Chapter 4 Transmission Media

Electromagnetic Spectrum

- Computers and other telecommunication devices transmit signals in the form of electromagnetic energy, which can be in the form of electrical current, radio wave, microwave, infrared light, or visible light.
- Electromagnetic signals can travel through a cable, a vacuum, air, or other transmission media.
- Transmission media can be divided into two broad categories: guided and unguided.

Figure 4-1

Electromagnetic Spectrum

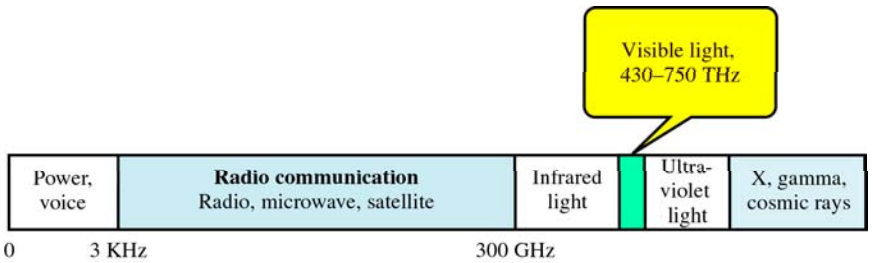
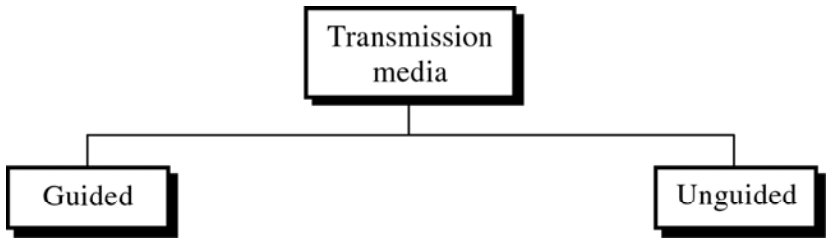


Figure 4-2

Classes of Transmission Media



Guided Media

- Guided media provide conduit from one device to another, the signal is directed and contained by the physical limits of the medium.
- Guided media include twisted-pair cable, coaxial cable, and fiber-optic cable.
  - Use metallic (copper) conductors (twisted-pair and coaxial cables) , or
  - Use glass or plastic cable (fiber-optic)

Figure 4-3

Categories of Guided Media

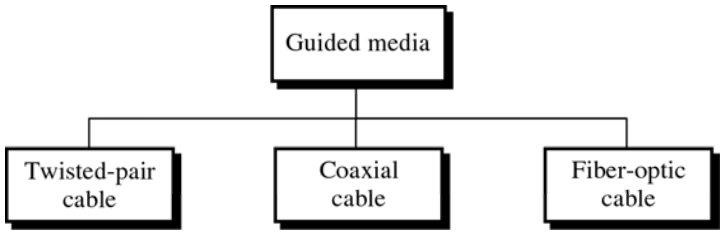
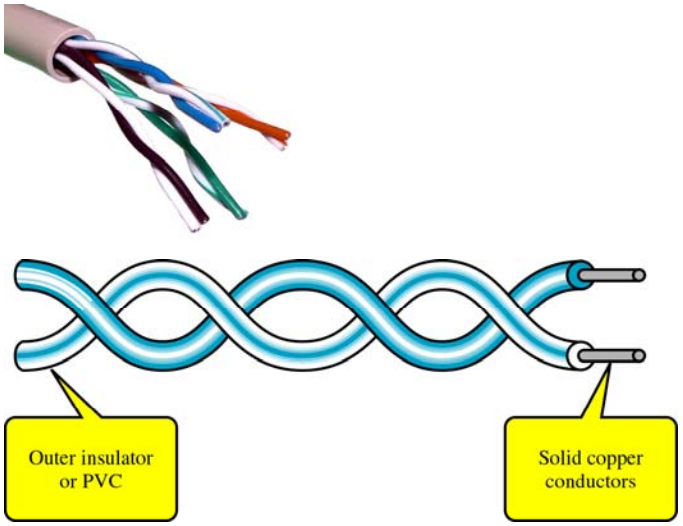


