

Data Communications

รศ.ดร. อรฉัตร จิตต์โสภกตร์

Email: orachat.ch@kmitl.ac.th

Tel: (02) 329-8341-2

Room: ECC-915

Topics

- o Layer 1: Physical Layer
 - o Ch 7: Transmission media (Physical)
 - o Ch 9: High speed digital access (Service)
- o Layer 2: Data Link Layer
 - o Ch 10: Error detection and correction
 - o Ch 11: Flow control
 - o Ch12: Point-to-Point Protocol
 - o Ch13: Multiple Access Protocol
- o Ch 14: Introduction to LAN

สัดส่วนของคะแนนที่เหลือ

- Activity 5%
- Quiz 5%
- Final 30%
- Assignment 20%

Chapter 7

Transmission Media

Figure 7.1 *Transmission medium and physical layer*

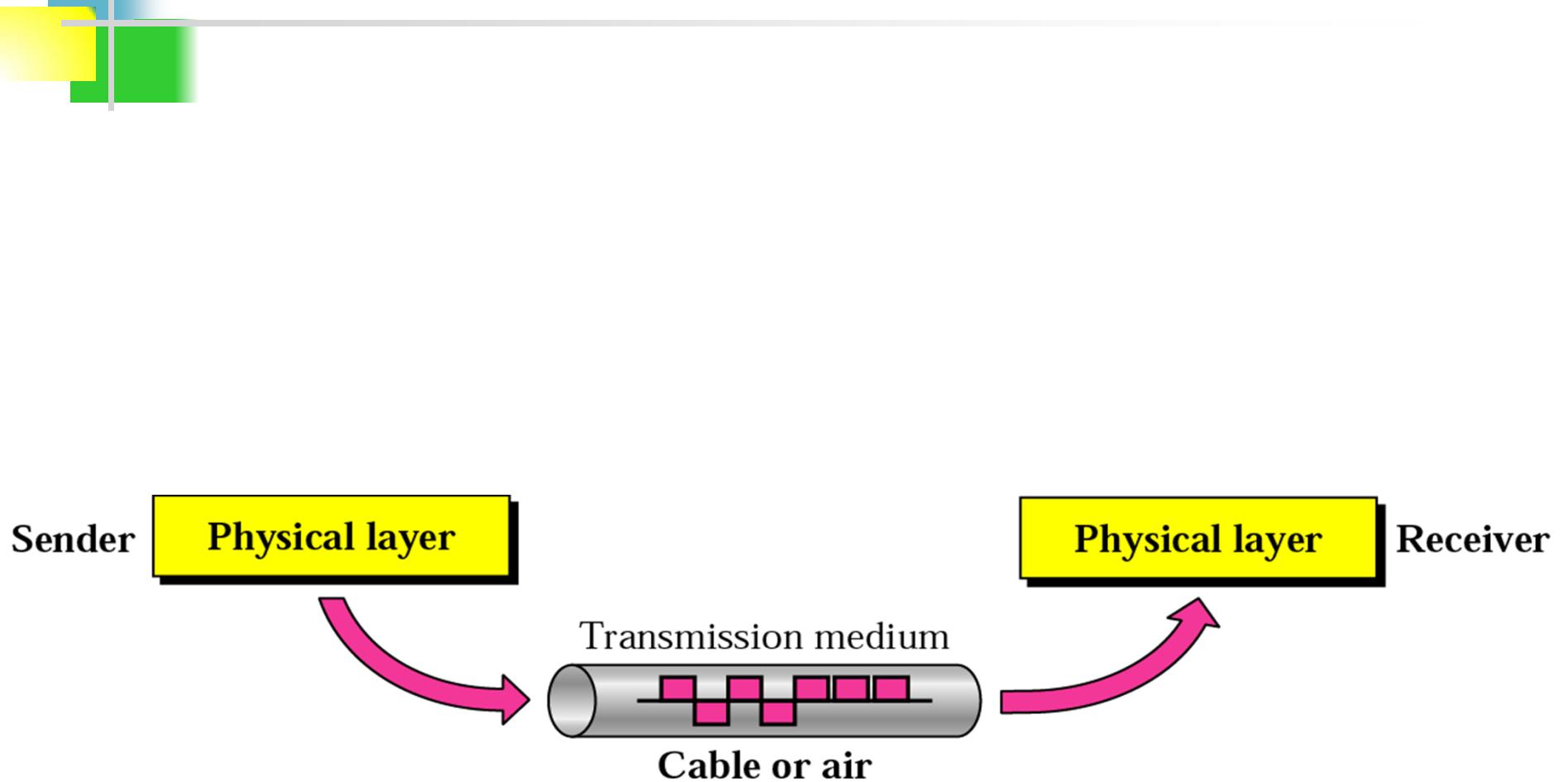
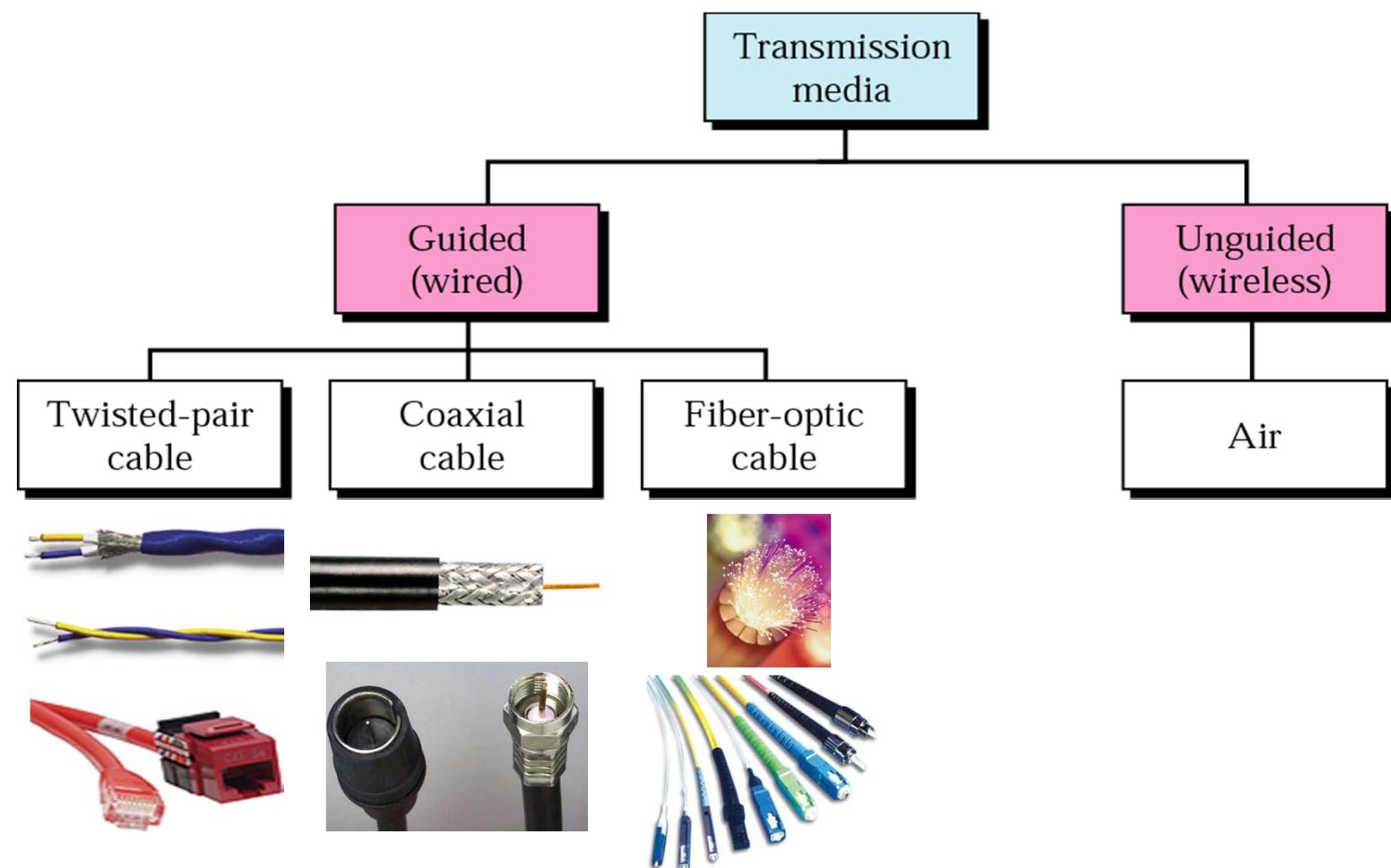


Figure 7.2 Classes of transmission media



MEDIA SELECTION CRITERIA

- Cost
 - Purchasing (owning)
 - Rent (Monthly or Leasing)
 - Maintenance
- Speed
 - Bandwidth
- Distance
 - Attenuation (depending on frequency)
 - Electromagnetic noise
- Delay
 - Propagation speed
- Expandability
- Environment
- Security

7.1 Guided Media

Twisted-Pair Cable

Coaxial Cable

Fiber-Optic Cable

Twisted Pair Cable

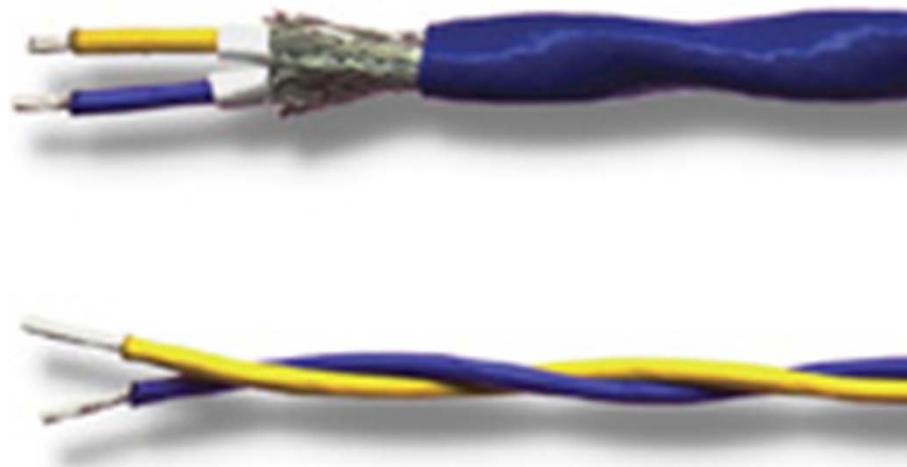


Figure 7.3 Twisted-pair cable

BW_{twisted-pair cable} = 5 MHz

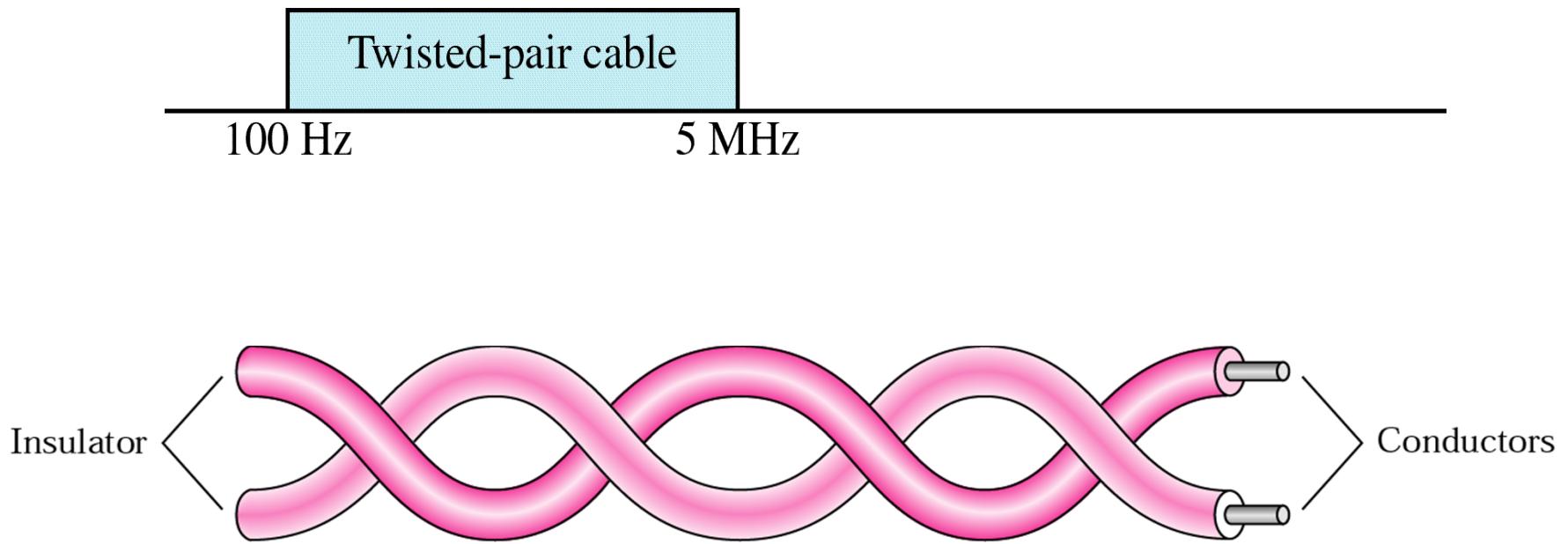
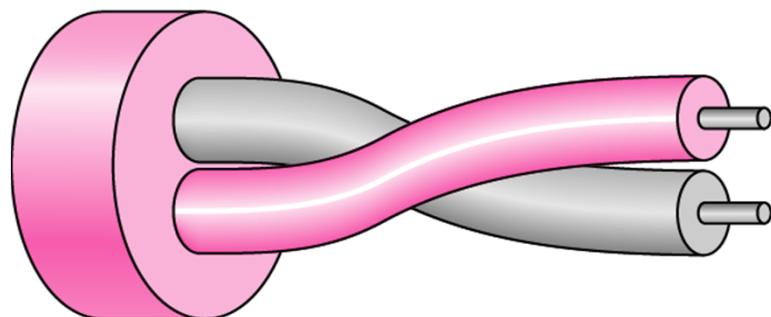
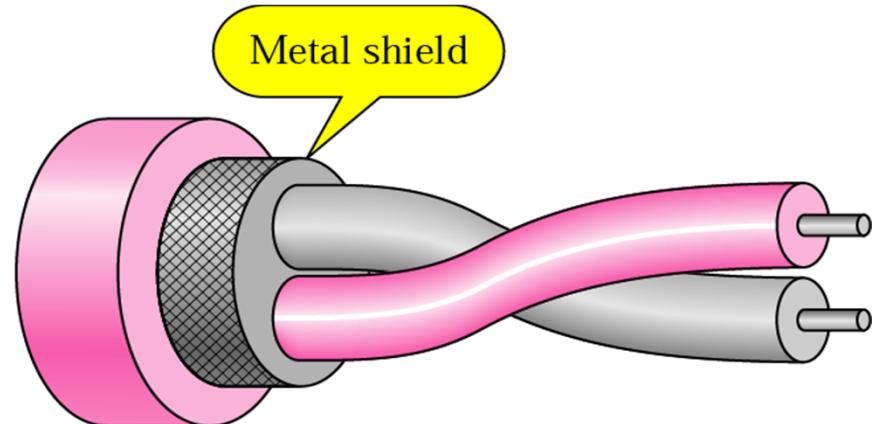


Figure 7.4 UTP and STP

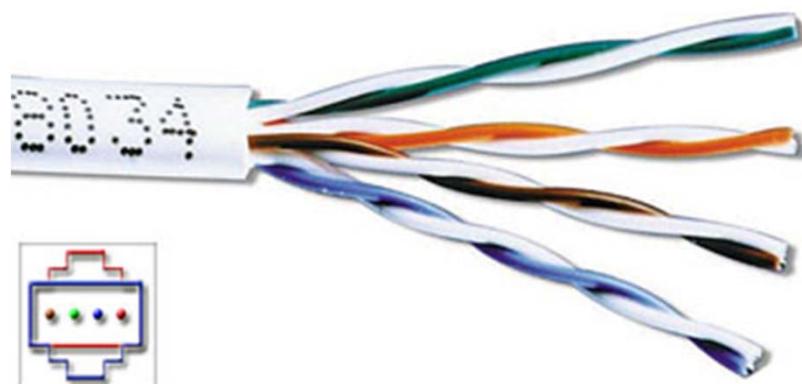


a. UTP



b. STP

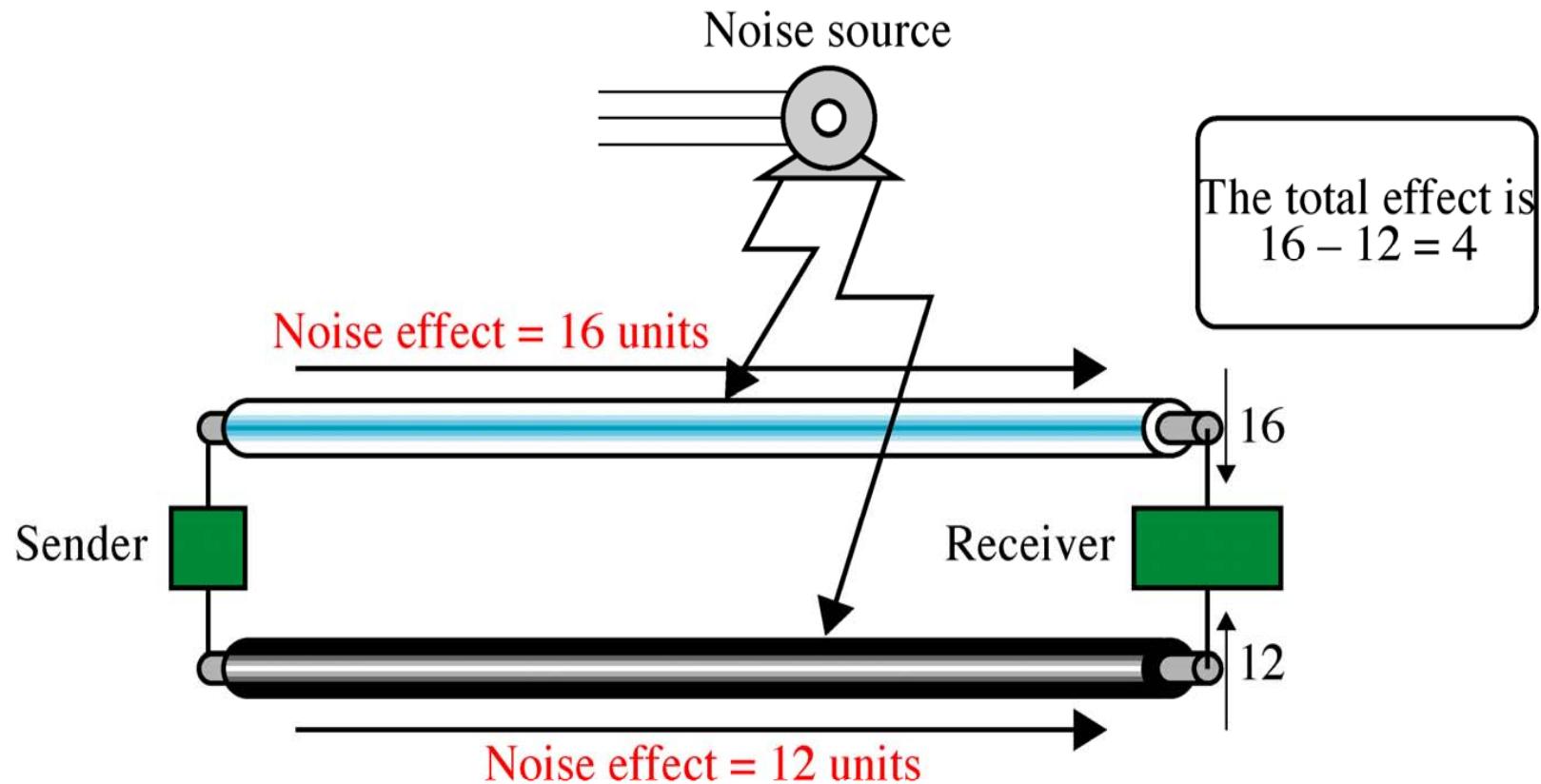
Unshielded twisted pair (UTP)



