Revision Notes

Class – 12 Physics

Chapter 15 - Communication System

Introduction

We live in an information-rich world. It is necessary to convey information from one entity to another. Communication is the act of successfully sending and receiving messages from one location to another.

In the preceding definition, the term "successful" connotes a variety of things, including

- The sender and receiver have a common understanding on how to interpret the information.
- Communication that is of high quality, with no additions, deletions, or changes to the real information.

The ever-increasing needs of humans in the sphere of communication put pressure on technology.

- Information complexity
- Transmission speed

Communication has evolved

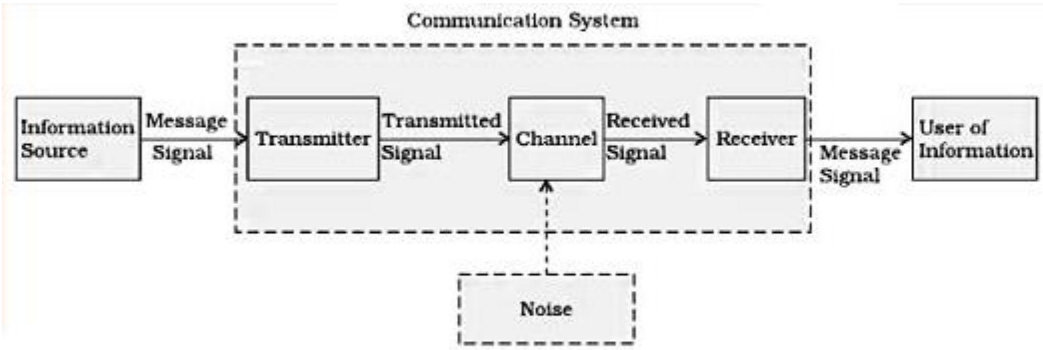
The table below depicts how actual couriers who travelled from one location to another evolved into today's reality, in which information is delivered to your doorstep at any time and with ease of access.

Time period	Event	Remarks

Time when Kings ruled	Notification to the public. Messages of peace and conflict from one country to another	Messengers were sent from one location to another. Drummers announced the King's decisions.
1835	F.B.Morse and Sir Charles Wheatstone invented the telegraph.	The number of messengers physically travelling from one location to another has decreased.
1876	Alexander Graham Bell and Antonio Meucci invented the telephone.	This communication is still very useful today.
1895	Jagadis Chandra Bose and G Marconi's Wireless Telegraphy	From wires to wireless, there has been a significant shift in communication history.
1936	John Logi Baird's television broadcast	Even today, it is in use.
1955	Alexander Bain's Radio FAX	Even today, it is in use.
1968	JCR LIcklider's ARPANET	File transfer from one computer to another was feasible for the first time on the internet.
1975	Bell Laboratories' Fiber Optics	Communication that is more cost-effective
1989-91	Tim Berners-World Lee's Wide Web	In today's environment, getting information has never been easier.

Communication System

The following is a diagram of a typical communication system



The basic elements of communication are the transmitter, channel, and receiver, as seen above. The transmitter and receiver may be in different geographical locations. The Channel is the link between the transmitter and receiver.

Information Source- The source generates a signal that contains the information that must be delivered.

Signal- The term "signal" refers to information in an electrical form suitable for transmission.

Transmitter – Converts the source signal into a format that can be transmitted across the channel.

Channel – The physical medium that connects the transmitter and receiver is the channel. Wires, cables, and wireless channels are all options for the channel.

Noise – Due to channel imperfections, the sent signal may be distorted as it travels down the channel.

As a result, noise is defined as unwanted signals that tend to disrupt the communication process from the transmitter to the receiver.

Receiver – The corrupted form of the signal reaches the receiver due to noise and other causes. For delivery to the user, the receiver must reconstruct the signal into a recognisable version of the original message. The output is the signal at the receiver.

Modes of communication

Point to point communication – The transmitter and receiver are connected by a single wire.

A single transmitter and receiver communicate with each other.

Telephone, as an example

Broadcast mode – Despite the fact that information is sent by a single transmitter, there are a vast number of receivers.

Television and radio are two examples

Communication – Terminology

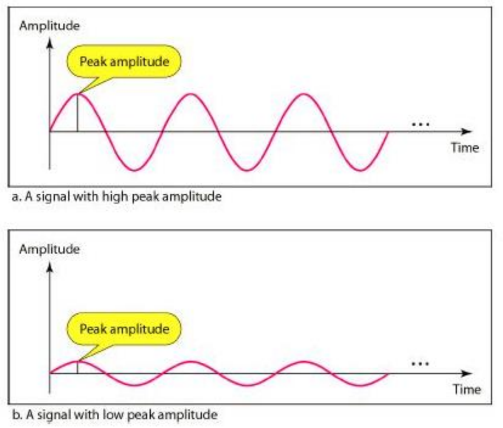
1. Transducer – A transducer is a device that transforms energy from one form to another. Electrical transducer: A device that translates physical variables such as pressure, displacement, force, and temperature into electrical signal fluctuations. As a result, the output would be an electrical signal.

