Class 4 ((Communication and Computer Networks))

Lesson 3... Transmission Media, Part 1

Abstract

The successful transmission of data depends principally on two factors: the quality of the signal being transmitted and the characteristics of the transmission medium. The objective of this lesson and the next is to provide the student with some details, sufficient background, for the nature of these two factors.

Key points;

Introduction

The transmission medium is the physical path between transmitter and receiver in a data transmission system. Transmission media can be classified as **guided** or **unguided**. In both cases, communication is in the form of electromagnetic waves.

With guided media, the waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, and optical fiber.

The atmosphere and outer space are examples of unguided media that provide a means of transmitting electromagnetic signals but do not guide them; this form of transmission is usually referred to as **wireless transmission**.

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

In the case of **guided media**, the medium itself is more important in determining the limitations of transmission.

For **unguided media**, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics.

One key property of signals transmitted by antenna is directionality. In general, signals at lower frequencies are omnidirectional; that is, the signal propagates in all directions from the antenna. At higher frequencies, it is possible to focus the signal into a directional beam.

In considering the design of data transmission systems, a key concern, is **data rate** and **distance**: the greater the data rate and distance, the better. A number of **design factors** relating to the transmission medium and to the signal determine the data rate and distance [William, CH3]:

Q\\ What are the major design factors in determining the data rate and distance ? List and explain?

- **Bandwidth**: With all other factors remaining constant, the greater the and width 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 suffer 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 it is also a problem with guided media. For guided media, interference can be caused by emanations from nearby 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.

GUIDED TRANSMSSION MEDIA

Guided media, which are those that provide a channel from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable. A signal travelling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current. Optical fiber is a cable that accepts and transports signals in the form of light [Behrouz, CH7].

For guided transmission media, the **transmission capacity** depends critically on the **distance** and on whether the medium is point-to-point or multipoint.

Please Note...

The Physical Structures of the connection can take many types, these are:

- **Point-to-Point** : A point-to-point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices. Most point-to-point connections use an actual length of wire or cable to connect the two ends, but other options, such as microwave or satellite links, are also possible. When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television's control system.
- **Multipoint:** A multipoint (also called multidrop) connection is one in which more than two specific devices share a single link. In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a

spatially shared connection. If users must take turns, it is a **timeshared** connection.

Also, the transmission of data (**data flow**) between two or more points can be **Simplex**, **Half duplex**, **Full duplex**.

- **Simplex**

  In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive (see Figure 1.2a). Keyboards and traditional monitors are examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output. The simplex mode can use the entire capacity of the channel to send data in one direction.

- **Half-Duplex**

  In half-duplex mode, each station can both transmit and receive, but not at the same time. : When one device is sending, the other can only receive, and vice versa.

  In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.

- **Full-Duplex**

  In full-duplex, both stations can transmit and receive simultaneously

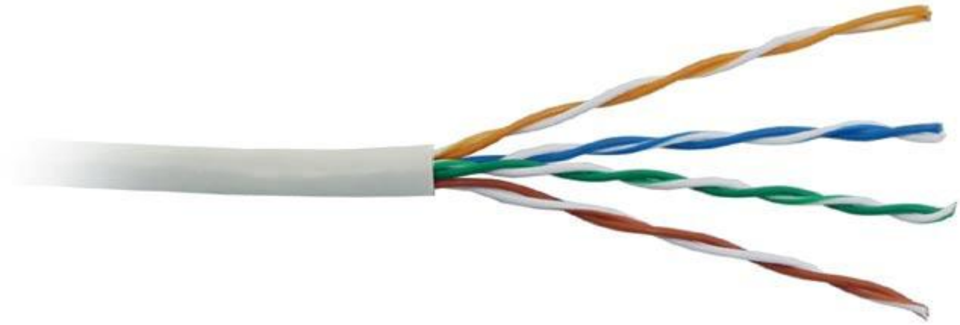
  The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time. In full-duplex mode, signals going in one direction share the capacity of the link: with signals going in the other direction. This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals travelling in both directions.

One common example of full-duplex communication is the telephone network. The capacity of the channel, however, must be divided between the two directions.