Shielded twisted pair (STP)



Effect of Noise on Parallel Lines



Noise on Twisted-Pair Lines

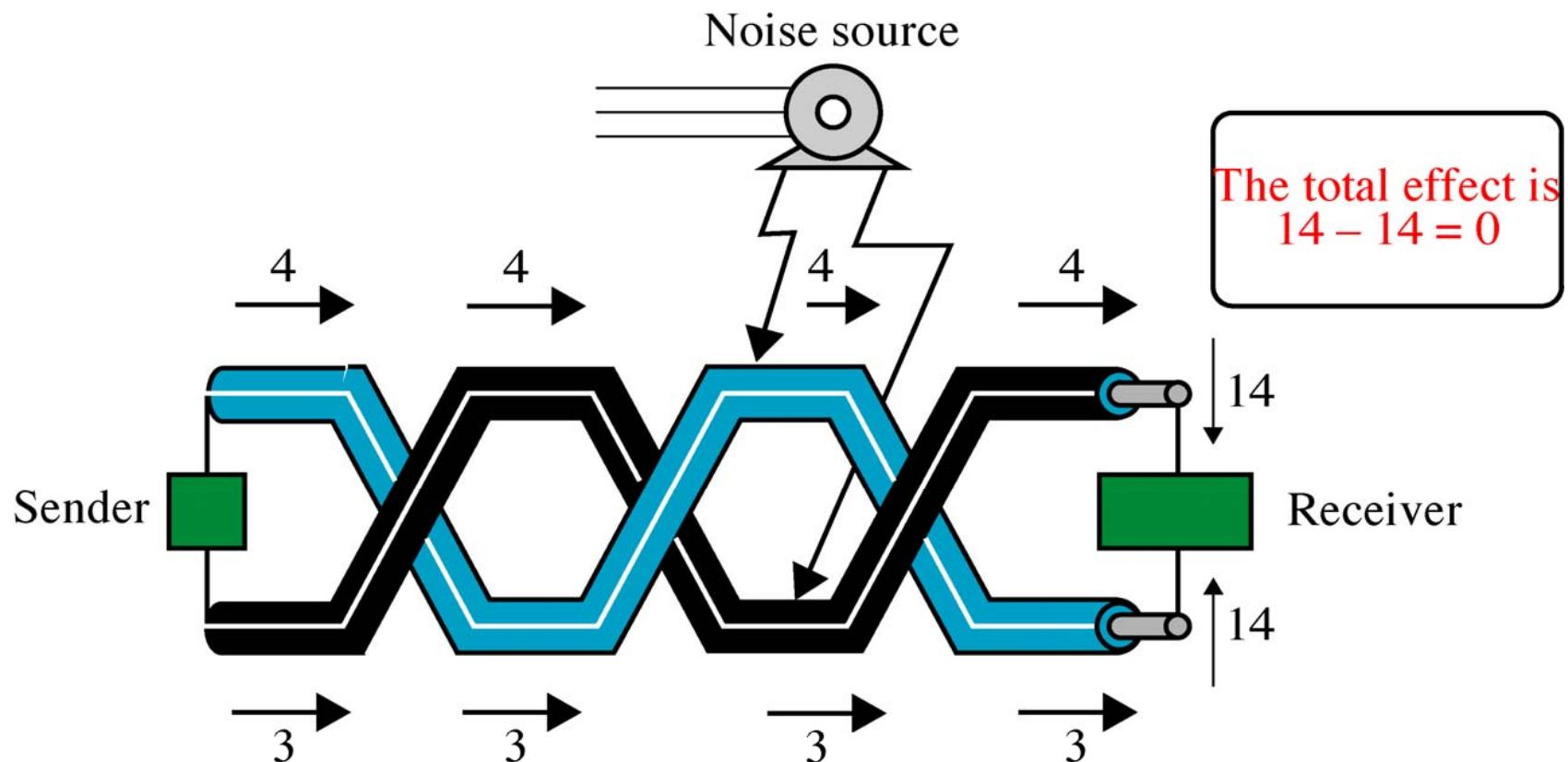
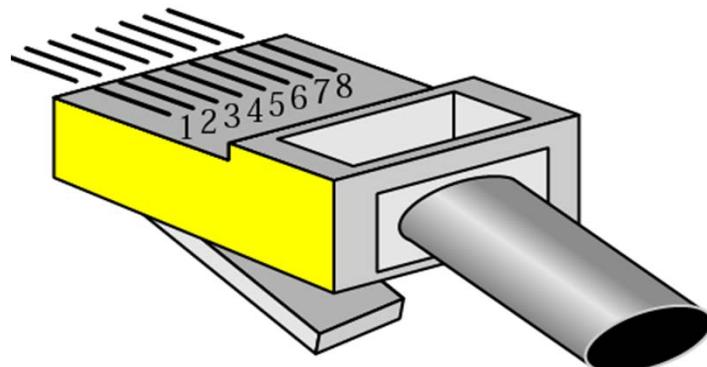


Table 7.1 Categories of unshielded twisted-pair cables (EIA)

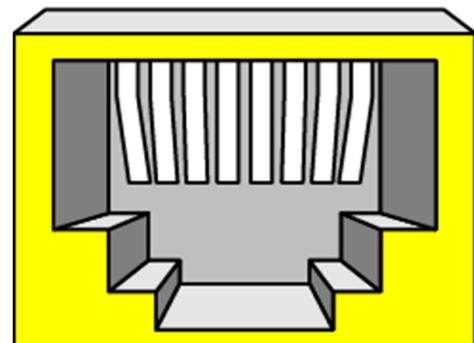
Category	Specification	Data Rate (Mbps)	Use
1	Unshielded twisted-pair used in telephone	1	Telephone
2	Unshielded twisted-pair originally used in T-lines	4 (1.544 Mbps)	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs (10BASE-T)
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100 (Fast Ethernet: 100BASE-T)	LANs
5E	An extension to category 5 that includes electromagnetic interference	1,000 (100BASE-T)	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	1,000 (Gigabit Ethernet: 100BASE-T)	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	10,000	LANs

maximum distance 100 m without repeater

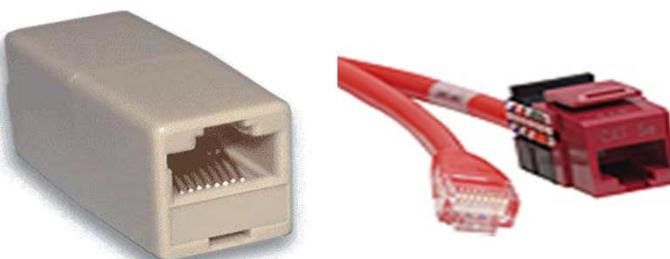
Figure 7.5 UTP connector



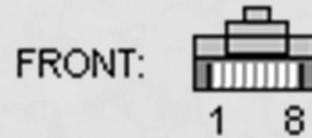
RJ-45 Male



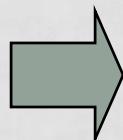
RJ-45 Female



UTP PIN ASSIGNMENT (NORMAL UTP CABLE)



PC



Hub or Switch

TIA/EIA 568B Wiring

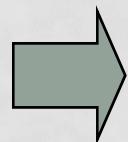
1		White and Orange
2		Orange
3		White and Green
4		Blue
5		White and Blue
6		Green
7		White and Brown
8		Brown

Name	NIC1	Color
TX+ (BI_DA+)	1	White/Orange
TX- (BI_DA-)	2	Orange
RX+ (BI_DB+)	3	White/Green
- (BI_DC+)	4	Blue
- (BI_DC-)	5	White/Blue
RX- (BI_DB-)	6	Green
- (BI_DD+)	7	White/Brown
- (BI_DD-)	8	Brown

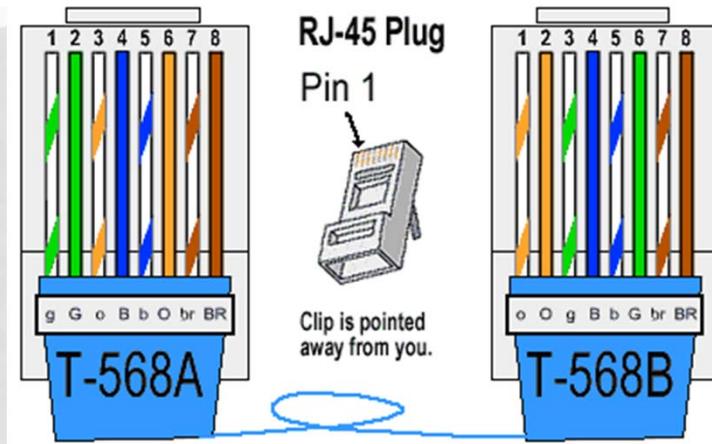
Both sides of Cable

UTP PIN ASSIGNMENT (CROSS UTP CABLE)

PC



PC



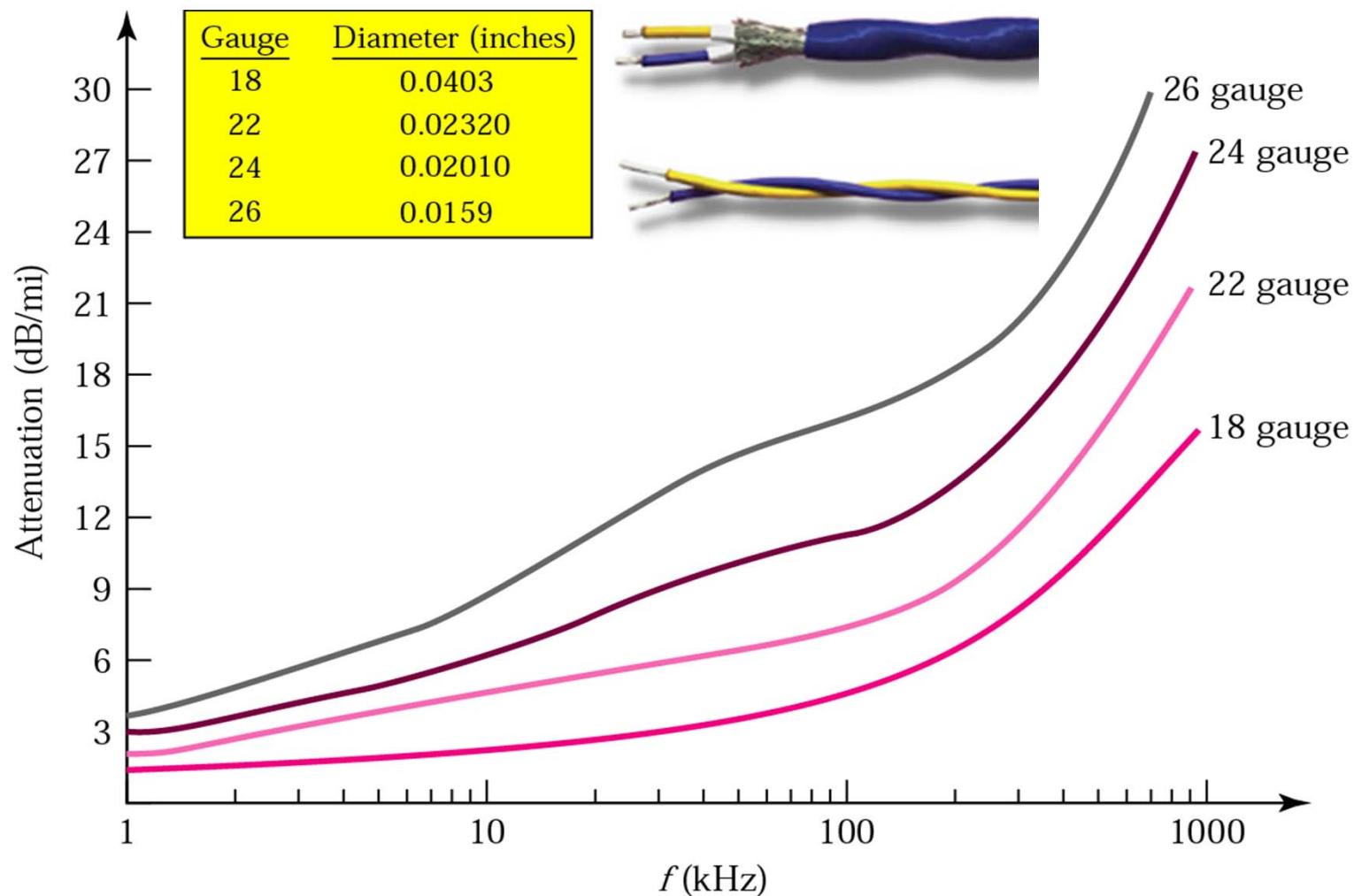
Name	NIC1	Color
TX+ (BI_DA+)	1	White/Orange
TX- (BI_DA-)	2	Orange
RX+ (BI_DB+)	3	White/Green
- (BI_DC+)	4	Blue
- (BI_DC-)	5	White/Blue
RX- (BI_DB-)	6	Green
- (BI_DD+)	7	White/Brown
- (BI_DD-)	8	Brown

One side of Cable

Name	NIC2	Color
RX+ (BI_DB+)	3	White/Orange
RX- (BI_DB-)	6	Orange
TX+ (BI_DA+)	1	White/Green
- (BI_DD+)	7	Blue
- (BI_DD-)	8	White/Blue
TX- (BI_DA-)	2	Green
- (BI_DC+)	4	White/Brown
- (BI_DC-)	5	Brown

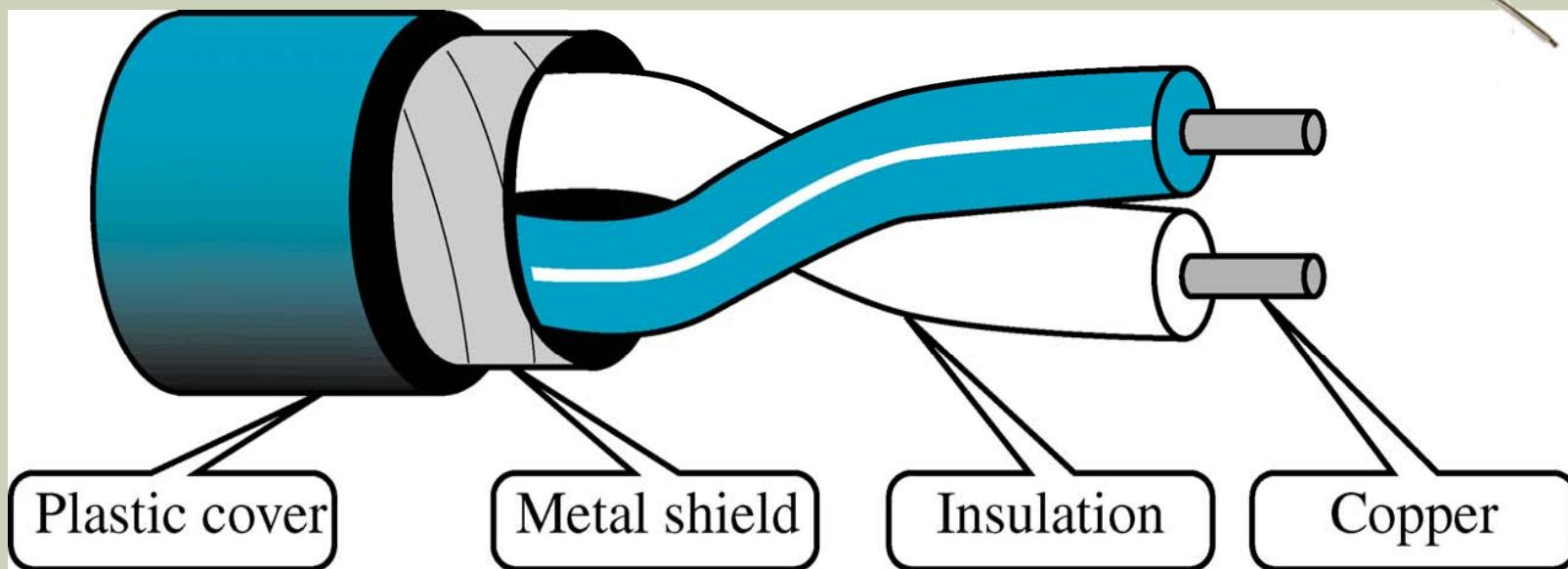
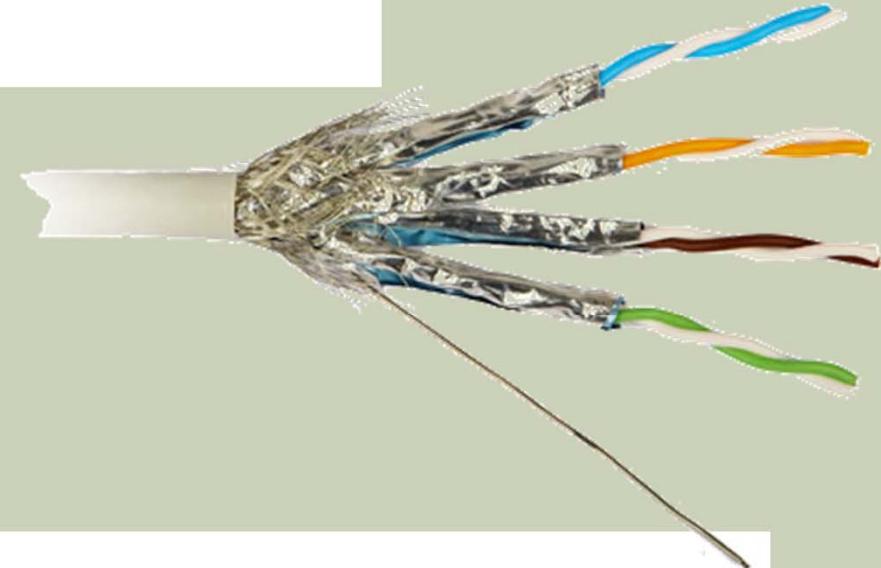
The other side of Cable