2. Signal Types – Signals are two sorts of information in electrical form appropriate for transmission.

Analog signal –

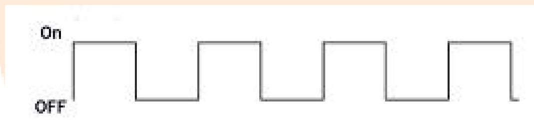
- Constant voltage and current fluctuations. As a result, single-valued time functions.
- A sine wave is a basic analogue signal.

Take, for example, television sound and picture transmissions.



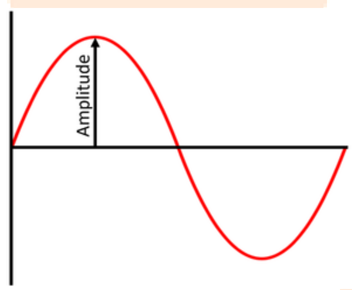
Digital signal – A digital step value is utilised;

- A binary system is used, with 0 representing a low level and 1 representing a high level.
- In popular use are universal digital coding schemes such as BCD (Binary Coded Decimal) and ASCII (American Standard Code of Information Interchange).

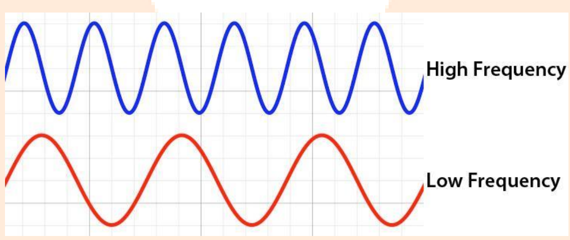


3. Amplitude –

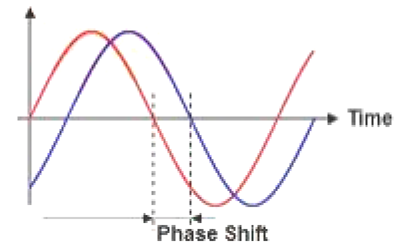
The maximum amount of vibration or oscillation when compared to the equilibrium position



4. Frequency – The frequency is defined as the number of waves that pass through a specific location in each amount of time.



5. Phase – The phase shift, which is the percentage of the wave cycle that has elapsed relative to the origin, indicates a phase difference between the two waves pictured below.



1. Attenuation- Attenuation refers to the signal's decrease of strength as it travels across a medium.

2. Amplification – Amplification is the technique of employing an electronic circuit to increase the signal's amplitude. The signal's intensity is likewise increased because of this. As a result, it compensates for signal attenuation.

3. Range – It's the furthest distance between the source and the destination at which the signal is strong enough to be received.

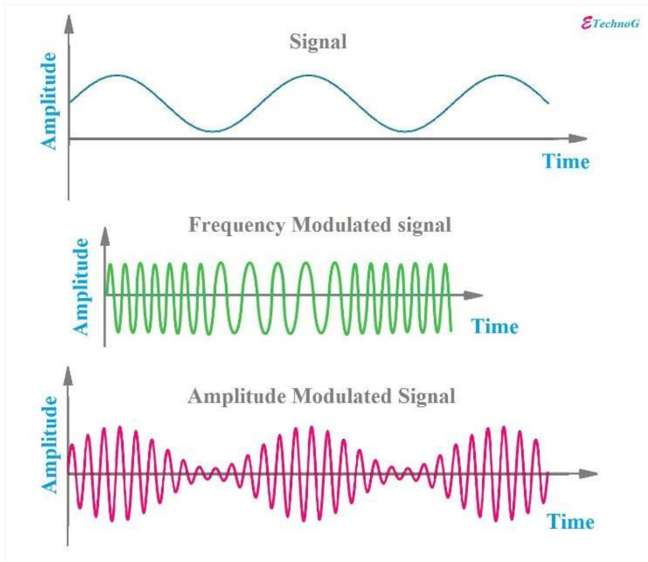
4. Bandwidth – The frequency range in which the equipment functions is referred to as this.

5. Modulation – Low-frequency information signals are incapable of being conveyed across long distances. As a result, it is superimposed on a high-frequency wave at the transmission point. This high-frequency wave serves as a data carrier. This is called modulation.