Figure 4-4

Twisted-Pair Cable



Twisted-Pair Cable

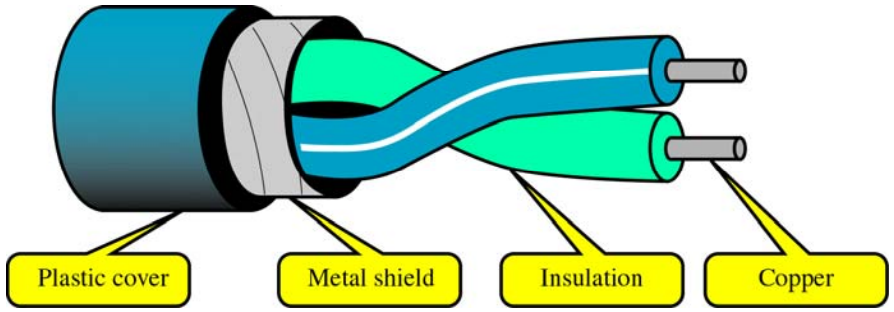
- It comes in two forms: unshielded (UTP) and shielded (STP).
- UTP
  - Most common type in use today (see Fig. 4-4)
  - The plastic insulation is color-banded for identification
  - Significantly reduced electromagnetic noise interference compared with two parallel flat wires
  - Cheap, flexible, and easy to install
  - Five standard categories from Cat. 1 the lowest quality to Cat. 5 the highest quality

Twisted-Pair Cable

- STP:
  - Has a metal foil or braided-mesh covering that encases each pair of insulated conductors (see Fig. 4-5)
  - The metal casing prevents the penetration of electromagnetic noise
  - It eliminates most crosstalk

Figure 4-5

Shielded Twisted-Pair Cable

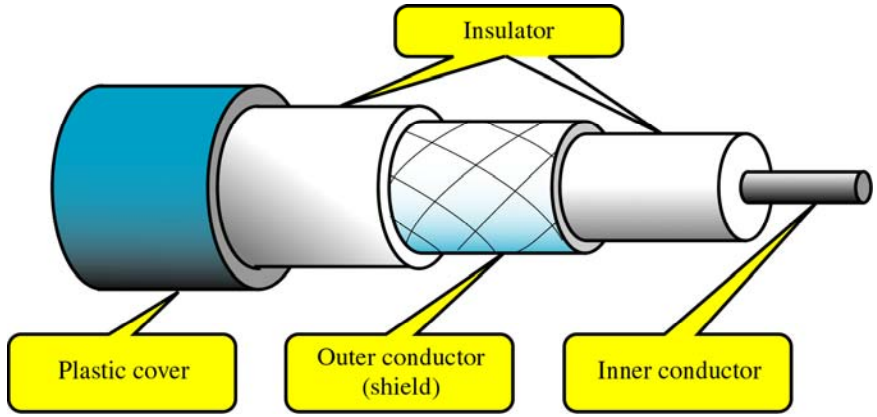


Coaxial Cable

- Carries signals of higher frequency ranges than twisted-pair cable.
- Uses a central core conductor of solid or stranded wire and an outer conductor of metal foil or braided-mesh (see Fig. 4-6).
- The outer metallic wrapping serves both as a shield against noise and the second condutor that completes the circuit.
- Coaxial cables are categorized by their RG ratings.

Figure 4-6

Coaxial Cable



Optical Fiber – Refraction

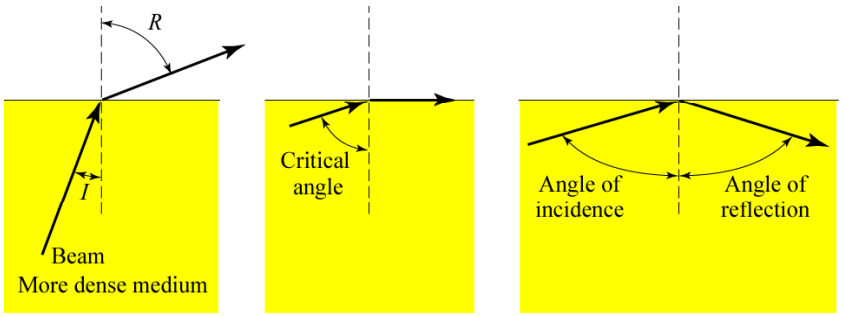
- Is made of glass or plastic and transmits signals in the form of light.
- The speed of the light is dependent on the medium. It travels the fastest in a vacuum.
- **Refraction** happens when a ray of light travelling through one medium suddenly enters another substance, causing the ray to change the direction.
- The beam is bent toward vertical axis if it moves from less dense into more dense medium. Otherwise it is bent away from the vertical axis (see Fig. 4-7).

