Communication System

DISCLAIMER

Communication System

Introduction

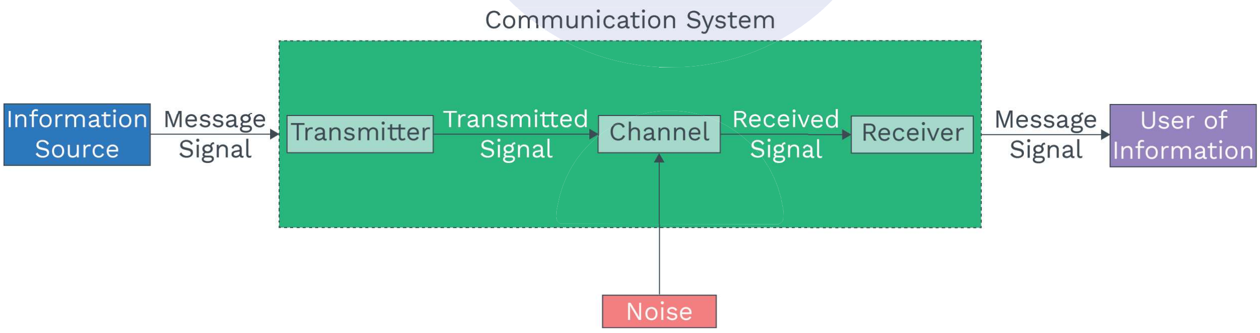
In Modern communication systems the information is first transferred into electrical signals & then sent electronically. This has the advantage of speed, reliability, and possibility of communicating over long distances. You are using these every day such as telephones, TV and radio transmission, satellite communication etc.

KEY POINTS

- Transmitter
- Channel
- Receiver

Elements of A communication System:-

Communication pervades all stages of life of all living creatures. Irrespective of its nature, every communication system has 3 essential elements- Transmitter, medium/channel and receiver. The block diagram shown in depicts the general form of a communication system.



Rack your Brain

A digital signal

1. is less reliable than analog signal
2. is more reliable than analog signal
3. is equally reliable as the analog signal
4. signal reliable is Meiningen

SOME MAJOR MILESTONES IN THE HISTORY OF COMMUNICATION		
YEAR	**EVENT**	**REMARKS**
Around 1565 A.D.	The reporting of the delivery of a child by queen using drum beats from a distant place to King Akbar.	It is believed that minister Birbal experimented with the arrangement to decide the number of drummers posted between the place where the queen stayed and the place where the king stayed.
1835	Invention of telegraph by Samuel F.B. Morse and Sir Charles Wheatstone	It resulted in tremendous growth of messages through post offices and reduced physical travel of messengers considerably.
1876	Telephone invented by Alexander Graham Bell and Antonio Meucci	Perhaps the most widely used means of communication in the history of mankind.
1895	Jagadis Chandra Bose and Guglielmo Marconi demonstrated wireless telegraphy.	It meant a giant leap – from an era of communication using wires to communicating without using wires. (wireless)
1936	Television broadcast(John Logi Baird)	First television broadcast by BBC
1955	First radio FAX transmitted across continent.(Alexander Bain)	The idea of FAX transmission was patented by Alexander Bain in 1843.
1968	ARPANET- the first internet came into existence(J.C.R. Licklider)	ARPANET was a project undertaken by the U.S. defence department. It allowed file transfer from one computer to another connected to the network.
1975	Fiber optics developed at Bell Laboratories	Fiber optical systems are superior and more economical compared to traditional communication systems.
1989-91	Tim Berners-Lee invented the **World Wide Web**.	WWW may be regarded as the mammoth encyclopedia of knowledge accessible to everyone round the clock throughout the year.

Basic Terminology Used In Electronic Communication System

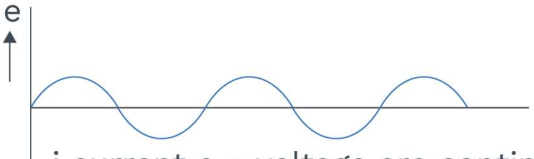
We have become familiar with some words like information source, transmitter, receiver, channel, noise, etc. It would be easy to know the principles underlying any communication if we get ourselves acquainted with the following basic terminology.

- **Transducer:-** Any device that converts one form of energy into another can be defined as a transducer. In electronic communication systems, we usually come across devices that have either their inputs or outputs in the electrical form. All electrical transducer may be defined as a device that converts some variable (pressure, displacement, force, temperature, etc) into corresponding variations in the electrical signal at its output.

- **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. They are essentially single valued functions of time. Sine wave signal 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. Digital signals are those which can take only discrete stepwise values. 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. There are several coding schemes useful for digital communication. They employ suitable combinations of number system such as the binary coded decimal (BCD). American Standard Code for Information Interchange (ASCII) is a universally popular digital code represent numbers, letters and certain characters.

analogue signal

i or e



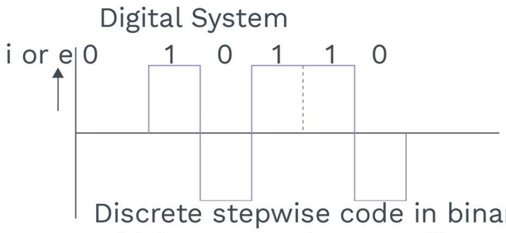
i current e = voltage are continuous and super position of sine and cosine waves

KEY POINTS

- Transducer
- Signal
- Noise
- Transmitter
- Receiver
- Attenuation
- Amplification
- Range
- Bandwidth
- Modulation
- Demodulation

Concept Reminder

Electronic communication refers to the faithful transfer of information or message (available in the form of electrical voltage and current) from one point to another point



Discrete stepwise code in binary
1-high or 'on', 0-low or 'off' 1,0

- **Noise:** Noise refers to the unwanted signals that tend to disturb the transmission and processing of message signals in a communication system. The source generating the noise may be located inside or outside the system
- **Transmitter:** A transmitter processes the incoming message signal to make it suitable for transmission through a channel and subsequent reception.
- **Receiver:** A receiver extracts the desired message signals from the received signals at the channel output.
- **Attenuation:** The loss of strength of a signal while propagating through a medium is known as attenuation.
- **Amplification:** It is the process of increasing the amplitude (and consequently the strength) of a signal using an electronic circuit called the amplifier. Amplification is necessary to compensate for the attenuation of the signal in communication systems. The energy needed for additional signal strength is obtained from a DC power source. Amplification is done at a place between the source and the destination wherever signal strength becomes weaker than the required strength.
- **Range:** It is the largest distance between a source and a destination up to which the signal is received with sufficient strength.
- **Bandwidth:** Bandwidth refers to the frequency range over which an equipment operates, or the portion of the spectrum occupied by the signal.

Rack your Brain

Modern communication system use:

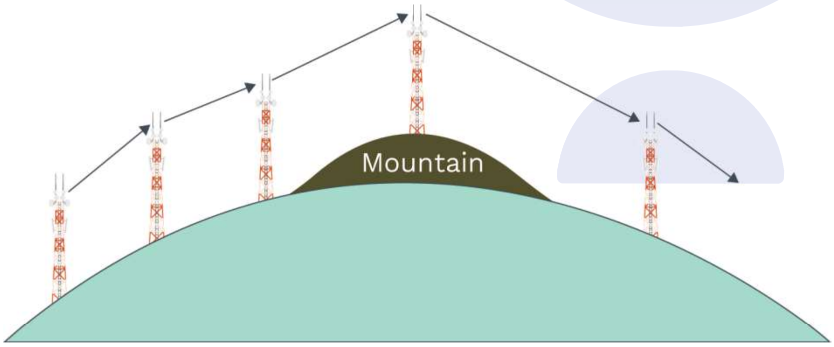
1. analog circuits
2. digital circuits
3. Combination of analog and digital circuits
4. discrete circuits

Rack your Brain

The audio signal-

1. cannot be sent directly over the air for large distance
2. can be sent directly over the air for large distance
3. possess very high frequency
4. possess very high intensity

- **Modulation:** The original low frequency message/ information signal cannot be transmitted to long distances. Therefore, at the transmitter, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation. As will be explained later, there are several types of modulation, abbreviated as AM, FM and PM.
- **Demodulation:** A repeater is a combination of a receiver and a transmitter. A repeater, picks up the signal from the transmitter, amplifies and retransmits to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend the range of a communication system as shown in figure. A communication satellite is essentially a repeater station in space.



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The process of changing some characteristic of a carrier wave in accordance with the intensity of the signal is called -
1. amplification
2. rectification
3. modulation
4. normalization

Bandwidth of Signals

(a) **Analogue signals:** The communication signals are of varied nature and have different range of frequencies e.g., speech signal has frequency range 300 Hz to 3100 Hz. Thus, the band width for speech is (3100 – 300) = 2800 Hz = 2.8 kHz. The audio range is 20 to 20 kHz the video signals have typical band width 4.2MHz. A TV signal has both audio and video, so its band width is 6 MHz

(b) **Digital Signals:** Digital signals are in the form of rectangular waves. However, a rectangular

Concept Reminder

Two important forms of communication system are: Analog and Digital. The information to be transmitted is generally in continuous waveform for the former while for the latter it has only discrete or quantised levels.

wave may be constructed using harmonic sine and or cosine waves of frequencies ν, 2ν, 3ν ....This implies infinite band width but for practical purposes higher harmonics can be neglected. No doubt the received waves are distorted version of original wave but information is not lost and rectangular signal is more or less received.

