Government Arts and Science College (Women), Sathankulam – 628704

Class : III B.Sc. (Computer Science)

Semester : V

Subject : Data Communication and Computer Network

Topic : Unit – II

Faculty : Mrs. A. Angeline Nancy Sophia M.Sc., M.Phil.,
Department of Computer Science

ANALOG AND DIGITAL

Data and signals can be either analog or digital in form.

Analog and Digital data

- Analog data refers to information that is continuous.

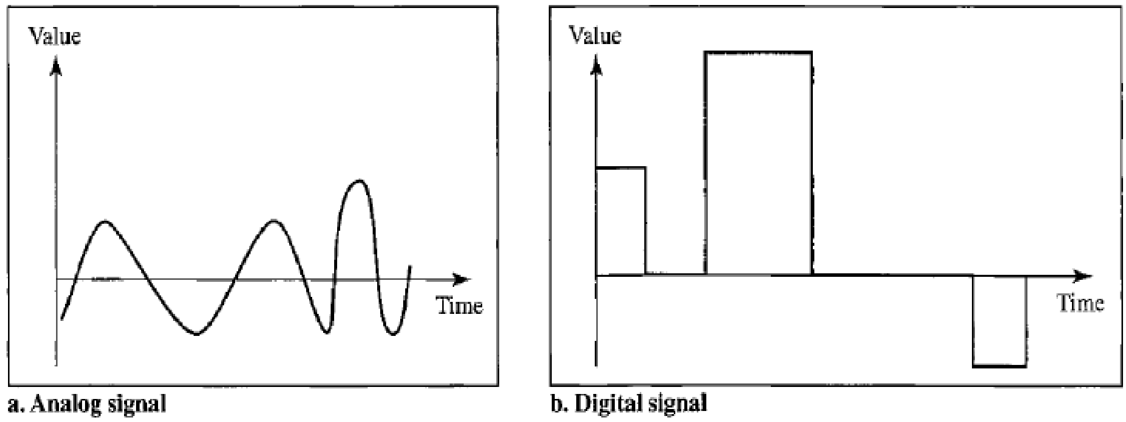
  Ex. Analog clock, sound made by human voice

- Digital data refers to information that has discrete states.

  Ex. Digital clock. Data stored in memory in the form of 0's and 1' s

Analog and Digital signals

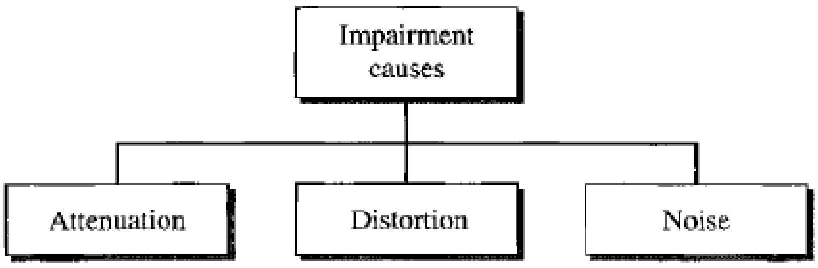
- Analog signals has infinitely many levels over a period of time.
- Digital signal have limited number of defined values.



a. Analog signal b. Digital signal

TRANSMISSION IMPAIRMENT

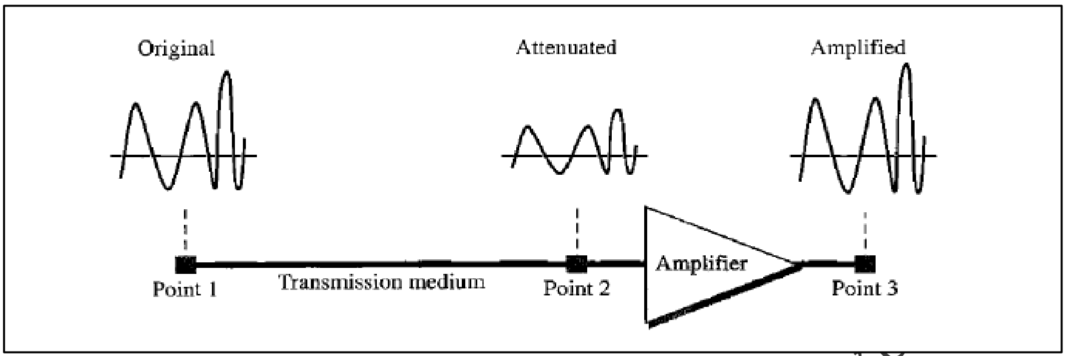
- Imperfection causes signal impairment.
- That is signal at the beginning of the medium is not the same as the signal at the end of the medium.



Attenuation

- It means loss of energy.
- When a signal travels through a medium, it loses some of its energy in overcoming the resistance of the medium.

- Some of the electrical energy is converted to heat.
- To compensate this loss, amplifiers are used to amplify the signal.



Decibel (dB)

- It measures the relative strengths of two signals or one signal at two different points.
- If the decibel is negative the signal is attenuated and positive if a signal is amplified.

$dB = 10 \log_{10} P_2/P_1$

P_1 and P_2 are the powers of a signal at point 1 and 2

Example 3.26

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that $P_2 = \frac{1}{2} P_1$. In this case, the attenuation (loss of power) can be calculated as

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}$$

A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.

Example 3.27

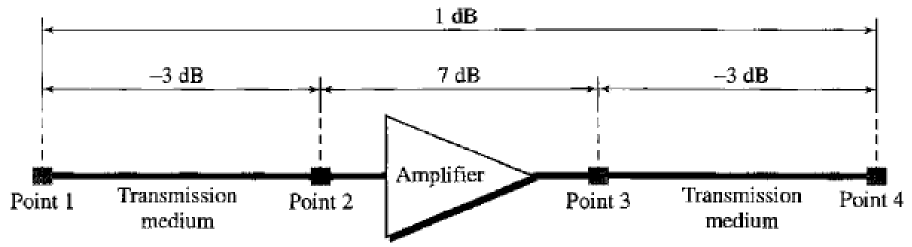
A signal travels through an amplifier, and its power is increased 10 times. This means that $P_2 = 10P_1$. In this case, the amplification (gain of power) can be calculated as

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{10P_1}{P_1} = 10 \log_{10} 10 = 10(1) = 10 \text{ dB}$$

Example 3.28

One reason that engineers use the decibel to measure the changes in the strength of a signal is that decibel numbers can be added (or subtracted) when we are measuring several points (cascading) instead of just two. In Figure 3.27 a signal travels from point 1 to point 4. The signal is attenuated by the time it reaches point 2. Between points 2 and 3, the signal is amplified. Again, between points 3 and 4, the signal is attenuated. We can find the resultant decibel value for the signal just by adding the decibel measurements between each set of points.

Figure 3.27 *Decibels for Example 3.28*



In this case, the decibel value can be calculated as

$$dB = -3 + 7 - 3 = +1$$

Example 3.29

Sometimes the decibel is used to measure signal power in milliwatts. In this case, it is referred to as dB_m and is calculated as $dB_m = 10 \log_{10} P_m$, where P_m is the power in milliwatts. Calculate the power of a signal if its $dB_m = -30$.

SECTION 3.4 TRANSMISSION IMPAIRMENT 83

Solution

We can calculate the power in the signal as

$$dB_m = 10 \log_{10} P_m = -30$$
$$\log_{10} P_m = -3 \qquad P_m = 10^{-3} \text{ mW}$$

Example 3.30

The loss in a cable is usually defined in decibels per kilometer (dB/km). If the signal at the beginning of a cable with −0.3 dB/km has a power of 2 mW, what is the power of the signal at 5 km?

Solution

The loss in the cable in decibels is $5 \times (-0.3) = -1.5$ dB. We can calculate the power as

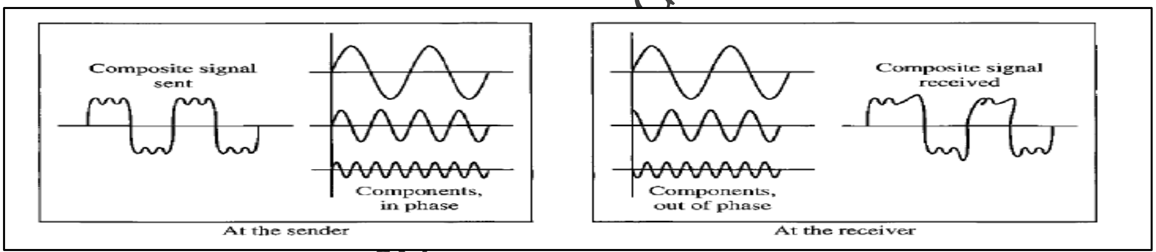
$$dB = 10 \log_{10} \frac{P_2}{P_1} = -1.5$$

$$\frac{P_2}{P_1} = 10^{-0.15} = 0.71$$

$$P_2 = 0.71 P_1 = 0.7 \times 2 = 1.4 \text{ mW}$$

Distortion

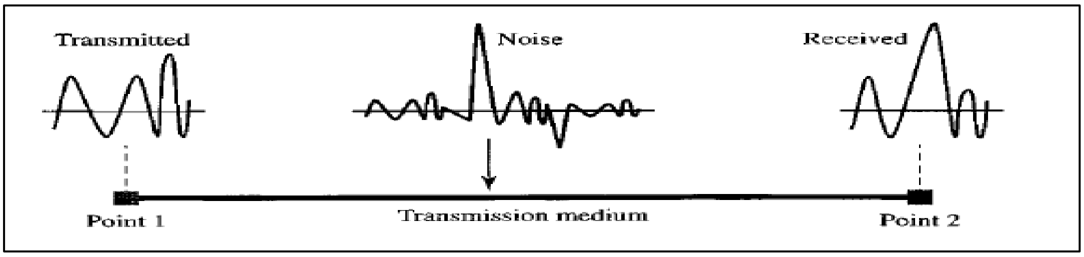
- Signal changes from its form or shape.
- Each signal component has its own propagation speed through a medium and therefore its own delay in arriving at the final destination.



Noise

Types of noise: thermal noise, induced noise, crosstalk and impulse noise.

- Thermal noise – random motion of electrons in a wire which creates an extra signal not sent by the transmitter.
- Induced noise – comes from motors and appliances.
- Crosstalk – effect of one wire on the other.
- Impulse noise – comes from power lines, lightning



Signal-to-Noise Ratio (SNR)

As we will see later, to find the theoretical bit rate limit, we need to know the ratio of the signal power to the noise power. The **signal-to-noise ratio** is defined as

$$\textbf{SNR} = \frac{\textbf{average signal power}}{\textbf{average noise power}}$$

We need to consider the average signal power and the average noise power because these may change with time. Figure 3.30 shows the idea of SNR.

SNR is actually the ratio of what is wanted (signal) to what is not wanted (noise). A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.

Because SNR is the ratio of two powers, it is often described in decibel units, SNR_{dB}, defined as

$$SNR_{dB} = 10 \log_{10} SNR$$

DATA RATE LIMITS

It is how fast we can send data in bits per second over a channel.

Data rate factors:

- Bandwidth available
- Level of the signals we use
- Quality of channel

Noiseless Channel: Nyquist Bit Rate

The Nyquist bit rate formula defines maximum bit rate

$$\text{BitRate} = 2 \times \text{bandwidth} \times \log_2 L$$

bandwitdth – bandwidth of the channel, L – number of signal levels used, Bitrate is the bit rate in bits per second

Example 3.34

Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 2 = 6000 \text{ bps}$$

Example 3.35

Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as

$$\text{BitRate} = 2 \times 3000 \times \log_2 4 = 12{,}000 \text{ bps}$$

Noisy Channel: Shannon capacity

Shannon capacity is used to determine the highest data rate for a noisy channel

capacity = bandwidth x $\log_2$ (1 + SNR)

bandwidth – bandwidth of the channel, SNR – signal-to-noise ratio, capacity – capacity of the channel in bits per second

Example 3.37

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$C = B \log_2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log_2 1 = B \times 0 = 0$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

Example 3.38

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000 Hz (300 to 3300 Hz) assigned for data communications. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B \log_2 (1 + \text{SNR}) = 3000 \log_2 (1 + 3162) = 3000 \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

PERFORMANCE

Bandwidth

One characteristic that measures network performance is bandwidth.

Bandwidth in Hertz – it is the range of frequencies contained in a composite signal or the range of frequencies a channel can pass.

Ex. Bandwidth of subscriber telephone line is 4khz.

Bandwidth in Bits per Seconds – bandwidth of a fast Ethernet network is 100Mbps

Throughput

It is measure of how fast we can send data through a network. A link may have a bandwidth of B bps, but we can send T bps through this link with T always less than B.

Example 3.44

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

Solution

We can calculate the throughput as

$$\text{Throughput} = \frac{12{,}000 \times 10{,}000}{60} = 2 \text{ Mbps}$$

The throughput is almost one-fifth of the bandwidth in this case.