Figure 7.6 UTP performance



Copper core: ขนาดใหญ่ ค่าการลดตอนลับภูมิภาคน้อย ส่งได้ไกลขึ้น

SHIELDED TWISTED-PAIR CABLE (CAT-7)



Coaxial Cable



Figure 7.7 *Coaxial cable*

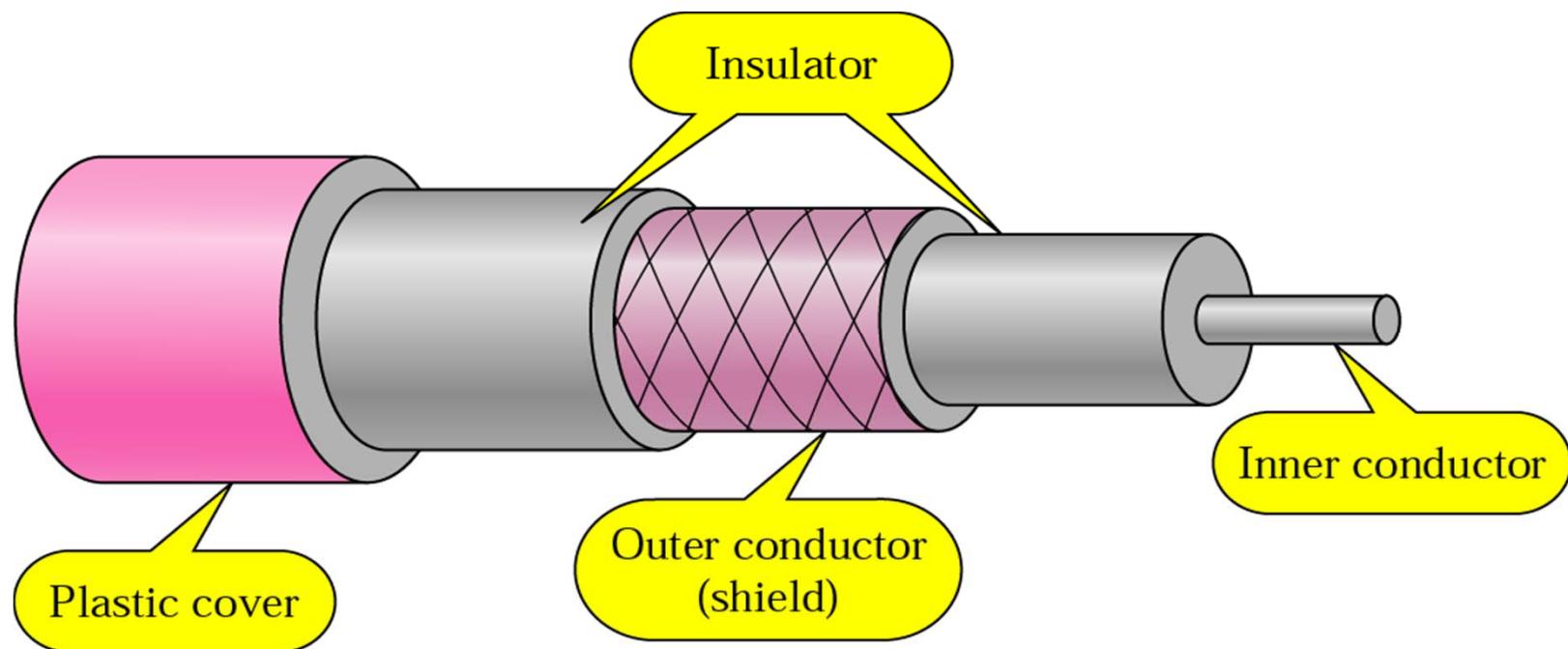
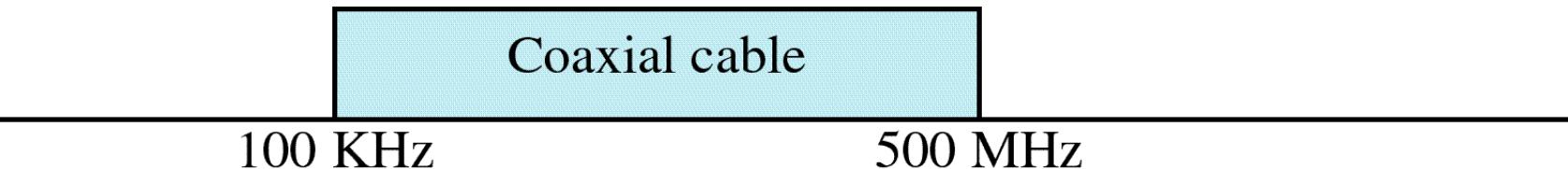
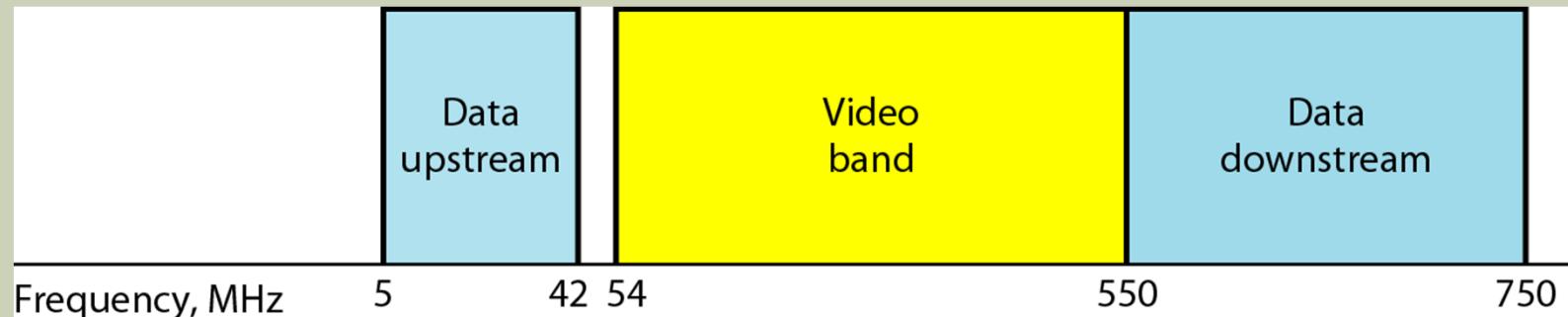


Table 7.2 Categories of coaxial cables

Category	Impedance	Use
RG-59	75Ω	Cable TV
RG-58	50Ω	Thin Ethernet (10Base2)
RG-11	50Ω	Thick Ethernet (10Base5)

Radio Government (RG) rating

Figure 9.16 *Division of coaxial cable band by CATV*

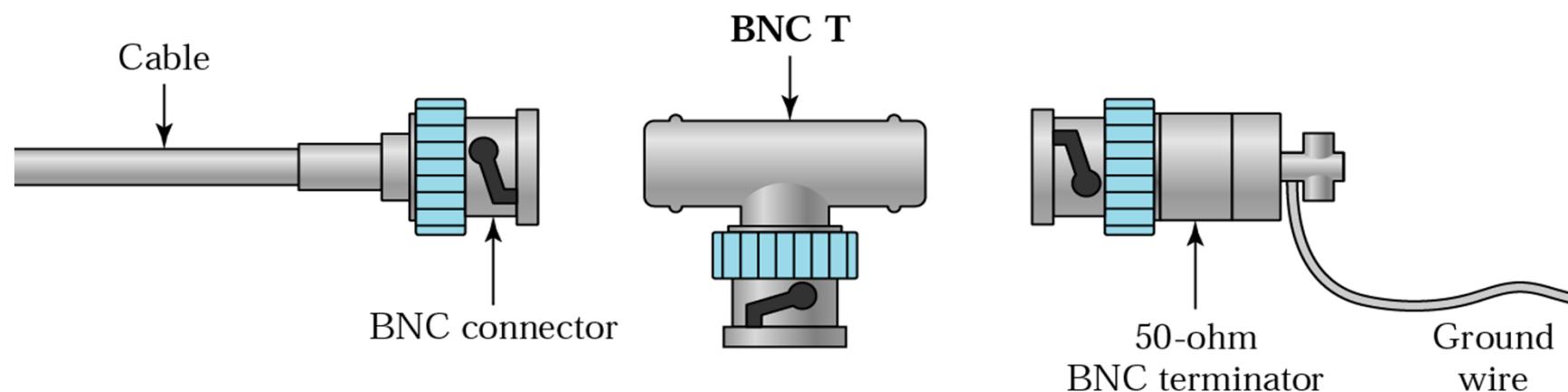
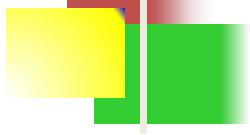


- **Subband division (6 MHz / channel)**
 - Video: 54 – 550 MHz
 - Upstream: 5 - 42 MHz
 - Downstream: 550 – 750 MHz
- **Modulation**
 - Upstream: QPSK -> 12 Mbps
 - Downstream: 64 QAM -> 30 Mbps

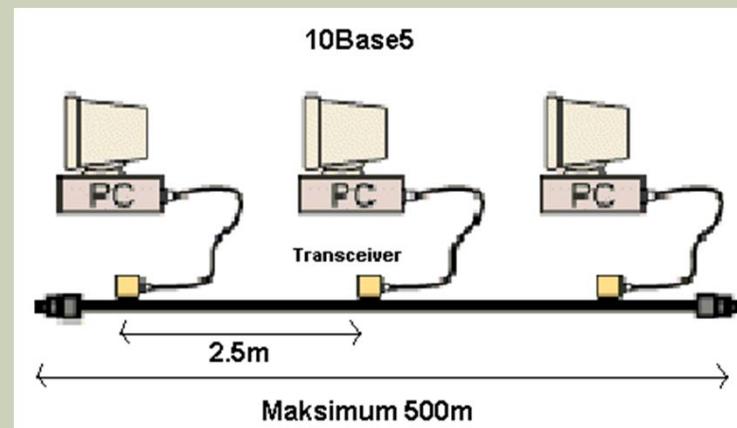
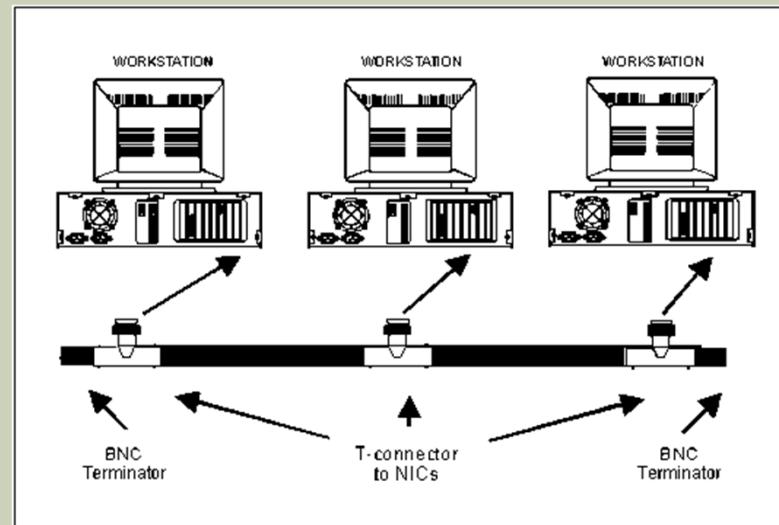
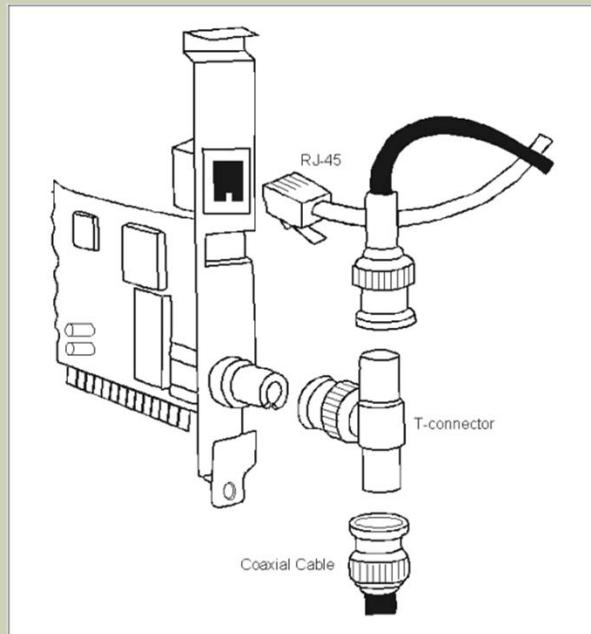
COAXIAL CONNECTORS (BNC)



Figure 7.8 BNC connectors



LAN on Coaxial cable (Bus topology)



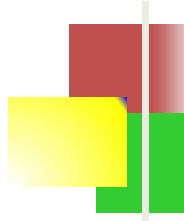
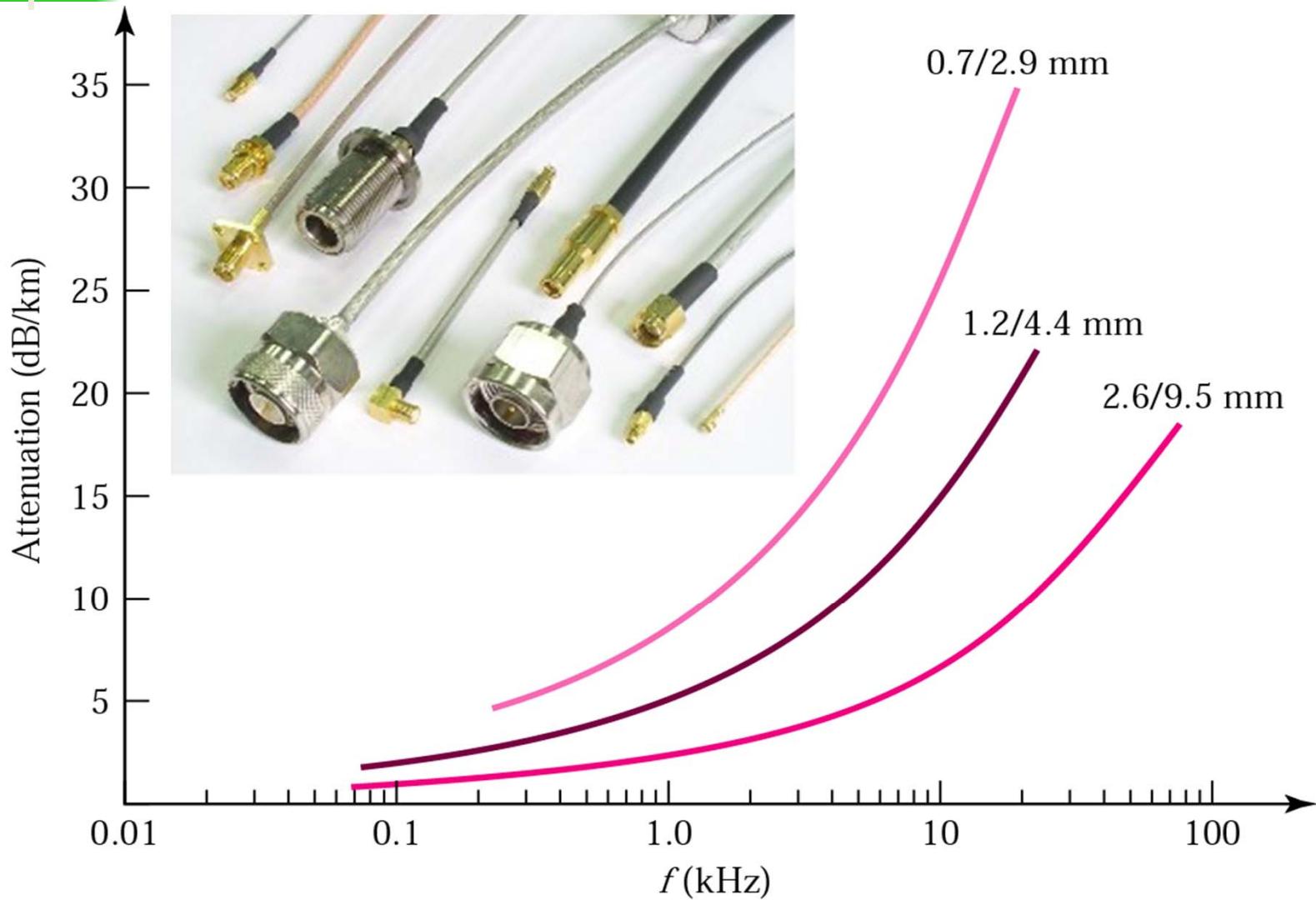


