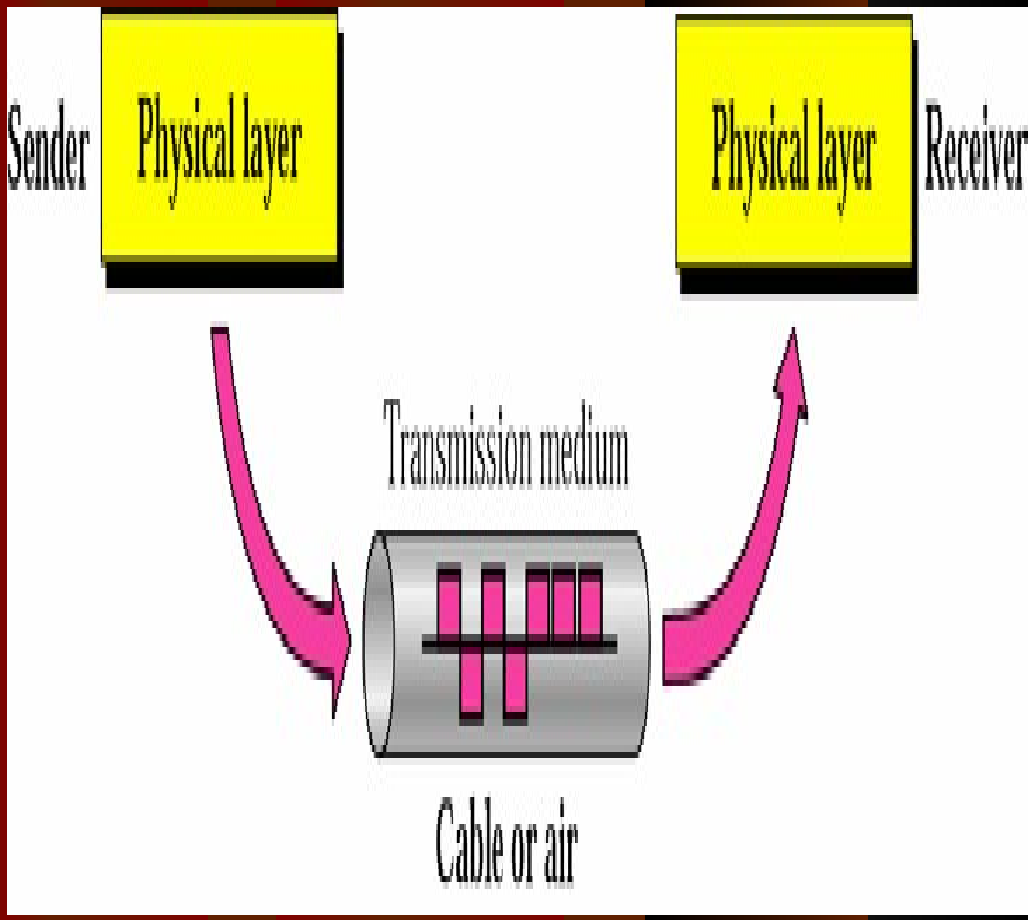
Transmission Media

Group Name :

Manish Mishra

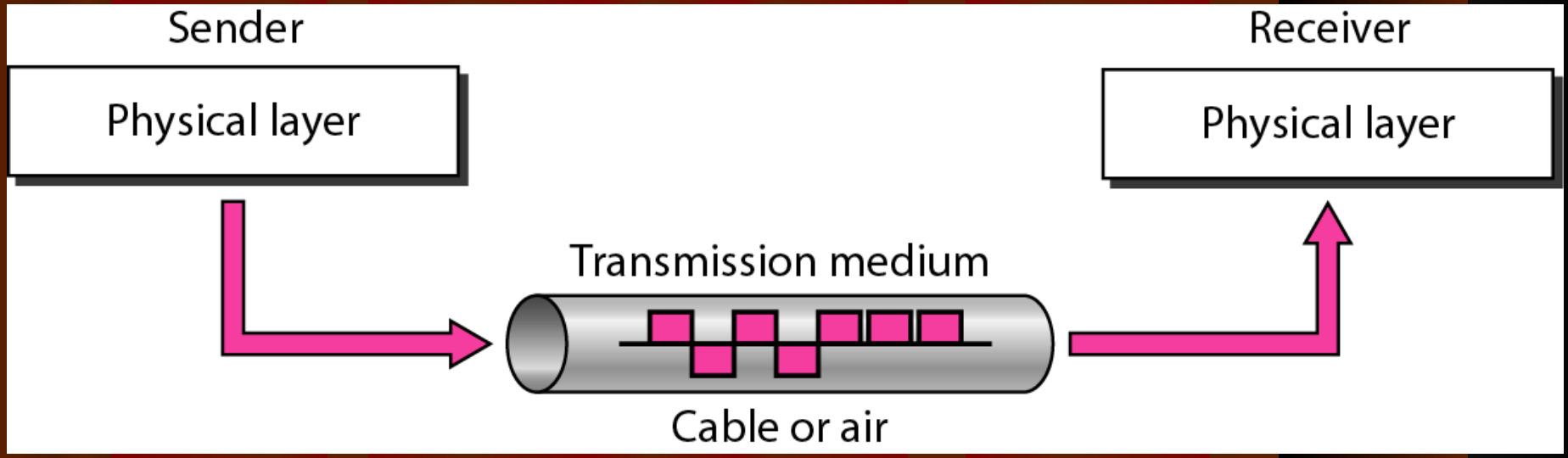
Transmission media

- Transmission media are located below the physical layer
- Computers use signals to represent data.
- Signals are ransmitted in form of electromagnetic energy.



Transmission Media

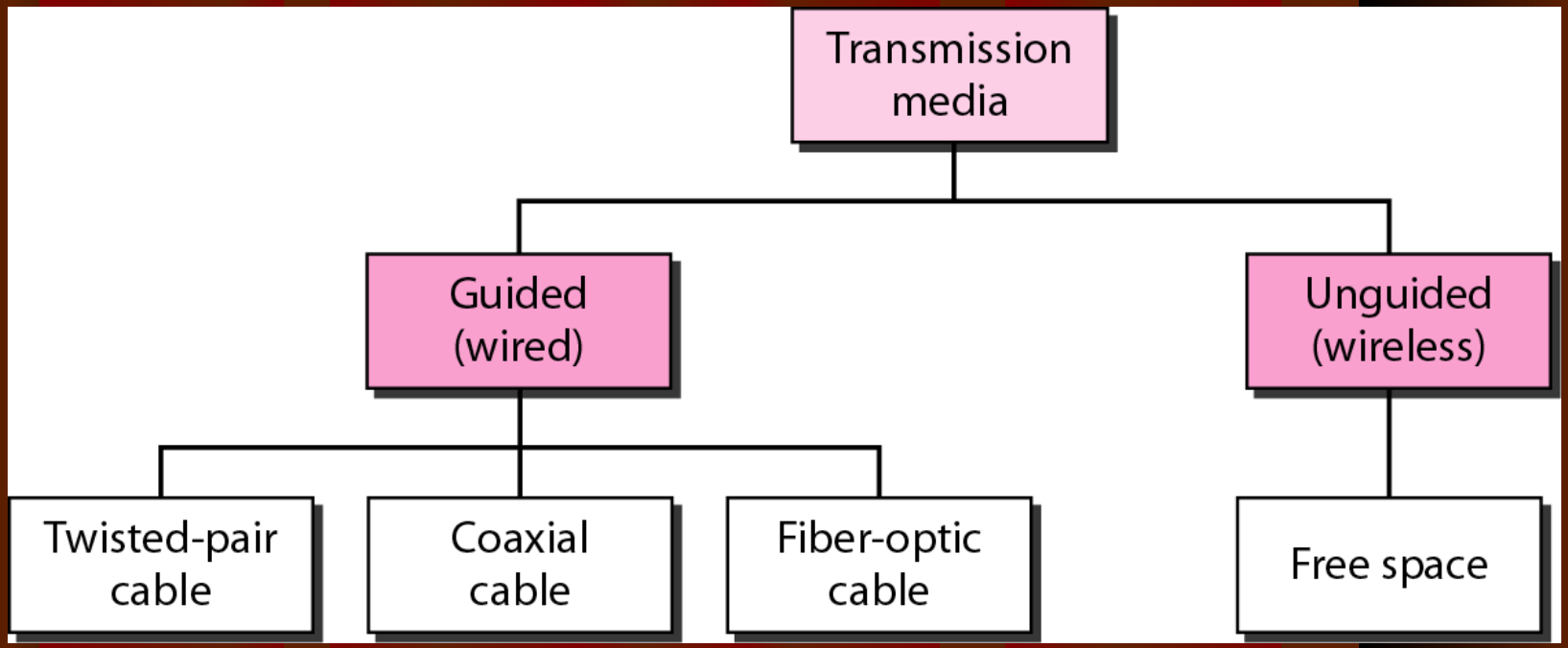
Transmission Media and Physical Layer



Transmission Media

- Guided Media (Wired)
  - Twisted-Pair Cable
  - Coaxial Cable
  - Fiber-Optic Cable
- Unguided Media (Wireless)
  - Radio Waves
  - Microwaves
  - Infrared

Classes of transmission media



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.

Overview

- Guided - wire / optical fibre
- Unguided - wireless
- Characteristics and quality determined by medium and signal
  - in unguided media - bandwidth produced by the antenna is more important
  - in guided media - medium is more important
- Key concerns are data rate and distance

Data Rate and Bandwidth

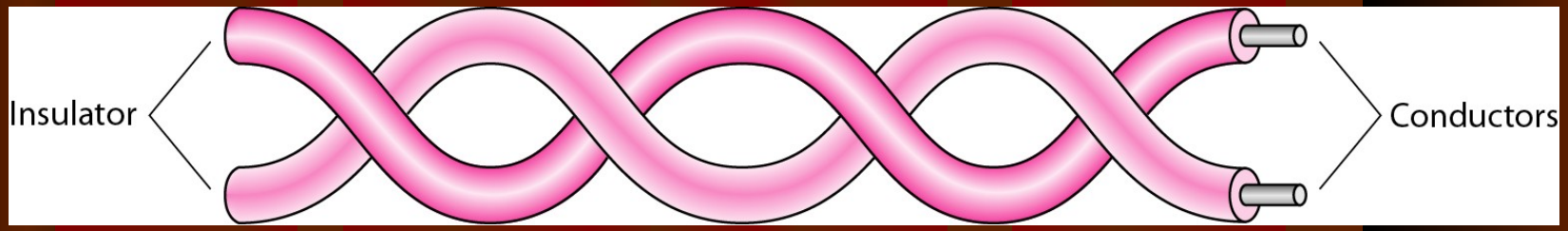
- Any transmission system has a limited band of frequencies
- This limits the data rate that can be carried

Design Factors

- Bandwidth
  - higher bandwidth gives higher data rate
- Transmission impairments
  - eg. attenuation
- Interference
- Number of receivers in guided media
  - more receivers introduces more attenuation

Guided Media – Twisted-pair Cable

Twisted-pair cable



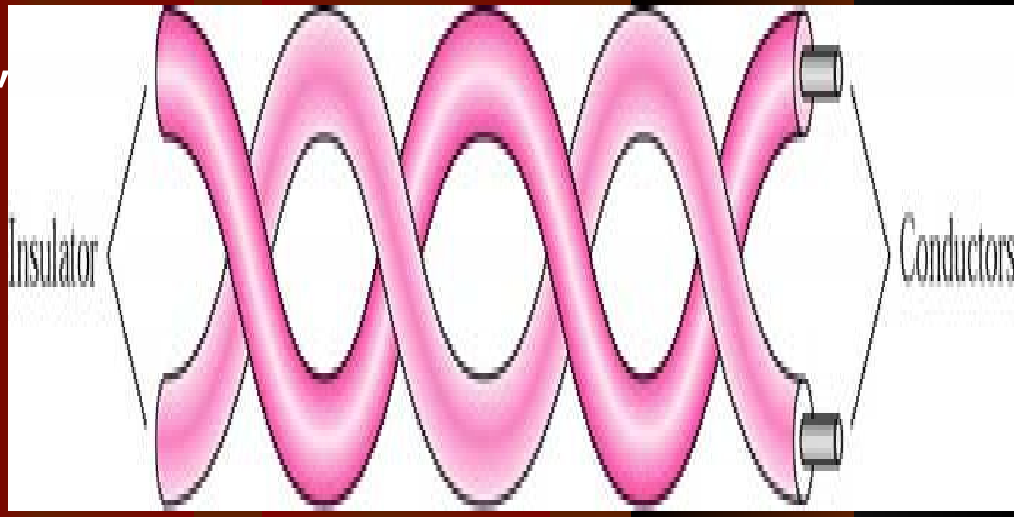
Twisted Pair

—Separately insulated
—Twisted together
—Often "bundled" into cables
—Usually installed in building during construction

(a) Twisted pair

Twisted pair

- One of the wires carries signal, the other is used only as a ground reference.
- The receiver uses the difference b/w the two levels.
- Twisting increases the probability that both wires are effected by the noise in the same manner, thus the difference at the receiver remains same.
- Therefore, number of twists per unit length determines the quality of the cable.

