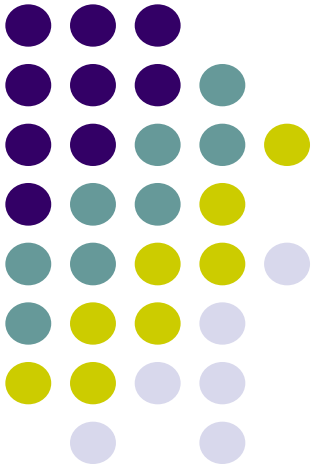
CME 3004 Computer Networks

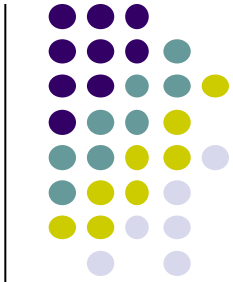
TRANSMISSION MEDIA



Basic Idea

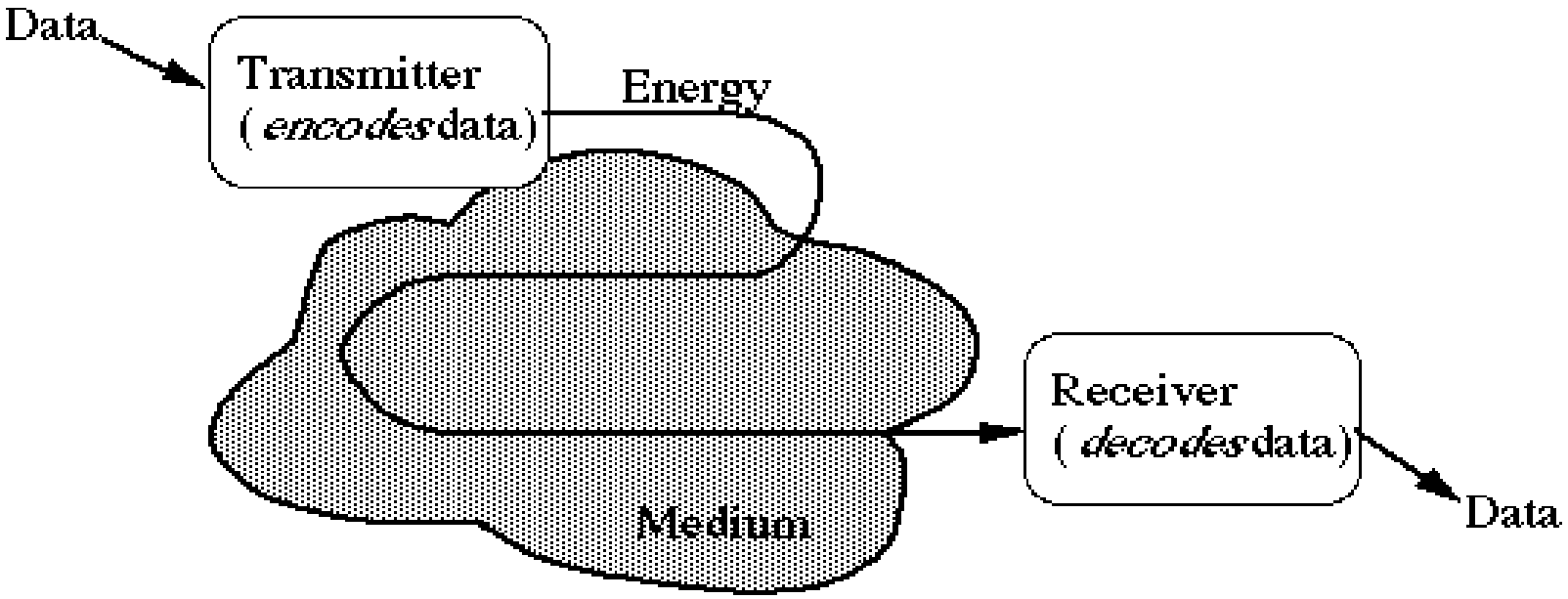
- Encode data as energy and transmit energy
- Decode energy at destination back into data
- Energy can be electrical, light, radio, sound, ...
- Each form of energy has different properties and requirements for transmission

