Chapter 7

Transmission Media

Figure 7.1 *Transmission medium and physical layer*

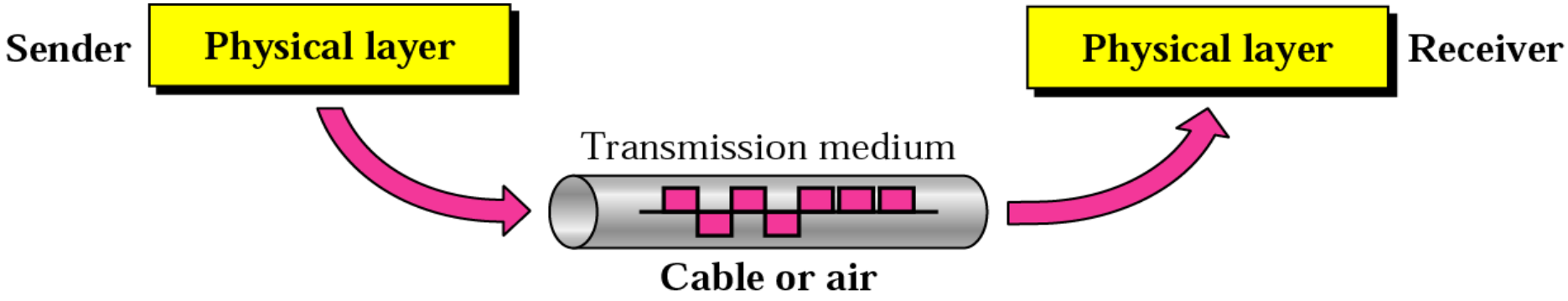


Figure 7.2 Classes of transmission media

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

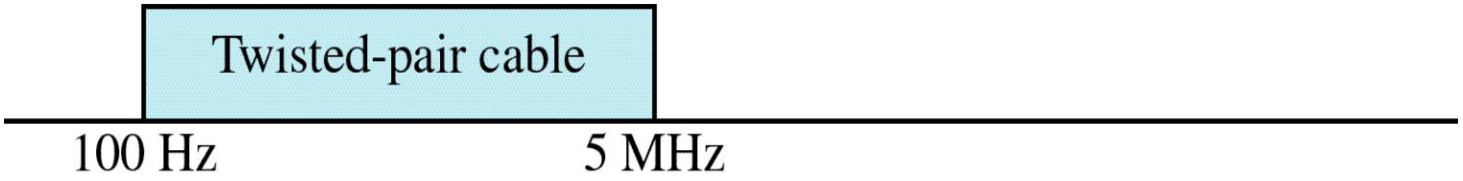
Coaxial Cable

Fiber-Optic Cable

Twisted Pair Cable

Figure 7.3 *Twisted-pair cable*

BW twisted-pair cable = 5 MHz



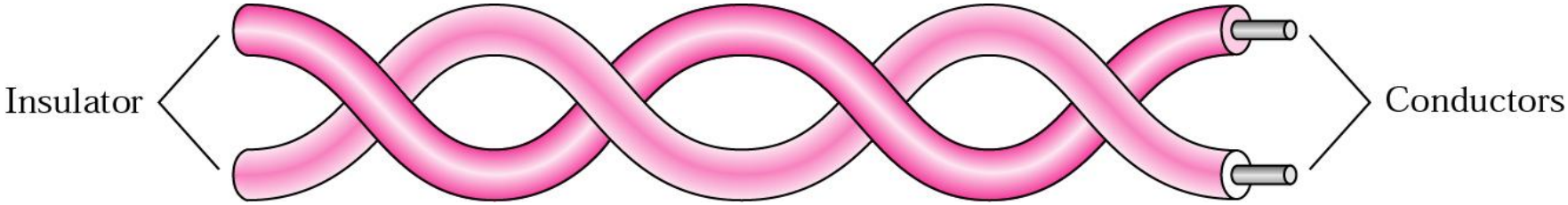
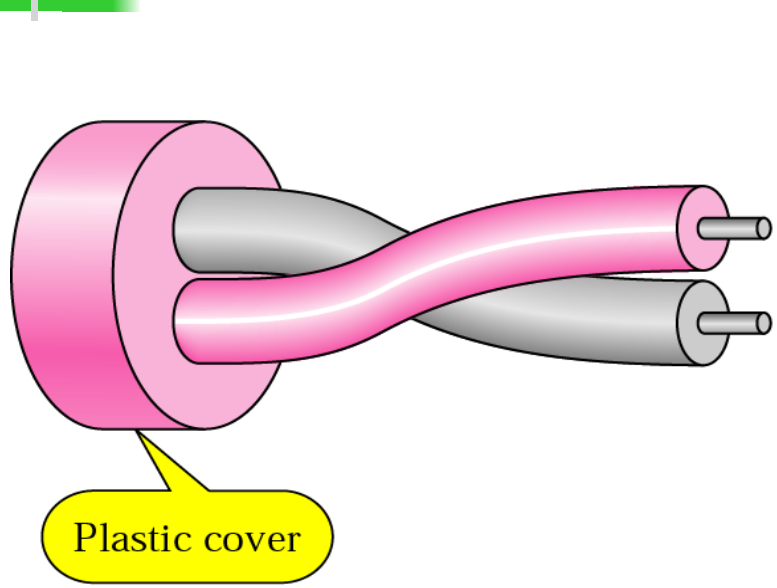
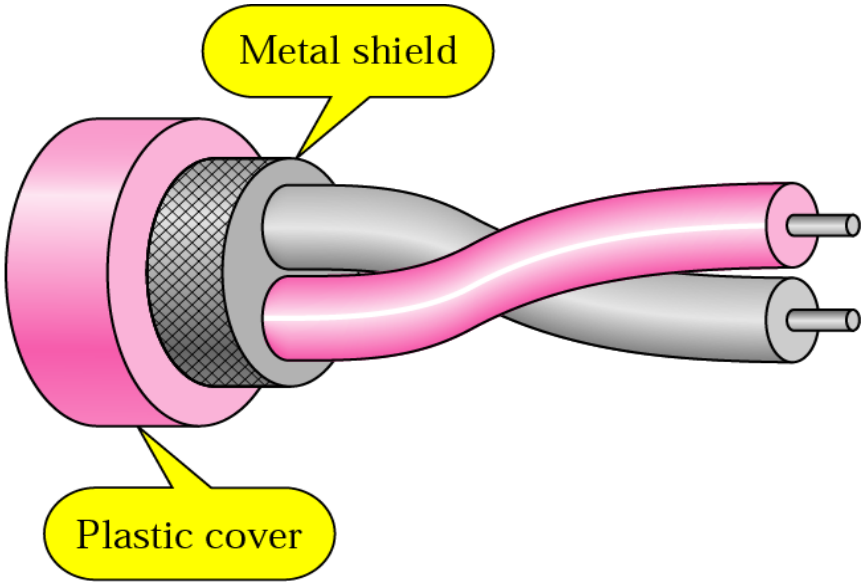


Figure 7.4 *UTP and STP*

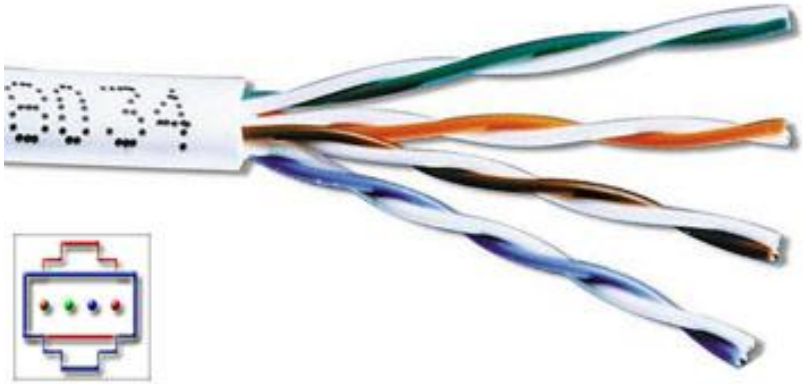


a. UTP



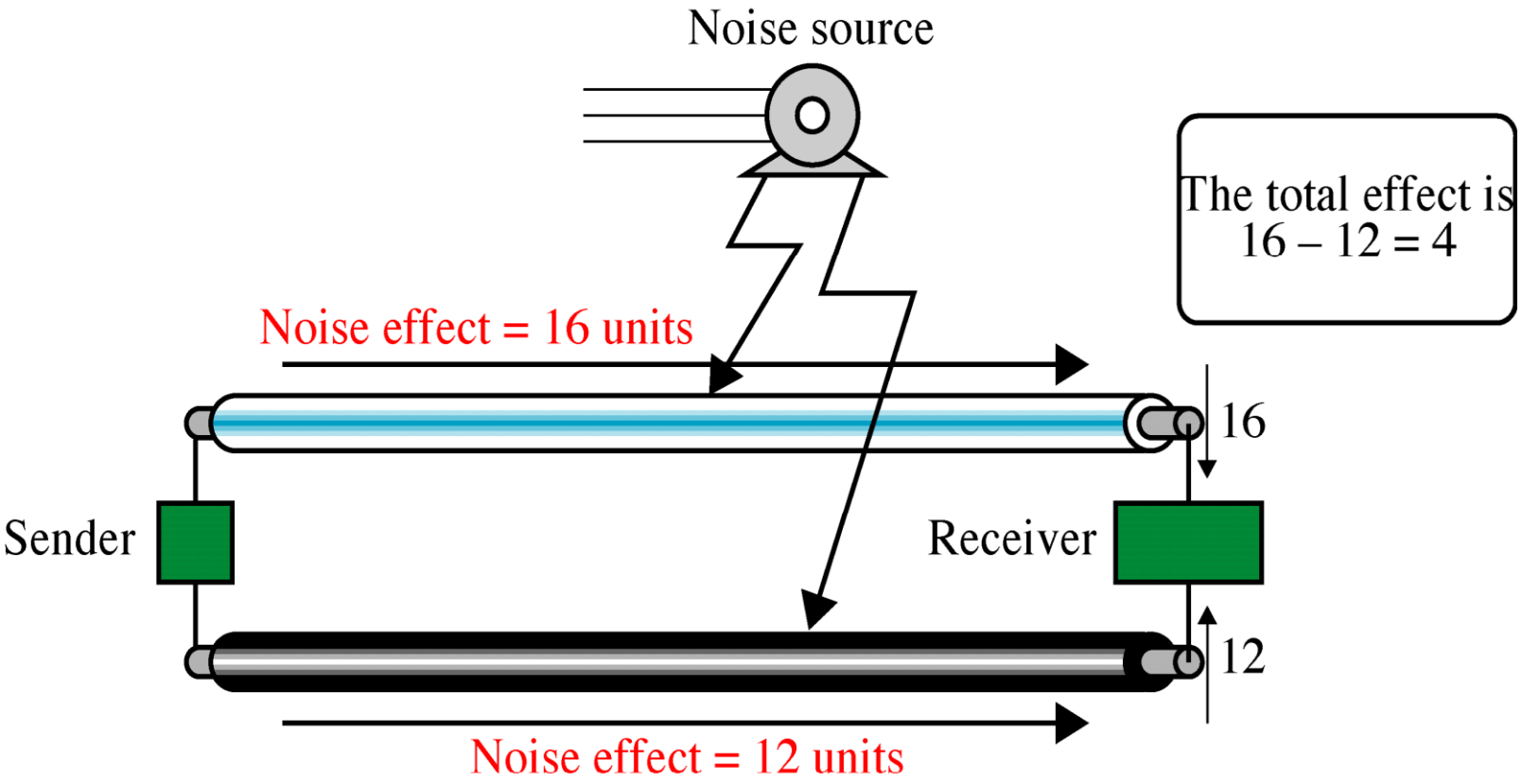
b. STP

Unshielded twisted pair (UTP)



Shielded twisted pair (STP)

Effect of Noise on Parallel Lines



Noise on Twisted-Pair Lines

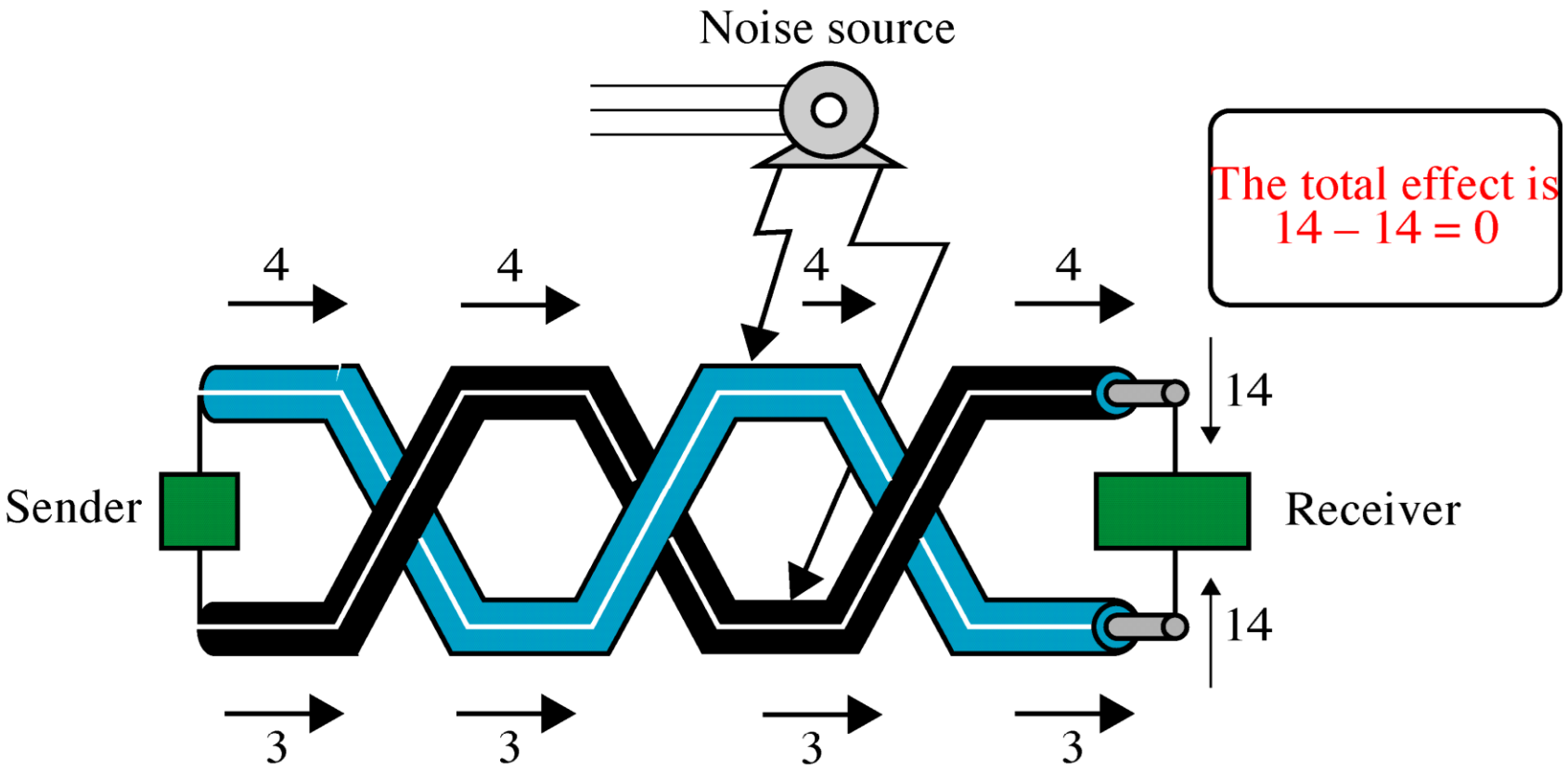


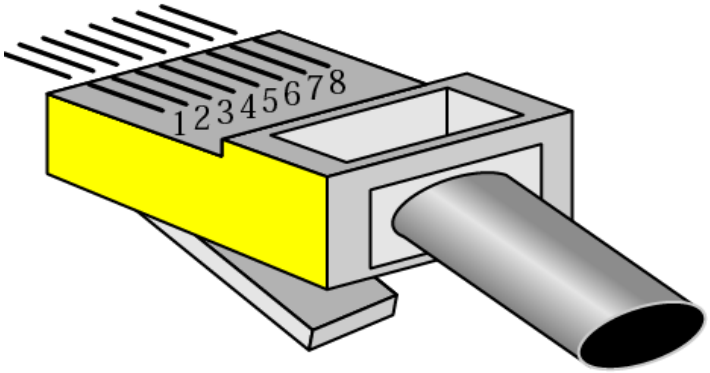
Table 7.1 *Categories of unshielded twisted-pair cables (EIA)*

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**	T-1 lines (1.544 Mbps)
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	LANs (Fast Ethernet: 100BASE-T)
5E	An extension to category 5 that includes electromagnetic interference	**1,000**	LANs **(100BASE-T)**
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**	LANs **(Gigabit Ethernet: 100BASE-T)**
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

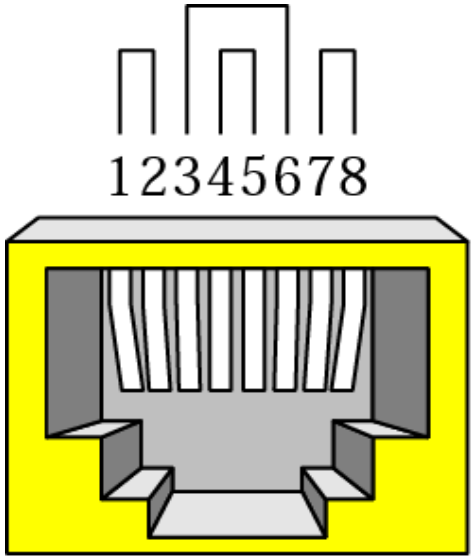
A 40GBASE-T standard, transporting 40 Gbit/s over up to 30 m Cat.8 cable

maximum distance 100 m without repeater

Figure 7.5 *UTP connector*

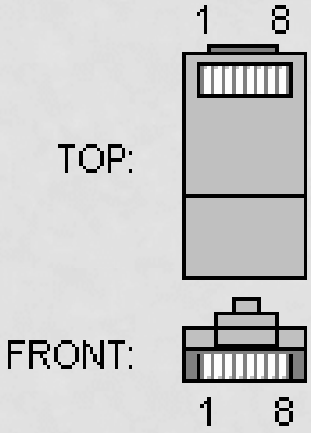


RJ-45 Male



RJ-45 Female

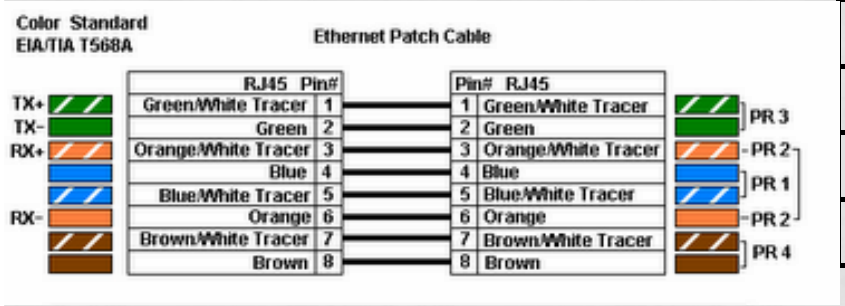
UTP PIN ASSIGNMENT (NORMAL UTP CABLE)



