It is concerned with the physical transmission of the data from computer to computer. There is one further level of software to be considered, the network level. It routes the packages across a particular network.	Network	Internet	It is the linchpin that holds the whole architecture together : it permits to send and receive packets, even if they are in random order.
It handles the transmission of a framed set of data (usually a sequence of bits) from one point in a network (node) to another one. This layer also represents the boundary between hardware (e.g., CRC) and software implementation (e.g., physical addressing).	Data Link	Host-to-network	The TCP/IP reference model does not really say much about what happens here, except to point out that the host has to connect to the network using some protocol so it can send IP packets over it. This protocol is not defined and varies from host to host and network to network.
The physical medium used to transmit the information. To specify this layer, it is necessary to define the physical properties of the connection, such as mechanical properties, electrical/optical properties, functional aspects of the data transmission (modulation/demodulation for example) and procedural aspects of data transmission (e.g., bit stuffing to ensure that special signals are un-equivocal).	Physical		

3.8.3 General Comparison

It includes the following topics

(a) Focus of Reliability Control
(b) Roles of Host System
(c) De-jure vs. De-facto

Focus of Reliability Control

- Implementation of the OSI model places emphasis on providing a reliable data transfer service, while the TCP/IP model treats reliability as an end-to-end problem.
- Each layer of the OSI model detects and handles errors, all data transmitted includes checksums. The transport layer of the OSI model checks source-to-destination reliability.
- In the TCP/IP model, reliability control is concentrated at the transport layer. The transport layer handles all error detection and recovery. The TCP/IP transport layer uses checksums, acknowledgments, and timeouts to control transmissions and provides end-to-end verification.

Roles of Host System

Hosts on OSI implementations do not handle network operations (simple terminal), but TCP/IP hosts participate in most network protocols. TCP/IP hosts carry out such functions as end-to-end verification, routing, and network control. The TCP/IP Internet can be viewed as a data stream delivery system involving intelligent hosts.

De-jure vs. De-facto (OSI)

OSI

- Standard legislated by official recognized body. (ISO)
- The OSI reference model was devised *before* the protocols were invented. This ordering means that the model was not biased toward one particular set of protocols, which made it quite general. The down side of this ordering is that the designers did not have much experience with the subject and did not have a good idea of which functionality to put in which layer.
- Being general, the protocols in the OSI model are better hidden than in the TCP/IP model and can be replaced relatively easily as the technology changes.
- Not so widespread as compared with TCP/IP. (Complex, costly)
- More commonly used as teaching aids.

De-jure vs. De-facto (TCP/IP)

TCP/IP

- Standards adopted due to widespread use. (Internet)
- The protocols came first, and the model was really just a description of the existing protocols. There was no problem with the protocols fitting the model, but it is hardly possible to be use to describe other models.
- "Get the job done" orientation.
  Over the years it has handled most challenges by growing to meet the needs.
- More popular standard for internetworking for several reasons:

- Relatively simple and robust compared to alternatives such as OSI.
- Available on virtually every hardware and operating system platform (often free).
- The protocol suite on which the Internet depends.

3.9 Criticism Of The Reference Models

We can find several elements showing that OSI and TCP/IP models and protocols are not perfect. These elements are discussed below:

3.9.1 Criticism of the OSI Model

The OSI Model is often criticized as being overly complex, offering too many choices. It is usually contrasted with the Internet or TCP/IP protocol suite by such critics. The concept of layers introduced in the OSI model has two motivations:

1. Primarily technically, but secondarily politically, it is a modularization technique, taken from software engineering and re-applied to the systems engineering of communications architectures (a term used instead of model).
2. Secondarily technically, but primarily politically, each layer (module) can be implemented by a different supplier, to a service specification and must only rely on the service specifications of other layers (modules).

By the Mid 1990's it was clear that the protocols inspired by the International Standards Organizations' Open Systems Interconnection Reference Model (OSIRM), in particular those promulgated by the CCITT and similar bodies had failed to gain any significant acceptance except at the lowest levels and there was widespread criticism of the OSIRM itself.

The failure of the protocols is related to a number of issues

- The protocols were slow to be finalized.
- The protocols were difficult to understand and implement.
- It was difficult to obtain copies of the standards documents.

In all respects the contrast with the protocols associated with the Internet is clear and stark. The Internet protocols are simple, described in plain English, freely available and had the advantage of being early in the field whereas the OSIRM/CCITT protocols are elaborate and abstruse. The Internet protocols were developed in response to a direct and immediate need. The Internet protocols were developed in the context of computer networking rather than the highly regulated world of the national telecommunication bodies that were heavily involved in the OSIRM protocol developments.

Even so it could be and has been suggested that the OSIRM based protocols could or would eventually replace the original Internet protocols as the OSIRM based protocols became better understood and the consequences of the informal design of the Internet protocols became clearer. It now seems most unlikely that this will happen. This is, of course, partly due to the complete market dominance of the Internet protocols and related products but there are also fundamental problems with the OSIRM.

The reference model further specifies seven levels (or layers). This seven-layer model has been reproduced in practically every text on communications, unfortunately the chosen levels bear little relation to the practicalities of communications protocol implementation and null layers and sub-layers are common.

The Internet protocols fit in a much less rigidly defined framework with no formally defined layers but hierarchical use of "lower" protocols by "higher" protocols being common. To those familiar with the formal framework of the OSIRM the Internet Protocols seem "adhoc" and pragmatic, as indeed they are. It is a matter of observation that the OSIRM community has not produced anything like the World Wide Web or the Usenet.

The OSIRM can be further criticized for inadequate support for the concept of interconnected networks and the various management functions such as name service. Interconnected networks imply that entities on two networks that are not directly connected can still communicate even though the networks may be quite different. This has always been fundamental for the Internet community. Such Internet protocols seem to fit between level 3 and level 4 of the OSIRM. They rely on network services to transport data from one part of a network to another (i.e. from one gateway to another) but they are used by end-to-end protocols such as TCP which belong at level 4 of the OSIRM.

Management services simply do not seem to fit very well into the hierarchical model. The simplest examples of management services are various name servers (such as DNS), connectivity tests (such as PING) and more general network management protocols (such as SNMP). Such things can be seen either as services in their own right or as facilities to be used by other services. The most striking issue concerning the OSI model is that it is perhaps the most studied and most unanimously accepted network structure and yet it is not the model that it is really implemented and used. **The specialists, who analyzed this failure, determined 4 main reasons that are stated below:**

1. It was not the right moment

David Clark from the MIT has developed the following theory regarding the manner to publish a standard at the right time. To him, in the cycle of life of a standard, there are 2 principal peaks of activity: the research carried out in the field covered by the standard, and the industrial investments for the implementation and deployment of the standard. These two peaks are separated by a off-peak of activity that actually appears to be the ideal moment for the publication of the standard : it is neither too early compared to research so that we control the technology, nor too late for the investments and manufacturers are ready to spend capital to implement it.

The OSI model was perfectly released regarding research, but alas, the TCP/IP model was already receiving huge investments (when the OSI model was released, the American universities were already successfully using TCP/IP) and the manufacturers did not feel like investing on it.

2. It was not the right technology

The OSI model is maybe to complete and too complex. The gap between the concrete use (implementation) and the model is sometimes significant. Indeed, few programs can use or wrongly use the 7 layers of the model: the session and presentation layers are hardly used and on contrary the data link and network layers are often split into several sub- layers, since they are pretty complex.

The OSI model is in fact too complex to be effectively and properly implemented. The committee that wrote the standard even had to leave aside some technical points, like security and coding, so much it was delicate to preserve a well-defined role to each layer completed with these extra technical points. This model is also redundant (the flow control and the error control appear in most layers). At the implementation level, TCP/IP is much more optimized and effective.

The most significant criticism that one can make against the OSI r odel is that it is not adapted at all to telecommunication applications on computer! Some choices are in disagreement with the way computers and software communicates. The standard actually uses "system interruptions" to report events, and with high level programming languages, that is not very realizable.

3. It was not the right implementation

This simply comes from the fact that the model is relatively complex, and therefore the first implementations were pretty heavy and slow. Conversely, the first implementation of TCP/IP in the Unix system of the Berkeley University (BSD) was free and relatively effective. Historically, people thus had a natural tendency to use TCP/IP.OSI Model was often synonym of "poor quality"

4. It was not the right policy

Actually, the OSI model suffered from its too strong standardization. The efforts of implementation of the model were above all "bureaucratic" and therefore people might have discredited the model.

3.9.2 The Future of the OSI Model

Regarding its use and implementation, and in spite of an update of the model in 1994, the OSI model has clearly lost the war against TCP/IP. Only few dominating manufacturers keep the model but it is likely to disappear, all the more quickly since the Internet (and thus TCP/IP) is developing.

However, the OSI model will still remain for a while in memories for several reasons. First, it is one of the first main efforts as regards standardization in the area of networks. Manufacturers now tend to do with TCP/IP, but also WAP, UMTS etc. what they were supposed to do with the OSI model, namely to propose standardizations from the beginning. The OSI model will also remain memories for another reason: even if TCP/IP is the model concretely used, people have tendency and use OSI like the current network model of reference. In fact, TCP/IP and OSI have very close structures, and it is especially the effort of standardization of OSI which imposed this general "confusion" between the 2 models. One commonly tends to consider TCP/IP as the real implementation of OSI.

From the above discussion we have concluded the following critiques of OSI Reference Model

- OSI protocols haven't been tested widely before having been standardized. They are not based on existing practice in large scale computer networking, like the Internet
- OSI standards are (compared to Internet standards) very expensive and difficult to obtain.
- The OSI reference model is too complex and has too many layers.
- Having to have to understand the very difficult documentation isn't very motivating.
- Promising new network technologies like ATM networks don't fit in the OSI reference model very well and many important techniques like LANs, RPC and stateless protocols became popular after the OSI reference model had been standardized.
- Having two completely incompatible alternative protocols (CLNP and X.25) at the network layer (and consequently many different transport layers that try to compensate for the differences) isn't what helps you in building up a fully interconnected easy to use and maintain global network.

3.9.3 Critiques of TCP/IP Model

- TCP/IP Model does not clearly distinguish the concepts of service, interface and protocol. So we can say that the TCP/IP model does not make the distinction between specifications and implementation : IP is a protocol that is an integral part of the specifications of the model.
- Consequently, the TCP/IP Model is not much of a guide for designing new networks using new technologies. This model is not general at all and efficient to describe other protocols.
- We can also speak about the host-network layer : Indeed, it is not a real abstraction layer, insofar as its specification is not accurate enough. The host-to-network layer is not really a layer at all in the normal sense that the term is used in the context of layered protocols. It is an interface between the network and data link layers. The TCP/IP Model does not include separate layers between Physical and Data Link layers: there is only a Host to Network Layer.

From the above criticisms we concluded two main points:

- OSI Model is very useful (except Session and Presentation layers) for discussing computer networks, but **OSI protocols are not very popular.**
- TCI/IP Model is almost non-existent, and on the contrary **TCP/IP protocols are very popular.**

Manufacturers are then obliged to propose solutions to fill in the lacks. Finally, we notice that the physical and data link layers are as important as the transport layer. From this fact, we may propose a hybrid model with 5 layers, which would gather the good points of every model:

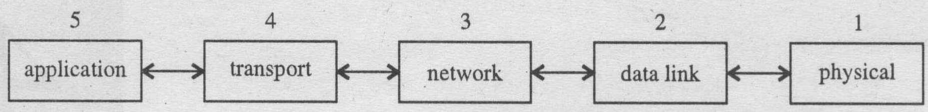


Fig. 3.13 Hybrid model of reference

Finally, this model is the real reference in the Internet world. We have kept most layers of the OSI model (all but the session and presentation layers) because they are well specified. On the other hand, OSI's protocols have no success and finally, we have kept those from the TCP/IP model.

● ● ●

4

Transmission Media

Introduction

Network media is the actual path over which an electrical signal travels as it moves from one component to another. Modern networks can utilize several types of network media. Most networks use some type of cable for the connection media. Air is sometimes used. Wireless technologies, such as infrared and satellite communications, will become increasingly important in the future. This chapter describes the common types of network media, including twisted-pair cable, coaxial cable, fiber-optic cable and wireless media.

A data communications network must have cabling to allow individual computers and other peripherals to talk to one another and share resources. And wouldn't it be easier if there were only one type available? There would be fewer hassles when it came time to figure out such things as line speeds, line capacities, variations in line distortion, and so on. However, there are a number of types, ranging in cost and capabilities.

4.1 Few Important Points about the Electrical Interface

- To transmit binary data over transmission channels, the binary digits making up each element to be transmitted must be converted into electrical signals.

Binary 1	+V volts
Binary 0	–V volts

- On receiving these signals, the receiver interprets +V volts as binary 1 and –V volts as binary 0.

- In practice transmitted electrical signals are attenuated and distorted by the transmission medium, so that the receiver is unable to discriminate between binary 1 and 0 signals.

The basic idea of data transmission is to encode data as energy and transmit energy and then decode energy at destination back into data. Energy can be electrical, light, radio; sound, ... Each form of energy has different properties and requirements for transmission.

4.1.1 Bit-Wise Data Transmission

Transmitted energy is carried through some sort of medium. Media can be copper, glass, air...

