Unit 3 Transmission Media

Bandwidth:-

1.Definition: Bandwidth in computer networking refers to the data rate supported by a network connection or interface.

2. One most commonly expresses bandwidth in terms of bits per second (bps).

3.Bandwidth describes the maximum data transfer rate of a network or Internet connection**.**

Baud rate:-

1. Baud rate refers to the number of signal or symbol changes that occur per second.
2. A symbol is one of several voltage, frequency, or phase changes.
3. A baud Rate is the number of times per second a signal in a communications channel changes.
4. NRZ binary has two symbols, one for each bit 0 or 1, that represent voltage levels.

Bit Rate:-

The bit rate is the number of bits transmitted per second.

Unit of bit rate is bits per second.

Note:-

Bps = baud per second x the number of bit per baud

i.e. Bit rate=baud rate*bits per seconds.

The Maximum Data Rate of a Channel

In 1924 H.Nyquist derived an equation expressing the maximum data rate for a finite bandwidth noiseless channel.

Theorem:-

Nyquist proved that if an arbitrary signal has been run through a low-pass filter of bandwidth H, the filtered signal can be completely reconstructed by making only 2H exact samples per second. Sampling the line faster than 2H times per second is pointless because the higher frequency components that such sampling could recover have already been filtered out. If the signal consists of V discrete levels,

Nyquist theorem states: Maximum data rate = 2H log2 V bits/sec

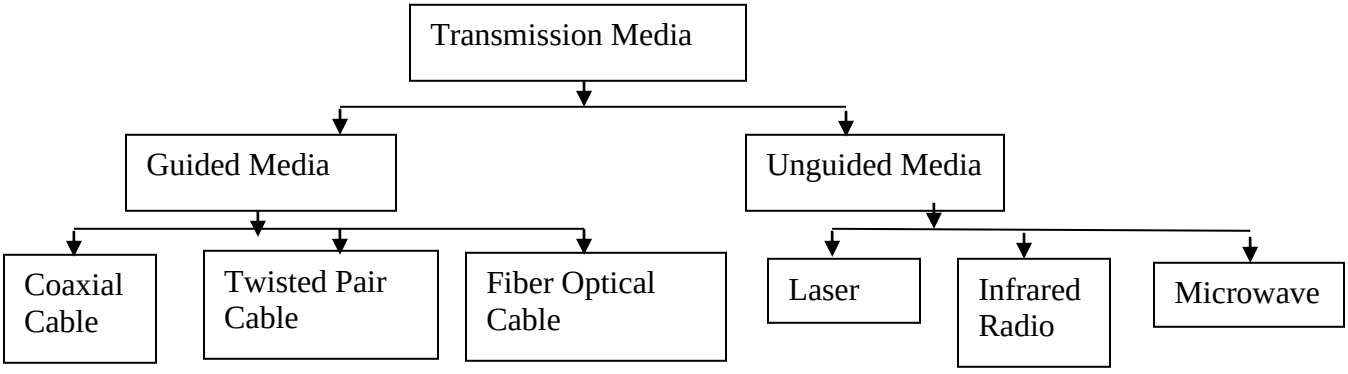
Shannon's Theorem

Shannon's theorem gives the maximum data rate for channels having noise (e.g., all real channels). Shannon's theorem states that the maximum data rate of a noisy channel of bandwidth *H*, signal-to-noise ratio of *S*/*N* is given by:

Max data rate = $H \log_2 (1+S/N)$

Transmission Media:-

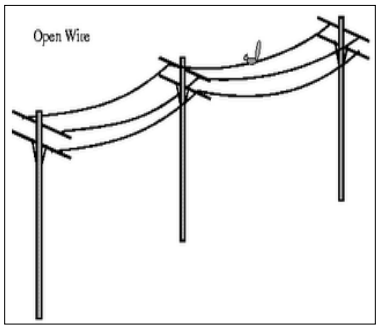
1. Transmission media is responsible to send data from one computer to another computer.
2. This can be sent using two methods- Analog method and Digital method.
3. These analog signals or waves or digital signals can be transmitted through transmission media. This transmission media is divided into two types: **Guided media and unguided media**.



4. Transmission media provides the physical entity for the conveyance of signals.
5. Electromagnetic energy, a combination of electrical and magnetic fields vibrating in relation to each other includes power, voice, radio waves, infrared light, visible light, ultraviolet light and X gamma and cosmic rays.
6. **Characteristics of transmission media:-**
   i. Characteristics and quality determined by medium and signal. For guided (wired), the medium is more important. For unguided (Wireless) the bandwidth produced by antenna is more important.
   ii. Higher the data rate needs higher bandwidth.
   iii. For guided medium, higher data rate needs closer repeaters.
   iv. For same signal bandwidth, data rate is much lower in unguided media as compared to optical fiber or coaxial cable.

A) <u>Guided Media</u>

1. **<u>Open wire</u>**:-

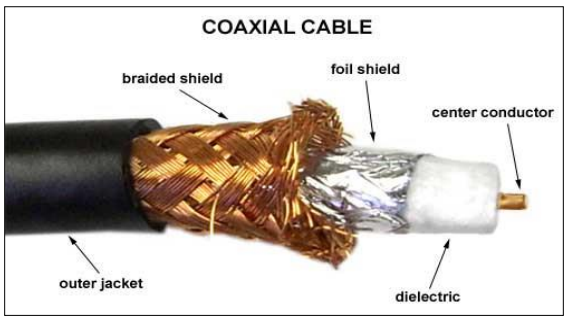


2. Open Wire is traditionally used to describe the electrical wire strung along power poles
3. There is a single wire strung between poles. No shielding or protection from noise interference is used.
4. We are going to extend the traditional definition of Open Wire to include any data signal path without shielding or protection from noise interference.
5. This can include multiconductor cables or single wires.
6. This media is susceptible to a large degree of noise and interference and consequently not acceptable for data transmission except for short distances under 20 ft.
7. Non-conductive spacers are used between the conducting wires to separate and supported them.
8. **Advantage**:-
   A. Construction is simple
9. **Disadvantage**:-
   A. High energy loss, since the wires are not shielded, energy loss via radiation is immense.
   B. The wire pair is cable of picking up random signals, resulting in interface (crosstalk).
10. **Used**:-
   A. To transmit acoustic waves for telephone application.

