Chapter 6

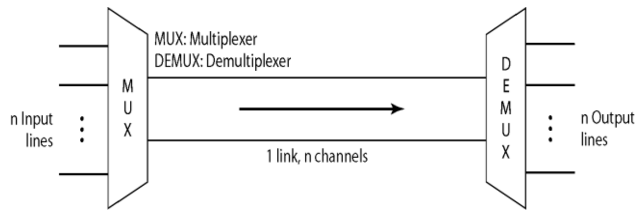
Bandwidth Utilization:
Multiplexing and Spreading

MULTIPLEXING

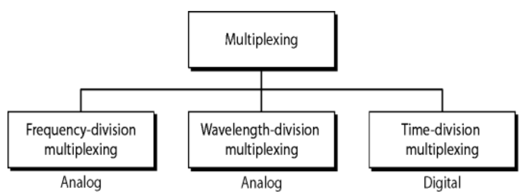
Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. Multiplexing is the simultaneous transmission of multiple signals across a single data link.

In a multiplexed system, *n* lines share the bandwidth of one link.
- *Multiplexer* combines transmission from different lines into a single stream (many-to-one)
- *Demultiplexer* separates the stream back into its component transmissions (one-to-many)
- Link is the physical path, channel refers to portion of a link, a link can have *n* channels

There are 3 basic multiplexing techniques:
- Frequency-division multiplexing (FDM) and wave-division multiplexing (WDM) are techniques for analog signals, while time-division multiplexing (TDM) is for digital signals.



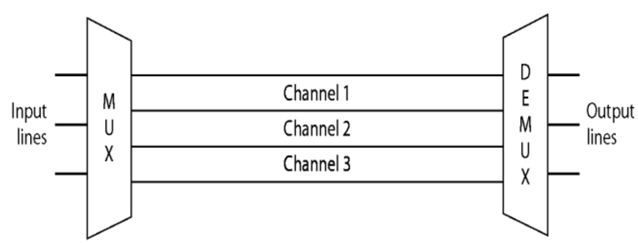
Dividing a link into channels



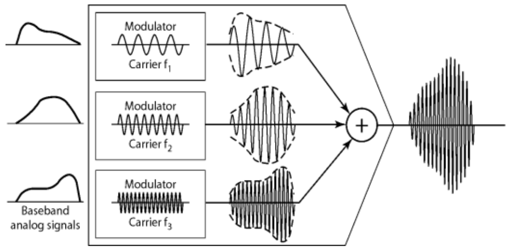
Categories of multiplexing

Frequency Division Multiplexing

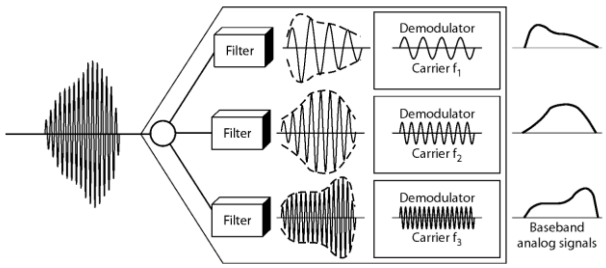
It is an analog Multiplexing technique that combines analog signals.
In FDM, each signal modulates a different carrier frequency. The modulated carriers are combined to form a new signal that is then sent across the link.
The demultiplexer uses a series of filters to decompose the multiplexed signals which are then demodulated and passed to output lines.
In FDM, **guard bands** (strips of unused bandwidth) keep the modulated signals from overlapping and interfering with one another.



Frequency-division multiplexing



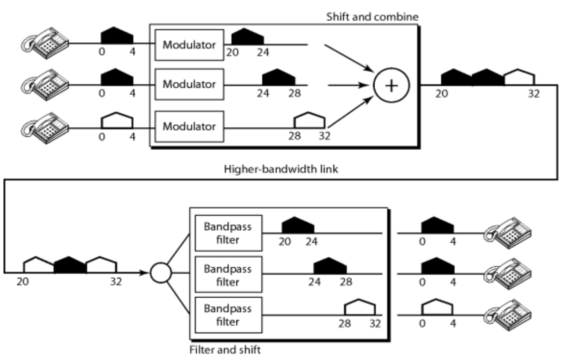
FDM process



FDM demultiplexing example

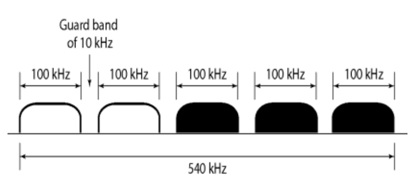
Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

We shift (modulate) each of the three voice channels to a different bandwidth, as shown in Figure 6.6. We use the 20- to 24-kHz bandwidth for the first channel, the 24- to 28-kHz bandwidth for the second channel, and the 28- to 32-kHz bandwidth for the third one. Then we combine them as shown in the figure below.



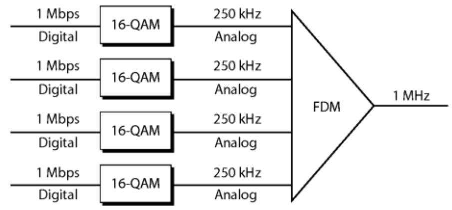
Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

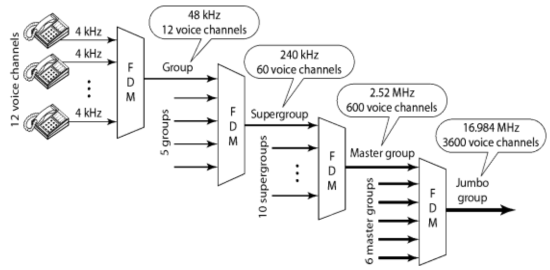
Solution
For five channels, we need at least four guard bands. This means that the required bandwidth is at least
5 × 100 + 4 × 10 = 540 kHz.



Four data channels (digital), each transmitting at 1 Mbps, use a satellite channel of 1 MHz. Design an appropriate configuration, using FDM.

Solution
The satellite channel is analog. We divide it into four channels, each channel having a 250-kHz bandwidth. Each digital channel of 1 Mbps is modulated such that each 4 bits is modulated to 1 Hz. One solution is 16-QAM modulation. Figure 6.8 shows one possible configuration





Analog hierarchy

Applications of FDM

Used In AM and FM radio broadcasting where air is the transmission medium.
Used in Television broadcasting
Used by Cellular Telephone companies to combine voice channels into successively larger groups for efficient transmission.

