

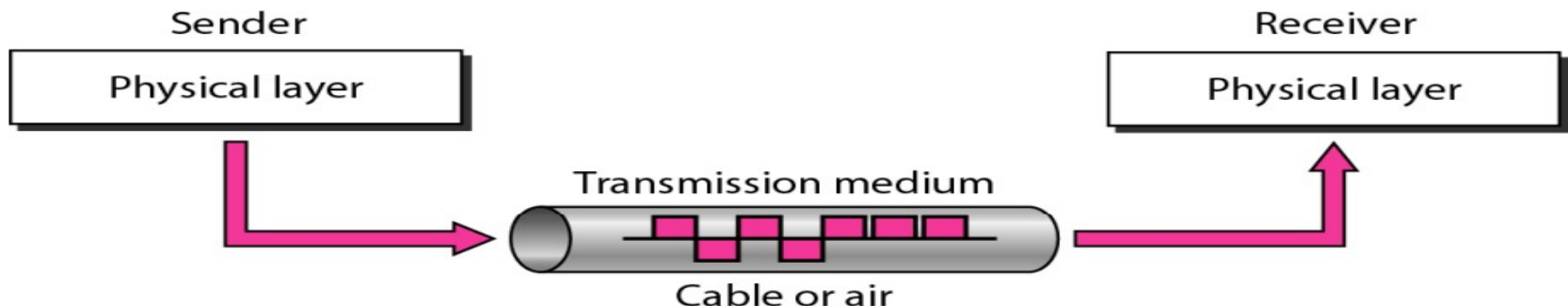
Chapter 3-5

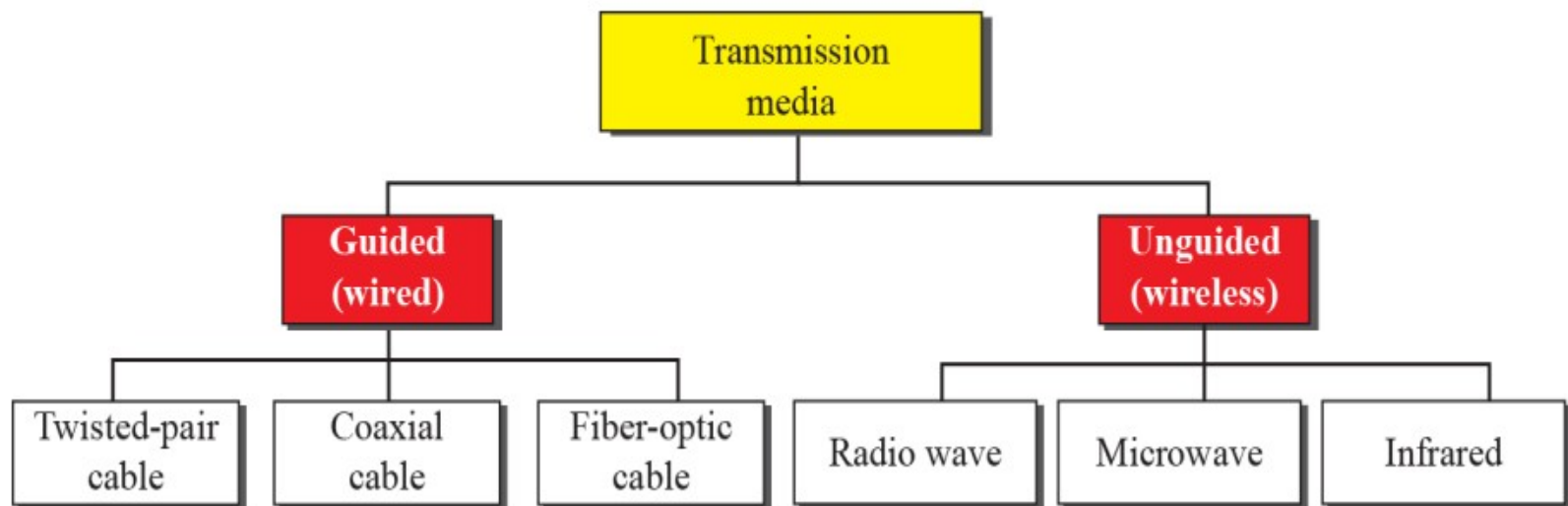
Transmission Media

- **Learning Objectives**
 - Outline the differences between Category 1, 2, 3, 4, 5, 5e, 6, and 7 twisted pair wire.
 - Outline the characteristics of coaxial cable including the advantages and disadvantages.
 - Outline the characteristics of fiber optic cable including the advantages and disadvantages.
 - Outline the characteristics of terrestrial microwave systems including the advantages and disadvantages.
 - Outline the characteristics of satellite microwave systems including the advantages and disadvantages as well as the differences between low earth orbit, middle earth orbit, geosynchronous earth orbit, and highly elliptical earth orbit satellites.
 - Describe the basics of wireless radio, including AMPS, D-AMPS, PCS systems, and third generation wireless systems.
 - Outline the characteristics of pager systems including the advantages and disadvantages.
 - Outline the characteristics of short-range transmissions, including Bluetooth
 - Describe the characteristics, advantages, and disadvantages of wireless application protocol
 - Outline the characteristics of broadband wireless systems including the advantages and disadvantages.
 - Apply the media selection criteria of cost, speed, distance and expandability, environment, and security to various media in a particular application.

Transmission media

- Is a pathway that carries the information from sender to receiver.
- Are located below the physical layer
- Are directly controlled by the physical layer.
- We use different types of cables or waves to transmit data.





Guided/Wired/Bound Transmission Media

- Are the cables that are tangible or have physical existence and are limited by the physical geography.
- provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable
- A signal traveling along any of these media is directed and contained by the physical limits of the medium.

Transmission Characteristics of Guided Media

	Frequency Range	Typical Attenuatio	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μ s/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μ s/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μ s/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 μ s/km	40 km

Twisted-pair cable(TP)

- Consists of two conductors (normally copper), each with its own plastic insulation, twisted together
- 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.
- 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.
- The two lines are twisted to minimize interference (noise) and crosstalk.

