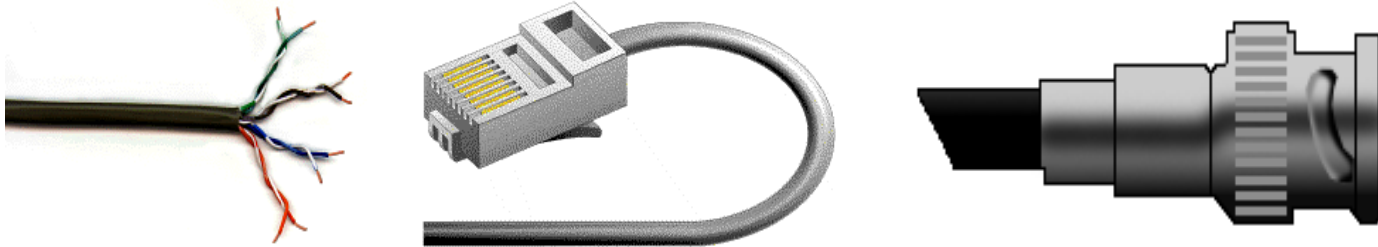


Transmission Media and Network Cabling



Transmission medium is the physical path between the transmitter and receiver.

What is Cable? Transmission Media

- ⌘ Transmission medium is the physical path between the transmitter and receiver.
- ⌘ It is the Transmission medium through which information usually moves from one network device to another.
- ⌘ In some cases, a network will utilize only one type of cable, other networks will use a variety of cable types.
- ⌘ Understanding the characteristics of different types of transmission media and how they relate to other aspects of a network is necessary for the development of a successful network.

Factors to Select Transmission Media

- ⌘ Data Rate and Bandwidth
- ⌘ Distance and Attenuation
- ⌘ Interference Characteristics
- ⌘ Number of receivers
- ⌘ Cost - Remember cabling is a long term investment!

Transmission Impairment

- ⌘ Impairments exist in all forms of data transmission media
 - ☐ Analog signal impairments result in random modifications that impair signal quality
 - ☐ Digital signal impairments result in bit errors (1s and 0s transposed)

Types of Media

- ⌘ Two major classes

- ⌘ **Conducted or guided media**

- ☑ use a conductor such as a wire or a fiber optic cable to move the signal from sender to receiver.

- ☑ Energy is confined to the medium and guided by it

- ⌘ **Wireless or unguided media**

- ☑ use radio waves of different frequencies and do not need a wire or cable conductor to transmit signals

- ☑ Electromagnetic waves propagate through the air

Guided Media Sub-types

- ⌘ Unshielded Twisted Pair (UTP) Cable
- ⌘ Shielded Twisted Pair (STP) Cable
- ⌘ Coaxial Cable
- ⌘ Fiber Optic Cable

Un-guided Media Sub-types

- ⌘ Terrestrial microwave transmission
- ⌘ Satellite transmission
- ⌘ Broadcast radio
- ⌘ Infrared

Twisted Pair Wires

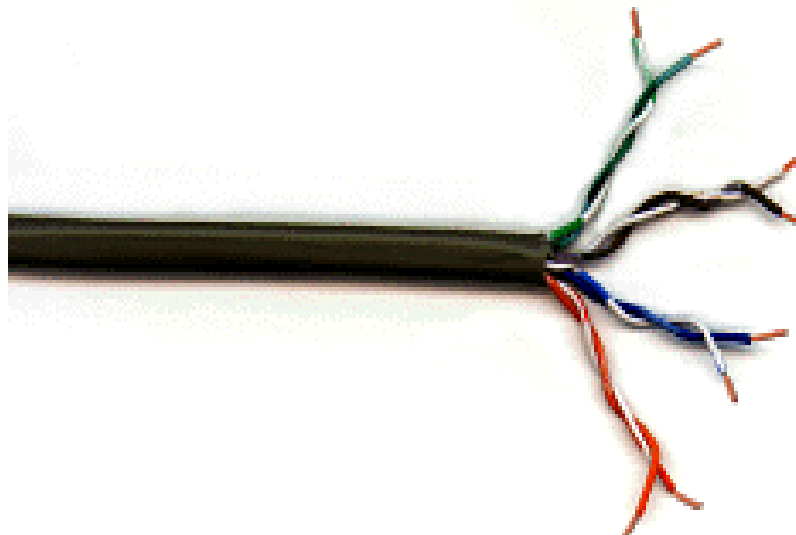
- ⌘ Consists of two insulated copper wires arranged in a regular spiral pattern to minimize the electromagnetic interference between adjacent pairs
- ⌘ Often used at customer facilities and also over distances to carry voice as well as data communications
- ⌘ Low frequency transmission medium

Twisted Pair

- Separately insulated
- Twisted together
- Often "bundled" into cables
- Usually installed in building during construction



(a) Twisted pair



Twisted Pair Types

⌘ Two varieties

☐ STP (shielded twisted pair)

- ☒ the pair is wrapped with metallic foil or braid to insulate the pair from electromagnetic interference

☐ UTP (unshielded twisted pair)

- ☒ each wire is insulated with plastic wrap, but the pair is encased in an outer covering

UTP (unshielded twisted pair)

⌘ 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 EIA/TIA (Electronic Industry Association/Telecommunication Industry Association) has established standards of UTP and rated five categories of wire.

Categories of Unshielded Twisted Pair

⌘ Type	Use
⌘ Category 1	Voice Only (Telephone Wire)
⌘ Category 2	Data to 4 Mbps (LocalTalk)
⌘ Category 3	Data to 10 Mbps (Ethernet)
⌘ Category 4	Data to 20 Mbps (16 Mbps Token Ring)
⌘ Category 5	Data to 100 Mbps (Fast Ethernet)

Differences between UTP Types

- ⌘ One difference between the different categories of UTP is the tightness of the twisting of the copper pairs.
- ⌘ The tighter the twisting, the higher the supported transmission rate and the greater the cost per foot.
- ⌘ Buy the best cable you can afford.

Benefits of UTP

- ⌘ Inexpensive and readily available
- ⌘ Flexible and light weight
- ⌘ Easy to work with and install

Disadvantages of UTP

- ⌘ Susceptibility to interference and noise
- ⌘ Attenuation problem
 - ☒ For analog, repeaters needed every 5-6km
 - ☒ For digital, repeaters needed every 2-3km
- ⌘ Relatively low bandwidth (3000Hz)

Twisted Pair - Applications

⌘ Telephone network

- ☑ Between house and local exchange (subscriber loop)

⌘ Within buildings

- ☑ To private branch exchange (PBX)

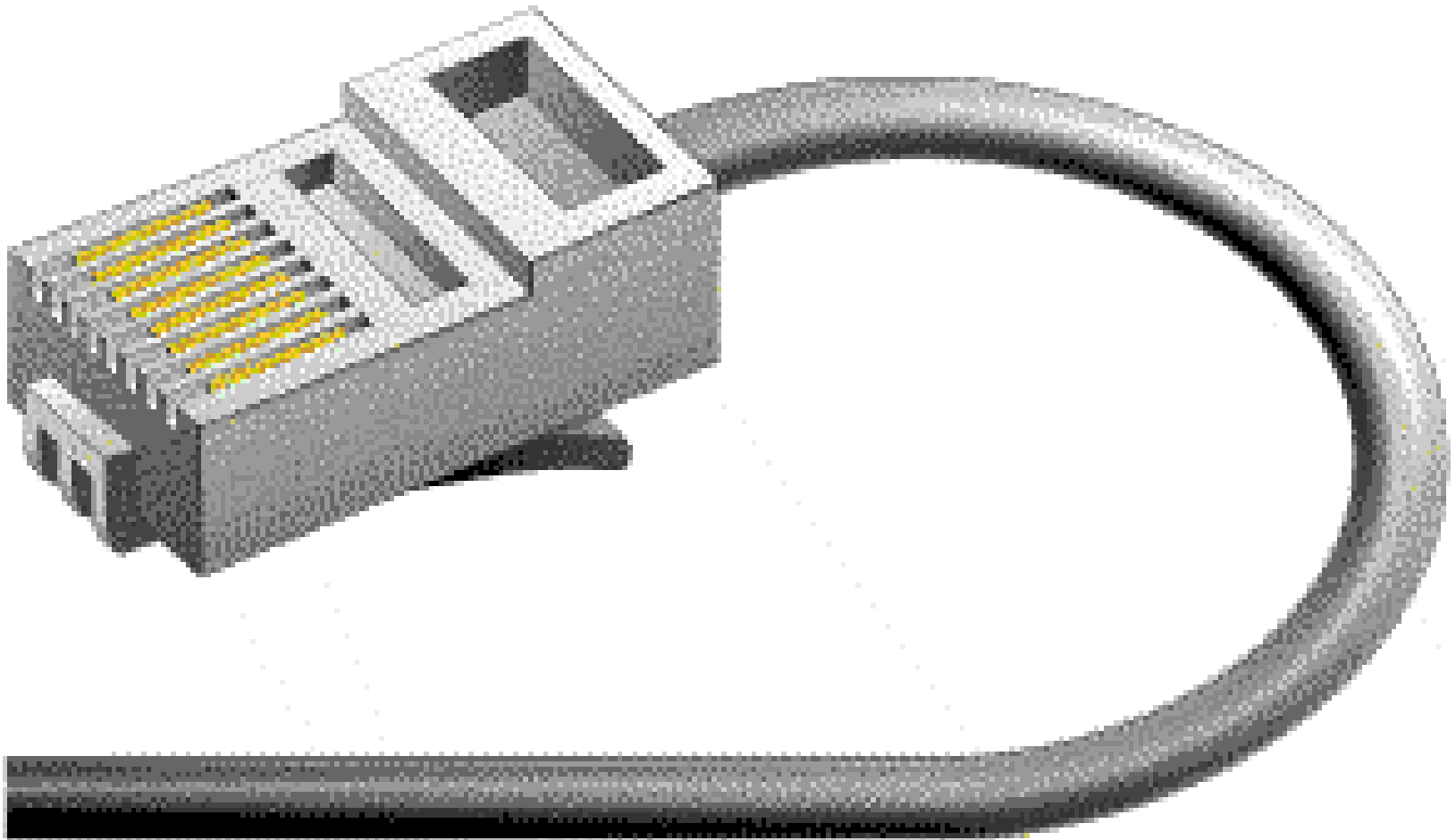
⌘ For local area networks (LAN)

- ☑ 10Mbps or 100Mbps

Unshielded Twisted Pair Connector

⌘ 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 (See figure). 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.

