10

Data Communication

Week 10 Transmission Media

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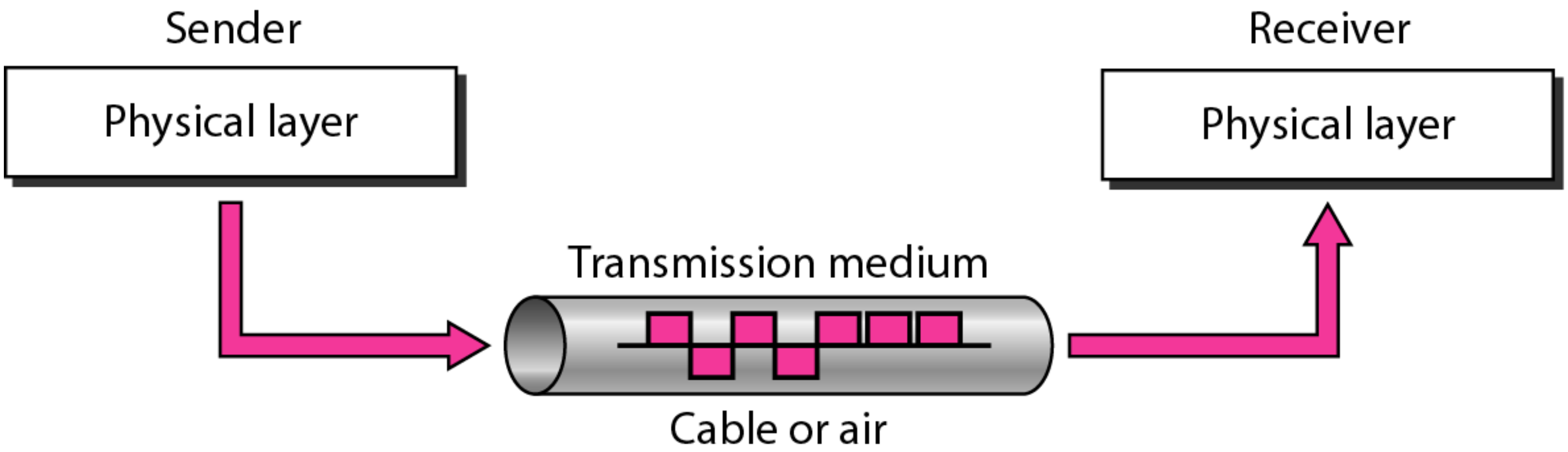
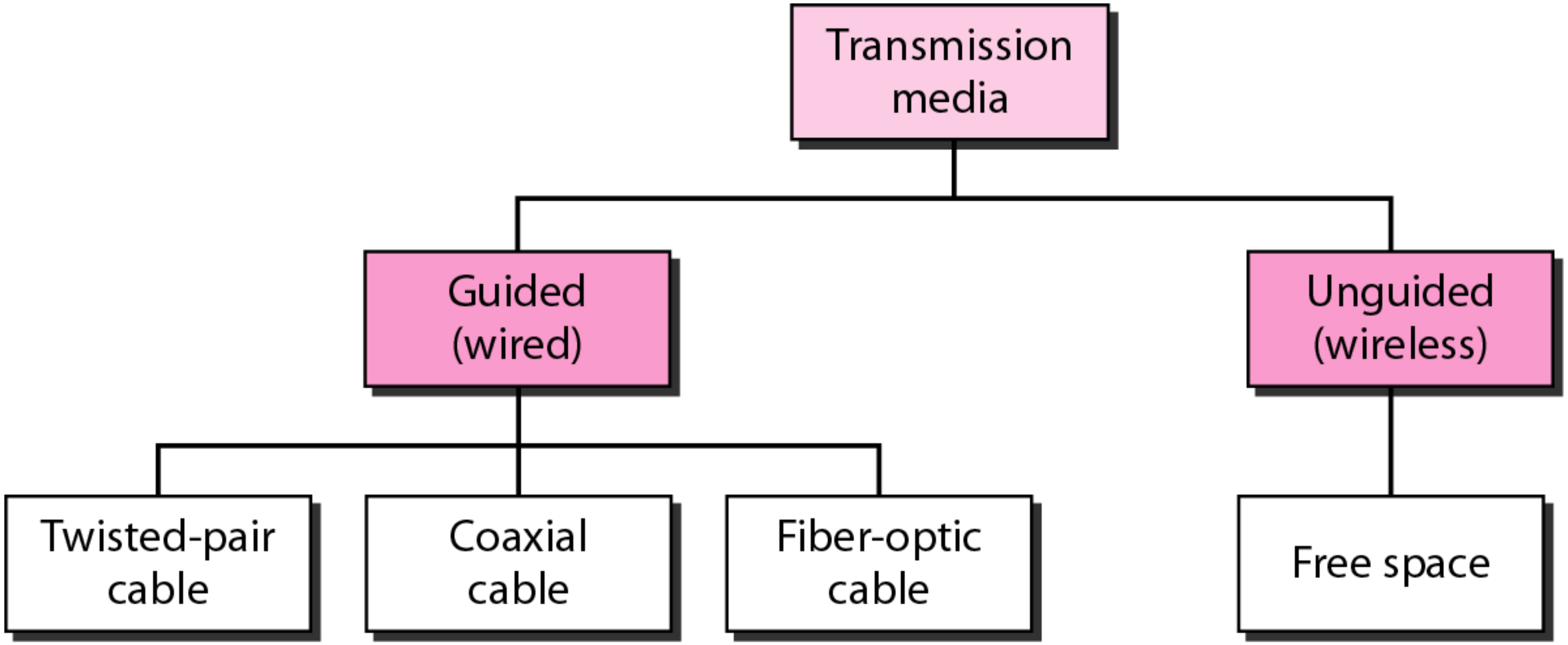
Transmission Media

- Transmission media are actually located below the physical layer and directly controlled by the physical layer



Classes of Transmission Media

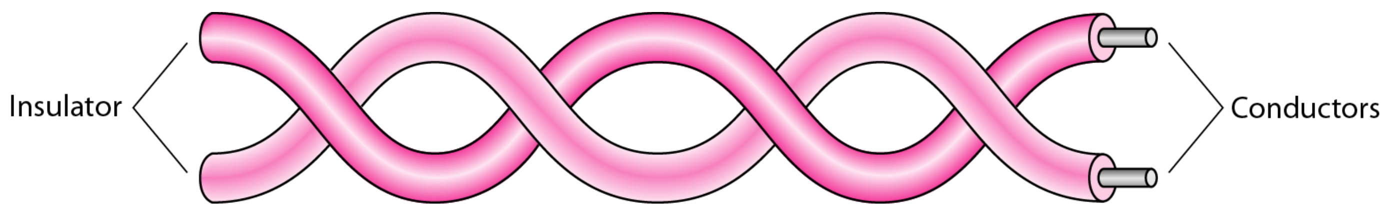


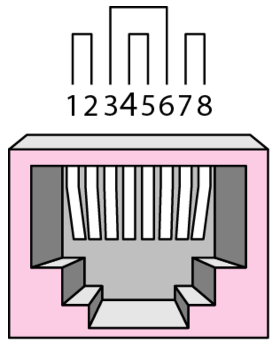
Categories Transmission Media

- Transmission media divided into two categories:
    - **Guided Media:**
        - Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.
    - **Unguided Media:**
        - Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

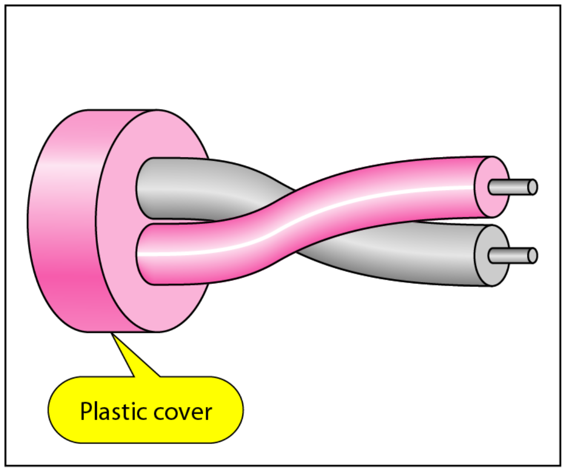
Twisted Pair Cable

- A twisted pair consist of two conductors (normally coppers), each with its own plastic insulation, twitted together.
- One of the wires is used to carry signal to the receiver, and the other is used only as a ground references