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



(a) Twisted pair

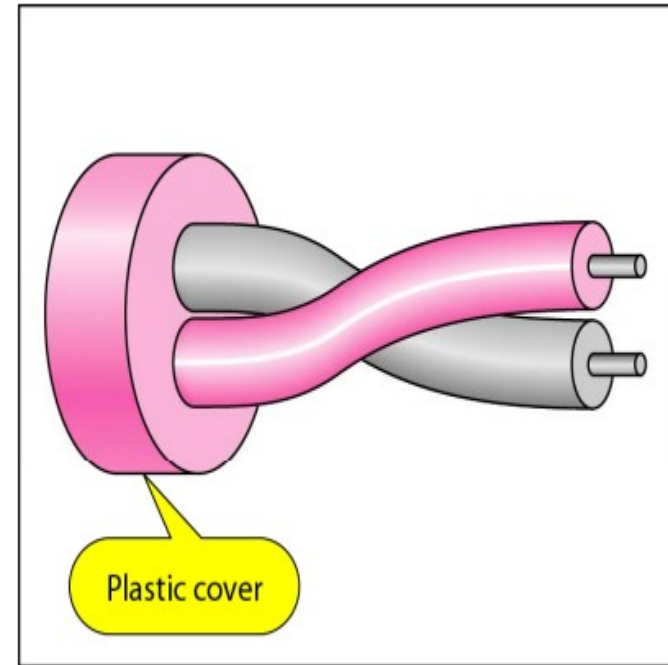


TP - Transmission Characteristics

- Analog
 - needs **amplifiers** every 5km to 6km
- Digital
 - can use either analog or digital signals
 - needs a **repeater** every 2-3km
- limited distance
- limited bandwidth (1MHz)
- limited data rate (100MHz)
- susceptible to interference and noise

Unshielded Twisted Pair (UTP)

- ordinary telephone wire
- cheapest
- easiest to install
- suffers from external EM interference



a. UTP

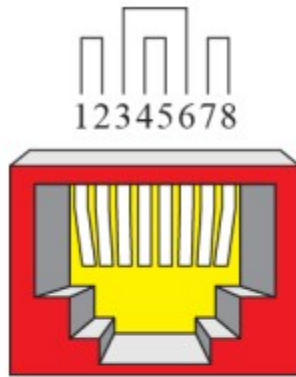
Categories of unshielded twisted-pair cables

<i>Category</i>	<i>Specification</i>	<i>Data Rate (Mbps)</i>	<i>Use</i>
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
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 SSTP (shielded screen twisted-pair). 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

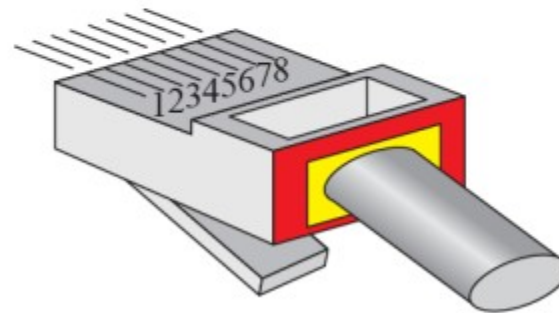
UTP Categories - Copper Cable

UTP Category	Data Rate	Max. Length	Cable Type	Application
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

UTP connector



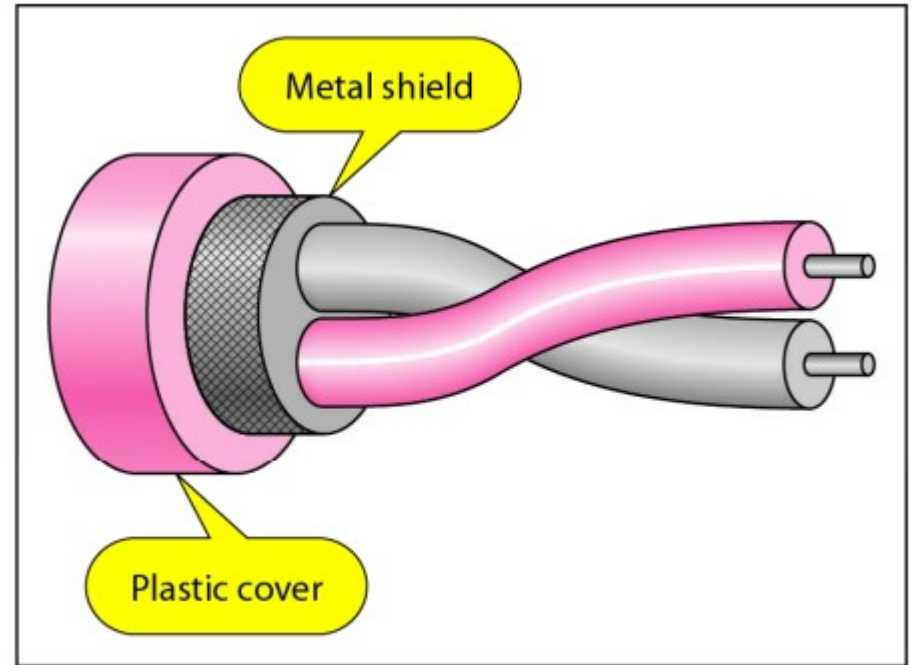
RJ-45 Female



RJ-45 Male

Shielded Twisted Pair (STP)

- metal braid or sheathing that reduces interference
- more expensive
- harder to handle (thick, heavy)
- in a variety of categories - see EIA-568



b. STP

- ***Applications***

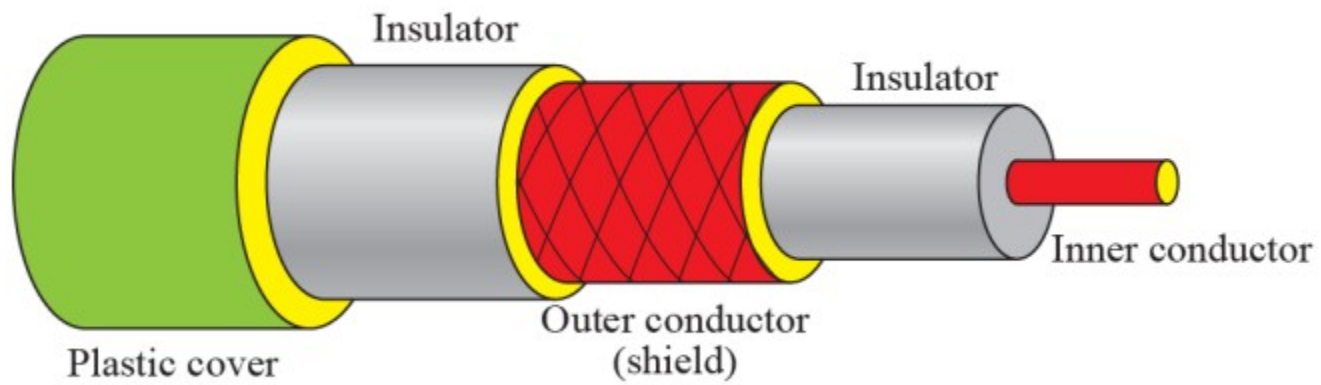
Twisted-pair cables are used in telephone lines to provide voice and data channels.

