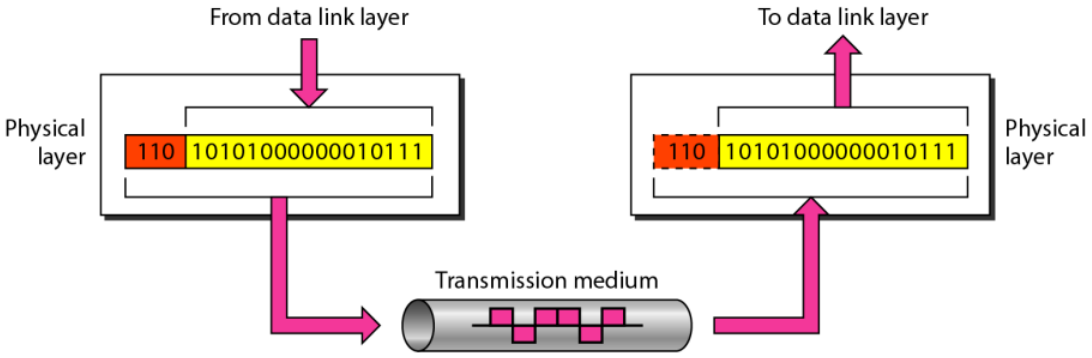
Physical layer



Main functions of the physical layer

- Coding /decoding signals
- Modulation/Demodulation
- Adaptation of the signal to the physical medium properties

2-1 ANALOG AND DIGITAL

Data can be analog or digital

- Analog data refers to information that is continuous
- Analog data take on continuous values
- Analog signals can have an infinite number of values in a range

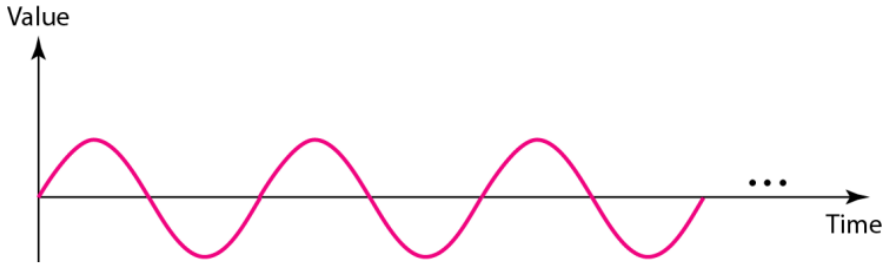
- Digital data refers to information that has discrete states
- Digital data take on discrete values
- Digital signals can have only a limited number of values

In data communications, we commonly use periodic analog signals and nonperiodic digital signals.

PERIODIC ANALOG SIGNALS

Periodic analog signals can be classified as simple or composite.

- A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals.
- A composite periodic analog signal is composed of multiple sine waves.



Frequency

Frequency is the rate of change with respect to time.

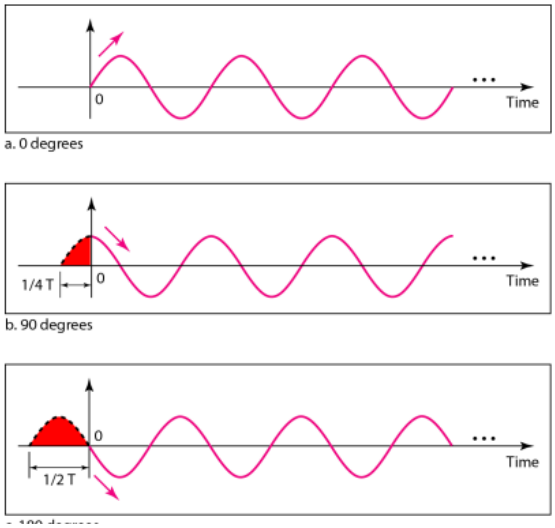
- ❑ Change in a short span of time means high frequency.
- ❑ Change over a long span of time means low frequency.