Figure 7.9 *Coaxial cable performance*

ที่ความถี่สูงขึ้น ขนาดของการลดTHONกำลังของสัญญาณจะมากขึ้น

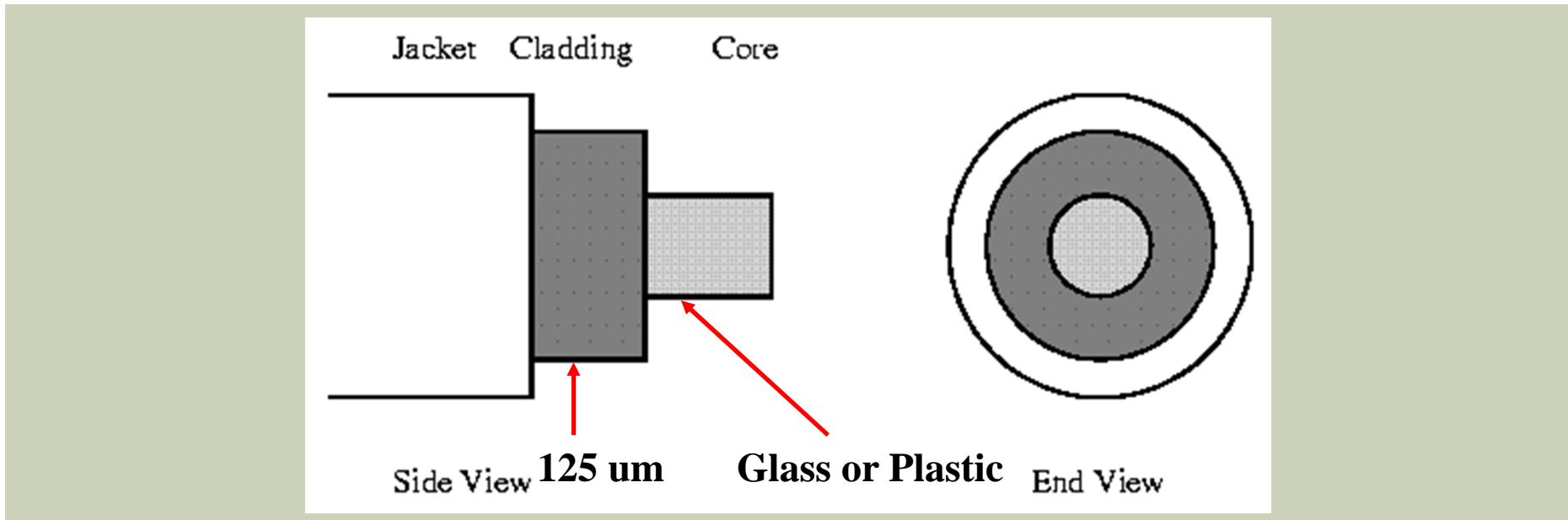


ขนาดของแกนตัวนำในสายขนาดใหญ่ขึ้น ส่งผลให้ขนาดของการลดทอนกำลังของสัญญาณจะน้อยลง

Fiber Optic Cable



FIBER OPTIC



ช่วง WAVELENGTH ที่ใช้งาน 1550 NM

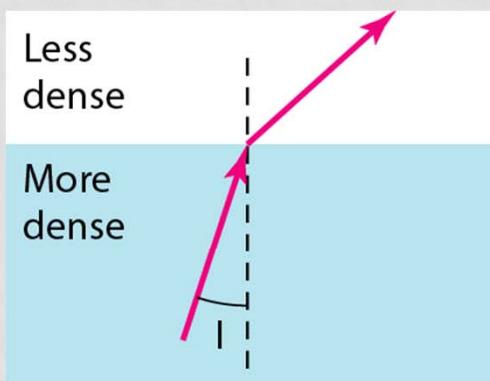
CHANNEL SPACE:

- SDH/SONET -> 50 GHz/ channel, 32 channels -> $2.5 \text{ Gbps} \times 32 = 80 \text{ Gbps}$
- (1999) Bell LAB: 10 GHz/ channel, 1022 channels -> $2.5 \text{ Gbps} \times 1022 = 2.555 \text{ Tbps}$
- (2002) NEC: 10 GHz/ channel, 273 channels -> $40 \text{ Gbps} \times 273 = 10.9 \text{ Tbps}$
- (2011) NEC: 10 GHz/ channel, 370 channels -> $274 \text{ Gbps} \times 370 = 101.7 \text{ Tbps}$

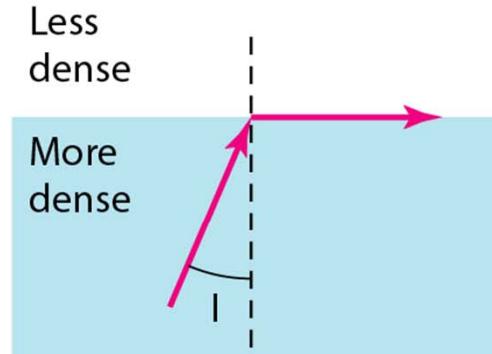
LIGHT REFLECTION

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

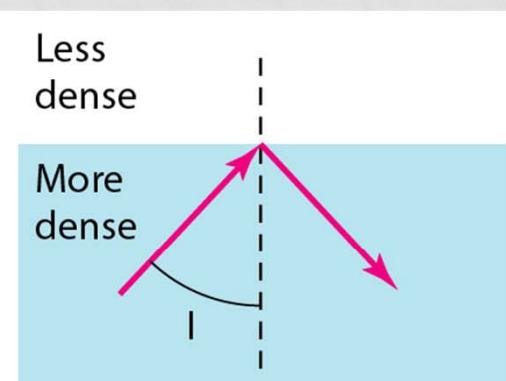
n_i = ดัชนีหักเหของตัวกลาง i



$i < \text{critical angle}$,
refraction



$i = \text{critical angle}$,
refraction



$i > \text{critical angle}$,
reflection

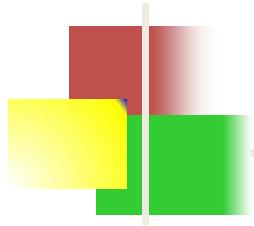
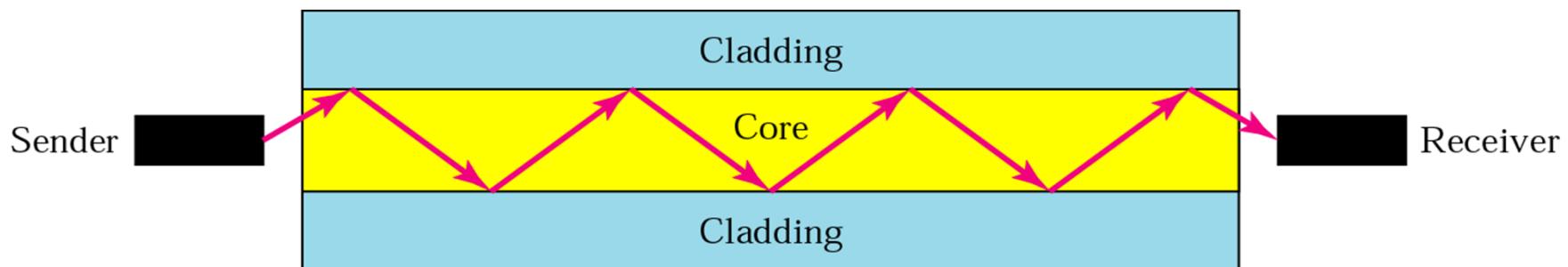
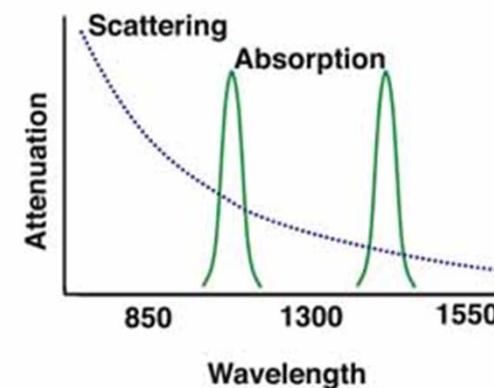
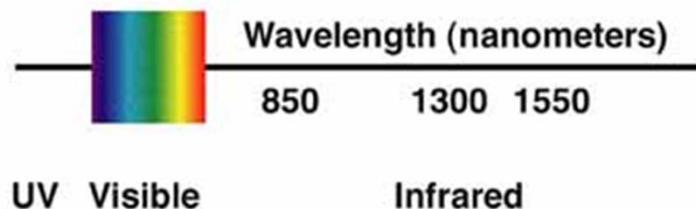


Figure 7.11 Optical fiber Frequency: 180 THz – 330 THz



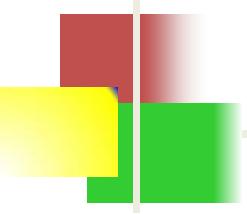
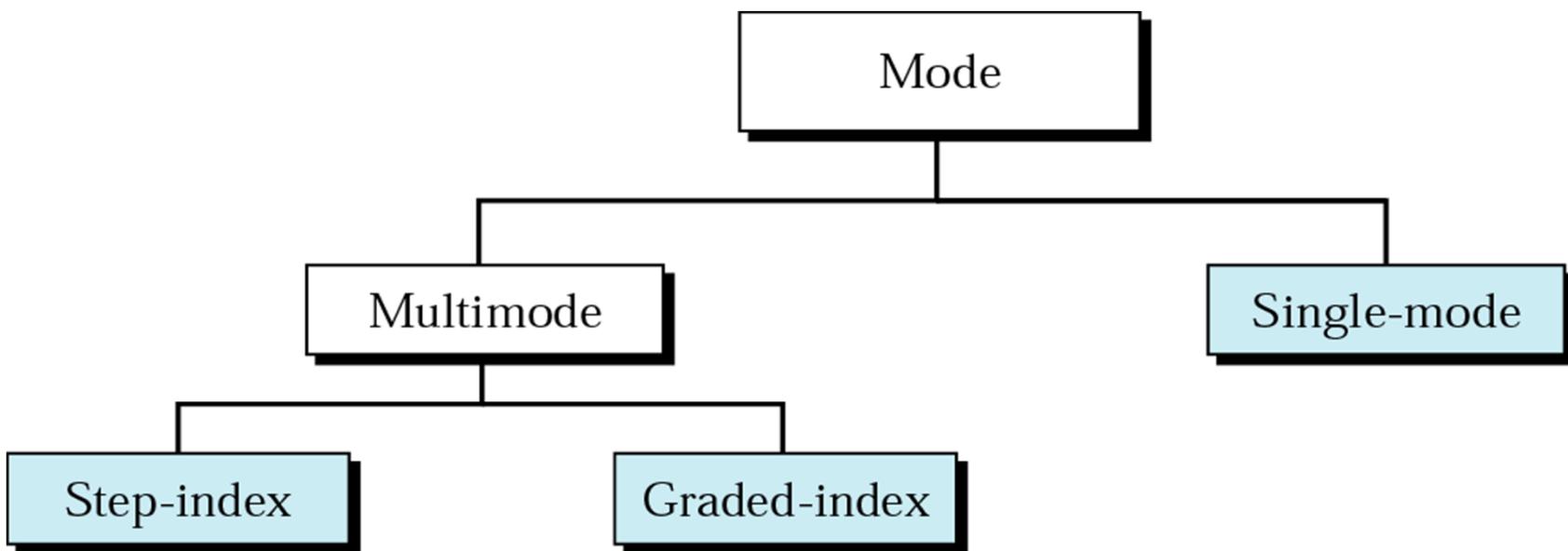


Figure 7.12 *Propagation modes*



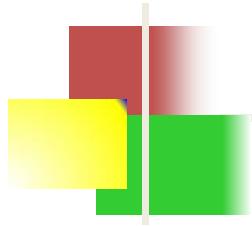
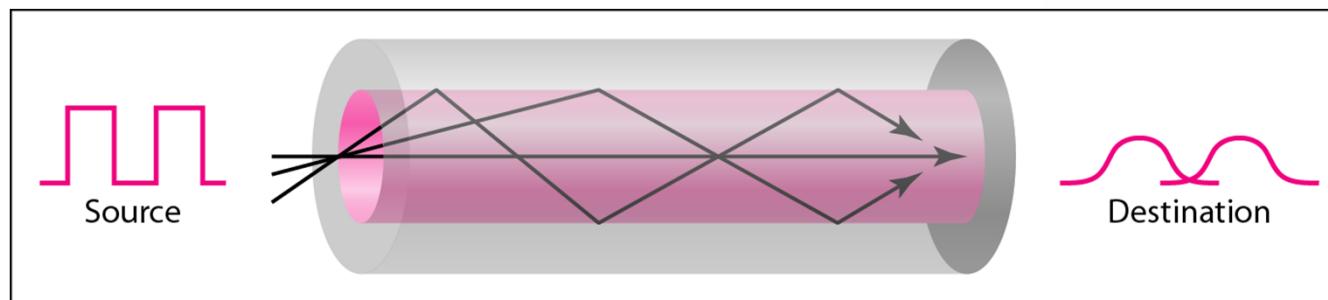
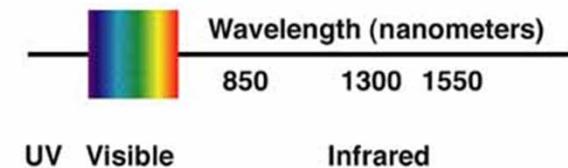
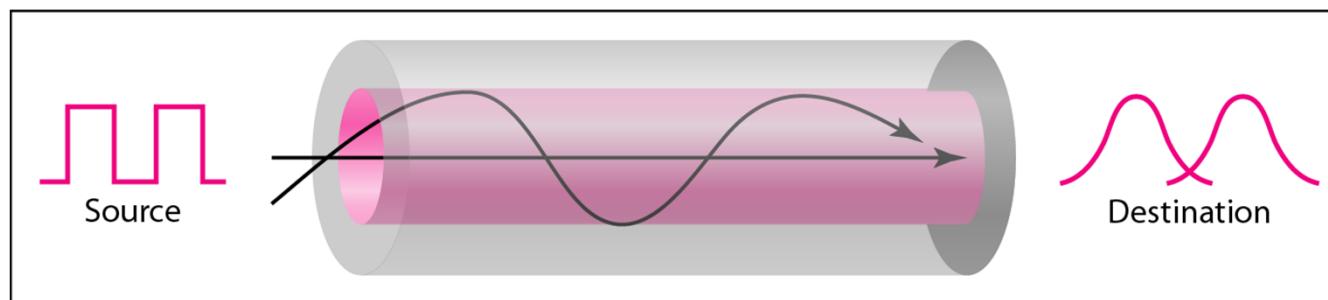