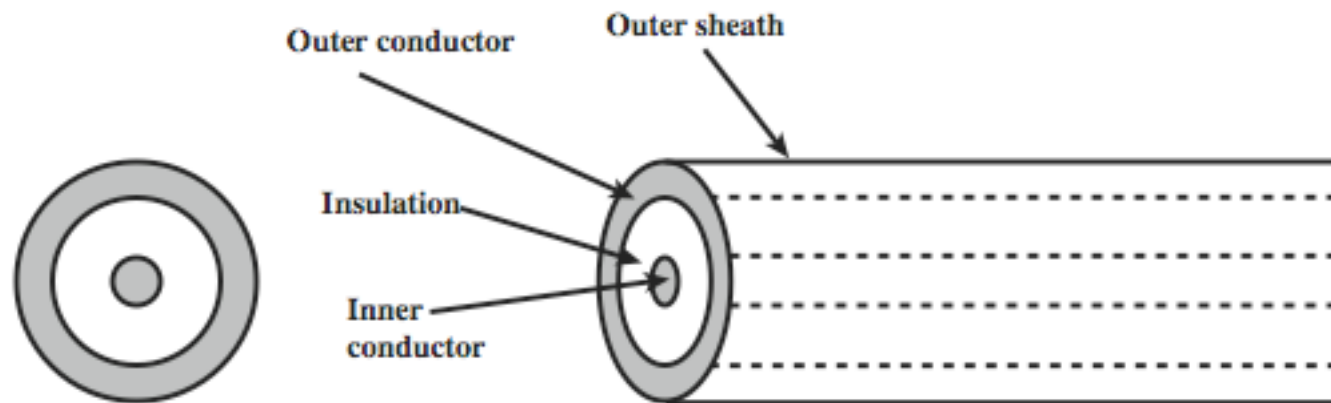
- The local loop-the line that connects subscribers to the central telephone office-commonly consists of unshielded twisted-pair cables.
- The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted pair cables.
- Local-area networks, such as 100Base-T and 100Base-T, also use twisted-pair cables.

Coaxial Cable(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, braid, or a combination of the two.
- The outer metallic wrapping serves both as a shield against noise 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

The outer shield protects the inner conductor from outside electrical signals. The distance between the outer conductor (shield) and inner conductor plus the type of material used for insulating the inner conductor determine the cable properties or impedance.





- Outer conductor is braided shield
- Inner conductor is solid metal
- Separated by insulating material
- Covered by padding

(b) Coaxial cable



Coaxial Cable - Transmission Characteristics

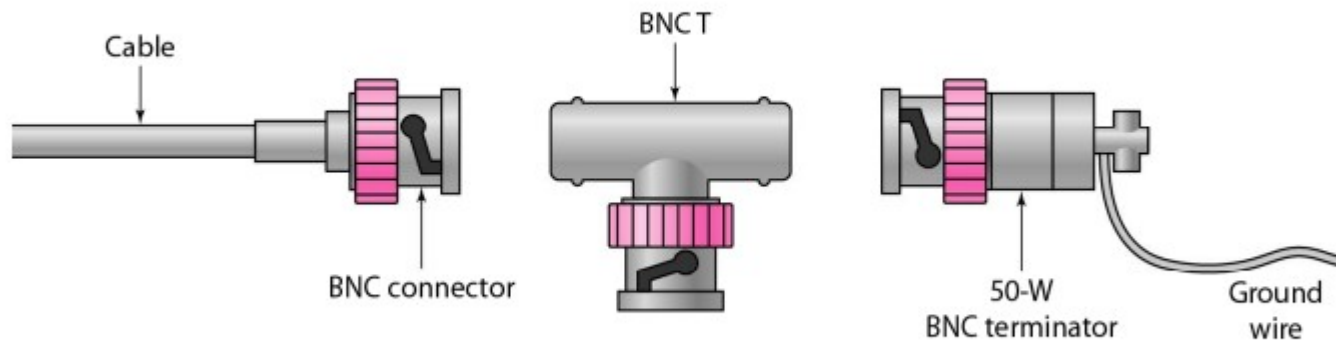
- Superior frequency characteristics to TP
- Performance limited by attenuation & noise
- Analog signals
 - amplifiers every few km
 - closer if higher frequency
 - up to 500MHz
- Digital signals
 - repeater every 1km
 - closer for higher data rates

- There are two major coaxial cable technologies, depending on the type of signal each carries: **baseband** or **broadband**.
- Coaxial cable also comes in two primary physical types: **thin coaxial cable** and **thick coaxial cable**.