GUIDED MEDIA

- **Twisted-Pair Cable**

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



One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. The receiver uses the difference between the two. The wires in a pair have thicknesses of from 0.016 to 0.036 inches.

In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals. If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources (e,g., one is closer and the other is farther). This results in a difference at the receiver. By twisting the pairs, a balance is maintained. The unwanted signals are mostly cancelled out.

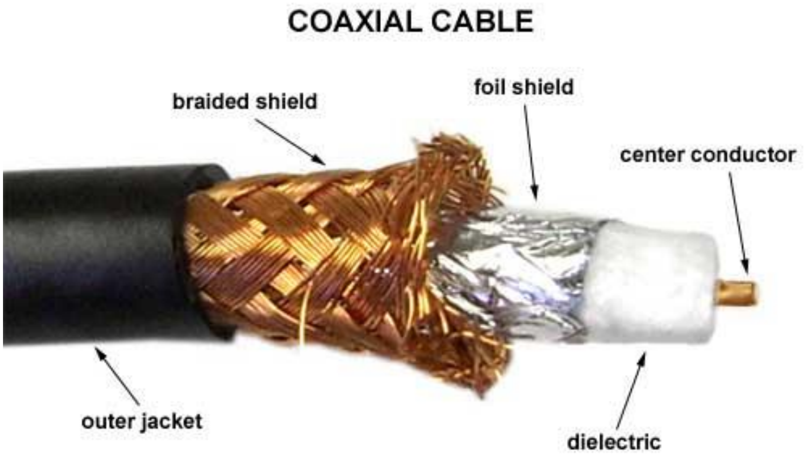
The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP). Due to its low cost, UTP cabling is used extensively for local-area networks (LANs) and telephone connections. UTP cabling does not offer as high bandwidth or as good protection from interference as coaxial or fiber optic cables, but it is less expensive and easier to work with.

Also there is a version of twisted-pair cable used called shielded twisted-pair (STP). STP cable has a metal foil covering that encases each pair of insulated conductors. Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive. STP cabling often is used in Ethernet networks, especially fast data rate Ethernets.

Twisted pairs can be used for transmitting either analog or digital information. The bandwidth depends on the thickness of the wire and the distance travelled, but several megabits/sec can be achieved for a few kilometers in many cases. Due to their adequate performance and low cost, twisted pairs are widely used and are likely to remain so for years to come. Twisted-pair cabling comes in several varieties. The garden variety is called Category 5 cabling, or ‘‘Cat 5.’’ Twisted pair may be used to transmit both analog and digital signals. For analog signals, amplifiers are required about every 5 to 6 km. For digital signals, repeaters are required every 2 or 3 km.

- **Coaxial Cable**

Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted pair cable, in part because the two media are constructed quite differently. Instead of having two wires, coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil. The outer metallic wrapping serves both as a shield against noise and as a conductor, which complete the circuit. This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