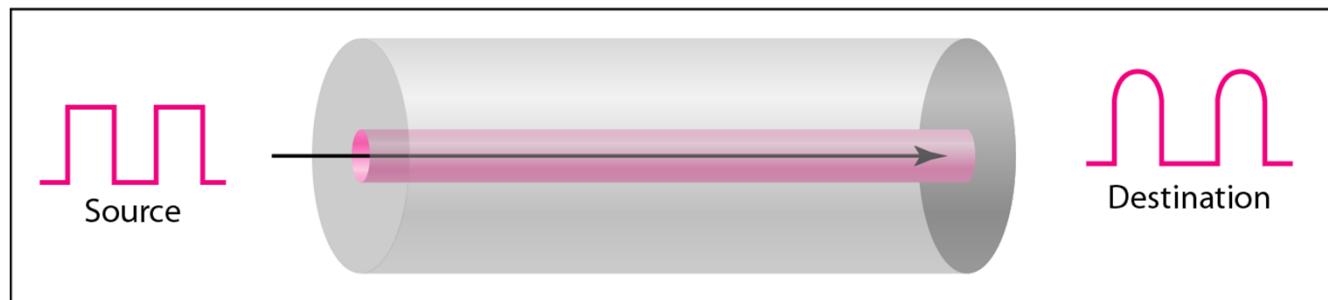
Figure 7.13 Modes



a. Multimode, step index



b. Multimode, graded index

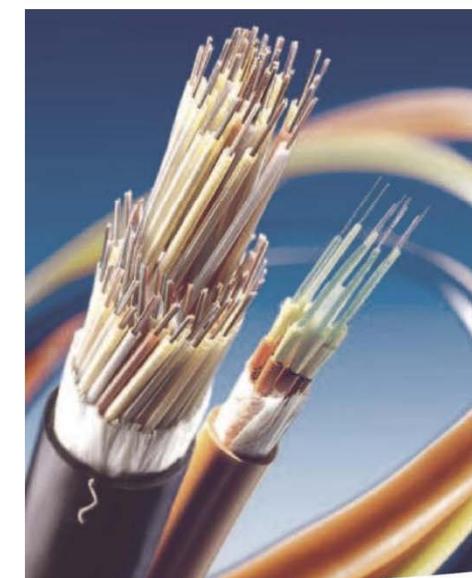
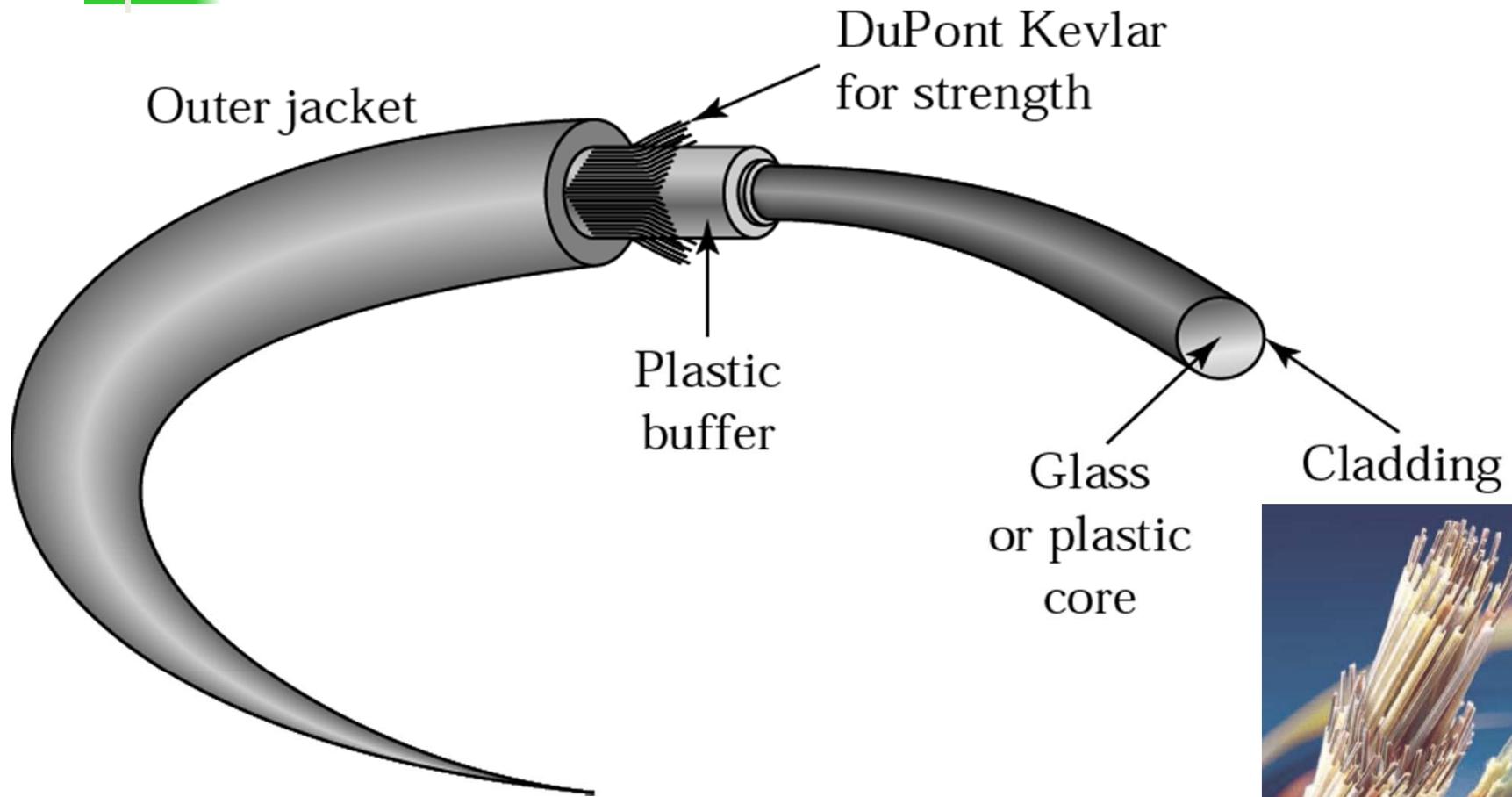


c. Single mode

Table 7.3 Fiber types

Type	Core	Cladding	Mode	Max. Distance
50/125	50	125	Multimode, graded-index	550 m / 2km with transceiver
62.5/125	62.5	125	Multimode, graded-index	220 m
100/125	100	125	Multimode, graded-index	N/A
7/125	7	125	Single-mode	1000BASE-LX (10 km) / 1000BASE-LH (High Laser Power -> 70 km)

Figure 7.14 Fiber construction



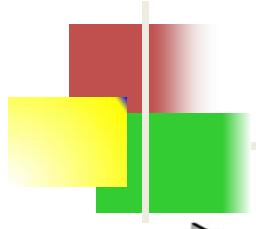
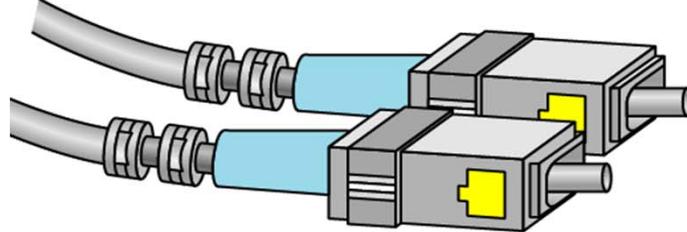
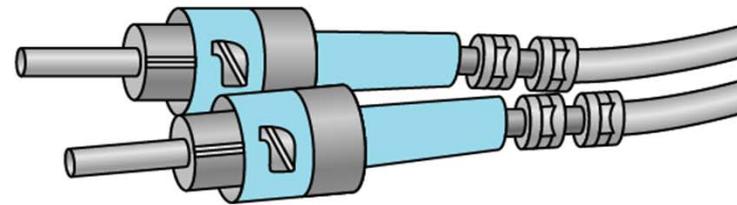


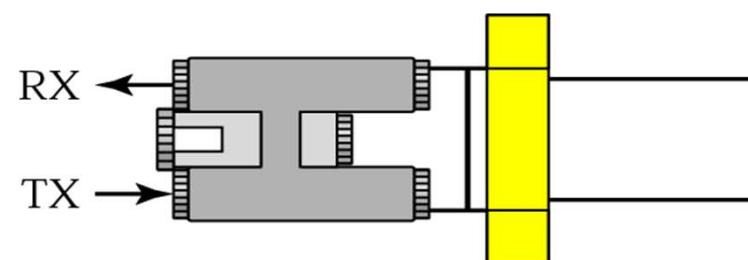
Figure 7.15 *Fiber-optic cable connectors*



SC connector



ST connector



MT-RJ connector



Transceiver (Fiber-Twisted pair)



FIBER OPTIC CONNECTOR



FC connector

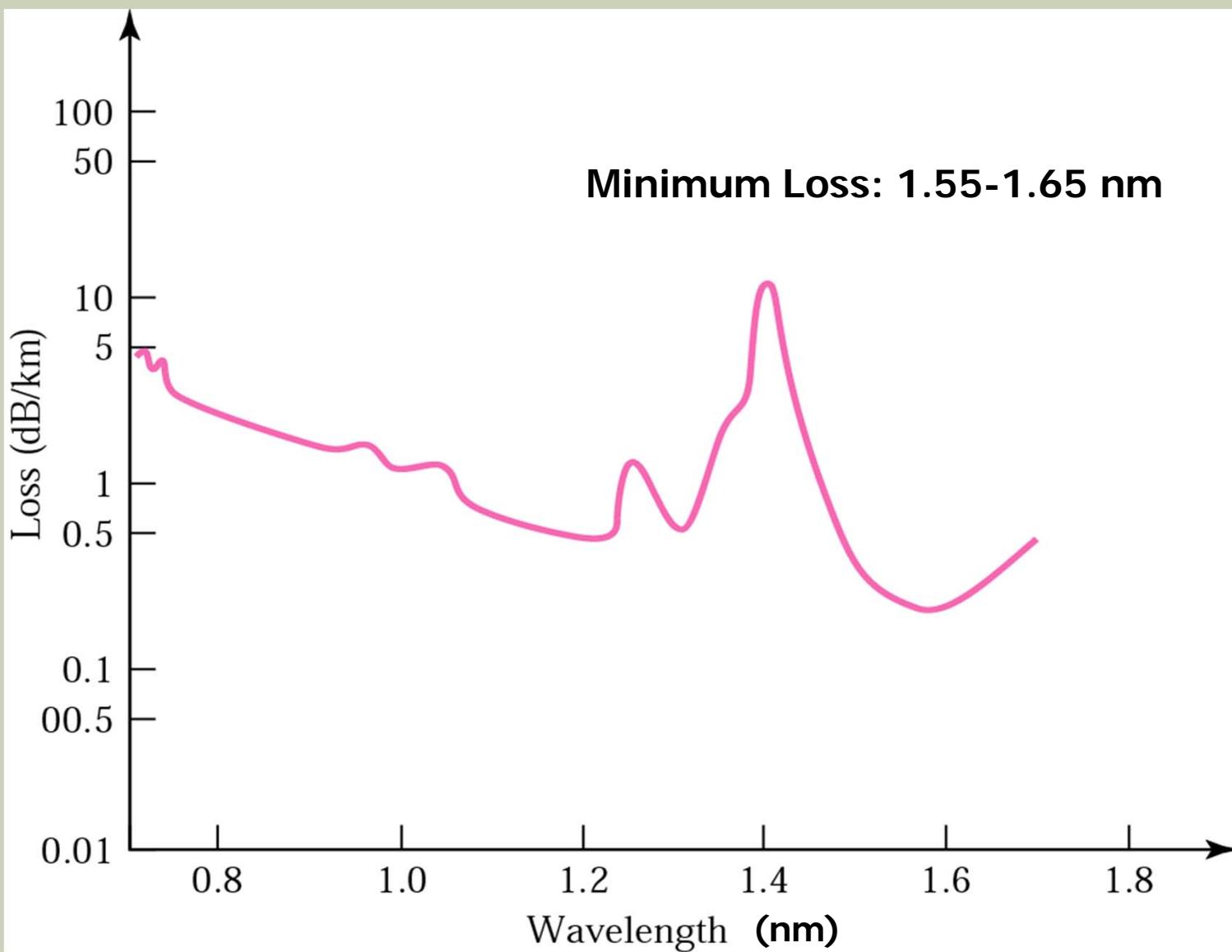


SC connector

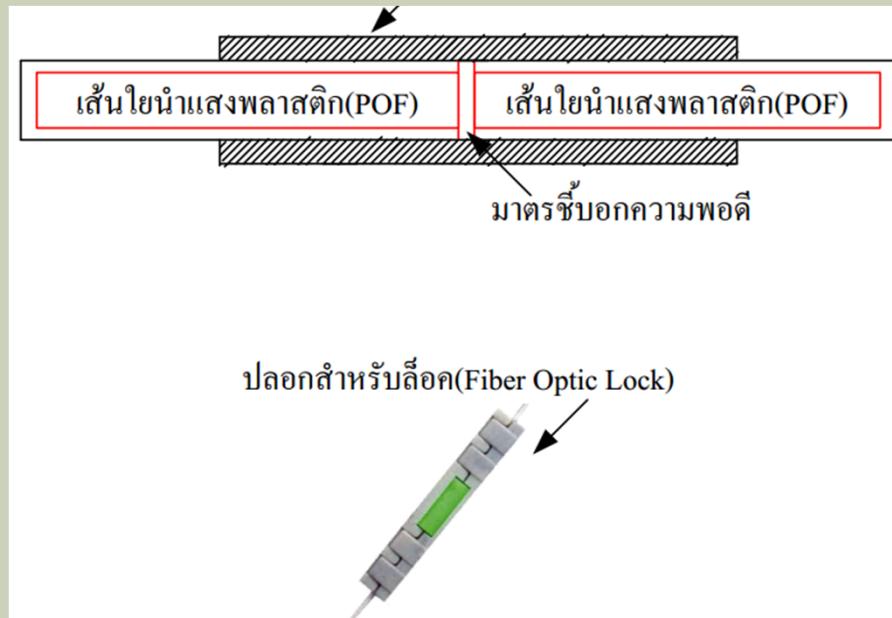
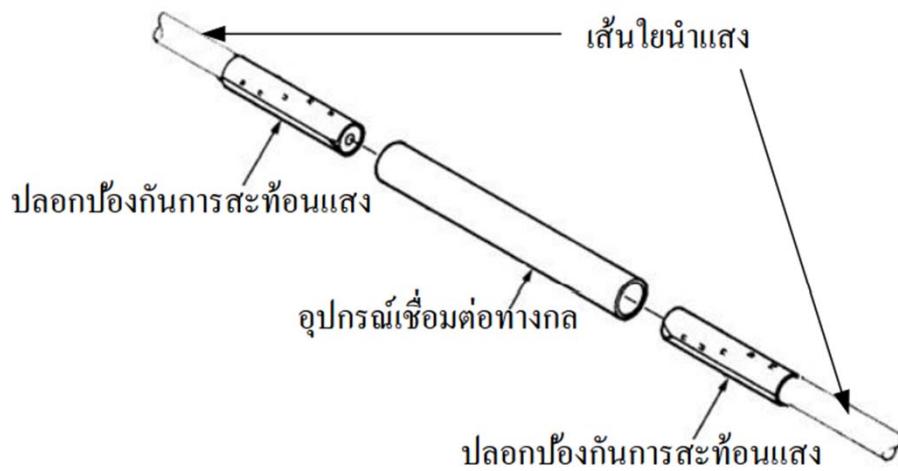


ST connector

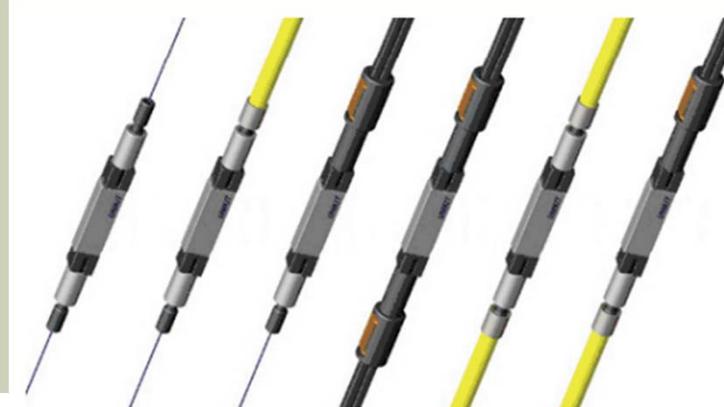
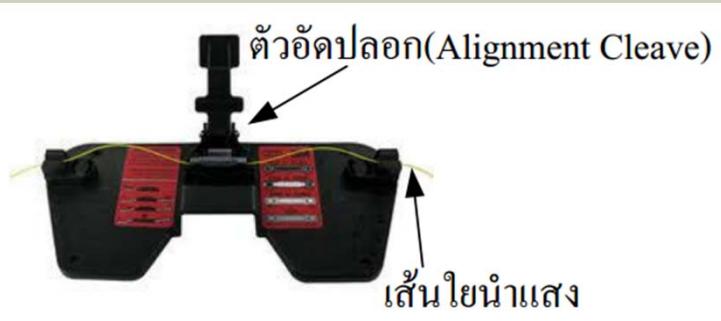
Figure 7.16 Optical fiber performance



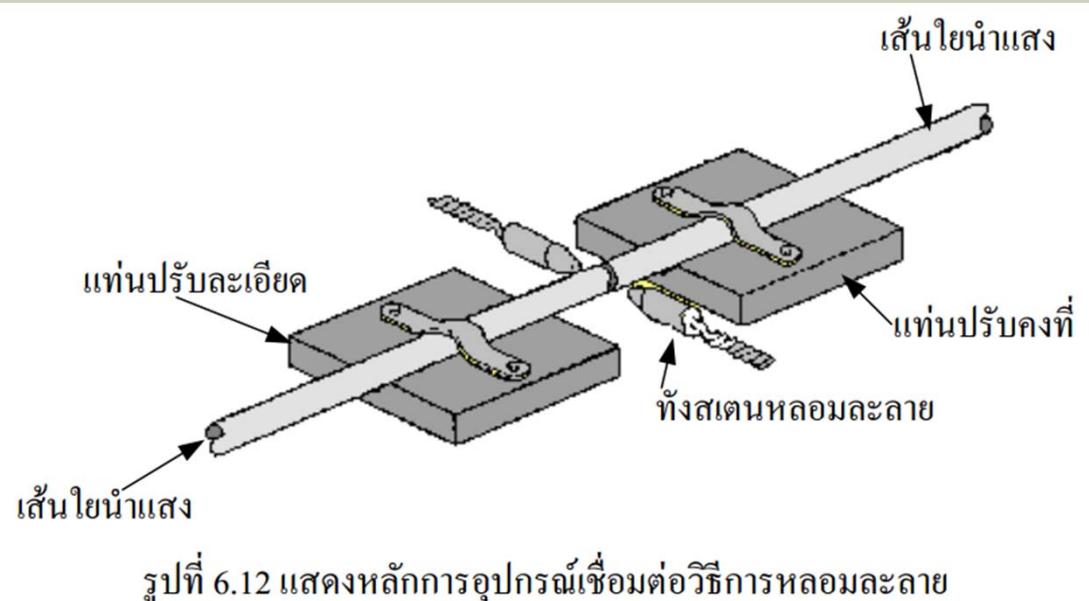
การเชื่อมต่อสาย FIBER



รูปที่ 6.11 แสดงหลักการอุปกรณ์เชื่อมต่อทางกล



การเชื่อมต่อสาย FIBER



ADVANTAGE OF FIBER OPTIC

- Very Large BW
 - Higher data rate
- Greater repeater spacing
 - Fewer repeaters with the same distance
 - lower cost and fewer sources of error
- Significantly Low Attenuation loss
- Not affected by electromagnetic fields (noise)
- Small size and light weight

