first subheading).
- Space wave propagation is utilised in very high frequency bands (VHF: 30 MHz - 300 MHz), ultra high frequency bands (UHF) and microwaves.
- Space wave propagation is suitable for line-of-sight (LOS) communication as well as satellite communication. This type of propagation is restricted by the line of sight distance and curvature of the earth.
- Line of sight distance is the distance between the transmitting antenna and the receiving antenna at which they are visible to each other. LOS distance is also known as the range of communication.
- The maximum LOS distance between the transmitting and receiving antennas of heights h_T and h_R can be given as;

  $$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

  where, R is the radius of the earth.
- By increasing the height of the transmitting and receiving antennas, this range can be increased.
- It has applications in TV transmission and radar communication.

5. MODULATION AND ITS NECESSITY

Modulation is the process by which low frequency (low energy) signals are superimposed with suitable high frequency carrier waves before transmission so as to make it travel over a long distance

Need of Modulation:

(*i*) **Height of the antenna:** The efficient radiation and reception of original signals require the transmitting and receiving antennas to have height comparable to a quarter wavelength of the signals used (*i.e.*, $h = \frac{\lambda}{4}$). This is not feasible as the signals have very high wavelengths.

Transmission with reasonable length of the antenna is possible with high frequency signals. Therefore, it is necessary to translate the information in the original low frequency base band signal into high or radio frequencies.

(*ii*) **Effective power radiated by the antenna:** The power radiated is inversely proportional to square of the wavelength. For an antenna of fixed height, the power radiated increases with decreasing ë, *i.e.*, increasing the frequency. Therefore for a good transmission, we need high frequencies. Superimposing the signals with high frequency radiowaves serves this purpose.

(*iii*) **Mixing up of signals from different transmitters:** When baseband information signals from many transmitters pass through the channel simultaneously, all these signals get mixed up and there is no simple way to distinguish among them. This can be resolved by using communication at high frequencies and allotting a band of frequencies to each message signal for its transmission.

Effects of Modulation

A sinusoidal carrier wave can be given as, $c(t) = A_c \sin(\omega_c t + \phi)$

$c(t),\ A_c,\ \omega_c$ and ϕ are the signal strength, amplitude, angular frequency and initial phase of the carrier wave.

During modulation any of the three parameters, vis amplitude, angular frequency or the phase of the carrier wave is modified by the information signal.

This results in three types of modulation:

(*i*) Amplitude modulation (AM) (*ii*) Frequency modulation (FM) (*iii*) Phase modulation (PM)

Modulation can be done with pulse shaped signals also. The significant characteristics of a pulse are pulse amplitude, pulse duration or pulse width, and pulse position. Accordingly, different types of pulse modulation are:

(*i*) Pulse amplitude modulation (PAM)

(*ii*) Pulse duration modulation (PDM) or pulse width modulation (PWM)

(*iii*) Pulse position modulation (PPM)

6. AMPLITUDE MODULATION (AM)

Amplitude modulation is the process in which the amplitude of a high frequency carrier wave is made proportional to the instantaneous amplitude of the audio frequency signal.

Theory: Let the carrier wave be represented by

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

Let the modulating signal be represented by

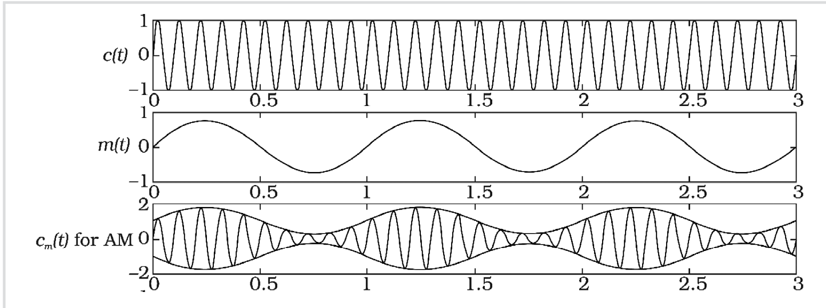
$$m(t) = A_m \sin \omega_m t$$

The modulated signal can be represented as

$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$
$$= A_c (1 + \quad \sin \omega_m t) \sin \omega_c t$$

(As the amplitude is changed according to the modulating signal)

Also, $\mu = \frac{A_m}{A_c}$, the modulation index. Usually $\quad \le 1$ to avoid distortion.