PC

Hub or Switch

TIA/EIA 568B Wiring

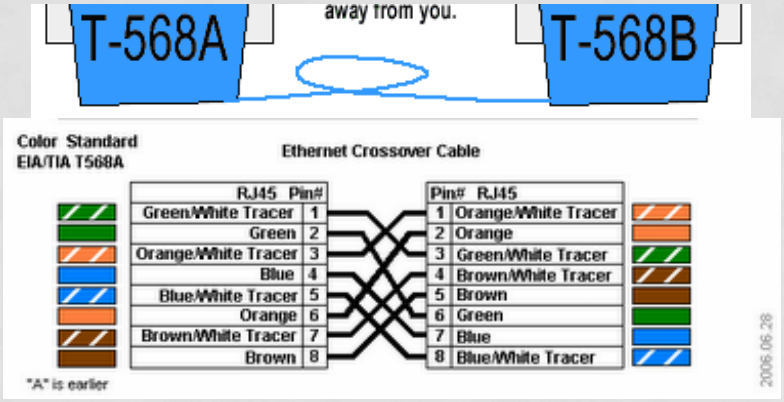


Name	NIC1	Color
TX+ (BI_DA+)	1	White/Orange
TX- (BI_DA-)	2	Orange
RX+ (BI_DB+)	3	White/Green
- (BI_DC+)	4	Blue
- (BI_DC-)	5	White/Blue
RX- (BI_DB-)	6	Green
- (BI_DD+)	7	White/Brown
- (BI_DD-)	8	Brown

Both sides of Cable

UTP PIN ASSIGNMENT (CROSS UTP CABLE)

PC → **PC**



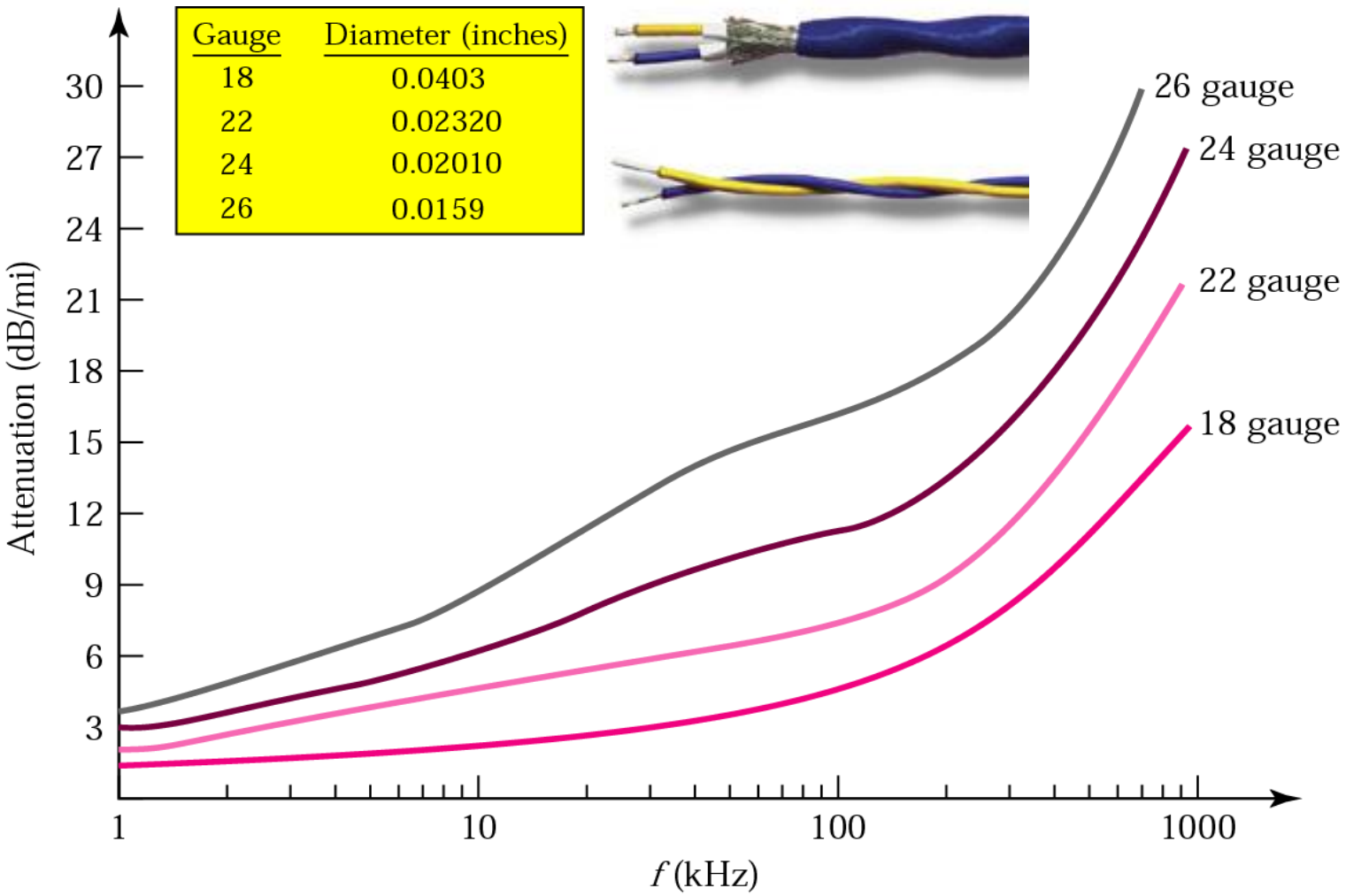
Name	NIC1	Color
TX+ (BI_DA+)	1	White/Orange
TX- (BI_DA-)	2	Orange
RX+ (BI_DB+)	3	White/Green
- (BI_DC+)	4	Blue
- (BI_DC-)	5	White/Blue
RX- (BI_DB-)	6	Green
- (BI_DD+)	7	White/Brown
- (BI_DD-)	8	Brown

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

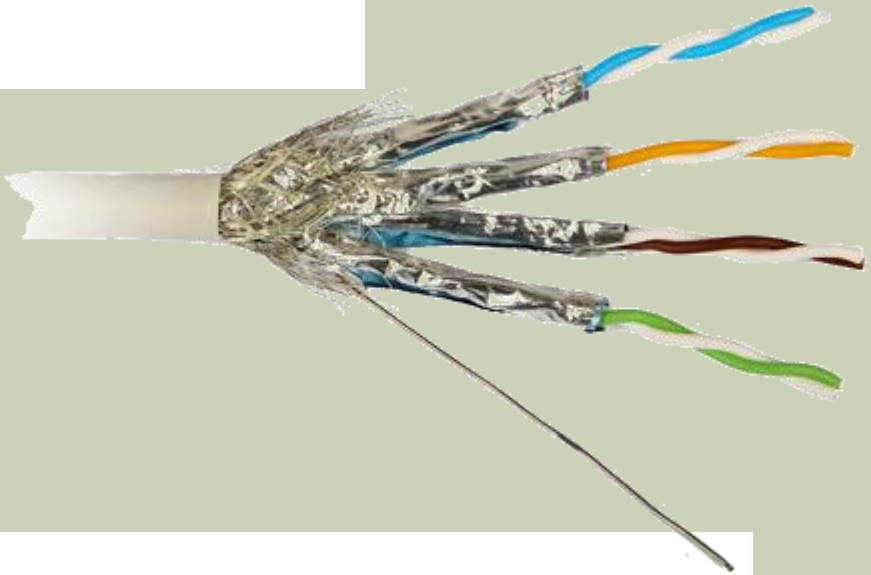
The other side of Cable

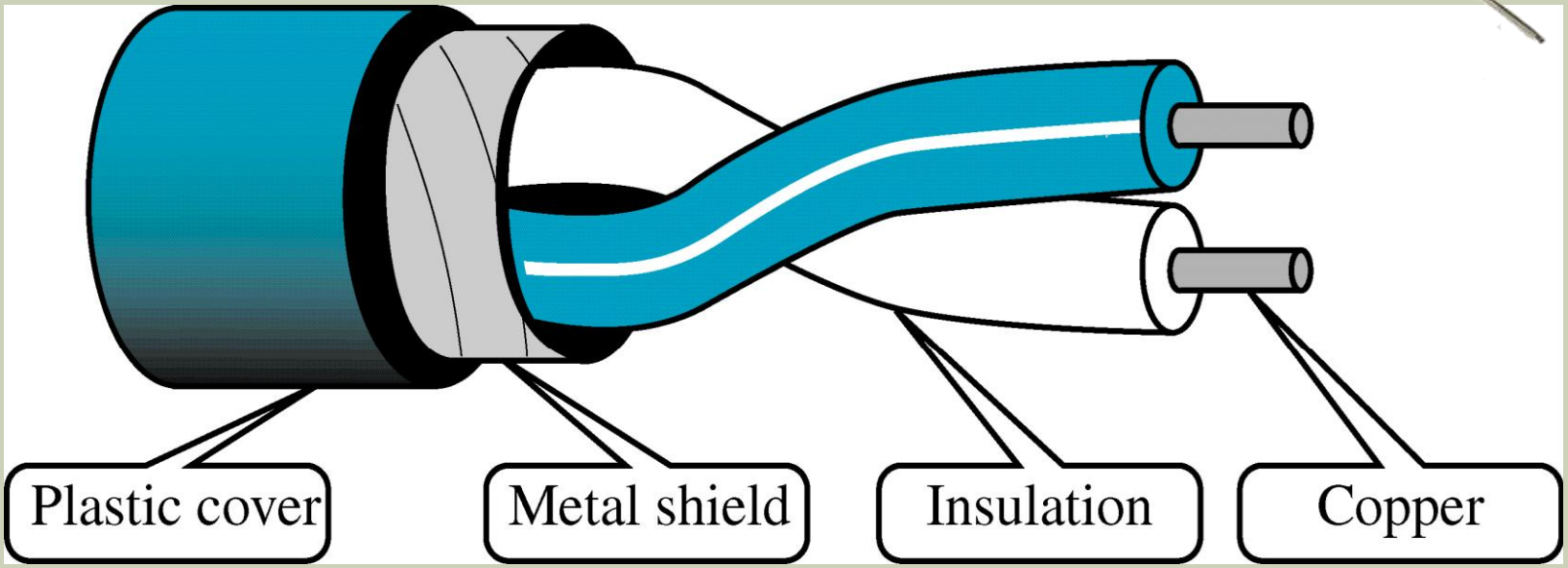
Figure 7.6 *UTP performance*



Copper core: ขนาดใหญ่ ค่าการลดทอนสัญญาณน้อย ส่งได้ไกลขึ้น

SHIELDED TWISTED-PAIR CABLE (CAT-7)





Coaxial Cable

Figure 7.7 *Coaxial cable*

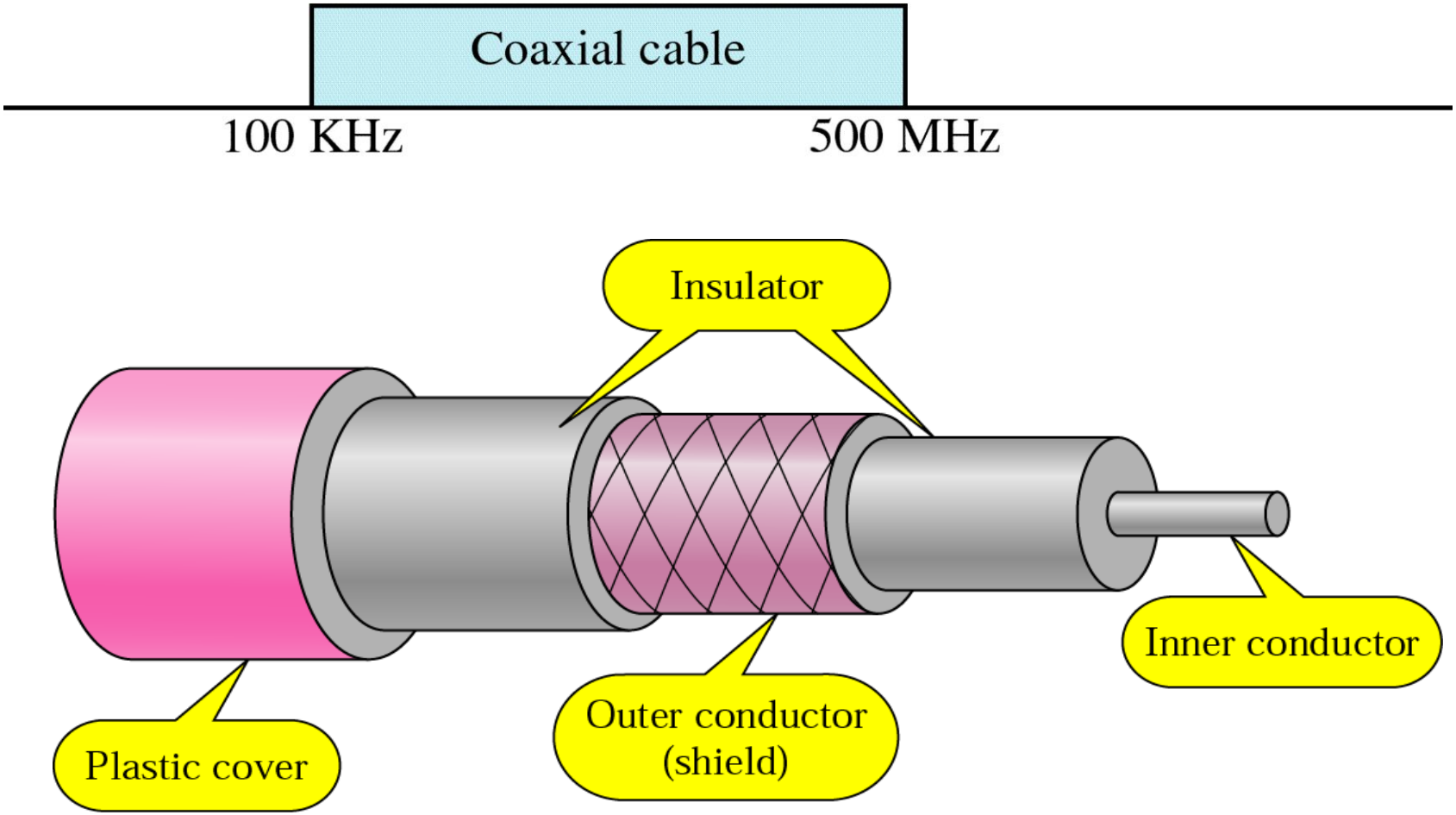
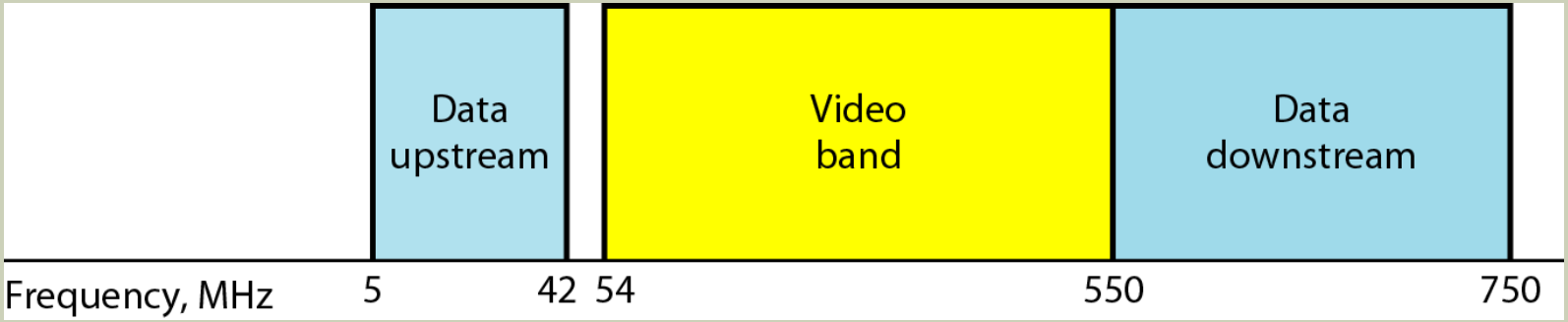


Table 7.2 Categories of coaxial cables

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

Radio Government (RG) rating

Figure 9.16 *Division of coaxial cable band by CATV*

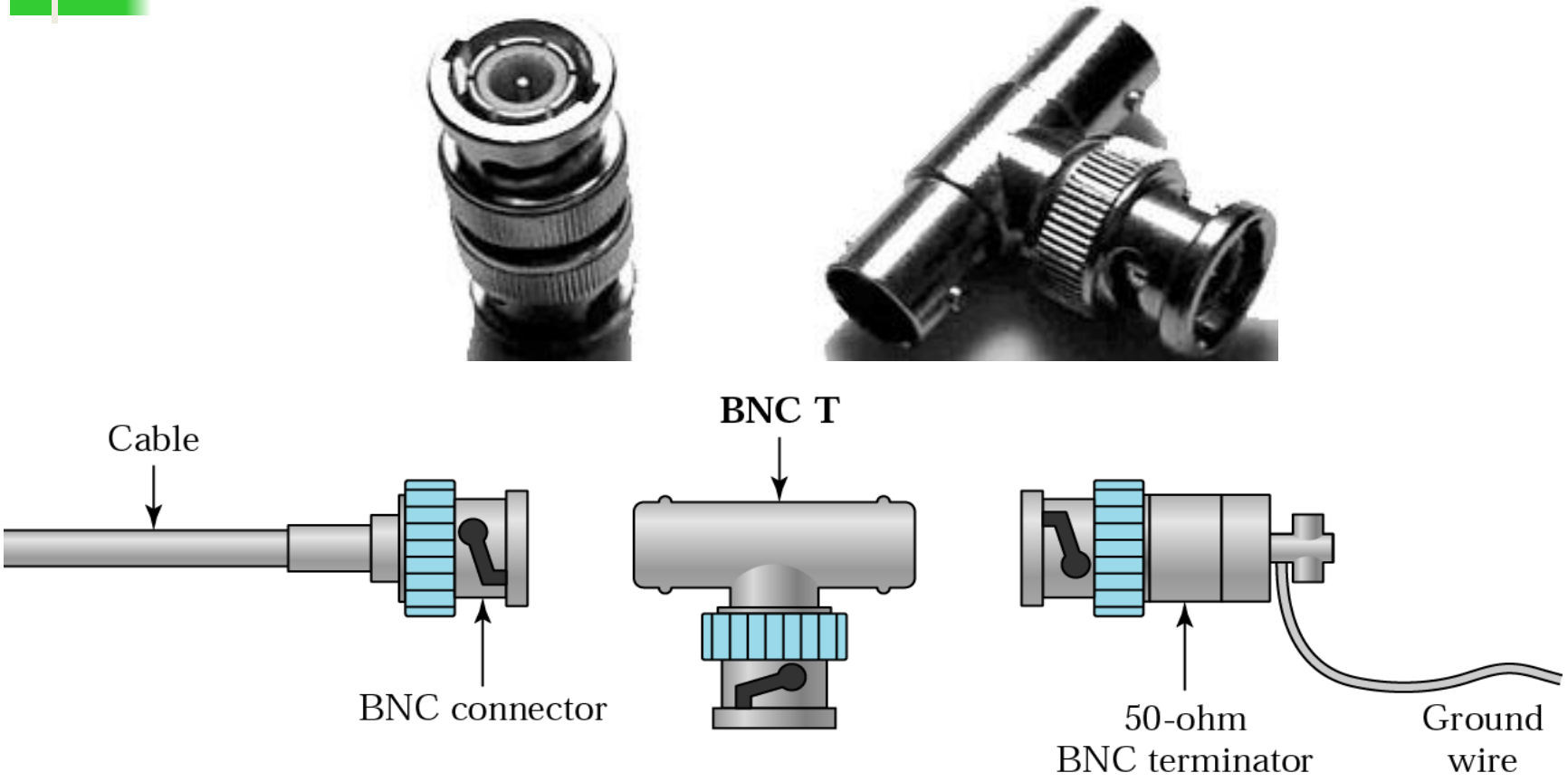


- Subband division (6 MHz / channel)
  - Video: 54 – 550 MHz
  - Upstream: 5 - 42 MHz
  - Downstream: 550 – 750 MHz

