Assignment-1

Topic : Transmission Media

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1. Introduction

In data and telecommunication, the process of transmission is divided into layers. Based on the type of model, we are following, the number of layers vary. In the two popular forms of conceptual model - the OSI and TCP/IP model, we can see 7 and 5 layers respectively; the last layer being the physical layer. Now, in these kinds of layered data transmission models, when the data reaches the ~~lower~~ lowest layer, it needs to be physically transferred to the destination. To do so a connection or medium is required for the signals to propagate from one node to another - it can be from source to destination and vice-versa. This medium which physically connects two components of the network by directly joining the physical layer of one node with the physical layer of another is called transmission medium. As the name implies, transmission medium enables direct data transmission between two components of a network. Unlike the abstract layers, the transmission medium is actually physical and would contribute to the actual signal propagation.

An analogy for the data transmission medium is the transmission medium for sound. When we speak, our vocal chords create sound waves which are created by vibrating the air molecules. These sound waves propagate directly through air. When these sound waves reach the ear of another person, they are interpreted as meaningful words. In our scenario, we can consider ourselves as the source node and person who is listening to us as the destination node. But only the source and destination is not sufficient for a meaningful verbal communication. We need a medium between us. In this scenario air is the medium that connects the speaker to the listener. Here, air is analogous to the data transmission medium in data communication.

Other examples can be-mailing someone, telephoning someone and so on. If we want to send a mail or letter to someone ~~ut~~, we need someone or something to do the delivery. In this case - a mailtruck and a mailman would fit the role. As communication changed, so did the underlying technology change. In telephone, the person i.e. mailman, was replaced by wires that would be connected to booths. From here on, the concept of wired data communication was introduced.

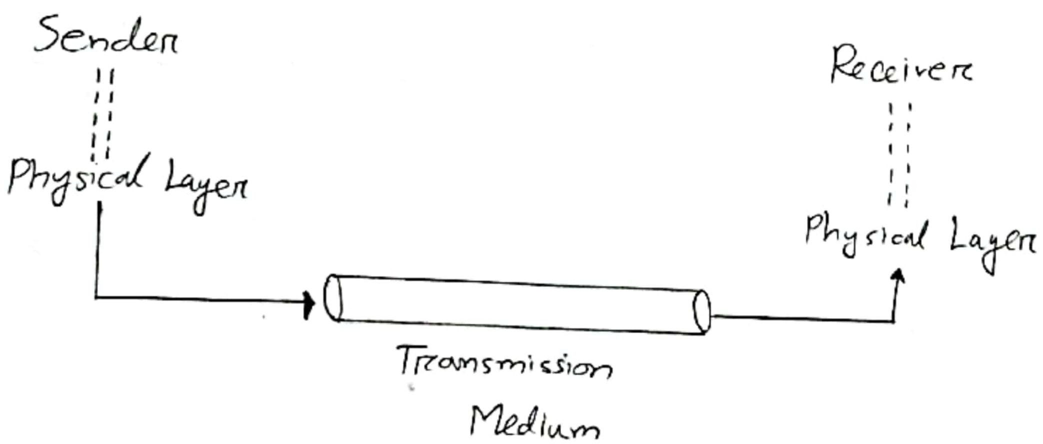


Fig: Conceptual Diagram of Transmission Medium

2. History of Transmission Medium

Witho the coming years, the field of wired data transmission changed dramatically. Firstly, it was due to the introduction of new technologies. Wired communication started with the telegraph by Morse in the 19th century. Telegraph also introduced the concept of transferring data using electric signals — a concept which would later be the foundation of modern ~~tele~~ telecommunications. The invention of telephone would also play a pivotal role in extending ~~to~~ the mode of data communication. The concept of signal conversion and concurrent or duplex communication was introduced. In can easily be inferred that transmission medium needs to be developed to be able to transfer telephone signals without any distortions. The early telephones lines were ~~haven~~ however noisy and would result in distortion, lag and ~~so~~ so on. The popularity of telephone also influenced the rapid development in the fields of data transmission. The challenge was to develop transmission medium with cheaper cost, higher signal accuracy, and better (or at least sufficient) speed. Telephone overhead lines were introduced but mostly metal wires were the prominent physical medium that enabled data transmission.

The field of data communication, however, witnessed another revolution in 1895 by Hertz when he was able to send high frequency signals without transfession medium. Marconi extended the idea of Hertz by sending telegraphic messages over the

Atlantic without any physical connection between source and destination. This began the journey of wireless data communication. For wireless communiation, the transmission medium is vacuum, and electromagnetic signals are used instead of electric signals.

Historically, science incorporated various theories to explain the wireless transmission medium. Ether was an example of such a conceptual medium used to transmit wireless signals such as light. However, modern theories concluded that, such electromagnetic signals can travel through vacuum. Light waves are now part of this ~~dive~~ diverse range of signals known as electromagnetic waves which includes gamma rays, x-rays, ultraviolet rays, visible light, infrared, microwaves and radio-waves. The classification is based on the frequency of waves going from high to ~~low~~ low.

Modern transmission medium covers these two types of data transmission - electrical and electromagnetic. The wired transmission of electrical signals evolved into twisted pair wires, coaxial cable, dielectric slab waveguides and so on. The transmission can also be done through optical medium such as optical fiber. We shall now look at the classification of transmission medium.

3. Classification

- Transmission Media
  - Guided (wired)
    - Twisted pair Cable
    - Coaxial Cable
    - Fiber-optics Cable
  - Unguided (wireless)
    - Free Space

The broaden classisification was done on the basis of path along a solid medium. Hence, guided transmission can also be referred as wired transmission.

For example - the broadband internet service that we receive through ethernet port is an example of guided transmission where the wire that connects our device withe the ISP is the guided transmission medium. Receiving radio signals on a radio is an example of unguided transmission and the vacuum is the unguided transmission medium.

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

4. Design Factors

The concerns that we face during data transmission are data rate and distance. The design factors pertaining to transmission medium and signal determine the data rate and ~~de~~ distance are explained below:

(i) Bandwidth: The data rate is directly proportional to the bandwidth of the signal.

(ii) Transmission Impairments: Impairments can be attentuation, distortion and noise. Impairements like attentuation limit the distance while distortion or noise creates inaccuracies which also hinders data flow with distance and time. In general twisted pairs suffer more impairements than coaxial cable which in turn suffers more than optical fiber.

(iii) Interferance: Interferance from competing signals in overlapping frequency bands can distort or wipe out a signal. For unguided media it is a major concern as there is more scope of interferance. For guided medium, interferance is caused due to emanations from nearby cables. Proper shielding can minimize this problem.

(iv) Number of receivers: A guided medium can be used to construct a point-to-point or shared link with ~~mt~~ multiple attachments. In latter case, each attachment introduces attentuation and distortion limiting distance and/or data rate.

5. Guided Media

Guided media which are those that provide a conduit from a device to another. It is also known as wired or bounded medium. Signals transmitted are ~~diread~~ directed and confined in a narrow pathway by using physical links. Guided media features high speed, security, and shorter distance communication reliability. However, the advancement in unguided medium has ensured its ~~dom~~ dominance in short distance communication (ex- bluetooth, wi-fi-technology) Similarly, advancement in optical fiber technology has ensured large distance guided data transmission.