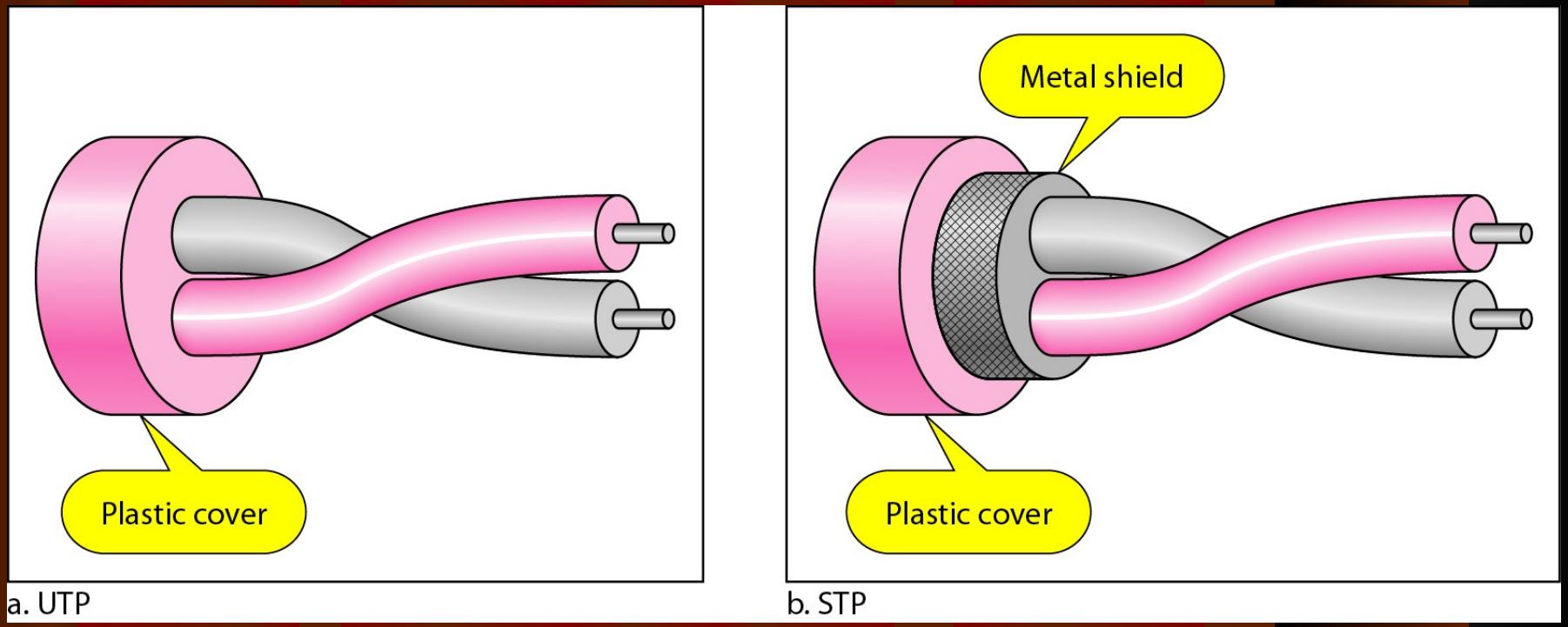


Twisted Pair - Transmission Characteristics

- analog
  - needs amplifiers every 5km to 6km
- digital
  - can use either analog or digital signals
  - needs a repeater every 2-3km
- limited distance
- limited bandwidth (1MHz)
- limited data rate (100MHz)
- susceptible to interference and noise

Unshielded Versus Shielded Twisted-Pair Cable

UTP and STP cables

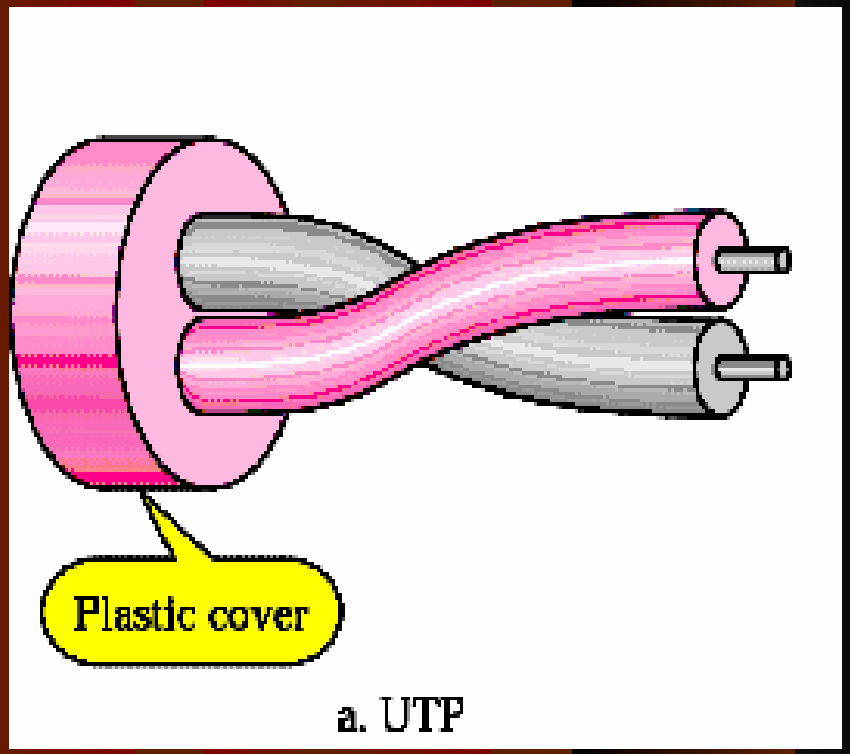


a. UTP

b. STP

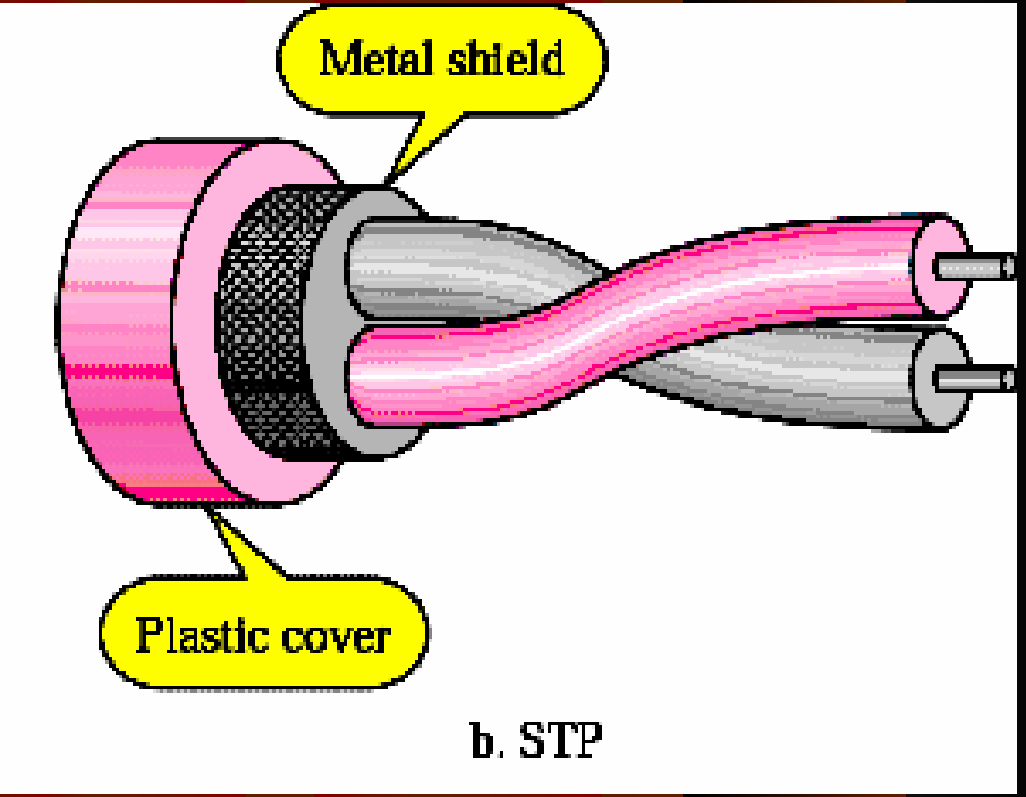
Unshielded Twisted Pair (UTP)

- Ordinary telephone wire
- Cheapest
- Easiest to install
- Suffers from external EM interference



Shielded Twisted Pair (STP)

- Metal braid or sheathing that reduces interference
- More expensive
- Harder to handle (thick, heavy)



Near End Crosstalk

- coupling of signal from one pair to another
- occurs when transmit signal entering the link couples back to receiving pair
- ie. near transmitted signal is picked up by near receiving pair

Categories of unshielded twisted-pair cables

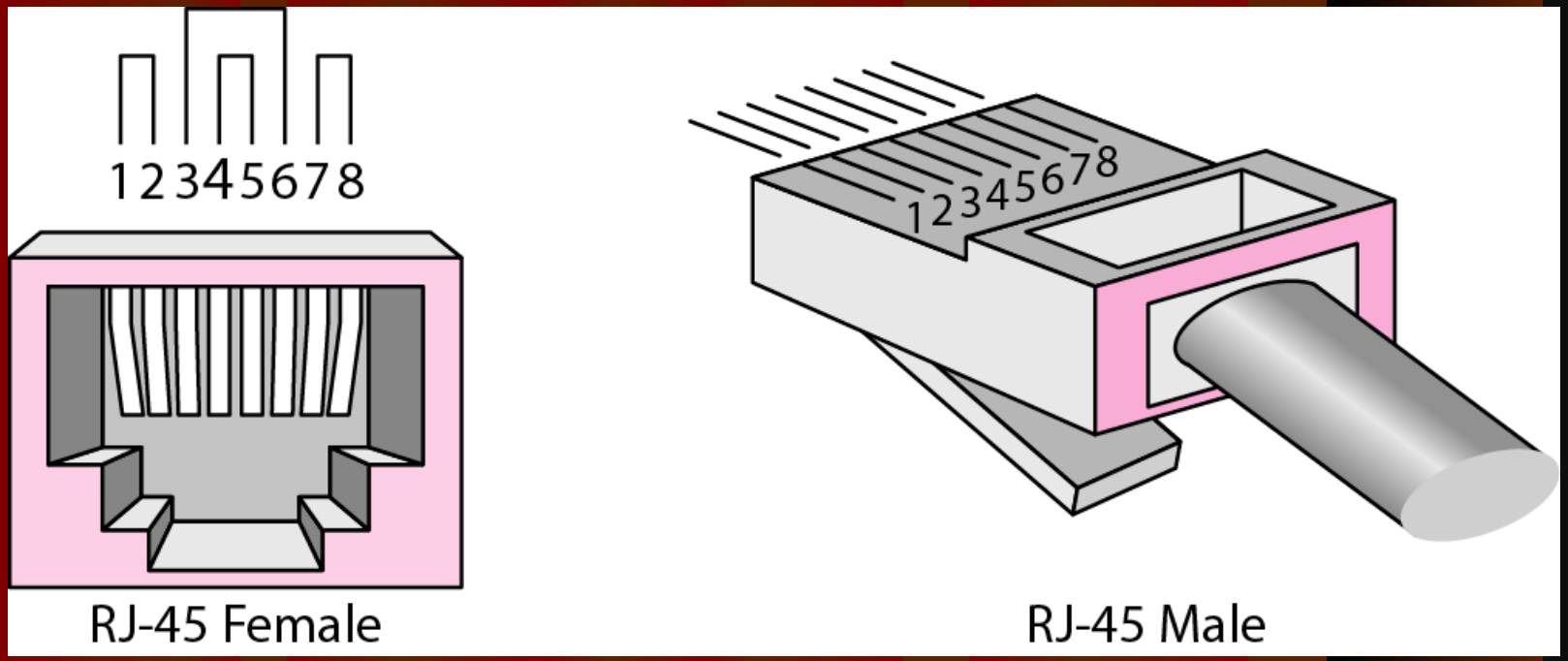
Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with 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

UTP Categories

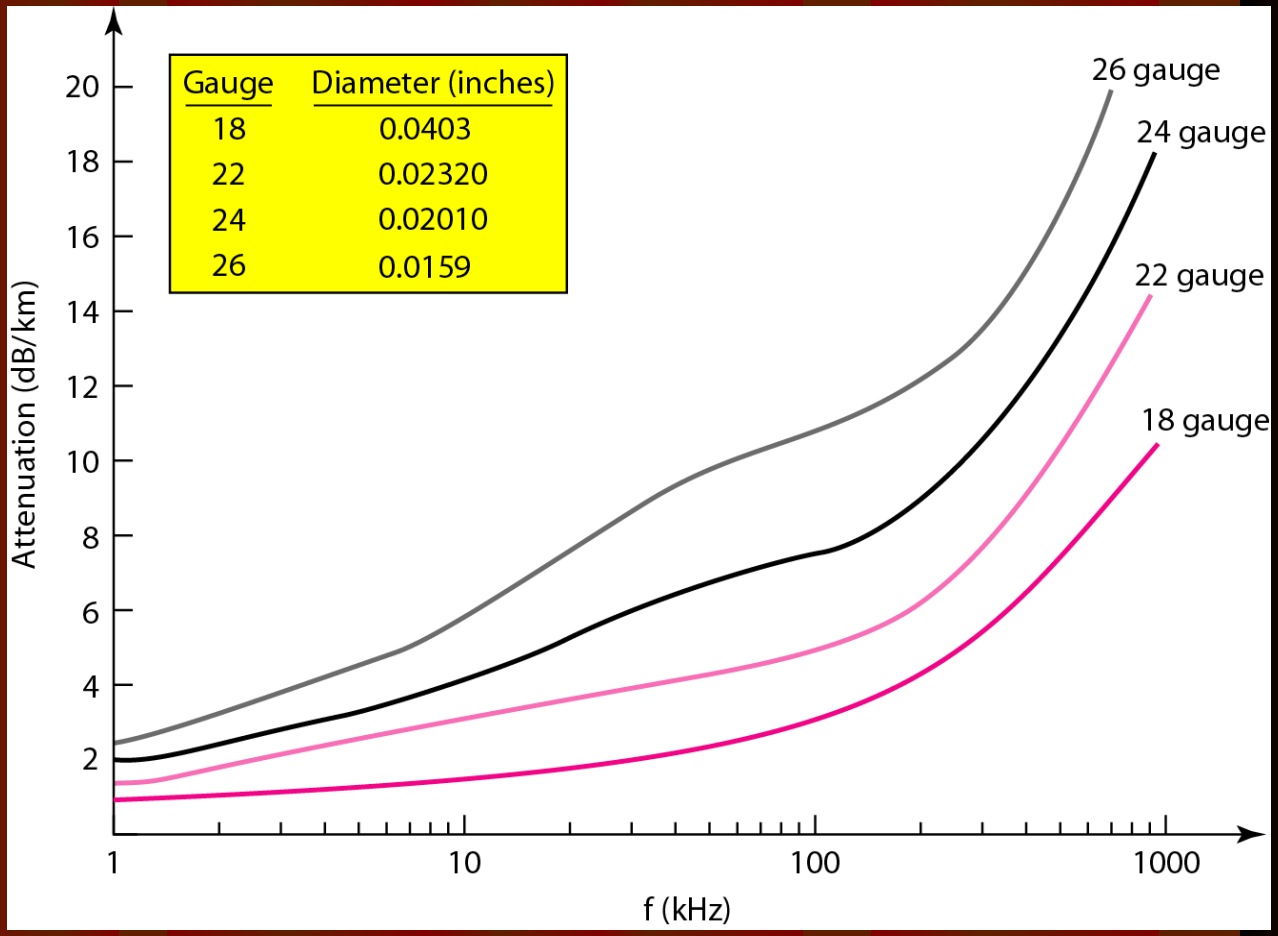
Category	Bandwidth	Data Rate	Digital/Analog	Use
1	very low	< 100 kbps	Analog	Telephone
2	< 2 MHz	2 Mbps	Analog/digital	T-1 lines
3	16 MHz	10 Mbps	Digital	LANs
4	20 MHz	20 Mbps	Digital	LANs
5	100 MHz	100 Mbps	Digital	LANs
6 (draft)	200 MHz	200 Mbps	Digital	LANs
7 (draft)	600 MHz	600 Mbps	Digital	LANs

Guided Media – UTP

UTP Connector



UTP Performance



Guided Media - UTP

- Applications:
  - Telephone lines connecting subscribers to the central office
  - DSL lines
  - LAN – 10Base-T and 100Base-T

