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LECTURE NOTES-Computer Network

BCA-IVth Semester

Lecture 2

COMMUNICATION CHANNELS

TRANSMISSION LINES

A transmission line is a pair of conducting wires held apart by an insulator or dielectric. They come in a variety of construction geometries. The simplest and least expensive form is two-wire (ribbon) cable. Twisted pair cable consists of two wires sheathed in an insulator and twisted together. Shielded pair cable contains two wires surrounded and separated by a solid dielectric. The dielectric is contained within a copper braid, that shields the conductors from external noise sources. The entire construction is housed in a flexible, waterproof cover.

The use of this kind of cable is limited by two factors: attenuation and cross-talk. There are three principle sources of attenuation. Resistance (or impedance) losses are simply the loss resulting from the resistance of the wires. This loss is minimised by the choice of a metal with low resistivity. Copper is chosen for this reason. (Gold is even better, and is in fact used on satellites to reduce losses.) Dielectric losses are caused by the heating effects when a varying electric field passes through a dielectric (insulator). Radiation losses occur because the cable acts as an antenna. All these losses increase with frequency.

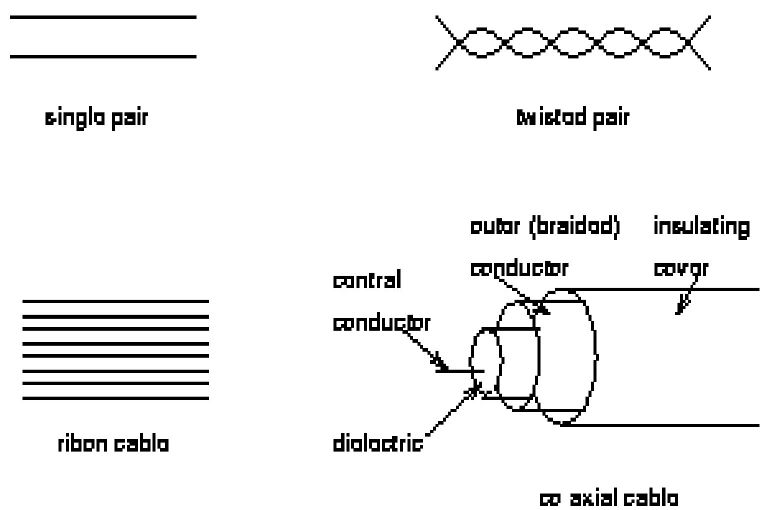


Figure: Some different types of transmission lines

When a transmission line can act as an antenna, it can also act as a receiver. Lines prone to radiation loss are also susceptable to **pick-up**, or **cross-talk**. The first two types described above are particularly prone to this fault. The shielded pair is designed to reduce this pick-up.

All these lines have strong attenuation at frequencies above 1MHz. They are generally used for low bit-rate communication. Two-wire ribbon cable is standard for the connection of individual telephone receivers. Twisted pair(s) is the normal method of connection for computer terminals and short high bit-rate connections.

Attenuation increases with both frequency and length. It is usually specified in dB/m at a particular frequency. Because of this fact, it is not possible to give hard-and-fast rules concerning the bandwidth availability of transmission lines. A twisted pair can support rates of several Mb/s over short distances (metres), but over long distances (kilometres) will be completely unsuitable at these data-rates.

For long distances, or data-rates in excess of several Mb/s, **coaxial cable** is used. Coaxial cable has a central wire, surrounded by a dielectric, in turn concentrically sheathed in a braided conductor. The cable is finally surrounded in a water-proof, flexible sheath. Coaxial cable is familiar to you -- it is the cable used to connect your television ariel. The supreme advantage of this method of construction is its resistance to radiation losses. The outer conductor acts to shield out any external fields, whist preventing any internal fields escaping.
Until the advent of optical fibre, coaxial lines were the standard method of long-distance, high bit-rate communication. They are expensive (but getting cheaper, especially as demand rises), and only used where necessary. Typical attenuation values for coaxial cable are 10dB/Km at 10KHz, 50dB/Km at 500MHz. For very long-haul routes, repeaters and equalisers are necessary.

Satellite communication

Satellite communication became a possibility when it was realised that a satellite orbiting at a distance of **36000Km** 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. In principle, three geostationary satellites correctly placed can provide complete coverage of the Earth's surface.

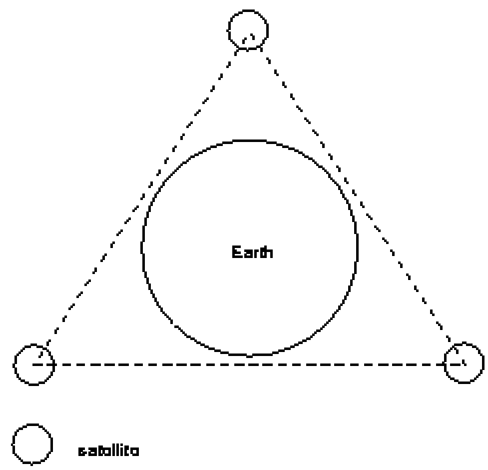


Figure: Geostationary satellites providing global coverage

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

Advantages:

1.The laying and maintenance of intercontinental cable is difficult and expensive.

2.The heavy usage of intercontinental traffic makes the satellite commercially attractive.

3.Satellites can cover large areas of the Earth. This is particularly useful for sparsely populated areas.

Disadvantages:

1.Technological limitations preventing the deployment of large, high gain antennas on the satellite platform.

2,Over-crowding of available bandwidths due to low antenna gains.

3.The high investment cost and insurance cost associated with significant probability of failure.

4.High atmospheric losses above 30GHz limit carrier frequencies.

A microwave antenna has two functions. It provides **gain** (i.e. amplification). It also directs the radiation into confined regions of space: the **antenna beam**. These properties are largely dependent on the antenna size.