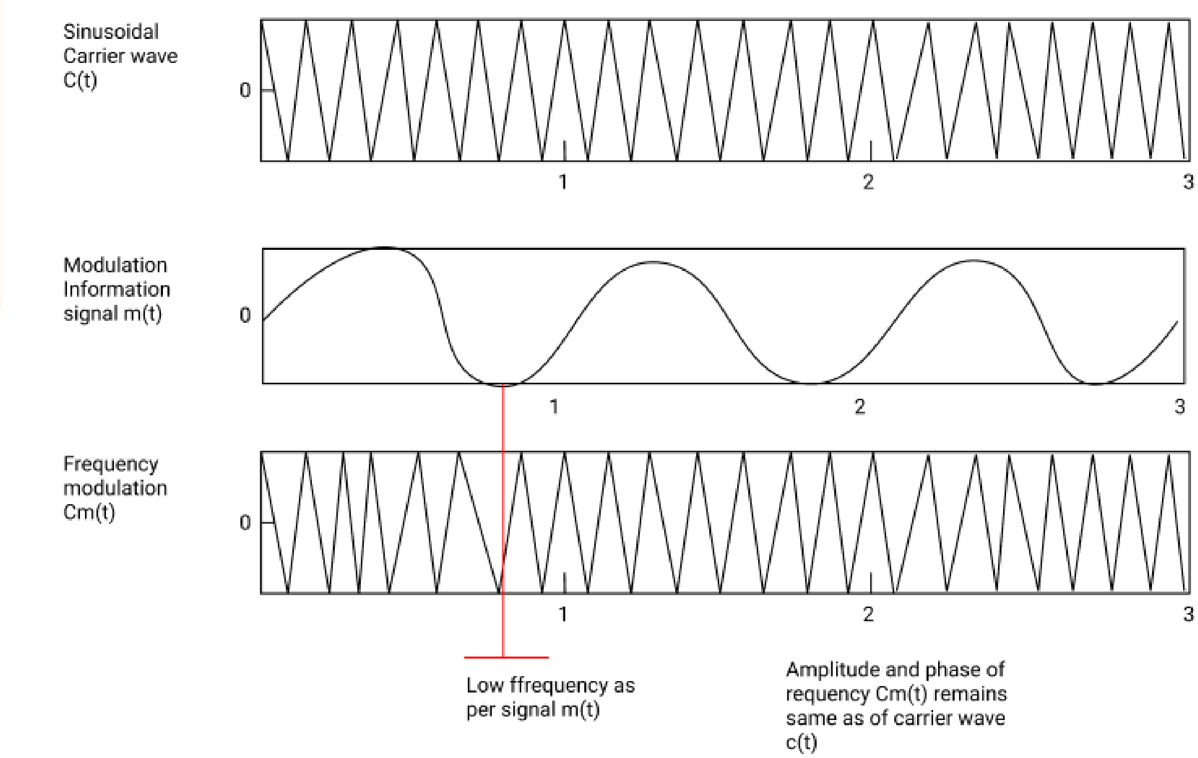
Sinusoidal wave modulation

There are three types of modulation: 1. amplitude modulation, 2. frequency modulation, and 3. phase modulation. Frequency modulation and phase modulation are two examples of frequency modulation.

Amplitude modulation – The carrier wave's amplitude varies in response to the information signal.

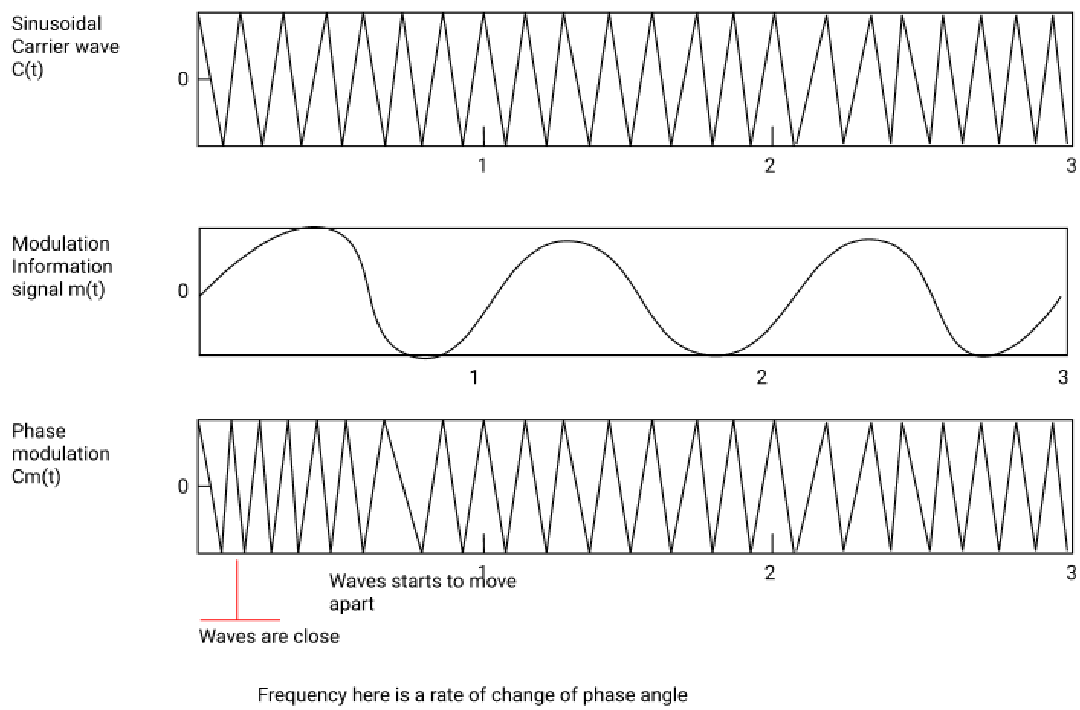


Frequency modulation –The carrier wave's frequency varies in response to the information signal.