Twisted Pair - Applications

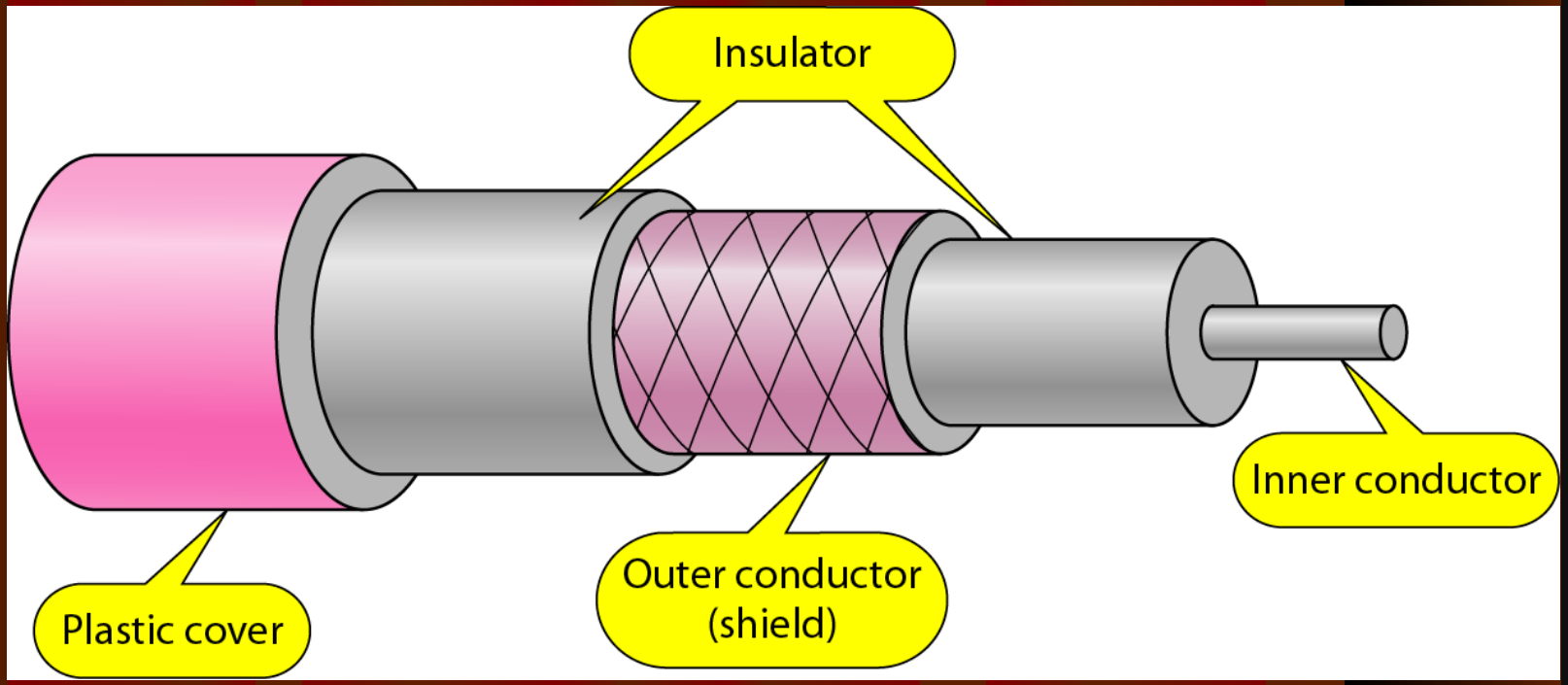
- Most common medium
- Telephone network
- Within buildings
- For local area networks (LAN)

Twisted Pair - Pros and Cons

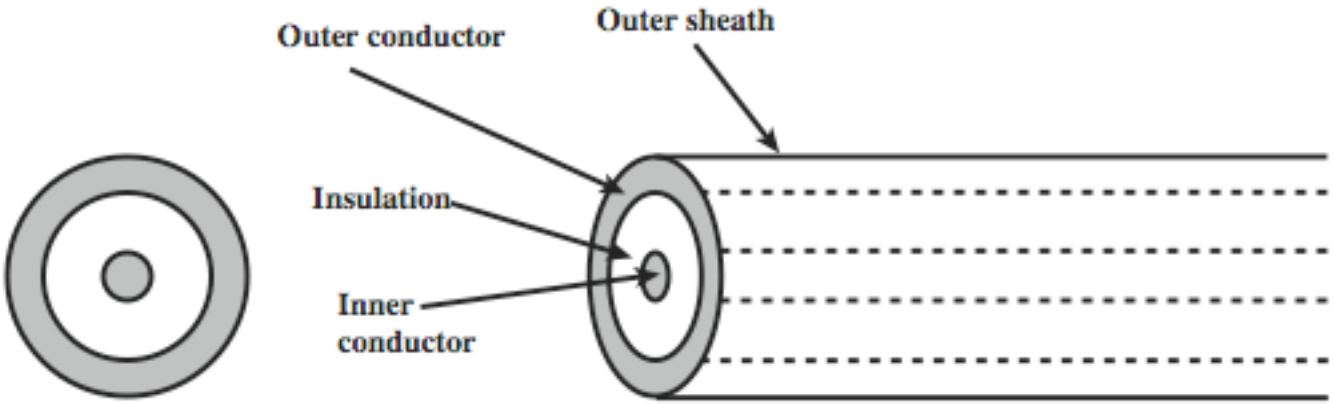
- Cheap
- Easy to work with
- Low data rate
- Short range

Guided Media – Coaxial Cable

Coaxial Cable



Coaxial Cable

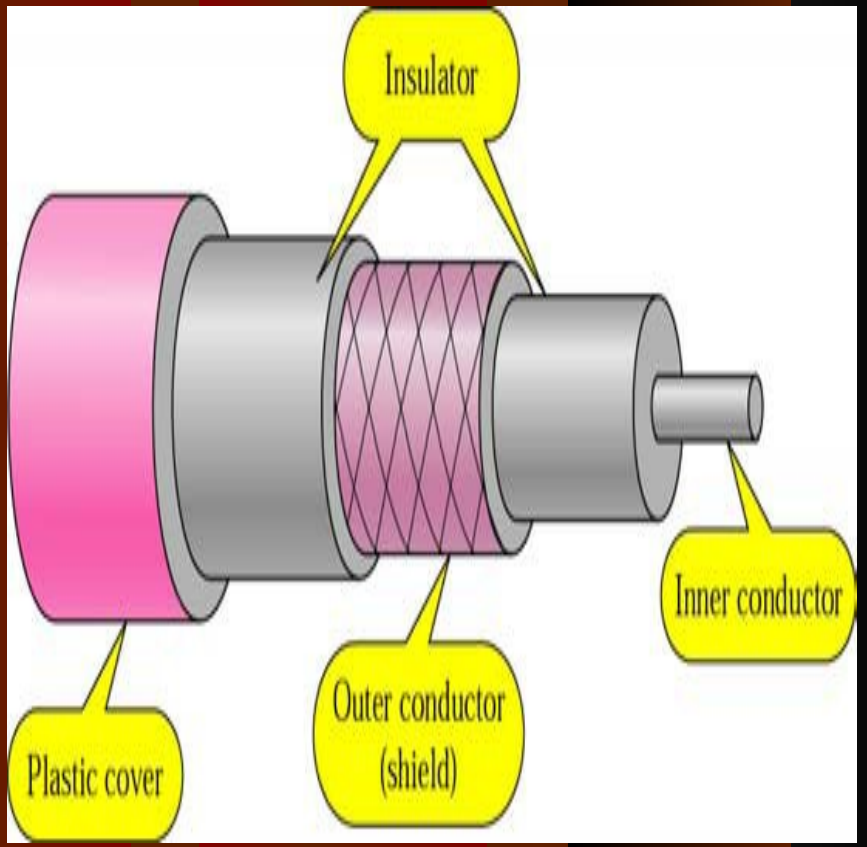


—Outer conductor is braided shield
—Inner conductor is solid metal
—Separated by insulating material
—Covered by padding

(b) Coaxial cable

Coaxial cable

- Inner conductor is a solid wire outer conductor serves both as a shield
- against noise and a second conductor



Coaxial Cable Applications

- Most versatile medium
- Television distribution
- Long distance telephone transmission
- Can carry 10,000 voice calls simultaneously
- Short distance computer systems links
- Local area networks

Coaxial Cable - Transmission Characteristics

- superior frequency characteristics to TP
- performance limited by attenuation & noise
- analog signals
  - amplifiers every few km
  - closer if higher frequency
  - up to 500MHz
- digital signals
  - repeater every 1km
  - closer for higher data rates

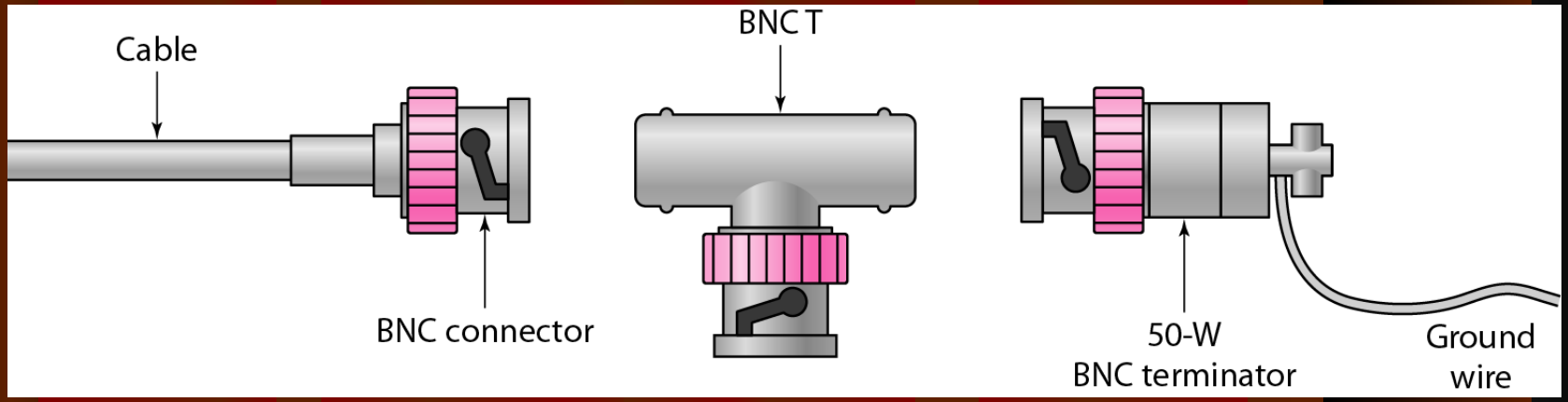
Guided Media – Coaxial Cable

Categories of coaxial cables

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

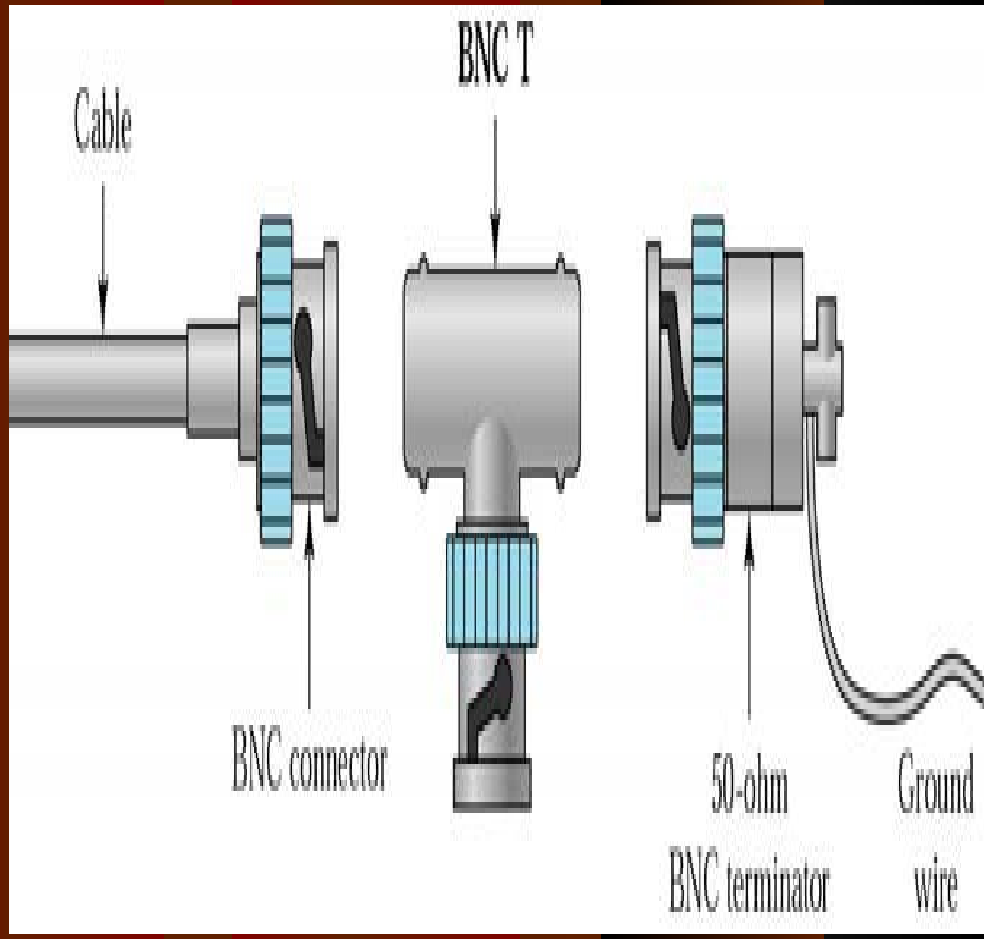
Guided Media – Coaxial Cable

BNC Connectors

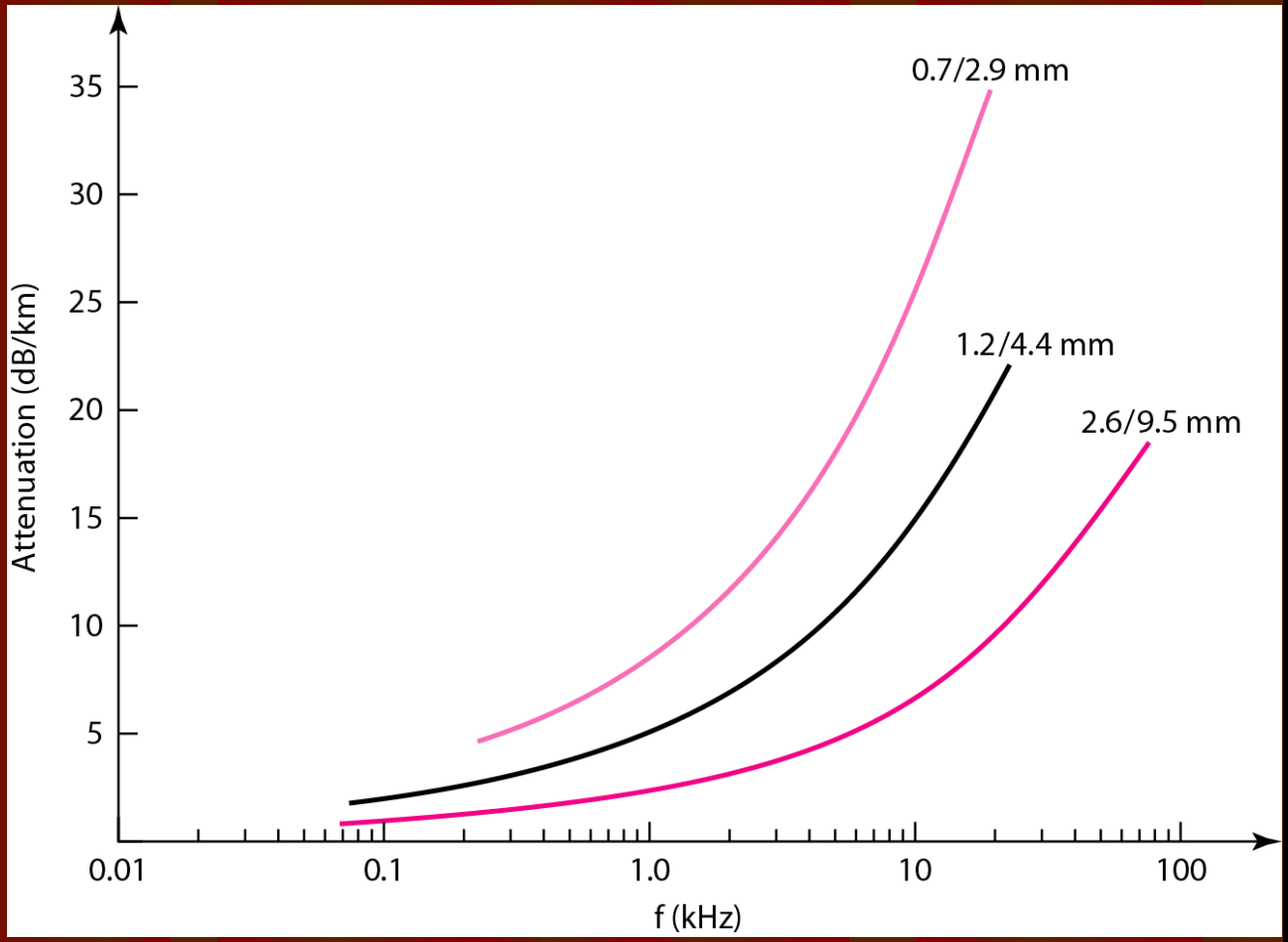


BNC connectors

- BNC = Bayone-Neill-Concelman
- BNC Connector is used to connect the end of the cable to a device
- BNC T is used in networks to branch out a cable for connection to a computer or other device
- BNC Terminator is used at the end of the cable to prevent the reflection of signal.



