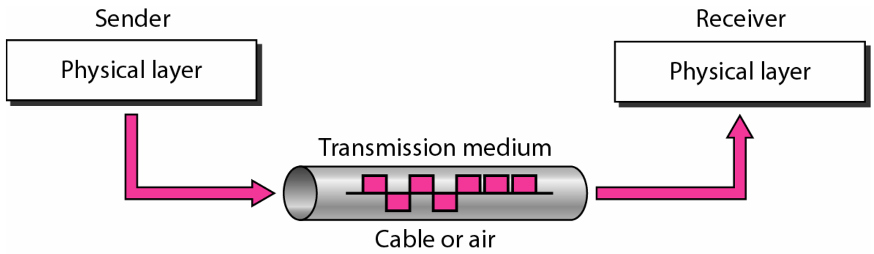
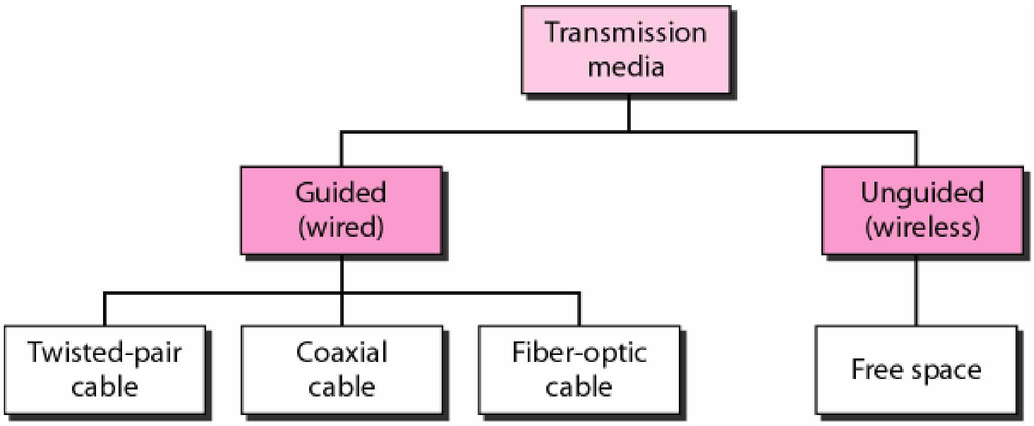
PHYSICAL LAYER

In this chapter, we are going to discuss transmission media. Transmission media are actually located below the physical layer and are directly controlled by the physical layer. You could say that transmission media belong to layer zero. Figure given below shows the position of transmission media in relation to the physical layer.



A transmission **medium** can be broadly defined as anything (either wire or air) that can carry information from a source to a destination. For example, the transmission medium for two people having a dinner conversation is the air. For a written message, the transmission medium might be a mail carrier, a truck, or an airplane. In data communications, the definition of the information and the transmission medium is more specific. The transmission medium is usually free space, metallic cable, or fiber-optic cable. The information is usually a signal that is the result of a conversion of data from another form.

In telecommunications, transmission media can be divided into two broad categories: guided and unguided. Guided media include twisted-pair cable, coaxial cable, and fiber-optic cable. Unguided medium is free space. The classification of transmission media is given in the below figure.



GUIDED MEDIA – WIRED

Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable. A signal traveling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current. Optical fiber is a cable that accepts and transports signals in the form of light.

1. **Twisted Pair Cable**

   A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure below.