Latency (Delay)

- It defines how long it takes for an entire message to arrive at the destination from the source.
- Made of 4 components

Latency = propagation time + transmission time + queuing time + processing delay

Propagation time

- Time required for a bit to travel from the source to the destination.

Propagation time = Distance / Propagation speed

propagation speed depends on the medium and the frequency of the signal.

Example: light is propagated with a speed of 3×10^8 m/s

Example 3.45

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4×10^8 m/s in cable.

Solution

We can calculate the propagation time as

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

Transmission time

- It depends on the size of the message and bandwidth of the channel

transmission time = Message size / Bandwidth

Example 3.46

What are the propagation time and the transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4×10^8 m/s.

Solution

We can calculate the propagation and transmission time as

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{2500 \times 8}{10^9} = 0.020 \text{ ms}$$

Queuing time

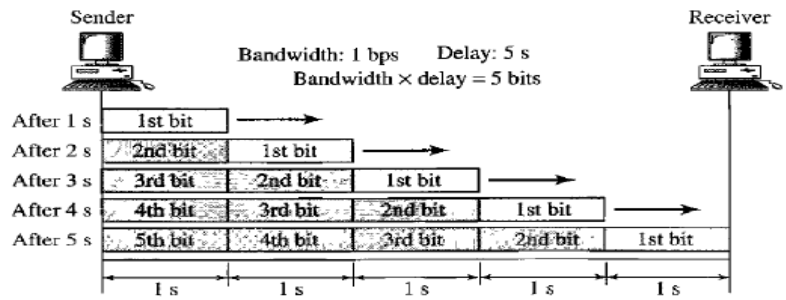
- The time needed for each intermediate or end device to hold the message before it can be processed.
- It changes with load imposed on the network.

Bandwidth-Delay Product

- Bandwidth and delay are two performance metrics of a link.

❑ **Case 1.** Figure 3.31 shows case 1.

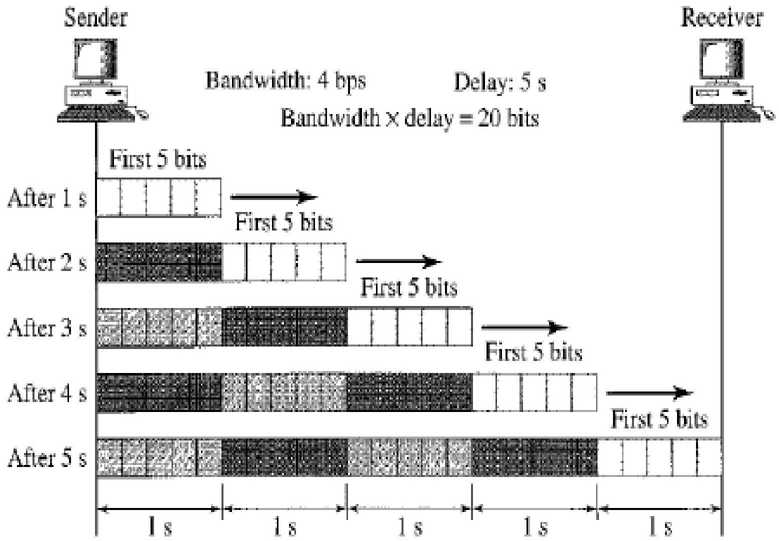
Figure 3.31 *Filling the link with bits for case 1*



Let us assume that we have a link with a bandwidth of 1 bps (unrealistic, but good for demonstration purposes). We also assume that the delay of the link is 5 s (also unrealistic). We want to see what the bandwidth-delay product means in this case.

- **Case 2.** Now assume we have a bandwidth of 4 bps. Figure 3.32 shows that there can be maximum 4 × 5 = 20 bits on the line. The reason is that, at each second, there are 4 bits on the line; the duration of each bit is 0.25 s.

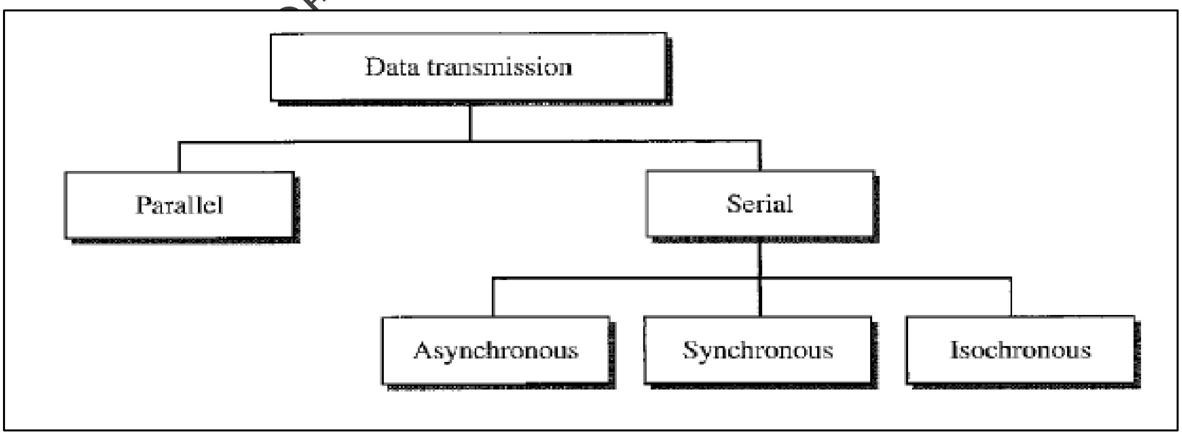
Figure 3.32 *Filling the link with bits in case 2*



Jitter

- Related to delay
- It is a problem if different packets of data encounter different delays and the application using the data at the receiver site is time-sensitive.

TRANSMISSION MODES



- Binary data may be organized in groups of n bits each.
- We can send data n bits at a time is called parallel transmission.
- Use n wires to send n bits at one time from one device to another with each clock tick.

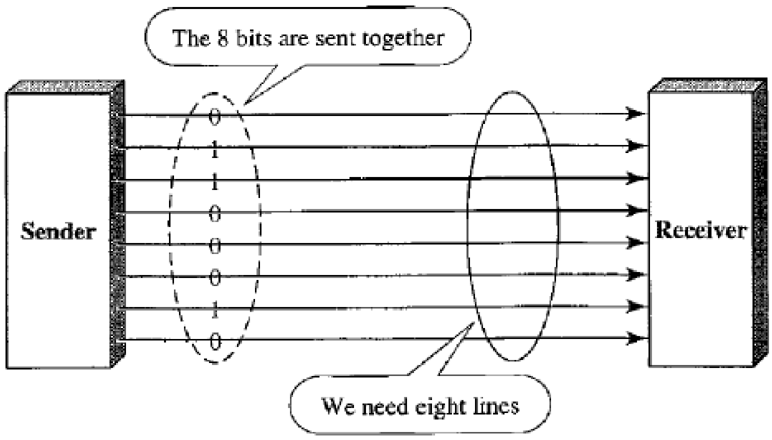
Advantage

- Increases transfer speed

Disadvantage

- Cost. Requires n communication lines to transmit the data stream. So it is limited to short distances.

Figure 4.32 *Parallel transmission*



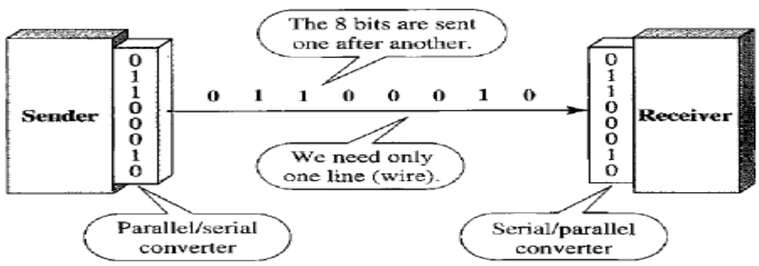
Serial Transmission

- We need only one communication channel to transmit data between two communication devices.
- It need conversion devices at the interface between the sender and the line and between the line and the receiver.
- Serial transmission occurs in three ways: synchronous, synchronous and isochronous.

Advantage:

- It reduces cost of transmission

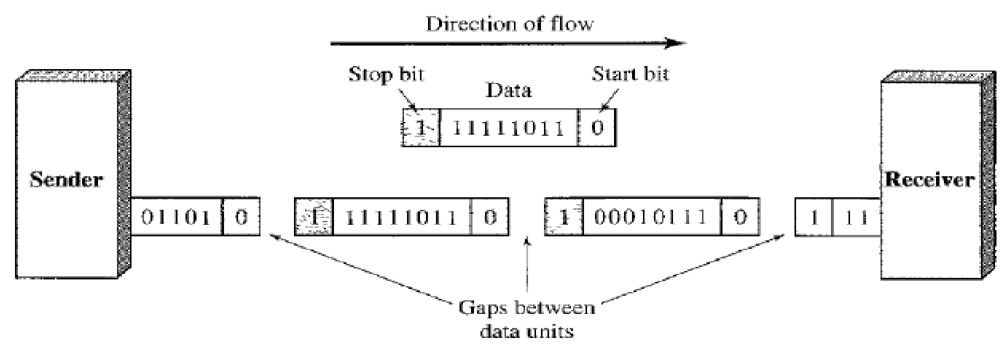
Figure 4.33 *Serial transmission*



- The timing of signal is not important.
- Information is received and translated by patterns.

- Patterns are based on grouping the bit stream into bytes.
- The receiver cannot predict when the text will arrive.
- So an extra bit is added to the beginning of each byte.
- This bit is usually a 0 and is called start bit.
- Bit 1 is appended at the end of the byte and is called stop bit.
- There may be a gap between each byte.
- The start and stop bits and gap alert the receiver the beginning and end of byte.
- When receiver detects a start bit, it sets a timer and begin counting bits.
- After n bits it looks for stop bits.
- As soon as it detects the stop bit, it waits until it detects the next start bit.

Figure 4.34 *Asynchronous transmission*



Advantage:

It is cheap and effective

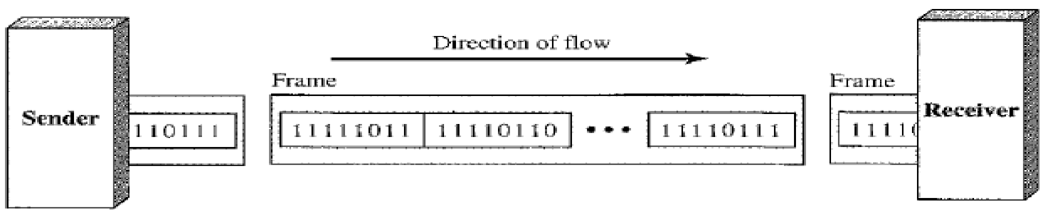
Synchronous Transmission

- The bit stream is combined into longer frames which contain multiple bytes.
- We send bits one after another without start or stop bits or gaps.
- The receiver separates the string and reconstruct the information.

Advantage:

- Faster than asynchronous transmission.

Figure 4.35 *Synchronous transmission*

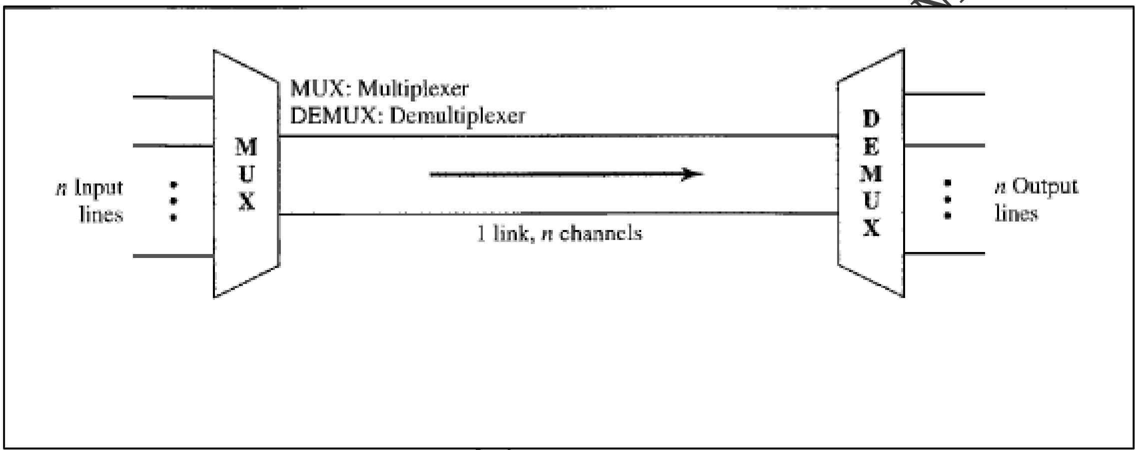


Isochronous Transmission

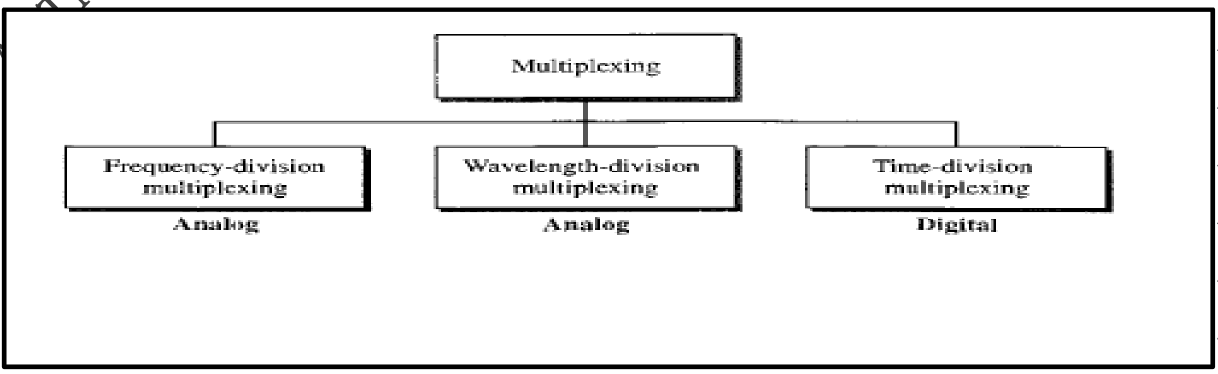
- In real-time audio and video synchronous transmission fails.
- For example TV images broadcast at the rate of 30 images per second and they must be viewed at the same rate.
- Isochronous guarantees that the data arrive at fixed rate.