- ❑ If a signal does not change at all, its frequency is zero
- ❑ If a signal changes instantaneously, its frequency is infinite.

Phase

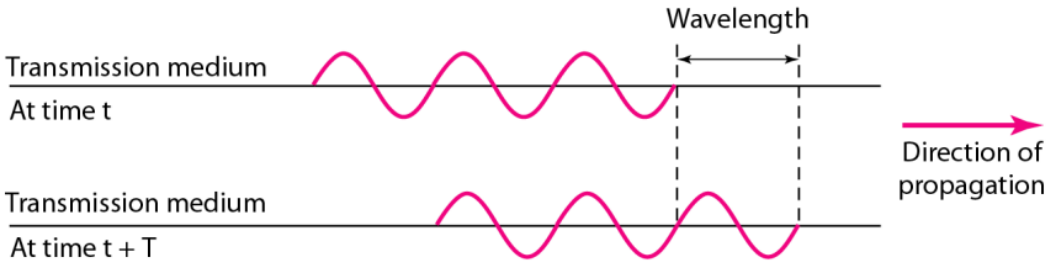
Phase describes the position of the waveform relative to time 0

Three sine waves with the same amplitude and frequency, but different phases



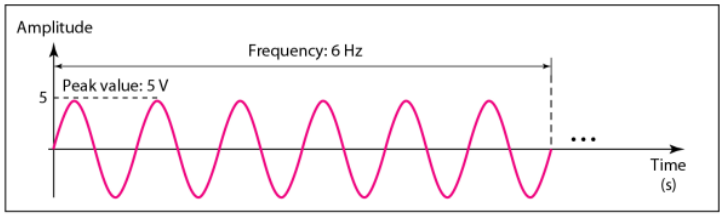
Wavelength and period

Wavelength = Propagation speed x Period
= Propagation speed / Frequency

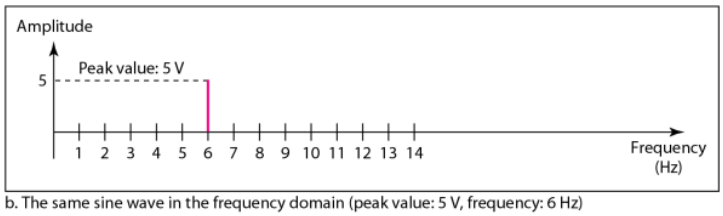


Time-domain and frequency-domain plots of a sine wave

A complete sine wave in the time domain can be represented by one single spike in the frequency domain.

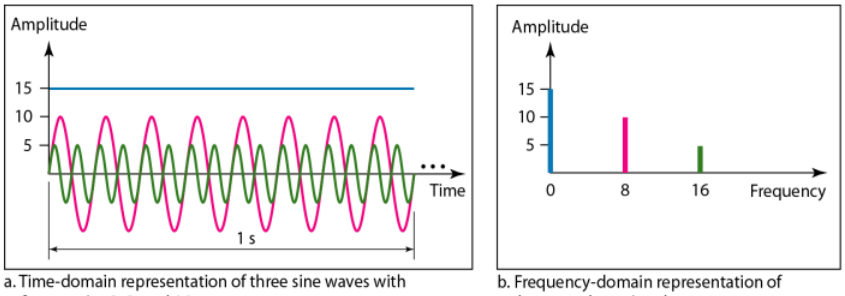


a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

Frequency Domain



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16

b. Frequency-domain representation of the same three signals

- The frequency domain is more compact and useful when we are dealing with more than one sine wave.

- A single-frequency sine wave is not useful in data communication
  - We need to send a composite signal, a signal made of many simple sine waves.