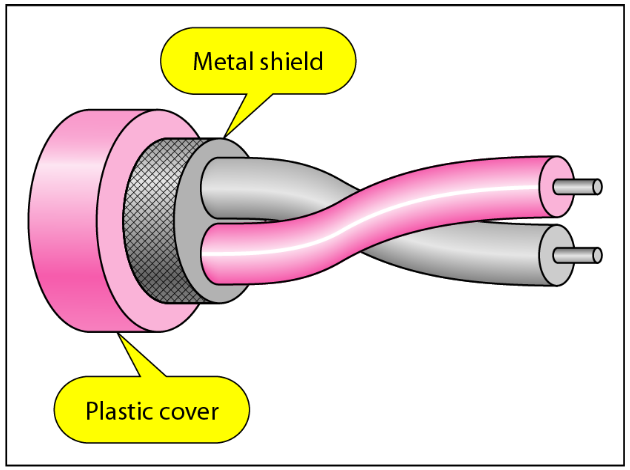




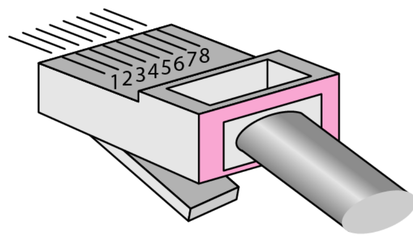
RJ-45 Female



a. UTP



b. STP

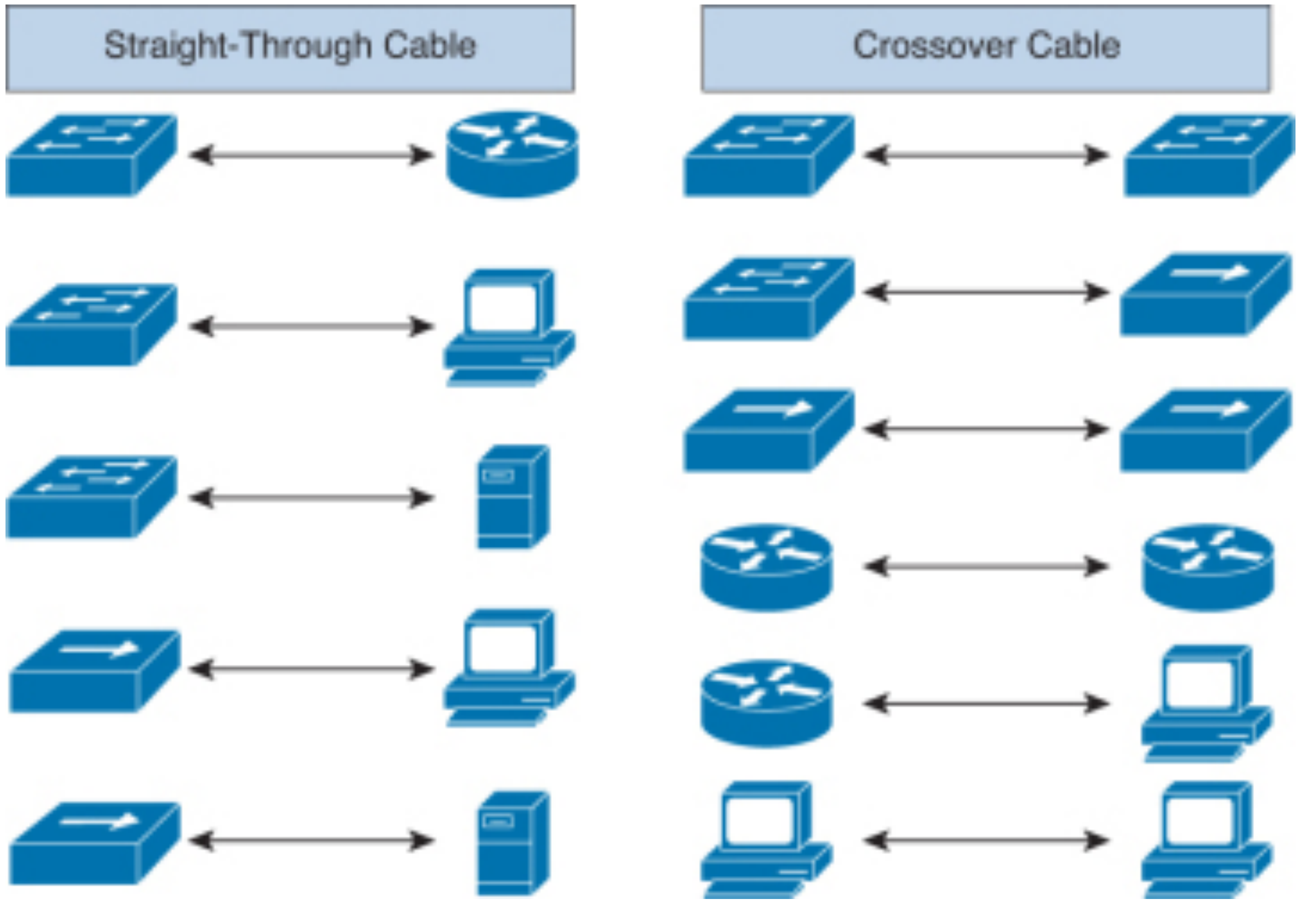


RJ-45 Male

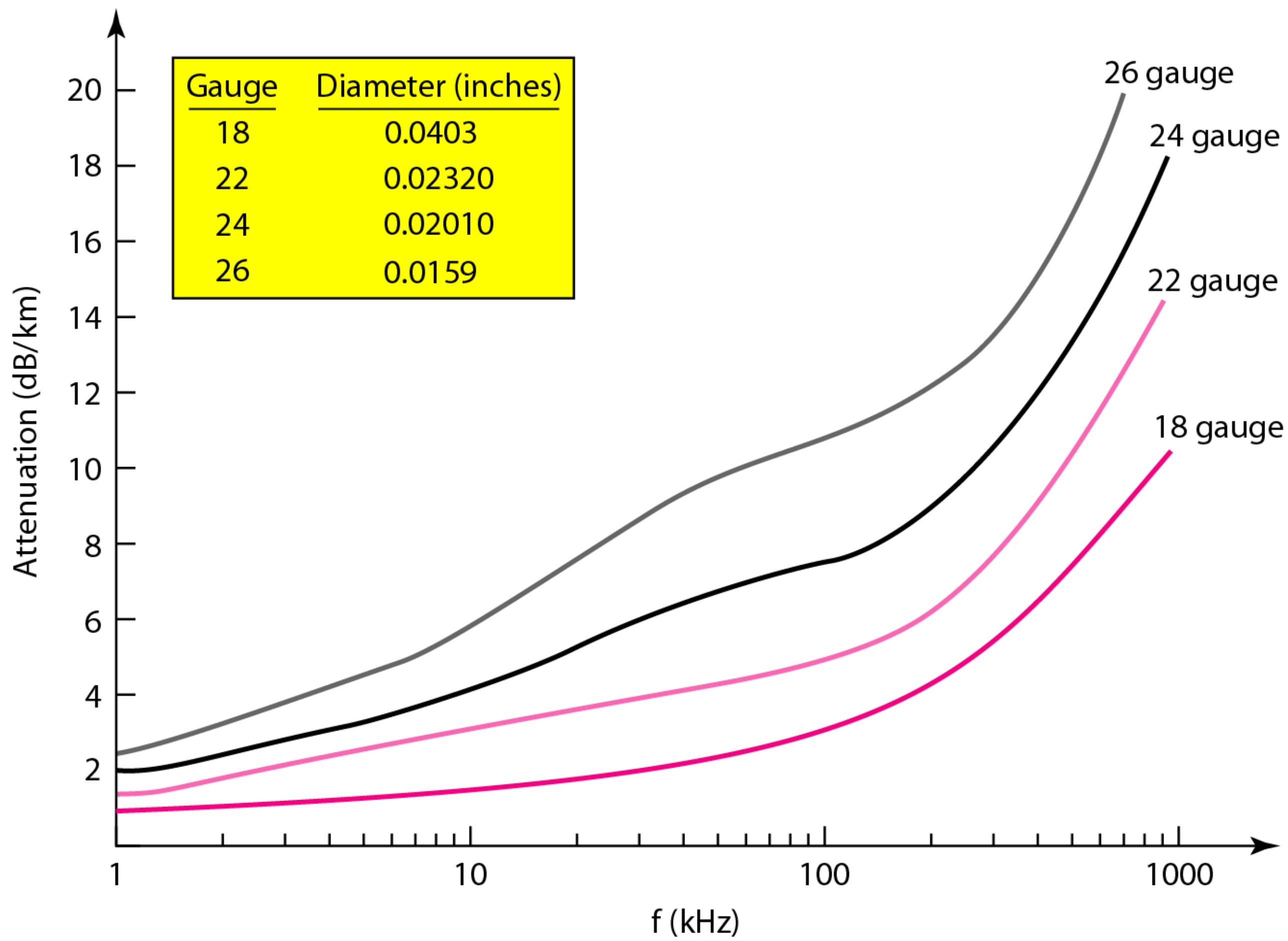
Twisted Pair Categories

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
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
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	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.	600	LANs