Implementation

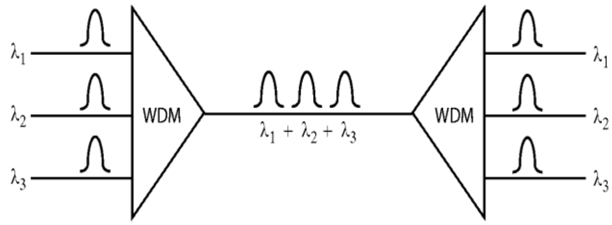
In case of radio and television broadcasting, there is no need for a physical multiplexer or demultiplexer as long as stations agree to send their broadcasts using different carrier frequencies.
In case of cellular telephone system, a base station needs to assign a carrier frequency to the telephone user as there is not enough bandwidth in a cell to permanently assign a range.

The Advanced Mobile Phone System (AMPS) uses two bands. The first band of 824 to 849 MHz is used for sending, and 869 to 894 MHz is used for receiving. Each user has a bandwidth of 30 kHz in each direction. How many people can use their cellular phones simultaneously?

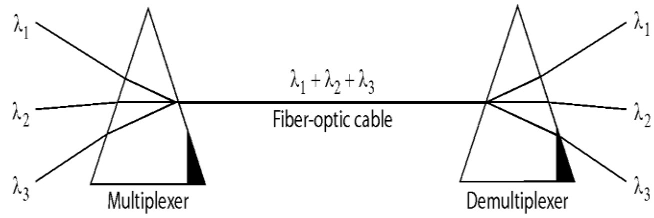
Solution
Each band is 25 MHz. If we divide 25 MHz by 30 kHz, we get 833.33. In reality, the band is divided into 832 channels. Of these, 42 channels are used for control, which means only 790 channels are available for cellular phone users.

Wavelength-Division Multiplexing

WDM is an analog multiplexing technique to combine optical signals.
WDM is similar in concept to FDM (combining different signals of different frequencies) except that the signals being multiplexed, however, are light waves.
WDM uses a fiber-optic cable, which has higher data rate than metallic transmission cable.
In WDM multiplexing and Demultiplexing are easily handled by a prism, which bends a beam of light based on the angle of incidence and the frequency.
WDM is used in SONET network.
A new method, called dense WDM multiplexes large number of channels by spacing them very close.



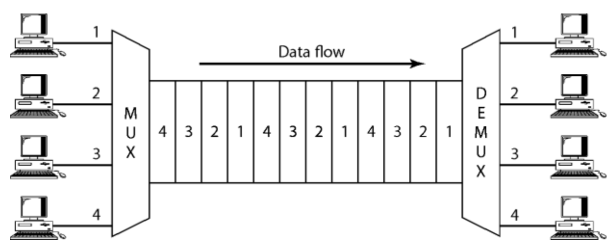
Wavelength-division multiplexing



Prisms in wavelength-division multiplexing and demultiplexing

<u>Time-Division Multiplexing</u>

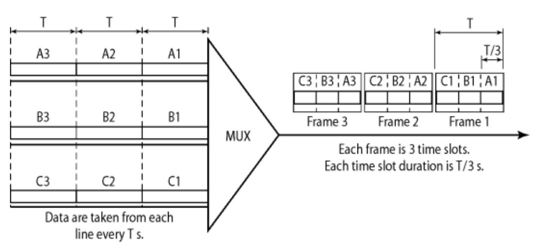
TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.
Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link.
In TDM the delivery is fixed and unvarying i.e all the data in a message from source 1 always go to one specific destination.
TDM can be divided into two different schemes: synchronous and statistical.



TDM

<u>Synchronous Time-Division Multiplexing</u>

In STDM the data flow of each input connection is divided into units, each unit occupies one input time slot.
A unit can be one bit, one character or one block of data.
In STDM, time slots are grouped into frames, a frame consists of one complete cycle of time slots.
The duration of an output time slot is n times shorter than the duration of an input time slot. If input time slot is T s, output time slot is T/n s, where n is the number of connections.
The data rate of output link must be n times the data rate of a connection.
In synchronous TDM, each input connection has an allotment in the output even if it is not sending data. **[Refer empty slots]**



NOTE: In synchronous TDM, the data rate of the link is n times faster, and the unit duration is n times shorter.

In Figure 6.13, the data rate for each input connection is 1 kbps. If 1 bit at a time is multiplexed (a unit is 1 bit), what is the duration of (a) each input slot, (b) each output slot, and (c) each frame?

Solution
We can answer the questions as follows:
a. The data rate of each input connection is 1 kbps. This means that the bit duration is 1/1000 s or 1 ms. The duration of the input time slot is 1 ms (same as bit duration).
b. The duration of each output time slot is one-third of the input time slot. This means that the duration of the output time slot is 1/3 ms.
c. Each frame carries three output time slots. So the duration of a frame is 3 × 1/3 ms, or 1 ms. The duration of a frame is the same as the duration of an input unit.

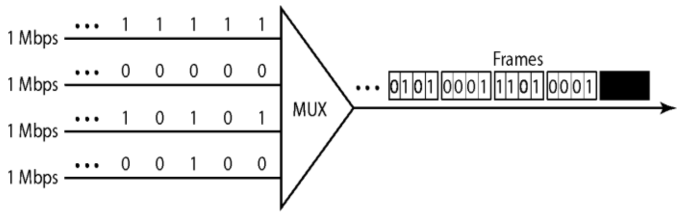


Figure 6.14 shows synchronous TDM with a data stream for each input and one data stream for the output. The unit of data is 1 bit. Find (a) the input bit duration, (b) the output bit duration, (c) the output bit rate, and (d) the output frame rate.

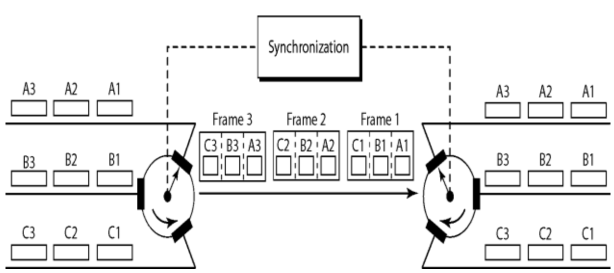
Solution
We can answer the questions as follows:
a. The input bit duration is the inverse of the bit rate:
1/1 Mbps = 1 μs.
b. The output bit duration is one-fourth of the input bit duration, or ¼ μs.
c. The output bit rate is the inverse of the output bit duration or 1/(4μs) or 4 Mbps. This can also be deduced from the fact that the output rate is 4 times as fast as any input rate; so the output rate = 4 × 1 Mbps = 4 Mbps.
d. The frame rate is always the same as any input rate. So the frame rate is 1,000,000 frames per second. Because we are sending 4 bits in each frame, we can verify the result of the previous question by multiplying the frame rate by the number of bits per frame.

Four 1-kbps connections are multiplexed together. A unit is 1 bit. Find (a) the duration of 1 bit before multiplexing, (b) the transmission rate of the link, (c) the duration of a time slot, and (d) the duration of a frame.