The RJ-45 Connector



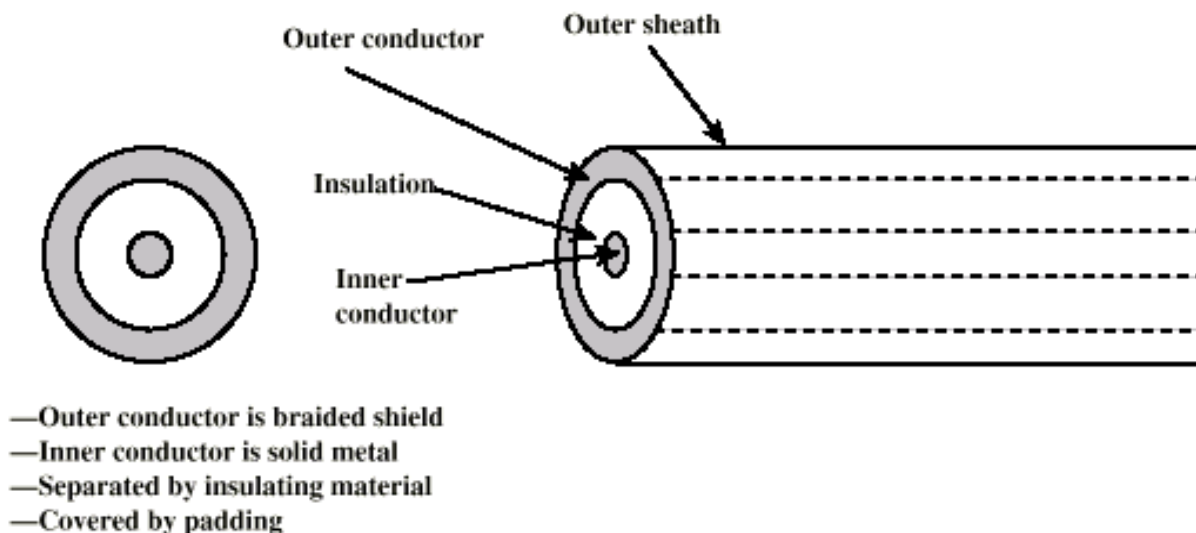
Shielded Twisted Pair (STP) Cable

- ⌘ A disadvantage of UTP is that it may be susceptible to radio and electrical frequency interference (RFI, EFI).
- ⌘ Shielded twisted pair (STP) is suitable for environments with electrical interference; however, the extra shielding can make the cables quite bulky.
- ⌘ Shielded twisted pair is often used on networks using Token Ring topology.
- ⌘ More expensive, harder to work with.



Coaxial Cable

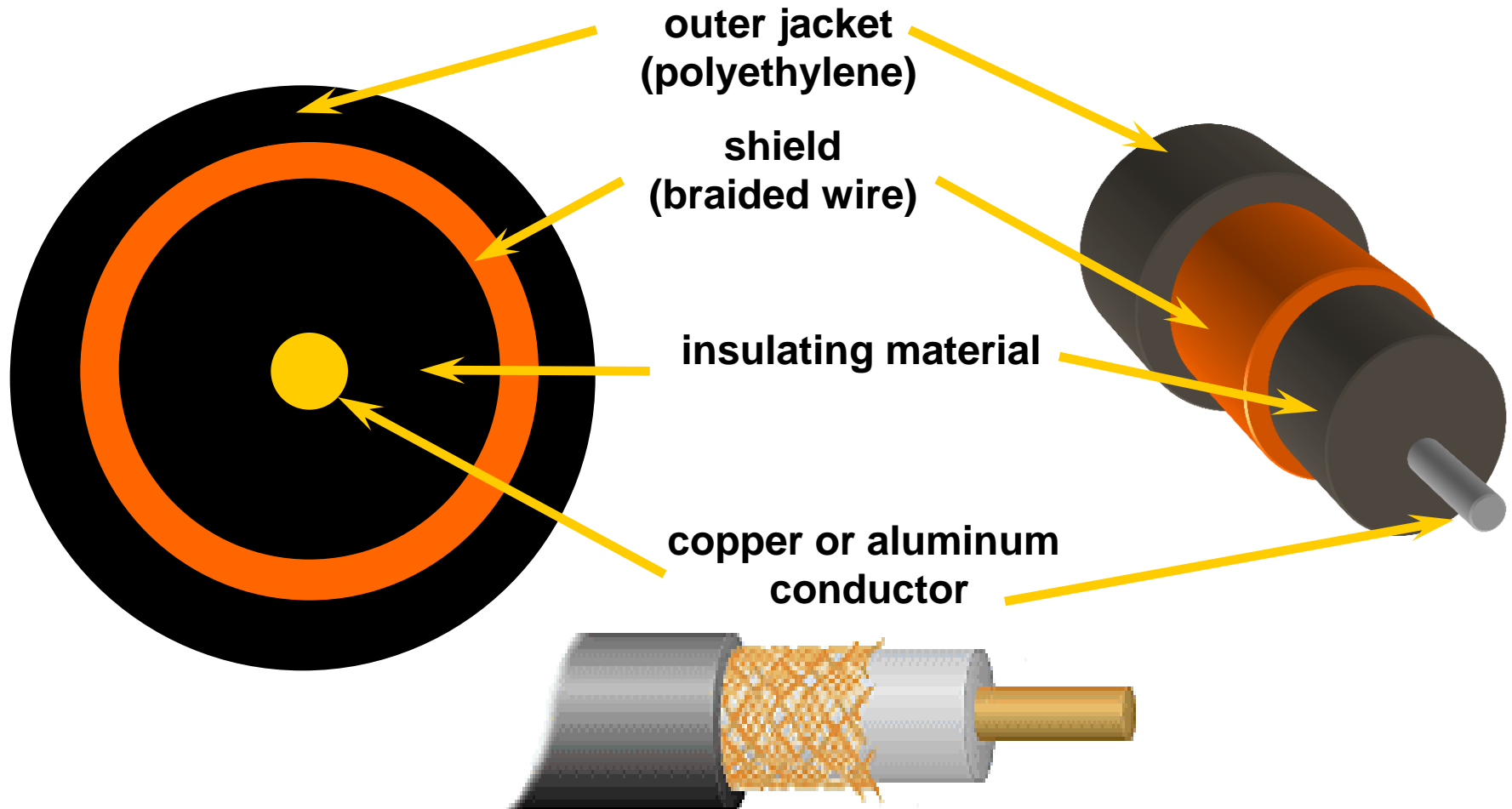
⌘ Coaxial cabling has a single copper conductor at its center. A plastic layer provides insulation between the center conductor and a braided metal shield (See figure). The metal shield helps to block any outside interference from fluorescent lights, motors, and other computers.



Coaxial Cable (or Coax)

- ⌘ Bandwidth of up to 400 MHz
- ⌘ Has an inner conductor surrounded by a braided mesh
- ⌘ Both conductors share a common center axial, hence the term “co-axial”

Coax Layers



Coax Advantages

- ⌘ Higher bandwidth

 - ☐ 400 to 600MHz

 - ☐ up to 10,800 voice conversations

- ⌘ Can be tapped easily (pros and cons)

- ⌘ Much less susceptible to interference than twisted pair

- ⌘ greater cable lengths between network devices than twisted pair cable.

Coax Disadvantages

- ⌘ High attenuation rate makes it expensive over long distance
- ⌘ Bulky - coaxial cabling is difficult to install

Coaxial Cable Applications

- ⌘ Most versatile medium
- ⌘ Television distribution
 - ☐ Ariel to TV
 - ☐ Cable TV
- ⌘ Long distance telephone transmission
 - ☐ Can carry 10,000 voice calls simultaneously
 - ☐ Being replaced by fiber optic
- ⌘ Short distance computer systems links
- ⌘ Local area networks

Thin Coax

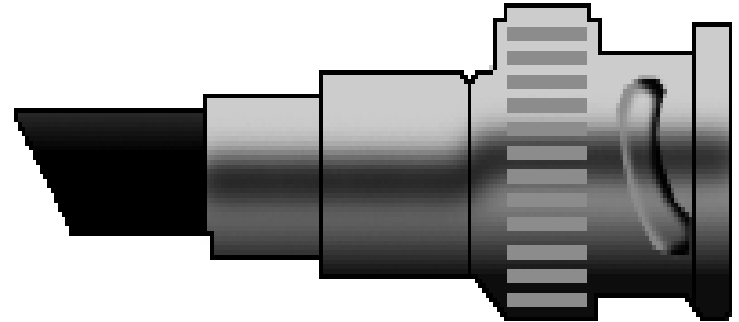
⌘ Thin coaxial cable is also referred to as thinnet. 10Base2 refers to the specifications for thin coaxial cable carrying Ethernet signals. The 2 refers to the approximate maximum segment length being 200 meters. In actual fact the maximum segment length is 185 meters. Thin coaxial cable is popular in school networks, especially linear bus networks.