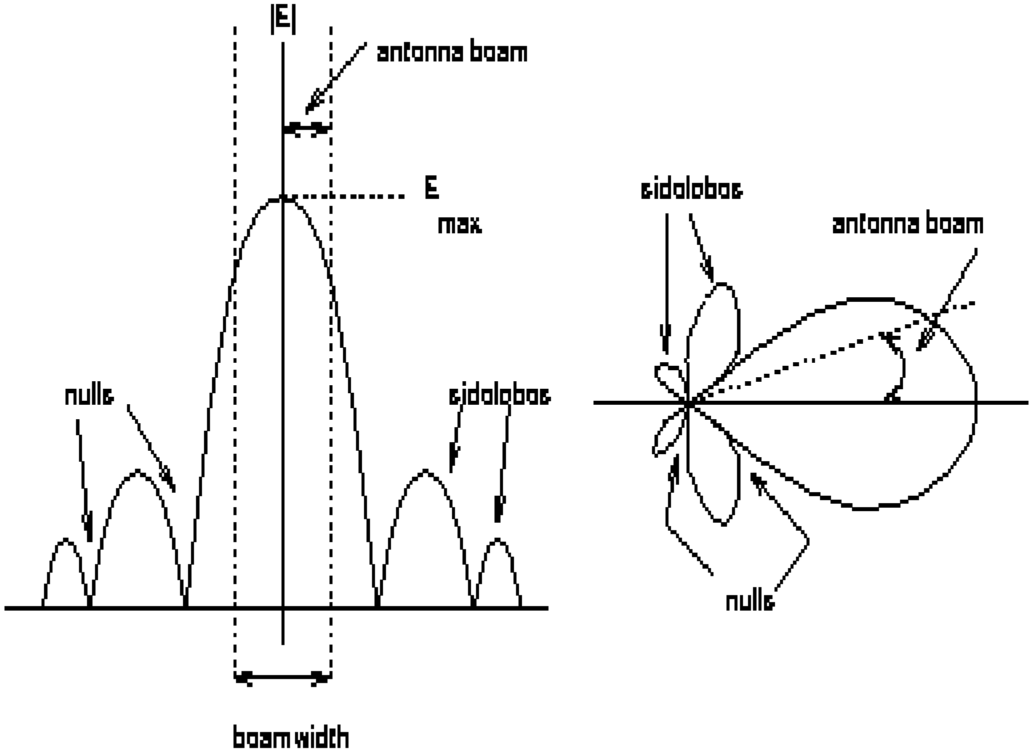


Figure: A typical antenna beam profile of a dish antenna

The cost of constructing an antenna is a strong function of its size. A rough rule of thumb is the the cost is proportional to the diameter cubed. Thus a doubling of the antenna size will result in the satellite cost increasing eight times. As a result, antenna sizes are limited. The limitation in antenna size means that the satellite beam is wide. In order to prevent electromagnetic interference with terrestrial stations, the power radiated by the satellite is limited by international convention. In any event power is severely limited on a satellite platform.
Because the radiated power is low, large receiving antennas are required. The larger the receiver antenna, the larger the antenna gain, and hence the

better the receiver SNR. The SNR is a function of the bandwidth, and the atmospheric attenuation. Ground stations close to the poles of the Earth have low elevation **look angles**, and signals have to pass through a thicker section of atmosphere.
A standard INTELSAT receiver is 30m in diameter. An antenna this large has a very narrow beam, typically 0.01°. A geostationary satellite is not truly stationary, it wanders slightly in the sky. The very narrow beam width of the receiver requires automatic tracking of the satellite, and continuous pointing of the receiver antenna. An INTELSAT ground station is thus a large, expensive piece of equipment.
Satellite systems are extremely expensive. As an example, the break down for a particular British satellite is as shown in Table .

Item	Cost [$Million]
Satellite construction	300
Investment finance	300
Insurance	300
Launch	100
	1000

Table: Example costs for a satellite system

The use of satellites for regional communication is possible if there is sufficient demand for traffic. By reducing the range of latitudes down to $\pm 60^\circ$, and reducing the bandwidth down to 50MHz, large reductions in satellite and ground station receiver costs are possible. One such **direct-to-user (DTU)** system is the Satellite Business System (SBS) covering a range of business and governments users with a demand for high speed data links in the US. The region is split into areas, roughly coincident with the satellite antenna gain contours, denoting increased cost of receiver technology. It is important to realise that the economies of satellite communication only make this regional communication possible if the system is heavily used.

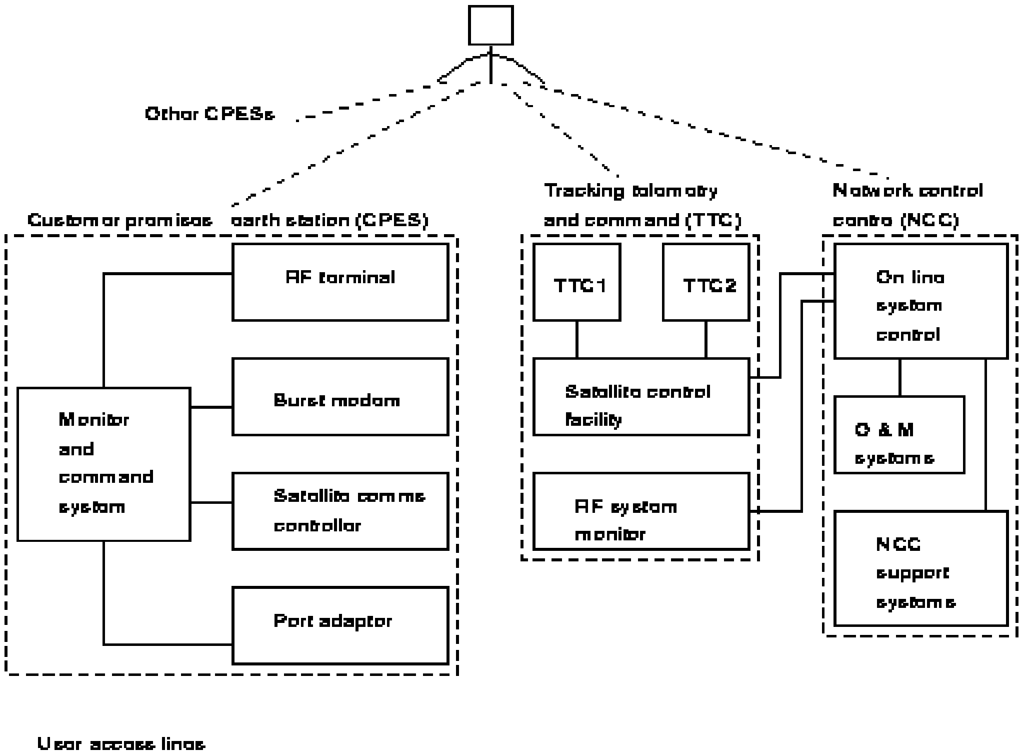


Figure: The Satellite Business System operational schematic

Improvements in satellite receiver technology have permitted smaller antennas to be used as ground station receivers. However, antennas are reciprocal. They have the same directional characteristics in transmit and receive. The use of low gain, wide beam earth stations for DTU systems has contributed considerably to the bandwidth overcrowding problem, particularly in the US.

Recently there has been interest in **low-earth orbiting (LEO)** satellites. Here, a satellite placed in a **1000Km** 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.

Optical Fibre Waveguide

For many years it has been appreciated that the use of optical (light) waves as a carrier wave provides an enormous potential bandwidth. Optical carriers are in the region of 10^{13}Hz to 10^{16}Hz, i.e. three to six orders of magnitude higher than microwave frequencies. However, the atmosphere is a poor transmission medium for light waves. Optical communication only became a widespread option with the development of low-loss dielectric waveguide. In addition to the potential bandwidth, optical fibre communication offers a number of benefits:

- Size, weight, flexibility. Optical fibres have very small diameters. A very large number of fibres can be carried in a cable the thickness of a coaxial cable.
- Electrical isolation. Optical fibres are almost completely immune from external fields. They do not suffer from cross-talk, radio interference, etc.
- Security. It is difficult to tap into an optical line. It is extremely difficult to tap into an optical line unnoticed.
- Low transmission loss. Modern optical fibre now has better loss characteristics than coaxial cable. Fibres have been fabricated with losses as low as $0.2dB/Km$.

