IT - 305 Data Communication **Unit #2**
September 16, 2019

Outline *Transmission Medium: Guided Transmission Media- Twisted pair cables, Co-axial cables, Fiber optic cables- Working principle, Advantages and disadvantages, UnGuided Transmission Media- Electromagnetic spectrum, Wireless Transmission, Wireless Propagation, Line-of-Sight Transmission, free-space path loss, infrared and satellite communication system Data Encoding and Modulation: Baseband Communication (Analog/Digital),*

Contents

1 Transmission Medium

The transmission media that are used to convey information can be classified as **guided** or **unguided**.

- **Guided media** provide a physical path along which the signals are propagated; these include twisted pair, coaxial cable, and optical fiber. In **guided media**, electromagnetic waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, and optical fiber.
- **Unguided media** employ an antenna for transmitting through air, vacuum, or water. Unguided transmission techniques commonly used for information communications include broadcast radio, terrestrial microwave, and satellite. For **unguided media**, wireless transmission occurs through the atmosphere, outer space, or water.

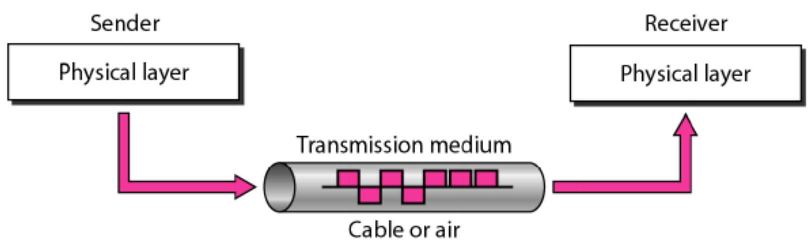

Figure 1:

A **transmission medium** can be broadly defined as anything that can carry information from a source to a destination.

1.1 Classes of Transmission media

Transmission media can be divided into two broad categories as shows in Figure 2: **Guided** and **Unguided**. Guided media include twisted-pair cable, coaxial cable, and fiber-optic cable. Unguided medium is free space.

1.1.1 Guided media (Wired)

Waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, or optical fiber.

1.1.2 Unguided media (Wireless)

It can be water or free space provides a means for transmitting electro-magnetic signals through air but do not guide them. - Wireless transmission.

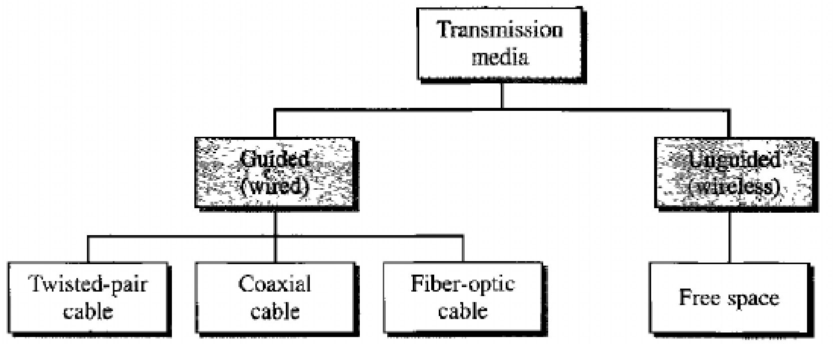

Figure 2: Classes of Transmission media

1.1.3 Quality of Transmission

The characteristics and quality of data transmission are determined by medium and signal characteristics. For guided media, the medium is more important in determining the limitations of transmission. For unguided, the bandwidth of the signal produced by the transmitting antenna is more important than the medium.

1.1.4 Guided Media: Twisted Pair

Twisted pair use metallic (copper) conductors that accept and transport signals in the form of electric current. A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern. Typically, a number of pairs are bundled together into a cable by wrapping them in a tough protective sheath. It consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure 3. One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.