Guided media include twisted-pair cable, coaxial cable and fiber-optic cable. A signal traveling through any of these media is directed and contained by the physical limits of the medium. The detailed description of each individual medium is given below:

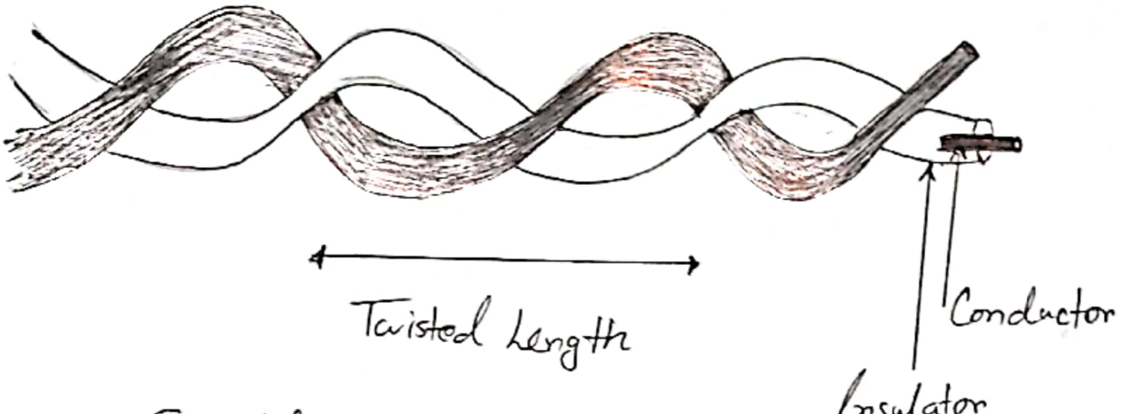
5.1 Twisted Pair

Twisted pair is the least expensive and most widely used transmission medium.

- **Description:** Twisted pair is the type of wiring in which two conductors a single circuit are twisted for the purpose of improving electromagnetic compatibility. Electromagnetic compatibility is the ability of electrical equipments in their electromagnetic environment to function acceptably by limiting unwanted signals, propagation and reception of electromagnetic energy. Such effects can cause unwanted phenomenon like electromagnetic interference (EMI) or even physical damage to the equipment. By increasing electromagnetic compatibility, the distance of transmission can be increased. In twisted pairs two insulated wires are twisted together and then bundled in a cable of pairs. The pairs are known as tip and rings. Neither of the wire is connected directly to the ground. The twist keeps conductors balanced with respect to themselves, the cable shield and other pairs. Often twisted pairs are called cable pairs.

Twisted pairs are commonly deployed in 25 or 50 pair bundles wrapped in a metal sheath known as binder. The sheath is grounded at cable ends. The binders are contained in an outer sheath of plastic to create an ~~insulated~~ insulated cable (polyolefin-insulated cable or PIC). The ~~pa~~ number usually ranges from 25 to 4200.

Over longer distances, cables may contain hundreds of pairs. The twisting tends to decrease crosstalk interference. The neighboring pairs in a ~~bundle~~ bunde typically have different twist lengths to reduce crosstalk. The length varies from 5 – 15 cm while a pair thickness varies from 0.4 to 0.9 mm.



- Seperately insulated
- Twisted together
- Often bundled into cables

• Modes of Operation:

(i) Differential mode signals: Signals applied between the wires of a twisted pair. Also known as metallic signal. Messages are transmitted as differential signals.

(ii) Common mode signals: Signals measured between two wires and ground. Also known as longitudal signals. Common mode signals are created by outside interference. (noise)

A two-way operation over a single twisted pair is achieved by the use of transformers, echo cancelling devices and adaptive filters. The principle is called hybrid mode which is a combination of ~~per~~ previous two modes. This mode eliminates the need to run a second pair to each subscriber to obtain a duplex transmission medium.

• **Mechanism:**

Twisted pair has a relatively straight-forward mechanism. One of the wires is used to carry signals to receiver and other one is used for ground reference. The receiver uses the difference between the two.

In addition to the signal sent by the sender on one of the wires, unwanted signals are also received due to the mechanism. The two wires, when set as parallel, will have different effect of unwanted signal. Since they will be on different locations in relation to noise or cross-talk sources, there will be a difference at the receiver. By twisting the pairs, a balance is maintained. For example - in one particular twist, one of the wires will get closer to the noise source and the other one goes further. In other twist, the reverse will occur. Twisting ~~makes~~ makes it possible that both wires are equally affected by the external influences. When the receiver calculates the difference between those two then the unwanted signals cancel each other out. So, it is clear that the number of twists per unit has an influence on the quality of the cable.

• Types of twisted pair

Twisted pairs are usually of two types based on shielding. Shielding is a way of covering the cable to prevent unwanted noise. The types of twisted pair are - (i) Unshielded Twisted Pair
(ii) Shielded Twisted Pair

(i) Unshielded Twisted Pair (UTP)

This is the most common version of twisted pair. It is same telephone lines that were in the early days of transmission medium. Unshielded twisted pair (UTP) has no shield or outer conductor to protect the signal from outside sources.

A list of features of unshielded twisted pair is given below:

(i) Least expensive and most available transmission medium

(ii) Lower performance compared to other forms of transmission medium.

(iii) Balanced transmission line

(iv) Prone to interference from outside sources

(v) Requires frequent repeaters — more suitable for short distance.

UTP is the most common cable used in computer networks. Modern Ethernet can use UTP. It is also used for short and medium-length connections for lower cost compared to coaxial or fiber optics.

UTP cable bandwidth has improved a lot over the years. They can now be used in video applications, primarily in security camera.

(ii) Shielded Twisted-Pair (STP)

A version of twisted pair was introduced by IBM in order to make the twisted pair uninfluenced from unwanted electromagnetic interferance. Such shielded cables have a metal ~~coit~~ foil or braided mesh, covering ~~the pa~~ that encases each pair of insulated conductors. A ~~ment~~ metal encasing would protect the inner twisted pairs from interference more than the unshielded counterparts.

A list of features pertaining to shielded twisted pair is given below:

(i) Cheap in cost but more expensive than unshielded canterparts.

(ii) Bulkier than their unshielded canterparts.

(iii) Enhanced performance due to reduction of emission of energy from subject conductors and reduction of interferance.

(iv) Lower signal loss due to the shield confining electromagnetic field associated with the confined signal and can thus maintain signal strength over great distance.

(v) Has more security and eliminates crosstalk from adjacent pair of cables.

(vi) Higher manufacturing and installation cost due to additional weight of shield and extra insulation.

(vii) Electrical grounding of shield requires more time and effort in installation process.

The additional cost of shielded copper historically has limited the wire's use to high-noise environments only and is seldom used outside IBM.