Coaxial cable performance



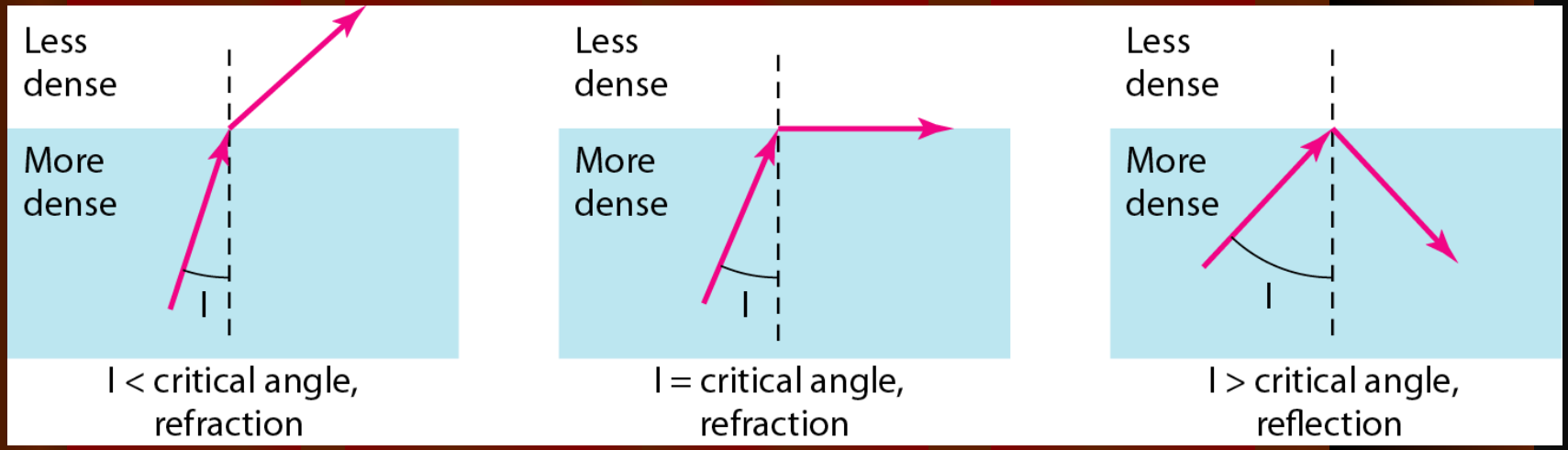
Guided Media – Coaxial Cable

- Applications:
  - Analog telephone networks
  - Cable TV networks
  - Traditional Ethernet LAN – 10Base2, 10Base5

Guided Media – Fiber-Optic Cable

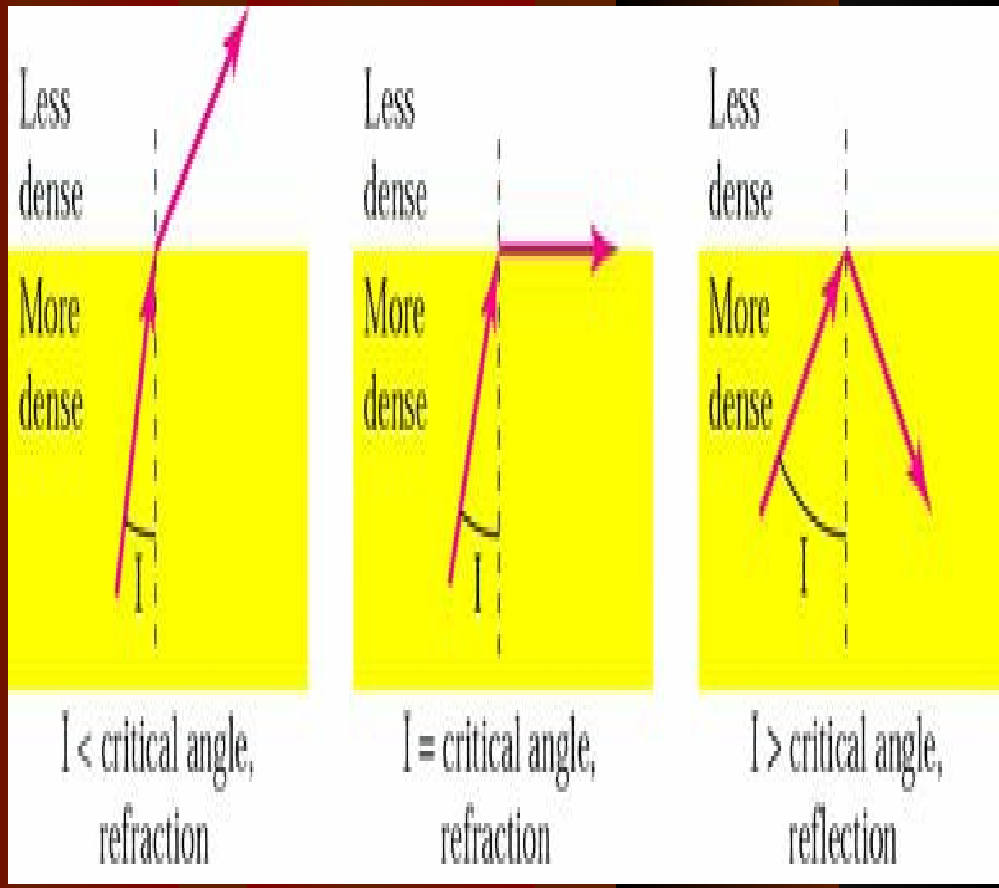
Fiber-optic cable transmit signals in the form of light.

Bending of light ray



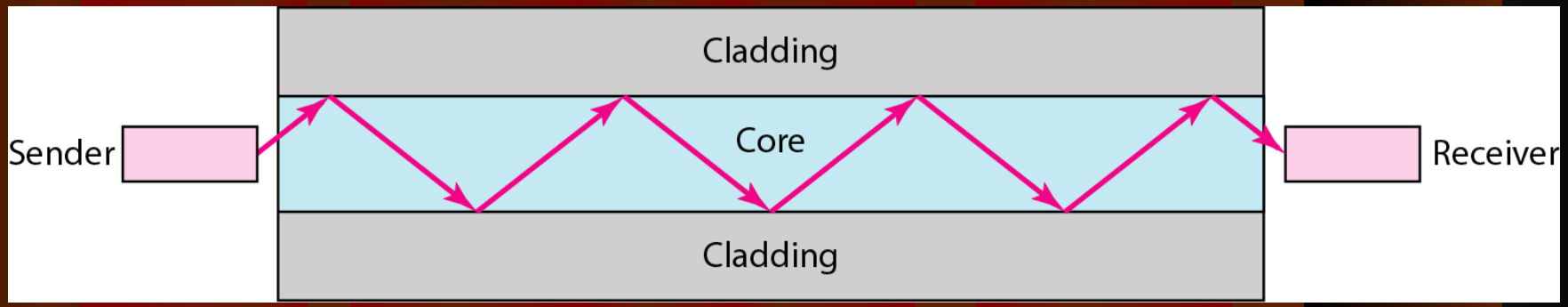
Bending of light ray

- Angle of Incidence (I): the angle the ray makes with the line perpendicular to the interface between the two substances
- Critical Angle: the angle of incidence which provides an angle of refraction of 90-degrees.



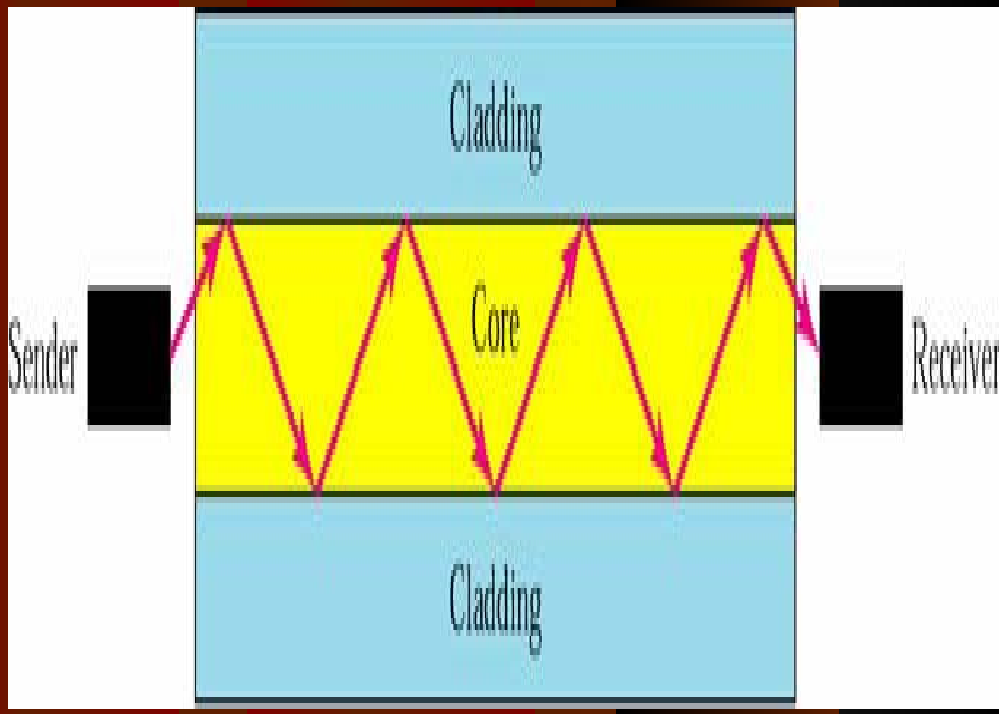
Guided Media – Fiber-Optic Cable

Optic Fiber

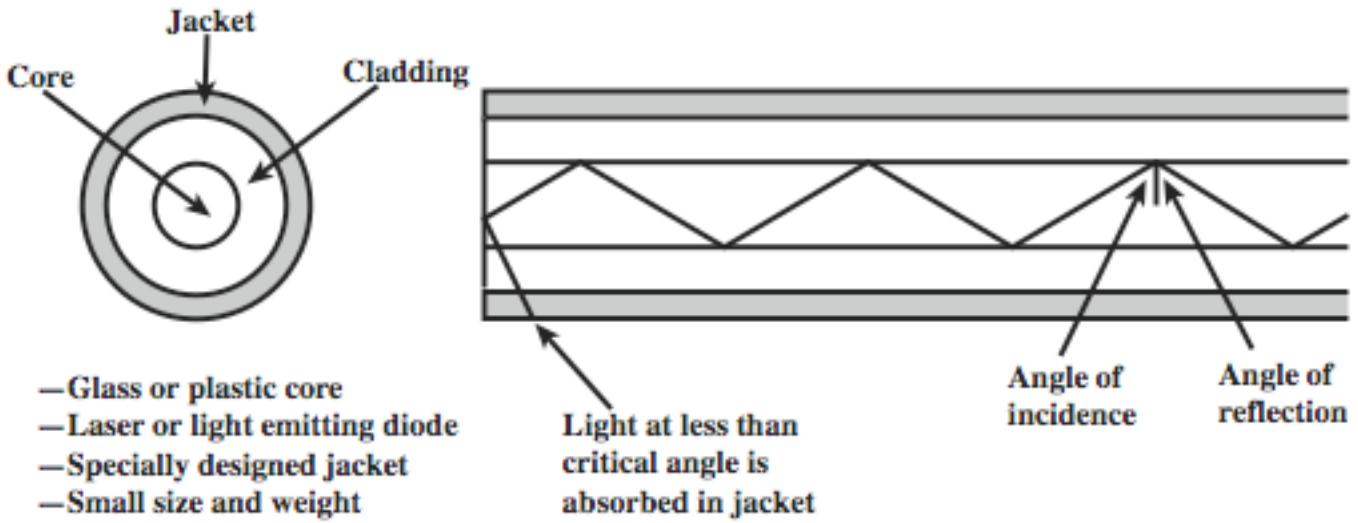


Optical fiber

- Uses reflection to guide light through a channel
- Core is of glass or plastic surrounded by Cladding
- Cladding is of less dense glass or plastic