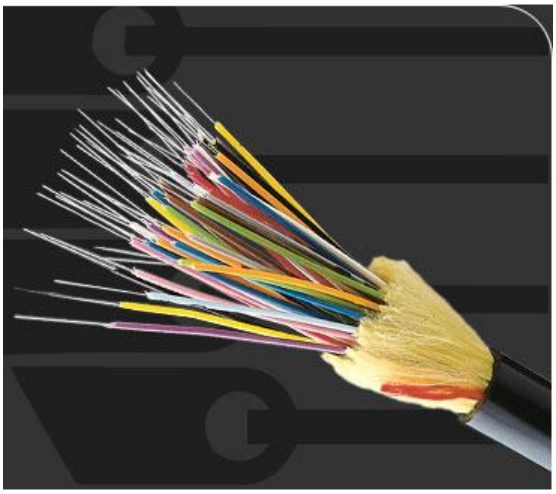


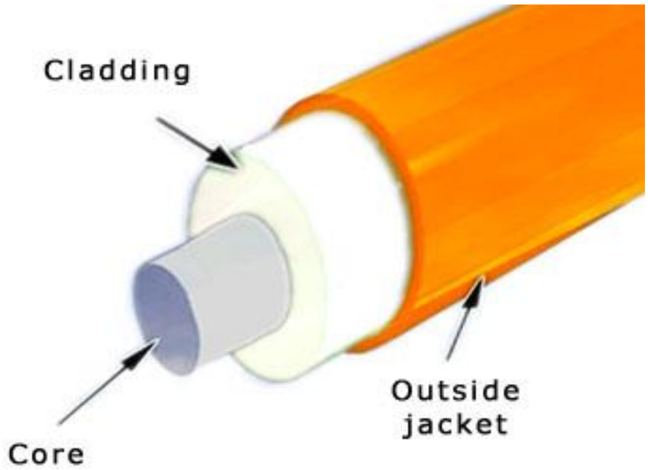
Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals. Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps. However, coaxial cable in telephone networks has largely been 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.

- **Fiber-Optic Cable**

An optical fiber is a thin (2 to 125 pm), flexible medium capable of conducting an optical ray. Various glasses and plastics can be used to make optical fibers. The lowest losses have been obtained using fibers of ultrapure fused silica. Ultrapure fiber is difficult to manufacture; higher-loss multicomponent 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.

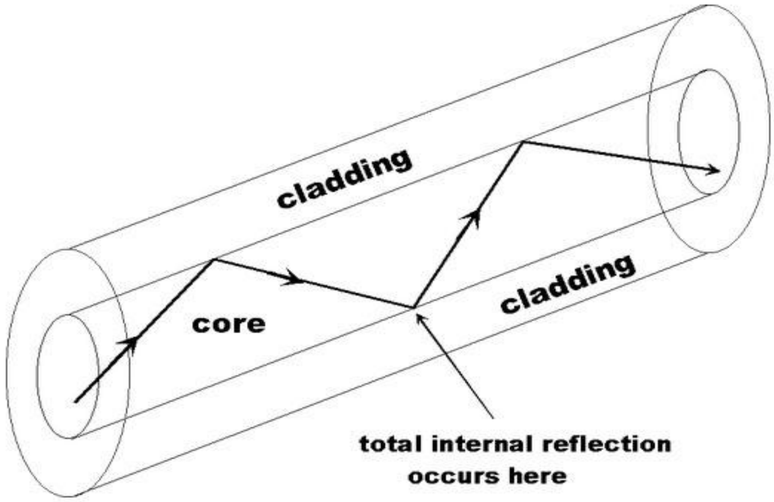
An optical fiber cable has a cylindrical shape and consists of three concentric sections: **the core**, **the cladding**, and **the jacket** (Figure below).





The core is the innermost section and consists of one or more very thin strands, or fibers, made of glass or plastic. Each fiber is surrounded by its own cladding, a glass or plastic coating that has optical properties different from those of the core. The outermost layer, surrounding one or a bundle of cladded fibers, is the jacket. The jacket is composed of plastic and other material layered to protect against moisture, abrasion, crushing, and other environmental dangers.

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



The following characteristics distinguish optical fiber from twisted pair or coaxial cable:

- **Greater capacity**. The potential bandwidth, and hence data rate, of optical fiber is immense; data rates of 2 Gbps over tens of kilometers have been demonstrated. Compare this to the practical maximum of hundreds of Mbps over about 1 km for coaxial cable and just a few Mbps over 1 km or up to 100 Mbps over a few tens of meters for twisted pair.
- **Smaller size and lighter weight**. Optical fibers are considerably thinner than coaxial cable or bundled twisted-pair cable. The corresponding reduction in weight reduces structural support requirements.
- **Lower attenuation**. Attenuation is significantly lower for optical fiber than for coaxial cable or twisted pair and is constant over a wide range.

- **Electromagnetic isolation**. Optical fiber systems are not affected by external electromagnetic fields. Thus, the system is not vulnerable to interference, impulse noise, or crosstalk.
- **Greater repeater spacing**. Fewer repeaters mean lower cost and fewer sources of error.