Straight Through and Crossover



UTP Performance

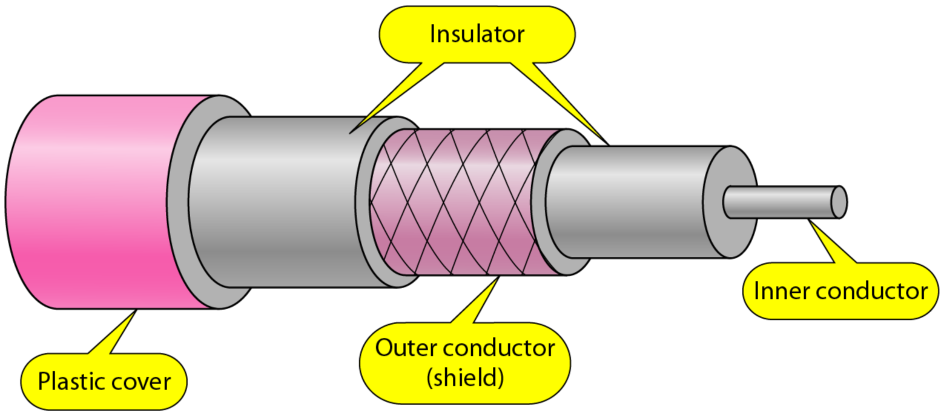


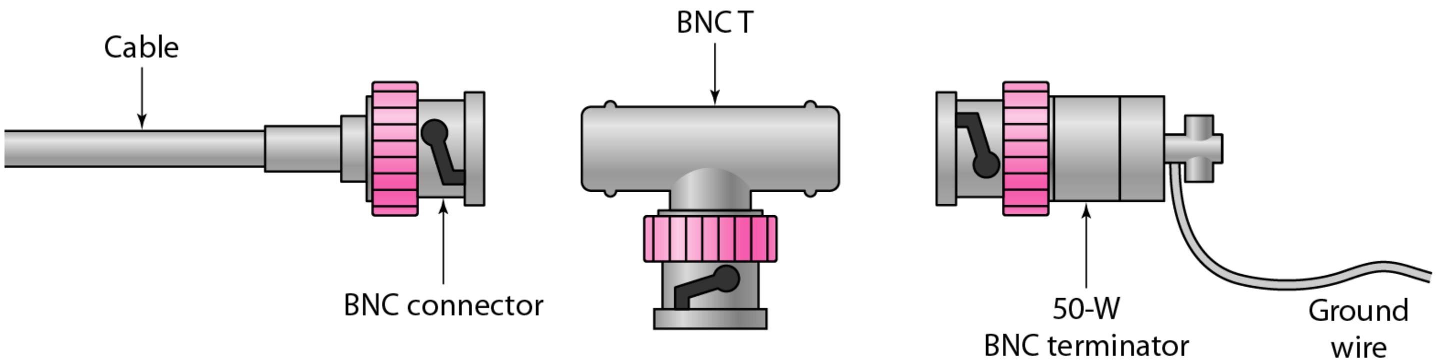
Applications

- Twisted-pair cables are used in telephone lines to provide voice and data channels. The local loop-the line that connects subscribers to the central telephone office commonly consists of unshielded twisted-pair cables.
- The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.
- Local-area networks, such as 10Base-T and 100Base-T, also use twisted-pair cables.

Coaxial Cable

- Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted- pair cable.
- Coaxial cables are categorised by their radio government (RG) ratings. Each RG number denotes a unique set of physical specifications