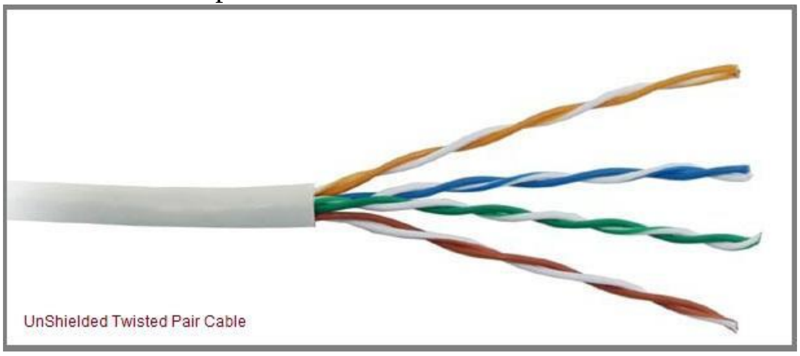
   

   One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. **The receiver uses the difference between the two**. In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals. If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources (e.g., one is closer and the other is farther). This results in a difference at the receiver. By twisting the pairs, a balance is maintained. For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true. Twisting makes it probable that both wires are equally affected by external influences (noise or crosstalk). This means that the receiver, which calculates the difference between the two, receives no unwanted signals. The unwanted signals are mostly cancelled.
   out.

   Twisted Pair is of two types :

   1. **Unshielded Twisted Pair (UTP)**

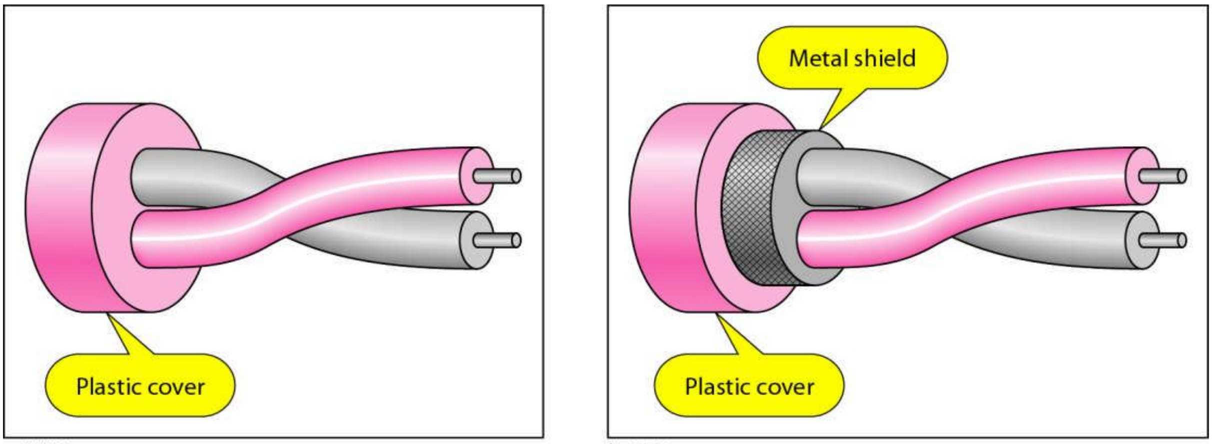
      It consists of two conductors usually copper, each with its own colour plastic insulator. Identification is the reason behind coloured plastic insulation. UTP cables consist of 2 or 4 pairs of twisted cable. Cable with 2 pair use RJ-11 connector and 4 pair cable use RJ-45 connector.

      UnShielded Twisted Pair Cable

   2. **Shielded Twisted Pair (STP)**

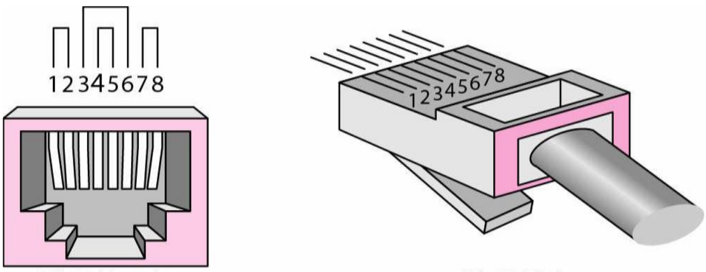
      STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors. Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.



a. UTP b. STP

Connectors

The most common UTP connector is RJ45 (RJ stands for registered jack), as shown in Figure below. The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.



