

CAP275: Data Communication and Networking

Unit-2: Physical Layer - Transmission Media

Dr. Manmohan Sharma
School of Computer Applications
Lovely Professional University

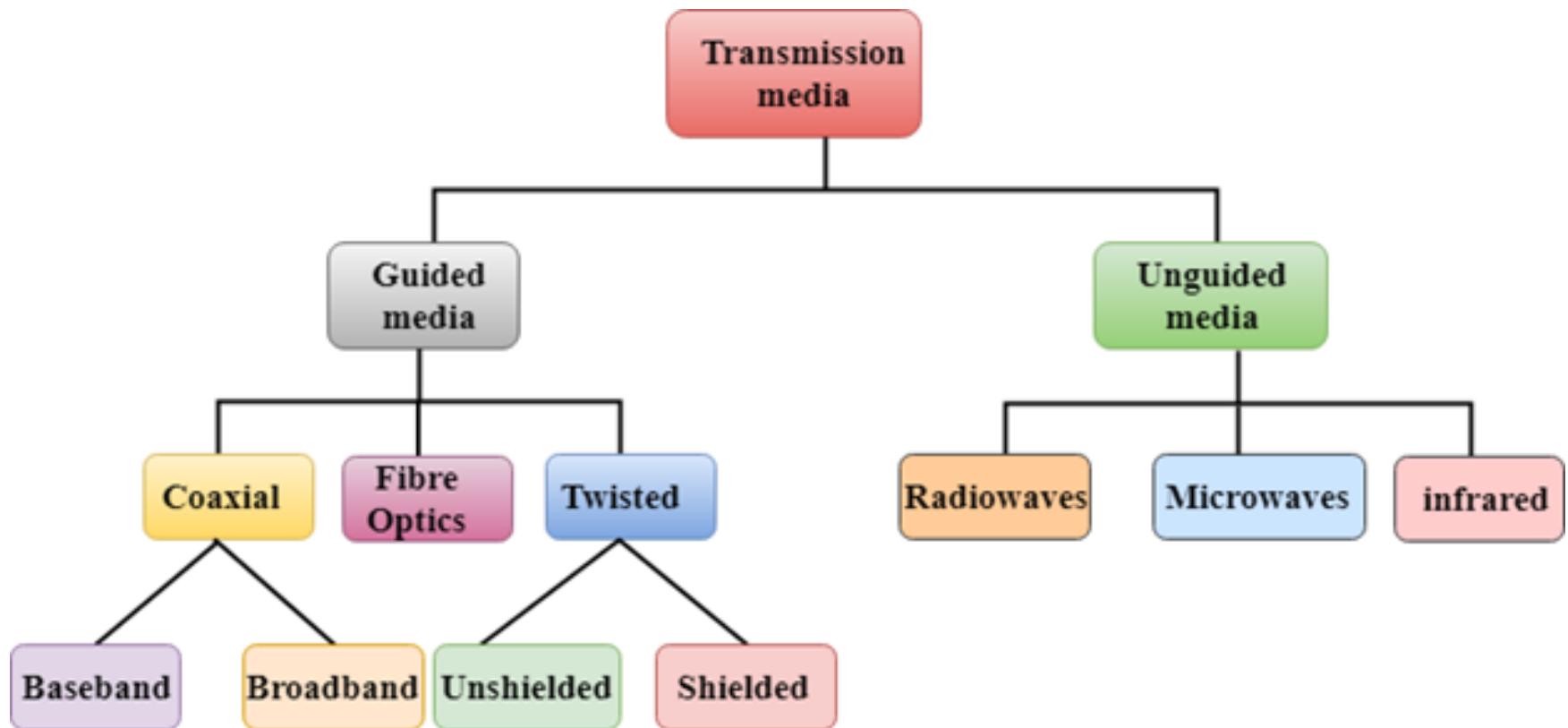
Transmission Media

- Transmission media is a communication channel that carries the information from the sender to the receiver. Data is transmitted through the electromagnetic signals.
- The main functionality of the transmission media is to carry the information in the form of bits through **LAN**(Local Area Network).
- It is a physical path between transmitter and receiver in data communication.
- In a copper-based network, the bits in the form of electrical signals.
- In a fibre based network, the bits in the form of light pulses.
- The transmission media is available in the lowest layer of the OSI reference model, i.e., **Physical layer**.

- In **OSI**(Open System Interconnection) phase, transmission media supports the Layer 1. Therefore, it is considered to be as a Layer 1 component.
- The electrical signals can be sent through the copper wire, fibre optics, atmosphere, water, and vacuum.
- The characteristics and quality of data transmission are determined by the characteristics of medium and signal.
- Transmission media is of two types are wired media and wireless media. In wired media, medium characteristics are more important whereas, in wireless media, signal characteristics are more important.
- Different transmission media have different properties such as bandwidth, delay, cost and ease of installation and maintenance.

Classification Of Transmission Media

- Transmission media is divided into two classes:
 - Guided (wired) Media
 - Unguided (wireless) Media



Factors Affecting Transmission Media

- **Bandwidth:** All the factors are remaining constant, the greater the bandwidth of a medium, the higher the data transmission rate of a signal.
- **Transmission impairment:** When the received signal is not identical to the transmitted one due to the transmission impairment. The quality of the signals will get destroyed due to transmission impairment.
 - **Attenuation:** Attenuation means the loss of energy, i.e., the strength of the signal decreases with increasing the distance which causes the loss of energy.
 - **Distortion:** Distortion occurs when there is a change in the shape of the signal. This type of distortion is examined from different signals having different frequencies. Each frequency component has its own propagation speed, so they reach at a different time which leads to the delay distortion.
 - **Noise:** When data is travelled over a transmission medium, some unwanted signal is added to it which creates the noise.
- **Interference:** An interference is defined as the process of disrupting a signal when it travels over a communication medium on the addition of some unwanted signal.

Guided Media

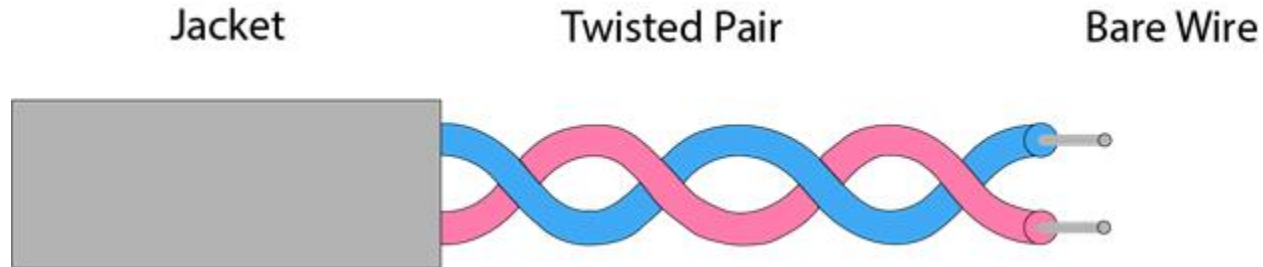
- It is defined as the physical medium through which the signals are transmitted. It is also known as Bounded media.
- Types Of Guided media:
 - Twisted pair
 - Unshielded Twisted Pair
 - Shielded Twisted Pair
 - Coaxial Cable
 - Baseband
 - Broadband
 - Fibre Optic
 - Single Mode
 - Multimode
 - Step Index
 - Graded Index

Transmission Characteristics of Guided Media

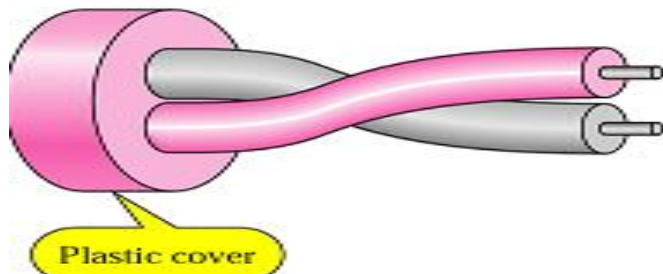
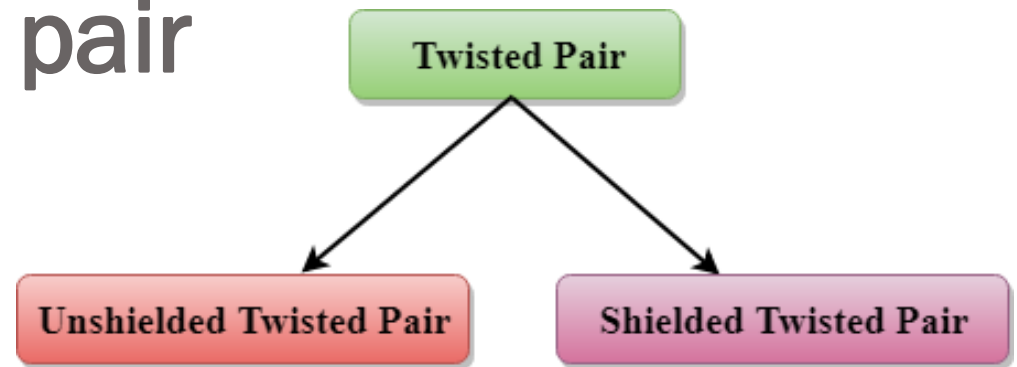
	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μ s/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μ s/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μ s/km	1 to 9 km
Optical fiber	186 to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

