Data Communication

BCE 6th Semester

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Unit 6: Transmission Media

- **Outline:**
- Electromagnetic Spectrum for Telecommunication
- Types of Propagation
- Guided Transmission Media: Twisted pair cable, Co-axial cable, Optical fiber
- Characteristics of Unguided Communication bands, Antennas
- Unguided Transmission Media: Terrestrial Microwave, Satellite Communication, Cellular Technology

Electromagnetic Spectrum for Telecommunication

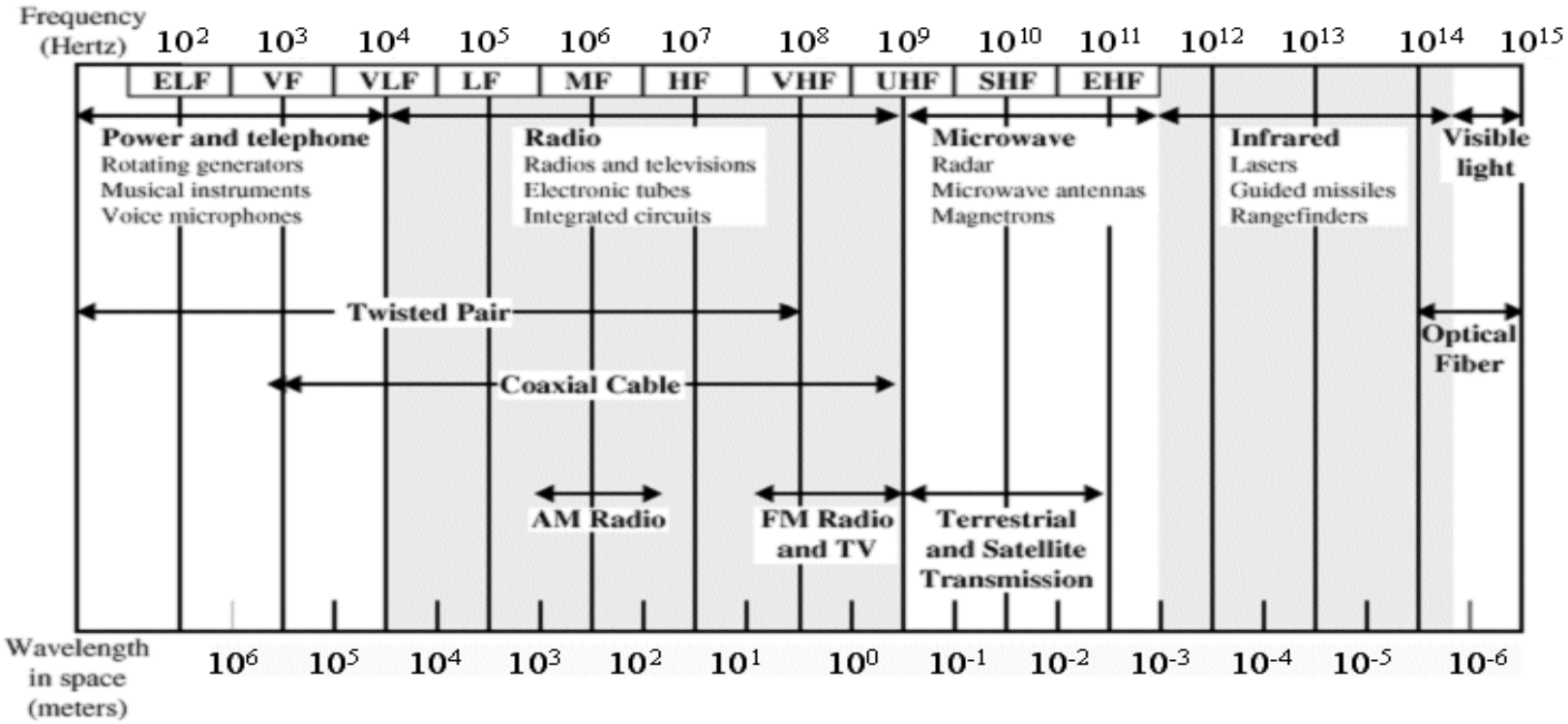


Figure 3.1 Electromagnetic Spectrum for Telecommunications

Electromagnetic Spectrum for Telecommunication

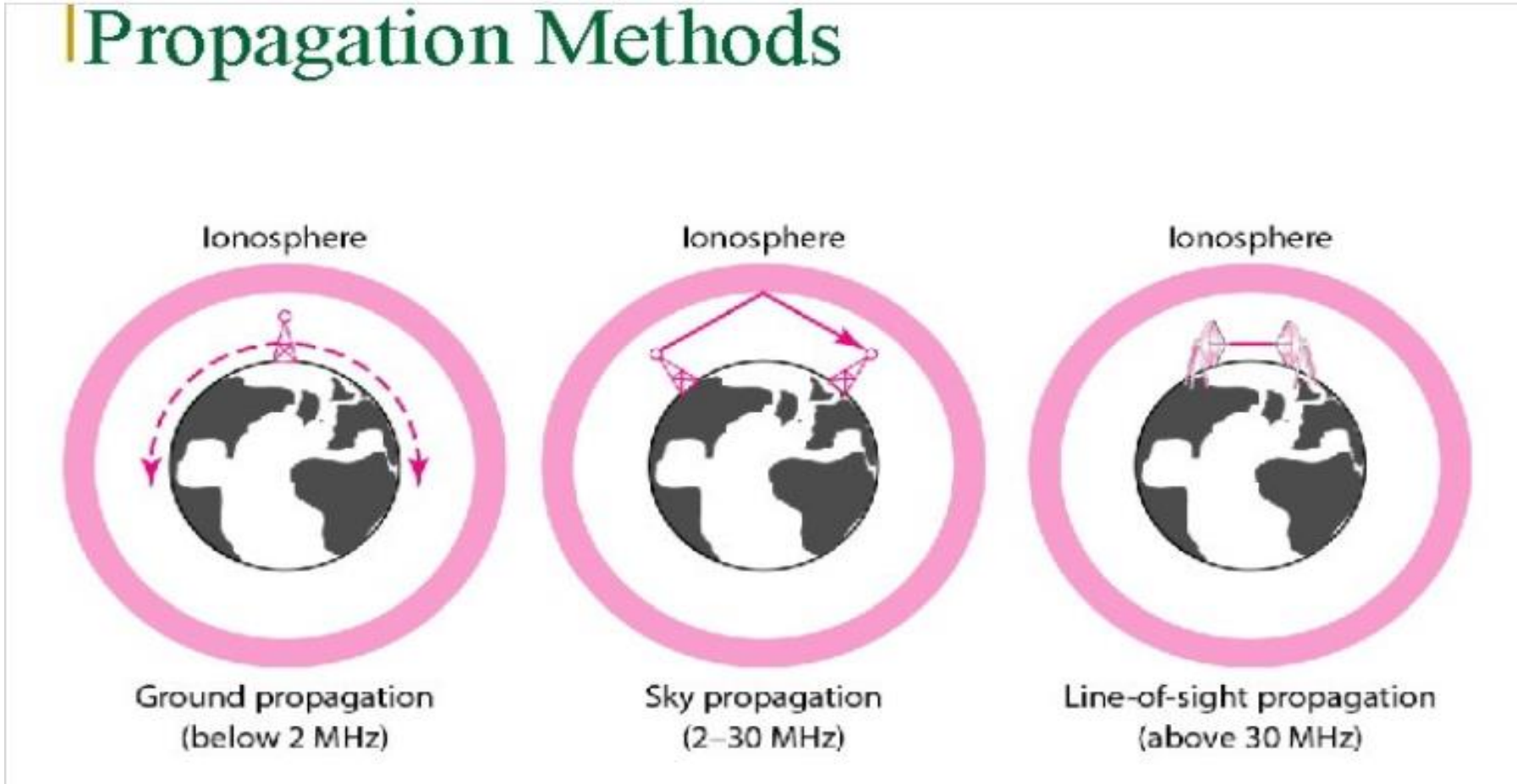
- The electromagnetic spectrum is the entire range of electromagnetic radiation according to the wavelength or frequencies.
- It has a range of frequencies from 1Hz to several Hz.
- The waves in order of increasing frequencies are radio waves, microwaves, infrared rays, visible light, UV rays, X-rays, and gamma rays.
- Among these ranges, the frequencies between Hz to several Hz are used for communication.