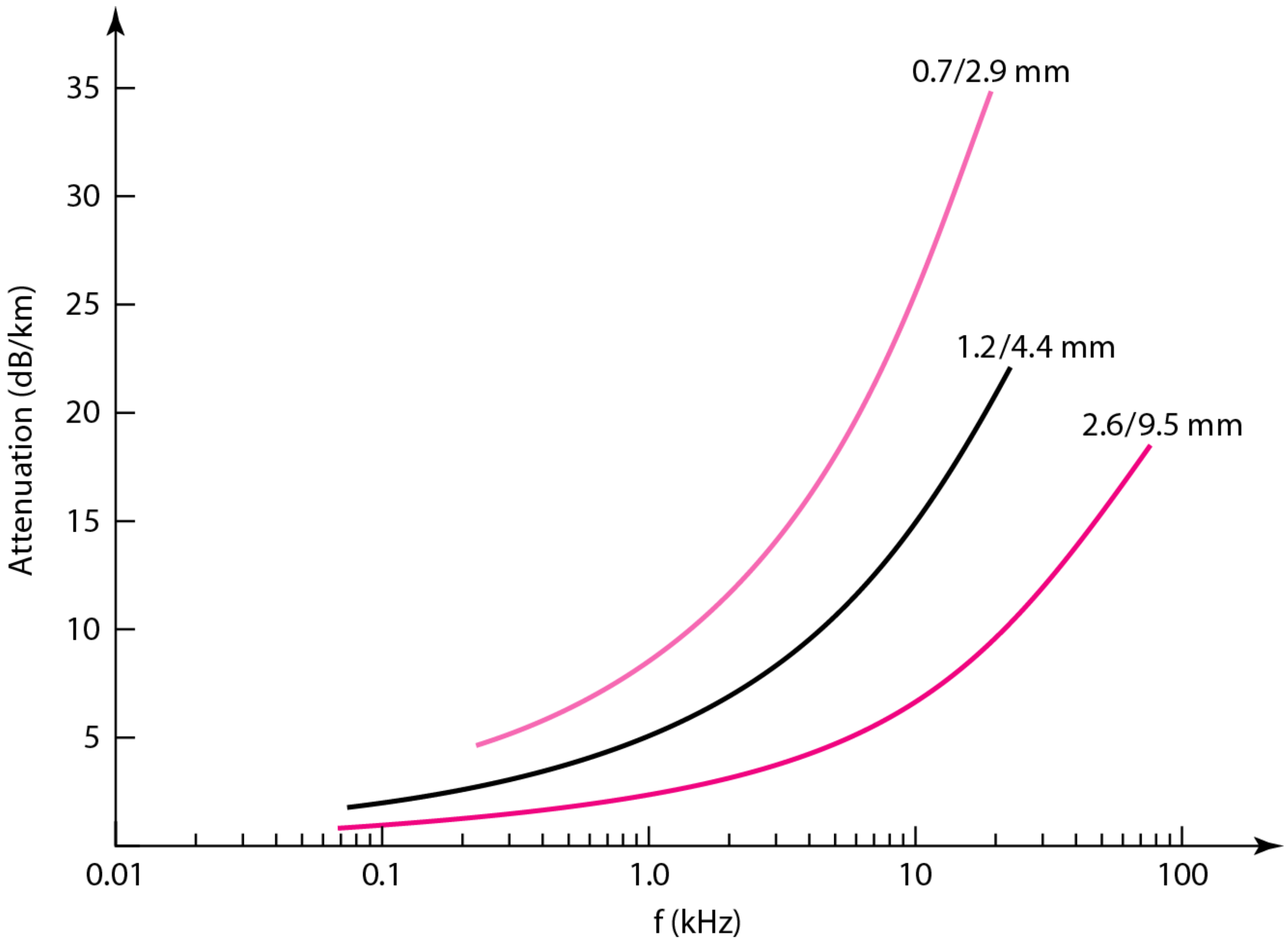




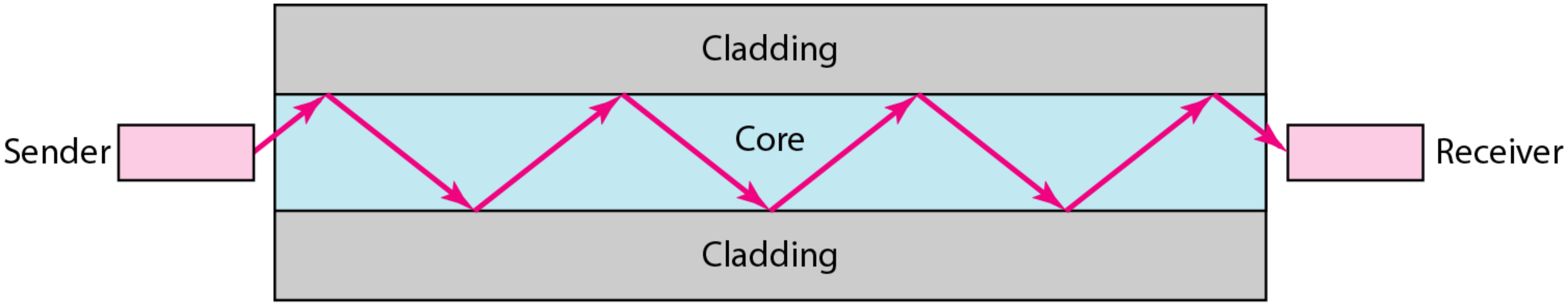
Coaxial Cable Categories

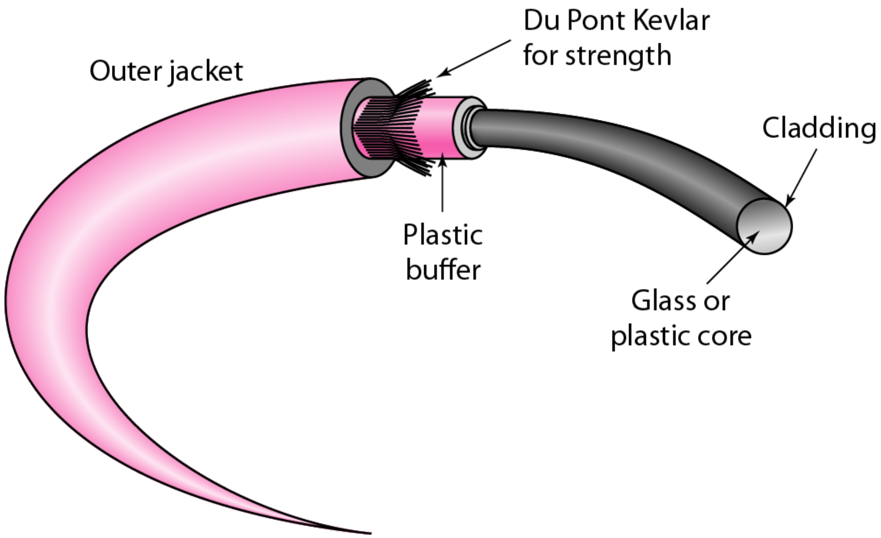
Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

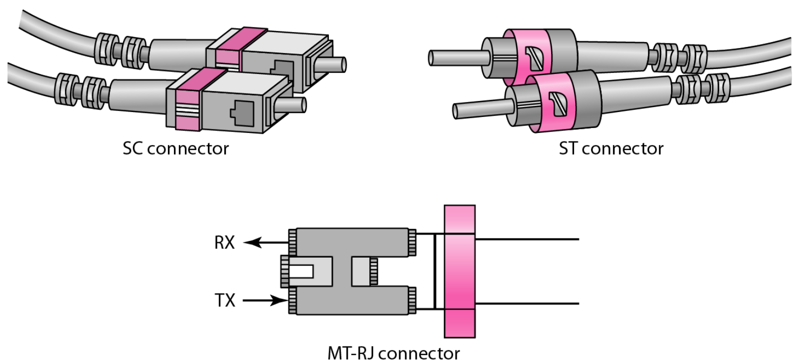
Coaxial Cable Performance



Optical Fiber

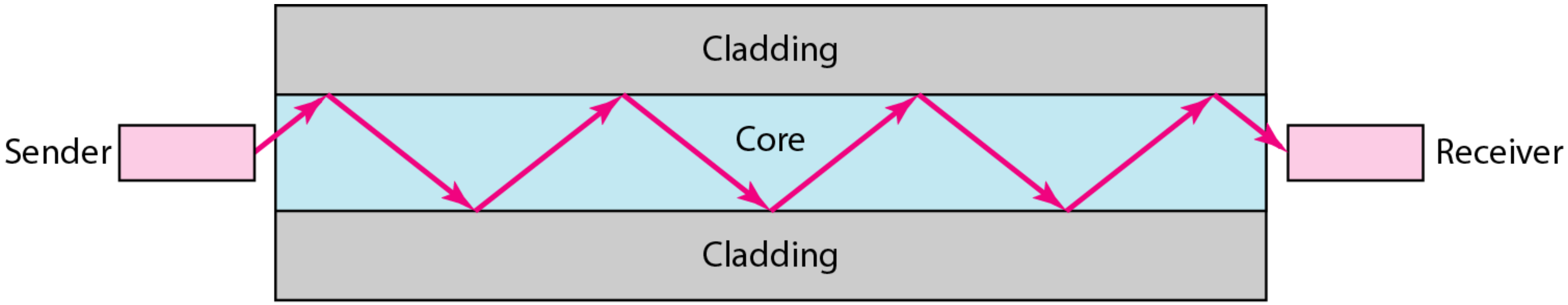






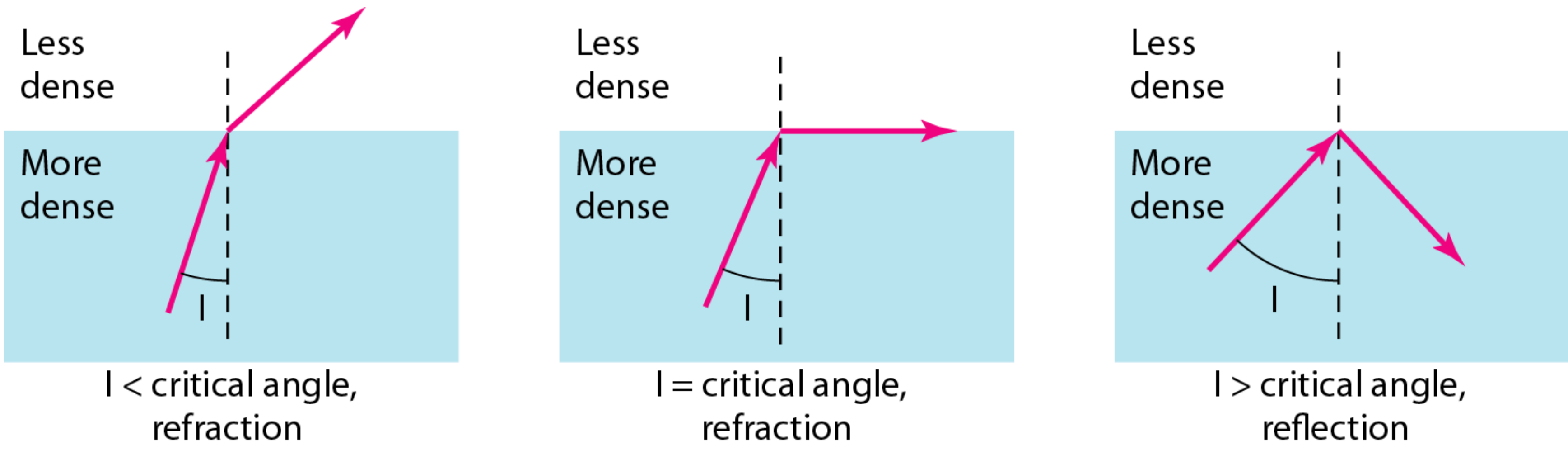
Optical Fiber

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light. To understand optical fiber, we first need to explore several aspects of the nature of light.

