

Unit-5

Physical layer and its design issues

Transmission media

Transmission media is a pathway that carries the information from sender to receiver. We use different types of cables or waves to transmit data. Data is transmitted normally through electrical or electromagnetic signals.

An electrical signal is in the form of current. An electromagnetic signal is series of electromagnetic energy pulses at various frequencies. These signals can be transmitted through copper wires, optical fibers, atmosphere, water and vacuum. Different Medias have different properties like bandwidth, delay, cost and ease of installation and maintenance. Transmission media is also called **Communication channel**.

Types of transmission media

- **Guided Transmission media**
- **Unguided Transmission media**

A. Guided Transmission media

Guided transmission media are more commonly known as the wired communication or bounded transmission media. The electromagnetic signals travel between the communicating devices through a physical medium/conductor. As the medium for transmission is a physical conductor, it also provides direction to the signal. But there are physical limitations of the conductor in the guided media. Like the length of the conductor, its installation cost, its maintenance, etc. The guided media is categorized further into three categories that are twisted-pair cable, coaxial cable and fiber-optic cable.

1. Twisted Pair Cable

This cable is the most commonly used and is cheaper than others. It is lightweight, cheap, can be installed easily, and they support many different types of network. Some important points :

- Its frequency range is 0 to 3.5 kHz.
- Typical attenuation is 0.2 dB/Km @ 1kHz.
- Typical delay is 50 μ s/km.
- Repeater spacing is 2km.

A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together. One of these wires is used to carry signals to the receiver, and the other is used only as 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. 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.

This results in a difference at the receiver.

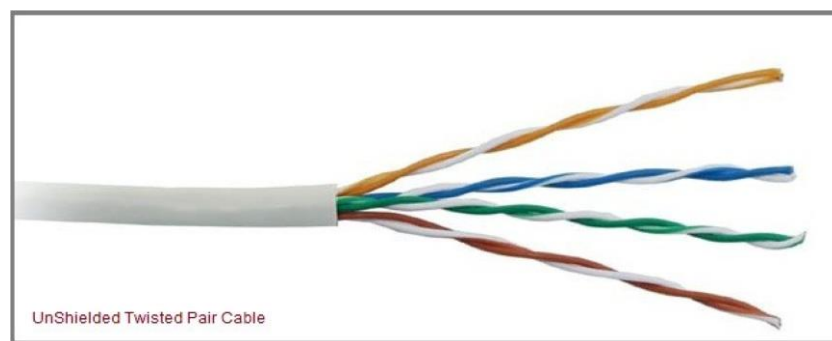
Twisted Pair is of two types:

- i Unshielded Twisted Pair (UTP)
- ii Shielded Twisted Pair (STP)

i. Unshielded Twisted Pair Cable

It is the most common type of telecommunication when compared with Shielded Twisted Pair Cable which consists of two conductors usually copper, each with its own color plastic insulator. Identification is the reason behind colored plastic insulation.

UTP cables consist of 2 or 4 pairs of twisted cable. Cable with 2 pair use RJ-11 connector and 4 pair cable use RJ-45 connector.



Advantages of using UTP :

- Installation is easy
- Flexible
- Cheap
- It has high speed capacity,
- 100 meter limit
- Higher grades of UTP are used in LAN technologies like Ethernet.

It consists of two insulating copper wires (1mm thick). The wires are twisted together in a helical form to reduce electrical interference from similar pair.

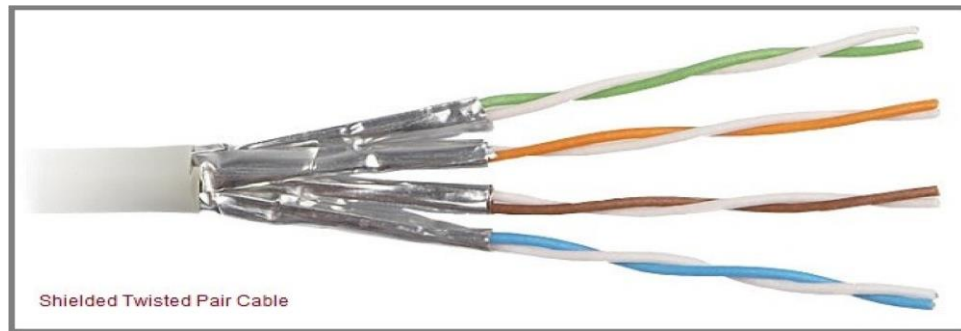
Disadvantages of using UTP

- Bandwidth is low when compared with Coaxial Cable
- Provides less protection from interference.

ii. **Shielded Twisted Pair Cable**

This cable has a metal foil or braided-mesh covering which encases each pair of insulated conductors. Electromagnetic noise penetration is prevented by metal casing. Shielding also eliminates crosstalk.