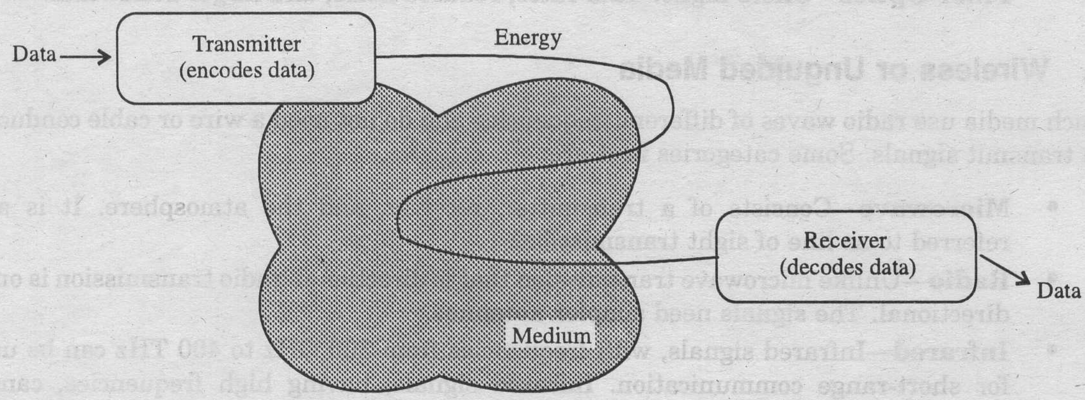


Fig. 4.1 Data transmission

So we can say that data transmission requires:

- ☐ *Encoding* bits as energy
- ☐ *Transmitting* energy through medium
- ☐ *Decoding* energy back into bits

Transmitter and receiver must agree on encoding scheme and transmission timing.

Measures of Transmission Rates

- *Baud* rate measures number of signal changes per second.
- *Bits* per second measures number of bits transmitted per second.
- In RS-232, each signal change represents one bit, so baud rate and bits per second are equal.
- If each signal change represents more than one bit, bits per second may be greater than baud rate.

4.2 Classification Of Transmission Media

There are two major classes of transmission media:

1. Conducted or Guided Media

Waves are guided along solid medium. Such media use a conductor such as a wire or a fiber optic cable to move the signal from sender to receiver.

Some basic categories in it are:

- **Twisted-pair wire**—Copper wire twisted into a spiral shape. Wires are twisted together to reduce noise and crosstalk.
- **Coaxial Cable**—Improved version of twisted pair. Consists of conductors insulated from each other enclosed in a polyethylene jacket.
- **Fiber-Optics**—Offers higher data rates, reduced noise, and larger bandwidth.

2. Wireless or Unguided Media

Such media use radio waves of different frequencies and do not need a wire or cable conductor to transmit signals. Some categories in it are:

- **Microwave**—Consists of a transmitter, receiver, and the atmosphere. It is also referred to as line of sight transmission.
- **Radio**—Unlike microwave transmission that is directional, radio transmission is omni directional. The signals need simpler antennas.
- **Infrared**—Infrared signals, with frequencies from 300 GHz to 400 THz can be used for short-range communication. Infrared signals, having high frequencies, cannot penetrate walls.
- **Satellites**—Satellites are transponders (units that receive on one frequency and retransmit on another) that are set in geostationary orbits directly over the equator.

4.2.1 Characteristics of A Medium

There are three important parameters for communication media:

Bandwidth: (Capacity) Number of bits per second. Greater bandwidth implies higher data rates

Delay: The time elapsed until data starts arriving at the other end.

Loss: Error rate.

Medium	Bandwidth	Delay	Loss
Truck with magnetic tapes or CDs	Very high	Very, very high	Low
Copper	Medium	Low	Varying, sensitive
Radio link • earth based • by satellite	 Quite high High	 Low High	 Medium Medium
Fiber optics	Very high	Low	Very high

Data transmissions depend on the characteristics of the signal and of the medium.

- For guided media, the medium is the dominant factor.
- For unguided media, the bandwidth of the signal is the dominant factor.

Now we will discuss each kind of transmission media in detail.

4.3 Magnetic Media

Data transmission between two machines takes place in the following way:

- The source machine writes data onto magnetic tapes or floppy disks.
- The tapes or disks are physically transported to the destination machine by a station wagon, truck, or airplane.
- The destination machine reads the data from the tapes or disks.

A simple calculation, suppose:

- A standard 8-mm video tape can hold 7 gigabytes.
- A box can hold 1000 tapes, for a total capacity of 7000 gigabytes.
- A box of tapes can be delivered anywhere in the US in 24 hours by Federal Express and other companies.

The effective bandwidth is 56-gigabits/86400 sec or 648 Mbps, which is slightly better than the high-speed version of ATM (622 Mbps). If the destination is only an hour away by road, the bandwidth is increased to over 15 Gbps. The cost is 10 cents per gigabyte - no network carrier on earth can compete with this!

Advantages : High bandwidth and cost effective.
Disadvantages : Off-line and poor delay characteristics.

4.4 Twisted Pair

Twisted pair is most widely used media for local data distribution. Twisted-pair cable is a type of cabling that is used for telephone communications and most modern Ethernet networks. A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against *crosstalk*, the noise generated by adjacent pairs. The twisting introduces an inductive component that opposes the capacitivity between the two threads. When electrical current flows through a wire, it creates a small, circular magnetic field around the wire. When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. Thus, the two magnetic fields cancel each other out. They also cancel out any outside magnetic fields. Twisting the wires can enhance this *cancellation effect*. Using cancellation together with twisting the wires, cable designers can effectively provide self-shielding for wire pairs within the network media.

While twisted-pair cable is used by older telephone networks and is the least expensive type of local-area network (LAN) cable, most networks contain some twisted-pair cabling at some point along the network.

Since some telephone sets or desktop locations require multiple connections, twisted pair is sometimes installed in two or more pairs, all within a single cable. For some business locations, twisted pair is enclosed in a shield that functions as a ground. This is known as shielded twisted pair (STP). Ordinary wire to the home is unshielded twisted pair (UTP).

In shielded twisted pair cables, each pair has a metal sheath around it for better protection against interference. Unshielded twisted pair lacks the sheath, but has the advantage of being more flexible and thinner. Twisted pair cable is being replaced over time by coaxial cable and fiber-optic cable, which have greater signal capacity.

Twisted pair is now frequently installed with two pairs to the home, with the extra pair making it possible for you to add another line (perhaps for modem use) when you need it. Twisted pair comes with each pair uniquely color-coded when it is packaged in multiple pairs. Different uses such as analog, digital, and Ethernet require different pair multiples.

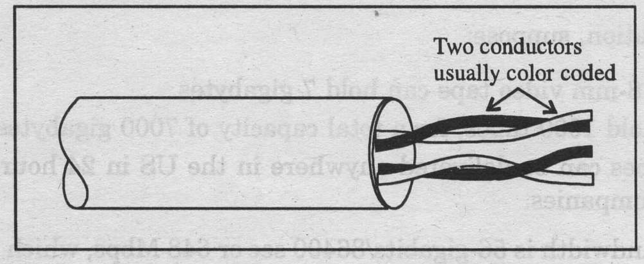


Fig. 4.2 Twisted-wire pairs (2 wire pairs shown)

Although twisted pair is often associated with home use, a higher grade of twisted pair is often used for horizontal wiring in LAN installations because it is less expensive than coaxial cable. The wire you buy at a local hardware store for extensions from your phone or computer modem to a wall jack is not twisted pair. It is a side-by-side wire known as silver satin. The wall jack can have as many five kinds of hole arrangements or pinouts, depending on the kinds of wire the installation expects will be plugged in (for example, digital, analog, or LAN).

The advantages of using telephone wires are their relative low cost and their availability. Their disadvantages include susceptibility to signal distortion errors and the relatively low transmission rates they provide over long distances. Twisted wire can handle a data flow of up to approximately one megabit per second (Mbps) over several hundred feet. For a small local-area network with a limited number of users, twisted-pair is an ideal choice because it is both inexpensive and easy to install. A phenomenon called **crosstalk exists** in twisted-wire pairs whenever transmission occurs at a high rate of speed. Crosstalk is taking place whenever you can hear someone else's conversation in the background; while you're trying to carry on a conversation with your party. With voice communications this really isn't a problem; however, crosstalk can inhibit the high-speed transmission required for data communications.

Twisted-wire pairs used in data communications are either private or public lines. **Private lines** are those provided by the user. **Public lines** are those provided by a common carrier such as American Telephone and Telegraph (AT&T). Generally, public lines are used whenever distances are great or the terrain or other environmental factors prohibit the use of private lines. Public lines may be either switched lines or leased lines.

Switched lines are used whenever the amount of data to be transmitted is short in duration or when many locations must be contacted for relatively short periods of time. There is a drawback. The telephone company cannot guarantee you exactly which path or switching equipment such a connection will use. Therefore, the speed and quality of the switched connection are questionable.

Leased lines come into play when the connection time between locations *A* and *B* is long enough to cover the cost of leasing, or if higher speeds than those available with switched lines must be attained. Leased lines can also be conditioned by the telephone company to lower the error rate and increase transmission speeds. Conditioned leased lines typically operate at speeds of up to 64,000 bits per second (bps). Very-high-speed connections are also available from the common carrier. These are designated *T*1, *T*2, *T*3 and *T*4 and offer transmission rates of 1.5, 6.3, 46, and 281 million bits per second (Mbps), respectively.

Two basic types of twisted-pair cable exist:

1. Unshielded twisted pair (UTP)
2. Shielded twisted pair (STP).

4.4.1 UTP Cable

Unshielded twisted pair is the most common kind of copper telephone wiring. UTP cable is a medium that is composed of pairs of wires. UTP cable is used in a variety of networks. Each of the eight individual copper wires in UTP cable is covered by an insulating material. In addition, the wires in each pair are twisted around each other.

UTP cable relies solely on the cancellation effect produced by the twisted wire pairs to limit signal degradation caused by electromagnetic interference (EMI) and radio frequency interference (RFI). To further reduce crosstalk between the pairs in UTP cable, the number of twists in the wire pairs varies. UTP cable must follow precise specifications governing how many twists or braids are permitted per meter (3.28 feet) of cable.

UTP cable offers many advantages.

1. **Size :** UTP is small and does not quickly fill up wiring ducts. Because UTP has an external diameter of approximately 0.43 cm (0.17 inches), its small size can be advantageous during installation. Because it has such a small external diameter, UTP does not fill up wiring ducts as rapidly as other types of cable. This can be an extremely important factor to consider, particularly when installing a network in an older building.
2. **Inexpensive :** UTP cable is less expensive than other types of networking media. In fact, UTP costs less per meter than any other type of LAN cabling.
3. **Easy installation :** It is thin, flexible and easy to string between walls.
4. As UTP can be used with most of the major networking architectures, it continues to grow in popularity.

UTP does have its disadvantages:

1. **Susceptibility to interference :** It is more susceptible to interference than most other types of cabling. The pair twisting does help, but it does not come close to making the cable impervious to electrical noise.
2. **Limited segment length :** It is limited to segments of 100 meters.

Although UTP was once considered to be slower at transmitting data than other types of cable, this is no longer true. In fact, UTP is considered the fastest copper-based medium today.

The following summarizes the features of UTP cable:

- Speed and throughput-10 to 1000 Mbps.
- Average cost per node-Least expensive.
- Media and connector size-Small.
- Maximum cable length-100 m (short).

Commonly used types of UTP cabling are as follows:

- **Category 1**—Used for telephone communications. Not suitable for transmitting data.
- **Category 2**—Capable of transmitting data at speeds up to 4 megabits per second (Mbps).
- **Category 3**—Used in 10BASE-T networks. Can transmit data at speeds up to 10 Mbps.
- **Category 4**—Used in Token Ring networks. Can transmit data at speeds up to 16 Mbps.
- **Category 5**—Can transmit data at speeds up to 100 Mbps.
- **Category 5e**—Used in networks running at speeds up to 1000 Mbps (1 gigabit per second [Gbps]).
- **Category 6**—Typically, Category 6 cable consists of four pairs of 24 American Wire Gauge (AWG) copper wires. Category 6 cable is currently the fastest standard for UTP.

4.4.2 STP Cable

STP is similar to UTP in that the wire pairs are twisted around each other. STP also has shielding around the cable to further protect it from external interference. The shielding further reduces the chance of crosstalk but the shielding increases the overall diameter and weight of the cable. The maximum segment length of STP cable is 100 meters.

Shielded twisted pair is a special kind of copper telephone wiring used in some business installations. An outer covering or shield is added to the ordinary twisted pair telephone wires; the shield functions as a ground.

Shielded twisted-pair (STP) cable combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil. The four pairs of wires then are wrapped in an overall metallic braid or foil, usually 150-ohm cable. As specified for use in Ethernet network installations, STP reduces electrical noise both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI).

The **advantages of STP include:**

1. Greater protection from interference and crosstalk due to shielding.
2. Better electrical characteristics than unshielded cables.
3. Easily terminated with modular connector.

The **disadvantages to STP include:**

1. **Cost :** STP has a higher cost per foot
2. **Grounding :** The STP Shield must be grounded at both ends. If it is improperly grounded, the shield acts like an antenna and picks up unwanted signals.
3. **Difficulty in installation :** Heavier, less flexible, STP is more difficult to install.
4. **Thickness :** Because of its thickness it may not fit down narrow cable ducts.
5. No segment length advantage despite the heavier and thicker cable.
6. Can be tapped, breaching security.

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.

Use Twisted-Pair Cable

- If your LAN is under budget constraints.
- If you want a relatively easy installation where computer connections are simple.
- DO NOT USE IF you must be absolutely sure of data integrity transmitted over great distances at high speeds.

4.5 Coaxial Cable

Coaxial Cable is high-capacity cable widely used for high-frequency transmission of telephone, television, and digital audio signals. The cable is very effective at carrying many analog signals at high frequencies.

Coaxial cable is often referred to as simply “coax”. Not only is coax the most commonly used cable, but also the least expensive, most reliable, most convenient, and easily maintained way of transferring electronic images in a CCTV system. Coax is available from many manufacturers and comes in a variety of sizes, shapes, colors, specifications and capabilities. Coaxial cables have become an essential component of our information superhighway. They are found in a wide variety of residential, commercial and industrial installations. From broadcast, community antenna television (CATV), local area network (LAN), closed circuit television (CCTV) to many other applications, coax has laid the foundation for a simple, cost effective communications infrastructure.