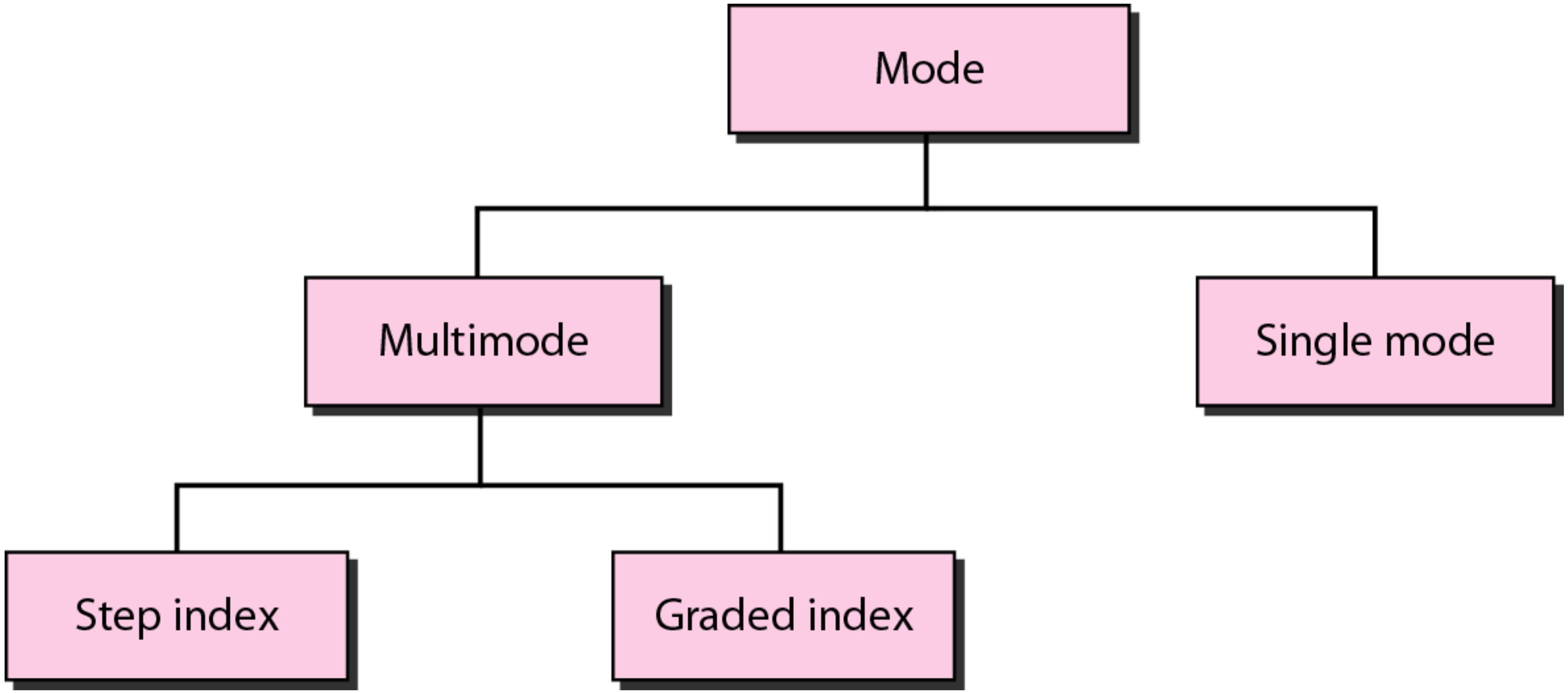


Nature of Lights

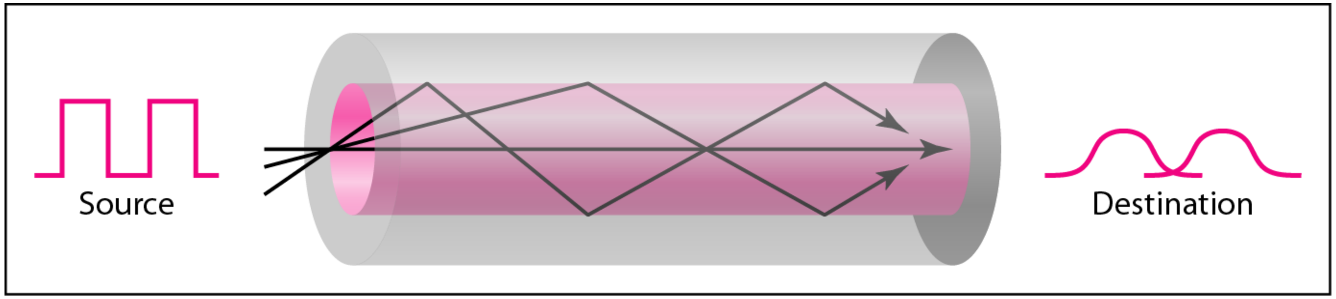
- Light travels in a straight line as long as it is moving through a single uniform substance. If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction. Figure below shows how a ray of light changes direction when going from a more dense to a less dense substance.



