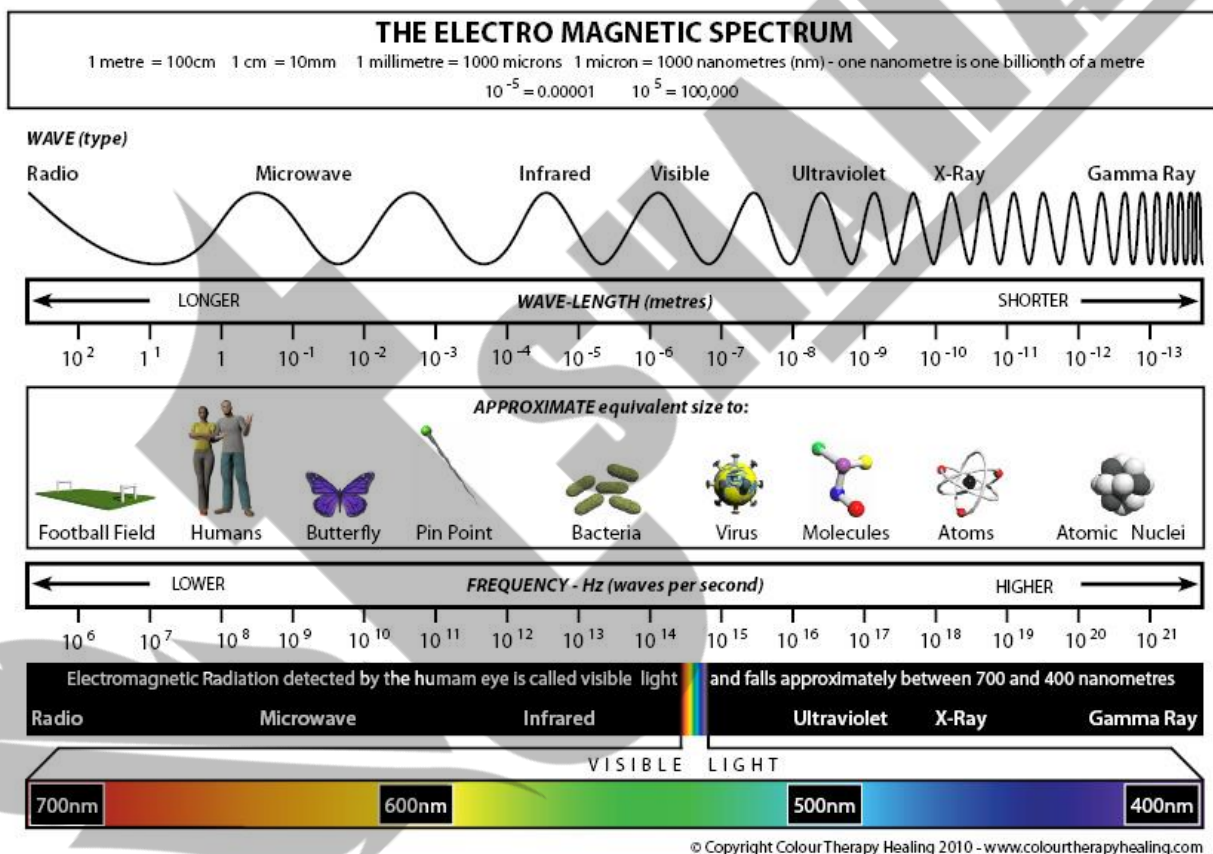


❖ Transmission Media

The transmission medium is the physical path between transmitter and receiver. A transmission medium can be broadly defined as anything that can carry information from a source to a destination. For example, the transmission medium for two people having a dinner conversation is the air. For a written message, the transmission medium might be a mail carrier, a truck, or an airplane.

The characteristics and quality of a data transmission are determined both by the characteristics of the medium and the characteristics of the signal.