Coaxial Cable is also widely used in the telecommunications industry, such as the telephone system where coax reaches the pole or drop nearest to the subscriber's house, and a twisted-pair cable comes into the house and to the telephone. Coaxial can also be a good solution for providing residences and small business with high-speed data access because it is generally wired in a bus topology, it requires less cable than other solutions and does not require a hub, cutting down on cost.

In contrast to twisted-pair wires, coaxial has the capacity to transmit information 80 times faster, has much higher bandwidth, offers greater protection from noise and interference and can support greater cable lengths between network devices. Coaxial cable also offers relatively high immunity to interference from noise sources, so it is often used in manufacturing environments.

Coaxial cable supports 10 to 100 Mbps and is relatively inexpensive, although it is more costly than UTP on a per-unit length. However, coaxial cable can be cheaper for a physical bus topology because less cable will be needed. Coaxial cable can be cabled over longer distances than twisted-pair cable. For example, Ethernet can run approximately 100 meters (328 feet) using twisted-pair cabling. Using coaxial cable increases this distance to 500m (1640.4 feet).

Coax Construction

Common "coax" cable RG59//U, RG6/U, and RG11/U is circular. Each has a center conductor surrounded by dielectric insulating material, which in turn is covered by a braid to shield against electromagnetic interference (EMI). The outer covering is the "jacket".

The coaxial cable's two conductors are separated by a nonconductive or dielectric material. The outer conductor (braid) acts as a shield and helps isolate the center conductor from spurious electromagnetic interference. The outer covering helps physically protect the conductors.

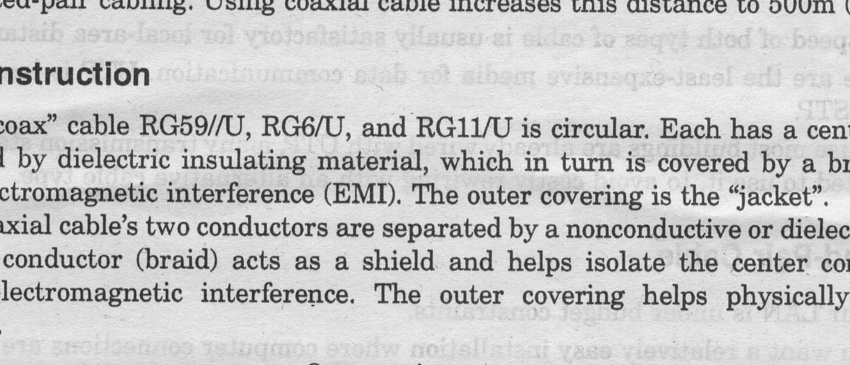


Fig. 4.3 Coaxial cable

Coaxial cable is called "coaxial" because it includes one physical channel that carries the signal surrounded (after a layer of insulation) by another concentric physical channel, both running along the same axis. Data is transmitted through the center channel, while the outer channel serves as a line to ground. These two conductors usually carry equal currents in opposite directions.

Description of Various Parts

Inner/Center Conductor

The center conductor is the primary means of carrying a video signal. The center conductor comes in varying diameters, usually ranging from 14 gauge to 22 gauge. The structure of the center conductor generally is solid copper or copper- clad steel, designated as bare copper weld or BCW. Variation in the size of the center conductor has an overall effect on the amount of DC resistance offered by cable. Cables that contain large diameter center conductors have lower resistances than cables with smaller diameters. This decreased resistance of large diameter cable enhances the ability of a cable to carry a video signal over a longer distance with better clarity, but it is also more expensive and harder to work with.

Dielectric Insulating Material

Surrounding the center conductor is an evenly made dielectric insulating material that is available in some form of either polyurethane or polyethylene. This dielectric insulator helps determine the operating characteristics of coax cable by maintaining uniform spacing between the center conductor and its outer elements over the entire length of the cable. Dielectrics made of cellular polyurethane or foam is less likely to weaken a video signal than those made with solid polyethylene. This lower attenuation is desirable when calculating the loss/length factor of any cable. Foam also gives a cable greater flexibility, which may make an installer's job easier. Although foam dielectric material offers the best performance, it can absorb moisture, which will change its electrical behavior.

Braid or Shield

Wrapped around the outside of the dielectric material is a woven copper braid (shield), which acts as a second conductor or ground connection between the camera and the monitor. It also acts as a shield against unwanted external signals commonly called electromagnetic interference or EMI, which may adversely affect a video signal. The amount of copper or wire strands in the braid determine how much EMI it keeps out. Commercial grade coax cables containing loosely woven copper braid have shielding coverages of approximately 80 percent. These cables are suitable for general-purpose use in applications where electrical interference is known to be low. They also work well when the cable is to be installed in metal conduit or pipe, which also aids in shielding.

Outer Jacket

The last component comprising a coax cable is the outer jacket. Although other materials are used, polyvinyl chloride or PVC, is commonly used in its construction. Available in many colors such as black, white, tan and gray, the jacket lends itself to both indoor and outdoor applications.

Coaxial cable offers several advantages

1. It can be run with fewer boosts from repeaters for longer distances between network nodes than either STP or UTP cable. Repeaters regenerate the signals in a network so that they can cover greater distances. Longer segment lengths than UTP or STP.
2. Coaxial cable is less expensive than fiber-optic cable, and the technology is well known; it has been used for many years for all types of data communication.
3. Familiar and fairly easy to install.
4. Better electrical characteristics (lower attenuation and great bandwidth) than shielded or unshielded cables.
5. Coaxial cable provides superior noise immunity over conventional twisted pairs. As with other media, its immunity to noise is subject to the impact of variables such as the application and the environment. Baseband systems usually provide immunity of 50 to 60 decibels (dB), while broadband systems operate with 85 to 100 dB.
6. Generally good data security.
7. Easy to connect.
8. *Built-in shielding* : The entire cable is surrounded by a non-conduction outer shield, usually made of rubber, Teflon or plastic.
9. More resistant to interference and attenuation than twisted-pair cabling. Attenuation is the loss of signal strength which begins to occur as the signal travels further along a copper cable.

Disadvantages of coaxial cable are :

1. Coaxial cable is not as easy to run as UTP, because it is not as flexible or thin.
2. *Expensive* : Coaxial cable is more expensive than UTP. High attenuation rate makes it expensive over long distance.
3. *Bulky* : Requires more room in wiring ducts than UTP.
4. May become obsolete due to technological advances.

Types of Coaxial Cable : Baseband and Broadband

There are many different forms of coaxial cable; however, they are usually divided into two classifications—those used for **baseband transmission**, and those used for **broadband transmission**. The primary distinction between the two cable types is the characteristic impedance. (Impedance is the measure of how much voltage must be applied to the cable to achieve a given signal strength. Measured in Ohms). Baseband cable has a characteristic impedance of 50 ohms and is used for digital transmission mainly in Ethernet networks, while broadband cable impedance is 75 ohms and is used for analog transmission like in cable television (CATV) and Cable Internet. Using the wrong cable will cause network problems.

4.5.1 Baseband Coaxial Cable

Baseband systems use digital encoding techniques to carry digital data over a digital transmission line. In baseband transmission, all of the available frequencies in the transmission medium are used by one signal. Base band is a 50 ohm cable, which is commonly used for digital transmission. The bandwidth possible depends on the length of the cables used. For example, with 1 km cables a data rate of 1 to 2 Gbps is feasible. Longer cables can also be used, but only at lower data rates or with periodic amplifiers.

The baseband coaxial cable is usually referred to as Ethernet cable, because it was originally used in the Ethernet Networks. In baseband systems there is no modulation of the signal. Transceivers are used to place digital signals directly onto the cable. These signals are encoded using some of the techniques such as Manchester or Differential Manchester phase encoding. The digital signal occupies the entire bandwidth of the cable; thus, baseband cables have only one channel in operation at any moment in time. Transmission is bidirectional. That is, a signal inserted at any point on the medium propagates in both directions to the ends.

Many baseband implementations operate in the range of 10 Mbps for standard Ethernet, although others, such as Token Ring at 16 Mbps, operate at higher rates.

Coax comes in several sizes. Standard Ethernet cable, called **Thick Coaxial** or Thick Ethernet, is about the diameter of a man's thumb and **Thin Coaxial** or Thin Ethernet, is about as thick as a woman's pinky finger. Thicker coax is more robust, harder to damage, and transmits data over longer distances. It's also more difficult to connect.

Baseband Summary

• Unmodulated digital signal. • Single channel. • Bidirectional propagation of signal. • No need of modems—low cost installation.	**Advantages—** 1. Simplicity 2. Low cost 3. Ease of installation and maintenance **Disadvantages—** 1. Limited distances 2. Data and voice only

4.5.2 Broadband Coaxial Cable

Broadband systems use modulation techniques to transmit digital data over analog carrier waves. Broadband transmission lines can be much longer than baseband lines. The word "Broadband" is a generic term. It refers to the wide bandwidth characteristics of a transmission medium and it's ability to carry numerous voice, video or data signals simultaneously. The medium could be coaxial cable, fiber-optic cable, UTP Media Twist or a wireless system.

Broadband is a 75 ohm cable that is commonly used for analog transmission. In broadband systems, analog signals are transmitted on the cable using both frequency and phase-modulation techniques. Broadband systems are divided up into multiple channels, frequently the 6Mhz channels used for television broadcasting. Each channel can also be used for CD-quality audio, or a digital bit stream that would be independent of the others. Television and data can also be mixed on one broadband cable.

Broadband and cable TV take advantage of coax's ability to transmit many signals at the same time. Each signal is called a channel. Each channel travels along at a different frequency, so it does not interfere with other channels. Signals are modulated into Radio Frequency (RF) channels that are 6 MHz or 7 MHz wide in bandwidth. By dividing services into separate channels, different types of signals can co-exist and travel in opposite directions "inbound and outbound" along the same coaxial cable.

Broadband systems offer significantly increased bandwidth capabilities due to the fact that there are multiple channels on each cable. Typical broadband implementations with highly saturated cables may yield aggregate bandwidths as high as 100 Mbps.

The broadband, and carrier band cables transmit analog signals, therefore modem converts the digital signal to analog signal prior to transmission of the data. A modem at the receiving end of the medium will convert the analog signal to a digital signal. The analog signal that carries digital data can travel longer distances and is more immune to electrical noise interferences, and signal degradation damage.

The carrier band cable that is sometimes called single channel broadband, covers only one analog frequency signal spectrum. Therefore, carrier band coaxial cables are less expensive than broadband coaxial cables, and the modems used in carrier band systems are less expensive than the modems used in broadband systems.

Coaxial cable can be used in both a point-to-point mode and a broadcast mode. In local network bus architectures, multiple devices are usually "dropped" from a single cable. Depending on the application and the required data rates, a broadband system may support thousands of connections. Amplifiers are usually placed at intervals of 0.5 to 1.5 km to regenerate the signals.

Broadband coaxial cables are divided into two types of systems:

1. Dual cable systems use two cables, one for each direction.
2. Mid-split systems use one cable, but the frequency is divided such that one portion of the frequency is used in one direction, the second is used for the other direction.

Broadband Summary

• Digital signal modulated onto RF carrier (analog). • Channel allocation based on FDM. • Head-End for bidirectional transmission. • Stations connected via RF modems.	**Advantages—** 1. Data, voice and video. 2. Greater distances. 3. Greater bandwidth.
	Disadvantages— 1. Cable design. 2. Alignment and maintenance. 3. High cost, requires modems. 4. Lack of well developed standards.

4.5.3 Uses of Coaxial Cable

Cable TV

Coaxial cable is used by cable TV companies to deliver service to user homes and businesses. Cable systems were originally designed to deliver broadcast television signals efficiently to subscribers' homes. To ensure that consumers could obtain cable service with the same TV sets they use to receive over-the-air broadcast TV signals, cable operators recreate a portion of the over-the-air radio frequency (RF) spectrum within a sealed coaxial cable line.

Circuits in coax network usually wired in bus topology, and need to have signal amplifiers installed at points along the network. The amplifiers can be one-way or two-way; the two-way amplifiers permit the provision of interactive services over the network, allowing consumers to select from a menu of services (for example, home shopping, videos on demand, or educational services).

Cable Internet

Cable Internet access is delivered through coaxial cable by a Cable Modem at the user's end. A Cable Modem sends and receives data to and from the Internet by using the existing coaxial cable TV network. Cable TV Networks are high band-with networks, i.e., 550 to 750 MHz by their very nature of design.

Digital data signals are transmitted over radio frequency (RF) carrier signals on a cable system. For two-way communication, there is one carrier signal that carries data in the "downstream" direction (from the cable network to the customer), and another that carries data in the "upstream" direction (from the customer to the cable network). Higher-frequency signals flow toward the subscriber and lower-frequency signals flow toward the broadcasting head-end. This upstream and downstream bandwidth is shared by the active data subscribers connected to a given cable network segment, typically 500 to 2,000 homes on a modern HFC network.

To deliver data services over a cable network, one television channel (in the 85–750 MHz range) is typically allocated for downstream traffic to homes and another channel (in the 5–65 MHz band) is used to carry upstream signals. Each downstream band can carry one analog video channel, up to 27 Mbps data stream. Typically, cable internet access provide has maximum of 1.5–6 Mbps of bandwidth on the system. However, due network sharing that bandwidth on the network segment performance can be much lower.

The cable modem access network operates at Layer 1 (physical) and Layer 2 (media access control/logical link control) of the Open System Interconnect (OSI) Reference Model. Thus, Layer 3 (network) protocols, such as IP traffic, can be seamlessly delivered over the cable modem platform to end-users.

A Cable Modem Termination System (CMTS) communicates through these channels with cable modems located in subscriber homes to create a virtual local area network (LAN) connection. All cable modems can receive from and send signals only to the CMTS, but not to other cable modems on the line. A typical CMTS consists of an Input interface, Router, Cable Modem card and a powerful Microprocessor. Most cable modems are external devices that connect to a personal computer (PC) through a standard Ethernet card or Universal Serial Bus (USB) connection.