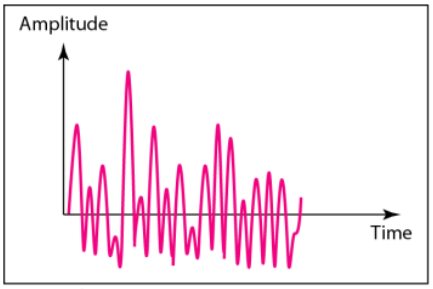
Fourier analysis

According to Fourier analysis,
any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

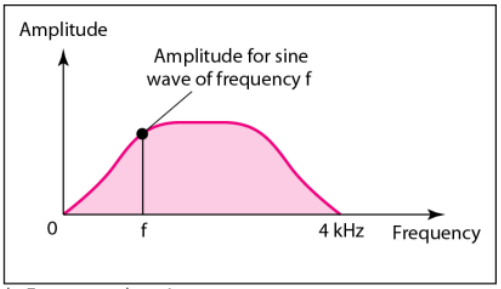
- If the composite signal is periodic, the decomposition gives a *series of signals with discrete frequencies;*
- If the composite signal is nonperiodic, the decomposition gives a *combination of sine waves with continuous frequencies.*

Time and frequency domains of a nonperiodic signal

- A nonperiodic composite signal
  - It can be a signal created by a microphone or a telephone set when a word or two is pronounced.
  - In this case, the composite signal cannot be periodic
    - ➢ because that implies that we are repeating the same word or words with exactly the same tone.



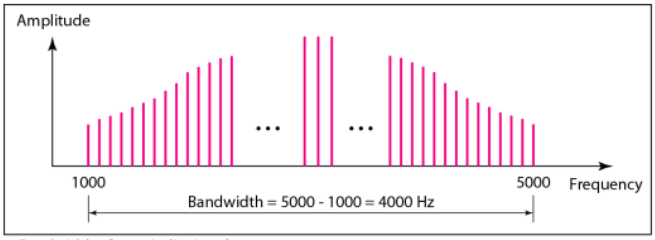
a. Time domain



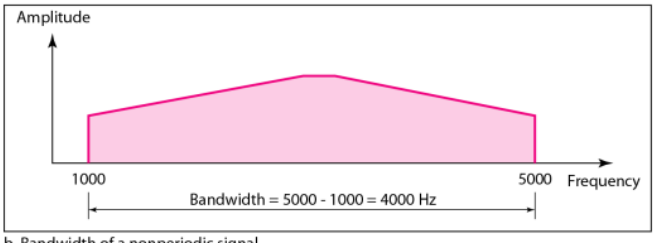
b. Frequency domain

Bandwidth

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.



a. Bandwidth of a periodic signal

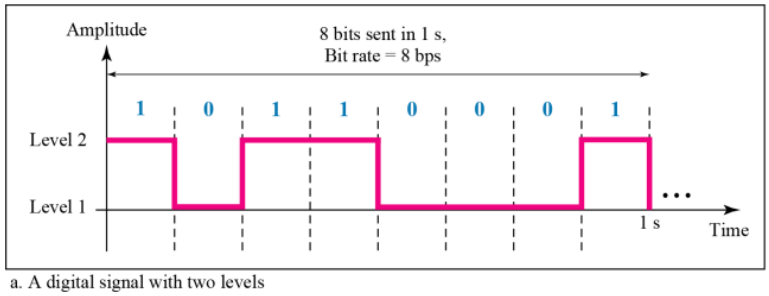


b. Bandwidth of a nonperiodic signal

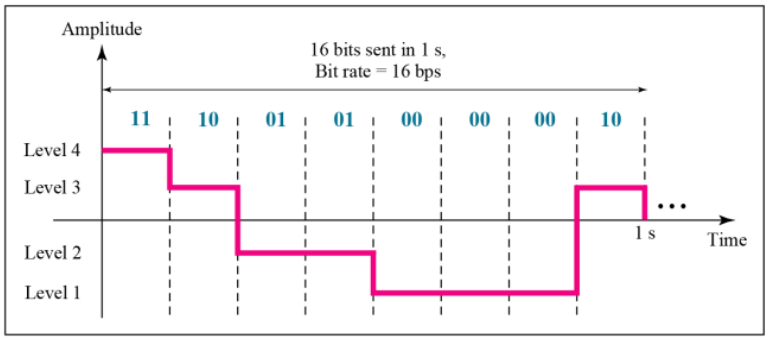
DIGITAL SIGNALS

- In addition to being represented by an analog signal, information can also be represented by a digital signal.
- For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.
- A digital signal can have more than two levels.
- In this case, we can send more than 1 bit for each level.