Optical Fiber



(c) Optical fiber

Optical Fiber - Benefits

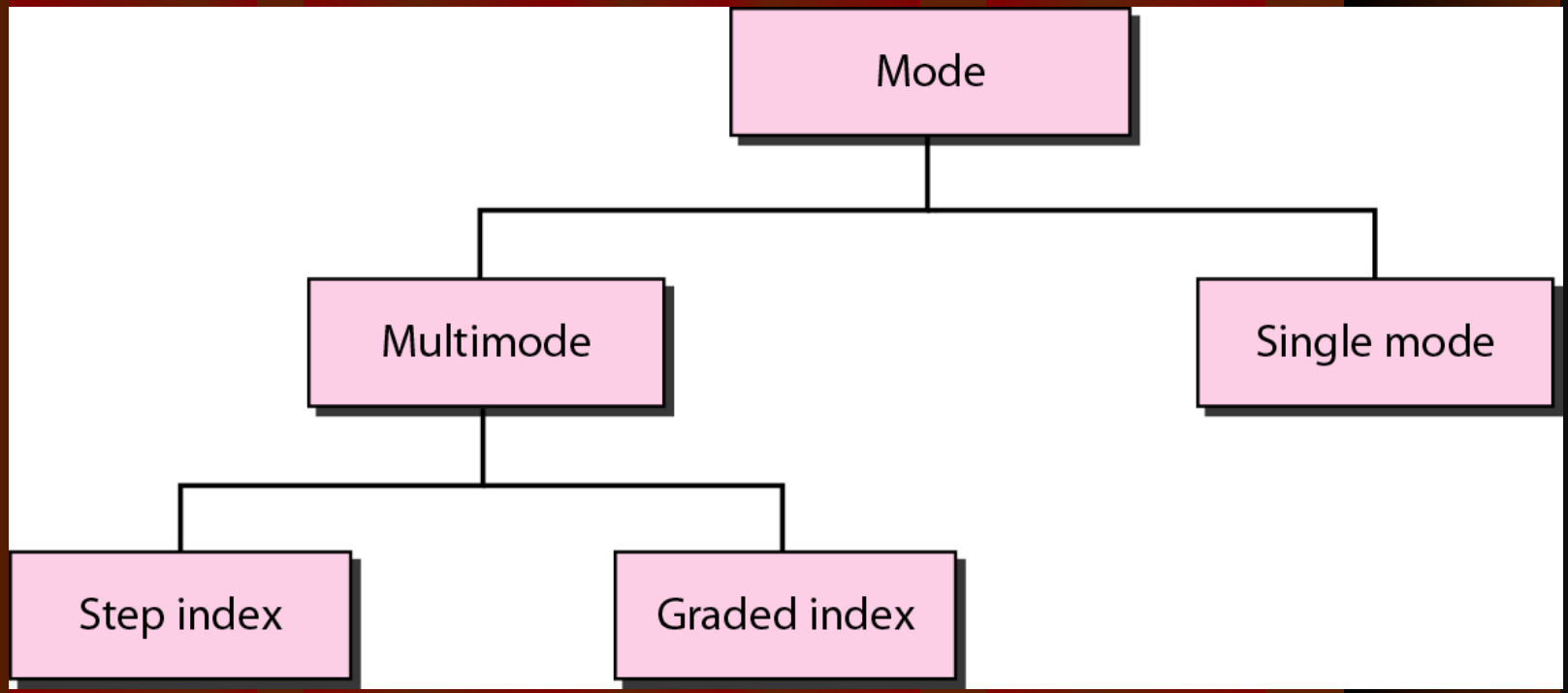
- greater capacity
  - data rates of hundreds of Gbps
- smaller size & weight
- lower attenuation
- electromagnetic isolation
- greater repeater spacing
  - 10s of km at least

Optical Fiber - Transmission Characteristics

- uses total internal reflection to transmit light
  - effectively acts as wave guide for 10^{14} to 10^{15} Hz
- can use several different light sources
  - Light Emitting Diode (LED)
    - cheaper, wider operating temp range, lasts longer
  - Injection Laser Diode (ILD)
    - more efficient, has greater data rate
- relation of wavelength, type & data rate