Twisted Pair

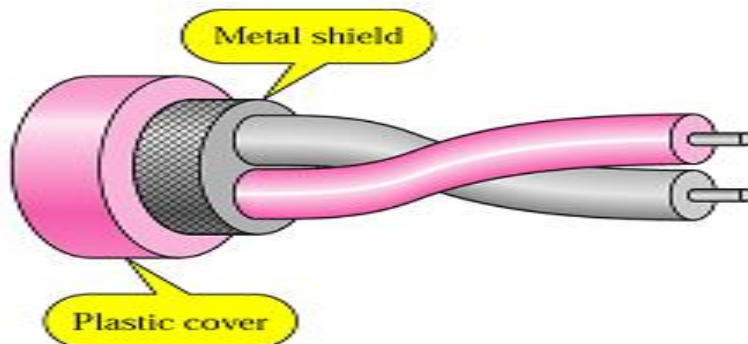
- Twisted pair is a physical media made up of a pair of cables twisted with each other.
- A twisted pair cable is cheap as compared to other transmission media.
- Installation of the twisted pair cable is easy, and it is a lightweight cable. The frequency range for twisted pair cable is from 0 to 3.5KHz.
- A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern.
- The degree of reduction in noise interference is determined by the number of turns per foot. Increasing the number of turns per foot decreases noise interference.



Types of Twisted pair



a. UTP



b. STP



Unshielded Twisted Pair

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)

Shielded Twisted Pair

A shielded twisted pair is a cable that contains the mesh surrounding the wire that allows the higher transmission rate.

The following summarizes the features of STP cable:

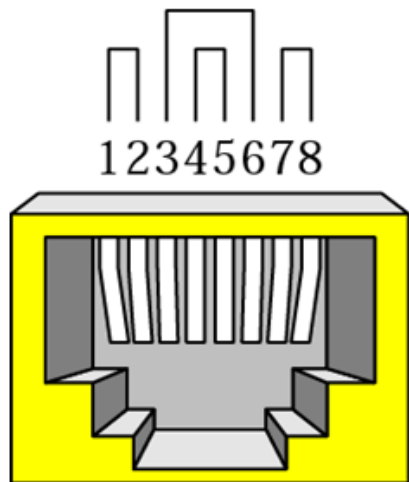
- Speed and throughput—10 to 100 Mbps
- Average cost per node—Moderately expensive
- Media and connector size—Medium to large
- Maximum cable length—100 m (short)

When comparing UTP and STP, keep the following points in mind:

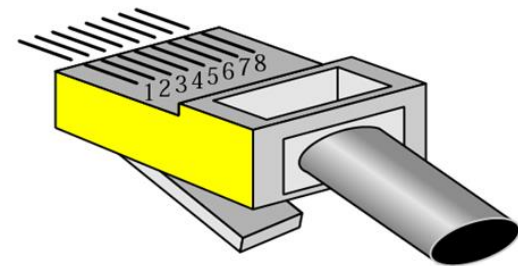
- The speed of both types of cable is usually satisfactory for local-area distances.
- These are the least-expensive media for data communication. UTP is less expensive than STP.
- Because most buildings are already wired with UTP, many transmission standards are adapted to use it, to avoid costly rewiring with an alternative cable type.

Connectors

- The most common UTP connector is RJ45 (RJ stands for registered jack)
- The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.



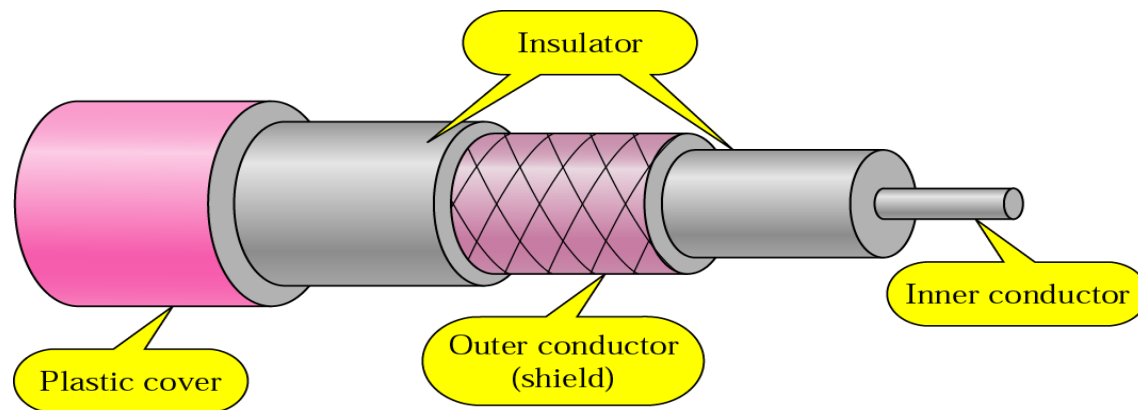
RJ-45 Female



RJ-45 Male

Coaxial Cable

- Coaxial cable is very commonly used transmission media, for example, TV wire is usually a coaxial cable.
- The name of the cable is coaxial as it contains two conductors parallel to each other.
- It has a higher frequency as compared to Twisted pair cable.
- The inner conductor of the coaxial cable is made up of copper, and the outer conductor is made up of copper mesh. The middle core is made up of non-conductive cover that separates the inner conductor from the outer conductor.
- The middle core is responsible for the data transferring whereas the copper mesh prevents from the **EMI**(Electromagnetic interference).

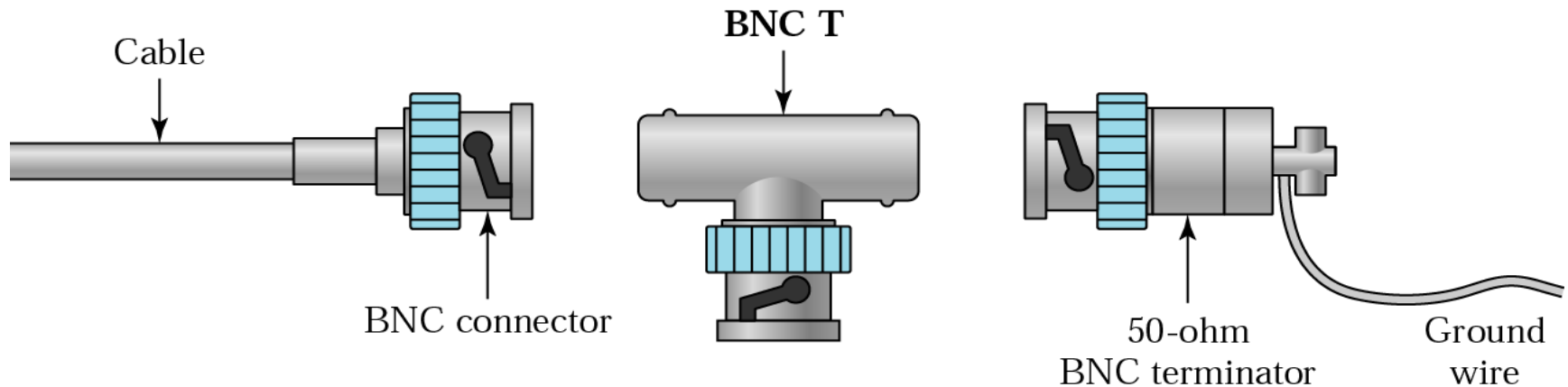


- **Coaxial cable is of two types:**
 - **Baseband transmission:** It is defined as the process of transmitting a single signal at high speed.
 - **Broadband transmission:** It is defined as the process of transmitting multiple signals simultaneously.

<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

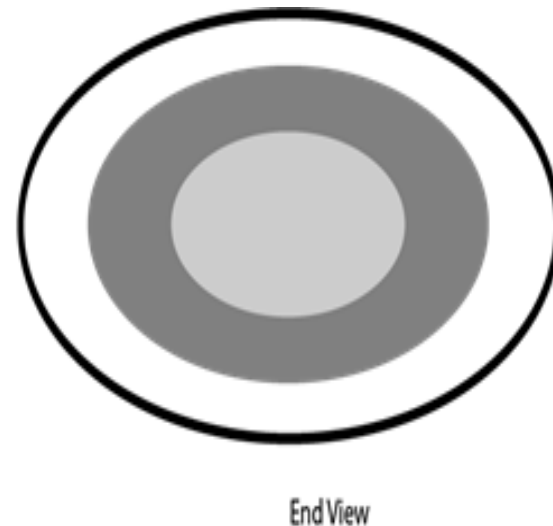
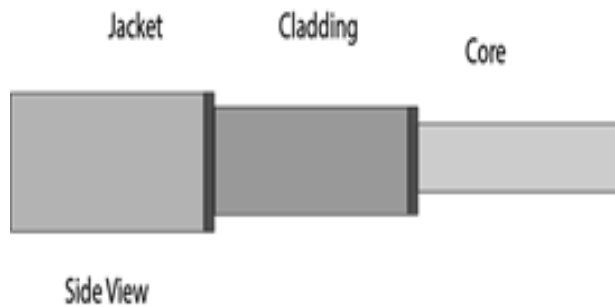
Connectors

- Bayonet Neill Concelman connectors are used for connection in Coaxial Cables.



