CISC 7332X T6

C05a: Transmission Media

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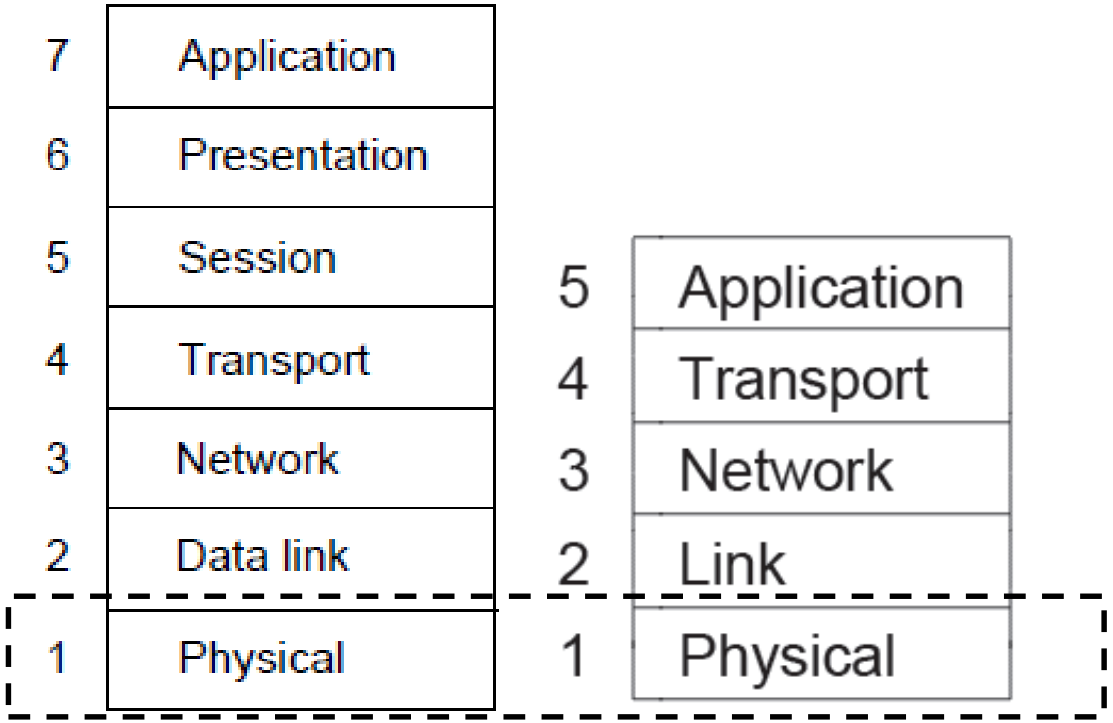
Review

- Discussed
  - Overview and network applications
    - Application requirement: bandwidth and latency
  - Reference models and example networks
  - Assignments
    - In-class: paper submission
    - Individual homework assignment: if not yet, submit it via Git/Github
      - Make a directory/folder matching the assignment number

Outline

- Guided transmission media
  - Magnetic media
  - Twisted pairs
  - Coaxial cable
  - Power lines
  - Fiber optics
- Wireless transmission
  - EM spectrum
  - Radio transmission
  - Microwave transmission
  - Infrared transmission
  - Light transmission
- Link terminology



Transmission Media

- Media have different properties, which result in different performance
  - Bandwidth, latency, jitter, cost …
- Many type of media have been thought of to send digital data
  - https://en.wikipedia.org/wiki/IP_over_Avian_Carriers

```
$ ping -c 9 -i 900 10.0.3.1
PING 10.0.3.1 (10.0.3.1): 56 data bytes
64 bytes from 10.0.3.1: icmp_seq=0 ttl=255 time=6165731.1 ms
```

Magnetic Media and Performance: Example

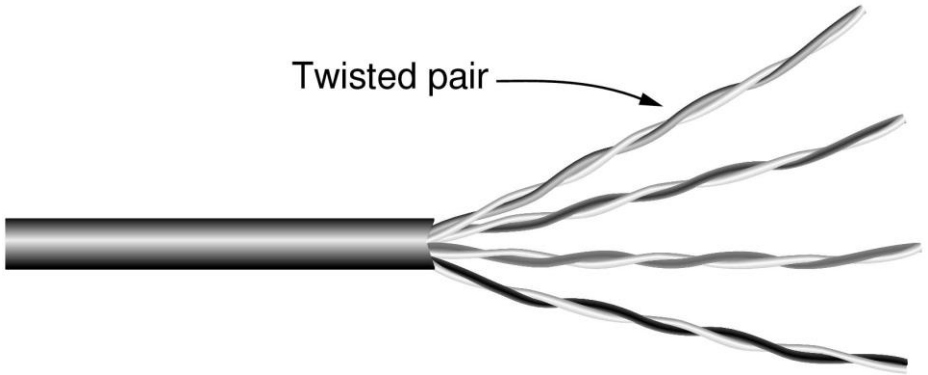
- Medium: truck loads of magnetic tapes
  - 1 box with 1,000 800GB
  - Takes 1 day to deliver
- Performance
  - How much is the delay?
  - How much is the data rate?
  - How is the data loss possibility?
  - How costly is it?

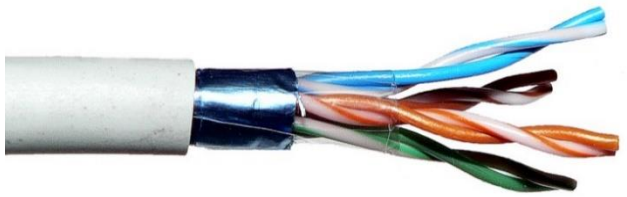
Guided Transmission

- Guided media
  - Wires
    - Twisted pairs
    - Coaxial cable
    - Power lines
  - Fiber cables

Twisted Pairs

- Very common; used in LANs, telephone lines
  - Twists reduce radiated signal (interference)

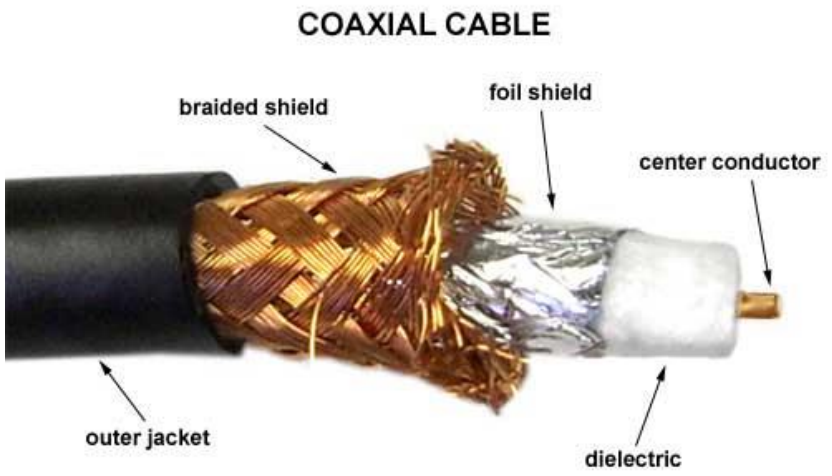




Shielded Twisted Pairs (STP)