Categories of coaxial cables

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

BNC connectors



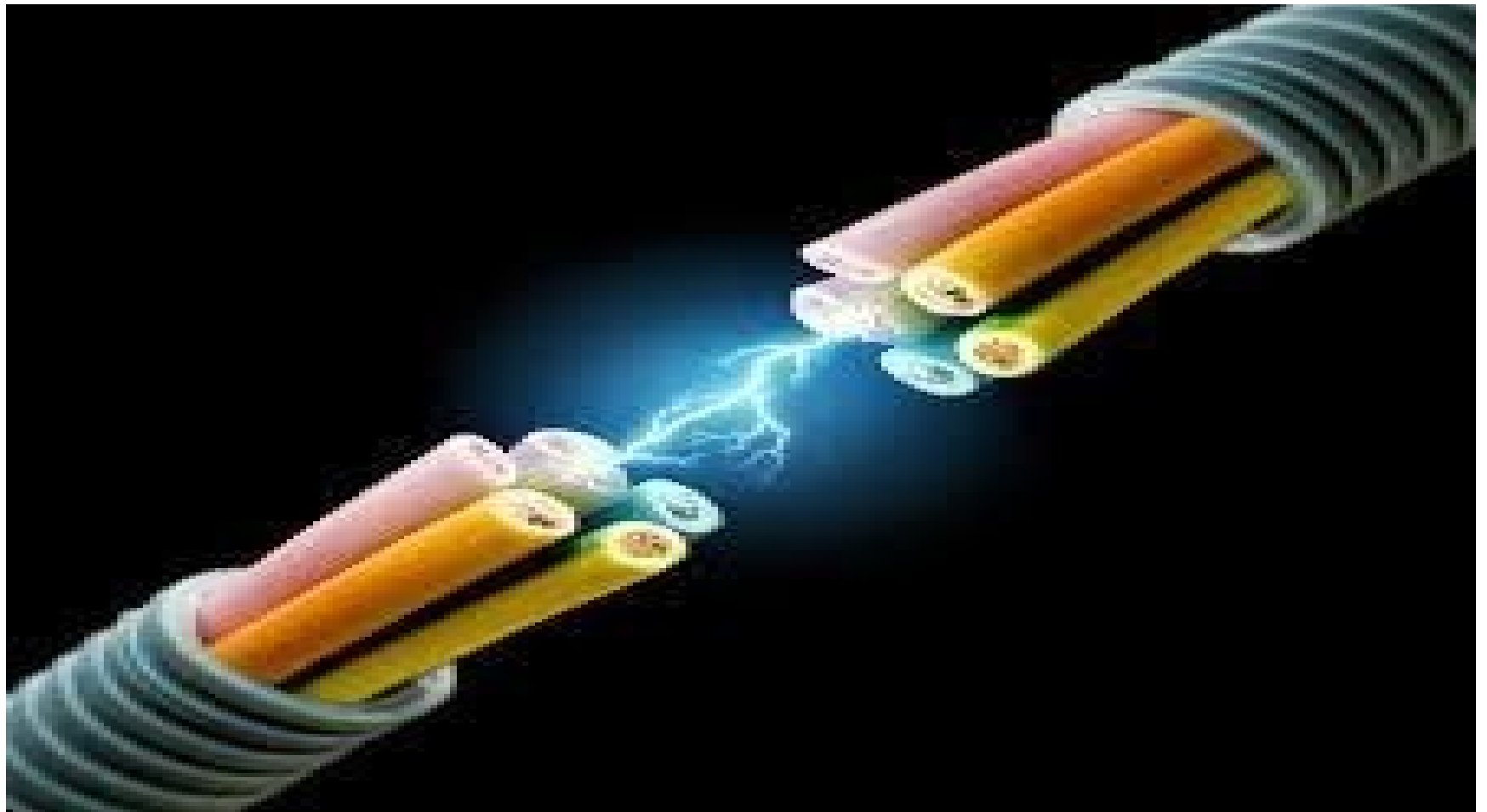
Applications

- 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. Because of its high bandwidth, and consequently high data rate, coaxial cable was chosen for digital transmission in early Ethernet LANs.

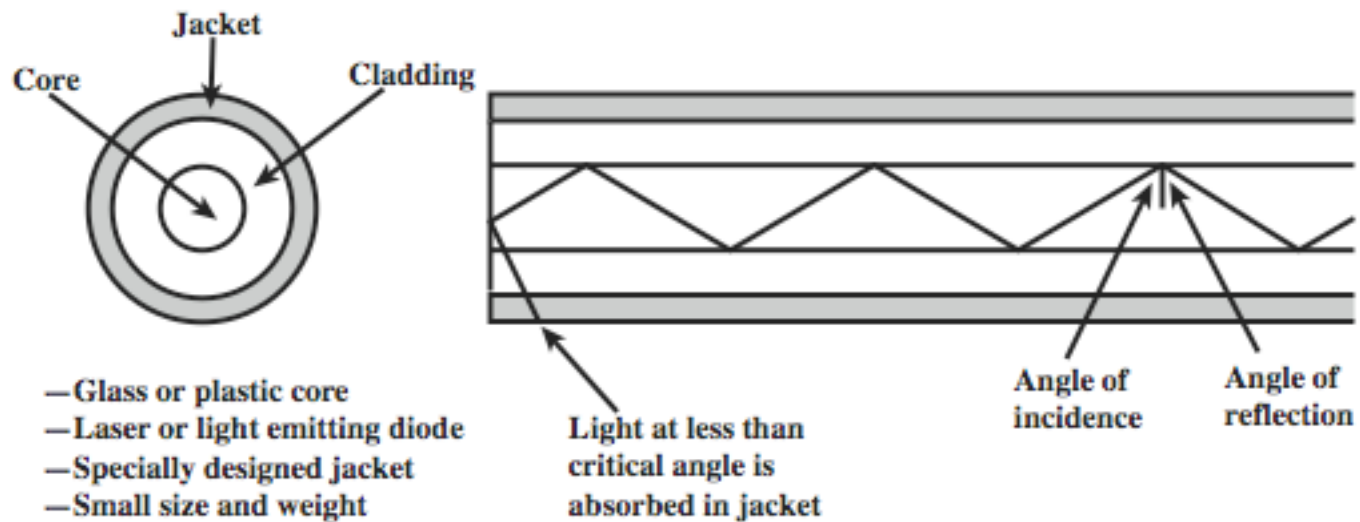
Optical fiber

- Fiber optic cable (or optical fiber) is a thin glass fiber cable approximately a little thicker than a human hair surrounded by a plastic coating that can carry information at frequencies in the visible light spectrum.
- Optical fiber is a cable that accepts and transports signals in the form of **light**.
- A light source, called a photo diode, is placed at the transmitting end and quickly switched on and off. The light pulses travel down the glass cable and are detected by an optic sensor called a photo receptor on the receiving end.

- Fiber optic cable is capable of transmitting data at over 100 Gbps (that's 100 billion bits per second!) over several kilometers.
- In addition to having almost **error free high** data transmission rates, fiber optic cable has a number of other advantages over twisted pair and coaxial cable.
- Since fiber optic cable passes electrically non conducting photons through a glass medium, it is immune to electromagnetic interference and virtually impossible to wiretap.