Solution
We can answer the questions as follows:
a. The duration of 1 bit before multiplexing is 1 / 1 kbps, or 0.001 s (1 ms).
b. The rate of the link is 4 times the rate of a connection, or 4 kbps.
c. The duration of each time slot is one-fourth of the duration of each bit before multiplexing, or 1/4 ms or 250 μs. Note that we can also calculate this from the data rate of the link, 4 kbps. The bit duration is the inverse of the data rate, or 1/4 kbps or 250 μs.
d. The duration of a frame is always the same as the duration of a unit before multiplexing, or 1 ms. We can also calculate this in another way. Each frame in this case has four time slots. So the duration of a frame is 4 times 250 μs, or 1 ms.

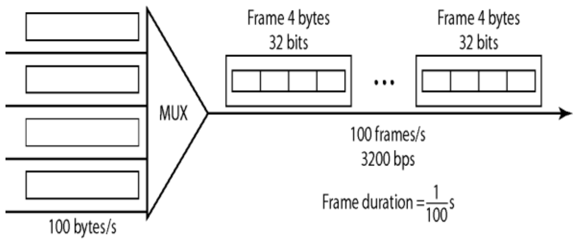
Interleaving: TDM can be visualized as two fast rotating switches, one on multiplexing side and the other on demultiplexing side.

Switches rotate at same speed, but in opposite directions.
On the multiplexing side, As the switch opens in front of a connection, that connection has the opportunity to send a unit onto the path. This process is called **interleaving**.
On the demultiplexing side, As the switch opens in front of a connection, that connection has the opportunity to receive a unit from the path.



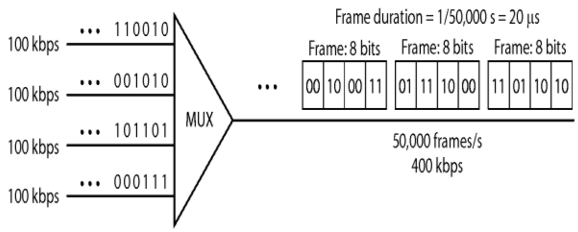
Four channels are multiplexed using TDM. If each channel sends 100 bytes /s and we multiplex 1 byte per channel, show the frame traveling on the link, the size of the frame, the duration of a frame, the frame rate, and the bit rate for the link.

Solution
The multiplexer is shown in Figure 6.16. Each frame carries 1 byte from each channel; the size of each frame, therefore, is 4 bytes, or 32 bits. Because each channel is sending 100 bytes/s and a frame carries 1 byte from each channel, the frame rate must be 100 frames per second. The bit rate is 100 × 32, or 3200 bps.

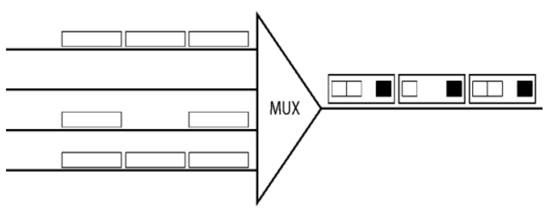


A multiplexer combines four 100-kbps channels using a time slot of 2 bits. Show the output with four arbitrary inputs. What is the frame rate? What is the frame duration? What is the bit rate? What is the bit duration?

Solution
Figure 6.17 shows the output for four arbitrary inputs. The link carries 50,000 frames per second. The frame duration is therefore 1/50,000 s or 20 μs. The frame rate is 50,000 frames per second, and each frame carries 8 bits; the bit rate is 50,000 × 8 = 400,000 bits or 400 kbps. The bit duration is 1/400,000 s, or 2.5 μs.



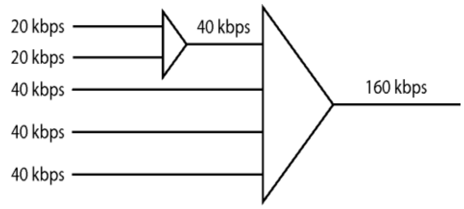
Empty Slots: if a source does not have data to send, the corresponding slot in the output frame is empty
Statistical TDM improves the efficiency by removing the empty slots from the frame.
Data Rate Management: if the data rates of the input lines are not the same, three strategies can be used. Namely: **multilevel multiplexing, multiple-slot allocation** and **pulse stuffing**.



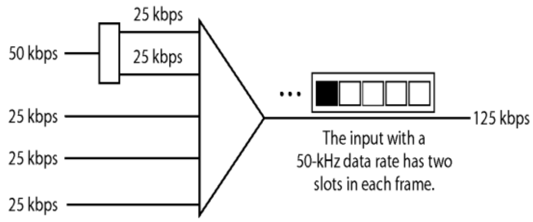
Empty slots

Strategies of Synchronous TDM

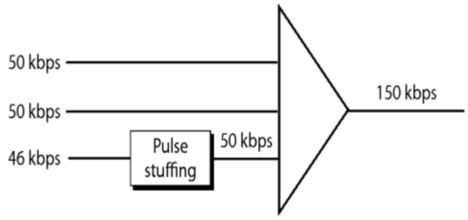
Multilevel Multiplexing: Is a technique used when the data rate of an input line is a multiple of others. See fig 6.19
Multiple-Slot Allocation: Allocate more than one slot in a frame to a single input line. See fig 6.20.
A serial-to-parallel converter is inserted in the input line to make two inputs out of one.
Pulse Stuffing or Bit stuffing or Bit padding: If the bit rates of sources are not multiple integers of each other, the above two techniques cannot be applied.
Solution is, to make the highest input data rate the dominant data rate and then add dummy bits to the input lines with lower rates.



Multilevel multiplexing



Multiple-slot multiplexing



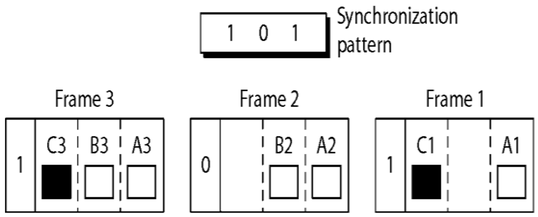
Pulse stuffing

<u>Syn.TDM – Frame Synchronizing</u>

If the multiplexer and demultiplexer are not synchronized, a bit belonging to one channel may be received by other channel.

To achieve this, one or more synchronization bits are added to the beginning of each frame.

These bits are called framing bits, and they follow a pattern (alternating between 0 and 1)



Framing bits

We have four sources, each creating 250 characters per second. If the interleaved unit is a character and 1 synchronizing bit is added to each frame, find (a) the data rate of each source, (b) the duration of each character in each source, (c) the frame rate, (d) the duration of each frame, (e) the number of bits in each frame, and (f) the data rate of the link.