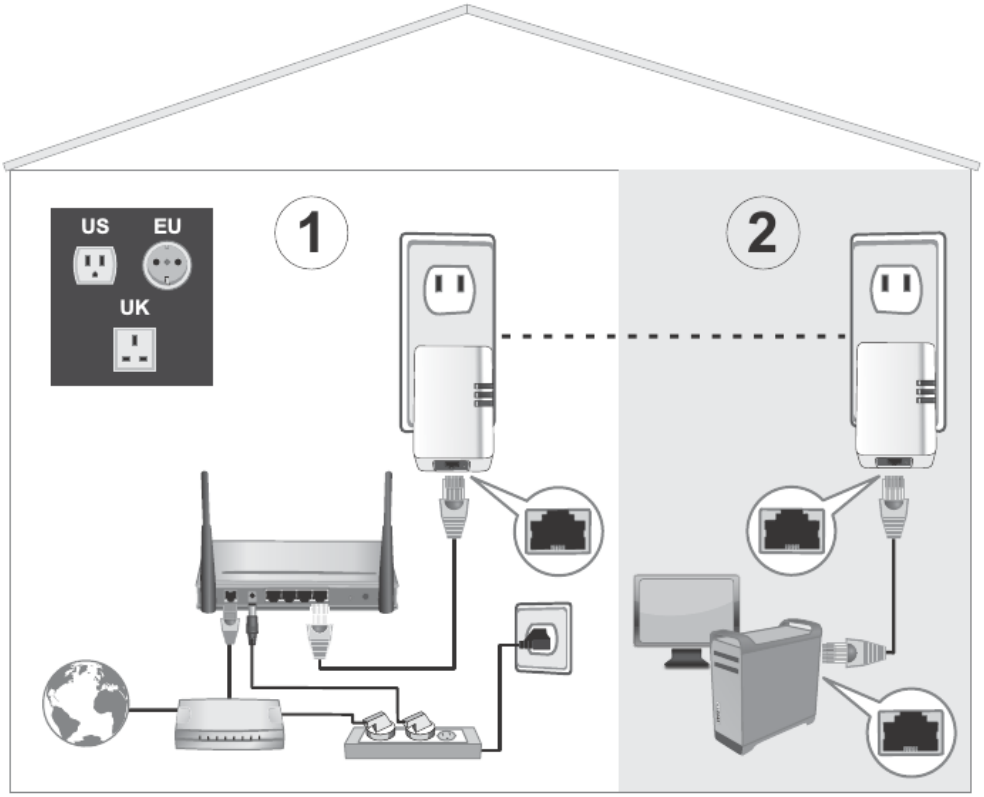
Coaxial Cable

- Also common. Better shielding and more bandwidth for longer distances and higher rates than twisted pair.



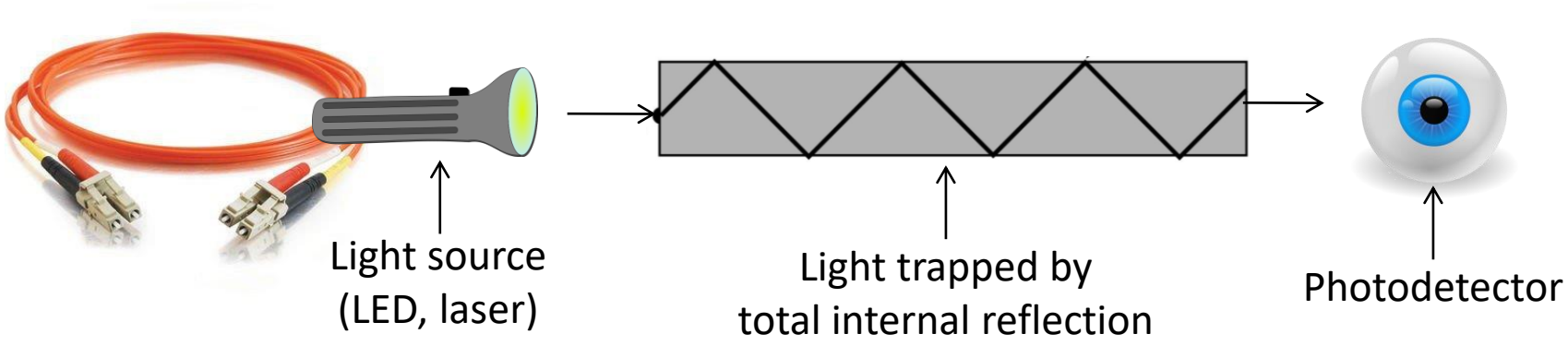
Power Lines

- Household electrical wiring is another example of wir



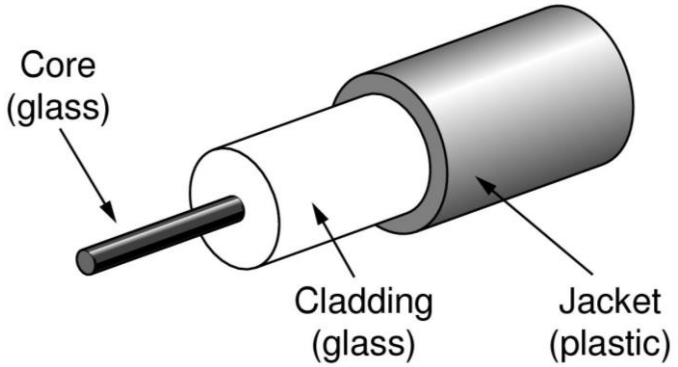
Fiber Cable

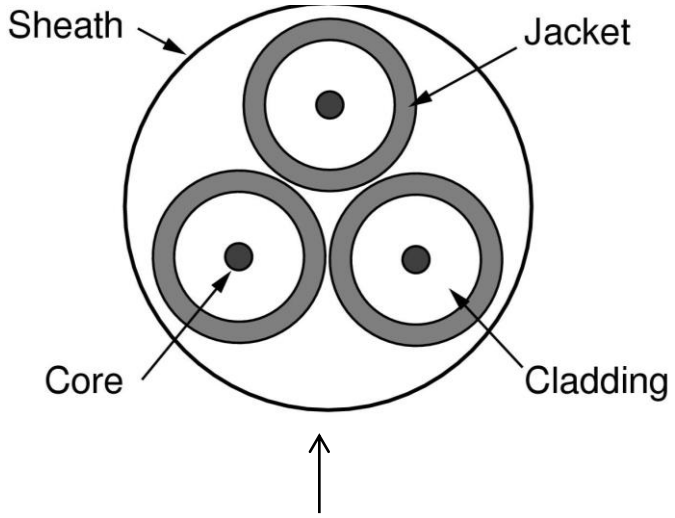
- Common for high rates and long distances
  - Long distance ISP links, Fiber-to-the-Home
  - Light carried in very long, thin strand of glass