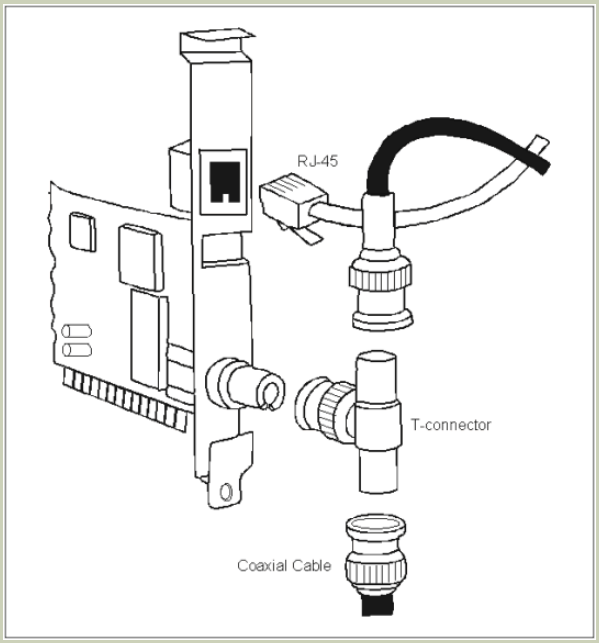
- Modulation
  - Upstream: QPSK -> 12 Mbps
  - Downstream: 64 QAM -> 30 Mbps

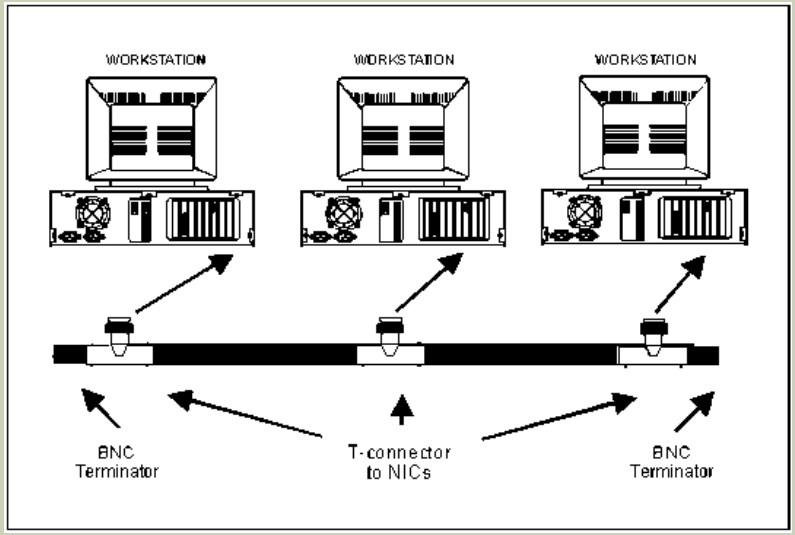
COAXIAL CONNECTORS (BNC)

Figure 7.8 *BNC connectors*



LAN on Coaxial cable (Bus topology)





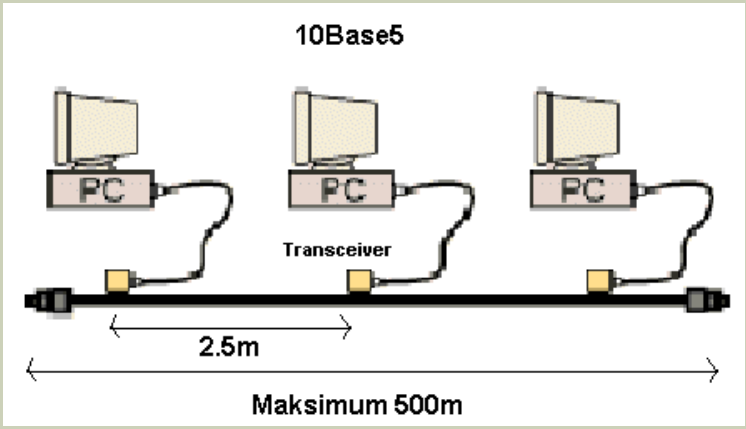
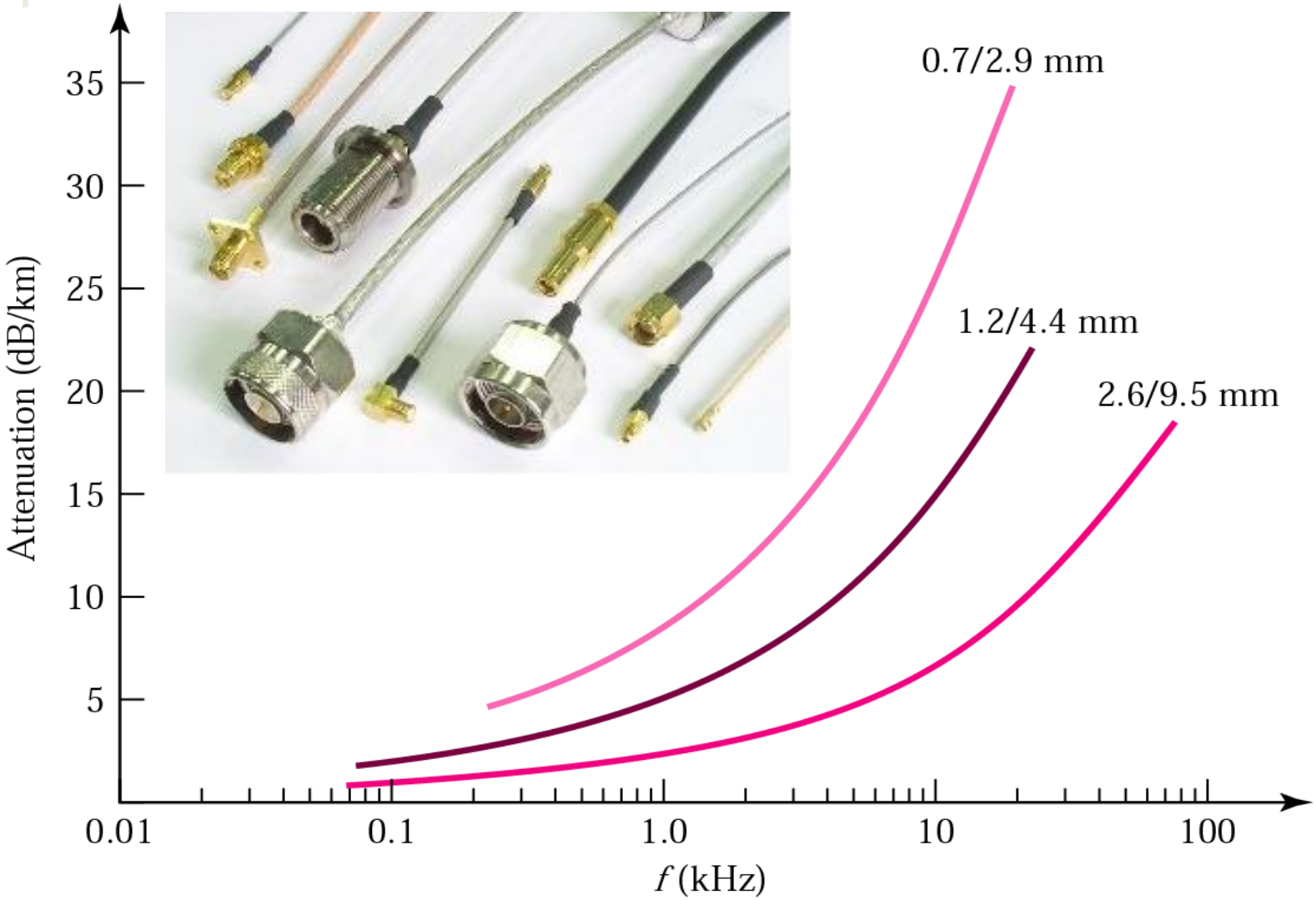


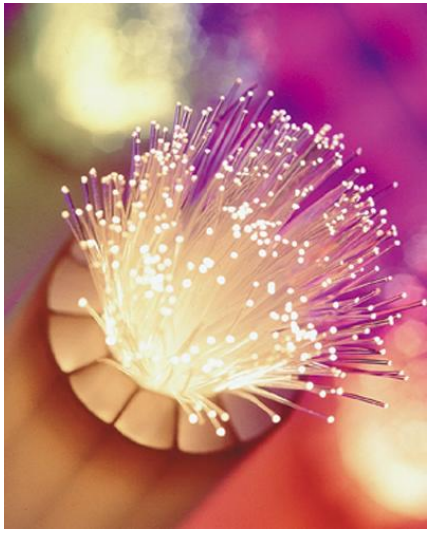
Figure 7.9 *Coaxial cable performance*

ที่ความถี่สูงขึ้น ขนาดของการลดทอนกำลังของสัญญาณจะมากขึ้น

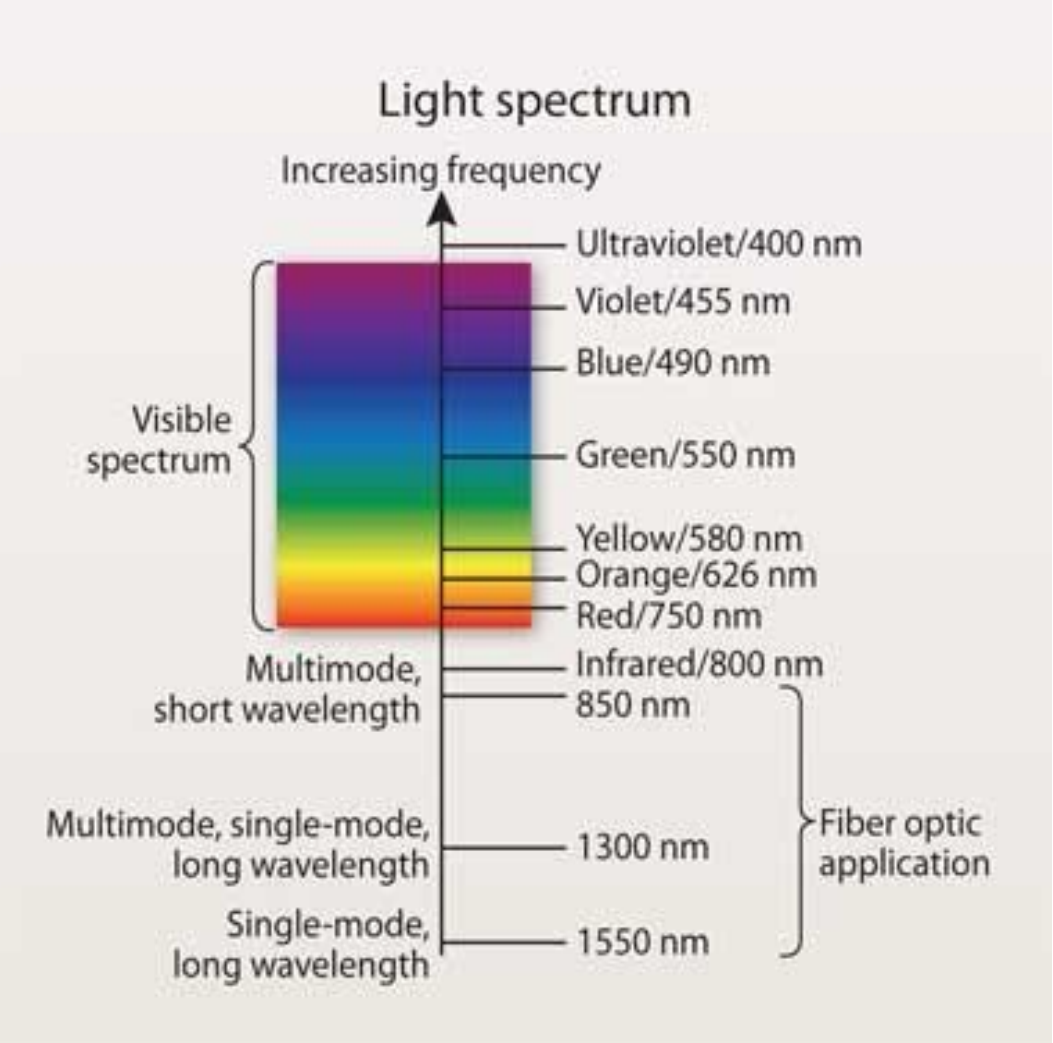


ขนาดของแกนตัวนำในสายขนาดใหญ่ขึ้น ส่งผลให้ขนาดของการลดทอนกำลังของสัญญาณจะน้อยลง

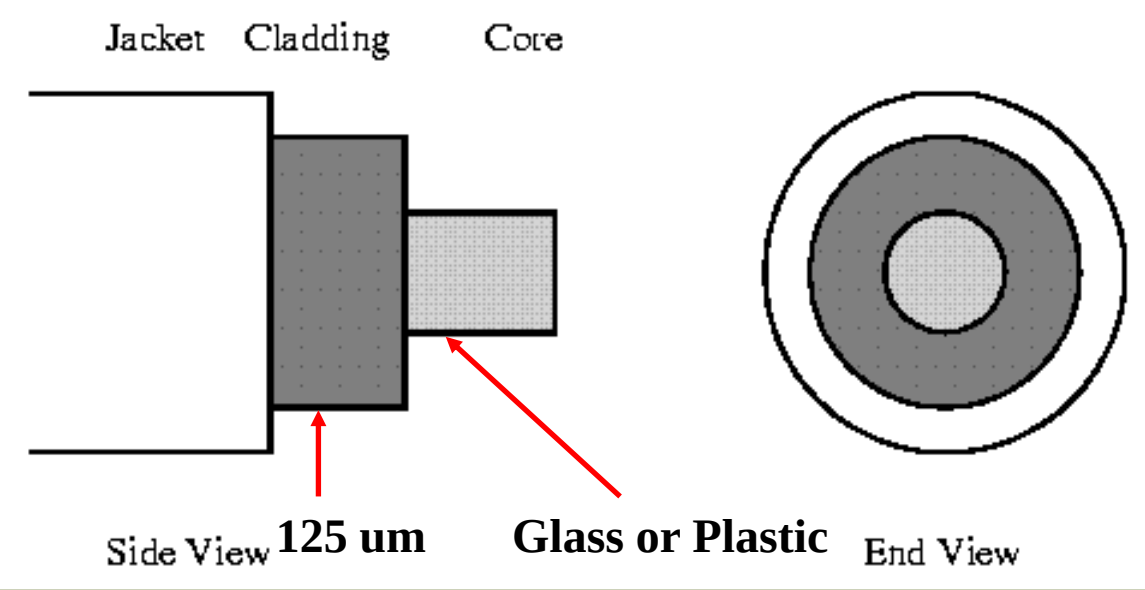
Fiber Optic Cable



Fiber Optic Frequency Range



FIBER OPTIC



ช่วง WAVELENGTH ที่ใช้งาน 1550 NM

CHANNEL SPACE:

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

LIGHT REFLECTION

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

n_i = ดัชนีหักเหของตัวกลาง i

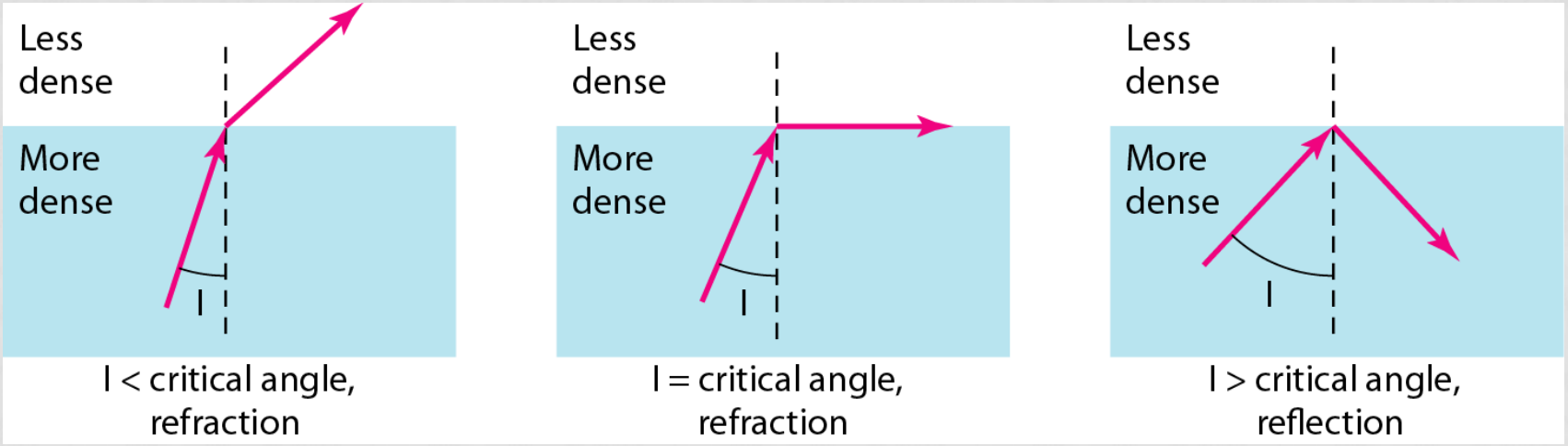
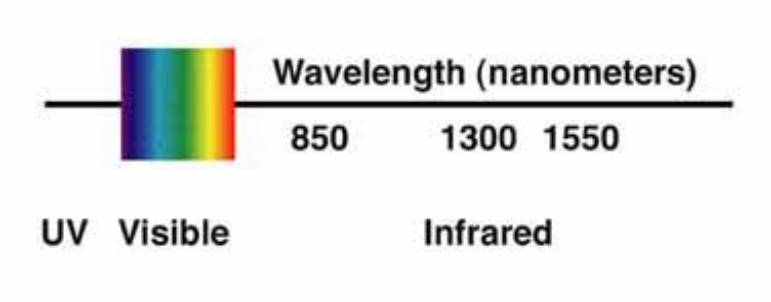
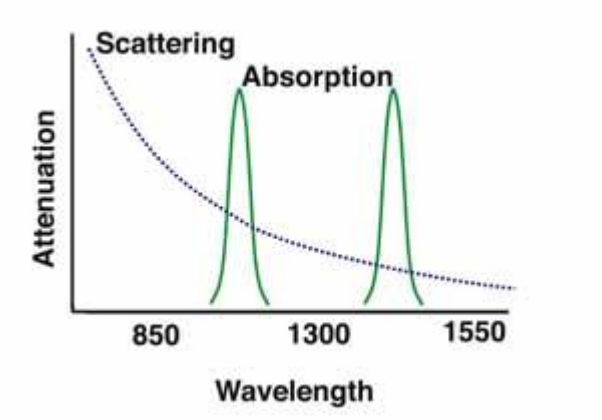