Table 1 gives an overview of various signal channels.

BAND - WIDTHS OF VARIOUS SIGNALS USED IN COMMUNICATION				
S.No.	**SIGNAL TYPE**	**SIGNAL FREQUENCY**	**BAND WIDTH**	**EXAMPLES**
1.	Voice	300 Hz - 3100 Hz	3100 - 300 = 2800 Hz	Telephone (Two wire)
2.	Music	20 Hz - 2000 Hz 20 Hz - 20 KHz	20,00 Hz (20 KHz) (20.KHz) 88 to 108 MHz	Both point to point to board cast
3.	Picture only		4.2 MHz	Picture transmission
4.	Picture + Sound (TV)		6 MHz	TV
5.	Computer Data		Depends on Data rate Generally GHz	Mobile / Desktop / Laptop etc

Bandwidth of Transmission Medium

The transmission media also have different band widths e.g., widely used coaxial cable has bandwidth ~ 750 MHz and operate below 18 GHz. The free space communication has wide range from 100 kHz to 10 GHz . Optical fibre operates at Tera hertz frequencies and has quite wide range 1 THz to 1000 THz (microwaves to UV). It provides a band width ~ 100 GHz.

Table 2 summarizes various channel band widths

BAND WIDTHS OF TRANSMISSION CHANNEL/ MEDIA USED IN COMMUNICATIONS			
S.No.	**CHANNEL**	**BANDWIDTH**	**EXAMPLES**
1.	Two wire	KHz	MW to SW
2.	Coaxial cable	750 Hz	HF
3.	Wave guides (hollow tube)	Dimension determine band width	Microwaves Tera-waves
4.	Optical fiber	1 THz to 1000 THz (IR to UV)	Optical
5.	Open space ground wave sky wave	< 1MHz 1 MHz-30 to 40 MHz	HF, VHF
6.	Space wave	> 40 MHz	VHF

SOME IMPORTANT WIRELESS COMMUNICATION FREQUENCY BANDS		
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

Space Communication

Propagation of Electromagnetic Waves in Space

In space radio communication, an antenna at the transmitter radiates electromagnetic waves which travel through space and reach the receiving antenna at the other end. During propagation not only the signal diminishes but there are several factors that influence the propagation. Atmosphere is highly dynamic system whose properties change not only with elevation but also with seasons. The propagation characteristics also depend on frequency band. The following frequency bands are used in radio communication

(a) Medium Frequency Band (MF) 300 – 3000 kHz

(b) High Frequency Band (HF) 3.0 – 30 MHz

(c) Very High Frequency Band (VHF) 30 – 300 MHz

(d) Ultra High Frequency Band (UHF) 300 – 3000 MHz

(e) Super High Frequency Band (SHF) 3.0 – 30 GHz

The following are the modes of communication through space:

Concept Reminder

Every message signal occupies a range of frequencies. The bandwidth of a message signal refers to the band of frequencies, which are necessary for satisfactory transmission of the information contained in the signal. Similarly, any practical communication system permits transmission of a range of frequencies only, which is referred to as the bandwidth of the system.

Ground Wave

To radiate signals with high efficiency, the antennas should have a size comparable to the wavelength λ of the signal (at least ~ λ/4). At longer wavelengths (i.e., at lower frequencies), the antennas have large physical size, and they are located on or very near to the ground. In standard AM broadcast, ground based vertical towers are generally used as transmitting antennas. For such antennas, ground has a strong influence on the propagation of the signal. The mode of propagation is called surface wave propagation and the wave glides over the surface of the earth. A wave induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the earth. The attenuation of surface waves increases very rapidly with increase in frequency. The maximum range of coverage depends on the transmitted power and frequency (less than a few MHz).

Sky Wave Transmission

The radio waves having frequency 2 to 30 MHz where propagating up the sky are reflected by ionosphere and return back to the earth. These waves used for communication, are known as sky waves. At a height 65 to 400 km above the earth the atmospheric gas absorbs ultraviolet and other high energetic cosmic radiations coming from sky and subsequently ionize there creating an ionic layer called ionosphere. Even in single reflection wave can cover about 4000 km distance, hence sky wave propagation is long range transmission as shown in figure.

Rack your Brain

If a carrier wave of 1000 kHz is used to carry the signal, minimum length of transmitting antenna will be equal to -

1. 300 m **2.** 150 m

3. 75 m **4.** 750 m

KEY POINTS

SKY wave transmission
- Virtual Height
- Critical frequency
- Maximum usable frequency
- Skip distance

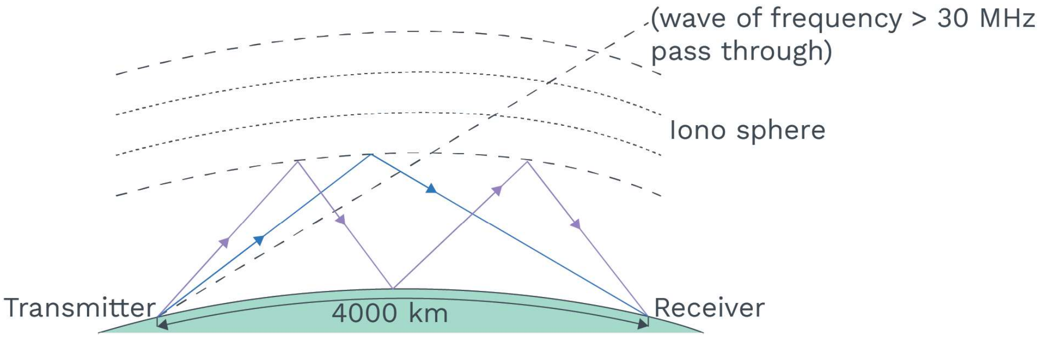
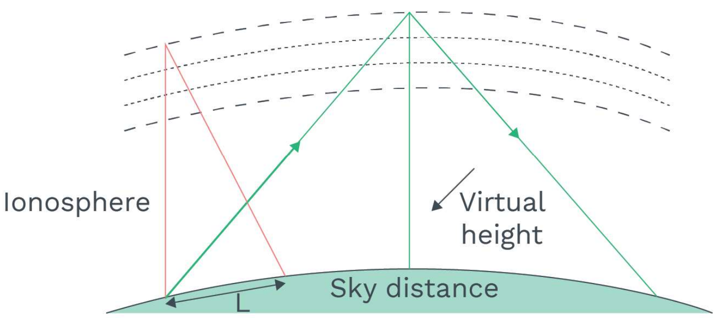


Figure. Sky wave propagation, long distance transmission

Round the globe, communication is possible using sky wave propagation. A few terms are important in sky wave propagation

(a) **Virtual Height:** The reflection of sky wave is through gradual bending like total reflection in the formation of mirage. Hence virtual height is the height through which angle of incidence is calculated to send waves at a given point as shown in figure.

(b) **Critical Frequency (f_c):** The maximum frequency reflected when beamed straight towards the layer. Frequency $f > f_c$ is not reflected.



(c) **Maximum Usable Frequency (MUF):** Radio waves when sent at an angle θ, the maximum usable frequency (MUF) is

$MUF = f_c / \cos\theta$ ....(1)

Rack your Brain

The types of modulation used for continuous wave and analogue signal are -

1. one only
2. two only
3. three only
4. none of these

Rack your Brain

In amplitude modulation what changes of the carrier wave occurs-

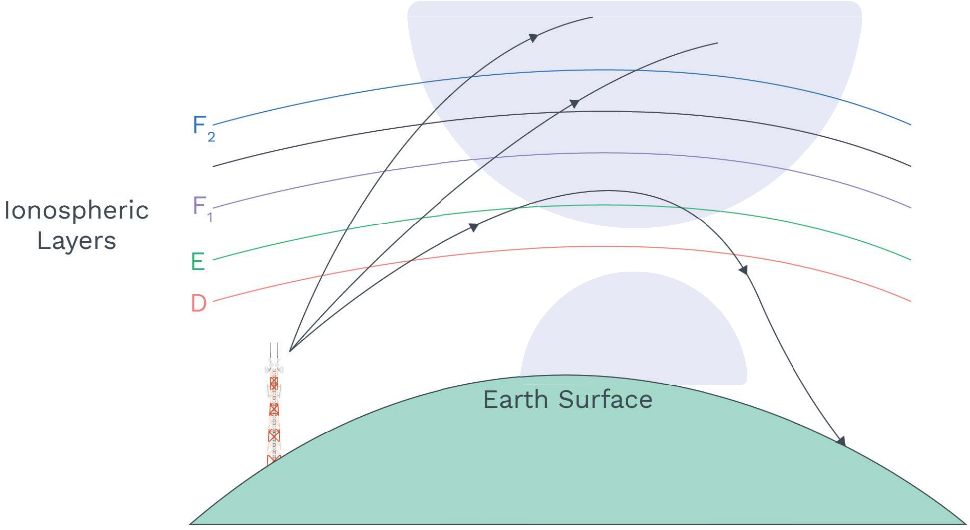
1. only the amplitude is change but frequency remains same
2. both the amplitude and frequency change equally
3. the amplitude and frequency change unequally
4. only phase changes

(d) **Skip Distance:** The smallest distance of receiver from the transmitter where wave of given frequency reaches. Obviously, it follows from figure that higher is angle of incidence on ionic layer more is the skip distance.