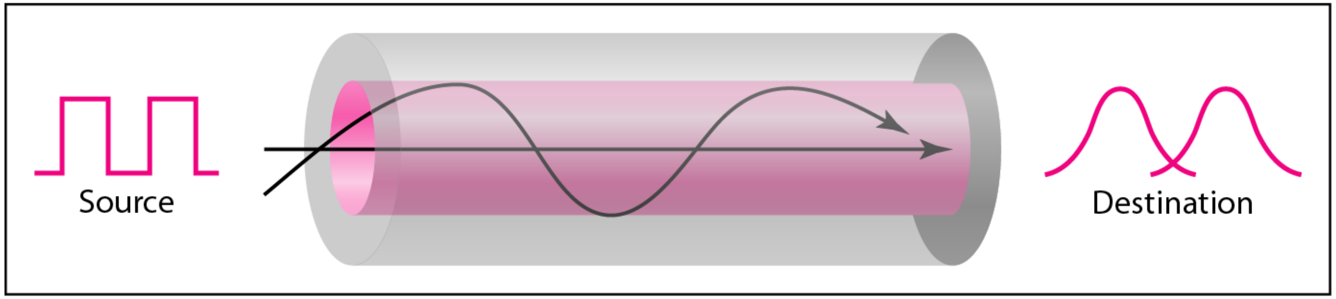
Fiber Optic Propagation Modes



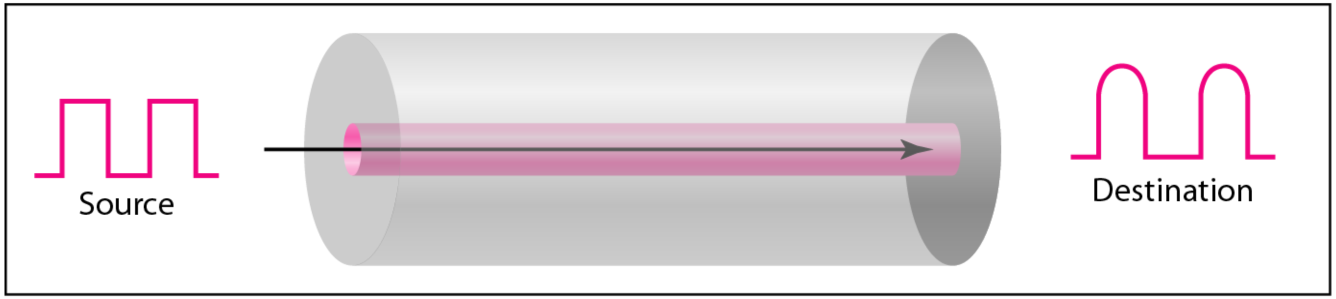
Modes



a. Multimode, step index



b. Multimode, graded index

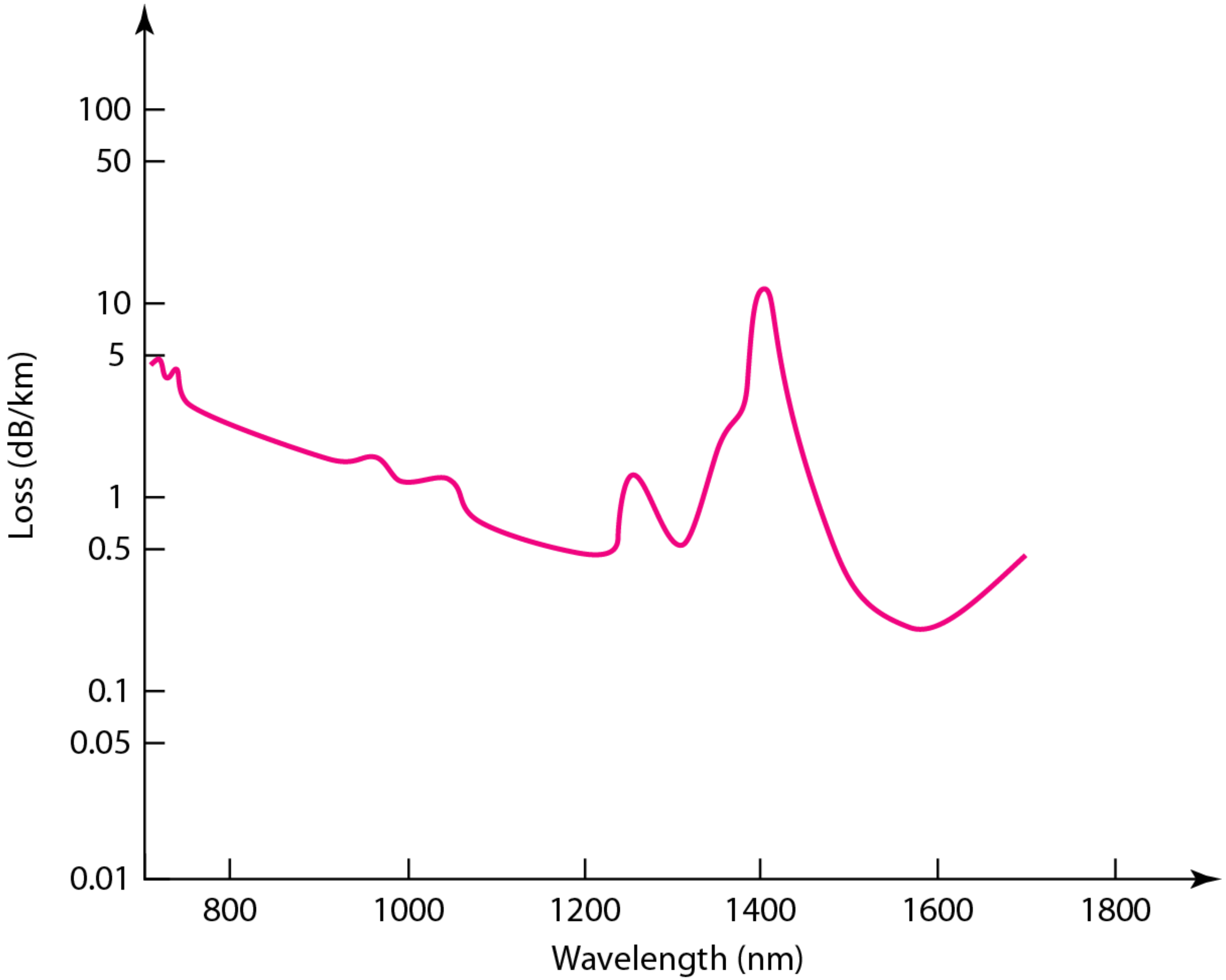


c. Single mode

Optical Fiber Types

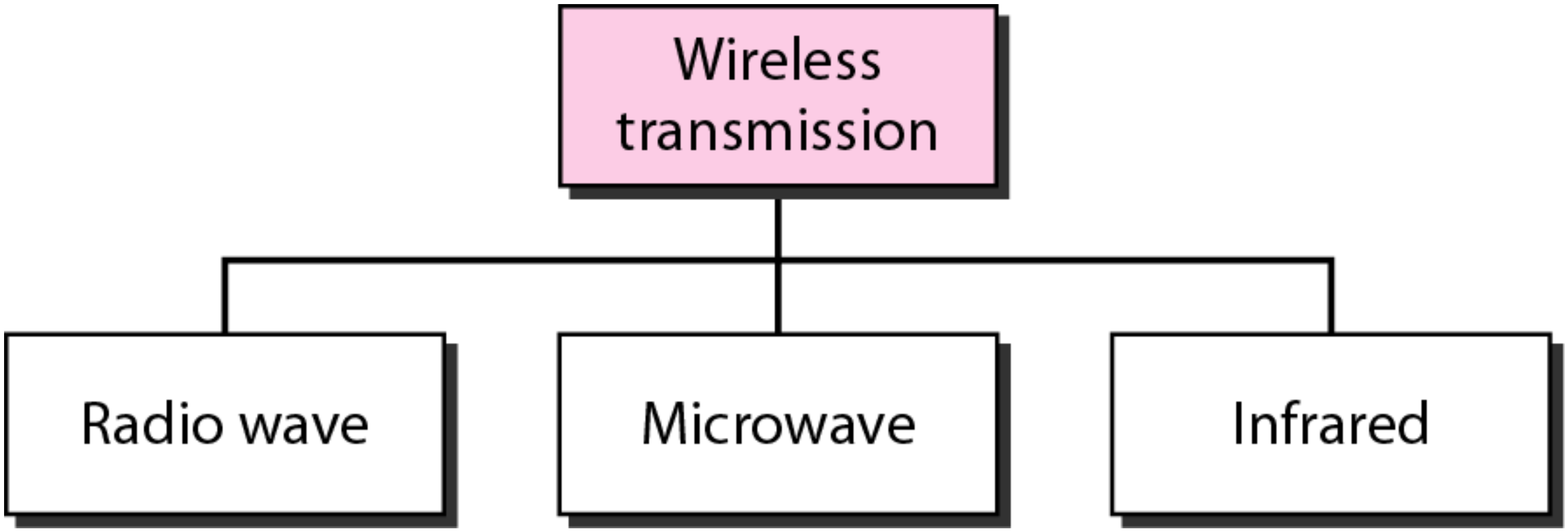
Type	*Core (µm)*	*Cladding (µm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

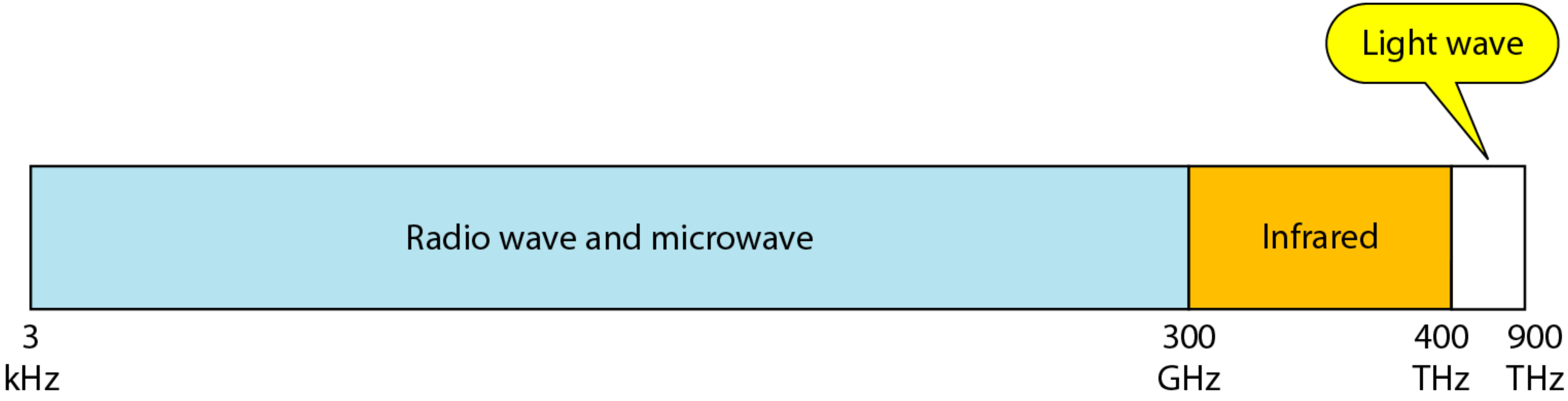
Optical Fiber Performance

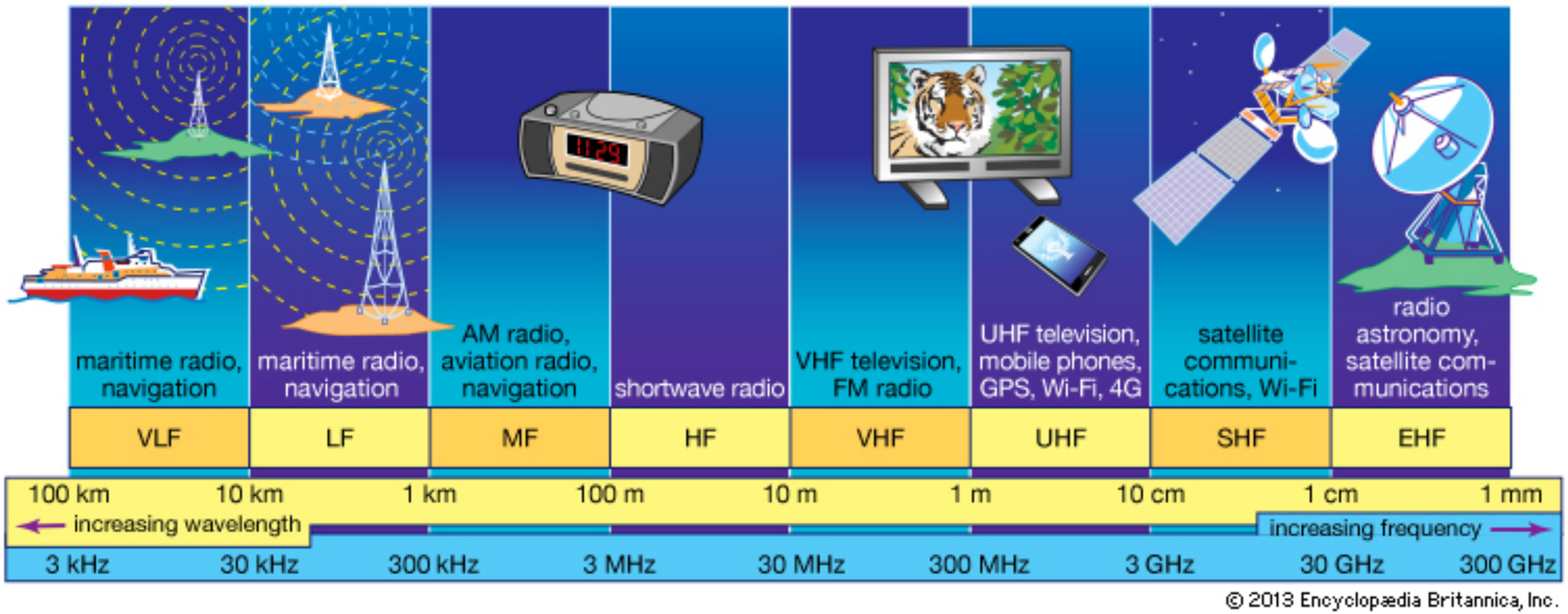


Unguided Media: Wireless

- Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.
    - Radio Waves
    - Microwaves
    - Infrared