Figure 7.11 *Optical fiber*

Frequency: 180 THz – 330 THz





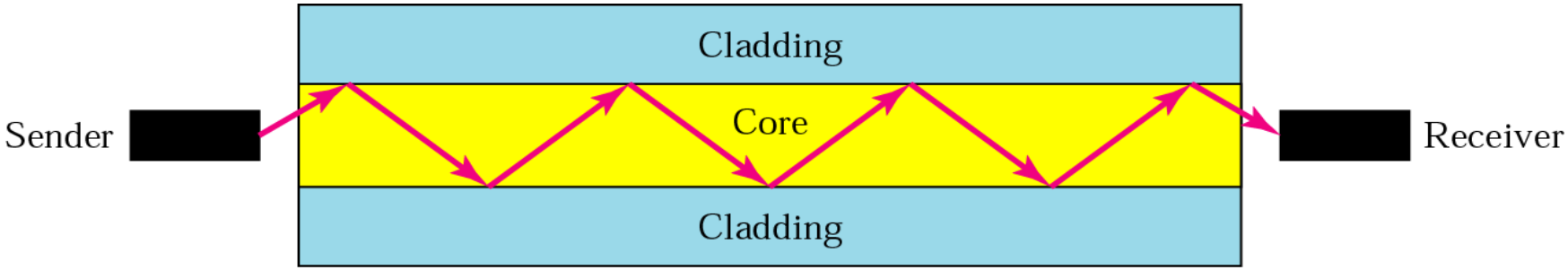


Figure 7.12 ***Propagation modes***

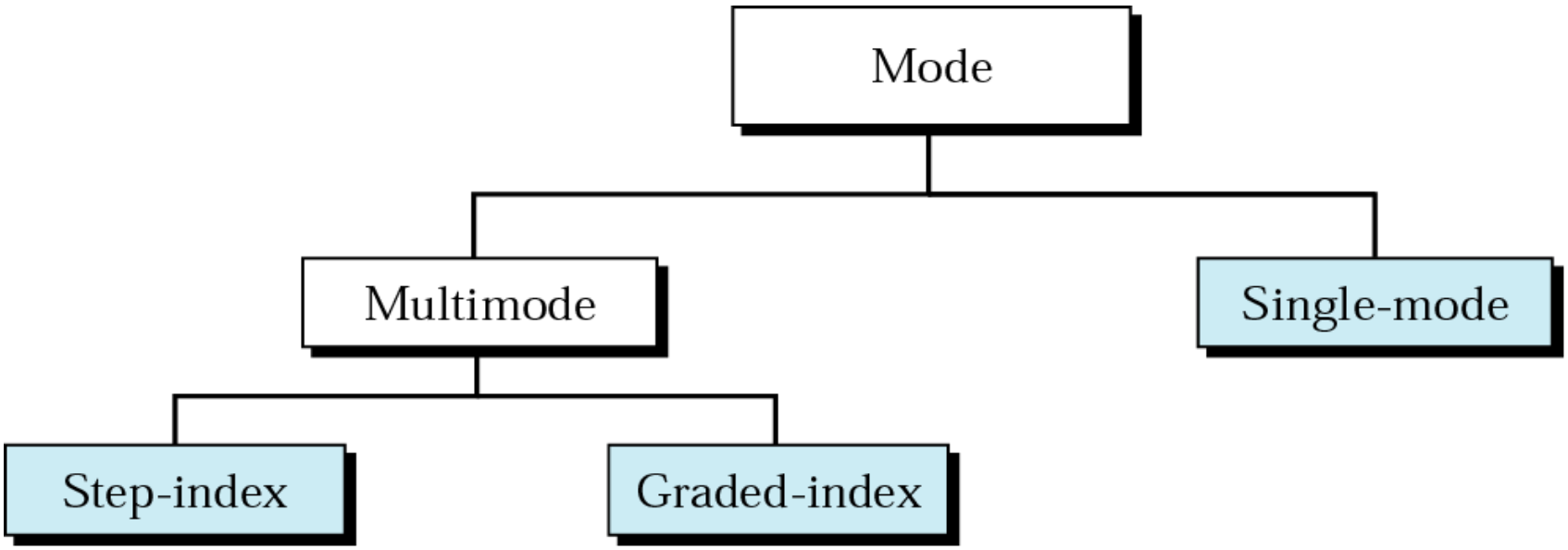
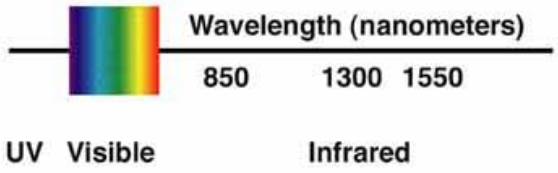
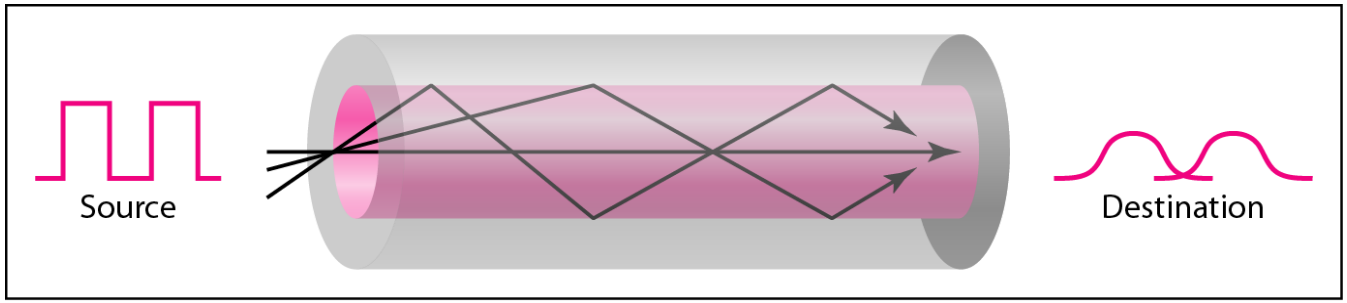
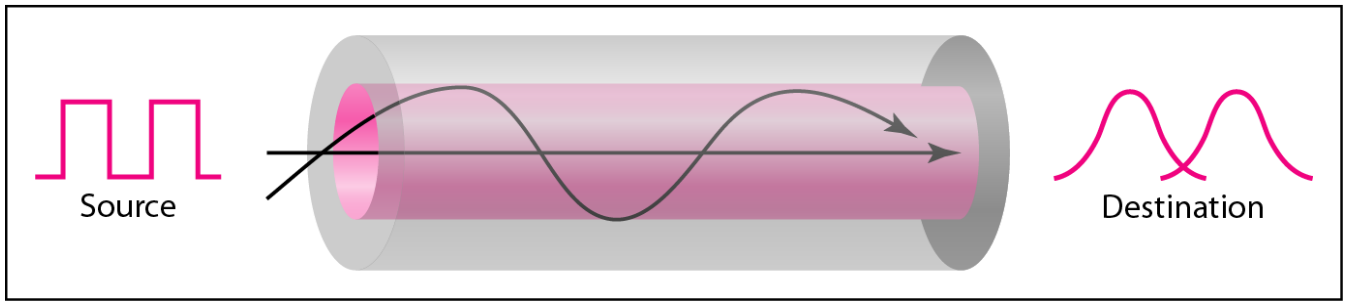


Figure 7.13 *Modes*

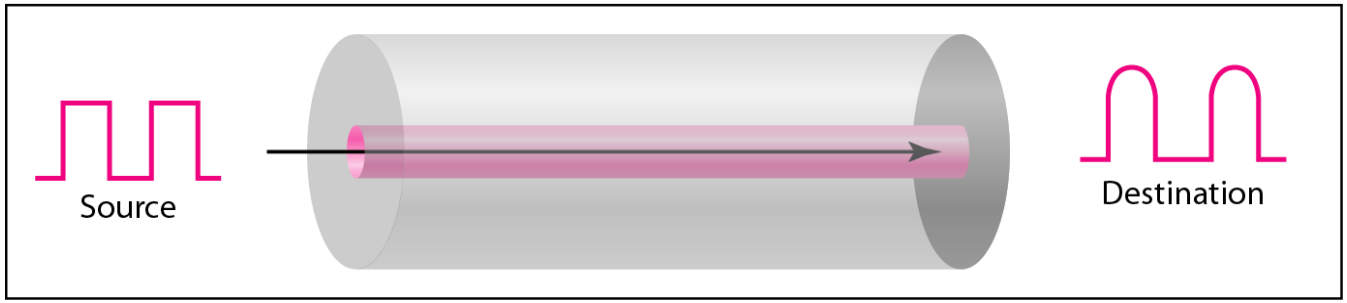




a. Multimode, step index



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*

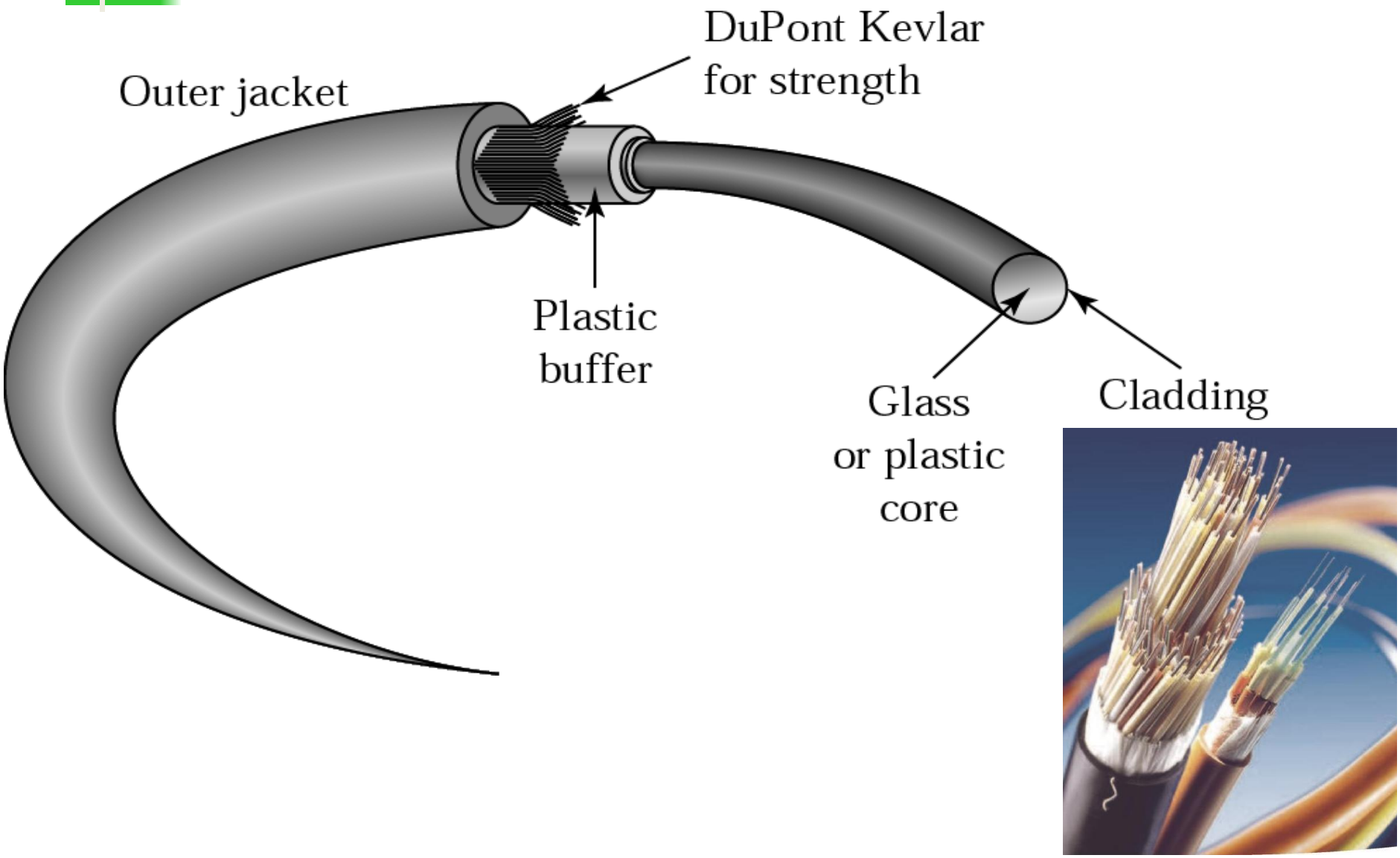
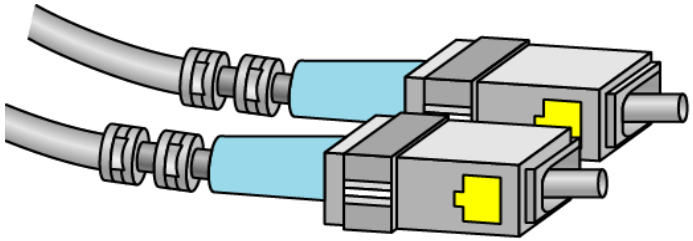
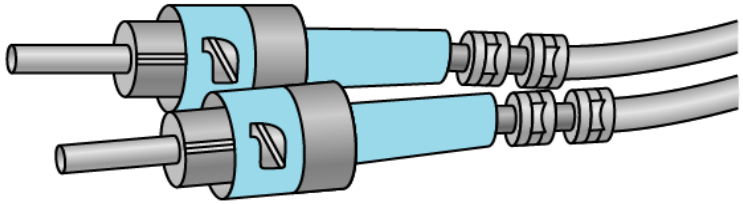


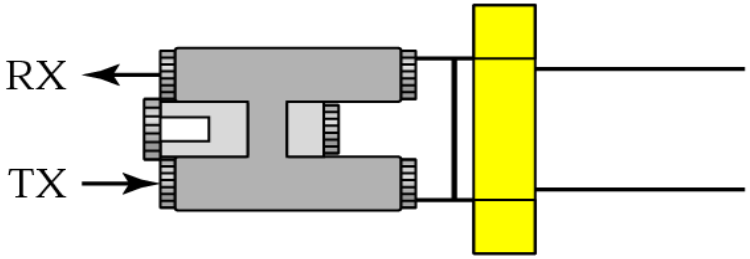
Figure 7.15 *Fiber-optic cable connectors*



SC connector

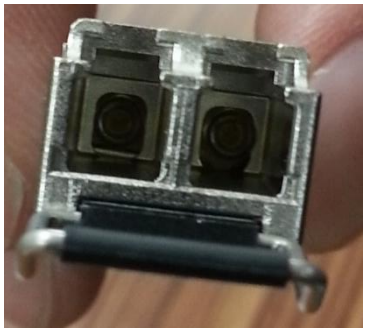


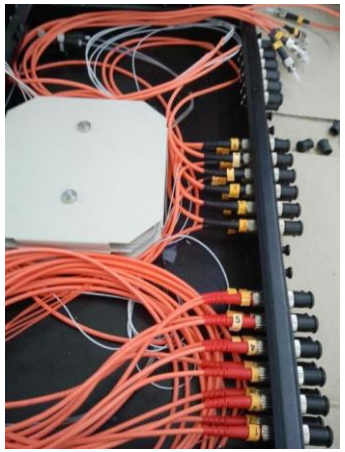
ST connector



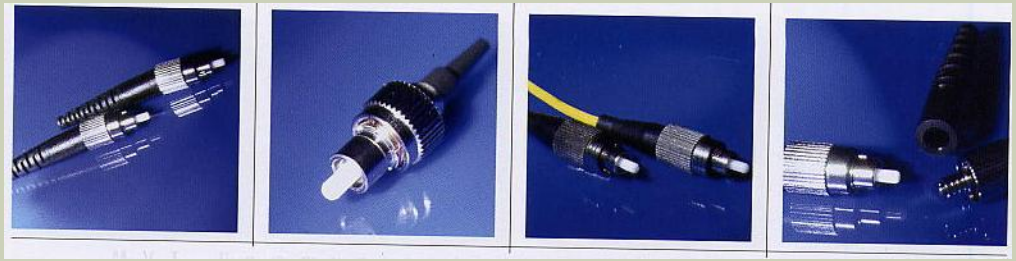
MT-RJ connector

Transceiver (Fiber-Twisted pair)