Two digital signals: one with two signal levels and the other with four signal levels

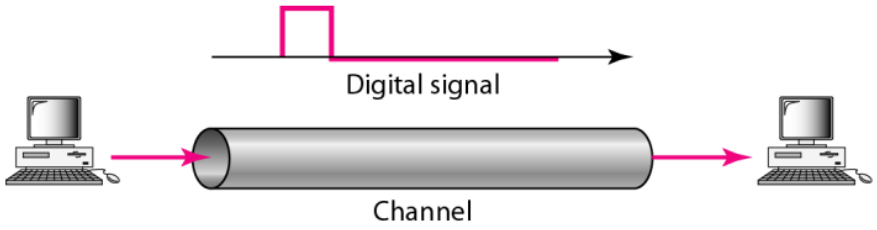


a. A digital signal with two levels



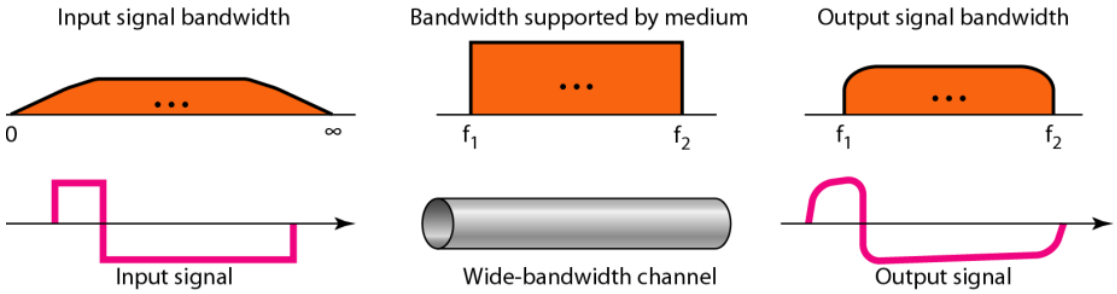
b. A digital signal with four levels

Baseband transmission



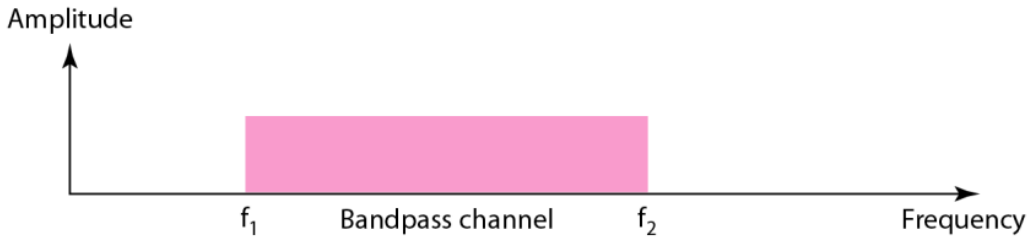
A digital signal is a composite analog signal with an infinite bandwidth.

Baseband transmission using a dedicated medium



Baseband transmission of a digital signal that preserves the shape of the digital signal is possible only if we have a low-pass channel with an infinite or very wide bandwidth.