Transmission media



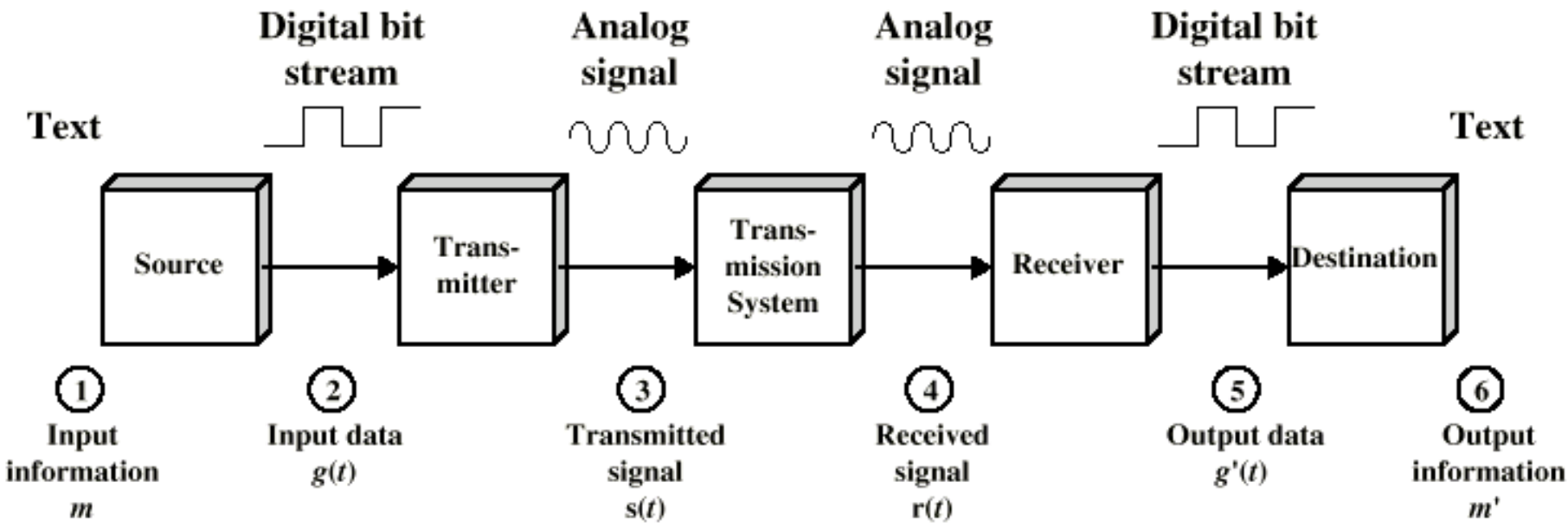
- Transmitted energy is carried through some sort of medium
- Transmitter encodes data as energy and transmits energy through medium
- Requires special hardware for data encoding
- Requires hardware connection to transmission medium

Transmission media (cont'd)



- Media can be copper, glass, air, ...

