DPIT127
Networks and Communications

WEEK 3

TRANSMISSION MEDIUM

Spring 2019

This Week

- **Last Week**
  - Any Questions?
  - Data & Signals (Modulation and Encoding Techniques)
- **This Week**
  - Transmission Wire & Media Categories

Introduction

The world of computer networks would not exist if there is no medium exist transfer data/information.

The two major types of transmission medium include:

- **Cable (Wired) media**
  - Unshielded twisted pair (UTP), shielded twisted-pair (STP) and coaxial cable
    - Inexpensive as compared to other media
- **Wireless media**
  - radio, microwave and satellite, infrared
    - Faster and requires less cost to deploy service at no-infrastructure spots, or where environments and cost prohibition apply to use cable.
- **Light**
  - Fiber Optics
    - High bandwidth and low noise

Media Characteristics

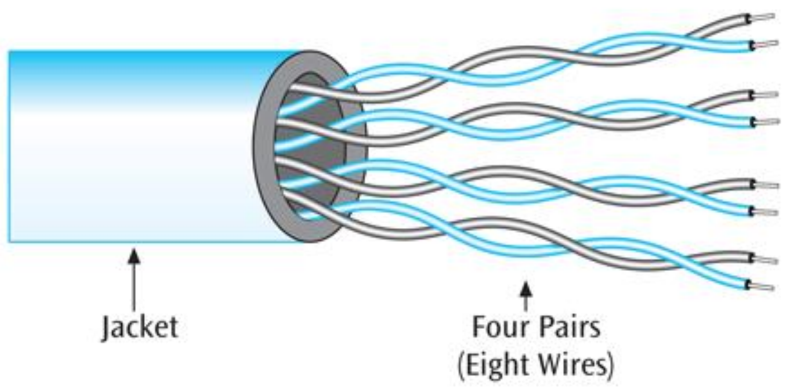
Media Type	Bandwidth	Performance	Repeater Spacing
Twisted-pair	1 MHz*	Poor to Fair $10^{-5} - 10^{-7}$	short 6,000ft/2km-analog 1,800ft/600m-digital
Coaxial cable	1 GHz	Good $10^{-7} - 10^{-9}$	short 8,000ft/2.5km
Microwave	100 GHz	Good $10^{-7} - 10^{-9}$	medium up to 45miles/72 km
Satellite	100 GHz	Good $10^{-7} - 10^{-9}$	long-very long up to 22,300miles/ 36,000 km for GEO
Fibre	75 THz	Great $10^{-11} - 10^{-13}$	long up to 4,000miles/6,000km

Twisted Pair Wire

- One or more pairs of single conductor wires are twisted across each other
- Twisted pair wire is classified by category 1 to 7. Although Categories 1, 2 and 4 are nearly obsolete
- Twisting the wires helps to eliminate electromagnetic interference
- Shielding can further help to eliminate interference

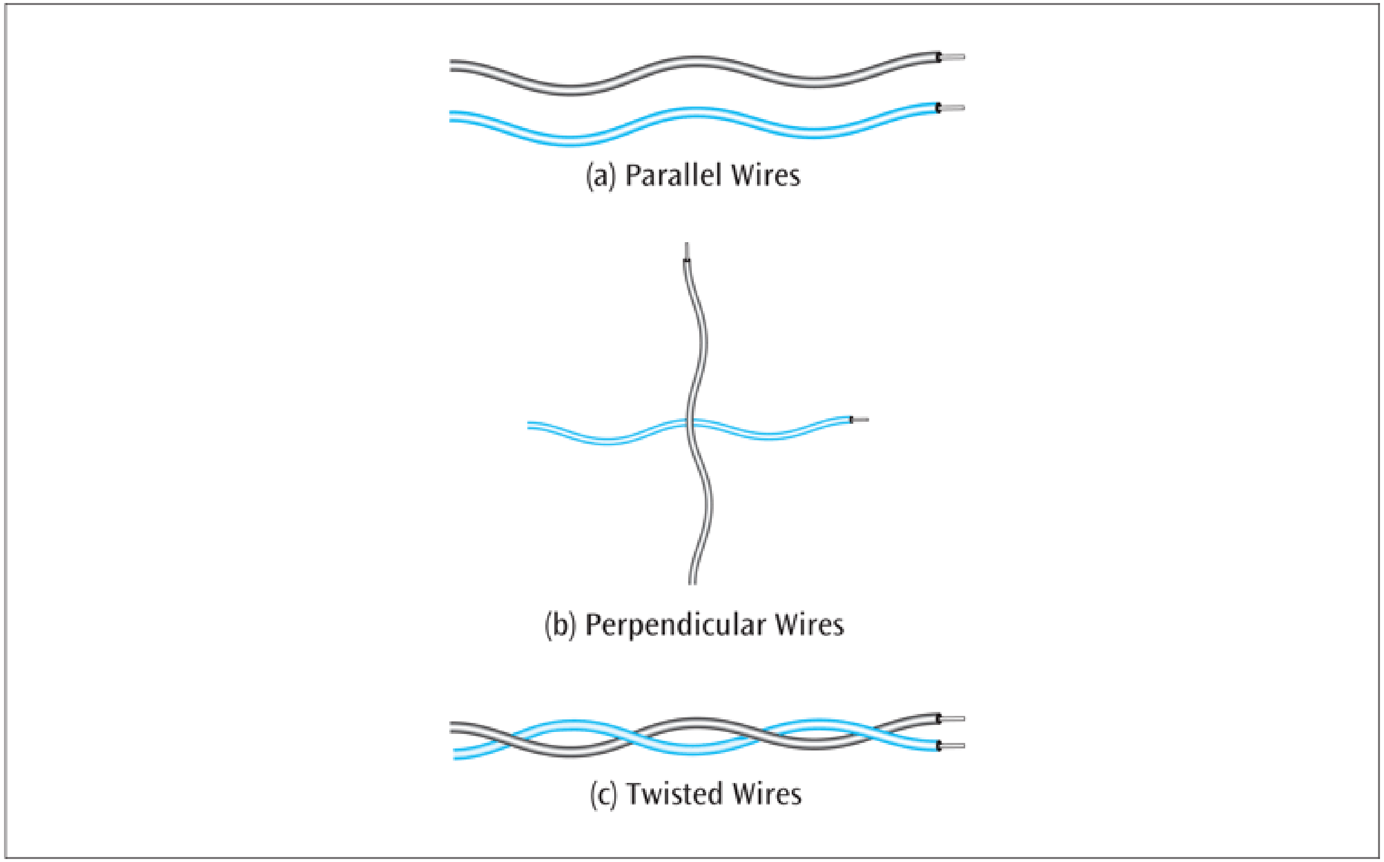
Twisted Pair Wire (continued)

Figure 3-1
Example of four-pair twisted pair wire



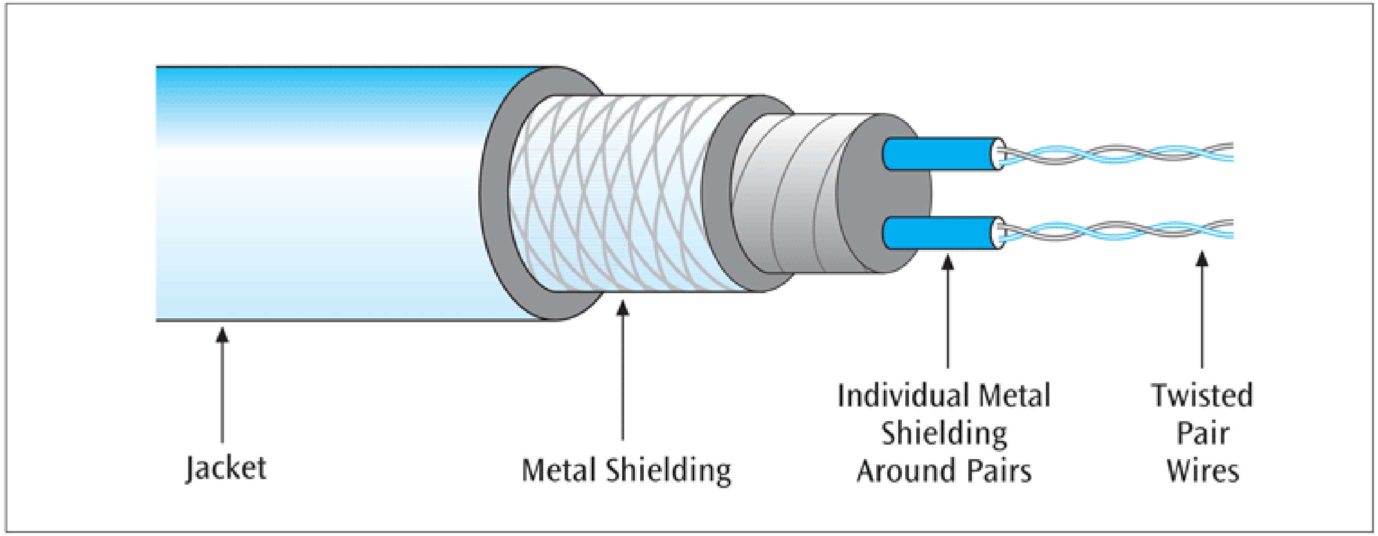
Twisted Pair Wire (continued)

