# 3...

# Transmission Media

## Objectives...

- To introduce Transmission Media and its types
- To learn about Guided Media such as Twisted Pair Cable, Coaxial Cable, Fiber Optic Cable.
- To study of various Unguided Media such as Wireless Transmission.

## 3.1 INTRODUCTION (S-23)

- Computers and other telecommunication devices use signals to represent data. These signals are transmitted from one device to another in the form of electromagnetic energy.
- Electromagnetic signals can travel through a vacuum, air or other transmission media.
- Transmission Medium is used to carry data from the transmitter to the receiver. It is a physical path between sending machine and receiving machine in data communication means it provides a pathway over which the data can travel from sender-to-receiver.
- Each of the messages can be sent in the form of data by converting them into binary digits. These binary digits are then encoded into a signal that can be transmitted over the appropriate medium.
- For example, a copper cable network uses bits as electrical signals while bits in a fiber network are available as light pulses.

### 3.1.1 Types of Transmission Media

- Transmission media can be divided into two broad categories: Guided (wired) and Unguided (wireless).
- Fig. 3.1 shows types of Transmission Media.

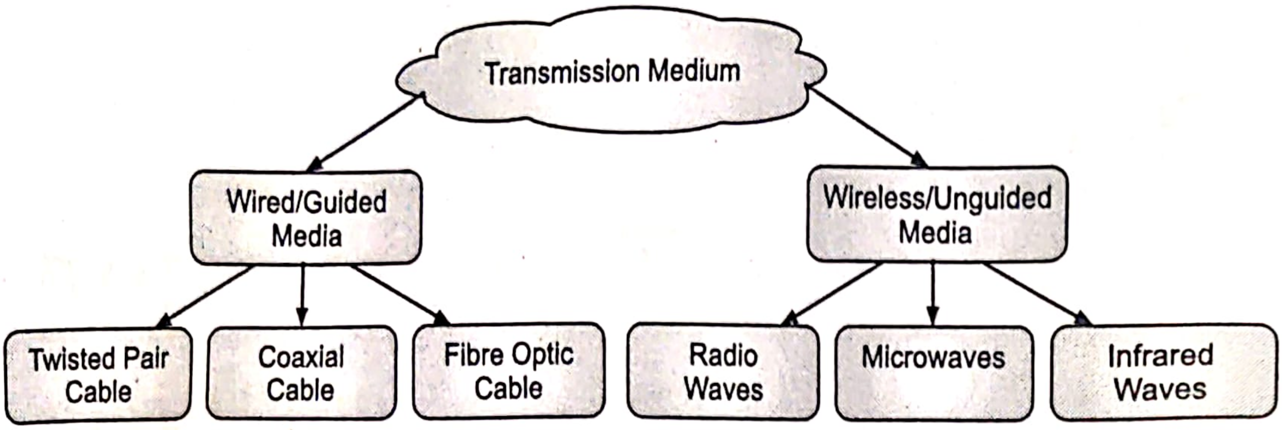



**Fig. 3.1: Types of Transmission Media**

**Types of Transmission Media:**

1. Wired or Guided Media or Bound Transmission Media
   - Twisted Pair Cable
   - Coaxial Cable
   - Fiber Optic Cable
2. Wireless or Unguided Media or Unbound Transmission Media
   - Radio Waves
   - Microwaves
   - Infrared Waves

**Design factors of Transmission Medium:**

- A number of design factors relating to the transmission medium and the signal determine the data rate and distance:
  - **Bandwidth:** All other factors remaining constant, the greater the bandwidth of a signal, the higher the data rate that can be achieved.
  - **Transmission impairments:** Impairments, such as attenuation, limit the distance. For guided media, twisted pair generally suffers more impairment than coaxial cable, which in turn suffers more than Optical fiber.
  - **Interference:** Interference from competing signals in overlapping frequency bands can distort or wipe out a signal. Interference is of particular concern for unguided media but is also a problem with guided media. For guided media, interference can be caused by discharges from nearby cables. For example, twisted pairs are often bundled together and channels often carry multiple cables. Interference can also be experienced from unguided transmissions. Proper shielding of a guided medium can minimize this problem.
  - **Number of receivers:** A guided medium can be used to construct a point-to-point link or a shared link with multiple attachments. In the latter case, each attachment introduces some attenuation and distortion on the line, limiting distance and/or data rate.

## 3.1.2 Characteristics of Transmission Media

1. **Medium and signal:** Characteristics and Quality determined by medium and signal. For guided (wired), the medium is more important. For unguided (wireless) the bandwidth produced by the antenna is more important.
2. **Data Rate:** Higher data rate needs higher bandwidth. For guided medium, higher data rate needs closer repeaters. For same signal bandwidth, data rate is much lower in unguided media compared to optical fiber or coaxial cable.

## 3.2 GUIDED MEDIA (W-18, S-22. S-23)

- Guided media also known as Bounded media.
- Guided transmission media uses a "cabling" system that guides the data signals along a specific path. Cabling is meant in a generic sense in the previous sentences and is not meant to be interpreted as copper wire cabling only.
- Cable is the medium through which information usually moves from one network device to another.

**Types:**

- There are four basic types of Guided Media are:
  1. Open Wire
  2. Twisted Pair
  3. Coaxial Cable
  4. Fiber-optic Cable

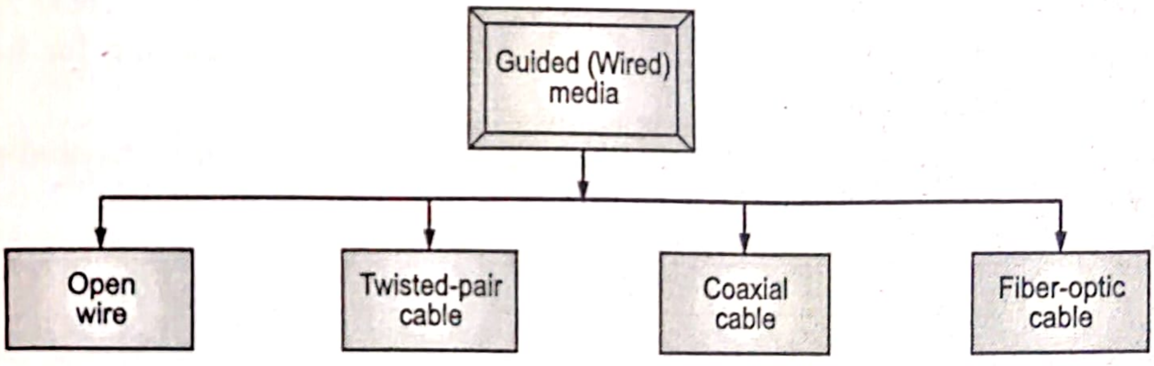



**Fig. 3.2: Types of Guided Media**

- Twisted Pair cable and Coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current. Optical fiber is a glass or plastic cable that accepts and transports signals in the form of light.

### 3.2.1 Open Wire

- Open wire is traditionally used to describe the electrical wire strung along power poles.
- There is a single wire strung between poles. No shielding or protection from noise interference is used.

- We are going to extend the traditional definition of Open Wire to include any data signal path without shielding or protection from noise interference. This can include multiconductor cables or single wires.
- 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.

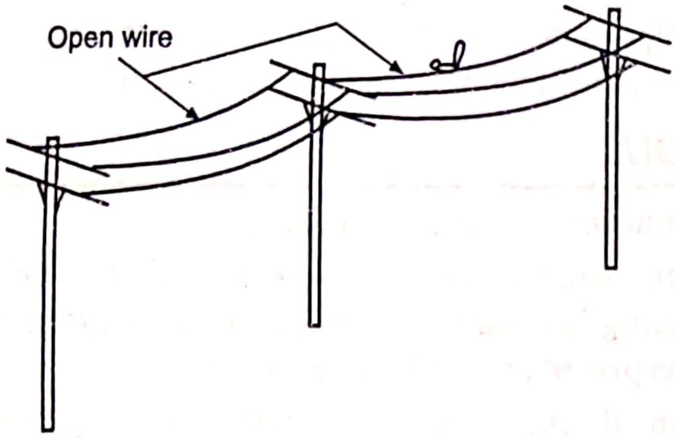



**Fig. 3.3: Open Wire**

## 3.2.2 Coaxial Cable

- A form of network cabling used primarily in older Ethernet networks and in electrically noisy industrial environments.
- The name "coax" comes from its two-conductor construction in which the conductors run concentrically with each other along the *axis* of the cable.
- Coaxial cabling has been largely replaced by twisted-pair cabling for Local Area Network (LAN) installations within buildings, and by fiber-optic cabling for high-speed network backbones.
- Coaxial cable (or coax) carries signals of higher frequency ranges than twisted-pair cable.

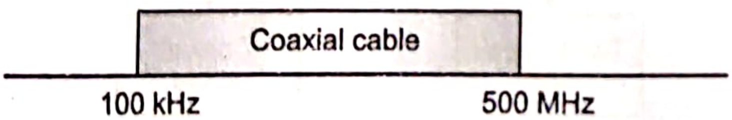



**Fig. 3.4: Frequency Range of Coaxial Cable**

### 3.2.2.1 Physical Structure

- Instead of having two wires, coax has a central core conductor of solid or standard wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid or a combination of the two (also usually copper).
- The outer metallic wrapping serves both as a shield against and as the second conductor, which completes the circuit. This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

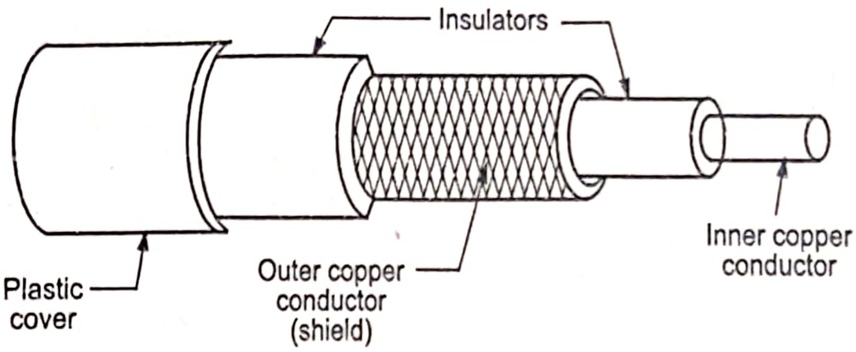



**Fig. 3.5: Physical structure of Coaxial Cable**

- Shielded concentric construction reduces interference and crosstalk.
- This cable can be used over longer distances and support more stations on a shared line than twisted pair.

### 3.2.2.2 Categories

- Although coaxial cabling is difficult to install, it is highly resistant to signal interference. In addition, it can support greater cable lengths between network devices than twisted pair cable.
- **Radio Government (RG) rating:** Coaxial cables are categorized by Radio Government (RG) rating. Each RG number denotes a unique set of physical specifications, including the wire gauge (gauge is the measure of the thickness of the wire) of the inner conductor, the thickness and type of inner insulator, the construction of the shield, and the size and type of the outer casting.
- Coaxial cabling comes in various types and grades. The most common types are:
  1. **Thicknet Cabling:** This is an older form of cabling used for legacy 10Base5 Ethernet backbone installations. This cabling is generally yellow in color and is referred to as RG-8 or N-series cabling. Strictly speaking, only cabling labelled as IEEE 802.3 cabling is true thicknet cabling. RG-9, RG-11 are used in thick Ethernet.

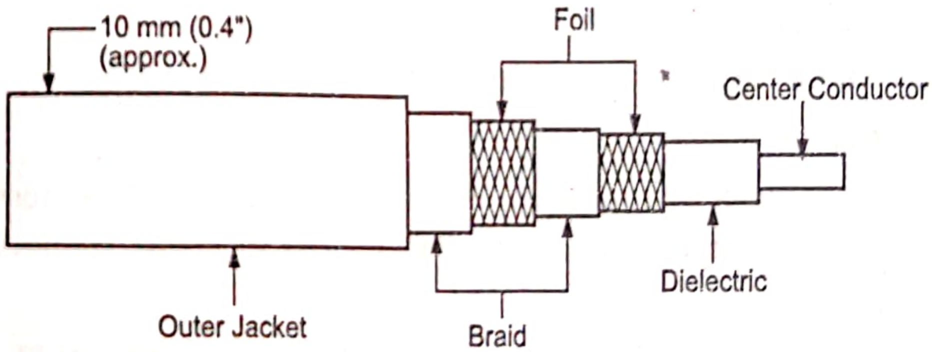



**Fig. 3.6: Thicknet Coaxial Cable**

  2. **Thinnet Coaxial Cabling:** This is used in 10Base2 networks for small Ethernet installations. This grade of coaxial cabling is generally designated as RG-58A/U cabling, which has a stranded conductor and 53-ohm impedance. This kind of cabling uses BNC connectors for connecting to other networking components and must have terminators at free ends to prevent signal bounce.

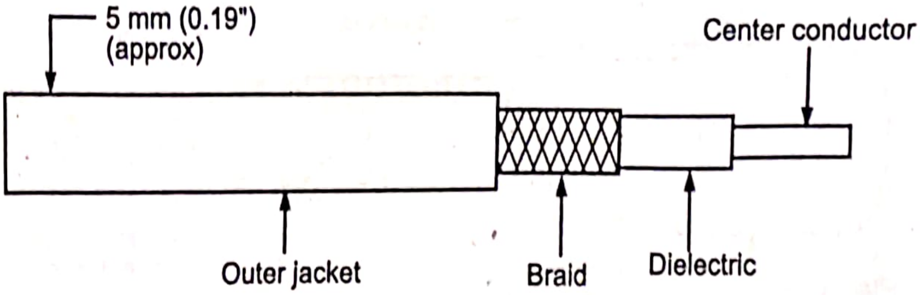



**Fig. 3.7: Thinnet Coaxial Cable**

3. **ARCNET Cabling:** This uses thin coaxial cabling called RG-62 cabling with an impedance of 93 ohms.
4. **RG-59 Cabling:** This is used for Cable Television (CATV) connections.