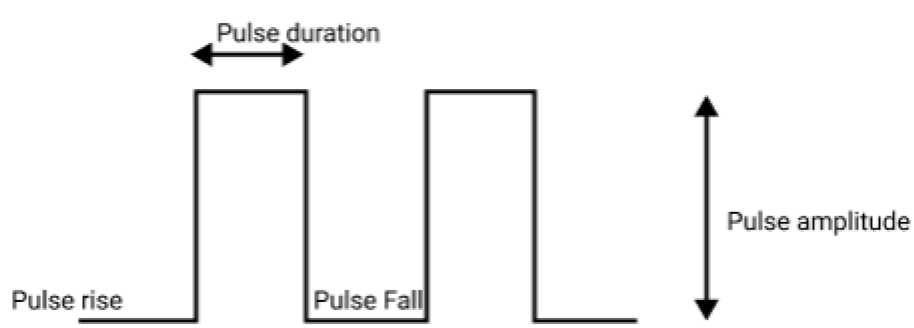
Phase modulation –

The carrier wave's phase changes in response to the information stream.



Pulse wave modulation

Pulse wave modulation can be divided into three categories: (a) pulse amplitude modulation, (b) pulse width modulation, and (c) pulse position modulation.



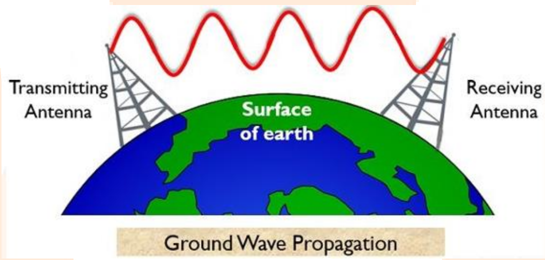
6. **Demodulation –** Demodulation is the process of retrieving information from the carrier wave at the receiver. This is the opposite of modulation.

7. **Repeater –** A repeater is a device that combines the functions of a receiver and a transmitter. The signal from the transmitter is picked up by a repeater, which amplifies it and retransmits it to the receiver. As a result, repeaters are employed to extend the communication system's range. A communication satellite, for example, is a space-based repeater station.

Electromagnetic waves propagation

When employing radio waves for communication, the transmitter antenna emits electromagnetic waves. These waves travel through space and eventually arrive at the receiving antenna on the other end. Some wave propagation methods have been briefly discussed below.

Ground or Surface wave propagation:



The ground has a significant influence on the transmission of signal waves from the sending antenna to the receiving antenna in this form of wave propagation. The signal wave travels across the earth's surface.

The ground wave produces current in the ground while propagating on the earth's surface. It also curves around the corners of the earth's objects.

As a result, the ground wave's energy is progressively absorbed by the earth, and the ground wave's power declines.

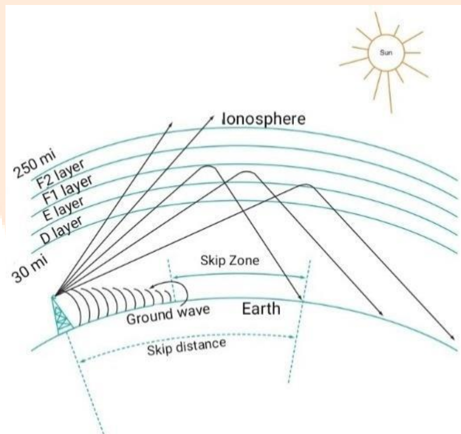
With increasing distance from the transmitting station, the ground wave's power drops. Attenuation is the term for the phenomena of a ground wave losing its power.

The attenuation of ground waves increases rapidly as the frequency of the waves increases.

As a result, ground wave communication is unsuitable for high-frequency signal waves or communication over long distances.

The antennas should have a size that is appropriate to the signal wavelength in order to broadcast signals efficiently.

Sky waves:



In the propagation of sky waves, the ionosphere plays a crucial role. The earth's atmosphere is separated into several parts, including the Troposphere, Stratosphere, Mesosphere, and Ionosphere, as we all know.

The ionosphere, often known as the thermosphere because of the rapid increase in temperature, is the outermost part of the earth's atmosphere.

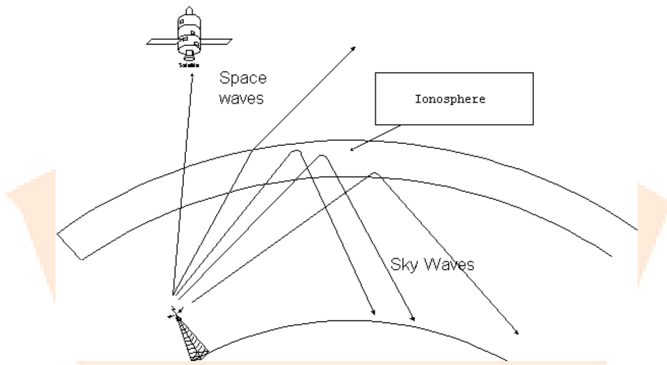
We have numerous layers above the troposphere, such as D (part of stratosphere), E (part of stratosphere), F1 (part of mesosphere), and F2 (part of mesosphere) (part of ionosphere)

The presence of a vast number of ions or charged particles gives the ionosphere its name. The absorption of UV and other high-energy light from the sun by the air molececues causes ionisation.