Figure 3-2
(a) Parallel wires—greater chance of crosstalk
(b) Perpendicular wires—lesser chance of crosstalk
(c) Twisted wires—crosstalk reduced because wires keep crossing each other at nearly perpendicular angles



Twisted Pair Wire (continued)

Figure 3-3
An example of shielded twisted pair



Twisted Pair Wire (continued)

Table 3-1

A summary of the characteristics of twisted pair wires

UTP Category	Typical Use	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
Category 1	Telephone wire	<100 kbps	5–6 kilometers (3–4 miles)	Inexpensive, easy to install and interface	Security, noise, obsolete
Category 2	T-1, ISDN	<2 Mbps	5–6 kilometers (3–4 miles)	Same as Category 1	Security, noise, obsolete
Category 3	Telephone circuits	10 Mbps	100 m (328 ft)	Same as Category 1, with less noise	Security, noise
Category 4	LANs	20 Mbps	100 m (328 ft)	Same as Category 1, with less noise	Security, noise, obsolete
Category 5	LANs	100 Mbps (100 MHz)	100 m (328 ft)	Same as Category 1, with less noise	Security, noise
Category 5e	LANs	250 Mbps per pair (125 MHz)	100 m (328 ft)	Same as Category 5. Also includes specifications for connectors, patch cords, and other components	Security, noise
Category 6	LANs	250 Mbps per pair (250 MHz)	100 m (328 ft)	Higher rates than Category 5e, less noise	Security, noise, cost
Category 7	LANs	600 MHz	100 m (328 ft)	High data rates	Security, noise, cost

Twisted Pair Summary

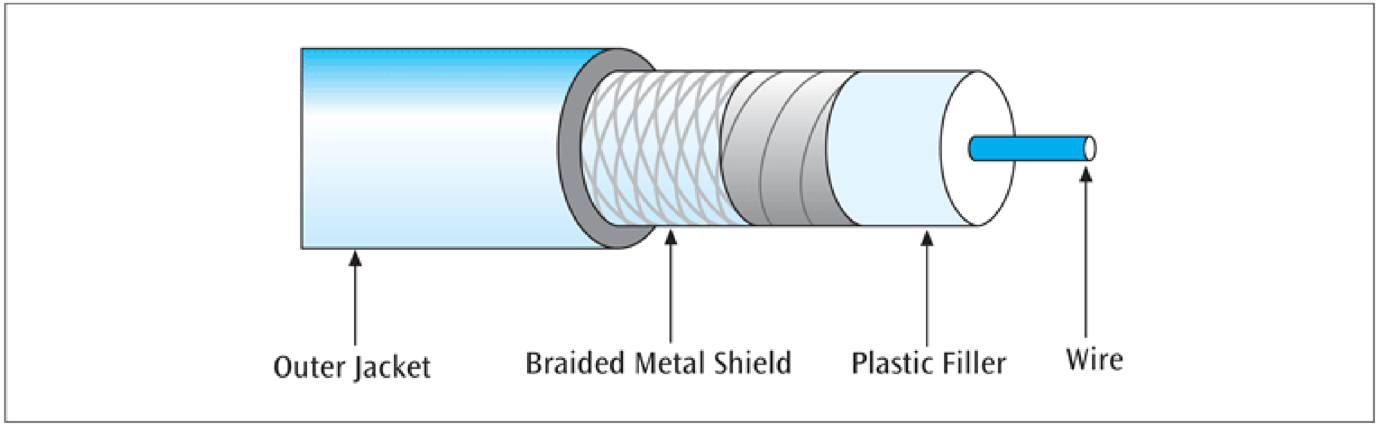
- Most common form of wire, largely available
- Relatively inexpensive
- Easy to install
- Limited frequency Spectrum
- Can suffer from electromagnetic noise, radio frequency interference
- High error rates
- Can be easily wire-tapped

Coaxial Cable

- A single wire wrapped in a foam insulation surrounded by a braided metal shield, then covered in a plastic jacket. Cable comes in various thicknesses
- Baseband coaxial technology uses digital signaling in which the cable carries only one channel of digital data
- Broadband coaxial technology transmits analog signals and can support multiple channels
- Better performance than twisted pair, large frequency spectrum (370, 550, 750 and 1000 MHz system), amplifiers are spaced at every 8000 feet /2.5 km

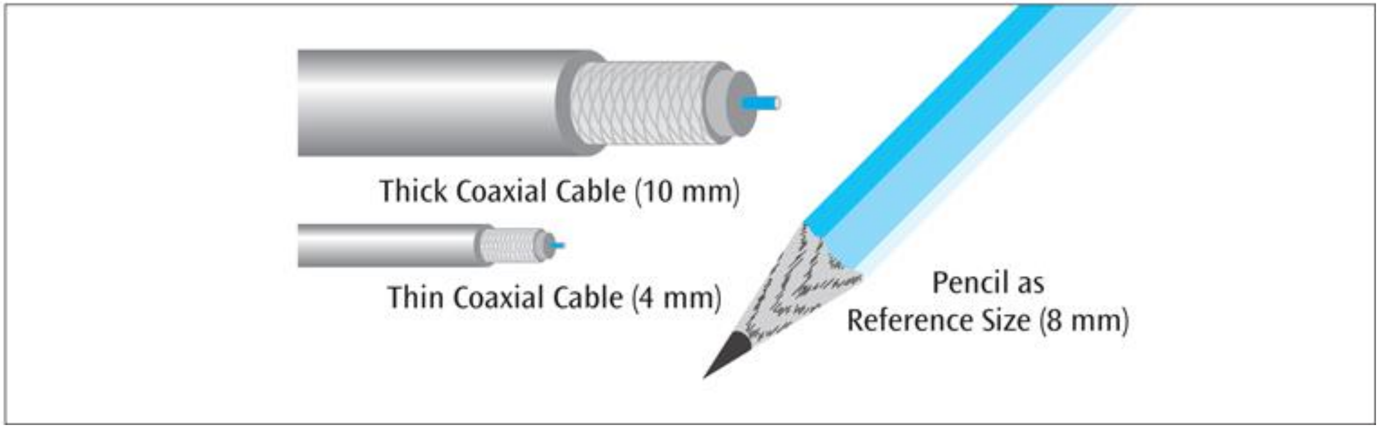
Coaxial Cable (continued)

Figure 3-4
Example of coaxial cable showing metal braid



Coaxial Cable (continued)

Figure 3-5
Examples of thick coaxial cable and thin coaxial cable



Coaxial Cable Summary

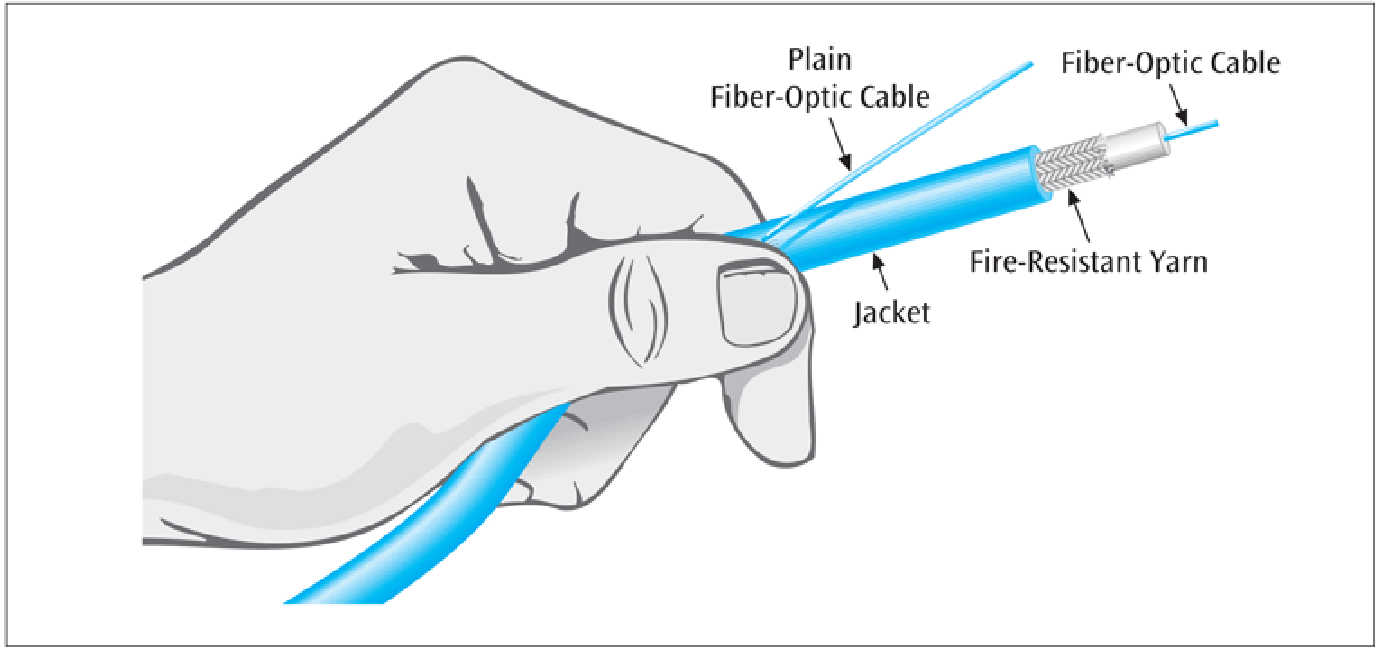
- Single wire surrounded by a braided shield
- Carry a wide bandwidth of frequencies to support high speed data and multimedia services
- Greater channel capacity
- Not as easy to install as twisted pair
- More expensive than twisted pair
- Low error rates due to distortion
- Higher spacing between repeaters due to shielding that overcome crosstalk and noise