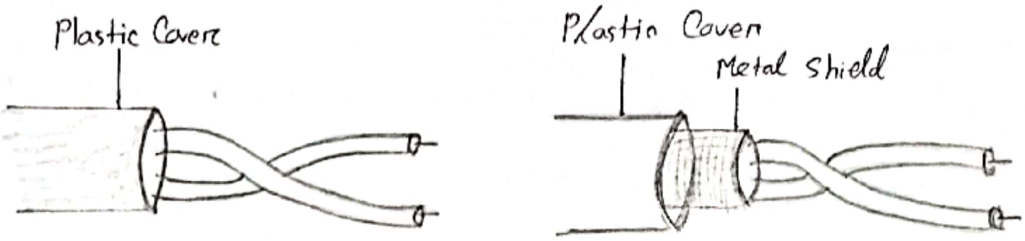


Fig: Shidded vs Unshielded Twisted Pair

- Concepts related to twisted pair

Twisting Process

The manufacturing process involves twisting the seperately insulated conductors in a helix with constant pitch or distance to make a 360° twist and hence, originated the term for the wire – twisted pair. Generally speaking, the tighter the twist – that is – more twists per foot, the better the performance of the wire.

In application involving multiple pairs, the lay length can become an issue. For example – for 4 pairs ~~of~~ in a Cat-5 cable, each pair has a slightly different twist ratio or twist pitch in order to minimize crosstalk. The difference in twist ratios result in a slightly different lay length, that is, physical length if the cable were to be untwisted and laid flat for each pair. This causes built-in propagation delay skew. As too much delay skew will cause transmission errors because of timing differences between signals spread across the various pairs, some cable manufacturers use foamed insulation on the conductors.

Gauge

Gauge is a measure of diameter of the conductor. The greater is the diameter of the wire, the lesser is the resistance and the stronger is the signal over a given distance, and the better is the performance of the medium. Thicker wires also have greater break strength.

American Wire Gauge (AWG) is ~~it~~ the standard measurement of gauge in the United States. The gauge numbers are retrogressive i.e. the larger the number, the thinner the conductor. The AWG number indicates the approximate number of wires that are laid side by side to span 1 inch.

Twisted pairs normally emloyed in ~~tel~~ telecommunication networks vary from 19 to 28 gauge, with the average ones being 24 gauge. The gauge values for different categories will be later shown.

Cable Shielding

When shielding is applied to a collection of pairs, it is usually referred as screening. Shielding is incorporated to prevent electro-magnetic interference as discussed previously in the shielded twisted pair section. Among vendors, words such as screening, shielding and STP (shielded twisted pair) attempts to internationally standardize various designations of shielded pairs by combining three letters – U for unshielded, S for braided shielding (in outer layer only) and F for foil shielding – to explicitly indicate the type of screen for overall cable protection, and for protecting individual pairs or quads using a two-part abbreviation in the form of x/xTP. For example – shielded Cat 5e, Cat 6/6A have (typically) F/UTP construction, while Cat 7/7A uses S/FTP construction.

Common shield construction type includes:

(i) Individual shield (U/FTP)

Individual shielding ~~with~~ with aluminum foil for each twisted pair or quad. Common names – pair in metal foil, shielded twisted pair, screened twisted pair. Prevents EMI from entering and exiting individual pairs and also protects neighboring pair from crosstalk.

(ii) Overall shied (F/UTP, S/UTP and SF/UTP)

Overall foil, and braided shield or braiding with foil accross all pairs within 100 ohm twisted pair cable resistance. Common names include: foiled ~~dut~~ twisted pair, shielded twisted pair, screened twisted pair. Prevents EMI from entering or exiting the cable.

(iii) Individual and overall shielding (F/FTP, S/FTP, SF/FTP)

Individual shielding using foil between the ~~twisted~~ twisted pair sets and also an outer foil or braided shielding. Common names: fully shielded twisted pair, screened foiled twisted pair, shielded foiled twisted pair, sreened shielded twisted pair. Prevents EMI from entering and exiting. Also prevents crosstalk from neighboring pairs.

An early example of shielded twisted pair is IBM STP-A, which is a 2-pair 150 ohm S/FTP cable defined in 1985 by IBM cabling system specifications, and used with token ring or FDDI networks.

Common Industry Nomenclature for Cable Construction Types

Industry abbreviations	ISO/IEC 11801 designation	Cable Shielding	Pair shielding
UTP, TP	U/UTP	None	None
STP, ScTP, ~~[illegible]~~ PiMF	~~U/FTP~~ U/FTP	None	Foil
FTP, STP, ScTP	F/UTP	Foil	None
STP, ScTP	S/UTP	Braiding	None
SFTP, S-FTP, STP	SF/UTP	Braiding and Foil	None
FFTP, STP	F/FTP	Foil	Foil
SSTP, SFTP, STP, STP PiMF	S/FTP	Braiding	Foil
SSTP, SFTP, STP	SF/FTP	Braiding and Foil	Foil

• Categories

Categories of unshielded twisted pair was developed by Electronic Industries Association (EIA) to standardize unshielded twisted pairs into 7 categories.

Category	Specification	Gauge (AWG)	Data Rate (MBPS)	Typical Applications
1	Unshielded twisted pair used in telephone	Various	<0.1	Analog voice grade, ISDN, low speed data, alarm cable
2	Unshielded twisted pair originally used in T lines	24	2	4 Mbps Token Ring LANs, T-1 lines
3	Improved CAT-2 used in LANs	24	10	Plain Old Telephone Service (POTS), ISDN, T1, 10-base T-LAN
4	Improved CAT-3 in Token Ring Networks	24	20	16 Mbps Token Ring LAN
5	Cable wire is normally 24 AWG with a jacket and outside sheath	24	100	10/100 base T-LAN
5e	Improved CAT-5 to minimize crosstalk and EMI	24	125	10/100 Base T-LAN, 155 Mbps ATM, 1000 base T-~~LAN~~
6	New category with matched components	23	200	1000 base T
7	Also called SSTP (shield screen twisted pair). Decreases cross-talk and increases data rate.	23	600	10 GbE LAN

• Categories of Outside Plant Cable (OSP)

Twisted pairs up to 3600 pairs are still used in outside plant (OSP) applications, but fiber optics have largely replaced them. Categories include:

(i) Overhead cables (hanging from poles)
(ii) Directly burial cables (directly in trenches in ground)
(iii) Indirect burial cables (ducts or conduits placed in trenches in ground)
(iv) Submarine cables ~~(...)~~ (underwater, miles deep)