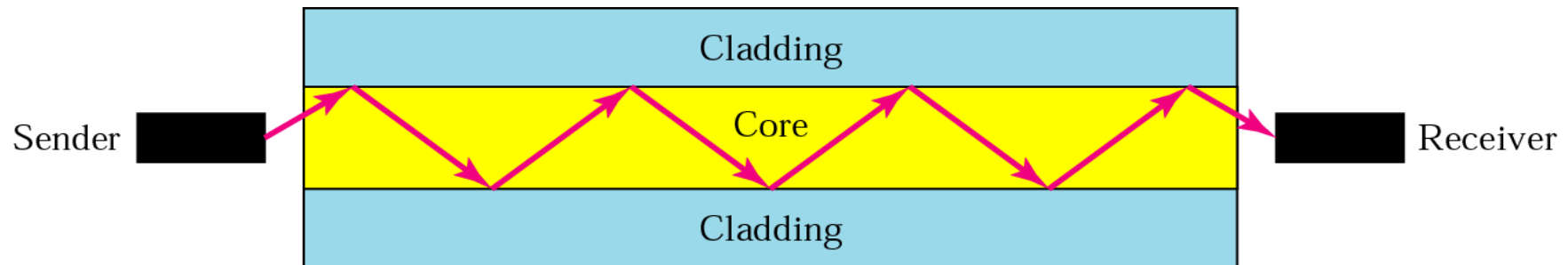
Fibre Optics Cable

- Fibre optic cable is a cable that uses light signals for communication.
- Fibre optic is a cable that holds the optical fibres coated in plastic that are used to send the data by pulses of light.
- The plastic coating protects the optical fibres from heat, cold, electromagnetic interference from other types of wiring.
- Fibre optics provide faster data transmission than copper wires.

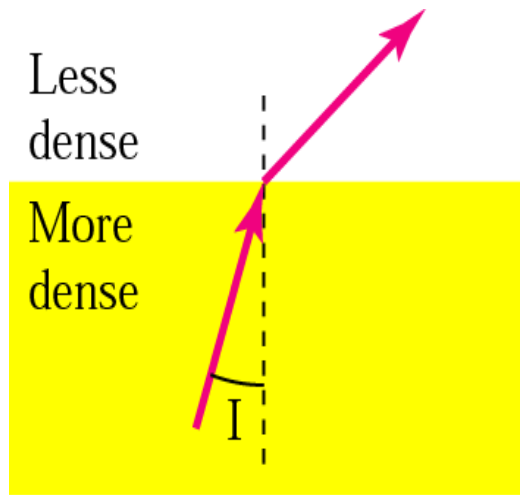


Basic elements of Fibre optic cable:

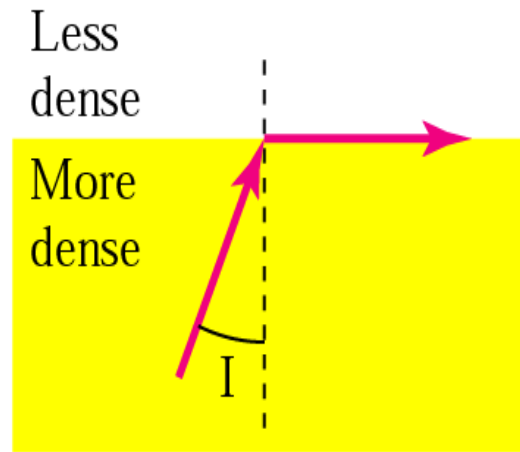
- **Core:** The optical fibre consists of a narrow strand of glass or plastic known as a core. A core is a light transmission area of the fibre. The more the area of the core, the more light will be transmitted into the fibre.
- **Cladding:** The concentric layer of glass is known as cladding. The main functionality of the cladding is to provide the lower refractive index at the core interface as to cause the reflection within the core so that the light waves are transmitted through the fibre.
- **Jacket:** The protective coating consisting of plastic is known as a jacket. The main purpose of a jacket is to preserve the fibre strength, absorb shock and extra fibre protection.



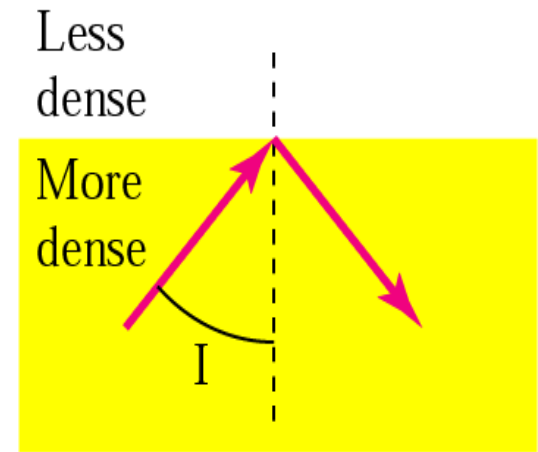
How Optical fiber works



$I < \text{critical angle,}$
refraction



$I = \text{critical angle,}$
refraction

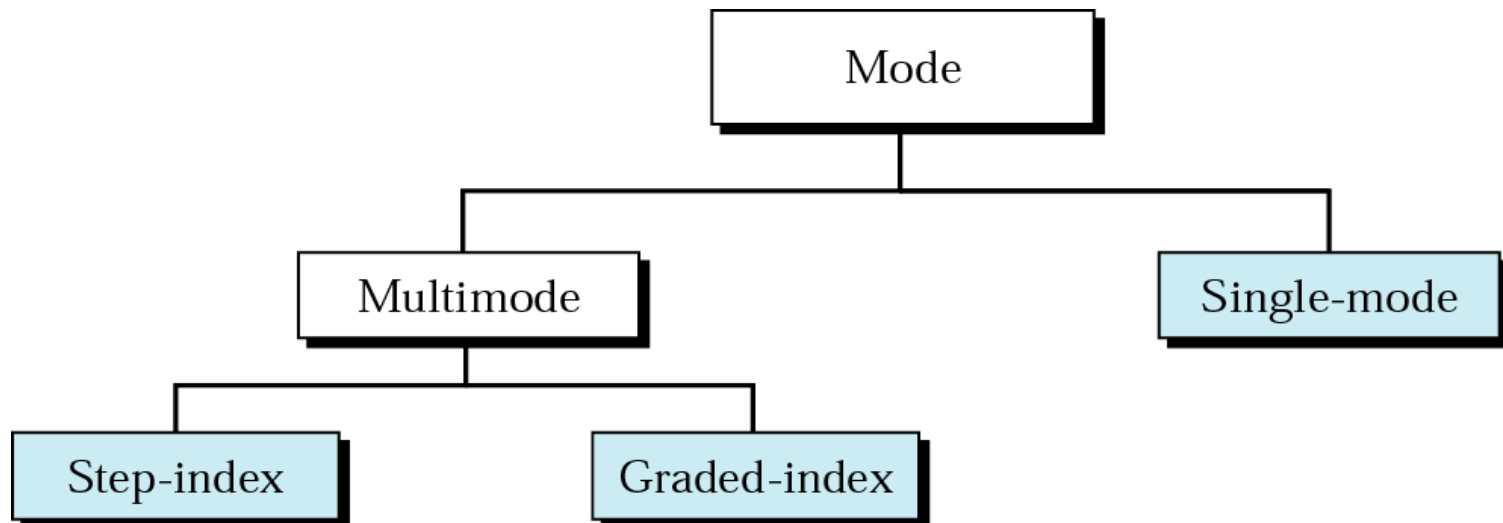


$I > \text{critical angle,}$
reflection

- <https://youtu.be/jZOg39v73c4>

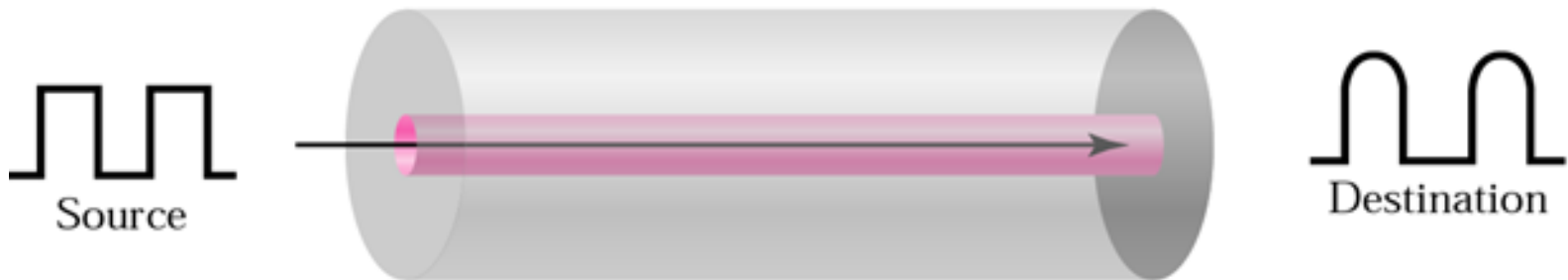
Propagation Modes

- There are 2 types of propagation mode in fiber optics cable which are multi-mode and single-mode.
- These provide different performance with respect to both attenuation and time dispersion.
- The single-mode fiber optic cable provides the better performance at a higher cost.