Light wave
Radio wave and microwave
Infrared
3 kHz
300 GHz
400 THz
900 THz


maritime radio, navigation
maritime radio, navigation
AM radio, aviation radio, navigation
shortwave radio
VHF television, FM radio
UHF television, mobile phones, GPS, Wi-Fi, 4G
satellite communi-cations, Wi-Fi
radio astronomy, satellite com-munications
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
100 km
10 km
1 km
100 m
10 m
1 m
10 cm
1 cm
1 mm
increasing wavelength
increasing frequency
3 kHz
30 kHz
300 kHz
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz
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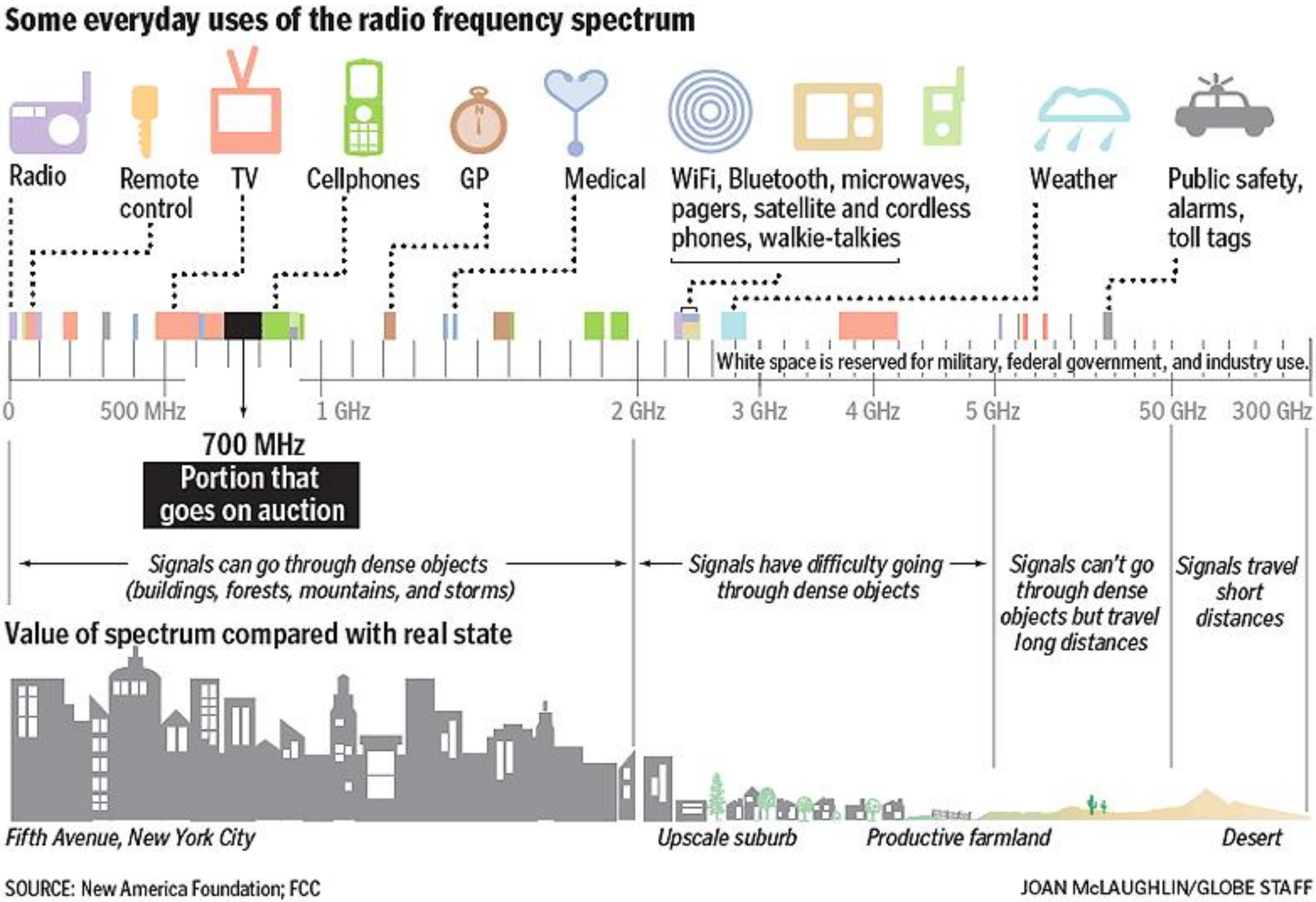
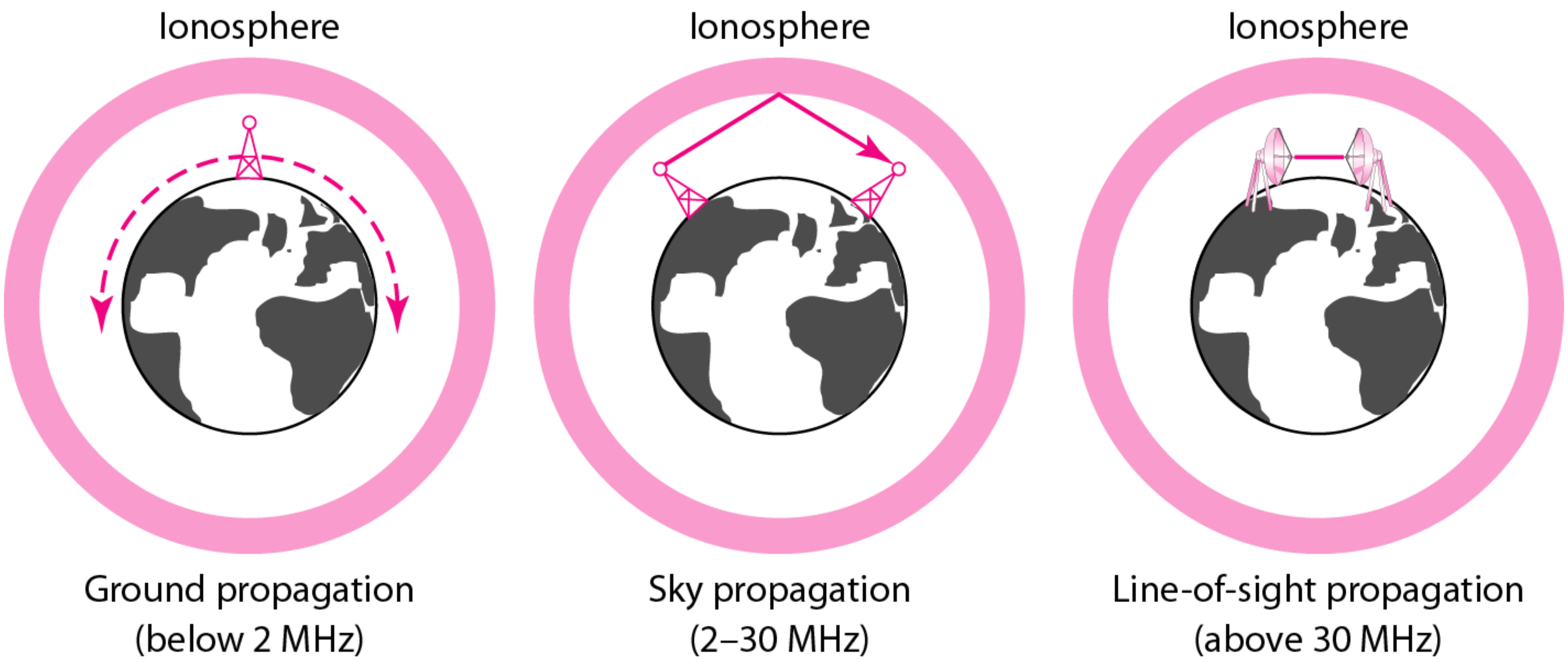

Some everyday uses of the radio frequency spectrum
Radio
Remote control
TV
Cellphones
GP
Medical
WiFi, Bluetooth, microwaves, pagers, satellite and cordless phones, walkie-talkies
Weather
Public safety, alarms, toll tags
White space is reserved for military, federal government, and industry use.
0
500 MHz
1 GHz
2 GHz
3 GHz
4 GHz
5 GHz
50 GHz
300 GHz
700 MHz
Portion that goes on auction
Signals can go through dense objects (buildings, forests, mountains, and storms)
Signals have difficulty going through dense objects
Signals can't go through dense objects but travel long distances
Signals travel short distances
Value of spectrum compared with real state
Fifth Avenue, New York City
Upscale suburb
Productive farmland
Desert
SOURCE: New America Foundation; FCC
JOAN McLAUGHLIN/GLOBE STAFF

Propagation Methods

- A signal radiated from an antenna travels alog one of three routes:
  - Ground wave
  - Sky wave or
  - Line of Sight (LOS)