2. **<u>Coaxial Cable:-</u>**

1. Coaxial cable (or "coax") is the most common cable used for transmission video signals. The name "coaxial" refers to the common axis of the two conductors.

2. **<u>Physical Description:-</u>**



i. **Center Conductor:** At the heart of a coaxial cable is a center conductor. Typically constructed of pure copper (in higher-end cables) or copper-coated steel or aluminum (in less-expensive cables), the center conductor is responsible for transmitting the cable's signal

ii. **Dielectric Insulator:** The dielectric insulator's purpose is two-fold; first, it acts as an insulator between the centers conductors and the outer braided / foil shielding. Second, it helps physically hold the center conductor in

the center of the cable. This is important, as signal loss can occur if the center conductor strays too close to the outer area of the cable. Various materials are commonly used for the dielectric. A few of the more common materials, in order of quality (from best to worst), are below:

- Foamed Polyethylene (FPE)
- Teflon
- Polyethylene (PE)
- Polypropylene (PP)
- Polyvinylchloride (PVC)

iii. **Braided Shield:** A braided shield protects the signal from EMI interference. When looking at cable specs, the braided shield will often be expressed in a percent coverage, which often ranges anywhere from 30% to 95% coverage. The higher the coverage, the better the protection.

iv. **Foil Shield:** Although not always present on coaxial cables, the foil shield serves to protect from RFI interference. Foil shields are almost always made out of aluminum foil, and simply wrap around the inner parts of the cable. Unlike braided shields, which have a percent coverage, foil shields always cover 100%.

v. **Outer Jacket:** The outer jacket is generally made out of flexible PVC (polyvinyl chloride) and serves primarily to hold the cable together and protect it from the elements.

3. There are two types of coax that are widely used:-

i. Baseband:-

a. Baseband coaxial cables are 50 ohm cables used for 'digital transmission'.
b. For 1Km cables the bandwidth is 1-2 Gbps.
c. Longer cables can be used with low data rates or periodic amplifiers.
d. Bidirectional propagation of the signal.
e. Advantage:- Simplicity, low cost, ease of installation and maintenance.
f. Disadvantage:- Limited distance, Data and voice only

ii. Broadband:-

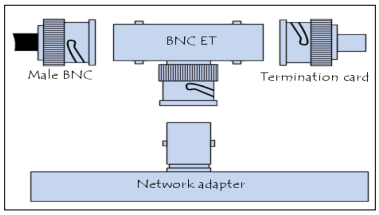
a. Broadband coaxial cable is 75 ohm cables used for analog transmission.
b. They use standard cable television technology.
c. To transmit digital signals on an analog network, each interface must have converters i.e. analog to digital for outgoing bit stream n vice versa
d. Broadband systems have developed dual cables. Since broadband is used for large area, it requires amplifiers which are unidirectional.
e. Advantage: - Data- voice and video, Greater distances, Greater bandwidth.
f. Disadvantage: - Cable design, High cost, requires modems, Lack of well developed standards.

7. **<u>Application</u>:-**

i. Used community antenna television (CATV).
ii. Used in traditional Ethernet local area network (LAN).
iii. Used in closed circuit television (CCTV).
iv. It is widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.

8. **<u>Connectors for coaxial cable:-</u>**

BNC connectors (*Bayonet-Neill-Concelman* or *British Naval Connector*) are connectors for coaxial cables. The BNC family is made up of the following elements:



i. **BNC cable connector**: is either soldered or crimped to the end of the cable.

ii. **BNC T-connector**: links a computer's network card to the network cable

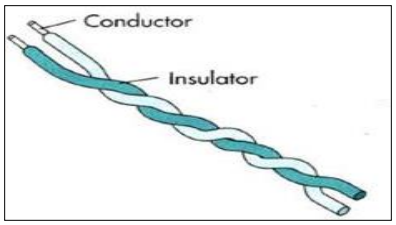
iii. **BNC barrel connector**: joins two lengths of coaxial cable, to make a longer cable.

iv. **BNC terminators**: placed at both ends of a bus cable to absorb stray signals. They are grounded. A bus network cannot function without them. It would be out of service.

9. **Performance**: - The attenuation is much higher in coaxial cables than twisted pair cable i.e. although coaxial cable has a much higher bandwidth; the signal weaker rapidly and requires the frequent use of repeaters.
10. **Advantage**:-
    i. Coaxial cable can support greater cable lengths between network devices than twisted pair cable. Thick coaxial cable has an extra protective plastic cover that helps keep moisture away.
    ii. Sufficient frequency range to support multiple channels, which allows for much greater throughput.
    iii. Lower error rates. Because the inner conductor is in a Faraday shield, noise immunity is improved, and coax has a lower error rates and therefore slightly better performance than twisted pair.
    iv. Greater spacing between amplifiers coax's cable shielding reduces noise and crosstalk, which means amplifiers can be spaced farther apart than with twisted pair.
    v. It provides better immunity than twisted pair.
11. **Disadvantage:-**
    i. Thick coaxial is that it does not bend easily and is difficult to install
    ii. More expensive to install compare to twisted pair cable.
    iii. The thicker the cable, the more difficult to work with.