It has same attenuation as unshielded twisted pair. It is faster than the unshielded and coaxial cable. It is more expensive than coaxial and unshielded twisted pair.



Advantages of using STP

- Easy to install
- Performance is adequate
- Can be used for Analog or Digital transmission
- Increases the signalling rate
- Higher capacity than unshielded twisted pair
- Eliminates crosstalk

Disadvantages of using STP

- Difficult to manufacture
- Heavy

Applications

- In telephone lines to provide voice and data channels. 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 Network, such as 10Base-T and 100Base-T, also use twisted-pair cables.

2. Coaxial Cable

Coaxial is called by this name because it contains two conductors that are parallel to each other. Copper is used in this as center conductor which can be a solid wire or a standard one. It is surrounded by PVC insulation, a sheath which is encased in an outer conductor of metal foil, braid or both.

Outer metallic wrapping is used as a shield against noise and as the second conductor which completes the circuit. The outer conductor is also encased in an insulating sheath. The outermost part is the plastic cover which protects the whole cable.

Here the most common coaxial standards.

- 50-Ohm RG-7 or RG-11 : used with thick Ethernet.
- 50-Ohm RG-58 : used with thin Ethernet.
- 75-Ohm RG-59 : used with cable television.
- 93-Ohm RG-62 : used with ARCNET.

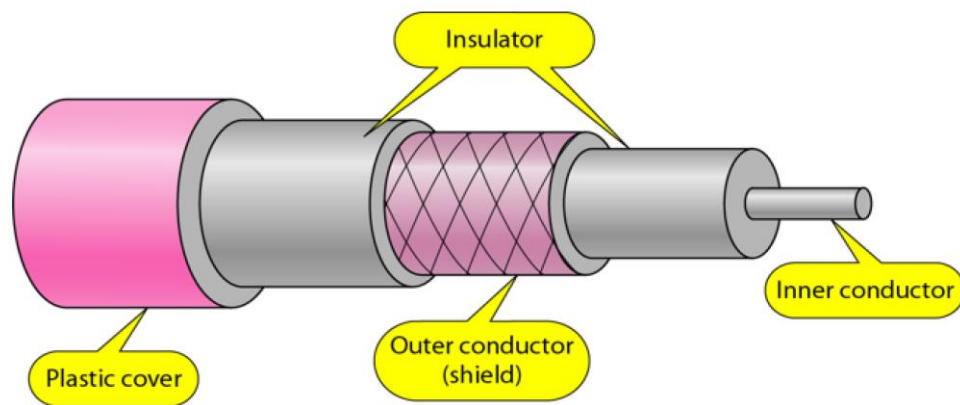


Figure: coaxial cable

There are two types of Coaxial cables :

- BaseBand** : This is a 50 ohm (Ω) coaxial cable which is used for digital transmission. It is mostly used for LAN's. Baseband transmits a single signal at a time with very high speed. The major drawback is that it needs amplification after every 1000 feet.
- BroadBand** : This uses analog transmission on standard cable television cabling. It transmits several simultaneous signal using different frequencies. It covers large area when compared with Baseband Coaxial Cable.

Advantages are :

- Bandwidth is high
- Used in long distance telephone lines.
- Transmits digital signals at a very high rate of 10Mbps.
- Much higher noise immunity
- Data transmission without distortion.
- The can span to longer distance at higher speeds as they have better shielding when compared to twisted pair cable

Disadvantages are

- Single cable failure can fail the entire network.
- Difficult to install and expensive when compared with twisted pair.
- If the shield is imperfect, it can lead to grounded loop.

Applications

- Coaxial cable was widely used in analog telephone networks, where a single coaxial network could carry 10,000 voice signals.
- Cable TV networks also use coaxial cables. In the traditional cable TV network, the entire network used coaxial cable. Cable TV uses RG-59 coaxial cable.
- 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. The 10Base-2, or Thin Ethernet, uses RG-58 coaxial cable with BNC connectors to transmit data at 10Mbps with a range of 185 m.

3. Optical Fiber

A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. For better understanding 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 substance. If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.

The below figure shows how a ray of light changes direction when going from a more dense to a less dense substance.