Electromagnetic Spectrum for Telecommunication

Band Name	Full Forms	Frequency Range	Propagation	Uses
ELF	Extremely Low Frequency	30 – 300Hz	Ground	Power line frequencies
LF	Low Frequency	3 – 300 KHz	Ground	Marine Communications, communication over twisted pair
MF	Medium Frequency	300KHz – 3MHz	Sky	AM radio, communication over coaxial cables
HF	High Frequency	3 – 30 MHz	Sky	Aircraft and ship communications
VHF	Very High Frequency	30 – 300 MHz	Sky and Line – of - Sight	FM radio, TV
UHF	Ultra High Frequency	300 MHz – 3GHz	Line – of - Sight	TV, cellular phone
SHF	Super High Frequency	3 – 30 GHz	Line – of - Sight	Satellite, microwave links
EHF	Extremely High Frequency	3 – 300GHz	Line – of - Sight	Radar, satellite
Infrared	Infrared Rays	300 Ghz – 400THz	Line – of - Sight	Consumer electronic goods
Visible Light	Visible Light rays	400 THz – 900 THz	Line – of - Sight	Fiber optic communications

Fig: The frequency bands and their uses in communication

Types of Propagation



Types of Propagation

- **Ground Wave Propagation**
- In ground wave 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.
- AM, FM, and television broadcasting can be done with the help of ground waves.

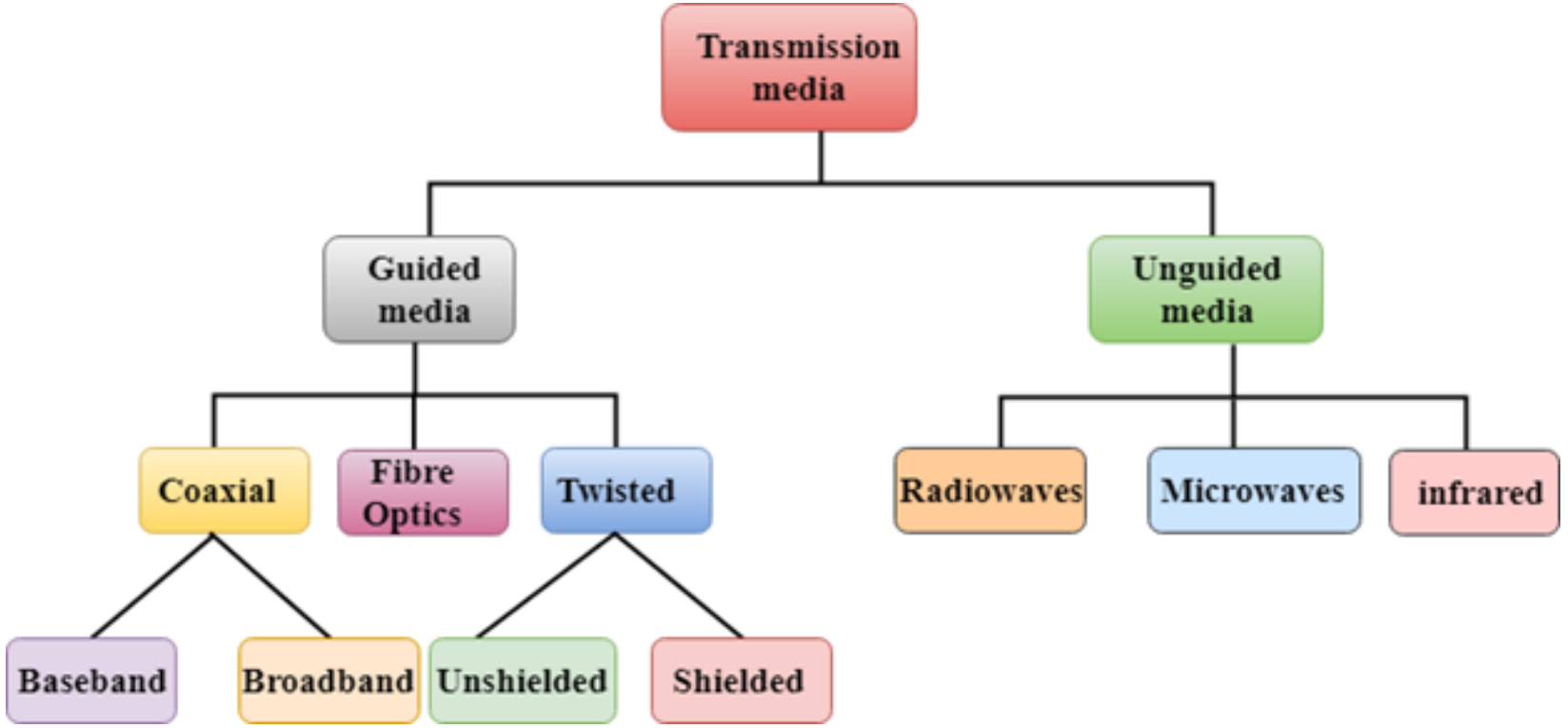
Types of Propagation

- **Sky wave Propagation**
- In skywave propagation, higher-frequency radio waves radiate upward into the ionosphere, reflecting earth.
- This type of transmission allows for greater distances with lower output power.
- Satellite Communication is a good example of Skywave Propagation.
- **Line of Sight(LOS) Propagation**
- In line-or-sight propagation, high-frequency signals are transmitted directly from antenna to antenna in straight lines.
- 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.
- FM radio, microwave, and satellite transmission are examples of line-of-sight propagation.

Transmission Media

- 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.
- In data communications, the definition of the information and the transmission medium is more specific.
- The transmission medium is usually free space, metallic cable, or fiber-optic cable.
- The information is usually a signal that is the result of a conversion of data from another form.