3) Twisted Pair Cable:-

1. **Twisted-pair cable is the most common type of cabling you can see in today's LAN networks.**
2. Twisted pair cables are so named because pairs of wires are twisted around one another
3. **Physical description:-**



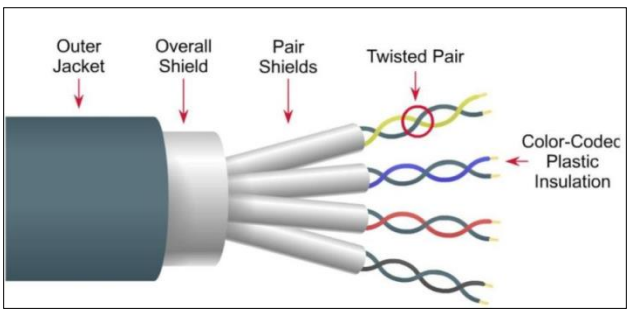
i. It consists of two plastic insulated 1 mm. thick copper wires.
ii. They are twisted around each other in a helical form.
iii. The number of pairs bounded together in a cable.
iv. In two wires one is used only for the carry signals to the reviver, and the other is used for ground reference.

5. Why the cable is twisted:-

i. If the two wires are parallel, the wire closers to the source of the noise gets more interface and ends up with a higher voltage level than the wire farther away, which results in an uneven load and a damaged signal.
ii. If however the two wires are twisted around each other at regular intervals, each wire is closer to the noise source for half the time and farther away for the other half.
iii. With the twisting, the cumulative effect of the interface is equal on both wires. The degree of the reduction in noise interface is determined specifically by the number of turns per foot. Increasing the number of turns per foot reduces the noise interface. To further improve noise rejection, a foil or wire braid shield is woven around the twisted pairs.

6. There are two types of twisted pair cable:-

i. Shielded twisted-pair (STP) *cable*:-



a. Which are combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil.

b. The four pairs of wires then are wrapped in an overall metallic braid or foil, usually 150-ohm cable.

c. As specified for use in Ethernet network installations, STP reduces electrical noise

both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI).

d. STP usually is installed with STP data connector, which is created especially for the STP cable. However, STP cabling also can use the same RJ connectors that UTP uses.\

e. Although STP prevents interference better than UTP, it is more expensive and difficult to install.

f. The following summarizes the features of STP cable:

A. Speed and throughput—10 to 100 Mbps
B. Average cost per node—Moderately expensive
C. Media and connector size—Medium to large
D. Maximum cable length—100 m (short)

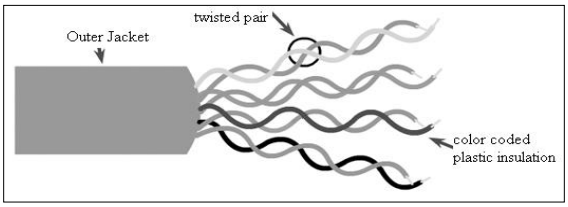
g. **Advantages of STP:**

A. Shielded
B. Faster than UTP and coaxial

h. **Disadvantages of STP:**

A. More expensive than UTP and coaxial
B. More difficult installation
C. High attenuation rate

ii. UTP Cable:-



a. UTP cable is a medium that is composed of pairs of wires.

b. UTP cable is used in a variety of networks. Each of the eight individual copper wires in UTP cable is covered by an insulating material. I

c. In addition, the wires in each pair are twisted around each other.

d. To reduce crosstalk between the pairs in UTP cable, the number of twists in the wire pairs varies..

e. When used as a networking medium, UTP cable has four pairs of either 22- or 24-gauge copper wire.

f. UTP used as a networking medium has an impedance of 100 ohms; this differentiates it from other types of twisted-pair wiring such as that used for telephone wiring, which has impedance of 600 ohms.

g. The following summarizes the features of UTP cable**:**

A. Speed and throughput—10 to 1000 Mbps
B. Average cost per node—Least expensive
C. Media and connector size—Small
D. Maximum cable length—100 m (short)

h. Commonly used types of UTP cabling are as follows:

A. Category 1—used for telephone communications. Not suitable for transmitting data.
B. Category 2—Capable of transmitting data at speeds up to 4 megabits per second (Mbps).
C. Category 3—used in 10BASE-T networks. Can transmit data at speeds up to 10 Mbps.
D. Category 4—used in Token Ring networks. Can transmit data at speeds up to 16 Mbps.
E. Category 5—can transmit data at speeds up to 100 Mbps.
F. Category 5e —Used in networks running at speeds up to 1000 Mbps (1 gigabit per second [Gbps]).
G. Category 6—Typically, Category 6 cable consists of four pairs of 24 American Wire Gauge (AWG) copper wires. Category 6 cables are currently the fastest standard for UTP.

i. **Advantages of UTP**
   A. Easy installation
   B. Capable of high speed for LAN
   C. Low cost