Fading: Due to arrival of many signals at the receiver emitted from the source simultaneously but reach receiver in time delay due to taking different paths diminish signal due to destructive interference. This is fading.

Concept Reminder

Low frequencies cannot be transmitted to long distances. Therefore, they are superimposed on a high frequency carrier signal by a process known as modulation.



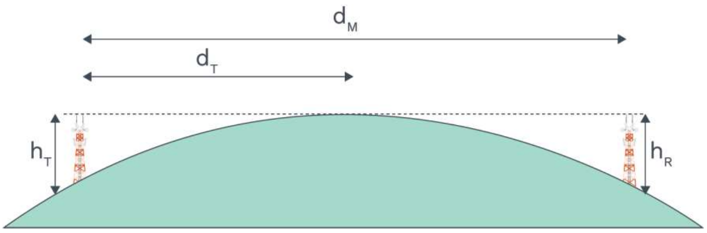
Space Wave

Another mode of radio wave propagation is by space waves. A space wave travels in a straight line from transmitting antenna to the receiving antenna. Space waves are used for line-of-sight (LOS) communication as well as satellite communication. At frequencies above 40 MHz, communication is essentially limited to line-of-sight paths. At these frequencies, the antennas are relatively smaller and can be placed at heights of many wavelengths above the ground. Because of line-of-sight nature of propagation, direct waves get blocked at some point by the

Concept Reminder

In modulation, some characteristic of the carrier signal like amplitude, frequency or phase varies in accordance with the modulating or message signal. Correspondingly, they are called Amplitude Modulated (AM), Frequency Modulated (FM) or Phase Modulated (PM) waves.

curvature of the earth as illustrated in Figure. If the signal is to be received beyond the horizon, then the receiving antenna must be high enough to intercept the line-of-sight waves.



Line of sight communication by space waves. If the transmitting antenna is at a height h_T, then you can show that the distance to the horizon d_M is given as

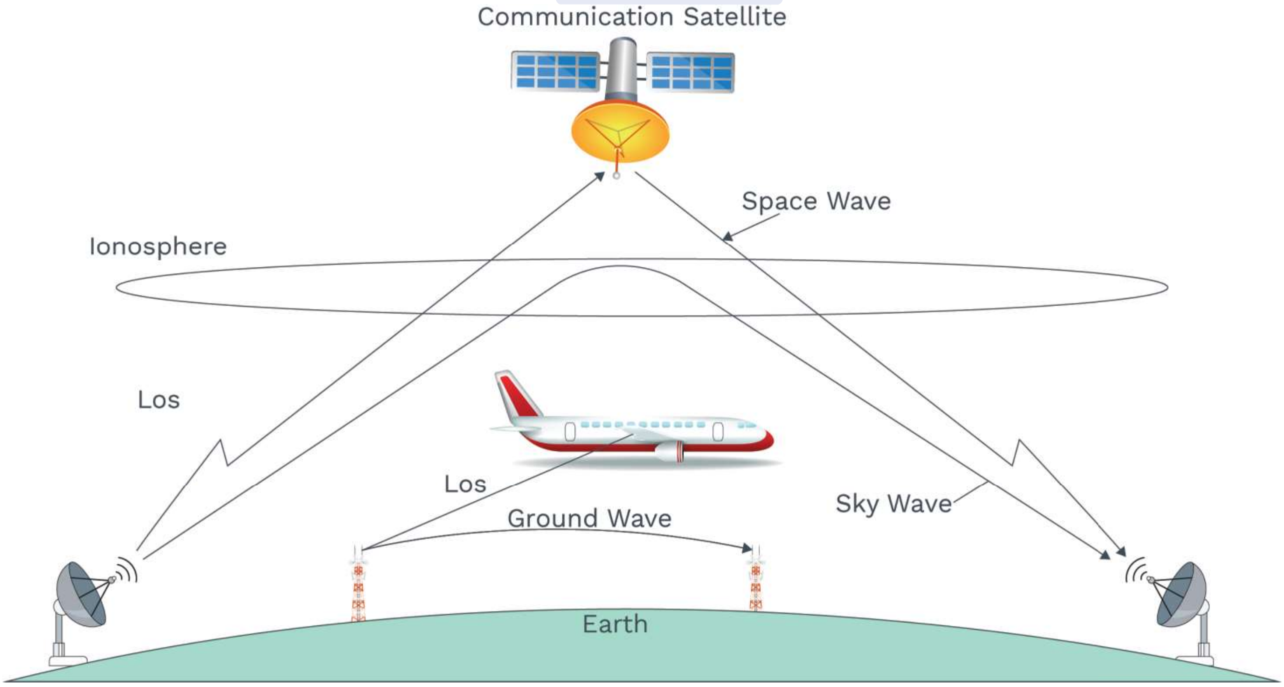
$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

where h_R is the height of receiving antenna.

Rack your Brain

Modulation factor determines
1. only the strength of the transmitted signal
2. only the quality of the transmitted signal
3. both the strength and quality of the signal
4. none of the above

Television broadcast, microwave links and satellite communication are some examples of communication systems that use space wave mode of propagation. Figure summarises the various modes of wave propagation discussed so far.



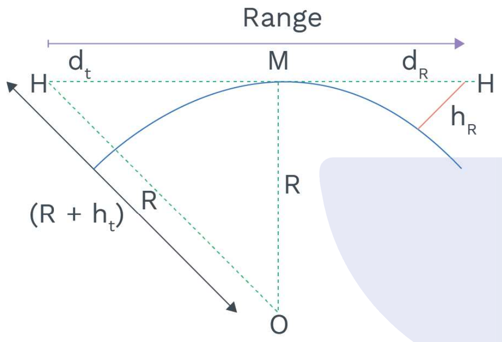
The range versus antenna height relation may easily be determined using geometry of figure.

In $\Delta HMO, HO^2 = HM^2 + MO^2$

$\Rightarrow (R + h_t)^2 = d_t^2 + R^2$, R = radius of the earth

$R^2 + h_t^2 + 2Rh_t = d_t^2 + R^2$

$2Rh_t + h_t{}^2 = d_t^2, h_t << R$



$d_t = \sqrt{2Rh_t}$

Similarly, $d_R = \sqrt{2Rh_R}$ .... (2)

Hence range

$d_m = (d_t + d_R) = \sqrt{2Rh_t} + \sqrt{2Rh_R}$ .... (3)

In case satellite located at a height h then

$d_m = d_R = d = \sqrt{2Rh}$ .... (4)

Area covered $\pi d^2 = 2\pi Rh$

Ex. A transmitting antenna at the top of a tower has a height 32 m and the height of the receiving antenna is 50 m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth 6.4 × 10^6 m.

Sol. $d_m = \sqrt{2 \times 64 \times 10^5 \times 32} + \sqrt{2 \times 64 \times 10^5 \times 50}\,m$

$= 64 \times 10^2 \times \sqrt{10} + 8 \times 10^3 \times \sqrt{10}\,m$

$= 144 \times 10^2 \times \sqrt{10}\,m = 45.5\,km$

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Degree of modulation is kept

1. at any value
2. less than 100%
3. greater than 100 %
4. may be at any value 100% to 200%

Concept Reminder

Pulse modulation could be classified as: Pulse Amplitude Modulation (PAM), Pulse Duration Modulation (PDM) or Pulse Width Modulation (PWM) and Pulse Position Modulation (PPM).

Ex. The process of superimposing signal frequency (i.e., audio wave) on the carrier wave is known as

Sol. Carrier + Signal $\rightarrow$ modulation

Ex. The maximum distance up to which TV transmission from a TV tower of height h can be received is proportional to

Sol. $d = \sqrt{2hR} \Rightarrow d \propto h^{1/2}$

Ex. The waves used in telecommunication are

Sol. In telecommunication microwaves are used.

Ex. At which of the following frequencies the communication will not be reliable beyond horizon

Sol. MHz travel is line of sight.

Ex. AM is used for broadcasting because

Sol. The receive system is quite simple and cheap.

Ex. UHF frequencies normally propagate via

Sol. UHF travels as space wave

Ex. A microwave link operates at central frequency 10 GHz and 2% is used for telephone channels. If telephone is allotted a band width of 8 kHz the number of channels that can be operated simultaneously is

Sol. Band width available $\frac{2}{100} \times 10^9$, one channel needs 8 kHz No of channels operating

$$= \frac{2 \times 10^7}{8.5 \times 10^3} = 2.35 \times 10^4$$

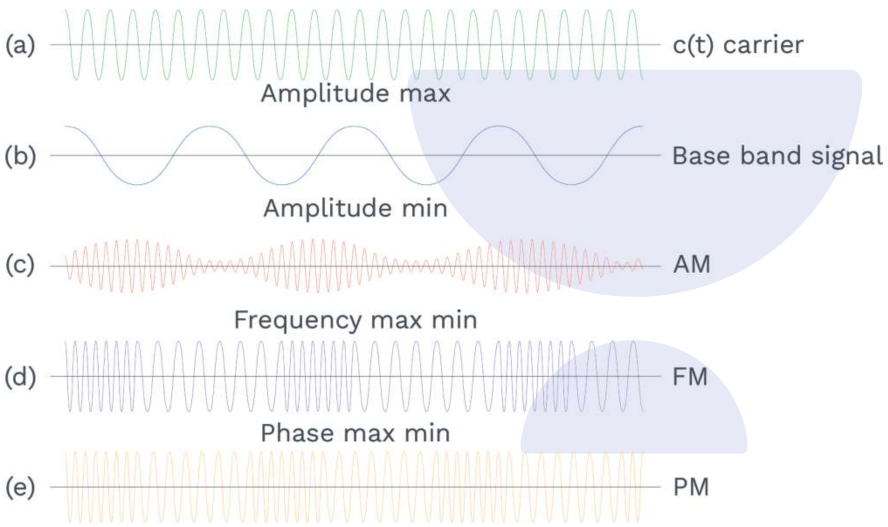
Rack your Brain

If the maximum and minimum voltage of an AM wave are $V_{max.}$ and $V_{min.}$ respectively then modulation factor–

1. $m = \frac{V_{max.}}{V_{max.} + V_{min.}}$
2. $m = \frac{V_{min.}}{V_{max.} + V_{min.}}$
3. $m = \frac{V_{max.} + V_{min.}}{V_{max.} - V_{min.}}$
4. $m = \frac{V_{max.} - V_{min.}}{V_{max.} + V_{min.}}$

Modulation And Its Necessity

The purpose of a communication system is to transmit information or message signals. Message signals are also known as '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'.