Solution

We can answer the questions as follows:

a. The data rate of each source is 250 × 8 = 2000 bps = 2 kbps.

b. Each source sends 250 characters per second; therefore, the duration of a character is 1/250 s, or 4 ms

c. Each frame has one character from each source, which means the link needs to send 250 frames per second to keep the transmission rate of each source.
d. The duration of each frame is 1/250 s, or 4 ms. Note that the duration of each frame is the same as the duration of each character coming from each source.
e. Each frame carries 4 characters and 1 extra synchronizing bit. This means that each frame is
4 × 8 + 1 = 33 bits.

Two channels, one with a bit rate of 100 kbps and another with a bit rate of 200 kbps, are to be multiplexed. How this can be achieved? What is the frame rate? What is the frame duration? What is the bit rate of the link?

Solution
We can allocate one slot to the first channel and two slots to the second channel. Each frame carries 3 bits. The frame rate is 100,000 frames per second because it carries 1 bit from the first channel. The bit rate is 100,000 frames/s × 3 bits per frame, or 300 kbps.

Syn.TDM – Digital Signal Service

Telephone companies implement TDM through a hierarchy of digital signals, called **digital signal service** or **digital hierarchy**.

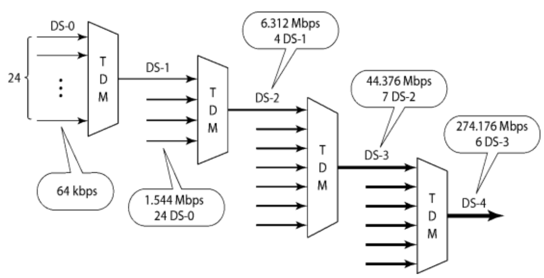
A **DS-0** service is a single digital channel of 64 kbps.

DS-1 is a 1.544 Mbps service; it can be used as a single service or it can be used to multiplex 24 DS-0 channels or any desired combination. Require 8 kbps of overhead.

DS-2 is a 6.312 Mbps service; it can be used as a single service or it can be used to multiplex 4 DS-1 channels, or 96 DS-0 channels or a combination of these types. Require 168 kbps of overhead.

DS-3 is a 44.376 Mbps service; 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 types; 1.368 Mbps of overhead.

DS-4 is a 274.176 Mbps service; it can be used to multiplex 6 DS-3 channels, 44 DS-2 channels, 168 DS-1 channels, 4032 DS-0 channels or a combination of these types.



Digital hierarchy

Syn.TDM – T Lines

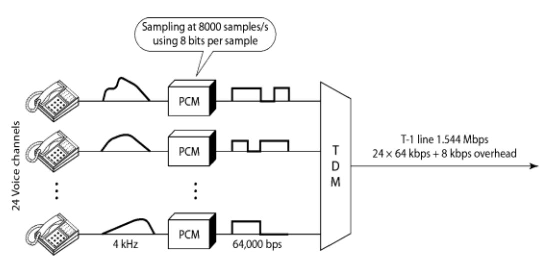
DS-0, DS-1 are names of services. To implement these services telephone companies use **T Lines** (T-1 to T-4).

These lines are with capacities matched to the data rates of DS-1 to DS-4 services.

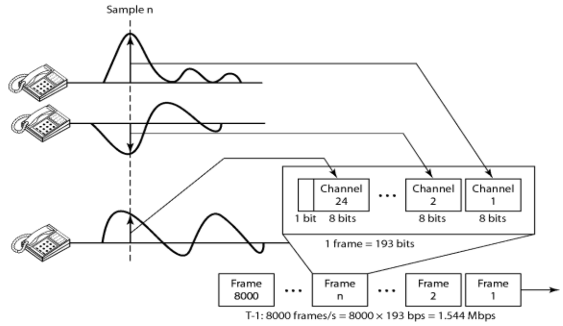
T Lines are designed for digital transmission, however they can also be used for analog transmission, provided the analog signals are first sampled, then time-division multiplexed.

T-1 Frame Structure: Each slot contains one signal element from each channel, 24 segments are interleaved in one frame. If a t-1 line carries 8000 frames , the data rate is 1.544 Mbps – the capacity of the line.

Europeans use a version of T Lines called **E Lines**. The two systems are identical, but their capacities differ.



T-1 line for multiplexing telephone lines



Statistical Time-Division Multiplexing

In synchronous TDM each input has a reserved slot in the output frame. This can be inefficient if some input lines have no data to send (Empty slots).

In statistical TDM, slots are dynamically allocated to improve bandwidth efficiency.

The multiplexer checks each input line in round robin fashion and allocates a slot for input line if the line has data to send; otherwise it skips the line and checks the next line.

In statistical multiplexing there are no preassigned output slots, therefore each slot need to include the address of the receiver. The addressing can be *n* bits to define *N* output lines with $n = log2N$. Ex: 8 lines need 3-bit address.

The ratio of data size to address size must be reasonable to make transmission efficient. Ex: it is inefficient to send 1 bit per slot as data when the address is 3 bits. In statistical TDM, a block of data is usually many bytes.

The frames in statistical TDM need not be synchronized so no need of synchronization bits.

In statistical TDM the capacity of the link is normally less than the sum of the capacities of each channel.

The designers of statistical TDM define the capacity of the link based on the statistics of the load for each channel.

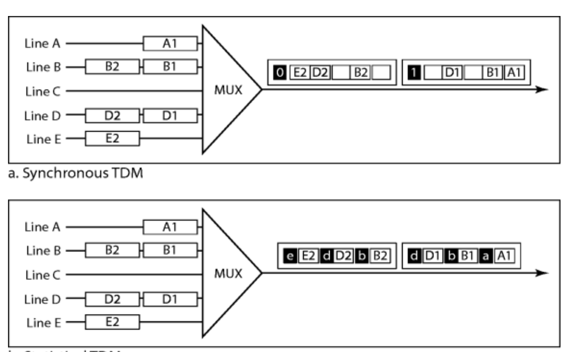
Synchronous TDM versus Statistical TDM

Synchronous:

Each input has a reserved slot in the output frame
No need of addressing
A unit can be 1 bit, 1 character, 1 byte or several bytes.
Need synchronization bits.
The capacity of the link is normally greater than or equal to the sum of the capacities of each channel.
Inefficient use of bandwith at certain times.

Statistical:

There are no preassigned output slots.
Each slot need to be addressed.
A block of data is usually many bytes.
Don’t need synchronization bits.
The capacity of the link is normally less than the sum of the capacities of each channel.
Efficient use of bandwidth at all times



a. Synchronous TDM
b. Statistical TDM

TDM slot comparison

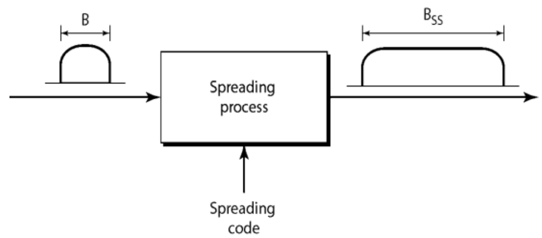
SPREAD SPECTRUM

In spread spectrum (SS), we combine signals from different sources to fit into a larger bandwidth, but our goals are to prevent eavesdropping and jamming. To achieve these goals, spread spectrum techniques add redundancy. Spread spectrum is designed to be used in wireless applications

After the signal is created by the source, the spreading process uses a spreading code and spreads the bandwidth.
- The spreading code is a series of numbers that look random, but are actually a pattern.