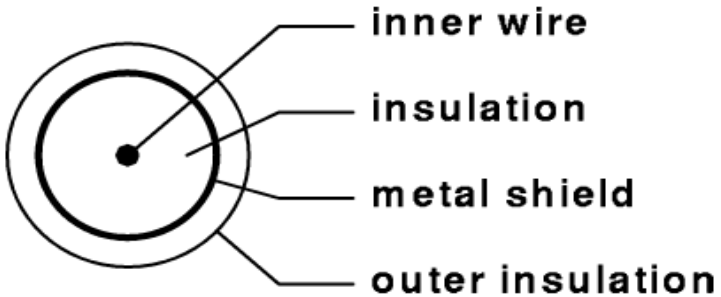
Data Communications



Simplified Data Communications Model

Copper wires

- Twisted pair

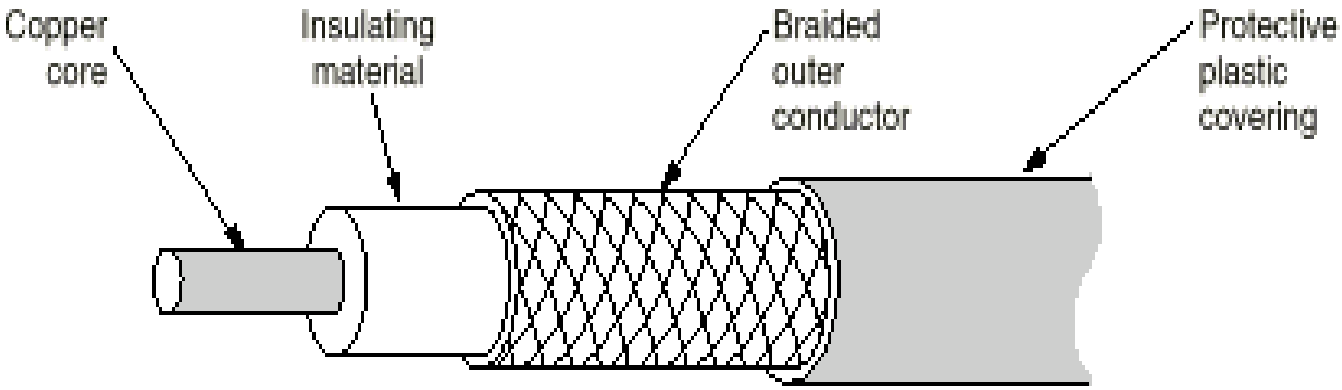


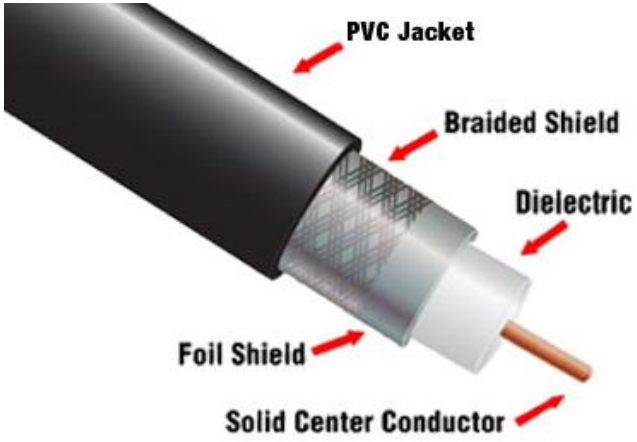
- Coaxial cable

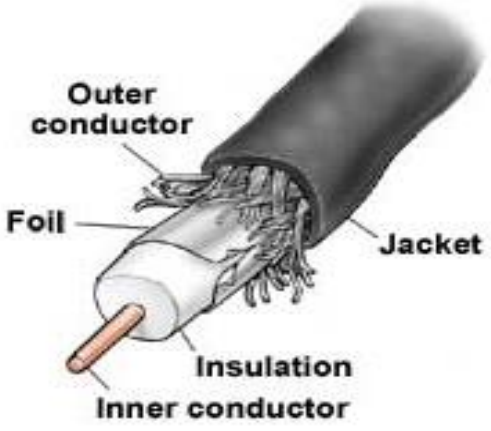
Co-axial Cable

- Coaxial cable includes shield for improved performance. The shield minimizes electrical and radio frequency interference.
- Coaxial cabling is the primary type of cabling used by the cable television industry and is also widely used for computer networks, such as Ethernet.
- Although more expensive than standard telephone wire, it is much less susceptible to interference and can carry much more data.

Co-axial Cable



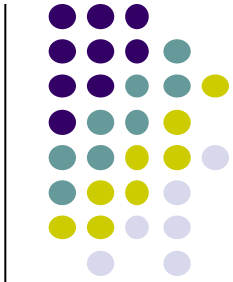




Coaxial Cable Applications

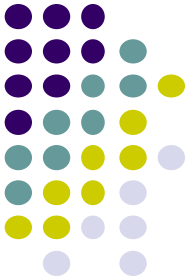
- Like twisted pair, coaxial cable consists of two conductors.
- Most versatile medium
- Television distribution
  - Ariel to TV
  - Cable TV
- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
  - Being replaced by fiber optic
- Short distance computer systems links
- Local area networks

Coaxial Cable - Transmission Characteristics



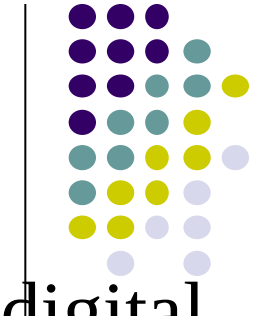
- Analog
  - Amplifiers every few km
  - Closer if higher frequency
  - Up to 500MHz
- Digital
  - Repeater every 1km
  - Closer for higher data rates

Twisted Pair (TP) Cable



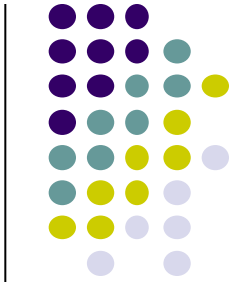
- A **twisted-pair cable** consists of two independently insulated wires twisted around one another.
- The use of two wires twisted together helps to reduce crosstalk and electromagnetic induction.
- While twisted-pair cable is used by older telephone networks and is the least expensive type of LAN cable, most networks contain some twisted-pair cabling at some point along the network.

Twisted Pair - Applications



- The most common medium for analog and digital signals is twisted pair.
- Telephone network
  - Between house and local exchange (subscriber loop, also called local loop)
- Within an office building
  - To the in-house private branch exchange (PBX)
- For connections to a digital data switch or digital private branch exchange within a building.
  - A data rate of 64 kbps is common.
- For local area networks (LAN)
  - 10Mbps or 100Mbps; now support up to 1 Gbps.

Twisted Pair – Adv. and Disadv.

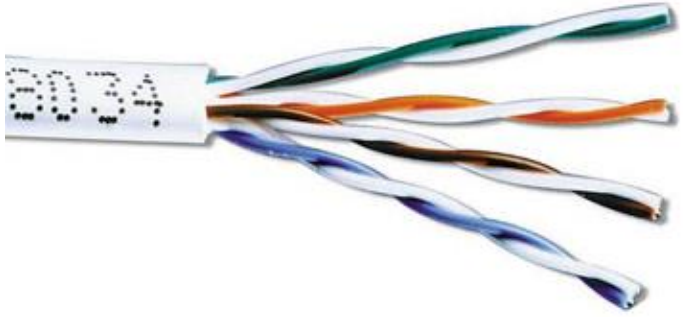


- Much less expensive than the other commonly used guided transmission media.
- Easy to work with (install and debug)
- Low data rate; comparing with other guided transmission medium.
- Short range

Twisted Pair (TP) Cable

- Two Types:
  - Shielded Twisted Pair (STP) has a fine wire mesh surrounding the wires to protect the transmission.

  - Unshielded Twisted Pair (UTP) UTP cabling does not offer as high bandwidth or as good protection from interference as coaxial or fiber optic cables, but it is less expensive and easier to work with.