Thick Coax

⌘ Thick coaxial cable is also referred to as thicknet. 10Base5 refers to the specifications for thick coaxial cable carrying Ethernet signals. The 5 refers to the maximum segment length being 500 meters. Thick coaxial cable has an extra protective plastic cover that helps keep moisture away from the center conductor. This makes thick coaxial a great choice when running longer lengths in a linear bus network. One disadvantage of thick coaxial is that it does not bend easily and is difficult to install.

Coaxial Cable Connectors

⌘ The most common type of connector used with coaxial cables is the Bayone-Neill-Concelman (BNC) connector (See figure). Different types of adapters are available for BNC connectors, including a T-connector, barrel connector, and terminator. Connectors on the cable are the weakest points in any network. To help avoid problems with your network, always use the BNC connectors that crimp, rather than screw, onto the cable.



Fiber Optic Cable

⌘ Fiber optic cabling consists of a center glass core surrounded by several layers of protective materials. It transmits light rather than electronic signals, eliminating the problem of electrical interference. This makes it ideal for certain environments that contain a large amount of electrical interference. It has also made it the standard for connecting networks between buildings, due to its immunity to the effects of moisture and lighting.

Fiber Optic Cable

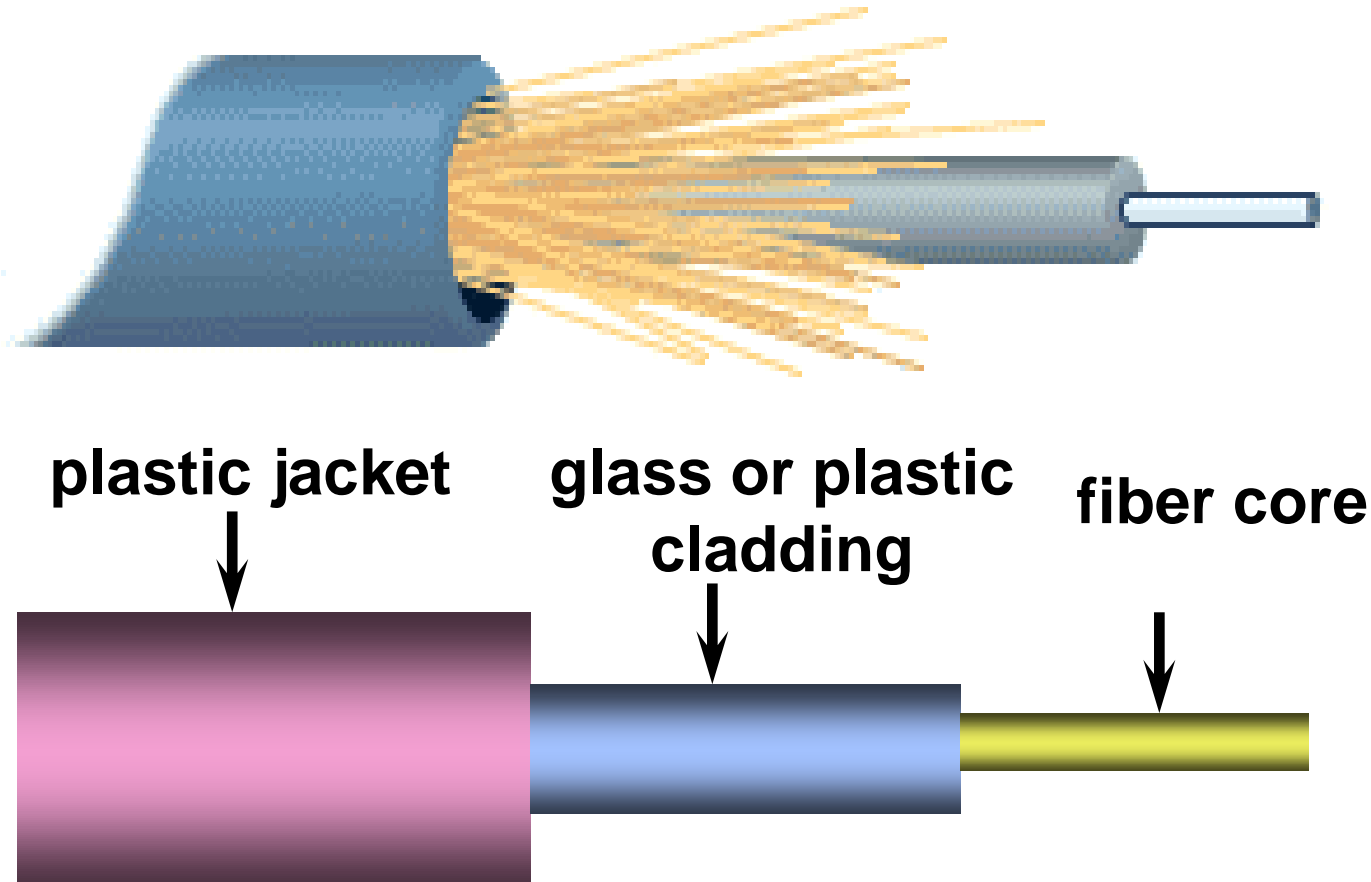
⌘ Fiber optic cable has the ability to transmit signals over much longer distances than coaxial and twisted pair. It also has the capability to carry information at vastly greater speeds. This capacity broadens communication possibilities to include services such as video conferencing and interactive services. The cost of fiber optic cabling is comparable to copper cabling; however, it is more difficult to install and modify. 10BaseF refers to the specifications for fiber optic cable carrying Ethernet signals.

Fiber Optic Cable

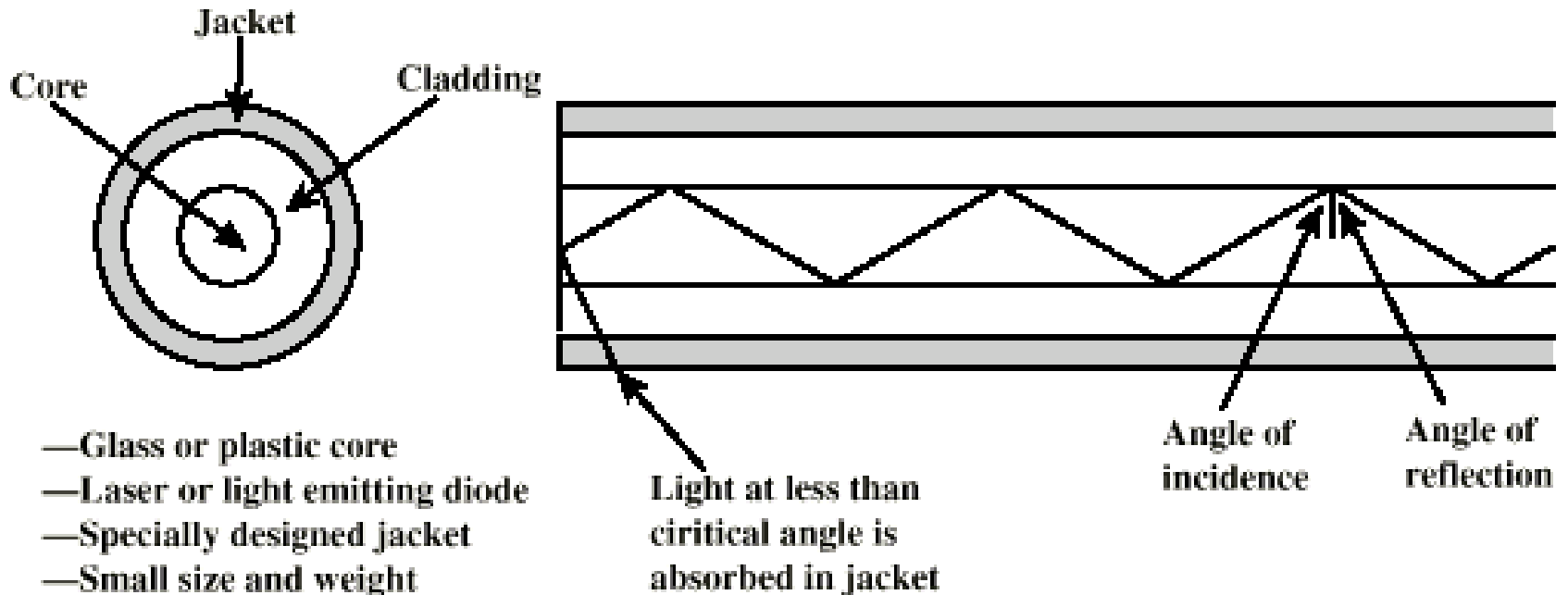
- ⌘ relatively new transmission medium used by telephone companies in place of long-distance trunk lines
- ⌘ also used by private companies in implementing local data communications networks
- ⌘ require a light source with injection laser diode (ILD) or light-emitting diodes (LED)