MULTIPLEXING

- It is the set of techniques that allows simultaneous transmission of multiple signals across a single data link.

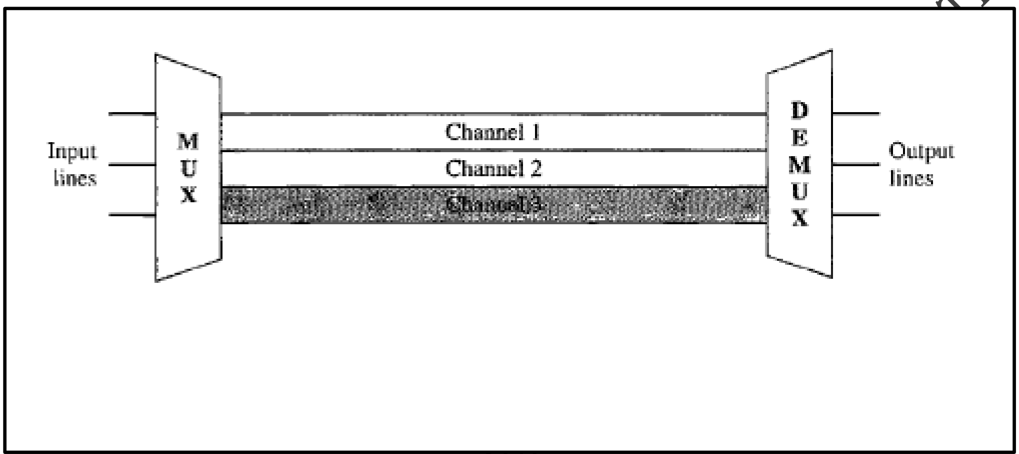


- The lines on the left directs their transmission to a multiplexer(MUX) which combines into a single stream.
- At the receiving end, it is fed into demultiplexer (DEMUX) which separates the stream and directs to their corresponding lines.
- Link refers to physical path
- Channel refers to the portion of link that carries transmission between a given pair of lines.
- One link can have many channels.

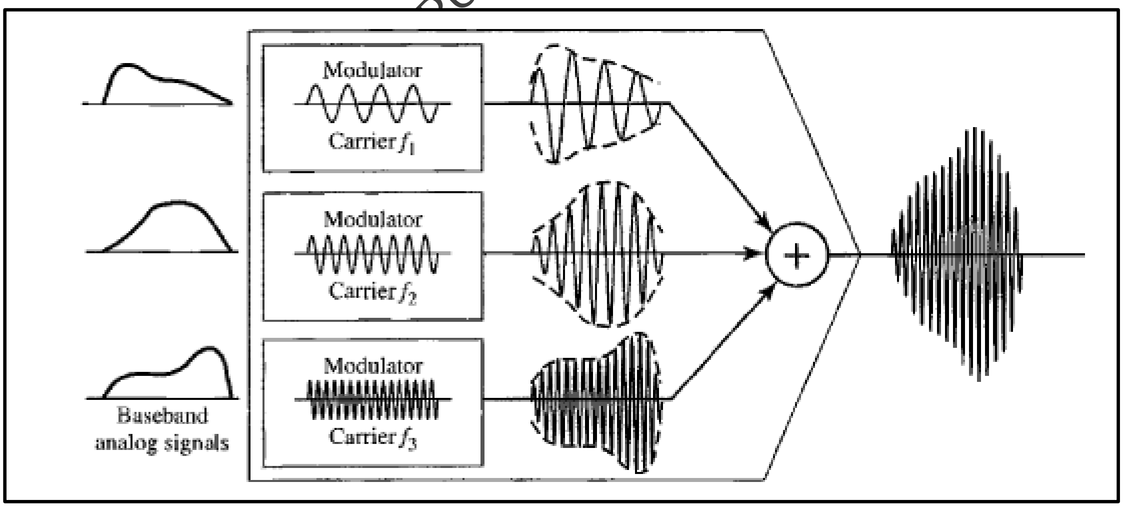


Frequency Division Multiplexing (FDM)

- It is an analog technique applied when the bandwidth of the link is greater than the combined bandwidths of signals.
- In FDM, signals generated by each sending device modulate different carrier frequencies.
- Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal.
- These bandwidth ranges are channels through which signals travel.
- Channels are separated by strips of unused bandwidth called guard bands to prevent signals from overlapping.

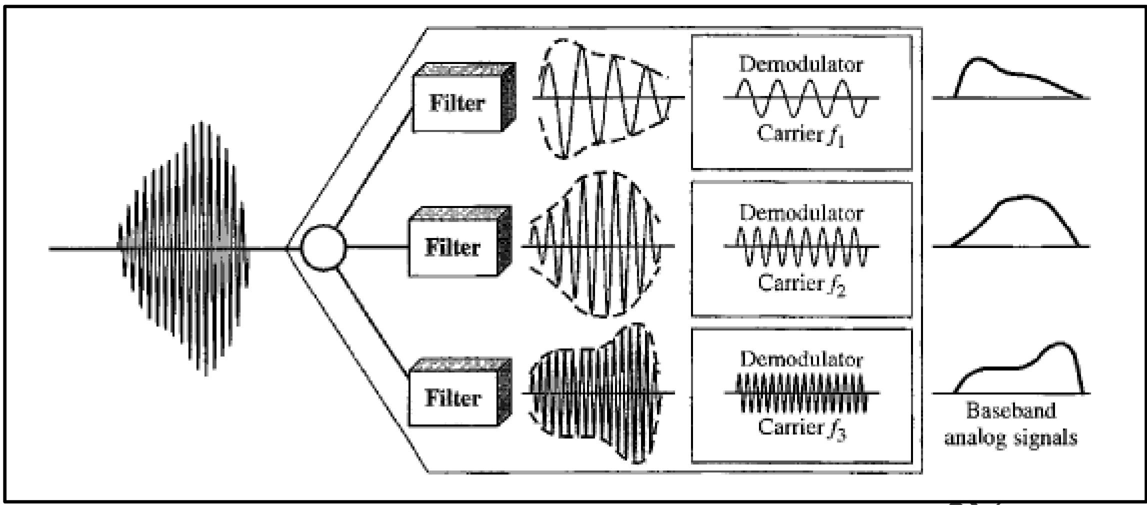


Multiplexing Process



- Each source generates a signal of a similar frequency range.
- These similar signals modulates different frequencies f1, f2 and f3 inside the multiplexer.
- The resulting signals are combined into a single composite signal and sent over a media link that has enough bandwidth.

Demultiplexing Process



- Demultiplexer uses a series of filters to decompose the multiplexed signal into its component signals.
- The signals are passed into a demodulator that separates them from their carriers and passes to the output lines.

Applications of FDM

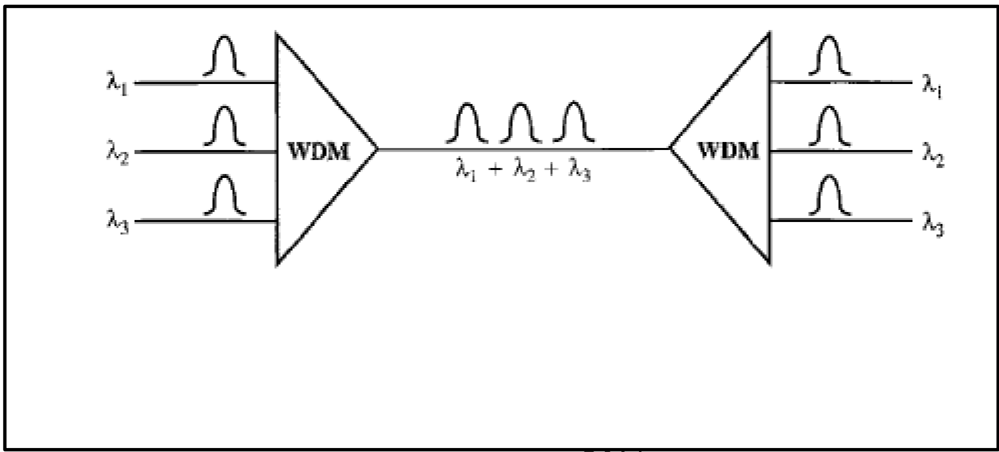
- A very common application of FDM is AM and FM radio broadcasting.
- Radio uses air as transmission medium.
- A special band from 530 to 1700 kHz is assigned to AM radio. All radio stations need to share the same band.
- Each AM station needs 10 kHZ. Each station uses different carrier frequency.
- The signal that goes to air is the combination of signals.
- A receiver receives all these signals but filters only the one which is desired.
- Without multiplexing only one AM station could broadcast to the common link.
- Another common use of FDM is television broadcasting. Each channel has its own bandwidth of 6MHz.
- The first generation of cellular telephones also uses FDM.

Implementation

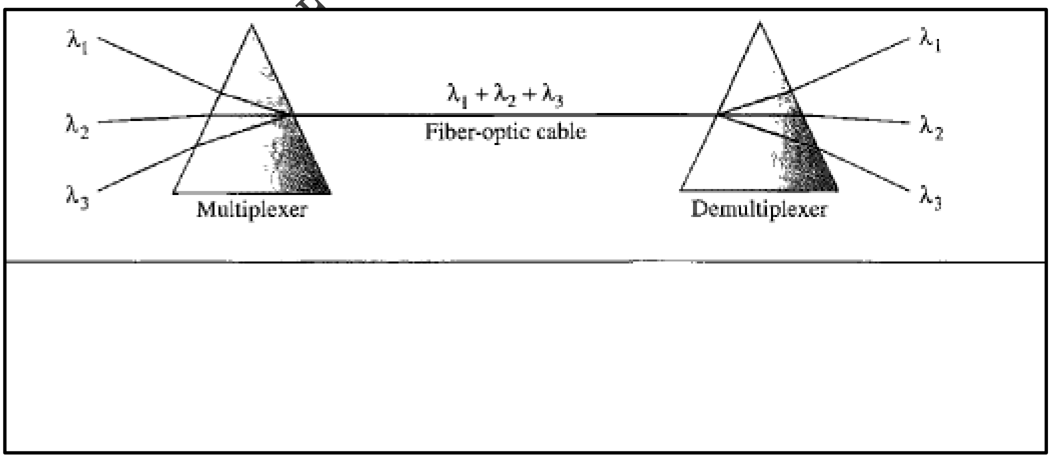
- FDM can be implemented very easily.
- As long as the station send their broadcasts to the air using different carrier frequencies, multiplexing is achieved.

Wavelength Division Multiplexing

- It is designed to use the high-data-rate capability of fiber-optic cable.
- The fiber optic data rate is higher than the data rate of metallic transmission cable.
- WDM is same as FDM but the multiplexing and Demultiplexing involve optical signals transmitted through fiber optic channels.
- We combine different signals of different high frequencies.



- We want to combine multiple light sources into one single light at the multiplexer and do the reverse at the demultiplexer.
- The combining and splitting of light sources are handled by a prism.
- Using this technique, a multiplexer can be made to combine several input beams of light of narrow band of frequencies into one output beam of wider band of frequencies.
- A demultiplexer can be used to make reverse process.