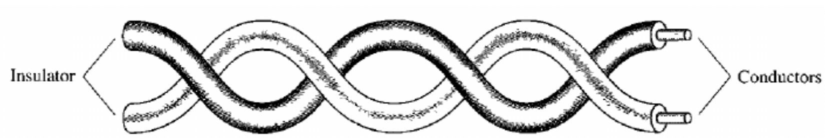

Figure 3: Twisted Pair Cable

Why twisting?
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. For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true. Twisting makes it probable that both wires are equally affected by external influences (noise or crosstalk).

1.1.5 Unshielded Versus Shielded Twisted-Pair Cable

The most common twisted-pair cable used in communications is referred to as **unshielded twisted-pair (UTP)**.
IBM has also produced a version of twisted-pair cable for its use called shielded twisted-pair (STP). STP cable has a metal foil or braided- mesh covering that encases each pair of insulated conductors.
Advantages and Disadvantages of STP
Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive. Figure 4 shows the difference between UTP and STP.

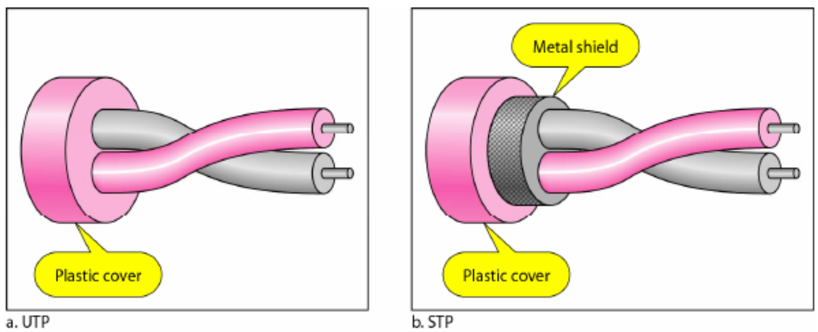

Figure 4: Twisted Pair Cable

1.2 Twisted Pair Cable 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. Table 5. I shows these categories.

1.2.1 UTP Connectors

The most common UTP connector is RJ45 (RJ stands for registered jack), as shown in Figure 6.

1.3 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 1OBase-T and 1OOBase-T, also use twisted-pair cables.

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
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

Figure 5: Twisted Pair Categories

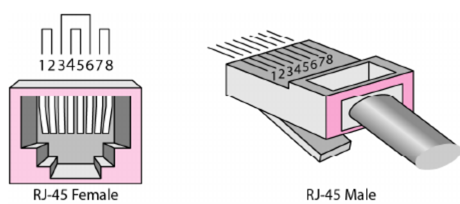

Figure 6: UTP Connector : RJ45

2 Coaxial Cable

Coaxial cable (or coax) carries *signals of higher frequency ranges than those in twisted-pair cables*, 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 as shows in Figure 7

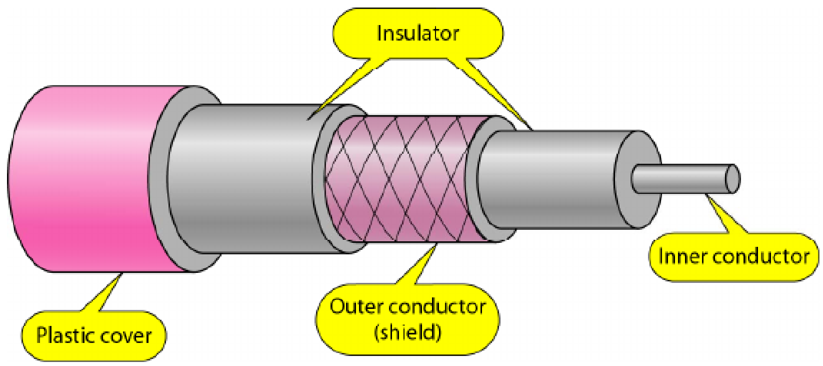

Figure 7: Coaxial cable

2.0.1 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. Table 8 shows the RG ratings.