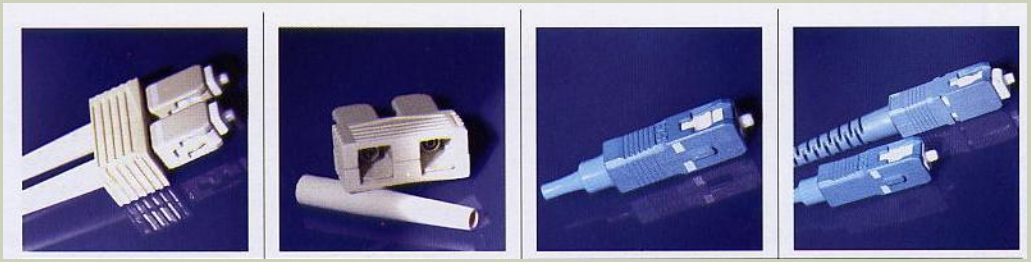




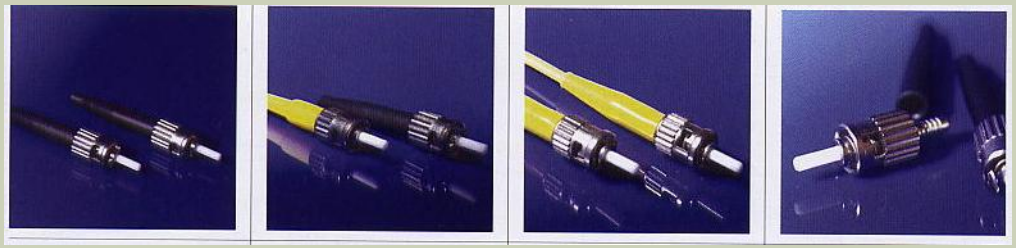
FIBER OPTIC CONNECTOR



FC connector

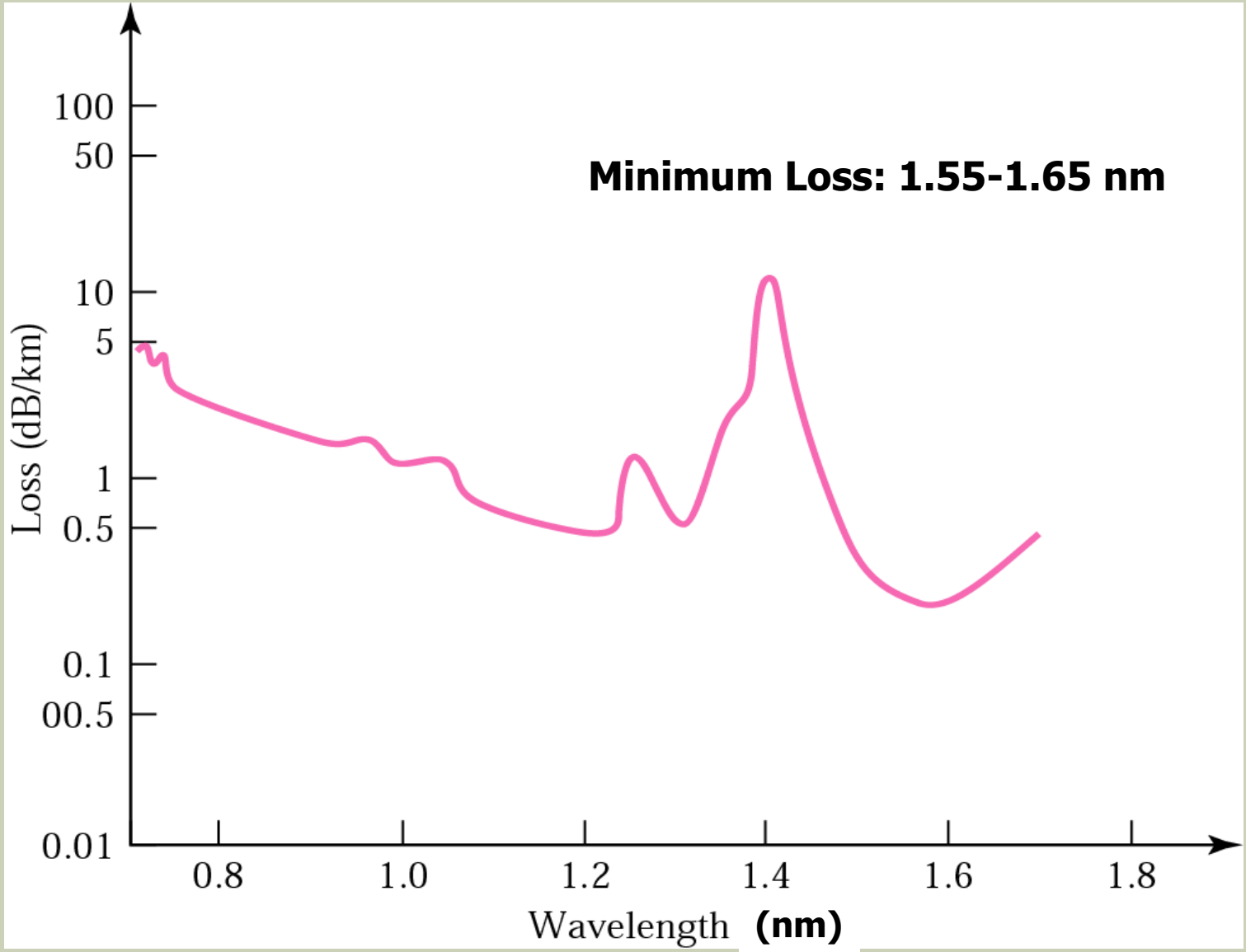


SC connector

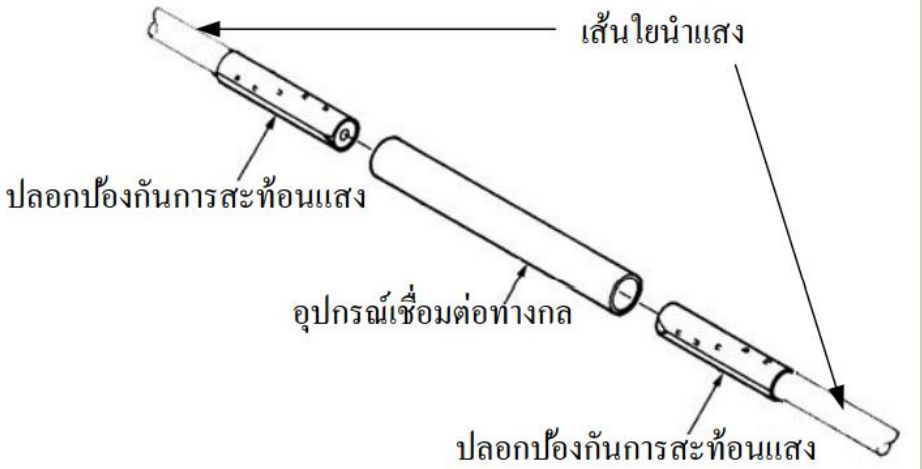


ST connector

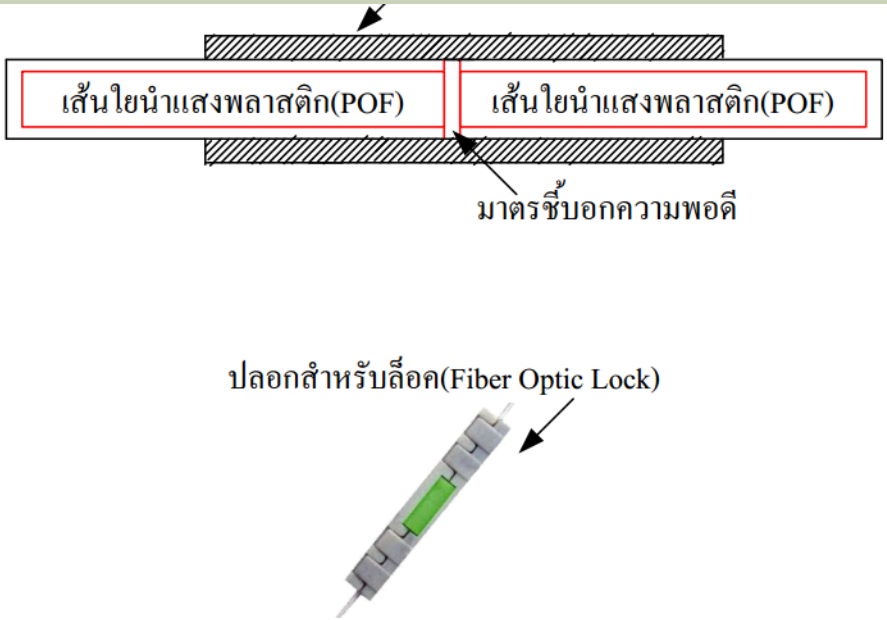
Figure 7.16 *Optical fiber performance*



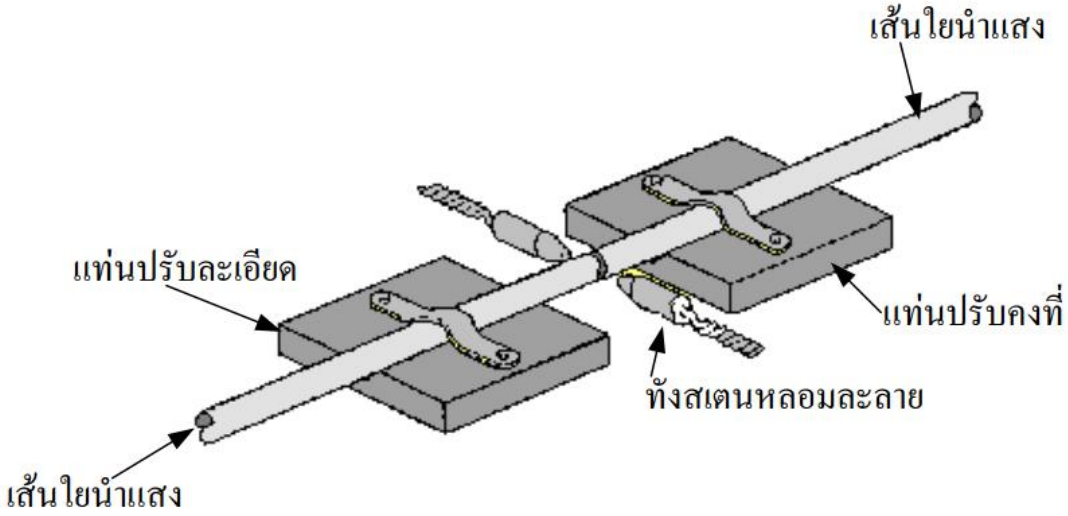
การเชื่อมต่อสาย FIBER



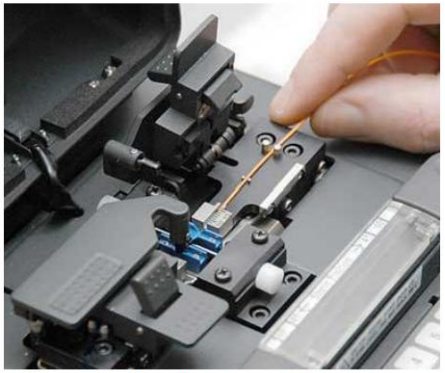
รูปที่ 6.11 แสดงหลักการอุปกรณ์เชื่อมต่อทางกล



การเชื่อมต่อสาย FIBER



รูปที่ 6.12 แสดงหลักการอุปกรณ์เชื่อมต่อวิธีการหลอมละลาย



รูปที่6.15 รูปเครื่องเชื่อมสายออปติคอลไฟเบอร์

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

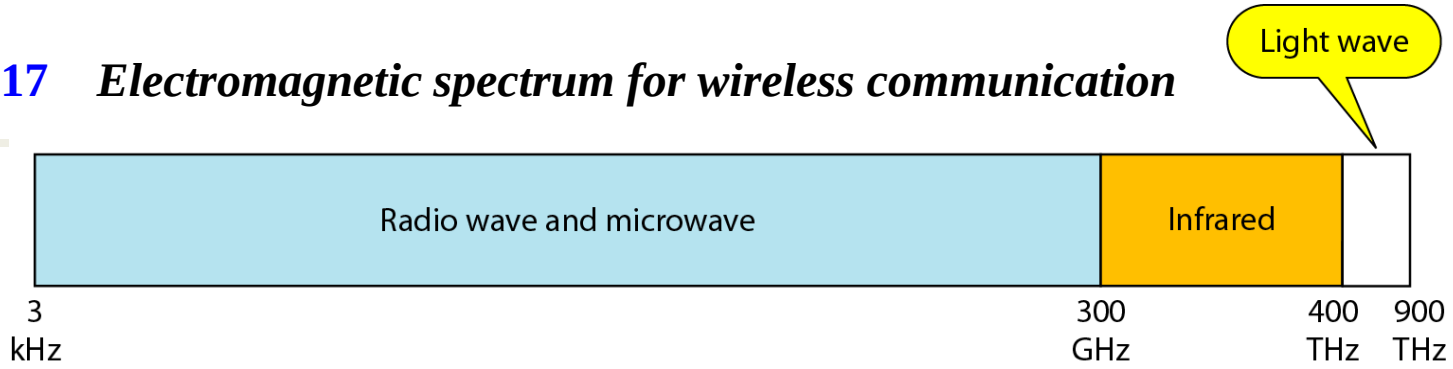
7.2 Unguided Media: Wireless

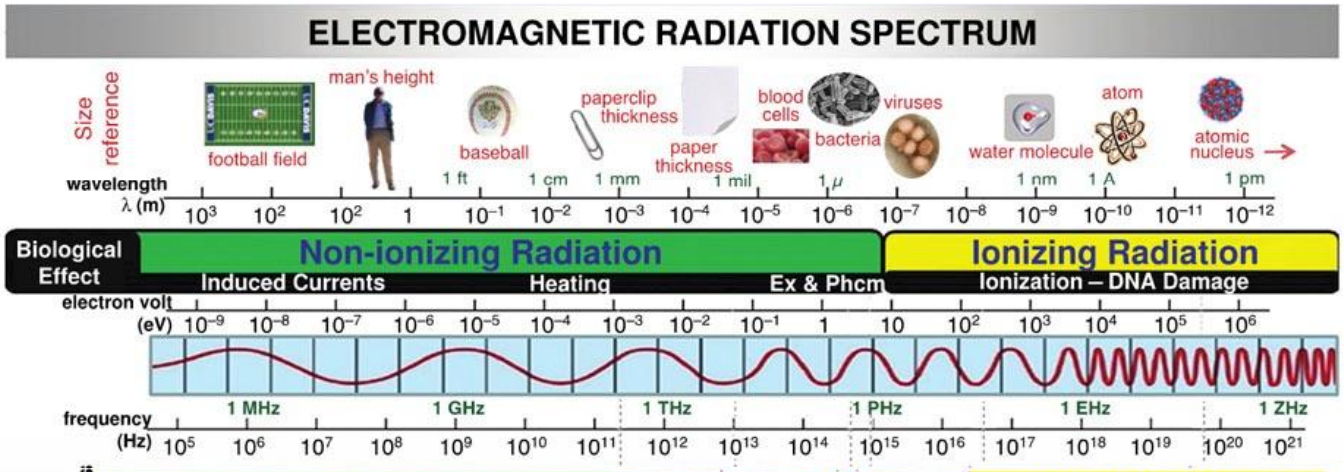
Radio Waves

Microwaves

Infrared

Figure 7.17 *Electromagnetic spectrum for wireless communication*





FCC: federal communications commission

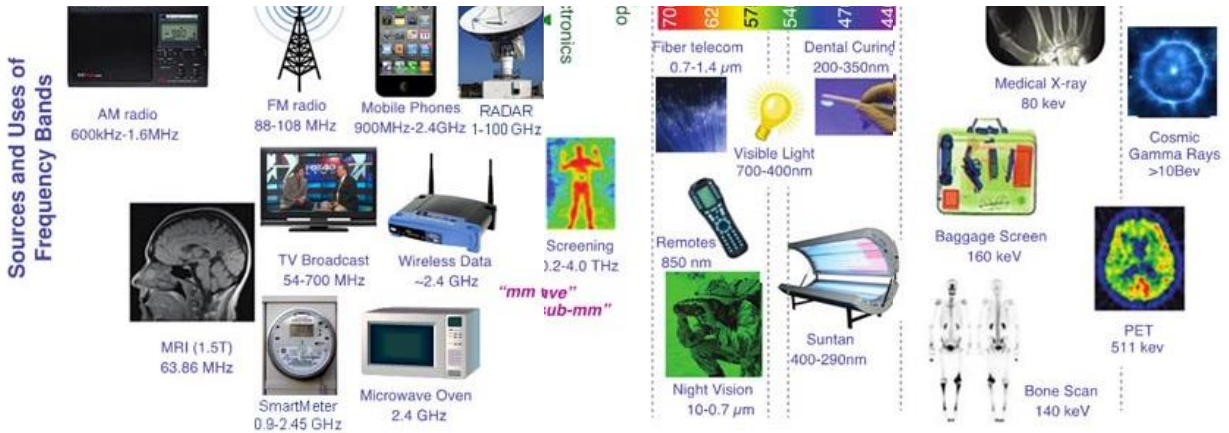
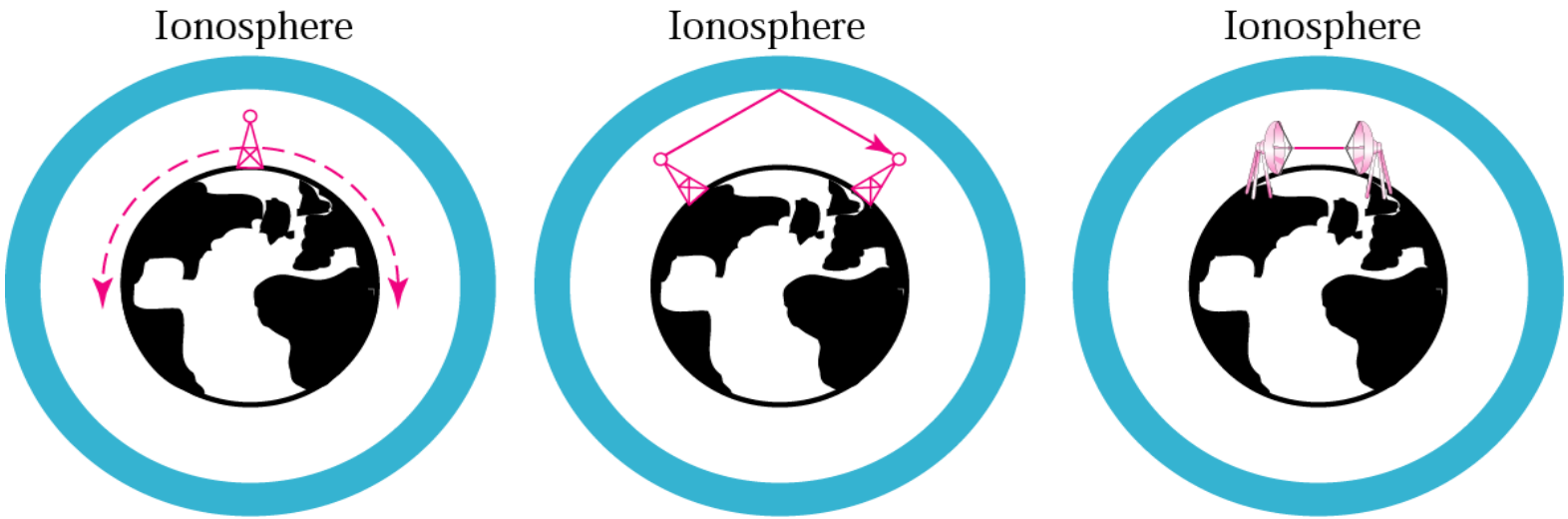


Figure 7.18 Radio & Microwave *Propagation methods*



Ground propagation
(below 2 MHz)

Sky propagation
(2 - 30 MHz)

Line-of-sight propagation
(above 30 MHz)

Walkie Talkie

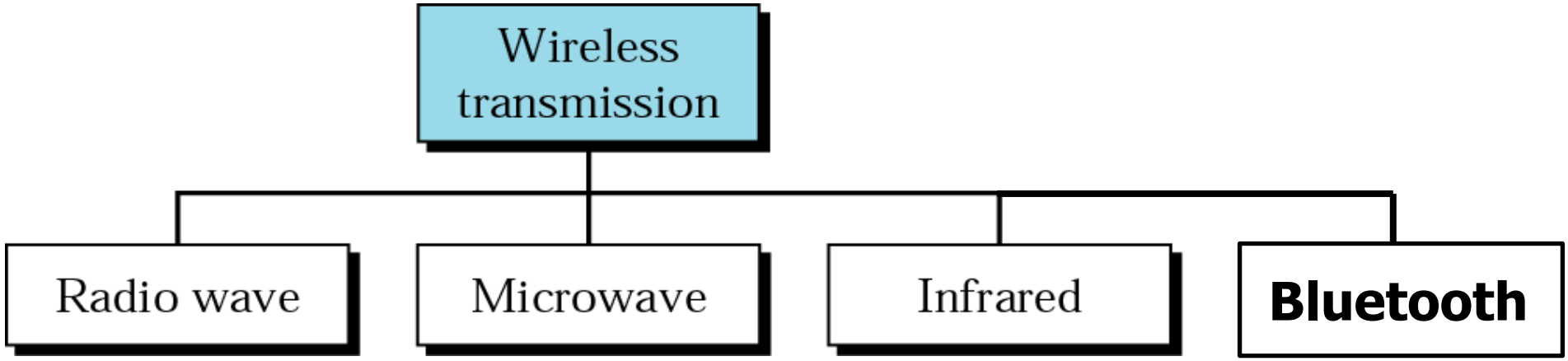
AM-FM Radio
VHF TV

UHF TV
Cellular phone
Satellite
Radar

Table 7.4 Bands

Band	*Range*	*Propagation*	*Application*
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