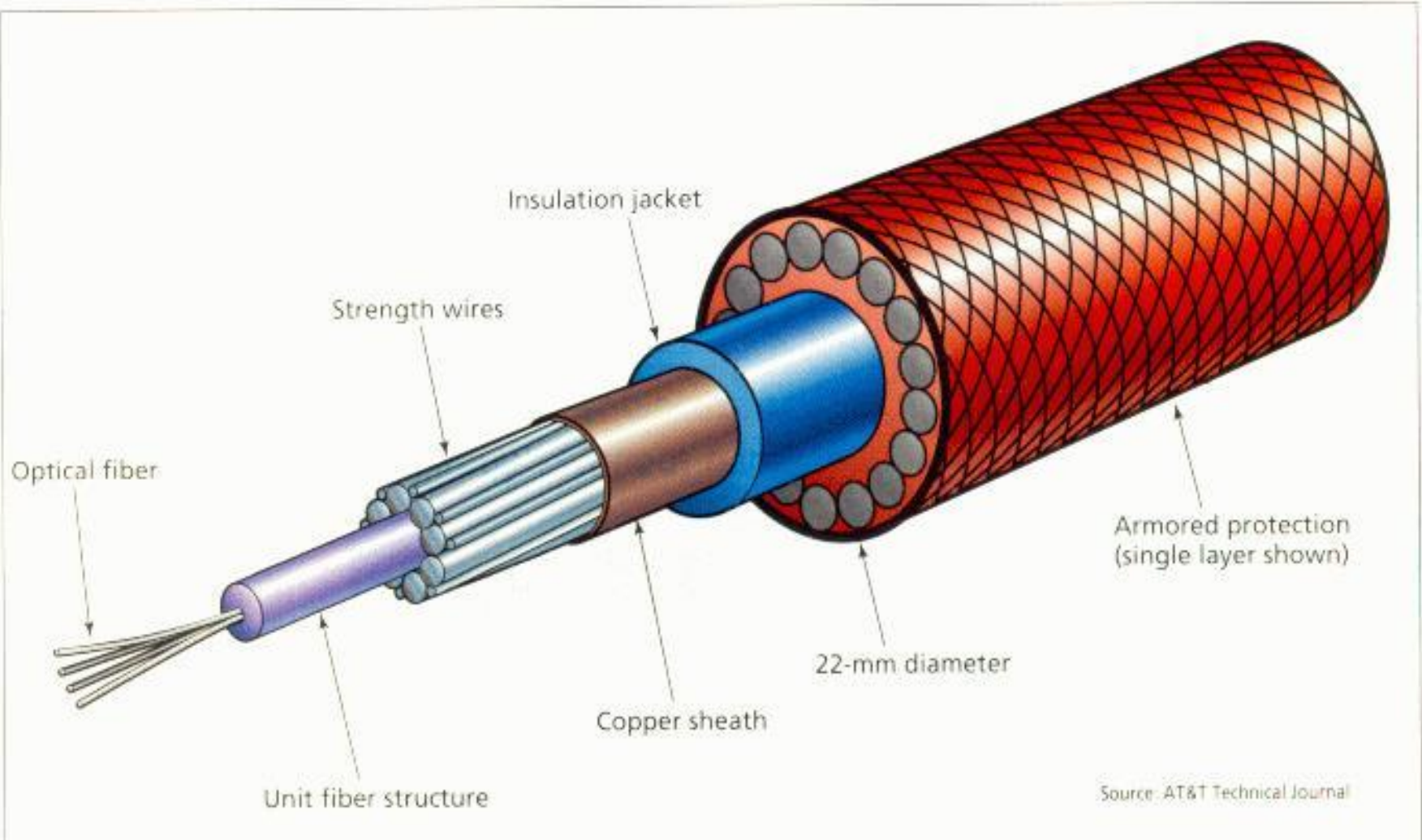
Fiber Optic Layers

⌘ consists of three concentric sections



Optical Fiber





Facts About Fiber Optic Cables

⌘ Facts about fiber optic cables:

- ☑ Outer insulating jacket is made of Teflon or PVC.
- ☑ Kevlar fiber helps to strengthen the cable and prevent breakage.
- ☑ A plastic coating is used to cushion the fiber center.
- ☑ Center (core) is made of glass or plastic fibers.

Optical Fiber - Transmission Characteristics

- ⌘ Act as wave guide for 10^{14} to 10^{15} Hz
 - ☑ Portions of infrared and visible spectrum
- ⌘ Light Emitting Diode (LED)
 - ☑ Cheaper
 - ☑ Wider operating temp range
 - ☑ Last longer
- ⌘ Injection Laser Diode (ILD)
 - ☑ More efficient
 - ☑ Greater data rate
- ⌘ Wavelength Division Multiplexing

Fiber Optic Types

⌘ multimode step-index fiber

☒ the reflective walls of the fiber move the light pulses to the receiver

⌘ multimode graded-index fiber

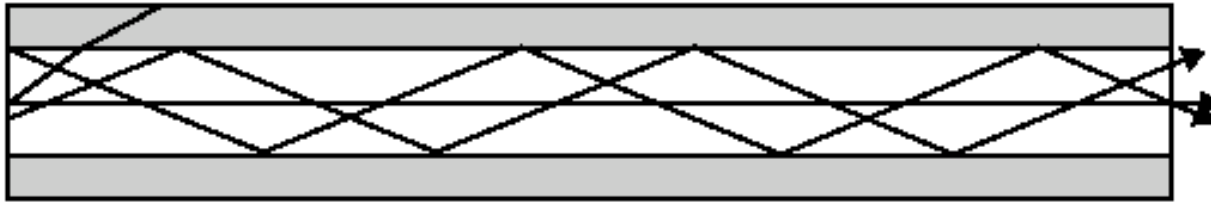
☒ acts to refract the light toward the center of the fiber by variations in the density

⌘ single mode fiber

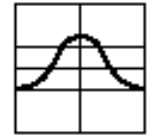
☒ the light is guided down the center of an extremely narrow core