RJ-45 Female RJ-45 Male

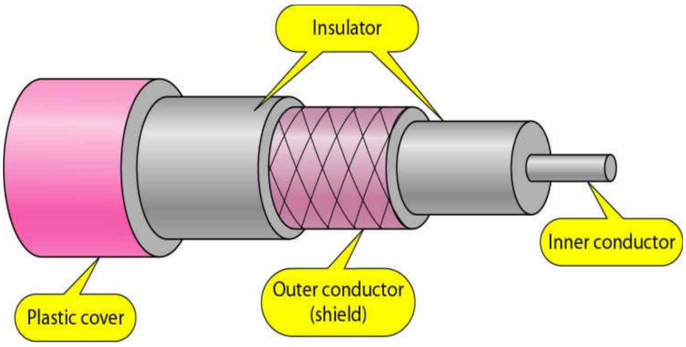
Applications

Twisted-pair cables are used in telephone lines to provide voice and data channels. Local-area networks, such as 10BaseT and l00Base-T, also use twisted-pair cables.

2. **Coaxial Cable**

Coaxial is called by this name because it contains two conductors that are parallel to each other. Copper is used in this as centre conductor which can be a solid wire or a standard one. It is surrounded by PVC installation, a sheath which is encased in an outer conductor of metal foil, barid or both.

Outer metallic wrapping is used as a shield against noise and as the second conductor which completes the circuit. The outer conductor is also encased in an insulating sheath. The outermost part is the plastic cover which protects the whole cable.



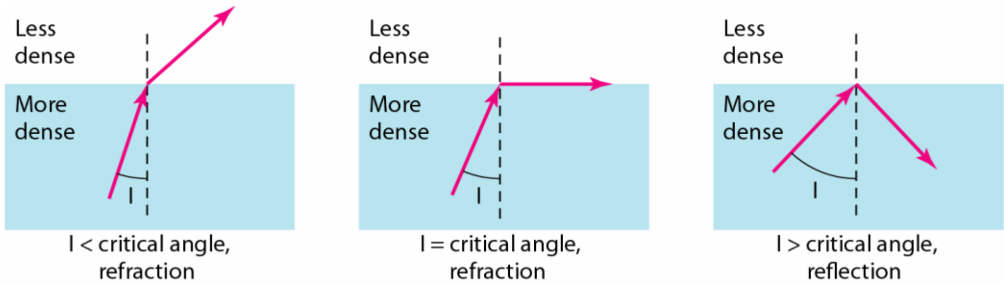
Applications

Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals. Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps. However, coaxial cable in telephone networks has largely been replaced today with fiber-optic cable. Cable TV networks also use coaxial cables. In the traditional cable TV network, the entire network used coaxial cable.

3. Fiber Optic Cable

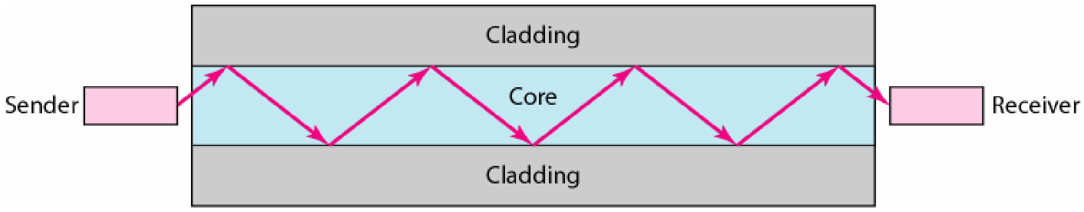
A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. To understand optical fiber, we first need to explore several aspects of the nature of light.

Light travels in a straight line as long as it is moving through a single uniform substance. If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction. Figure below shows how a ray of light changes direction when going from a more dense to a less dense substance.