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

Figure 8: Categories of coaxial cables

2.0.2 Coaxial cable connectors

To connect coaxial cable to devices, we need coaxial connectors. The most common type of connector used today is the *Bayone-Neill-Concelman (BNe)*, connector. Figure 9 shows three popular types of these connectors:

- The **BNC connector**: used to connect the end of the cable to a device, such as a TV set.

- The **BNC T connector**: used in Ethernet networks to branch out to a connection to a computer or other device, and
- **The BNC terminator**: used at the end of the cable to prevent the reflection of the signal.

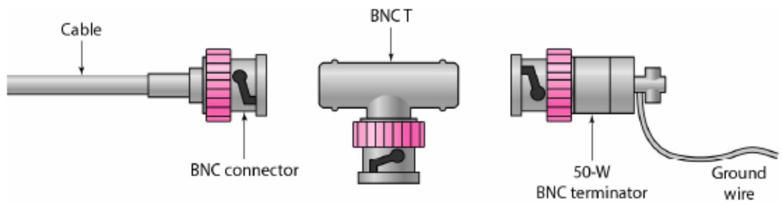

Figure 9: Co-axial cable connector : BNC connectors

2.0.3 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.
- Use in Cable TV networks
- In the traditional cable TV network, the entire network used 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.

3 Fiber Optic Cable

To understand optical fiber, we first need to explore several aspects of the nature of light.

3.1 Nature of light

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. Figure 10 shows how a ray of light changes direction when going from a more dense to a less dense substance.
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.

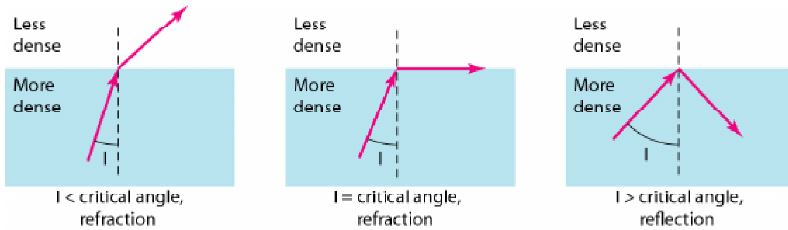

Figure 10: Bending of light ray

- If the angle is greater than the critical angle [1], the ray reflects (makes a turn) and travels again in the denser sub- stance.

Note that the critical angle is a property of the substance, and its value differs from one substance to another.
Optical fibers use reflection to guide light through a channel as shown in Figure 11.

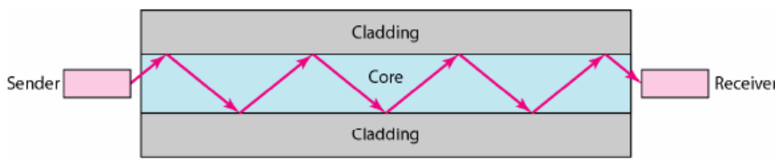

Figure 11: Optical fiber

3.2 Propagation Modes

Two propagation modes: Multimode and single mode, each requiring fiber with different physical characteristics. Figure shows propagation modes.

- **Multimode** is so named because multiple beams from a light source move through the core in different paths. How these beams move within the cable depends on the structure of the core, as shown in Figure 13
  - **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.

[1] The angle of incidence beyond which rays of light passing through a denser medium to the surface of a less dense medium are no longer refracted but totally reflected.

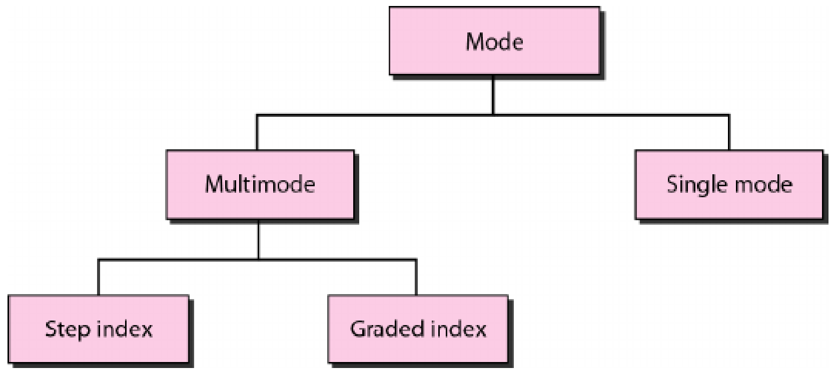

Figure 12: Propagation modes

  - **Multimode graded-index fiber**, decreases the distortion of the signal through the cable. The word index here refers to the index of refraction. As we saw above, the index of refraction is related to density. 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. Figure 13 shows the impact of this variable density on the propagation of light beams.