Bandwidth of a bandpass channel



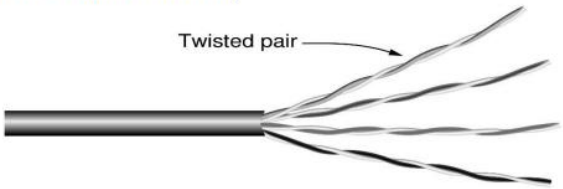
If the available channel is a bandpass channel, we cannot send the digital signal directly to the channel; we need to convert the digital signal to an analog signal before transmission.

2-2 TRANSMISSION MEDIA

- **Twisted pair (1)**
  - Simply two wires twisted together – thickness=1mm
    The twisting cuts down on electrical interference.
  - Heavily used in the phone system
    Typical office has four pairs for phones.
  - Until some Kilometers/ Some Mbps
  - For Analog and Digital

Transmission Media (2)

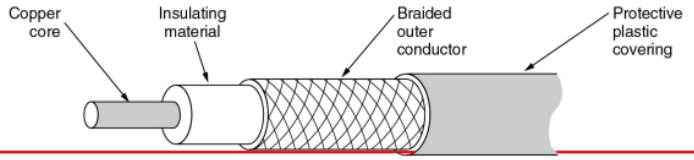
- Twisted pair (2)
  - Bandwidth depends on thickness and distance
    Need repeater for long distances
  - Category 3 and 5 - with 5 having more twists and better insulation.
  - Popular by UTP (Unshielded Twisted Pair)



Category 5 UTP cable with four twisted pairs

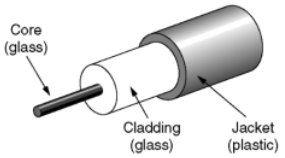
Transmission Media (3)

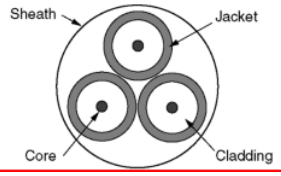
- Baseband Coaxial cable
  - **Used for digital transmissions (called baseband.)**
  - **Good noise immunity.**
  - **Data rates as high as 2 Gbps for 1 Km distance.**
  - **Now being replaced by fiber.**
- Broadband Coaxial cable
  - **Used for analog transmissions (called broadband.)**
  - **Can run 300 MHz for long distances.**
  - **Analog signaling has better S/N than digital signaling.**
  - **Interfaces must convert digital signals to analog and vice versa.**
  - **Designed for long distances - can use amplifiers.**



Transmission Media (4)

- Fiber Optic (1)
  - Transmission of light through fiber
  - Bandwidth more than 50,000 Gbps !
    But now restricted to 1Gbps!
    Reason: Electrical and optical signal conversion
  - Including 3 components:
    1. Light source: Pulse of light=1, absence of light=0
    2. Transition medium: an ultra-thin fiber of glass
    3. detector: generate an electrical pulse when light falls on it
  - Similar to coax (without braid)





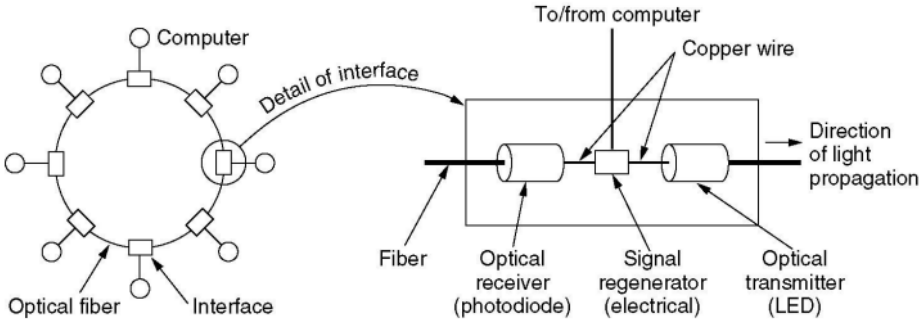
Transmission Media (5)

- Fiber Optic (2)
  - Thickness of core: 8~10 microns or 50 microns
  - Two typically light sources:
    1. LED (Light Emitting Diode)
       response time=1ns ➔ data rate = 1Gbps
    2. Semiconductor laser