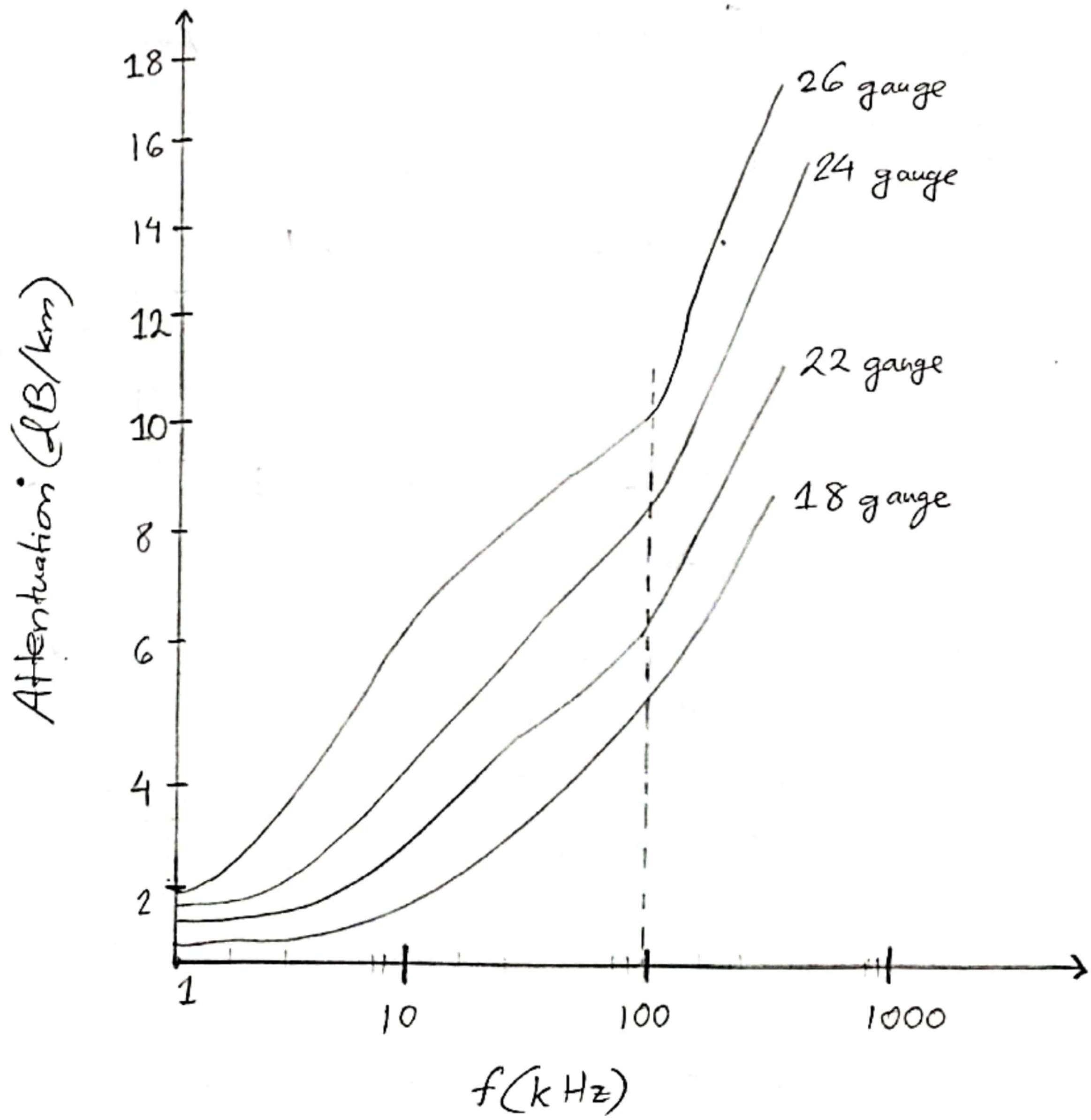
OSP must be rugged and durable, as they are exposed to various extremes of temperatures, pressure, rodent and so on. Air pressurizers and water-blocking gel keep cable free of moisture.

• Connectors

The most common type of UTP connector is RJ45 (RJ means registered jack). The RJ45 is a keyed connector, meaning it can be inserted in only one way. The CAT5e and RJ45 is the most successful cable and connector for Ethernet.

• **Performance**

One of the methodologies used in measuring performance of twisted pair cable is to compare attentuation vs frequency and distance. A twisted pair can pass wide range of frequencies. With increasing frequency, the attentuation measured in decibels per kilometer (dB/km) sharply increases with frequencies abae 100 kHz.



• Applications:

Twisted pair cables are used in telephone lines to provide voice and data channels. The local loop – a line that connects subscribers to the central telephone office – commonly consists of unshielded pair cables. ~~We discuss~~ The DSL lines that are used by the telephone companies to provide high-date-rate connections.

The most important application of LANs in modern day uses twisted pairs as it is cheap and available. In the category tab we can see how the applications of twisted pair vary in various form of LAN connection. Local Area Networks such as 10Base-T and 100Base-T use twisted pair cables, generally unshielded. Cat-6 SFTP and Cat-7-SFTP are both used in high speed (100Base-T and 1000Base-T) LANs at signalling rates of 750 MHz.

• Transmission Characteristics

Twisted pairs are used to transmit both analog and digital signals. For analog, amplifiers are required about every 5-6 km. For digital, repeaters are required every 2-3 km.

For point-to point, a bandwidth up to 1 MHz is possible for analog and few Mbps is possible for digital at long distance and up to 10 Gbps at large distance.

5.2 Coaxial Cable

Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted pair, because these 2 cables are constructed quite differently. It is a very robust shielded copper cable. Coaxial cable was first introduced in 1858 following transatlantic cable installations.

• **Description:**

Instead of having 2 wires coax has a central core conductor of solid or stranded wire enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid or combination of the two. The outer metallic wrapping serves both as shield against noise and as a second conductor which completes the circuit. The insulating sheath of the outer conductor is a plastic cover.

The outer shield generally consists of a solid metal foil, although a braided or stranded metal screen is sometimes used The metal used for inner conductor may be copper, silvered copper, tinned copper, copper-clad aluminum, copper-covered steel. The outer shield generally comprises an aluminum sheath, aluminum braid, bare copper braid, silvered copper braid or tinned copper braid. Twinaxial (twinax) cables contain two thin coax cables contained within a single cable sheath and were once popular in linking IBM terminals to cluster controllers.

Regardless of the specifics, the center conductor(s) are ~~its~~ always used as carriers. A single coaxial has a diameter of from 1 to 2.5 cm.

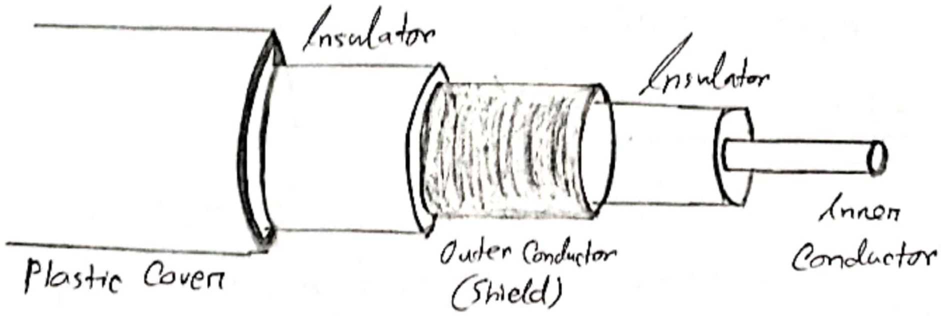


Fig: Coaxial Cable

• Mechanism:

The center conductor carries the signal. The outer conductor generally is used only for electrical grounding and maintains at 0 volt. So, coax is an electrically unbalanced medium. A balun (balanced/unbalanced) connector is used to connect balanced twisted pair and unbalanced coax.

The mechanism of coax is hence relatively straightforward and can thereby propagate both digital and analog signals in similar ~~to~~ ways. While center conductor carries data, surrounding layers shield the cables from EMI. The dielectrics or first layers provides insulation and latter layers provide shielding for keeping electrical impulses and radio transmissions out.

• Cable Standards and Category

Coaxial cables are categorized by their Radio Government (RG) ratings. Each RG number denotes a unique physical specification, including the wire gauge of the inner conductor, thickness and type of inner insulator, construction of shield and, size and type of outer casing.