### 3.2.2.3 Advantages and Disadvantages

**Advantages:**

- Coaxial cable supports both analog and digital signals.
- It has superior frequency characteristics compared to twisted pair.
- It can support higher frequencies and data rates.
- Shielded concentric construction makes it less susceptible to interference and crosstalk than twisted pair.
- Constraints on performance are attenuation, thermal noise and intermodulation noise.
- Requires amplifiers every few kilometers for long distance transmission.
- Usable spectrum for analog signaling up to 500 MHz.
- For both analog and digital transmission, closer spacing is necessary for higher frequencies/data rates.

**Disadvantages:**

- They are more prone to lightning strikes.
- Single cable failure can disrupt the entire network

### 3.2.2.4 Connectors

- To connect coaxial cable to devices, we need coaxial connector. The most common type of connector used today is the Bayone-Neill-Concelman or BNC connector.

**BNC Connector:**

- The BNC (Bayonet Neill-Concelman) connector is a very common type of RF connector used for terminating coaxial cable.

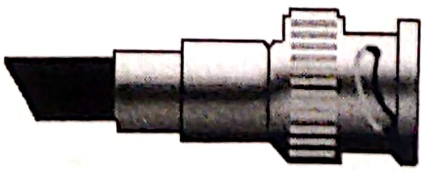


**Fig. 3.8: BNC Connector**

- The BNC connector is used for RF signal connections, for analog and Serial Digital Interface video signals, amateur radio antenna connections, aviation electronics (avionics) and many other types of electronic test equipment.
- It is an alternative to the RCA connector when used for composite video on commercial video devices, although many consumer electronics devices with RCA jacks can be used with BNC-only commercial video equipment via a simple adapter.
- BNC connectors were commonly used on 10base2 thin Ethernet networks, both on cable interconnections and network cards; though these have largely been replaced by newer Ethernet devices whose wiring does not use coaxial cable. Some ARCNET networks use BNC-terminated coax.

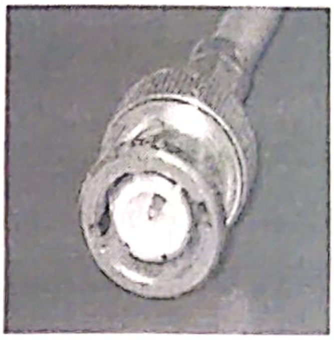


Fig 3.9 (a) Photograph of BNC Connector

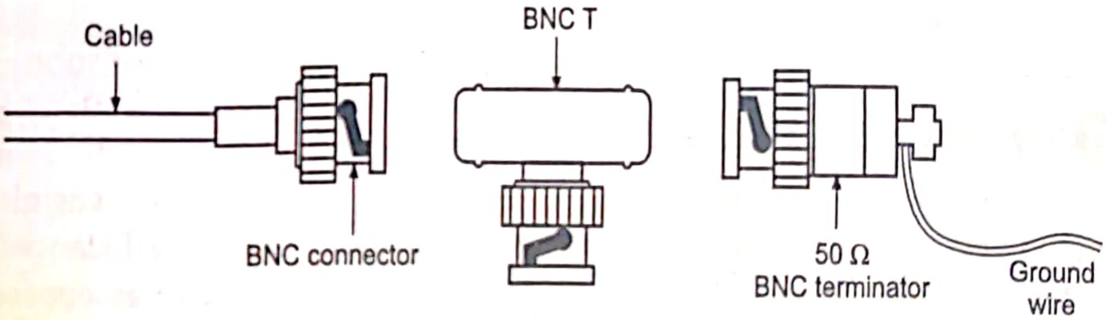



Fig. 3.9 (b): Types of BNC connector

- Fig. 3.9(b) shows 3 popular types of these connectors: the BNC connector, the BNC T connector, and the BNC terminator.
- The BNC is used to connect the end of the cable to a device, such as a TV set. The BNC T connector is used in Ethernet networks to branch out to a connection to a computer or other device. The BNC terminator is used at the end of the cable to prevent the reflection of the signal.
- BNC connectors exist in 50 and 75 ohm versions. Originally all were 50 ohm and were used with cables of other impedances, the small mismatch being negligible at lower frequencies. The 75 ohm types can sometimes be recognized by the reduced or absent dielectric in the mating ends.
- The different versions are designed to mate with each other, although the impedance mismatch in the cable may lead to signal reflections.

- Typically, they are specified for use at frequencies up to 4 and 2 GHz, respectively.
- 75 ohm BNC Connectors are primarily used for video and DS3 Telco central office applications whereas 50 ohm connectors are used for data and RF.

### 3.2.2.5 Applications of Coaxial Cable

1. The use of coaxial cable started in analog telephone networks where a single coaxial network could carry 10,000 voice signals.
2. 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 toady with fiber-optic cable).
3. Most common use is in cable TV.
4. Coaxial cabling is often used in heavy industrial environments where motors and generators produce a lot of Electromagnetic Interference (EMI) and where more expensive fiber-optic cabling is unnecessary because of the slow data rates needed.
5. Another common application of coaxial cable is in traditional Ethernet LANs. Because of its high bandwidth and consequently high data rate, coaxial cable was chosen for digital transmission in early Ethernet LANs.
6. 10Base-2 or Thin Ethernet, uses RG-58 coaxial cable with BNC connectors to transmit data at 10 Mbps with a range of 185 m.
7. 10Base5 or Thick Ethernet, uses RG-11 to transmit 10 Mbps with a range of 5000 m.

## 3.2.3 Twisted-Pair Cable (S-22)

- Twisted-pair cable is least expensive and most widely used for data transmission. Twisted-pair cables are most effectively used in systems that use a balanced line method of transmission: Polar Line Coding (Manchester Encoding) as opposed to Unipolar Line Coding (TTL logic).

### 3.2.3.1 Physical Structure

- A twisted pair cable consists of two conductors (normally copper), each with its own plastic insulation, twisted together.
- One of the wire is used to carry signals to the receiver and the other is used only a ground reference.

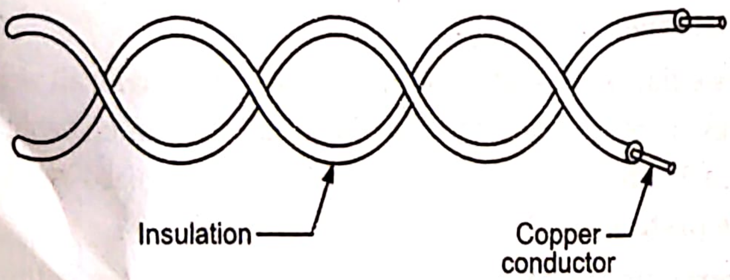



**Fig. 3.10: Twisted-Pair Cable**

- These cables are color coated to identify each cable.
- Any noise that appears on one wire of the pair would occur on the other wire. Because the wires are of opposite polarities, they are 180 degrees out of phase. When the noise appears on both wires, it cancels or nulls itself out at the receiving end.
- The twists in the cabling reduce the effects of crosstalk and make the cabling more resistant to electromagnetic interference (EMI), which helps maintain a high signal-to-noise ratio for reliable network communication.

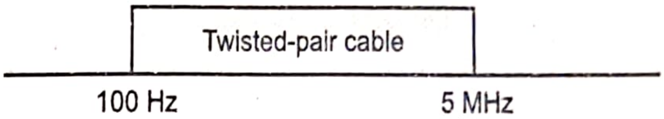


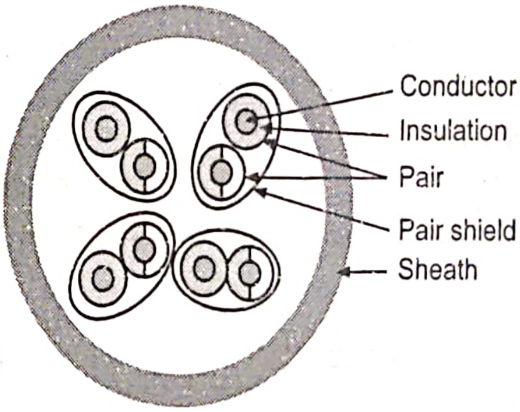

**Fig. 3.11: Frequency Range for Twisted-Pair Cable**

### 3.2.3.2 Categories of Twisted Pair Cable

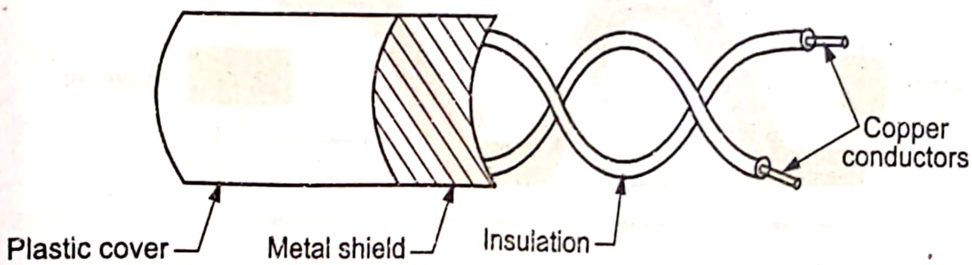
- Twisted Pair cable can be either *Unshielded TP (UTP)* cable or *Shielded TP (STP)* cable.

**1. Shielded TP (STP):**

- IBM produced a version of TP cable for its use called Shielded Twisted Pair (STP).
- These are cables with a shield. Shielding means metallic material added to cabling to reduce susceptibility to noise due to electromagnetic interference (EMI).
- STP cables have a metal foil covering each pair of insulator conductors.




**(a) Internal structure of STP cable**



(b)

Fig. 3.12: STP cable

**Categories of STP:**

- STP cabling comes in various grades or categories defined by the EIA/TIA wiring standards, as shown in the Table 3.1.

**Table 3.1: STP Cabling Categories**

| Category | Description |
|---|---|
| **IBM Type 1** | Token Ring transmissions on AWG #22 wire up to 20 Mbps. |
| **IBM Type 1A** | Fiber Distributed Data Interface (FDDI), Copper Distributed Data Interface (CDDI), and Asynchronous Transfer Mode (ATM) transmission up to 300 Mbps. |
| **IBM Type 2A** | Hybrid combination of STP data cable and CAT3 voice cable in one jacket. |
| **IBM Type 6A** | AWG #26 patch cables. |

**Effect of Noise on Twisted-Pair Lines:**

- Metal casing used in STP improves the quality of cable by preventing the penetration of noise. It also can eliminate a phenomenon called **Crosstalk**.

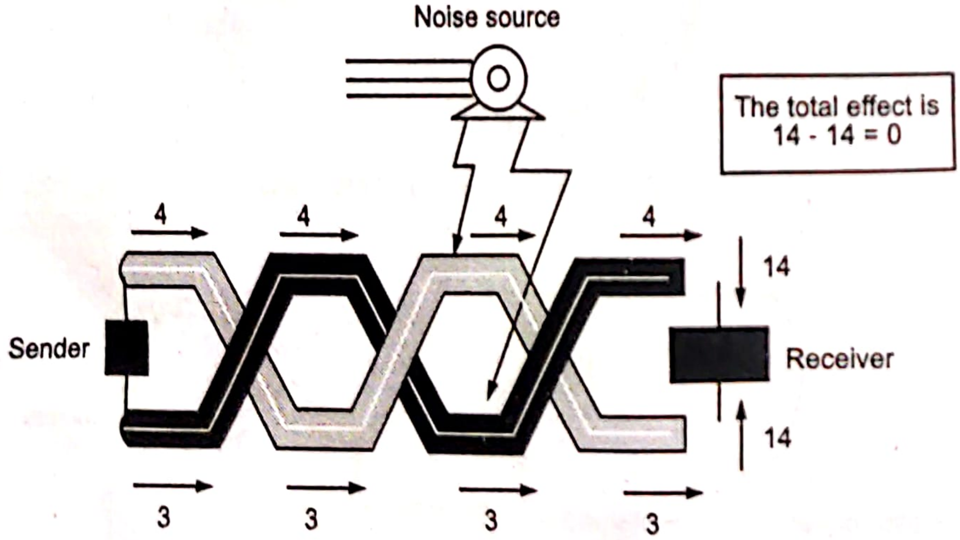



Fig. 3.13: Effect of Noise on Twisted-Pair Lines

- **Crosstalk** is the undesired effect of one circuit (or channel) on another circuit (or channel). It occurs when one line picks up some of the signal traveling down another line.
- Crosstalk effect can be experienced during telephone conversations when one can hear other conversations in the background.

**Characteristics:**

- It has an impedance of 150 ohms, has a maximum length of 90 meters and is used primarily in networking environments with a high amount of EMI due to motors, air conditioners, power lines or other noisy electrical components. STP cabling is the default type of cabling for IBM Token Ring networks.
- The data transmission rate is higher in STP.
- Due to metal foil covering, STP is more expensive as compared to UTP.

**2. Unshielded Twisted Pair (UTP):**

- Cables without a shield are called Unshielded Twisted Pair or UTP.
- UTP is cheap, flexible, and easy to install. It is used in many LAN technologies, including *Ethernet* and *Token Ring*.
- Twisted-pair cabling used in Ethernet networking is usually Unshielded Twisted-Pair (UTP) cabling, while Shielded Twisted-Pair (STP) cabling is typically used in Token Ring networks.