Spread spectrum achieves its goals through two principles:
- The bandwidth allocated to each station needs to be larger than what is needed.
- The expanding of original bandwidth must be done by a process that is independent of the original signal means the spreading process occurs after the signal is created by the source

There are two techniques to spread the bandwidth: frequency hopping spread spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS)

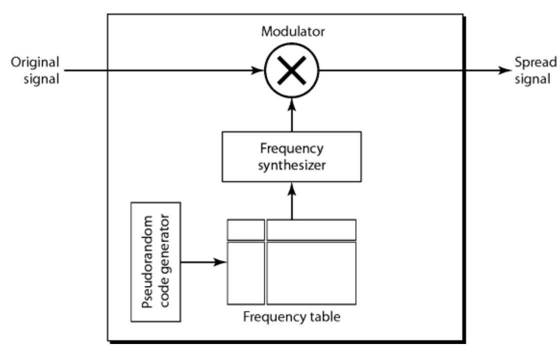


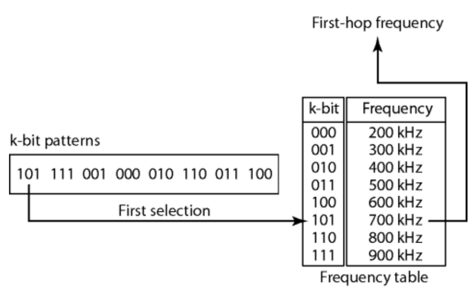
Spread spectrum

Frequency Hopping Spread Spectrum

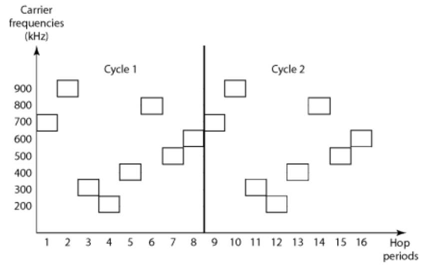
FHSS technique uses M different carrier frequencies that are modulated by the source signal.
- At one moment, signal modulates one carrier frequency, at next moment signal modulates another carrier frequency.

FHSS Layout:
- A **pseudorandom code generator** creates a k-bit pattern for every hopping period Th.
- The frequency table uses the pattern to find the frequency to be used for this hopping period and passes it to the frequency synthesizer.
- The frequency synthesizer creates a carrier signal of that frequency, and the source signal modulates the carrier frequency.
- The k-bit patterns get repeated after 2k hoppings.





Frequency selection in FHSS



FHSS cycles

This scheme accomplishes the goals of spreading.

If intruders try to intercept the transmitted signal, they can access only small piece of data b'coz they does not know the spreading sequence to quickly adapt themselves to the next hop.

The scheme also has antijamming effect. A malicious sender may be able to send noise to jam the signal for one hopping period, but not for the whole period.

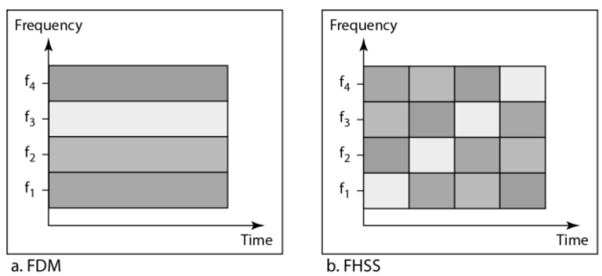
Bandwidth sharing:if the number of hopping frequencies is M, we can multiplex M channels into one by using the same Bss bandwidth.

This is possible b'coz a station uses juz one frequency in each hopping period; M-1 other frequencies can be used by other M-1 stations.

FHSS is similar to FDM

In FDM each station uses 1/M of bandwidth, but allocation is fixed.

In FHSS each station uses 1/M of bandwidth, but allocation changes hop to hop



Direct Sequence Spread Spectrum

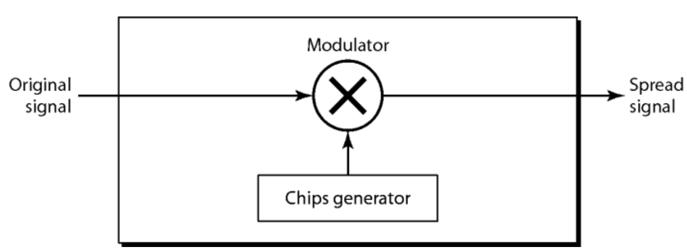
In DSSS, each data bit is replaced with *n* bits called chips or spreading code.

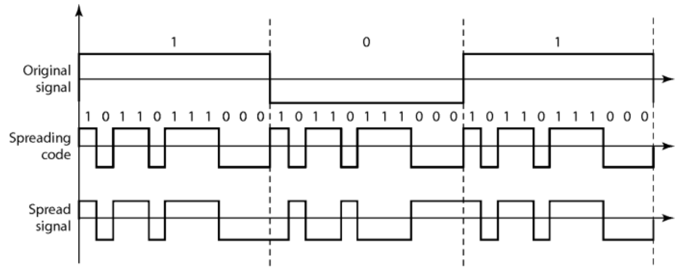
Ex: The famous Bark Sequence where n is 11 having the pattern 10110111000.

Spread signal can provide privacy if the intruder does not know the code.

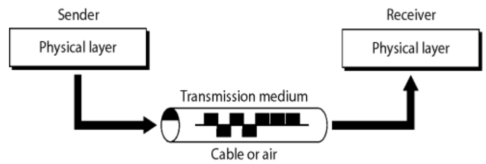
It can also provide immunity against interference if each station uses a different code

Bandwidth sharing in DSSS depends on the spreading code's capability of combining and separating spread signals.





Chapter 7
Transmission Media



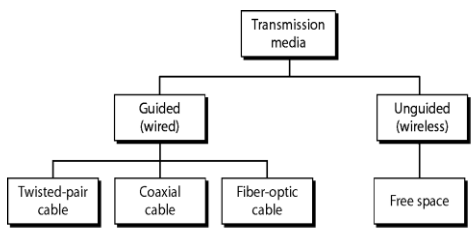
Transmission Media are located below the physical layer and are directly controlled by the physical layer

Transmission media can be defined as anything that can carry information from a source to destination.

Communication is achieved by transmitting signals from one device to another in the form of electromagnetic energy.