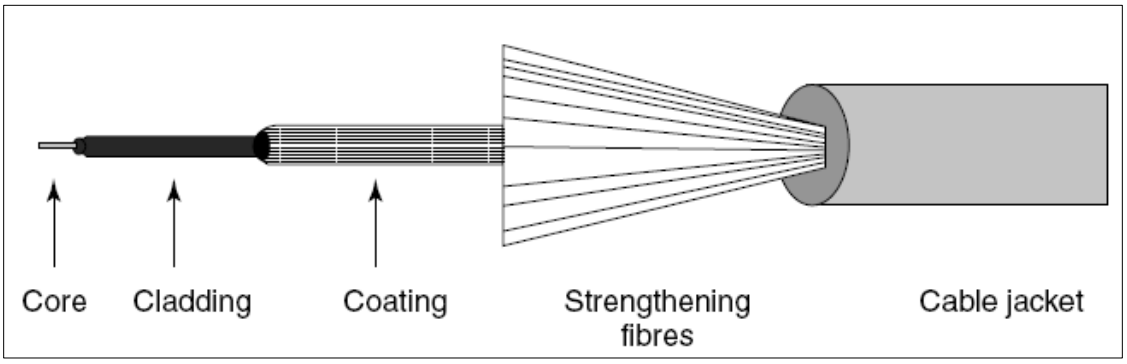
j. **Disadvantages of UTP**
   A. Short distance due to attenuation

Fiber Optical Cable:-

1. Fiber optical cable is glass cabling media that sends network signals using light.
2. Fiber optical cable has higher bandwidth capacity than copper cabling and is used mainly for high-speed network Asynchronous Transfer Mode(ATM) or Fiber Distributed Data Interface (FDDI) backbones, long cable runs and connections to high-performance workstations.

3. Physical Structure:-

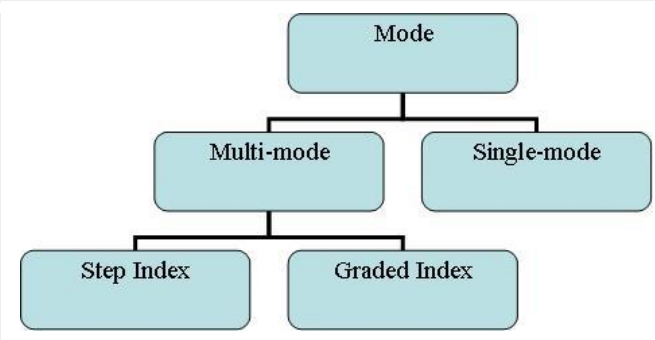
- In recent years it has become apparent that fiber-optics are steadily replacing copper wire as an appropriate means of communication signal transmission.
- They span the long distances between local phone systems as well as providing the backbone for many network systems.
- Other system users include cable television services, university campuses, office buildings, industrial plants, and electric utility companies.
- A fiber-optic system is similar to the copper wire system that fiber-optics is replacing. The difference is that fiber-optics use light pulses to transmit information down fiber lines instead of using electronic pulses to transmit information down copper lines.
- Looking at the components in a fiber-optic chain will give a better understanding of how the system works in conjunction with wire based systems.



- At one end of the system is a transmitter. This is the place of origin for information coming on to fiber-optic lines.
- The transmitter accepts coded electronic pulse information coming from copper wire. It then processes and translates that information into equivalently coded light pulses. A light-emitting diode (LED) or an injection-laser diode (ILD) can be used for generating the light pulses.
- Using a lens, the light pulses are funneled into the fiber-optic medium where they travel down the cable.
- Think of a fiber cable in terms of very long cardboard roll (from the inside roll of paper towel) that is coated with a mirror on the inside.
- If you shine a flashlight in one end you can see light come out at the far end - even if it's been bent around a corner.
- Light pulses move easily down the fiber-optic line because of a principle known as total internal reflection. "This principle of total internal reflection states that when the angle of incidence exceeds a critical value, light cannot get out of the glass; instead, the light bounces back in.

- When this principle is applied to the construction of the fiber-optic strand, it is possible to transmit information down fiber lines in the form of light pulses.
- Fiber optic cable functions as a "light guide," guiding the light introduced at one end of the cable through to the other end. The light source can either be a light-emitting diode (LED)) or a laser.
- The light source is pulsed on and off, and a light-sensitive receiver on the other end of the cable converts the pulses back into the digital ones and zeros of the original signal.
- Even laser light shining through a fiber optic cable is subject to loss of strength, primarily through dispersion and scattering of the light, within the cable itself. The faster the laser fluctuates, the greater the risk of dispersion. Light strengtheners, called repeaters, may be necessary to refresh the signal in certain applications.
- While fiber optic cable itself has become cheaper over time - a equivalent length of copper cable cost less per foot but not in capacity. Fiber optic cable connectors and the equipment needed to install them are still more expensive than their copper counterparts.

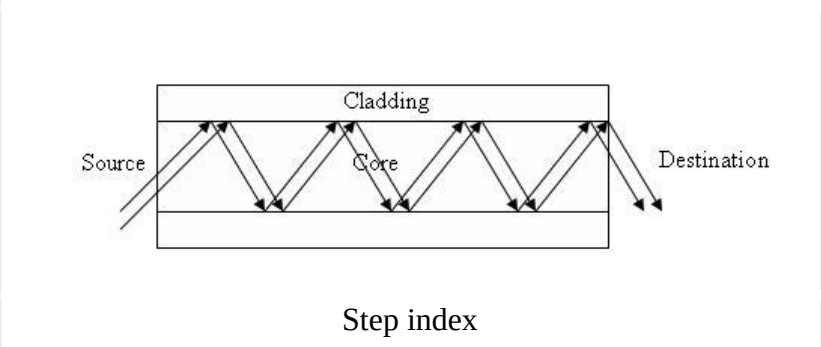
4. **Propagation Mode**
   - According to the mode of propagation, optical fiber is classified into two: single-mode and multi-mode.