Optical Fiber – Reflection

- The **incident angle** that results an refracted angle of 90 degree is known as the critical angle.
- The **reflection** happens when the angle of the incidence of the beam is greater than the critical angle, and the light no longer passes into the other medium at all, but gets reflected back.
- The angle of incidence = The angle of reflection
- Optical fibers use reflection to guide light through a channel.

Figure 4-7

Refraction and Reflection



a. Refraction b. Critical angle c. Reflection

Optical Fiber – Reflection

- A glass or plastic core is surrounded by a **cladding** of less dense glass or plastic, such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it (see Fig. 4-9).
- Information is encoded onto a beam of light as a series of on-off flashes that represent 1 and 0 bits.

Propagation Modes

- Current technology supports two modes for propagating light along optical channels, **multimode** and **single mode,** each using fiber with different physical characteristics.
- In multimode, multiple beams move through the core in different paths. There are two forms of multimode, **step-index** and **graded-index**.

Multimode, Step-Index Fiber

- Multimode, step-index fiber
  - The density of the core remains constant
  - A beam of light moves in a straight line until it reaches the interface between the core and cladding
  - At the interface there is a sudden change of direction of the beam due to reflection
  - Creates considerable amount of distortion in the signal

Multimode, Graded-index Fiber

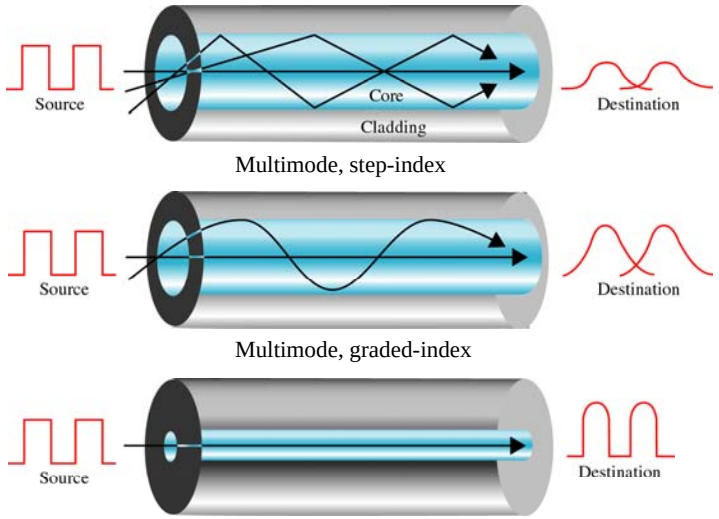
- Multimode, graded-index fiber
  - One with varying densities, highest at the center of the core and decreases gradually to its lowest at the edge
  - Change of the direction of the beam is gradual
  - Decreased distortion of the signal through the cable

Single Mode Fiber

- Single mode fiber
  - Uses a highly focused source of light that limits beams to small range of angles, all close to horizontal
  - Use step-index fiber with much smaller diameter and substantially lower density than that of multimode fibers
  - Due to decrease in density, the critical angle is close to 90 degrees, the propagation of beams are almost horizontal, all beams arrive at the destination “together” and can be recombined without distortion to the signal