4.6 Fiber Optics

Our current "age of technology" is the result of many brilliant inventions and discoveries, but it is our ability to transmit information and the media we use to do it, that is perhaps most responsible for its evolution. Progressing from the copper wire of a century ago to today's fiber optic cable, our increasing ability to transmit more information, more quickly and over longer distances has expanded the boundaries of our technological development in all areas.

Fiber-optic cable is a networking medium capable of conducting modulated light transmissions. It is the best choice if a secure network is needed. Because the cable transmits light, the transmissions are immune to interference caused by electrical or electronic devices. Also, if your network will run through an area of heavy industrial activity or a work place with strong radio frequency interference, fiber optic cable is the most appropriate choice.

Fiber optics is being used to transmit television, voice, and digital data signals by light waves over flexible hair like threads of glass and plastic. It has evolved into a system of great importance and use since the 1980's.

4.6.1 Fiber Optic Cable

It consists of thousands of clear glass fiber strands, each approximately the thickness of a human hair. If you look closely at a single optical fiber, you will see that it has the following parts:

- Core—Thin glass center of the fiber where the light travels.
- Cladding—Outer optical material surrounding the core that reflects the light back into the core.
- Buffer coating—Plastic coating that protects the fiber from damage and moisture.

Hundreds or thousands of these optical fibers are arranged in bundles in optical cables. The bundles are protected by the cable's outer covering, called a jacket.

Transmission is made possible by the transformation of digital data into modulated light beams, which are sent through the cable by a laser light-emitting diode (LED) type device at incredibly fast speeds. Transmission rates available (as of 1990) range up to approximately 1 billion (or giga) bits per second (Gbps), with speeds over 2 Gbps possible. When thinking in terms of frequencies, light frequencies are extremely high. They are approximately 600,000 times that of the highest television channel. In terms of data communications, the higher the frequency of the signal, the more information it can carry. Put simply, every hair like fiber within a fiber optic cable has the capacity to carry many hundreds of local-area network channels simultaneously.

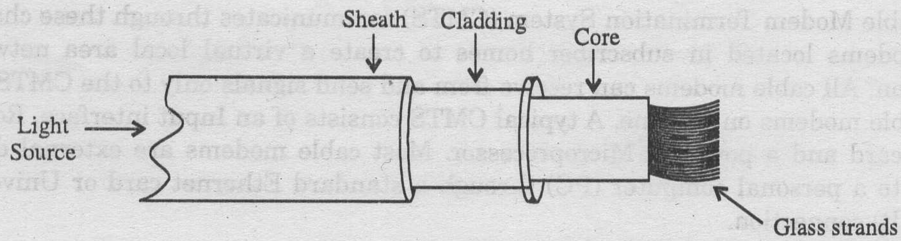


Fig. 4.4 Fibre optic cable

Fiber

Some 10 billion digital bits can be transmitted per second along an optical fiber link in a commercial network, enough to carry tens of thousands of telephone calls. Hair-thin fibers consist of two concentric layers of high-purity silica glass the core and the cladding, which are enclosed by a protective sheath. Light rays modulated into digital pulses with a laser or a light-emitting diode move along the core without penetrating the cladding.

The light stays confined to the core because the cladding has a lower refractive index-a measure of its ability to bend light. Refinements in optical fibers, along with the development of new lasers and diodes, may one day allow commercial fiber-optic networks to carry trillions of bits of data per second.

Construction

Today's low-loss glass fiber optic cable offers almost unlimited bandwidth and unique advantages over all previously developed transmission media. The basic point-to-point fiber optic transmission system consists of three basic elements: the optical transmitter, the fiber optic cable and the optical receiver.

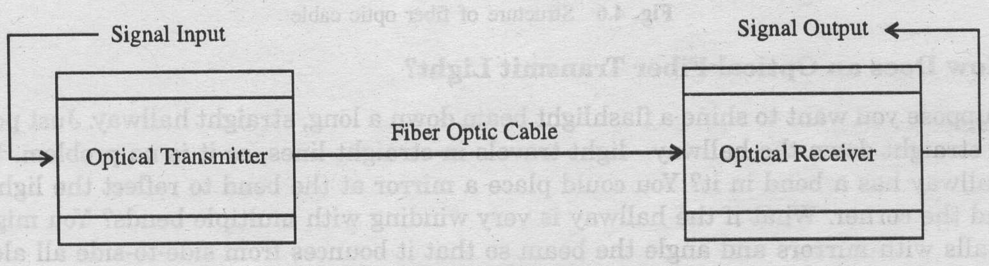


Fig. 4.5 Fiber optic transmission system

The Optical Transmitter : The transmitter converts an electrical analog or digital signal into a corresponding optical signal. The source of the optical signal can be either a light emitting diode, or a solid-state laser diode. The most popular wavelengths of operation for optical transmitters are 850, 1300, or 1550 nanometers.

The Fiber Optic Cable : The cable consists of one or more glass fibers, which act as wave-guides for the optical signal. Fiber optic cable is similar to electrical cable in its construction, but provides special protection for the optical fiber within. For systems requiring transmission over distances of many kilometers or where two or more fiber optic cables must be joined together, an optical splice is commonly used.

The Optical Receiver : The receiver converts the optical signal back into a replica of the original electrical signal. The detector of the optical signal is either a PIN-type photodiode or avalanche-type photodiode.

Composition of Optical Fiber :

- Silica based glass or plastic filaments are spun and packed into bundles of several hundreds or thousands. Bundles may be put together as rods or ribbons and sheets.

- These bundles are flexible and can be twisted and contorted to conduct light and images around corners.
- The thin glass center of the fiber where the light travels is called the "core".
- The outer optical material surrounding the core that reflects the light back into the core is called the "cladding".
- In order to protect the optical surface from moisture and damage, it is coated with a layer of buffer coating.

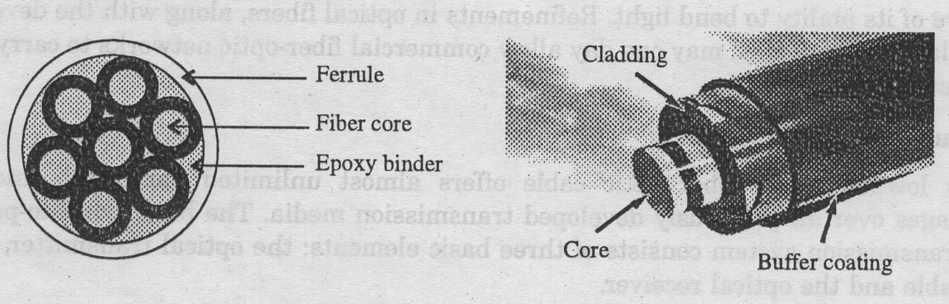


Fig. 4.6 Structure of fiber optic cable

How Does an Optical Fiber Transmit Light?

Suppose you want to shine a flashlight beam down a long, straight hallway. Just point the beam straight down the hallway—light travels in straight lines, so it is no problem. What if the hallway has a bend in it? You could place a mirror at the bend to reflect the light beam around the corner. What if the hallway is very winding with multiple bends? You might line the walls with mirrors and angle the beam so that it bounces from side-to-side all along the hallway. This is exactly what happens in an optical fiber.

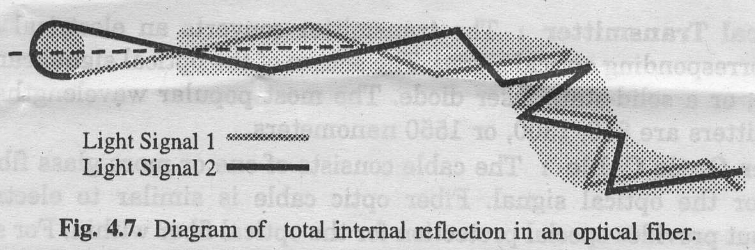


Fig. 4.7. Diagram of total internal reflection in an optical fiber.

The light in a fiber-optic cable travels through the core (hallway) by constantly bouncing from the cladding (mirror-lined walls), a principle called total internal reflection. Because the cladding does not absorb any light from the core, the light wave can travel great distances. However, some of the light signal degrades within the fiber, mostly due to impurities in the glass. The extent that the signal degrades depends on the purity of the glass and the wavelength of the transmitted light (for example, 850 nm = 60 to 75 percent/km; 1,300 nm = 50 to 60 percent/km; 1,550 nm is greater than 50 percent/km). Some premium optical fibers show much less signal degradation—less than 10 percent/km at 1,550 nm.

Types of Fiber Optic Cable

There are two types of fiber optic cable commonly used:

1. Single mode optical fiber.
2. Multimode optical fiber.

4.6.2 Single Mode Cable

It is a single stand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. Single Mode fiber with a relatively narrow diameter, through which only one mode will propagate carries higher bandwidth than multimode fiber, but requires a light source with a narrow spectral width. Synonyms are mono-mode optical fiber, single-mode fiber, single-mode optical waveguide, and uni-mode fiber.

Single-mode fiber gives you a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.

Single-mode optical fiber is an optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest typically 1300 to 1320 nm.

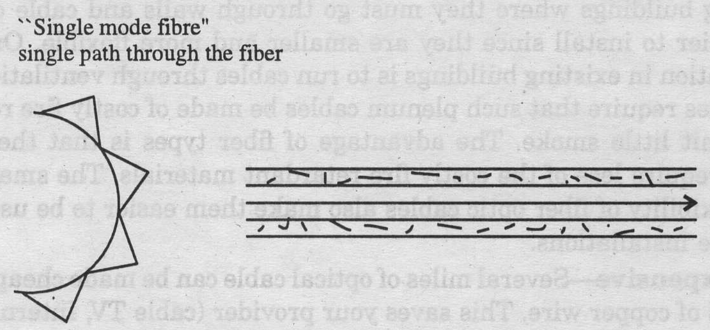


Fig. 4.8 Single mode cable

4.6.3 Multimode Cable

Multimode cable is made of glass fibers, with a common diameter in the 50-to-100 micron range for the light carry component (the most common size is 62.5). POF is a newer plastic-based cable that promises performance similar to glass cable on very short runs, but at a lower cost.

Multimode fiber gives you high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core typically 850 or 1300 nm. Typical multimode fiber core diameters are 50, 62.5, and 100 micrometers. However, in long cable runs (greater than 3000 feet [914.4 mL]), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.

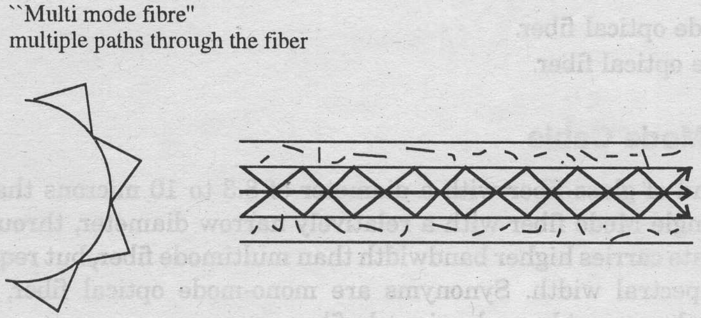


Fig. 4.9 Multimode cable

4.6.4 Advantages and Disadvantages of Fiber Optics over Copper Wire

The advantages of fiber optics over copper wire are discussed below:

1. **Ease Of Installation**—Increasing transmission capacity of wire cables generally makes them thicker and more rigid. Such thick cables can be difficult to install in existing buildings where they must go through walls and cable ducts. Fiber cables are easier to install since they are smaller and more flexible. One way to simplify installation in existing buildings is to run cables through ventilation ducts. However, fire codes require that such plenum cables be made of costly fire retardant materials that emit little smoke. The advantage of fiber types is that they are smaller and hence require less of the costly fire retardant materials. The small size, lightweight and flexibility of fiber optic cables also make them easier to be used in temporary or portable installations.
2. **Less expensive**—Several miles of optical cable can be made cheaper than equivalent lengths of copper wire. This saves your provider (cable TV, Internet) and you money.
3. **Thinner**—Optical fibers can be drawn to smaller diameters than copper wire. A 3/8-inch (12 pair) fiber/cable operating at 140 Mb/s can handle as many voice channels as a 3-inch diameter copper (900) twisted-pair cable.
4. **High Bandwidth Over Long Distances**—Fiber optics have a large capacity to carry high speed signals over longer distances without repeaters than other types of cables. The information carrying capacity increases with frequency. This however, doesn't mean that optical fiber has infinite bandwidth, but it's certainly greater than coaxial cables. Generally, coaxial cables have a bandwidth parameter of a few MHz/km, where else the fiber optic cable has a bandwidth of 400MHz/km. (These figures are just approximations and do vary from cable to cable!) This is an important factor that leads to the choice of fiber for data communications.
5. **Low Loss**—Current single-mode fibers have losses as low as 0.2 dB per km. Multimode losses are down to 1 dB (at 850 or 1300 nm). This creates opportunities for longer distances without costly repeaters.