Optical Fiber



(c) Optical fiber

Optical Fiber - Benefits

- greater capacity
 - data rates of hundreds of Gbps
- smaller size & weight
- lower attenuation
- electromagnetic isolation
- greater repeater spacing
 - 10s of km at least

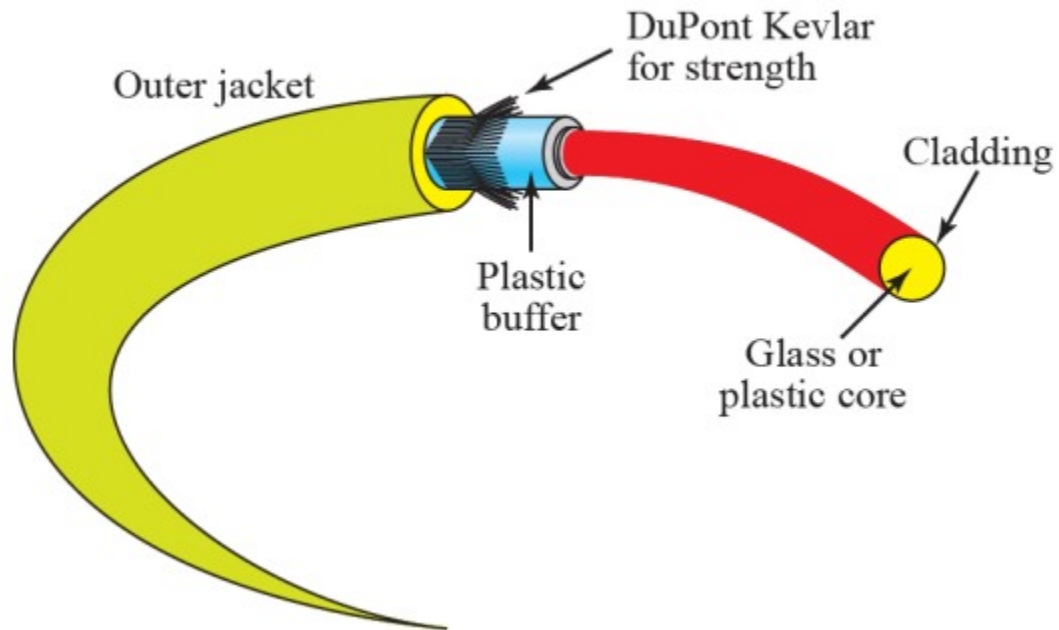
Optical Fiber - Transmission Characteristics

- uses total internal reflection to transmit light
 - effectively acts as wave guide for 10^{14} to 10^{15} Hz
- can use several different light sources
 - Light Emitting Diode (LED)
 - cheaper, wider operating temp range, lasts longer
 - Injection Laser Diode (ILD)
 - more efficient, has greater data rate
- relation of wavelength, type & data rate

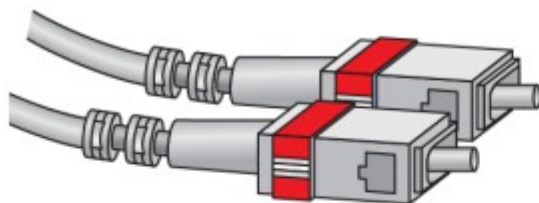
Fiber types

<i>Type</i>	<i>Core (μm)</i>	<i>Cladding (μm)</i>	<i>Mode</i>
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