**Categories of UTP:**

- UTP cabling comes in different grades for different purposes.
- The Electronic Industries Association (EIA) has developed standards to classify UTP cable into seven categories. Categories are determined by cable quality, with CAT 1 as the lowest and CAT 7 as the highest.

**Table 3.2: Categories of UTP cables**

| Category | Data Rate | Digital/Analog | Use |
|---|---|---|---|
| CAT 1 | < 100 Kbps | Analog | Telephone systems |
| CAT 2 | 4 Mbps | Analog/Digital | Voice + Data transmission |
| CAT 3 | 10 Mbps | Digital | Ethernet 10BaseT LANs |
| CAT 4 | 20 Mbps | Digital | Token based or 10baseT LANs |
| CAT 5 | 100 Mbps | Digital | Ethernet 100BaseT LANs |
| CAT 6 | 200 Mbps | Digital | LANs |
| CAT 7 | 600 Mbps | Digital | LANs |

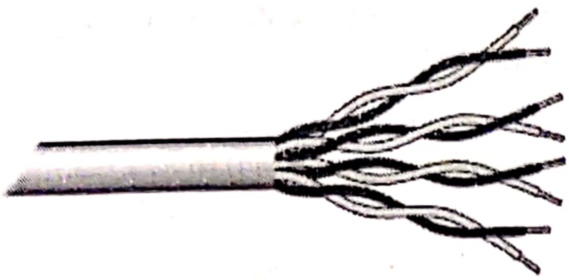
**Characteristics:**

- The quality of UTP may vary from telephone-grade wire to extremely high-speed cable. The cable has four pairs of wires inside the jacket.

- Each pair is twisted with a different number of twists per inch to help eliminate interference from adjacent pairs and other electrical devices.
- The tighter the twisting, the higher the supported transmission rate and the greater the cost per foot.

### 3.2.3.3 Connectors

- The standard connector for unshielded twisted pair cabling is an RJ-45 connector. This is a plastic connector that looks like a large telephone-style connector.



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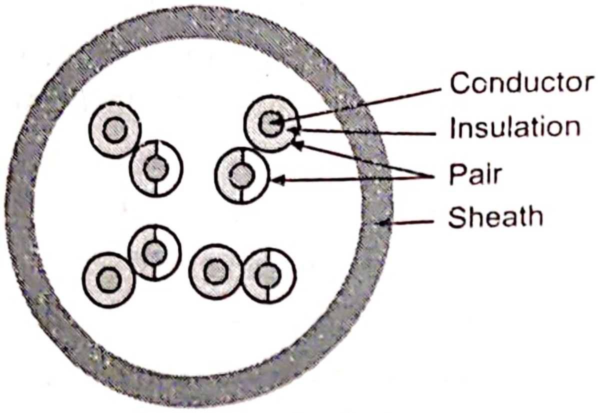
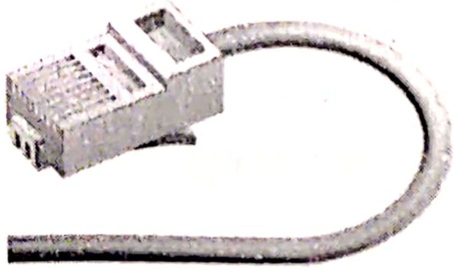



(b)

**Fig. 3.14: Unshielded Twisted Pair Cable**

- A slot allows the RJ-45 to be inserted only one way. RJ stands for Registered Jack, implying that the connector follows a standard borrowed from the telephone industry.
- This standard designates which wire goes with each pin inside the connector.



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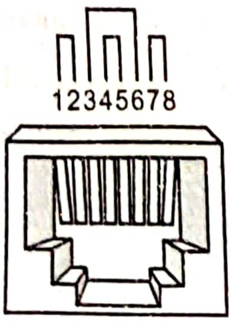
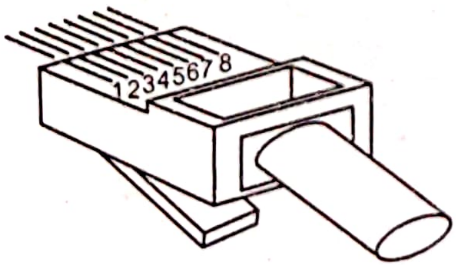



(b) RJ-45 Female connector




(c) RJ-45 Male connector

**Fig. 3.15: RJ-45 connector**

### 3.2.3.4 Transmission Characteristics

- Requires amplifiers every 5-6 km for analog signals.
- Requires repeaters every 2-3 km for digital signals.
- Attenuation is a strong function of frequency.
- Higher frequency implies higher attenuation.
- Susceptible to interference and noise.
- Improvement possibilities.
- Shielding with metallic braids or sheathing reduces interference.
- Twisting reduces low frequency interference.
- Different twist length in adjacent pairs reduces crosstalk.

### 3.2.3.5 Comparison of Unshielded and Shielded Twisted Pairs

**Table 3.3: Difference between UTP and STP**

| BASIS OF COMPARISON | UTP | STP |
|---|---|---|
| **Electromagnetic Interference** | Electromagnetic interference and noise is more in UTP. | STP cable reduce electrical noise within the cable and from outside of the cable (e.g. EMI, RFI). |
| **Speed** | It offers speed or throughput of about 10 to 1000 Mbps. | It offers speed or throughput of about 10 to 100 Mbps. |
| **Distance** | It offers maximum cable length of about 100 meters. | It supports maximum segment of length about 100 meters. |
| **Characteristic** | Each of the 8 individual copper wires in UTP cable is covered by insulating material. In addition, wires in each pair are twisted around each other. | Each pair of wires in STP cable is wrapped in an overall metallic foil usually 150 Ohm cable. |
| **Attenuation** | Attenuation is high when compared to STP. | Attenuation is low when compared to UTP. |
| **Application** | Widely used for data transmission within short distance and is very popular for home network connecting. | Mainly used for connection of enterprises over a long distance. |
| **Crosstalk Generation** | The generation of crosstalk is high when compared to STP. | The generation of crosstalk is quite less when compared to UTP. |

*Contd....*

| | | |
|---|---|---|
| Cost | Cheaper in cost | Costlier than UTP. |
| Grounding | Grounding cable is not required. | Grounding cable is required. |

### 3.2.3.6 Applications of Twisted Pair Cable

1. This is the most common transmission media for both digital and analog signals.
2. TP cables are used in telephone lines to provide voice and data channels.
3. The DSL lines that are used by the telephone companies to provide high data rate connections also use high bandwidth capability UTP cable.
4. Local Area Network (LAN) also uses twisted-pair cable.

## 3.2.4 Fiber-optic Cable (W-18; S-19, S-22; W-22)

- Fiber-optic is a glass cabling media that sends network signals using light.
- Fiber-optic cabling 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.
- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- The use of fiber-optics was generally not available until 1970 when Corning Glass Works was able to produce a fiber with a loss of 20 dB/km.
- Today's optical fiber attenuation ranges from 0.5 dB/km to 1000 dB/km depending on the optical fiber used. Attenuation limits are based on intended application.

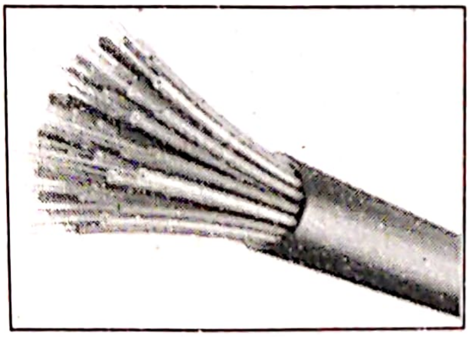


**Fig. 3.16: Fiber-optic Cable**

### 3.2.4.1 Characteristics of Optical Fiber

1. **Capacity:**
   - Much higher bandwidth.
   - Transmits data over long distances.
2. **Smaller size and lightweight:**
   - Very thin for similar data capacity.
   - Much lighter and easy to support in terms of weight (structural properties).

3. **Significantly lower attenuation.**
4. **EM isolation (Resistance to noise):**
   - Not affected by external EM (Electromagnetic) fields.
   - Not vulnerable to interference, impulse noise or crosstalk.
   - No energy radiation; little interference with other devices; security from eavesdropping.
5. **Greater repeater spacing:** Lower cost and fewer error sources.
6. **Speed:** Fiber optic networks operate at high speeds - up into the Gigabits.
7. **Distance:** Signals can be transmitted further without needing to be "refreshed" or strengthened.
8. **Maintenance:** Fiber-optic cable costs much less to maintain.

### 3.2.4.2 Physical Structure

- The cable consists of one or more strands of glass. The center of each strand is called a core. This core provides pathway for light to travel. A glass or plastic core is surrounded by layer of glass known as **Cladding**.
- Optical fiber uses reflection to guide light through a channel. 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. Information is encoded onto a beam of light as a series of on-off flashes that represents 1's and 0's.
- 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 transmit themselves down the line.

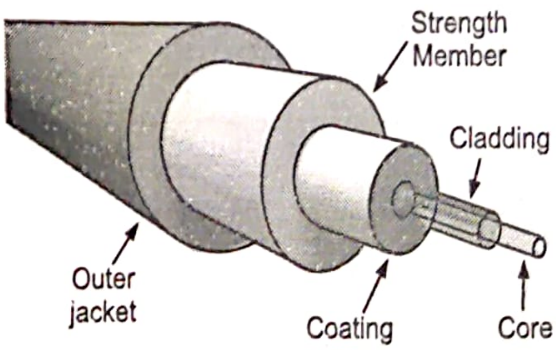



**Fig. 3.17: Fiber Optic Cable Construction**

- 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. If you shine a flashlight in one you can see light at the far end - even if bent the roll 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.
- The light is "guided" down the center of the fiber called the "core". The core is surrounded by an optical material called the "cladding" that traps the light in the core using an optical technique called "total internal reflection."
- The core and cladding are usually made of ultra-pure glass, although some fibers are all plastic or a glass core and plastic cladding.
- The fiber is coated with a protective plastic covering called the "primary buffer coating" that protects it from moisture and other damage.

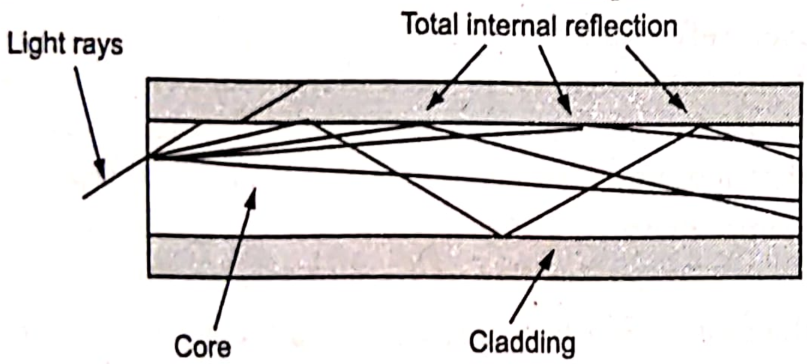



**Fig. 3.18: Inner structure of Fiber Optic**

- Transparent glass or plastic fibers, which allows light to be guided from one end to the other with minimal loss.

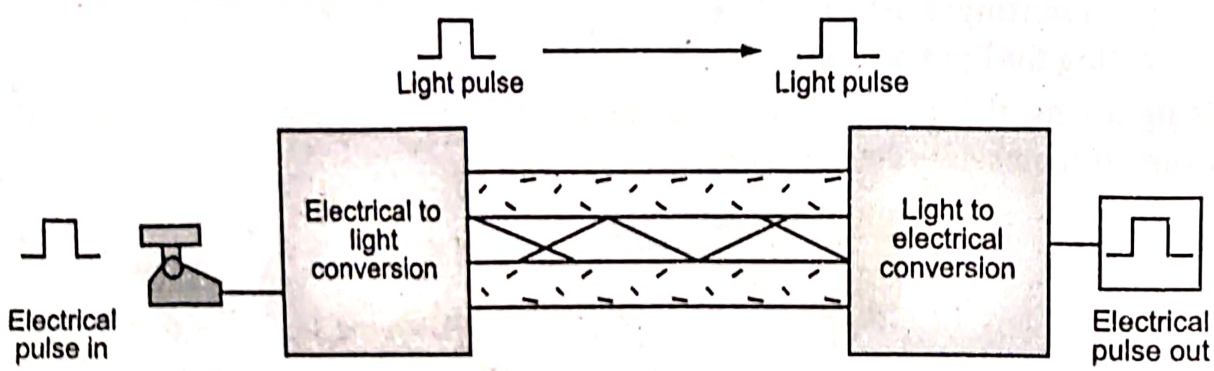



**Fig. 3.19: Data Transmission using Fiber Optic Cable**

- 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 signals.
- While fiber-optic cable itself has become cheaper over time - an 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.
- The bndwidth of a fiber-optic cable depends on the distance as well as the frequency. Bandwidth is usually expressed in frequency distance form, for example in MHz-km. In other words, a 500-MHz-km fiber-optic cable can transmit a signal a distance of 5 kilometers at a frequency of 100 MHz (5 × 100 = 500) or a distance of 50 kilometers at a frequency of 10 MHz (50 × 10 = 500). In other words, there is an inverse relationship between frequency and distance for transmission over fiber-optic cables.