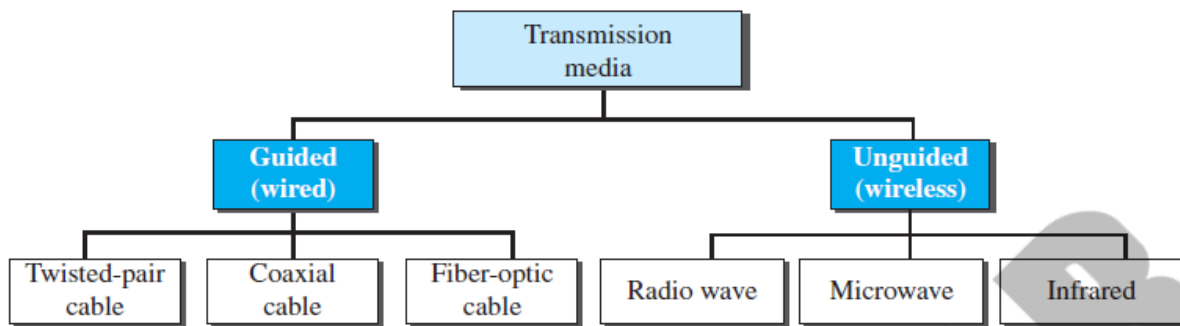
- ✚ In guided media, the medium itself is more important in determining the limitations of transmission.
- ✚ In unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics.



There are two types of Transmission Media:

- ✓ **Guided Transmission Media**
- ✓ **Unguided Transmission Media**

Their details are as follows:



❖ Guided Transmission Media

1. Twisted Pair Cable

The least expensive and most widely used guided transmission medium is twisted pair. A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern. A wire pair acts as a single communication link. One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. The receiver uses the difference between the two. Typically, a number of these pairs are bundled together into a cable by wrapping them in a tough protective sheath, or jacket. Over longer distances, cables may contain hundreds of pairs. The twisting tends to decrease the crosstalk interference between adjacent pairs in a cable.

Applications

By far the most common guided transmission medium for both analog and digital signals is twisted pair. It is the most commonly used medium in the telephone network and is the workhorse for communications within buildings. The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.

There are following two types of twisted pair cable:

- ✓ **Unshielded Twisted Pair Cable (UTP)**
- ✓ **Shielded Twisted Pair Cable (STP)**



Unshielded Twisted Pair Cable

Unshielded twisted pair (UTP) consists of one or more twisted-pair cables, typically enclosed within an overall thermoplastic jacket, which provides no electromagnetic shielding. The most common form of UTP is ordinary voice-grade telephone wire, which is pre-wired in residential and office buildings. For data transmission purposes, UTP may vary from voice-grade to very high-speed cable for local area networks (LANs). For high-speed LANs, UTP typically has four pairs of wires inside the jacket, with each pair twisted with a different number of twists per centimeter to help eliminate interference between adjacent pairs. The tighter the twisting, the higher the supported transmission rate and the greater the cost per meter.

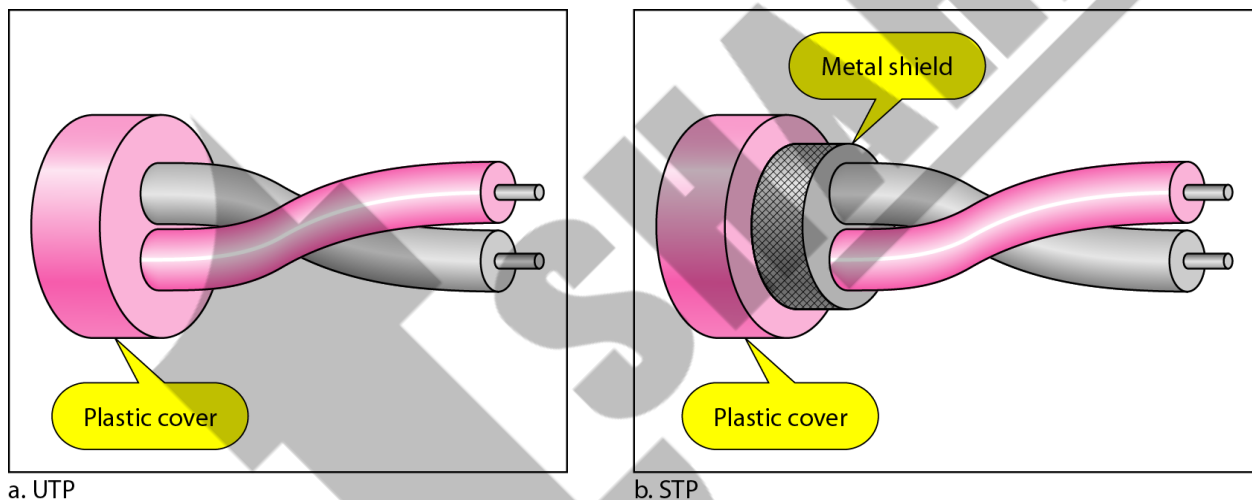
Unshielded twisted pair is subject to external electromagnetic interference, including interference from nearby twisted pair and from noise generated in the environment.