Size of Antenna: -

To transmit any signal minimum height of transmitting antenna is $\frac{'\lambda'}{4}$ required.

- So, to decrease the height of transmitting antenna wavelengths is to be decrease and frequency is to be increase. To increase the transmitted signal modulation is required.
- For a signal of frequency 15 KHz the minimum height of antenna.

$$h_{min} = \frac{\lambda}{4} \qquad \text{--- (i)}$$

we know that

$$c = \nu\lambda$$

Concept Reminder

For transmission over long distances, signals are radiated into space using devices called antennas. The radiated signals propagate as electromagnetic waves and the mode of propagation is influenced by the presence of the earth and its atmosphere. Near the surface of the earth, electromagnetic waves propagate as surface waves. Surface wave propagation is useful up to a few MHz frequencies.

$$\Rightarrow \lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{15 \times 10^3} = \frac{30 \times 10^7}{15 \times 10^3} = 2 \times 10^4 \text{ m}$$

Hence, minimum height of transmitting antenna from eq. (1)

$$h_{min} = \frac{2 \times 10^4}{4}$$

$$= \frac{2 \times 10^4}{4} = 5000 \text{ meter}$$

Practically an antenna cannot be constructed of so much height. Therefore, to decrease the height of antenna modulation is required.

1. Radiated power of antenna: -

Practically it is observed that the radiated power of any transmitting antenna is directly proportional to the $\left(\frac{l}{\lambda}\right)^2$.

Hence, $\boxed{P_{radiated} \propto \left(\frac{l}{\lambda}\right)^2}$

Here, l = length of antenna

λ = wavelength of signal which is to be transmit.

- For a fixed length antenna if the wavelength decreases then radiated power increases. To decreases wavelength frequency of the signal is to be increase for which modulation is required.

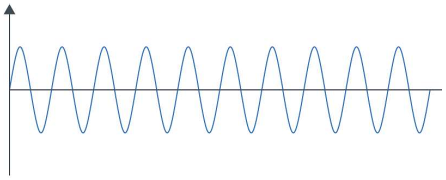
Mixing of Signals From Different Transmitters

If signals are transmitted at base band (original frequency band) then receiver shall receive signal from many transmitters simultaneously and they get mixed. If these signals are modulated on different carrier frequencies, the mixing is avoided and the receiver shall get desired signal by tuning at that CW frequency. In digital communication carrier wave is in the form of pulses the modulation may be pulse amplitude, pulse duration and pulse width modulation as

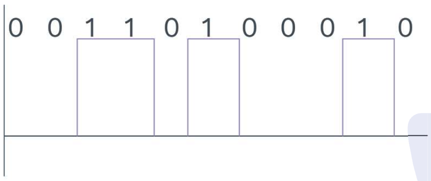
KEY POINTS

- Size of Antenna
- Radiated power of antenna

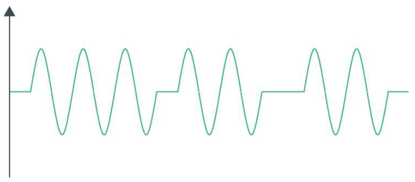
illustrated in Figure. The flow chart of figure below summarizes various types of modulations



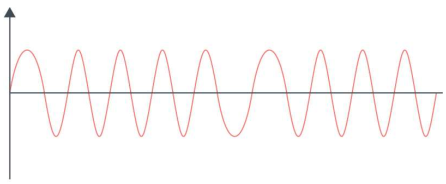
(A) Carrier wave



(B) Modulating source code



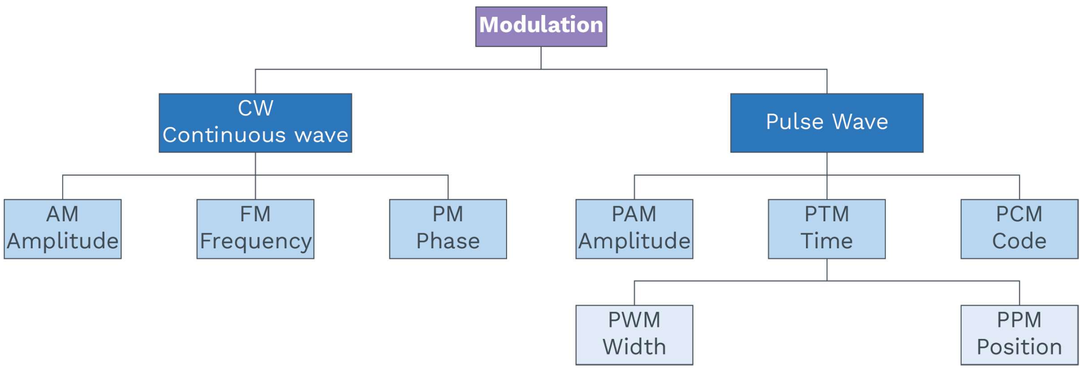
(C) ASK modulated wave



(D) FSK modulated wave

Concept Reminder

Long distance communication between two points on the earth is achieved through reflection of electromagnetic waves by ionosphere. Such waves are called sky waves. Sky wave propagation takes place up to frequency of about 30 MHz. Above this frequency, electromagnetic waves essentially propagate as space waves. Space waves are used for line-of-sight communication and satellite communication.



Properties of Amplitude Modulation

(a) Frequency spectrum: In amplitude modulated (AM) wave the amplitude of carrier wave varies with signal i.e., signal is superimposed in amplitude. If carrier wave be $C(t) = A_c \sin \omega_c t$ and the message signal be

$m(t) = A_m \sin \omega_m t$ then modulated signal will be

$C_m(t) = (V_c + V_m \sin \omega_m t) \sin \omega_c t$ .... (6)

$C_m(t) = (V_c + V_m \sin \omega_m t) \sin \omega_c t$

$$= V_c\left(1 + \frac{V_m}{V_c} \sin \omega_m t\right) \sin \omega_c t \quad \text{......... (7)}$$

Where $= \frac{V_m}{V_c}$ is called modulation index.

It is generally less than 1 ($\mu < 1$)

$$C_m(t) = V_c \sin \omega_c t + \left(\frac{V_m}{V_c}\right) V_c \sin \omega_c t \cdot \sin \omega_m t$$

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

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

..... (8)

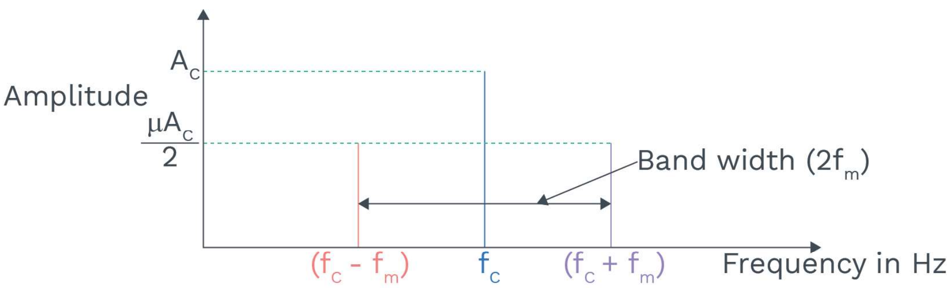
Equation (8) shows three set of angular frequencies original carrier viz., $(\omega_c), (\omega_c - \omega_m)$ known as lower side band and $(\omega_c + \omega_m)$ upper side band of frequencies. The amplitude modulated frequency spectrum is shown in figure.

$(f = \omega / 2\pi)$

Rack your Brain

The AM wave contains three frequencies, viz:

1. $\frac{f_c}{2}, \frac{f_c + f_s}{2}, \frac{f_c - f_s}{2}$
2. $2f_c, 2(f_c + f_s), 2(f_c - f_s)$
3. $f_c, (f_c + f_s), (f_c - f_s)$
4. f_c, f_c, f_c



If broadcasted bands are sufficiently separated so that side bands do not overlap, different stations can operate without any interference.