### 3.2.4.3 Propagation Modes

- There are two different modes for propagating light along optical channels: *multimode* and *single mode.*

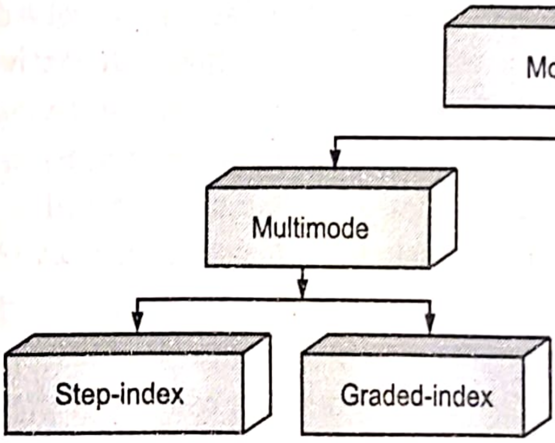



**Fig. 3.20: Propagation Modes**

1. **Multimode:**

- Multimode is so named because multiple beams from a light source move through the core in different paths. Multimode cable is made of glass fibers, with a common diameters in the 50-100 micron range for the light carry component, (the most common size is 62.5).
- Multimode fiber gives high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths or modes, as they travel through the cable's core typically 850 or 1300 nm. Typical multimode fiber core diameters are 50, 62.5 and 100 micrometers. However, in long cable runs (greater than 3000 feet [914.4 meter]), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.

a. **Step-index Multimode Fiber:** 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 straight line until it reaches the interface of the core and the cladding. At the interface, there is an sudden change to a lower density that alters the angle of beam's motion. The term **step-index** refers to the suddenness of this change.

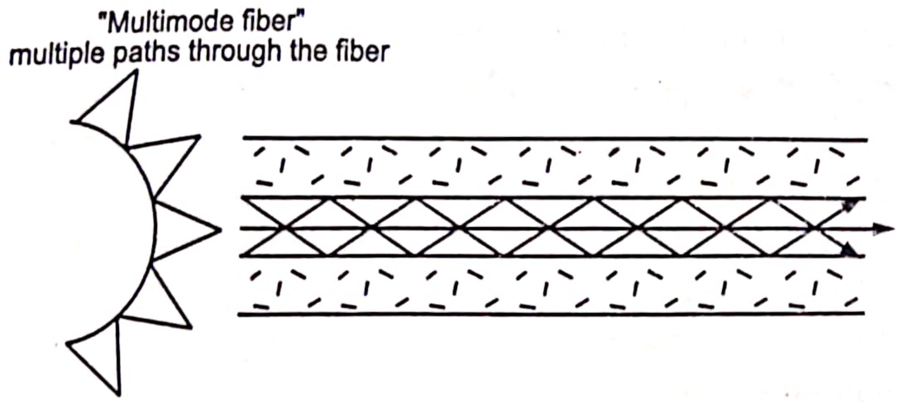



**Fig. 3.21: Multimode, Step-Index Fiber**

- Step-index multimode fiber has a large core up to 100 microns in diameter. As a result, some of the light rays that make up the digital pulse may travel a direct route, whereas others zigzag as they bounce off the cladding. These alternative pathways cause the different groupings of light rays, referred to as modes, to arrive separately at a receiving point. The pulse, an aggregate of different modes, begins to spread out, losing its well-defined shape. The need to leave spacing between pulses to prevent overlapping limits bandwidth that is, the amount of information that can be sent.
- Consequently, this type of fiber is best suited for transmission over short distances, in an endoscope, for instance. It is less costly variety of multimode fiber, it uses a wide core with a uniform index of refraction, causing the light beams to reflect in mirror fashion off the inside surface of the core by the process of total internal reflection. Because light can take many different paths down the cable and each path takes a different amount of time, signal distortion can result when step-index fiber is used for long cable runs. Use this type only for short cable runs.

b. **Multimode Graded-Index Fiber:**

- A second type of fiber, called *multimode graded-index fiber*, decreases this distortion of the signal through the cable. The word *index* here refers to the index of refraction.
- Index of refraction is related to density. A graded-index fiber, therefore, is one with varying density. Density is highest at the center of the core and decreases gradually to its lowest at the edge.
- Graded-index multimode fiber contains a core in which the refractive index diminishes gradually from the center axis out toward the cladding. The higher refractive index at the center makes the light rays advance moving slowly down the

axis more than those near the cladding. Also, rather than zigzagging off the cladding, light in the core curves helically because of the graded index, reducing its travel distance. The shortened path and the higher speed allow light at the periphery to arrive at a receiver about the same time as the slow, but straight rays in the core axis. In the result, a digital pulse suffers less dispersion.

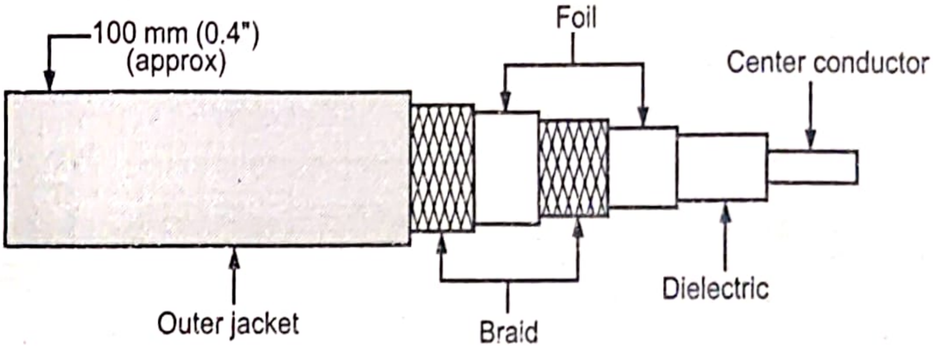



**Fig. 3.22: Multimode Graded-Index Fiber**

**2. Single Mode:**

- Single mode uses step-index fiber and a highly focused source of light that limits beams to small range of angles, all close to the horizontal.
- Single Mode cable is a single stand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission.
- Single Mode Fiber with a relatively narrow diameter, through which only one mode will propagate typically 1310 or 1550 nm.
- Carries higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width. Single-mode fiber is also called as Mono-mode optical fiber, Single-mode optical waveguide, Unimode fiber.
- The single mode fiber is manufactured with a much smaller diameter than that of multimode fibers and with substantially lower density (index of refraction). The decrease in density results in a critical angle that is close enough to 90 degrees to make the propagation of beams almost horizontal.

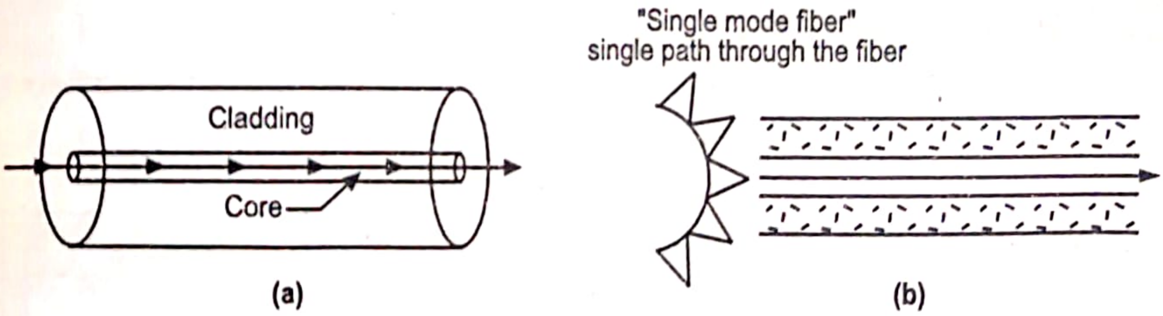
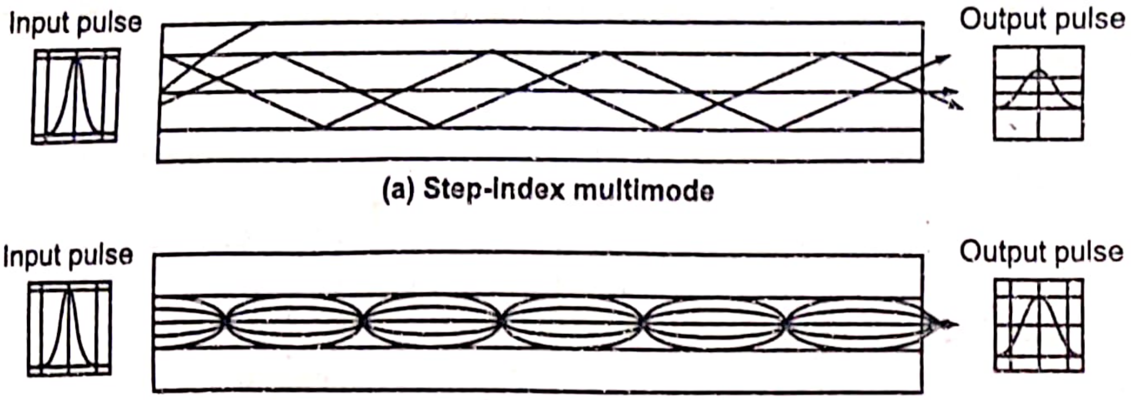



**Fig. 3.23: Single-Mode Fiber**

- Single-mode fiber gives you a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode.

- The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.




(b) Graded-index multimode

**Fig. 3.24: Optical Fiber Transmission Modes**

**Table 3.4: Single Mode and Multimode Characteristics**

| Parameters | Single Mode Fiber | Multimode Fiber |
|---|---|---|
| **Bandwidth** | High | Lower |
| **Signal Quality** | High | Lower |
| **Main Source of Attenuation** | Chromatic Dispersion | Modal Dispersion |
| **Fiber Designs** | Step index and Dispersion shifted | Step index and Graded index |
| **Application** | Long transmission, higher bandwidth | Short transmission, lower bandwidth |
| **Core/cladding** | 8.3/125 | 62.5/125 |
| **Light source** | ILD | LED/ILD |

### 3.2.4.4 Types of Optical Fiber

- Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding, both expressed in microns (micrometer).

**Table 3.5: Optical Fiber Types**

| Fiber Type | Core | Cladding |
|---|---|---|
| 62.5/125 | 62.5 | 125 |
| 50/125 | 50.0 | 125 |
| 100/140 | 100.0 | 140 |
| 8.3/125 | 8.3 | 125 |

- The last size listed is used only for single mode. Single mode fiber has a very small core causing light to travel in a straight line and typically has a core size of 8 or 10 microns.
- Multimode fiber supports multiple paths of light and has a much larger core and has a core size of 50 or 62.5 microns.

### 3.2.4.5 Connectors

- Fiber connector, also called fiber optic cable connectors, are often used to link optical fibers where connect or disconnect capability is needed.
- Fiber optic cable connectors come in many configurations and usages. Some of them are given below:
  1. **SC (Subscriber Channel) Fiber Optic Connector:** SC, also called a square connector or subscriber connector. It was developed by Nippon Telegraph and Telephone. It is used for cable TV and uses a push/pull locking system.
  2. **ST (Straight Tip) Fiber Optic Connector:** It is used for connecting cable to networking devices. SC is mainly used in multimode fiber optic cable, campuses and buildings.
  3. **MT-RJ Fiber Optic Connector:** MT-RJ stands for Mechanical Transfer Registered Jack. MT-RJ is a fiber-optic cable connector that is very popular for small form factor devices due to its small size. The MT-RJ utilizes two fibers and integrates them into a single design that looks similar to a RJ45 connector.
  4. **LC Fiber Optic Connector:** LC refers to Lucent Connector. It is a push-pull, small form factor connector that uses a 1.25mm ferrule, half the size of the SC. LC, due to the combination of small size and latch feature, is ideal for high-density connections
  5. **FC Fiber Optic Connector:** FC is short for Ferrule Connector. It is a round, threaded fiber optic connector that was designed by Nippon Telephone and Telegraph in Japan. The FC connector is applied for single-mode optic fiber and polarization-maintaining optic fiber. The FC is a screw type connector with a 2.5mm ferrule, which was the first fiber optic connector to use a ceramic ferrule. However, FC is becoming less common and mostly replaced by SC and LC because of its vibration loosening and insertion loss.
  6. **MPO/MTP fiber connector:** This connector is a multi-fiber connector which combines fibers from 12 to 24 fibers in a single rectangular ferrule. It's often used in 40G and 100G optical parallel connections. Compared with other fiber connectors mentioned above, MPO/MTP fiber connectors are more complicated. Because there are key-up and key-down, male and female MPO/MTP connectors.

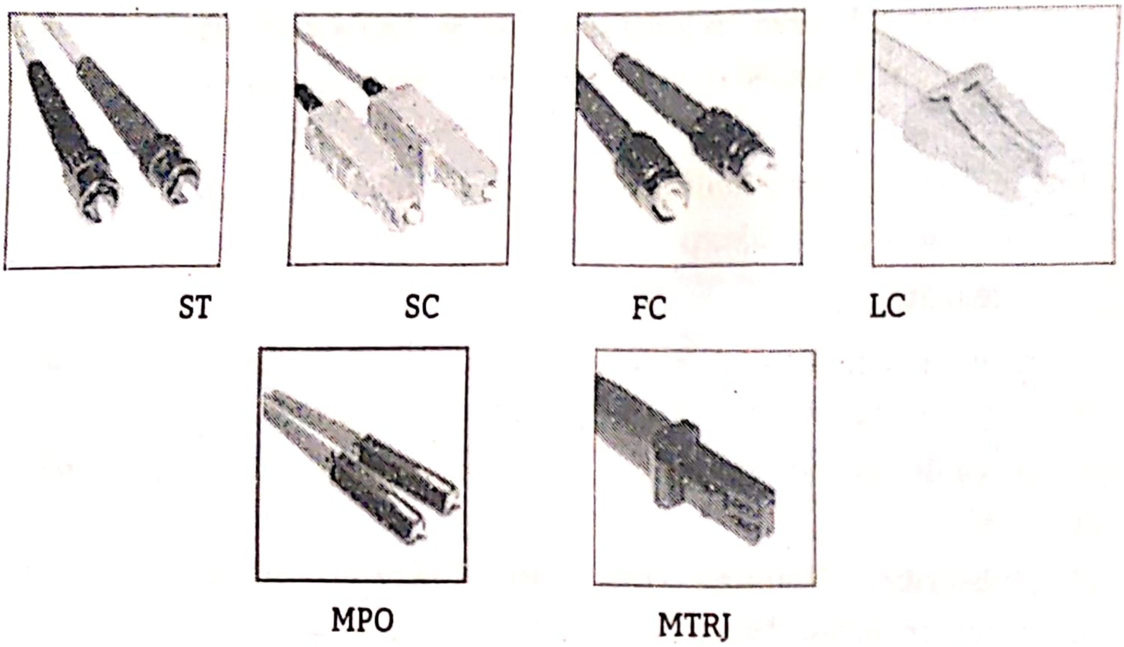



**Fig. 3.25: Fiber optic cable connectors**

## 3.2.4.6 Applications of Fiber-optic Cable

1. Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective. SONET network provides such backbone.
2. Some cable TV companies use a combination of optical-fiber and coaxial cable.
3. Telephone companies also using optical-fiber cable.
4. The continuing improvements in performance and decline in prices, together with the inherent advantages of optical fiber, have made it increasingly attractive for local area networking. Local Area Networks (LANs) such as 100BaseFx network (Fast Ethernet) and 1000Base-X also use fiber-optic cable.
5. In military applications, it is used for long-distance telecommunications.