Figure 4-8

Propagation Modes

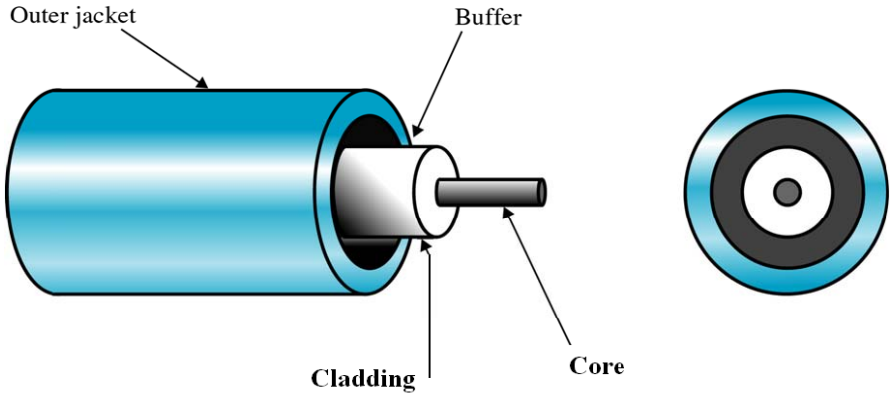


Cable Composition

- Both core and cladding are made of either glass or plastic of different densities.
- The inner core must be ultrapure and completely regular in size and shape, or it will alter the angle of reflection and distort the signal.
- The buffer layer protects the inner fiber from moisture.
- The entire cable is encased in an outer jacket.

Figure 4-9

Fiber Construction



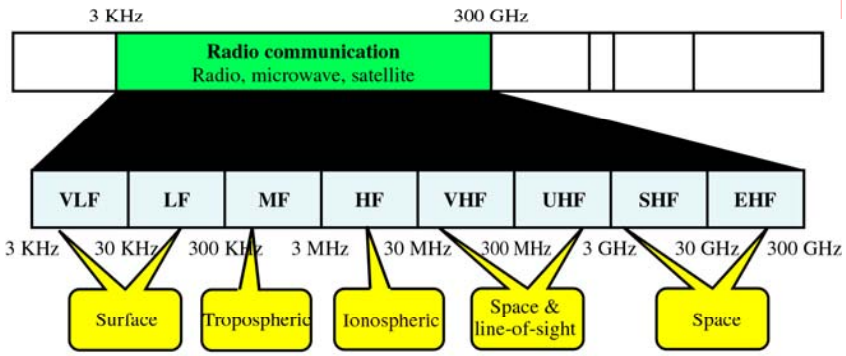
Unguided Media

- **Unguided media** or **wireless** communication transport electromagnetic waves through air or a vacuum, and everyone who has a device is capable of receiving them.
- Uses the section of electromagnetic spectrum known as radio communication (3 KHz – 300 GHz), which is divided into eight bands, to transmit signals (Fig. 4-10).
- Radio wave transmission uses five different types of propagation: **surface**, **tropospheric**, **ionospheric**, **line-of-sight**, and **space** (Fig. 4-11).

Figure 4-10

Radio Communication Band

VLF	Very low frequency	VHF	Very high frequency
LF	Low frequency	UHF	Ultra high frequency
MF	Middle frequency	SHF	Super high frequency
HF	High frequency	EHF	*Extremely high frequency*



Types of Propagation

- **Surface propagation** – lowest frequency radio waves travel in all directions that follow the curvature of the planet, hugging the earth; can also take place in seawater
- **Tropospheric propagation** – a signal can either be directed in a straight line from antenna to antenna (limited distance) or broadcasted into the upper layer of the troposphere where it is reflected back (greater distance)

Types of Propagation

- **Ionospheric propagation** – higher frequency radio waves radiate upward into the ionosphere where they are reflected back to earth; allows for greater distances with lower power output
- **Line-of-sight propagation** – very high frequency signals are transmitted in straight lines directly from antenna to antenna; parabolic antennas that produce narrow, highly directional signals are used

Types of Propagation

- **Space propagation** – highest frequency signals are broadcasted into the space toward an orbiting satellite, where the signals are received and rebroadcasted back to the receiver on the earth; dramatically increases the distance coverable by a signal