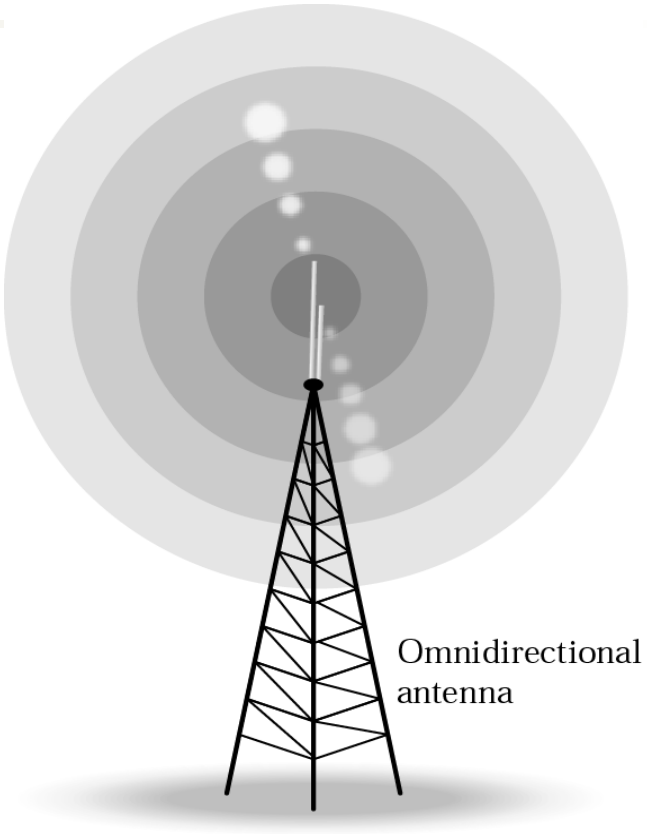
Figure 7.19 *Wireless transmission waves*



Radio & Microwave communication

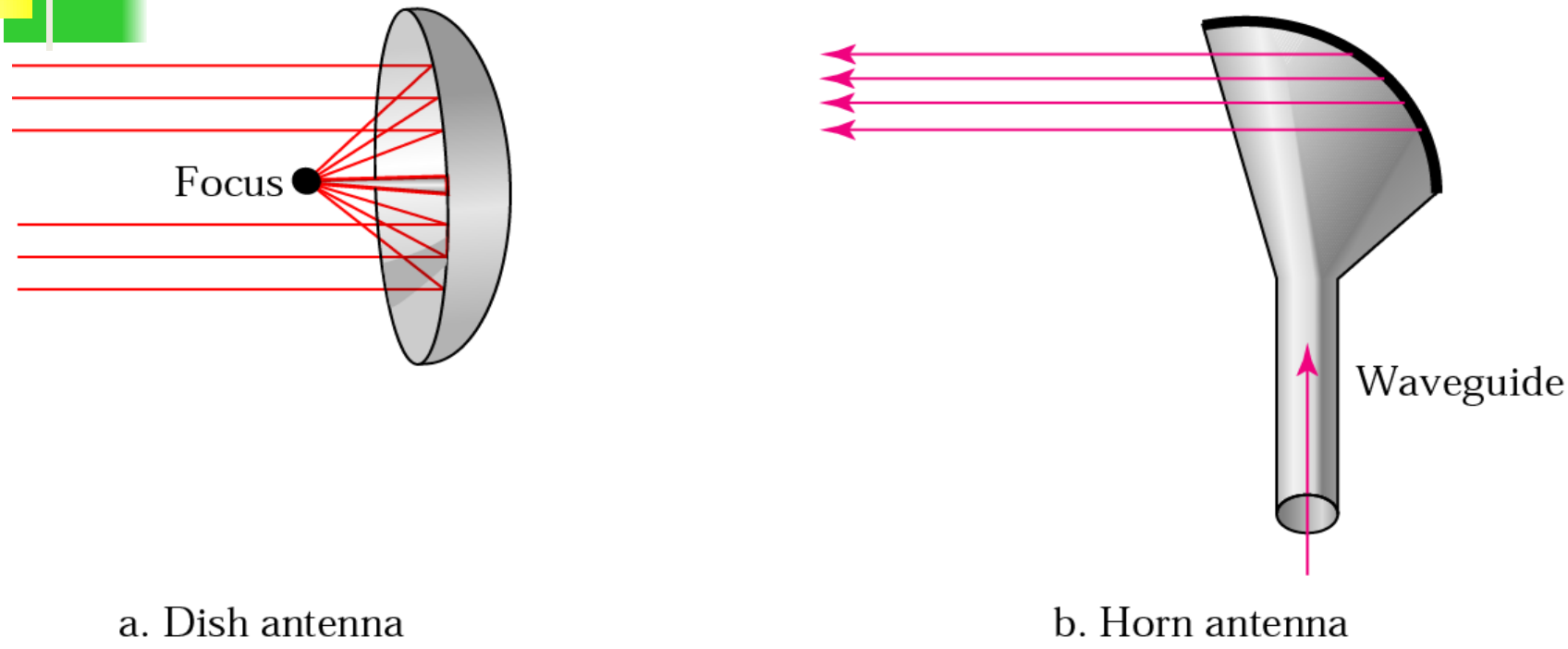
(ANTENNA: Omnidirection vs Unidirection)

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*

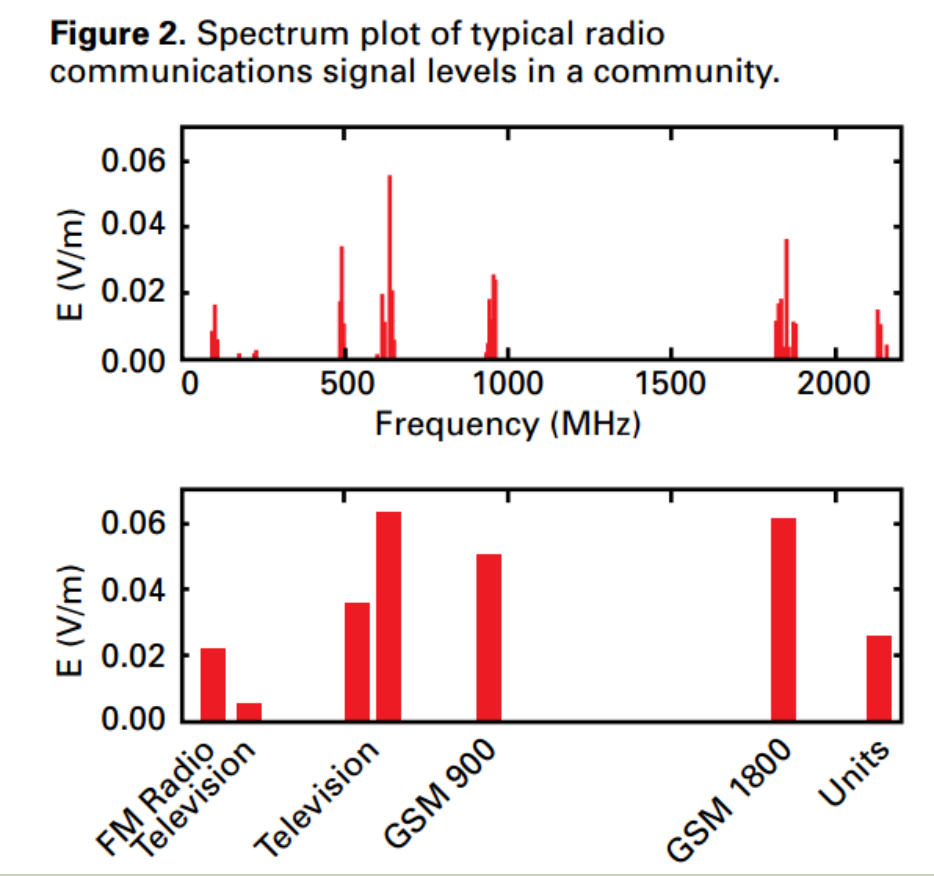


Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Microwave communication applications

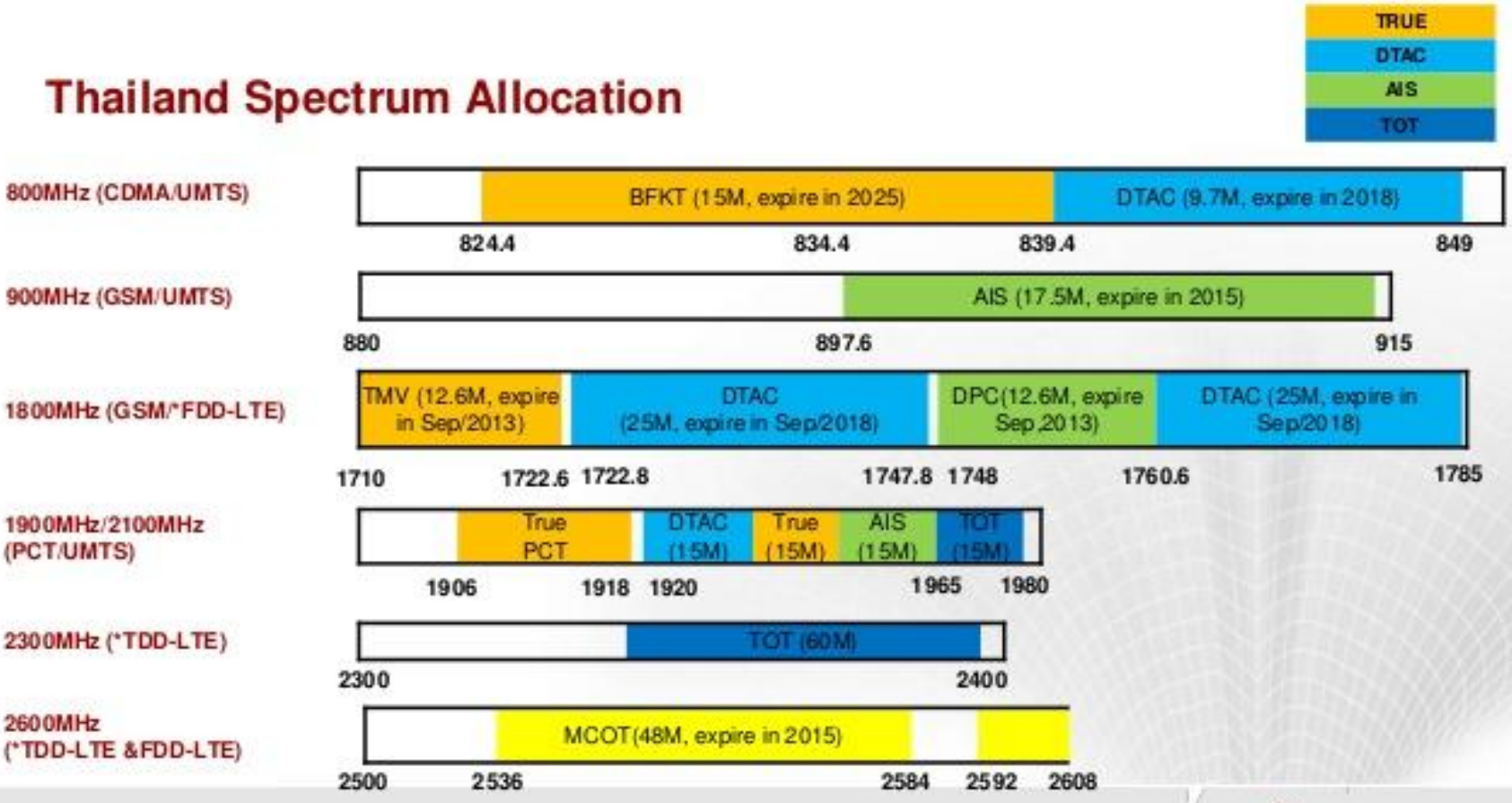
Mobile vs Satellite

CELLULAR COMMUNICATIONS

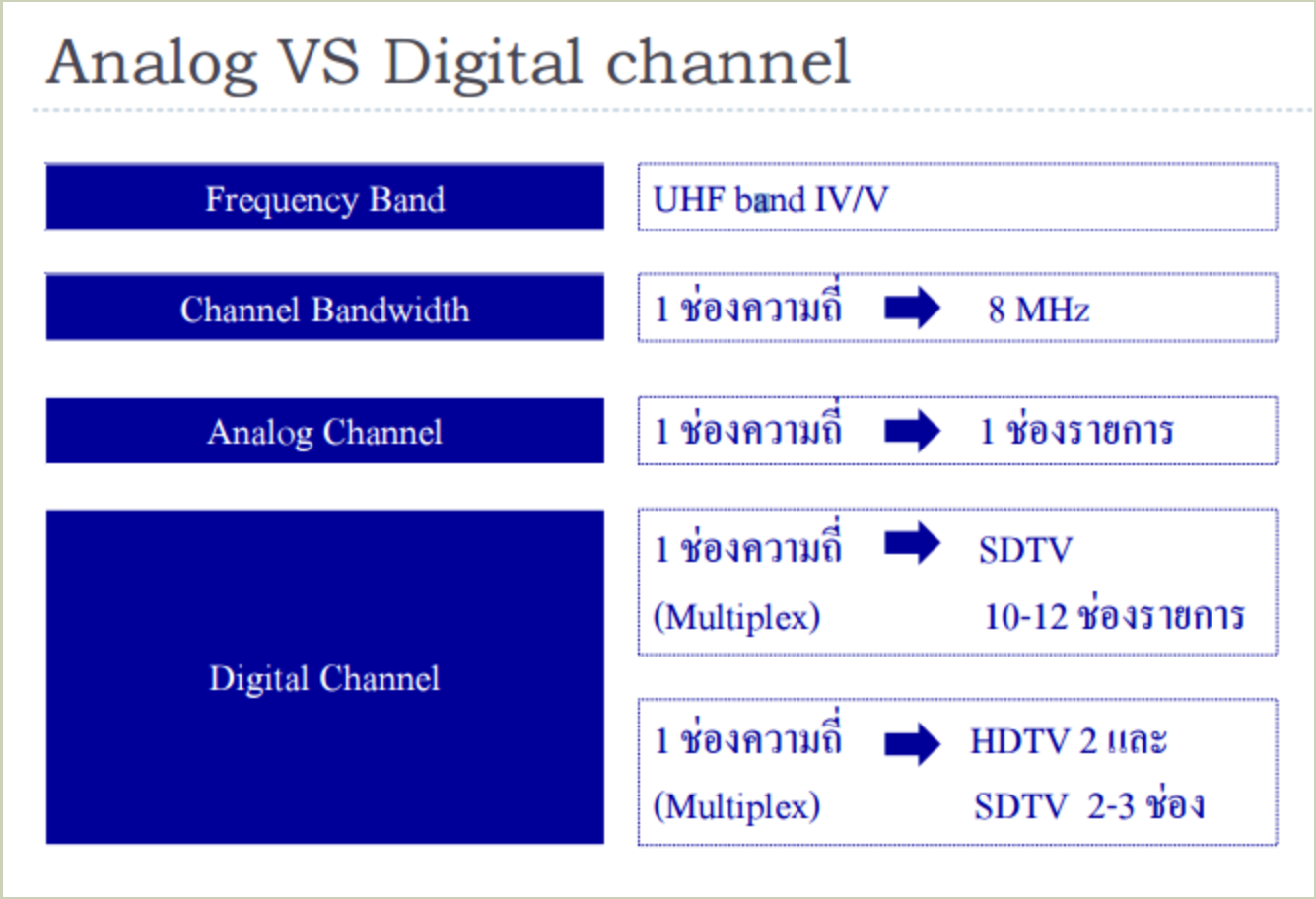


- GSM900 (AIS)
  - 890–915 MHz (uplink)
  - 935–960 MHz (downlink)
  - 124 RF channels (channel numbers 1 to 124) spaced at 200 kHz
- GSM1800/CDMA1800 (DTAC/AIS/TRUE)
  - 1,710–1,785 MHz (uplink)
  - 1,805–1,880 MHz (downlink)
  - 374 channels (channel numbers 512 to 885) spaced at 200 kHz
- CDMA2100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

Thailand Spectrum Allocation



TELEVISION



- http://www4.nbtc.go.th/getattachment/Weblink/Hot-link

มาตรฐานต่าง ๆของโทรทัศน์ระบบดิจิตอล

น่าจะมีมาตรฐานโทรทัศน์ดิจิทัลเพียง มาตรฐานเดียว

ATSC (Advanced Television System Committee in USA)

- ใช้งานในประเทศสหรัฐอเมริกา แคนาดา และเกาหลีใต้

ISDB (Integrated Services Digital Broadcasting)

- ใช้งานในประเทศญี่ปุ่น บราซิล และกลุ่มประเทศอเมริกาใต้

DVB (Digital Video Broadcasting)

- ใช้งานจำนวนมากในหลายประเทศ โดยเป็นมาตรฐานที่พัฒนามาจากทวีปยุโรป

DMB-T (Digital Multimedia Broadcasting)