Fiber-Optic Cable

- A thin glass cable approximately a little thicker than a human hair surrounded by a plastic coating and packaged into an insulated cable
- A photo diode or laser generates pulses of light which travel down the fiber optic cable and are received by a photo receptor

Fiber-Optic Cable (continued)

Figure 3-6
A person holding a plain fiber-optic cable and a fiber-optic cable in an insulated jacket



Fiber-Optic Cable (continued)

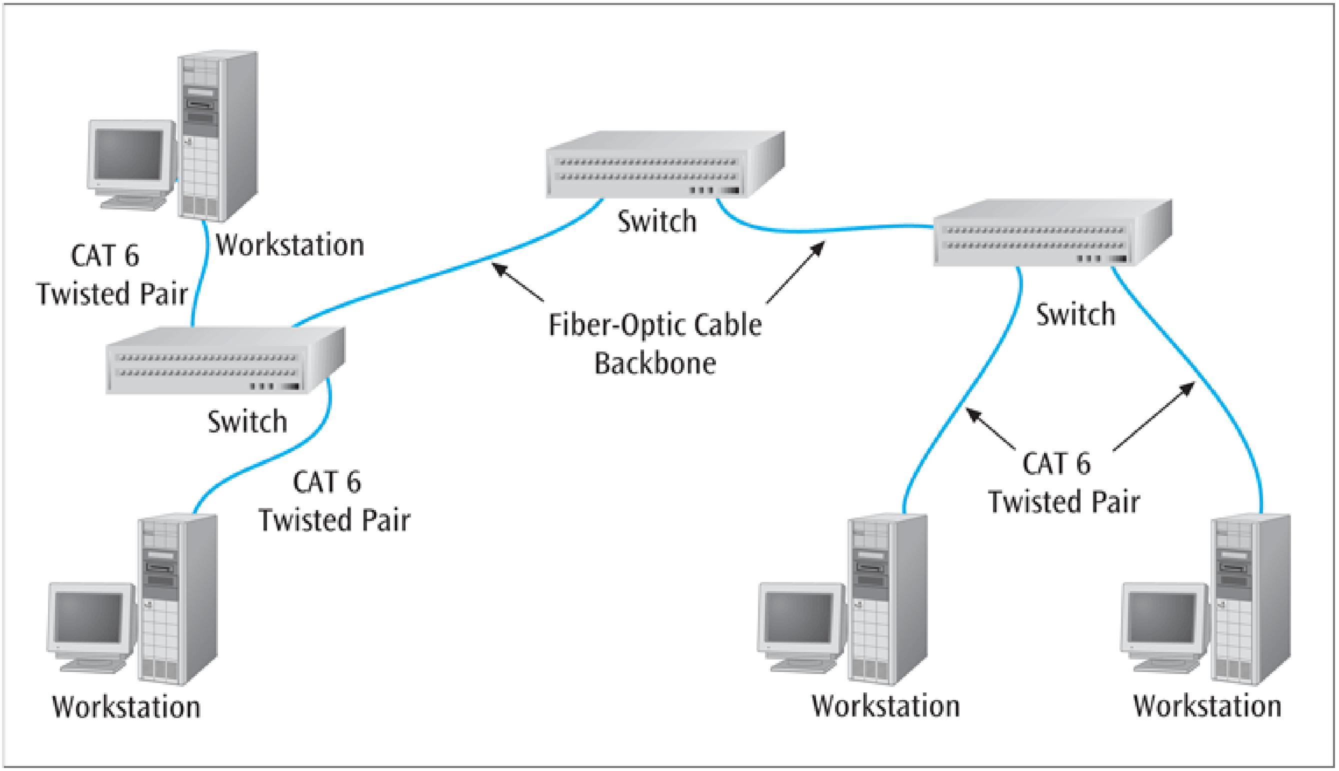
- Fiber-optic cable is capable of supporting millions of bits per second for 1000s of meters
- Thick cable (62.5/125 microns) causes more ray collisions, so you must transmit slower. This is step index multimode fiber. Typically use LED for light source, shorter distance transmissions
- Thin cable (8.3/125 microns) – very little reflection, fast transmission, typically uses a laser, longer transmission distances; known as single mode fiber

Fiber-Optic Cable (continued)

Figure 3-7
A fiber-optic cable with multiple strands of fiber

Fiber-Optic Cable (continued)

Figure 3-8
A fiber-optic backbone with Category 6 twisted pair running to the workstations



Fiber-Optic Cable (continued)

- Fiber-optic cable is susceptible to reflection (where the light source bounces around inside the cable) and refraction (where the light source passes out of the core and into the surrounding cladding)
- Thus, fiber-optic cable is not perfect either. Noise is still a potential problem
- Incurs high installation cost
- Vulnerable to physical damage and caused by flora or wildlife

Fiber-Optic Cable (continued)

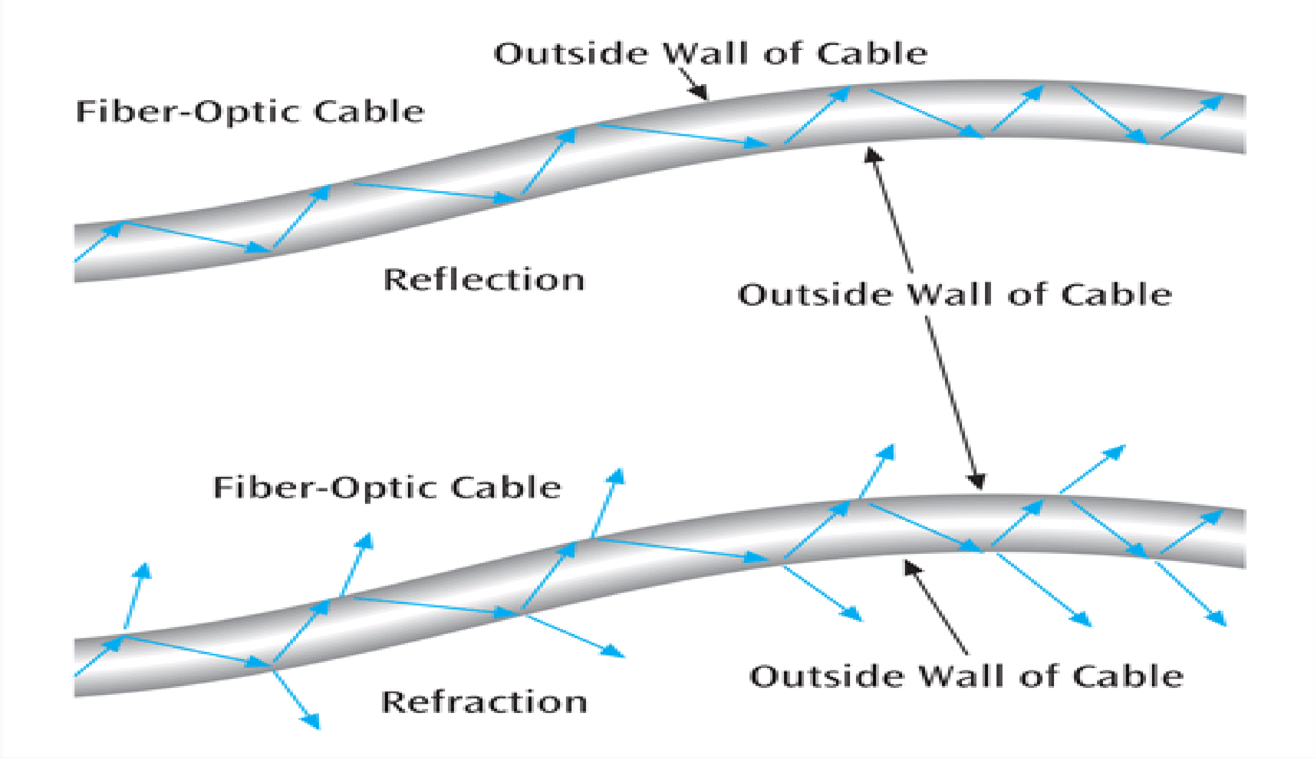


Figure 3-9 *A simple demonstration of reflection and refraction in a fiber-optic cable*

Fiber-Optic Cable Summary

- Fiber optic cable can carry the highest data rate for the longest distances
- Initial cost-wise, more expensive than twisted pair, but less than coaxial cable
- But when you consider the superiority of fiber, initial costs outweighed by capacities
- Low in weight and mass
- Not affected by electromagnetic noise and cannot be easily wiretapped, low error bit rate