Single-mode

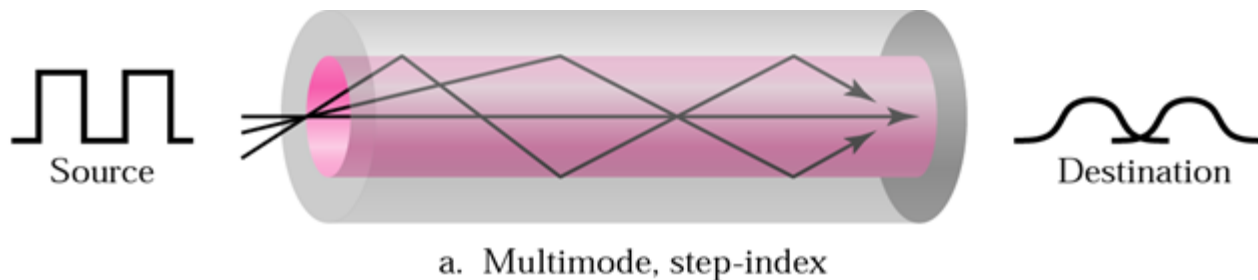
- The diameter of the core is fairly small relative to the cladding. Typically, the cladding is ten times thicker than the core.
- When fiber core radius is reduced, fewer angles will reflect. By reducing the radius of the core to the order of a wavelength, only a single angle or mode can pass – the axial ray.
- Single mode propagation exists only above a certain specific wavelength called the cutoff wavelength.



c. Single-mode

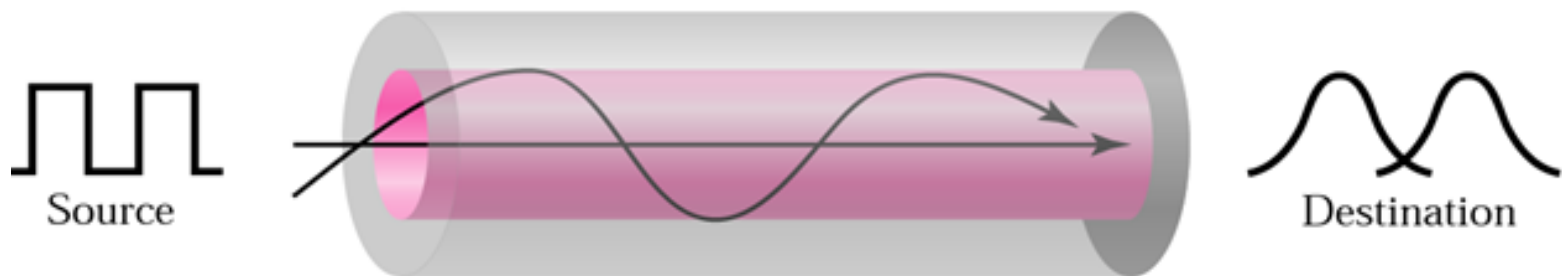
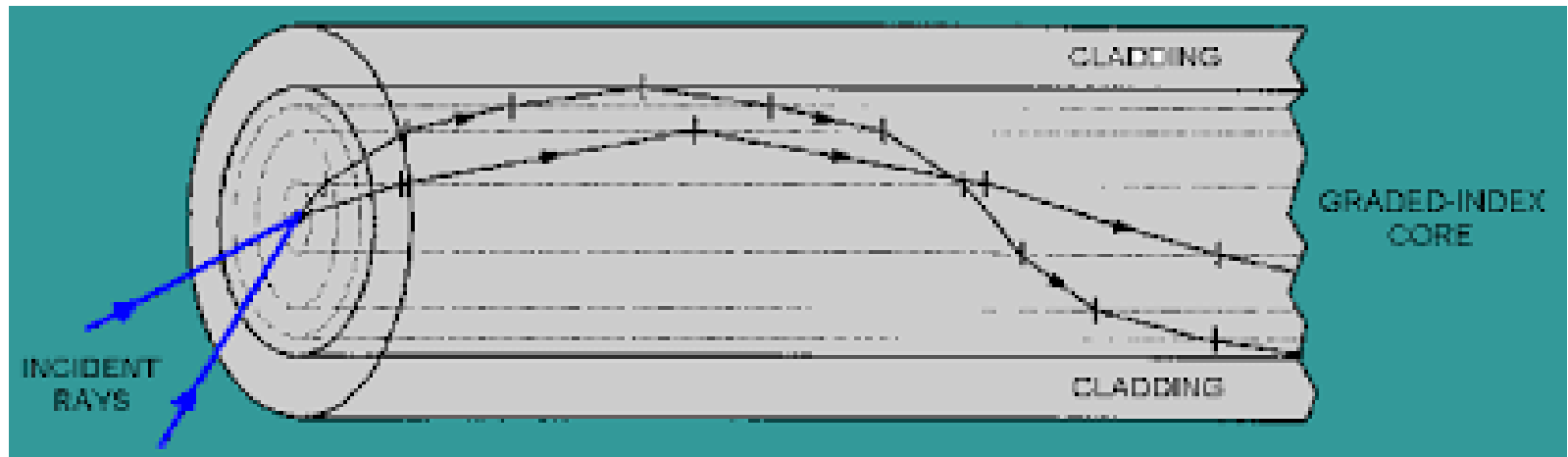
Multi-mode Step Index

- Refers to the variety of angles that will reflect. Multiple propagation path exists, signal elements spread out in time and hence the data rate.



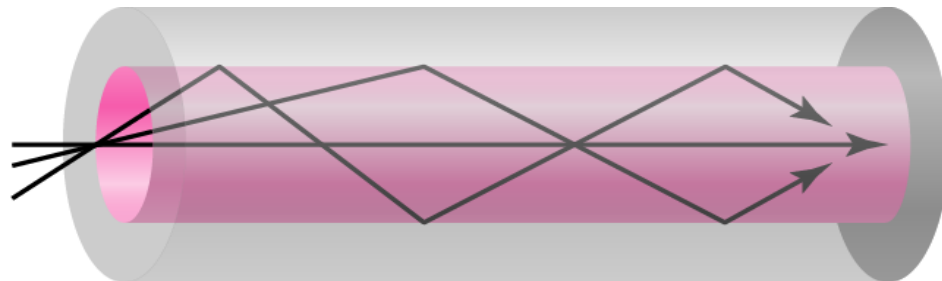
Multi-mode Graded Index

- By varying the refractive index of the core, rays may be focused more efficiently than multimode.