(b) **Modulation Index**: The ratio of change in amplitude of the carrier wave to amplitude of original carrier wave is called modulation index or modulation factor, m_a, $m_a = \frac{kV_m}{V_C}$

factor k determines the maximum change in amplitude for given amplitude of the modulating wave. On amplitude modulation, the maximum and minimum amplitudes are A_{max} and A_{min} then maximum change in amplitude is $(V_{max} - V_C)$ and so

$$m_a = \frac{V_{max} - V_C}{V_C} \quad \dots (9)$$

For example (i) if $V_C = V$ and $V_m = \frac{V}{2}$ then

$$m_a = V + \frac{V}{2} - V = V/2 = 50\%$$

(ii) If $V_C = V$ and $V_m = V$ then $V_{max} = 2V$

$$m_a = \frac{2V - V}{V} = 1 \text{ or } 100\%$$

(iii) If $V_C = V$, $V_m = 3/2V$ then $V_{max} = 5/2$ V

and $m_a = \frac{(5/2)V - V}{V} = \frac{3}{2}$ or 150% V

In this case the carrier is over modulated > 100% it may be noted that modulation factor m_a, determines the strength and quality of the

Rack your Brain

In AM wave, carrier power is given by -

1. $P_c = \frac{2E_c^2}{R}$
2. $P_c = \frac{E_c^2}{R}$
3. $P_c = \frac{E_c^2}{2R}$
4. $P_c = \frac{E_c^2}{\sqrt{2}R}$

signal transmitted. Audio signal is generally AM modulated and hence higher is modulation the stronger and clearer will be the signal.

If $= 1$ modulation index may be expressed in terms of maximum and minimum amplitude, V_{max} and V_{min}

$$m_a = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \quad \text{.... (10)}$$

If carrier wave is modulated with many signals, then total modulation index is given by

$$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2} \quad \text{.... (11)}$$

(c) Bandwidth Required: The required band width is from lower side band to upper side band hence,

$$\Delta f = \frac{(\omega_c + \omega_m)}{2\pi} - \frac{\omega_c - \omega_m}{2\pi} = \frac{2\omega_m}{2\pi} = 2f_m \quad \text{... (12)}$$

(c) Power in AM Wave: Power dissipated in any circuit having resistance R and supplied at rms

voltage V_{rms} is given by $\left(\frac{V_{rms}^2}{R}\right)$. The total power is the sum of the power in side bands plus the power in carrier wave. Total power transmitted in carrier wave

$$P_{Total} = P_{LSB} + P_{USB} + P_{CW}$$

$$= \left(\frac{m_a V_C}{2 \times \sqrt{2}}\right)^2 \frac{1}{R} + \left(\frac{m_a V_C}{2 \times \sqrt{2}}\right)^2 \frac{1}{R} + \left(\frac{V_C}{\sqrt{2}}\right)^2 \frac{1}{R} = \frac{V_C^2}{2R}\left(1 + \frac{m_a^2}{2}\right)$$

.... (13)

(i) The ratio of power transmitted to carrier power

$$\frac{P_{Total}}{P_{CW}} = \frac{\frac{V_C^2}{2R}\left(1 + \frac{m_a^2}{2}\right)}{\left(\frac{V_C^2}{2R}\right)} = \left(1 + \frac{m_a^2}{2}\right) \quad \text{.... (14)}$$

Rack your Brain

A geo-synchronous satellite is :

1. located at a height of 35,860 km to ensure global coverage
2. appears stationary over the earth's magnetic pole
3. not really stationary at all, but orbits the earth 24 hrs
4. motionless in space (except for its spin)

Rack your Brain

Fraction of total power carried by side bands is given by

1. $\frac{P_S}{P_T} = m^2$
2. $\frac{P_S}{P_T} = \frac{1}{m^2}$
3. $\frac{P_S}{P_T} = \frac{2 + m^2}{m^2}$
4. $\frac{P_S}{P_T} = \frac{m^2}{2 + m^2}$

(ii) Fraction of power transmitted in the side band

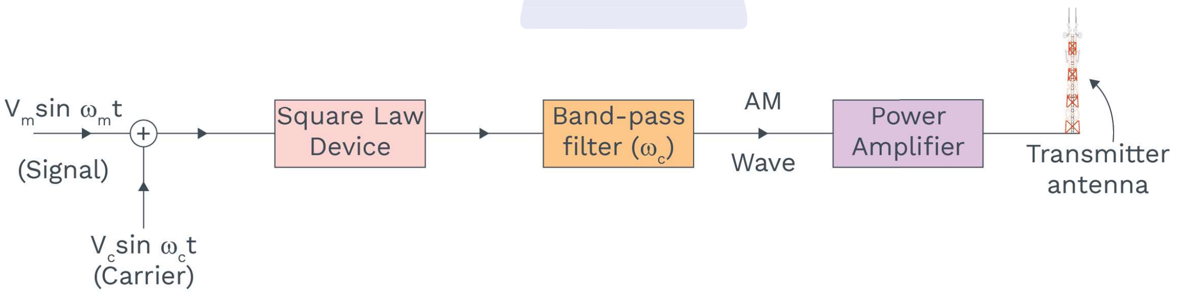
$$\frac{P_{SB}}{P_{Total}} = \frac{\frac{1}{R}\left(\frac{m_a V_C}{2\sqrt{2}}\right)^2}{\frac{V_C^2}{2R}\left(1+\frac{m_a^2}{2}\right)} = \left(\frac{m_a^2 / 2}{1+m_a^2 / 2}\right) \quad \text{.... (15)}$$

Distortion free maximum power transfer. For distortion free transmission $m_a = 0$ So

$$\frac{I_{Total}}{I_{CW}} = \sqrt{1+\frac{m_a^2}{2}} \quad \text{.... (16)}$$

Production Of Amplitude Modulated Wave

To add the signal to the amplitude of CW the voltage signal is mixed up in mixer and sampled by square law device. The output is filtered by a band pass filter centred around carrier frequency. The signal is amplified by power amplifier before transmission as shown in the following block diagram



Detection of Amplitude Modulated Signal

The signal is received by receiving antenna. As received signal is weak due to attenuation in the channel, it has to be amplified. The detection or high frequency is difficult so, it is changed to low frequency called intermediate frequency, (IF). This converted signal is detected and amplified. The AM wave is rectified that rejects lower part of AM wave. Finally envelop is detected (filtering

Rack your Brain

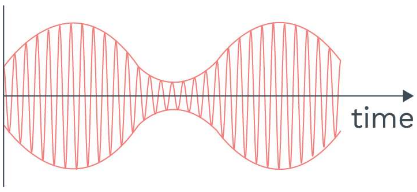
The Intelsat satellite is used for:

1. In house radio communication
2. Intercontinental communication
3. radar communication
4. none of the above

Concept Reminder

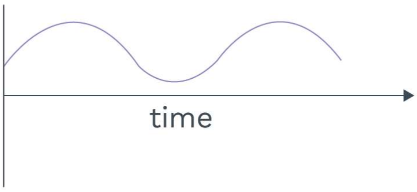
If an antenna radiates electromagnetic waves from a height h_T, then the range d_T is given by $\sqrt{2Rh_T}$ where R is the radius of the earth.

CW component). The entire process is shown in the following block diagram of Figure



AM input wave

Rectified wave

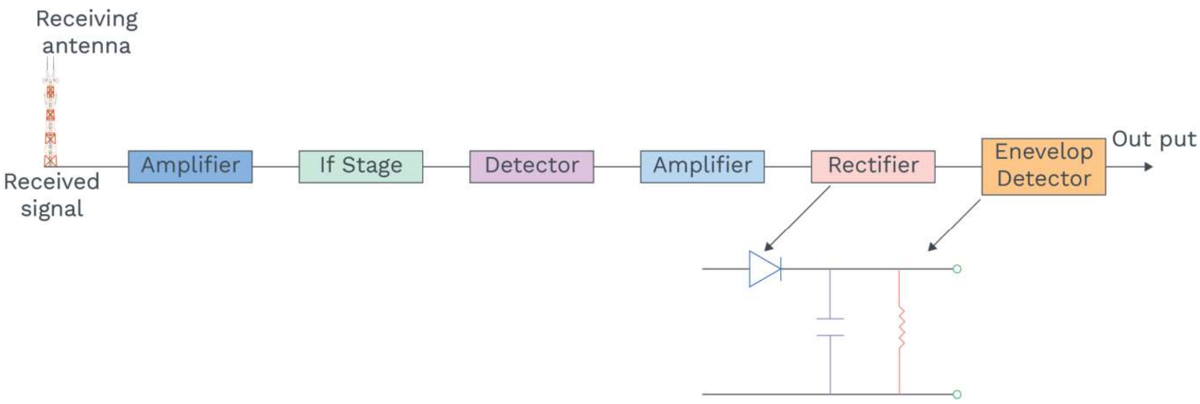


Output (without RF component)

Rack your Brain

Which of the following is/are the limitations of amplitude modulation?

1. Clear reception
2. High efficiency
3. Small operating range
4. Good audio quality



Limitations of AM wave Transmission

AM communication has the following problems

(i) Reception is noisy become audio noise caused by various

(ii) Efficiency is low, machines get mixed
(iii) Operating range is small
(iv) Audio quality is poor.

Ex. An AM wave has 1800 watt of total power content, for 100% modulation the carrier should have power content equal to

Sol. $P_t = P_c\left(1+\frac{m_a^2}{2}\right)$; Here $m_a = 1$

$\Rightarrow \quad 1800 = P_c\left(1+\frac{(1)^2}{2}\right)$

$\Rightarrow \quad P_c = 1200\,W$

Ex. A Television tower has a height of 75 m. What is the maximum distance and area up to which this TV transmission can be received? Take radius of the earth as 6.4 × 10^6 m.