Conducted Media

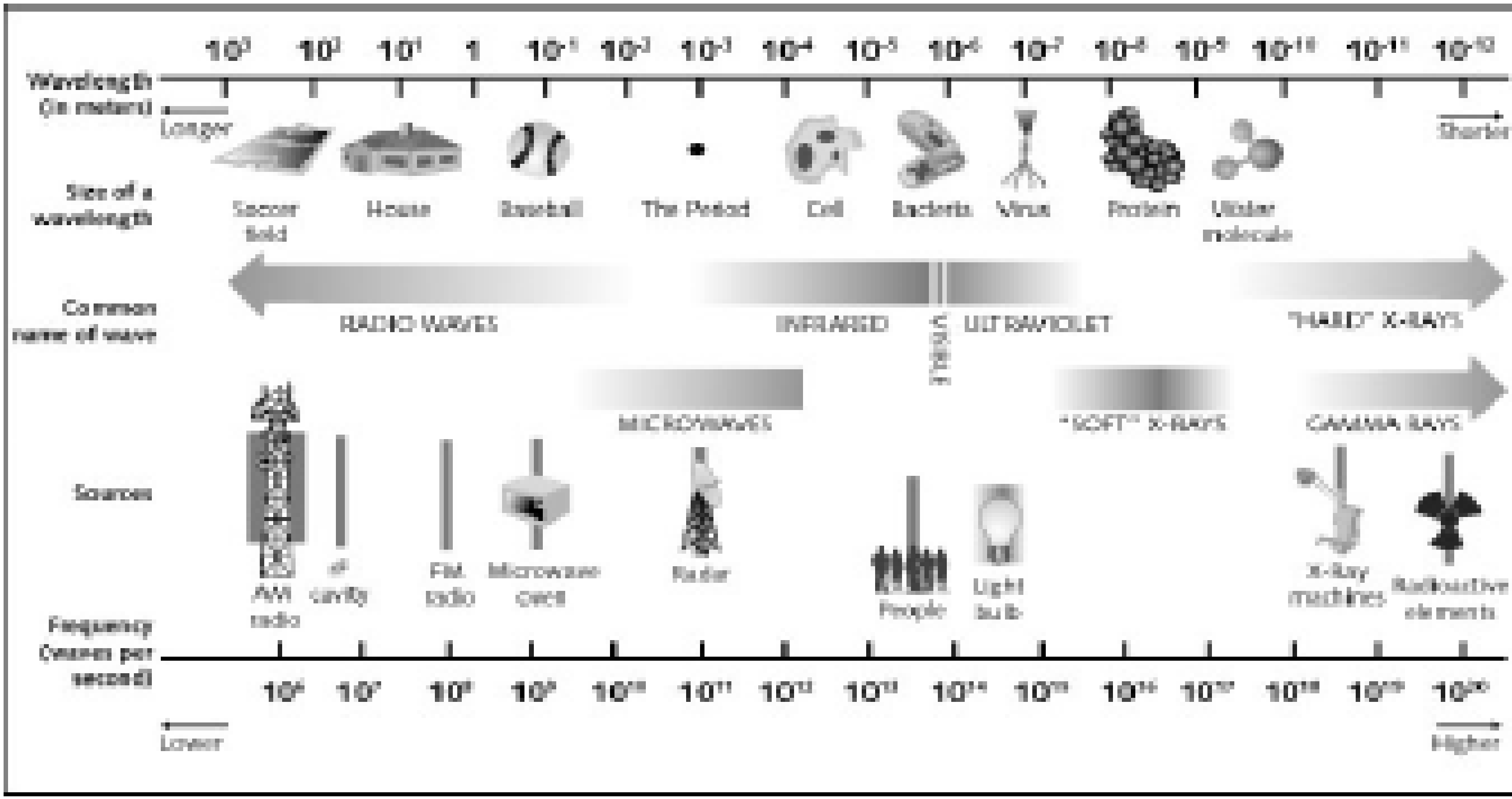
Table 3-3 A summary of the characteristics of conducted media

Type of Conducted Medium	Typical Use	Maximum Data Rate	Maximum Transmission Range	Advantages	Disadvantages
Twisted pair Category 1, 3	Telephone systems	<2 Mbps	5–6 kilometers (3–4 miles)	Inexpensive, common	Noise, security, obsolete
Twisted pair Category 5, 5e, 6, 7	LANs	100–1000 Mbps	100 m (328 feet)	Inexpensive, versatile	Noise, security
Thin Coaxial Cable (baseband single channel)	LANs	10 Mbps	100 m (328 feet)	Low noise	Security
Thick Coaxial Cable (broadband multichannel)	LANs, cable TV, long-distance telephone, short-run computer system links	10–100 Mbps	5–6 kilometers (3–4 miles) (at lower data rates)	Low noise, multiple channels	Security
LED Fiber-Optic	Data, video, audio, LANs	Gbps	300 meters (approx. 1000 feet)	Secure, high capacity, low noise	Interface expensive but decreasing in cost
Laser Fiber-Optic	Data, video, audio, WANs, MANs	100s Gbps	100 kilometers (approx. 60 miles)	Secure, high capacity, very low noise	Interface expensive

Wireless Media

- Radio, satellite transmissions, and infrared light are all different forms of electromagnetic waves that are used to transmit data
- Technically speaking – in wireless transmissions, space is the medium
- Two different types of waves
  - Infrared
  - Radio waves

Electromagnetic Spectrum



Terrestrial Microwave Transmission

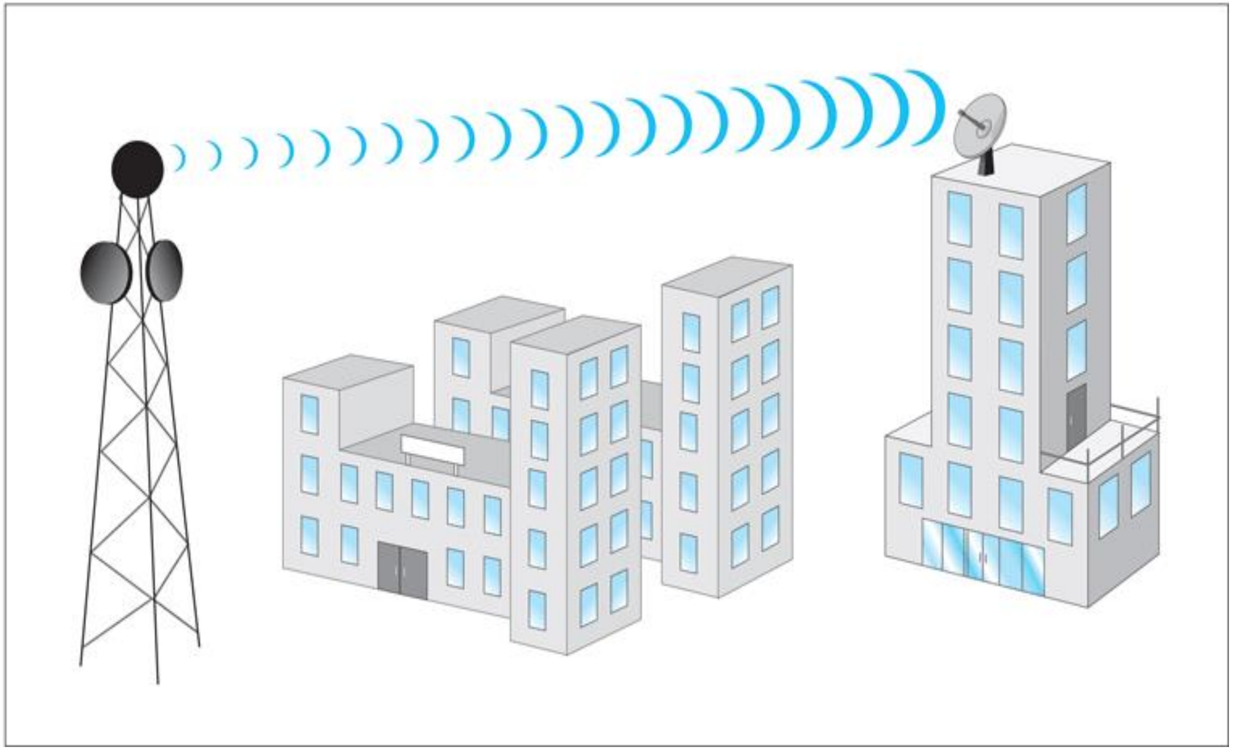
- Land-based, line-of-sight transmission
- Approximately 20-30 miles between towers
- Transmits data at hundreds of millions of bits per second
- Signals will not pass through solid objects
- Popular with telephone companies and business to business transmissions

Terrestrial Microwave Transmission (continued)

Figure 3-11
A typical microwave tower and antenna

Terrestrial Microwave Transmission (continued)

Figure 3-12
A microwave antenna on top of a free-standing tower transmitting to another antenna on the top of a building