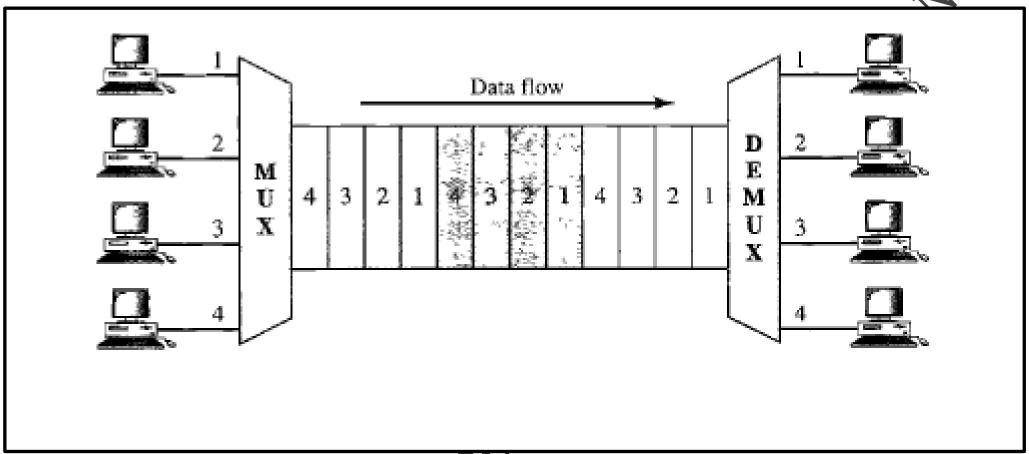
Application of WDM

- SONET (Synchronous Optical Network) network in which multiple optical fiber lines are multiplexed and demultiplexed.

- A new method dense WDM(DWDM) can multiplex a large number of channels by spacing channels very close to one another.

Time Division Multiplexing (TDM)

- TDM is a digital process that allows several connections to share the high bandwidth of a link.
- Each connection occupies a portion of time in the link.
- Digital data from different sources are combined into one timeshared link.
- Portions of signals 1, 2, 3 and 4 occupy the link sequentially.
- Analog data can be sampled, changed to digital data and then multiplexed.



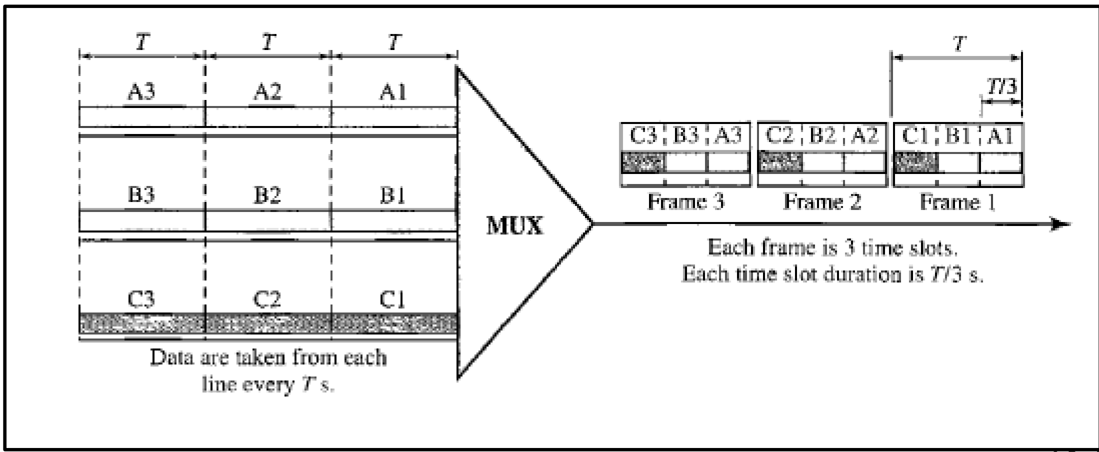
- TDM can be divided into Synchronous TDM and Statistical TDM.

Synchronous Time Division Multiplexing

Each input connection has an allotment in the output even if it is not sending data.

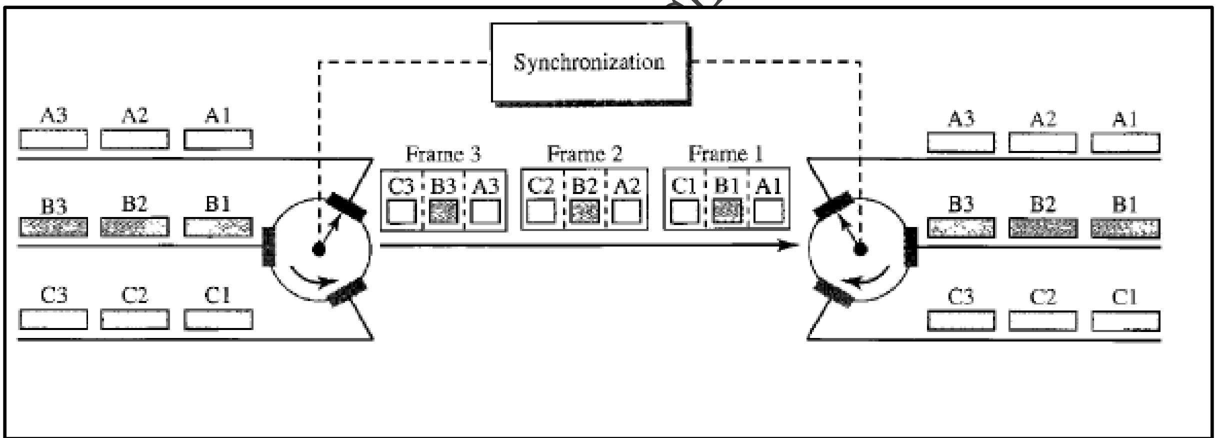
Time slots and frames

- Each connection is divided into units and each unit occupies one input time slot.
- A unit can be 1 bit, one character or one block of data.
- Duration of output slot is n times shorter than the duration of an input time slot
- If an input time slot is T s, the output time slot is T/n s, where n is number of connections.



- Data units from each input connection is collected into a frame.
- If we have n connections, a frame is divided into n time slots and one slot is allocated for each unit.
- Duration of each slot is T/n and for each frame is T
- Frame consists of one complete cycle of time slots, one slot for each sending devices.

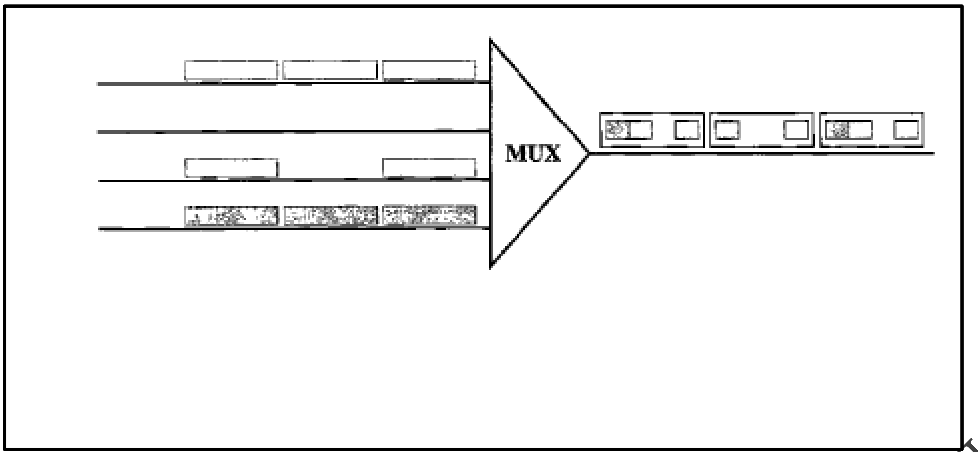
Interleaving



- TDM has two fast rotating switches, one on the multiplexing side and other on Demultiplexing side.
- Switches are synchronized and rotate at the same speed but in opposite directions.
- On multiplexing side, the switch opens in front of a connection and send a unit onto a path. This process is called interleaving.
- On Demultiplexing side, the switch opens in front of connection to receive from the path.

Empty slots

- If a source does not have data to send, the corresponding slot in the output frame is empty.



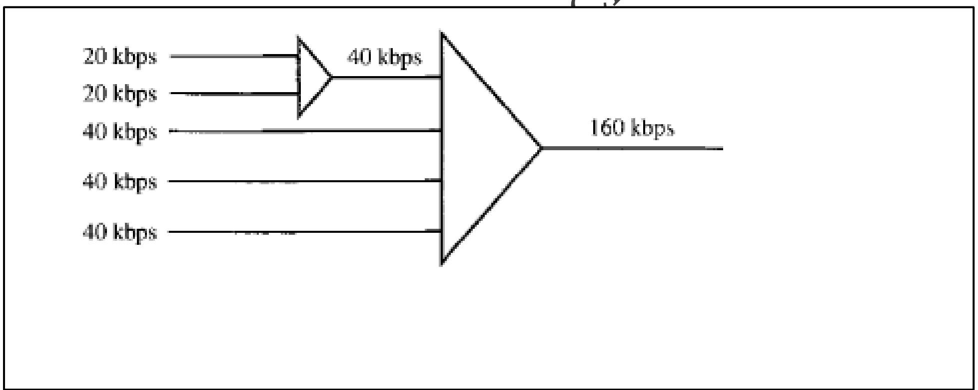
- The first output frame has three slots, the second frame has two slots and third frame has three slots

Data Rate Management

If the data rates are not same we three strategies:

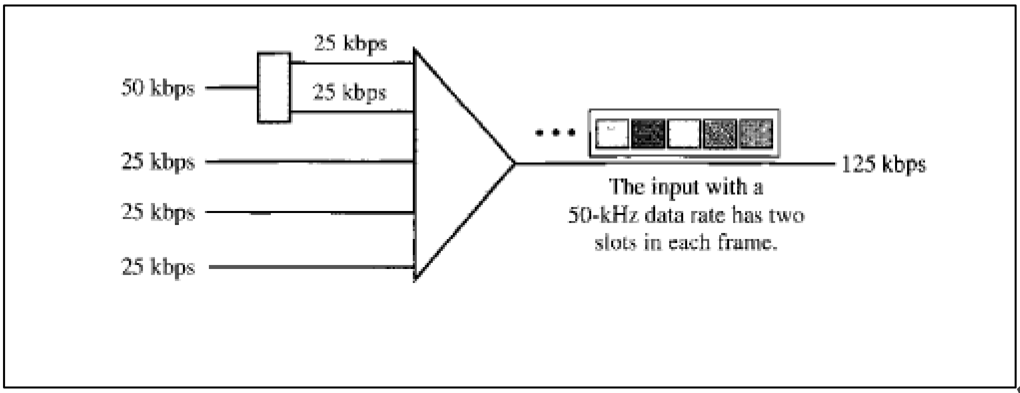
- Multilevel multiplexing

It is used when data rate of an input line is a multiple of others. For example we have two inputs of 20kbps and three inputs of 40 kbps. The first two input lines can be multiplexed together to provide a data rate equal to the last three. A second level of multiplexing can create an output of 160 kbps.



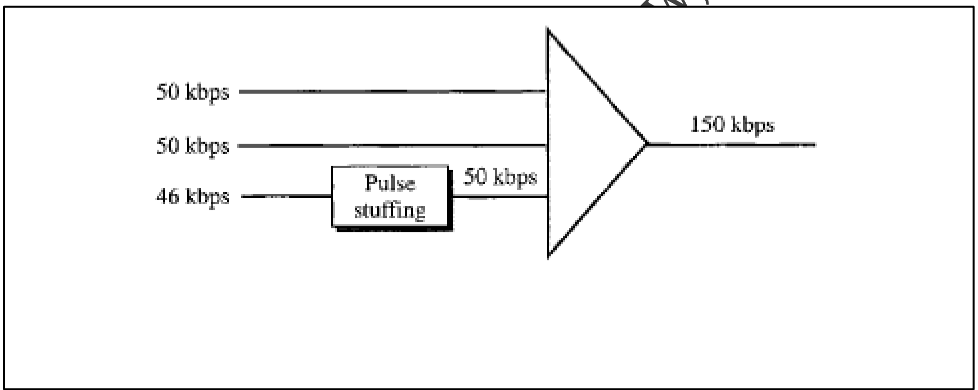
- Multiple-slot allocation

It is more efficient to allot more than one slot in a frame to a single input line. For example the input line with a 50 kbps data rate can be given two slots in the output. We insert serial to parallel converter in the line to make two inputs out of one.