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

Band	Frequency Range	Free-Space Wavelength Range	Propagation Characteristics	Typical Use
ELF (extremely low frequency)	30 to 300 Hz	10,000 to 1000 km	GW	Power line frequencies; used by some home control systems.
VF (voice frequency)	300 to 3000 Hz	1000 to 100 km	GW	Used by the telephone system for analog subscriber lines.
VLF (very low frequency)	3 to 30 kHz	100 to 10 km	GW; low attenuation day and night; high atmospheric noise level	Long-range navigation; submarine communication
LF (low frequency)	30 to 300 kHz	10 to 1 km	GW; slightly less reliable than VLF; absorption in daytime	Long-range navigation; marine communication radio beacons
MF (medium frequency)	300 to 3000 kHz	1,000 to 100 m	GW and night SW; attenuation low at night, high in day; atmospheric noise	Maritime radio; direction finding; AM broadcasting.
HF (high frequency)	3 to 30 MHz	100 to 10 m	SW; quality varies with time of day, season, and frequency.	Amateur radio; international broadcasting, military communication; long-distance aircraft and ship communication
VHF (very high frequency)	30 to 300 MHz	10 to 1 m	LOS; scattering because of temperature inversion; cosmic noise	VHF television; FM broadcast and two-way radio, AM aircraft communication; aircraft navigational aids
UHF (ultra high frequency)	300 to 3000 MHz	100 to 10 cm	LOS; cosmic noise	UHF television; cellular telephone; radar; microwave links; personal communications systems
SHF (super high frequency)	3 to 30 GHz	10 to 1 cm	LOS; rainfall attenuation above 10 GHz; atmospheric attenuation due to oxygen and water vapor	Satellite communication; radar; terrestrial microwave links; wireless local loop
EHF (extremely high frequency)	30 to 300 GHz	10 to 1 mm	LOS; atmospheric attenuation due to oxygen and water vapor	Experimental; wireless local loop
Infrared	300 GHz to 400 THz	1 mm to 770 nm	LOS	Infrared LANs; consumer electronic applications
Visible light	400 THz to 900 THz	770 nm to 330 nm	LOS	Optical communication

Line of Sight (LOS) Transmission

- For any type of wireless communication the signal disperse with distance. Therefore, an antenna with a fixed area will receive less power the farther it is from the transmitting antenna.
- For satellite dommunication this is the primary mode of signal loss. Even if no other sources of attenuation or impairment are assumed, a transmitted signal attenuates over distance because the signal is being spread over a larger and larger area. This form of attenuation is known as **free space loss**.
- For ideal isotropic antenna, free space loss is

$$\boxed{\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}}$$

where

P_t = signal power at the transmitting antenna
P_r = signal power at the receiving antenna
λ = carrier wavelength
d = propagation distance between antennas
c = speed of light (3×10^8 m/s)

- For other antennas, we must take into account the gain of the antenna, which yields the following free space equation:

$$\boxed{\frac{P_t}{P_r} = \frac{(4\pi)^2(d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}}$$

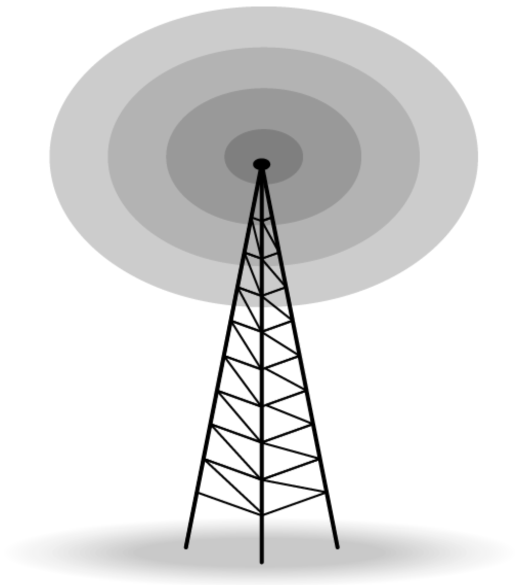
where

G_t = gain of the transmitting antenna
G_r = gain of the receiving antenna
A_t = effective area of the transmitting antenna
A_r = effective area of the receiving antenna

$$\boxed{\begin{aligned} L_{\mathrm{dB}} &= 20\log(\lambda) + 20\log(d) - 10\log(A_t A_r) \\ &= -20\log(f) + 20\log(d) - 10\log(A_t A_r) + 169.54\ \mathrm{dB} \end{aligned}}$$

Omnidirectional Antennas

- Radio waves use omnidirectional antennas that send out signals in all directions.
- Based on wavelength, strength, and the purpose of transmission, we can have several types of Antennas.
- Figure below shows an omnidirectional antenna.



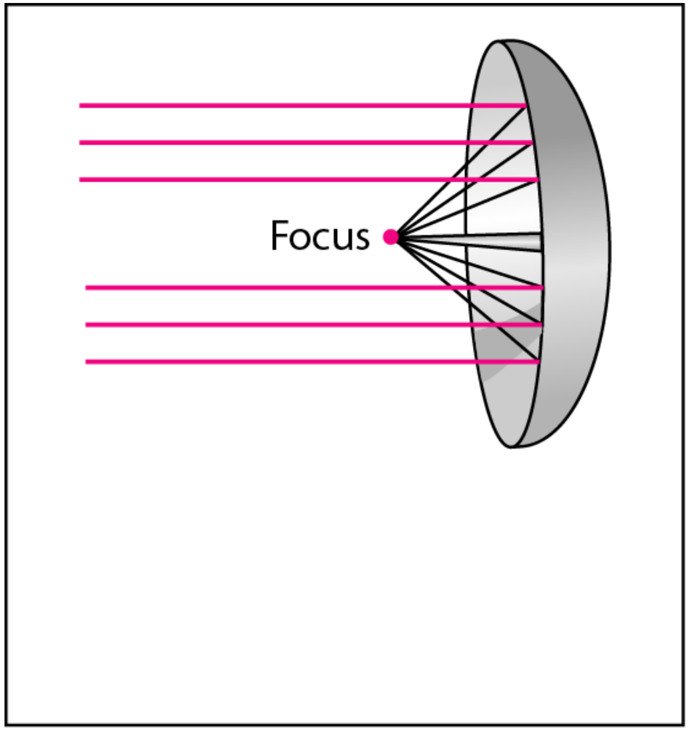
- Applications: The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receiver. AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

Microwaves

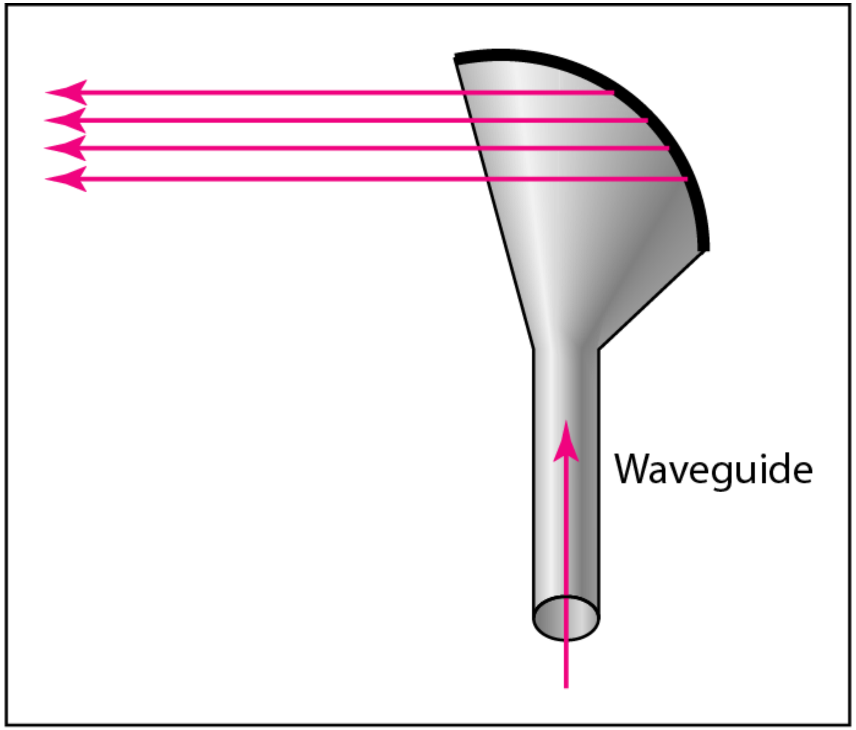
- Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves.
- Microwaves are unidirectional. When an antenna transmits microvawe waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.
- The following describes some characteristics of microwave propagation:
    - Microwave propagation is line-of-sight
    - Very High Frequency mirowaves cannot penetrate walls
    - The microwave band is relatively wide, almost 299 GHz. There fore wider subbands can be assigned, and a high data rate is possible
    - Use of certain portions of the band requires permission from authorities.

Unidirectional Antennas

- Microvawa need unidirectional antennas that send out signal in one direction. Two types od antennas are used for microwave communications: the parabolic dish and the horn.



a. Dish antenna



b. Horn antenna

Applications

- Radio waves are used for multicast communications, such as radio and television, and paging systems.
- Microwaves are used for unicast communication such as cellular telephones, satellite networks,
  and wireless LANs.
- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Infrared

- Infrared waves, with frequencies from 300 GHz to 400 THz (wavelength from 1 mm to 770 nm), can be used for short-range communication.
- Infrared waves, having high frequencies cannot penetrate walls.
- Applications: communication between devices, such as keyboard, mice, PCs and printers.