b. Multimode, graded-index

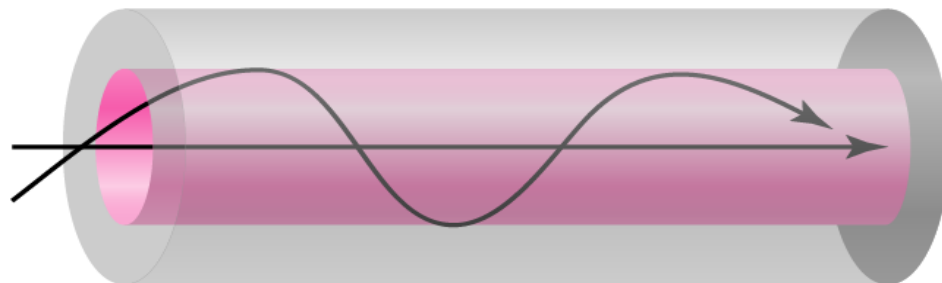
Source



Destination

a. Multimode, step-index

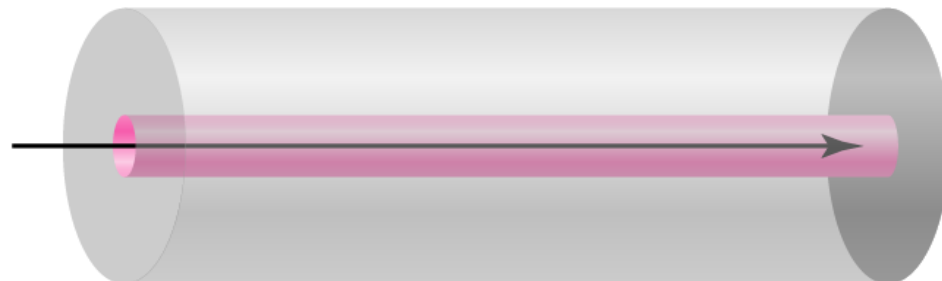
Source



Destination

b. Multimode, graded-index

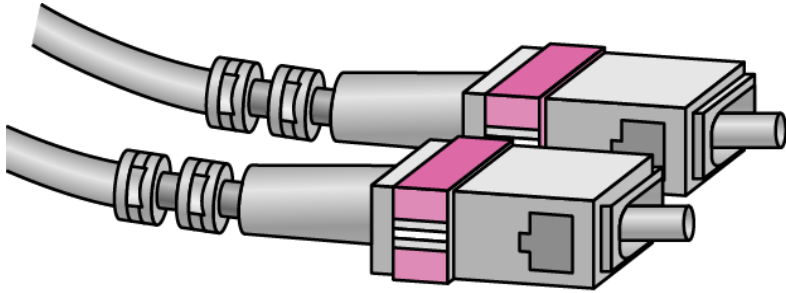
Source



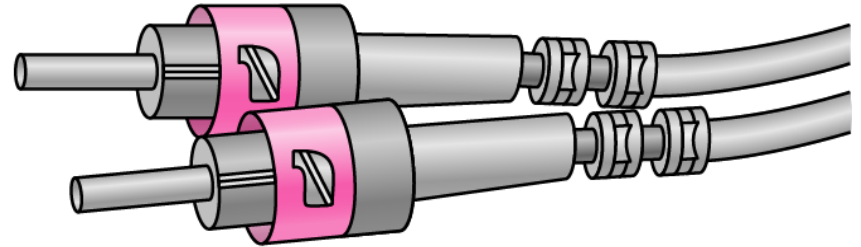
Destination

c. Single-mode

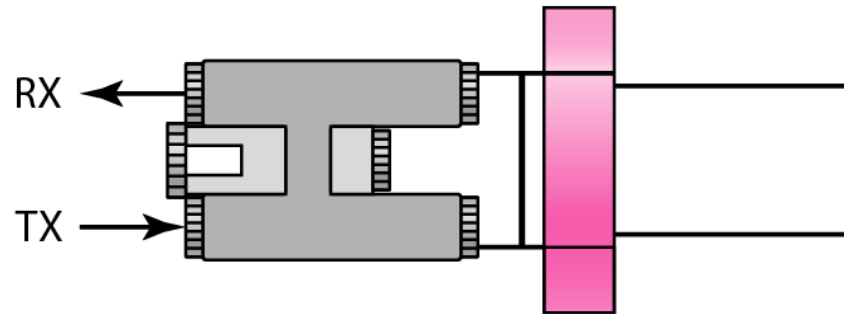
Fiber-optic cable connectors



SC connector



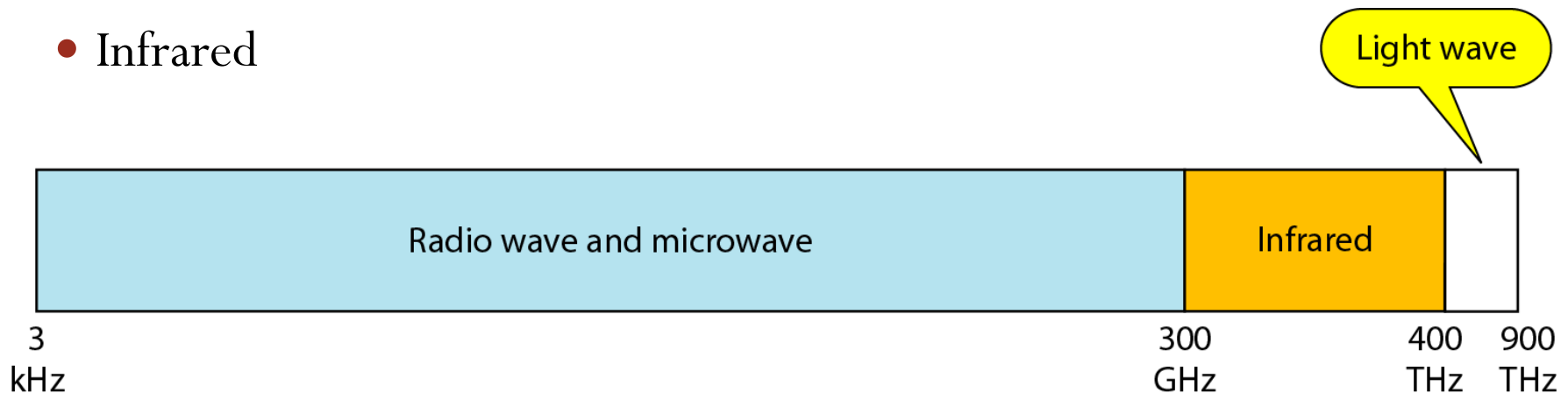
ST connector



MT-RJ connector

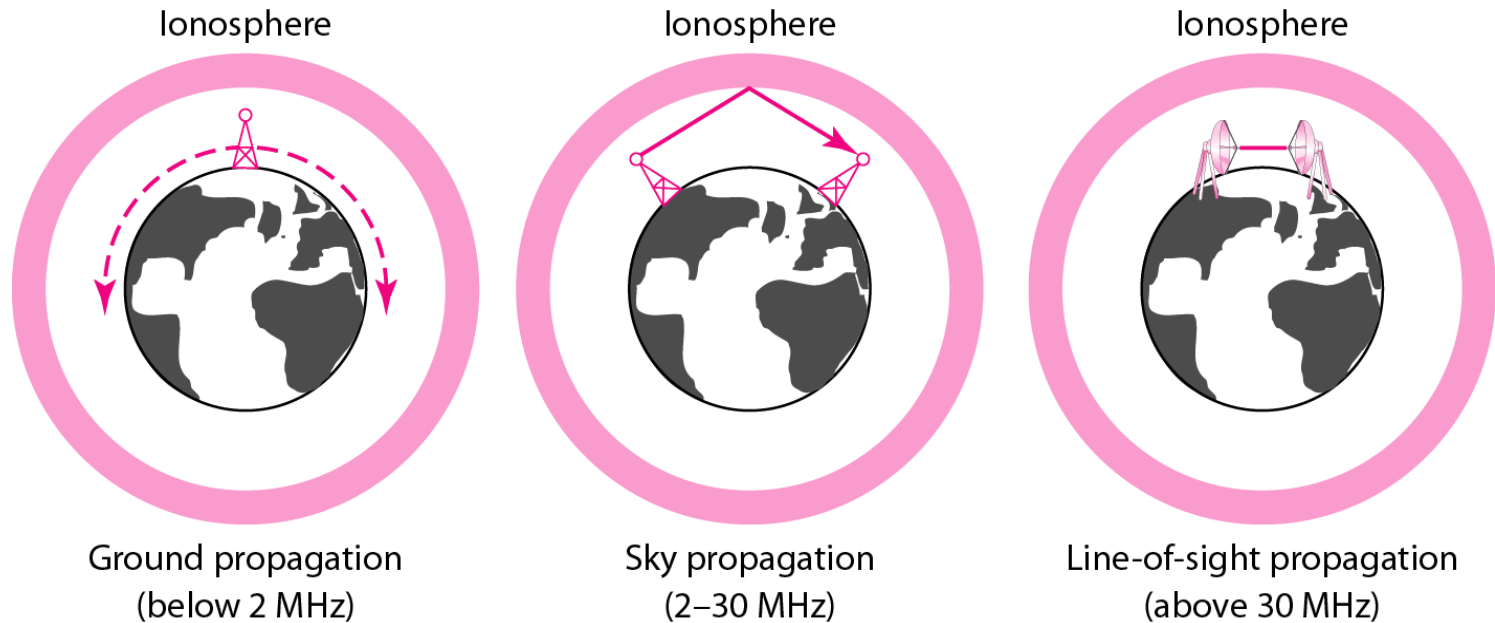
Unguided Transmission

- An unguided transmission transmits the electromagnetic waves without using any physical medium. Therefore it is also known as **wireless transmission**.
- In unguided media, air is the media through which the electromagnetic energy can flow easily.
- Unguided transmission is broadly classified into three categories:
 - Radio waves
 - Microwaves
 - Infrared