Classification of Transmission Media

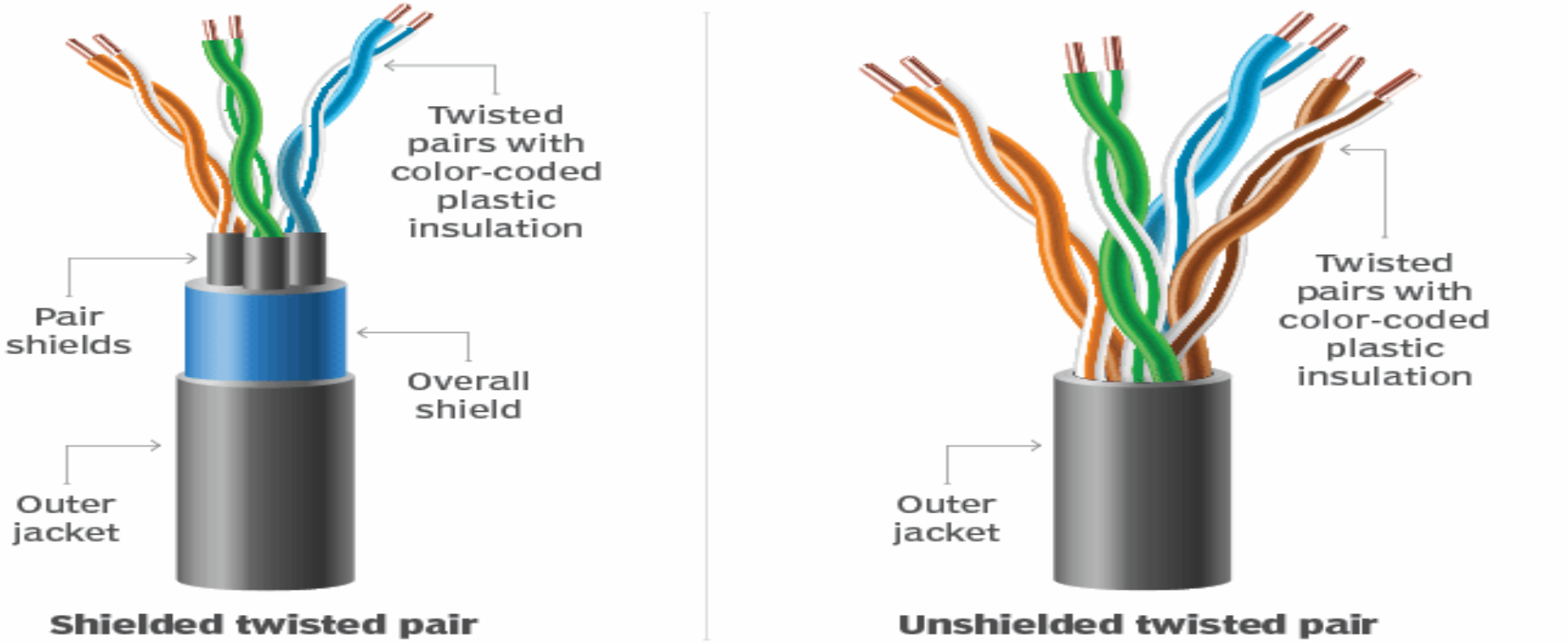


Guided Media

- **Guided 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 traveling 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.

Guided Media

- **Twisted-Pair Cable**
- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in figure.



Twisted Pair Cable

- UTP (Unshielded Twisted Pair)
- UTP is an unshielded twisted pair cable used in computer and telecommunications mediums.
- Its frequency range is suitable for transmitting both data and voice via a UTP cable.
- Therefore, it is widely used in the telephone, computers, etc.
- It is a pair of insulated copper wires twisted together to reduce noise generated by external interference.
- It is a wire with no additional shielding, like aluminium foil, to protect its data from the exterior.

UTP Cable Categories

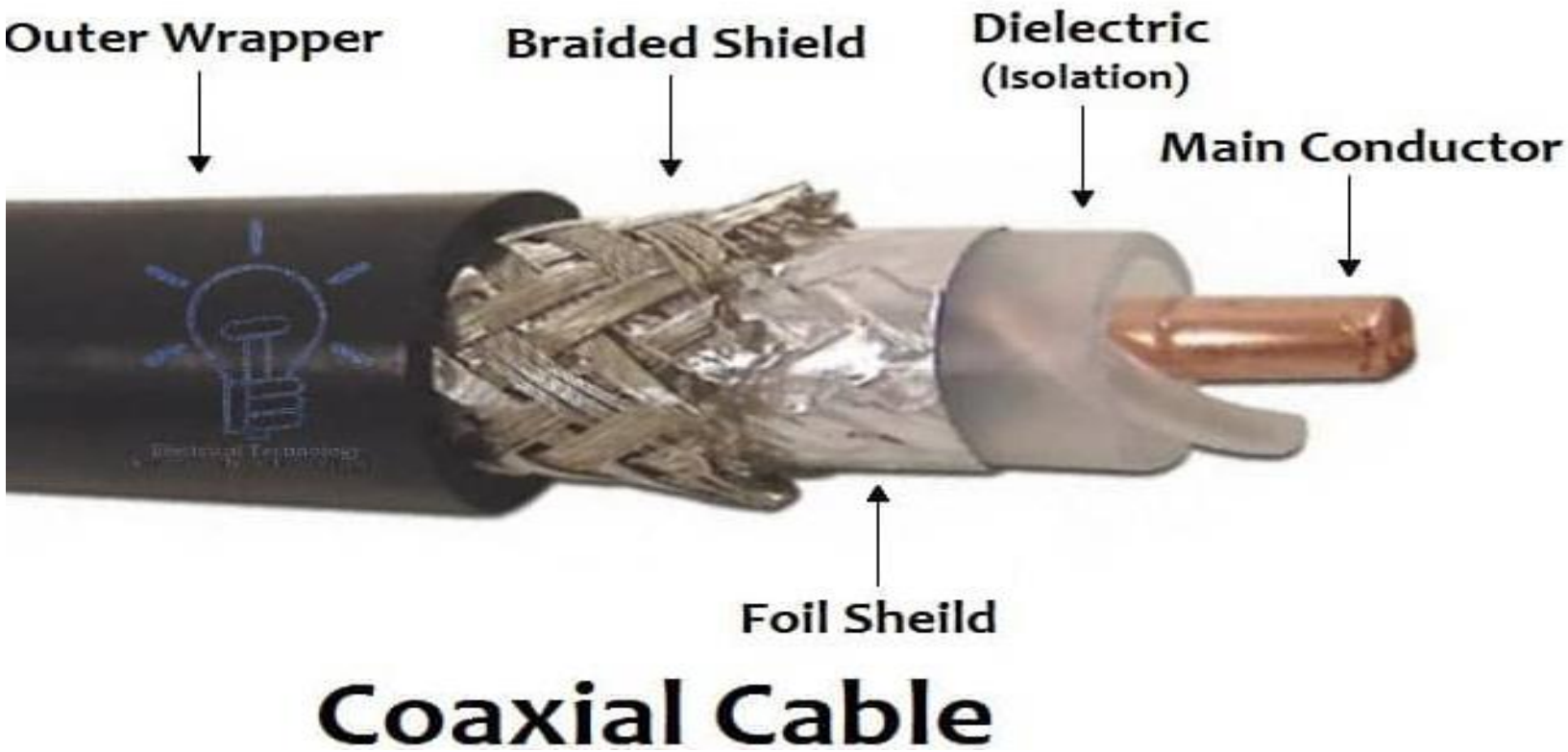
UTP Categories - Copper Cable				
UTP Category	**Data Rate**	**Max. Length**	**Cable Type**	**Application**
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	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)

Firewall.cx
Routing Information & Expertise To Network Professionals

Twisted Pair Cable

- STP (Shielded twisted pair):
- A shielded twisted pair is a type of twisted pair cable that contains an extra wrapping foil or copper braid jacket to protect the cable from defects like cuts, losing bandwidth, noise, and signal to the interference.
- It is a cable that is usually used underground, and therefore it is costly than UTP.
- It supports the higher data transmission rates across the long distance.
- We can also say it is a cable with metal sheath or coating that surround each pair of the insulated conductor to protect the wire from external users and prevent electromagnetic noise from penetrating.