Shielded Twisted Pair Cable

In an environment with a number of sources of potential interference (e.g., electric motors, wireless devices, and RF transmitters), shielded twisted pair (STP) may be a preferred solution. Shielded twisted pair cable is manufactured in three different configurations:

1. Each pair of wires is individually shielded with metallic foil, generally referred to as foil twisted pair (FTP).
2. There is a foil or braid shield inside the jacket covering all wires (as a group). This configuration is sometimes designated as screened twisted pair (F/UTP).
3. There is a shield around each individual pair, as well as around the entire group of wires. This is referred to as fully-shielded twisted pair or shielded/foil twisted pair (S/FTP).

The shielding reduces interference and provides better performance at higher data rates. However, it may be more expensive and installers familiar with UTP technology may be reluctant to work with a new media type.



Categories

The Electronic Industries Association (EIA) has developed standards to classify unshielded twisted-pair cable into seven categories. Categories are determined by cable quality, with 1 as the lowest and 7 as the highest. Each EIA category is suitable for specific uses.

Category	Specification	Data Rate (Mbps)	Use
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs

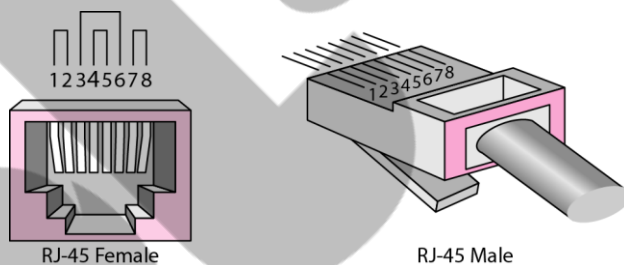
Category	Specification	Data Rate (Mbps)	Use
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called <i>SSTP (shielded screen twisted-pair)</i> . Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

Performance

One way to measure the performance of twisted-pair cable is to compare attenuation versus frequency and distance. A twisted-pair cable can pass a wide range of frequencies. However, with increasing frequency, the attenuation, measured in decibels per kilometer (dB/km), sharply increases with frequencies above 100 kHz. Note that gauge is a measure of the thickness of the wire.

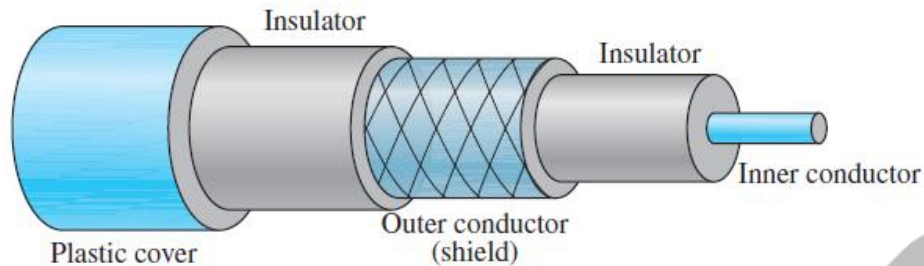
Connectors

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



2. Coaxial Cable

Coaxial cable, like twisted pair, 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. The inner conductor is held in place by either regularly spaced insulating rings or a solid dielectric material. The outer conductor is covered with a jacket or shield. A single coaxial cable has a diameter of from 1 to 2.5 cm. Coaxial cable can be used over longer distances and support more stations on a shared line than twisted pair.