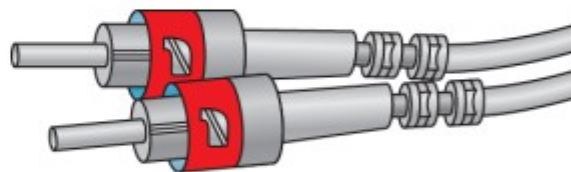
Fiber construction



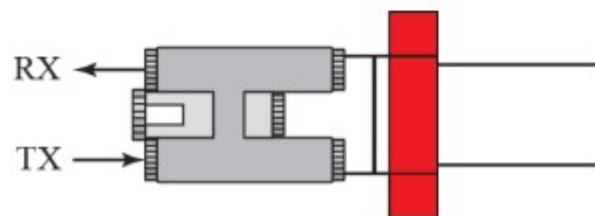
Fiber-optic cable connector



SC connector



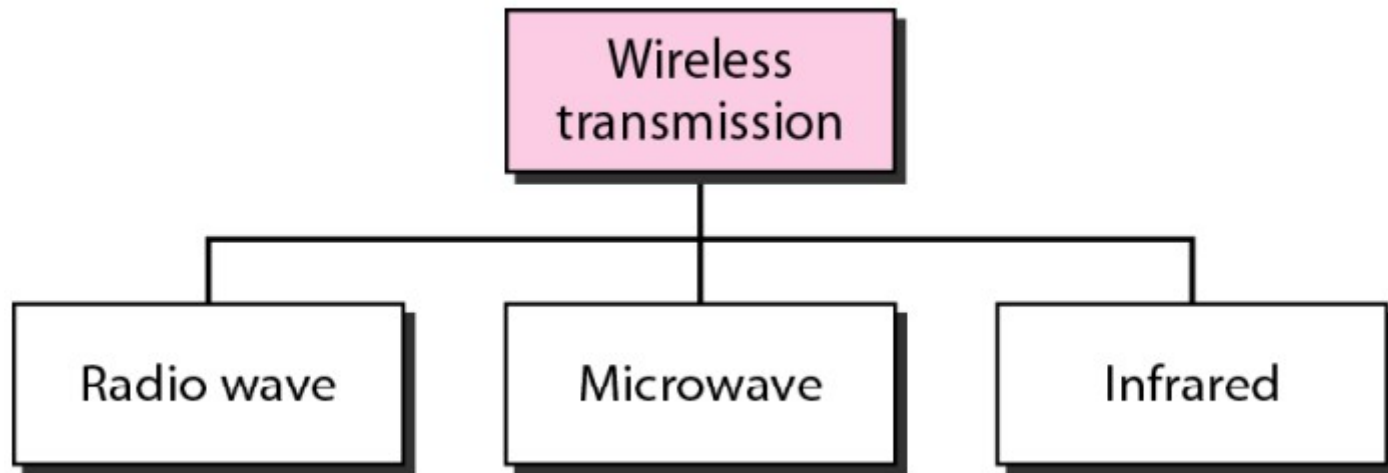
ST connector



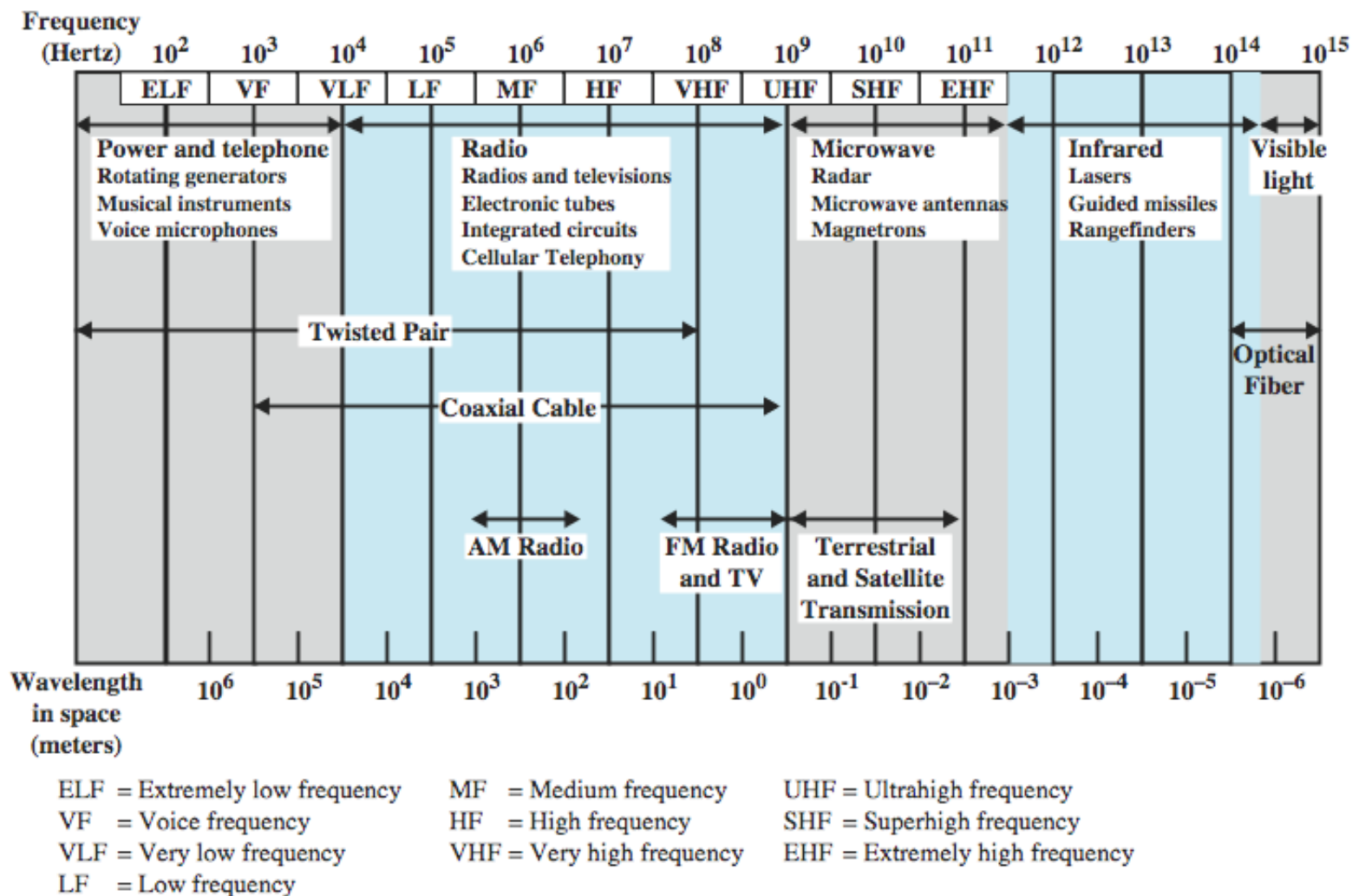
MT-RJ connector

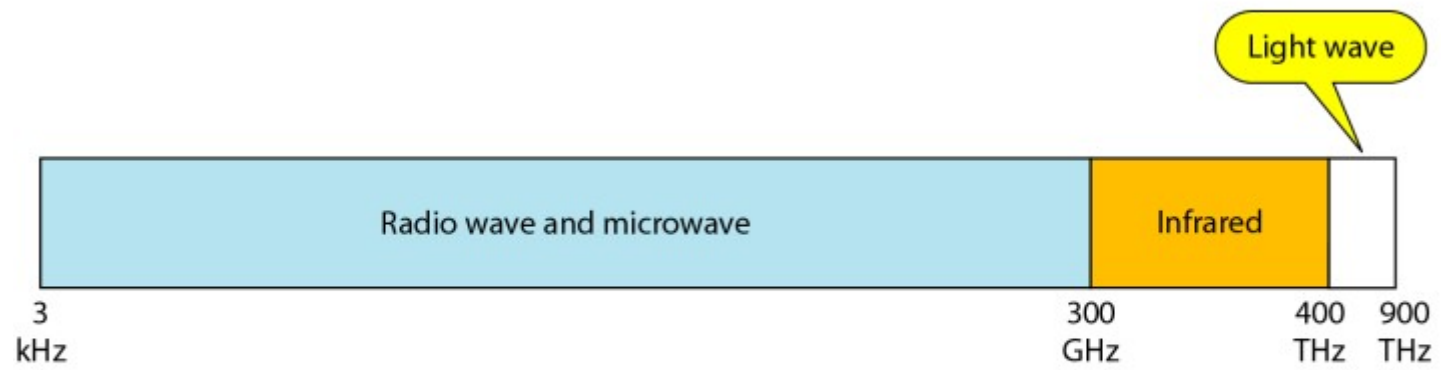
Unguided/Unbound Transmission Media

- transport waves without using a physical conductor- data signals flows through the air.
- are the ways of transmitting data without using any cables.
- These media are not bounded by physical geography.
- Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.
- This type of transmission is often referred to as **Wireless communication**.