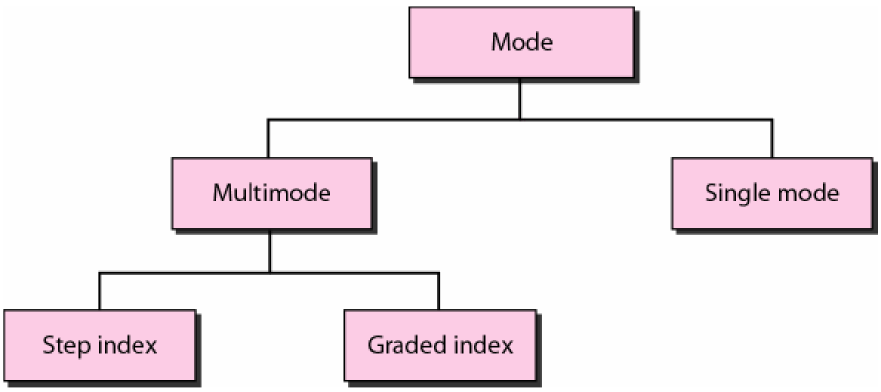
As the figure shows, if the angle of incidence *I* is less than the critical angle, the ray refracts and moves closer to the surface. If the angle of incidence is equal to the critical angle, the light bends along the interface. If the angle is greater than the critical angle, the ray reflects (makes a turn) and travels again in the denser substance. Note that the critical angle is a property of the substance, and its value differs from one substance to another.

Optical fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it as shown in the following Figure



Fiber optic cable has bandwidth more than 2 Gbps (Gigabytes per Second)

Propagation Modes
Current technology supports two modes (Multimode and Single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics. Multimode can be implemented in two forms: Step-index or Graded-index.



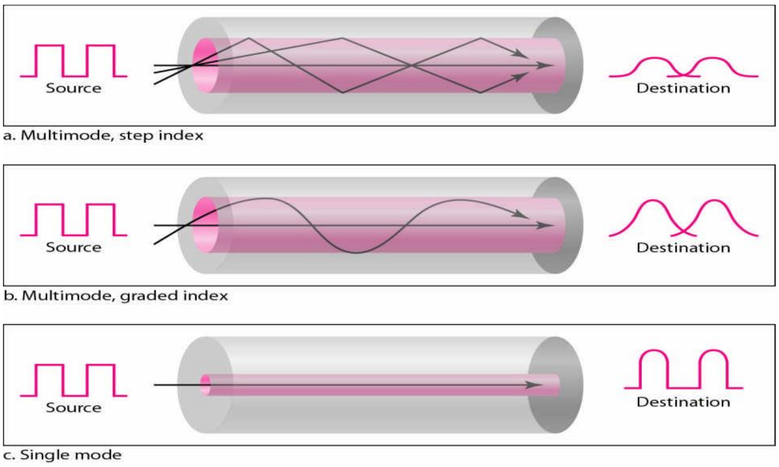
Multimode
It is called Multimode because multiple beams from a light source move through the core in different paths. How these beams move within the cable depends on the structure of the core, as shown in Figure below.

In **Multimode Step-index fiber**, the density of the core remains constant from the center to the edges. A beam of light moves through this constant density in a straight-line until it reaches the interface of the core and the cladding. At the interface, there is an abrupt change due to a lower density; this alters the angle of the beam's motion. The term ***step index*** refers to the suddenness of this change, which contributes to the distortion of the signal as it passes through the fiber.

A second type of fiber, called **Multimode Graded-index fiber**, decreases this distortion of the signal through the cable. A Graded-index fiber, therefore, is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge. Figure below shows the impact of this variable density on the propagation of light beams.