Electromagnetic energy , a combination of electric and magnetic fields, includes power, radio waves, infrared light, visible light, ultraviolet light, X, gamma and cosmic rays

Transmission Media can be divided into two broad categories:
Guided and Unguided
Guided include Twisted-pair, coaxial, fiber-optic cables.
Unguided medium is free space (air, vacuum…)



GUIDED MEDIA

Guided media, which are those that provide a conduit(outer surface) 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 that accepts and transports signals in the form of light.

Twisted-Pair Cable

Twisted-pair cable consists of two insulated copper wires twisted together.
One of the wires is used to carry signals to the receiver.
Other wire is used as a ground reference.
The receiver uses the difference between the two.

In addition to the signal sent, interference(noise) and crosstalk may affect both wires and create unwanted signals.

The effect of these unwanted signals is not the same in both wires if they are parallel b'coz relative to noise they are at different locations (one is closer other is farther). This results in a difference at the receiver.

Twisting allows each wire to have approximately the same noise environment.

Means the receiver, which calculates the difference between the two, receives no unwanted signals. The number of twists per unit of length (e.g inch) does affect the quality of the cable.

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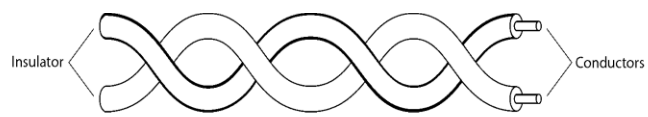


There are two types of twisted pair cables:

Unshielded Twisted-pair (UTP): Most commonly used in communications.

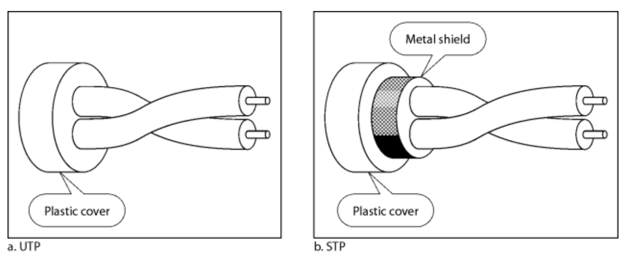
EIA classified UTP into seven categories determined by cable quality, with 1 as the lowest and 7 as the highest.

Shielded Twisted-pair (STP): Introduced by IBM and is seldom(rarely) used outside IBM.

STP has a metal foil or braided mesh covering that encases each pair of insulated copper wires.

Metal casing improves the quality of cable by preventing the penetration of noise or crosstalk.

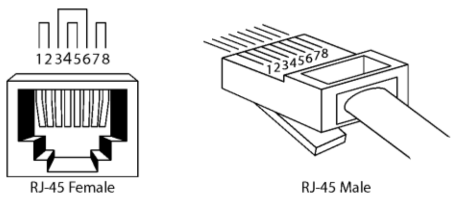
STP is bulkier and more expensive.



Category	Bandwidth	Data Rate	Digital/Analog	Use
1	very low	< 100 kbps	Analog	Telephone
2	< 2 MHz	2 Mbps	Analog/digital	T-1 lines
3	16 MHz	10 Mbps	Digital	LANs

4	**20 MHz**	**20 Mbps**	**Digital**	**LANs**
5	**100 MHz**	**100 Mbps**	**Digital**	**LANs**
6 (draft)	**200 MHz**	**200 Mbps**	**Digital**	**LANs**
7 (draft)	**600 MHz**	**600 Mbps**	**Digital**	**LANs**

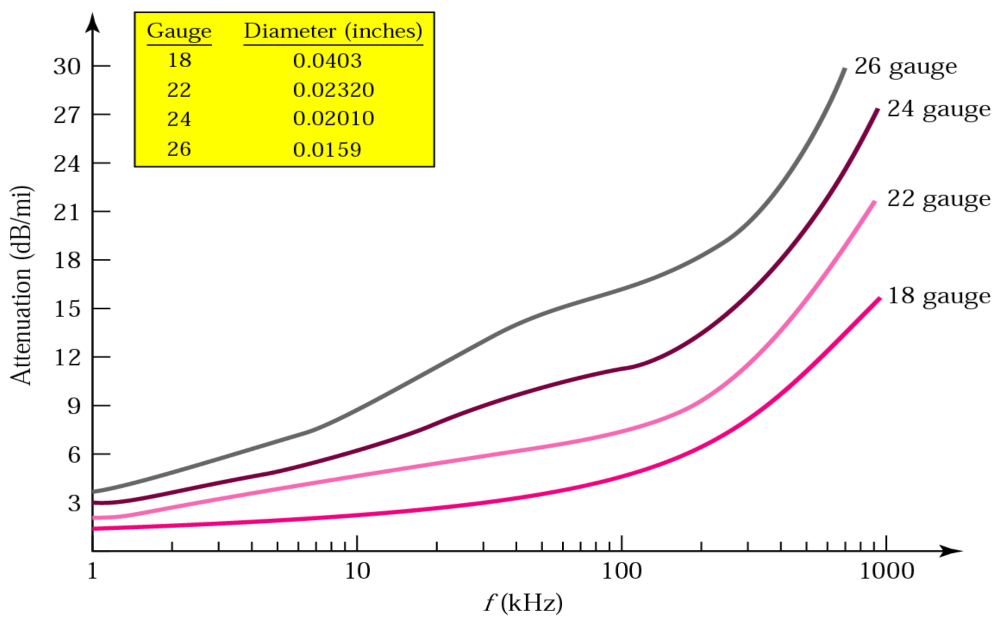
UTP Connector



UTP Performance:

of twisted-pair cable is measured by comparing attenuation Versus frequency and distance.

Twisted-pair cable can pass wide range of frequencies. However with increasing frequency, attenuation also increases



Applications:

Twisted-pair cable is used in telephone lines for voice and data communications.

The local loop that connects subscribers to central telephone office commonly consists of UTP cables.

DSL lines that telephone companies provide also use UTP cables.

LAN's such as 10Base-T and 100Base-T also use Twisted-pair cables.

Coaxial Cable

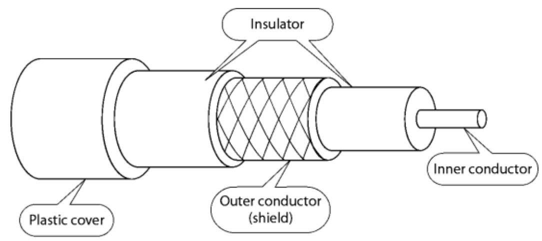
Coaxial cable carries signals of higher frequency ranges than those in twisted-pair cable

It has the following layers (starting from the center):

A metallic rod-shaped inner conductor

An insulator enclosing the core (rod).
A metallic outer conductor(shield or metal foil)
An insulator covering the outer conductor
And a plastic cover protecting the whole cable.

Coaxial cables are categorized by their Radio Government (RG) ratings.