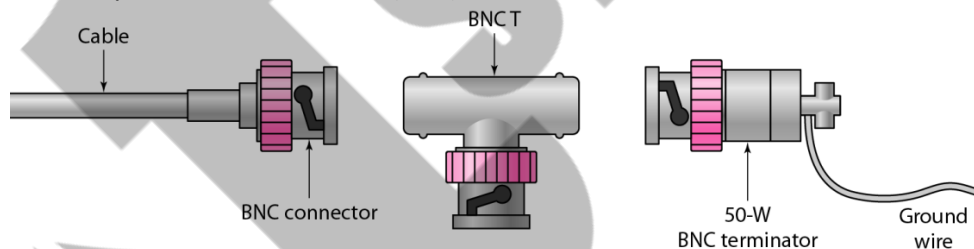
Coaxial Cable Standards

Coaxial cables are categorized by their Radio Government (RG) ratings. Each RG number denotes a unique set of physical specifications, including the wire gauge of the inner conductor, the thickness and type of the inner insulator, the construction of the shield, and the size and type of the outer casing. Each cable defined by an RG rating is adapted for a specialized function

Category	Impedance	Use
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

Connectors

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



The BNC connector 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.

Performance

The attenuation is much higher in coaxial cable than in twisted-pair cable. In other words, although coaxial cable has a much higher bandwidth, the signal weakens rapidly and requires the frequent use of repeaters. Its performance is limited by attenuation and noise but in frequency characteristics it is superior to twisted pair cable.

Application

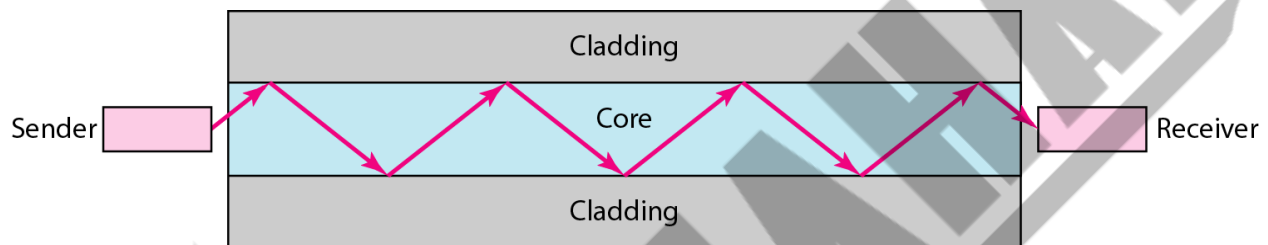
Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals. Later it was used in digital telephone networks where a single coaxial cable could

carry digital data up to 600 Mbps. However, coaxial cable in telephone networks has largely been replaced today with fiber optic cable.

Cable TV networks also use coaxial cables. In the traditional cable TV network, the entire network used coaxial cable. Later, however, cable TV providers replaced most of the media with fiber-optic cable; hybrid networks use coaxial cable only at the network boundaries, near the consumer premises. Cable TV uses RG-59 coaxial cable.

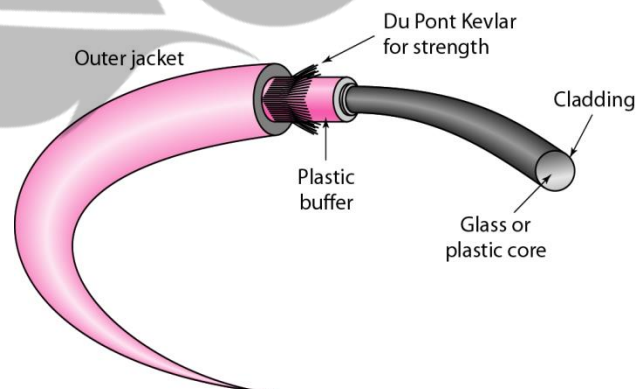
Another common application of coaxial cable is in traditional Ethernet LANs (see Chapter 13). Because of its high bandwidth, and consequently high data rate, coaxial cable was chosen for digital transmission in early Ethernet LANs.

3. Fiber Optic Cable



An optical fiber is a thin, flexible medium capable of guiding an optical ray. Various glasses and plastics can be used to make optical fibers. Ultrapure fiber is difficult to manufacture; higher-loss multi-component glass fibers are more economical and still provide good performance. Plastic fiber is even less costly and can be used for short-haul links, for which moderately high losses are acceptable.