Coaxial Cable



Coaxial Cable Categories

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

Coaxial Cable

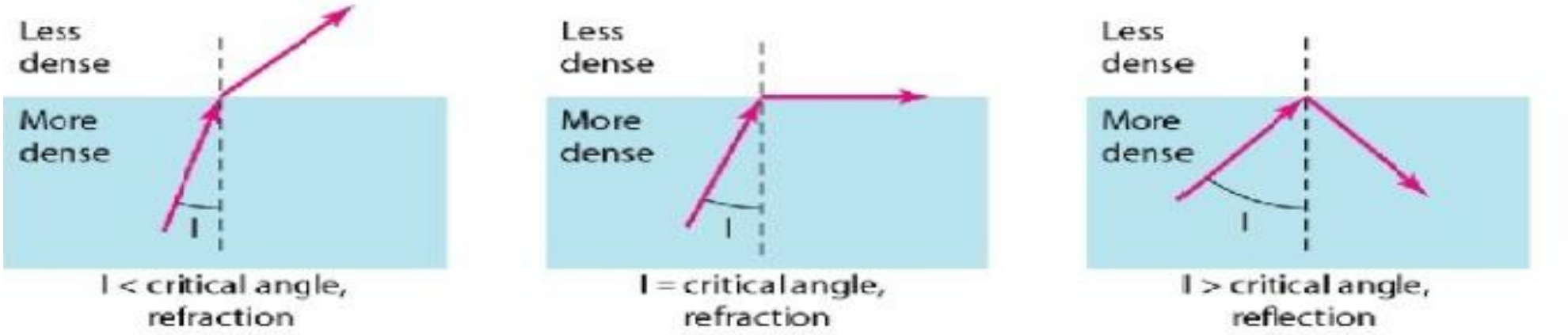
- Applications
- Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.
- Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps.
- Cable TV networks also use coaxial cables.
- 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.
- 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.

Guided Media

- **Fiber Optic Cable:**
- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- To understand optical fiber, we first need to explore several aspects of the nature of light.
- Light travels in a straight line as long as it is moving through a single uniform.
- If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.
- Figure shows how a ray of light changes direction when going from a more dense to a less dense substance.

Fiber Optic Cable

Bending of light ray

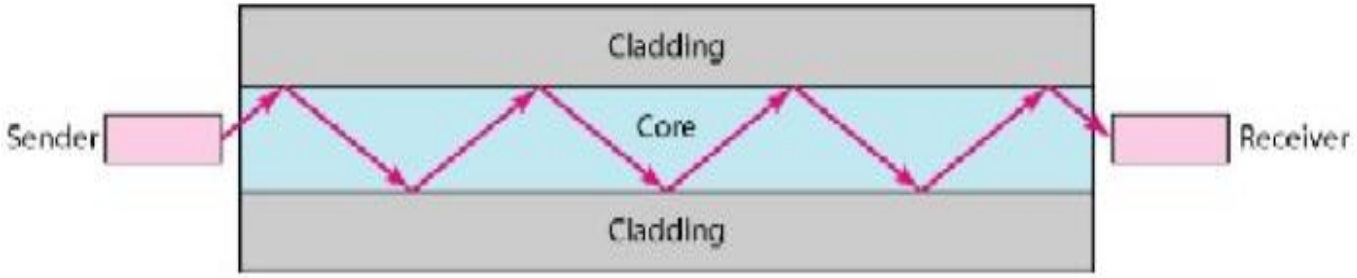


Fiber Optic Cable

- 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.

Construction of Fiber Optic Cable

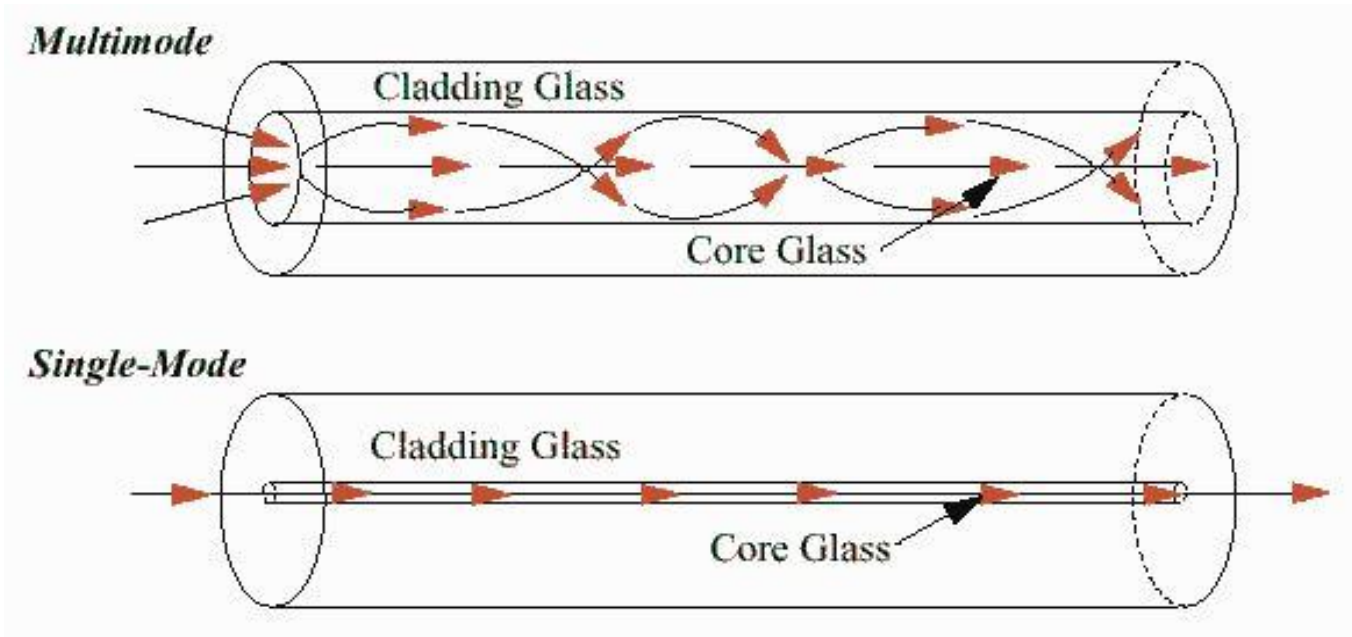
- Optical fibers use reflection to guide light through a channel.
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.
- The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being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



Fiber Optic Cable

- An optical fiber consists of a core surrounded by cladding where the core is the denser medium and cladding is the relatively rarer medium.
- On the basis of the mode of propagation of light there are two kinds of fiber cables:
- **Single-Mode Optical Fiber Cable :**
- SMF (Single-Mode Fibers) is the fiber cable that is designed to carry only a single mode of light which is the transverse mode.
- These are used for the long-distance transmission of signals.
- **Multi-Mode Optical Fiber Cable :**
- Multimode fiber cables are the type of fiber cables that transmit data via their core of larger diameters enabling an average, single-mode transceiver multiple modes of light to propagate through it.
- However, this limits the maximum length of transmission links possible due to modal dispersion.
- These fibers are thus used for the short-distance transmission of signals.