## 3.2.4.7 Advantages

- Advantages of fiber-optic cables are given below:
  1. **Higher Bandwidth:** Higher data rate than TP and coaxial cable.
  2. **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 after every 5 km for coaxial or TP cable.
  3. **Noise resistance:** Because fiber-optic transmission uses light rather than electricity, noise is not a factor. External light, the only possible interference, is blocked from the channel by the outer jacket.
  4. **Light-weight:** Fiber-optic cables are much lighter than copper cables.
  5. **More immune to tapping (or Security):** Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antennas that can easily be tapped.

6. **Amount of data transfer:** Optical fiber can carry thousands of times more information than copper wire. For example, a single-strand fiber strand could carry all the telephone conversations in the United States at peak hour Fiber is more lightweight than copper.
7. **Reliability:** Fiber is more reliable than copper and has a longer life span.
8. **General capacity:** Fiber optic cable can carry signals for longer distance without repeater than co-axial cable.

### 3.2.4.8 Disadvantages

- Disadvantages of fiber-optic cable are listed below:
  1. **Installation/Maintenance expertise:** Installation and Maintenance need expertise that is not yet available everywhere.
  2. **Unidirectional:** Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
  3. **Cost:** Fiber-optic cable is more expensive.
  4. **Fragility:** Glass fiber is more easily broken than wire, making it less useful for applications where hardware portability is required.
  5. **Limited physical arc of cable:** It is breakable, if bend it too much.

### 3.2.4.9 Comparison of Guided Medias

- **Trade-offs between Electrical and Optical cable:**
  1. Electrical is cheaper, especially for short distances, because silicon circuits can send and receive over wires directly. Other semiconductor materials are required to implement the lasers for optical communication. Thus, optical requires multiple die and has a higher base cost.
  2. Optical provides better performance at high-bandwidths and long distances. Glass propagates light better than copper propagates electrical currents.

**Table 3.6: Comparison of Guided Medias**

| Sr. No. | Twisted-Pair Cable | Coaxial Cable | Fiber Optic Cable (FOC) |
|---|---|---|---|
| 1. | It uses electrical signals for transmission. | It uses electrical signals for transmission. | It uses optical form of signal (i.e. light) for transmission. |
| 2. | It uses metallic conductor to carry the signal. | It uses metallic conductor to carry the signal. | It uses glass or plastic to carry the signal. |
| 3. | Noise immunity is low. Therefore more distortion. | Higher noise immunity than twisted-pair cable due to the presence of shielding conductor. | Highest noise immunity as the light rays are unaffected by the electrical noise. |

| | | | |
|---|---|---|---|
| 4. | Affected due to external magnetic filed. | Less affected due to external magnetic filed. | Not affected by the external magnetic filed. |
| 5. | Cheapest | Moderately costly | Costly |
| 6. | Can support low data rates. | Moderately high data rates. | Very high data rates. |
| 7. | Power loss due to conduction and radiation. | Power loss due to conduction. | Power loss due to absorption, scattering, dispersion. |
| 8. | Short circuit between two conductors is possible | Short circuit between two conductors is possible | Short circuit is not possible |
| 9. | Low bandwidth | Moderately high bandwidth | Very high bandwidth |

## 3.3 UNGUIDED MEDIA (S-18)

- Unguided media are natural parts of the Earth's environment that can be used as physical paths to carry electrical signals.
- The atmosphere and outer space are examples of unguided media that are commonly used to carry signals.
- These media can carry electromagnetic signals such as microwaves, infrared light waves and radio waves.
- Network signals are transmitted through all transmission media as a type of waveform. When transmitted through wire and cable, the signal is an electrical waveform.
- When transmitted through fiber-optic cable, the signal is a light wave: either visible or infrared light. When transmitted through Earth's atmosphere or outer space, the signal can take the form of waves in the radio spectrum, including VHF and microwaves, or it can be light waves, including infrared or visible light (For example, lasers).
- Recent advances in radio hardware technology have produced significant advancements in wireless networking devices: the cellular telephone, wireless modems, and wireless LANs.
- Typically, a wireless network uses infrared light or radio transmissions to distribute data. Infrared networks communicate by using beams of infrared light. They have a maximum range of 100 meters.
- Theoretically, they can transmit at 10 Mbps, but 1-3 Mbps is more typical. Narrow band radio networks can cover an area up to 5,000 square meters at up to 4.8 Mbps.

- Their disadvantage is that they offer little security. Spread-spectrum radio networks use multiple frequencies. These multiple channels provide network security.
- They can transmit data at up to 1 Mbps at a range of 800 feet indoors, though 300 Kbps is more typical.

**Applications:**

- Some common applications of wireless data communication are:
  1. Accessing the Internet using a cellular phone.
  2. Establishing a home or business Internet connection over satellite.
  3. Beaming data between two hand-held computing devices.
  4. Using a wireless keyboard and mouse for the PC.

## 3.3.1 Electromagnetic Spectrum for Wireless Communication

**(W-18; S-18, 19)**

- All electromagnetic waves travel at the speed of light (300,000,000 metres per second) in a vacuum, whatever their frequency (in copper or fibre, the speed drops to approximately two thirds of this value, and is slightly frequency dependent).
- The relationship between frequency, wavelength and the speed of light (c) in a vacuum is given by:

$$F\lambda = C$$

- Since, C is a constant, if wavelength is known, then frequency can be calculated and vice versa. Thus, a frequency of 1 MHz would give a wavelength of approximately 300 meters, and a 1 cm wavelength would give a frequency of approximately 30 GHz. The Electromagnetic Spectrum is shown in Fig. 3.37.

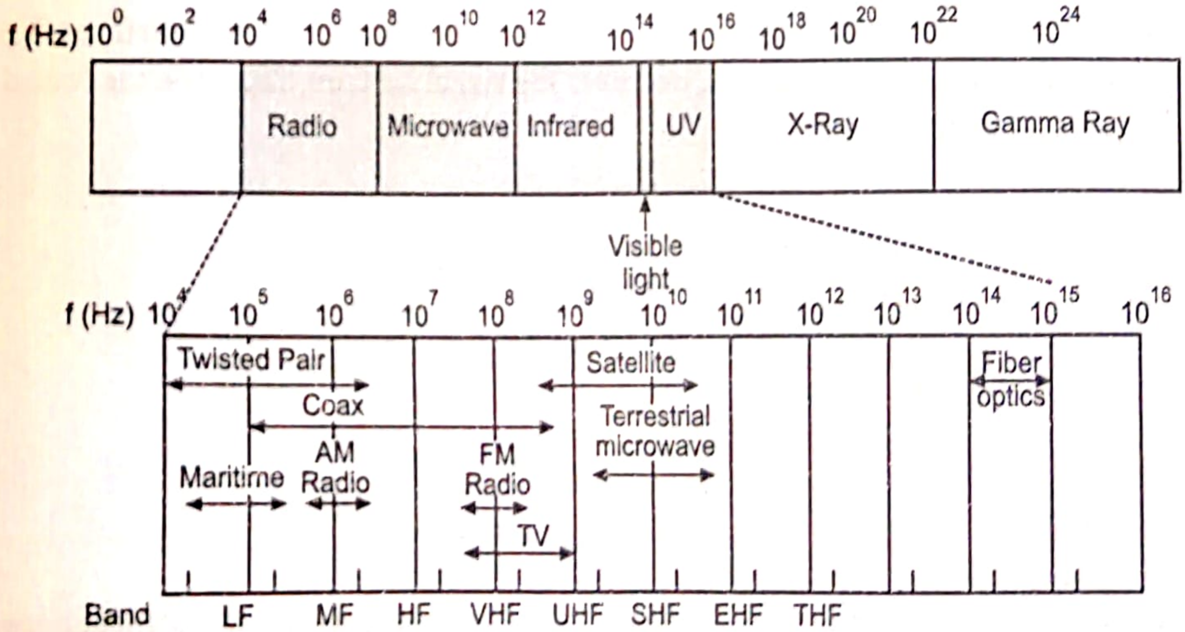



**Fig. 3.26: The Electromagnetic Spectrum**

- The parts of the electromagnetic spectrum which can be used for transmitting information using amplitude, frequency or phase modulation are shown using a darker shading and include radio, microwave, infrared and visible light.

## 3.3.2 Propagation Methods (W-18, S-18, S-19, W-22)

- Basically, the propagation method classified into three categories:
  1. Ground wave propagation
  2. Sky wave propagation
  3. Line-of-Sight (LOS)

### 3.3.2.1 Ground Wave Propagation

- Radio waves in the VLF (Very Low Frequency) 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.
- Ground wave propagation more or less follows the contour of the earth and can propagate considerable distances, well over the visual horizon. This effect is found in frequencies up to about 2 MHz.

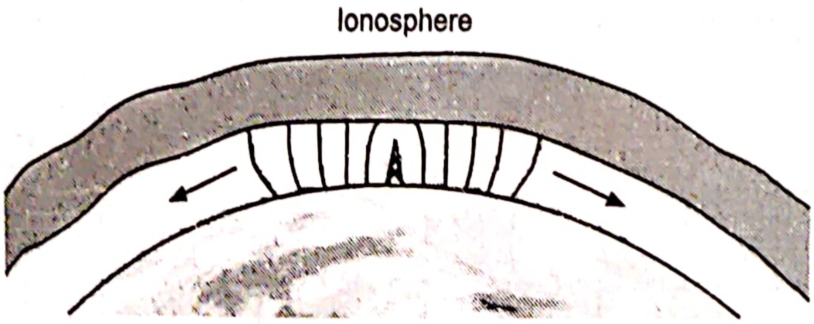



**Fig. 3.27: Ground Waves**

- *Electromagnetic* waves in this frequency range are scattered by the atmosphere in *such a way* that they do not penetrate the upper atmosphere. The best-known *example of* ground wave communication is AM radio.

### 3.3.2.2 Sky Wave Propagation

- Radio waves in the LF (Low Frequency) and MF (Medium Frequency) 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.
- The HF (High Frequency) band operates almost exclusively with sky waves. The higher frequencies have less attenuation and less refraction in the ionosphere as compared to MF (Medium Frequency).
- 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.

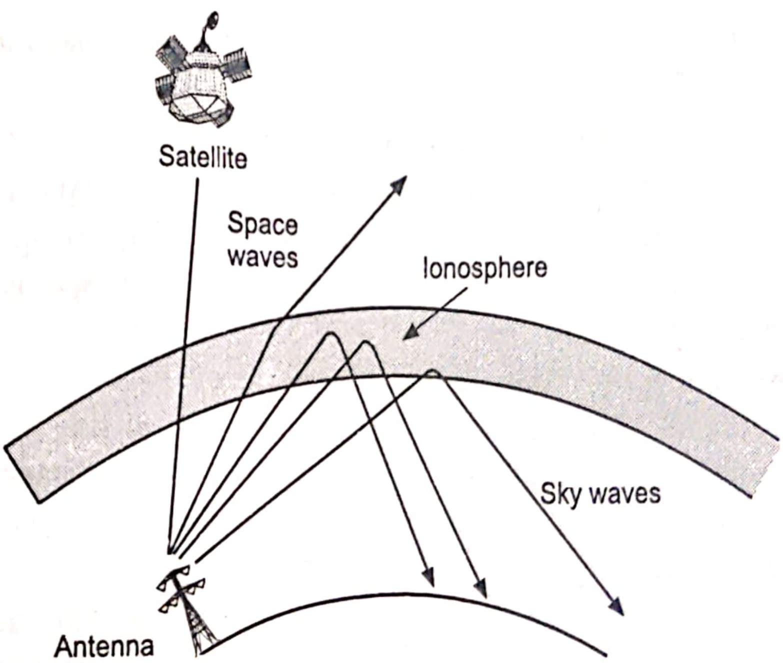



**Fig. 3.28: Sky Wave Propagation**

- 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.