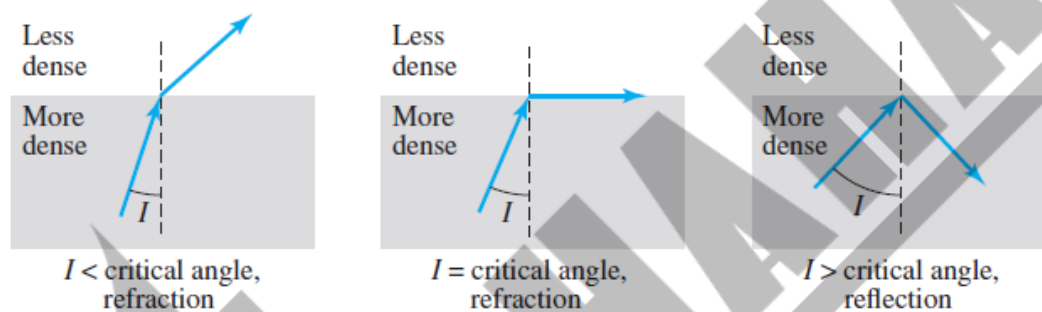
An optical fiber **strand** (also called an optical waveguide) has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the buffer coating. The **core** is the innermost section and consists of thin strands made of glass or plastic; the core has a diameter in the range of 8 to 62.5 μm . The core is surrounded by a **cladding**, which is a glass or plastic coating that has optical properties different from those of the core and a diameter of 125 μm . The interface between the core and cladding acts as a reflector to confine light that would otherwise escape the core. The outermost layer is the buffer coating, which is a hard plastic coating that protects the glass from moisture and physical damage.



Fiber Optics Composition

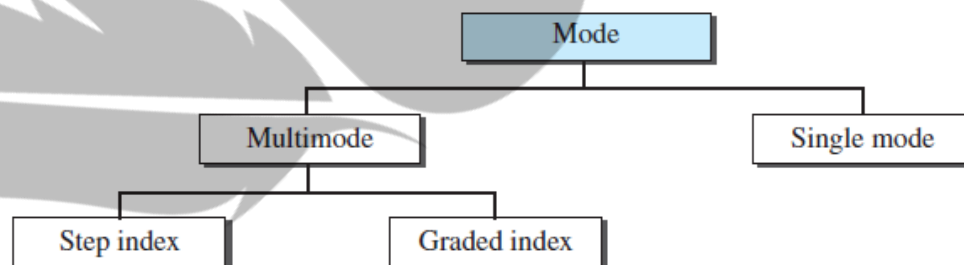
Fiber optic cable provides protection to the fiber from stress during installation and from the environment once it is installed. Cables may contain from only one to hundreds of fibers inside. The outermost layer of the cable, surrounding one or a bundle of fibers, is the jacket. The jacket is composed of plastic and other materials, layered to protect against moisture, abrasion, crushing, and other environmental dangers.

Light travels in a straight line as long as it is moving through a single uniform substance. If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.



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

Propagation Modes



Single Mode

Single-mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The single-mode fiber itself is manufactured with a much smaller diameter than that of multimode fiber, and with substantially lower density (index of refraction). This **single-mode** propagation provides superior performance for the following reason. Because there is a single transmission path with single-mode transmission, the distortion found in multimode cannot