6. **Immunity to Electromagnetic Interference**—Electromagnetic Interference is a common type of noise that originates with one of the basic properties of electromagnetism. Magnetic field lines generate an electrical current as they cut across conductors. The flow of electrons in a conductor generates a magnetic field that changes with the current flow. Electromagnetic Interference does occur in coaxial cables, since current does cut across the conductor. Fiber optics is immune to this EMI since signals are transmitted as light instead of current. Thus, they can carry signals through places where EMI would block transmission.
7. **Higher carrying capacity**—Because optical fibers are thinner than copper wires, more fibers can be bundled into a given-diameter cable than copper wires. This allows more phone lines to go over the same cable or more channels to come through the cable into your cable TV box.
8. **Light signals**—Unlike electrical signals in copper wires, light signals from one fiber do not interfere with those of other fibers in the same cable. This means clearer phone conversations or TV reception.
9. **Low power**—Because signals in optical fibers degrade less, lower-power transmitters can be used instead of the high-voltage electrical transmitters needed for copper wires. Again, this saves your provider and you money.
10. **Digital signals**—Optical fibers are ideally suited for carrying digital information, which is especially useful in computer networks.
11. **Non-flammable**—In some cases, transmitting signals electrically can be extremely dangerous. Most electric potentials create small sparks. The sparks ordinarily pose no danger, but can be really bad in a chemical plant or oil refinery where the air is contaminated with potentially explosive vapours. One tiny spark can create a big explosion. Potential spark hazards seriously hinder data and communication in such facilities. Fiber optic cables do not produce sparks since they do not carry current. Since the only carrier in the fiber is light, there is no possibility of a spark from a broken fiber. Even in the most explosive of atmospheres, there is no fire hazard, and no danger of electrical shock to personnel repairing broken fibers.
12. **Lightweight**—An optical cable weighs less than a comparable copper wire cable. Fiber-optic cables take up less space in the ground. The same fiber-optic cable weighs approximately 132 lbs per kilometer. The twisted pair cable weighs approximately 16,000 lbs.
13. **Non-conductivity**—This allows for installation in areas with high electromagnetic interference such as utility lines, railroad tracks and power-carrying lines or even areas with a high lightening-strike incidence. Fiber optic cables are virtually unaffected by outdoor atmospheric conditions, allowing them to be lashed directly to telephone poles or existing electrical cables without concern for extraneous signal pickup. A serious concern with outdoor cables in certain computer networks is that they can be hit by lightning, causing destruction to wires and other cables that are involved in the network. Certain computer companies are aware of this problem and trying to solve it by having protective devices for wire circuits to block current and voltage surges. Any conductive cables can carry power surges or ground loops. Fiber optic cables can be made non-conductive by avoiding metal in their design.

14. **Security**—Magnetic fields and current induction work in two ways. They don't just generate noise in signal carrying conductors; they also let the information on the conductor to be leaked out. Fluctuations in the induced magnetic field outside a conductor carry the same information as the current passing through the conductor. Shielding the wire, as in coaxial cables can reduce the problem, but sometimes shielding can allow enough signal leaks to allow tapping, which is exactly what we wouldn't want. There are no radiated magnetic fields around optical fibers; the electromagnetic fields are confined within the fiber. That makes it impossible to tap the signal being transmitted through a fiber without cutting into the fiber. Since fiber optics do not radiate electromagnetic energy, emissions cannot be intercepted and physically tapping the fiber takes great skill to do undetected. Thus, the fiber is the most secure medium available for carrying sensitive data.
15. **Wide Temperature Range**—Fibers and cables can be manufactured to meet temperatures from –40°F to +200°F. Resistance to temperatures of 1,000°F has been recorded.
16. **Fewer Repeaters**—Few repeaters, if any, are required because of increased performance of light sources and continuing increases in fiber performance.
17. **Stable Performance**—Fiber optics is affected less by moisture that means less corrosion and degradation. Therefore, no scheduled maintenance is required. Fiber also has greater temperature stability than copper systems.
18. **Topology Compatibility**—Fiber is suitable to meet the changing topologies and configurations necessary to meet operation growth and expansions. Technologies such as wavelength division multiplexing (WDM), optical multiplexing, and drop and insert technologies are available to upgrade and recon-figure system designs.
19. **Material Availability**—Material (silica glass) required for the production of fiber is readily available in a virtually unending supply.

Despite the many advantages of fiber-optic systems, there are some disadvantages:

1. **Overload**—Unlike electrical cables where only one signal is allowed, optical cables have the ability for multiple light signals to simultaneously move through the cable; sometimes so many signals are moving through the cable that it becomes jammed and information slows down.
2. **Different signals**—Most devices work of electrical signals so to use an optical cable, the signal must be converted to light, sent through the wire, and then converted back to an electrical signal; in a copper wire, the signal always stays electrical.
3. **Fear of New Technologies**—Because the technology is considered to be new, people are reluctant to change and use these methods. The use of metric and physics is still an unfamiliar area to many established users. Many industries are just more comfortable with the use of standard electrical systems and do not like new systems.
4. **Economic Evaluation**—The major practical problem with fiber optics is that it usually costs more than ordinary wires. All costs elements involved in economic evaluation can be grouped into two main classes; which are investment costs and

operation costs. The investment costs usually includes expenditures related to acquiring and owning properties and plants, in this case changing wires to fiber optic cables. All investment costs should be considered, such as those incurred for equipment and materials (also including storage and handling costs), engineering costs and miscellaneous costs. Operation costs include the usage of fiber optics and the wear and tear of it. The higher cost of fiber is often not by itself. Fiber optic cables are much cheaper than coaxial cables. The main difference comes when all the other components of fiber optics add up, such as transmitters, receivers, couplers and connectors. Fiber systems require separate transmitters and receivers because they cannot directly use the electrical output of computer devices; that signal must be converted into optical form and then converted back into electrical form. Fiber optic connectors and couplers are more expensive than any other electrical components. These costs are the ones that add up and form the major disadvantage of fiber optics.

5. **System Reconfiguration**—One of the drawbacks in fiber optics is system reconfiguration. Converting existing hardware and software for the use of fiber optics does take a lot of time and money that also reduces the turnover for any profit-making firm in the market. Sometimes it may be more convenient to transmit high-speed computer data serially (one bit after another) than sending several bits at a time in parallel over separate wires. This changeover requires modification in both hardware and software. Minor differences can cause old programs to crash and make data in old files unreadable. Even though the need for such modifications can be reduced by designing fiber optic systems with interfaces that look just like electric ones, it would not make most efficient use of fiber transmission capacity and would increase costs.
6. **Limitations in Local Area Networks**—In Local Area Networks, fiber optics are not used as widely as one would expect. One reason is the implementation requires great deal of changes in current networks and systems. This requires a lot of time and effort that the management is not willing to sacrifice. People are comfortable with what they have and don't want to change. Although most problems regarding program changing can be solved, the solutions to it will take much longer than expected. Thus, any new program has to be a big improvement over the old one to justify a significant change (although the great improvement usually means that the old program does not work).

Another fundamental problem in fiber optic LANs is the change in technology. The hardware and software to make LAN run efficiently add up to an expensive package. If many terminals in a building must be in constant touch with each other and a variety of other hardware, such as printers and storage devices, LAN will be cost efficient. However, if the real need is to keep the terminals in touch with a mainframe computer, it would be cheaper to run cables between them and the mainframe. If the terminals need to talk to each other, ordinary telephone lines could very well be used, as telephone lines are much cheaper than fiber optics.

Fiber-Optic Considerations

■ **USE IF :**

- Need to transmit @ very HIGH speeds over LONG distances in a very secure media.

■ **DON'T USE IF :**

- Are under a tight budget.
- Do not have the expertise available to properly install it and connect devices to it.

Fiber-Optic Cable Characteristics

- Can accommodate data transfer much faster than coaxial or twisted pair cable.
- Data sent as pulses of light over threads of glass at gigabits-per second.
- TWO small glass strands : one send and one receives (together know as the "core").
- Lines are free of electromagnetic interference.
- Difficult to tap.
- Data can travel for miles without a signal degradation.
- Laser transmitters send the modulated light pulses and optical receivers receive them.
- Two major types of fiber optic cable exist : Single-mode and multimode.

Single Mode	Multimode
Often used for inter-city telephone trunks and video applications	Usually specified for LANs and WANs

4.7 Cabling Summary

Now that we've examined the major bounded media, let's take a quick look at how they compare.

Twisted Pair Cable			
	Advantages		Disadvantages
1.	Inexpensive	1.	Susceptible to RFI and EMI
2.	Often available in existing phone system	2.	Not as durable as coax
3.	Well tested and easy to get	3.	Doesn't support as high a speed as other media

Coaxial Cable			
	Advantages		Disadvantages
1.	Fairly resistant to RFI and EMI.	1.	Can be effected by strong interference.
2.	Supports faster data rates than twisted pair.	2.	More costly than TP.
3.	More durable than TP.	3.	Bulkier and more rigid than TP.

Fiber Optic Cable			
	Advantages		Disadvantages
1.	Highly secure.	1.	Extremely costly in product and service.
2.	Not affected by RFI and EMI.	2.	Sophisticated tools and methods for installation.
3.	Highest bandwidth available.		
4.	Very durable.	3.	Complex to layout and design.

Point-to-point transmission			
	Data rate	Bandwidth	Repeater distance
Twisted pair	4 Mbps	3 MHz	2-10 km
Coaxial cable	500 Mbps	350 MHz	1-10 km
Optical fiber	2 Gbps	2 GHz	10-100 km

4.8 Wireless Transmission

The above discussed technologies require physical connections in order to transmit signals. Wireless transmission means sending and receiving signals without wires. Examples include radio, microwave, and satelite. Today we use all of these forms to transmit data. The dream of being able to communicate data in networks without having deal with the constraints of physical cabling is very much realized today. Wide area networks obviously make use of wireless technology to transmit data around our globe. The acceptance of wireless networks on the local level has been significantly hindered, however, for a number of reasons.

The transmissions and receptions in wireless media are achieved by means of an antenna and can be

- **Directional :** Point-to-point focused beams employing high frequencies.

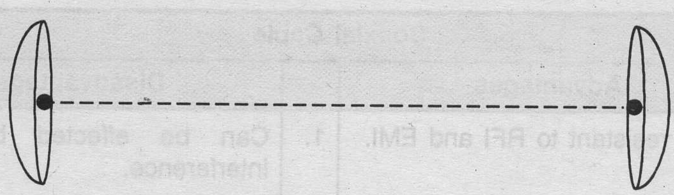


Fig. 4.10. Directional

- **Omni directional** : Waves propagating in all directions using signals of lower frequencies.

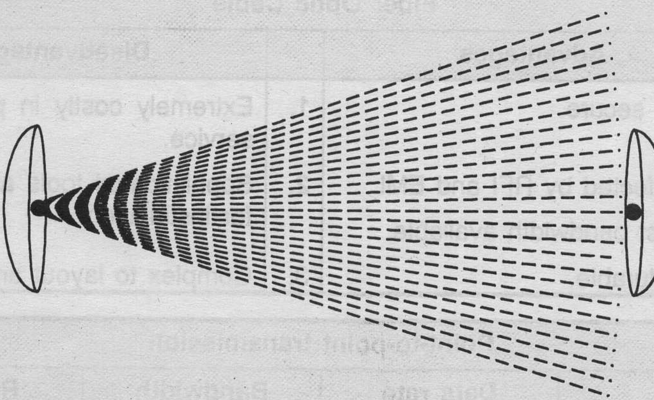


Fig. 4.11. Omni directional

Meaning of Wireless

"Wireless" means transmitting signals over invisible radio waves instead of wires. Garage door openers and television remote controls were the first wireless devices to become a part of everyday life. Now the cordless keyboard and mouse, PDAs and digital and cellular phones are commonplace.

Working of Wireless Networks

Wireless data is predominately transferred over two kinds of networks : wide area networks (WANs) and local area networks (LANs). These networks are similar to their wired counter-parts-they just use radio waves instead of copper or fiber.

WANs can cover areas as large as several countries. Wireless LANs, already popular in airports and hotels, are often used to replace or enhance wired LANs. They can cover a range of 500 feet indoors and up to 1,000 feet outdoors. They may service a smaller area than their WANs, but LANs can transfer data much faster, at speeds up to 11 Mbps. Wireless LANs are used primarily for data; they do not usually support voice traffic.

Technologies Involved

First a word about how wireless technologies are referred to. You'll read a lot about "generations" of wireless, which correspond to the rate and quality of data and voice transmission. The first generation was analog voice (the earliest cell phones). The second generation is digital (such as more efficient cell phones with voice and data at rates of 9.6 Kbps to 14.4 Kbps). Currently carriers are working on what they call 2.5 generation or 2.5 G, transmission rates, which will carry data up to 114Kbps. The future is 3 G, which will include multimedia and data transmission rates of up to 2 Mbps to 5 Mbps, advanced roaming capabilities, as well as the sought after (by some) "always-on" potential.

When it comes to WANs, there are so many technologies used to send data through the air. One of the most used and talked about is wireless application protocol (WAP). WAP-enabled devices offer a limited version of the Web designed to work on the small black-and-white screens of phones and PDAs. When WAP service first came out during the summer of 2000, market hype depicted it as the Internet on a phone. But how could the Net fit on such a little screen? Even though WAP failed in the consumer marketplace, it is still among the most common ways to send data to phones and PDAs.

Within the current digital world of wireless, there are four primary technologies: code-division multiple access (CDMA), global system for mobile communication (GSM), integrated dispatch enhanced network (iDEN), which is used by Nextel, and time division multiple access (TDMA). Bluetooth, a LAN technology, enables devices rather than a network to communicate. With an operating range of only 30 feet, Bluetooth can be used in a headset to wirelessly listen to audio on a computer and send photographs from a digital camera to the computer.

Difference between Wireless and Mobile

A laptop is a mobile device. The Lotus Notes application on that laptop is mobile because it resides on the laptop but needs to connect through a wired modem connection before it can be used. A cell phone is a wireless device. The Lotus Notes application on that cell phone is wireless because it can receive data wirelessly-that is, without being plugged into a wired connection.

The Evolution of Wireless

Wireless technology is not new and has been widely used in many industries for years. Manufacturing, courier services, and retail are just some of the industries successfully using wireless for inventory control, package tracking, and pricing applications to increase productivity and streamline procedures. In the past, wireless technology was used for dedicated applications, but this is rapidly changing with the advent of wireless LAN standards and 802.11 technologies.

The popularity of wireless networking is growing and users have recognized the many benefits of using mobile technology.