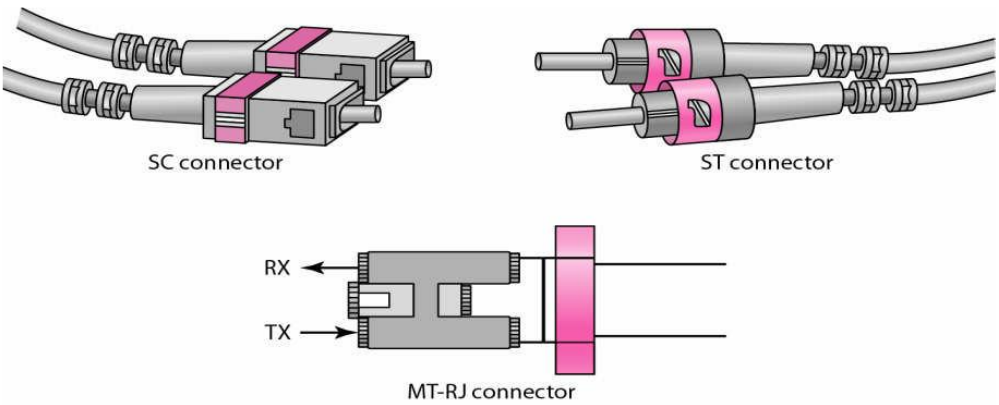
Single-Mode

Single-mode uses Step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The single mode fibers itself is manufactured with a much smaller diameter than that of multimode fiber, and with substantially lower density. The decrease in density results in a critical angle that is close enough to 90° to make the propagation of beams almost horizontal. In this case, propagation of different beams is almost identical, and delays are negligible. All the beams arrive at the destination "together" and can be recombined with little distortion to the signal



Optical Fiber Cable – Connectors

There are three types of connectors for fiber-optic cables, as shown in Figure below. The **Subscriber Channel** (SC) **connector** is used for cable TV. It uses a push/pull locking system. The **Straight-Tip** (ST) **connector** is used for connecting cable to networking devices. It uses a bayonet locking system and is more reliable than SC. The **Mechanical Transfer- Registered Jack (**MT-RJ**)**is a connector that is the same size as **RJ45**.



Applications

Fiber-optic cable is often found in backbone networks (The SONET network) because its wider bandwidth is cost-effective. Today, with wavelength-division multiplexing (WDM), we can transfer data at a rate of 1600 Gbps. Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network. Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises. LANs such as 100Base-FX network (Fast Ethernet) and 1000Base-X (Gigabit Ethernet) also use fiber-optic cable.

Advantages of Optical Fiber

Fiber-optic cable has several advantages over metallic cable (twisted pair or coaxial)

- **Higher bandwidth**: Fiber-optic cable can support dramatically higher bandwidths(data rates) than either twisted-pair or coaxial cable. Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available.
- **Less signal attenuation**: Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.
- **Immunity to electromagnetic interference**: Electromagnetic noise cannot affect fiber-optic cables.
- **Resistance to corrosive materials**: Glass is more resistant to corrosive materials than copper.
- **Light weight**: Fiber-optic cables are much lighter than copper cables.
- G**reater immunity to tapping**: Fiber-optic cables are more immune to tapping than copper cables.

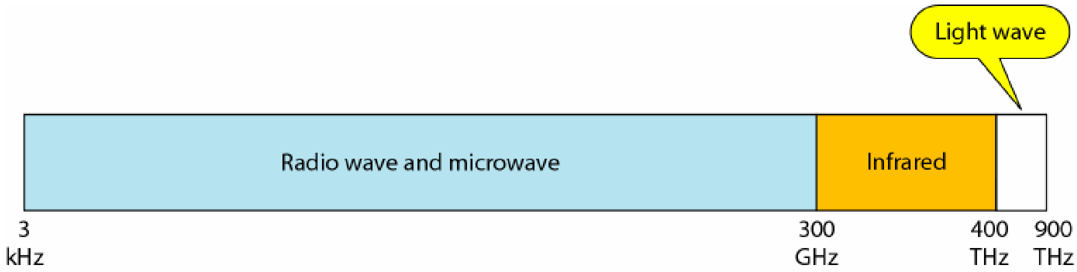
Disadvantages of Optical Fiber

There are some disadvantages in the use of optical fiber.