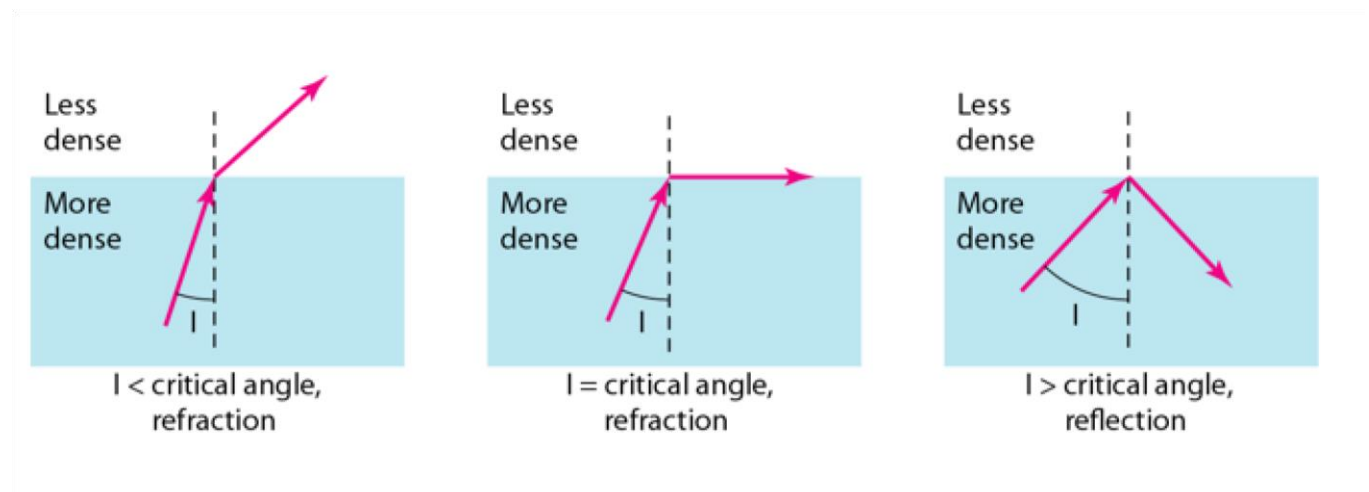


Figure: Bending of the light

- 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 **greater** than the critical angle, the ray **reflects** (makes a turn) and travels again in the denser substance.
- If the angle of incidence is **equal** to the critical angle, the ray refracts and **moves parallel** to the surface as shown.

Note: The critical angle is a property of the substance, and its value differs from one substance to another.

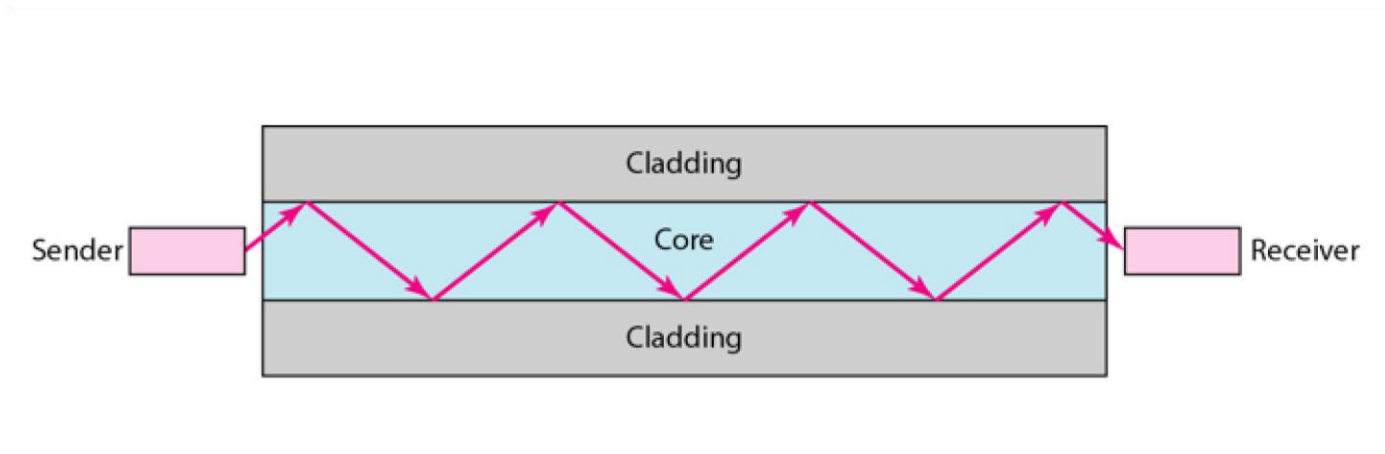


Figure: Internal view of an optical fiber

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.

Propagation Modes

Current technology supports two modes (**Multimode** and **Single mode**) for propagating light along optical channels, each requiring fiber with different physical characteristics. Multimode can be implemented in two forms: **Step-index** and **Graded-index**.