Some of the benefits of wireless technology are stated below:

- True mobility—the means to conduct business without physical cable attachment to the network.
- Increased productivity.
- Lower cabling costs—can eliminate the need for new cable plants or extensions of existing cabling.

- New network access—provides network access where it was previously difficult to deploy traditional wired LANs (e.g., manufacturing, warehousing, temporary office space, leased buildings, etc.).
- Broad OS support—Windows, Macintosh, Palm OS, etc.
- Easy installation.
- Rapid deployment.
- Lower long term costs.

Limitations of wireless technology

Despite the many benefits of wireless technology, enterprise users are only beginning to adopt wireless LANs. Unlike wired networks, wireless networks transmit their data over open-air waves—through walls, ceilings, and floors—giving possible access to anyone within range of the radio waves. The lack of strong security in early implementations of 802.11b technology using Wired Equivalent Privacy (WEP) security showed the danger and ease of how wireless LANs could be compromised—giving enterprises no confidence in deploying immature wireless LAN technology.

1. First and foremost, you need to realize that wireless communications will never be perfect. The experience will never mimic what you're used to seeing on your PC.
2. When it comes to WANs, bandwidth and spectrum are major limitations. The networks are slow. When transmitting data, you're forced to send smaller bits of data just so the information moves as quickly as possible. The size of the device that's accessing the information is also an issue.
3. Phones and PDAs have small screens-often only a couple of inches in diameter-and it is not easy to see large documents on them. Think of a contractor trying to read an architect's blueprints on a job site.
4. When it comes to voice transmission, you need to remember that wireless is a radio-based technology, which calls for transmission towers and receivers that are positioned to dodge interference

Wireless Networking

The traditional approach to networking computers involves a physical connection between systems on the network. Wireless networking is based on transmission that is not propagated over physical media. Of special interest is application of the wireless technology to urban networking—a Metropolitan Area Network (MAN).

Under the broadest definition of the term, existing wireless communications systems include radio, infrared and cellular technologies—that is, radio and TV broadcasting, cellular telephony, specialized mobile radio, wireless data, microwave and satellite services. As with other communication technologies, wireless systems are converting to digital. At this point in time, wireless technologies have not evolved sufficiently to serve as replacements to traditional wire-based technologies, but do provide promising solutions in certain niches or gaps not well served by wire.

Wireless networking is a collective term for solutions for two quite different problems:

- In some cases, it can be difficult or impossible to install a conventional wired network infrastructure; this is one place where wireless technologies are used.
- The other area of activity is solving the problem of the mobile or portable network device.

4.8.1 The Electromagnetic Spectrum

In this section we shall consider the physical properties of free-space electromagnetic waves, and how the atmosphere influences the propagation of electromagnetic waves. In the following sections, we shall describe how these properties have determined the selection of frequencies for communication.

The electromagnetic spectrum is divided up into a number of bands, as shown in table below:

Table 4.1 The frequencies of the electro-magnetic spectrum

Description	Frequency	Wavelength
High frequency	3—30 MHz	100—10 m
VHF	50—100 MHz	6—3 m
UHF	400—1000 MHz	75—30 cm
Microwaves	3×10^9—10^{11} Hz	10 cm—3 mm
Milimetre waves	10^{11}—10^{12} Hz	3 mm—0.3 mm
Infrared	10^{12}—6×10^{14} Hz	0.3 mm—0.5 μm
Light	6×10^{14}—8×10^{14} Hz	0.5 μm—0.4 μm
Ultra-voilet	8×10^{14}—10^{17} Hz	0.4 μm—10^{-9} m
X-rays	10^{17}—10^{19} Hz	10^{-9} m—10^{-13} m
Gamma rays	$> 10^{19}$ Hz	$< 10^{-13}$ m

Propagation of waves in free-space is different from that in cable or waveguides. With respect to signal propagation, these latter are one-dimensional systems and a wave does not lose energy as it travels, except that due to absorption or scattering. In three-dimensions waves radiate spherically. When waves traveling in free-space are obstructed, new waves result from the interaction. There are four types of interaction:

1. **Reflection :** This occurs when a wave meets a plane object. The wave is reflected back without distortion.
2. **Refraction :** This occurs when a wave encounters a medium with a different wave speed. The direction and speed of the wave is altered.
3. **Diffraction :** This occurs when the wave encounters an edge. The wave has the ability to turn the corner of the edge. This ability of waves to turn corners is called diffraction. It is markedly dependent on frequency—the higher the frequency, the

less diffraction. Very high frequencies (light) hardly diffract at all; "light travels in straight lines".

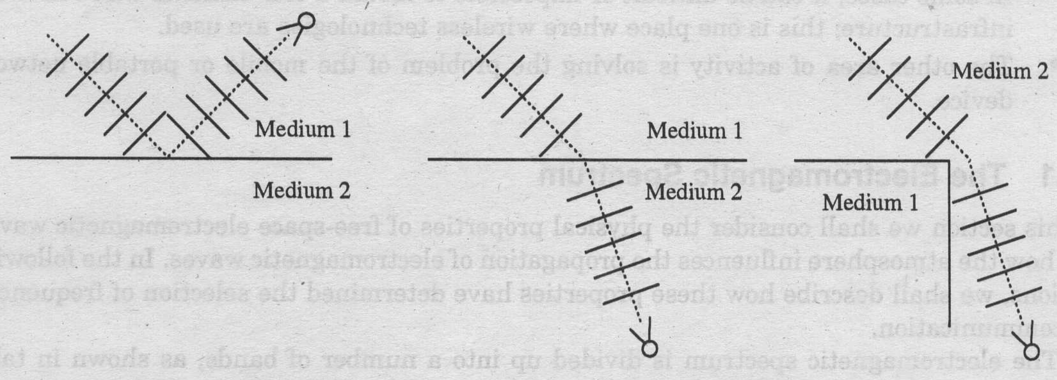


Fig. 4.12 Reflection, refraction and diffraction of an electromagnetic wave

4. **Scattering :** Catch-all description of wave interactions that are too complex to be described as reflection, refraction or diffraction. Typically the result of scattering is to remove radiation of the wave and re-radiate it over a wide range of directions. Scattering too is strongly frequency dependent. Usually it will increase with frequency.

4.8.2 Different Types of Unguided Media

Unguided transmission media is data signals that flow through the air. They are not guided or bound to a channel to follow. They are classified by the type of wave propagation.

RF Propagation

There are three types of RF (radio frequency) propagation:

- Ground Wave
- Ionospheric
- Line of Sight (LOS)

Ground wave propagation follows the curvature of the Earth. Ground waves have carrier frequencies up to 2 MHz. AM radio is an example of ground wave propagation.

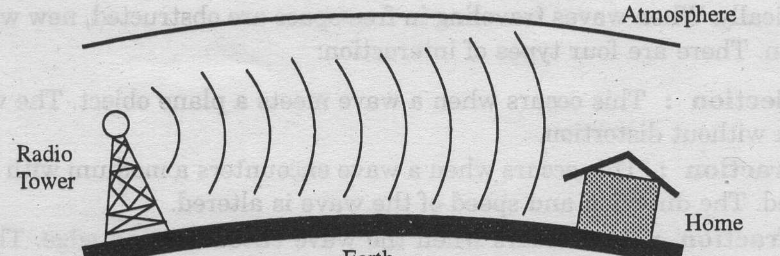


Fig. 4.13 Ground wave propagation

Ionospheric propagation bounces off of the Earth's ionospheric layer in the upper atmosphere. It is sometimes called double hop propagation. It operates in the frequency range of 30–85 MHz. Because it depends on the Earth's ionosphere, it changes with the weather and time of day. The signal bounces off of the ionosphere and back to earth. Ham radios operate in this range.

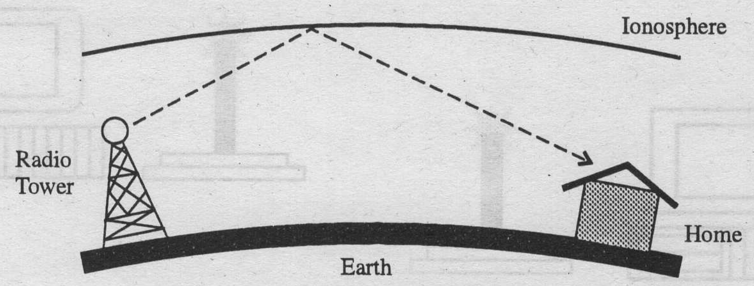


Fig. 4.14 Ionospheric propagation

Line of sight propagation transmits exactly in the line of sight. The receive station must be in the view of the transmit station. It is sometimes called space waves or tropospheric propagation. It is limited by the curvature of the Earth for ground-based stations (100 km, from horizon to horizon). Reflected waves can cause problems. Examples of line of sight propagation are: FM radio, microwave and satellite.

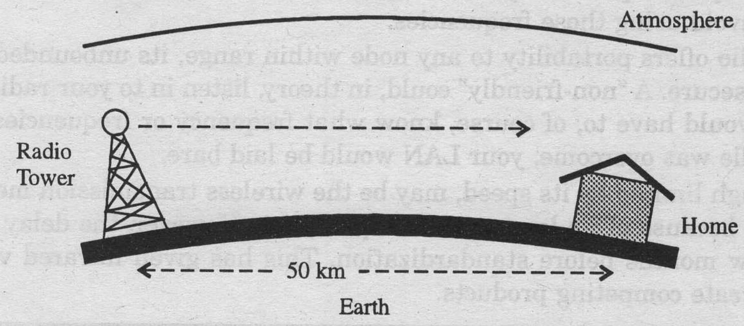


Fig. 4.15 Line of sight propagation

Unguided media can travel from source to destination in several ways, ground propagation, sky propagation and line of sight propagation. Various types of unguided media are explained below.

4.9 Radio Waves

Electromagnetic waves in the frequency range between 3 kHz and 1 GHz are radio waves and waves ranging between 1 and 300 GHz are called microwaves. Radio transmitters are omni directional and can easily penetrate walls, floors, ceiling and the like. Electrically speaking, the waves that are classified as radio waves have certain frequencies that are grouped together for certain uses. Some are available for data transmission, but the bandwidth necessary to perform high-speed data transfers is not found at any given slot on the radio spectrum. Many vendors are now employing spread-spectrum technology where the available slots in the radio spectrum are all used together. Using this technology, speeds at upto 2 Mbps have been achieved.

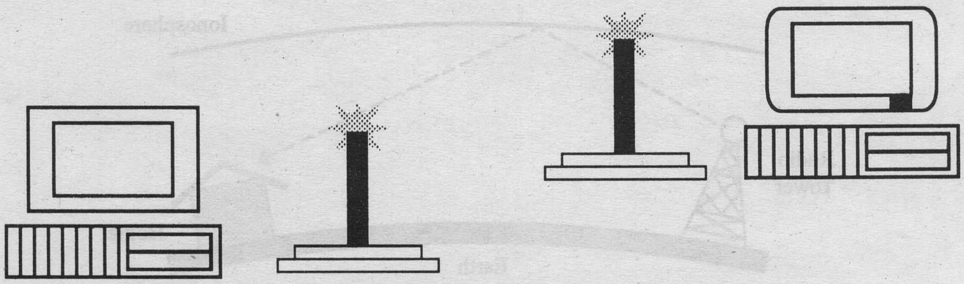


Fig. 4.16 Radio-based LANs use portable transmitters and receivers at each LAN device

Radio-based LANs do have to contend with the interference that occurs daily in the workplace. That interference can come from a number of different electrical sources and can be quite impacting on LAN performance. For radio systems using only a small portion of the radio spectrum (narrowband systems), this could mean that problem might be insurmountable. The vendors of spread-spectrum products claim that their products can isolate interference problems and avoid using those frequencies.

Though radio offers portability to any node within range, its unbounded nature makes it somewhat less secure. A "non-friendly" could, in theory, listen in to your radio broadcasts. The eavesdropper would have to, of course, know what frequency or frequencies you were using. Once that hurdle was overcome, your LAN would be laid bare.

Radio, though limited by its speed, may be the wireless transmission method of choice for many desktops because of its low cost and capabilities. However, the delay of regulation has cost radio a few months before standardization. This has given infrared vendors at least a little time to create competing products.

Radio	
Advantages	**Disadvantages**
1. Transmission not line of sight.	1. Limited bandwidth means less data throughput.
2. Inexpensive products.	2. Some frequencies subject to FCC regulation.
3. Direct point-to-point linking to receiving station.	
4. Ideal for portable devices.	3. Highly susceptible to interference.

4.10 Microwave Link Communication

Electromagnetic waves in the frequency range 1 to 300 GHz are called microwaves. Microwave transmission is line of sight transmission. The transmit station must be in visible contact with the receive station. This sets a limit on the distance between stations depending on the local geography. Typically the line of sight due to the Earth's curvature is only 50 km to the horizon! Repeater stations must be placed so the data signal can hop, skip and jump across the country.

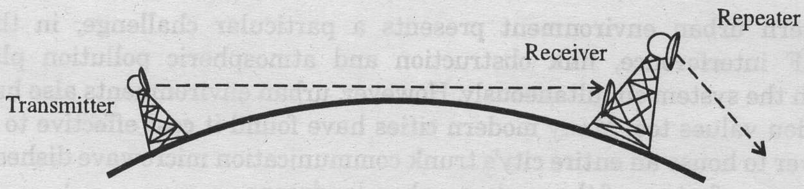


Fig. 4.17 Line of sight transmission

Microwaves are omni directional and the transmitting antenna can narrowly focus the wave. Microwaves need omnidirectional antennas that send out signals in one direction. Due to their unidirectional properties, microwaves are very useful for unicast communication between a sender and a receiver. They are used in cellular telephones, satellite networks and wireless LANS.