The primary disadvantage of optical fibre are the technical difficulties associated with reliable and cheap connections, and the development of an optical circuit technology that can match the potential data-rates of the cables. The speed of these circuits, which are electronically controlled, is usually the limiting factor on the bit-rate. The difficulty of connection and high-cost of associated circuitry result in optical fibres being used only in very high bit-rate communication. There is considerable current debate as to whether optics will ever completely replace electronic technology. In addition, good phase control of an optical signal is extremely difficult. Optical communications are forced to use the comparatively crude method of ASK modulation.

Optical fibre is a waveguide. The fibre (in its simplest form) consists of a core of glass of one refractive index, and a cladding of a slightly lower refractive index. The fibre is then surrounded by a refractive sheath. Typical fibre dimensions are $1000\mu m$ to $1500\mu m$ diameter.

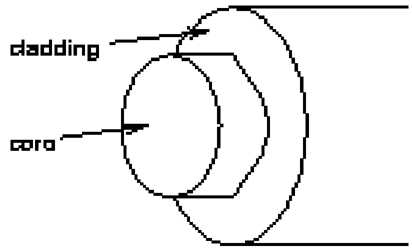


Figure: The basic structure of a fibre optic waveguide

In simple terms, the action of a waveguide can be partially understood by considering the rays down the fibre. A light-wave entering the fibre is either refracted into the cladding, and attenuated, or is totally internally reflected at the core/cladding boundary. In this manner it travels along the length of the fibre. The maximum angle at which it may enter the guide and travel by total internal reflection is termed the acceptance angle. It is also possible for the wave to follow a helical path down the guide. These rays are called skew-rays.

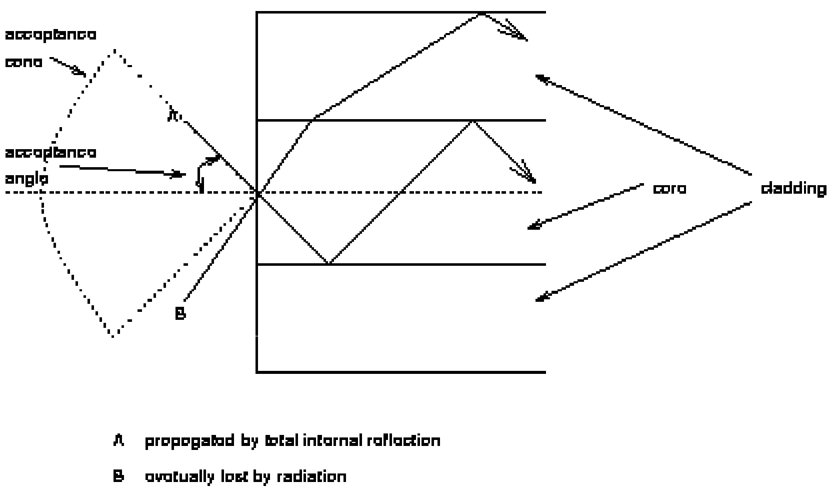
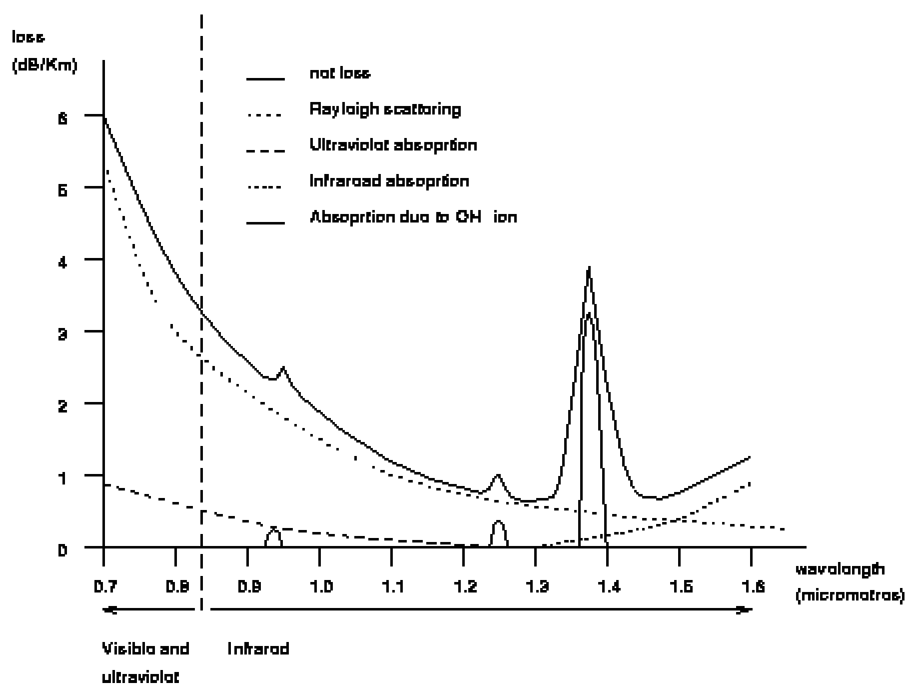


Figure: Waveguide action of an optical fibre

However, this view is too simple to explain all features of waveguide behaviour. In fact, it is not possible for the wave to take any ray down the guide. Only certain rays can be taken. These rays are called modes. For any particular frequency, there is a different ray. The modal action of a waveguide is a consequence of the wave nature of the radiation. A mono-mode fibre is a fibre that only has one acceptable ray-path per frequency. A multi-mode fibre has a number of possible rays that light of a particular frequency may take.

The attenuation of light in the guide has a number of sources. Absorption of light occurs in the glass and this decreases with frequency. Scattering of light from internal imperfections within the glass -- Rayleigh scattering -- increases with frequency. Waveguide imperfections account for low-level loss that is approximately constant with wavelength. Bending the waveguide changes the local angle of total internal reflection and loss increases through the walls. A combination of these effects results in a minimum absorption of about $2\ dB/Km$ to $5\ dB/Km$ in the $0.8\mu m$ to $1.8\mu m$ wavelength region. It is these wavelengths that are used for transmission.

In addition to attenuation, optical waveguides also suffer from dispersion. The dispersion has two sources. Due to the modal behaviour, a waveguide is an intrinsically dispersive device. Put simply, rays of different frequency travel on different paths having different lengths. Because the different frequencies travel different lengths they take different times. In addition to the waveguide dispersion, however, is the material dispersion. Glass is an intrinsically dispersive media. In single mode fibres the material



dispersion dominates the waveguide dispersion.

The bandwidth of optical fibres is dominated by the dispersion. In fact, the bandwidth of individual fibres is actually much the same as high quality co-

axial cable. It is ironic that the principle justification for optical communication, very large bandwidth, has not in practise been realised. However, it is possible to lay many hundreds of optical fibres in the same cable cross-section as a single co-axial cable.
Fibre optic cable is available in three basic forms:

1. Stepped-index fibre. In this type of fibre, the core has a uniform refractive index throughout. This generally has a core diameter of $100\mu m$ to $500\mu m$. This is a multi-mode fibre.