Sol.

$d = \sqrt{2Rh} = \sqrt{2\times 6.4\times 10^6\times 5} = 3.1\times 10^4 m = 31 km$

Area covered = $\pi r^2 = 3018\,km^2$

Ex. A Television tower has a height of 100 metre. How much population is covered by the Television broadcast if the average population density around the tower is 1000 km^{-2}? Given: radius of earth = 6.37 × 10^6 m.

Sol. $h = 100 m$, $R = 6.37\times 10^6$ m, Average population density = 1000 km^{-2} = $1000(10^3)^{-2}$ m^{-2} = 10^{-3} m^{-2}

Distance up to which the transmission could be viewed, $d = \sqrt{2hR}$

Total area over which transmission could be viewed $= \pi d^2 = 2\pi hR$

Rack your Brain

To avoid noise the frequency above which transmission of electrical energy is practical ?

1. 0.2 kHz 2. 2 kHz
3. 20 kHz 4. 200 kHz

Concept Reminder

Amplitude modulated signal contains frequencies $(\omega_c - \omega_m), \omega_c$ and $(\omega_c + \omega_m)$.

Population covered = $10^{-3} \times 2\pi hR = 10^{-3} \times 2 \times 3.14 \times 100 \times 6.37 \times 10^6$ = 40 lakh

Ex. Which of following is the disadvantage of FM over AM

Sol. Frequency modulation requires much wider channel (7 to 15 times) as compared to AM.

Ex. Sinusoidal carrier voltage of frequency 1.5 MHz and amplitude 50 V is amplitude modulated by sinusoidal voltage of frequency 10 kHz producing 50% modulation. The lower and upper side-band frequencies in kHz are

Sol. Here, f_c = 1.5 MHz = 1500 kHz, f_m = 10 kHz

$\therefore$ Lower side band frequency

$= f_c - f_m$ = 1500 kHz – 10 kHz = 1490 kHz

Upper side band frequency

$= f_c + f_m$ = 1500 kHz + 10 kHz = 1510 kHz

KEY POINTS

- Frequency modulated wave
- FM side Band

Frequency Modulated Wave

Most of the noises affect the amplitude of the signal and hence signal to noise ratio is greatly improved if amplitude of CW remains unaffected. This is what is done in frequency modulation where the frequency of CW varies with the signal.

(a) Analysis

Consider a voltage signal $V_m = V_m \cos\omega_m t$ to be frequency modulated on a carrier voltage wave $V_c = V_c \cos(\omega_c t + \theta_0)$. Where $\omega_m = 2\pi f_m, \omega_c = 2\pi f_c$ are respectively angular frequencies of signal and the carrier waves and V_m and V_c are their amplitude θ_0 is initial phase of carrier. The instantaneous phase of carrier wave (CW)

$$\phi(t) = \omega_c t + \theta_0$$

The angular frequency of modulated wave shall be

$$\omega = \omega_c + k V_m \cos\omega_m t$$

Where k is frequency conversion factor which is

Concept Reminder

Amplitude modulated waves can be produced by application of the message signal and the carrier wave to non-linear device, followed by a band pass filter.

constant. The phase of FM wave at any instant shall be

$$\phi(t) = \int \omega dt = \int (\omega_c + kV_m \cos \omega_m t)\, dt$$

$$\phi(t) = \omega_c t + \frac{kV_m}{\omega_m} \sin \omega_m t \quad .... (17)$$

Hence equation of FM voltage wave is

$$V_{FM}(t) = V_c \sin\left[\omega_c t + \frac{kV_m}{\omega_m} \sin \omega_m t\right] \quad .... (18)$$

The instantaneous frequency of FM wave is given by

$$f = \frac{1}{2\pi} \partial\phi(t)$$

$$\therefore \ f = \frac{1}{2\pi}\omega_c + \frac{kV_m}{2\pi} \cos \omega_m t \quad .... (19)$$

The maximum and minimum frequencies are obviously,

$$f_{max} = f_c + \frac{kV_m}{2\pi} \quad .... (20\ a)$$

$$f_{min} = f_c - \frac{kV_m}{2\pi} \quad .... (20\ b)$$

The maximum change in frequency from the mean value is called frequency deviation

$$f_d = (f_{max} - f_c) = (f_c - f_{min}) = \frac{kV_m}{2\pi} \quad .... (21)$$

The total variation of frequency from the maximum to minimum is called carrier swing. It is twice the frequency deviation.

$$CS = 2f_d = \frac{kV_m}{\pi} \quad .... (22)$$

Frequency modulation index m_f is defined as ratio of frequency deviation to the modulation frequency

$$m_f = \frac{f_d}{f_m} = \frac{\omega_d}{\omega_m} = \frac{kV_m}{\omega_m} \quad .... (23)$$

The equation of FM wave becomes

Rack your Brain

What type of modulation is employed in India for radio transmission?

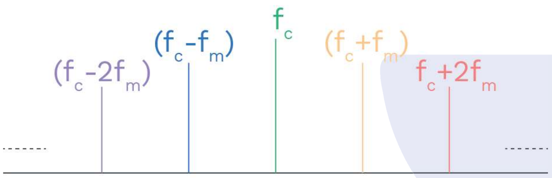
1. Pulse modulation
2. Frequency modulation
3. Amplitude modulation
4. None of these

$$v_{FM} = V_C \sin(\omega_c t + m_f \sin\omega_m t) \quad \text{.... (24)}$$

(b) Frequency spectrum

FM Side Bands:

Equation (23) may be expanded and trigonometric manipulations shall show that there are series of side bands $(f_c \pm f_m), (f_c \pm 2f_m), (f_c \pm 3f_m)$ etc. with decreasing amplitudes. Side bands are equally spaced on either side of carrier frequency f_c as shown in Figure.



Frequency spectrum of FM signal

(c) Frequency bands in use

As pointed out frequency modulation (FM) has better quantity of transmission with large band width. The manmade noises and atmosphere changes do not affect transmission quality. Also, the fidelity is good for the transmission of music. The frequency bands in use are:

(a) 88 to 108 MHz FM Radio
(b) 47 to 230 MHz VHF TV
(c) 470 to 960 MHz UHF TV

Digital COMMUNICATION: Data Transmission & Ret rival

Digital communication ensures less noise and less error communication. Here carrier is a digital pulsating wave in binary code 0 and 1. The signal which is analogue is digitized. There are many encoding steps: source coding channel coding, etc. Typical digital communication system is shown in diagram.

There are normally three steps (i) converting signal into pulses of the same height and negligible

Concept Reminder

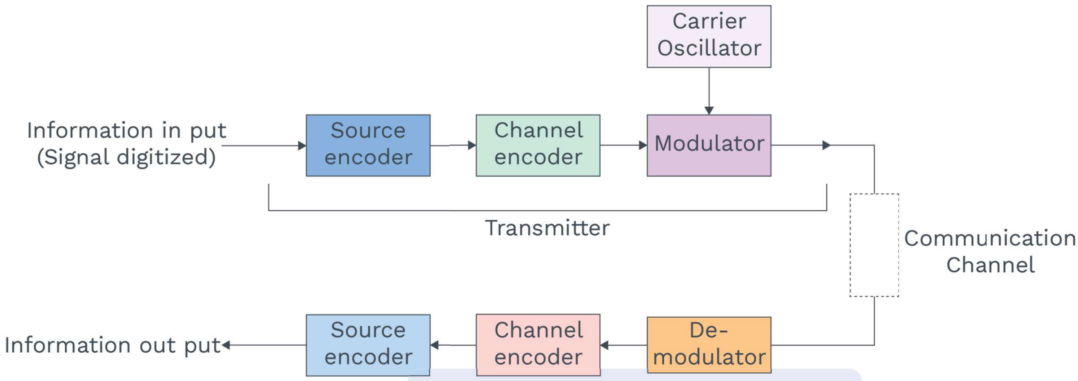
AM detection, which is the process of recovering the modulating signal from an AM waveform, is carried out using a rectifier and an envelope detector.

Rack your Brain

For a carrier frequency of 100 kHz and a modulating frequency of 5 kHz what is the band width of AM transmission–

1. 5 kHz 2. 10 kHz
3. 20 kHz 4. 200 kHz

width (ii) quantization and (iii) coding quantized pulses following some rule.



Digital communication system : Block diagram

Modem

Is short term used for modulator and demodulator. As seen in Figure modulator and demodulator are needed for two-way communication and a single modem unit serves the purpose.

Modulation Used

In digital communication modulation techniques used are shown in figure which is quite illustrative. Modern communication system commonly use frequency shifting keys.