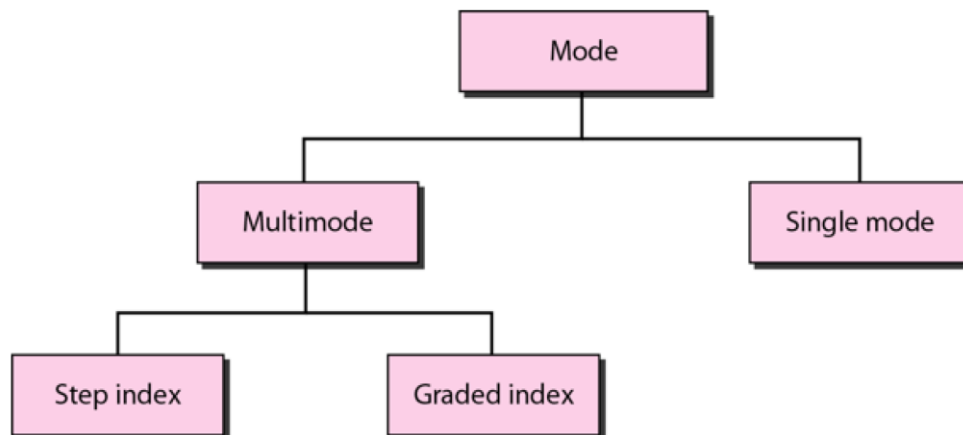


Figure: Propagation modes

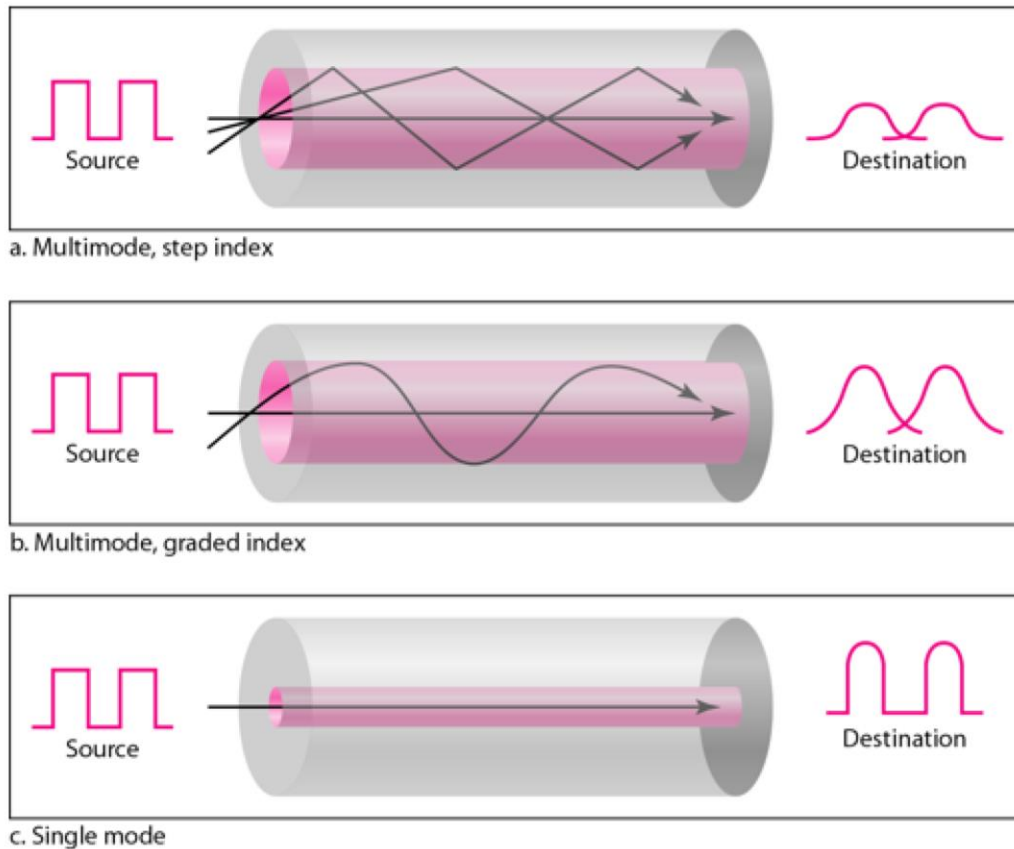
Multimode

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 the below figure.

- In **multimode 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. 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.
- In **multimode graded-index fiber**, this distortion gets decreases through the cable. The word index here refers to the index of refraction. This index of refraction is related to the 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.

Single Mode

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. The decrease in density results in a critical angle that is close enough to 90 degree to make the propagation of beams almost horizontal.