Modes of Propagation

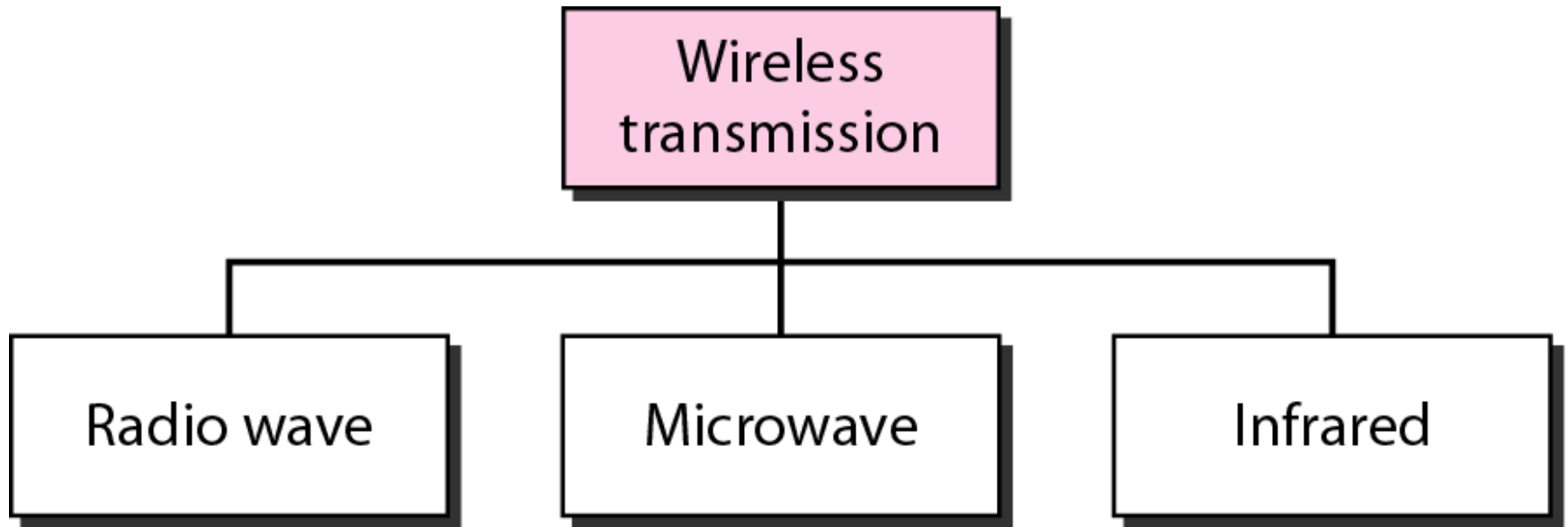
- In Radio communication systems, we use wireless electromagnetic waves as the channel. The antennas of different specifications can be used for these purposes.
- The mode of propagation of electromagnetic waves in the atmosphere and in free space may be divided into the following three categories:



Bands

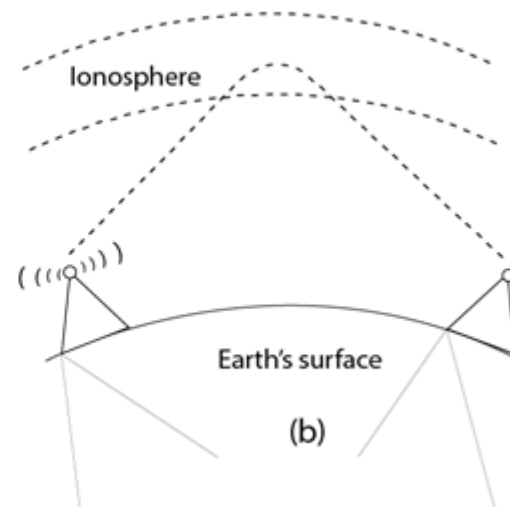
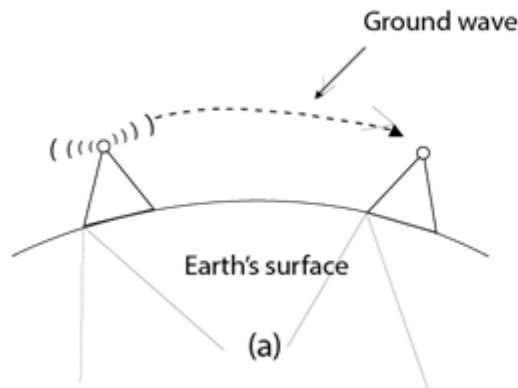
<i>Band</i>	<i>Range</i>	<i>Propagation</i>	<i>Application</i>
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (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

Wireless Transmission Waves

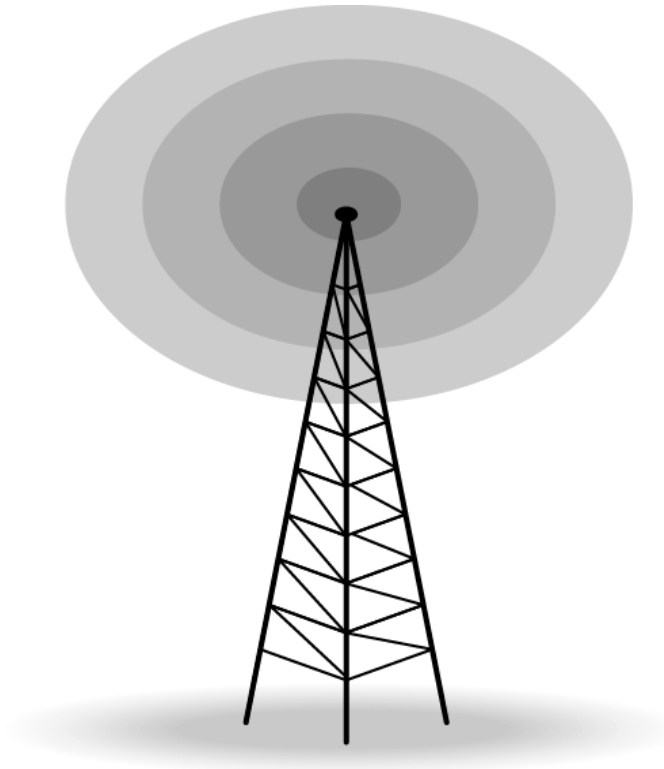


Radio waves

- Radio waves are the electromagnetic waves that are transmitted in all the directions of free space.
- Radio waves are omnidirectional, i.e., the signals are propagated in all the directions.
 - The range in frequencies of radio waves is from 3Khz to 1 khz.
- In the case of radio waves, the sending and receiving antenna are not aligned, i.e., the wave sent by the sending antenna can be received by any receiving antenna.
 - An example of the radio wave is **FM radio**.



- Radio waves are used for multicast communications, such as radio and television, and paging systems. They can penetrate through walls.
- Highly regulated. Use omni directional antennas



- **Applications of Radio waves:**

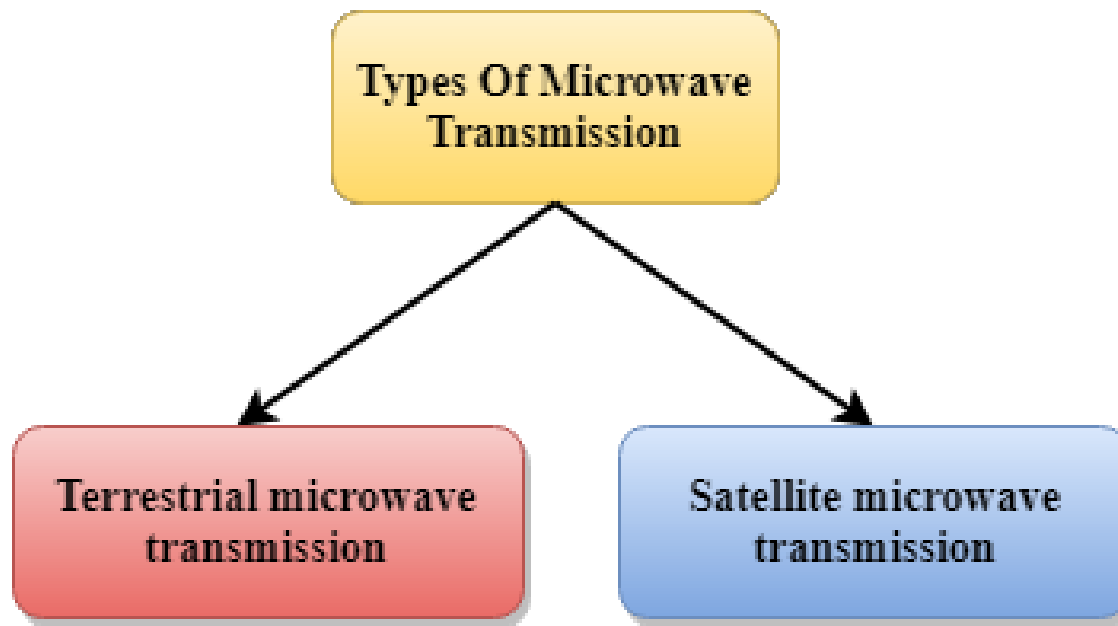
- A Radio wave is useful for multicasting when there is one sender and many receivers.
- An FM radio, television, cordless phones are examples of a radio wave.