Fiber and Fiber Optic Cable

- (a) Side view of a single fiber. (b) end view of a sheath with 3 fibers

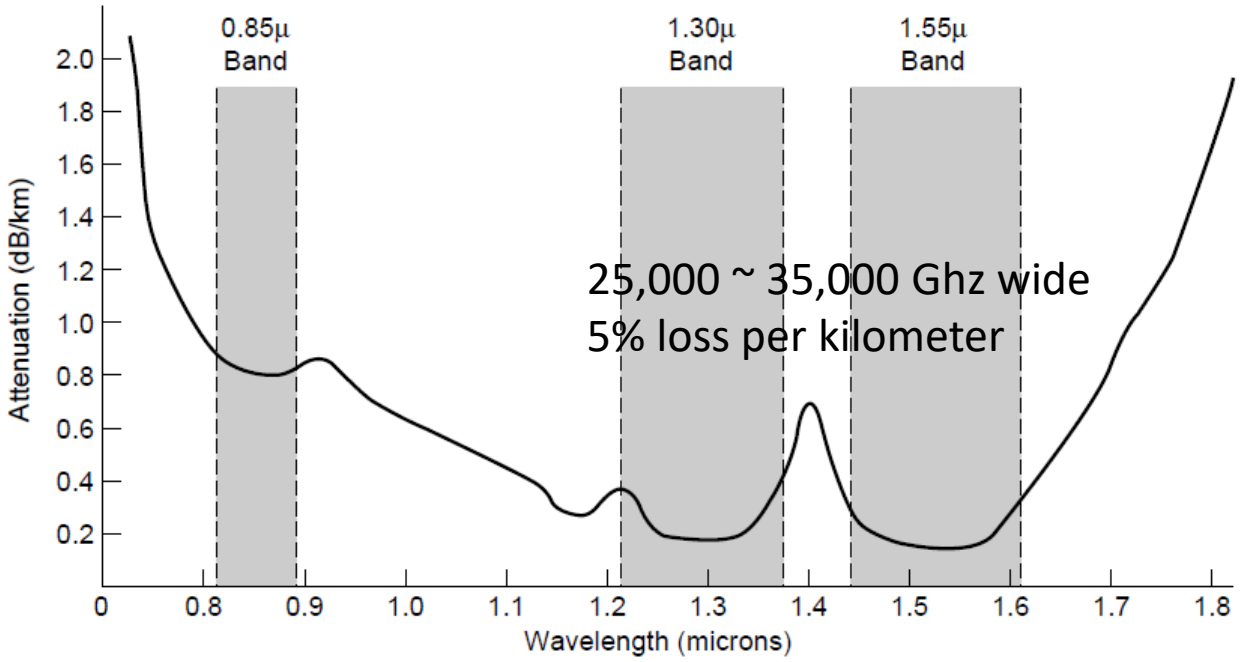




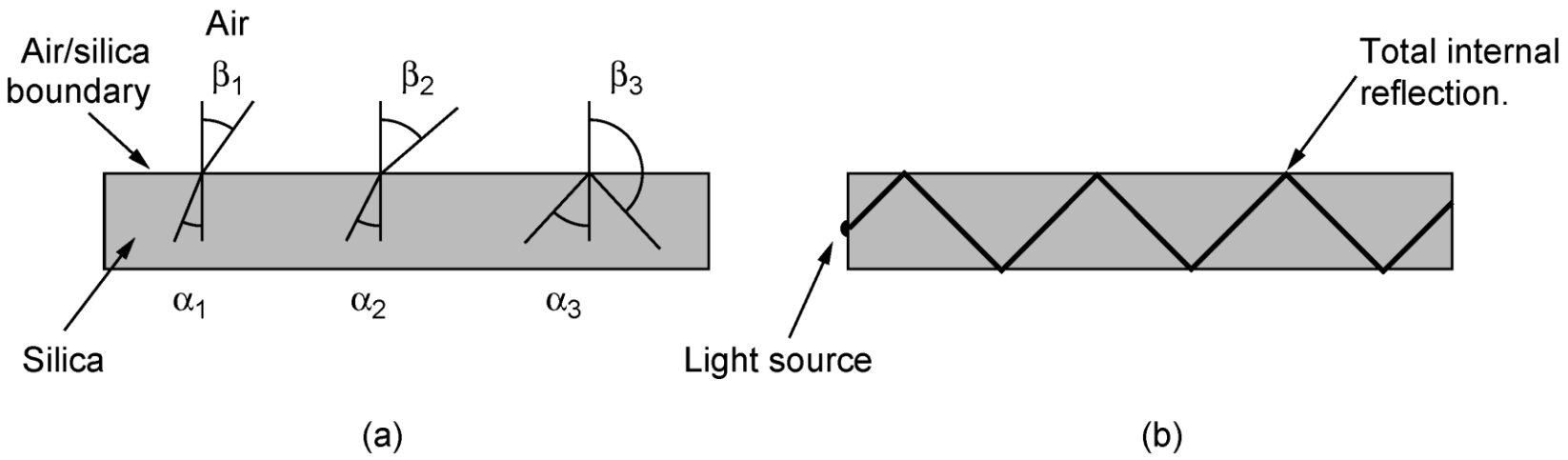
Fibers in a cable

Transmission of Light Through Fiber

- Fiber has enormous bandwidth (THz) and tiny signal loss, thus high rates over long distances



Light Transmission



- (a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles. (b) Light trapped by total internal reflection.

Mode of Transmission

- Single-mode
  - Core so narrow (10um) light can't even bounce around
  - Used with lasers for long distances, e.g., 100km
- Multi-mode
  - Other main type of fiber
  - Light can bounce (50um core)
  - Used with LEDs for cheaper, shorter distance links

Comparison of Wire and Fiber

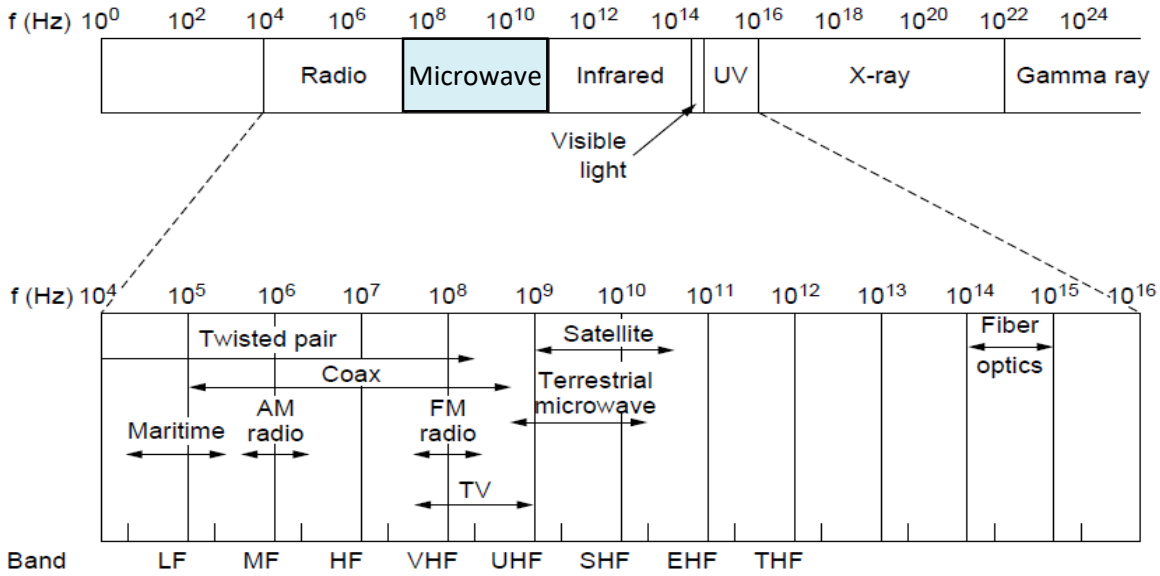
Property	Wires	Fiber
Distance	Short (100s of m)	Long (tens of km)
Bandwidth	Moderate	Very High
Cost	Inexpensive	Less cheap
Convenience	Easy to use	Less easy
Security	Easy to tap	Hard to tap