Optical Fiber Transmission Modes

Input pulse

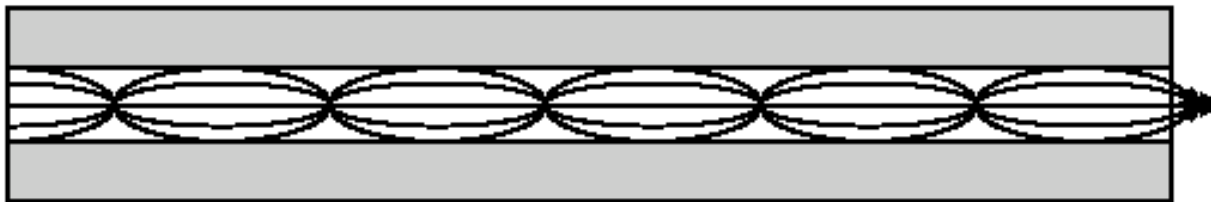


Output pulse

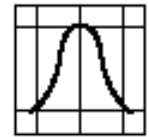


(a) Step-index multimode

Input pulse

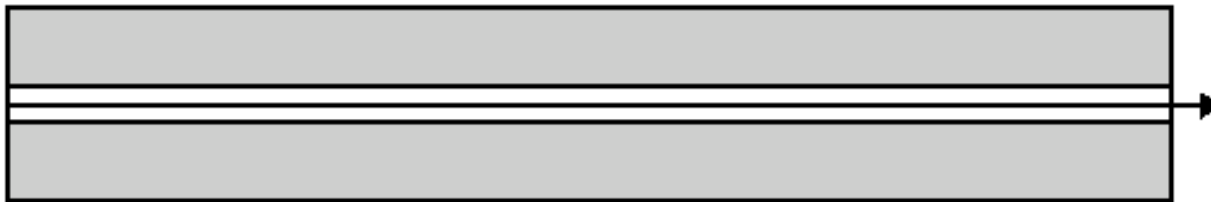


Output pulse

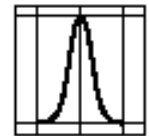


(b) Graded-index multimode

Input pulse

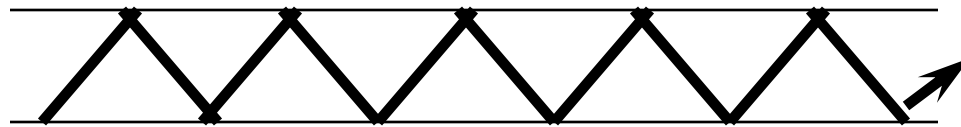


Output pulse

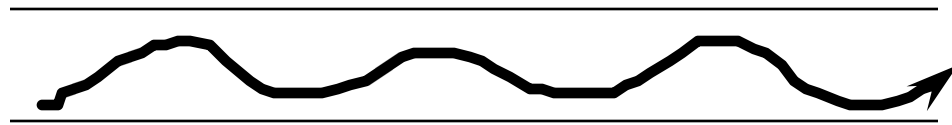


(c) Single mode

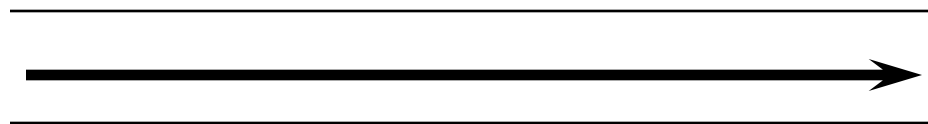
Fiber Optic Signals



**fiber optic multimode
step-index**



**fiber optic multimode
graded-index**



fiber optic single mode

Fiber Optic Advantages

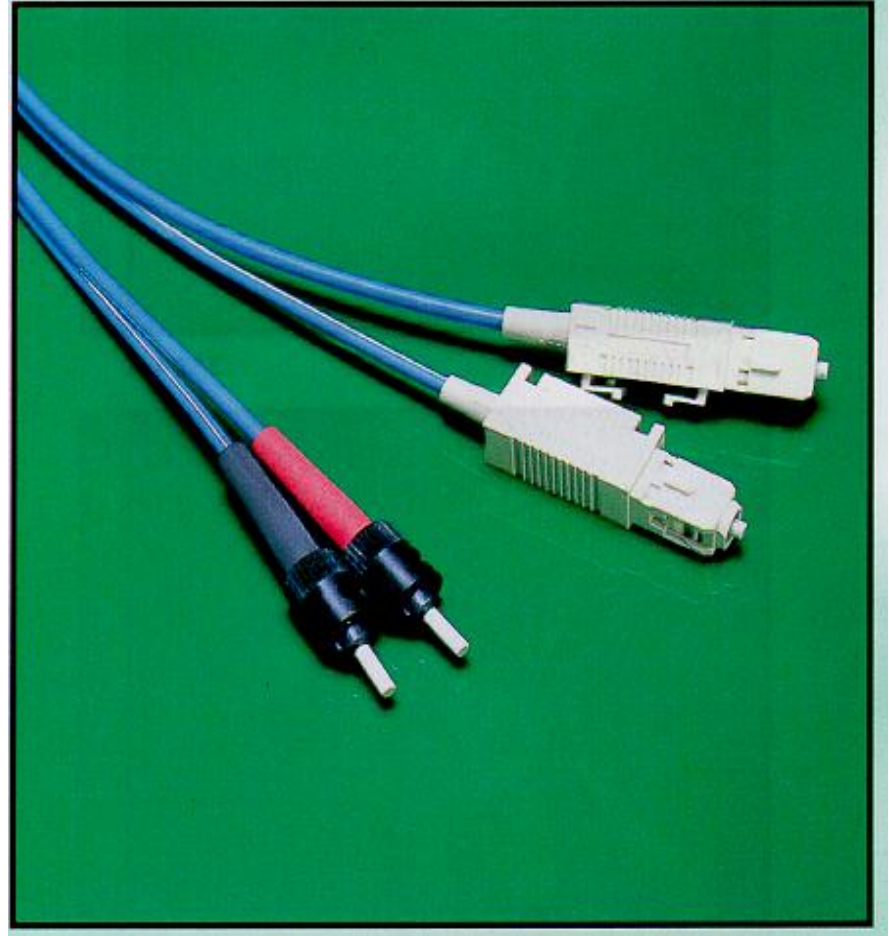
- ⌘ Greater capacity - data rates of hundreds of Gbps
- ⌘ Smaller size and lighter weight
- ⌘ Lower attenuation
- ⌘ Electromagnetic isolation - immunity to environmental interference and highly secure due to tap difficulty and lack of signal radiation
- ⌘ Greater repeater spacing - 10s of km at least

Fiber Optic Disadvantages

- ⌘ Expensive over short distance
- ⌘ Requires highly skilled installers
- ⌘ Adding additional nodes is difficult

Fiber Optic Connector

⌘ The most common connector used with fiber optic cable is an ST connector. It is barrel shaped, similar to a BNC connector. A newer connector, the SC, is becoming more popular. It has a squared face and is easier to connect in a confined space.



Wireless (Unguided Media)

⌘ Transmission

- ☑ Transmission and reception are achieved by means of an antenna

⌘ Directional

- ☑ transmitting antenna puts out focused beam
- ☑ transmitter and receiver must be aligned

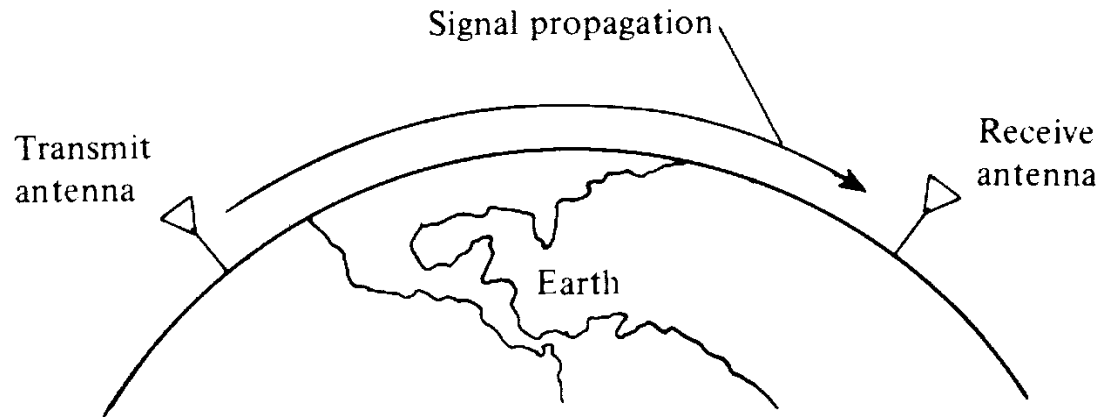
⌘ Omnidirectional

- ☑ signal spreads out in all directions
- ☑ can be received by many antennas

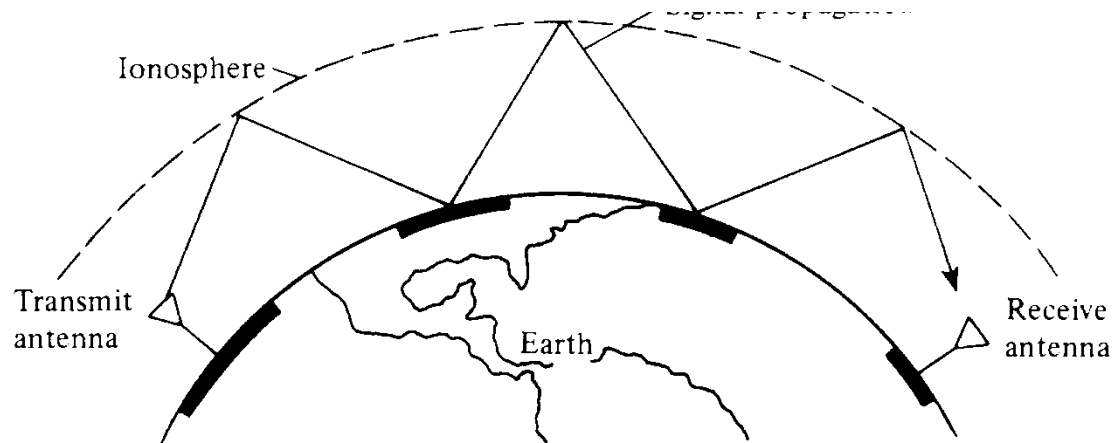
Wireless (Unguided Media) Frequencies

- ⌘ Three general ranges of frequencies
- ⌘ 2GHz to 40GHz microwave frequencies
 - ☑ Microwave
 - ☑ Highly directional
 - ☑ Point to point
 - ☑ Satellite
- ⌘ 30MHz to 1GHz
 - ☑ Omnidirectional
 - ☑ Broadcast radio
- ⌘ 3×10^{11} to 2×10^{14}
 - ☑ Infrared

Propagation of Radio Frequencies

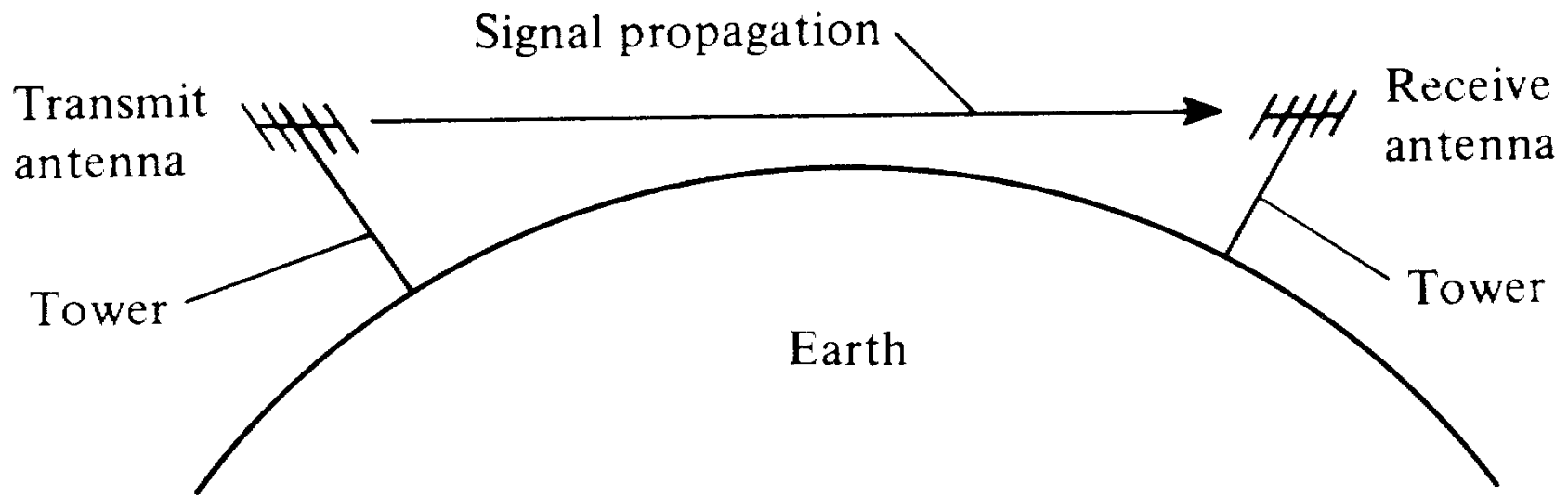


(a) Ground-Wave Propagation (Below 2 MHz)



(b) Sky-Wave Propagation (2 to 30 MHz)

Propagation of Radio Frequencies (continued)



(c) Line-of-Sight (LOS) Propagation (Above 30 MHz)

FIGURE 1-2 Propagation of radio frequencies.