Category	Impedence	Use
RG-59	75Ω	Cable TV
RG-58	50~~60~~Ω	Thin Ethernet
RG-11	50~~60~~Ω	Thin Ethernet

• Concepts related to Coaxial Cables

Coaxial splitter: When more than one device requires a signal then the incoming signal from the coaxial cable can be split into multiple signals. The small devices that are designed to attach to the coaxial cables to split the signals are called coaxial splitters.

Coaxial Port: A coaxial port is a single female RCA connector. The port on a device is labelled as coaxial but can also be named as 'digital in' or digital out, This port is usually color-coded orange or black.

• Connectors:

Coaxial cable connectors are used to connected other devices and maintain cable shielding. The two distinct common types are male and female. Male connectors have male pin protruding from center and female connectors have recessed hole to receive the pin. The most common type of connectors are:

(i) BNC Connector (Baynet Neill-Concleman)

(ii) TNC Connector (Threaded Neil-Concelman)

(iii) SMB Connector (Subminiature Version-B)

(iv) 7/6 DIN Connector (Deutsches Institut für Normung)

(v) MCX Connector (Micro-coaxial)

(vi) RCA Connector (Radio Corporation of America)

The most common type of connector is BNC, with three popular types - BNC T connect, BNC connector and BNC terminator.

BNC is used to connect end of a cable (for ex-TV set) for device. BNC is used in ethernet to branch out a connection to a computer or other device. BNC is used at the end to prevent reflection of signal.

Performance:

Performance is measured for coaxial pairs, the same way we measured for twisted pairs. In the plotted graph, we notice the attenuation is higher in ~~aac~~ coaxial cables than in twisted pair cable. So, even though coaxial cables are capable of providing ~~transferring~~ higher bandwidth, the signal weakens rapidly and required frequent use of repeaters.

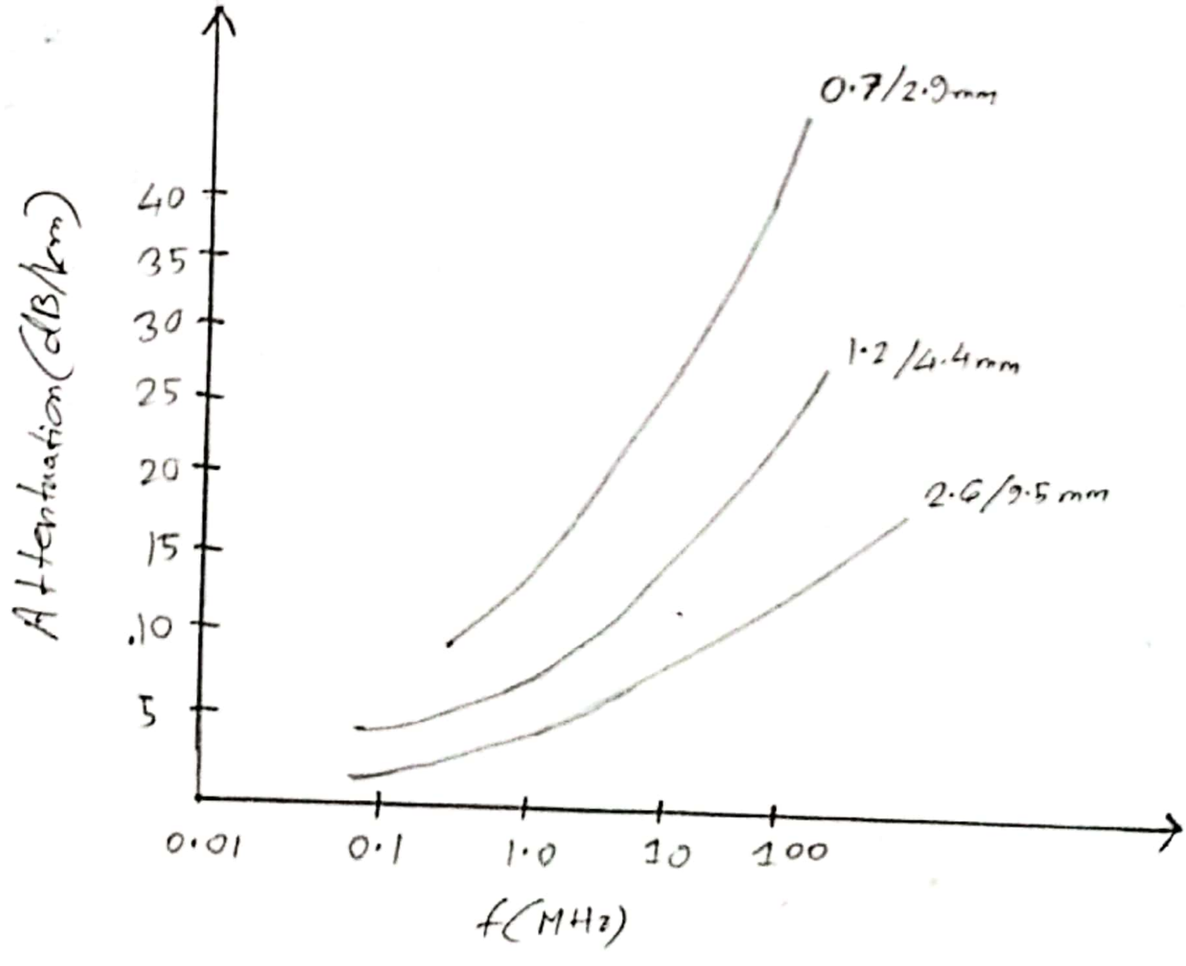


Fig: Coaxial Cable Performance

• Applications:

(i) Television Distribution:

Coaxial cables are widely used as means of distributing TV signal to home -i.e- cable TV. From its modest beginning as Community Antenna Television (CATV), cable ~~tablet~~ TV reaches many homes delivering hundreds of TV channels up ~~to~~ to a few 10 kilometre range using coaxial cable.

(ii) Long-distance telephone transmission:

Coaxial cable has traditionally been used for long-distance telephone network. Although it faced challanges from optical fiber, terrestrial microwave and satellite, it's still not obsolete in current day and age. Using frequency division multiplexing (FDM), a coaxial cable can ~~main~~ carry over 10,000 voice channels simultaneously.

(iii) Short-run computer system links

Using digital signalling, coaxial cable can provide high speed I/O channels on computer systems.

(iv) Local Area Networks

Coaxial cables are used in ethernets. Because of high bandwidth, and consquently high data rate, they ~~obs~~ were chosen for digital transmission for early LANs.

• Transmission Characteristics :

Coaxial cable is used to transmit both digital ~~and~~ and analog signals. As coaxial cables have frequency characteristics superior to that of twisted pair, they can be used for higher frequencies and data rates. Because of its shielded, concentric construction, it is less susceptible to interference and crosstalk. The principles constraints on performance are attenuation, thermal noise and intermodulation noise. The latter is present only when the FDM or frequency bands are in use on cable.

For long distance transmission of analog signals, amplifiers are needed every few kilometers with closer spacing for higher frequency. The usable spectrum for analog signaling extends to ~~about~~ about 500 MHz. Same is required for digital signals.

5.3 Optical Fiber

A fiber optic is a glass or plastic cable and transmits signal in the form of light.