In skywave propagation, the phenomena of electromagnetic waves bending in this layer and diverting them towards the earth is beneficial. In optics, this is analogous to total internal reflection.

In sky wave propagation, radiowaves with frequencies ranging from 1710 kHz to 40 MHz are propagated.

Space waves:



From the transmitting antenna to the receiving antenna, space waves travel in a straight path.

As a result, space waves are employed for line-of-sight communication like television broadcasting, microwave links, and satellite communication.

The field of vision Communication is hampered by (a) line of sight distance and (b) the earth's curvature.

The line-of-sight propagation is impeded at some point due to the curvature of the globe.

The line-of-sight distance between the transmitting and receiving antennas is the distance at which they can see each other. It's also known as the dM range of communication.

The transmitting and receiving antennas' heights can be increased to extend the range of space wave communication.

The maximum line of sight distance (communication range) dM between two transmitting antennas of height hT and receiving antennas of height hR above the earth is calculated as follows:

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

Modulation and its necessity

In general, a message signal is not a single frequency sinusoidal signal. However, it is dispersed throughout a frequency range known as the signal bandwidth.

If we want to send an electronic signal in the audio frequency range, say 20 Hz to 20 kHz, over a long distance, we must consider things like

a. Size of antenna: Both transmission and reception need the use of an antenna.

The antenna should be at least 4 times the wavelength of the signal, where is the wavelength of the signal.

If we choose frequency 15,000= Hz in the audio frequency range. Then

$$\lambda = \frac{c}{10^8 \times 3} = \vartheta$$

=15,000 = 20,000 m is the result.

As a result, antenna length

$$\frac{\lambda}{4} = \frac{20,000}{4} = 5000m$$

An antenna with a height of 5000 metres is almost hard to design.

As a result, the transmission frequency should be increased to the point where the antenna length is within 100 metres, which is practicable.

This demonstrates the importance of transforming low-frequency signals to high-frequency signals before to transmission.

b. Antenna's effective power radiated:

The antenna's effective power rating

$$P = \frac{E}{t}$$

$$E = h\vartheta = \frac{hc}{\lambda}\left(\frac{c}{\lambda}\right)$$

$$P = \frac{E}{t} = \frac{hc}{\lambda}\left(\frac{c}{\lambda}\right)$$

According to research, if l is the antenna's linear length, then P is proportional to

$$\left(\frac{I}{\lambda}\right)^2$$

As a result, great power and thus narrow wavelength and high frequency waves are necessary for good transmission.

In this scenario, too, high frequency waves are unavoidable.

c. Avoiding signal mixing from many transmitters:

When multiple transmitters transmit baseband information signals at the same time, the signals become jumbled.

It's impossible to tell the difference between them.

Communication at high frequencies and allocating a band of frequencies to each emitter to avoid mixing are two possible solutions.

This is what various radio and television stations are claiming.

As a result, we recognise the importance of modulation.

Band width

The amount of data that can be transmitted in each length of time is also known as bandwidth.

Signals – Bandwidth:

Voice, music, pictures, or computer data can all be used as message signals.

The frequency ranges of each of the are distinct.

The frequency of speech signals ranges from 300Hz to 3100Hz. As a result, the bandwidth is 3100 - 300 = 2800 Hz.

Because of the high frequencies produced by musical instruments, any music requires a bandwidth of 20kHz.

The bandwidth required for video transmissions to transmit a picture is 4.2 MHz.

For transmission, the television signal, which includes both sound and picture, is normally given a bandwidth of 6MHz.

Transmission Medium – Bandwidth:

Different types of transmission media have varying bandwidth capabilities.

Coaxial cables, a commonly used wire media, with a bandwidth of about 750 MHz.

Radio waves can be used to communicate in free space at frequencies ranging from hundreds of kHz to a few GHz.

In the frequency range of 1THz to 1000 THz (THz – Tera Hertz; 1THz = 1012Hz), optical fibres are utilised.

As previously stated, allotting a band of frequencies to a certain transmitter is common practise to avoid signal mixing.

This frequency allocation is managed by the International Telecommunication Union.

Fixed frequency bands are used for services such as FM broadcasting, television, cellular mobile radio, and satellite communication.

Let's take a closer look at amplitude modulation.

Amplitude modulation

The amplitude of the carrier wave is modified in line with the amplitude of the information signal or modulating signal in amplitude modulation, as we all know.