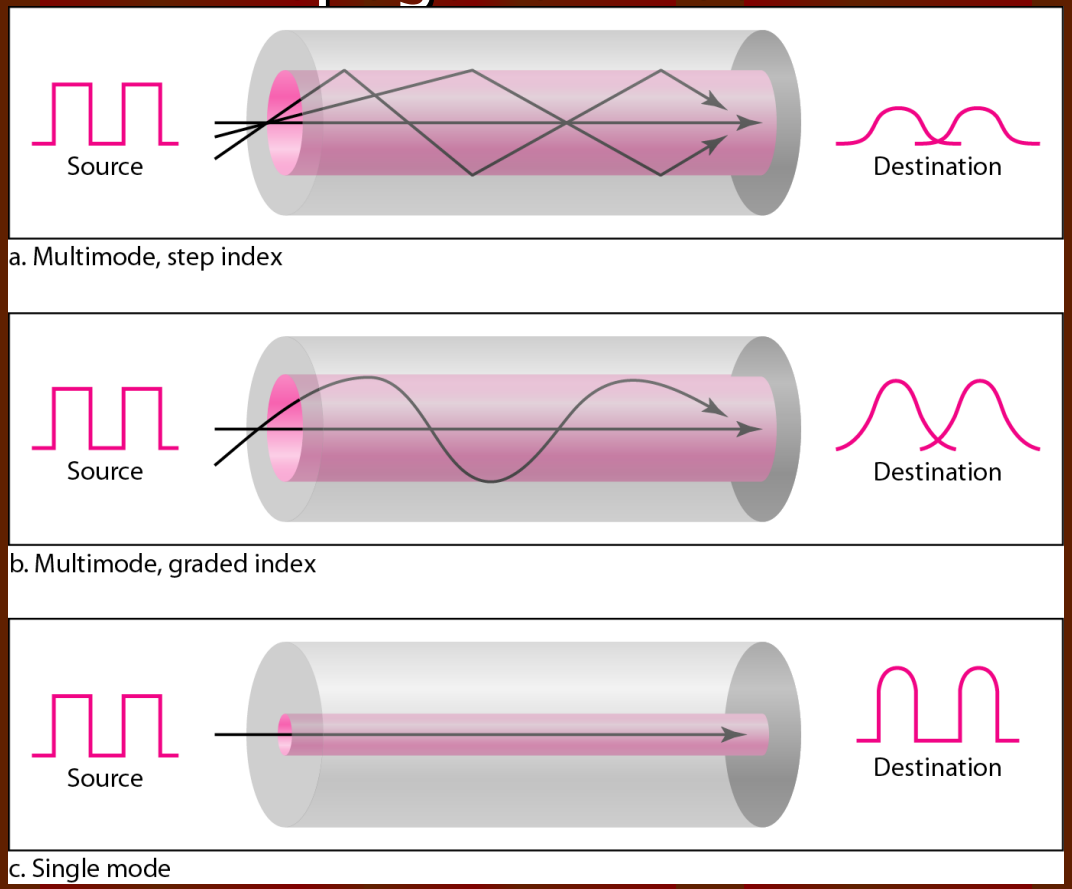
Guided Media – Fiber-Optic Cable

Propagation Modes

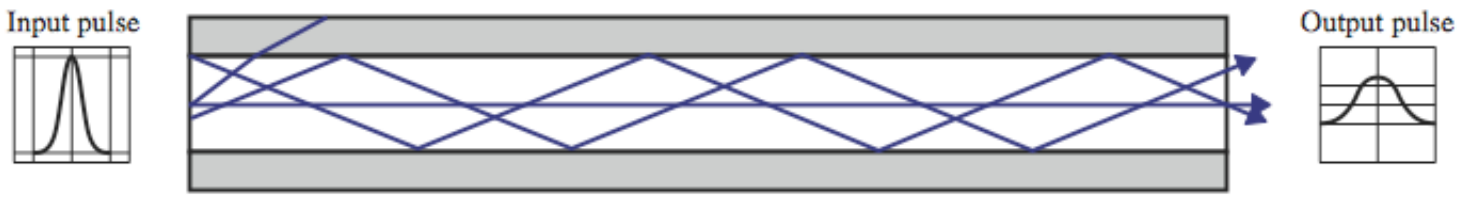


Guided Media – Fiber-Optic Cable

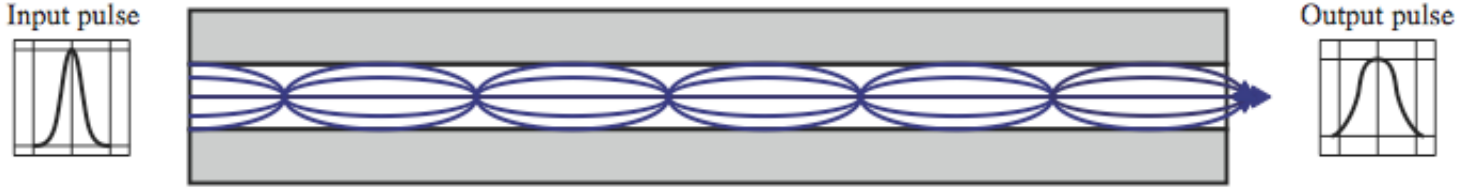
Propagation Modes



Optical Fiber Transmission Modes



(a) Step-index multimode

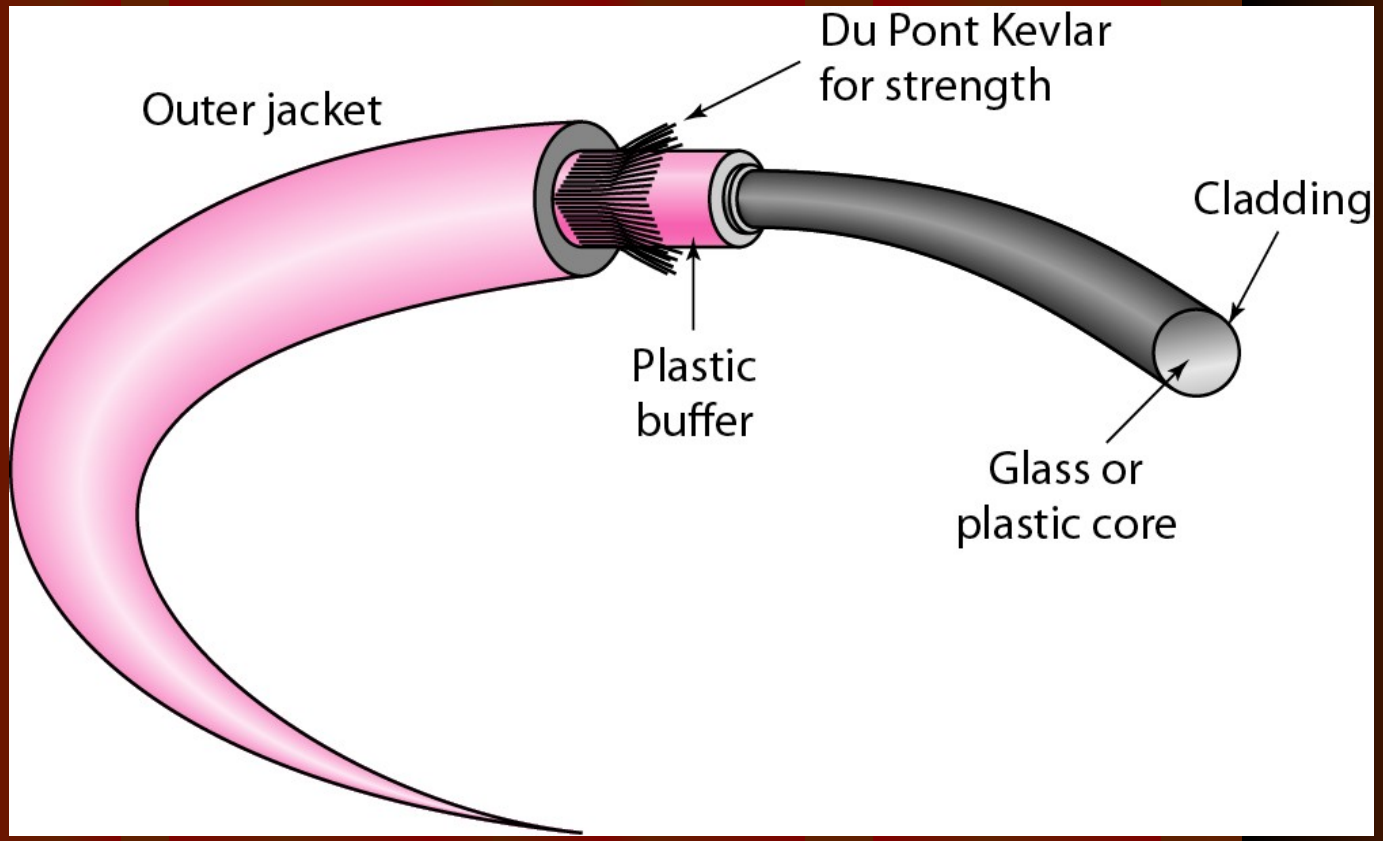


(b) Graded-index multimode

(c) Single mode

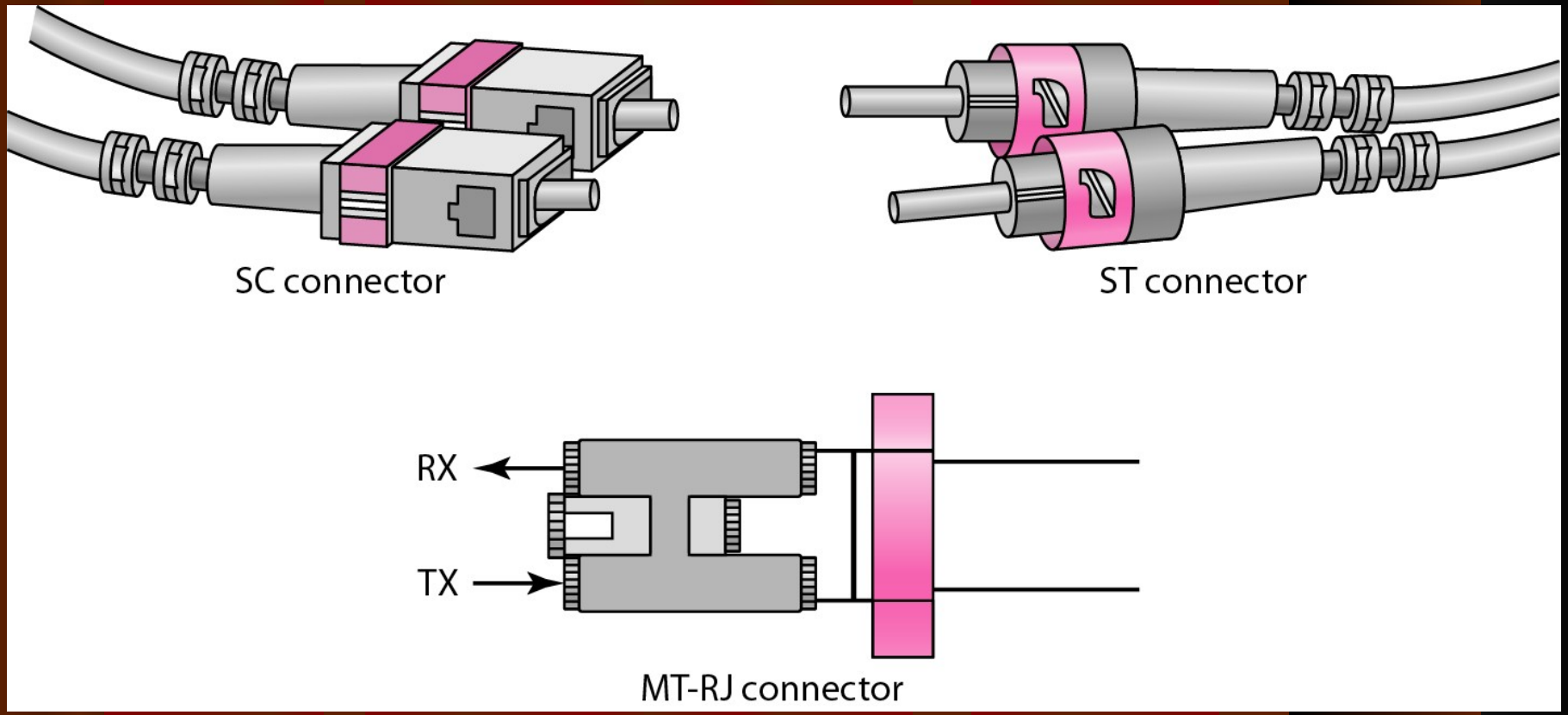
Guided Media – Fiber-Optic Cable

Fiber Construction



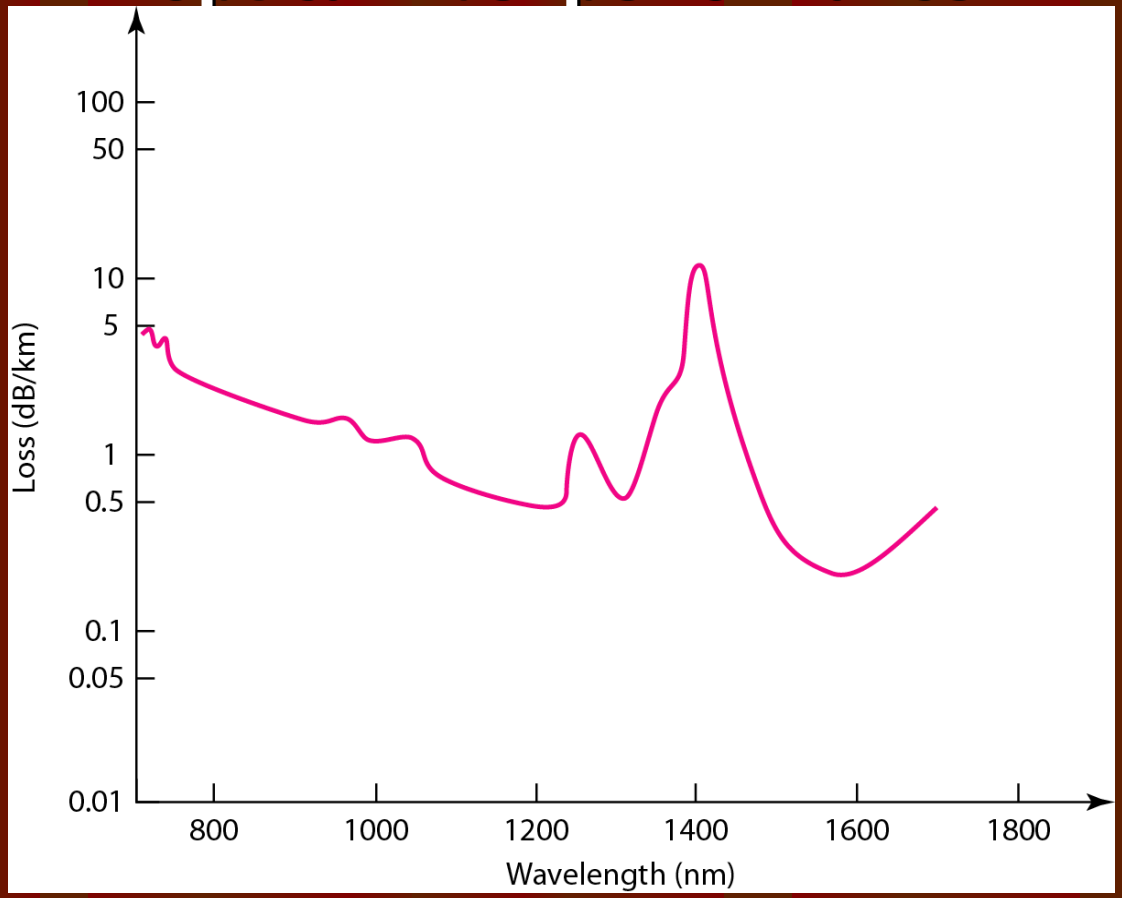
Guided Media – Fiber-Optic Cable

Fiber-optic Cable Connectors



Guided Media – Fiber-Optic Cable

Optical fiber performance



Guided Media – Optical Fiber Cable

- Applications:
  - Backbone networks – SONET
  - Cable TV – backbone
  - LAN
    - 100Base-FX network (Fast Ethernet)
    - 100Base-X

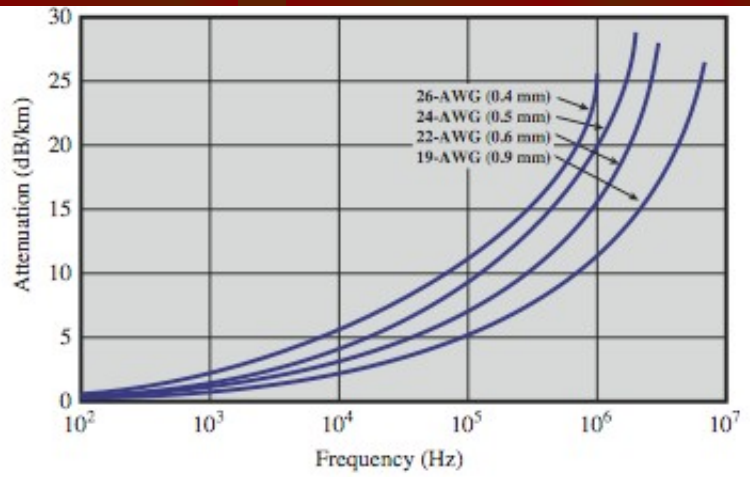
Frequency Utilization for Fiber Applications

Wavelength (in vacuum) range (nm)	Frequency Range (THz)	Band Label	Fiber Type	Application
820 to 900	366 to 333		Multimode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	C	Single mode	WDM
1561 to 1620	192 to 185	L	Single mode	WDM

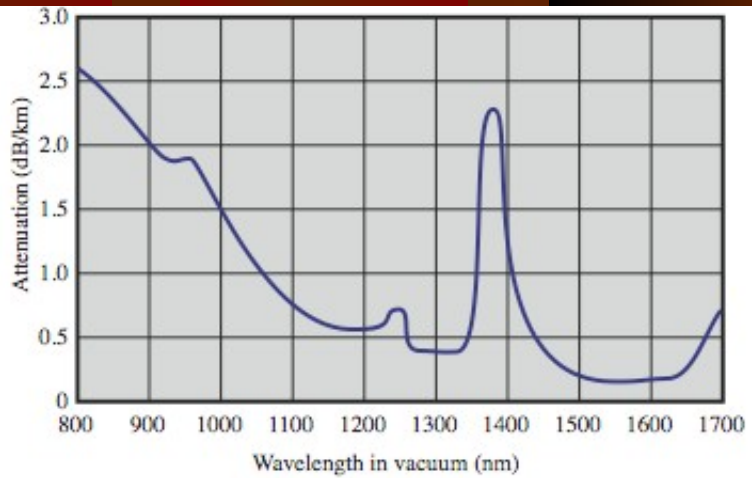
Transmission Characteristics of Guided Media

	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/ km	5 μs/km	40 km

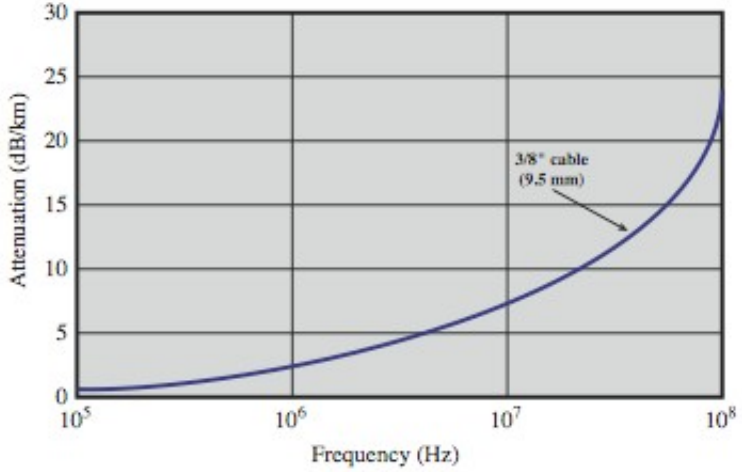
Attenuation in Guided Media



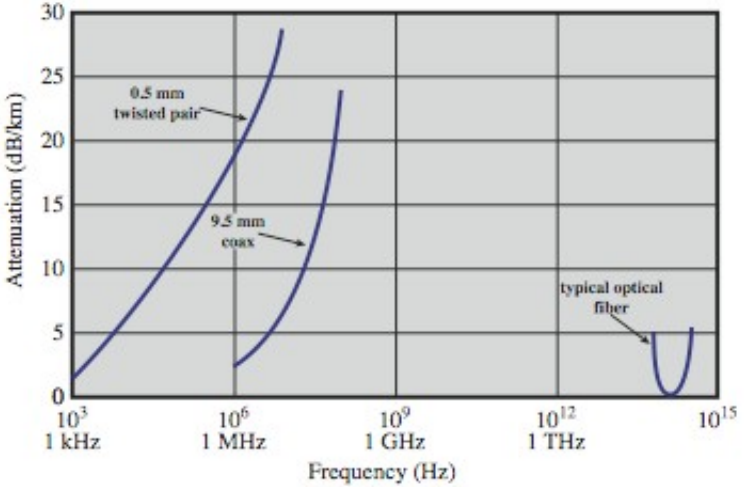
(a) Twisted pair (based on [REEV95])



(c) Optical fiber (based on [FREE02])



(b) Coaxial cable (based on [BELL90])



(d) Composite graph

Comparison of Physical Media

Table 8-1 Comparison of physical media

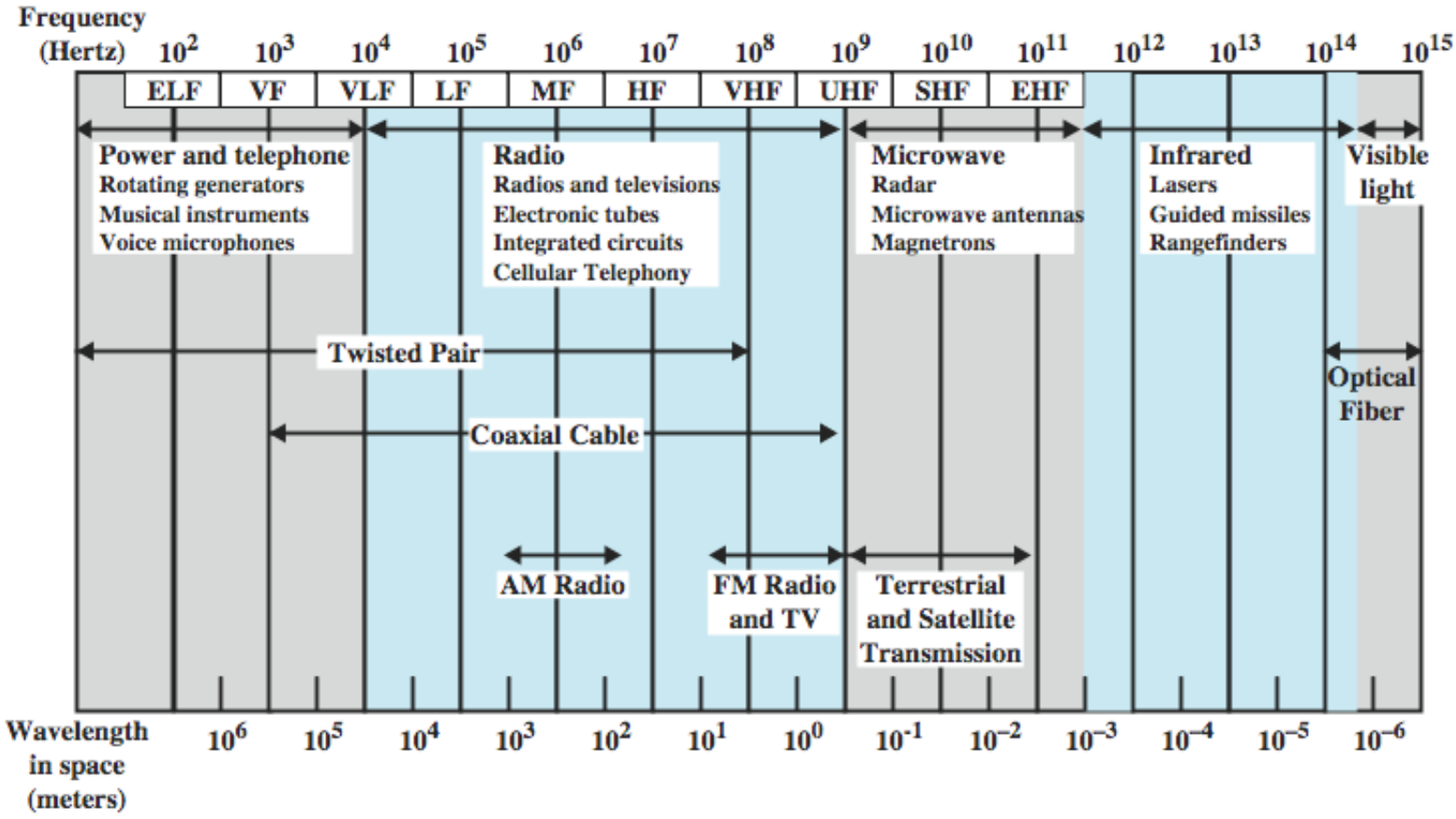
Media	Throughput Potential	Cost of Installation and Maintenance	Security	Scalability	Noise Immunity
Coaxial cable	Up to 10 Mbps	More expensive than twisted-pair cable, but less expensive than fiber	Fair security	In most cases, can extend longer than twisted-pair, but not as long as fiber optic cable before requiring repeaters (depending on transmission method used)	More noise-resistant than twisted-pair, but less noise-resistant than fiber
Shielded twisted-pair (STP)	Up to 1 Gbps, though typically used for up to 100 Mbps	Less expensive than coaxial cable or fiber, but more expensive than UTP	Fair security (not as good as coaxial cable, but better than twisted-pair)	Can extend farther than unshielded twisted-pair networks, but not as far as fiber optic networks	More noise-resistant than UTP, but less noise-resistant than coaxial cable or fiber

Comparison of Physical Media

Table 8-1 Comparison of physical media (Continued)

Media	Throughput Potential	Cost of Installation and Maintenance	Security	Scalability	Noise Immunity
Unshielded twisted-pair (UTP)	Depending on the Category rating, from 128 Kbps to 1 Gbps, though typically used for up to 100 Mbps	The least expensive network medium	The poorest security of all wireline media	Can extend the shortest distance of all media before requiring a repeater; however, due to network design, adding nodes is usually simple	The least noise-resistant medium
Single-mode fiber optic cable	The highest throughput potential of all media; can handle fastest network speed available, 1 Gbps, and more	The highest cost of all network media	Excellent security	Can extend the longest of all media before requiring repeaters; can accommodate more nodes than coaxial or twisted-pair cable	Unaffected by noise
Multimode fiber optic cable	High throughput potential, but not as high as single-mode fiber; can handle fastest network speed available, 1 Gbps, and more	High cost media, second only to single-mode fiber	Excellent security	Can extend longer than twisted-pair or coaxial cable, but not as long as single-mode fiber before requiring repeaters; can accommodate more nodes than coaxial or twisted-pair cable	Unaffected by noise