- พัฒนาและใช้งานในประเทศจีน

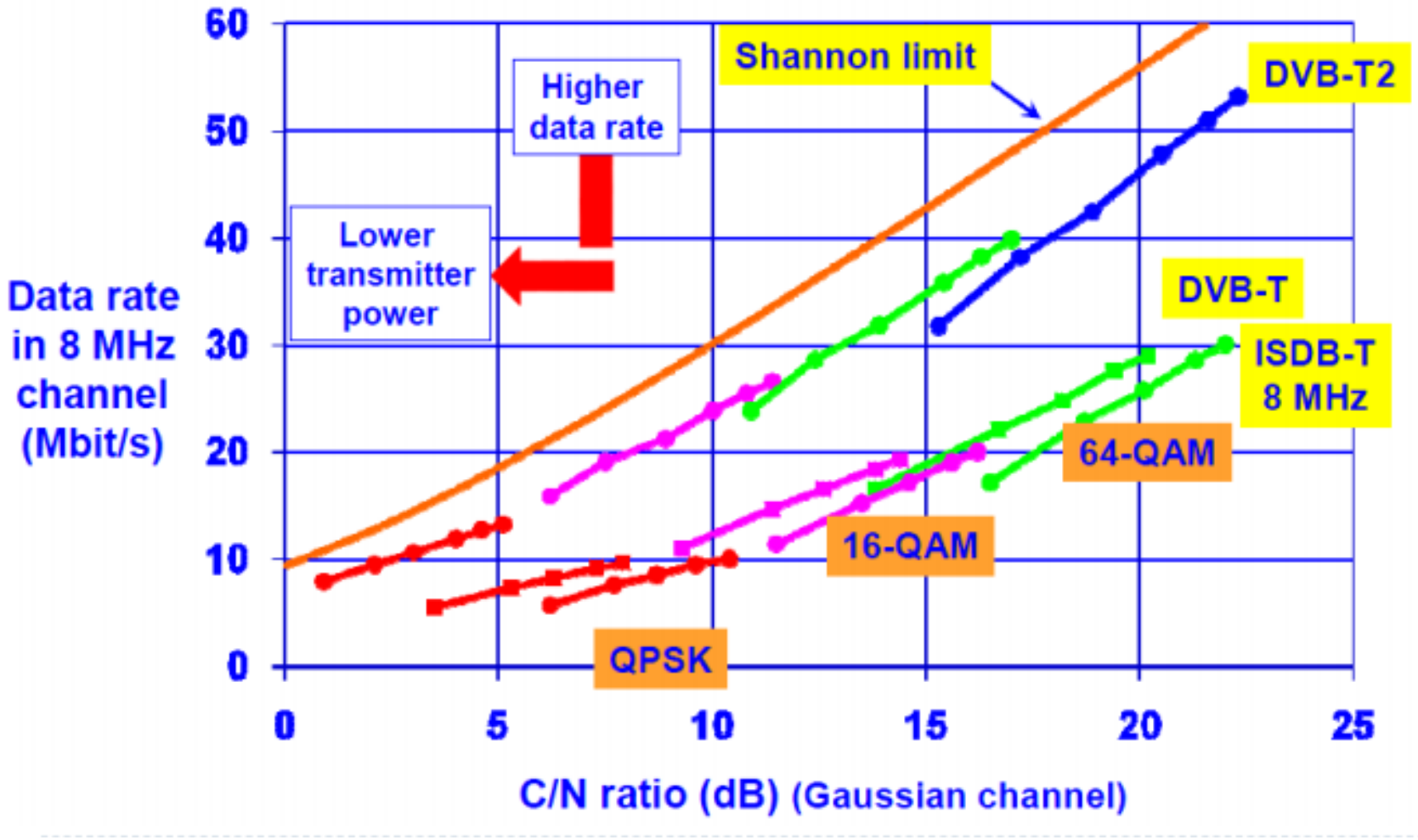
- http://www4.nbtc.go.th/getattachment/Weblink/Hot-link

เปรียบเทียบคุณสมบัติของมาตรฐานต่างๆ

		ATSC	DVB-T	DVB-T2	ISDB-T
Maintained by		Advance Television System Committee	Digital Video Broadcasting Project		Association of Radio Industries and Business
Compression	Video	MPEG-2 Video	MPEG-2 Video or H.264/ MPEG-4 AVC		
	Audio	Dolby AC-3	MPEG-2 Audio or AAC or HE-AAC or Dolby AC-3		AAC (Advanced Audio Coding)
System transport stream		MPEG-2 System	MPEG-2 System	MPEG-2 System/GSE	MPEG-2 System
Modulation	modulation schemes	8-VSB	COFDM (QPSK, 16QAM, 64QAM)	COFDM (QPSK, 16QAM, 64QAM, 256QAM)	BST-COFDM (QPSK, DQPSK, 16QAM, 64QAM)
	No. of subcarriers	Single-carrier (1)	Multi-carrier (FFT Size): 2k, 8k	Multi-carrier (FFT Size): 1k, 2k, 4k, 8k, 16k, 32k	Multi-carrier: (1) Mode 1 (1,405) (2) Mode 2 (2,809) (3) Mode 3 (5,617)
Channel Bandwidth		6 MHz (7, 8 MHz possible)	7 or 8 MHz (6 MHz possible)		6 MHz (7, 8 MHz possible)

- http://www4.nbtc.go.th/getattachment/Weblink/Hot-link

ประสิทธิภาพของ DVB-T/T2 และ ISDB (ช่องสัญญาณ 8 MHz)

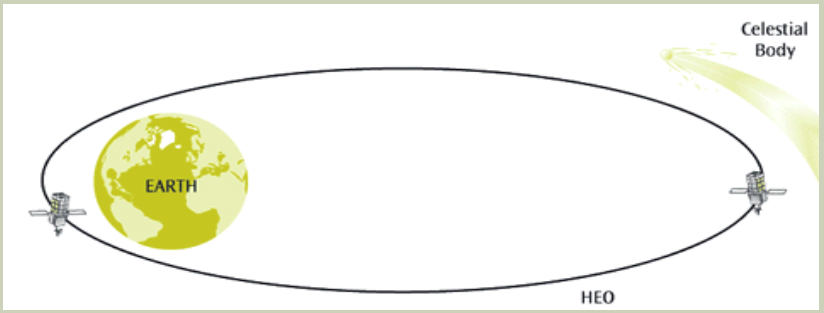


- http://www4.nbtc.go.th/getattachment/Weblink/Hot-link

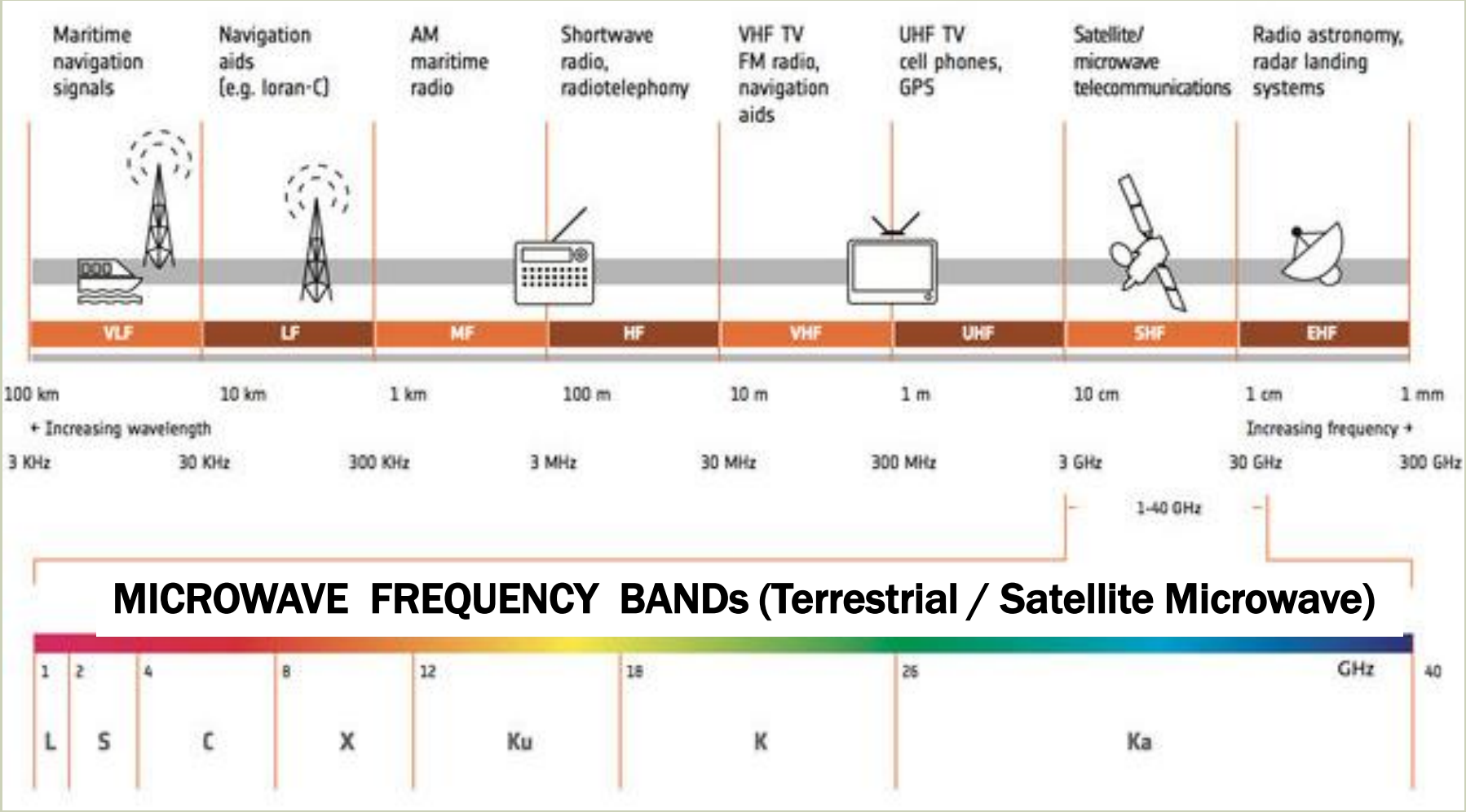
MICROWAVE

Terrestrial Microwave

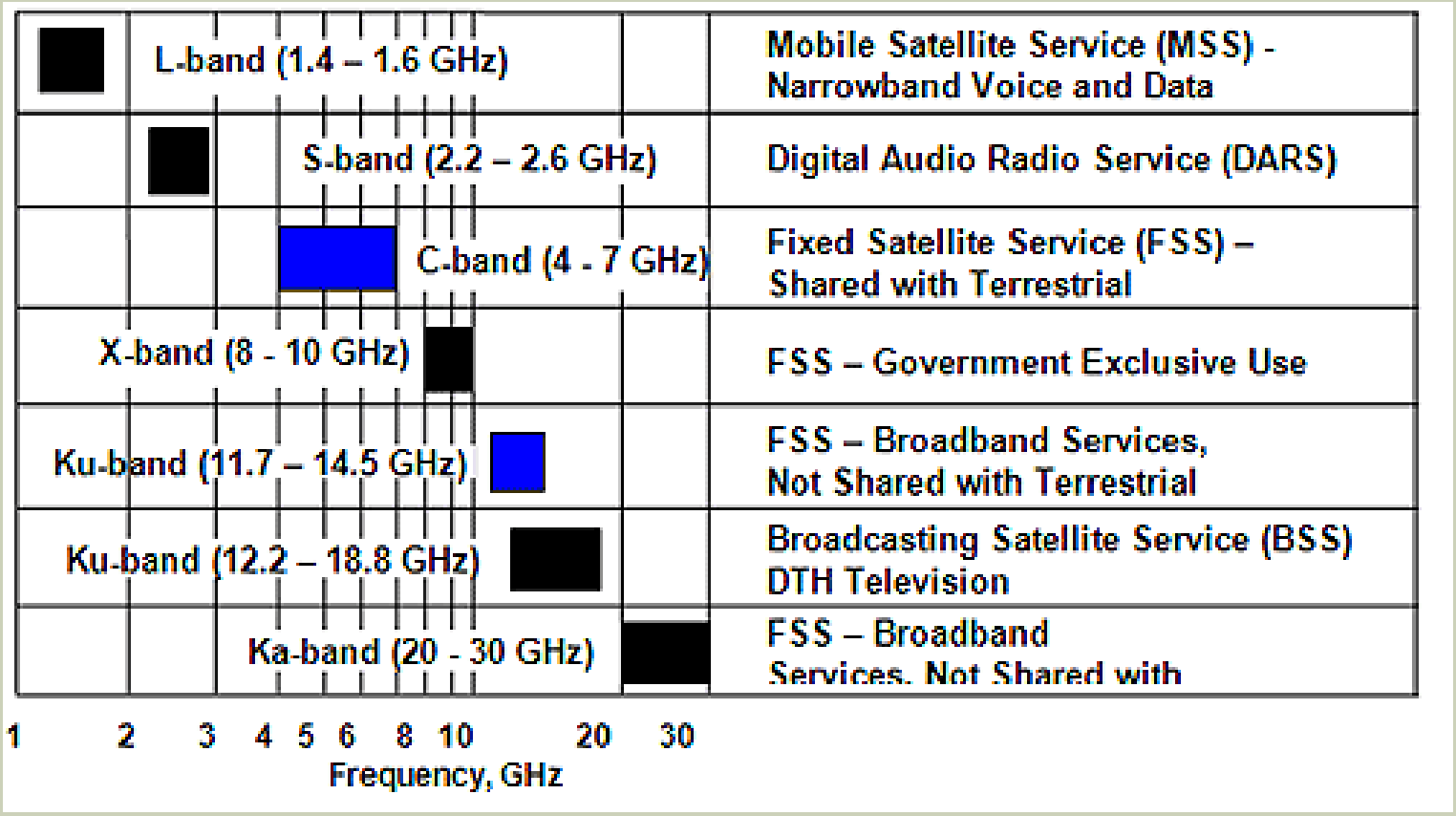
Satellite Microwave



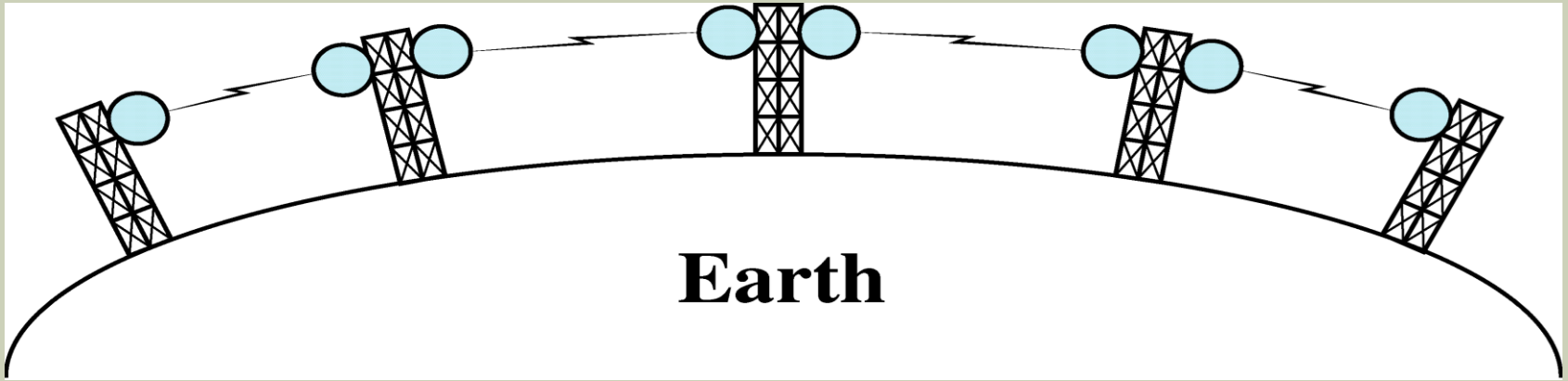
MICROWAVE FREQUENCY ALLOCATION



TERRESTRIAL / SATELLITE MICROWAVE



TERRESTRIAL MICROWAVE



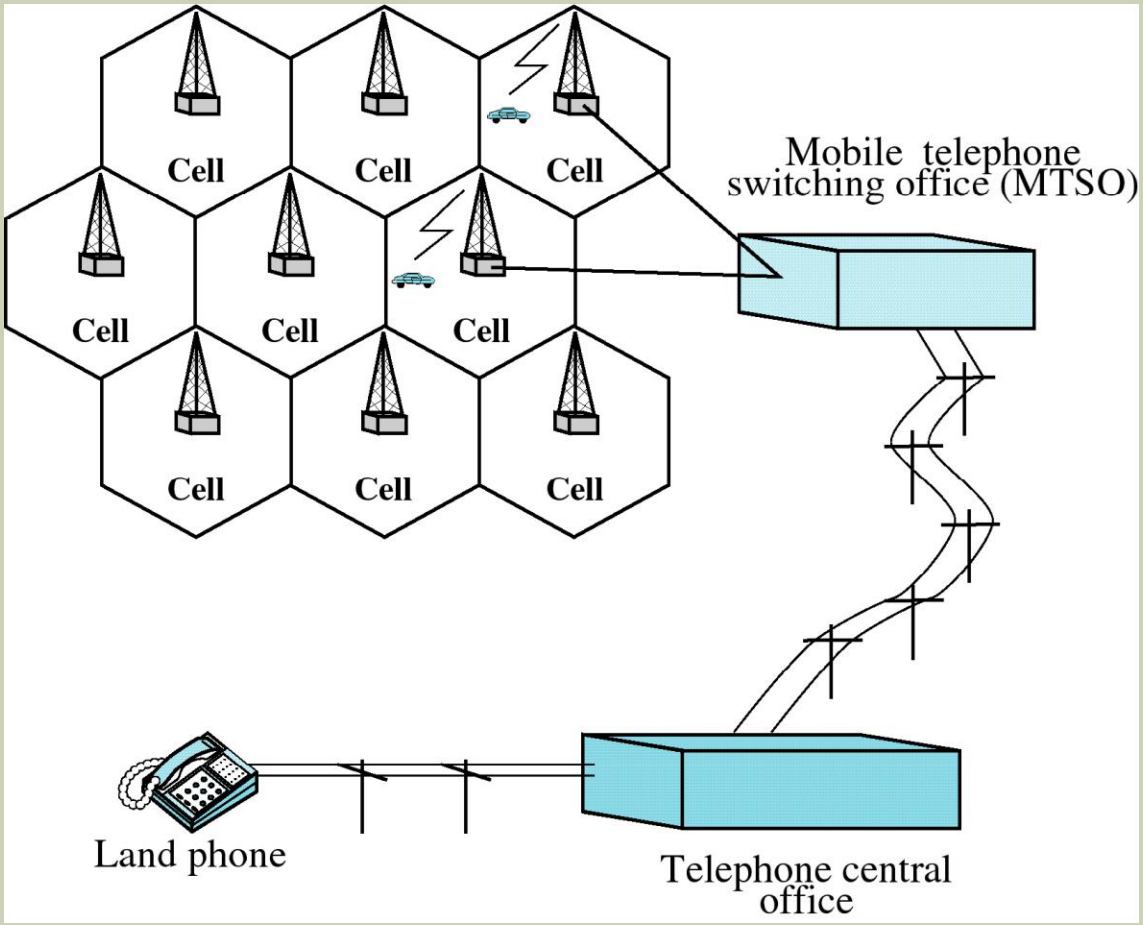
Land-based, line-of-sight transmission

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

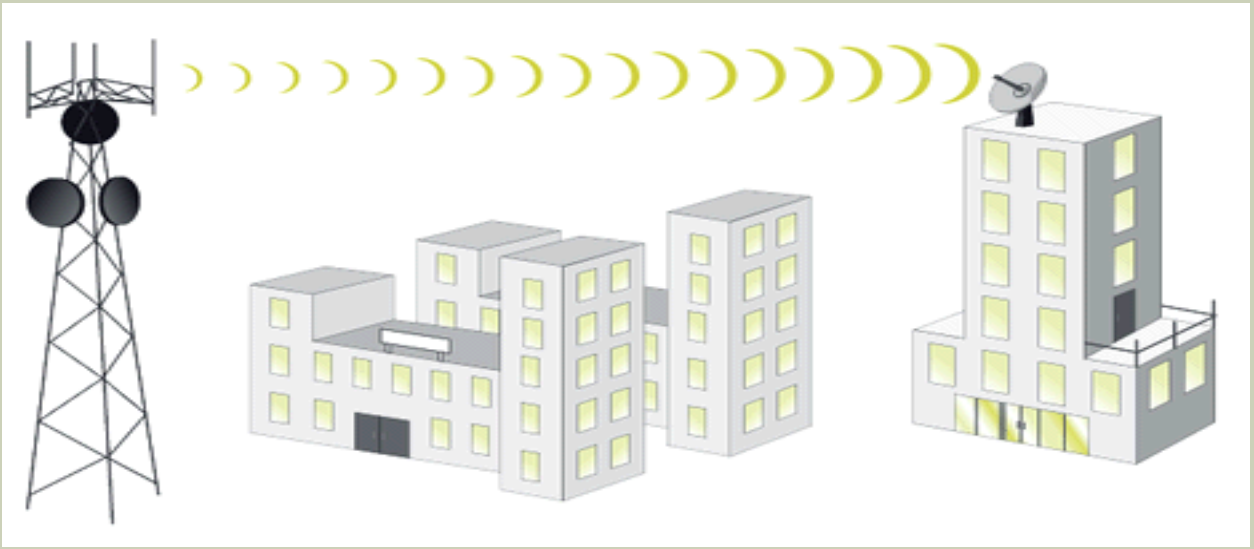
Transmits data at hundreds of millions of bits per second