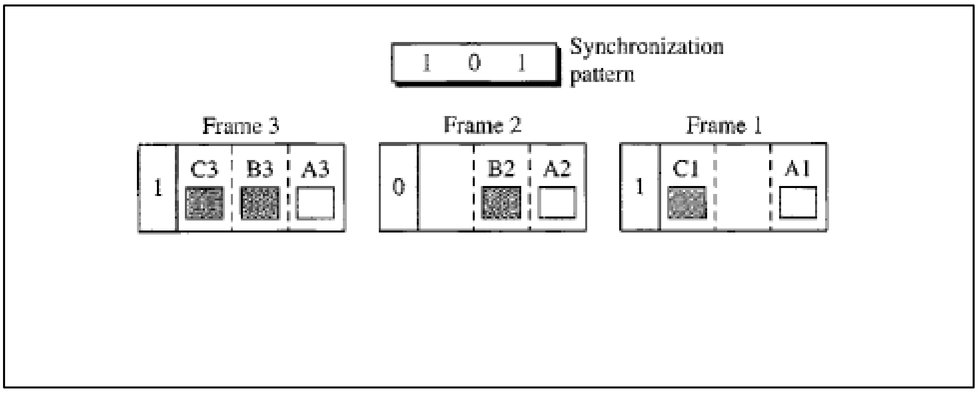
- Pulse stuffing

Sometimes the bit rates are not of multiple integers. To make the highest input rate the dominant by adding dummy bits to the input lines with lower rate. This will increase their rates. This technique is called pulse stuffing, bit padding or bit stuffing.



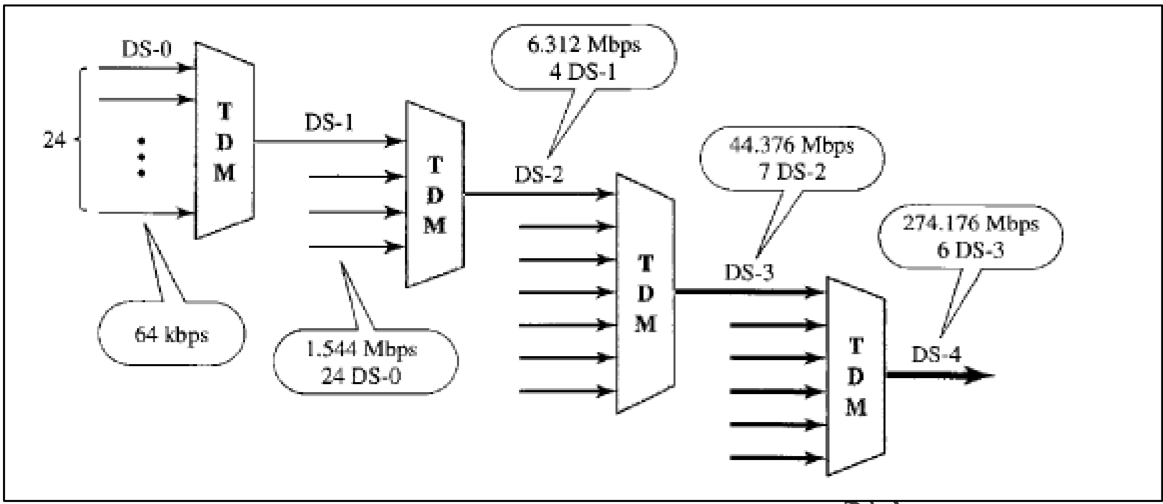
Frame synchronizing

If the multiplexer and demultiplexer are not synchronized, a bit belonging to one channel may be received by the wrong channel. So one or more synchronization bits are added to the beginning of each frame. These bits called framing bits, follow a pattern, frame to frame and allows the demultiplexer to synchronize with the incoming stream. This synchronization consists of 1 bit per frame alternating between 0 and 1.



Digital Signal service

Telephone companies implement TDM through a hierarchy of digital signals called digital signal (DS) service or digital hierarchy.



- DS-0 service is a single digital channel of 64 kbps
- DS–1 is a 1.544 Mbps service; 24 times 64 kbps plus 8 kbps of overhead. It can be used as single service or it can be used to multiplex 24 DS-0 channels or any other combination that can fit within its 1.544 Mbps capacity.
- DS-2 is a 6.312 Mbps service; 96 times 64 kbps plus 168 kbps of overhead. It can be used as a single service or it can be used to multiplex 4 DS-1 channels, 96 DS-0 channels or combination of these.
- DS-3 is a 44.376 Mbps service; 672 times 64 kbps plus 1.368 Mbps of overhead. It can be used as a single service or it can be used to multiplex 7 DS-2 channels, 28 DS-1 channels, 672 DS-0 channels or a combination of these service types.
- DS-4 is a 274.176 Mbps service; 4032 times 64 kbps plus 16.128 Mbps o overhead. It can be used to multiplex 6 DS-3 channels, 42 DS-2 channels, 168 DS-1 channels and 4032 DS-0 channels or a combination of these.

T Lines

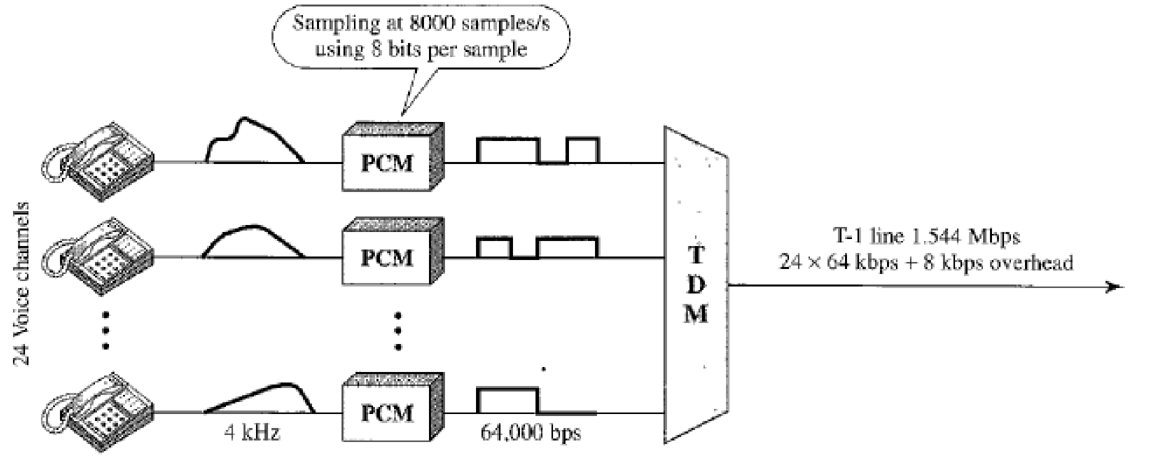
To implement DS-0 and DS-1 services, the telephone companies use T lines.

Service	Line	Rate (Mbps)	Voice Channels
DS-1	T-1	1.544	24
DS-2	T-2	6.312	96
DS-3	T-3	44.736	672
DS-4	T-4	274.176	4032

The T-1 line is used to implement DS-1; T-2 is used to implement DS-2 and so on.

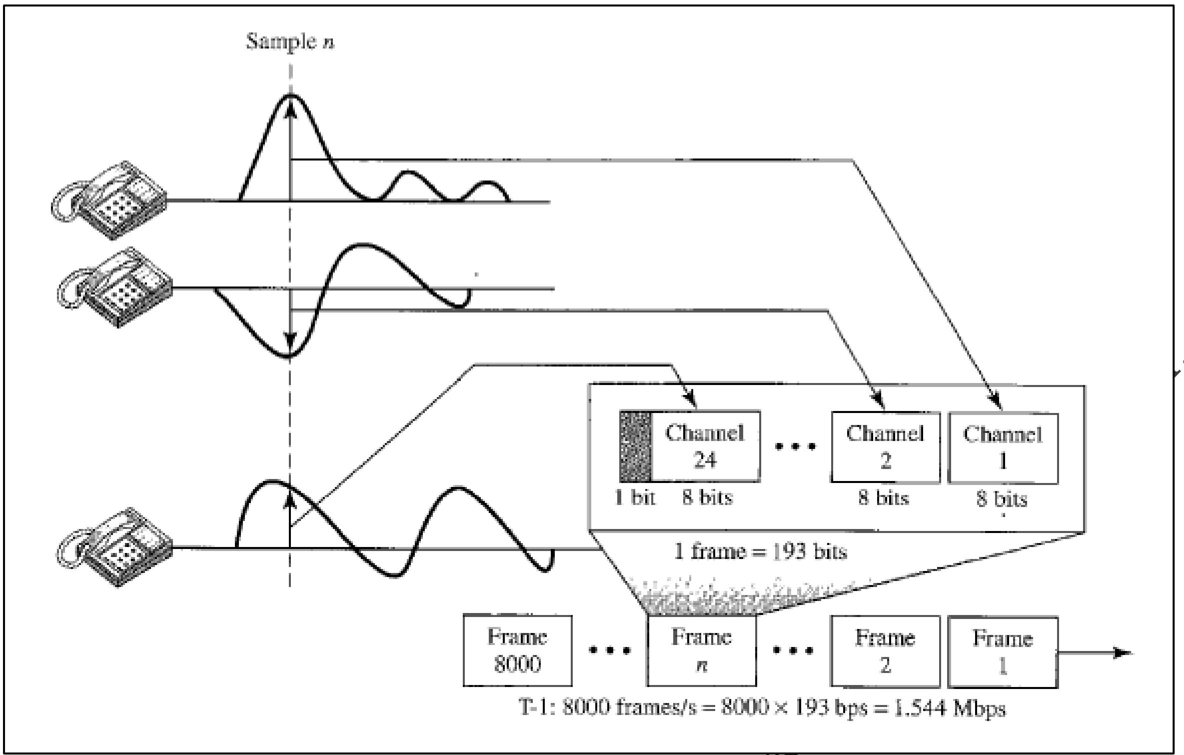
T lines for analog transmission

T lines are designed for the transmission of digital data, audio or video. They can also be used for analog transmission by sampling analog signals and then time division multiplexed.



T-1 Frame

The frame used on a T-1 line is usually 193 bits divided into 24 slots of 8 bits each plus 1 extra bit for synchronization (24 x8+1 =193). If a T-1 line carries 8000 frames, the data rate is 1.544 Mbps (193 x 8000 = 1.544 Mbps) ie the capacity of the line.



E Lines

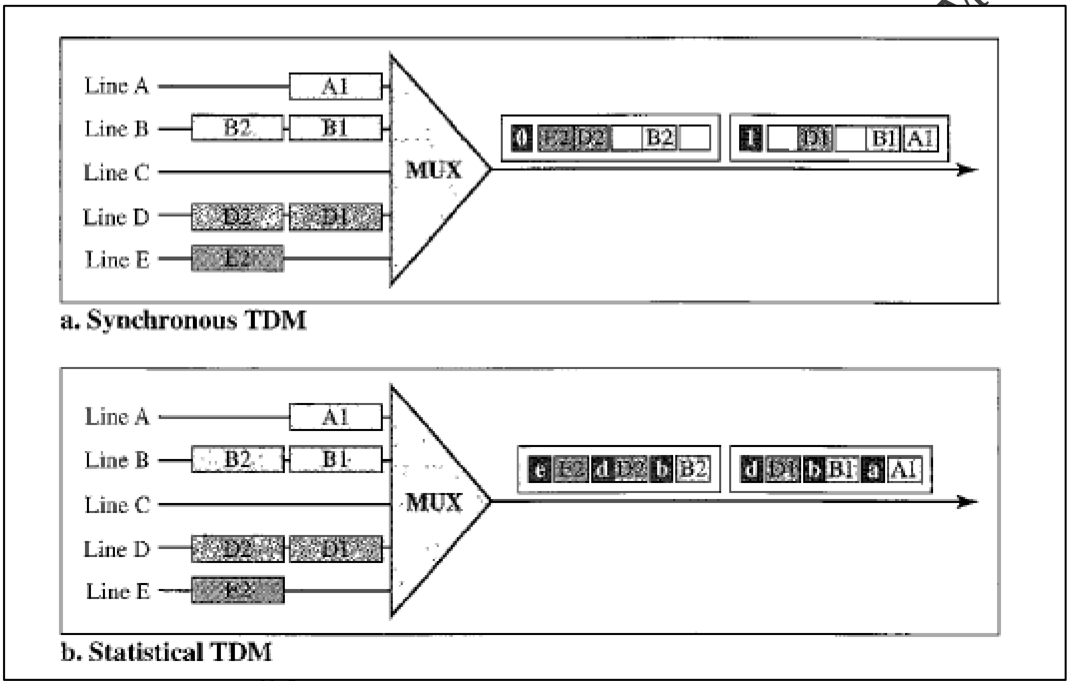
Europeans use a version of T lines called E lines.

Table 6.2 *E line rates*

Line	*Rate (Mbps)*	*Voice Channels*
E-1	2.048	30
E-2	8.448	120
E-3	34.368	480
E-4	139.264	1920

Statistical Time-Division Multiplexing

- In statistical time-division multiplexing, slots are dynamically allocated to improve bandwidth efficiency.
- The number of slots in each frame is less than the number of input lines.
- The multiplexer checks each input in round robin fashion.
- It allocates a slot for an input and if the line has data to send otherwise it skips the line and checks the next line.