- **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). The decrease in density results in a critical angle that is close enough to 90^o to make the propagation of beams almost horizontal. In this case, propagation of different beams is almost identical, and delays are negligible. All the beams arrive at the destination "together" and can be recombined with little distortion to the signal (see Figure 13).

3.3 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. The common sizes are shown in Table 14.

3.4 Fiber Optic Connectors

- The subscriber channel (SC) connector is used for cable TV.
- The straight-tip (ST) connector is used for connecting cable to networking devices.
- MT-RJ is a connector that is the same size as RJ45.

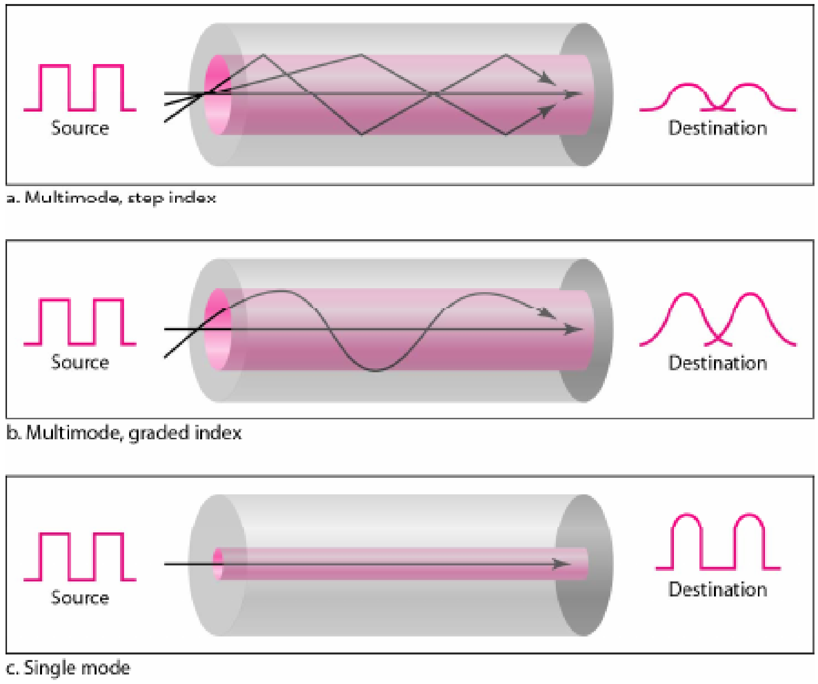

Figure 13: Modes

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

Figure 14: Fiber Types

3.5 Applications

- Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective.
- 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.

3.6 Advantages of Optical Fibers

- **Higher bandwidth**: Fiber-optic cable can support dramatically higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable.
- **Less signal attenuation**: Fiber-optic transmission distance is significantly greater than