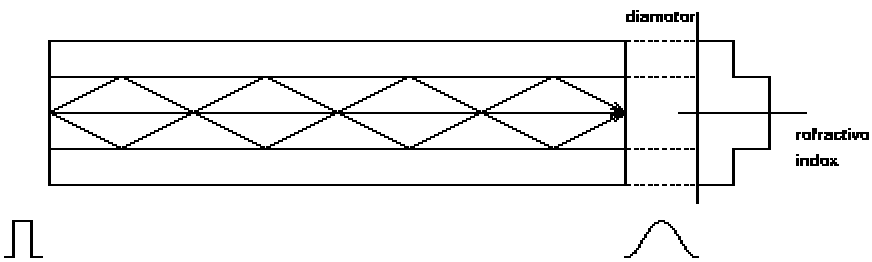


Figure: Stepped-index fibre

2. Graded-index fibre. In this type of fibre, the core has a refractive index that gradually decreases as the distance from the centre of the fibre increases. This generally has a core diameter of $50\mu m$. This is a multi-mode fibre. (Figure ❑.)

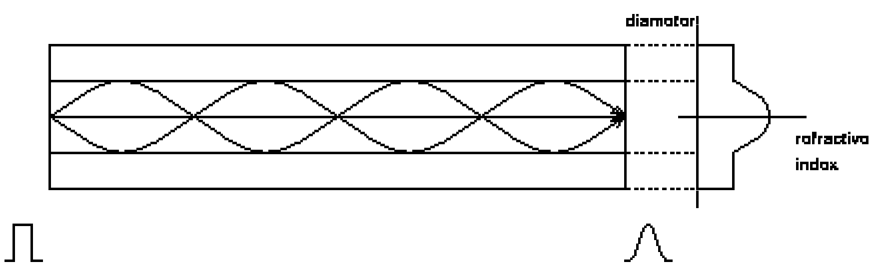


Figure: Graded-index fibre

3. Mono-mode fibre. As the name suggests, the distinguishing characteristic of this fibre is that allows only a single ray path. The radius of the core of this type of fibre is much less than that of the other two, however it does have a uniform refractive index. (Figure ❑.)

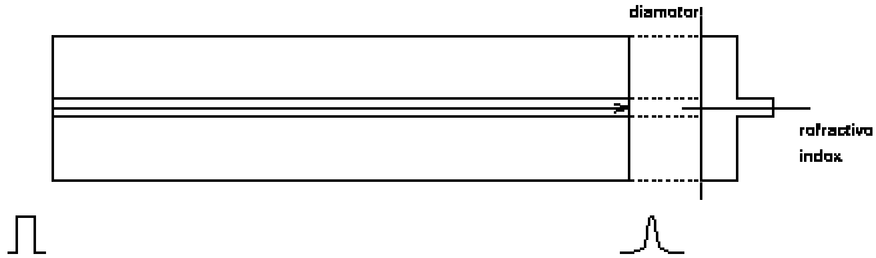
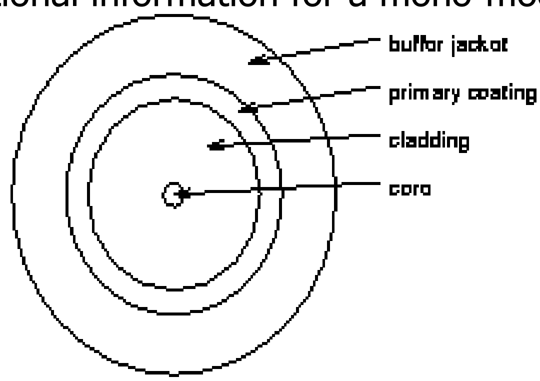


Figure: Mono-mode fibre

From, 1 to 3, we find that the cost of production increases, the complexity of transmitter and receiver increases, while the dispersion decreases. This latter property change means that the mono-fibre also has the potential to provide greater bandwidth. As it becomes cheaper to produce mono-mode fibre technology, we will see an increased use of this type of optical fibre. Figure ❑gives typical operational information for a mono-mode fibre.



core diameter	3 – 10μm
cladding diameter	50 – 125μm
buffer jacket diameter	50 – 125μm
acceptance angle	8 – 10°

Figure: Operational information for a mono-mode fibre

Microwave Link Communication

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 limitied. In practise, bandwidth allocations of 50MHz in the carrier range 300MHz to 1GHz 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

mm wave region would be advantageous. However, for technical reasons, no efficient method of producing large quantities of mm power have been found. This is a necessity, given the increase in atmospheric attenuation at mm wave frequencies.

Mobile Communications:

The use of mobile radio-telephones has seen an enormous boost in the 1980s and 1990s. Previous to this time, citizen band (CB) radio had served a limited market. However, the bandwidth assignation for CB radio was very limited and rapidly saturated. Even in the U.S., a total of only 40 10KHz channels were available around 27MHz. The use of digital mobile telephones has a number of advantages over CB radio:

- Access to national and international telephone system.
- Privacy of communication.
- Data independent transmission.
- An infinitely extendable number of channels.

Mobile communications are usually allocated bands in the 50MHz to 1GHz band. At these frequencies the effects of scattering and shadowing are significant. Lower frequencies would improve this performance, but HF bandwidth is not available for this purpose. The primary problems associated with mobile communication at these frequencies are:

- Maintaining transmission in the fading circumstances of mobile communication.
- The extensive investigation of propagation characteristics required prior to installation.

Mobile communication work by limiting transmitter powers. This restricts the range of communication to a small region. Outside this region, other transmitters can operated independently. Each region is termed a **cell**. These cells are often represented in diagrams as hexagons. In practise the cell shape is determined by local propagation characteristics. Together the cells will completely cover the area supplied with mobile communication coverage (Figures ❑and ❑).

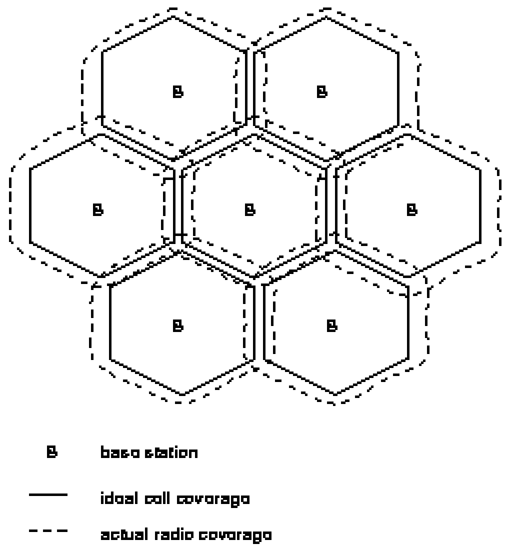


Figure: Use of cells to provide geographical coverage for mobile phone service

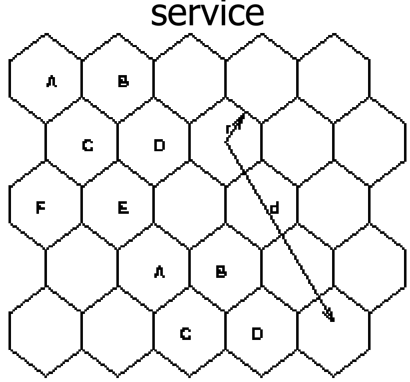


Figure: Frequency re-use in cells

Within each cell, the user communicates with a transmitter within the cell. As the mobile approaches a cell boundary, the signal strength fades, and the user is passed on to a transmitter from the new cell. Each cell is equipped with cell-site(s) that transmit/receive to/from the mobile within the cell. Within a single cell, a number of channels are available. These channels are (usually) separated by frequency. Then a mobile initiates a call, it is assigned an idle channel within the current cell by the **mobile-services switching centre (MSC)**. He/she uses the channel within the cell until he/she reaches the boundary. He/she is then allocated a new idle channel within the next cell.