Wireless Transmission

- Electromagnetic Spectrum
- Radio Transmission
- Microwave Transmission
- Light Transmission
- Wireless vs. Wires/Fiber

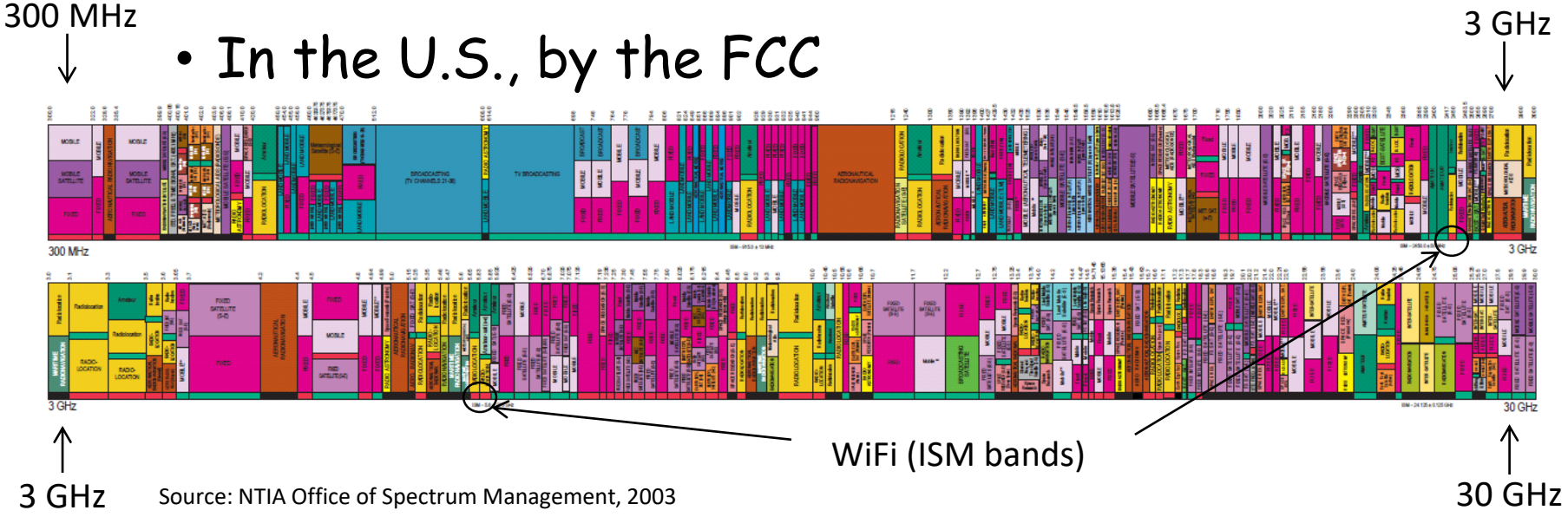
Electromagnetic Spectrum

- Different bands have different uses
  - Radio: wide-area broadcast; Infrared/Light: line-of-sight; Microwave: LANs and 3G/4G;



EM Spectrum Management

- To manage interference, EM spectrum is carefully divided, and its use regulated and licensed, e.g., sold at auction.
  - In the U.S., by the FCC



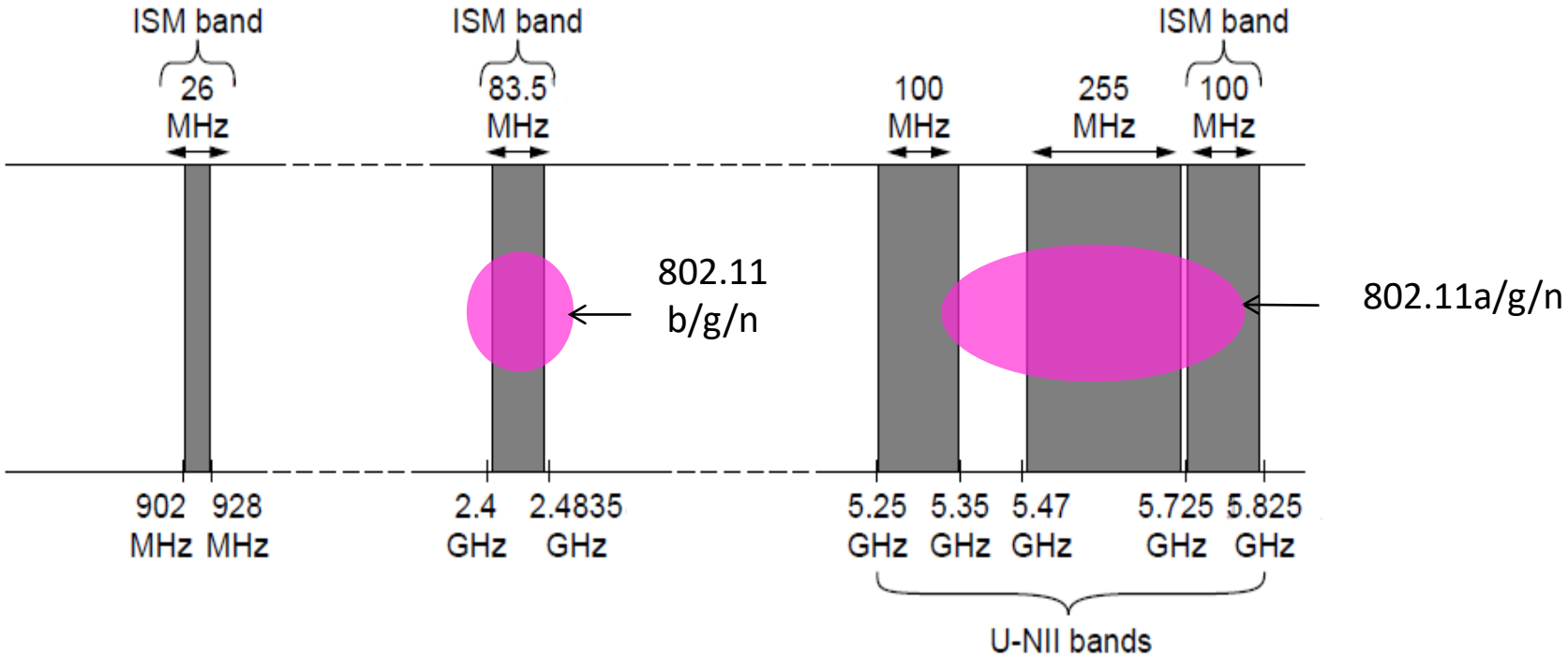
Source: NTIA Office of Spectrum Management, 2003