Advantages of optical fiber

Fiber optic has several advantages over metallic cable:

- Higher bandwidth
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials
- Light weight
- Greater immunity to tapping

Disadvantages of optical fiber

There are some disadvantages in the use of optical fiber:

- Installation and maintenance
- Unidirectional light propagation
- High Cost

Applications are

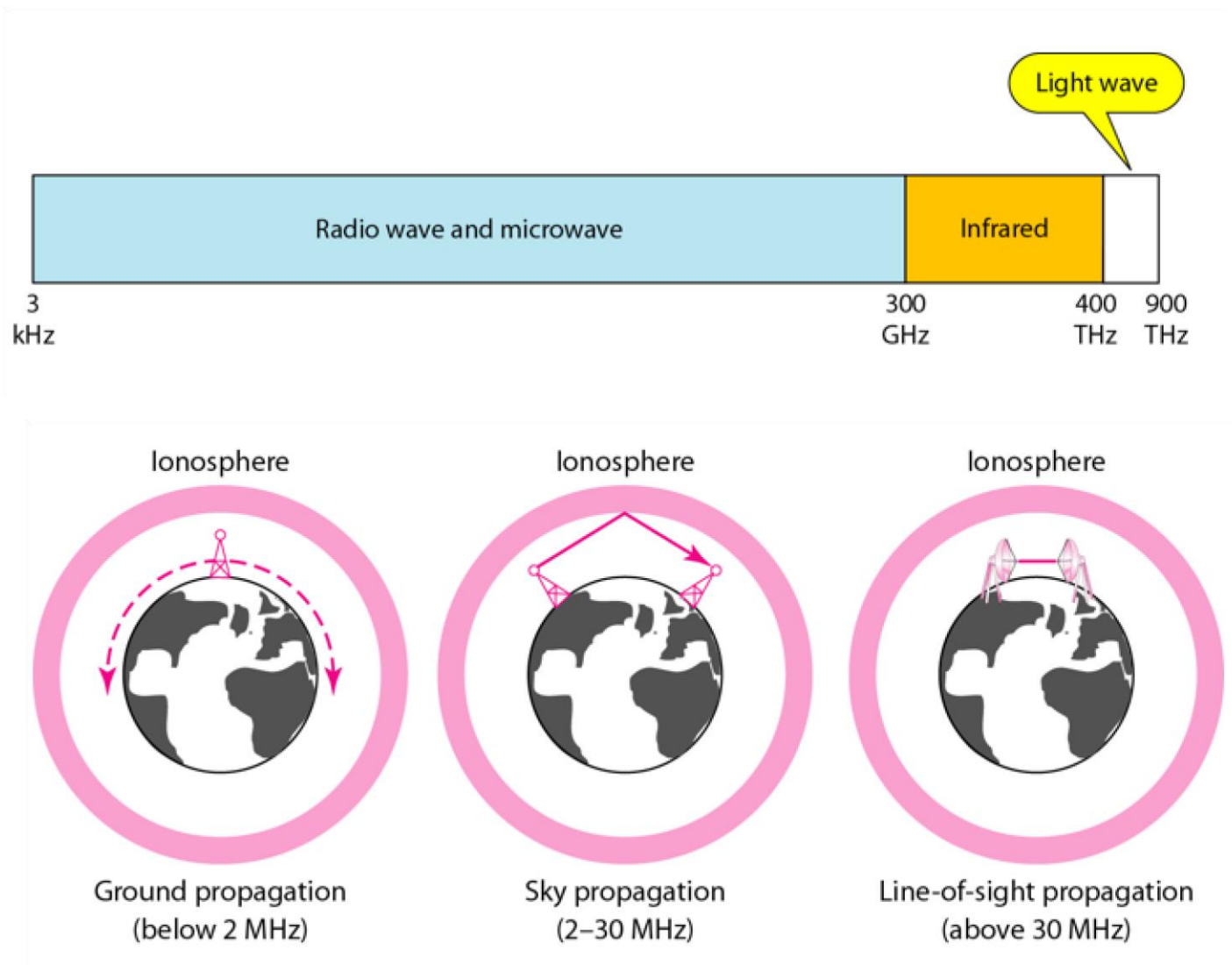
- Often found in backbone networks because its wide bandwidth is cost-effective.

- Some cable TV companies use a combination of optical fiber and coaxial cable thus creating a hybrid network.
- Local-area Networks such as 100Base-FX network and 1000Base-X also use fiber-optic cable.

B. Unguided Transmission media

Unguided medium 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.

The below figure shows the part of the electromagnetic spectrum, ranging from 3 kHz to 900 THz, used for wireless communication.



Unguided signals can travel from the source to the destination in several ways: **Ground propagation**, **Sky propagation** and **Line-of-sight propagation** as shown in above figure.

Propagation Modes

- **Ground Propagation** : In this, 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.
- **Sky Propagation** : In this, higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to Earth. This type of transmission allows for greater distances with lower output power.
- **Line-of-sight Propagation** : in this type, very high-frequency signals are transmitted in straight lines directly from antenna to antenna.

We can divide wireless transmission into three broad groups:

1. Radio waves
2. Micro waves
3. Infrared waves

1. Radio waves

Electromagnetic waves ranging in frequencies between 3 KHz and 1 GHz are normally called radio waves.

Radio waves 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 send waves that can be received by any receiving antenna. The omnidirectional property has disadvantage, too. The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signal using the same frequency or band.