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Transmission Media (6)

- Fiber Optic (3)
  - Properties include total internal reflection and attenuation of particular frequencies.
  - Fiber Optic Networks - can be used for LANs and long-haul.
  - A fiber-optic LAN



Transmission Media (7)

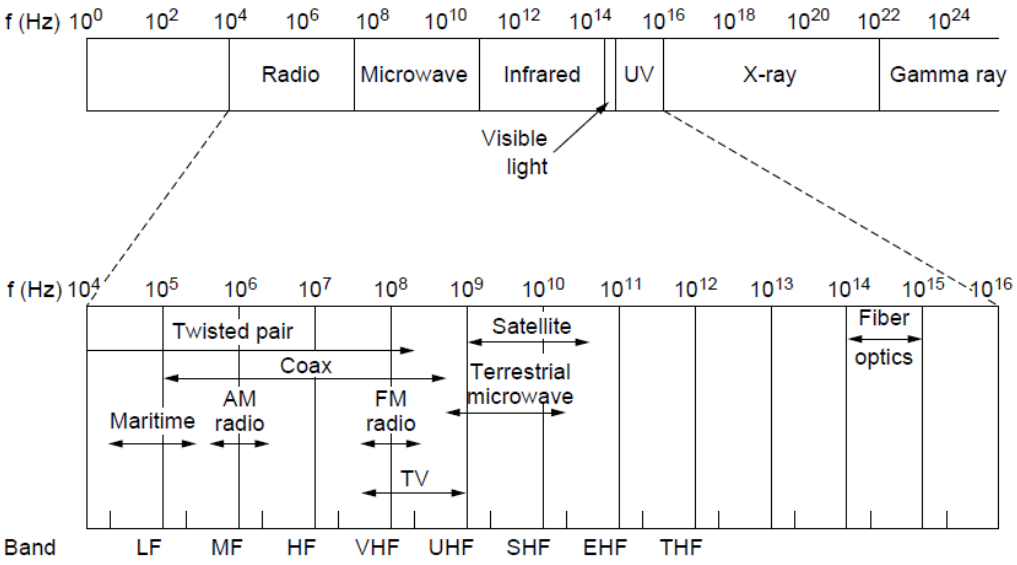
- Comparison of fiber optic and copper wire

	Fiber	Copper
Bandwidth	Higher	Lower
Distance between repeaters	30 KM	5 Km
Interference	Low	High
Physical	Smaller/Lighter	-
Flow	Uni-directional	Bi-directional

Transmission Media (8)

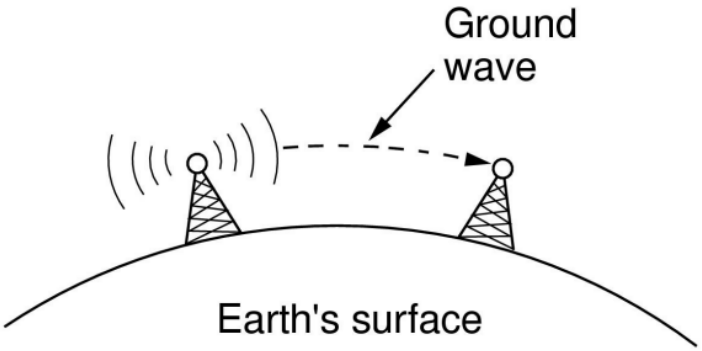
- Connector
- Repeater
  - Signal Regeneration
  - Clean up
  - Amplify
  - Distance Extension
- Hub
  - Repeater functionality, plus...
    - Concentration Point
    - Signal Distribution Device
    - Management Functions