Optical fiber propagation mode

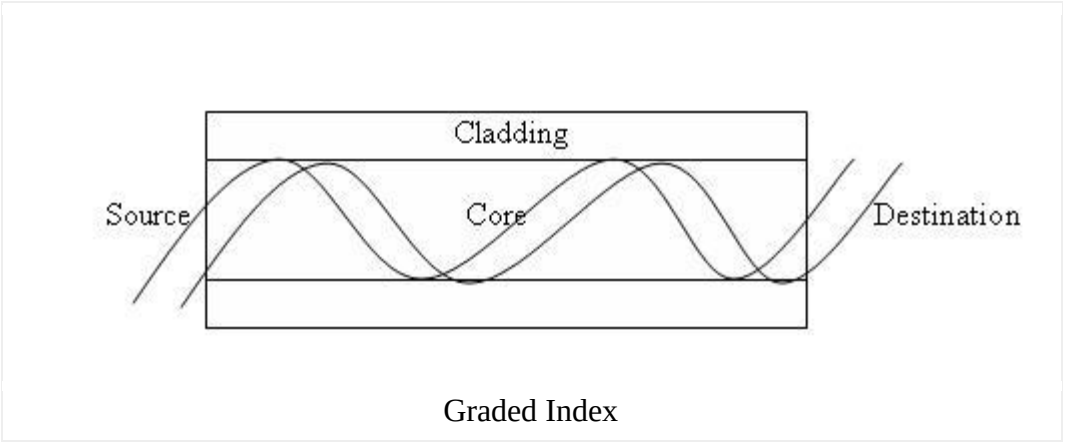
a) **Multi-mode**

- Multimode fiber optic cable has a large diameter core that allows multiple modes of light to propagate. How these different light beams are move within the optical fiber depends on the construction of the core.
  i) In **step-index** optical fiber, the density of the core is remains same constant throughout the core. That means the density is constant from center to edges of the core. When a light reaches the interface of the core and the cladding, there is a sudden change due to change in the density. The following figure shows a step index optical fiber.



Step index

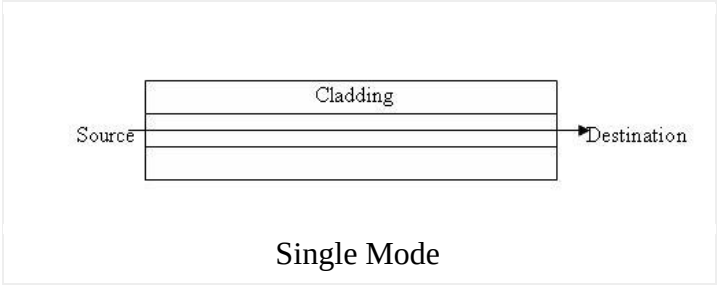
ii) In the case of **graded index** fiber, density is highest at the center of the core and decrease slowly to its lowest at the edge. There fore the light beams are propagate as shown below,



Graded Index

b) **Single-Mode**

- Single-mode fiber optic cable has a small diameter and small dense core that allows only one mode of light to propagate.
- The decrease in density results in a critical angle that is close to 90 degree to make the movement of the beams horizontally. All beams arrive at the destination together and it is the responsibility of the receiver to distinguish them.

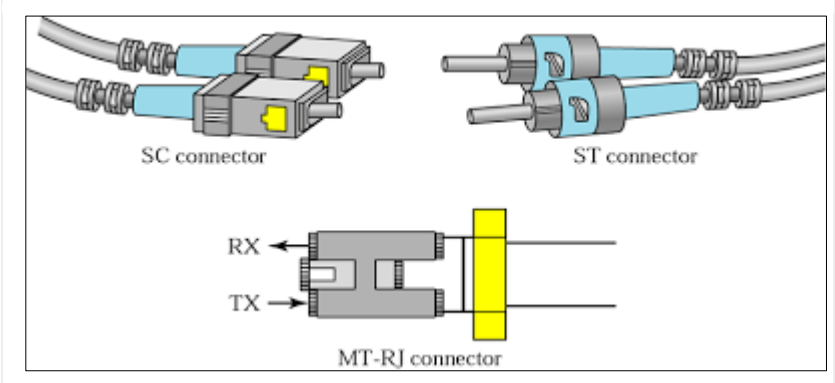


Single Mode

5. Connectors

There are three types of connectors for fiber-optic cable.

- 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.
- **MT-RJ** is a connector that is the same size as RJ45.



6. Advantages

- Higher bandwidth. Fiber-optic cable can support dramatically higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable.

- Less signal attenuation. The distance of transmission is significantly greater than that of other guided media. A signal can run for 50 kilometers without requiring regeneration.
- Immunity to electromagnetic interference. EM noise cannot affect fiber-optic cables.
- Resistance to corrosive materials. Glass is more resistant to corrosive materials than copper.
- Lightweight. Fiber-optic cables are much lighter than copper cables.
- More immune to tapping. Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antennas that can be easily tapped.