Terrestrial Microwave Transmission

- ⌘ Uses the radio frequency spectrum, commonly from 2 to 40 GHz
- ⌘ Transmitter is a parabolic dish, mounted as high as possible
- ⌘ Used by common carriers as well as by private networks
- ⌘ Requires unobstructed line of sight between source and receiver
- ⌘ Curvature of the earth requires stations (called repeaters) to be ~30 miles apart

Terrestrial Microwave Transmission

⌘ Distance between antennas:

⌘ $d = 7.14 (Kh)^{1/2}$, d = distance in km, h is antenna height in meters, K = constant = $4/3$

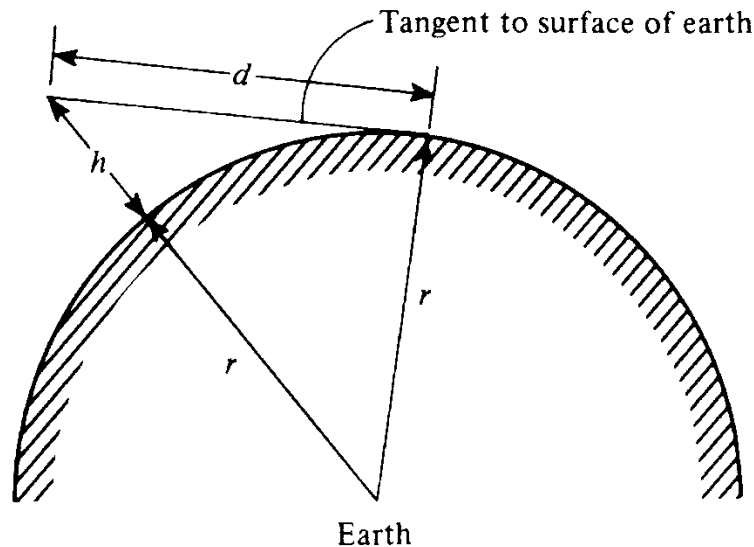


FIGURE 1-3 Calculation of distance to horizon.

Terrestrial Microwave Applications

- ⌘ Long-haul telecommunications service for both voice and television transmission
- ⌘ Short point-to-point links between buildings for closed-circuit TV or a data link between LANs

Terrestrial Microwave Communications

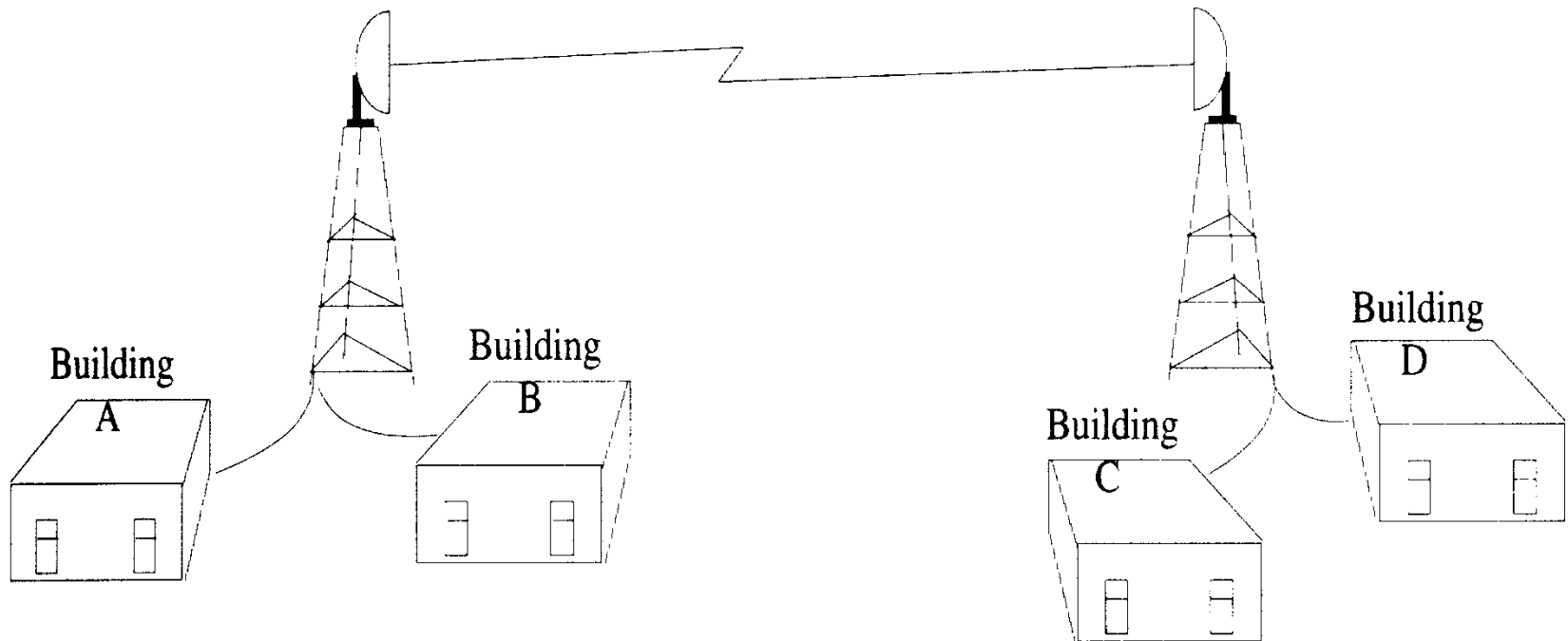


Figure 1.13 Conceptual view of microwave communication.

Microwave Transmission Advantages

- ⌘ Co cabling needed between sites
- ⌘ Wide bandwidth
- ⌘ Multi-channel transmissions
- ⌘ Used for long haul or high capacity short haul
- ⌘ Requires fewer amplifiers and repeaters

Microwave Transmission Disadvantages

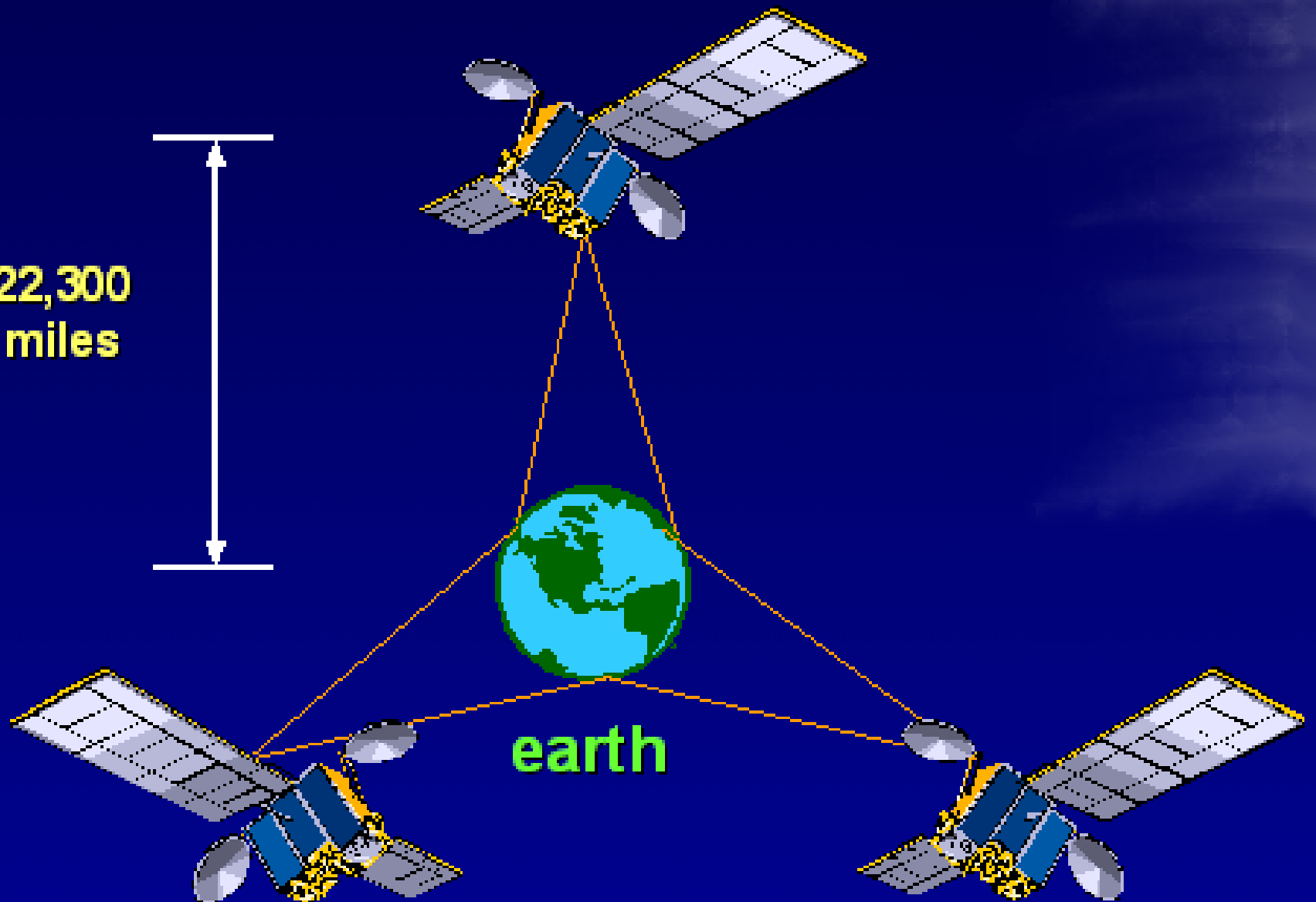
- ⌘ Line of sight requirement
- ⌘ Expensive towers and repeaters
- ⌘ Subject to interference such as passing airplanes and rain
- ⌘ Frequency bands are regulated