• Description:

An optical fiber is a thin (2 to 125 um), a flexible medium capable of guiding an optical ray. Various glasses and plastic are used to construct fiber optical cable. The lowest losses have been obtained using fibers of ultrapure fused silica. Ultrapure fiber is difficult to manufacture; higher-loss multicomponent glass fibers are more economical and still provide good performance. Plastic fiber is even less costly and can be used for short-haul links, for which moderately high losses are acceptable.

An optical fiber has a cylindrical shape and consists of three concentric sections - the core, the cladding and the jacket. Core is the innermost layer consting of very thin strands, the diameter is in range of 8 to ~~50~~ 50 um. Each fiber is surrounded by cladding with diameter of 125 um. The outermost layer is surrounded of jacket and is composed of plastic.

Mechanism:

Light travels in a straight line as long as it is moving through a uniform substance. If a ray of light travels from one substance to another, the direction of ray changes. This phenomenom is called refraction.

As from the figure, the angle of incidence I is less than the critical angle, the ray reflects and moves closer to the surface. If the angle of incidence is equal to the critical angle, the light bends along the interface. If angle is greater than critical angle, the ray reflects and travels again in the denser substance. Critical angle varies from substance to substance.

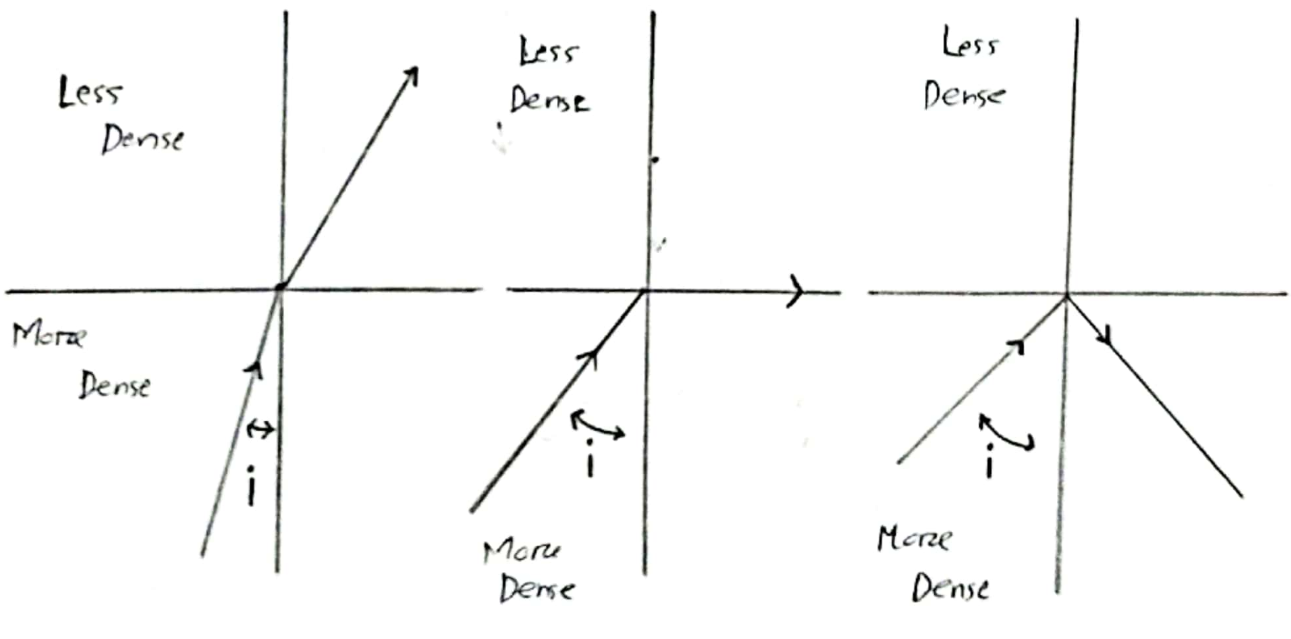
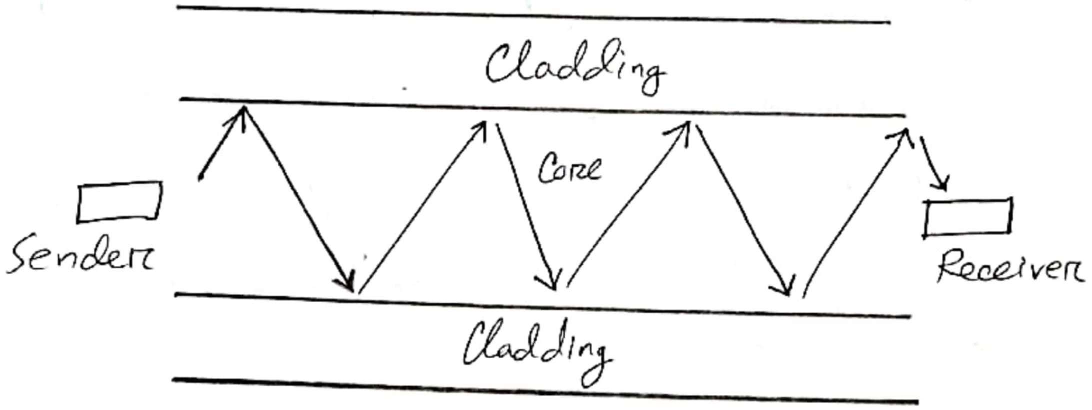
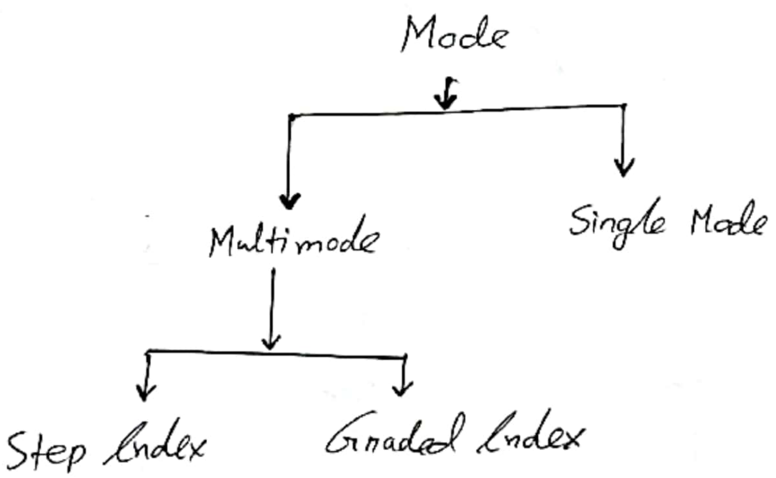


Fig: Refraction of light

Optical fiber use reflection to guide light through a channel. A glass or plastic core is surrounded by cladding of less dense glass or plastic. The difference in density of two materials be such that total internal reflection occurs within the wire.



• <u>Propagation Mode:</u>



(i) Multi-mode: Multiple beams from a light source ~~mak~~ move through core in different paths. How these beams move depend on the core structure.

In multimode step-index fiber, the density of core remains constant from the center to the edges. A beam of light moves in constant density in a straight line until it reaches the core and the cladding. The abrupt change due to lower density at the interface is why it is called step-index.

A second type of fiber - also called multimode graded-index fiber decreases distortion of signal through cable. A graded index fiber has varying density.