Part of the US frequency allocations

ISM Bands (Unlicensed Bands)

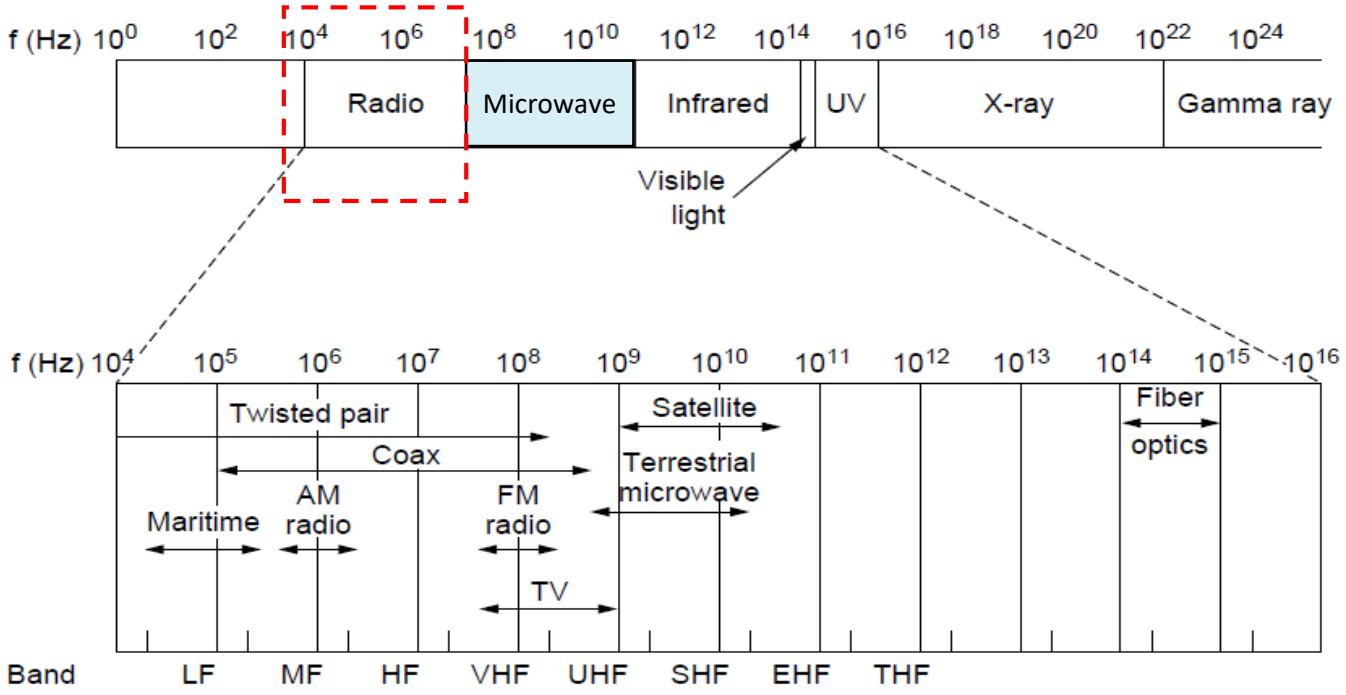
- Fortunately, there are also unlicensed bands
  - The industrial, scientific and medical (ISM) bands
    - Free for use at low power; devices manage interference
    - Widely used for networking; WiFi, Bluetooth, Zigbee, etc.

ISM Bands in the U.S.



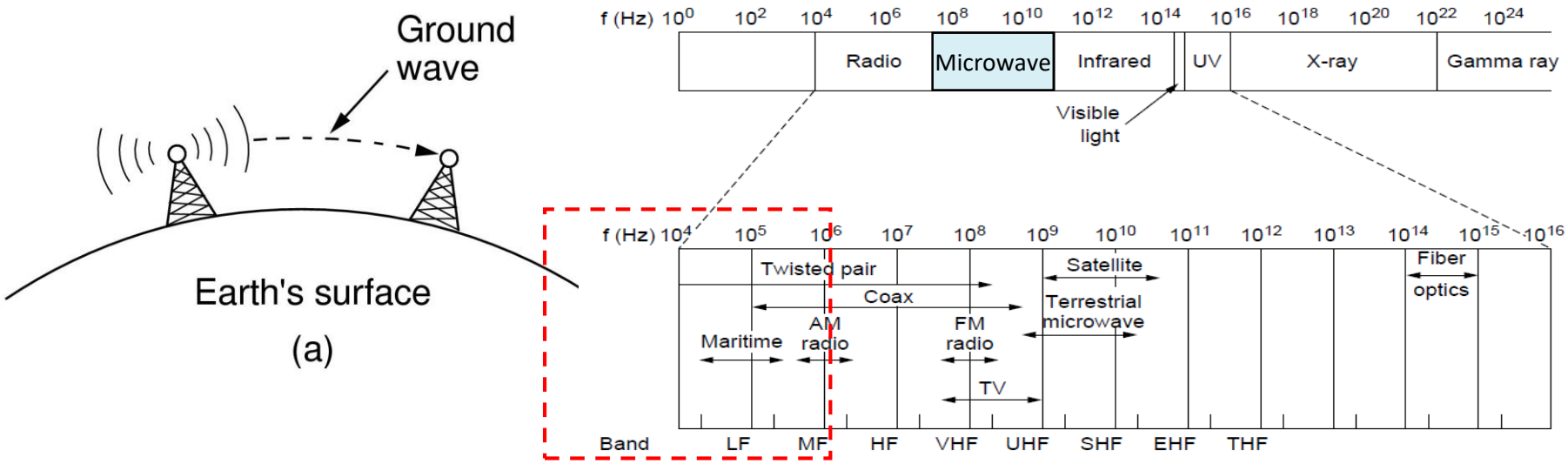
Radio Transmission

- Radio signals penetrate buildings well and propagate for long distances with path loss