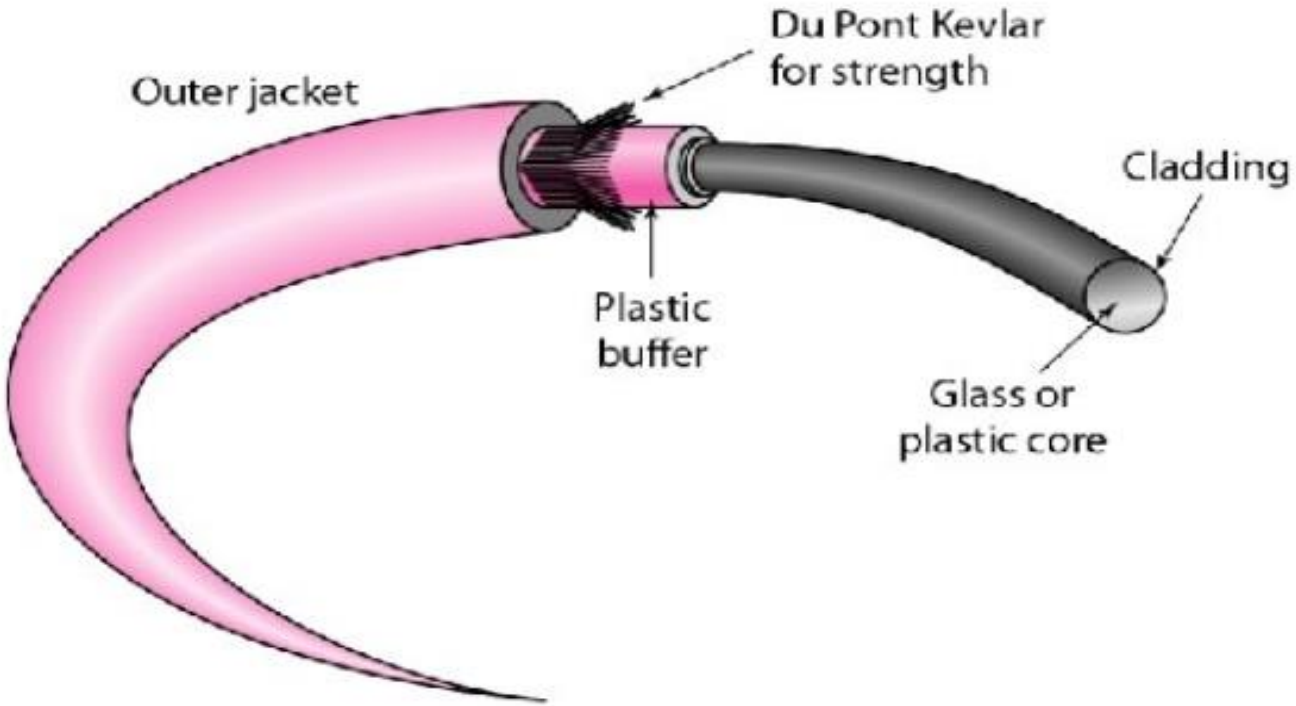
Fiber Optic Cable



Construction of Fiber Optic Cable

- Cable Composition
- Figure shows the composition of a typical fiber-optic cable.
- The outer jacket is made of either PVC or Teflon.
- Inside the jacket are Kevlar strands to strengthen the cable.
- Kevlar is a strong material used in the fabrication of bulletproof vests.
- Below the Kevlar is another plastic coating to cushion the fiber.
- The fiber is at the center of the cable, and it consists of cladding and core.

Construction of Fiber Optic Cable



Fiber Optic Cable

- 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.
- Local-area network such as Fast Ethernet uses fiber-optic cable.

Fiber Optic Cable

- **Advantages and Disadvantages of Optical Fiber**
- **Advantages**
- 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 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: Electromagnetic noise cannot affect fiber-optic cables.
- Resistance to corrosive materials: Glass is more resistant to corrosive materials than copper.

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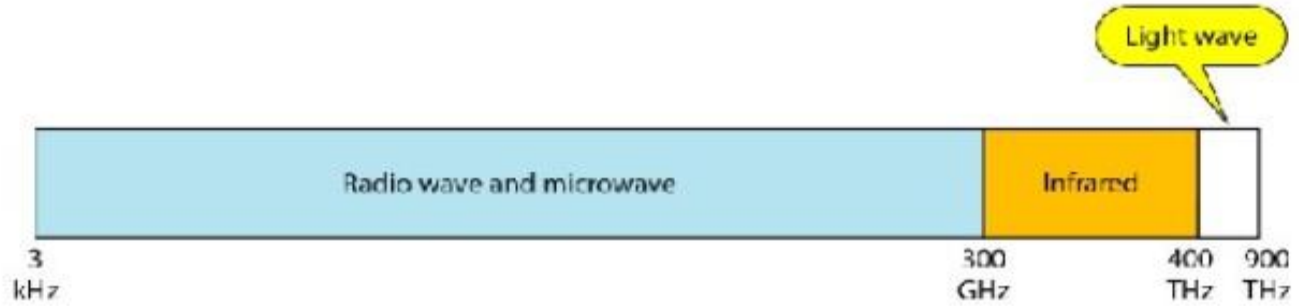
Fiber Optic Cable

- Light weight: Fiber-optic cables are much lighter than copper cables.
- Greater immunity to tapping: Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped
- **Disadvantages**
- 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

Unguided Media(Wireless)

- 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.