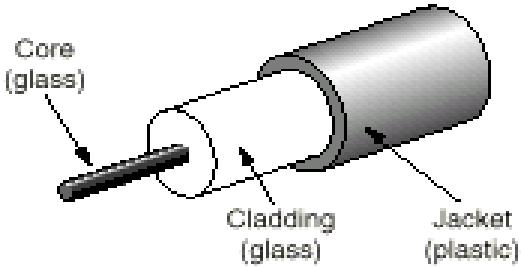
Glass fibers

- Thin glass fiber carries light with encoded data
- Plastic jacket allows fiber to bend without breaking
- Fiber is very clear and designed to reflect light internally for efficient transmission
- Fiber optics has several advantages over traditional copper communications lines:
  - Fiber optic cables have a much greater bandwidth than metal cables. This means that they can carry more data.
  - Fiber optic cables are less susceptible than metal cables to interference.
  - Fiber optic cables are much thinner and lighter than metal wires.
  - Data can be transmitted digitally (the natural form for computer data) rather than analogically.

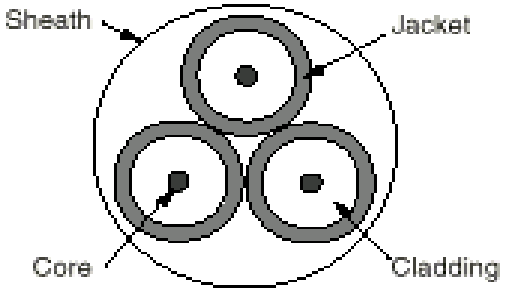
Glass fibers (cont'd)

- Light emitting diode (LED) or laser injects light into fiber
- Light sensitive receiver at other end translates light back into data

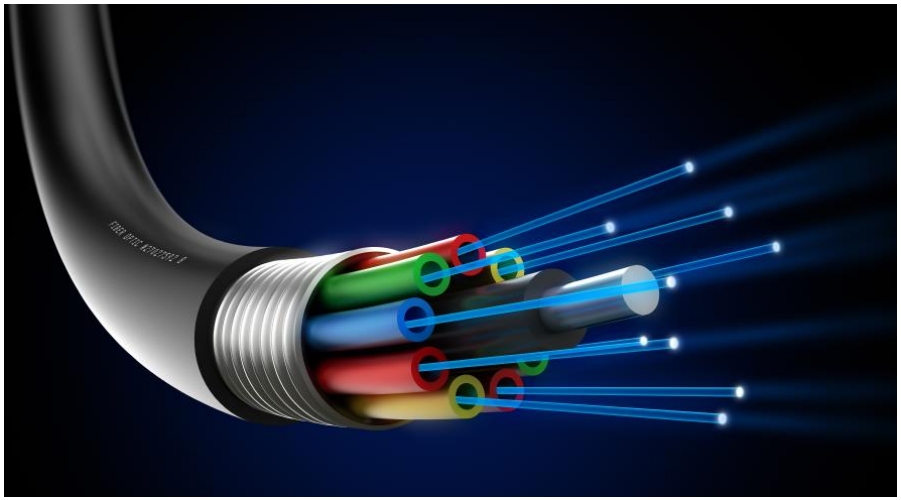
Fiber Cable



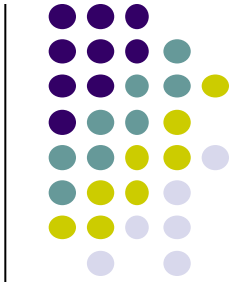
(a)



(b)