Figure 4-11

Types of Propagation

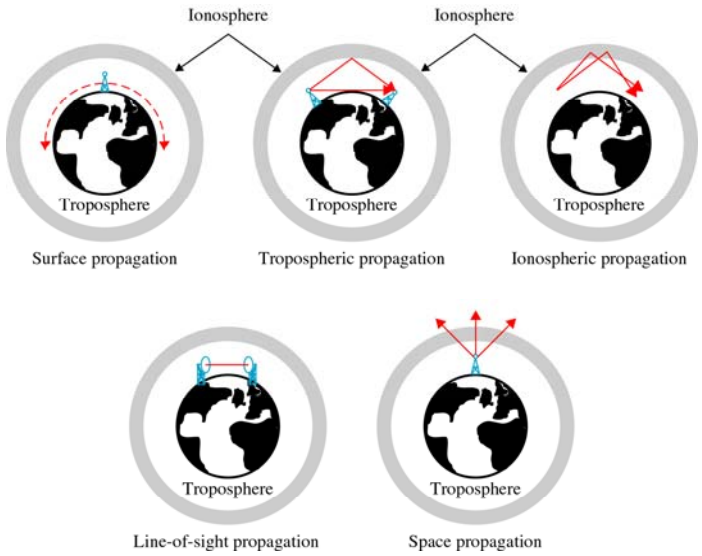
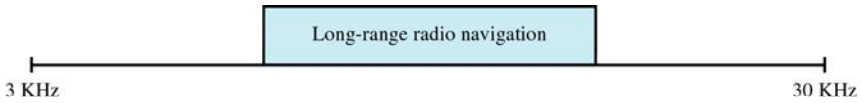