**Layers in Ionosphere:**

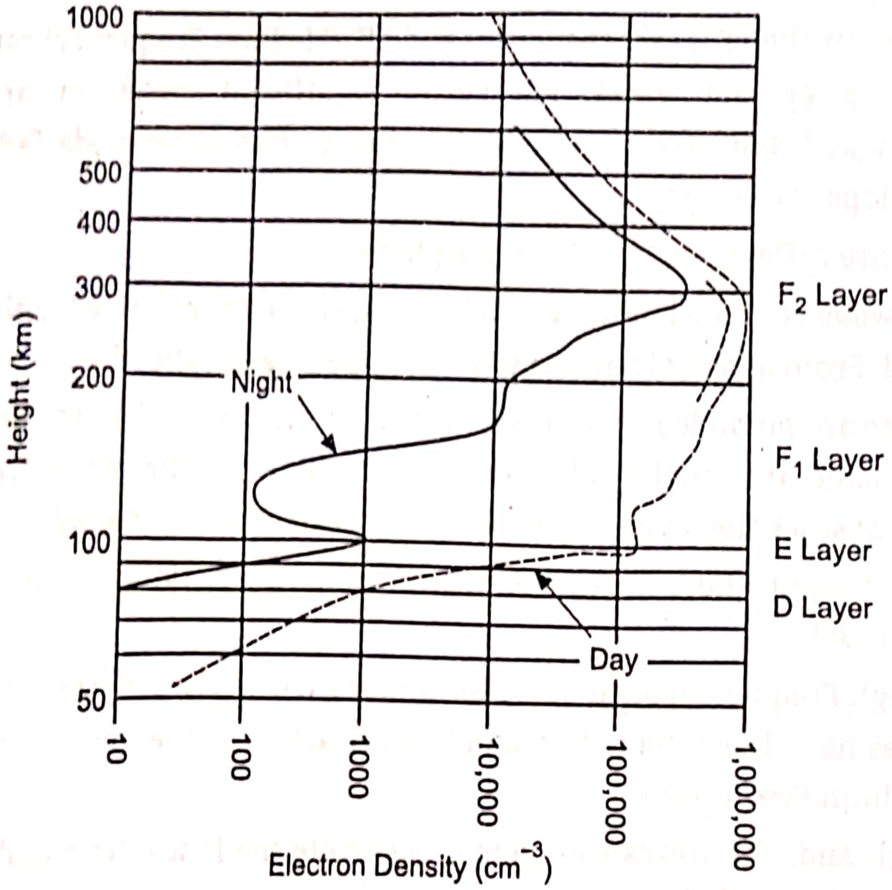



**Fig. 3.29: Layers in Ionosphere**

- The ionosphere has several well-defined regions in altitude.
  - **D-region:** About 75-95 km. Relatively weak ionization. Responsible for strong absorption of MF during daylight.
  - **E-region:** 95-150 km. An important player in ionospheric scatter of VHF.
  - **F-region:** 150-400 km. This region 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.
  - **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 Fig. 3.29, the skip zone extends to about 1400 miles. The transmitted frequency was 5 MHz and the critical frequency was 3 MHz in this example.
  - **Maximum Useable Frequency (MUF):** This defined for two stations. The maximum frequency that will reflect back to the receiving station from the transmitter. Beyond the MUF, the wave will become a space wave. At MUF the skip

zone extends to just short of the receiver. In Fig. 3.29, the MUF for a receiver at 1400 miles is 5 MHz.

- **Lowest Useable Frequency (LUF):** This again defined for two stations. At low frequencies, the signal will be attenuated before it can be reflected. The LUF increases with sunlight and is a maximum near noon.
- **Optimum Frequency for Traffic (OFT):** This frequency for two stations, taking into account the exact conditions in the ionosphere. There will be the perfect frequency that gives the strongest signal. This can be predicted by powerful modeling programs and is the best guarantee of success in HF. The daytime variation if HF propagation is characterized a simple rule-of-thumb: the frequency follows the sun. At noon, the OFT is generally higher than at night.

### 3.3.2.3 Line-of-Sight

- Above 30 MHz neither ground wave nor sky wave propagation modes operate and then the communication must be by line of sight. For satellite communication, a signal above 30 MHz is not reflected by the ionosphere and therefore a signal can be transmitted between an earth station and a satellite overhead that is not beyond the horizon.

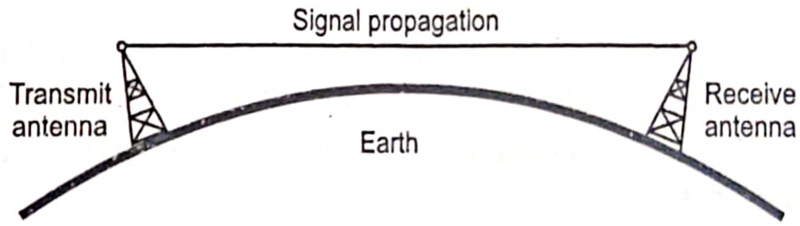



**Fig. 3.30: Line-of-sight (LOS) propagation (above 30 MHz)**

**Effects in Line-of-sight Propagation:**

- In the VHF (Very High Frequency) 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.
  1. **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.

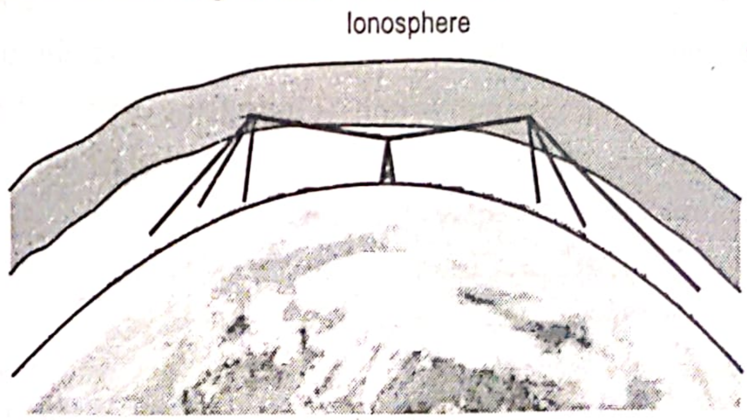



**Fig. 3.31: Ionospheric Scatter**

2. **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 fewer than 400 miles.

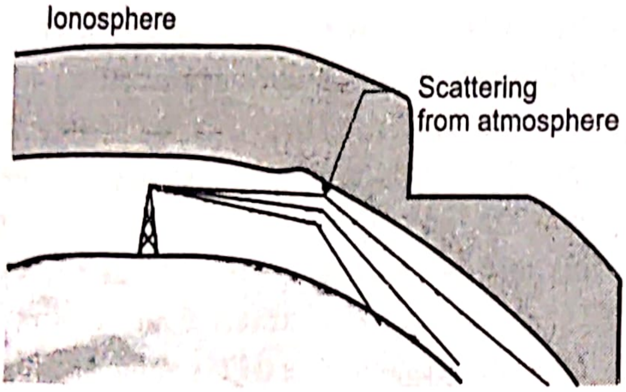



**Fig. 3.32: Toposperic Scatter**

3. **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 %.
4. **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.

### 3.3.3 Wireless Transmission (S-18, S-19, S-22, W-22)

- 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.
- The demand of the wireless communications is increasing exponentially.
- The wireless communication can be performed in a variety of ways such as wireless Ethernet, GSM, Bluetooth, Infrared, Wi-Fi and Wi-Max.
- Similarly, the broadband wireless is an emerging wireless technology that allows the simultaneous delivery of the voice, video and data signals.
- All these technologies based on the different standards and specifications. The wireless communication standards are based on the 802.11 specifications.

- Wireless transmission is the transfer of information over a distance without the use of electrical conductors or "wires".
- The distances involved may be short such as a few meters as in television remote control or long such as thousands or millions of kilometers for radio communications.

### 3.3.3.1 Radio Waves

- Radio waves are widely used for both indoor and outdoor communication because they are easy to generate, can travel over long distances and can penetrate buildings easily.
- Radio waves used omnidirectional antennas that send out signals to all directions.
- Radio waves are omni-directional. When an antenna transmits radio waves, they are propagated in all directions. This means the sending and receiving antennas do not have to be aligned.
- The properties of radio waves are dependent on frequency.
    - At **low frequencies**, they pass through obstacles well, but the power falls off sharply as the distance from the transmitter increases.
    - At **high frequencies**, radio waves tend to travel in straight lines and bounce off obstacles. They are also absorbed by rain.
    - At **all frequencies**, they are subject to electromagnetic interference from electrical equipment such as electric motors.
- The ability to travel over large distances means that radio transmissions can also interfere with each other, which is one of the main reasons why the use of radio transmitters is tightly controlled by governments.

**Radio Transmission Using Ground Wave Propagation:**

- In the very low to medium frequency bands, radio waves follow the ground, as illustrated below, and can be detected at distances of up to about 1000 kilometers (Also called as Ground wave Propagation).

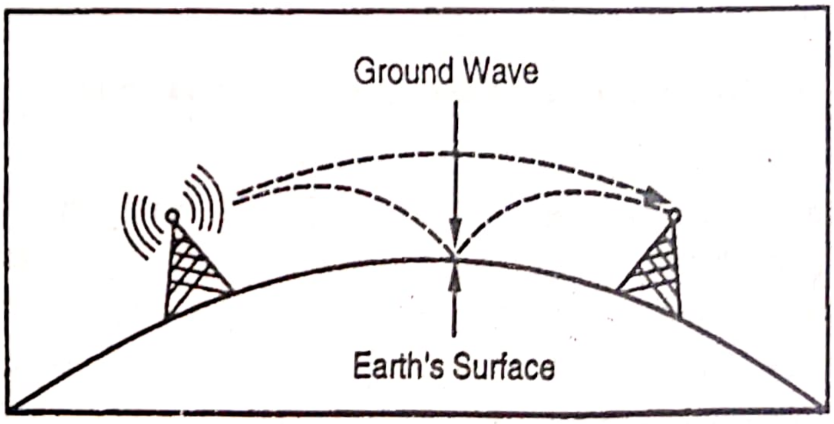



**Fig. 3.33: Radio Transmission Using Ground Wave Propagation**

- Radio waves at these frequencies can easily pass through buildings and are subsequently widely used by terrestrial radio stations.
- The relatively low bandwidth, however, means that they are not suitable for data communication.

**Radio waves radiated by a Base Station's antenna:**

- RF is part of electromagnetic spectrum that ranges from 3 Hz – 300 GHz. Radio wave is radiated by an antenna and produced by alternating currents fed to the antenna.
- RF is used in many standard as well as proprietary wireless communication systems.
- RF has long been used for radio and TV broadcasting, wireless local loop, mobile communications, and amateur radio.
- High (HF) and very high (VHF) frequency radio waves that reach the ionosphere, which is a layer of charged particles approximately 100-500 km above the earth's surface, are refracted by it and sent back to earth.
- These bands are used by amateur radio operators to talk over long distances, and are also used for military radio communications.
- Radio waves have virtually no distance limitations. However, the radio waves are government regulated, expensive, and can be tapped into. This can be used across continents.

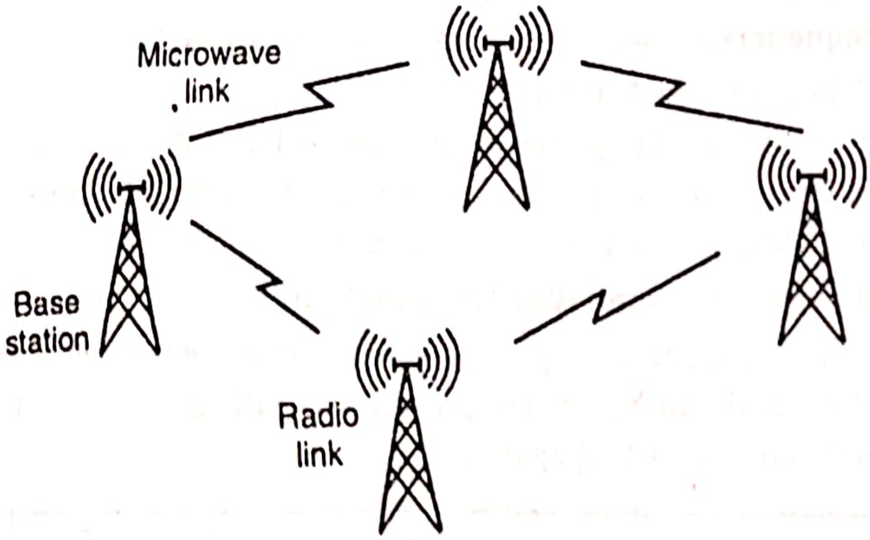



**Fig. 3.34: Radio waves radiated by a Base Station's antenna**

**Applications:**

- The omnidirectional 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.
- Microwaves 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.

### 3.3.3.2 Infrared Waves

- Unguided infrared waves are widely used for short-range communication. Infrared technology allows computing devices to communicate via short-range wireless signals.
- With infrared, computers can transfer files and other digital data bi-directionally.
- The infrared transmission technology used in computers is similar to that used in consumer product (Television and VCRs) remote control units.
- Used for very short line of sight transmission, remote car locking systems, wireless security alarms. Infrared light is part of electromagnetic spectrum that is shorter than radio waves but longer than visible light.
- Computer infrared network adapters both transmit and receive data through ports on the rear or side of a device.
- Infrared adapters are installed in many laptops and handheld personal devices. Its frequency range is between 300 GHz and 400 THz that correspond to wavelength from 1 mm to 750 nm.
- Infrared is also one of the physical media in the original wireless LAN standard, that's IEEE 802.11.
- Infrared networks were designed to support direct two-computer connections only, created temporarily as the need arises. However, extensions to infrared technology also support more than two computers and semi-permanent networks.
- Infrared communications work by sending and receiving pulses of infrared light. These pulses consist of periods of light and darkness.

**IrDA specifications for Infrared technology:**

- Infrared use in communication and networking was defined by the IrDA (Infrared Data Association).