- **Advantages of Radio transmission:**

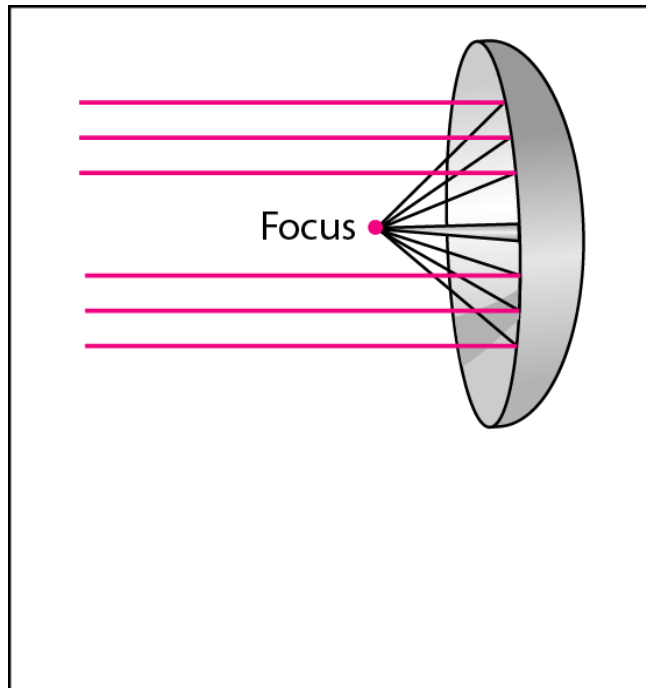
- Radio transmission is mainly used for wide area networks and mobile cellular phones.
- Radio waves cover a large area, and they can penetrate the walls.
- Radio transmission provides a higher transmission rate.

Microwaves

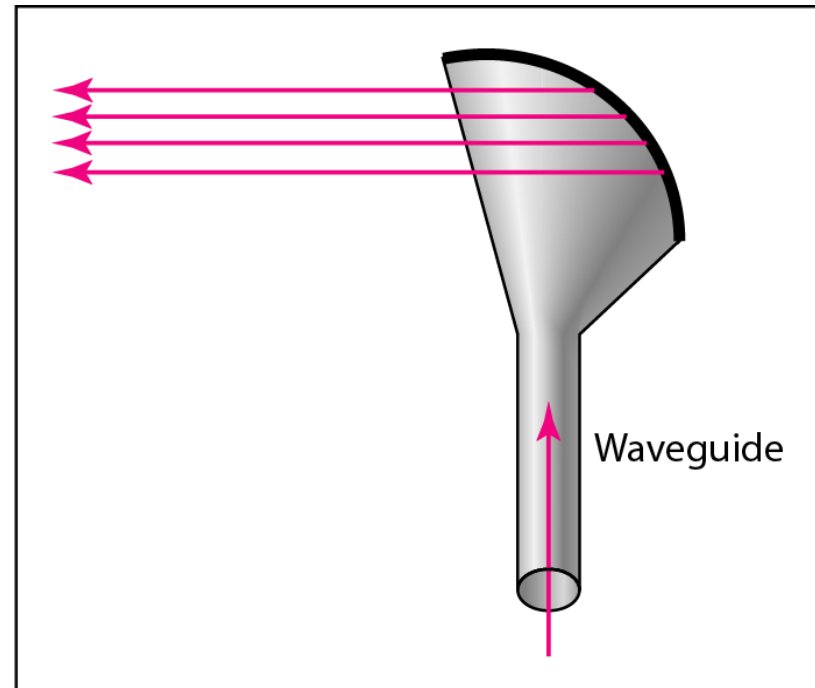
- Microwaves are of two types:
 - Terrestrial microwave
 - Satellite microwave communication



- Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.
- Higher frequency ranges cannot penetrate walls.
- Use directional antennas, point to point line of sight communications.



a. Dish antenna



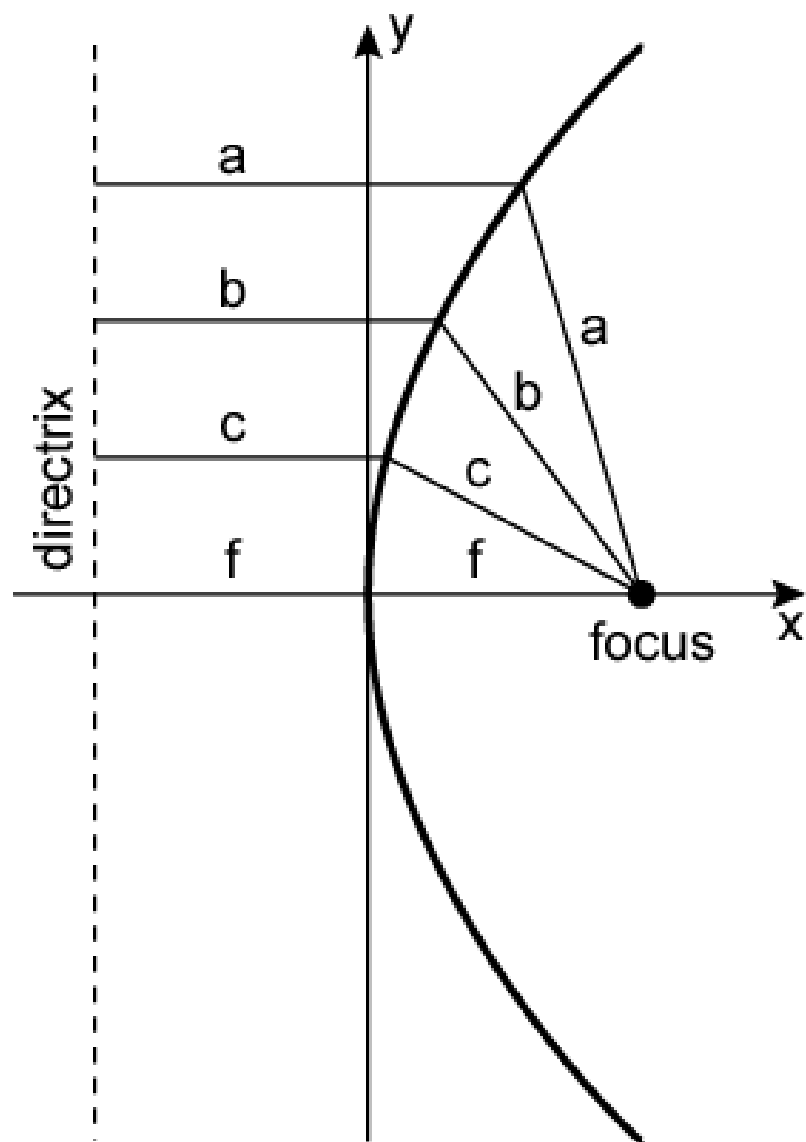
b. Horn antenna

Terrestrial Microwave Transmission

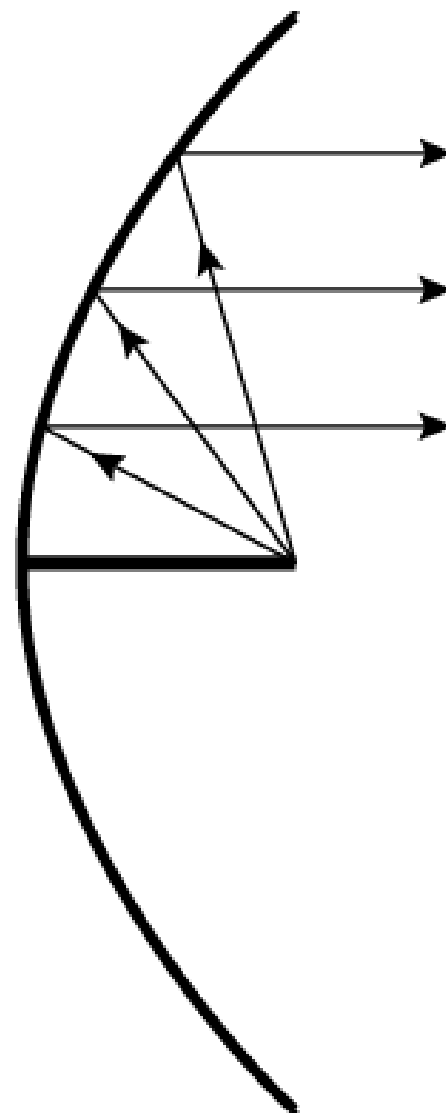
- Terrestrial Microwave transmission is a technology that transmits the focused beam of a radio signal from one ground-based microwave transmission antenna to another.
- Microwaves are the electromagnetic waves having the frequency in the range from 1GHz to 1000 GHz.
- Microwaves are unidirectional as the sending and receiving antenna is to be aligned, i.e., the waves sent by the sending antenna are narrowly focussed.
- In this case, antennas are mounted on the towers to send a beam to another antenna which is km away.
- It works on the line of sight transmission, i.e., the antennas mounted on the towers are the direct sight of each other.

Characteristics of Terrestrial Microwave:

- **Frequency range:** The frequency range of terrestrial microwave 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 distance.
- **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.