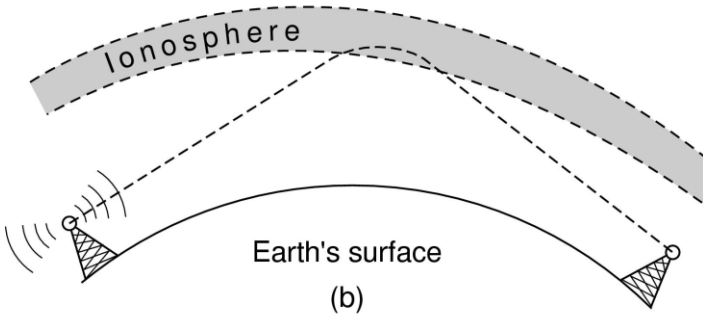
Ground Wave

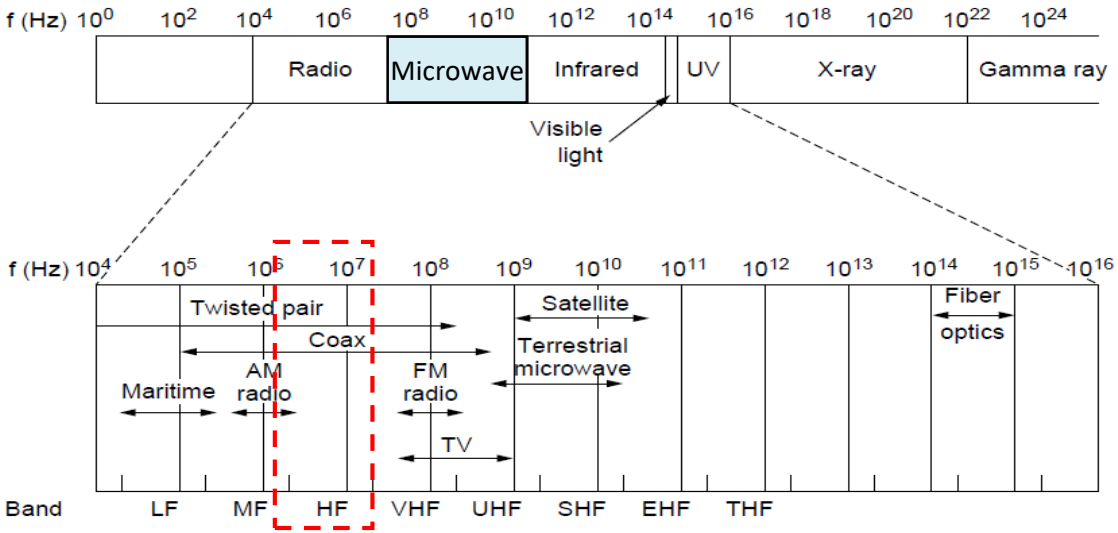
- In the VLF, LF, and MF bands, radio waves follow the curvature of the earth



HF Band

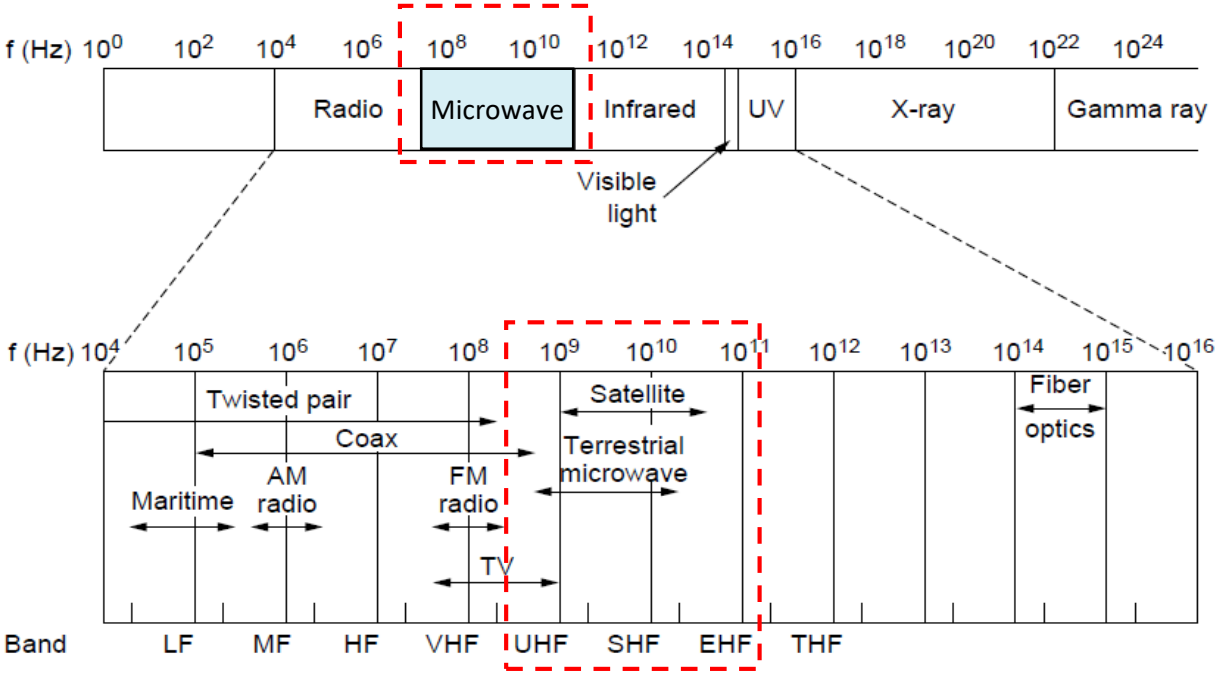
- In the HF band, radio waves bounce off the ionosphere.





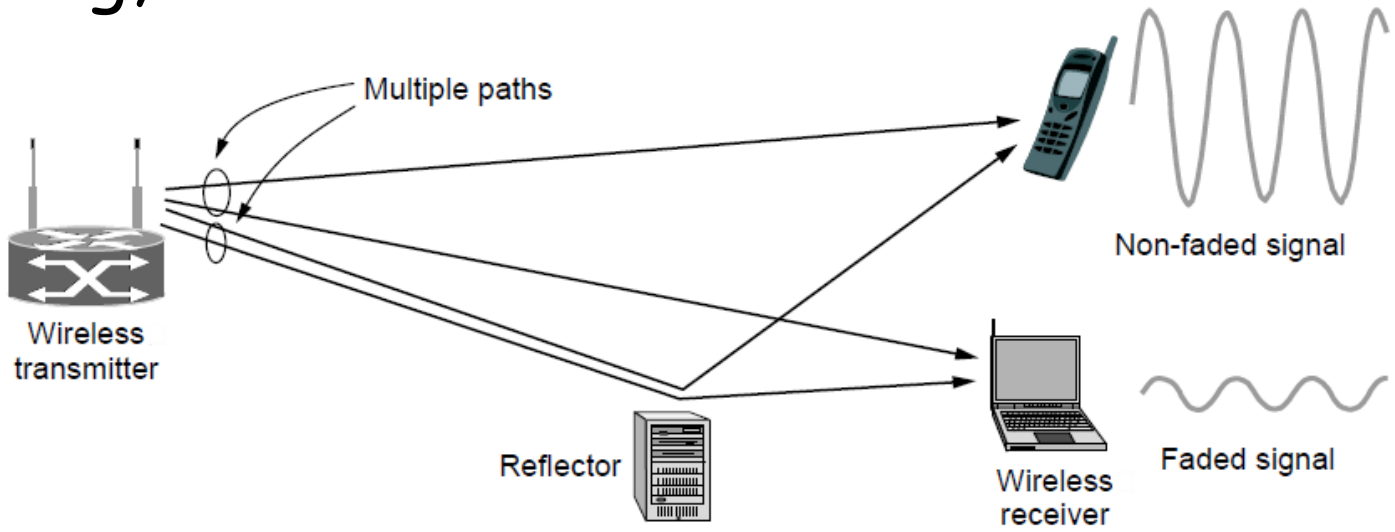
Microwave

- Microwaves have much bandwidth and are widely used indoors (WiFi) and outdoors (3G, satellites)