Please Note [Tanenbaum, Ch2]:

- An optical transmission system has three key components: **the light source**, the **transmission medium**, and the **detector**. Conventionally, a pulse of light indicates a 1 bit and the absence of light indicates a 0 bit. The transmission medium is an ultra-thin fiber of glass. The detector generates an electrical pulse when light falls on it. By attaching a light source to one end of an optical fiber and a detector to the other, we have a unidirectional data transmission system that accepts an electrical signal, converts and transmits it by light pulses, and then reconverts the output to an electrical signal at the receiving end.
- When a light ray passes from one medium to another the ray is refracted (bent) at the silica/air boundary, as shown in the Fig

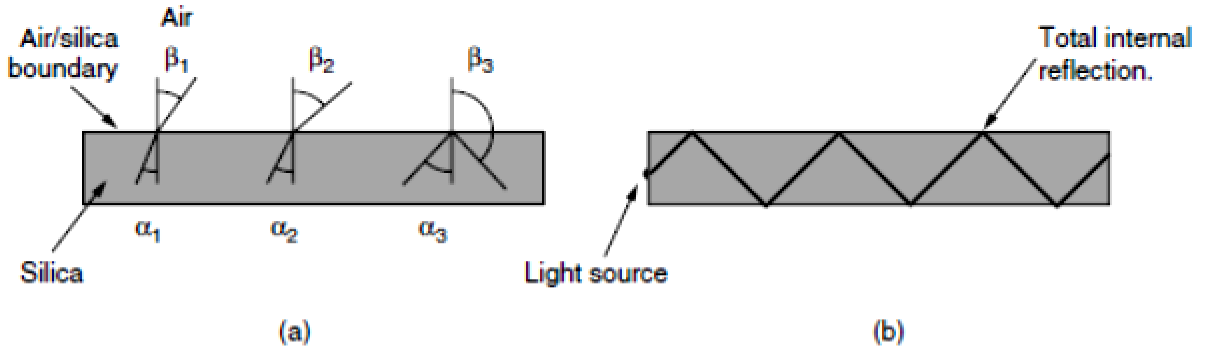


Figure 2-6. (a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles. (b) Light trapped by total internal reflection.

Here we see a light ray incident on the boundary at an angle **α** emerging at an angle **β**. The amount of refraction depends on the properties of the two media For angles of incidence above a certain critical value, the light is refracted back into the silica; none of it escapes into the air. Thus, a light ray incident at or above the critical angle is trapped inside the fiber, as shown in the Fig. (b), and can propagate for many kilometers with virtually no loss.

Two different types of **light source** are used in fiber optic systems: the light emitting diode (LED) and the injection laser diode (ILD). Both are semiconductor devices that emit a beam of light when a voltage is applied. The LED is less costly, operates over a greater temperature range, and has a longer operational life. The ILD, which operates on the laser principle, is more efficient and can sustain greater data rates.

Propagation Mode

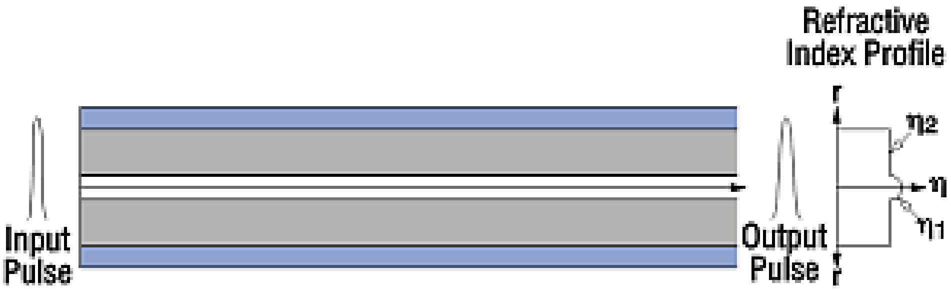
The sketch of Fig. 2-6(b) shows only one trapped ray, but since any light ray incident on the boundary above the critical angle will be reflected internally, many different rays will be bouncing around at different angles. Each ray is said to have a different mode, so a fiber having this property is called a multimode fiber.

However, if the fiber's diameter is reduced to a few wavelengths of light the fiber acts like a wave guide and the light can propagate only in a straight line, without bouncing, yielding a single-mode fiber. Single-mode fibers are more expensive but are widely used for longer distances. Currently available single-mode fibers can transmit data at 100 Gbps for 100 km without amplification.