(a) Parabola



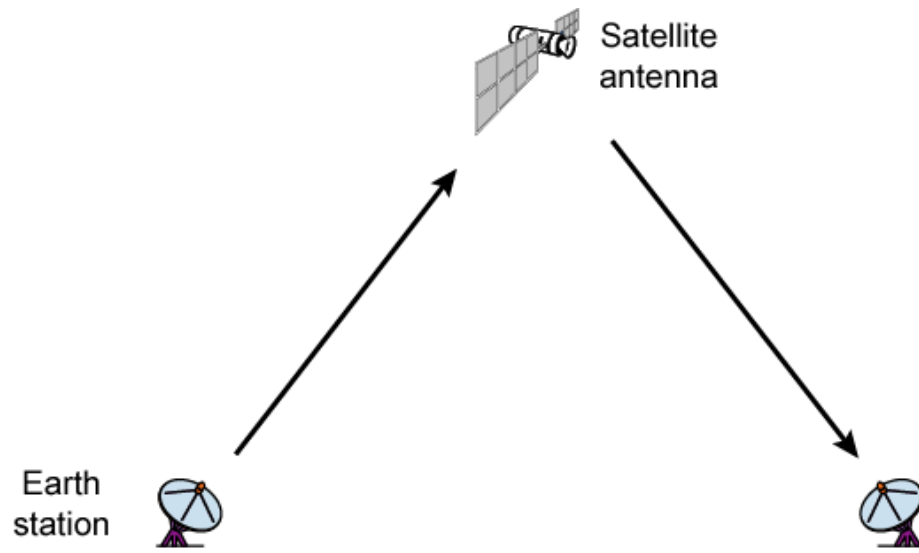
(b) Cross-section of parabolic antenna showing reflective property

Satellite Microwave Communication

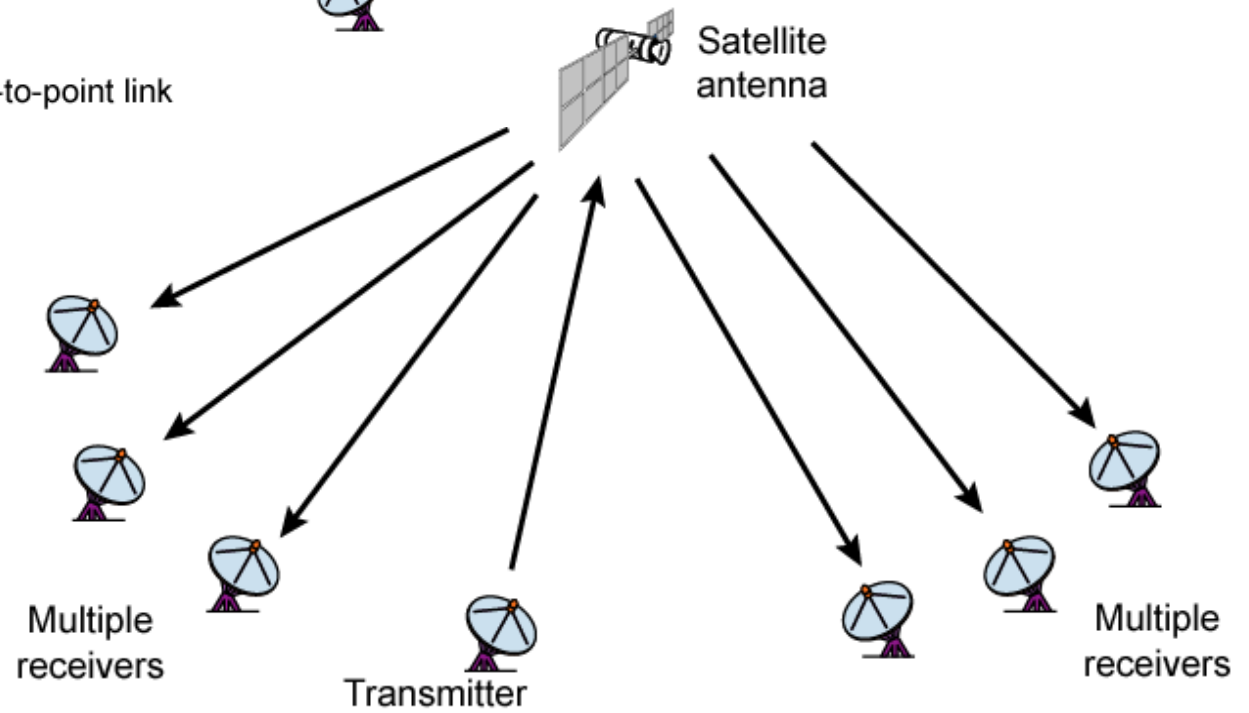
- A satellite is a physical object that revolves around the earth at a known height.
- Satellite communication is more reliable nowadays as it offers more flexibility than cable and fibre optic systems.
- We can communicate with any point on the globe by using satellite communication.

How Does Satellite work?

- The satellite accepts the signal that is transmitted from the earth station, and it amplifies the signal. The amplified signal is retransmitted to another earth station.
- <https://www.youtube.com/watch?v=hXa3bTcIGPU>



(a) Point-to-point link



(b) Broadcast link

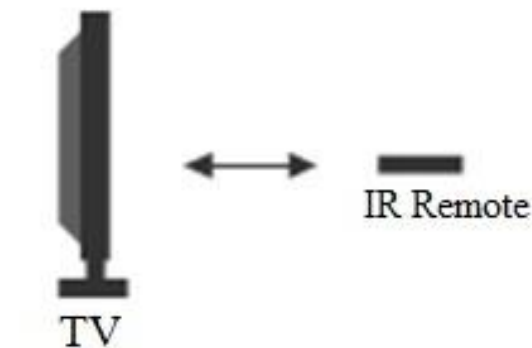
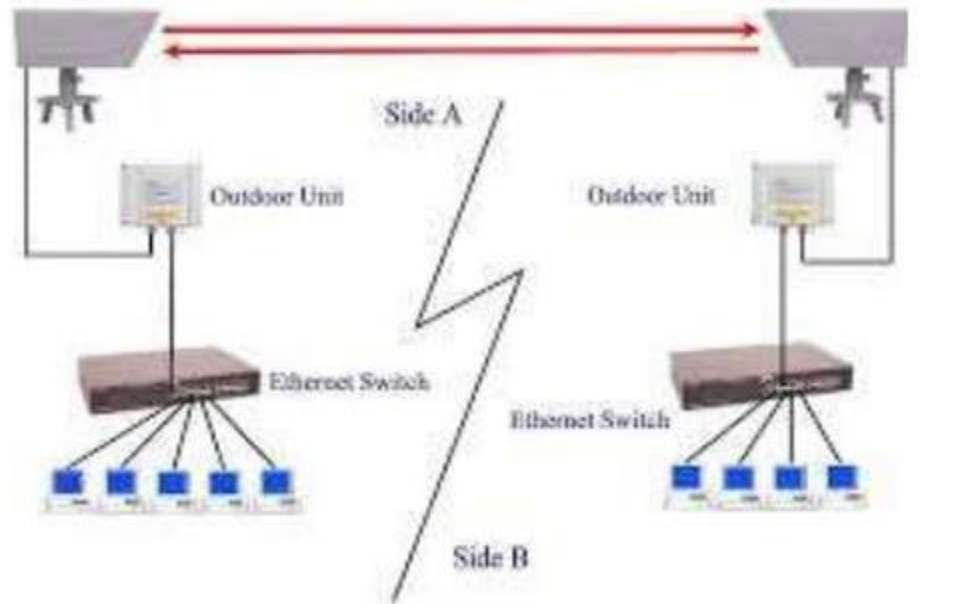
Infrared

- An infrared transmission is a wireless technology used for communication over short ranges.
- The frequency of the infrared is in the range from 300 GHz to 400 THz.
- It is used for short-range communication such as data transfer between two cell phones, TV remote operation, data transfer between a computer and cell phone resides in the same closed area.

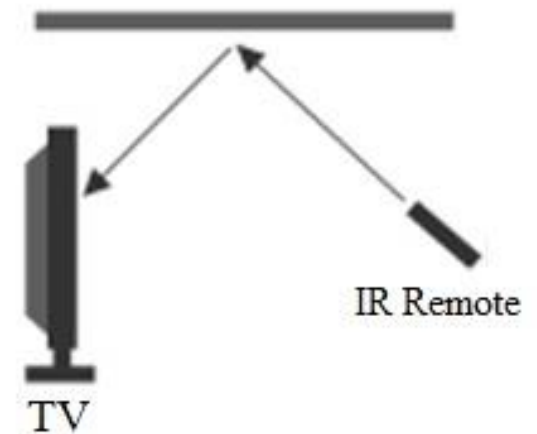
Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Infrared Transmission

Point –to –Point Transmission:



Point to Point



Diffuse

Characteristics of Infrared

- It supports high bandwidth, and hence the data rate will be very high.
- Infrared waves cannot penetrate the walls. Therefore, the infrared communication in one room cannot be interrupted by the nearby rooms.
- An infrared communication provides better security with minimum interference.
- Infrared communication is unreliable outside the building because the sun rays will interfere with the infrared waves.