Figure 4-12

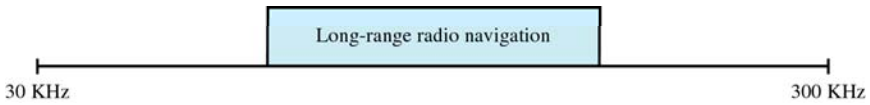
Frequency Range for VLF



Surface Propagation

Figure 4-13

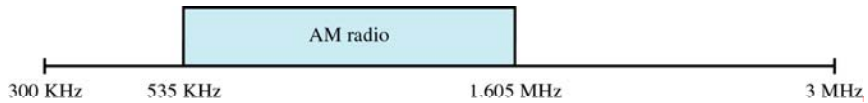
Frequency Range for LF



Surface Propagation

Figure 4-14

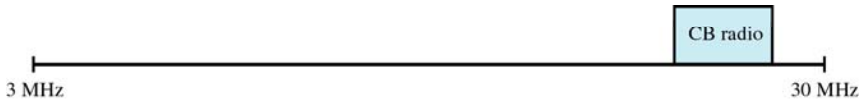
Frequency Range for MF



Tropospheric Propagation

Figure 4-15

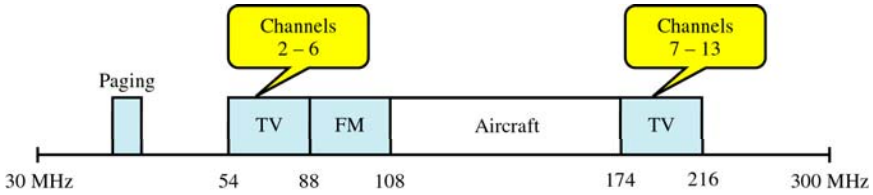
Frequency Range for HF



Ionospheric Propagation

Figure 4-16

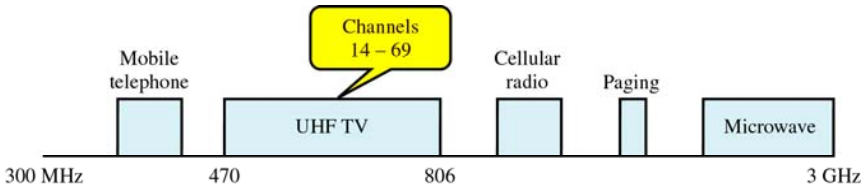
Frequency Range for VHF



Line-of-sight Propagation

Figure 4-17

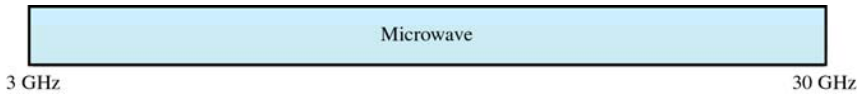
Frequency Range for UHF



Line-of-sight Propagation

Figure 4-18

Frequency Range for SHF



Line-of-sight + Space Propagations

Figure 4-19

Frequency Range for EHF

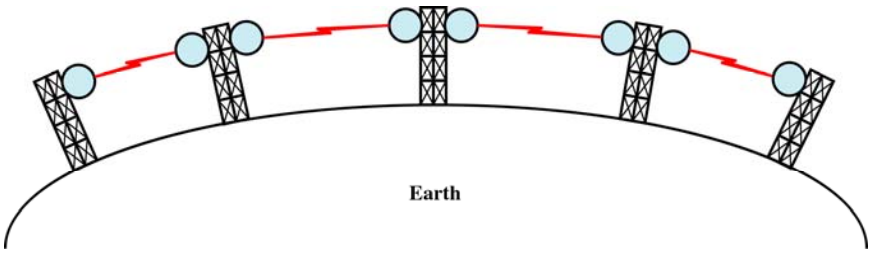
Space Propagation

Terrestrial Microwave

- Microwaves requires line-of-sight transmission
- Distance coverable depends to a large extent on the height of the antenna
- Repeaters are installed to increase the distance served by terrestrial microwave
- Widely used in instances in which it would be impractical to run cables

Figure 4-20

Terrestrial Microwave



Satellite Microwave

- The satellite that is orbiting the earth acts as a super tall antenna and repeater.
- Satellite relays allow microwave signals to span continents and oceans with a single bounce.
- **Geosynchronous** satellites provide full and constant global transmission
  - The satellites must remain fixed above certain spots
  - Must move along the only orbit at the equatorial plane
  - At least three satellites are needed

Figure 4-21

Satellite Communication

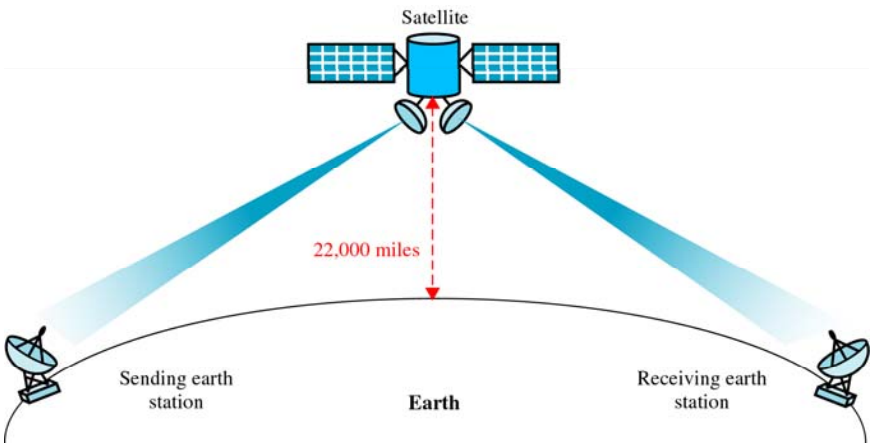
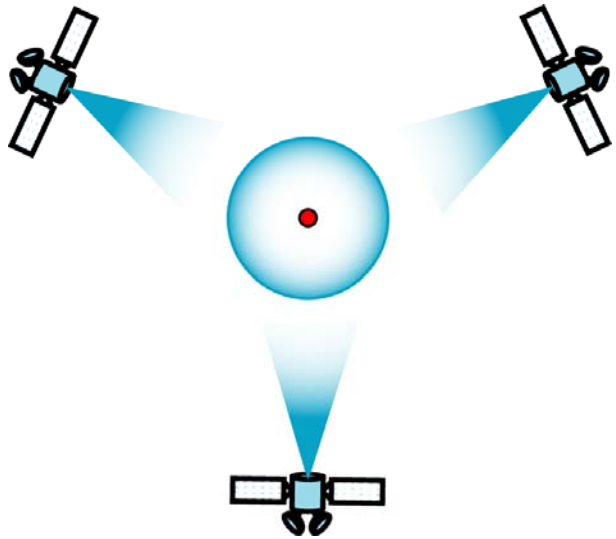


Figure 4-22

Satellite in Geosynchronous Orbit

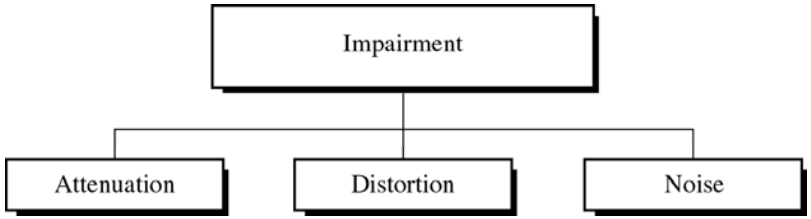


Transmission Impairment

- Transmission media are not perfect and can cause impairment in the signal sent through the medium.
- Signals sent at the beginning of the medium may not be the same as the ones received at the end of the medium.
- Three types of impairment usually occur: **attenuation**, **distortion**, and **noise**.