Addressing

- In synchronous TDM there is no need for addressing because synchronization and preassigned relationships between the inputs and outputs serve as an address.
- In statistical TDM there is no fixed relationship between inputs and outputs.
- So we include address of the receiver inside each slot
- Addressing in simplest form is n bits to define N different output lines with $n = \log_2 N$

Slot size

Slot carries both data and address in statistical TDM. A block of data is usually many bytes while the address is just few bytes.

No synchronization bit

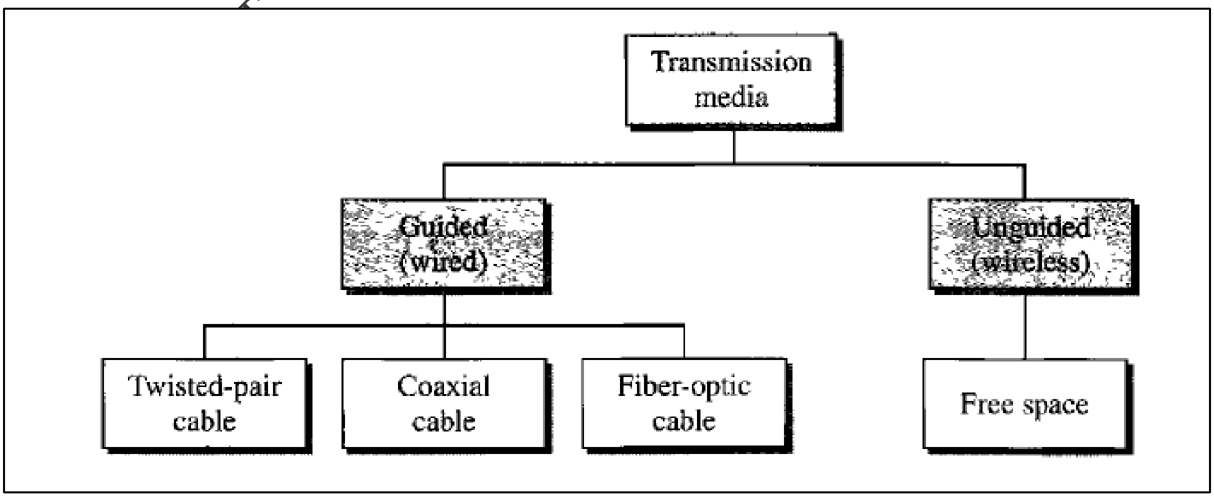
Frames need not be synchronized so no need for synchronization bits.

Bandwidth

The capacity of the link is less than the sum of the capacity of each channel. During peak times, some slots need to wait.

TRANSMISSION MEDIUM

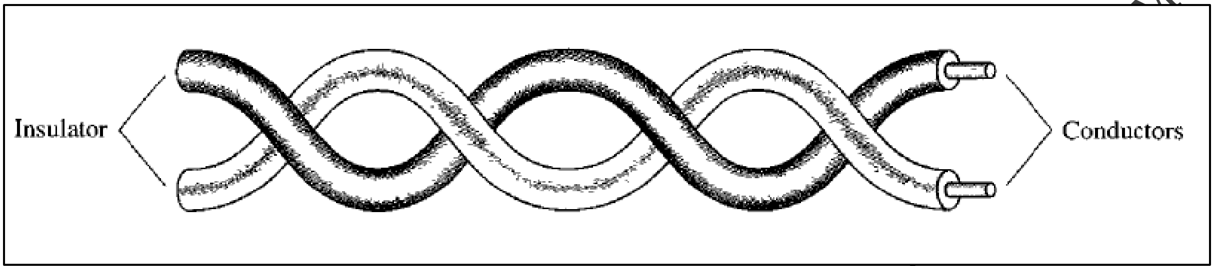
- Carry information from a source to a destination.
- It is usually free space, metallic cable or fiber optic cable.
- The information is usually a signal that is the result of a conversion of data from another form.
- Long distance communication started with the invention of telegraph in the 19^{th} century
- Voice became possible after invention of telephone in 1869.
- Wireless communication started in 1895 when Hertz was able to send high frequency signals.
- Use of optical fibers has increased the data rate incredibly.
- Computers and other telecommunication devices use signals to represent data.
- These signals are transmitted in the form of electromagnetic energy which is a combination of electric and magnetic fields vibrating in relation to each other.
- It includes power, radio waves, infrared light, visible light, ultraviolet light, gamma and cosmic rays.
- Transmission media divided into guided and unguided media



Guided Media

- It provides a channel from one device to another include twisted-pair cable, coaxial cable and fiber-optic cable.
- Twisted-pair and coaxial cable use metallic conductors that accept and transport signals in the form of electric current.
- Optical fiber is a cable accepts and transports signals in the form of light.

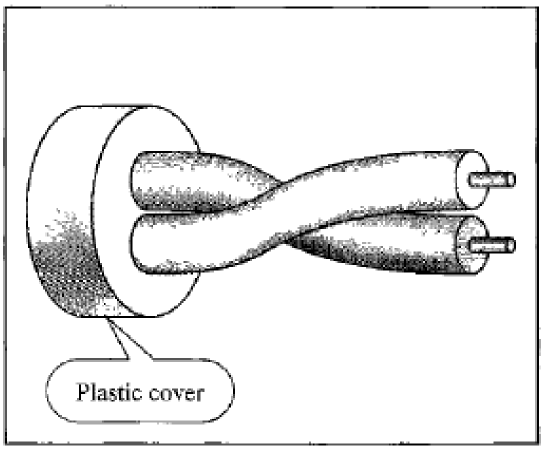
Twisted-Pair Cable



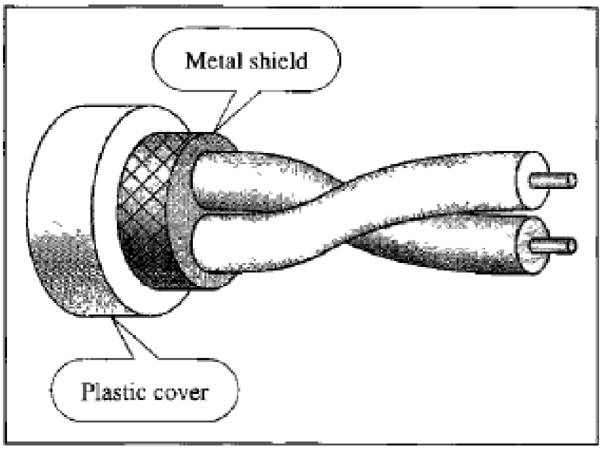
- It consists of two conductors each with its own plastic insulation, twisted together.
- One wire is used to carry signals to the receiver and the other as ground reference.
- Signal sent by the sender on one of the wires, interference and crosstalk may affect both wires and create unwanted signals.
- If two wires are parallel the effect of unwanted signals are not same.
- By twisting the pairs a balance is maintained ie. Both wires are equally affected by external influences.

Unshielded Versus Shielded Twisted-Pair Cable

- The most common twisted-pair cable used in telecommunications is unshielded twisted-pair(UTP)
- Shielded Twisted-pair cable (STP) has a metal foil or braided-mesh covering each pair of insulated conductors.
- Metal casing improves the quality of cable by preventing the penetration of noise or crosstalk.



a. UTP



b. STP

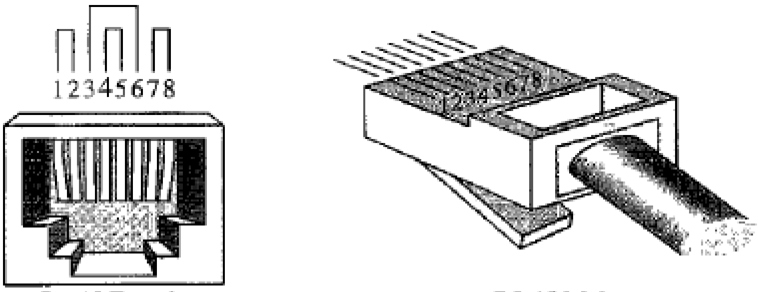
Categories

The Electronic Industries Association (EIA) developed standards to classify unshielded twisted-pair cable into seven categories.

Category	Specification	Data Rate (Mbps)	Use
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

Connectors

The most common UTP connector is RJ45 (RJ stands for registered jack). It is a keypad connector which means that it can be inserted in only one way.



RJ-45 Female RJ-45 Male

Performance

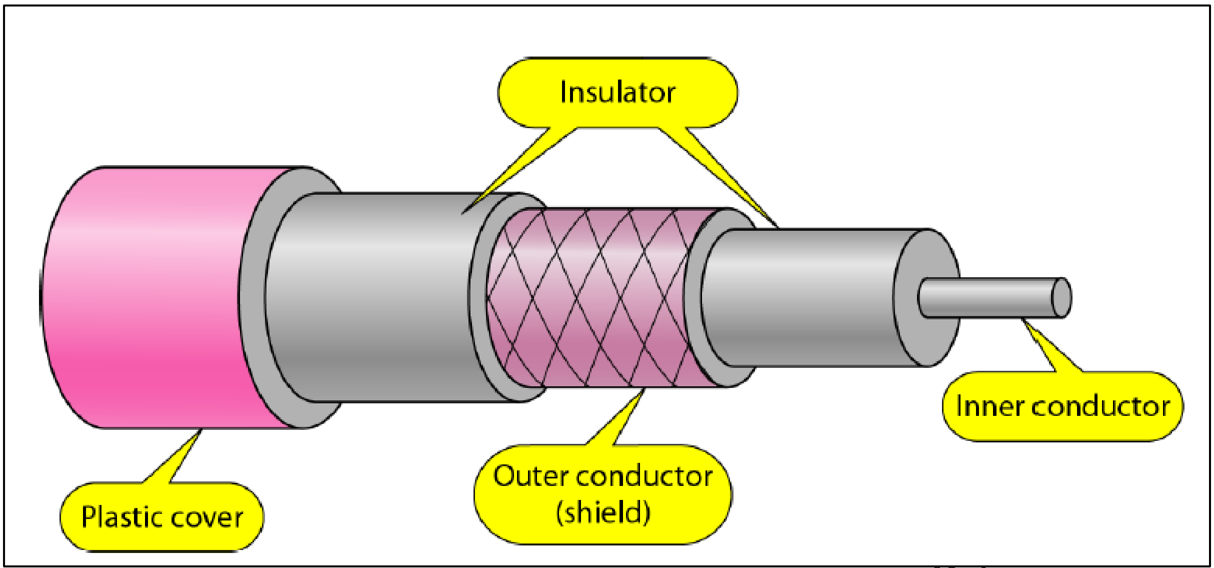
- Its performance is measured by comparing attenuation versus frequency and distance.
- With increasing frequency, the attenuation measured in decibels per kilometer (db/km).

Applications

- Twisted-pair cables are used in telephone lines to provide voice and data channels.
- The line that connects subscribers to the central telephone use unshielded twisted-pair cables.
- Local-area networks, such as 10Base-T and 100Base-T use twisted-pair cables.

Coaxial cable

- It carries signals of higher frequency ranges.
- It has a central core conductor of solid or stranded wire enclosed in an insulating sheath, which in turn encased in an outer conductor of metal foil, braid or combination of two.
- The outer metallic wrapping serves as a shield against noise and completes the circuit.
- The outer conductor is enclosed in an insulating sheath and whole cable is protected by a plastic cover.



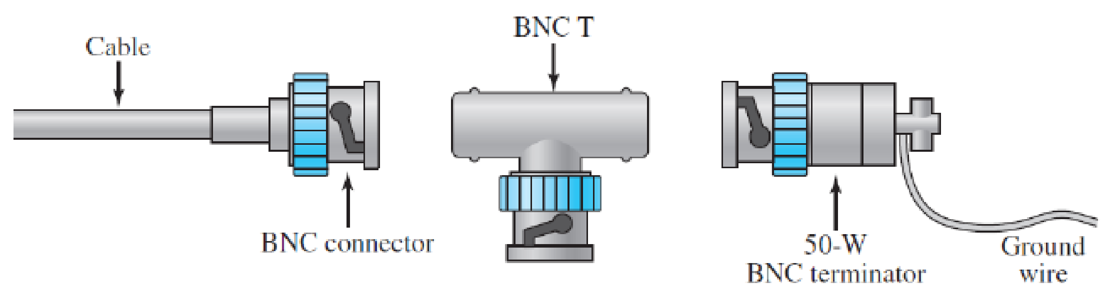
Coaxial cable standards

The cables are categorized by radio government(RG) ratings. Each RG denotes a unique set of specifications which include wire gauge of the inner conductor, the thickness and type of inner insulator, the construction of shield and the size and type of outer casing.

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

Coaxial Cable Connectors

- The most common type of connector is the Bayone-Neill-Concelman(BNC) connector.
- There are three types of connector.
- It has BNC connector used to connect the end of a cable to a TV set.
- BNC T connector is used in Ethernet to branch out a connection to a computer or other device.
- BNC terminator used at the end of the cable to prevent the reflection of the signal.