For example, the American **advanced mobile phone service (AMPS)** makes use of a 40MHz channel in the 800 - 900MHz band. This band is split into a 20MHz transmit and 20MHz receive bandwidth. These bands are split into 666 two-way channels, each having a bandwidth of 30KHz. These channels are subdivided into 21 sets of channels, arranged in 7 groups of 3.

The nominally hexagonal pattern contains 7 cells, a central one and its 6 nearest neighbours. Each cell is assigned a different group in such a way that at least two cells lie between it and the next block using that set. With a total of 666 channels, it is possible to assign three sets of 31 channels per cell.

The great strength of this type of network is the ease with which more channels may be introduced. As demand rises, one simply reduces the cell size. Then the same number of channels is available in a smaller area, increasing the total number of channels per unit area. In a well planned system, the density of cells would reflect the user density.

AMPS is a **first generation** mobile phone system. It uses analogue modulation. It is one of six incompatible first generation systems that exist around the world. Currently, **second generation** systems are being introduced. These are digital in nature. One aim of the second generation mobile systems was to try and develop one global standard, allowing use of the same mobile phone anywhere in the world. However, there are are currently three digital standards in use, so this seems unlikely. The pan-European standard is known as **GSM (Groupe Special Mobile)**, and is now available in the UK. The services planned for the GSM are similar to those for ISDN (e.g. call forwarding, charge advice, etc.). Full GSM will have 200KHz physical channels offering 270Kb/s. Currently, one physical channel is split between 8 users, each having use of 13Kb/s (the rest is used for channel overhead). The aims of the GSM system were:

- Good speech quality
- Low terminal cost
- Low service cost
- International roaming
- Ability to support hand-held portables
- A range of new services and facilities (ISDN!)

The heart of the mobile telephone network is the MSC. Its task is to acknowledge the paging of the user, assign him/her a channel, broadcast his/her dialed request, return the call. In addition it automatically monitors the signal strength of both transmitter and receiver, and allocates new channels as required. This latter process, known as **hand-off**, is completely hidden to the user, although is a major technical problem. In addition, the MSC is responsible for charging the call (Figure ❑). The decision making ability of the MSC relies to a great extent on modern digital technology. It is the maturity of this technology that has permitted the rapid growth of mobile communications.

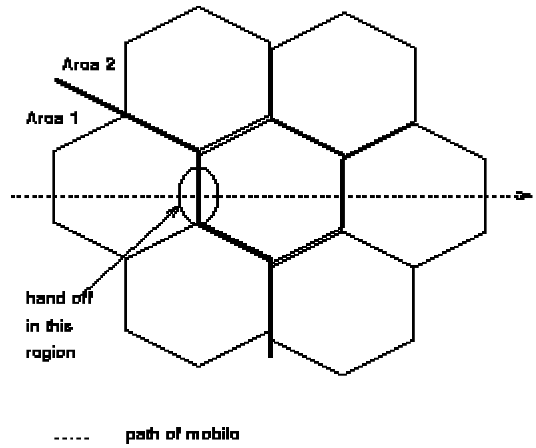


Figure: Hand-off between cells

The principle problem with mobile communication is the variation in signal strength as the communicating parties move. This variation is due to the varying interference of scattered radiation -- **fading**. Fading causes rapid variation in signal strength. The normal solution to fading, increasing the transmitter power, is not available in mobile communication where transmitter power is limited.

There is considerable research into suitable modulation schemes to cope with fading. The presence of fading has a severe effect on the BER. It can reduce the BER by several orders of magnitude over the non-fading case. In addition, some modulation schemes cope better than others. Surprisingly, coherent AM modulation is better than coherent FM in the fading environment. In any event BERs of 10^{-3} are typical, in comparison with BERs of 10^{-6} for non-fading channels. There should be no surprise if your mobile phone has a worse performance than that in your home.

The installation of a mobile telephone system requires a large initial effort in determining the propagation behaviour in the area covered by the network. Propagation planning, by a mixture of observation and computer simulation, is necessary if the system is to work properly. At UHF and VHF frequencies, the effects of obstructions is significant. Some of the effects that need to be considered are:

- **Free space loss.** This significantly increases in urban environments. Studies have indicated that a $(\text{distance})^{-4}$ relationship is more often followed than a $(\text{distance})^{-2}$ law.
- **Effect of street orientation.** Streets have a significant waveguide effect. Variations of up to 20dB have been measured in urban environments as a result of street direction.
- **Effects of foliage.** Propagation in rural areas is significantly effected by the presence of leaves. Variations of **18dB** between summer and winter have been observed in forested areas.
- **Effect of tunnels.** Tunnels can introduce signal attenuation of up to 30dB according to the tunnel length and frequency.

Sunlight and Rainbows:

Formation of rainbows involves light passing from air into water droplet and back out again.

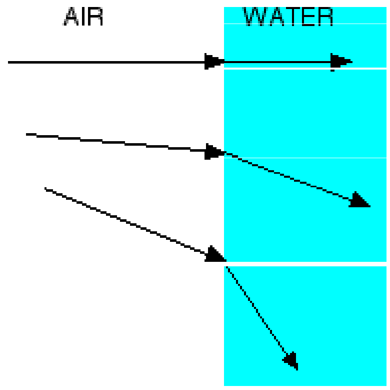
What happens to light when if passes from one material (air) into another (water) ?
FOUR effects happen.

These ALL happen together, but we will examine them one at a time.

- refraction
  - = light bends
- dispersion
  - = different colors bend differently
- reflection
  - = light bounces
- absorption
  - = light is lost

Refraction:

light bends as it passes from one material into another



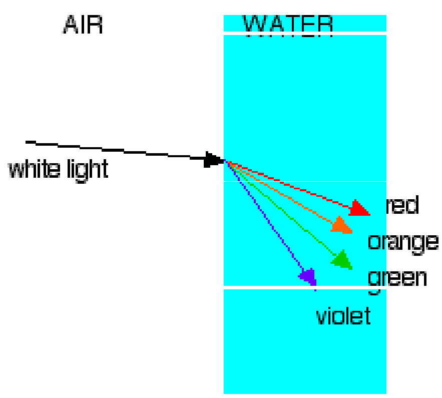
going from air into water, light is bent closer to the interface
the shalower the angle of incidence, the more it is refracted

(angle of incidence is the angle between coming in perpendicular to the interface and how the light is coming in)

[Demo: pencil in water, penny under cup]

Dispersion:

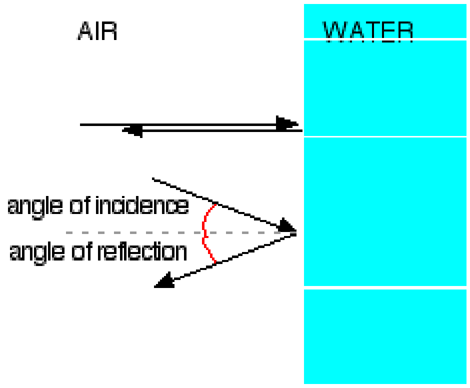
violet light bends more than red light



Reflection:

some light bounces back

angle of incidence = angle of reflection



Absorption:

some light can be absorbed in the material

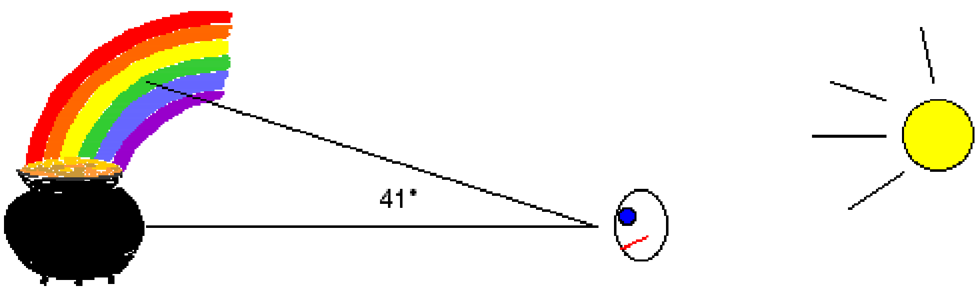
this is not a big issue for air or water

RAINBOWS:

combination of reflection, refraction and dispersion

primary rainbow always:

- appears 41 degrees above the horizon
- has the Sun behind you
- has the Sun relatively low in the sky (morning or evening)
- has red on the outside of the bow (top)
- has violet on the inside of the bow (bottom)

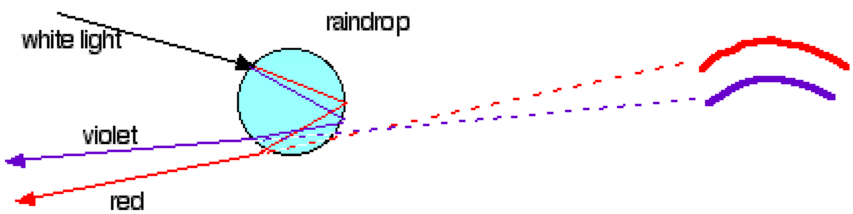


sometimes observe a secondary rainbow

- appears at higher angle above horizon
- has colors reversed (red on inside, violet on outside)

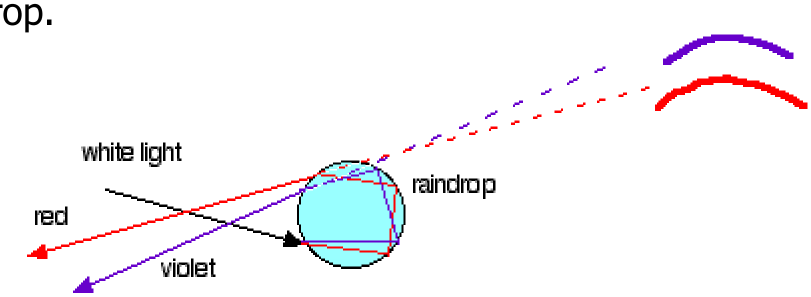
formation of primary rainbow

light rays are refracted and dispersed on entering drop, reflected from back surface of drop and refracted again as they leave drop.



formation of secondary rainbow

light rays enter near bottom of drop and are refracted and dispersed on entering drop, reflected TWICE from back surface of drop and refracted again as they leave drop.



All raindrops are scattering light in these ways - but you only see the light that is scattered toward you. Some light is being scattered over your head to the person behind you. Other light is hitting the ground ahead of you. As you move the rainbow is always at the same height. You can never be directly under a rainbow !!!

<u>Micro Waves Transmission:</u>

The electromagnetic spectrum consists of various types of radiation, characterized by wavelength (λ) and frequency (v). The frequency of the wave can be visualized as the number of wave crests that move by an observer in a second (**Figure 7.1**). Microwave radiation refers to the region of the spectrum with frequencies between ~10^9 Hz to ~10^{11} Hz. This type

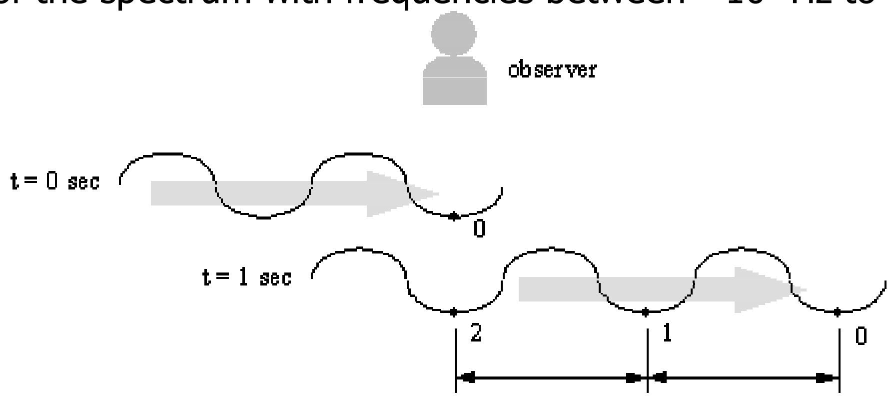


Figure 7.1 How to measure the frequency of a wave.
In the case shown here, the frequency of the wave is 2 Hz, or 2 cycles per second.

of radiation lies between infrared radiation and radio waves.

Recall that waves with shorter wavelength (lower frequency) have higher energy. The frequency of visible (green) light at λ = 500 nm is approximately 6×10^{14} Hz. The frequency of radiation used in microwave ovens is approximately 2.5×10^9 Hz, with a wavelength of 12 cm. This means that the microwave radiation used to heat food is actually less energetic than visible light. Why, then, are microwave ovens so efficient at heating food?

7.2 Water Molecules and Microwaves

Water molecules (H_2O) are polar; that is, the electric charges on the molecules are not symmetric (**Figure 7.2**). The alignment and the charges on the atoms are such that the hydrogen side of the molecule has a positive (+) charge, and the oxygen side has a negative (-) charge.

Electromagnetic radiation have electric charge as well; the "wave" representation shown in Figure 7.1 is actually the electric charge on the wave as it flips between positive and negative. For a microwave oscillating at 2.5×10^9 Hz, the charge changes signs nearly 5 billion times a second (2 times 2.5×10^9 Hz).

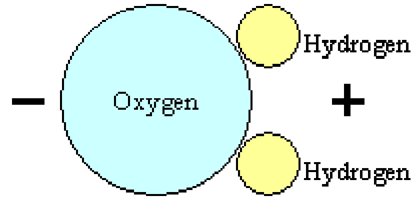


Figure 7.2 Water molecule

Electric charges are similar to magnetic charges: opposites attract. When oscillating electric charge from radiation interacts with a water molecule, it causes the molecule to flip (**Figure 7.3**). Microwave radiation used in ovens are specially tuned to the natural frequency of water molecules to maximize this interaction. Therefore, as a result of the radiation hitting the molecules, the water molecule flips back and forth 5 billion times a second. Because temperature measures how fast molecules move in a substance, the vigorous movement of the water molecules raises the temperature of water.