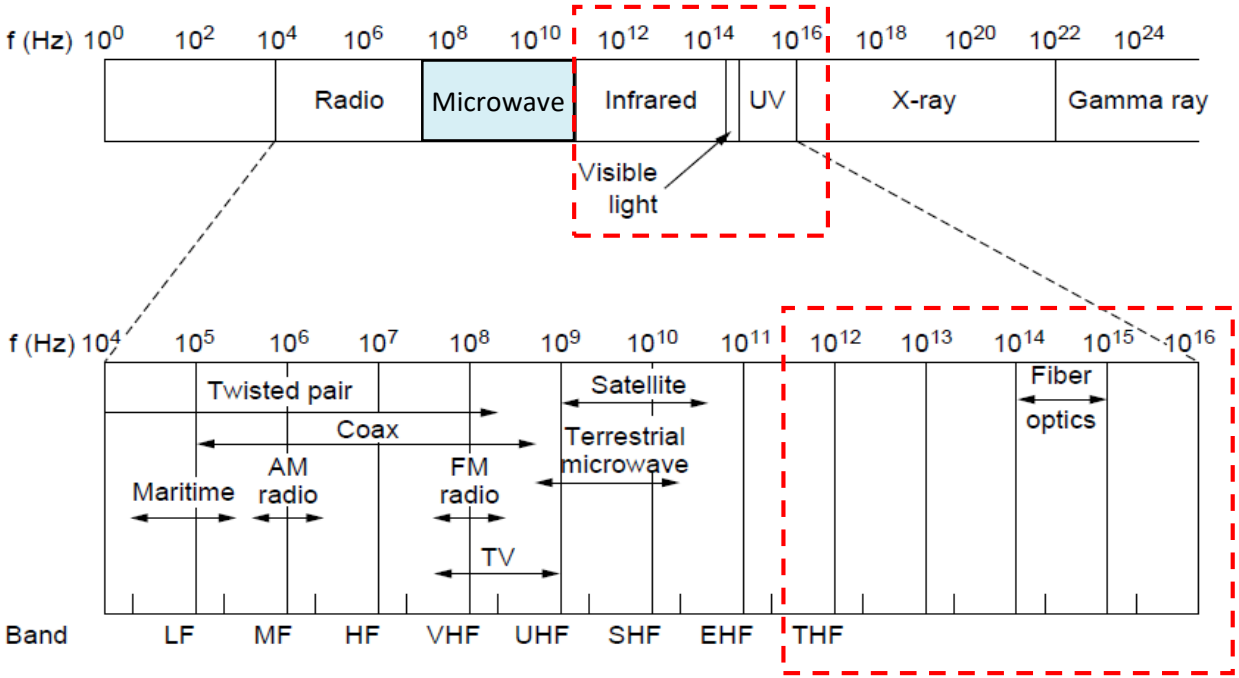
Microwave Transmission

- Signal is attenuated/reflected by everyday objects
- Strength varies with mobility due multipath fading, etc.



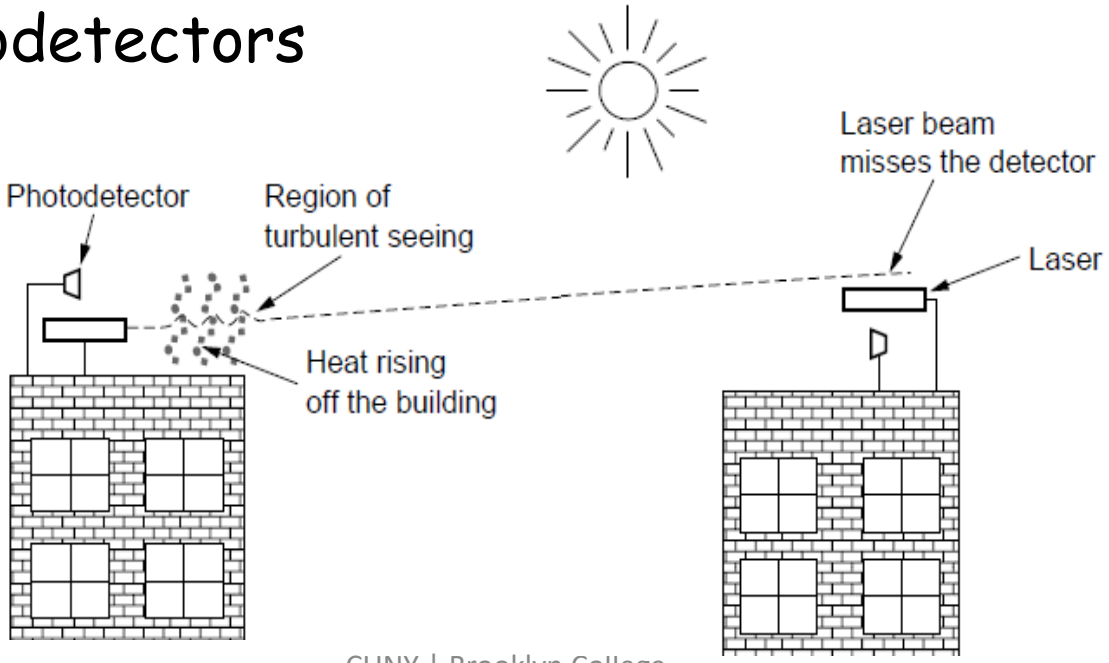
Light

- Line-of-sight light (no fiber) can be used for links



Light Transmission

- Light is highly directional, has much bandwidth
  - Use of LEDs/cameras and lasers or photodetectors