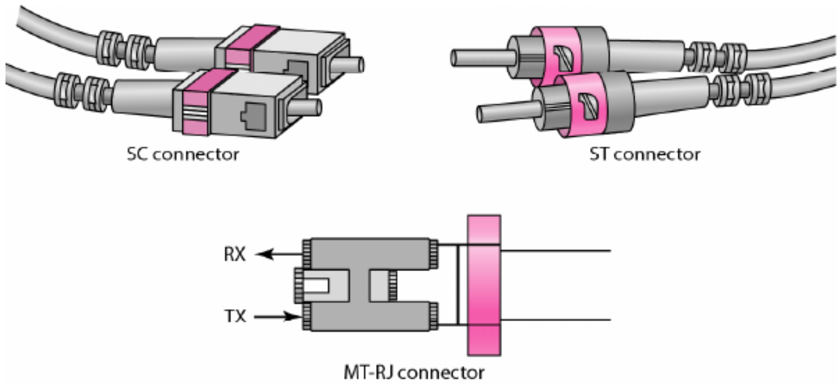

Figure 15: Fiber Connectors

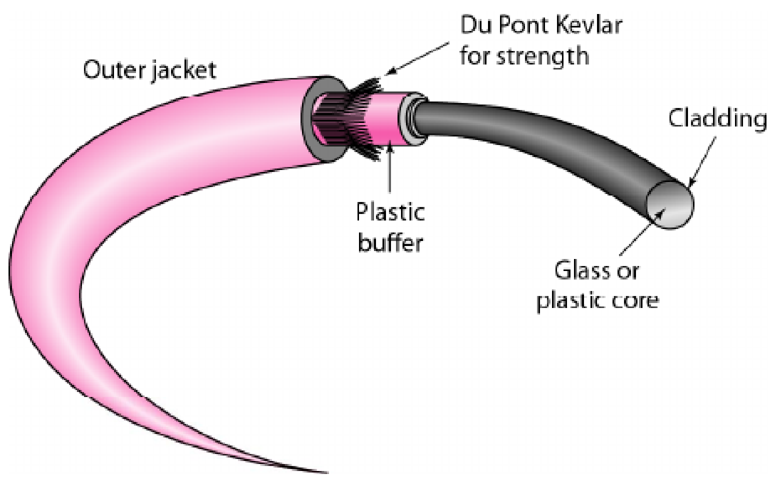

Figure 16: Fiber Constructions

that of other guided media. A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.

- Immunity to electromagnetic interference.
- Resistance to corrosive materials.
- Light weight

3.7 Disadvantages of Optical Fibers

- Installation and maintenance. Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.

- Unidirectional light propagation. Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.

- Cost. 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.

4 Unguided media

Unguided media 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.

4.1 Electromagnetic spectrum used for wireless communication

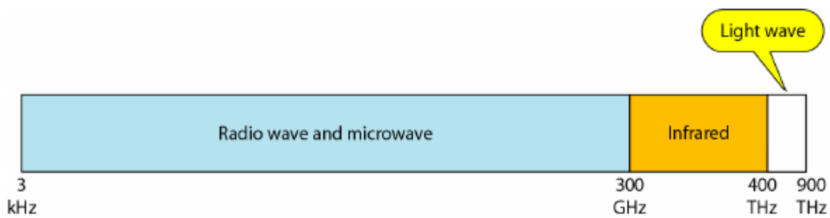

Figure 17: Electromagnetic spectrum for wireless communication

4.2 Propagation methods

Unguided signals can travel from the source to destination in several ways shows in Figure 18

- **Ground**: 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**: 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**: In line-or-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.

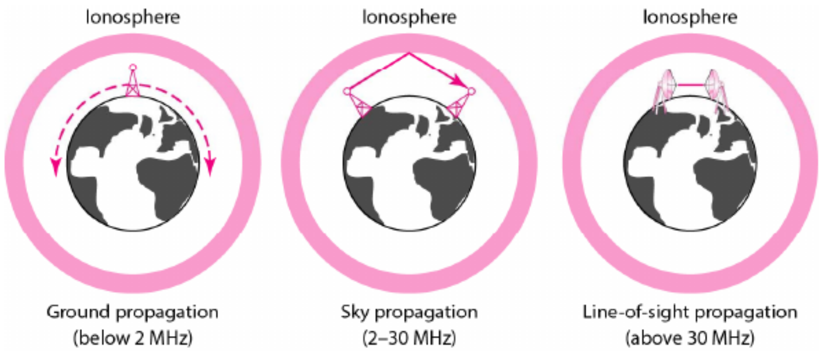

Figure 18: Propagation methods

4.3 Radio and Microwaves 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).

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

Figure 19: Radio and Microwaves bands

4.4 Wireless Transmission

We can divide wireless transmission into three broad groups: radio waves, microwaves, and infrared waves as shown in Figure 7.19.