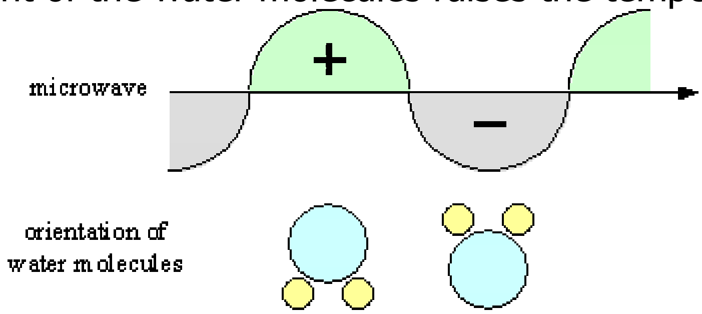


Figure 7.3 Interaction between water molecule and microwave

Switched- Lines Transmission:

Switched lines are accessed only on an as-needed basis. Switching means that the path between the two end-points of the switched line remains present only for the duration of the connection.
Leased-Lines Leased lines (also known as dedicated lines), on the other hand, are full-time, permanent connections between two end points. They are more expensive than switched lines, and their fee is often based on the distance of the line and speed of the circuit. Switched lines are ideal when only occasional access is needed between a LAN and a remote location. Full-time, heavy-duty access would usually require the use of a dedicated line.

Leased Line Transmission:

Leased lines are dedicated digital circuits connecting two fixed points across a private network. They are in fact the most secure and reliable type of voice and data connections available today.

Need of Leased Lines:

- **Secure and private**

Because Leased Line is dedicated entirely to you, it's yours to use exclusively.

- **High throughput**
  Because no one else ever uses it you have total access to it - 24 hours a day - meaning there's never a delay in sending information.

- **Reliable**
  Leased Line is delivered on Copper or Faber optic transmission networks and is monitored around the clock to provide you with a highly reliable service.

- **Financial predictability**
  Leased Lines offers you a fixed monthly charge.

Functioning of Leased Lines:

Leased lines are essentially private reserved pathways (or pipe lines) through the service providers network that are rented by the user to carry traffic. Connection to the network requires data transmission equipment such as a router together with a Data Service Unit (DSU) to provide an interface to the network.

Applications:

The capacity of leased lines vary between 64Kbps to 2Mbps speeds. 64Kbps leased lines are useful for networks with moderate traffic requirements that have steady and sustained patterns ie. large file transfers between a limited number of sites. While the 2Mbps is used for heavier applications, a leased line along with an Internet connection puts the internet at your permanent disposal whenever you need to access it, with no interruptions or wastage of time. Currently leased lines are by far the most popular method of connecting corporate networks.

So, hence , leased line is a permanent telephone connection between two points set up by a telecommunications common carrier. Typically, leased lines are used by businesses to connect geographically distant offices. Unlike normal dial-up connections, a leased line is always active. The fee for the connection is a fixed monthly rate. The primary factors affecting the monthly fee are distance between end points and the speed of the circuit. Because the connection doesn't carry anybody else's communications, the carrier can assure a given level of quality.

For example, a T-1 channel is a type of leased line that provides a maximum transmission speed of 1.544 Mbps. You can divide the connection into different lines for data and voice communication or use the channel for one high speed data circuit. Dividing the connection is called *multiplexing*.
Increasingly, leased lines are being used by companies, and even individuals, for Internet access because they afford faster data transfer rates and are cost-effective if the Internet is used heavily.

Telecommunications lines:

Telecommunications lines can be grouped into two main categories, depending on their method of transmission: analog and digital. Analog transmission takes place in the form of continuous waves. Digital transmission takes place in the form of discrete on and off pulses. Digital lines are faster, more reliable, and can carry more traffic than analog lines; they are also more expensive. Analog lines would typically be chosen only for light traffic involving relatively few users.

ANALOG LINES

POTS(Plain Old Telephone Service) Lines :

As the name suggests, POTS lines are telephone lines that are used for data communication. They are analog lines that require the use of a modem at each end. Their chief advantage is their cost and their ubiquity (i.e. anyone with a phone line can attach a computer to it via modem). However, they are have narrow bandwidth (i.e. are slow) and are subject to noise. With the fastest modems and latest data compression techniques, downloading speed over a POTS line is limited to 53.3Kbps; uploading speed is limited to 36.6Kbps. Several types of POTS lines are available, ranging from basic voice grade to higher quality lines more suitable for sending data. Usually, POTS lines are switched, dial-up lines, but dedicated POTS lines (which are expensive) are also available. POTS lines are suitable for very light traffic (e.g. e-mail, web surfing, connecting to online services such as Dialog) involving only a few users. Often, they are used to give dial-in access to remote library users.

DIGITAL LINES

56K Lines

56K lines are digital lines that have a bandwidth of 56Kbps. They require the use of a CSU/DSU to connect to a LAN and can be either switched or leased. They are good for light lan-to-lan traffic, involving uses such as e-mail, file transfer, and even running applications from a server, provided that the number of users is limited. For example, a library with several catalogers that need to connect to OCLC may use a 56K line for direct access to that bibliographic utility. Switched 56K lines are fairly inexpensive.

T-1 Lines

The "T-carrier" is a standard for digital lines. T-1 lines are a type of T-carrier. They have 24 channels (23 for data and 1 for link management) that run at 64Kbps each. That gives them a total bandwidth of 1.5Mbps. They require the use of a CSU/DSU to connect to a LAN. T-1s are expensive, high speed dedicated lines that are used for heavy traffic. They are good for connecting LANs with heavy traffic to other remote LANs and to the Internet. For example, a T-1 line can be used to connect a large library (with many users) to an Internet Service Provider or to a consortium catalog and database. T-1s can carry both voice and data. If a library does not need to lease an entire T-1 line (i.e. all 24 channels), it can lease only as many channels as are needed. This is called a "fractional T-1" line.

T-3 Lines

T-3 lines are another type of T-carrier. They are the equivalent of 28 T-1 lines, and have a total bandwidth of 45Mbps. (In other words, they have 672 channels running at 64Kbps each.) T-3s are very expensive and only used for moving tremendous amounts of data. Internet Service Providers use them to connect to the Internet backbone, and they may be employed by institutions such as medical centers that need to provide intensive long distance medical imaging. The T-3 standard is usually employed over fiber-optic cabling (rather than copper) or sometimes through a microwave medium. Connecting a LAN to a T-3 line would typically require a fiber optic access device. As with T-1 lines, individual channels of T-3 lines can be leased as "fractional T-3" lines.

Infrared Transmission:

It refers to energy in the region of the electromagnetic radiation spectrum at wavelengths longer than those of visible light, but shorter than those of radio waves. Correspondingly, infrared frequencies are higher than those of microwaves, but lower than those of visible light.