Satellite

Microwave Transmission

- ⌘ A microwave relay station in space
- ⌘ Can relay signals over long distances
- ⌘ Geostationary satellites
 - ☐ remain above the equator at a height of 22,300 miles (geosynchronous orbit)
 - ☐ travel around the earth in exactly the time the earth takes to rotate

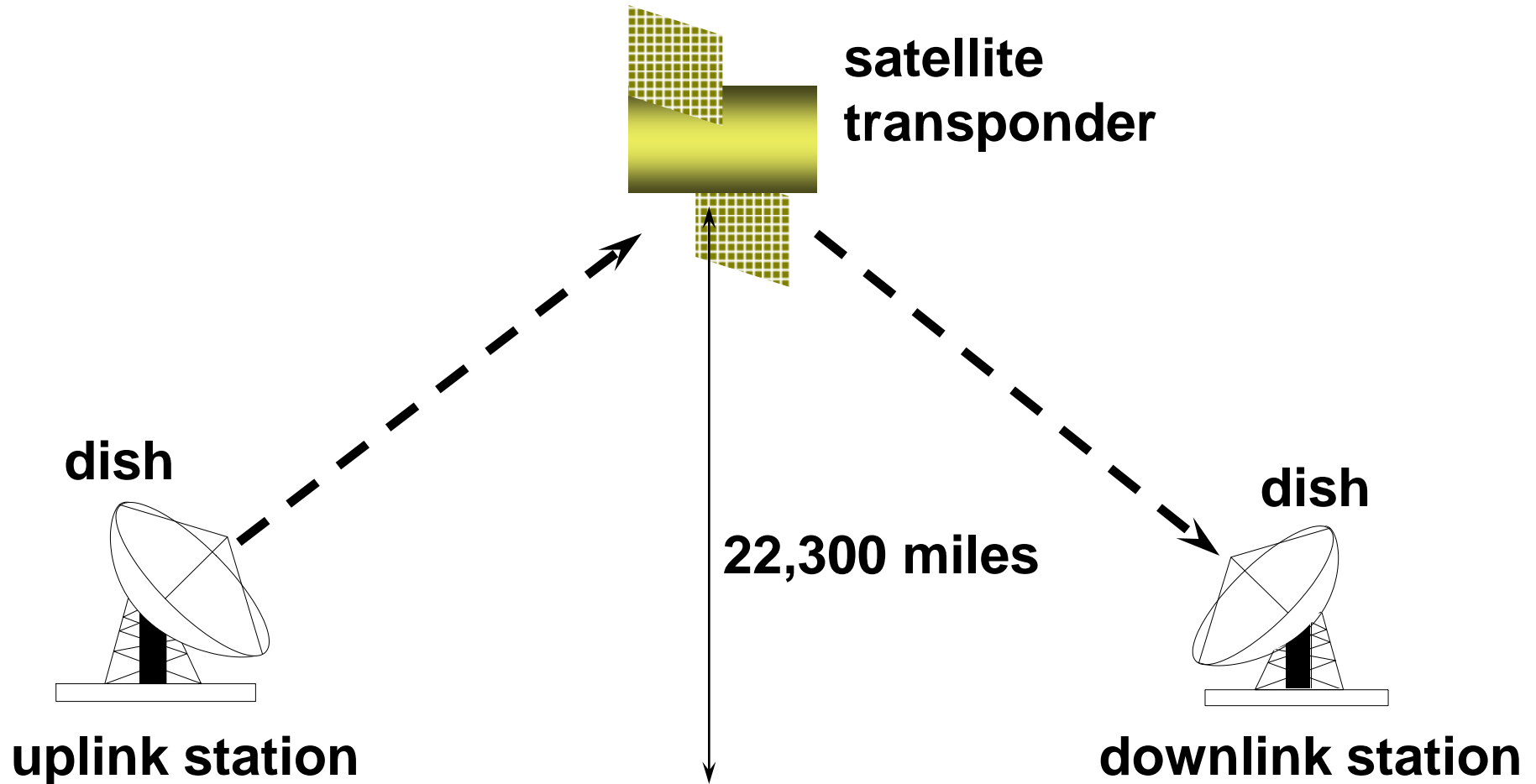
22,300
miles



Satellite Transmission Links

- ⌘ Earth stations communicate by sending signals to the satellite on an uplink
- ⌘ The satellite then repeats those signals on a downlink
- ⌘ The broadcast nature of the downlink makes it attractive for services such as the distribution of television programming

Satellite Transmission Process



Satellite Transmission Applications

⌘ Television distribution

- ☐ a network provides programming from a central location

- ☐ direct broadcast satellite (DBS)

⌘ Long-distance telephone transmission

- ☐ high-usage international trunks

⌘ Private business networks

Principal Satellite Transmission Bands

⌘ C band: 4(downlink) - 6(uplink) GHz

☐ the first to be designated

⌘ Ku band: 12(downlink) - 14(uplink) GHz

☐ rain interference is the major problem

⌘ Ka band: 19(downlink) - 29(uplink) GHz

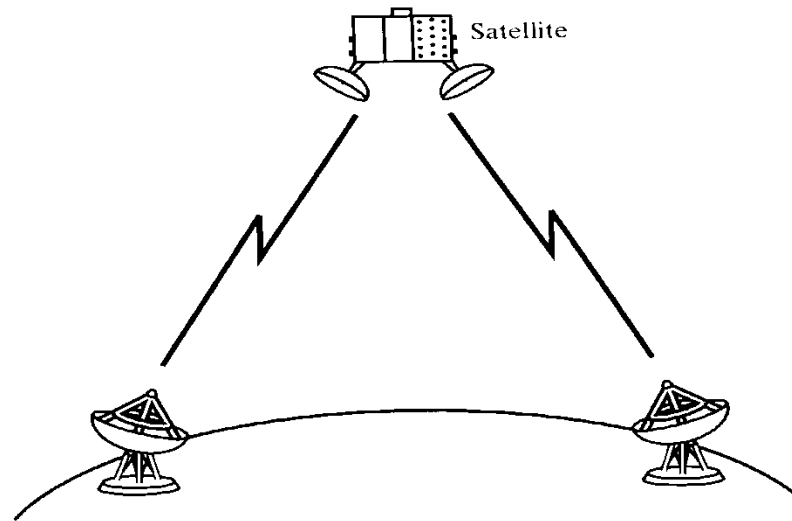
☐ equipment needed to use the band is still very expensive

Satellite Advantages

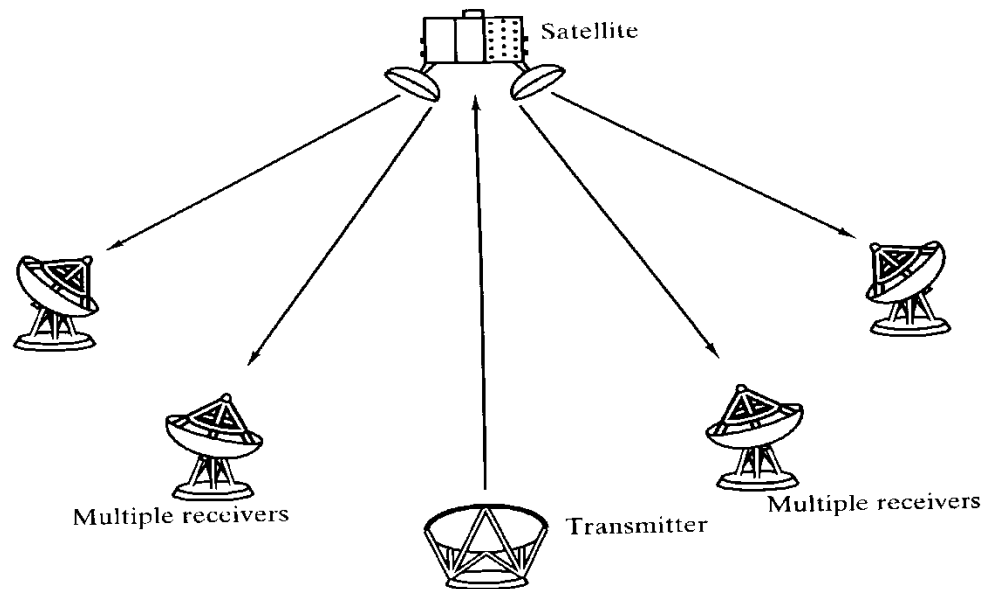
- ⌘ Can reach a large geographical area
- ⌘ High bandwidth
- ⌘ Cheaper over long distances

Satellite Disadvantages

- ⌘ High initial cost
- ⌘ Susceptible to noise and interference
- ⌘ Propagation delay (0.25 sec) - requires sophisticated flow control



(a) Point-to-point link via satellite microwave



(b) Broadcast link via satellite microwave

FIGURE 4.16 Satellite Communications Configurations.