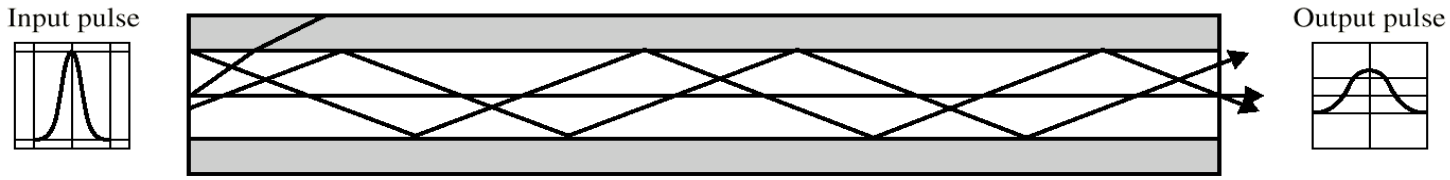


Optical Fiber - Applications

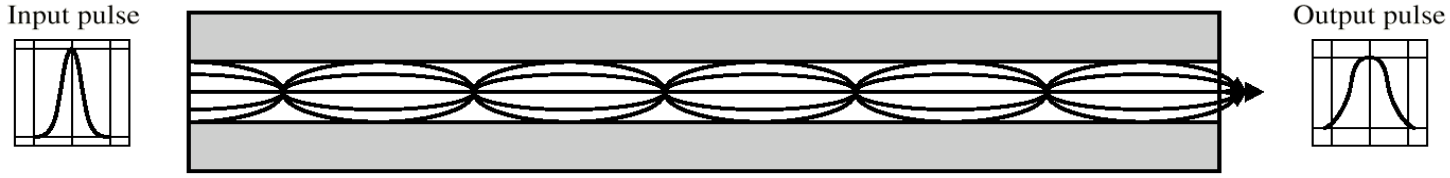


- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs

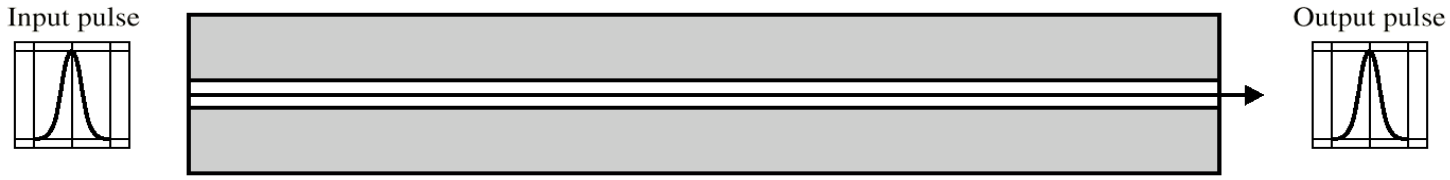
Optical Fiber Transmission Modes



(a) Step-index multimode

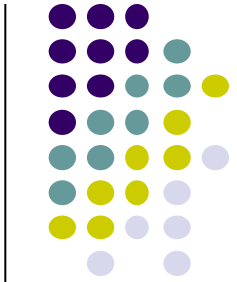


(b) Graded-index multimode



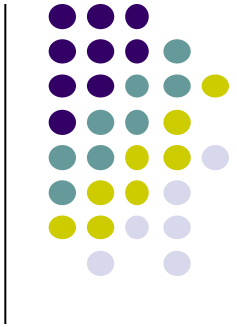
(c) Single mode

Fiber Transmission Modes



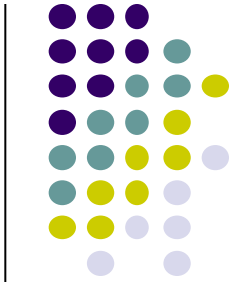
- Step-Index multimode
  - Variety of angles will reflect.
  - Different path lengths and times to traverse the fiber.
- Single-mode:
  - Single transmission path.
  - Used for long distance applications.
- Graded-index multimode:
  - Varying index of reflection of the core.
  - Used for short distance applications, LANs

Transmission Characteristics of Guided Media



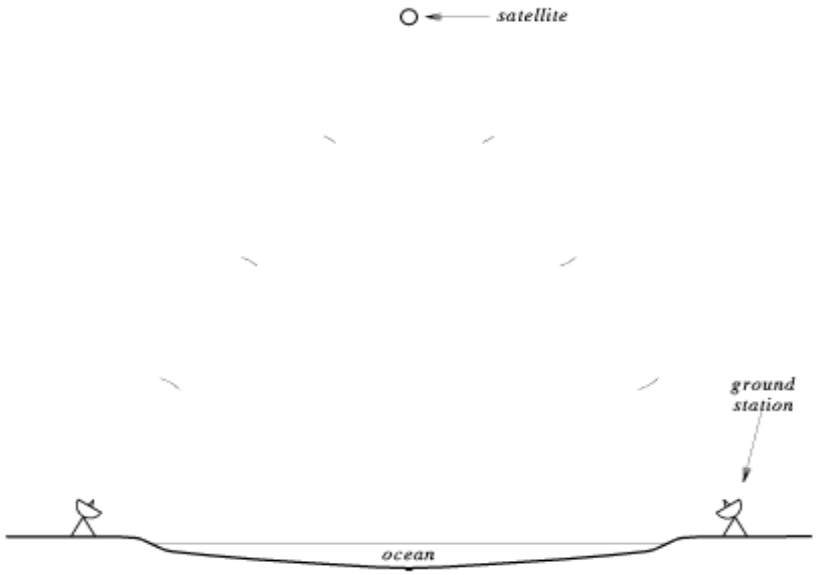
	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 μs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 μs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 μs/km	1 to 9 km
Optical fiber	186 to 370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

Radio



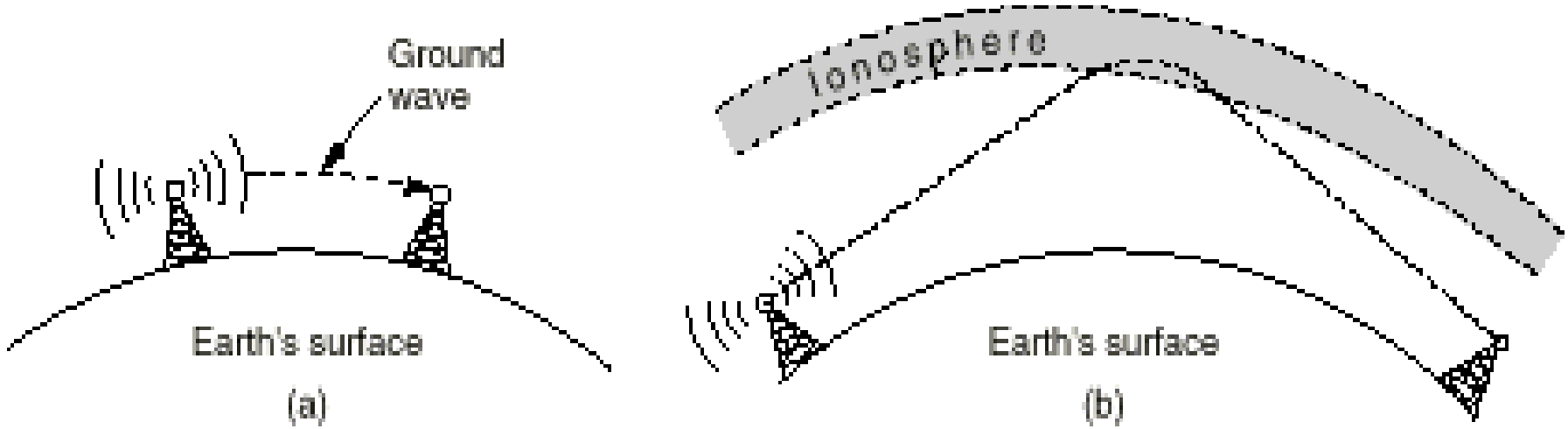
- Data transmitted using radio waves
- Energy travels through the air rather than copper or glass
- Conceptually similar to radio, TV, cellular phones
- Can travel through walls and through an entire building