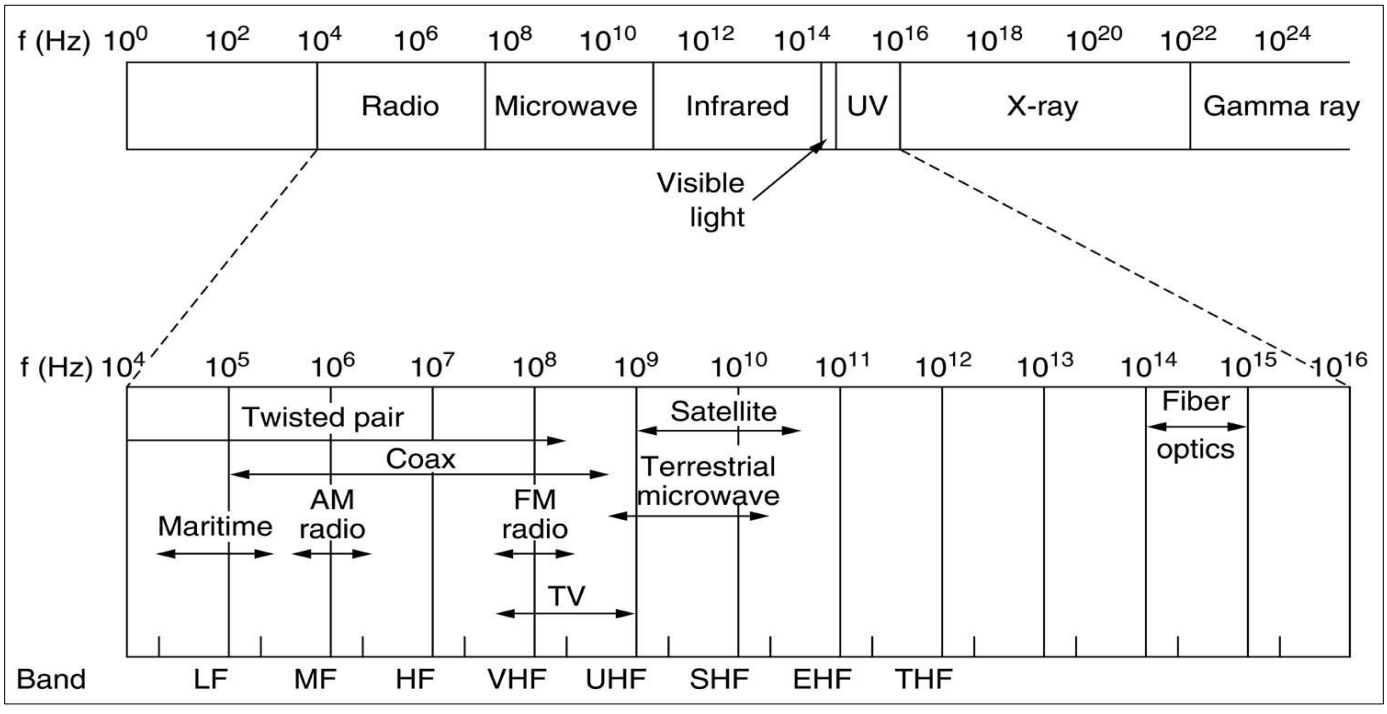
7. **Disadvantages**
   - Installation/maintenance. Fiber-optic is a relatively new technology. I/M need expertise that is not yet available everywhere.
   - Unidirectional. Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
   - Cost. The cable and the interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified. Also, a laser light source can cost thousands of dollars, compared to hundreds of dollars for electrical signal generators.
   - Fragility. Glass fiber is more easily broken than wire, making it less useful for applications where hardware portability is required.

WIRELESS TRANSMISSION (Unguided Media)

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.

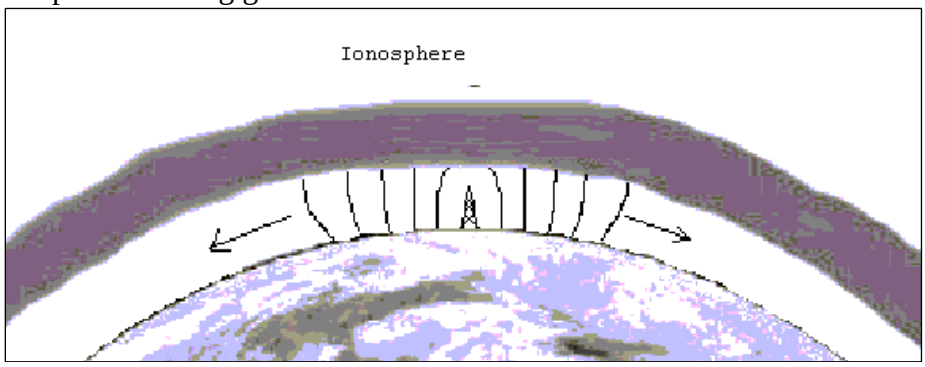
Electromagnetic Spectrum for wireless Communication:-

- Wireless transmission is a form of unguided media. Wireless communication involves no physical link established between two or more devices, communicating wirelessly. Wireless signals are spread over in the air and are received and interpret by appropriate antennas.
- When an antenna is attached to electrical circuit of a computer or wireless device, it converts the digital data into wireless signals and spread all over within its frequency range. The receptor on the other end receives these signals and converts them back to digital data.
- A little part of electromagnetic spectrum can be used for wireless transmission.



1) Ground Wave

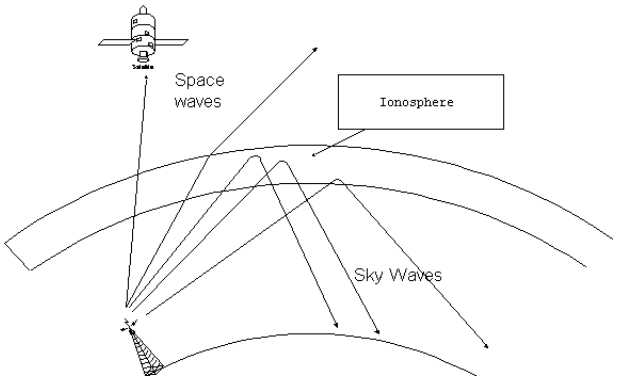
- Radio waves in the VLF band propagate in a ground, or surface wave.
- The wave is connected at one end to the surface of the earth and to the ionosphere at the other.
- The ionosphere is the region above the troposphere (where the air is), from about 50 to 250 miles above the earth. It is a collection of ions, which are atoms that have some of their electrons stripped off leaving two or more electrically charged objects.
- The sun's rays cause the ions to form which slowly recombine.
- The propagation of radio waves in the presence of ions is drastically different than in air, which is why the ionosphere plays an important role in most modes of propagation.
- Ground waves travel between two limits, the earth and the ionosphere, which acts like a duct. Since the duct curves with the earth, the ground wave will follow. Therefore very long range propagation is possible using ground waves.