In the case of a sinusoidal modulating wave,

$$m(t) = A_m \sin \omega_m t \quad \ldots\ldots\ldots\ldots(1)$$

A_m is the Amplitude of modulating wave

$\omega_m - 2\pi\omega_m$ is the Angular frequency of modulating wave

For carrier wave

$$C_m(t) = A_c \sin \omega_c t \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where

A_c is Amplitude of carrier wave

$\omega_m - 2\pi\omega_c$ is the Angular of carrier wave

The amplitude of the carrier wave is altered by adding the amplitude of the modulating signal.

$A_c + A_m \sin\omega_m t \; C_m(t) = (A_c + A_m \sin\omega_m t)\sin\omega_c t$ ....(3)

Equation (3) RHS by

A_c should be multiplied and divided.

$C_m(t) = A_c(A_c / A_c + A_m / A_c \sin\omega_m t)\sin\omega_c t$ ....(4)

Replace $A_m / A_c = \mu$

To avoid distortion,

μ is called the Amplitude Modulation Index and is always less than or equal to 1.

$C_m(t) = A_c sin\omega_c t + \mu A_c \sin\omega_c t \sin\omega_m t$ ....(5)

We know that,

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

Here,

$$\sin\omega_c t \sin\omega_m t = \left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]$$

$$C_m(t) = \frac{A_c \sin\omega_c t + \mu A_c}{2\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]} \qquad ....(6)$$

$$C_m(t) = \frac{A_c \sin\omega_c t + \mu A_c}{2\left[\dfrac{\cos(\omega_c - \omega_m)t - \mu A_c}{\cos(\omega_c + \omega_m)t}\right]}$$

The amplitude modulated signal, as shown in Equation (6), is made up :

Frequency ω_c carrier wave

The frequency of a sinusoidal wave $\omega_c - \omega_m$

The frequency of a sinusoidal wave $\omega_c + \omega_m$

Side bands refer to the two additional waves. Side band frequencies are the frequencies of these bands.

Lower side band frequency = $\omega_c - \omega_m$

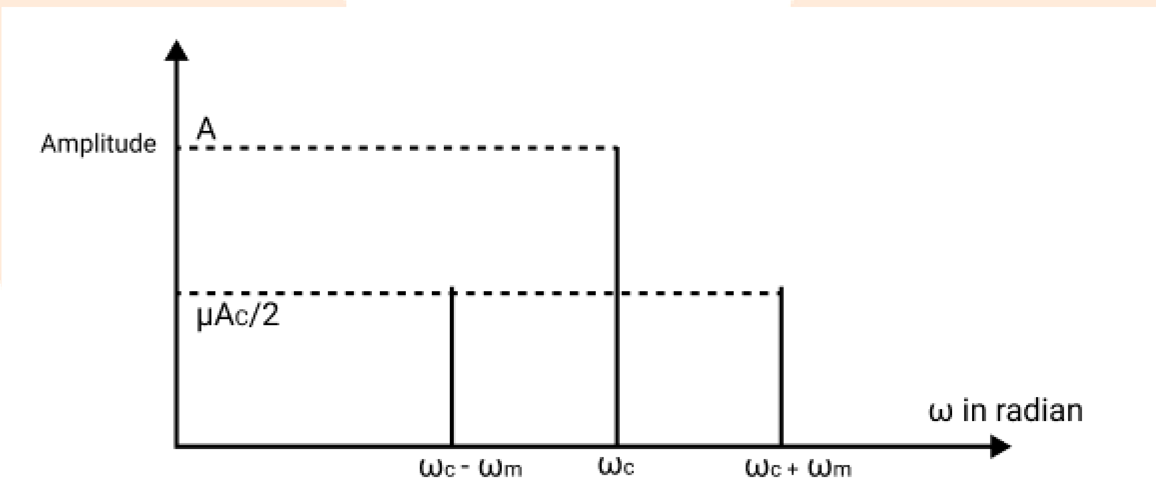
Upper side band frequency = $\omega_c + \omega_m$

The AM wave's band width is equal to the frequency of the lower side band minus the frequency of the upper side band.

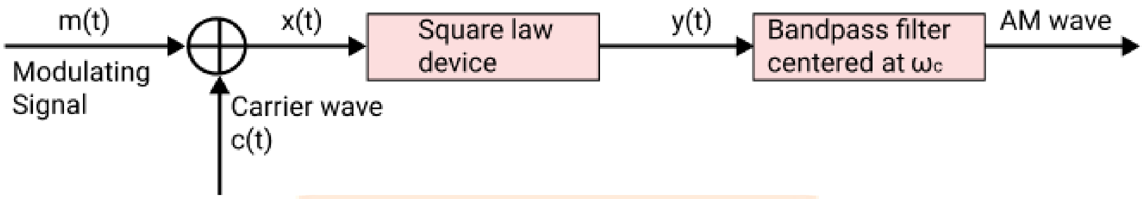
$$(\omega_c + \omega_m) - (\omega_c - \omega_m) = 2\omega_m$$