Radio (cont'd)



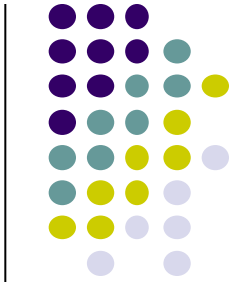
- Can be long distance or short distance
  - Long distance with satellite relay
  - Short distance - wireless computer network

Radio (cont'd)



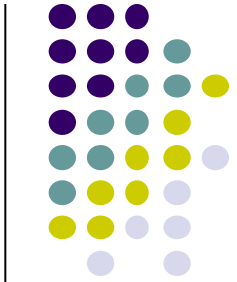
(a) In the VLF, LF and MF bands, radio waves follow the curvature of the earth, (b) In the HF, they bounce off the ionosphere.

Microwave



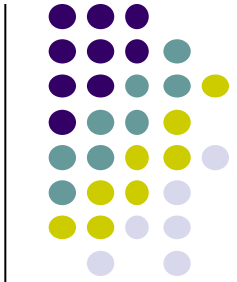
- High frequency radio waves
- Unidirectional, for point-to-point communication
- Antennas mounted on towers relay transmitted data

Infrared



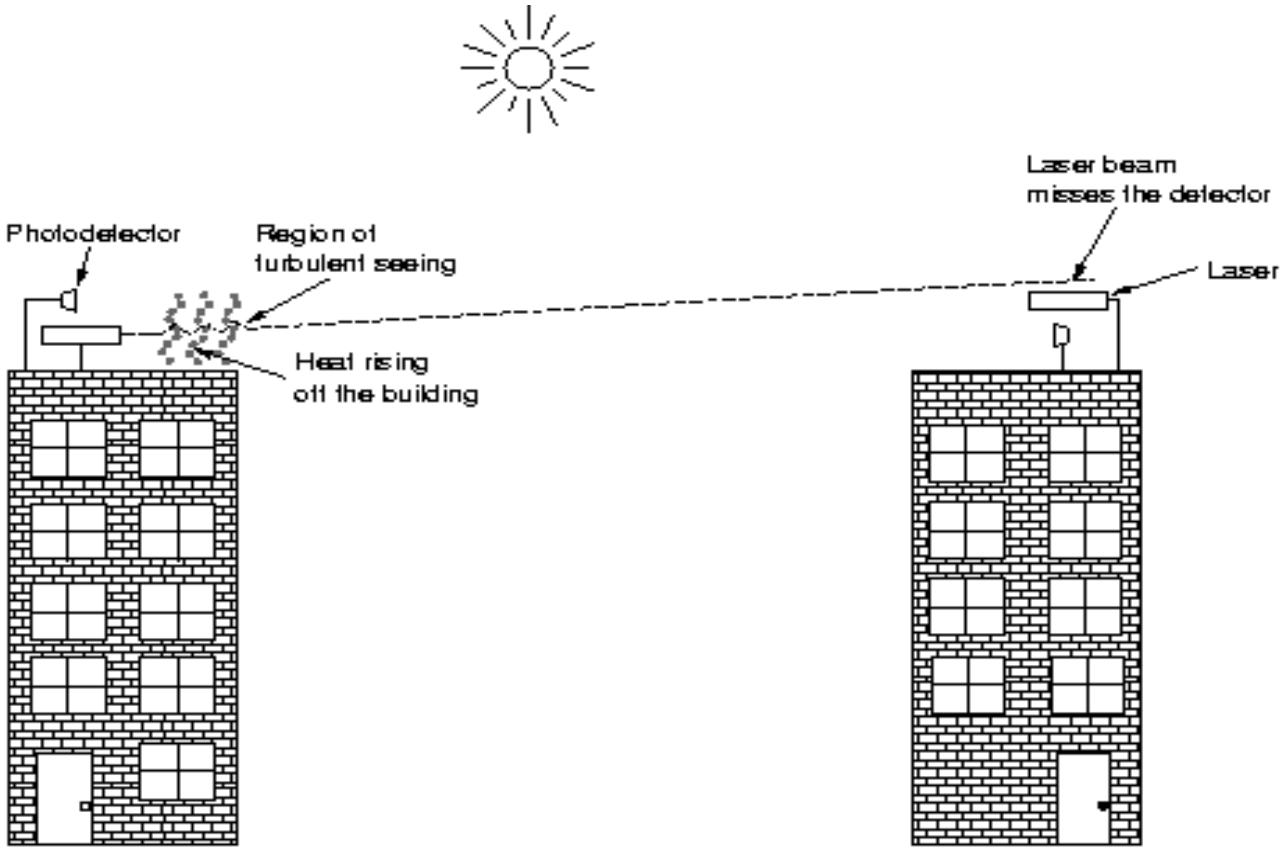
- Infrared light transmits data through the air
- Similar to technology used in TV remote control
- Can propagate throughout a room (bouncing off surfaces), but will not penetrate walls
- Becoming common in personal digital assistants (PDAs) and portable computers