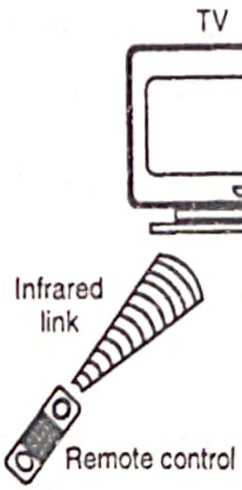



**Fig. 3.35: TV Remote Control uses Infrared**

- Using IrDA specifications, infrared can be used in a wide range of applications, For example, file transfer, synchronization, dial-up networking, and payment. However, IrDA is limited in range (up to about 1 meter).
- It also requires the communicating devices to be in LOS (Line of Sight) and within its 30-degree beam-cone. Infrared technology used in local networks exists in three different forms:
  1. **IrDA-SIR** (slow speed) infrared supporting data rates up to 115 Kbps.
  2. **IrDA-MIR** (medium speed) infrared supporting data rates up to 1.15 Mbps.
  3. **IrDA-FIR** (fast speed) infrared supporting data rates up to 4 Mbps.

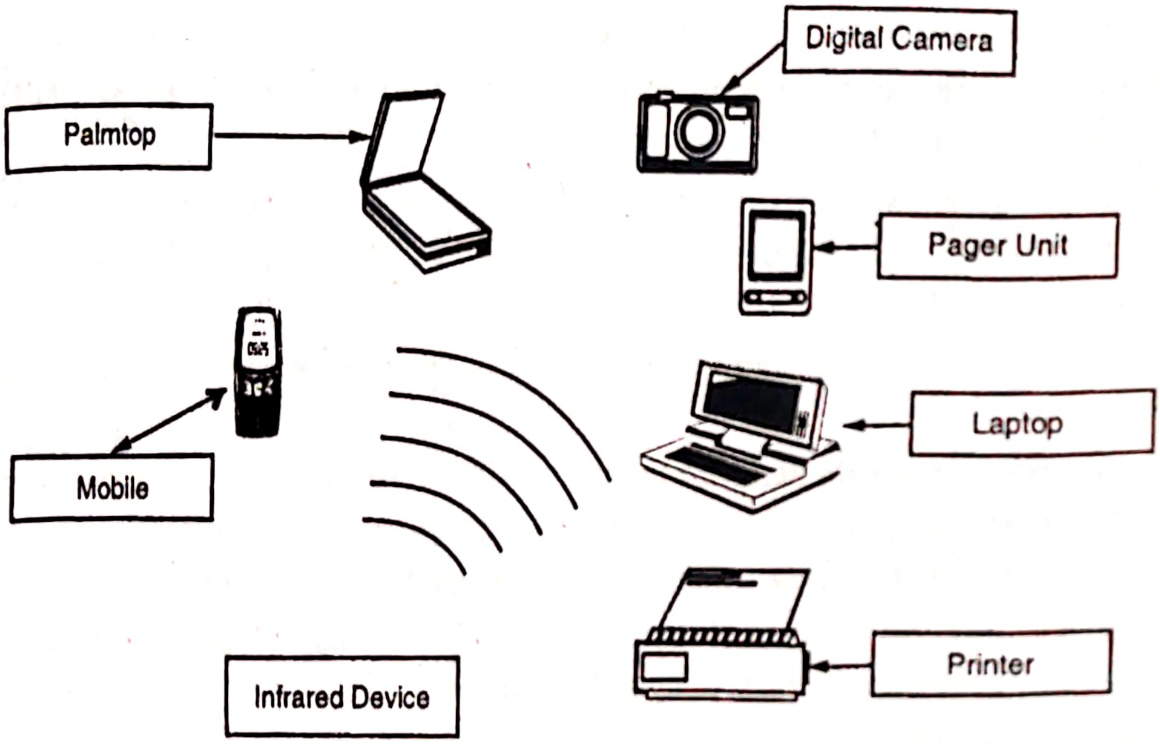



**Fig. 3.36: Device Communicates using Infrared**

**Advantages:**

- Infrared transmitters are (relatively) directional, cheap, and easy to manufacture.
- Infrared data and communication is a mode of communication that now plays an important role in wireless data communication.
- It suits the use of laptop computers, wireless data communication and other digital equipment such as personal assistants, cameras, mobile telephones and pagers.
- An infrared system in one room of a building will not interfere with similar systems in nearby rooms, and the possibility of eavesdropping is far lower than with radio based systems.
- IR can be used over longer interconnections and has applicability to Local Area Networks (LANs). However, the maximum effective distance is approximately 1 mile, with a maximum bandwidth of 16 Mbps.

- Infrared is therefore a realistic alternative for indoor wireless LANs, and the computers and offices within a building can be equipped with infrared transmitters and receivers which can be designed to be either directional or diffuse. In the latter case, signals bounce off walls and other objects to reach the receiver.

**Disadvantages:**

- The major drawback is that infrared waves will not pass through solid objects. The communication between the devices requires that each have a transceiver, (a combination of a transmitter and a receiver) in order to communicate. This capability is provided by microchip technology.
- However, devices may also require further, specialized software allowing communication to be synchronized.
- Infrared communication is now common as a means of wireless communication between devices. It will not penetrate buildings and therefore is secure. Infrared communication is more secure than other options, such as radio, but it cannot be used outside due to interference by the Sun.

**Applications of IR (Infrared):**

- The short distance of interconnection drives the main application of this technology between appliances.
- Thus, according to the IrDA, at present, the main benefits and applications are:
  - Sending a document from a notebook computer to a printer.
  - Co-ordinating schedules and telephone books between desktop and hand-held (notebook) computers.
  - Sending faxes from a hand-held computer, via a public telephone, to a distant fax machine.
  - Beaming images from digital cameras to a desktop computer.
  - Exchanging messages, business cards and other information between hand-held personal computers.
- For some of these functions, an interconnection between the hand-held or laptop computer and the desktop PC/printer in the form of an IR port is required. Alternatively an IR adapter can be used.

### 3.3.3.3 Microwave

- At frequencies of 1 GHz and above, electromagnetic waves travel in straight lines and can be narrowly focused. Microwave is the upper part of RF spectrum.
- Because of the availability of larger bandwidth in microwave spectrum, microwave is used in many applications such as wireless PAN, wireless LAN, fixed broadband wireless access (wireless MAN), satellite communications, radar and as backhaul in cellular networks.

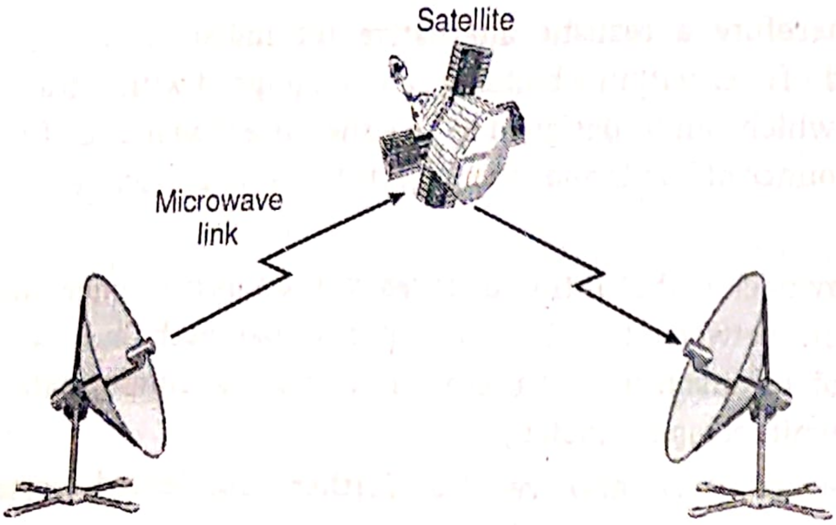



Fig. 3.37: Microwave Link using Dish Antenna and Satellite

- A parabolic dish antenna can be used to focus the transmitted power into a narrow beam to give a high signal to noise ratio, and before the advent of optical fiber, some long distance telephone transmission systems were heavily dependent on the use of a series of microwave towers.
- Because microwaves travel in a straight line, the curvature of the earth limits the maximum distance over which microwave towers can transmit, so repeaters are needed to compensate for this limitation.

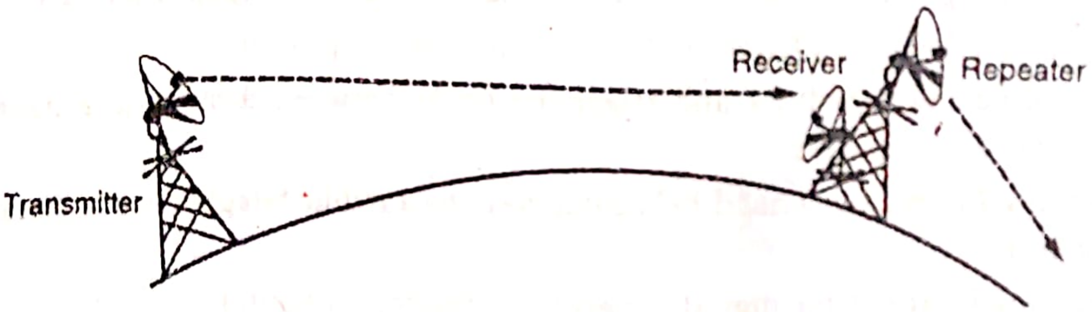



Fig. 3.38: Microwave Transmission with Repeater

**Propogation Losses:**

- As a general rule, the higher the towers are, the further apart they can be. At these higher frequencies, the transmitted waves do not easily pass through buildings.
- Moreover, even though the beam may be well focused at the transmitter, there is still some divergence in space. Some waves may be refracted by low-lying atmospheric and will take longer to arrive at their destination than direct waves.
- Therefore, the delayed waves may arrive out of phase with the direct waves and cancel out the signal. This effect known as *Multipath Fading*.
- Rain can also be a problem, as frequencies around 8 GHz are absorbed by water.
- At higher frequencies, more expensive electronics are required, and transmissions can be subject to interference from radar installations and microwave ovens. Microwave does, however, have several advantages over fiber.

**Advantages of Microwave Transmission:**

- Obstacles such as roads, railways and rivers may make laying cables difficult whereas, these problems do not exist for microwave and rights of way are not an issue.
- Erecting simple towers or mounting antenna on top of tall buildings is usually far cheaper than laying several kilometers of cable. Microwave also removes the need for reliance on telephone companies. In addition, governments worldwide have set aside the frequency band from 2.400 GHz to 2.484 GHz for unlicensed transmissions, so use of these frequencies does not require a license, and is therefore popular for various forms of short range wireless networking.
- Microwaves have a medium distance limitation and require line of sight. This is good between buildings or between satellites and satellite dishes. Weather and Solar conditions may affect transmission.
- Microwaves are used for long distance communication like cellular phones, garage door openers, and much more.
- Microwave transmission is line of sight transmission. The Transmit station must be in visible contact with the receive station.
- This sets a limit on the distance between stations depending on the local geography. Typically the line of sight due to the Earth's curvature is only 50 km to the horizon. Repeater stations must be placed so the data signal can hop, skip and jump across the country.
- Microwaves operate at high operating frequencies of 3 to 10 GHz. This allows them to carry large quantities of data due to the large bandwidth.

**A. Terrestrial Microwave Transmission**

- Communication is accomplished through line of sight parabolic dish antenna located on elevated sites.
- Long distance communication is possible by using a series of relay stations. The distance between the stations is dependent on the height above the ground.
- Used for voice and television transmission and private communications and telephone networks For example: emergency services, utilities etc. Utilizes a wide frequency band, 2 to 40 GHz but is susceptible to attenuation and interference.
- Attenuation can rise markedly in poor atmospheric conditions e.g. rain. But adversely affects the higher end of the frequency band, which is only used for short distance transmission.
- Natural noise severely affects transmission frequencies below 2 GHz. Quick to install and overcomes the problems of laying cables in congested locations or over difficult terrain.

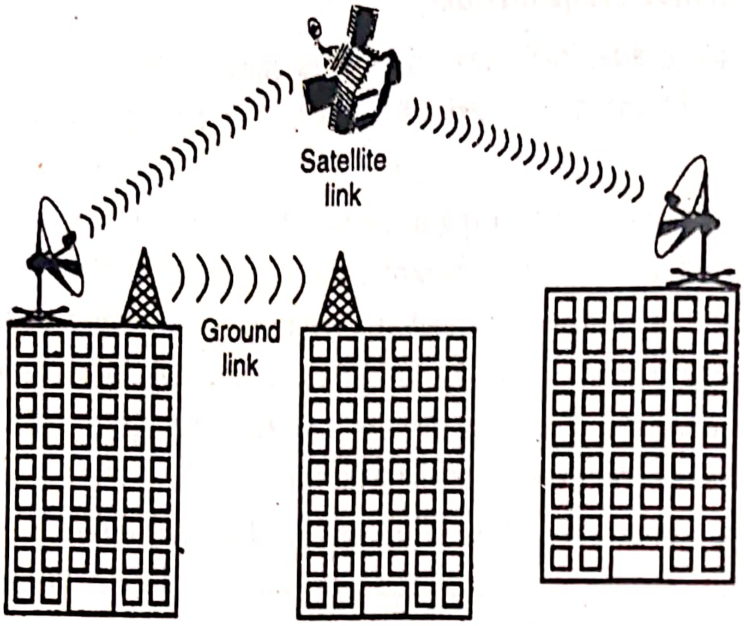



Fig. 3.39: Example of Terrestrial and Satellite Microwave Links

**Applications:**

- The primary use for terrestrial microwave systems is in long haul telecommunications service. Microwave is commonly used for both voice and television transmission.
- Use of microwave is for short point-to-point links between buildings. This can be used for closed-circuit TV or as a data link between Local Area Networks.
- A business can establish a microwave link to a long-distance telecommunications facility in the same city, bypassing the local telephone company.
- Another important use of microwave is in cellular systems.