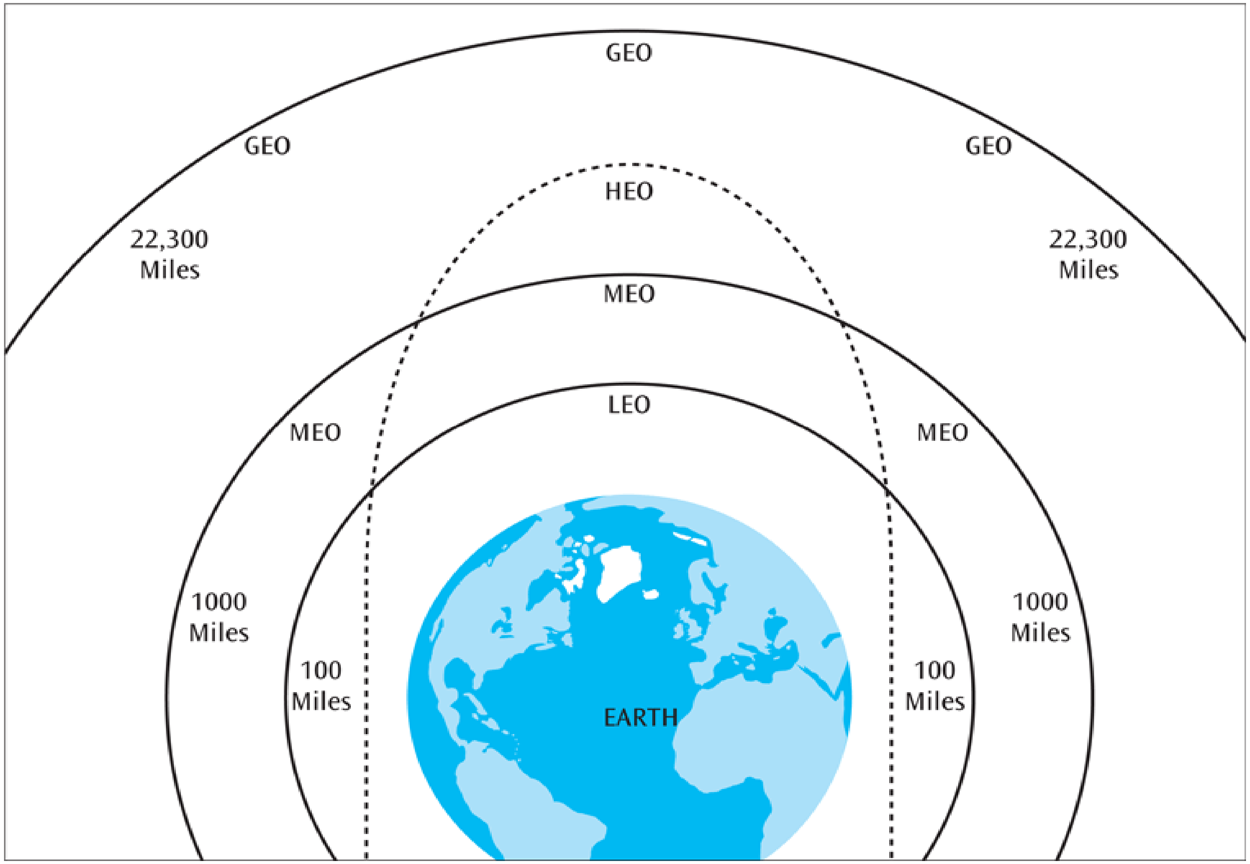


Satellite Microwave Transmission

- Like terrestrial microwave except the signal travels from a ground station on earth to a satellite and back to another ground station
- Can also transmit signals from one satellite to another
- Satellites can be classified by how far out into orbit each one is (LEO, MEO, GEO, and HEO)

Satellite Microwave Transmission (continued)

Figure 3-13
Earth and the four Earth orbits: LEO, MEO, GEO, and HEO



Satellite Microwave Transmission (continued)

LEO (Low-Earth-Orbit) – 100 to 1000 miles out
- Used for wireless e-mail, special mobile telephones, pagers, spying, videoconferencing

MEO (Middle-Earth-Orbit) – 1000 to 22,300 miles
- Used for GPS (global positioning systems) and government

GEO (Geosynchronous-Earth-Orbit) – 22,300 miles
- Always over the same position on earth (and always over the equator)
- Used for weather, television, government operations

Satellite Microwave Transmission (continued)

HEO (Highly Elliptical Earth orbit) – satellite follows an elliptical orbit

- Used by the military for spying and by scientific organizations for photographing celestial bodies

Satellite Microwave Transmission (continued)

Satellite microwave can also be classified by its configuration (see next figure):

- Bulk carrier configuration
- Multiplexed configuration
- Single-user earth station configuration (e.g., VSAT)

Satellite Microwave Transmission (continued)

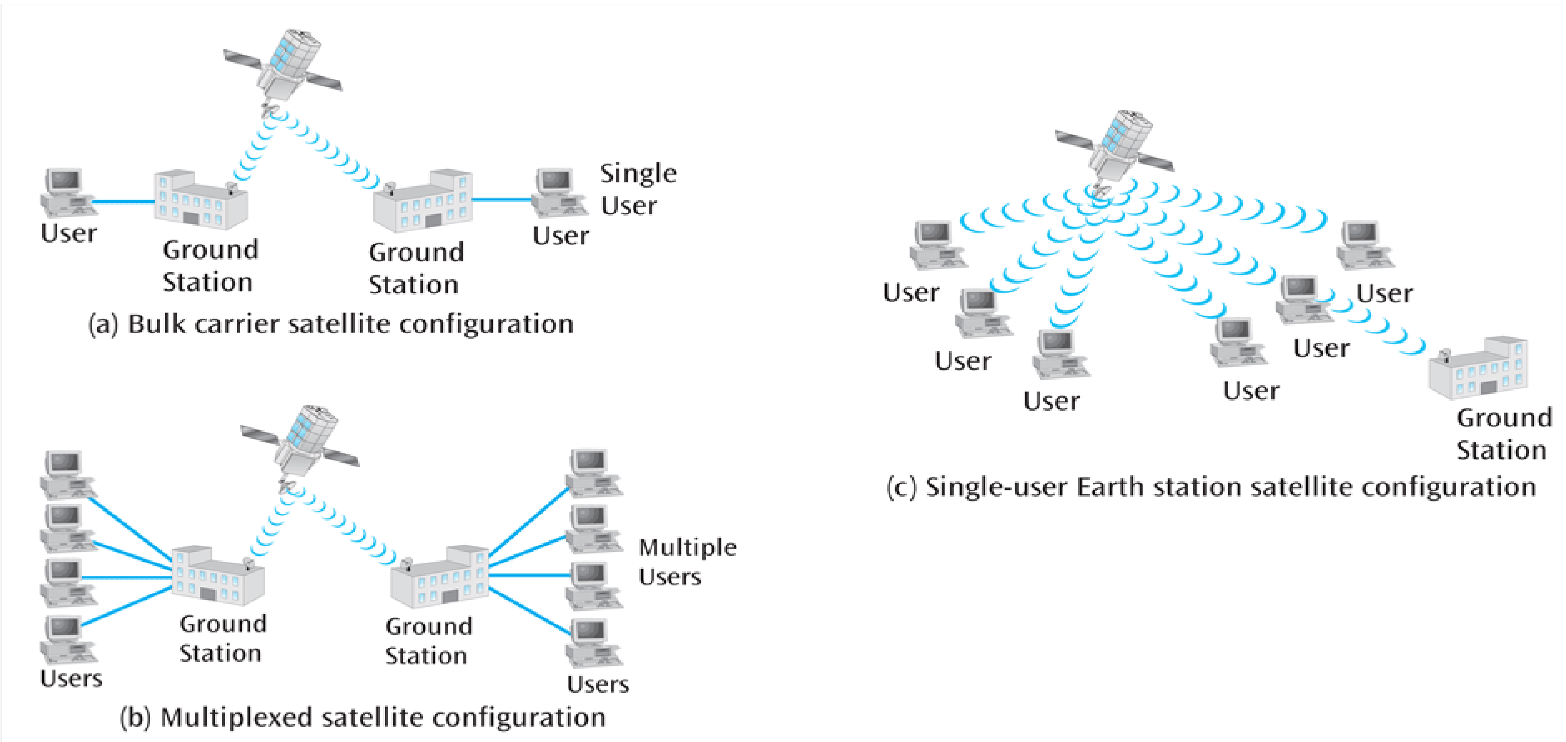
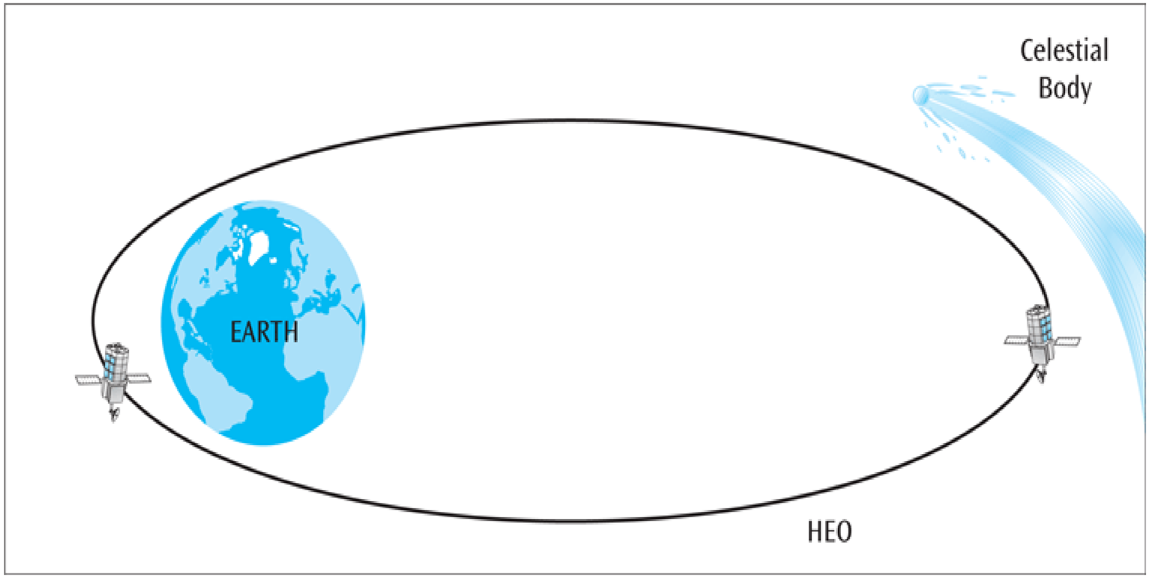