Radio waves, particularly with those of low and medium frequencies, can penetrate walls. This characteristic can be both an advantage and a disadvantage. It is an advantage because, 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

Radio waves use omnidirectional antennas that send out signals in all directions.



Applications

- The omni directional 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, and paging are examples of multicasting.

2. Micro Waves

Electromagnetic waves having frequencies between 1 and 300 GHz are called micro waves. Micro waves are unidirectional. When an antenna transmits microwaves, 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.

The following describes some characteristics of microwaves propagation:

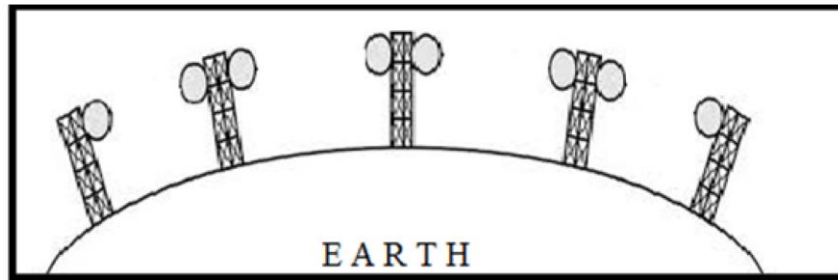
- Microwave propagation is line-of-sight. Since the towers with the mounted antennas need to be in direct sight of each other, towers that are far apart need to be very tall.
- Very high-frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside the buildings.
- The microwave band is relatively wide, almost 299 GHz. Therefore, wider sub-bands can be assigned and a high data rate is possible.
- Use of certain portions of the band requires permission from authorities.

There are 2 types of Microwave Transmission :

a. Terrestrial Microwave

For increasing the distance served by terrestrial microwave, repeaters can be installed with each antenna .The signal received by an antenna can be converted into transmittable form

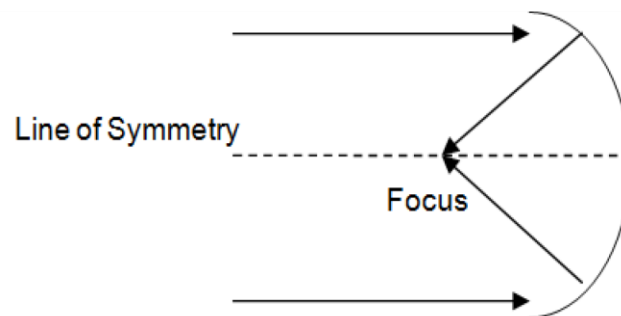
and relayed to next antenna as shown in below figure. It is an example of telephone systems all over the world.



There are two types of antennas used for terrestrial microwave communication :

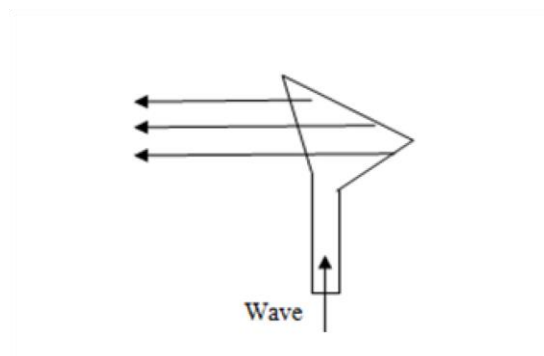
- Parabolic Dish Antenna

In this every line parallel to the line of symmetry reflects off the curve at angles in a way that they intersect at a common point called focus. This antenna is based on geometry of parabola. They are used in satellite communication, broadcast reception, space communication, radar



- Horn Antenna

It is a like gigantic scoop. The outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by curved head.



Advantages of Microwave Transmission

- Used for long distance telephone communication
- Carries 1000's of voice channels at the same time