Figure

2) Sky Waves

- Radio waves in the LF and MF ranges may also propagate as ground waves, but suffer significant losses, or are attenuated, particularly at higher frequencies.
- But as the ground wave mode fades out, a new mode develops: the sky wave. Sky waves are reflections from the ionosphere.
- While the wave is in the ionosphere, it is strongly bent, or refracted, ultimately back to the ground.
- From a long distance away this appears as a reflection. Long ranges are possible in this mode also, up to hundreds of miles.
- Sky waves in this frequency band are usually only possible at night, when the concentration of ions is not too great since the ionosphere also tends to attenuate the signal.
- However, at night, there are just enough ions to reflect the wave but not reduce its power too much.



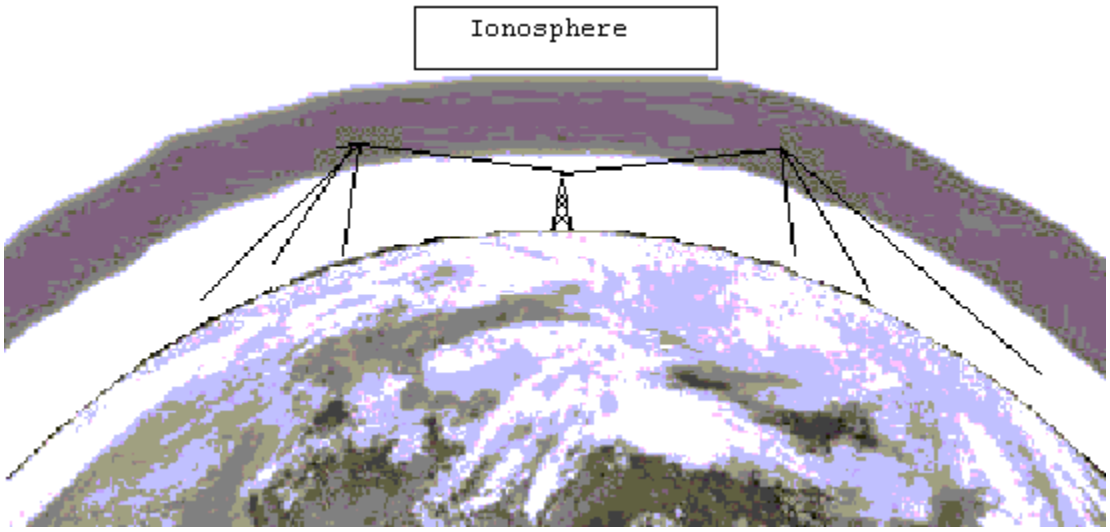
Figure

- The HF band operates almost exclusively with sky waves.

- The higher frequencies have less attenuation and less refraction in the ionosphere as compared to MF.
- At the high end, the waves completely penetrate the ionosphere and become space waves. At the low end, they are always reflected.
- The HF band operates with both these effects almost all of the time.
- The characteristics of the sky wave propagation depend on the conditions in the ionosphere which in turn are dependent on the activity of the sun. The ionosphere has several well-defined regions in altitude.
    i. D-region: about 75-95 km. Relatively weak ionization. Responsible for strong absorption of MF during daylight
    ii. E-region: 95-150 km. An important player in ionospheric scatter of VHF.
    iii. F-region: 150-400 km. Has separate F1 and F2 layers during the day. The strongest concentration of ions. Responsible for reflection of HF radio waves. Since the propagation characteristics depend on frequency, several key frequencies can de defined:
    iv. Critical frequency: The minimum frequency that will penetrate the ionosphere at vertical incidence. The critical frequency increases during the daylight and decrease at night. At other angles, the wave will be reflected back. At frequencies above the critical frequency, some range of waves from vertical incidence and down will become space waves. This will cause a gap in coverage on the ground known as a skip zone. In figure xx, the skip zone extends to about 1400 miles. The transmitted frequency was 5 MHz and the critical frequency was 3 MHz in this example.

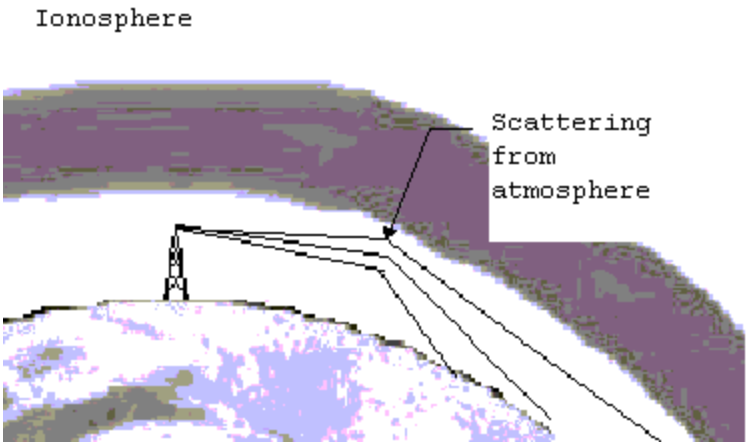
3) Line of Sight

- In the VHF band and up, the propagation tends to straighten out into line-of-sight(LOS) waves.
- However the frequency is still low enough for some significant effects.
- Ionospheric scatter. The signal is reflected by the E-region and scattered in all directions. Some energy makes it back to the earth's surface. This seems to be most effective in the range of 600-1000 miles.