Scientists divide the infrared radiation (IR) spectrum into three regions. The wavelengths are specified in microns (symbolized µ, where 1 µ = 10^{-6} meter) or in nanometers (abbreviated nm, where 1 nm = 10^{-9} meter = 0.001 5). The **near IR band** contains energy in the range of wavelengths closest to the visible, from approximately 0.750 to 1.300 5 (750 to 1300 nm). The **intermediate IR band** (also called the **middle IR band**) consists of energy in the range 1.300 to 3.000 5 (1300 to 3000 nm). The **far IR band** extends from 2.000 to 14.000 5 (3000 nm to 1.4000 x 10^4 nm).

Infrared is used in a variety of wireless communications, monitoring, and control applications. Here are some examples:

- Home-entertainment remote-control boxes
- Wireless (local area networks)
- Links between notebook computers and desktop computers
- Cordless modem
- Intrusion detectors
- Motion detectors
- Fire sensors
- Night-vision systems
- Medical diagnostic equipment
- Missile guidance systems
- Geological monitoring devices

Transmitting IR data from one device to another is sometimes referred to as beaming.

Near Infrared Transmission

Near Infrared Transmission (NIT) analyzers utilize a lead-sulfide detector that measures the amount of electromagnetic radiation transmitted through a sample that was irradiated with light at several different wavelengths. The operating principle is that certain constituents have molecular bonds that stretch and bend causing absorbance at certain wavelengths of infrared radiation in proportion to the amount of constituent present. NIT analyzers measure the electromagnetic radiation actually transmitted through a sample. In order for this technology to work, the cell thickness or path length must be constant and must not be too deep. Whole kernels are used and infrared light, in effect, bounces or is reflected from surfaces of many kernels before it emerges on the opposite side of the sample cell for

detection. An equation that relates log 1/T (log of 1/transmission) values at selected key wavelengths to wet chemistry values enables a calibration to be developed. Again, sufficient samples have to be scanned to represent the full range of constituents.
NIT is widely used for measuring percentages of protein, oil, moisture, and fiber in corn and other grains and oilseeds. In addition, starch content can be measured in corn. Typical standard error of predictions for protein, oil, starch content, and fiber have been 0.25%, 0.18%, 0.84%, and 0.10%, respectively, when expressed on dry basis moisture. Because grinding is not required, samples may be run in less than 1 minute.

Radio Waves Transmission:

For the propagation and interception of radio waves, a transmitter and receiver are employed. A radio wave acts as a carrier of information-bearing signals; the information may be encoded directly on the wave by periodically interrupting its transmission (as in dot-and-dash telegraphy) or impressed on it by a process called modulation. The actual information in a modulated signal is contained in its sidebands, or frequencies added to the carrier wave, rather than in the carrier wave itself. The two most common types of modulation used in radio are amplitude modulation (AM) and frequency modulation (FM). Frequency modulation minimizes noise and provides greater fidelity than amplitude modulation, which is the older method of broadcasting.

In its most common form, radio is used for the transmission of sounds (voice and music) and pictures (television). The sounds and images are converted into electrical signals by a microphone (sounds) or video camera (images), amplified, and used to modulate a carrier wave that has been generated by an oscillator circuit in a transmitter. The modulated carrier is also

amplified, then applied to an antenna that converts the electrical signals to electromagnetic waves for radiation into space. Such waves radiate at the speed of light and are transmitted not only by line of sight but also by deflection from the ionosphere.Receiving antennas intercept part of this radiation, change it back to the form of electrical signals, and feed it to a receiver. The most efficient and most common circuit for radio-frequency selection and amplification used in radio receivers is the superheterodyne. In that system, incoming signals are mixed with a signal from a local oscillator to produce intermediate frequencies (IF) that are equal to the arithmetical sum and difference of the incoming and local frequencies. One of those frequencies is applied to an amplifier. Because the IF amplifier operates at a single frequency, namely the intermediate frequency, it can be built for optimum selectivity and gain. The tuning control on a radio receiver adjusts the local oscillator frequency. If the incoming signals are above the threshold of sensitivity of the receiver and if the receiver is tuned to the frequency of the signal, it will amplify the signal and feed it to circuits that demodulate it, i.e., separate the signal wave itself from the carrier wave.

There are certain differences between AM and FM receivers. In an AM transmission the carrier wave is constant in frequency and varies in amplitude (strength) according to the sounds present at the microphone; in FM the carrier is constant in amplitude and varies in frequency. Because the noise that affects radio signals is partly, but not completely, manifested in amplitude variations, wideband FM receivers are inherently less sensitive to noise. In an FM receiver, the limiter and discriminator stages are circuits that respond solely to changes in frequency. The other stages of the FM receiver are similar to those of the AM receiver but require more care in design and assembly to make full use of FM's advantages. FM is also used in television sound systems. In both radio and television receivers, once the basic signals have been separated from the carrier wave they are fed to a loudspeaker or a display device (usually a cathode-ray tube), where they are converted into sound and visual images, respectively.

Uses of Radio Waves

The prime purpose of radio is to convey information from one place to another through the intervening media (i.e., air, space, nonconducting materials) without wires. Besides being used for transmitting sound and television signals, radio is used for the transmission of data in coded form. In the form of radar it is used also for sending out signals and picking up their reflections from objects in their path. Long-range radio signals enable astronauts to communicate with the earth from the moon and carry information from space probes as they travel to distant planets. For navigation of ships and aircraft the radio range, radio compass (or direction finder), and radio time signals are widely used. Radio signals sent from global positioning satellites can also be used by special receivers for a precise indication of position. Various remote-control devices, including rocket and artificial satellite operations systems and automatic valves in pipelines, are activated by radio signals. The development of the transistor and other microelectronic devices led to the development of portable transmitters and receivers. Cellular and cordless telephones are actually radio transceivers. Many telephone calls routinely are relayed by radio rather than by wires; some are sent via radio to relay satellites. Some celestial bodies and interstellar gases emit relatively strong radio waves that are observed with radio telescopes composed of very sensitive receivers and large directional antennas.

Laser Transmission:

Infrared laser transmission provides interconnection between points that have direct line of sight. You can think of it as fiber without the cable. Laser links eliminate the need for securing right of ways, and costly overhead or buried cable installations. The systems we offer provide a totally transparent and cost effective connection between buildings at distances up to 4000 meters.

Since laser links transmit infra red light waves, these systems provide advantages over microwave and spread spectrum radio. They are immune to interference, communication security is better and installation is easier and faster. Infrared transmission also eliminates need for radio interference studies and FCC licensing.

Optical wireless laser communication systems designed for point-to-point line of sight applications.

This technology is ideally suited for:

- Inter-building LAN, voice and video connections
- Broadband Internet connectivity

- Internet service provision
- CCTV

Key features:

- High bandwidth – upgradeable from E1/T1 to higher than gigabit speeds
- Distances of up to 4Km
- Cost effective alternative or back up to leased lines
- Safe, secure and reliable

Optical laser technology can be affected by extreme adverse weather conditions, for instance dense fog, particularly when transmission distances are over 2km. To prevent such conditions from interrupting service, ALLnet recommends using a back-up link such as an unlicensed radio connection.