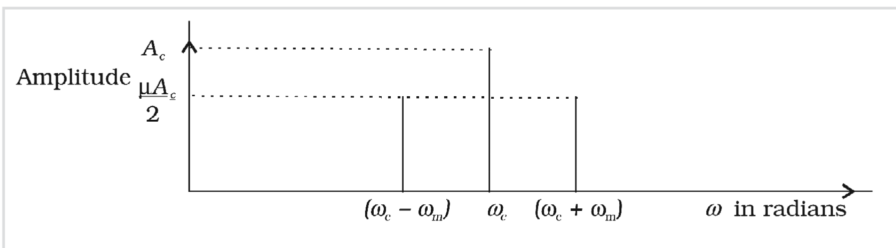


Now, $c_m(t) = A_c \sin\omega_c t + A_c \sin\omega_m t . \sin\omega_c t$

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

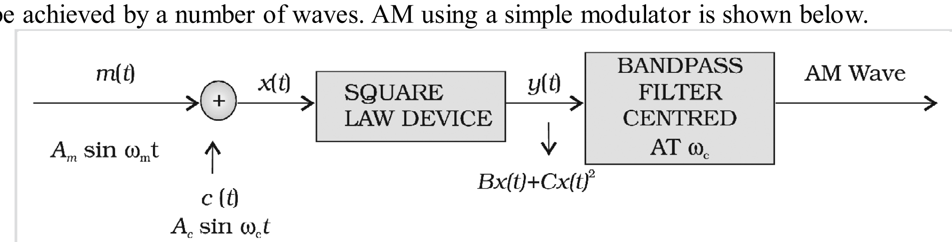
(using $\sin A \sin B = \frac{1}{2}[\cos(A-B) - \cos(A+B)]$)

Here, $(\omega_c - \omega_m)$ is called the lower side frequency and $(\omega_c + \omega_m)$ is referred to as the upper side frequency. The modulated signal consists of additional frequencies (apart from ω_c) known as sidebands. It is shown below.



7. PRODUCTION OF THE AM WAVE

AM can be achieved by a number of waves. AM using a simple modulator is shown below.



The modulating signal, $A_m \sin\omega_m t$, is added to the carrier signal, $A_c \sin\omega_c t$, to produce their resultant signal $x(t)$ which is passed through a square law device.

Here, $x(t) = A_m \sin\omega_m t + A_c \sin\omega_c t$ … (*i*)

The square law device is a non-linear device that produces the output

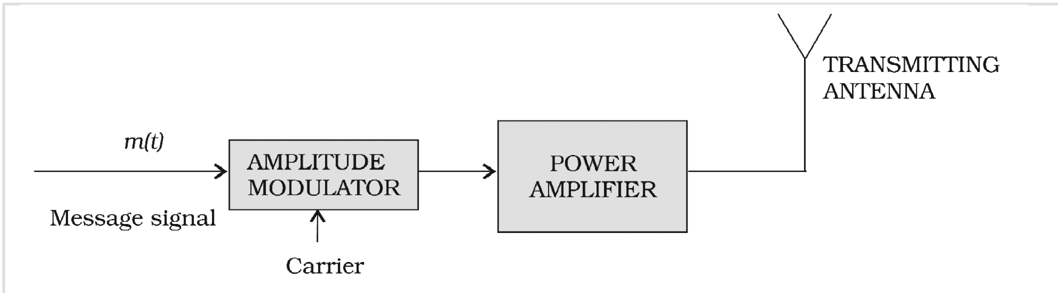
$y(t) = Bx(t) + Cx^2(t)$ … (*ii*)

Putting (*i*) in (*ii*) and simplifying,

$$y(t) = BA_m \sin\omega_m t + BA_c \sin\omega_c t$$
$$+\frac{CA_m^2}{2} + A_c^2 - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t \qquad \ldots (iii)$$
$$+ CA_m A_c \cos(\omega_c - \omega_m)t - CA_m A_c \cos(\omega_c + \omega_m)t$$

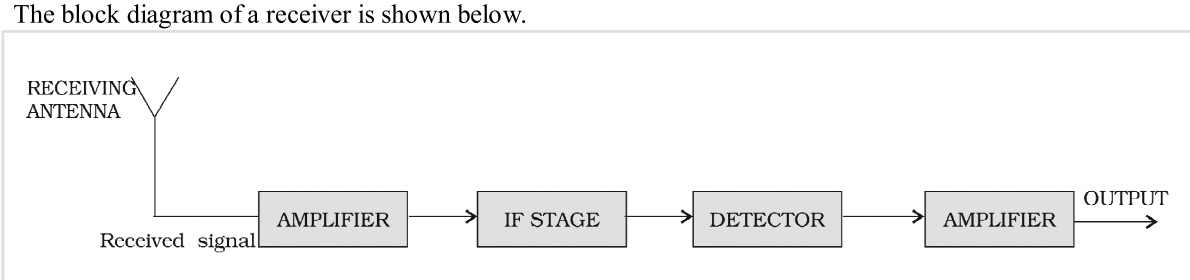
Equation (*iii*) shows that the signal has dc components also, which is eliminated using a band pass filter. The output of the band pass filter is the AM wave. These AM waves are further amplified by a power amplifier and then transmitted using a suitable antenna.

The block diagram of an AM transmitter is given below.