Electromagnetic Spectrum



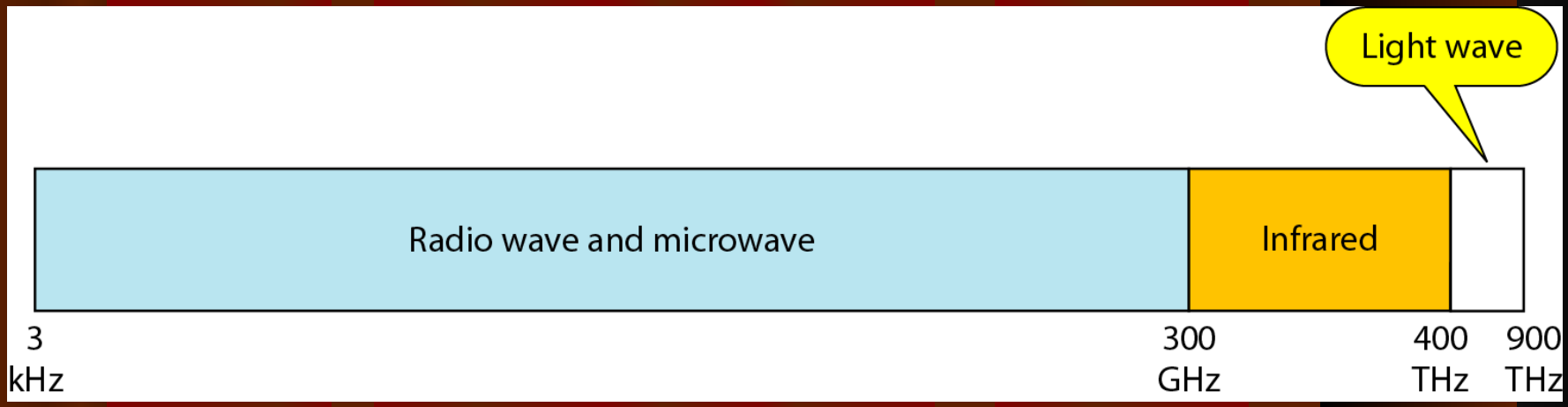
ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

Wireless Transmission Frequencies

- 2GHz to 40GHz
  - microwave
  - highly directional
  - point to point
  - satellite
- 30MHz to 1GHz
  - omnidirectional
  - broadcast radio
- 3×10^{11} to 2×10^{14}
  - infrared
  - local

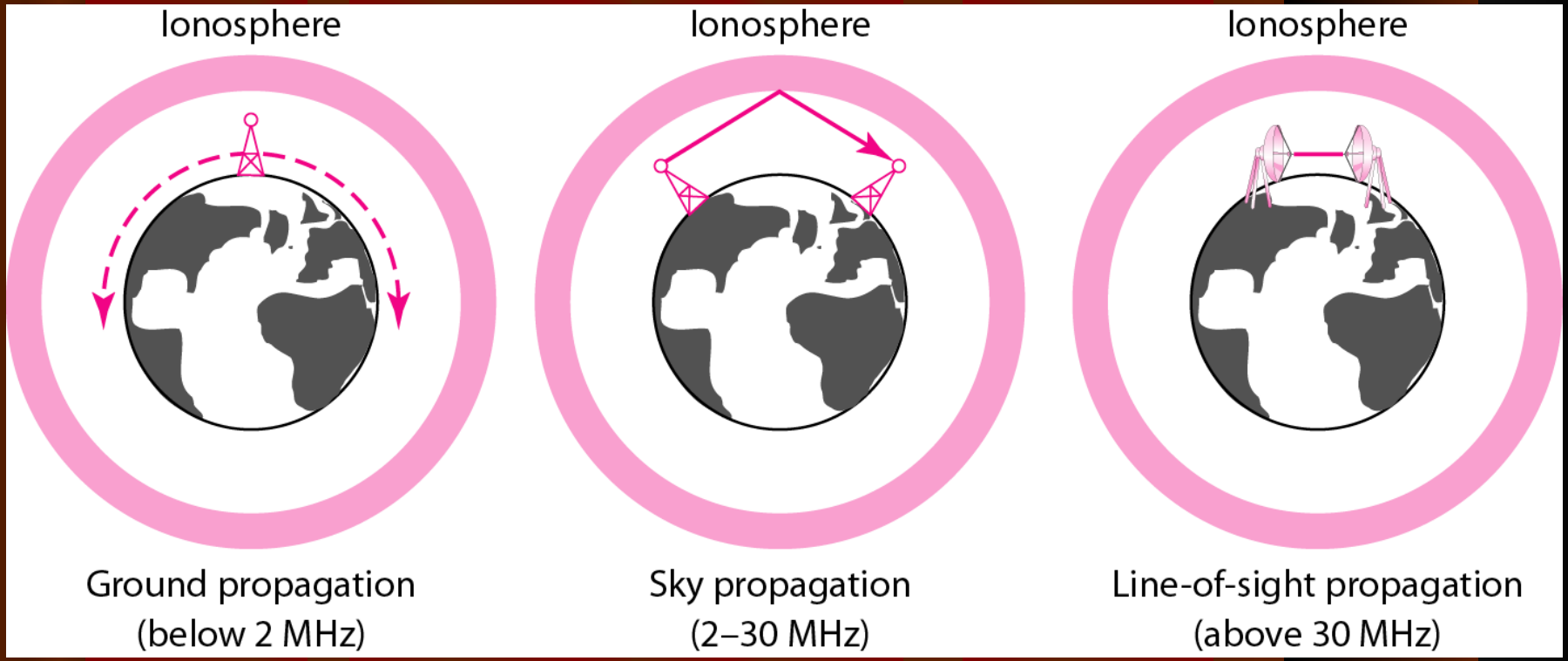
Unguided Media

Electromagnetic spectrum for wireless communication



Unguided Media

Propagation Methods

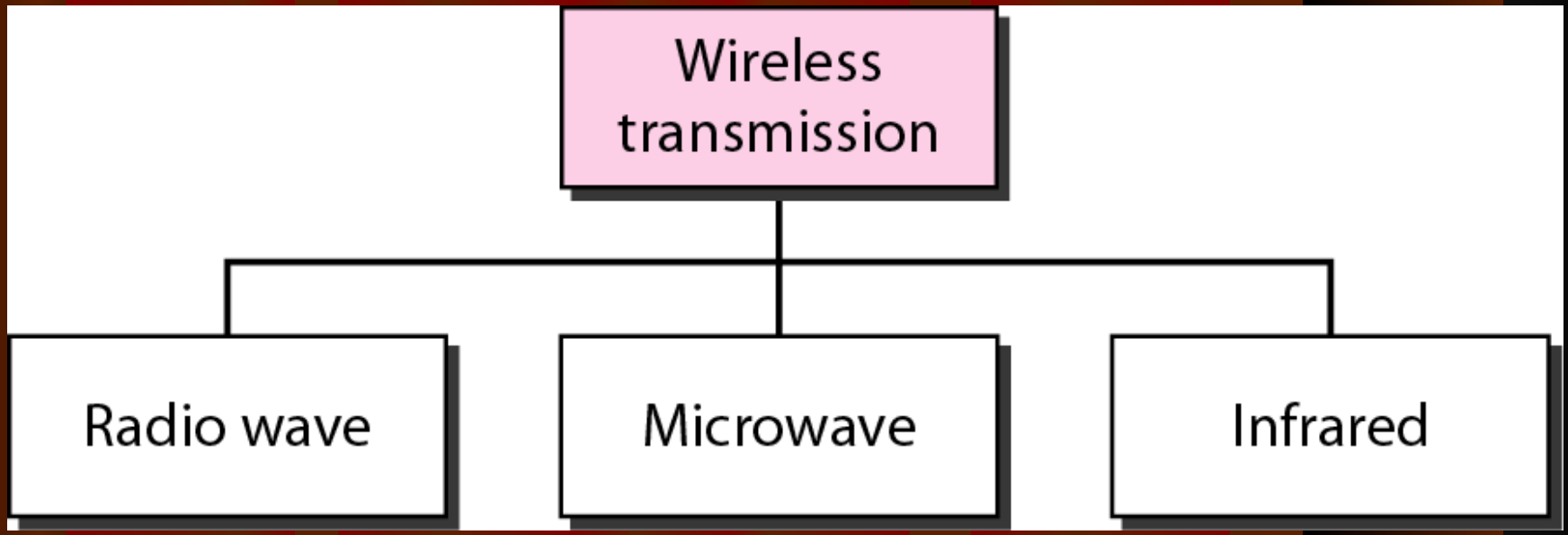


Bands

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

Unguided Media

Wireless transmission waves

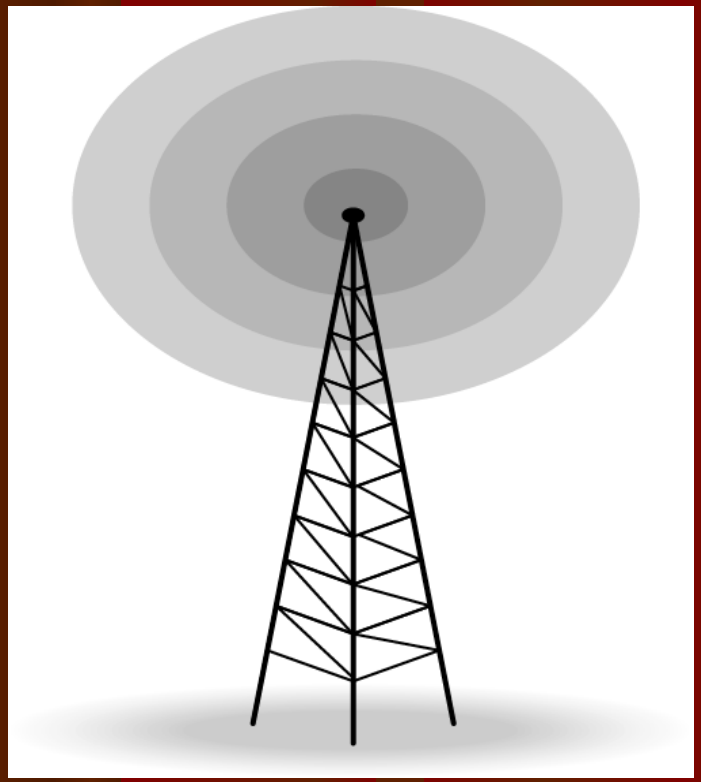


Broadcast Radio

- radio is 3kHz to 300GHz
- use broadcast radio, 30MHz - 1GHz, for:
  - FM radio
  - UHF and VHF television
- is omnidirectional
- still need line of sight
- suffers from multipath interference
  - reflections from land, water, other objects

Unguided Media – Radio Waves

Omnidirectional Antenna



- Frequencies between 3 KHz and 1 GHz.
- are used for multicasts communications, such as radio and television, and paging system.

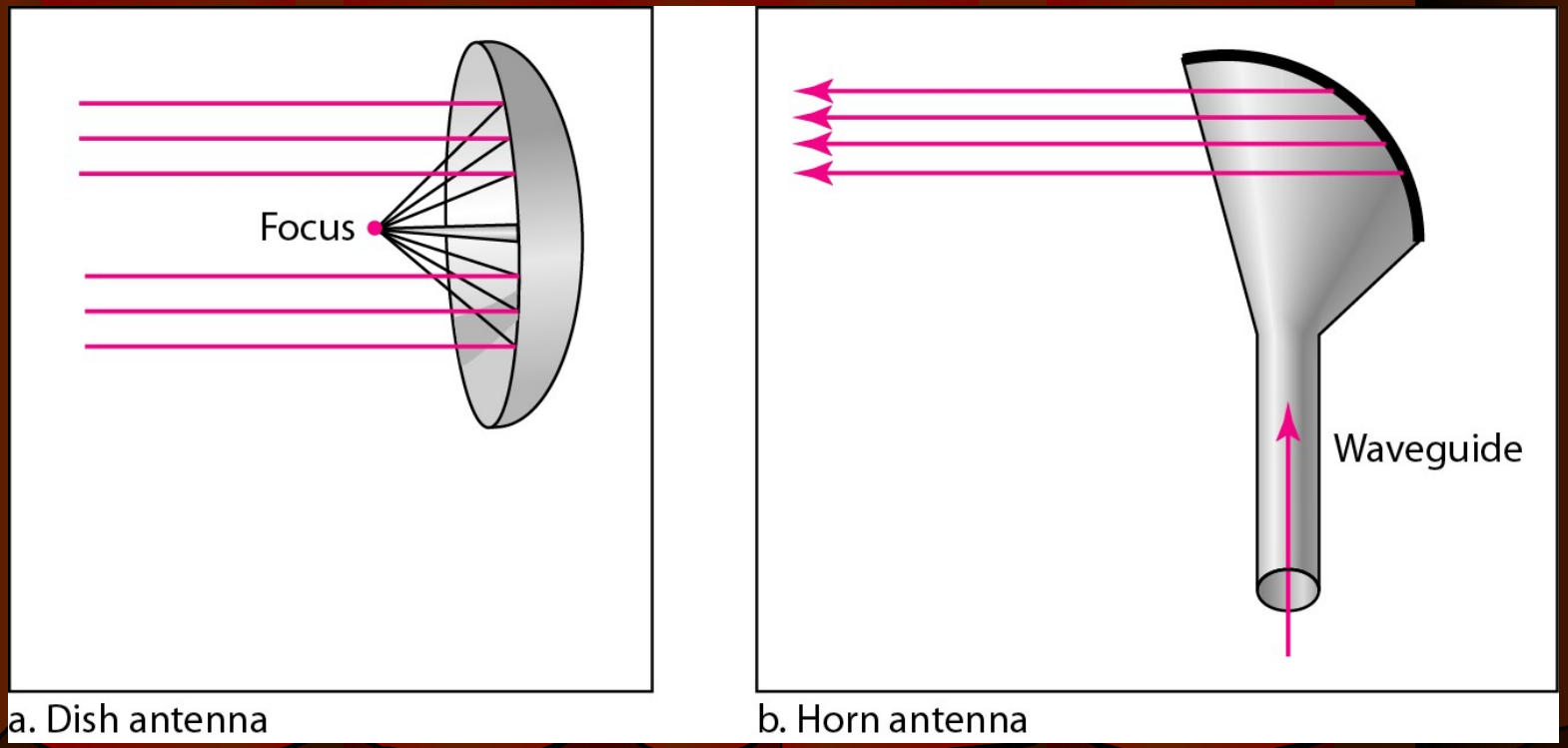
Terrestrial Microwave

- used for long haul telecommunications
- and short point-to-point links
- requires fewer repeaters but line of sight
- use a parabolic dish to focus a narrow beam onto a receiver antenna
- 1-40GHz frequencies
- higher frequencies give higher data rates
- main source of loss is attenuation
  - distance, rainfall
- also interference

Unguided Media – Microwaves

- Frequencies between 1 and 300 GHz.
- Used for unicast communication such as cellular phones, satellite networks and wireless LANs.