Performance

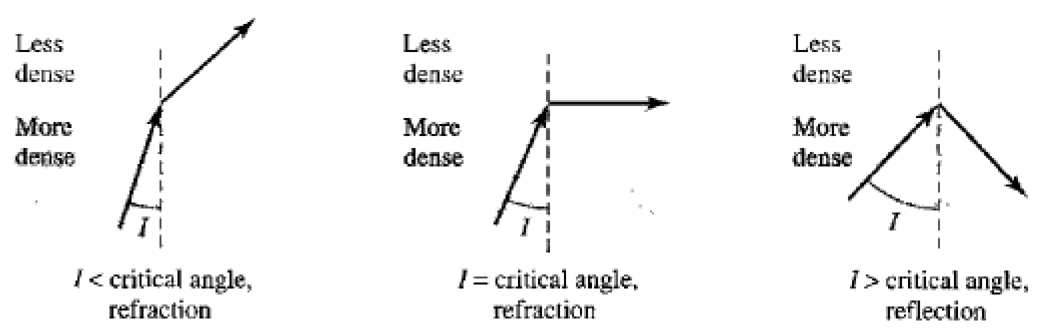
- Attenuation is much higher in coaxial cables.
- Though it has higher bandwidth the signal weakens rapidly and requires repeaters.

Applications

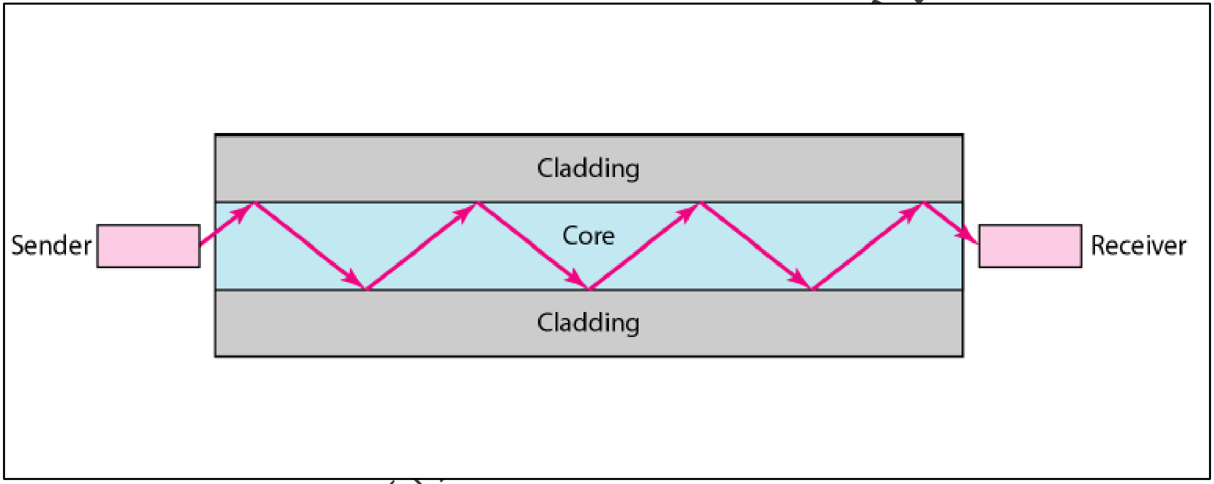
- Widely used in analog telephone networks where a single coaxial cable can carry 10,000 voice signals.
- Used in digital telephone networks where a single cable can carry data upto 600 Mbps.
- Cable TV networks also coaxial cable.
- It is also used in traditional Ethernet LANs.

Fiber-Optic Cable

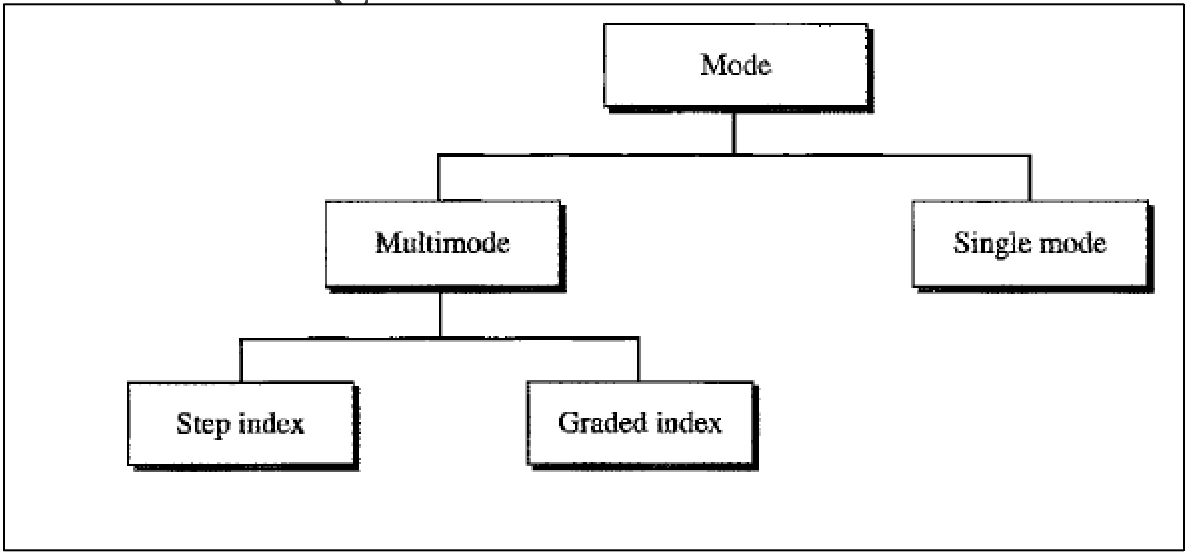
- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- Light travels in a straight line through a single substance.
- If a ray travelling through one substance suddenly enters another substance the ray changes direction.



- If the angle of incidence I is less than the critical angle, the ray refracts and moves closer to the surface.
- If the angle of incidence I is equal to the critical angle, the light bends along the interface.
- If the angle of incidence I is greater than the critical angle, the ray reflects and travels again in the denser substance.
- Optical fibers use reflection to guide light through a channel.
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.
- The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding.



Propagation modes

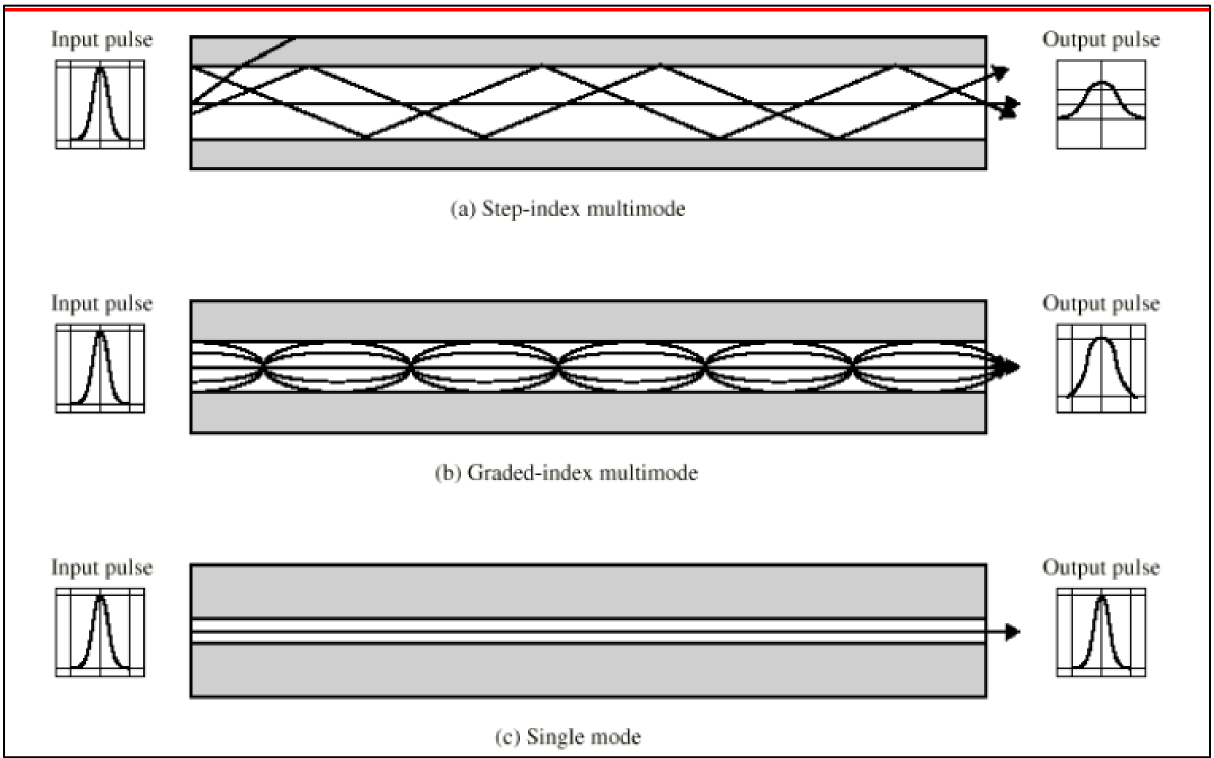


Single mode:

- It uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal.
- Propagation of different beams is almost identical and delays are negligible.
- All the beams arrive at the destination together and can be recombined with little distortion to the signal.

Multimode:

- It is named so because multiple beams from a light source move through the core in different paths.
- It is implemented in two forms: step-index and graded-index.
- **Multimode step-index fiber**
  - The density of core remains constant from the center to the edges.
  - A beam of light moves through this constant density in a straight line until it reaches the surface of the core and cladding.
  - The term step-index refers to sudden change which contributes to the distortion of the signal as it passes through the fiber.
- **Multimode graded-index fiber**
  - It decreases the distortion of the signal through the cable.
  - Index refers to index of refraction.
  - It is a fiber with varying densities.
  - Density is highest at the center of the core and decreases gradually to its lowest edge.

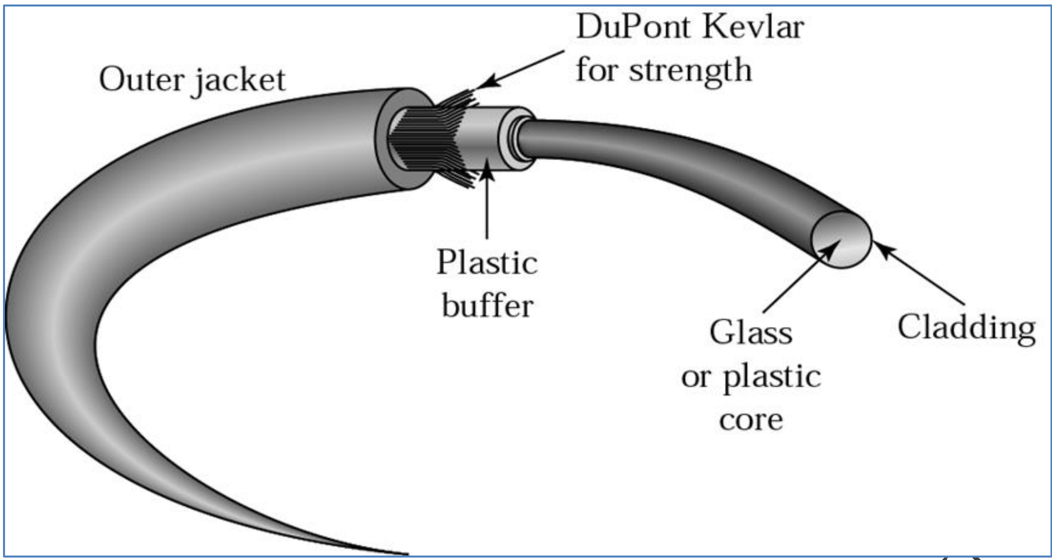


Fiber sizes

It is defined by the ration of the diameter of their core to the diameter of their cladding expressed in micrometers.