Disadvantages of Microwave Transmission

- It is Very costly

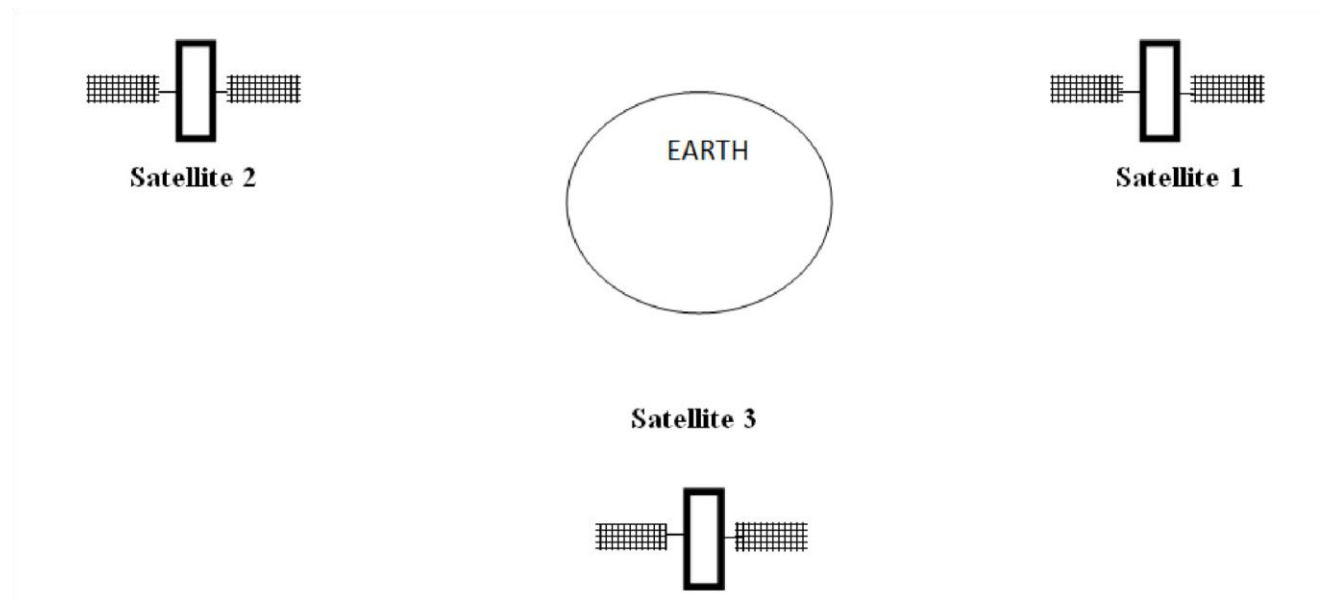
Applications

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.

b. Satellite Microwave

This is a microwave relay station which is placed in outer space. The satellites are launched either by rockets or space shuttles carry them.

These are positioned 36000KM above the equator with an orbit speed that exactly matches the rotation speed of the earth. As the satellite is positioned in a geo-synchronous orbit, it is stationery relative to earth and always stays over the same point on the ground. This is usually done to allow ground stations to aim antenna at a fixed point in the sky.



Features of Satellite Microwave :

- Bandwidth capacity depends on the frequency used.
- Satellite microwave deployment for orbiting satellite is difficult.

Advantages of Satellite Microwave :

- Transmitting station can receive back its own transmission and check whether the satellite has transmitted information correctly.
- A single microwave relay station which is visible from any point.

Disadvantages of Satellite Microwave :

- Satellite manufacturing cost is very high
- Cost of launching satellite is very expensive
- Transmission highly depends on whether conditions, it can go down in bad weather

3. Infrared Waves

Infrared waves, with frequencies from 300 GHz to 400 THz, 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.

When we use 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

- a. 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.
- b. The Infrared Data Association (IrDA), an association for sponsoring the use of infrared waves, has established standards for using these signals for communication between devices such as keyboards, mouse, PCs and printers.
- c. Infrared signals can be used for short-range communication in a closed area using line-of sight propagation.

ISDN

ISDN is a telephone network based infrastructure that allows the transmission of voice and data simultaneously at a high speed with greater efficiency. This is a circuit switched telephone network system, which also provides access to Packet switched networks.

ISDN supports a variety of services. A few of them are listed below –

- Voice calls

- Videotext
- Electronic Mail
- Database access
- Data transmission and voice
- Connection to internet
- Electronic Fund transfer
- Image and graphics exchange
- Document storage and transfer
- Audio and Video Conferencing
- Automatic alarm services to fire stations, police, medical etc.

Types of ISDN

Primary Rate Interface (PRI)

The Primary Rate Interface or Primary Rate Access, simply called the ISDN PRI connection is used by enterprises and offices. The PRI configuration is based on T-carrier or T1 in the US, Canada and Japan countries consisting of **23 data** or bearer channels and one control or delta channel, with 64kbps speed for a bandwidth of 1.544 M bits/sec. The PRI configuration is based on E-carrier or E1 in Europe, Australia and few Asian countries consisting of **30 data** or bearer channels and **two-control** or delta channel with 64kbps speed for a bandwidth of 2.048 M bits/sec.

The ISDN BRI interface is used by larger organizations or enterprises and for Internet Service Providers.

Narrowband ISDN

The Narrowband Integrated Services Digital Network is called the **N-ISDN**. This can be understood as a telecommunication that carries voice information in a narrow band of frequencies. This is actually an attempt to digitize the analog voice information. This uses 64kbps circuit switching.

The narrowband ISDN is implemented to carry voice data, which uses lesser bandwidth, on a limited number of frequencies.

Broadband ISDN

The Broadband Integrated Services Digital Network is called the **B-ISDN**. This integrates the digital networking services and provides digital transmission over ordinary telephone wires, as

well as over other media. The CCITT defined it as, “Qualifying a service or system requiring transmission channels capable of supporting rates greater than primary rates.”