Laser

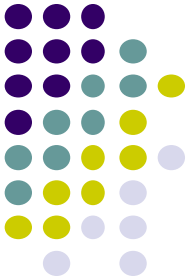


- Unidirectional, like microwave
- Higher speed than microwave
- Uses laser transmitter and photo-sensitive receiver at each end
- Point-to-point, typically between buildings
- Can be adversely affected by weather

Laser (cont'd)

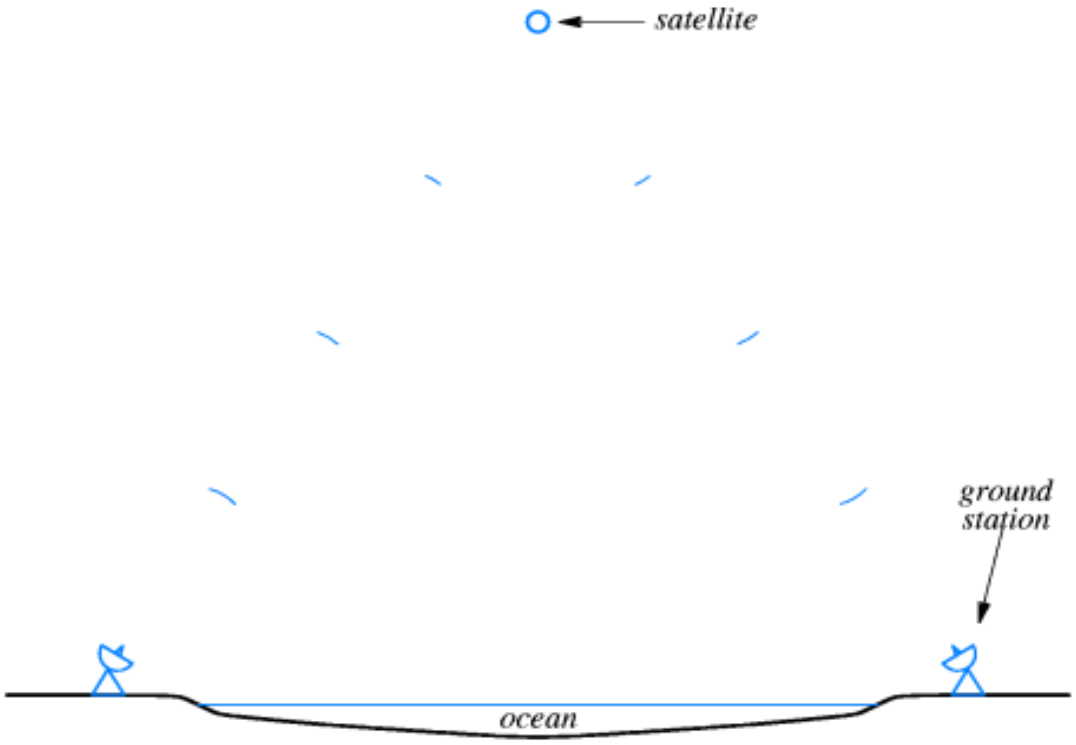

Photodetector
Region of
turbulent seeing
Heat rising
off the building
Laser beam
misses the detector
Laser

Satellites

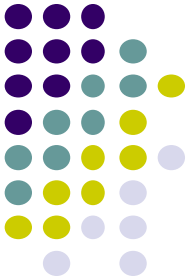


- Although radio transmissions do not bend around the surface of the earth, RF technology can be combined with satellites to provide communication across longer distances, such as ocean.
- The satellite contains a *transponder* that consists of a radio receiver and transmitter. Transponder accepts incoming radio transmission, amplifies it and transmits the amplified signal back toward the ground at a slightly different angle than it arrived.
- Because placing a communication satellite is expensive, single satellite usually contains multiple transponders that operate independently (typically six to twelve).

Satellites (cont'd)

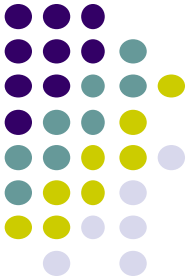


Geosynchronous Satellites



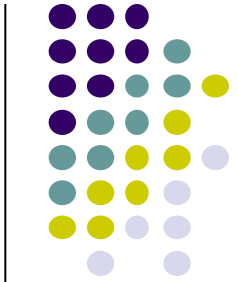
- Communication satellites can be grouped into categories according to the their height at which they orbit.
- Geosychronous Satellites are placed in an orbit that is exactly synchronized with the rotation of the earth. Such an orbit is classified as a Geostationary Earth Orbit (GEO).
- The distance required for geosynchronous orbit is 35,785 kilometers (22,236 miles) from the earth (High Earth Orbit).