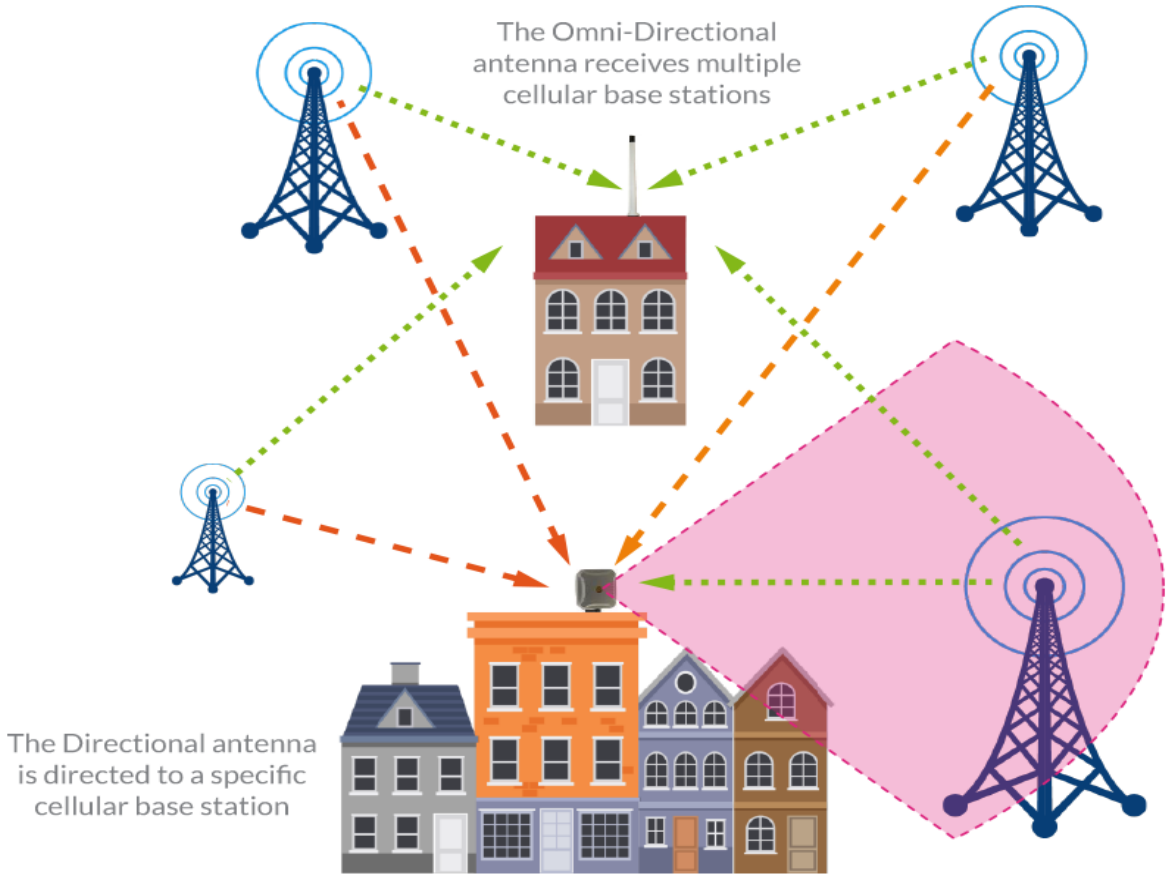
Unguided Media(Wireless)

- **Radio Waves**
- Waves ranging in frequencies between 3 kHz and 1 GHz are called radio 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.
- Radio waves, particularly those waves that propagate in the sky mode, can travel long distances.

Unguided Media(Wireless)

- 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.

Unguided Media(Wireless)



Unguided Media(Wireless)

- 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 are examples of multicasting.

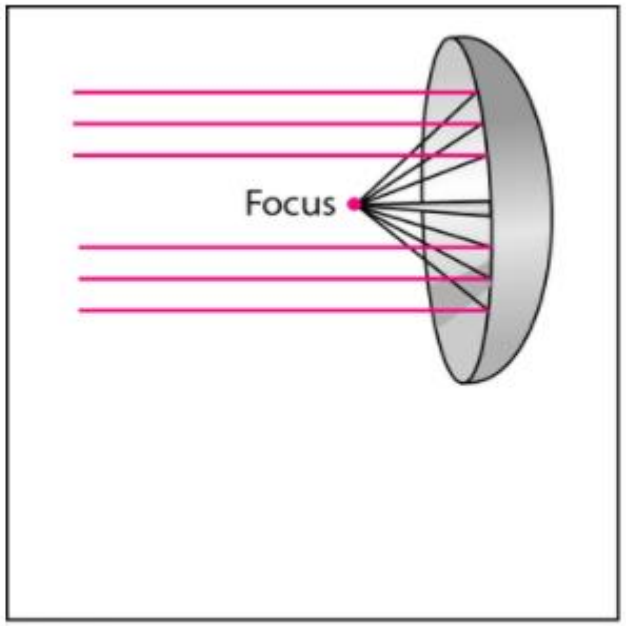
Unguided Media(Wireless)

- **Microwaves**
- Electromagnetic waves having 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.

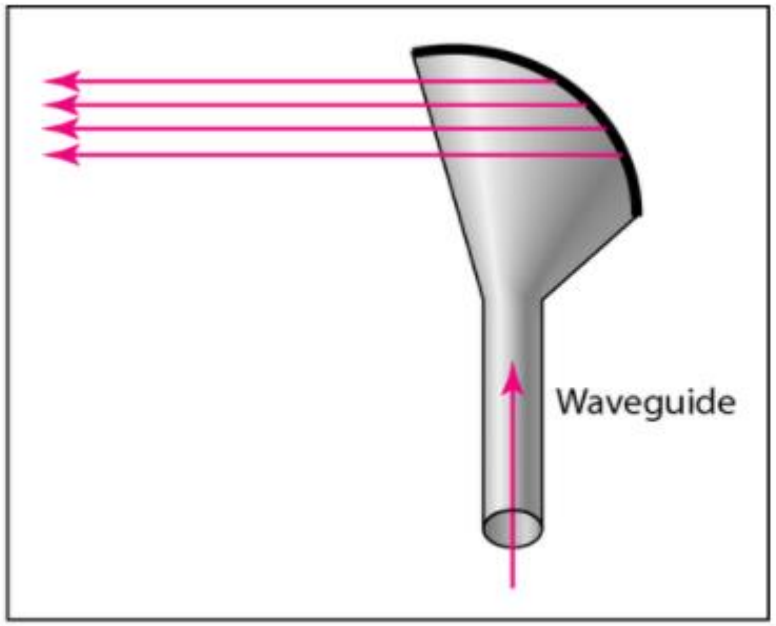
Unguided Media(Wireless)

- 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 (see Figure).
- 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.
- 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.

Unguided Media(Wireless)



a. Dish antenna



b. Horn antenna

Unguided Media(Wireless)

- **Characteristics of Microwave:**
- **Frequency range:** The frequency range of microwaves is from 4-6 GHz to 21-23 GHz.
- **Bandwidth:** It supports the bandwidth from 1 to 10 Mbps.
- **Short distance:** It is inexpensive for short distances.
- **Long distance:** It is expensive as it requires a higher tower for a longer distance.
- **Attenuation:** Attenuation means loss of signal.
- It is affected by environmental conditions and antenna size.