Electromagnetic Spectrum



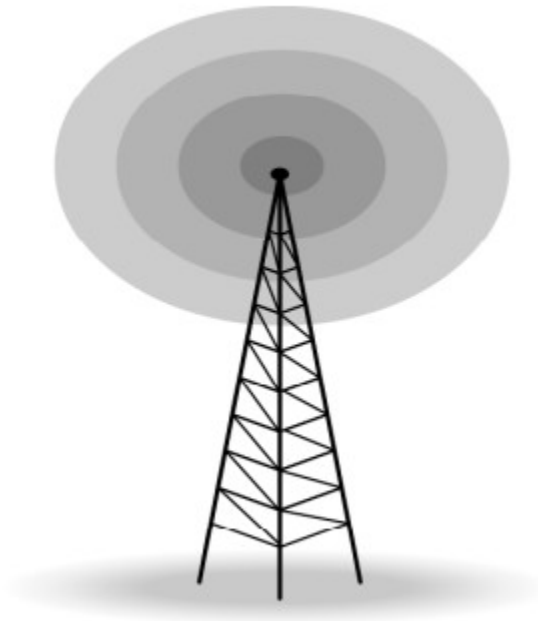


Radio Waves

- Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called **radio waves**.
- Radio waves, for the most part, are omnidirectional.
- the sending and receiving antennas do not have to be aligned.
- 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 are used for multicast communications, such as radio and television, and paging systems.

- Radio waves 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.

Omnidirectional antenna

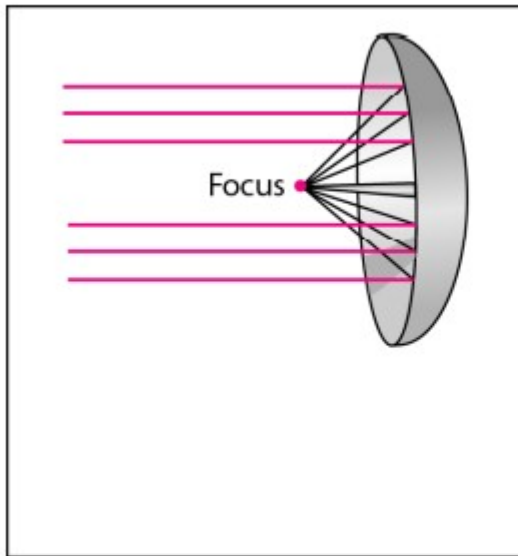


Microwaves

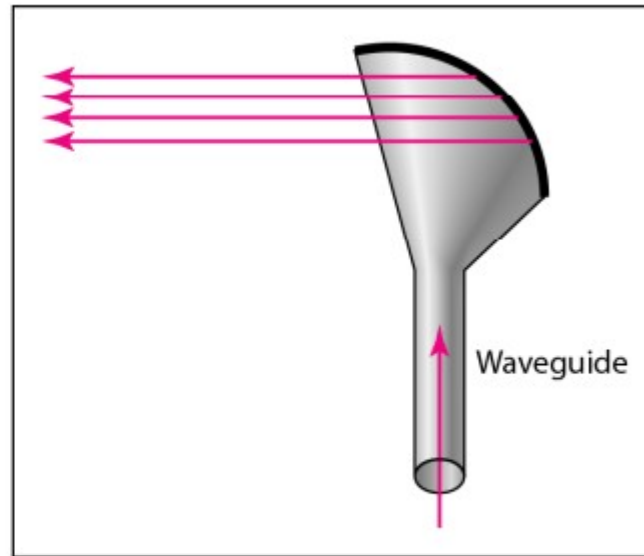
- Electromagnetic waves having frequencies between 1 and 300 GHz are called **microwaves**.
- Microwaves are unidirectional--This means that the sending and receiving antennas need to be aligned.
- Microwave propagation is line-of-sight.
- Very high-frequency microwaves cannot penetrate walls.

- Use of certain portions of the band requires permission from authorities.
- Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed between the sender and the receiver.
- Microwaves are used for unicast communication such as cellular telephones, satellite networks, telephones, satellite networks, and wireless LANs

Unidirectional antennas



a. Dish antenna



b. Horn antenna

Infrared

- 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.
 - However, this same characteristic makes infrared signals useless for long-range communication.

- we cannot use infrared waves outside a building because the sun's rays contain infrared waves that can interfere with the communication.
- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Bluetooth

- is a short-range radio hookup that resides on a microchip.
- It was initially developed by Swedish mobile phone maker Ericsson in 1994 as a way to let laptop computers make calls over a mobile phone.
- over 20,000 companies have signed on to make Bluetooth the low-power short-range wireless standard for a wide range of devices.
- Originally published as IEEE 802.15.1 standards
- Named after Danish king **Harald Blatand (Bluetooth)** who united dissonant Danish tribes into a single kingdom.

- An industry consortium known as the Bluetooth SIG (Special Interest Group) publishes Bluetooth standards.
- Bluetooth devices within 10 m of each other can share up to 2.1 Mbps or 24 Mbps of capacity.
- uses short-wavelength UHF radio waves in the ISM (Industrial, Scientific and Medical) band from 2.4 to 2.485 GHz