Figure 4-23

Impairment Types



Attenuation

- **Attenuation** means loss of energy. As a signal travels through a medium, it loses some of its energy in order to overcome the resistance of the medium.
- To compensate for the loss of energy, amplifiers are used to amplify the signal.
- Let P_1 and P_2 be the strengths of a signal at point 1 and 2 (or two signals). The **decibel** (**dB**) measures the relative strengths of P_1 and P_2 .

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

  $dB < 0$ (P_2 is attenuated relative to P_1)

  $dB > 0$ (P_2 is amplified relative to P_1)

Figure 4-24

Attenuation

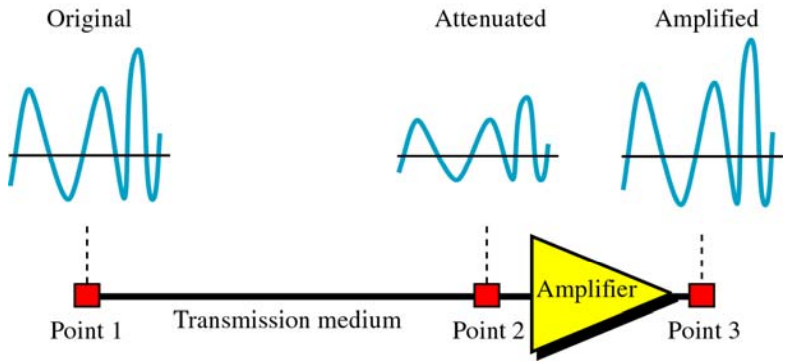
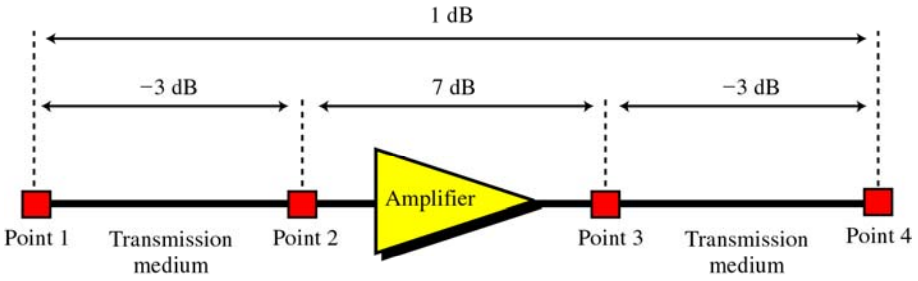


Figure 4-25

Example 4.3



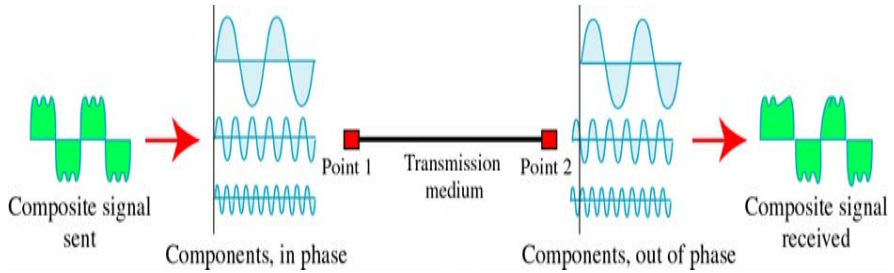
$\mathbf{P_2 = ½\ P_1}$ $\mathbf{P_3 = 5\ P_2}$ $\mathbf{P_4 = ½\ P_3}$

Distortion

- **Distortion** means the signal has changed its form or shape.
- Occurs in a composite signal, made of different frequencies – each component has its own propagation speed and its own delay in arriving at the final destination.