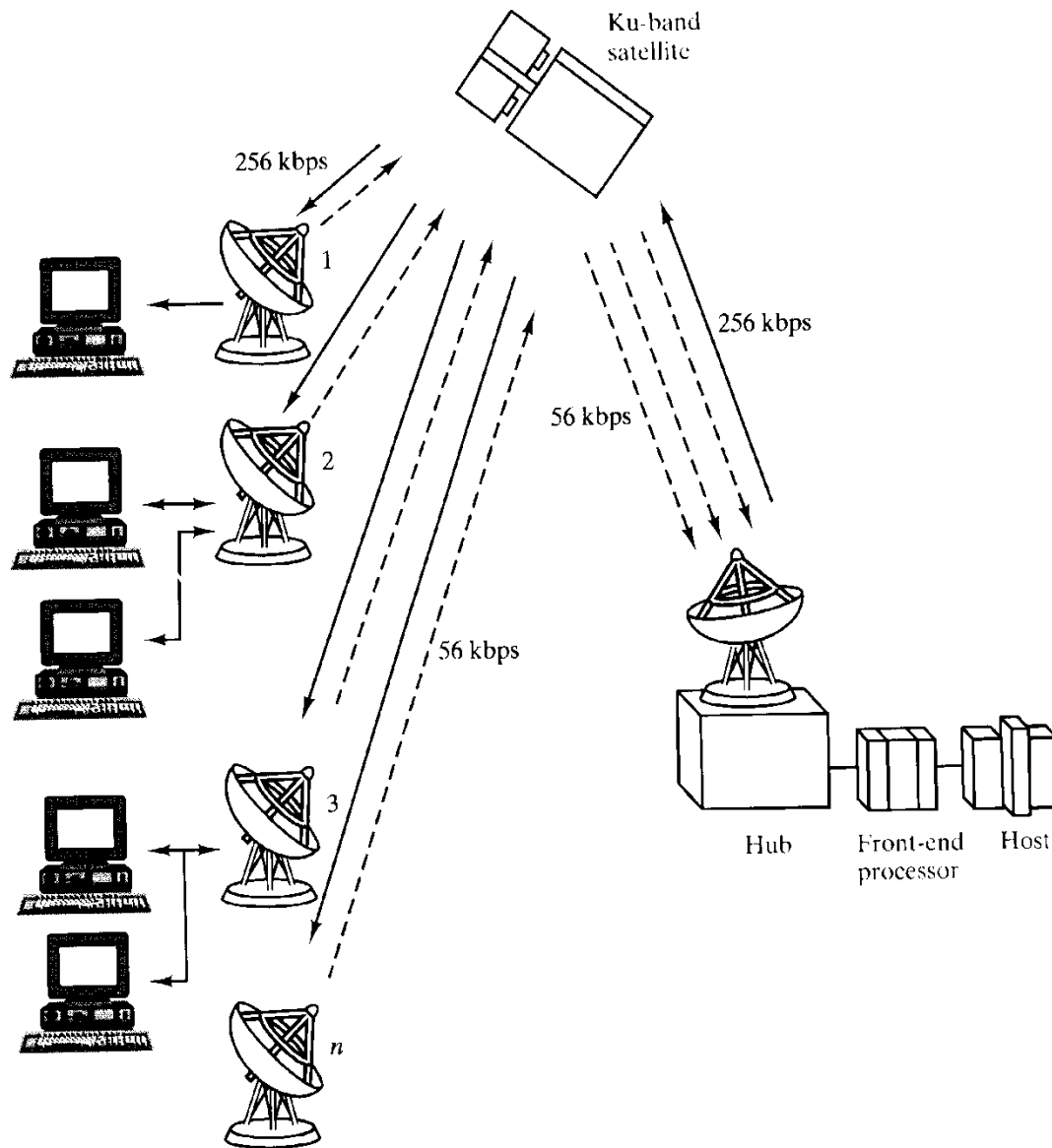


FIGURE 4.17 VSAT Configuration.

Infrared

- ⌘ Transceivers operate with line of sight or reflection from light-colored surface
- ⌘ Modulate noncoherent infrared light
- ⌘ e.g. TV remote control, IRD port
- ⌘ Advantages
 - ☑ Does not penetrate walls - enhanced security
 - ☑ No licensing of frequencies
- ⌘ Disadvantages
 - ☑ Operate on limited distances

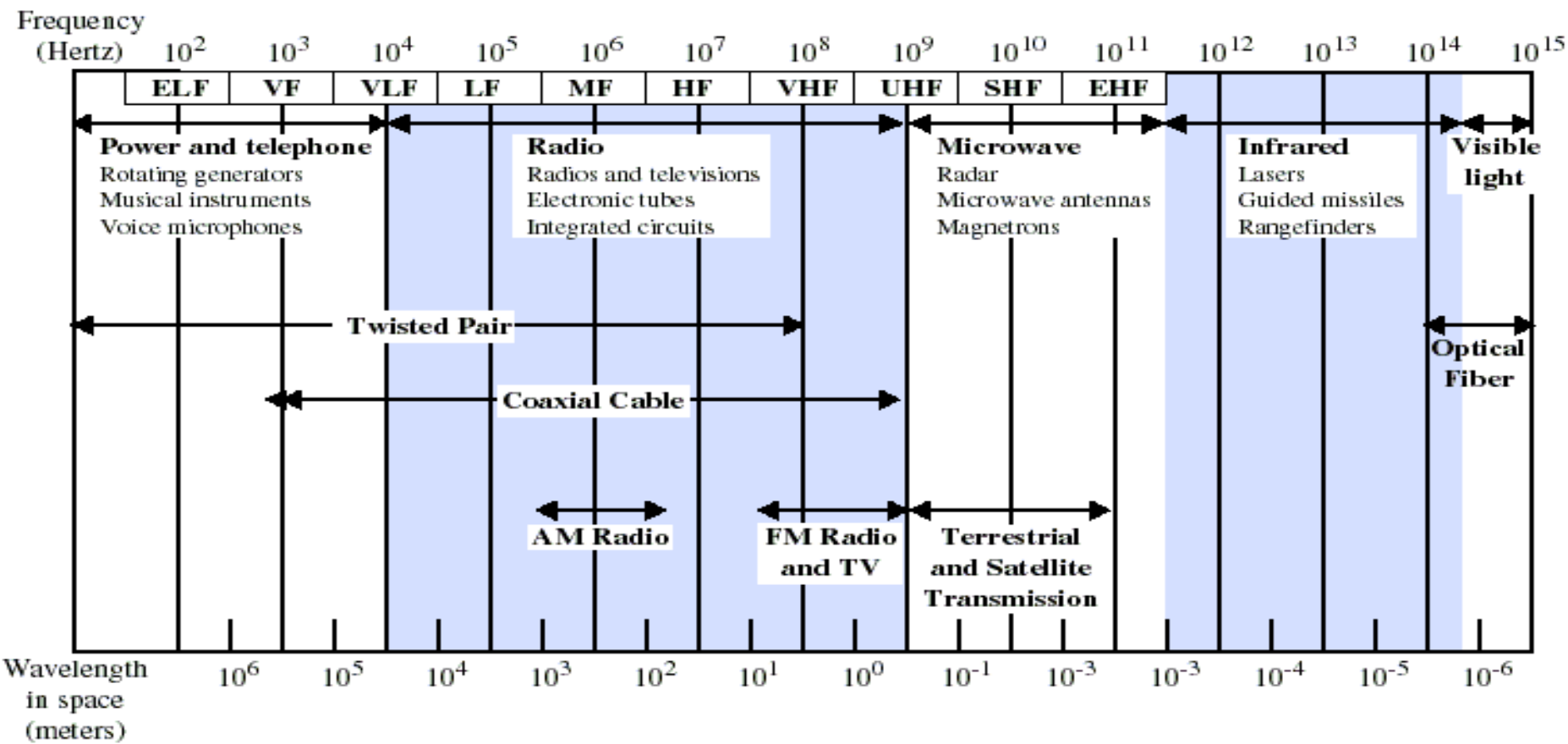


Figure 4.14 Electromagnetic Spectrum for Telecommunications

Summary

	Twisted pair	coaxial	optical fiber	microwave	satellite
Data rate	1-100 Mbps	10 Mbps	400-500 Mbps	200-300 Mbps	1-2 Mbps
interference	electrical	electrical	immune	solid object	atmospheric condition
distance	up to 1 mile (1-2 Mbps for 1 mile 10 Mbps for 100 m 2.4 kbps for 10 miles)	2-3 miles	20-30 miles	20-30 miles	