The maturity of radio frequency (RF) technology has permitted the use of microwave links as the major trunk channel for long distance communication. The use of microwave links has major **advantages** over cabling systems :

- **Freedom from land acquisition rights**—The acquisition of rights to lay cabling, repair cabling, and have permanent access to repeater stations is a major cost in the provision of cable communications. The use of radio links, that require only the acquisition of the transmitter/receiver station, removes this requirement. It also simplifies the maintenance and repair of the link.
- **Ease of communication over difficult terrain**—Some terrains make cable laying extremely difficult and expensive, even if the land acquisition cost is negligible.

The use of microwave links has a number of **disadvantages** that mainly arise from the use of free-space communication:

- **Bandwidth allocation is extremely limited**—The competition for RF bandwidth from various competing users leads to very strict allocations of bandwidth. Unlike cabling systems, that can increase bandwidth by laying more cables, the radio frequency (RF) bandwidth allocation is finite and limited. In practice, bandwidth allocations of 50MHz in the carrier range 300 MHz to 1 GHz are typical.
- **Atmospheric effects**—The use of free-space communication results in susceptibility to weather effects, particularly rain.
- **Transmission path needs to be clear**—Microwave communication requires line-of-sight, point-to-point communication. The frequency of repeater stations is determined

by the terrain. Care must be taken in the system design to ensure freedom from obstacles. In addition, links must be kept free of future constructions that could obstruct the link.

- **Interference**—The microwave system is open to RF interference.
- **Restrictive Costs**—The cost of design, implementation and maintenance of microwave links is high. Many countries are not well equipped with good technical resources to provide efficient and continuous operation.

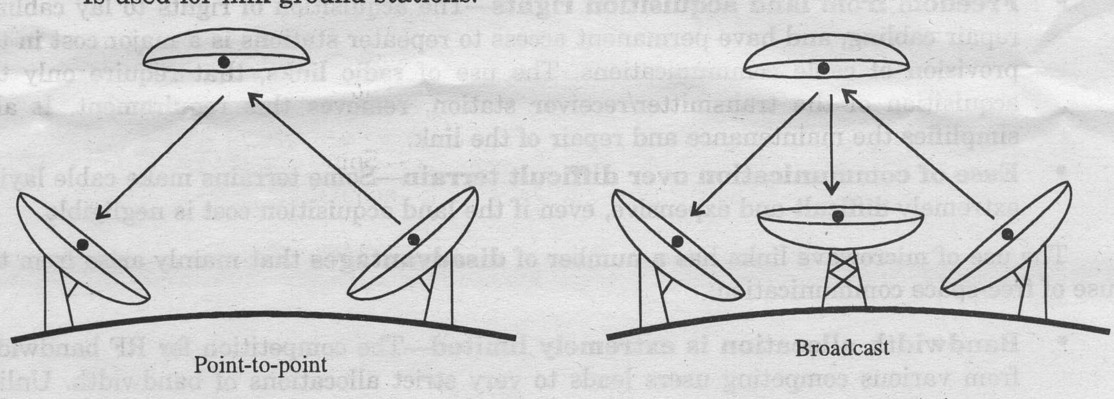
The modern urban environment presents a particular challenge, in that bandwidth allocation, RF interference, link obstruction and atmospheric pollution place maximum constraints on the system simultaneously. However, urban environments also have the highest land acquisition values too. Many modern cities have found it cost effective to build a single, very high tower to house an entire city's trunk communication microwave dishes. These towers are now a common feature of the modern urban landscape.

As the demand for bandwidth increases, microwave links will become increasingly unable to deliver. The use of increased carrier frequencies in the millimetre wave region would be advantageous. However, for technical reasons, no efficient method of producing large quantities of millimetre power have been found. This is a necessity, given the increase in atmospheric attenuation at millimetre wave frequencies.

4.11 Satellite Communication

A communication satellite:

- Is used for link ground stations.



(a) Point-to-point transmission (b) Broadcast transmission

Fig. 4.18

- Operates on a number of frequency bands, called transponder channels.
- Receives transmissions on one frequency band (uplink), and transmits on another frequency (downlink).
- Satellite period of rotation equals the earth's period of rotation at height of 34,784 km.
- Used for TV distribution, long-distance telephone, and business networks.

Satellites are transponders (units that receive on one frequency and retransmit on another) that are set in geostationary orbits directly over the equator. These geostationary orbits are 36,000 km from the Earth's surface. At this point, the gravitational pull of the Earth and the centrifugal force of Earth's rotation are balanced and cancel each other out. Centrifugal force is the rotational force placed on the satellite that wants to fling it out into space.

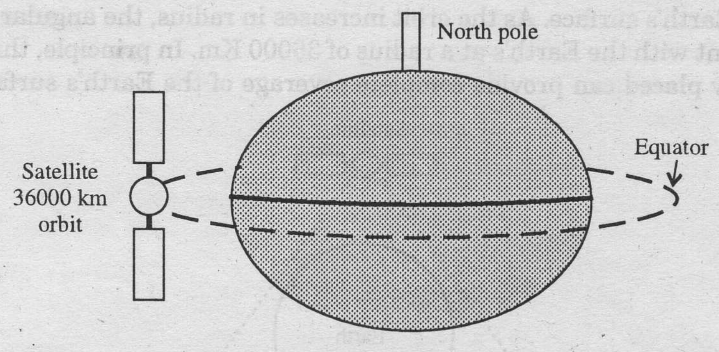


Fig. 4.19 (a) Geostationary satellite

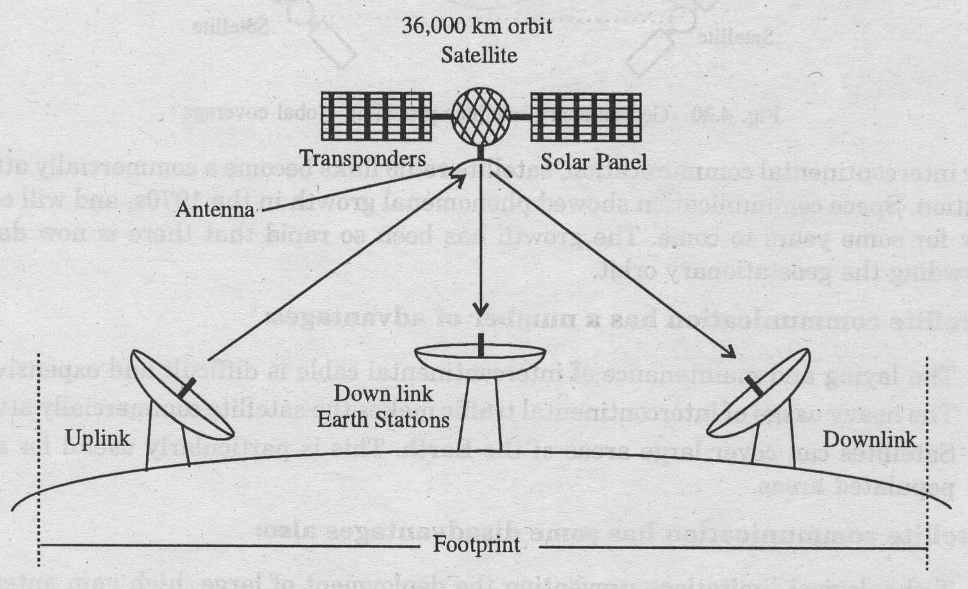


Fig. 4.19 (b) Satellite communication

The uplink is the transmitter of data to the satellite. The downlink is the receiver of data. Uplinks and downlinks are also called Earth stations because they are located on the Earth. The footprint is the "shadow" that the satellite can transmit to, the shadow being the area that can receive the satellite's transmitted signal. (As shown in figure 4.19 (b))

Satellite communication became a possibility when it was realised that a satellite orbiting at a distance of 36000 Km from the Earth would be geostationary, i.e. would have an angular orbital velocity equal to the Earth's own orbital velocity. It would thus appear to remain stationary relative to the Earth if placed in an equatorial orbit. This is a consequence of Kepler's law that the period of rotation T of a satellite around the Earth was given by:

$$T = \frac{2\pi r^{3/2}}{\sqrt{(gsR^2)}}$$

where r is the orbit radius, R is the Earth's radius and $gs = 9.81 \text{ ms}^{-2}$ is the acceleration due to gravity at the Earth's surface. As the orbit increases in radius, the angular velocity reduces, until it is coincident with the Earth's at a radius of 36000 Km. In principle, three geostationary satellites correctly placed can provide complete coverage of the Earth's surface (Fig. 4.20).

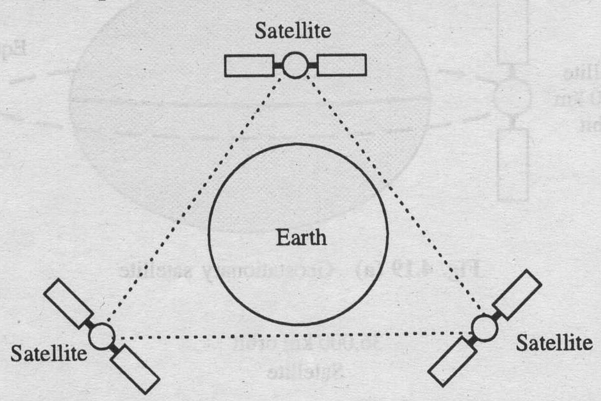


Fig. 4.20 Geostationary satellites providing global coverage

For intercontinental communication, satellite radio links become a commercially attractive proposition. Space communication showed phenomenal growth in the 1970s, and will continue to grow for some years to come. The growth has been so rapid that there is now danger of overcrowding the geostationary orbit.

Satellite communication has a number of advantages:

- The laying and maintenance of intercontinental cable is difficult and expensive.
- The heavy usage of intercontinental traffic makes the satellite commercially attractive.
- Satellites can cover large areas of the Earth. This is particularly useful for sparsely populated areas.

Satellite communication has some disadvantages also:

- Technological limitations preventing the deployment of large, high gain antennas on the satellite platform.
- Over-crowding of available bandwidths due to low antenna gains.
- The high investment cost and insurance cost associated with significant probability of failure.
- High atmospheric losses above 30 GHz limit carrier frequencies.

Satellite systems are extremely expensive. As an example, the break down for a particular British satellite is as shown in Table 4.2.

Table 4.2 Example costs for a satellite system

Item	Cost ($ Million)
Satellite construction	300
Investment finance	300
Insurance	300
Launch	100
	1000

Recently there has been interest in **low-earth orbiting (LEO)** satellites. Here, a satellite placed in a **1000 Km** orbit has an orbital time of 1 hour. These satellites can be operated in a **store-and-forward** mode, picking up data at one part of the globe and physically transferring it to another. Because the data-rates and orbit radius are greatly reduced, small, low-cost satellites and ground stations are possible. However, such satellites have yet to demonstrate any commercial success.

4.12 Infrared Waves

Infrared signals, with frequencies from 300 GHz to 400 THz can be used for short-range communication. Infrared signals, having high frequencies, cannot penetrate walls. This can be advantageous since it prevents interference between one system in one room and another system in another room. However this characteristic make infra-red signals useless for long distance communications.

Infrared technology uses the invisible portion of the light spectrum with wavelengths just a little less than those of red light. These frequencies are very high offering nice data transfer rates. Modern infrared LANs can achieve throughput at 16 Mbps with potential for better. We are used to seeing infrared technology utilized for our television or VCR remotes.

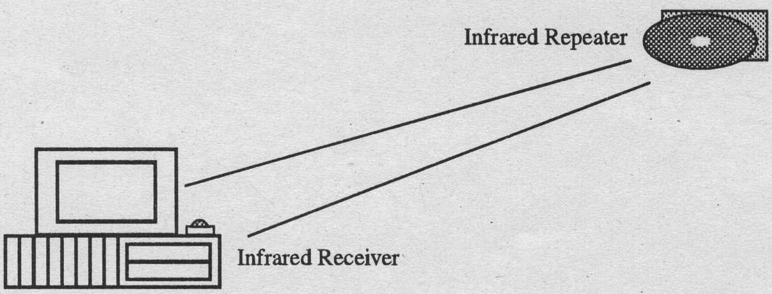


Fig. 4.21 Infrared transmissions offer potential for high-speed data transfer but are limited by inability to penetrate walls and floors.

Infrared technology involves the use of an infrared transmitter like a LED along with a receiver, typically a photodiode. These components operate in a line-of-sight fashion. That is, nothing can obstruct the pathway between them. Fortunately these signals can be bounced off walls and ceilings providing transmission around obstacles. Line-of-sight means, however, that these signals cannot be broadcast through walls, severely limiting infrared LANs.

Modern infrared systems use a repeater device simply to retransmit a signal from one room into another. This device is generally mounted on the ceiling or high in a corner to alleviate as many obstacles as possible. These systems also use a process called "diffusion" to send the signal in a wide path across a room thus reducing the chance of signals not getting past a single obstacle.

The good news about infrared technology is that it may not be very costly to implement. Since infrared items have been around a while, significant resources exist to mass produce infrared products. Advances in the technology will probably lead to faster products without as many limitations. Infrared transmissions now are limited to a relatively short distance, and used outdoors, are extremely susceptible to atmospheric conditions.

Infrared	
Advantages	**Disadvantages**
1. Higher bandwidth means superior throughput to radio.	1. Limited in distance.
2. Inexpensive to produce.	2. Cannot penetrate physical barriers like walls, ceilings, floors, etc.
3. No longer limited to tight interroom line-of-sight restrictions.	

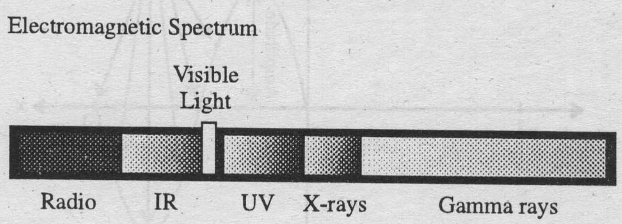
● ● ●

5

Electromagnetic Signals And Modulation

5.1 Electromagnetic Waves

All energy in the universe travels in waves and those waves radiate outwards from a source, just as waves ripple outwards from a stone tossed in a pond. Without actually going into the physics of particle or wave theory, nearly all signals are part of the electromagnetic spectrum and those that are not are based on kinetic energy (such as sound).