Wireless vs. Wires/Fiber

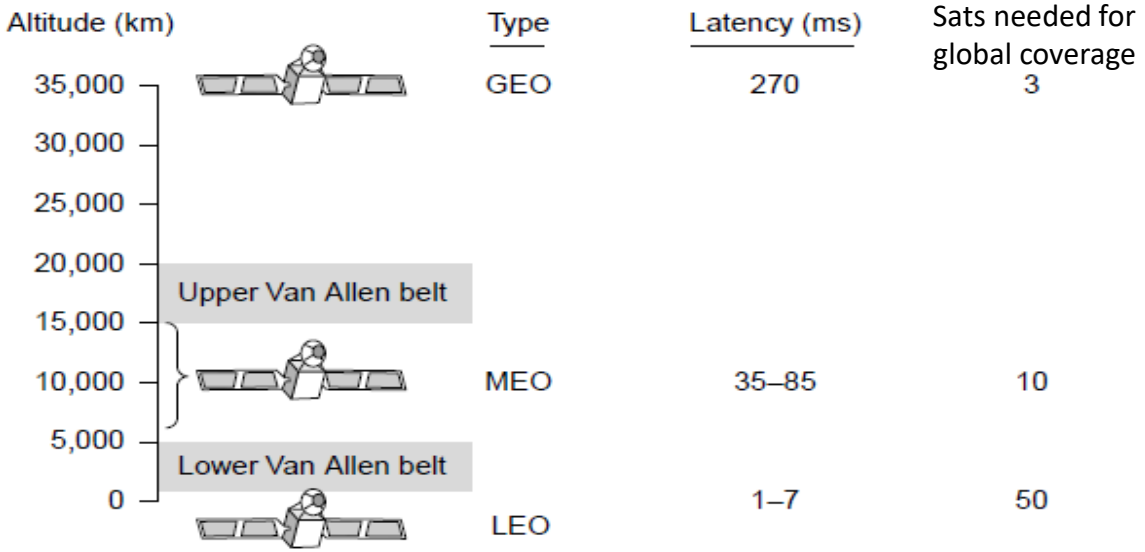
- Wireless:
  - + Easy and inexpensive to deploy
  - + Naturally supports mobility
  - + Naturally supports broadcast
  - Transmissions interfere and must be managed
  - Signal strengths hence data rates vary greatly
- Wires/Fiber:
  - + Easy to engineer a fixed data rate over point-to-point links
  - Can be expensive to deploy, esp. over distances
  - Doesn't readily support mobility or broadcast

Communication Satellites

- Satellites are effective for broadcast distribution and anywhere/anytime communications
  - Kinds of Satellites
  - Geostationary (GEO) Satellites
  - Low-Earth Orbit (LEO) Satellites
  - Satellites vs. Fiber

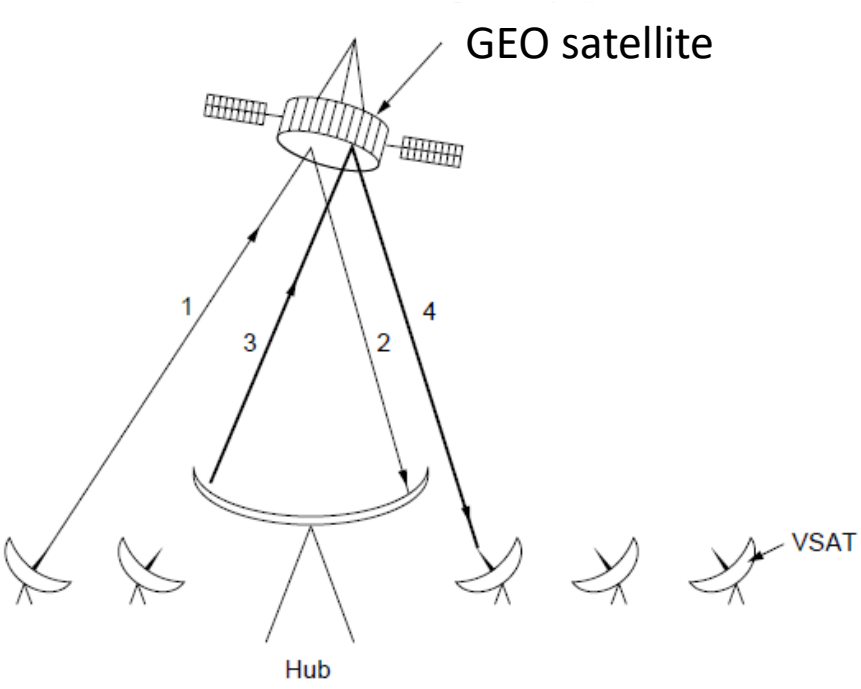
Kinds of Satellites

- Satellites and their properties vary by altitude
  - Geostationary (GEO), Medium-Earth Orbit (MEO), and Low-Earth Orbit (LEO)



Geostationary (GEO) Satellites

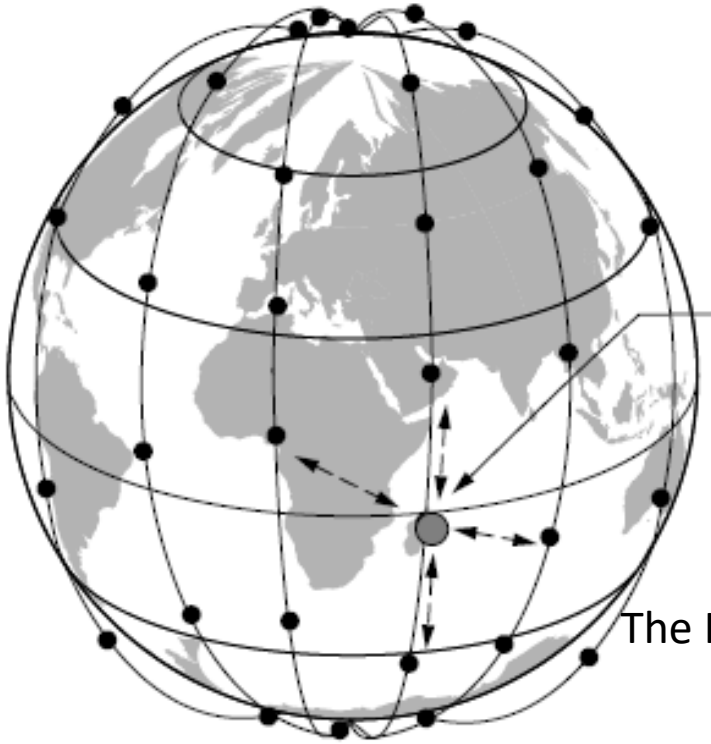
- GEO satellites orbit 35,000 km above a fixed location
  - VSAT (computers) can communicate with the help of a hub
  - Different bands (L, S, C, Ku, Ka) in the GHz are in use but may be crowded or susceptible to rain.



Low-Earth Orbit (LEO) Satellites

- Systems such as Iridium use many low-latency satellites for coverage and route communications via them

The Iridium Satellites



The Iridium satellites form six necklaces around the earth.

Satellite vs. Fiber

- Satellite:
  - + Can rapidly set up anywhere/anytime communications (after satellites have been launched)
  - + Can broadcast to large regions
  - Limited bandwidth and interference to manage
- Fiber:
  - + Enormous bandwidth over long distances
  - Installation can be more expensive/difficult

Questions?

- Guided transmission media
  - Magnetic media
  - Twisted pairs
  - Coaxial cable
  - Power lines
  - Fiber optics
- Wireless transmission
  - EM spectrum
  - Radio transmission
  - Microwave transmission
  - Infrared transmission
  - Light transmission

Link Terminology

- Full-duplex link
  - Used for transmission in both directions at once
  - e.g., use different twisted pairs for each direction
- Half-duplex link
  - Both directions, but not at the same time
  - e.g., senders take turns on a wireless channel
- Simplex link
  - Only one fixed direction at all times; not common

Questions?

- Full, half, simplex links?