Figure

- Tropospheric scatter. Again, the wave is scattered, but this time, by the air itself. This can be visualized like light scattering from fog. This is a strong function of the weather but can produce good performance at ranges under 400 miles.



Figure

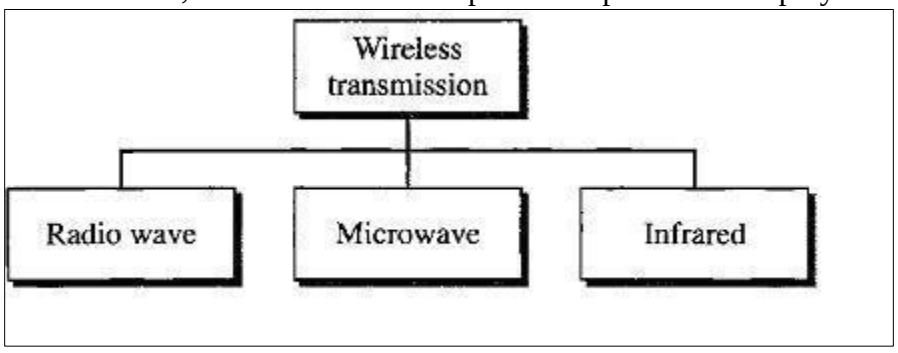
- Tropospheric ducting. The wave travels slower in cold dense air than in warm air. Whenever inversion conditions exist, the wave is naturally bent back to the ground. When the refraction matches the curvature of the earth, long ranges can be achieved. This ducting occurs to some extend always and improves the range over true the line-of-sight by about 10 %.
- Diffraction. When the wave is block by a large object, like a mountain, is can diffract around the object and give coverage where no line-of-sight exists.
- Beyond VHF, all the propagation is line-of-sight. Communications are limited by the visual horizon. The line-of-sight range can be found from the height of the transmitting and receiving antennas by:

$$R = \sqrt{13h_t} + \sqrt{13h_R}$$

where h_t and h_r are the heights of the antennas in meters, and R will be in km (the conversion factor is already taken into account in the factor 13).

Wireless Transmission:-

- The wireless transmission is the sending and receiving of the data packets over the distance without the use of wires.
- The wireless network transmission is the ideal for the locations where the physical medium like coaxial cables, UPT/STP and fiber optic is not possible to deploy.



1. Radio Waves

- Radio waves, for the most part, are omnidirectional.
- 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.
- A sending antenna sends waves that can be received by any receiving antenna. The omnidirectional 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 because for Example, an AM radio can receive signals inside a building.
- The radio wave band is relatively narrow, just under 1 GHZ, compared to the microwave band. When this band is divided into sub bands, the sub bands are also narrow, leading to a low data rate for signal communications.
- **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.

2. Infrared

- It is with frequencies from 300GHz to 400THz(wavelength from 1 mm to 770nm),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 neighbors.
- 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.

Application

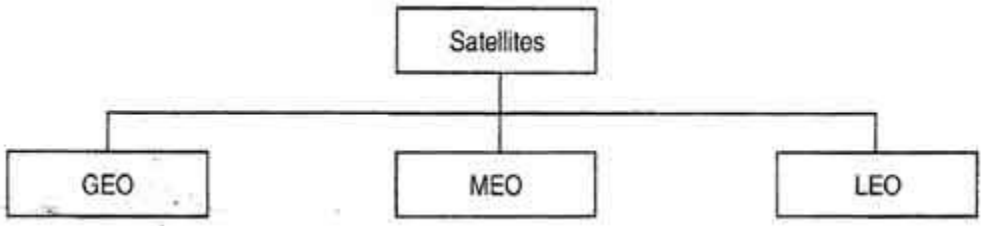
The infrared band, almost 400THz has an excellent potential for data transmission, Such a wide bandwidth can be used to transmit digital data with a very high data rate. The infrared Data Association (IrDA), an association for sponsoring the use of infrared waves, has established standards for using these signals for communication between devices such as keyboards, mice, PCs, and printers. For example, some manufactures provide a special port called the IrDA port that allows a wireless keyboard to communicate with a PC. The standard originally defined a data rate of 75kbps for a distance up to 8 m. The recent standard defines a data rate of 4 Mbps. Infrared signals defined by IrDA transmit through line of sight; the IrDA port on the keyboard needs to point to the PC for transmission to occur.

3. Microwaves

- 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. The curvature of

the earth as well as other blocking obstacles does not allow two short towers to communicate by using microwaves. 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 subbands can be assigned, and a high data rate is possible
    - Use of certain portions of the band requires permission from authorities.
- **Application**
    - 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.
- Satellites are used for variety of purposes as communication, remote sensing, and weather forecasting and for scientific purposes.

Categories of Satellites



Based on the location of the orbit, satellites can be divided into three categories.

1. Geo-stationary Earth Orbit (GEO)
2. Low-Earth Orbit (LEO)
3. Middle-Earth-Orbit (MEO)
    - GEO satellites are usually at 35,800 km above the earth's surface.
    - MEO satellites are located at attitudes between 5,000 and 15,000 km.
    - LEO satellites are normally below an attitude of 2000 km.
    - There are two Van Allen belts that contain charged particles.
    - A satellite orbiting in one of these two belts would be totally destroyed by energetic charged particles.