All radiation is said to have *wavelength*, *amplitude*, *frequency*, *phase* and power. Everything from gamma rays all the way down through the visible light spectrum to radio waves are all electromagnetic energy and differ primarily in frequency.

The wavelength of electromagnetic energy is measured in distance (meters), its frequency is measured in time (cycles per second) as is its phase (what value the wave has at any single instant in time), and amplitude is measured in power (electron volts).

Electromagnetic waves are frequently represented mathematically using a sine wave on a cartesian graph. A sine wave begins with a high value at the origin (where the X and sin X cross in the graph below), rises, falls and then returns the X-axis. This single sine cycle is said to pass through 360 *degrees of phase*. When represented on a polar-rectal graph, you get a circle (360 degrees). In polar rectal coordinates, the values are a distance from the origin plus an angle from 0 degrees.

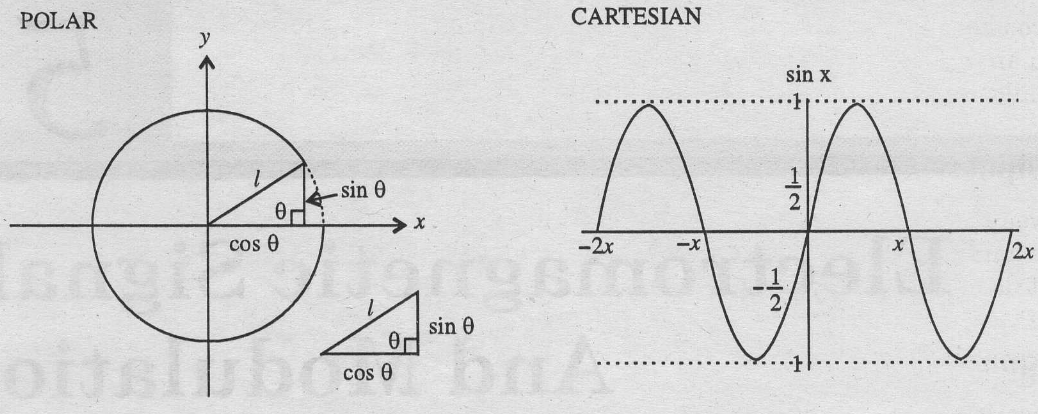


Fig. 5.1 Representation of electromagnetic waves

Below is a graph that illustrates a specific frequency at 1 hertz. It shows it's **amplitude**, its **frequency** (1 *hertz per second*) and its **phase** value at several points in time between zero seconds and 1 second.

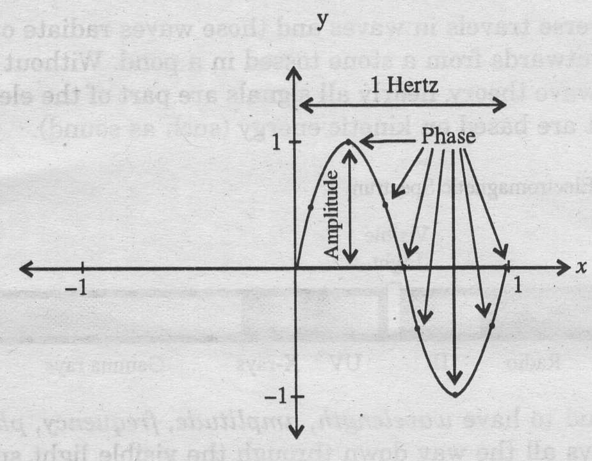


Fig. 5.2 Graph representing amplitude frequency and phase of an electromagnetic wave

Frequency

Frequency is how fast you shake the string with your hand. The faster you shake your hand, the more 'waves' you make. The number of 'waves' that happen in one second is the 'frequency' of a signal. The high points of the moving string are the maximums, and the lowest points are the minimums. The distance between one minimum and the next maximum is referred to as a 'wave'. The distance between the minimum of the first wave and the minimum of the next wave is called the 'period'.

Amplitude

If you keep moving your hand at the same speed, but change the distance you raise your hand, you are changing the amplitude. Big movements create larger waves, small movements create smaller waves. How 'high' (or 'low') the wave goes is referred to as 'amplitude'.

Output Power and Signal Strength

If you crack the string like a whip, it hits the door with force. The harder you 'crack' the string, the harder it hits the door. This is 'output power'. You can move your hand the same distance, but do it with more force and the string reacts with more force.

Signalling

Once a system of computing devices and cabling has been built, a method of getting the information onto the transmission media must exist. This is called the signalling technique. Electromagnetic signal can be either *continuous* or *discrete*. A **continuous signal** is one in which the signal intensity varies in a smooth fashion over time, i.e., no break or no discontinuous in the signal.

A **discrete signal** is one in which the signal intensity maintain a constant level for same period of time and then changes to another constant level.

The movement of the signal over its transmission path is referred to as *signal propagation*.

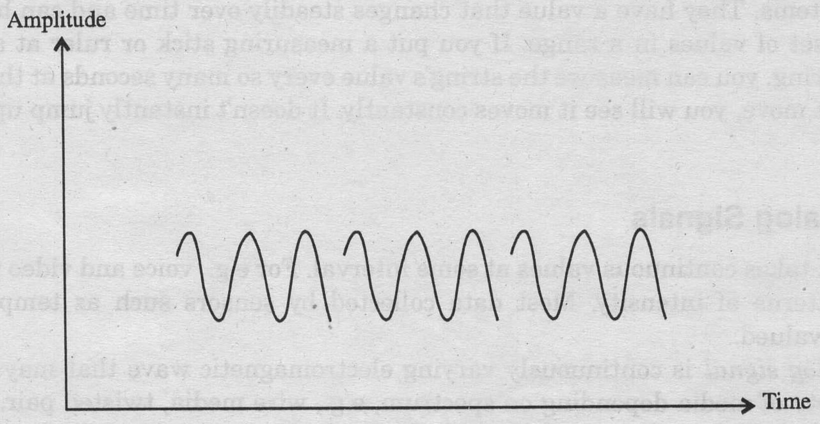


Fig. 5.3 Continuous Signal

The sine wave is the fundamental continuous signal.

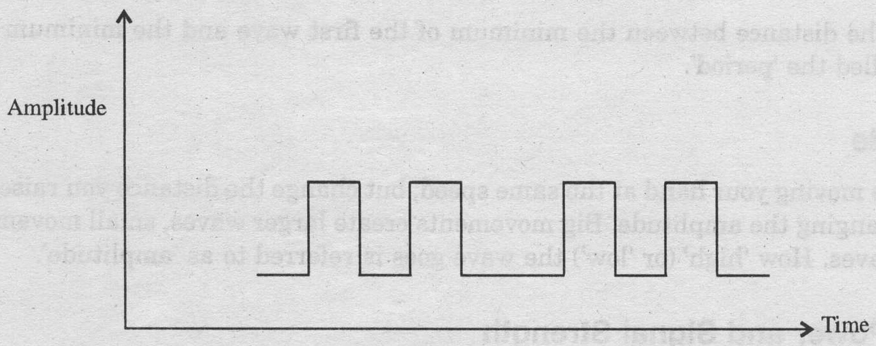


Fig. 5.4 Discrete Signal

5.2 Analog communications

In the analog communications, information is represented as a continuous electromagnetic wave form. Analog is best explained by examining the transmission of a natural form of information, such as sound or human speech, over an electrified copper wire. Information which is analog in its native form (voice and image) can vary continuously in terms of intensity (volume or brightness) and frequency (tone or color). Those variations in the native information stream are translated in an analog electrical network into variations in the amplitude and frequency of the carrier signal. In other words, the carrier signal is modulated (varied) in order to create an analog of the original information stream.

Bandwidth, in the analog world, is measured in hertz (Hz).

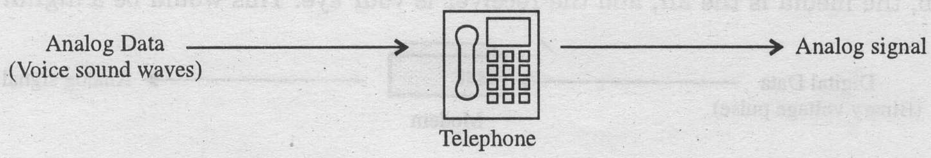
A string tied to a doorknob would be an 'analog' system. Analog systems are also known as wave systems. They have a value that changes steadily over time and can have any one of an infinite set of values in a range. If you put a measuring stick or ruler at a specific point along the string, you can measure the string's value every so many seconds at that point. When you watch it move, you will see it moves constantly. It doesn't instantly jump up and down the ruler.

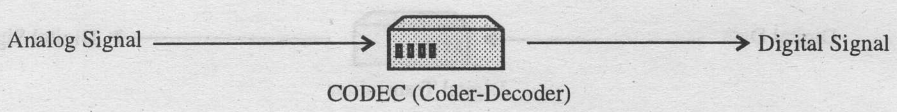
5.2.1 Analog Signals

Analog data takes continuous values at some interval. For e.g., voice and video is continuously varying patterns of intensity. Most data collected by sensors such as temp, pressure are continuous-valued.

An *analog signal* is continuously varying electromagnetic wave that may be propagated over a variety of media depending on spectrum, e.g., wire media, twisted pair, co-axial cable, fiber optic cable etc. Analog signals are used to represent analog data. Generally, analog data are a function of time and occupy frequency spectrum, such data can be represented by an electromagnetic signal occupying the same spectrum. When the signalling technique in a local area network implementation is analog, the network is known as a **BROADBAND** network. Broadband networks require the presence of a carrier signal.

Broadband = Analog





5.3 Digital Communications

Digital communications represents information in binary form (1's and 0's) through a series of discrete blips or pulses. While the natural world is analog in nature, computers (which are decidedly unnatural beings) are digital in nature. Computers process, store, and communicate information in *binary* form. That is to say that a unique combination of 1's and 0's has a specific meaning in a computer language. A bit (*binary digit*) is an individual 1 or 0. Multiple bits travel across a network in a *digital bit stream.*

5.3.1 Digital Signals

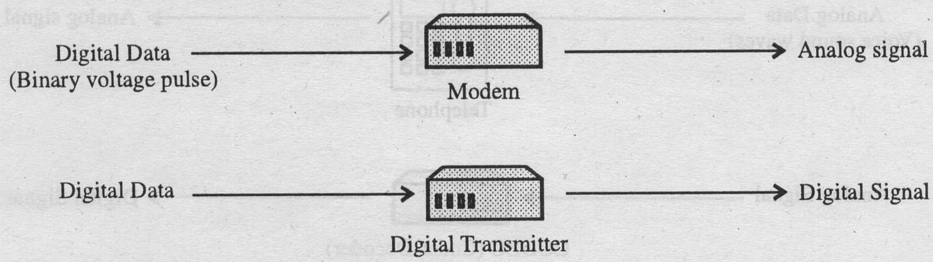
Digital signaling, in an electrical network, involves a signal that varies in voltage to represent one of two discrete and well-defined states : such as a positive (+) voltage and a null, or zero (0) voltage (unipolar); or a positive (+) or a negative (–) voltage (bipolar). The receiver monitors the signal, at a specific frequency and for a specific duration (*bit time*) to determine the state of the signal. Various data transmission protocols employ different physical states of the signal, such as voltage level or voltage transition. Because of the discrete nature of each bit transmitted, the bit form is often referred to as a *square wave*.

Digital signaling in an optical network can involve either the pulsing on and off of a light stream or a variation in the intensity of the light signal. Digital transmission over radio systems (e.g., microwave, cellular or satellite) can be accomplished by varying the amplitude of the signal. In the digital world, bandwidth is measured in *bits per second* (*bps*). The amount of bandwidth required depends on the amount of raw data to be sent, the desired speed of transmission of that set of data, and issues of transmission cost.

When the signalling technique in a local area network implementation is digital, the network is known as a **BASEBAND** network.

Baseband = Digital

Our string example is *not* a digital system. A digital system would be to flick the light switch on and off. There's no 'in between' values, unlike our string. If the switch you are using is not a dimmer switch, then the light is either on, or off. In this case, the transmitter is the light bulb, the media is the air, and the receiver is your eye. This would be a *digital* system.



5.4 Media And Propagation Of Signals

The actual process of carrying a signal from point to point is called *propagation*. Copper, aluminum, tin or nickel wire is used to *propagate* electricity. Erbium-doped glass fibers, or plastic strands are used to *propagate* light. The air itself is used to propagate laser beams, radio waves or microwave.

The copper, aluminum, nickel, tin, glass fibers, plastic and the air are all referred to as *media* (or *the medium of transmission*). Our string *propagates* the movement of our hand to the doorknob. The time it takes to *propagate* a signal through a device or piece of media is called *propagation delay* or *latency*.

5.4.1 Transmitters, Receivers and Transmission Media

When you shake the string, you create a wave that radiates outwards from your hand down the string to the doorknob. This string is what we are using to transmit our signal. The string is the *transmission media*, our hand and arm is the *transmitter* and the doorknob is the receiver.

A device that can both transmit *and* receive is called a *transceiver*. Media is the stuff used to connect all the devices together. That can be the air, a cable or radio waves.

5.4.2 Carrier Signal

The process of data transmission requires some sort of signal to carry information across a medium. For copper medium, a signal can be the electrical voltage on the line. On optical cabling, it is the light. Through the atmosphere, it can be a radio, microwave or infrared signal. The carrier signal (sometimes called a carrier wave) provides the base signal into which data is inserted using some type of modulation technique. (Discussed later) Many systems have error detectors that signal a problem when the carrier signal disappears (no voltage on the copper wire, no light in the optical cable, etc.).