Low Earth Orbit (LEO) Satellites



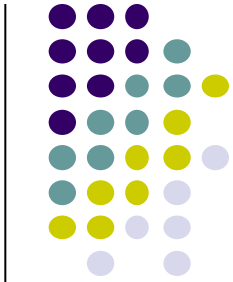
- LEO Satellites orbit a few hundred miles above the earth (200-400 miles).
- Their period of rotation is faster than the rotation of the earth, they do not stay above a single point on the earth's surface.

Choosing a medium



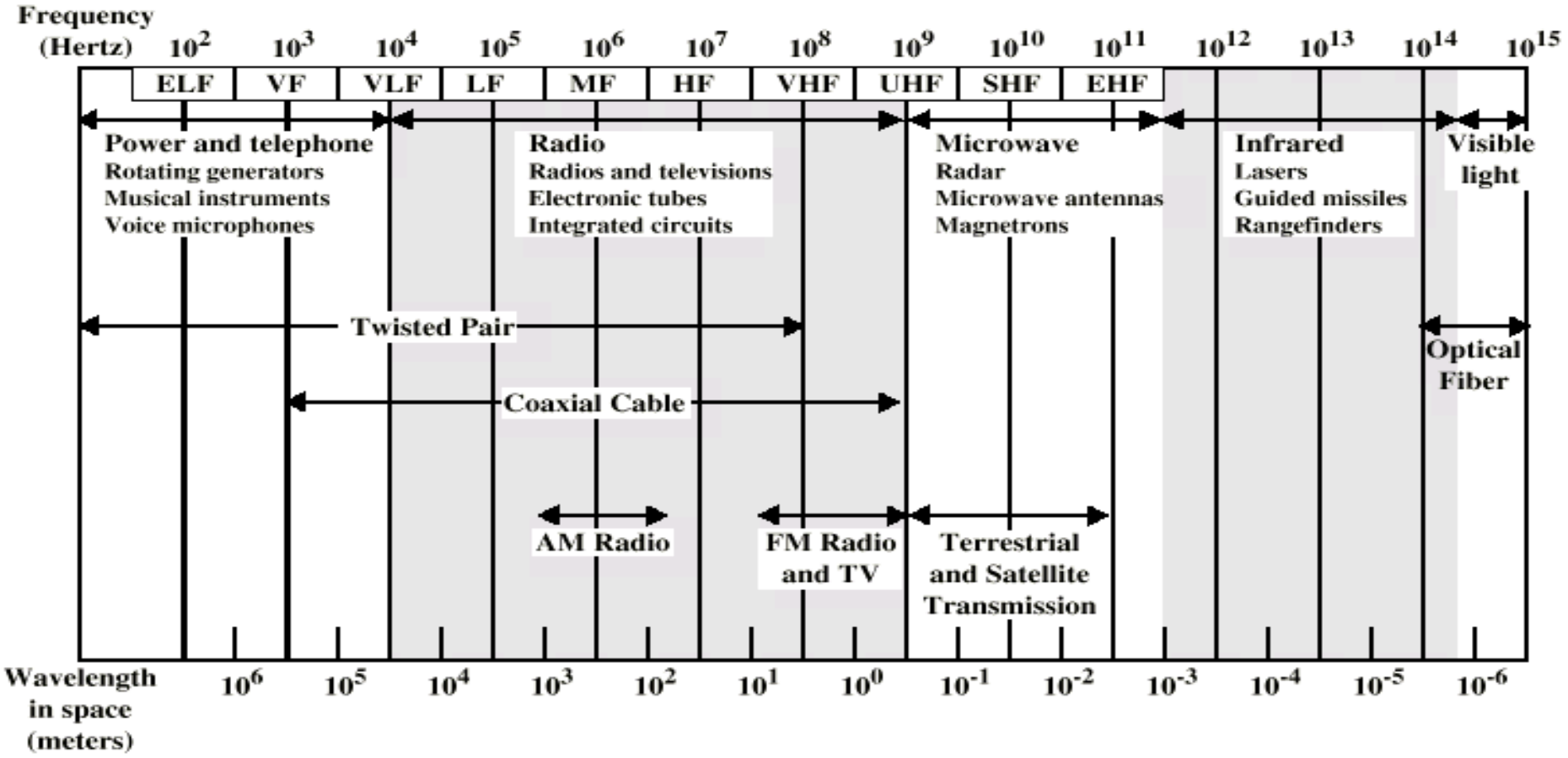
- Copper wire is mature technology, rugged and inexpensive; maximum transmission speed is limited
- Glass fiber:
  - Higher speed
  - More resistant to electro-magnetic interference
  - Spans longer distances
  - Requires only single fiber
  - More expensive; less rugged

Choosing a medium (cont’d)

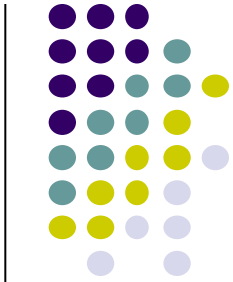


- Radio and microwave don't require physical connection
- Radio and infrared can be used for mobile connections
- Laser also does not need physical connection and supports higher speeds

Electromagnetic Spectrum for Telecommunications



Media in use at DEÜ



- Copper/fiber for long-distance connection to Internet and between campuses
- Fiber between buildings
- Copper within buildings