1- Single-mode Step Index

Single mode propagation exists only above a certain specific wavelength called the cutoff wavelength. Single-mode fiber optic cable is fabricated from glass. Because of the thickness of the core, plastic cannot be used to fabricate single-mode fiber optic cable.

Less time dispersion of course means higher bandwidth and this is in the 50 to 100 GHz/ km range. However, single mode fiber optic cable is also the most costly in the premises environment. For this reason, it has been used more with Wide Area Networks than with premises data communications. It is attractive more for link lengths go all the way up to 100 km. Nonetheless, single-mode fiber optic cable has been getting increased attention as Local Area Networks have been extended to greater distances over corporate campuses.



Single-Mode Step Index

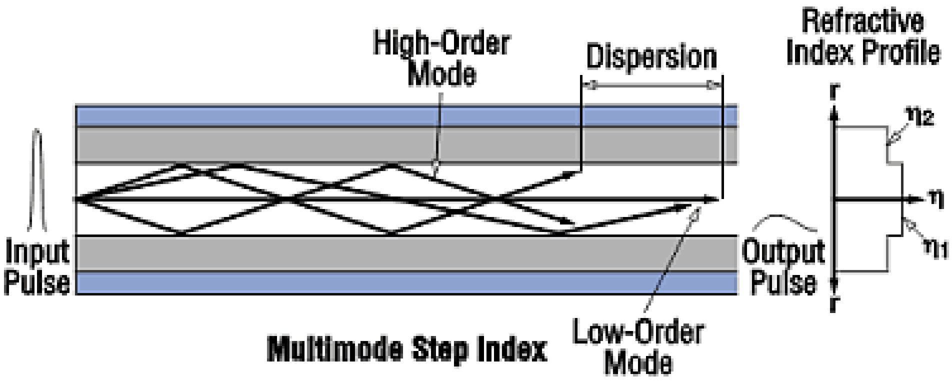
Multi-mode Step Index

The diameter of the core is fairly large relative to the cladding. Note that the output pulse is significantly attenuated relative to the input pulse. It also suffers significant time dispersion.

The higher order modes, the bouncing rays, tend to leak into the cladding as they propagate down the fiber optic cable. They lose some of their energy into heat. This results in an attenuated output signal. Consequently, they do not all reach the right end of the fiber optic cable at the same time. When the output pulse is constructed from these separate ray components the result is time dispersion.

Fiber optic cable that exhibits multi-mode propagation with a step index profile is thereby characterized as having higher attenuation and more time dispersion than the other propagation candidates have. However, it is also the least costly and in the premises environment the most widely used. It is especially attractive for link lengths up to 5 km.

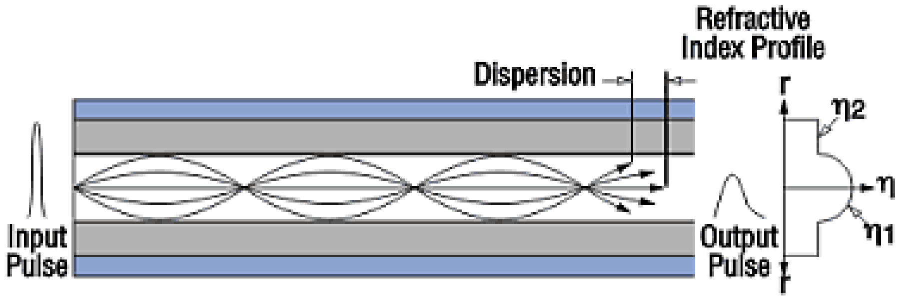
Usually, it has a core diameter that ranges from 100 microns to 970 microns. It can be fabricated either from glass, plastic or PCS.



Multi-mode Graded Index

There is no sharp discontinuity in the indices of refraction between core and cladding. The core here is much larger than in the single-mode step index. When comparing the output pulse and the input pulse, note that there is some attenuation and time dispersion, but not nearly as great as with multi-mode step index fiber optic cable.

Fiber optic cable that exhibits multi-mode propagation with a graded index profile is thereby characterized as having attenuation and time dispersion properties somewhere between the other two candidates. Likewise its cost is somewhere between the other two candidates. This type of fiber optic cable is extremely popular in premise data communications applications.



Multimode Graded Index