(Twice the modulating signal's frequency)

Diagrammatic depiction



Amplitude modulated wave generation



The modulating signal is represented by, as we all know.

$$m(t) = A_m \sin \omega_m t \;\ldots\ldots\ldots\ldots(1)$$

A_m is the Amplitude of modulating wave

$\omega_m - 2\pi\omega_m$ is the Angular frequency of modulating wave

For carrier wave

$C_m(t) = A_c \sin \omega_c t \;\ldots\ldots\ldots\ldots\ldots(2)$

Where

A_c is Amplitude of carrier wave

$\omega_m - 2\pi\omega_c$ is the Angular of carrier wave

As a result of the modulating signal being added to the carrier wave, the representation is

$$x(t) = A_m \sin \omega_m t + A_c \sin \omega_c t$$

A square law gadget receives the above signal (non-linear device)

$$y(t) = Bx(t) + C\left[x(t)\right]^2$$

B and C are Arbitrary constants

Substitute with $x(t)$ in $y(t)$ using the formula

$$(A+B)^2 = A^2 + B^2 + 2AB$$

$$y(t) = B\left[A_m \sin \omega_m t + A_c \sin \omega_c t\right] + C\left[A_m \sin \omega_m t + A_c \sin \omega_c t\right]^2$$
$$= \ B\left[A_m \sin \omega_m t + A_c \sin \omega_c t\right] + C\left[A_m^{\ 2} \sin^2 \omega_m t + A_c^{\ 2} \sin^2 \omega_c t + 2A_m A_c \sin \omega_m t \sin \omega_{ct}\right]$$

We know that,

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

$$\sin \omega_c t \sin \omega_m t = \frac{1}{2}\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]$$

Which is also,

$$\sin^2 A = \frac{(1-\cos 2A)}{2}$$

Therefore,

$$\sin^2 \omega_c t = \frac{(1-\cos 2\omega_c t)}{2}$$
$$\sin^2 \omega_m t = \frac{(1-\cos 2\omega_m t)}{2}$$

$y(t)$ can also be written as

$$y(t) = B\left[A_m \sin \omega_m t + A_c \sin \omega_c t\right] + \frac{cA_m^{\ 2}}{2}(1-\cos 2\omega_c t) + 2A_m A_c (\frac{c}{2})\left[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t\right]$$

$$y(t) = BA_m \sin \omega_m t + BA_c \sin \omega_c t + \frac{c}{2}\left[A_m^{\ 2} + A_c^{\ 2}\right] - \frac{cA_m^{\ 2}}{2\cos 2\omega_m t} - \frac{cA_c^{\ 2}}{2\cos 2\omega_c t} + cA_m A_c \cos(\omega_c - \omega_m)t$$
$$-cA_m A_c \cos(\omega_c + \omega_m)t$$

There is a d.c. term in the equation above

$$\frac{1}{2}c\left[A_m^{\ 2} + A_c^{\ 2}\right]$$

and the sinusoidal waves of frequency which is

$$\omega_c, \omega_m, 2\omega_m, \left(\omega_c - \omega_m\right) and \left(\omega_c + \omega_m\right)$$

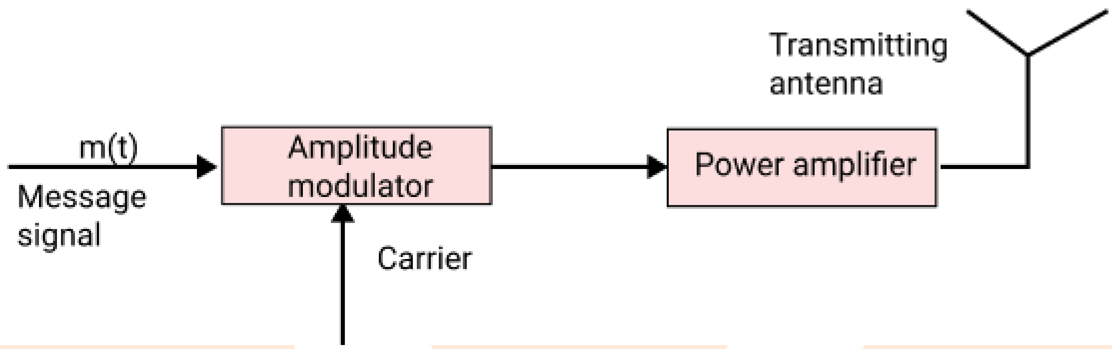
The signal is routed through a band pass filter with a central frequency of ω_c

Low and high frequencies are rejected because of this. The filter rejects d.c,

$\omega_c, \omega_m, 2\omega_m, (\omega_c - \omega_m)$ and the frequencies $(\omega_c - \omega_m)$ *and* $(\omega_c + \omega_m)$ are passed.

The wave is amplitude modulated.