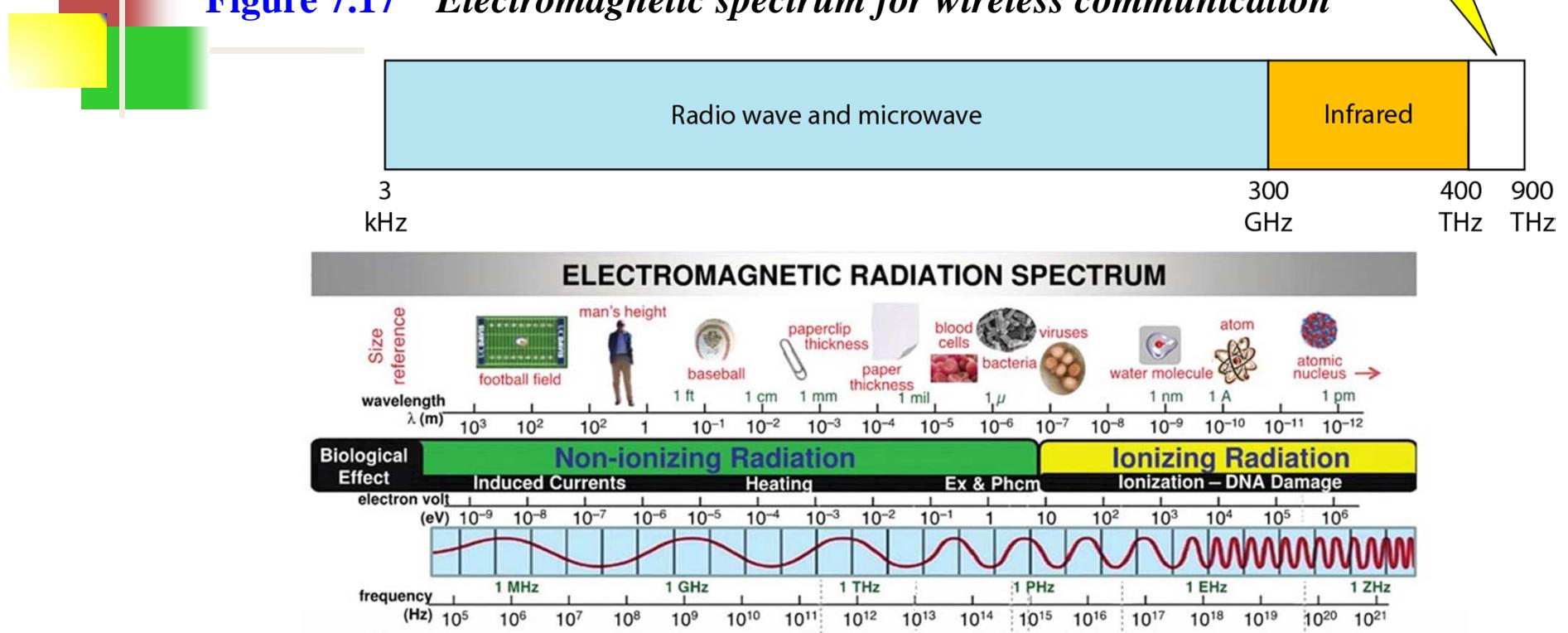
7.2 Unguided Media: Wireless

Radio Waves

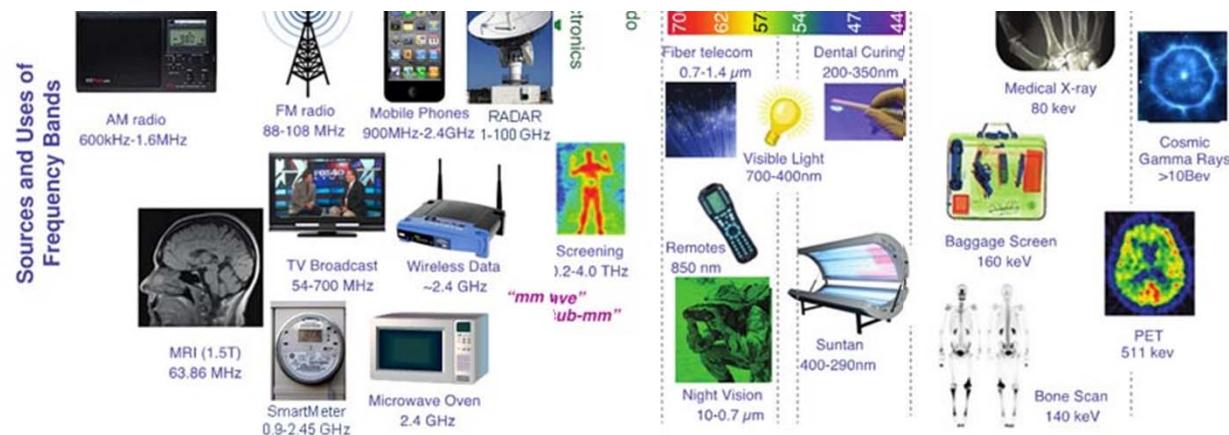
Microwaves

Infrared

Figure 7.17 Electromagnetic spectrum for wireless communication



FCC: federal communications commission



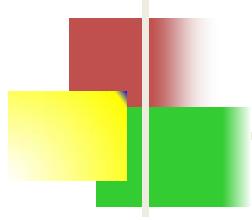
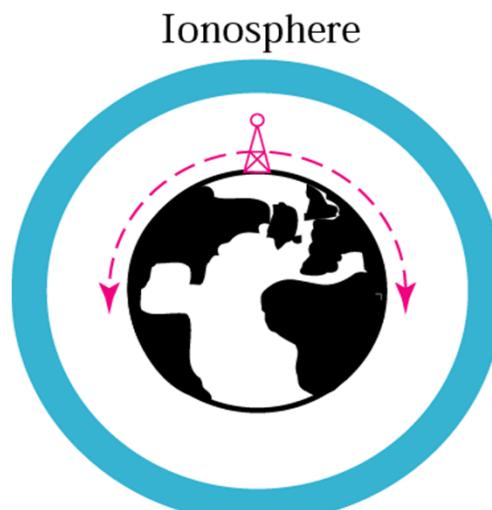
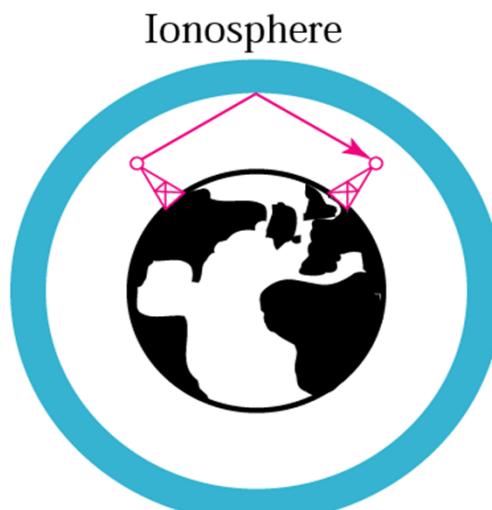


Figure 7.18 Radio & Microwave Propagation methods



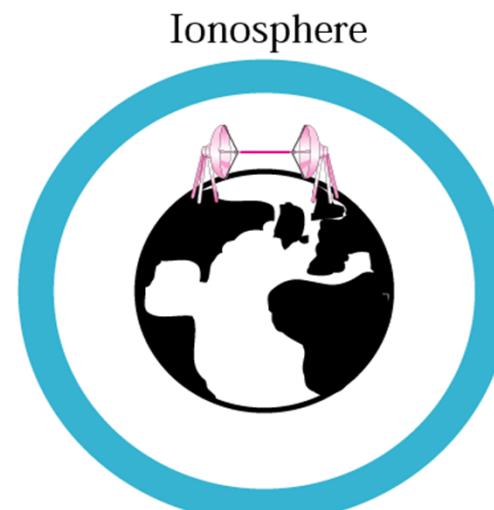
Ground propagation
(below 2 MHz)

Walkie Talkie



Sky propagation
(2 - 30 MHz)

AM-FM Radio
VHF TV



Line-of-sight propagation
(above 30 MHz)

UHF TV
Cellular phone
Satellite
Radar

Table 7.4 Bands

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

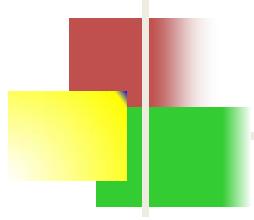
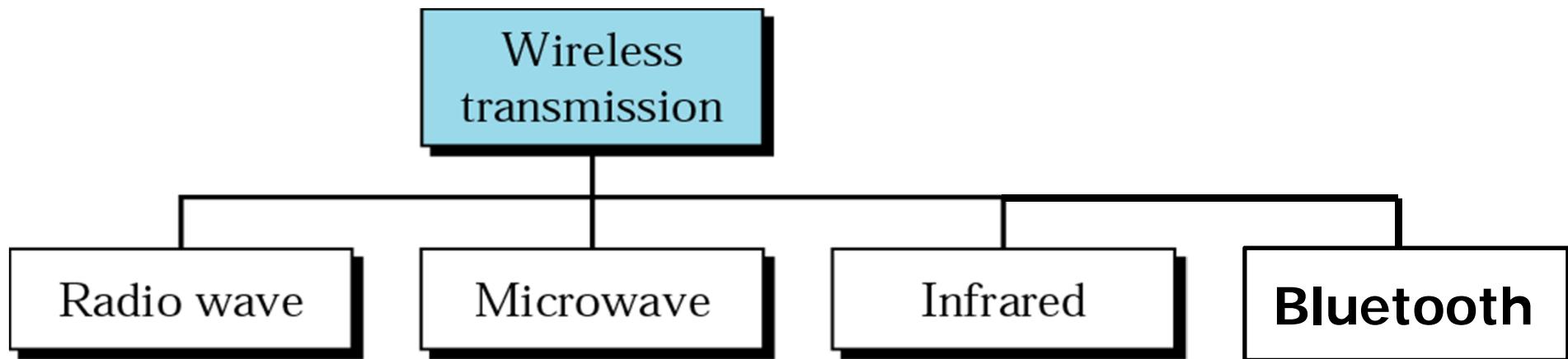


Figure 7.19 *Wireless transmission waves*





Radio & Microwave communication

(ANTENNA: Omnidirection vs Unidirection)

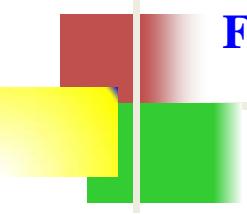
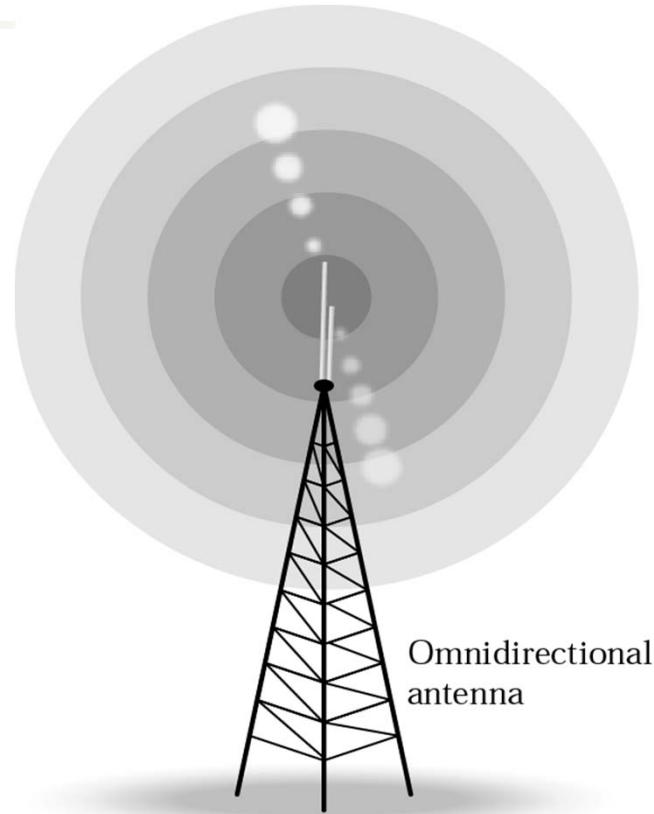


Figure 7.20 *Omnidirectional antennas*



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

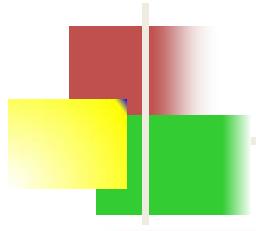
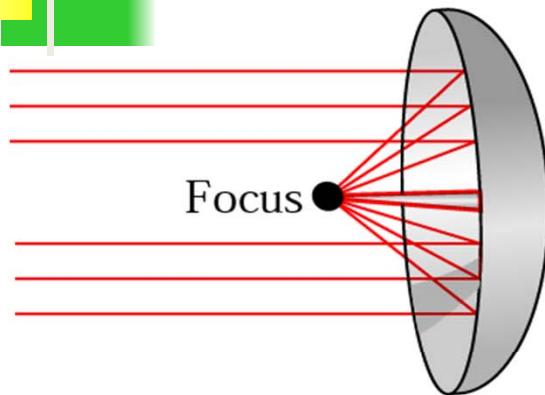
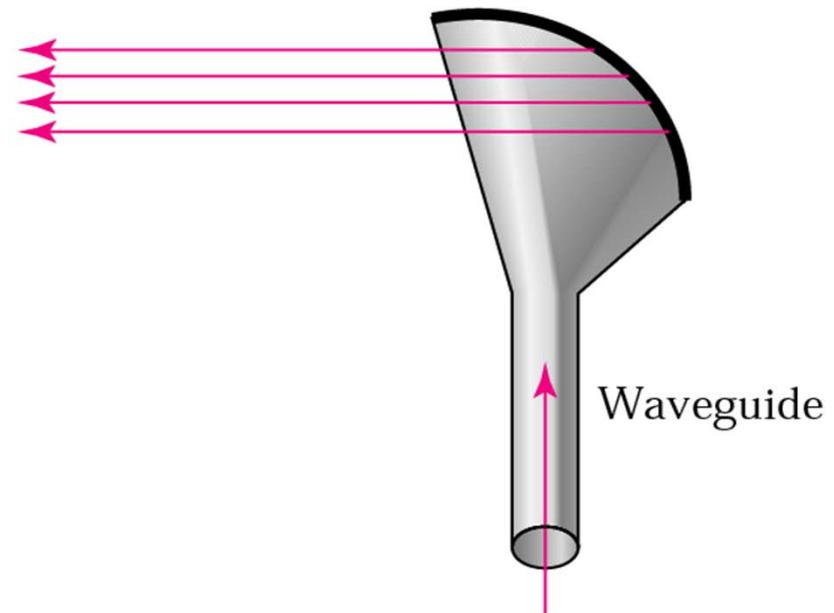


Figure 7.21 *Unidirectional antennas*



a. Dish antenna



b. Horn antenna

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

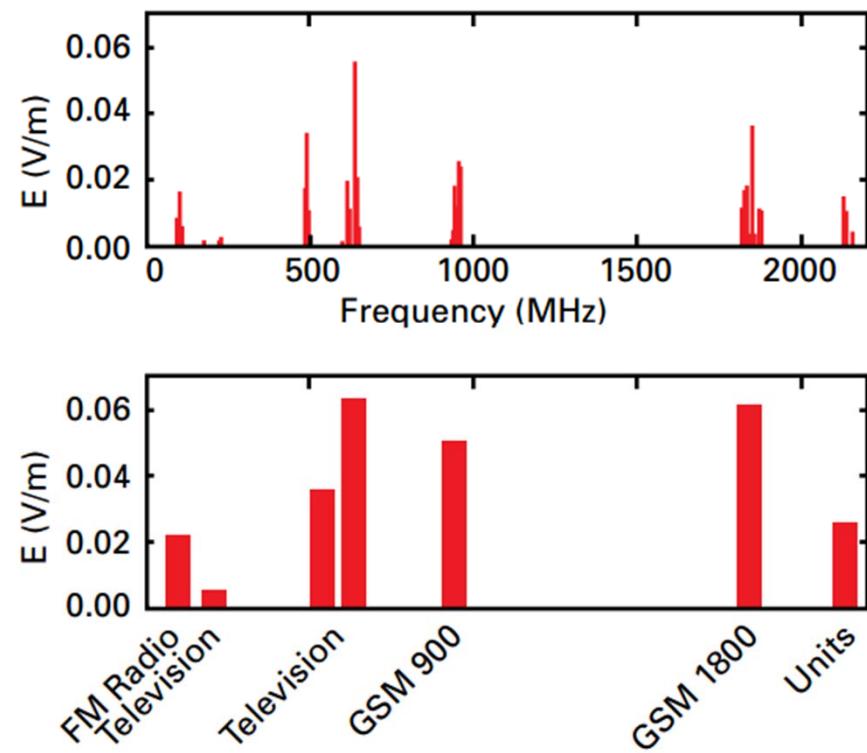


Microwave communication applications

Mobile vs Satellite

CELLULAR COMMUNICATIONS

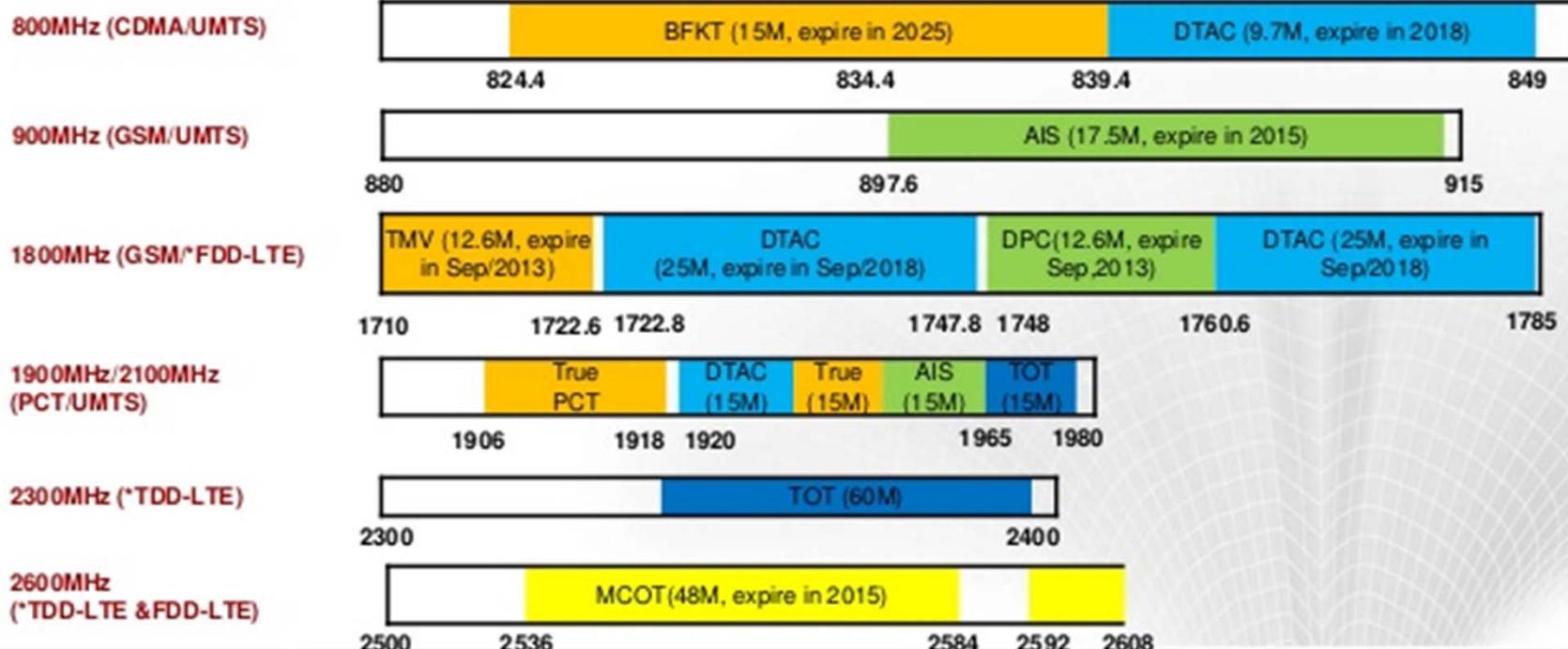
Figure 2. Spectrum plot of typical radio communications signal levels in a community.