Optical Communication:-

Typical optical communication system is shown in diagram. It uses optical frequency as carrier, so it has the following advantages

(i) There is no electromagnetic interference

(ii) Enormous channel capacity

(iii) Requires optical fibre as communication channel

(iv) Mostly used in LAN (Local area networking) Setup for digital communication (Block diagram)

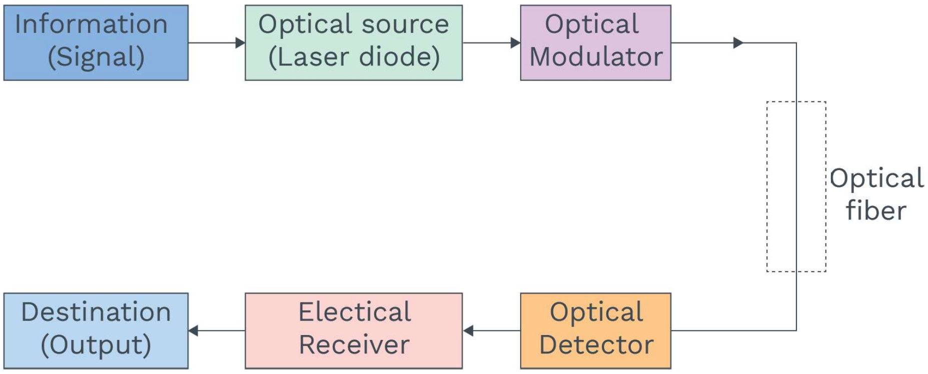
Concept Reminder

Email-It permits exchange of text/graphic material using email software. We can write a letter and send it to the recipient through ISP's (Internet Service Providers) who work like the dispatching and receiving post offices.

Rack your Brain

Intelsat satellite works as a:

1. transmitter
2. repeater
3. absorber
4. none of these



Optical communication system: Transmitter and receiver sections use modem, modulator demodulator. Optical communication system is similar to digital communication system except the source is pulsating laser (IR), detector is optical diode and channel is optical fibre.

Satellite Communications

In the age of IT explosion where enormous data need be transmitted and received, there occurs a need of higher frequency bands and more channels. This is possible only with satellite communication. As discussed earlier, the signal from the transmitting station is sent to communication satellite equipped with transmitting and receiving systems known as radio Transponder (RT). The signal transmitted and received by satellite is called up-link whereas transmitted by satellite and received at ground is called down link to avoid confusion the frequencies of up and down links are kept different. The commonly used satellite system consists of three geostationary satellites located on the vertices of an equilateral triangle having verticals on a geostationary orbit to cover entire globe space. Most of the satellites are in geostationary orbit yet there are two more orbits which are used for communication satellites. These are polar circular orbit near the earth about 1000 km, high, its inclination is 90°. The another

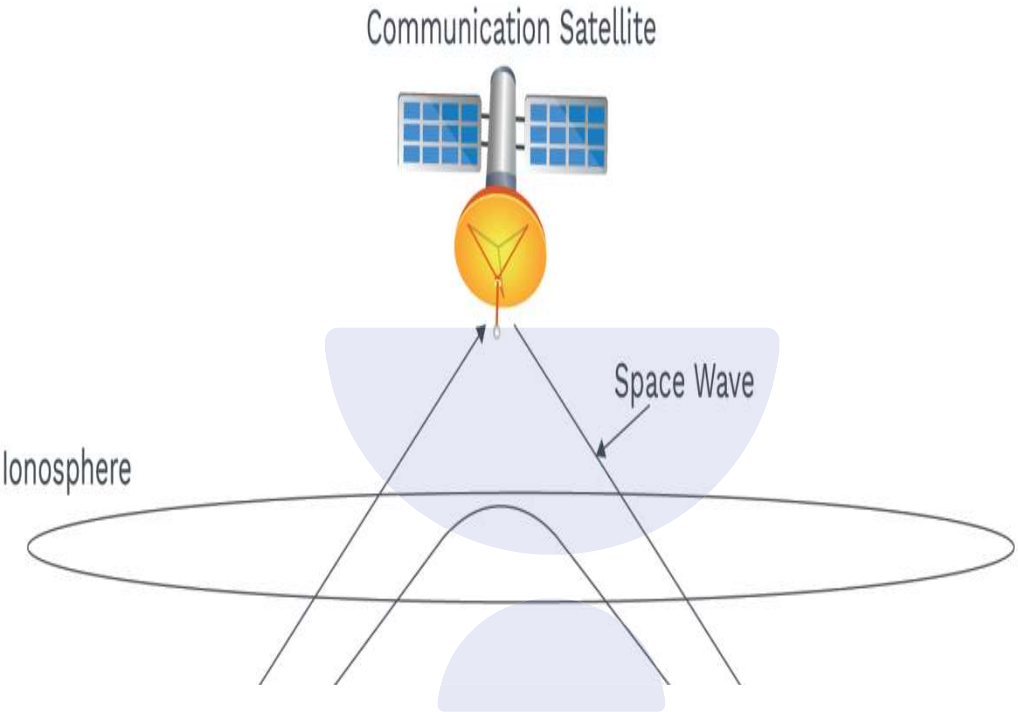
Concept Reminder

File transfer – A FTP (File Transfer Programmes) allow transfer of files/software from one computer to another connected to the Internet.

Rack your Brain

Which one of the following subsystems is used for satellite's orbit position and altitude?
1. Thrust subsystem
2. Power subsystem
3. Antenna subsystem
4. Stabilization subsystem

is highly elliptical orbit inclined at 63° to fulfil the need of high-altitude regions. Commonly known as 63° slot Finally figure shows the summary of various communication systems.



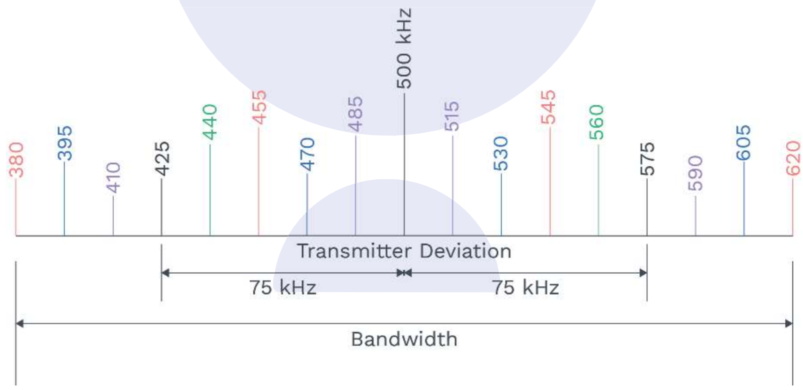
STANDARD CLASSIFICATION SPECTRUM OF FREQUENCY USED IN COMMUNICATION				
CARRIER	**FREE SPACE**	**CLASS**	**PROPAGATION**	**SERVICE**
Frequency 10 - 30 kHz	Wavelength (meters) 3×10^4 - 10^4	Very Low Frequency (VLF)	Characteristic At all times of day year. Attenuation is low.	Long distance point to point communication
30 - 300 kHz	10^4 - 10^3	Low Frequency (LF)	During day time absorption exceeds that with VLF. During night time, propagation is similar to VLF	Long distance point to point communication Navigation
300 - 300 kHz	10^3 - 10^2	Medium Frequency (MF)	Day time attenuation is high; Night time attenuation is low (ionospheric propagation)	Broadcasting; ship t0 shore communication
30 - 30 MHz	10^2 - 10	High Frequency (HF)	Ionospheric propagation	National and international broadcast: point to point telephone and telegraph communication: Aviation
30 - 300 MHz	10 - 1.0	Very High Frequency (VHF)	Tropospheric propagation (typical range equals line of sight)	Radar; Television; F.M. Broadcast; Short distance communication
300 - 3000 MHz	1 - 0.1	Ultra High Frequency (UHF)	do	Fascimile; Television Relay Air navigation
300 - 30,000	0.1 - 0.01	Super High Frequency (SHF)	do	Radar navigation; Radio Relay.

EXAMPLES

Q1 **The carrier frequency is 500 kHz. The modulating frequency is 15 kilohertz, and the deviation frequency is 75 kilohertz. Find**
(a) modulation index
(b) Number of side bands
(c) Band width

Sol: $MI = \frac{\Delta f}{f_m} = 5$

We can have that there are 16 significant sidebands for a modulation index of 5.



To determine total bandwidth for this case, we use:

$bW = f_m \times (\text{number of sidebands})$ $bW = 15 \times 16 = 240$ kHz

Q2 **How many AM broadcast stations can be accommodated in a 100 kHZ band-width if the highest modulating frequency of carrier is 5 kHZ ?**

Sol: Any station being modulated by a 5 kHz signal will produce an upper side frequency 5 kHz above its carrier and a lower side frequency 5 kHz below its carrier, thereby requiring a bandwidth of 10 kHz. Thus, Number of stations accommodated

$$= \frac{\text{Total bandwidth}}{\text{Bandwidth per station}} = \frac{100}{10} = 10$$

Q3 **How many 500 kHz waves can be on a 10 km transmission line simultaneously?**

Sol: Let λ be the wavelength of 500 kHz signal. Then,

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{5.0 \times 10^5} m = 600 m$$

The number of waves on the line can be found from,

$$n = \frac{d}{\lambda} = \frac{10 \times 10^3}{600} = 16.67$$

Q4 **A two-wire transmission line has a capacitance of 20 pF/m and a characteristic impedance of 50 Ω**
(a) What is the inductance per metre of this cable?
(b) Determine the impedance of an infinitely long section of such cable.