Figure 3-14 *Bulk carrier facilities, multiplexed Earth station, and single-user Earth station configurations of satellite systems*

Satellite Microwave Transmission (continued)

Figure 3-15
Diagram of a highly elliptical Earth orbit satellite



Satellite Microwave Transmission (continued)

Band Number	Symbol	Frequency	Common Use
4	VLF (very low frequency)	3–30 kHz	Radio navigations systems
5	LF (low frequency)	30–300 kHz	Radio beacons
6	MF (medium frequency)	300 kHz–3 MHz	AM radio
7	HF (high frequency)	3–30 MHz	CB radio
8	VHF (very high frequency)	30–300 MHz	VHF TV, FM radio
9	UHF (ultra high frequency)	300 MHz–3 GHz	UHF TV, cell phones, pagers
10	SHF (superhigh frequency)	3–30 GHz	Satellite
11	EHF (extremely high freq)	30–300 GHz	Satellite, radar systems

Satellite Microwave Transmission (continued)

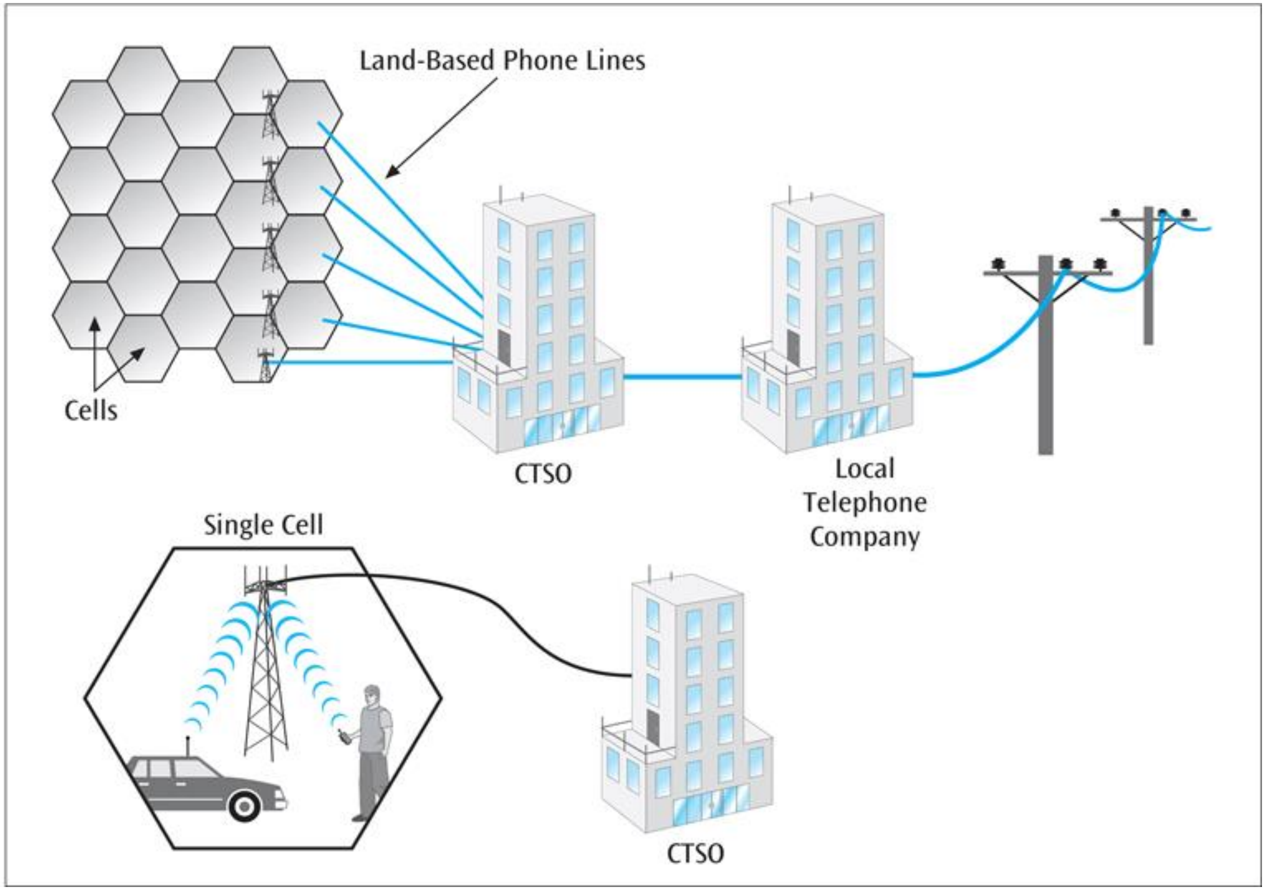
Radar Band	Frequency	Common Use
L	~1–2 GHz	GPS, government use, GSM cell phones
S	2–4 GHz	Weather systems, digital satellite radio system
C	4–8 GHz	Commercial satellite systems
X	~7–12.5 GHz	Some communication satellites, weather
Ku	12–18 GHz	NASA, television station remotes to station
Ka	18–40 GHz	Communication satellites
V	50–75 GHz	Not heavily used
W	75–111 GHz	Misc (military, car radar systems)

Cellular Telephones

- Wireless telephone service, also called mobile telephone, cell phone, and PCS
- To support multiple users in a metropolitan area (market), the market is broken into cells
- Each cell has its own transmission tower and set of assignable channels

Cellular Telephones (continued)

Figure 3-16
One cellular telephone market divided into cells



Cellular Telephones (continued)

Figure 3-17
A cellular telephone tower

Cellular Telephones (continued)

Figure 3-18
Cell phone towers disguised as trees

Cellular Telephones (continued)

1st Generation

- AMPS (Advanced Mobile Phone Service) – first popular cell phone service; used analog signals and dynamically assigned channels
- D-AMPS (Digital AMPS) – applied digital multiplexing techniques on top of AMPS analog channels

Cellular Telephones (continued)

2nd Generation

- PCS (Personal Communication Systems) – essentially all-digital cell phone service
- PCS phones came in three technologies:
  - TDMA – Time Division Multiple Access
  - CDMA – Code Division Multiple Access
  - GSM – Global System for Mobile Communications

Cellular Telephones (continued)

2.5 Generation

- AT&T Wireless, Cingular Wireless, and T-Mobile now using GPRS (General Packet Radio Service) in their GSM networks (can transmit data at 30 kbps to 40 kbps)
- Verizon Wireless, Alltel, US Cellular, and Sprint PCS are using CDMA2000 1xRTT (one carrier radio- transmission technology) (50 kbps to 75 kbps)
- Nextel uses IDEN technology

Cellular Telephones (continued)

3rd Generation

- UMTS (Universal Mobile Telecommunications System) – also called Wideband CDMA
  - The 3G version of GPRS
  - UMTS not backward compatible with GSM (thus requires phones with multiple decoders)
- 1XEV (1 x Enhanced Version) –3G replacement for 1xRTT
  - two forms:
    - 1xEV-DO for data only
    - 1xEV-DV for data and voice

Cellular Telephones (continued)

4th Generation

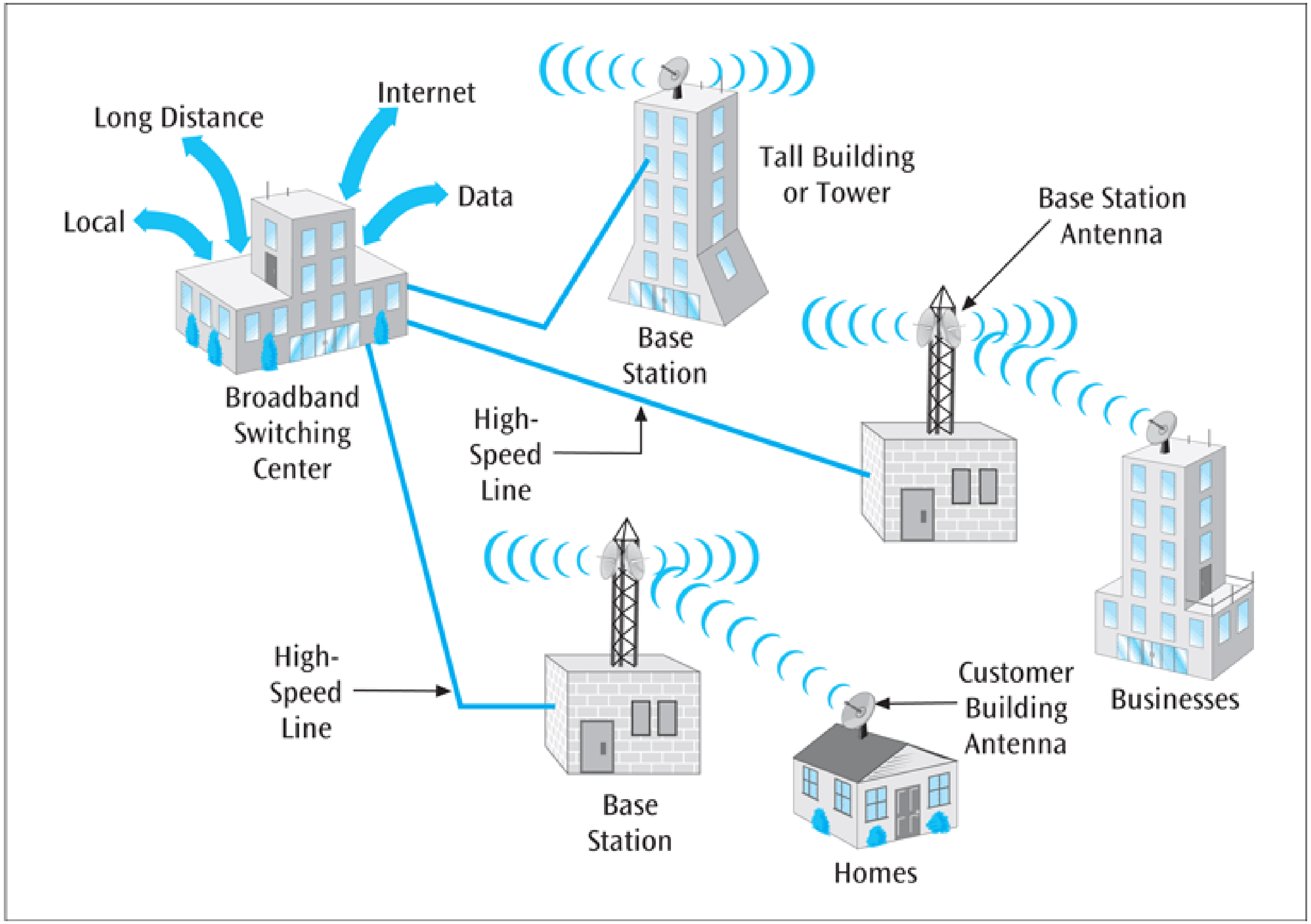
- LTE (Long Term Evolution) – theoretical speeds of 100 Mbps or more, actual download speeds 10-15 Mbps
- WiMax – theoretical speeds of 128 Mbps; actual download speeds 4 Mbps (didn’t make it for cellular)
- HSPA (High Speed Packet Access) – 14 Mbps downlink, 5.8 Mbps uplink; (didn’t make it)
- HSPA+ – theoretical downlink of 84 Mbps, 22 Mbps uplink (T-Mobile) (didn’t make it)