- **Installation and maintenance**: Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.
- **Unidirectional light propagation**: Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
- **Cost**: The cable and the interfaces are relatively more expensive than those of other guided media

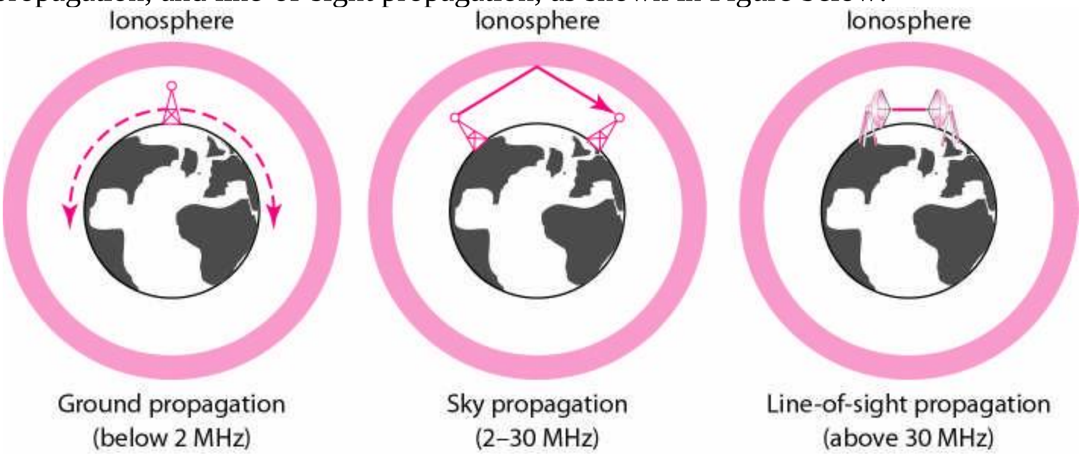
UNGUIDED MEDIA – WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication. Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them. Figure 6.15 shows the part of the electromagnetic spectrum, ranging from 3 kHz to 900 THz, used for wireless communication.



Propagation Methods

Unguided signals can travel from the source to destination in several ways: ground propagation, sky propagation, and line-of-sight propagation, as shown in Figure below.



In **Ground propagation**, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in **all directions** from the transmitting antenna and follow the curvature of the planet. Distance depends on the amount of power in the signal: The greater the power, the greater the distance.

In **Sky propagation**, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth. This type of transmission allows for greater distances with lower output power.

In **Line-or-sight propagation**, very high-frequency signals are transmitted in straight-line directly from antenna to antenna. Antennas must be directional, facing each other and either tall enough or close enough together not to be affected by the curvature of the earth. Line-of sight propagation is tricky because radio transmissions cannot be completely focused.

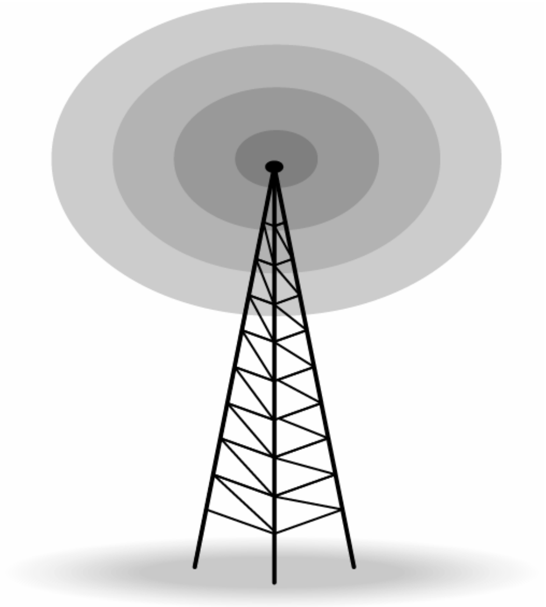
RADIO WAVES

Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called Radio waves.

Radio waves, for the most part, are omni directional. When an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned. The omni directional property has a disadvantage, too. The radio waves

transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.
Radio waves, particularly those waves that propagate in the sky mode, can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio.
Radio waves, particularly those of low and medium frequencies, can penetrate walls. This characteristic can be both an advantage and a disadvantage. It is an advantage because, for example, an AM radio can receive signals inside a building. It is a disadvantage because we cannot isolate a communication to just inside or outside a building. The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band.