**B. Satellite Microwave Transmission**

- Overcomes the line of sight problems of terrestrial microwave and can be used for point-to-point or broadcast transmission.

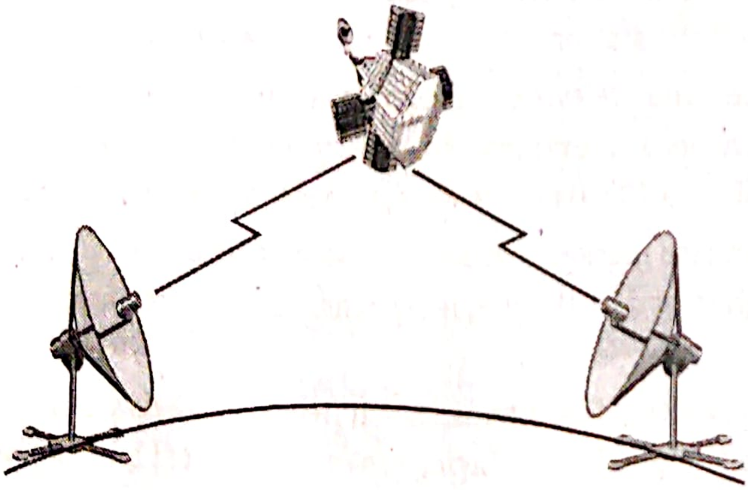



Fig. 3.40: Point-to-Point Link via Satellite Microwave

- Uses an uplink and downlink frequency, a common frequency set is referred to as the 4/6 range which uses a downlink frequency of 4 GHz and an uplink frequency of 6 GHz.
- A microwave transmitter uses the atmosphere or outer space as the transmission medium to send the signal to a microwave receiver.
- The microwave receiver then either relays the signal to another microwave transmitter or translates the signal to some other form, such as digital impulses, and relays it on another suitable medium to its destination.
- Originally, this technology was used almost exclusively for satellite and long-range communication. Recently, however, there have been developments in cellular technology that allow you complete wireless access to networks, intranets and the Internet.
- IEEE 802.11 defines a MAC and physical access control for wireless connection to networks. Used for TV distribution, long-distance telephone, and business networks.

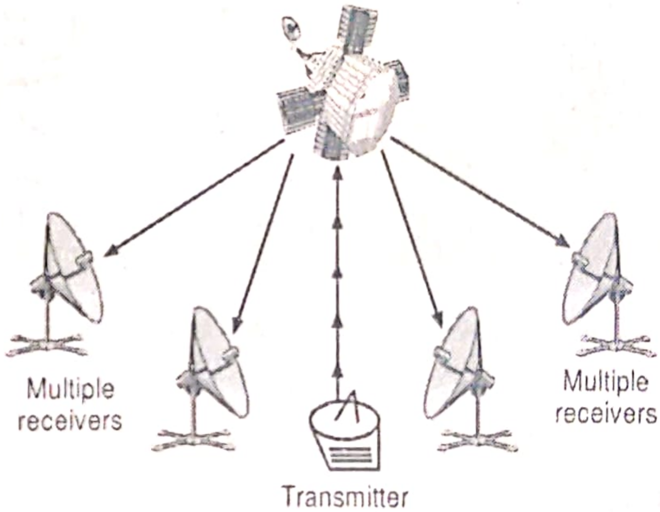



**Fig. 3.41: Broadcast Link via Satellite Microwave**

- One important difference between infrared and microwave transmission is that the former does not penetrate walls. Thus the security and interference problems encountered in microwave systems are not present. Furthermore, there is no frequency allocation issue with infrared, because no licensing is required.

**Advantages of satellite microwave transmission:**

1. They require no right of way acquisition between towers.
2. They can carry high quantities of information due to their high operating frequencies.
3. Low cost land purchase: each tower occupies small area.
4. High frequency/short wavelength signals require small antenna.

**Disadvantages:**

1. Attenuation by solid objects such as birds, rain, snow and fog.

2. Reflected from flat surfaces like water and metal.
3. Diffracted (split) around solid objects.
4. Refracted by atmosphere, thus causing beam to be projected away from receiver.

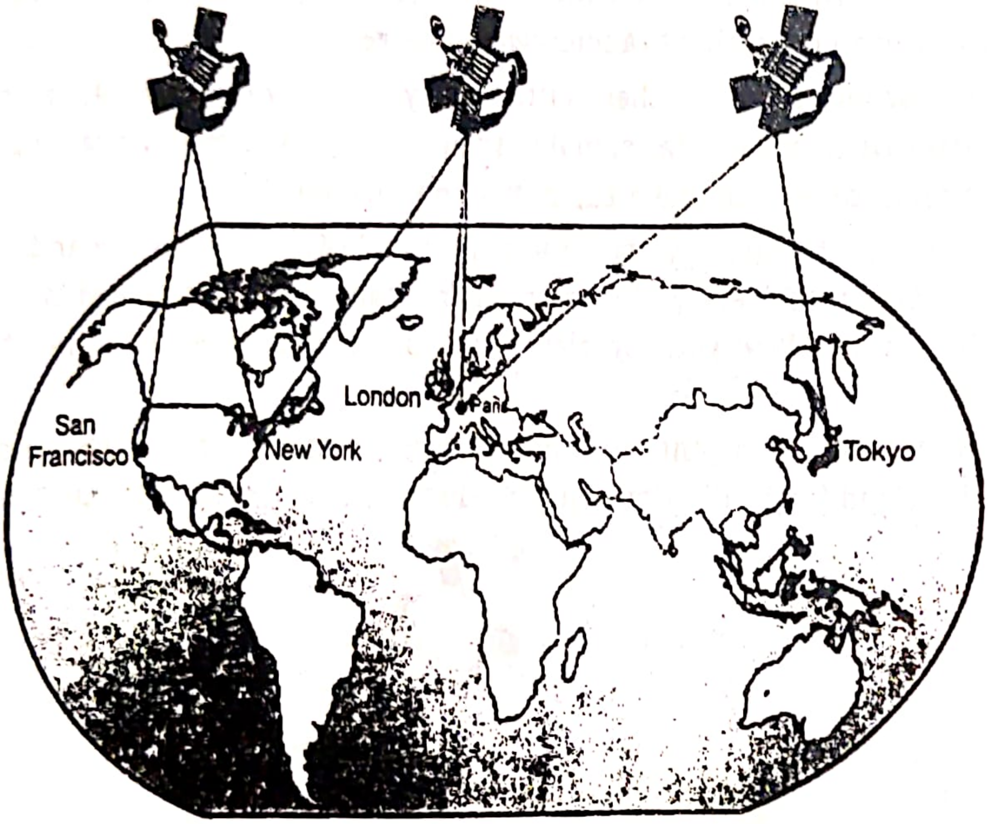



**Fig. 3.42: Satellite Microwave Link for Worldwide Communication**

**Applications:**

- The most important applications for satellites are the following:
  1. Television distribution
  2. L ong-distance telephone transmission
  3. Private business networks for global organizations.
  4. Microwave transmitters and receivers, especially satellite systems, are commonly used to transmit network signals over great distances.

## 3.4 COMPARISON OF GUIDED AND UNGUIDED MEDIA

**Table 3.7: Difference between Guided Media and Unguided Media**

| Sr. No. | Guided Media | Unguided Media |
|---|---|---|
| 1. | The signal energy is contained and bounded within a solid medium. | The signal energy propagates in the form of unbounded electromagnetic waves. |
| 2. | Used for point-to-point communication | Used for broadcasting. |

*Contd...*

| | | |
|---|---|---|
| 3. | Twisted-pair cable, coaxial cable, fiber optical cables are example of bounded media. | Radio and infrared light are the examples of unbounded media. |
| 4. | Attenuation depends exponentially on the distance. | Attenuation is proportional to square of distance. |

## Summary

- Transmission media is a communication channel that carries the information from the sender to the receiver. Data is transmitted through the electromagnetic signals.
- Types of transmission Media are: Guided (wired) and Unguided Media (wireless).
- Examples of Wired transmission media are: Twisted pair, Fiber-optic, Coaxial cable.
- Twisted Pair is the least expensive and most widely used guided transmission medium. It consists of two insulated copper wires arranged in a regular spiral pattern.
- Types of twisted pair : Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP).
- Coaxial cable consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor.
- Coaxial cable is widely used as a means of distributing TV signals to individual homes — cable TV.
- An optical fiber is a thin, flexible medium capable of guiding an optical ray.
- An unguided transmission transmits the electromagnetic waves without using any physical medium. Therefore it is also known as wireless transmission.
- Examples of wireless transmission media are Radio waves, Microwaves, Bluetooth, Wi-Fi, Satellites, Infrared.
- Radio waves are the electromagnetic waves that are transmitted in all the directions of free space.
- Microwaves are the electromagnetic waves having the frequency in the range from 1GHz to 1000 GHz.
- Microwaves are of two types: Terrestrial microwave and Satellite microwave.
- The satellite accepts the signal that is transmitted from the earth station, and it amplifies the signal. The amplified signal is retransmitted to another earth station.
- An infrared transmission is a wireless technology used for communication over short ranges. The frequency of this in the range from 300 GHz to 400 THz.

- Wireless transmissions propagate in three modes: ground-wave, sky-wave, and line-of-sight.
- Ground wave propagation follows the contour of the earth, while sky wave propagation uses reflection by both earth and ionosphere. Line of sight propagation requires the transmitting and receiving antennas to be within line of sight of each other.
- Current technology supports two modes (multimode and single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics. Multi- mode can be implemented in two forms: step-index or graded-index.

## Check Your Understanding

1. BNC stands for ______.
   (a) Bayonet Neill–Concelman (b) Boys Net–Concelman
   (c) Bayonet Neill–Connector (d) Bayonet Network–Concelman
2. The "RJ" in RJ45 stands for ____.
   (a) Resistance Jet (b) Registered Jack
   (c) Routing Jack (d) Radio Jack
3. Which of following is not Unguided Media?
   (a) Microwaves (b) Radio Waves
   (c) Ifrared (d) Fiber Optic
4. _______cables carry data signals in the form of Light.
   (a) Coaxial (b) Fiber optic
   (c) Twisted Pair (d) None of these
5. ________cables consists of two insulated copper wire twisted together.
   (a) Coaxial (b) Fiber optic
   (c) Twisted Pair (d) one of these
6. ________ cable consists of an inner copper core and a second conducting outer sheath.
   (a) Twisted-pair (b) Coaxial
   (c) Fiber-optic (d) Shielded twisted-pair
7. In fiber optics, the signal is ________.
   (a) light (b) radio
   (c) infrared (d) very low-frequency waves.
8. Signals with a frequency between 2 MHz and 30MHz use ________propagation.
   (a) ground (b) Sky
   (c) line-of-sight (d) none of the above

9. A parabolic dish antenna is a(n) ________ antenna.
   (a) omnidirectional (b) bidirectional
   (c) unidirectional (d) horn
10. Which of the following is not a guided medium?
   (a) twisted-pair cable (b) coaxial cable
   (c) fiber-optic cable (d) atmosphere

**ANSWERS**

| | | | | |
|---|---|---|---|---|
| 1. (a) | 2. (b) | 3. (d) | 4. (b) | 5. (c) |
| 6. (d) | 7. (a) | 8. (b) | 9. (c) | 10. (d) |

## Practice Questions

**Q.I Answer the following questions in short.**

1. What is transmission media?
2. What are types of transmission media?
3. Which are types of twisted-pair cables?
4. Write the types of wireless data transmission?
5. What is propagation mode in fiber-optic cable?
6. What is infrared?
7. What is Wireless LAN?
8. What is unguided media?

**Q.II Answer the following questions.**

1. With suitable diagram describe transmission media.
2. Explain coaxial cable with diagram.
3. Enlist various characteristics of transmission media.
4. State various applications of TP cable.
5. With suitable diagram describe STP and UTP cables.
6. Enlist various applications of fiber optic cable.
7. Explain guided media in brief.
8. With suitable diagram describe electromagnetic spectrum in brief.
9. Compare guided and unguided media.
10. State advantages and disadvantages of wireless LAN.
11. State various applications Infrared.
12. Differentiate between Fiber Optic and Twisted Pair Cable.
13. Write a short note on.
    i) BNC Connector ii) Propagation Mode iii) Guided Media
14. Explain in detail 'Line of-sight'
15. Explain wireless transmission and explain any one media in detail.

16. What is Connector? Explain RJ-45 and BNC connector.
17. What is Wireless Communication? Explain need of Wireless Communication in transmission.
18. Explain Radio waves as a wireless transmission.

**Q.III Define the following terms:**

1. Ground wave propagation
2. Sky wave propagation
3. Wireless LAN
4. Guided and Unguided media
5. Radio waves

## Previous Exams Questions

**Summer 2018**

1. Explain wireless transmission and explain any one media in detail. [5M]

**Ans.** Please refer to Section 3.3.3

2. Explain propagation method. [5M]

**Ans.** Please refer to Section 3.3.2

3. Write notes on Unguided Media [5M]

**Ans.** Please refer to Section 3.3

**Winter 2018**

1. Explain Optic Fiber Cable in detail. [5M]

**Ans.** Please refer to Section 3.2.4.

2. What are different propagation methods? Explain any one. [5M]

**Ans.** Please refer to Section 3.3.2.

3. Write notes on Guided Media. [5M]

**Ans.** Please refer to Section 3.2

**Summer 2019**

1. Explain wireless transmission. Explain any one media in detail. [5M]

**Ans.** Please refer to Section 3.3.3.

2. Explain optic fiber cable in detail. [5M]

**Ans.** Please refer to Section 3.2.4.

3. Explain propagation method. [5M]

**Ans.** Please refer to Section 3.3.2.

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