4.4.1 Radio waves

Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves;

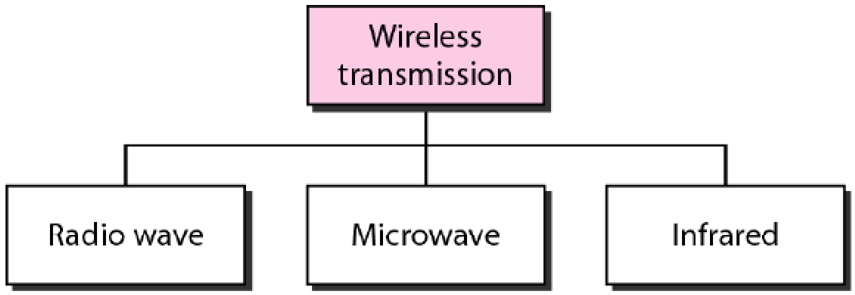

Figure 20: Wireless transmission waves

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.

Advantages and Disadvantages

- Propagation 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 subbands, the subbands are also narrow, leading to a low data rate for digital communications.

Omni-directional antenna 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, and paging are examples of multicasting.

4.4.2 Microwaves

Waves ranging in frequencies between 1 and 300 GHz are called microwaves.

Microwaves are **unidirectional**. When an antenna transmits microwave waves, 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.

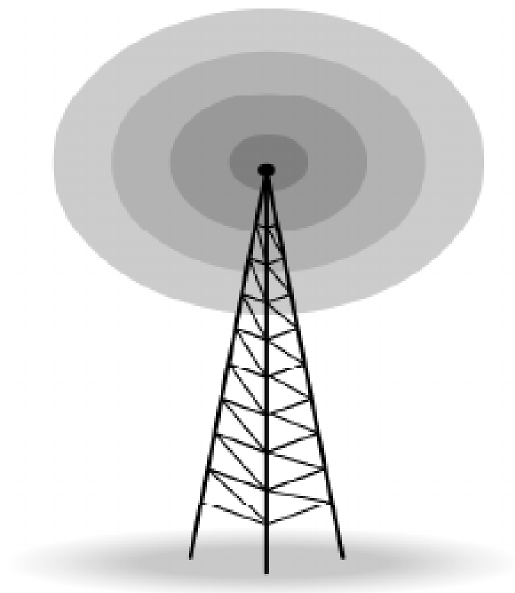

Figure 21: Omni-directional antenna

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 do 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 subbands 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 as shown in Figure 22.

- **Parabolic dish antenna**: 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

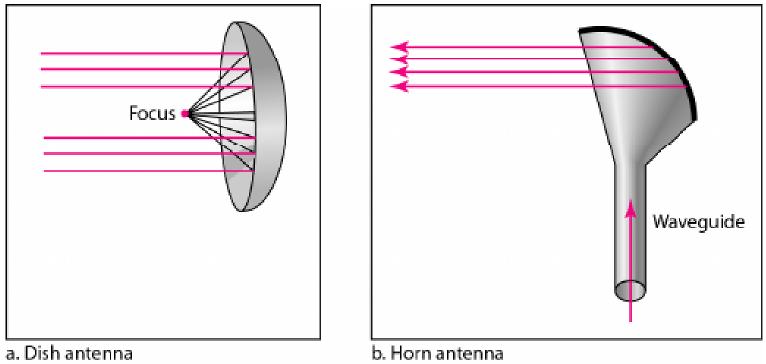

Figure 22: Unidirectional Antenna

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.

- **Horn antenna:** Outgoing transmissions are broadcast through a horn aimed at the dish. The micro waves hit the dish and are deflected outward in a reversal of the receipt path.

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.

4.4.3 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. For example 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.

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.
- Use for communication between devices such as keyboards, mice, PCs, and printers.

References