- **GSM900 (AIS)**
 - 890–915 MHz (uplink)
 - 935–960 MHz (downlink)
 - 124 RF channels (channel numbers 1 to 124) spaced at 200 kHz
- **GSM1800/CDMA1800 (DTAC/AIS/TRUE)**
 - 1,710–1,785 MHz (uplink)
 - 1,805–1,880 MHz (downlink)
 - 374 channels (channel numbers 512 to 885) spaced at 200 kHz
- **CDMA2100 (3G/4G)(DTAC/AIS/TRUE)**
 - 1,885–2,025 MHz (uplink)
 - 2,110–2,200 MHz (downlink)



Thailand Spectrum Allocation

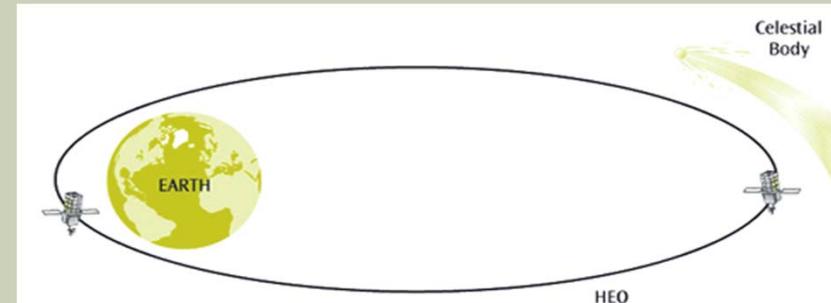


MICROWAVE

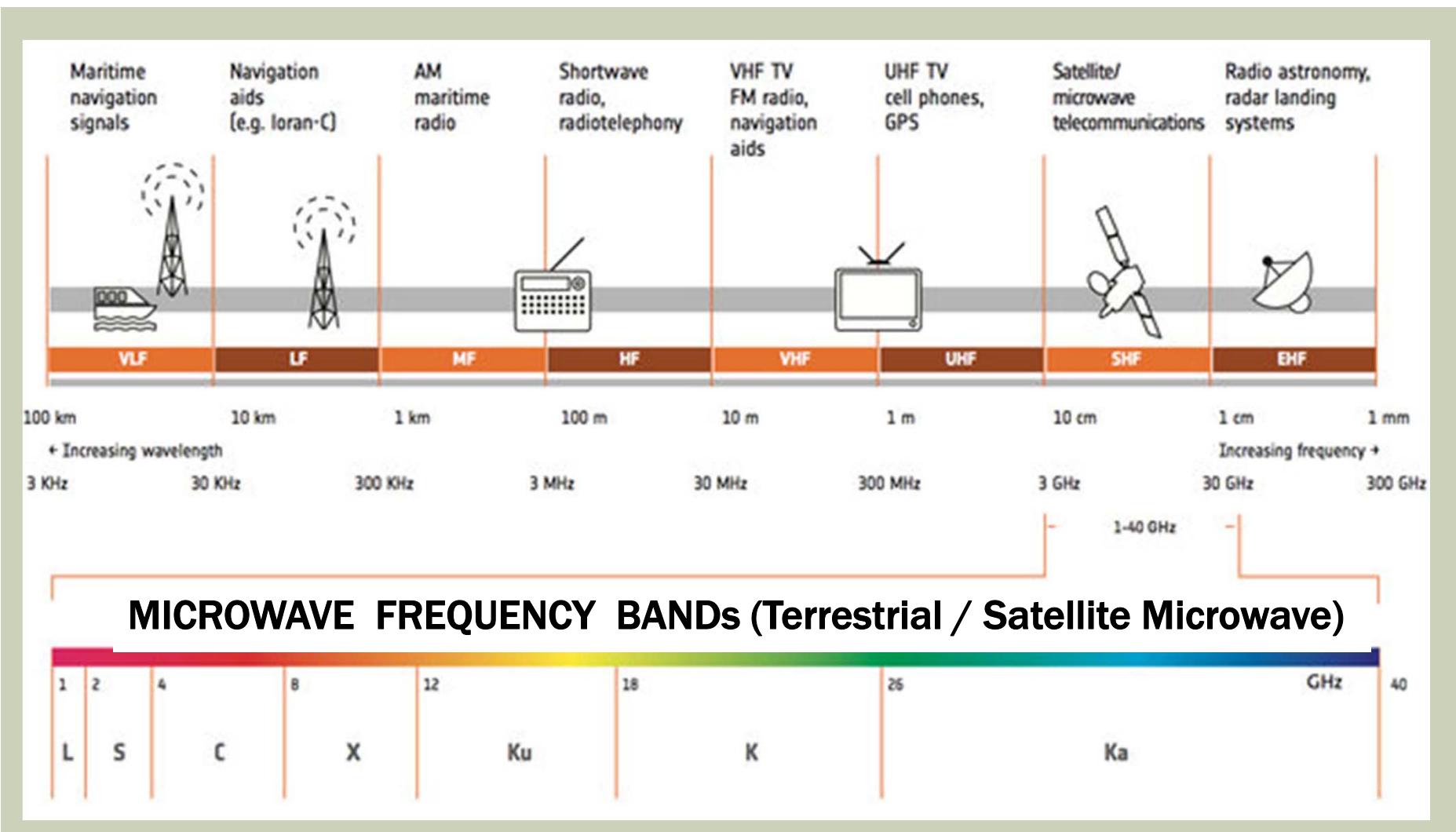
Terrestrial Microwave



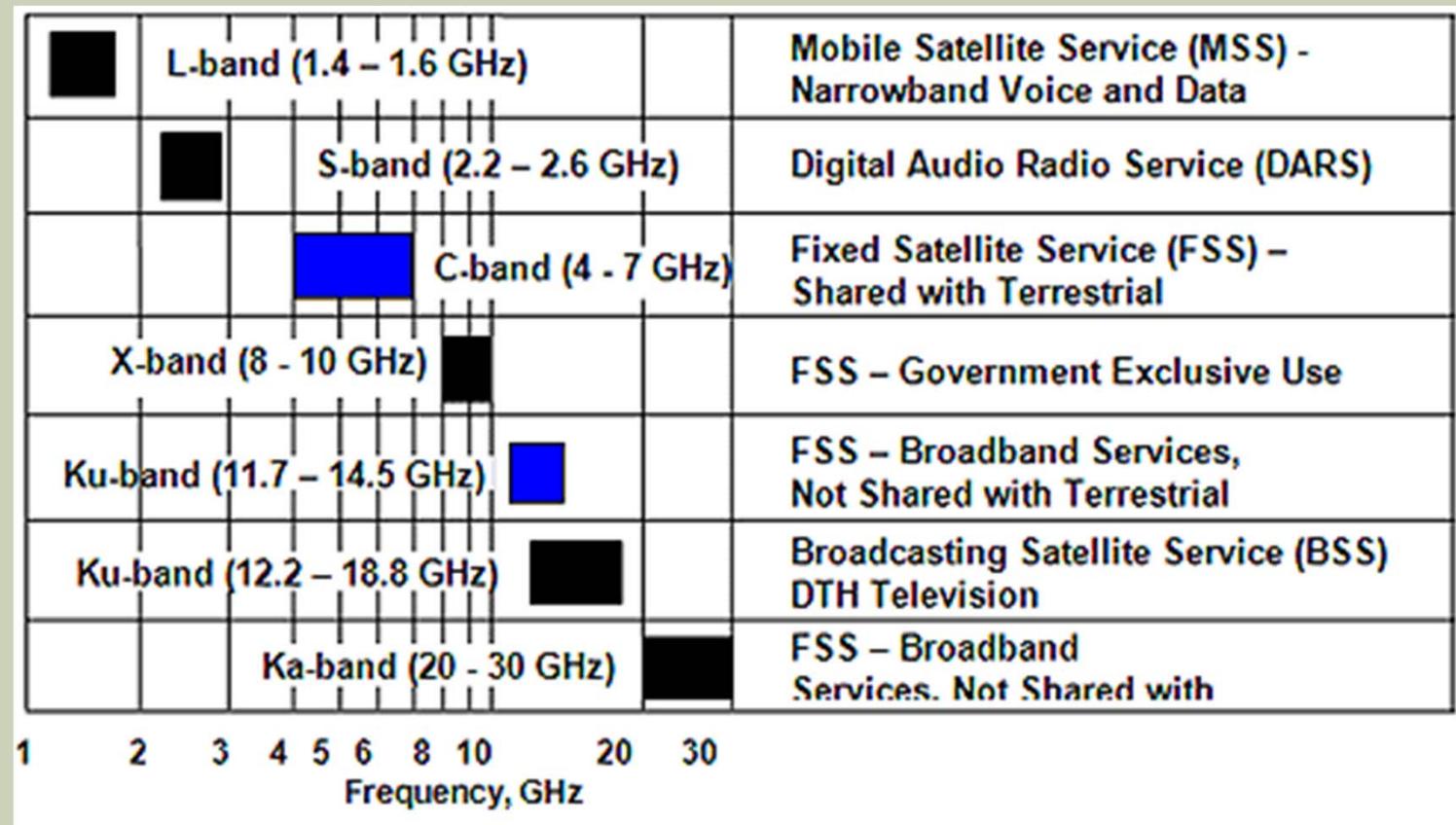
Satellite Microwave



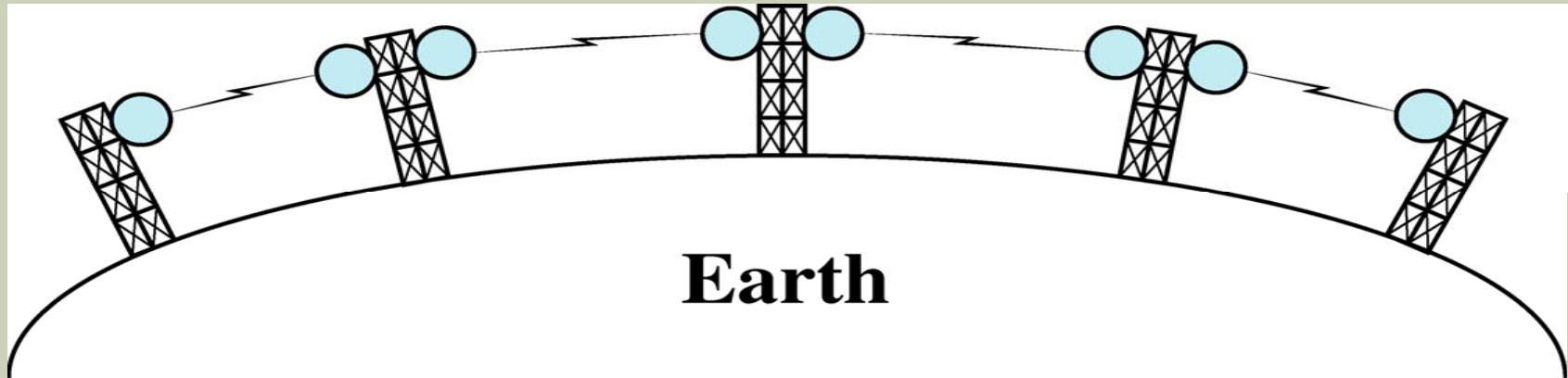
MICROWAVE FREQUENCY ALLOCATION



TERRESTRIAL / SATELLITE MICROWAVE



TERRESTRIAL MICROWAVE



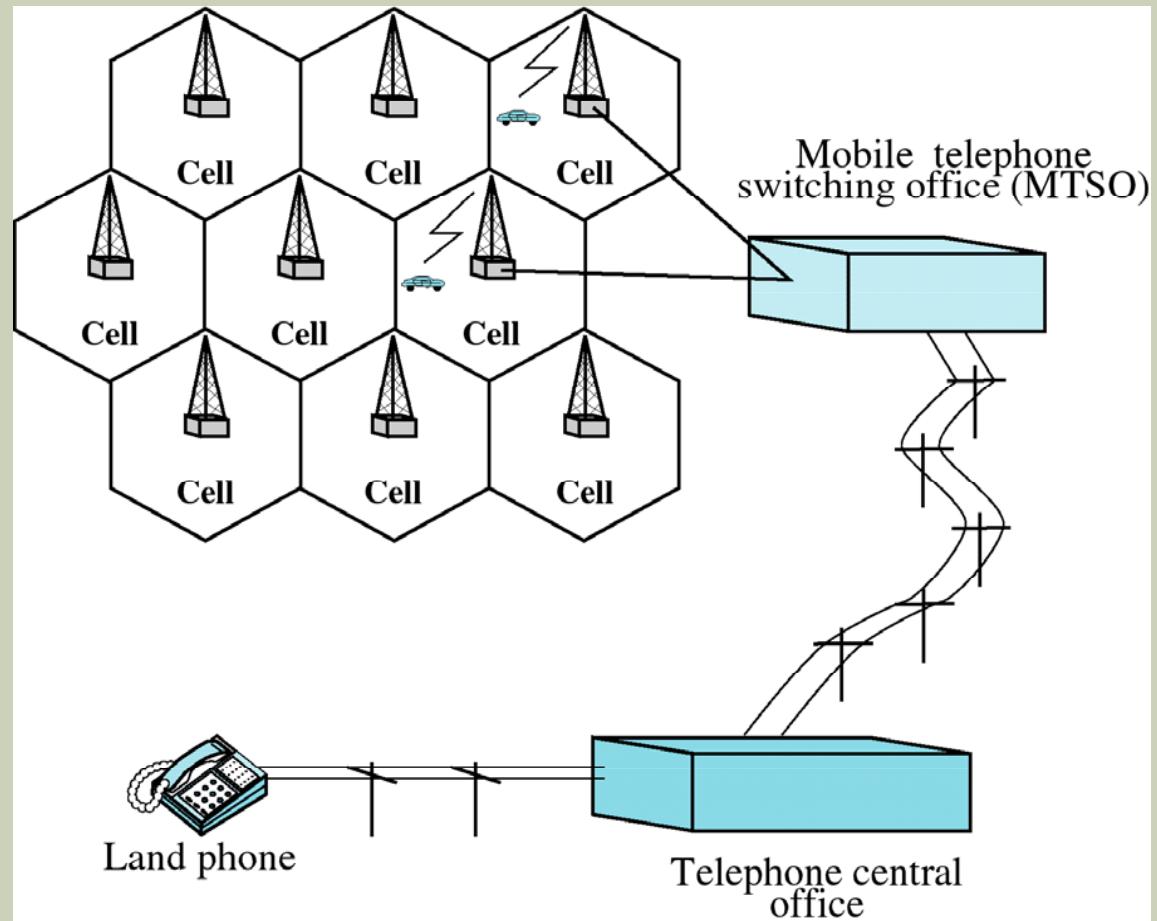
Land-based, line-of-sight transmission

Approximately 20-30 miles (~50 km) maximum between towers

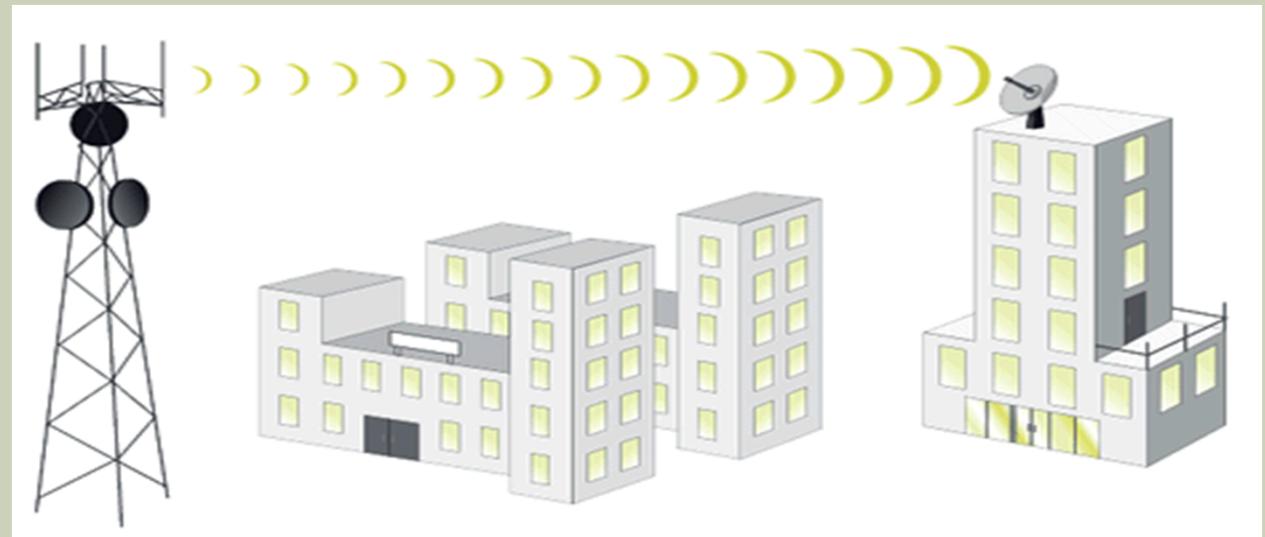
Transmits data at hundreds of millions of bits per second