Wireless Transmission



The electromagnetic spectrum and its uses for communication

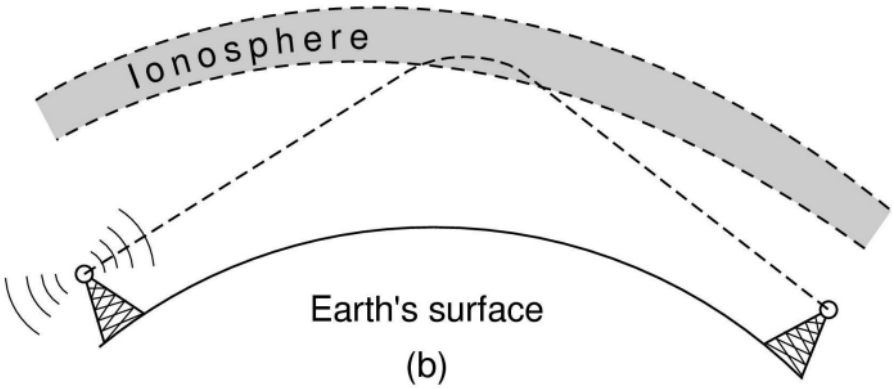
Radio Transmission



(a)

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

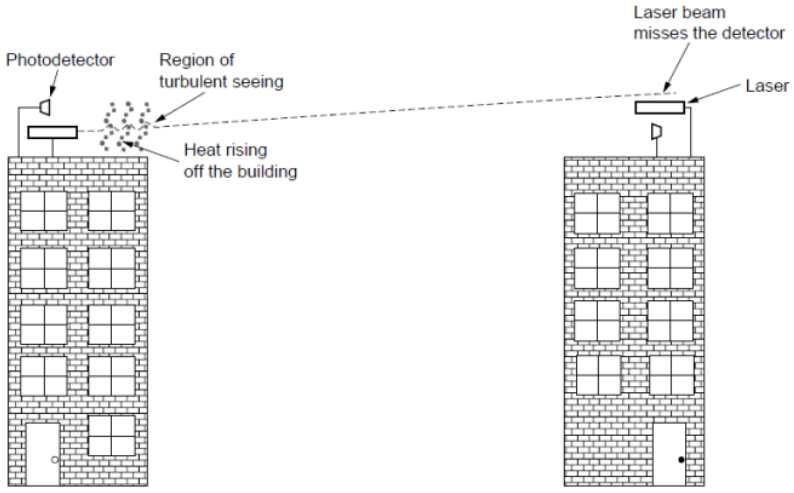
Radio Transmission(2)



(b)

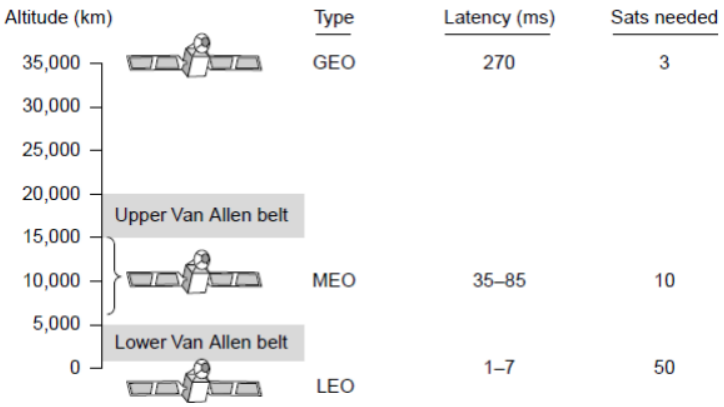
In the HF band, they bounce off the ionosphere.

Light Transmission



Convection currents can interfere with laser communication systems. A bidirectional system with two lasers is pictured here.

Communication Satellites



Communication satellites, some properties, including: altitude above earth, round-trip delay time, number of satellites for global coverage.

2-4 TRANSMISSION IMPAIRMENT

- Signals travel through transmission media, which are not perfect.
- The imperfection causes signal impairment.
- This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium.
- What is sent is not what is received.
- Three causes of impairment are attenuation, distortion, and noise.