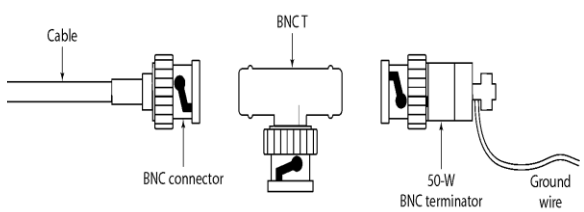


Each RG number denotes a unique set of physical specifications which include
The wire gauge of the inner conductor, the thickness and type of insulator, the construction of shield.

Coaxial cables are connected to devices using coaxial connectors.
BNC Connector : (Bayone-Neill-Concelman) is used to connect the end of the cable to a device such as TV set
BNC T Connector : Used in Ethernet networks to branch out a connection.
BNC Terminator : Used at the end of the cable to prevent the reflection of the signal.

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

Categories of co-axial cables



BNC connectors

Performance of Coaxial cable is measured in the same way as with twisted pair.
The attenuation is much higher in Coaxial-cables than in twisted-pair cable and requires frequent use of repeaters.

<u>Applications</u>

Coaxial cable is used in cable TV networks (RG-59) and traditional Ethernet LANs (RG-58), Thick Ethernet uses RG-11.
Coaxial cable in telephone networks has been replaced today with fiber-optic cables

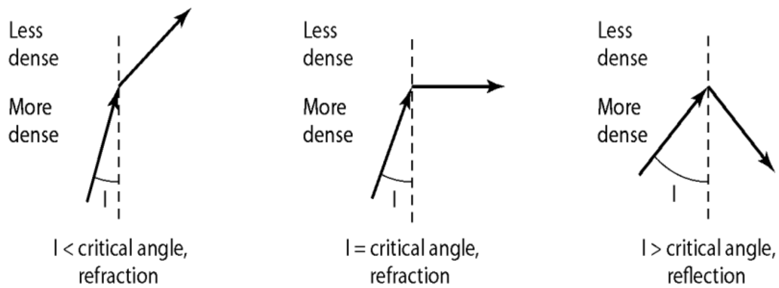
Fiber-Optic Cable

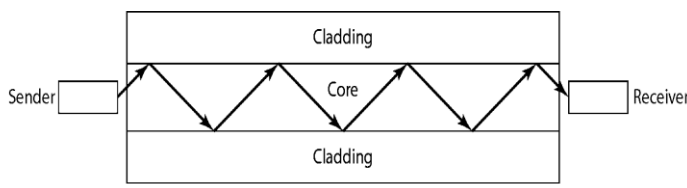
Nature of light:

Light travels in a straight line as long as it is moving through a single uniform substance.
If a ray of light traveling through a substance enters another substance of different density, the ray bends.

If the angle of incidence *I* is less than the critical angle, the ray refracts
If equal to, the light bends along the interface.
If greater than the ray reflects and travels again in denser substance

Fiber-optic cables are composed of a glass or plastic inner core surrounded by cladding of less dense glass or plastic, all encased in an outside jacket.
Fiber-optic cables transmit signals in the form of light. The light is guided through a channel by reflection.

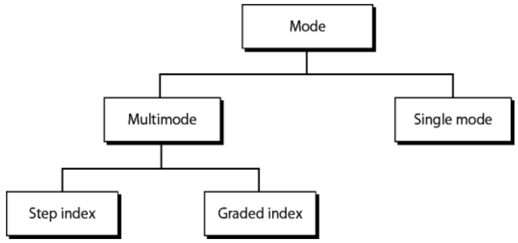




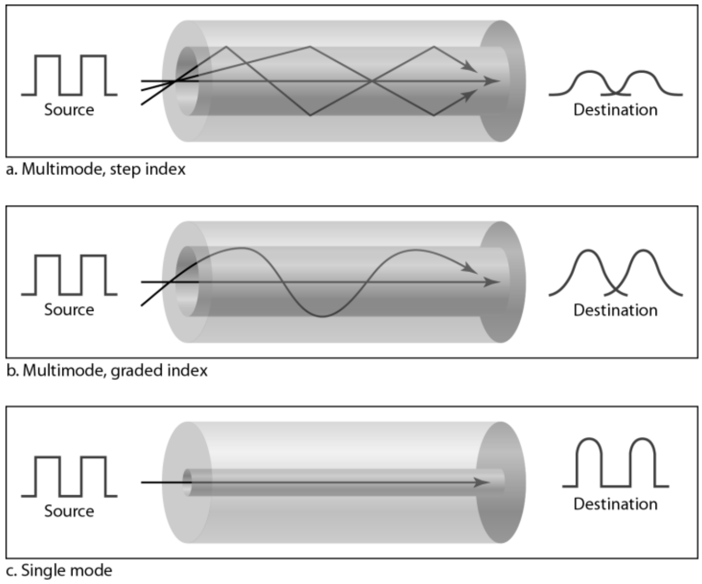
Signal propagation in optical fibers can be **multimode** (multiple beams from a light source) or **single-mode** (essentially one beam from a light source).
How these beams move within the cable depends on the structure of the core.

Multimode can be implemented in two forms : **step-index** or **graded-index**
In multimode step-index propagation, the core density is constant from center to edges and the light beam moves in a straight line and changes direction suddenly at the interface between the core and the cladding. Suddenness of change contributes to distortion of the signal

In multimode graded-index propagation, the core density decreases with distance from the center to edge. This causes a curving of the light beams and decreases distortion of the signal.
Single-mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal.
Single-mode fiber is manufactured with a smaller diameter than that of multimode fiber, and with lower density
Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding.



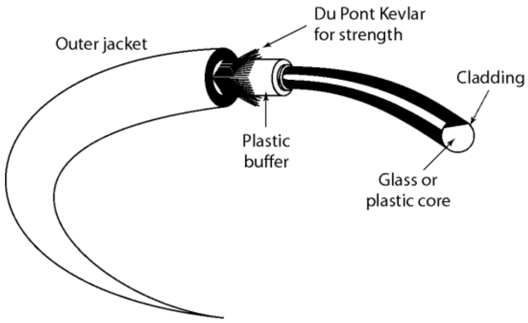
Propagation modes



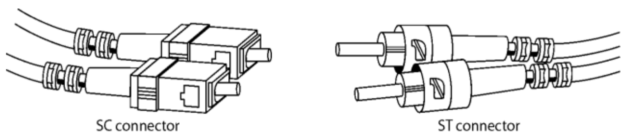
Fiber Construction

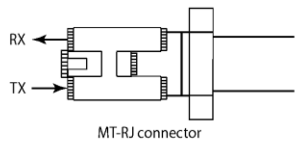
The outer jacket is made of either PVC or Teflon.
Inside the jacket are Kevlar strands to strengthen the cable.
Below the kevlar is plastic coating to cushion the fiber.
Fiber is at the center of the cable and consists of cladding and core.