Sol: (a) The characteristic impedance. $Z = \sqrt{L / C}$

$$L = \left(Z^2\right)\left(C\right) = \left(50\right)^2 \left(20 \times 10^{-12}\right) H = 0.05 H / m$$

(b) The characteristic impedance of a transmission line is the impedance that an infinite length of line would present to a power supply at the input end of the line. Thus, $Z_{\infty} = Z_0 = 50\,\Omega$

Q5 **T.V. transmission tower at a particular station has a height of 160 m.**
(a) What is the coverage range?
(b) How much population is covered by transmission, if the average population density around the tower is 1200 per km²?
(c) What should be the height of tower to double the coverage range.

Sol: (a) Coverage range $d = \sqrt{2Rh}$

$$= \sqrt{2 \times 6400 \times 10^3 \times 160 m}$$

$= 45.254$ km

(b) Population covered

$= \text{(population density)} \times \text{(area covered)}$

$= (1200) \times (\pi d^2)$

$= (2400\pi Rh) = 2400 \times 3.14 \times 6.4 \times 10^3 \times 0.16 = 77.17$ lac.

(c) Coverage range $\propto \sqrt{h}$

Therefore, coverage range can be doubled by making height of the tower four times to 640 m. So, height of the tower should be increased by 480 m.

Q6 **An audio signal given by $e_s = 15 \sin 2\pi(200t)$ modulates a carrier wave given by $e_c = 60 \sin 2\pi(100{,}000t)$. If calculate**

(a) Percent modulation

(b) Frequency spectrum of the modulated wave.

Sol: (a) Signal Amplitude, B = 15

Carrier amplitude, A = 60

$$m = \frac{B}{A} = \frac{15}{60} = 0.25$$

$\therefore$ Percentage modulation = 0.25 × 100 = 25%

(b) By comparing the given equations of signal and carrier with their standard form

$$e_s = E_s \sin \omega_s t = E_s \sin 2\pi f_s t \text{ and}$$

$$e_c = E_c \sin \omega_c t = E_c \sin 2\pi f_c t$$

We have signal frequency $f_s = 2000$ Hz and carrier frequency $f_c = 100{,}000$ Hz

The frequencies present in modulated wave

(i) $f_c = 100{,}000 \text{ Hz} = 100 \text{ kHz}$

(ii) $f_c - f_s = 100{,}000 - 2000 = 98 \text{ kHz}$

(iii) $f_c + f_s = 100 \text{ kHz} + 2 \text{ kHz} = 102 \text{ kHz}$

Therefore, frequency spectrum of modulated wave extends from 98 kHz to 102 kHz is called band width.

Q7 **The antenna current of an AM transmitter is 8A when only the carrier is sent but it increases to 8.93 A when the carrier is modulated. Find percent modulation.**

Sol: The modulated or total power carried by AM

Wave $P_T = P_C\left(1+\frac{m^2}{2}\right)$. If R is load resistance.

I_m is the current when carrier is modulated and I_c the current when unmodulated, then

$$\frac{P_T}{P_C} = \frac{I_m^2 R}{I_c^2 R}; \quad \therefore \quad 1+\frac{m^2}{2} = \frac{I_m^2 R}{I_c^2 R}$$

Given $I_m = 8.93A,\ I_c = 8A$

$$\therefore \qquad m^2 = 2\left[\left(\frac{8.93}{8.0}\right)^2 - 1\right] \Rightarrow m = 0.7$$

Therefore, percentage modulation = 70%.

Q8 **A sinusoidal carrier voltage of 80 volts amplitude and 1 MHz frequency is amplitude modulated by a sinusoidal voltage of frequency 5 kiloHertz producing 50% modulation. Find the amplitude and frequency of lower and upper side bands.**

Sol: Amplitude of both LSB and USB are equal and given by

$$= \frac{mE_c}{2} = \frac{0.5 \times 80}{2} = 20 \text{ volts}$$

Now frequency of LSB = $f_c - f_s$

$= (1000 - 5)$ kHz = 995 kHz

Frequency of USB = $f_c + f_s$

$= (1000 + 5)$ kHz = 1005 kHz

Q9 **The load current in the transmitting antenna of an unmodulated AM transmitter is 6 Amp. What will be the antenna current when modulation is 60%?**

Sol: Total power carried by AM wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right) \qquad ...(1)$$

Where P_C is the power of carrier component and m is the modulation factor. If R is the resistance, I_m the antenna loads current when modulation is 60% and I_c is the antenna load current when unmodulated, then

$$\frac{P_T}{P_C} = \frac{I_m^2 R}{I_c^2 R}, \quad \therefore \quad 1+\frac{m^2}{2} = \frac{I_m^2}{I_c^2} \quad \text{using (1)}$$

or $$I_m = I_c\sqrt{\left\{\left(1+\frac{m^2}{2}\right)\right\}}$$

Given $I_c = 6.4\ \text{Amp}, m = 0.6$

$$I_m = 6\left[1+\frac{(0.6)^2}{2}\right]^{1/2} = 6\left[1.086\right] = 6.52\ \text{Amp}.$$

Q10 **A carrier wave of 1000 W is subjected to 100% modulation. Calculate (i) Power of modulated wave, (ii) power is USB, (iii) power is LSB**

Sol: (i) Total power of modulated wave

$$P_T = P_C\left(1+\frac{m^2}{2}\right) = 1000\left(1+\frac{1^2}{2}\right) = 1500\ \text{watt}$$

(ii) Power in USB $= \frac{1}{2} P_{SB}$

Where power carried by side bands is given by amplitude modulation and detection

$$P_{SB} = P_C\left(\frac{m^2}{2}\right) = 1000\left(\frac{1^2}{2}\right) = 500\ \text{watt}$$

$$P_{USB} = \frac{1}{2}P_{SB} = \frac{1}{2} \times 500 = 250 \text{ watt}$$

(iii) Since power LSB = Power in USB

$$P_{LSB} = P_{USB} = 250 \text{ watt}$$

Q11 **A transmitting antenna at the peak of a tower height 32 metre and the height of the receiving antenna is 50 metre. Calculate the maximum distance between both antenna for satisfactory communication in LOS mode? Given radius of earth 6.4×10^6 m.**

Sol: $$d_m = \sqrt{2 \times 64 \times 10^5 \times 32} + \sqrt{2 \times 64 \times 10^5 \times 50\,m}$$

$$= 64 \times 10^2 \times \sqrt{10} + 8 \times 10^3 \times \sqrt{10}\ m$$

$$= 144 \times 10^2 \times \sqrt{10}\ m = 45.5\,km$$

Q12 **A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine**
(a) modulation index
(b) the side bands produced

Sol: (a) modulation index = 10/20 = 0.5

(b) The side bands are at $(1000 + 10)\text{kHz} = 1010$ kHz & $(1000 - 10\,\text{kHz}) = 990\,\text{kHz}$.

Mind Map

COMMUNICATION SYSTEMS

MODES OF COMMUNICATION

Point to Point Communication
Communication takes place over a link between a single transmitter and a receiver.

Broadcast Mode Communication
Large number of receivers corresponding to a single transmitter.

BASIC COMMUNICATION TECHNIQUE

Transmitter
Converts the message signal suitable for transmission.

Communication Channel
A medium that connects a transmitter to a receiver.

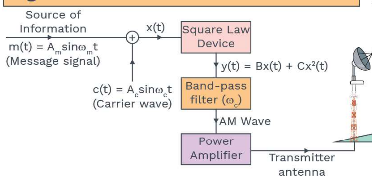
Receiver
Retrives the message signal into original form.

Modulation
Process of variation of some characteristic of a high frequency wave in accordance with the message signal.

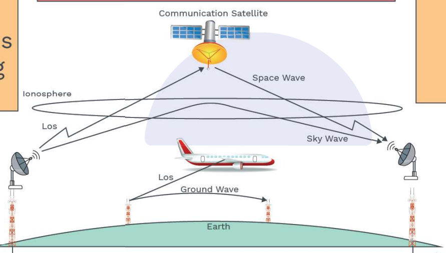
Phase Modulation

Frequency Modulation

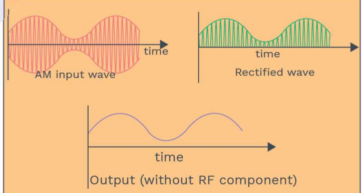
Amplitude Modulation
Amplitude of the high frequency carrier wave changes in accordance with modulating signal.

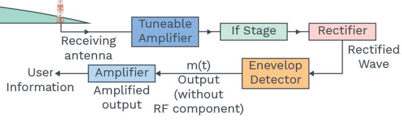


Necessity of Modulation
- To reduce the size of antenna, need a high frequency carrier wave.
- We need high power transmission as $P \propto (1/\lambda)^2$
- To avoid the mixing up of signals a band of frequency is allotted to each user for different radio channels.



Demodulation
Process of recovering the audio signal from the modulated wave is called demodulation or dectection.



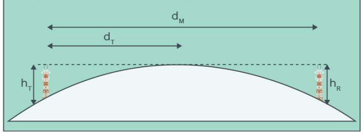


SPACE COMMUNICATION

Space Wave Propagation
A radio wave transmitted from an antenna, directly reaches the receiving antenna by LOS propagation.

Maximum LOS distance

$$d_m = \sqrt{2h_T R} + \sqrt{2h_R R}$$



Ground Wave Propagation
Here EM wave glides over the earth surface along its curvature from transmitter to receiver placed close to the surface of earth.

Sky Wave Propagation
The radio wave directed towards the sky and reflected by the ionosphere towards the desired location on the earth.

Critical frequency $\upsilon_c = 9(N_{max})^{\frac{1}{2}}$