Demodulation of AM Waves

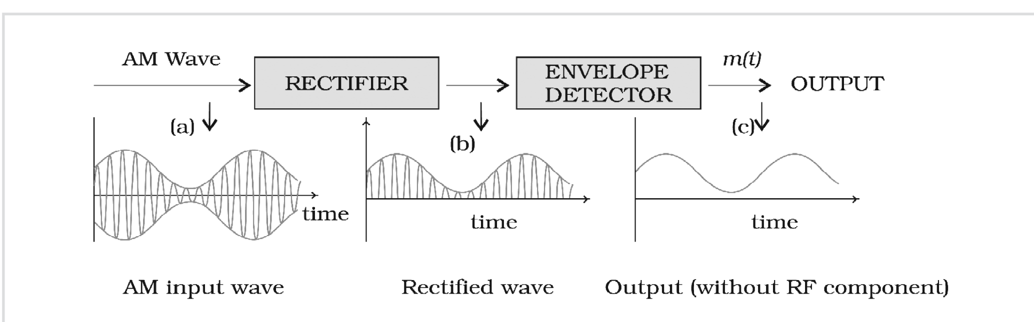
- Demodulation or detection refers to the reconstruction of the original signal from the modulated waves. This is done at the receiver.
  The block diagram of a receiver is shown below.



- During transmission, the waves undergo attenuation. Therefore, the incoming AM waves are amplified using a radio frequency amplifier.
- Then the carrier frequency is changed to a lower frequency by means of an intermediate frequency (IF) stage.
- The resulting signals are fed to the detector in which the original audio frequency signals are extracted.
- Then they are amplified using an AF amplifier and the output is fed to the device which reproduces the signals in the original form (e.g. loud speaker converts electrical signals into corresponding sound waves).

Detection

- AM waves contain both positive and negative portions.
- Detection is done by a rectifier, which rejects negative portion and admits only the positive part.
- The modulating signal is retrieved by an envelope detector, which may use a RC circuit.
  The following figure shows the process of detection.



Limitations of AM

- The quality of audio signals is poor.
- The audio signal is affected by atmospheric and industrial noise or disturbances.
- The efficiency is low.

Previous Years Questions

2012

1. Distinguish between 'Analog and Digital signals'.

2. Write any two factors which justify the need for modulating a signal.

Draw a diagram showing an amplitude modulated wave by superposing a modulating signal over a sinusoidal carrier wave.

2011

1. (i) Define modulation index.

(ii) Why is the amplitude of modulating signal kept less than the amplitude of carrier wave?

2. Draw a schematic diagram showing the (i) ground wave (ii) sky wave and (iii) space wave propagation modes for em waves.

Write the frequency range for each of the following:

(i) Standard AM broadcast (ii) Television (iii) Satellite communication

2010

1. Explain the function of a repeater in a communication system.

2. What is the range of frequencies used in satellite communication? What is common between these waves and light waves ?

3. What is space wave propagation ? Give two examples of communication system which use space wave mode.

A TV tower is 80 m tall. Calculate the maximum distance upto which the signal transmitted from the tower can be received. **[Ans. 32 km]**

2009

1. By what percentage will the transmission range of a TV tower be affected when the height of the tower is increased by 21%. **[Ans. 10%]**

2008

1. A transmitting antenna at the top of a tower has a height of 36 m and the height of the receiving antenna is 49m. What is the maximum distance between them, for satisfactory communication in the LOS mode. (Radius of earth = 6,400 km)

[Ans. 55 km]

2. Draw a plot of the variation of amplitude versus ω for an amplitude modulated wave. Define modulation index. State its importance for effective amplitude modulation.

2007

1. Why is frequency modulation preferred over amplitude modulation for transmission of music.

2. What should be the length of dipole antenna for a carrier wave of frequency 6×10^8 Hz. **[Ans. 1 m]**

3. A TV tower has a height of 71 m. What is the maximum distance upto which TV transmission can be received. Given that the radius of the earth = 6400 km. **[Ans. 30.14 km]**

4. Suggest a possible communication channel for the transmission of a message signal which has a bandwidth of 5 MHz. **[Ans. Video signal & TV signals]**

5. What is modulation. Explain the need of modulating a low frequency information signal.

2006

1. What is meant by sky wave propagation of EM waves.

2. Define the term modulation. Name three different types of modulation used for a message signal using a sinusoidal continuous carrier wave. Explain the meaning of any one of these.

2005

1. What should be the length of the dipole antenna for a carrier wave of frequency 3×10^8 Hz.

2. Give reasons for the following: **[Ans. 0.5 m]**

(*i*) Long distance radio broadcasts use short-wave bands.

(*ii*) Satellites are used for long distance TV transmission.

3. Distinguish between analog and digital communication. Write any two modulation techniques employed for the digital data.

2004

1. Name the type of modulation scheme preferred for digital communication.

2. Why is shortwave band used for long distance radio broadcast.

3. A T.V. tower has a height of 400 m at a given place. Calculate the coverage range, if the radius of the earth is 6,400 km. **[Ans. 71.5 km]**