Fiber-optic cable connectors Are of three types
Subscriber channel connector **(SC)** : Used for cable TV, Uses a push/pull locking system
Straight-tip connector **(ST)** : Used for connecting cable to network devices, Uses a bayonet locking system and is more reliable than SC.
MT-RJ connector



Fiber Construction





Performance
The plot of attenuation versus wavelength shows that attenuation is flatter than in case of other guided media.

Need fewer repeaters (10 times less)

Applications

Fiber-optic cable is used in backbone networks
Used in cable TV networks to provide backbone structure along with coaxial cables at user premises
Used Fast Ethernet networks (LAN).

Advantages of Optical Fiber over metallic cable:

Higher bandwidth: Fiber-Optic cable can support higher bandwidth (and hence data rates) than twisted-pair or coaxial cable.
Less signal attenuation: Fiber-optic transmission distance is greater than that of other guided media.
A signal can run for 50km without requiring regeneration where as repeaters are needed every 5km for coaxial or twisted-pair.
Immunity to electromagnetic interference: electromagnetic noise cannot affect fiber-optic cables.
Resistance to corrosive materials: Glass is more resistant to corrosive materials than copper.
Light weight: Fiber cables are much lighter than copper cables.

Greater immunity to tapping: Fiber-optic cables are more immune to tapping than copper cables.
Copper cables create antenna effects that can easily be tapped.
Disadvantages of Optical Fiber

Installation and Maintenance: Fiber-optic installation and maintenance require expertise.
Unidirectional light propagation: Two fibers are needed for bidirectional communication.
Cost: The cable and interfaces are more expensive than those of other guided media
Optical fiber is used only if the demand for bandwidth is high

UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication. Signals are broadcast through free space and are available to anyone who has a device capable of receiving them

Wireless data is transmitted through **ground propagation, sky propagation** and **line-of-sight propagation.**

In **ground propagation** low-frequency radio waves travel through the lowest portion of the atmosphere, these signals follow the curvature of the planet

Distance depends on the amount of power in the signal: the greater the power, the greater the distance

In **sky propagation** high-frequency radio waves travel upward into the ionosphere where they are reflected back to earth

These signals travel greater distances with lower output power

In **line-of-sight propagation** very high-frequency signals are transmitted in straight lines directly from antenna to antenna

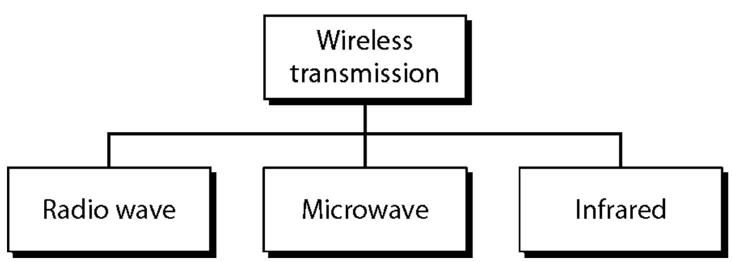
Antennas must be directional, facing each other and tall enough so that they are not affected by the curvature of the earth .

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

Waves ranging in frequencies between 1 and 300 GHz are called microwaves
The section of electro magnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called bands

Wireless transmission can be classifed as radio waves, microwaves and infrared waves based on the behavior of the waves.

REFER TABLE 7.4 ON PG. 204 FOR RANGE OF BANDS



Radio Waves

Radio waves are transmitted in all directions (omnidirectional).

The sending and receiving antennas do not have to be aligned.

Omnidirectional has a disadvantage.

The radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band.

Radio waves propagate long distances and are suitable for long distance broadcasting such as AM radio.

Low frequency and medium frequency radio waves can penetrate walls which is an advantage.

For Ex: AM radio can receive signals inside a building

The radio wave band is narrow, the subbands will also be narrow leading to low data rate.

The radio wave band is under government regulation and needs permission from authorities for using any part of the band.

Applications

Radio waves are useful for multicasting (one sender, many receivers)

AM and FM radio, television, cordless phones and paging are examples of multicasting

NOTE: Radio waves are used for multicast communications, such as radio and television, and paging systems.

Microwaves

Microwaves are unidirectional; propagation is line of sight; this means that the sending and receiving antennas need to be aligned.

Advantage of unidirectional property is that a pair of aligned antennas does not interfere with another pair of aligned antennas.

Repeaters are often needed for long distance microwave communication.

Very high-frequency microwaves cannot penetrate walls. This characteristic can be a disadvantage if receivers are inside buildings.

Microwave band is relatively wide, therefore wider subbands can be assigned and a high data rate is possible.

Use of certain portions of band require permission from authorities.

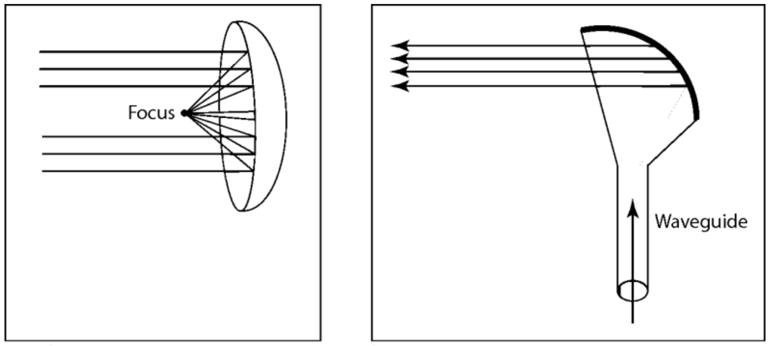
Microwave communication uses two types of antennas

The **parabolic dish antenna** – is based on the geometry of a parabola: Every line parallel to the line of symmetry reflects off the curve at angles such that all lines intersect at a common point called the focus.

Parabolic dish works as a funnel, catching a wide range of waves and directing them to a common point.

The **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 the curved head.

Received transmissions are collected by the scooped shape of the horn and are deflected down into stem.



a. Dish antenna b. Horn antenna

NOTE: Microwaves are used for unicast communication such as cellular telephones, satellite networks and wireless LANs.

<u>Infrared Waves</u>

Electromagnetic waves ranging in frequencies from 300GHz to 400 THz are Infrared waves.
High frequency infrared waves cannot penetrate walls.
This is advantageous; a short range communication system in one room cannot be affected by another system in the next room.
Infrared waves cannot be used outside a building because the sun rays contain infrared waves that can interfere with the communication
The Infrared Data Association (IrDA), is an association for sponsoring the use of infrared waves.
EX: Some manufacturers provide a special port called the IrDA port that allows a wireless keyboard to communicate with a PC
NOTE: Infrared signals can be used for short-range communication in a closed area such as those between a PC and a peripheral device using line-of-sight propagation.