Omni directional Antenna
Radio waves use omni directional antennas that send out signals in all directions. Based on the wavelength, strength, and the purpose of transmission, we can have several types of antennas. Figure below shows an omni directional antenna.



Applications
The omni directional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers. AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

MICRO WAVES

Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas.

The following describes some characteristics of microwave propagation:

- Microwave propagation is line-of-sight. Since the towers with the mounted antennas need to be in direct sight of each other, towers that are far apart need to be very tall. Repeaters are often needed for long distance communication.
- Very high-frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside buildings.
- The microwave band is relatively wide, almost 299 GHz. Therefore wider sub-bands can be assigned, and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

Unidirectional Antenna

Microwaves need unidirectional antennas that send out signals in one direction. Two types of antennas are used for microwave communications: the parabolic dish and the horn.

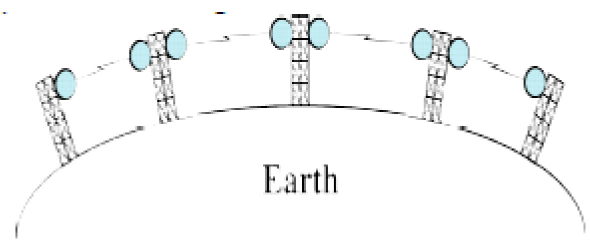
A **parabolic dish** antenna is based on the geometry of a parabola:
Every line parallel to the line of symmetry (line of sight) reflects off the curve at angles such that all the lines intersect in a common point called the focus. The parabolic dish works as a funnel, catching a wide range of waves and directing them to a common point. In this way, more of the signal is recovered than would be possible with a single-point receiver.
Outgoing transmissions are broadcast through a horn aimed at the dish. The microwaves hit the dish and are deflected outward in a reversal of the receipt path.

A **horn antenna** looks like a gigantic scoop. Outgoing transmissions are broadcast up a stem (resembling a handle) and deflected outward in a series of narrow parallel beams by the curved head. Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and are deflected down into the stem.

We can categories the Microwave systems into two categories such as terrestrial-microwave and satellite-microwave systems.

Terrestrial Microwaves

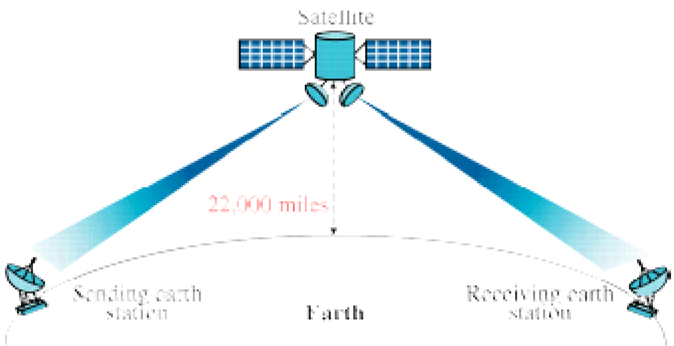
Terrestrial microwave uses parabolic dish, signals are highly focused and line of sight is maintained between sender and receiver (see Figure below). It is used in Long haul telecommunications.



Satellite Microwaves

In this, satellite acts as a relay station (repeater). Satellite receives signals on one frequency (uplink) from sending earth station, amplifies or repeats the signals and transmits on another frequency (downlink) to the receiving earth station. Satellite need to be positioned in the geosynchronous orbit (height of 36,000 km from earth) with the help of space shuttle.

Geosynchronous means stationary with respect to the earth, hence the position of particular Earth Station with respect to the satellite remains constant at all times(see Figure below). It is used in Television, Long distance telephone and Private business networks.



Microwaves Applications

Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed between the sender and the receiver. They are used in cellular phones, satellite networks, and wireless LANs.

INFRA RED

Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another; a short-range communication system in one room cannot be affected by another system in the next room. When we use our infrared remote control, we do not interfere with the use of the remote by our neighbours. However, this same characteristic makes infrared signals useless for long-range communication. In addition, we cannot use infrared waves outside a building because the sun’s rays contain infrared waves that can interfere with the communication.