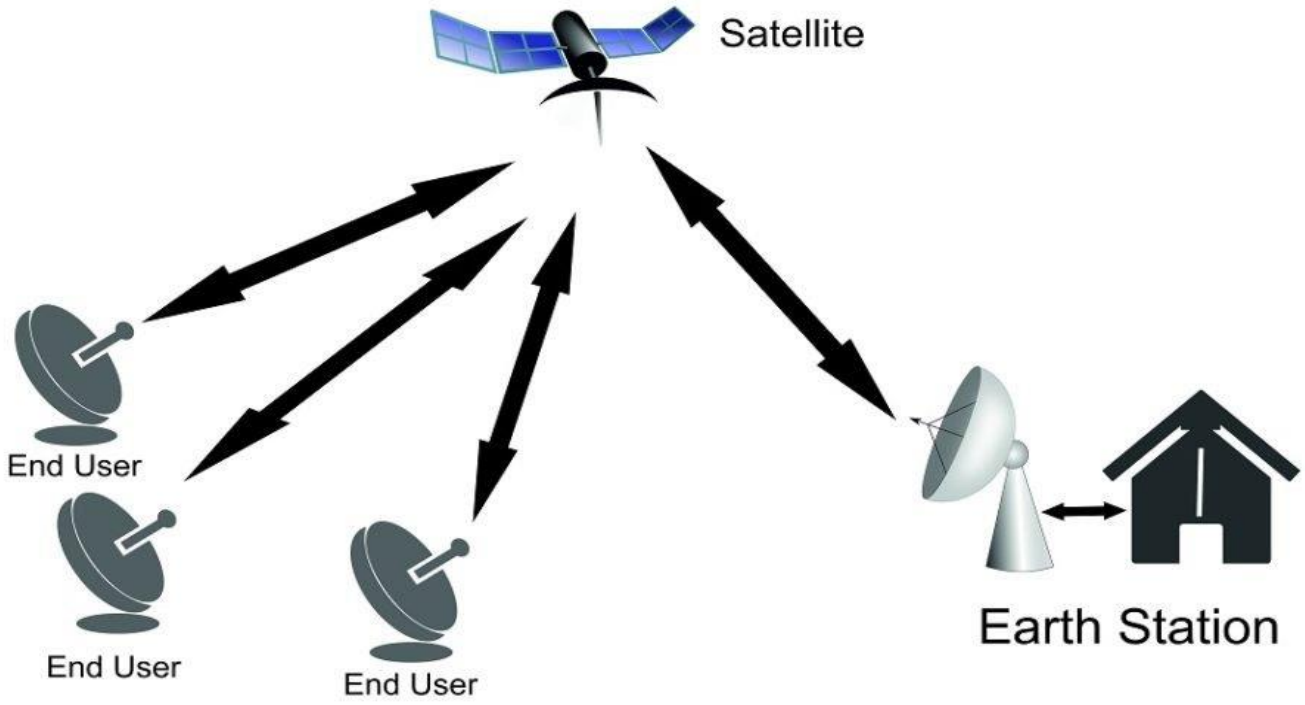
Unguided Media(Wireless)

- **VSAT(Very Small Aperture Terminal)**
- A very small aperture terminal (VSAT) is a small telecommunication earth station that receives and transmits real-time data via satellite.
- A VSAT end user needs a box that interfaces between the user's computer and an outside antenna with a transceiver.
- The transceiver receives or sends a signal to a satellite transponder in the sky.
- The satellite sends and receives signals from an earth station computer that acts as a hub for the system.
- For one end user to communicate with another, each transmission has to first go to the hub station which retransmits it via the satellite to the other end user's VSAT.

Unguided Media(Wireless)

- VSAT is designed to serve both businesses and individuals and involves the use of specific technology and devices that are designed to facilitate effective telecommunications and Internet connectivity.
- When the system is comprised of multiple users, in order to establish communications with one another the data must be transmitted to the station-based PC which sends the signal to the sky satellite.
- The satellite sky transponder then forwards the data transmission to the end user’s VSAT antenna and finally to the end user’s device.
- A main advantage of VSAT is it provides companies with complete control over their own communications infrastructure without having to depend upon third party sources.

Unguided Media(Wireless)

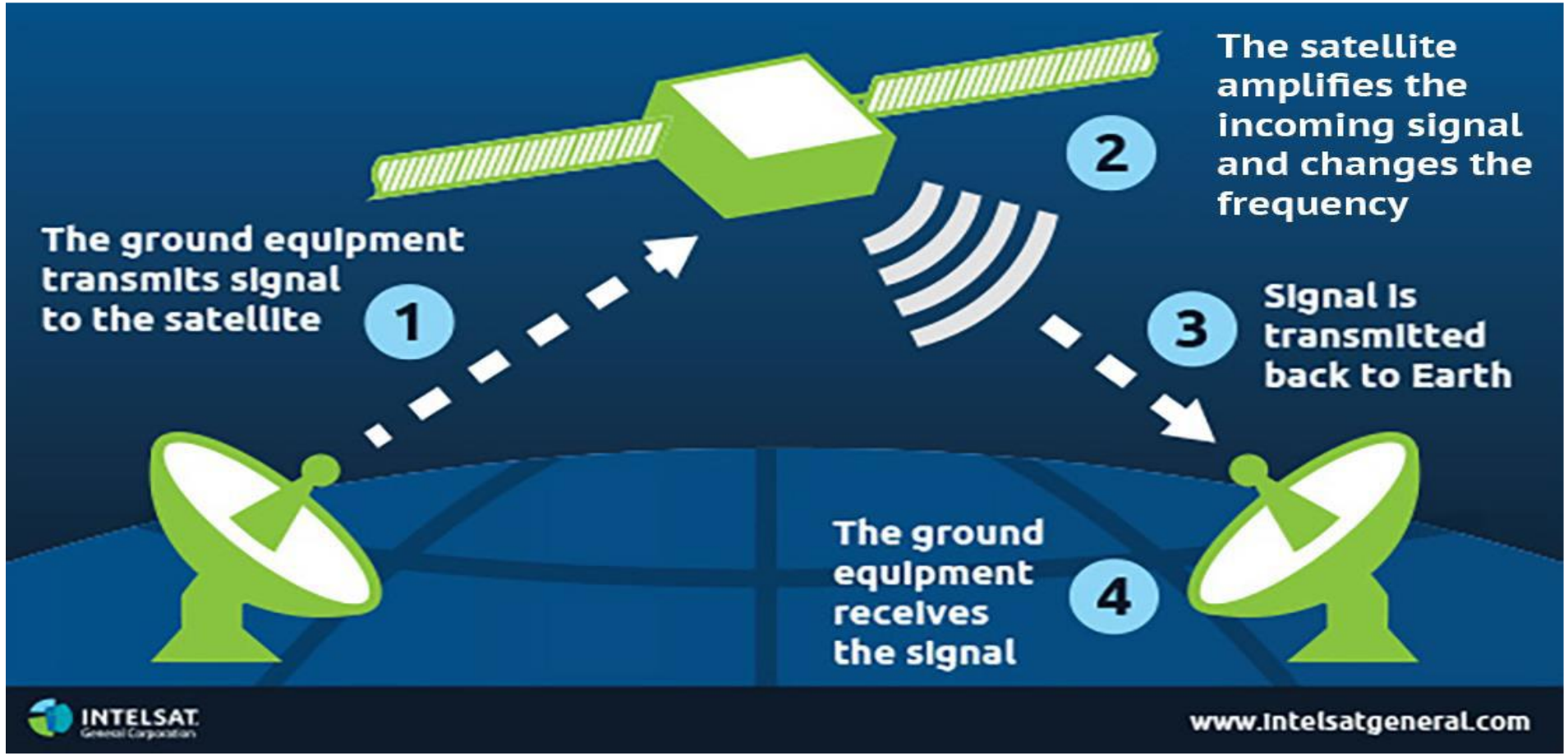


VSAT Communication System

Unguided Media(Wireless)