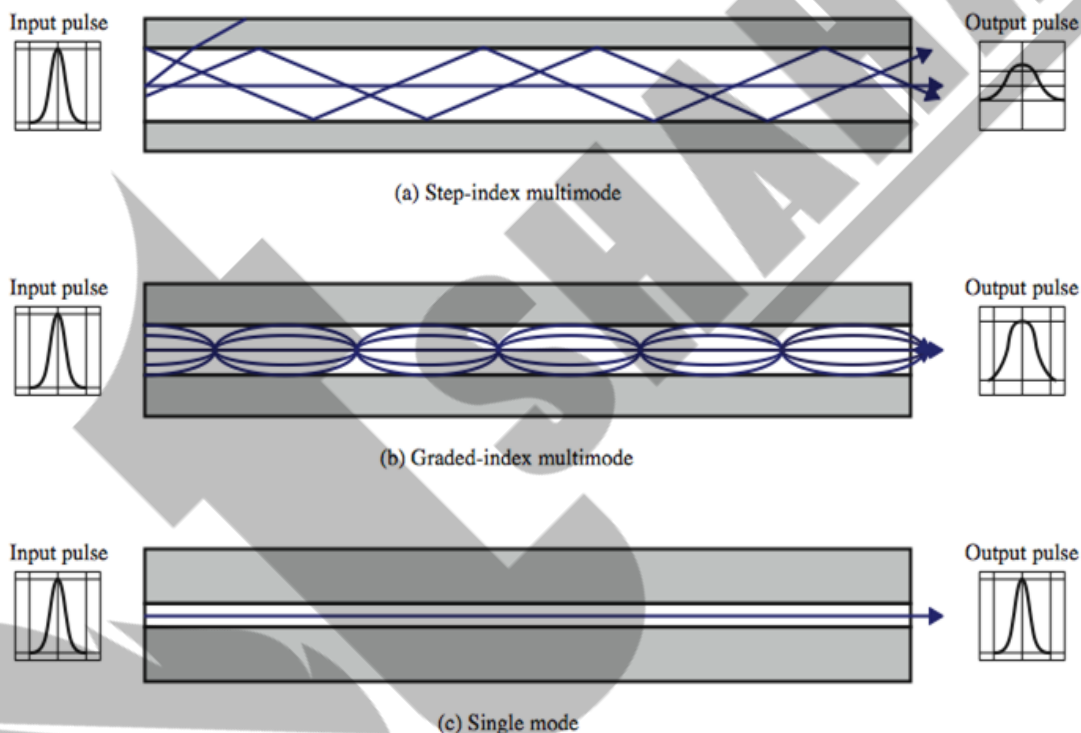
occur. Single-mode is typically used for long-distance applications, including telephone and cable television.

Multimode

Multimode is so named because multiple beams from a light source move through the core in different paths.

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

A graded-index fiber, therefore, is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge.



Advantages of Fiber Optics

- ✓ Fiber Optics networks work at a very high speed.
- ✓ The information carrying capacity of fiber optics is very high. (Data rates of Hundreds of Gbps)
- ✓ Fiber optics is lighter and smaller in size than twisted pair and coaxial cable.
- ✓ It is more secure and reliable form of data transmission.
- ✓ It is not affected by electromagnetic waves.
- ✓ A signal can run for 50 km without requiring regeneration.
- ✓ Glass is more resistant to corrosive materials than copper.
- ✓ Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped.

Disadvantages of Fiber Optics

- ✓ It is difficult to install. Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.
- ✓ It is expensive. 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.
- ✓ Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.

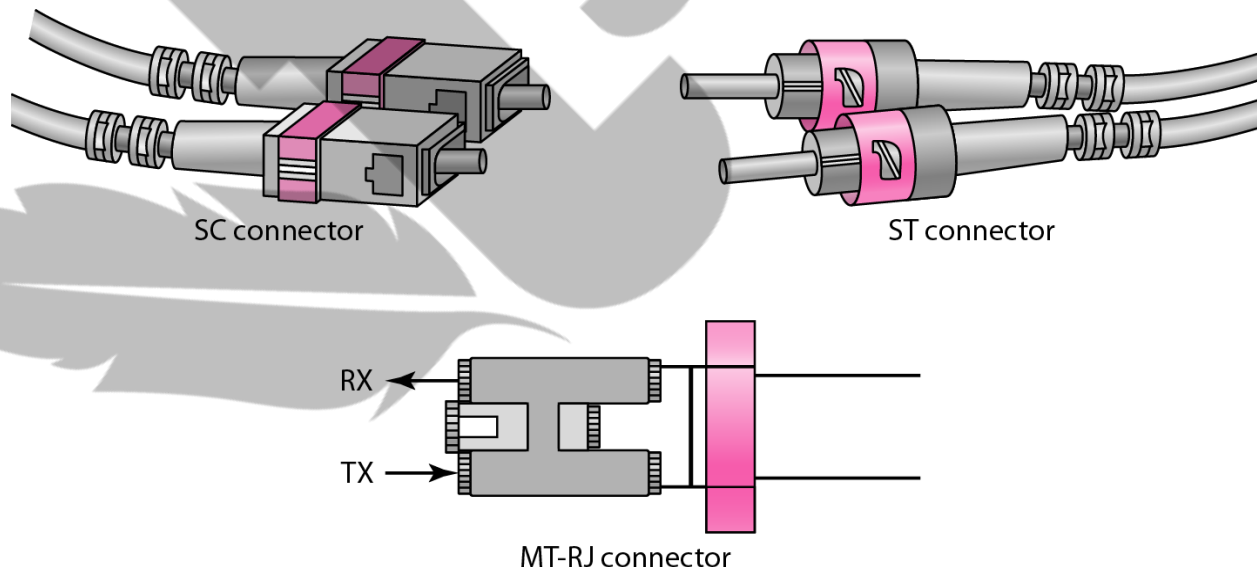
Fiber Sizes

Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding, both expressed in micrometers.