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

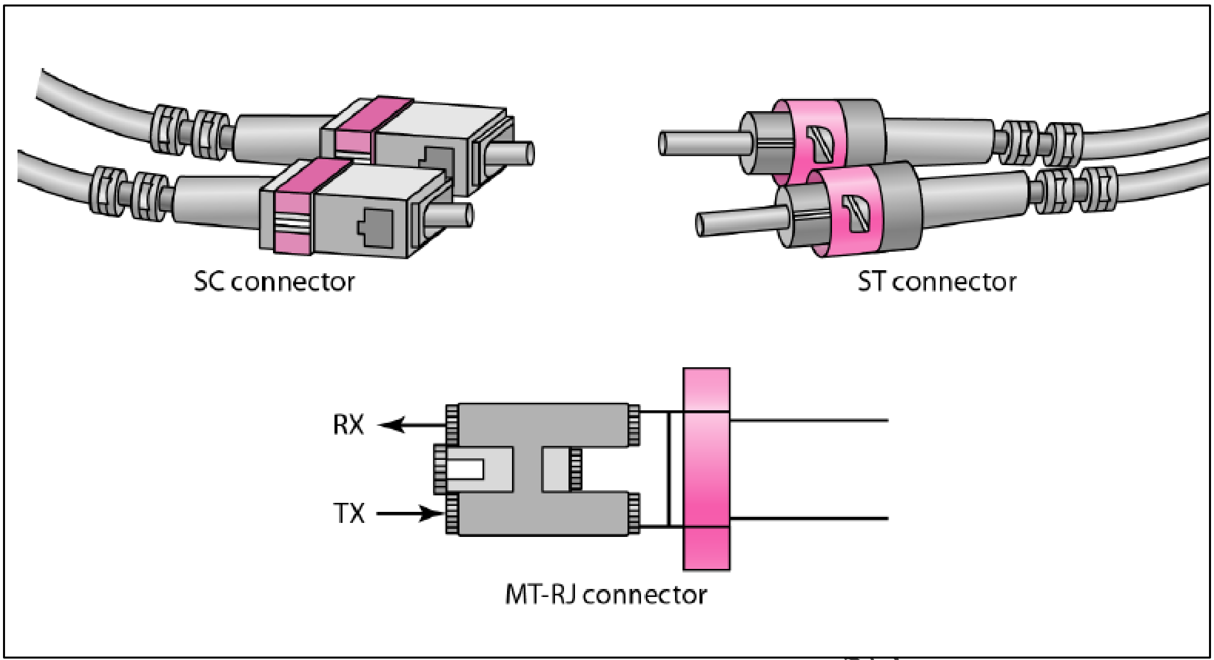
Cable Composition



- The outer jacket is made of either PVC or Teflon
- Inside jacket is made of Kevlar strands to strengthen the cable.
- Kevlar is a strong material used in bulletproof vests.
- Below Kevlar is another plastic coating.
- The fiber at the center of the cable consists of cladding and core.
-

Fiber-Optic Cable Connectors

- There are three types of fiber-optic cables.
- The Subscriber Channel (SC) connector is used for cable TV. It uses push/pull locking system.
- The Straight-tip (ST) connector is used for connecting cable to networking devices. It uses bayonet locking system.
- MT-RJ is the same size as RJ45



Performance

- Attenuation is flatter than twisted-pair cable and coaxial cable.
- We need fewer repeaters.

Applications

- It is often found in backbone networks because its bandwidth is cost-effective.
- Some cable TV companies use a combination of optical fiber and coaxial cable.
- Local-area networks such as 100Base-FX network and 1000Base-X also use fiber-optic cable.

Advantages of optical fiber

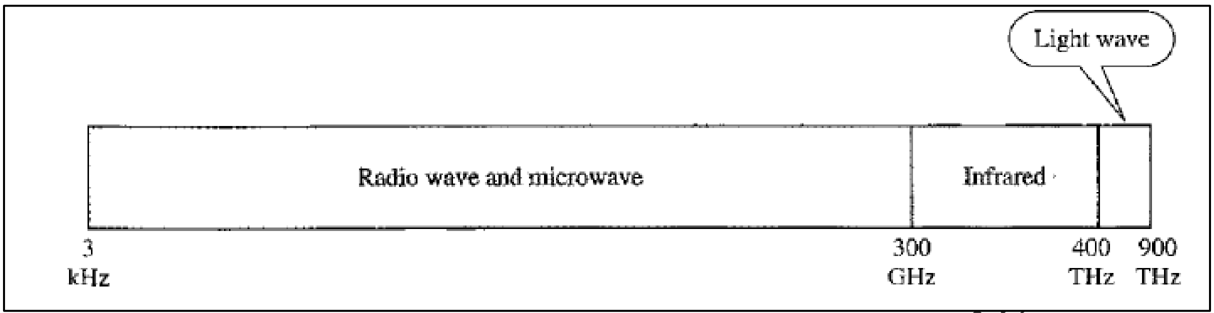
- Higher bandwidth
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials
- Light weight
- Greater immunity to tapping

Disadvantages of optical fiber

- Installation and maintenance – requires expertise
- Unidirectional light propagation – two fibers needed for bidirectional communication
- Cost – more expensive

UNGUIDED MEDIA

- Transports electromagnetic waves with physical conductor.
- It is referred to as wireless communication.
- Signals are broadcast through free space.

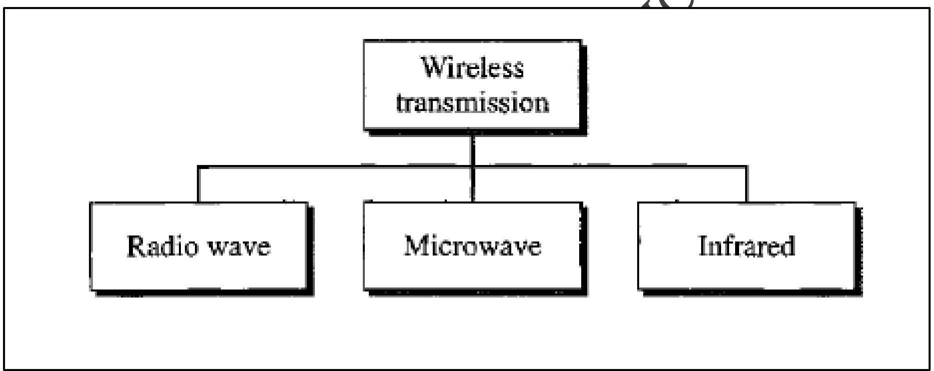


- It can travel from source to destination in several ways: ground propagation,
- sky propagation and line-of-sight propagation.
- Ground propagation:
    - Radio waves travel through lowest portion of the atmosphere.
    - Low-frequency signals emerge in all directions.
    - Distance depends on the amount of power in the signal: greater the power, greater the distance
- Sky propagation:
    - Higher-frequency radiate upward into ionosphere where they reflect back to earth.
    - Allows greater distances with lower output power.
- Line-of-sight propagation:
    - Very high-frequency signals transmitted directly from antenna to antenna.
    - Antennas must be directional, facing each other and either tall enough or close enough together.

Bands

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

Wireless transmission waves



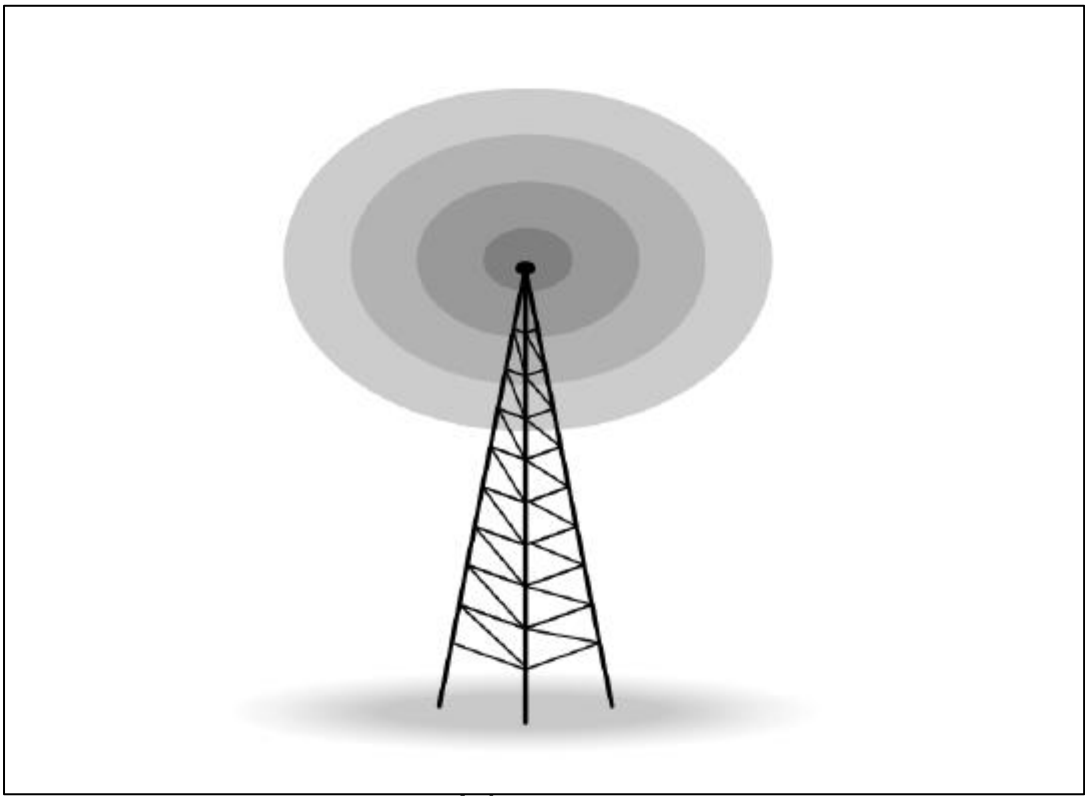
Radio Waves

- Electromagnetic waves ranging in frequencies between 3kHz and 1 GHz are called radio waves.
- They are omnidirectional. When an antenna transmits radio waves they are propagated in all directions.
- Radio waves transmitted by one antenna are capable to interference by another antenna using the same frequency or band.
- They propagate in the sky mode and travel long distances.
- They can penetrate walls but we cannot isolate a communication inside or outside a building.

- Radio wave band is relatively narrow, leading to a low data rate for digital communication.

Omnidirectional Antenna

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



Applications

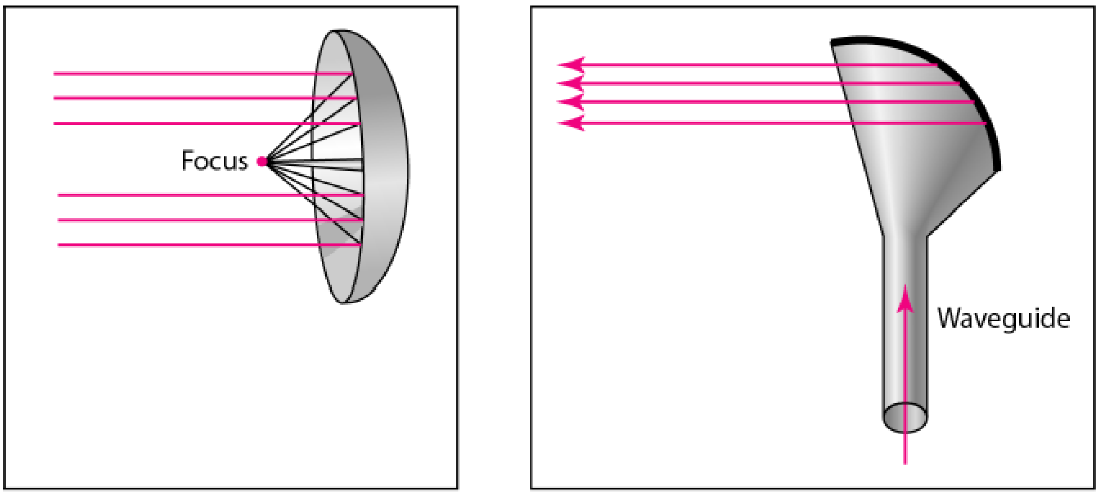
- Useful for multicasting, in which there is one sender but many receivers.
- AM and FM radio, television, cordless phones and paging are examples of multicasting.

Microwaves

- Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.
- They are unidirectional.
- Sending and receiving antennas need to be aligned.
- Microwave propagation is line-of-sight. Repeaters are often needed for long distance communication.
- Very high-frequency microwaves cannot penetrate walls.
- Band is relatively wide therefore wider subbands can be assigned at high data rate

Unidirectional Antenna

- Microwaves need unidirectional antennas that send out signals in one direction. Two antennas are used: parabolic dish and horn.
- Parabolic dish antenna:
    - Every line parallel to the line of symmetry reflects off the curve at angles such that all lines intersect in a common point called focus.
    - Parabolic dish works as a funnel, catching wide range of waves and directing them to a common point.
    - Outgoing transmissions are broadcast through a horn at the dish.
    - The microwaves hit the dish and are deflected outward in a reversal of the path.
- Horn antenna:
    - Looks like a gigantic scoop.
    - Outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by curved head.
    - Received transmissions are collected by the scooped shape and are deflected down into the stem.



a. Dish antenna b. Horn antenna

Applications

- Used in cellular phones, satellite networks and wireless LANs

Infrared

- Infrared waves with frequencies from 300 GHz to 400Thz used for short-range communication.
- It cannot penetrate walls.

- We cannot use infrared waves outside building because the sun's rays contain infrared waves that can interfere communication.

Applications

- Used to transmit digital data with very high data rate.
- Infrared Data Association (IrDA) established standards for using these signals for communication between keyboards, mice PCs and printers.
- Infrared signals transmit through line of sight.