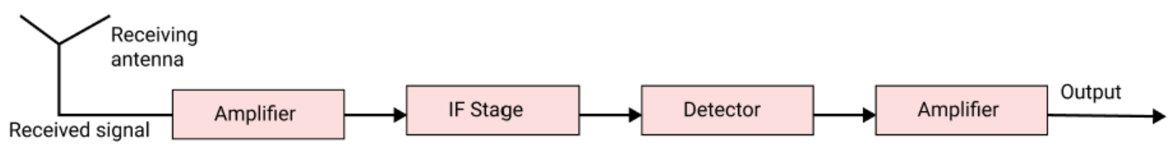
As such, this wave cannot be passed. It must be amplified before being fed to a suitable antenna for radiation.



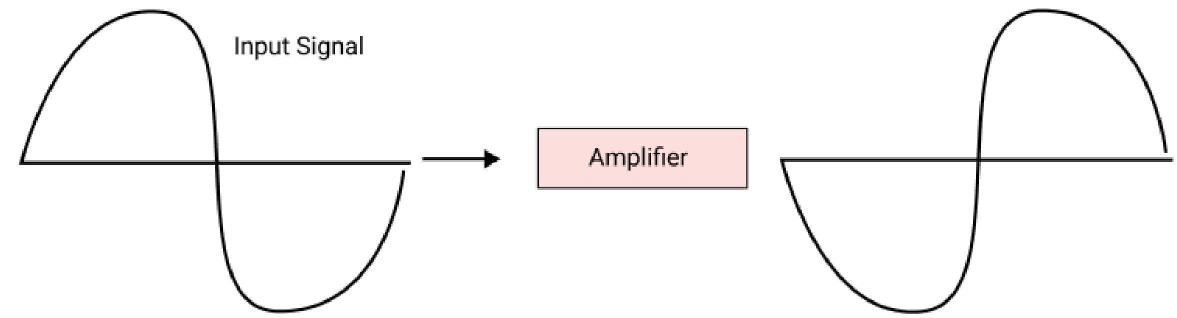
Amplitude modulated wave detection

The process of recovering the modulating signal from the modulated carrier wave is known as detection.

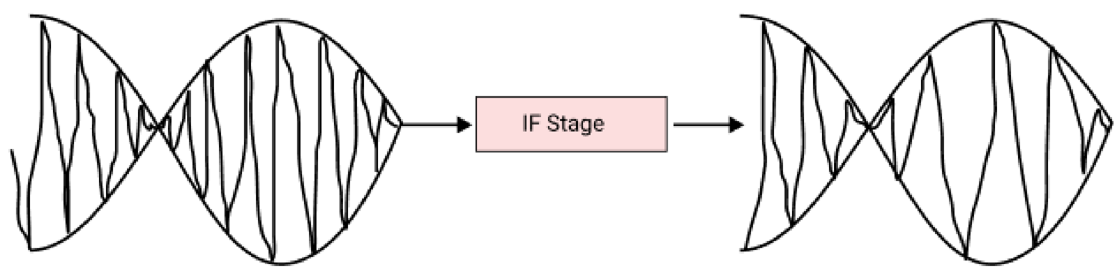
The sent message is weakened as it travels across the channel.



The signal is received by the receiving antenna, which is subsequently amplified.



Intermediate frequency (IF) stage changes the carrier frequency to a lower frequency.



Process of Detection:

After that, it goes through the detector.

As a result, INPUT stands for modulated carrier wave of frequencies

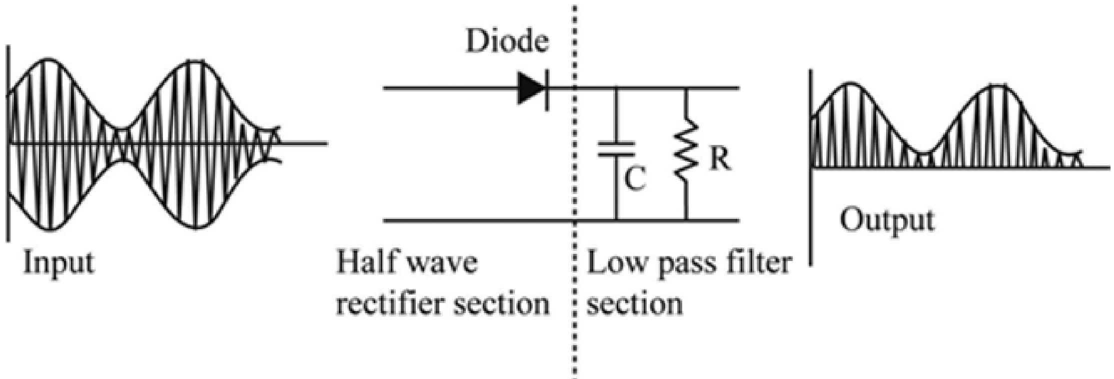
$\omega_c\left(\omega_c-\omega_m\right) and \left(\omega_c+\omega_m\right)$

OUTPUT – Original signal

$m(t)$ of frequency ω_m

Rectifier, as we know, is made up of a simple circuit that produces the following input and output:

The envelope detector returns the signal's envelope.



Amplitude modulated wave detection block diagram