Unidirectional Antenna



Satellite Microwave

- satellite is relay station
- receives on one frequency, amplifies or repeats signal and transmits on another frequency
  - eg. uplink 5.925-6.425 GHz & downlink 3.7-4.2 GHz
- typically requires geo-stationary orbit
  - height of 35,784km
  - spaced at least 3-4° apart
- typical uses
  - television
  - long distance telephone
  - private business networks
  - global positioning

Unguided Media – Infrared

- Frequencies between 300 GHz to 400 THz.
- Can not penetrate walls.
- Used for short-range communication in a closed area using line-of-sight propagation.

Infrared

- modulate noncoherent infrared light
- end line of sight (or reflection)
- are blocked by walls
- no licenses required
- typical uses
  - TV remote control
  - IRD port

Antennas

- electrical conductor used to radiate or collect electromagnetic energy
- transmission antenna
  - radio frequency energy from transmitter
  - converted to electromagnetic energy byy antenna
  - radiated into surrounding environment
- reception antenna
  - electromagnetic energy impinging on antenna
  - converted to radio frequency electrical energy
  - fed to receiver
- same antenna is often used for both purposes

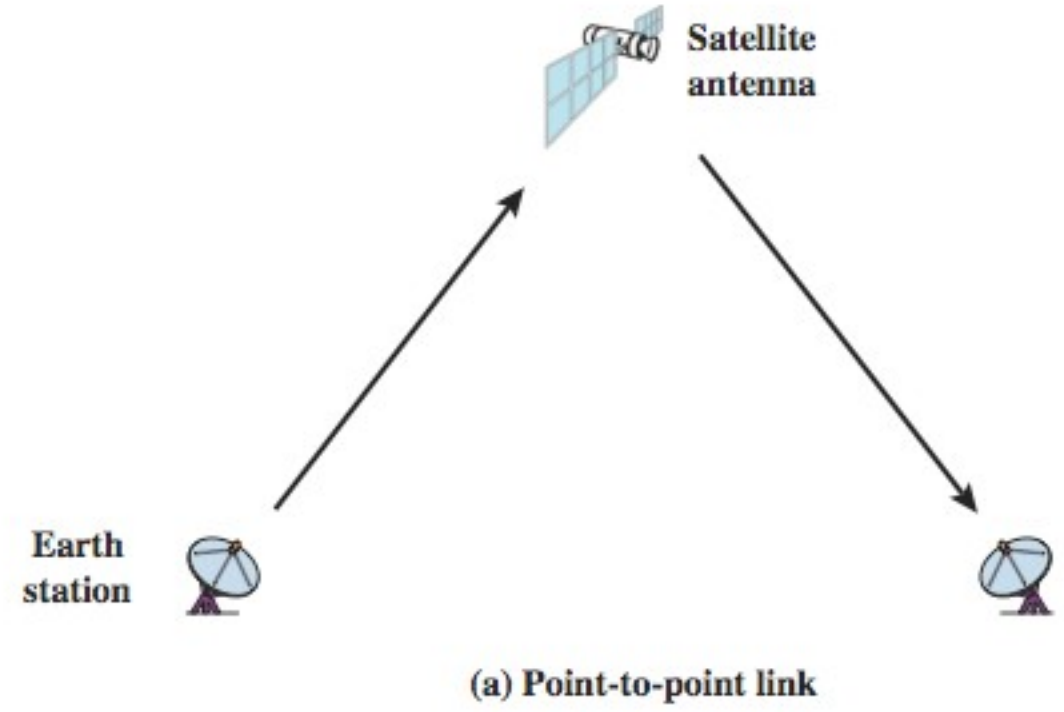
Radiation Pattern

- power radiated in all directions
- not same performance in all directions
  - as seen in a radiation pattern diagram
- an isotropic antenna is a (theoretical) point in space
  - radiates in all directions equally
  - with a spherical radiation pattern

Antenna Gain

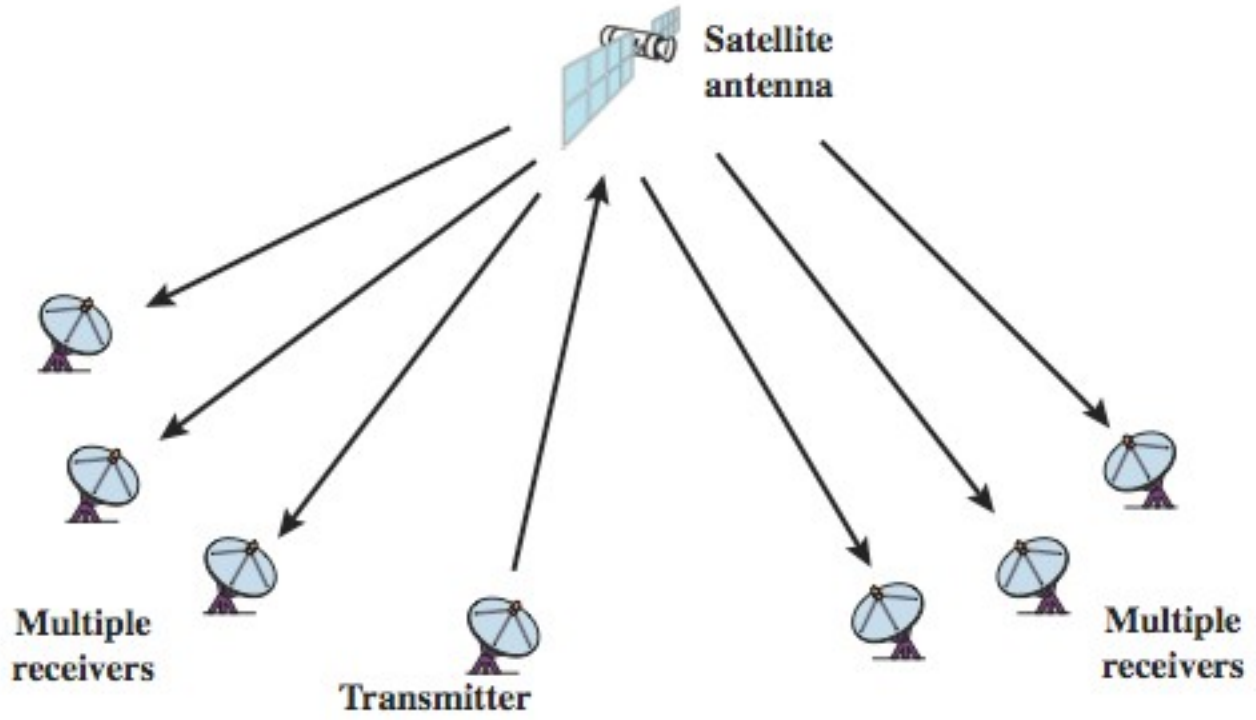
- measure of directionality of antenna
- power output in particular direction verses that produced by an isotropic antenna
- measured in decibels (dB)
- results in loss in power in another direction
- effective area relates to size and shape
  - related to gain

Satellite Point to Point Link



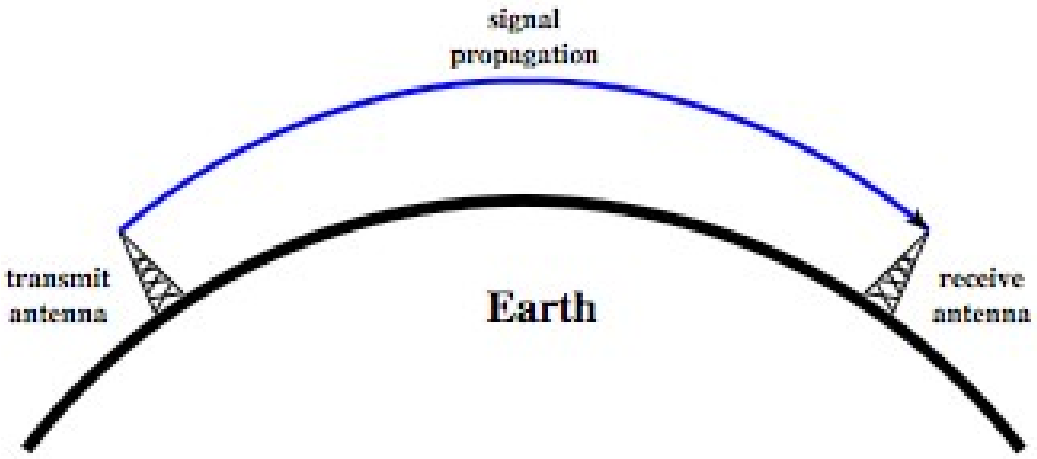
(a) Point-to-point link

Satellite Broadcast Link



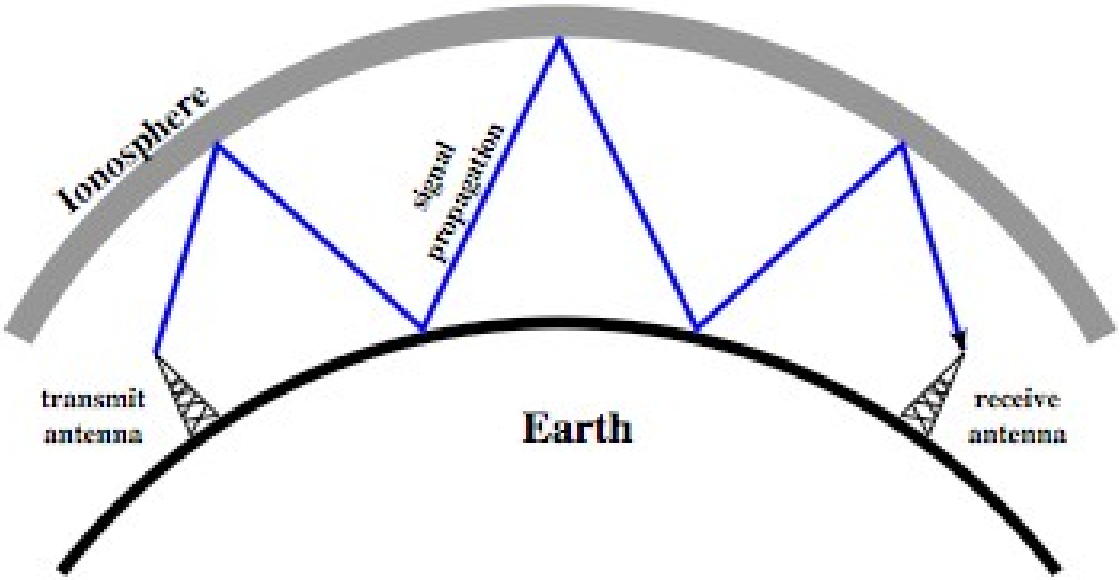
(b) Broadcast link

Wireless Propagation Ground Wave



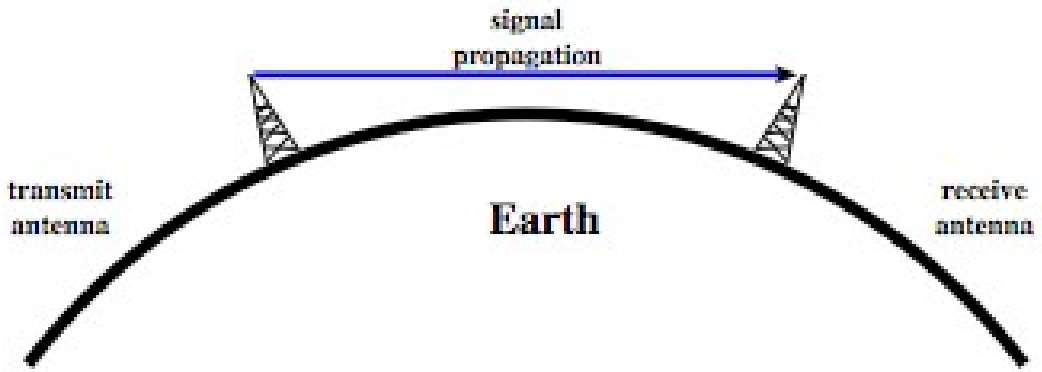
(a) Ground-wave propagation (below 2 MHz)

Wireless Propagation
Sky Wave



(b) Sky-wave propagation (2 to 30 MHz)

Wireless Propagation Line of Sight



(c) Line-of-sight (LOS) propagation (above 30 MHz)

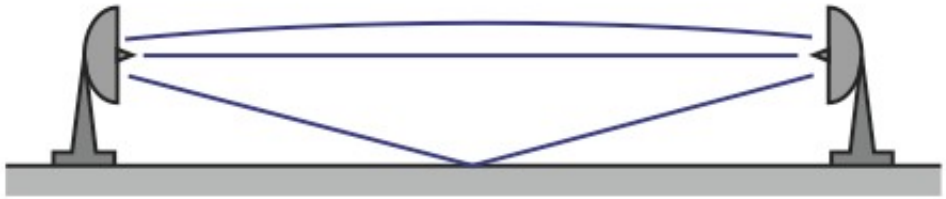
Refraction

- velocity of electromagnetic wave is a function of density of material
  - ~3 x 10^8 m/s in vacuum, less in anything else
- speed changes as move between media
- Index of refraction (refractive index) is
  - `sin(incidence)/sin(refraction)`
  - varies with wavelength
- have gradual bending if medium density varies
  - density of atmosphere decreases with height
  - results in bending towards earth of radio waves
  - hence optical and radio horizons differ

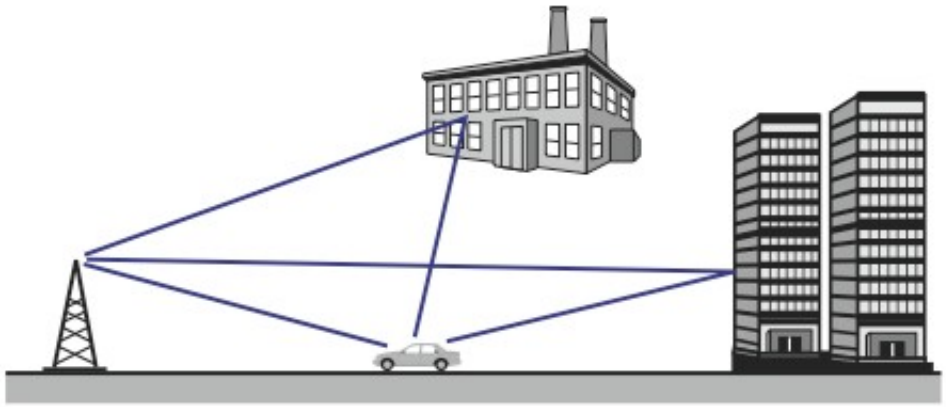
Line of Sight Transmission

- Free space loss
  - loss of signal with distance
- Atmospheric Absorption
  - from water vapour and oxygen absorption
- Multipath
  - multiple interfering signals from reflections
- Refraction
  - bending signal away from receiver

Multipath Interference



(a) Microwave line of sight



(b) Mobile radio

Comparison of Media

Medium	Cost	Speed	Atten	Interfere	Security
UTP	Low	1-100M	High	High	Low
STP	Medium	1-150M	High	Medium	Low
Coax	Medium	1M–1G	Medium	Medium	Low
Fibre	High	10M–2G	Low	Low	High
Radio	Medium	1-10M	Varies	High	Low
Microwv	High	1M–10G	Varies	High	Medium
Satellite	High	1 M–10G	Varies	High	Medium
Cellular	High	9.6–19.2K	Low	Medium	Low

THE - END