(ii) Single Mode: Single mode use step index fiber and a ~~Single~~ highly focused source of light that limits beams to a small change so that it is close to horizontal. The single mode fiber is manufactured with a smaller diameter than multimode and with lesser density. All beams arriving at destination together can be recombined with a little distortion to signal.

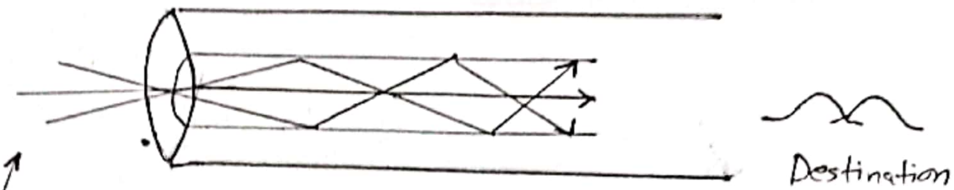


Fig: Multimode, step index

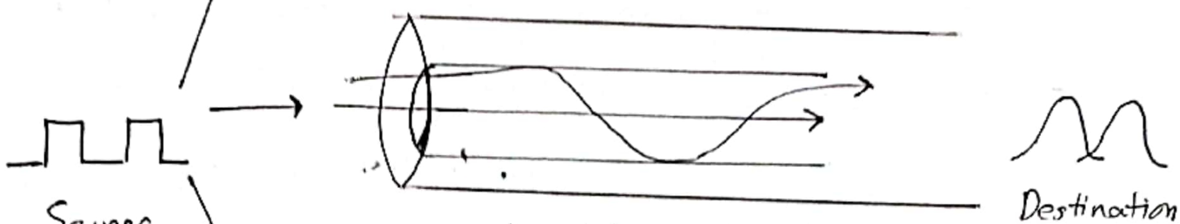


Fig: Multimode, graded index

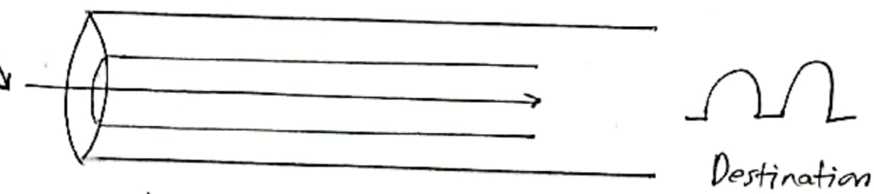


Fig: Single Mode

• Fiber Sizes

Optical fibers are defined by ratio of diameter to their core and diameter to the cladding, both expressed in micrometers. The common sizes are:

Type	Core (um)	Cladding(um)	Mode
50/125	50.0	125	Multi-mode, graded index
62.5/125	62.5	125	Multi-mode, graded index
100.00/125	100.0	125	Multi-mode, graded index
7/125	7.0	125	Single Mode

• **Cable Types:** A list of cable types are given below:-

(i) OFC – Optical Fiber Conductive
(ii) OFN – Optical Fiber Non-conductive
(iii) OFCG – Optical Fiber Conductive, General Use
(iv) OFNG – Optical Fiber Non-conductive, General Use
(v) ADSS – All dielectric self-supporting

• **Connectors:** There are 3 types of connectors used for fiber optic cables – (i) Subscriber Channel (SC) connector

- used for cable TV
- push/pull locking system

(ii) Straight-Tip (ST) connector

- connecting cable for networking devices
- bayonett locking system

(iii) MT-RJ

- Connector of RJ-45 size

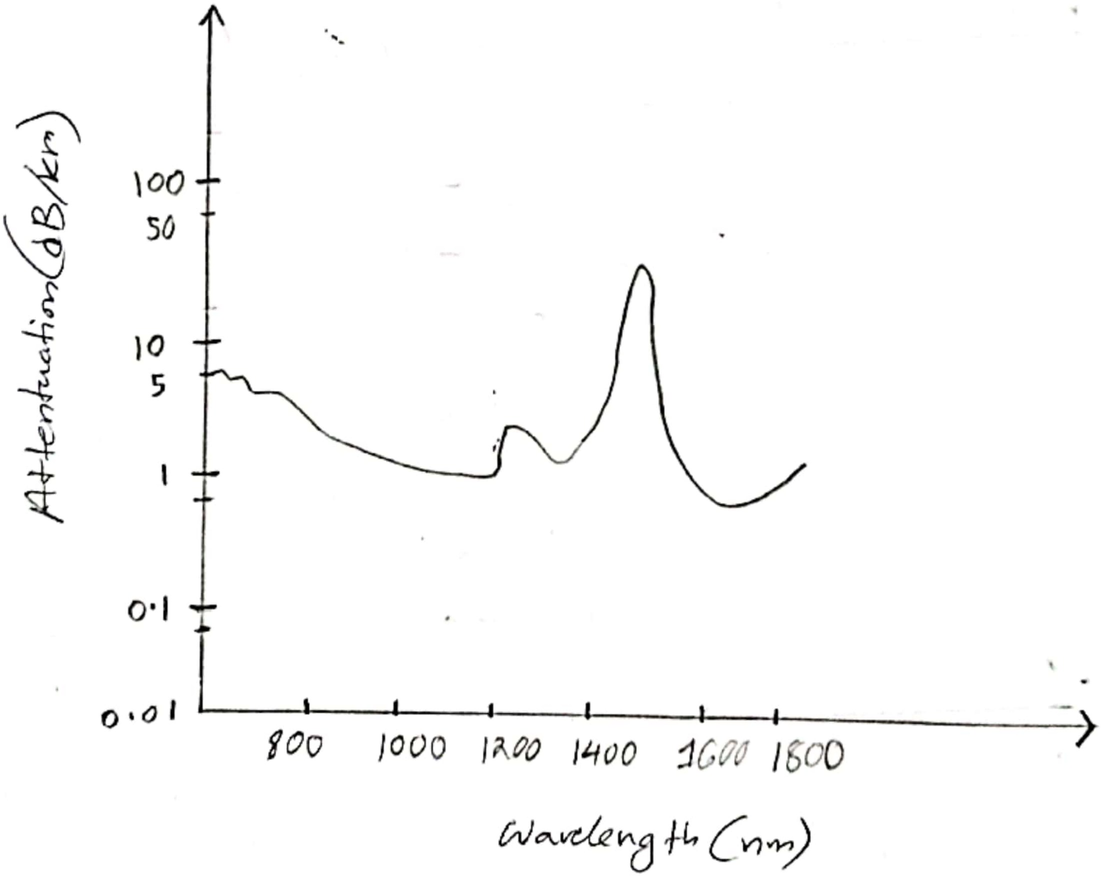
• **Applications:**

Fiber optic is often found in backbone of networks because of bandwidth and cost efficiency. With wavelength-division multiplexing (WDM), we can transfer data at a rate of 1600 Gbps. SONET networks create such a backbone.

Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating hybrid network. This is cost effective connection. Local networks use 100Base-FX network (Fast Ethernet) and 1000 Base-X also use fiber-optic cable.

• ~~Application~~

• Performance: The plot of attentuation versus wavelength shows a very interesting phenomenon. Attentuation is flatter than in the case of twisted-pair cable and coaxial cable. The performance is such that we need fewer repeaters.