The broadband ISDN speed is around 2 MBPS to 1 GBPS and the transmission is related to ATM, i.e., Asynchronous Transfer Mode. The broadband ISDN communication is usually made using the fiber optic cables.

As the speed is greater than 1.544 Mbps, the communications based on this are called **Broadband Communications**. The broadband services provide a continuous flow of information, which is distributed from a central source to an unlimited number of authorized receivers connected to the network. Though a user can access this flow of information, he cannot control it.

Advantages of ISDN

ISDN is a telephone network based infrastructure, which enables the transmission of both voice and data simultaneously. There are many advantages of ISDN such as –

- As the services are digital, there is less chance for errors.
- The connection is faster.
- The bandwidth is higher.
- Voice, data and video – all of these can be sent over a single ISDN line.

Disadvantages of ISDN

The disadvantage of ISDN is that it requires specialized digital services and is costlier.

However, the advent of ISDN has brought great advancement in communications. Multiple transmissions with greater speed are being achieved with higher levels of accuracy.

PSTN

PSTN stands for Public Switched Telephone Network, or the traditional circuit-switched telephone network. This is the system that has been in general use since the late 1800s. Using underground copper wires, this legacy platform has provided businesses and households alike with a reliable means to communicate with anyone around the world for generations. The phones themselves are known by several names, such as PSTN, landlines, Plain Old Telephone Service (POTS), or fixed-line telephones. PSTN phones are widely used and generally still accepted as a standard form of communication. However, they have seen a steady decline over the last decade.

How PSTN phone lines works?

Step #1 – Your telephone set converts sound waves into electrical signals. These signals are then transmitted to a terminal via a cable.

Step #2 – The terminal collects the electrical signals and transmits these to the central office (CO).

Step #3 – The central office routes the calls in the form of electrical signals through fiber optic cable. The fiber optic conduit then carries these signals in the form of light pulses to their final destination.

Step #4 – Your call is routed to a tandem office (a regional hub responsible for transmitting calls to distant central offices) or a central office (for local calls).

Step #5 – When your call reaches the right office, the signal is converted back to an electrical signal and is then routed to a terminal.

Step #6 – The terminal routes the call to the appropriate telephone number. Upon receiving the call, the telephone set converts the electrical signals back to sound waves.

This may sound complicated, but the thing to remember is that it takes a few seconds for your call to reach its destination. This process is facilitated by using fiber optic cables and a global network of switching centers.

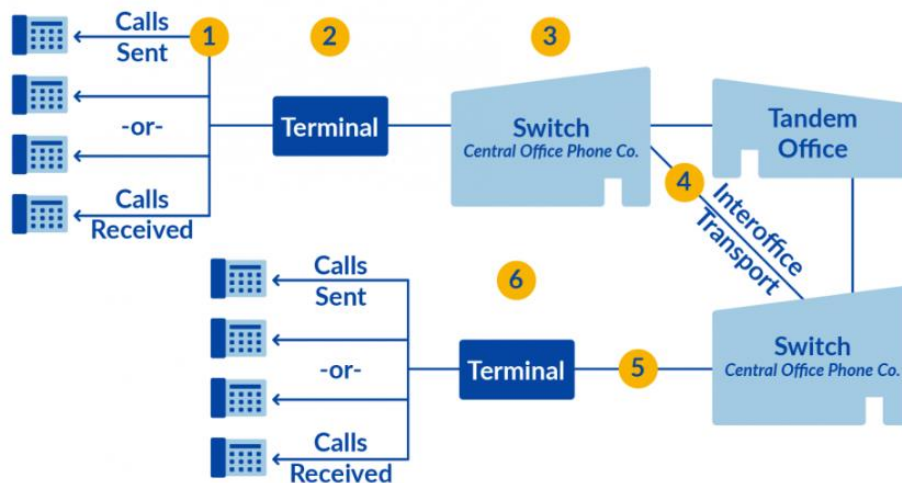


Figure: Plain Old Telephone Service (POTS) Networking

Difference between ISDN and PSTN

ISDN	PSTN
1. ISDN lines are digital	1. PSTN lines are analogue
2. ISDL are used for bigger companies.	2. PSTN lines are used for small companies
3. ISDN allows two simultaneous connection.	3. PSTN doesn't allows two simultaneous connection.
4. ISDN can make faster call than PSTN.	4. PSTN are slower than ISDN.
5. ISDN are designed for transmission of data as well as voice.	5. PSTN are designed for transmission of voice only.
6. The ISDN provides 128 kbit/s, which is really good for the Internet.	6. PSTN has a disadvantage that it does not make the most possible use of the broadband.
7. ISDN provides better voice quality than PSTN.	7. PSTN is not as better as ISDN.