- **Satellite:**
- A communications satellite is an artificial satellite that relays and amplifies radio telecommunications signals via a transponder
- It creates a communication channel between a source transmitter and a receiver at different locations on Earth.
- Communications satellites are used for television, telephone, radio, internet, and military applications.
- The purpose of communications satellites is to relay the signal around the curve of the earth allowing communication between widely separated geographical points.
- Applications: Television, Internet, Military

Unguided Media(Wireless)



Antennas

- An Antenna (or sometimes called an Aerial), is an electrical device that converts electric power into electromagnetic waves (or simply radio waves) and vice-versa.
- A signal from a transmission line or the guiding device (hence the term guided wave) like a co-axial cable, is given to an antenna, which then converts the signal into electromagnetic energy to be transmitted through space (hence the term free space).
- Antenna can be used for both Transmission and Reception of electromagnetic radiation i.e. a Transmitting Antenna with collect electrical signals from a transmission line and converts them into radio waves whereas a Receiving Antenna does the exact opposite i.e. it accepts radio waves from the space and converts them to electrical signals and gives them to a transmission line.

Antennas

- **Different types of antennas:**
- **Wire Antennas**
- One of the most commonly used antennas is wire antennas.
- They can be found in vehicles (automobiles), ships, aircraft, buildings, etc.
- Wire Antennas come in different shapes and sizes like straight wire (Dipole), Loop, and Helix.
- **Short Dipole Antenna**
- Perhaps the simplest of all antennas is the Short Dipole Antenna.
- It is a special case of the Dipole antenna.
- In its simplest form, it is basically an open circuit wire with the signal being fed at the center.
- The term “short” in short dipole antenna doesn’t directly refer to its size but rather to the size of the wire relative to the wavelength of the signal.

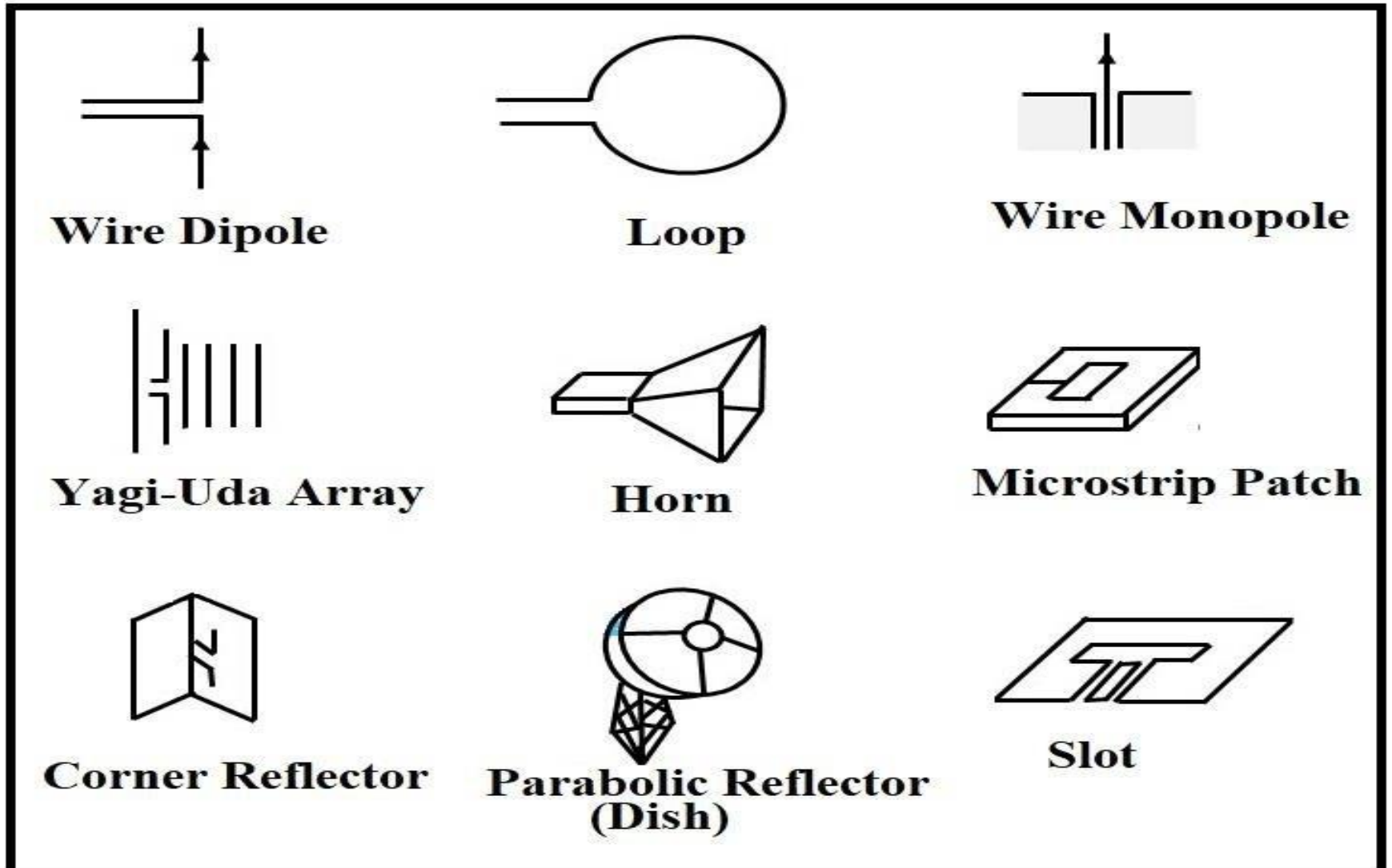
Antennas

- **Dipole Antenna**
- A Dipole Antenna is made up of two conductors on the same axis and the length of the wire needs to be small compared to the wavelength.
- **Loop Antenna**
- A Loop antenna is formed by single or multiple turns of wire forming a loop.
- The radiation produced by a loop antenna is comparable to a short dipole antenna.
- **Monopole Antenna**
- A special case of Dipole antenna is the monopole antenna i.e. it is half of the dipole antenna.
- **Aperture Antennas**
- A class of directional antennas, Aperture Antennas have an opening in the surface.
- Usually, an aperture antenna consists of Dipole or Loop Antenna in a guiding structure with an opening to emit radio waves.

Antennas

- **Slot Antenna**
- A type of aperture antenna which contains one or more slots cut on the surface of the waveguide.
- They are usually used in microwave frequencies and have an omnidirectional radiation pattern.
- **Horn Antenna**
- One of the most popular antennas is the Horn Antenna, which effects the transition between the transmission line and wave propagating in free space.
- It acts as a natural extension to a waveguide.

Antennas


Wire Dipole
Loop
Wire Monopole
Yagi-Uda Array
Horn
Microstrip Patch
Corner Reflector
Parabolic Reflector
(Dish)
Slot

THANK YOU