Advantages: (i) Higher bandwidth

(ii) Less signal attentuation

(iii) Immunity to EMI

(iv) Resistance to corrosive materials

(v) Light weight

(vi) Greater immunity to tapping

Disadvantages: (i) Installation and maintainance

(ii) Undirectional light propagation

(iii) Higher Cost

6. Unguided Media

Unguided medium transports electromagnetic wave without any physical conduct. We have three general ranges that interest our discussion for wireless transmission.

For unguided media transmission and reception are done by means of antenna Signals are normally ~~broa~~ broadcasted through free space and will thus be available to anyone.

6.1 Antenna

An antenna is defined as an electrical conductor or system of conductors used either for radiating electromagnetic energy or for collecting electromagnetic energy. For transmission of a signal, the electrical energy is converted to electromagnetic energy by the antenna and radiated to the surrounding environment. For signal reception, electromagnetic energy impinging on ~~the~~ the antenna is converted into radio frequency electrical energy and fed to receiver. In two way-communication, is used as sender and receiver. An isotropic antenna is a point in space that radiates power in all direction equally. Another type of antenna is parabolic ~~refle~~ reflective antenna, which is used in terrestrial microwave and satellite application.

6.2 Antenna Gain

An antenna gain is a measure of directionality of an antenna. Antenna gain is defined as the power output in a particular direction compared to that produced in any direction by a perfect omnidirectional antenna (iso-tropic antenna)

A concept related to antenna gain is effective area to an antenna. The effective area of an antenna is related to the physical size of the antenna and shape. The relationship between antenna gain and effective area is

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

where G = antenna gain
A_e = effective area
f = carrier frequency
c = speed of light
λ = carrier wavelength

6.3 Propagation Methods

Unguided signals can travel from source to destination in several ones. The primary ones are:

(i) Ground Propagation: In this propagation, radio waves travel through the lowest portion of the atmosphere. The low signals emanate in all directions from the transmitting antenna and follow the curvature of planet. Distance depends on power of signal - greater power means greater distance.

(ii) Sky Propagation: Higher frequency radio-waves radiate upward into ionosphere and are reflected back to earth. This allows greater distance with low ~~output~~ output power.

(iii) Line-of-sight Propagation: Very high frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be uni-directional directly facing each other, either tall enough or close enough to not be affected by curvature of earth. Line-of-sight transmission is tricky because radio transmissions cannot be completely focused.

6.4 Bands

The section of electromagnetic spectrum from radio-waves to micro-waves 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
(i) Very Low Frequency (VLF)	3-30 kHz	Ground	Long-range radio navigation
(ii) Low Frequency (LF)	30-300 kHz	Ground	Radio beacons and navigational locators
(iii) Middle Frequency (MF)	300 kHz - 3 MHz	Sky	AM radio
(iv) High Frequency (HF)	3-30 MHz	Sky	Citizens band (CB), ship/aircraft
(v) Very High Frequency (VHF)	30-300 MHz	Sky and Line-of-sight	VHF TV, FM radio
(vi) Ultrahigh Frequency (UHF)	300 MHz - 3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
(vii) Superhigh Frequency (SF)	3-30 GHz	Line-of-sight	Satellite
(viii) Extremely High Frequency (EHF)	30-300 GHz	Line-of-sight	Radar, satellite

• For optical line of sight, and radio line of sight, with no intervening obstacles,

$$\text{optical line of sight, } d = 3.57\sqrt{h}$$
$$\text{radio line of sight, } d = 3.57\sqrt{Kh}$$

where, d is distance between an antenna and horizon in kilometres

h is antenna height in meters

K is an adjustment factor to account for ~~refracti~~ refraction

6.5 Radio Waves

Electromagnetic waves reanging in 3 kHz to 1 GHz frequency are called radio-waves. As it is quite similar to microwaves (1-300 GHz), theirs frequencies often ~~overall~~ overlap resulting in unclean demarcation between these two. However, behavior of radio-waves is a better classification.

• Characteristics:

(i) Radio waves are mostly omnidirectional - they are propagated in all directions by antenna.

(ii) Broadcasting does not require dish-shaped antennas.

(iii) Antennas don't need to be rigidly mounted to a precise allignment.

(iv) Waves can be received by any receiving antennas

(v) Can travel long-distance and suitable for long distance broadcasting such as AM radios, for radio waves that propogate in sky.

(vi) Radio waves of low and medium frequency can penetrate walls.

(vii) Suspectible to interference by other signals in the same frequency band.

(viii) Radio waves bands are relatively narrow, compared to that of microwaves and the subbands are also narrow which leads to low data rate for digital communication.

- Applications

(i) Used for broadcasting to cover VHF and part of UHF band

(ii) AM, FM radio is used to receive radio waves and enjoy voice-channels.

(iii) UHF and VHF ~~tele~~ televisions use radiowaves to receive signals.

• Transmission characteristics :

(i) Transmission is limited to line of sight for radio waves above 30 MHz as the ionosphere is transparent to them.

(ii) Distant transmitters will not interfere with each other due to reflection from atmosphere.

(iii) Broadcast radios are less sensitive to attenuation from rainfall.

(iv) A primary source of impairment is multipath interference. Reflection from land, water and natural or human-made objects can create multiple paths between antennas.

6.6. Terestrial Microphone

• **Description** : The most common type of microwave antenna is the parabolic "dish" antenna. A typical size is about 3 m in diameter. The antenna is fixed rigidly and focuses a narrow beam to achieve line of sight transmission, Microwave antennas are usually located at a substancial height from ground. To achieve long distance transmission, a series of of microwave relay towers is used and point to point microwave links are stung together over desired distance.

• **Applications:**

(i) Primary use for terrestrial microwave systems is in long-haul telecommunications service as an alternate to coaxial cable or optical fiber.

(ii) Commonly used for voice and television transmission.

(iii) Short point-to-point links between buildings.

(iv) Short-haul microwave can also be used for bypass application.

• **Performance:** Typical Digital Microwave Performance

Band (GHz)	Bandwidth (MHz)	Data Rate (Mbps)
2	7	12
6	30	90
11	40	135
18	220	274

6·7 Satellite Microwave

• Description: A communication satellite, in effect, a microwave relay station. It links 2 or more ground-based micro-wave transmitters known as earth stations or ground stations. The satellites receive transmission on one frequency band, amplifies or repeats the signal and transmits to another frequency (downlink)

• Applications:

(i) Television Distribution
(ii) Long-distance Telephone Transmission
(iii) Private Business Networks
(iv) Global positioning

6·8 Infrared

Infrared communication is achieved to modulate noncoherent infrared light. It is done using transceivers.

Characteristics:

(i) Frequency ranges from 300 GHz to 400 THz
(ii) Have high frequencies and can not penetrate walls.
(iii) Transeivers must be within line of sight directly or via reflection from a light colored surface.
(iv) No frequency allocation issue and licensing required

Applications:

(i) Excellent for short range communication devices.

(ii) Widely used in TV and other short-ranged ~~remoted~~ remotes.

(iii) Used in IrDA port for ~~wirelt~~ wireless communication between PC and keyboard.

~~Ex~~

The ~~ID~~ IrDA port standard defined 75 kbps data rate upto 8 m. Recent standards improved it to ~~8 m~~ 4 Mbps.