Popular with telephone companies and business to business transmissions

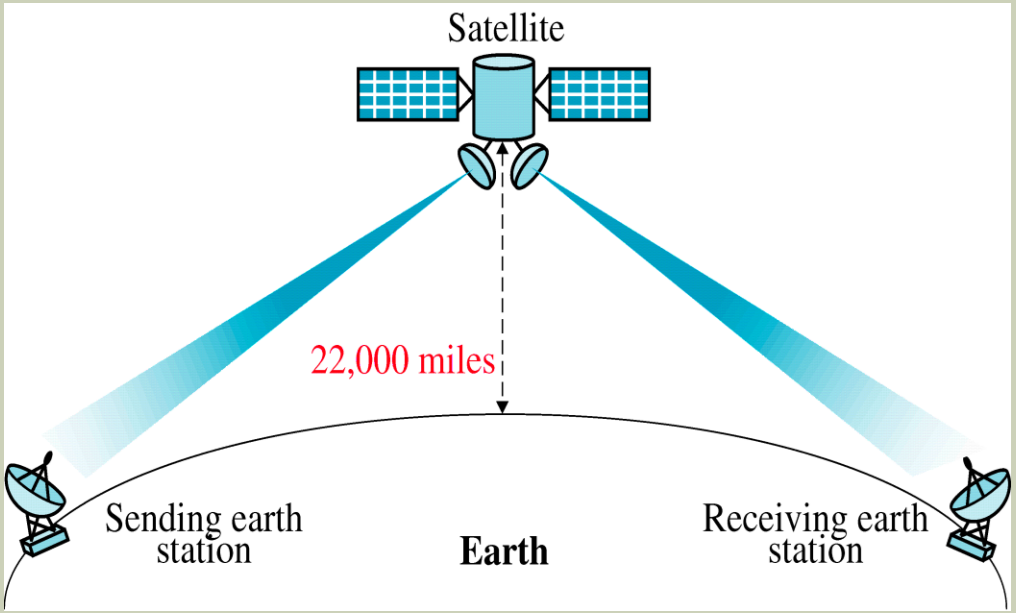
CELLULAR SYSTEM



OFTEN THE MICROWAVE ANTENNAS ARE ON TOWERS AND BUILDINGS



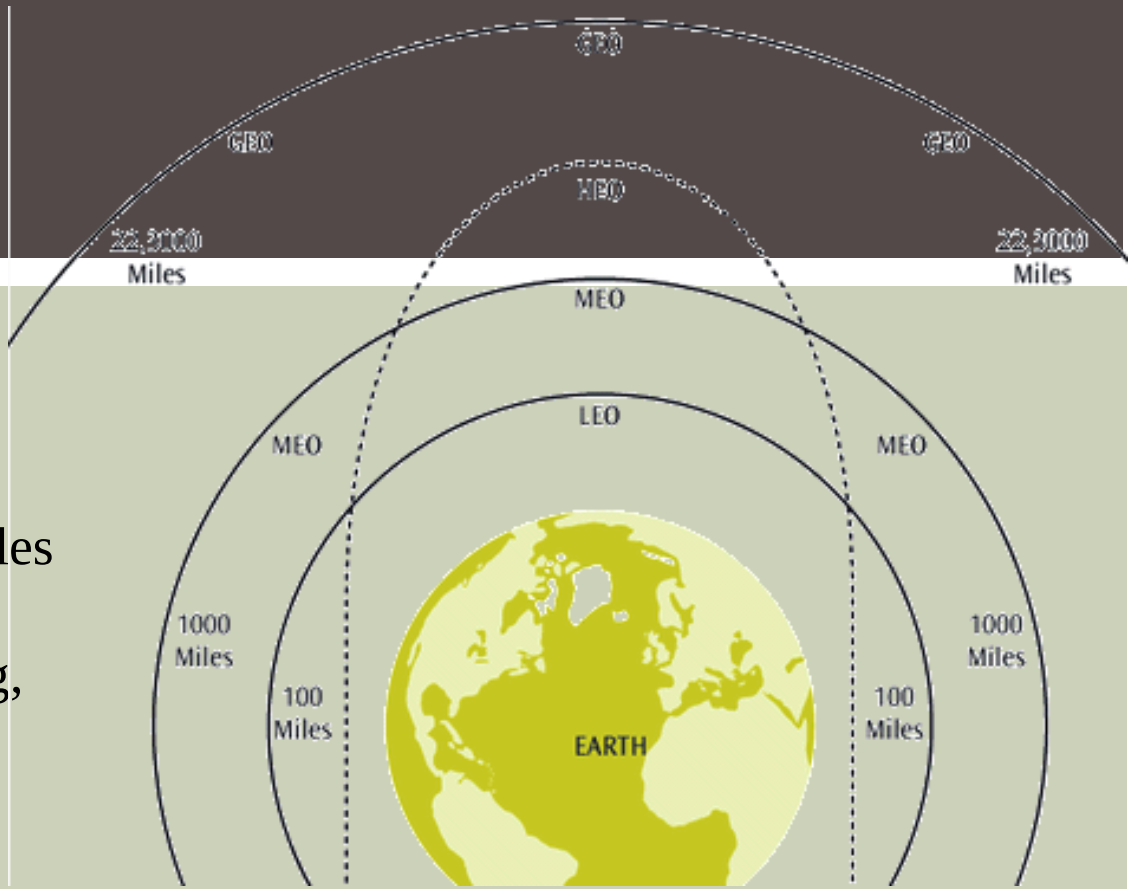
SATELLITE COMMUNICATION



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

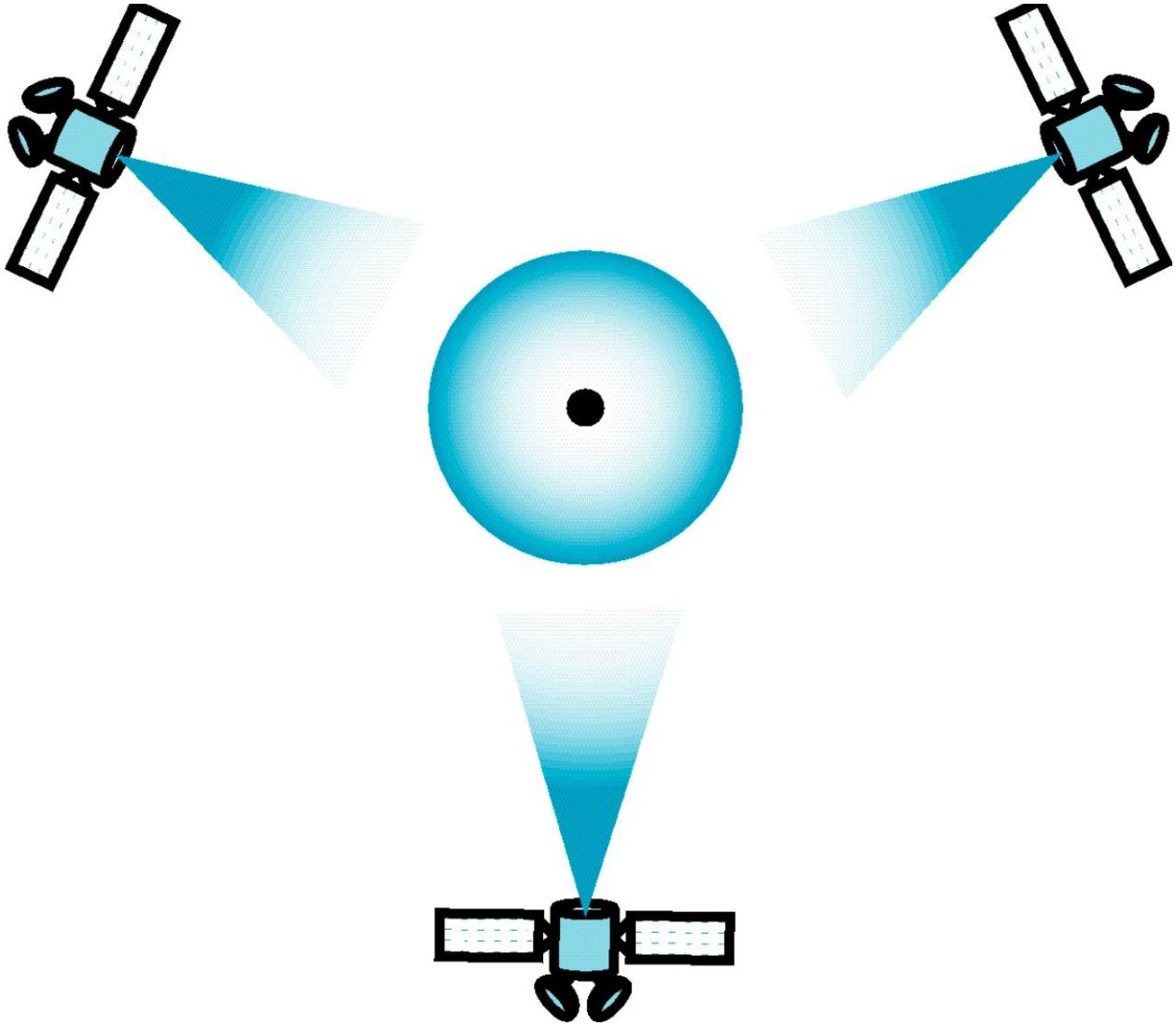


LEO - Low Earth Orbit – 100 miles
Used for pagers, wireless e-mail, special mobile telephones, spying, videoconferencing.

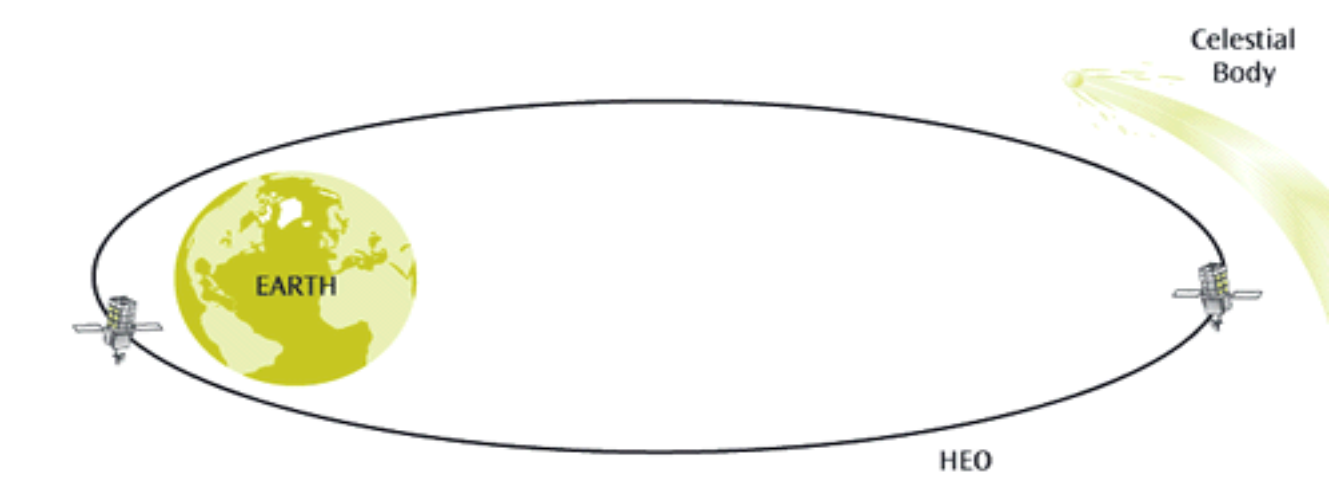
MEO - Middle Earth Orbit - 1000 miles.
Used for GPS and government.

GEO - Geosynchronous Orbit - 22,300 miles. Used for weather, television, and government operations.

Geosynchronous Orbit



HEO ORBIT

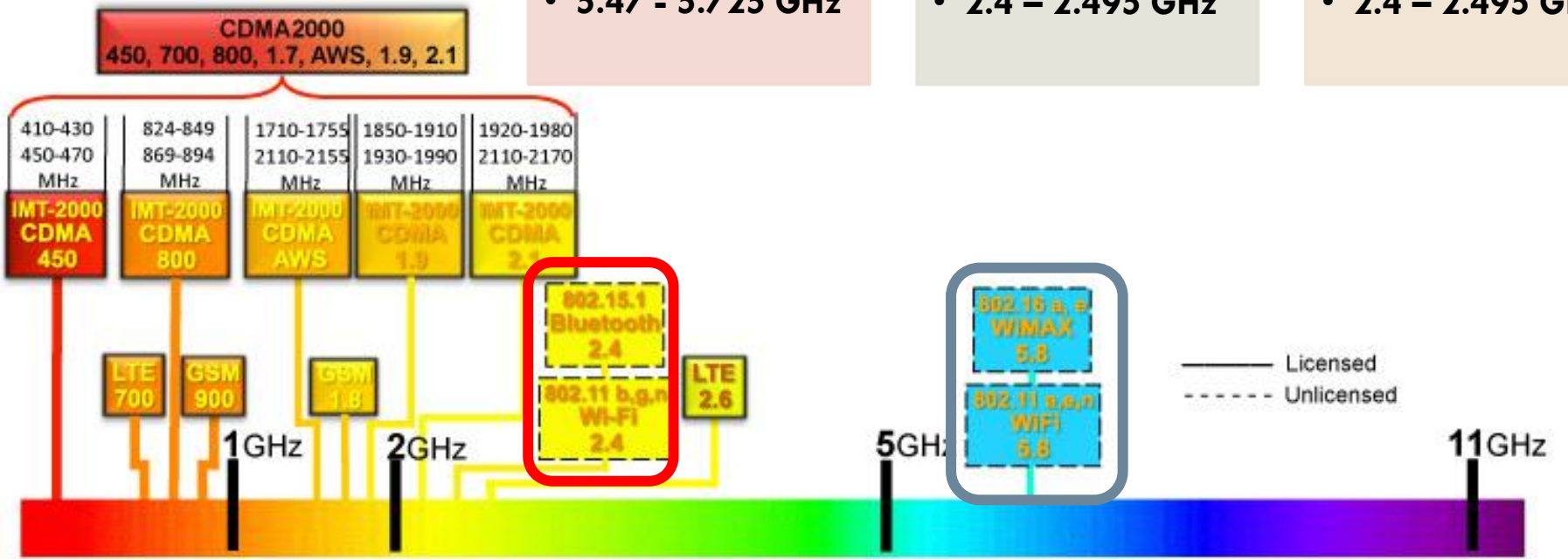


A fourth type of orbit used by the military for spying and by scientific organizations for photographing celestial bodies.

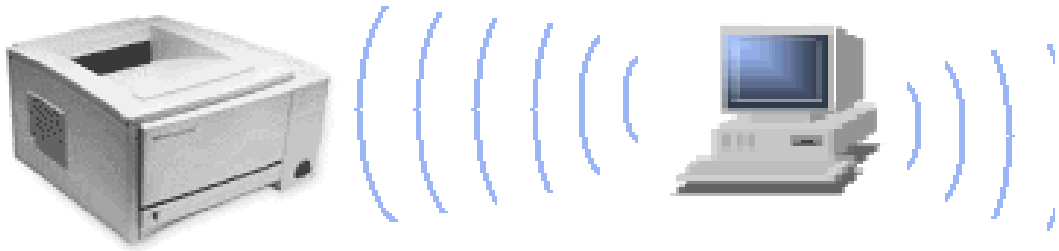
When satellite is far out into space, it takes photos. When satellite is close to earth, it transmits data.

WiFi

802.11 a	802.11 b	802.11 g
• 5.8 GHz • 20 MHz / channel • 5.47 - 5.725 GHz	• 2.4 GHz • 22 MHz / channel • 2.4 – 2.495 GHz	• 2.4 GHz • 20 MHz / channel • 2.4 – 2.495 GHz



Bluetooth



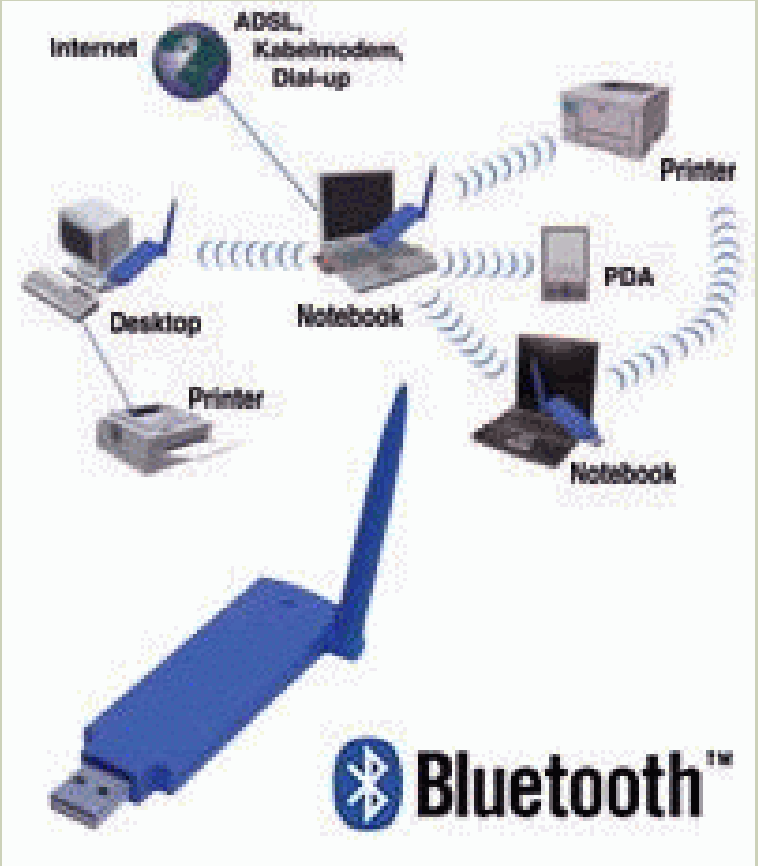

Bluetooth Headset
Bluetooth Printer
Bluetooth Enabled
Bluetooth PC
JBT-2001UC
Bluetooth Camera
Bluetooth
USB Dongle
Bluetooth PDA
Bluetooth Handy

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