WiMax - Broadband Wireless Systems

- Delivers Internet services into homes, businesses and mobile devices
- Designed to bypass the local loop telephone line
- Transmits voice, data, and video over high frequency radio signals
- Maximum range of 20-30 miles and transmission speeds in Mbps
- IEEE 802.16 set of standards

WiMax (continued)

Figure 3-19
Broadband wireless configuration in a metropolitan area



Bluetooth

- Bluetooth is a specification for short-range, point-to-point or point-to-multipoint voice and data transfer
- Bluetooth can transmit through solid, non-metal objects
- Its typical link range is from 10 cm to 10 m, but can be extended to 100 m by increasing the power

Bluetooth (continued)

- Bluetooth will enable users to connect to a wide range of computing and telecommunication devices without the need of connecting cables
- Typical uses include phones, pagers, modems, LAN access devices, headsets, notebooks, desktop computers, and PDAs

Ultra-Wideband

- UWB not limited to a fixed bandwidth but broadcasts over a wide range of frequencies simultaneously
- Many of these frequencies are used by other sources, but UWB uses such low power that it “should not” interfere with these other sources
- Can achieve speeds up to 100 Mbps but for small distances such as wireless LANs

Ultra-Wideband (continued)

- Proponents for UWB say it gets something for nothing, since it shares frequencies with other sources. Opponents disagree
- Cell phone industry against UWB because CDMA most susceptible to interference of UWB
- GPS may also be affected
- One solution may be to have two types of systems – one for indoors (stronger) and one for outdoors (1/10 the power)

Infrared Transmissions

- Transmissions that use a focused ray of light in the infrared frequency range
- Very common with remote control devices, but can also be used for device-to-device transfers, such as PDA to computer
- Less susceptible to interference

Near-Field Communications

- Used for very close distances or devices touching
- Magnetic induction (such as radio frequency ID) used for transmission of data
- Commonly used for data transmission between cellphones (non-Apple devices)

ZigBee

- Based upon IEEE 802.15.4 standard
- Used for low data transfer rates (20-250 Kbps)
- Also uses low power consumption
- Ideal for heating, cooling, security, lighting, and smoke and CO detector systems
- ZigBee can use a mesh design – a ZigBee-enabled device can both accept and then pass on ZigBee signals

Wireless Media (continued)

Table 3-4 Summary of wireless media

Type of Wireless Medium	Typical Use	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
Terrestrial Microwave	Long-haul telecommunications, building to building	100s-Mbps	20–30 miles	Reliable, high speed, high volume	Long haul, expensive to implement, line-of-sight
Satellite LEO	Communications such as e-mail, paging, worldwide mobile phone network, spying, remote sensing, video conferencing	100s-Mbps	Depends on number of satellites	High-speed transfers, very wide distance, some applications inexpensive	Some applications expensive, interference
Satellite MEO	GPS-style surface navigation systems	100s-Mbps	Depends on number of satellites	High-speed transfers, wide distance	Expensive to lease, some interference
Satellite GEO	Signal relays for cable and direct television	100s-Mbps	One-third the Earth's circumference (8000 miles)	Very long distance, high speed, and high volume	Expensive to lease, some interference
Satellite HEO	Global surveillance, scientific applications	100s-Mbps	Variable	Variability of distance	Expensive
Cellular (AMPS and D-AMPS)	Cellular telephones	19.2 kbps	Each cell: 0.5–50 mile radius, but nationwide coverage	Widespread, inexpensive applications	Noise
PCS	Cellular telephones	9.6 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	Slow data rates
GPRS, 1xRTT	Cellular telephones	30–75 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	Slow data rates

Wireless Media (continued)

Type of Wireless Medium	Typical Use	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
UMTS	Cellular telephones	320 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	
EV-DO	Cellular telephones	500 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	
Infrared	Short-distance data transfer	16 Mbps	1.5 miles	Fast, inexpensive, secure	Short distances, line-of-sight
WiMAX	Wireless Internet access	30 Mbps	30 miles	High speed	
Bluetooth	Short-distance transfer	722 kbps	30 feet (10 meters)	Universal protocol	Limited Distances
Wireless LANs	Local area networks	100 Mbps	<328 feet (<100 meters)	Relative ease of use	Several standards
Free Space Optics	Short-distance, high-speed transfers	45 Mbps	1000s feet (100s meters)	High speed	Line-of-sight, affected by fog
Ultra-wideband	Short-distance, high-speed transfers	100 Mbps	<328 feet (100 meters)	High speed, not restricted to fixed frequencies	May interfere with other sources
Near-field communications	Very short distances, high-speed transfers	Depends upon underlying technology	Inches	High speeds	Only for short distances
ZigBee	Short-to-medium distance, low-speed transfers	250 Kbps	Unlimited distance (mesh)	Low power	Low transfer speeds

Media Selection Criteria

Cost

Speed

Distance and expandability

Environment

Security

Cost

- Different types of costs
  - Initial cost – what does a particular medium cost to purchase? To install?
  - Maintenance / support cost
- ROI (return on investment) – if one medium is cheaper to purchase and install but is not cost effective, where are the savings?

Speed

Two different forms of speed:

- **Propagation speed** – the time to send the first bit across the medium
  - This speed depends upon the medium
  - Airwaves and fiber are speed of light
  - Copper wire is two thirds the speed of light
- **Data transfer speed** – the time to transmit the rest of the bits in the message
  - This speed is measured in bits per second

Expandability and Distance

- Certain media lend themselves more easily to expansion
- Don’t forget right-of-way issue for conducted media and line-of-sight for certain wireless media

Environment

Many types of environments are hazardous to certain media

- Electromagnetic noise
- Scintillation and movement
- Extreme environmental conditions

Security

If data must be secure during transmission, it is important that the medium not be easy to tap

- Make the wire impervious to electromagnetic wiretapping
- Encrypt the signal going over the medium