Type	Core (μm)	Cladding (μm)	Mode
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

Fiber Optics Connectors

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



Performance

Its performance is better than Twisted Pair and Coaxial Cable. It provides more bandwidth and less attenuation. It also provides more distance without repeater.

Applications

Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective. Today, with wavelength-division multiplexing (WDM), we can transfer data at a rate of 1600 Gbps.

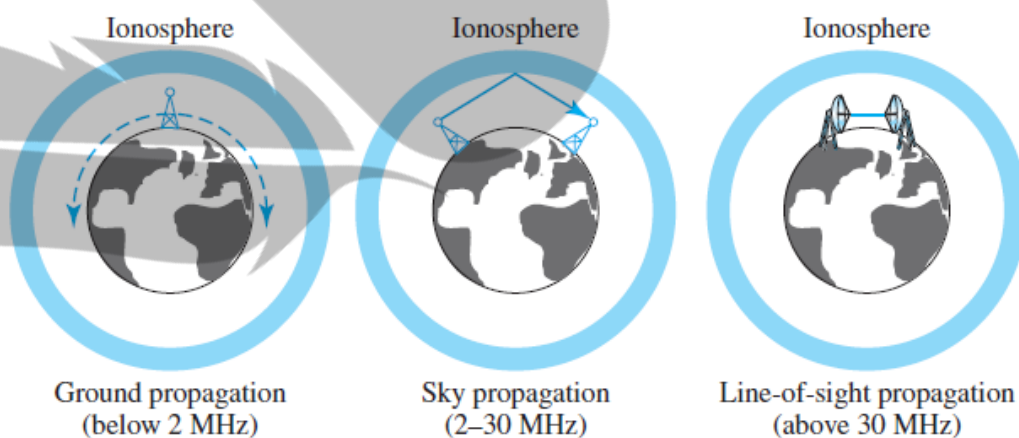
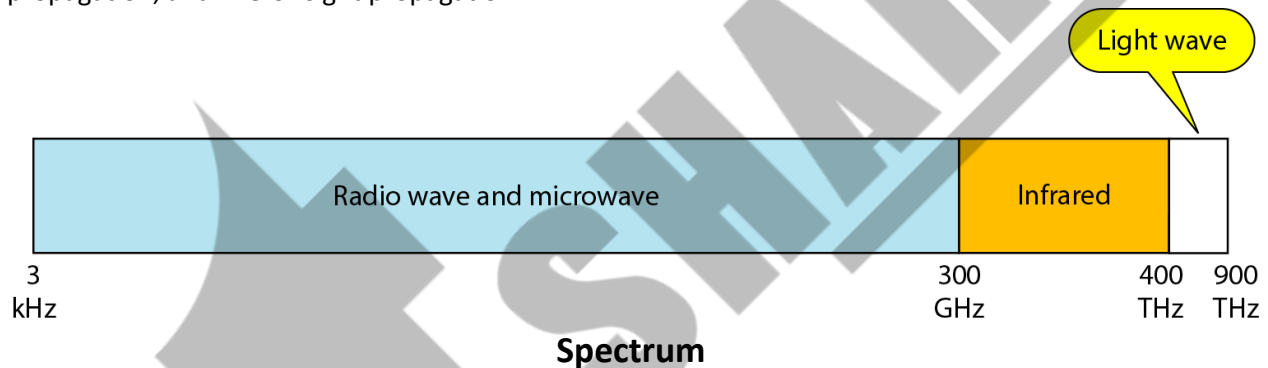
Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network. Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises. This is a cost-effective configuration since the narrow bandwidth requirement at the user end does not justify the use of optical fiber.