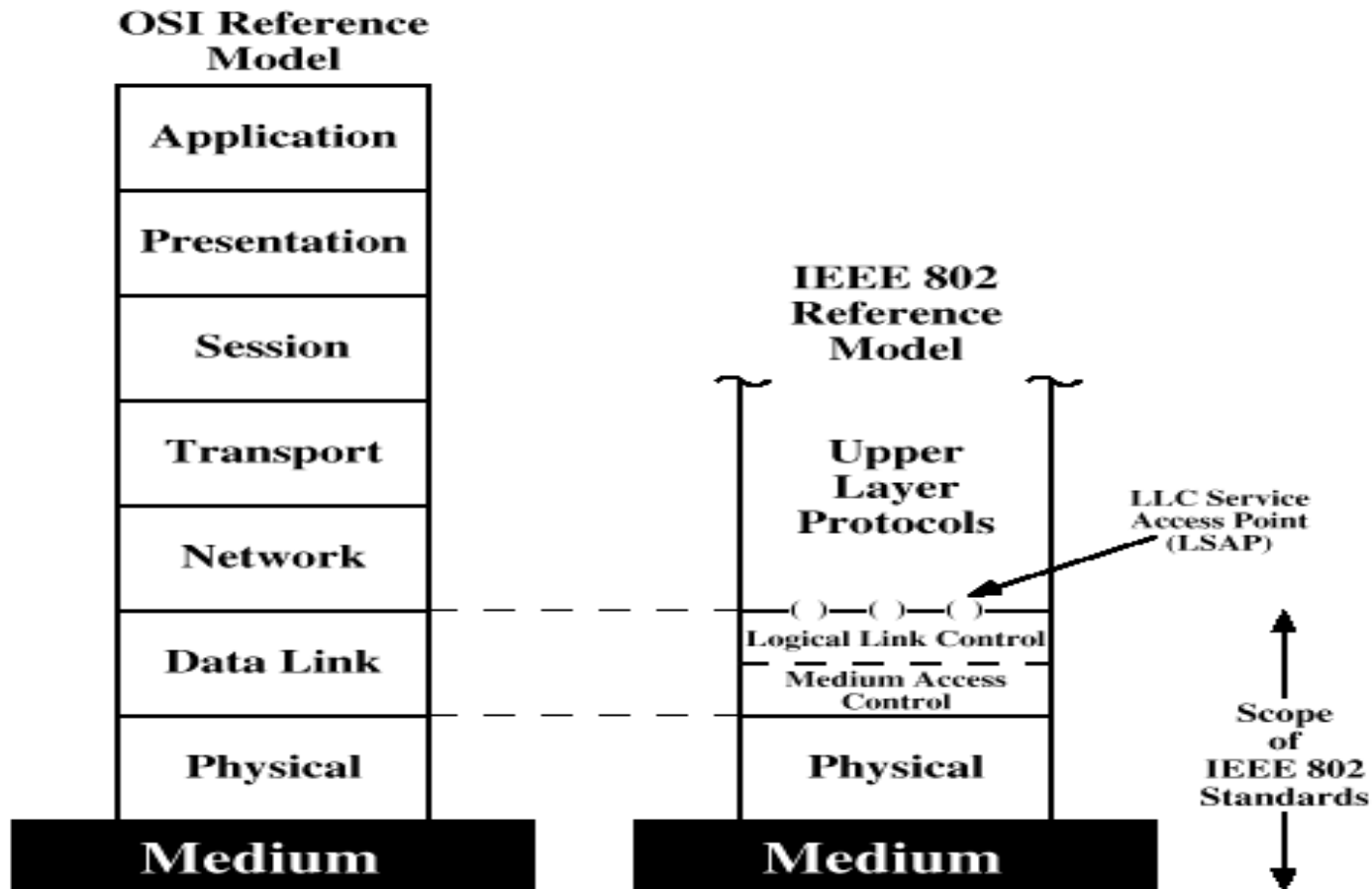
- Is globally unlicensed (but not unregulated) Industrial, Scientific and Medical (ISM) band.
- Bluetooth is intended to support an open-ended list of applications, including data (e.g., schedules and telephone numbers), audio, graphics, and even video.
- The following are some examples of the capabilities that Bluetooth can provide consumers:
 - Make calls from a wireless headset connected remotely to a cell phone.
 - Control communication between a smartphone and a car stereo system.

- Control of peripherals such as a keyboard, mouse, or speaker from a computer or tablet.
- Call home from a remote location to turn appliances on and off, set the alarm, and monitor activity.
- Set up home networks so that a couch potato can remotely monitor air conditioning, the oven, and children's Internet surfing.

- Top uses in order of volume are for the following devices:
 - Mobile handsets
 - Voice handsets
 - Stereo headsets and speakers
 - Personal computers and tablets
 - Human interface devices, such as mice and keyboards
 - Wireless controllers for video game consoles
 - Cars, Machine-to-machine applications: credit-card readers, industrial automation, and so on.

IEEE 802.11 (WiFi)

- 802.11 standard focuses on the bottom two layers of the OSI model, the physical layer (PHY) and data link layer (DLL).



802.11

- Two network architectures are defined in the IEEE 802.11 standard
 - **Point-to-point (ad hoc) *network***
 - Two wireless-capable devices
 - is used to support Mutual communication between wireless clients
 - is created spontaneously and does not support access to wired networks.
 - Doesn't require AP
 - Simple to setup
 - Interference with other networks and potential security risks
 - Provides an Independent Basic Service Set (IBSS)

– Infrastructure network

- Communication between wireless clients and wired network resources
- Uses AP
- An AP and its associated wireless clients define the coverage area
- **Single AP**
 - One Access Point (AP)
 - Connected to wired infrastructure
 - Wireless LAN Controller (WLC) – optional
 - » Lightweight AP (with WLC)
 - » Autonomous AP (Without WLC)
 - Creates a Basic Service Area (BSA)
 - Provides a Basic Service Set (BSS)

- **Multiple Aps**

- More than one Aps
- Connected to Wired infrastructure
- Wireless LAN Controller – Optional
 - » Lightweight AP (with WLC)
 - » Autonomous AP (without WLC)
- Creates an Extended Service Area (ESA)
- Provides an Extended Services Set (ESS)

- Based on the 802.11 standard:
 - 802.11a
 - 802.11b
 - 802.11g
 - 802.11n (WiFi 4)
 - 802.11ac (WiFi 5)
 - 802.11ax (WiFi 6)

Standard	Year	Frequency (GHz)	Data Rate (Mbps)	Technology	Range (Indoor)	Range (Outdoor)
802.11b	1999	2.4	11		35m	120m
802.11a	1999	5	54	Uses OFDM (Orthogonal Frequency Division Multiplexing)	35m	120/5000m
802.11g	2003	2.4	54	Uses OFDM	38m	140m
802.11n	2009	2.4/5	600	Uses MIMO (Multiple Input Multiple Output)	70m	250m
802.11ac	2014	2.4/5	450 /1300	MU-MIMO (Multi User MIMO)	35m	-
802.11ax	2019	2.4/5	10000 - 15000	Orthogonal Frequency Division Multiple Access (OFDMA)	30m	120m

Media Selection Criteria

- When designing or updating a computer network, the selection of one type of media over another is an important issue.
- The principal factors you should consider in your decision include **cost, speed, expandability, distance, environment, and security.**