Popular with telephone companies and business to business transmissions

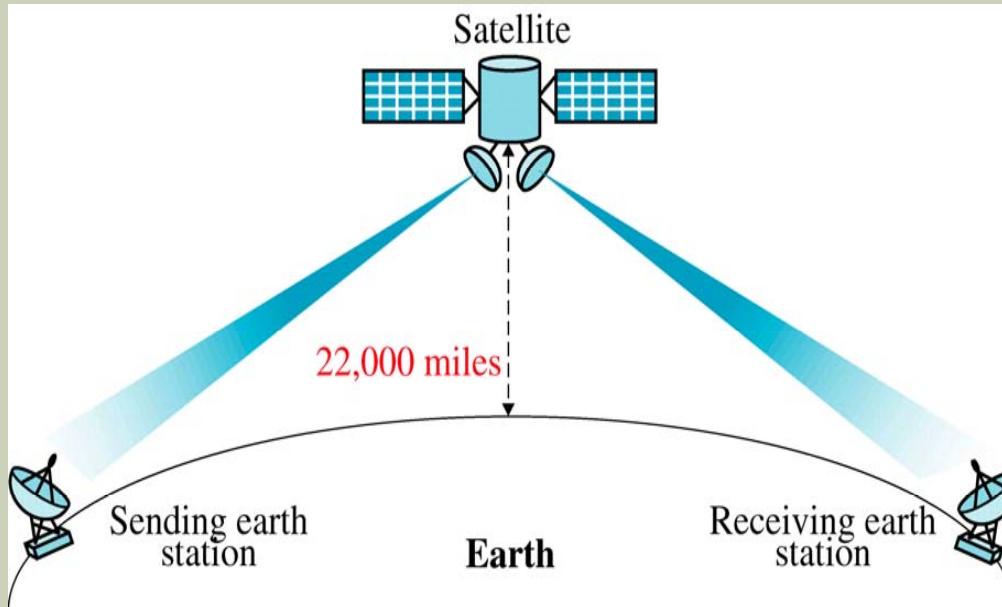
CELLULAR SYSTEM



OFTEN THE MICROWAVE ANTENNAS ARE ON
TOWERS AND BUILDINGS



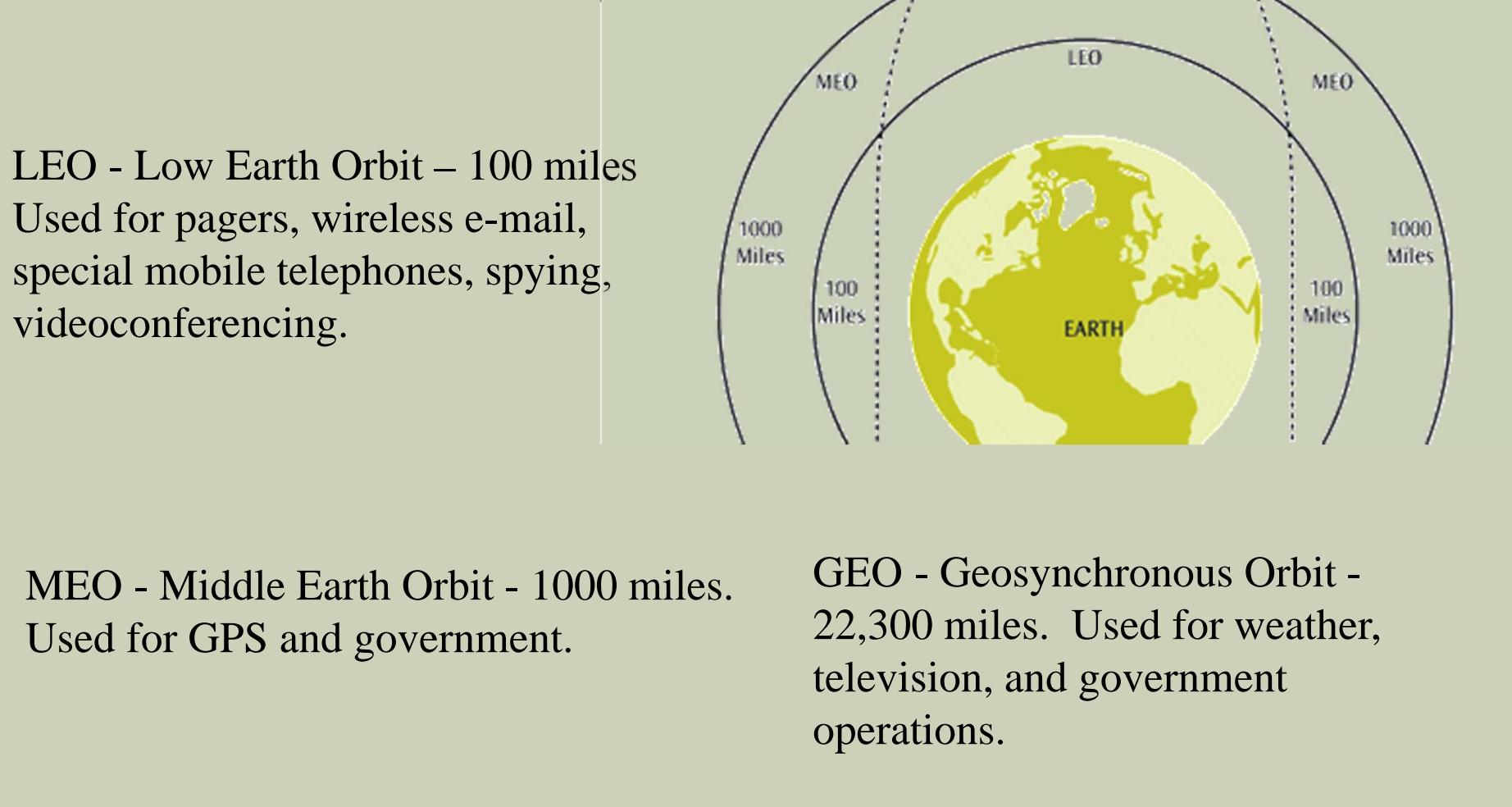
SATELLITE COMMUNICATION



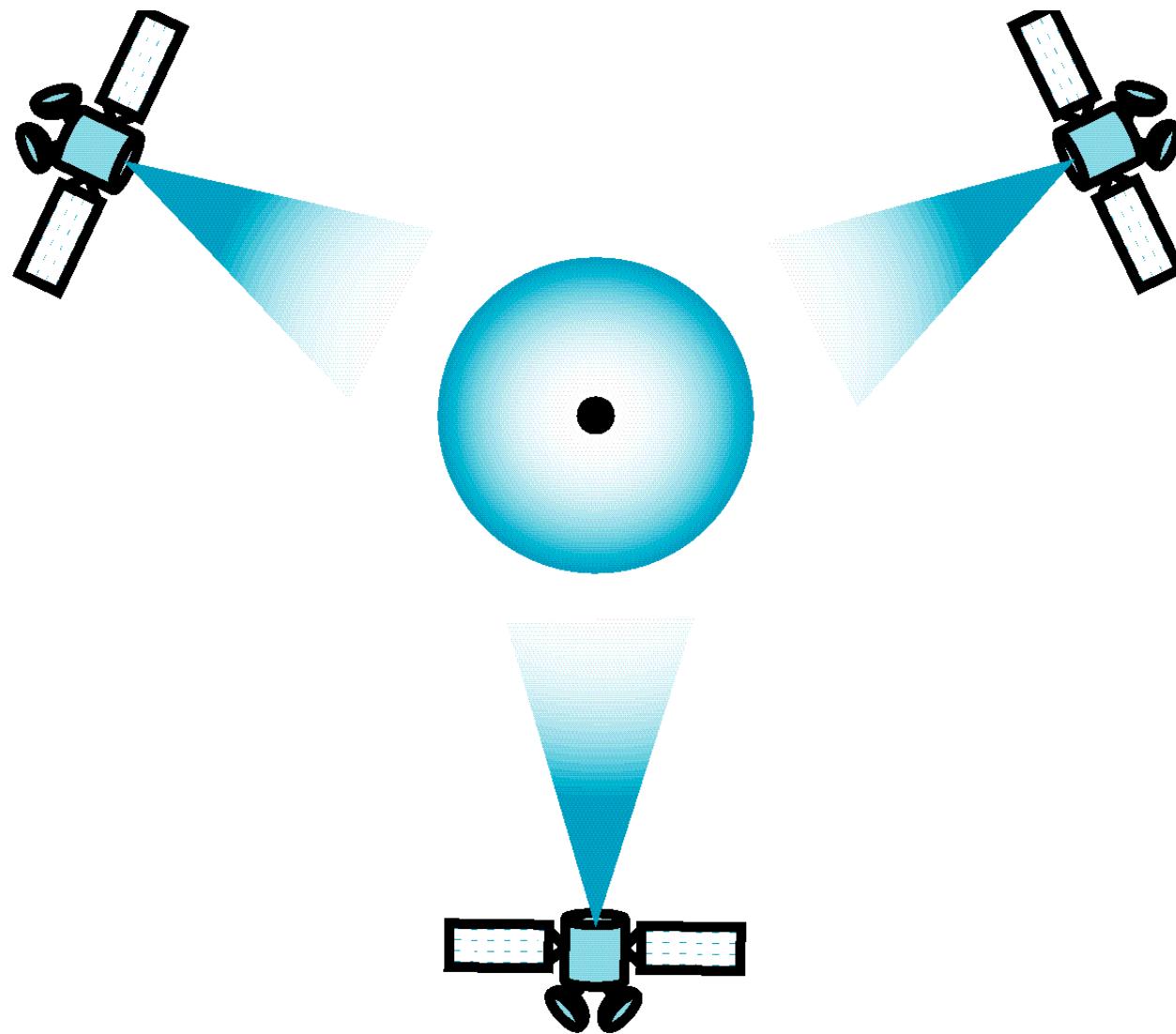
Similar to terrestrial microwave except the signal travels from a ground station on earth to a satellite and back to another ground station.

Satellites can be classified by how far out into orbit each one is (LEO, MEO, GEO, and HEO).

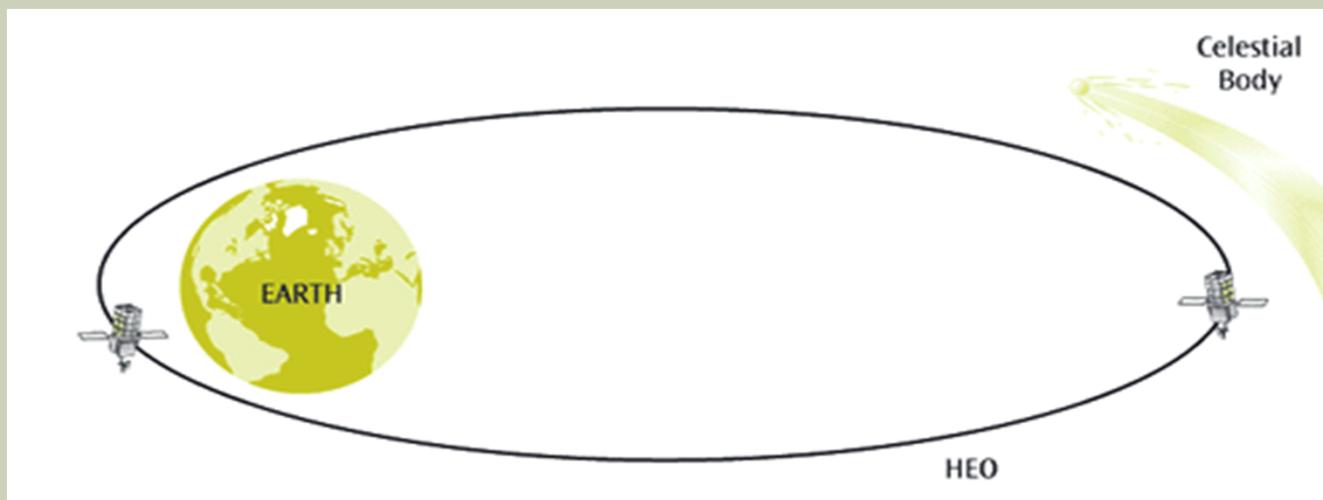
SATELLITE MICROWAVE



Geosynchronous Orbit



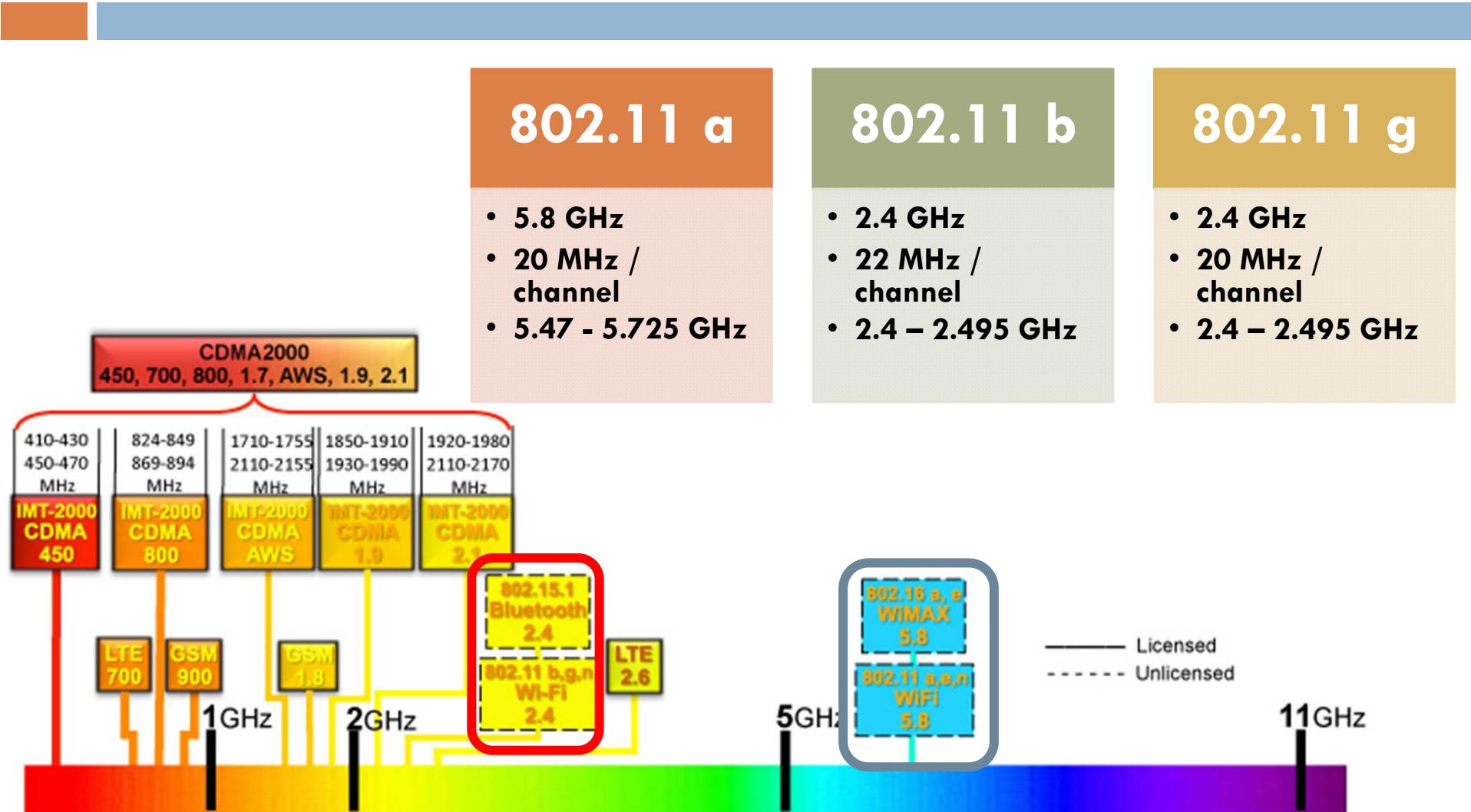
HEO ORBIT



A fourth type of orbit used by the military for spying and by scientific organizations for photographing celestial bodies.

When satellite is far out into space, it takes photos. When satellite is close to earth, it transmits data.

WiFi



Bluetooth





BLUETOOTH

- Operate in noisy radio frequency environments
 - 2.402 GHz - 2.480 GHz
 - omni-directional
 - Point-to-multipoint
- frequency-hopping scheme
 - 79 hops (RF channels) 1 MHz apart.
 - bandwidth is reduced in Japan, France and Spain
 - The maximum frequency hopping rate is 1600 hops/s
- link range
 - Usually 10 centimeters to 10 meters
 - Can be extended to more than 100 meters by increasing the transmit power
- Small amounts of data
 - 1Mbps over short distances (up to 10 meters).

BLUETOOTH

- Very Low power device
- Based on the **IEEE 802.11 standard**
- **Not** designed to carry heavy traffic loads
- Fast acknowledgement



BLUETOOTH

- Bluetooth Special Interest Group (SIG)
 - Ericsson, Intel, Nokia, Toshiba and IBM.
- telephones, tablets, media players, Lego Mindstorms NXT, PlayStation 3, PS Vita, the Nintendo Wii, and some high definition headsets, modems, and watches
- Bluetooth vs. Wi-Fi (IEEE 802.11)
 - Wi-Fi is usually access point-centered,
 - with an asymmetrical client-server connection with all traffic routed through the access point,
 - Bluetooth is usually symmetrical, between two Bluetooth devices.
 - Bluetooth serves well in simple applications where two devices need to connect with minimal configuration like a button press, as in headsets and remote controls,





Infared Transmission

Infrared signals can be used for **short-range** communication in a closed area using **line-of-sight** propagation.



INFARED TRANSMISSION

- Short-range communication
- Frequency
 - 100 GHz – 1000 THz
- Use a focused ray of light
 - Point-to-point
 - Line-of-sight
 - 100 Kbps – 16 Mbps
 - Broadcast
 - Reflective
 - 1 Mbps
- Device-to-device transfers
 - remote control
 - PDA
 - Notebook
 - Cellular phone
- IrDA standard: Infrared Data Association