Figure 4-26

Distortion

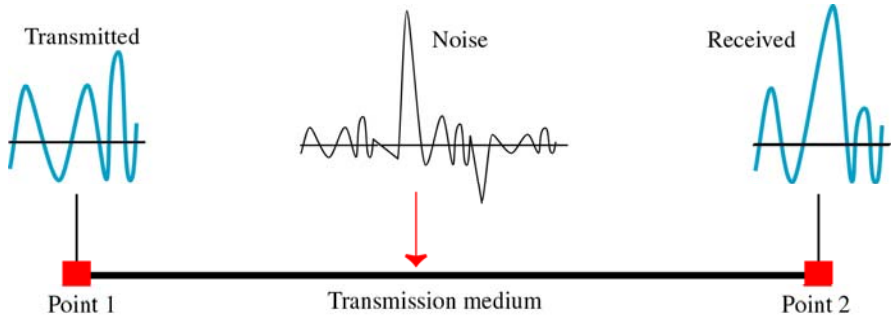


Noise

- Noise can be caused by:
  - Thermal noise is the random motion of electrons in a wire that creates an extra signal
  - Induced noise comes from sources such as motors and appliances
  - Crosstalk is the effect of one wire on the other
  - Impulse noise is a spike that come from power lines, lighting, …

Figure 4-27

Noise



Performance

- To measure the performance of transmission media, three concepts are used.
- **Throughput** is the number of bits that pass through an imaginary wall in the media in one second
- **Propagation speed** is the distance a signal or a bit can travel through a medium in one second
- **Propagation time** is the time required for a signal (or a bit) to travel from one point of the media to another

  Propagation time = Distance / Propagation speed

Figure 4-28

Throughput

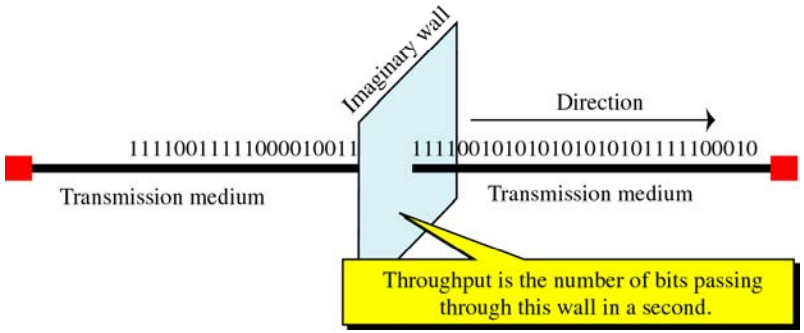
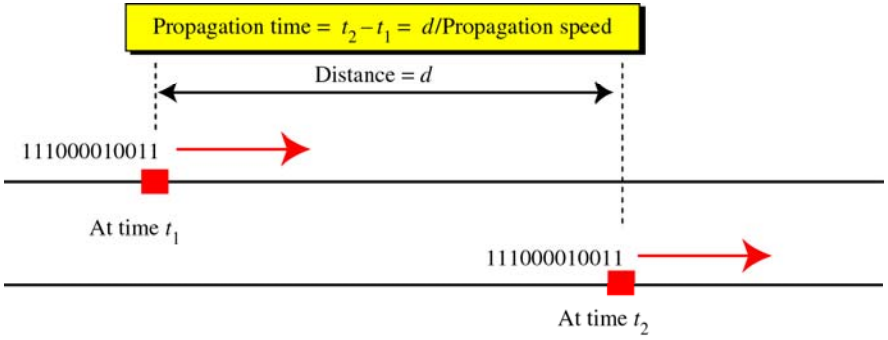


Figure 4-29

Propagation Time



Summary

- Transmission media for LANs can be divided into two broad categories: guided and unguided.
- Twisted-pair cable, coaxial cable and fiber-optic cable are most popular types of guided media for LANs.
- Metal cables transmit signals in the form of electrical current.
- Optical fibers transmit signals in the form of light.
- The most common unguided medium for LANs is air.
- Radio waves are used to transmit data through the air.

Summary

- Radio wave propagation is dependent on frequency. There are five types of propagation: surface, tropospheric, ionospheric, line-of-sight, and space.
- Terrestrial microwave uses line-of-sight propagation, and repeaters are used to increase the distance.
- Satellite communication uses a satellite in geosynchronous orbit to relay signals. A system of three correctly spaced satellites can cover most of the earth.

Summary

- Attenuation, distortion, and noise are forms of transmission impairment.
- The performance of a transmission medium is measured by its throughput, propagation speed, and propagation time.