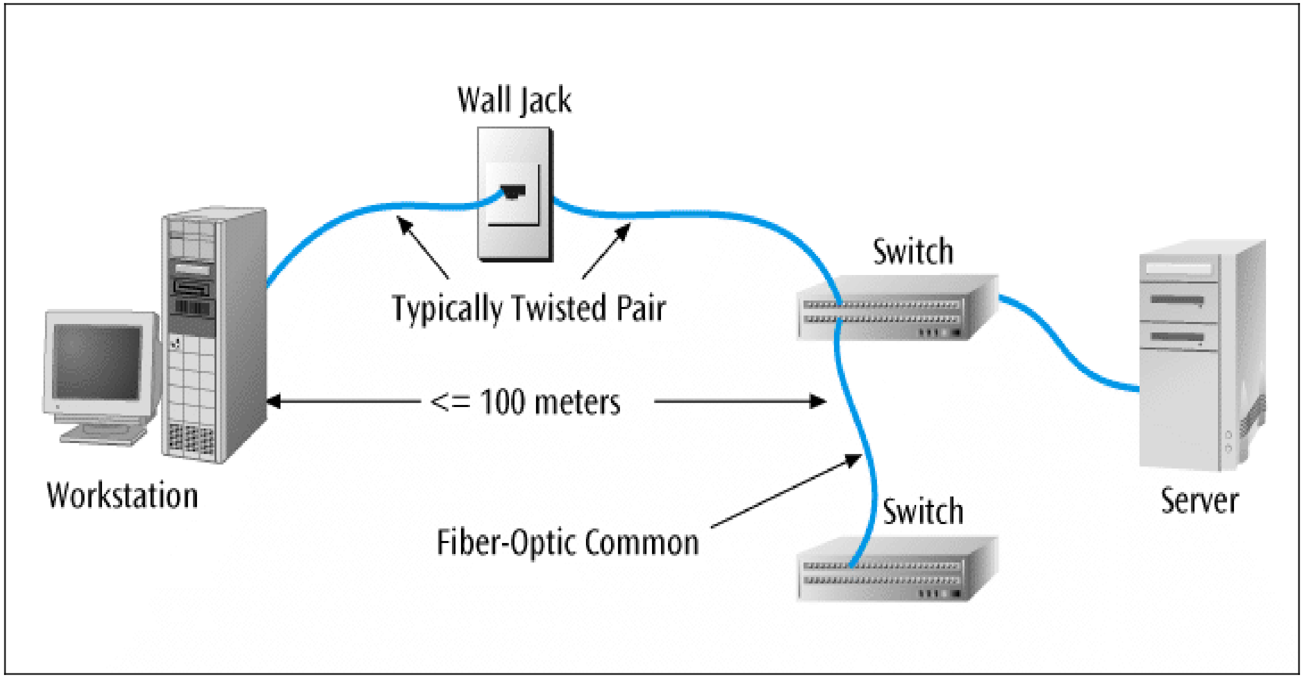
Conducted Media in Action: Two Examples

First example – simple local area network

- Hub typically used
- To select proper medium, consider:
  - Cable distance
  - Data rate

Conducted Media in Action: Two Examples (continued)

Figure 3-20
Example of a wiring situation involving a workstation and a local area network



Conducted Media in Action: Two Examples (continued)

Second example – company wishes to transmit data between buildings that are one mile apart

- Is property between buildings owned by company?
  - If not consider using wireless
  - When making decision, need to consider:
    - Cost
    - Speed
    - Expandability and distance
    - Environment
    - Security

Wireless Media In Action: Three Examples

First example – you wish to connect two computers in your home to Internet, and want both computers to share a printer

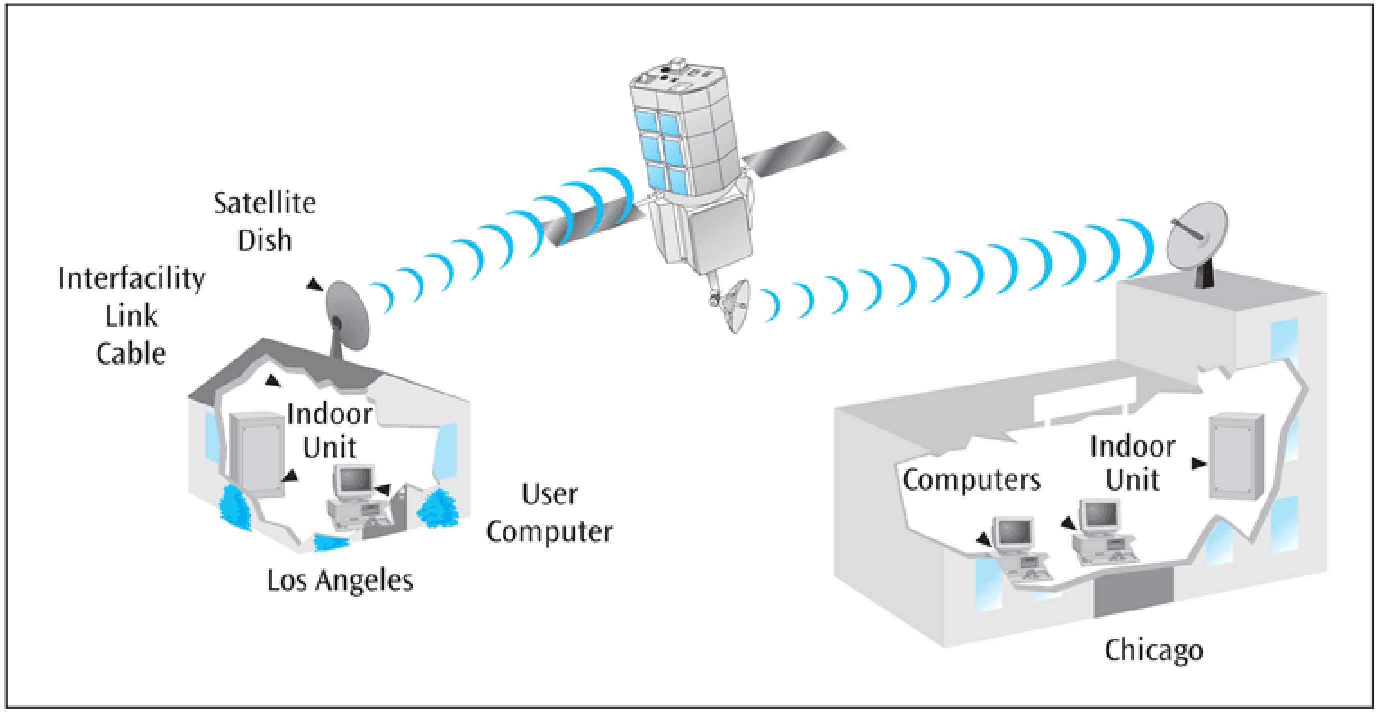
- Can purchase wireless network interface cards
- May consider using Bluetooth devices

Second example – company wants to transmit data between two locations, Chicago and Los Angeles

- Company considering two-way data communications service offered through VSAT satellite system

Wireless Media In Action: Three Examples (continued)

Figure 3-21
VSAT satellite solution for DataMining Corporation



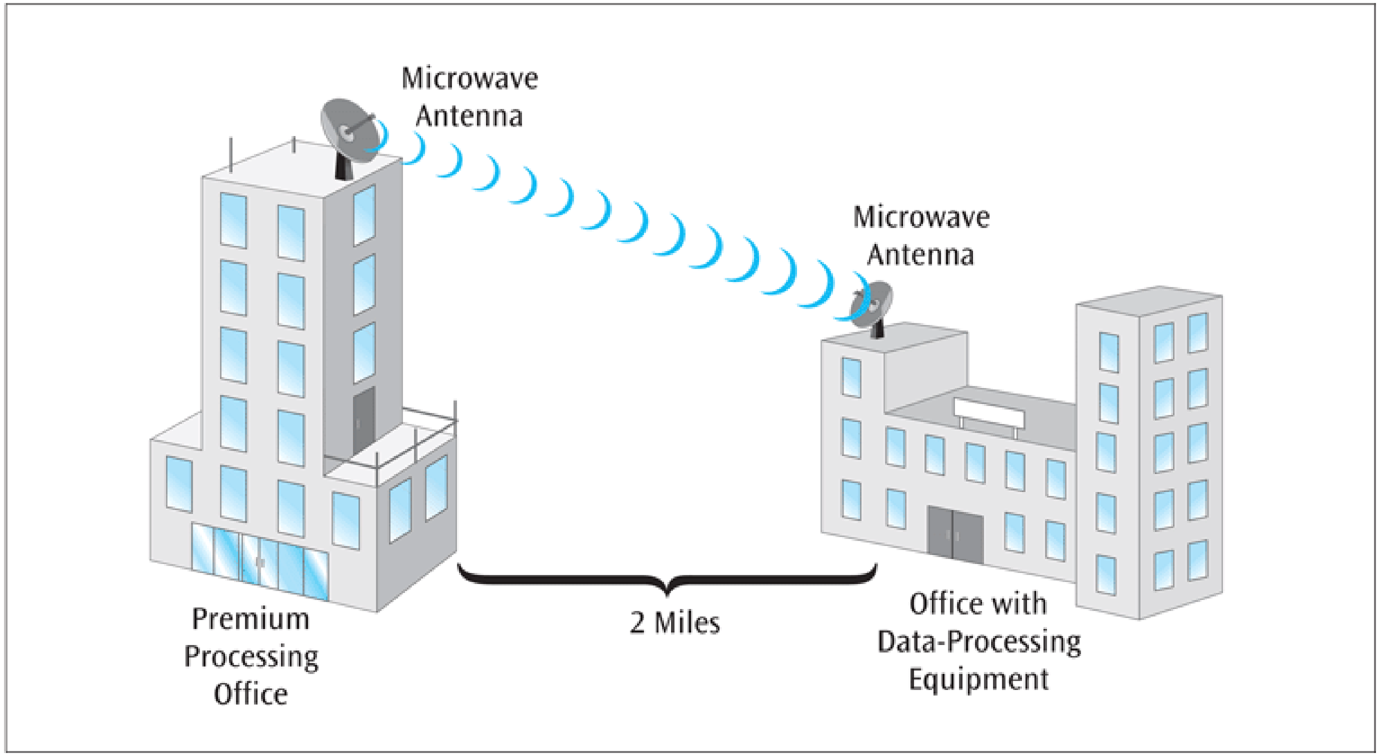
Wireless Media In Action: Three Examples (continued)

Third example – second company wishes to transmit data between offices two miles apart

- Considering terrestrial microwave system

Wireless Media In Action: Three Examples (continued)

Figure 3-22
Microwave communication between American Insurance's corporate buildings



Readings

Chapter 3 of the Textbook