Local-area networks such as 100Base-FX network (Fast Ethernet) and 1000Base-X also use fiber-optic cable.

❖ Unguided Transmission Media

Unguided medium 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.

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



Propagation Modes

- ✚ **Ground Propagation:** In ground propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the planet. Distance depends on the amount of power in the signal: The greater the power, the greater the distance.
- ✚ **Sky Propagation:** In sky propagation, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth. This type of transmission allows for greater distances with lower output power.
- ✚ **Line of Sight Propagation:** In line-of-sight propagation, very high-frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other and either tall enough or close enough together not to be affected by the curvature of the earth. Line-of sight propagation is tricky because radio transmissions cannot be completely focused.

Bands

The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called bands, each regulated by government authorities. These bands are rated from very low frequency (VLF) to extremely high frequency (EHF).

<i>Band</i>	<i>Range</i>	<i>Propagation</i>	<i>Application</i>
very low frequency (VLF)	3–30 kHz	Ground	Long-range radio navigation
low frequency (LF)	30–300 kHz	Ground	Radio beacons and navigational locators
middle frequency (MF)	300 kHz–3 MHz	Sky	AM radio
high frequency (HF)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft
very high frequency (VHF)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
ultrahigh frequency (UHF)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
superhigh frequency (SHF)	3–30 GHz	Line-of-sight	Satellite
extremely high frequency (EHF)	30–300 GHz	Line-of-sight	Radar, satellite

1. Radio Waves

Radio waves are used for **multicast communications**, such as radio and television. They can penetrate through walls. Although there is no clear-cut demarcation between radio waves and microwaves, electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves; waves ranging in frequencies between 1 and 300 GHz are called microwaves. However, the behavior of the waves, rather than the frequencies, is a better criterion for classification.

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. It is an advantage because, for example, an AM radio can receive signals inside a building. It is a disadvantage because we cannot isolate a communication to just inside or outside a building. The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band. When this band is divided into sub-bands, the sub-bands are also narrow, leading to a low data rate for digital communications.

Omni Directional Antenna

Radio waves use omnidirectional antennas that send out signals in all directions. Based on the wavelength, strength, and the purpose of transmission, we can have several types of antennas.

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.



Radio waves are used for multicast communications, such as radio and television, and paging systems.

2. Microwaves

Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs. Higher frequency ranges cannot penetrate walls. Use directional antennas - point to point line of sight communications.

Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwaves, 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 sub-bands can be assigned, and a high data rate is possible.
- ✓ Use of certain portions of the band requires permission from authorities.

Unidirectional Antenna

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

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

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

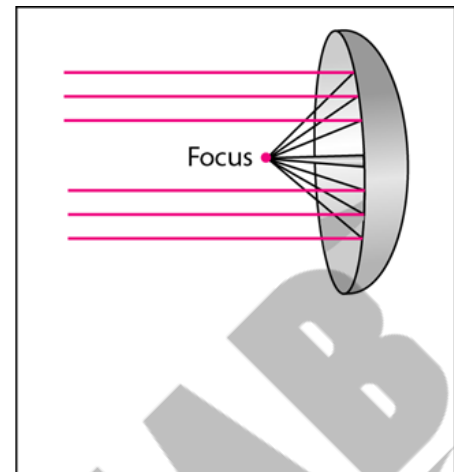
Applications

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

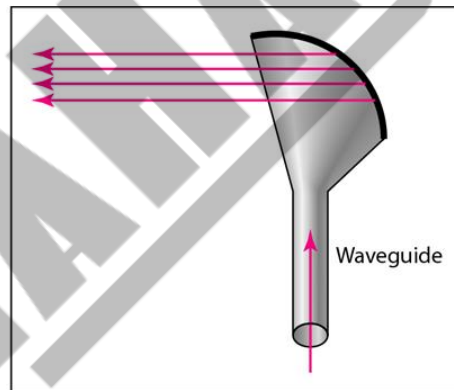
Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

3. Infrared Waves

Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication. Infrared waves, having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another; a short-range communication system in one room cannot be affected by another system in the next room. When we use our infrared remote control, we do not interfere with the use of the remote by our 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.



a. Dish antenna



b. Horn antenna



✚ Applications

The infrared band, almost 400 THz, 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 manufacturers 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 75 kbps 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.

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation



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