# BLG 337E- Principles of Computer Communications

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## PHY Layer (3)

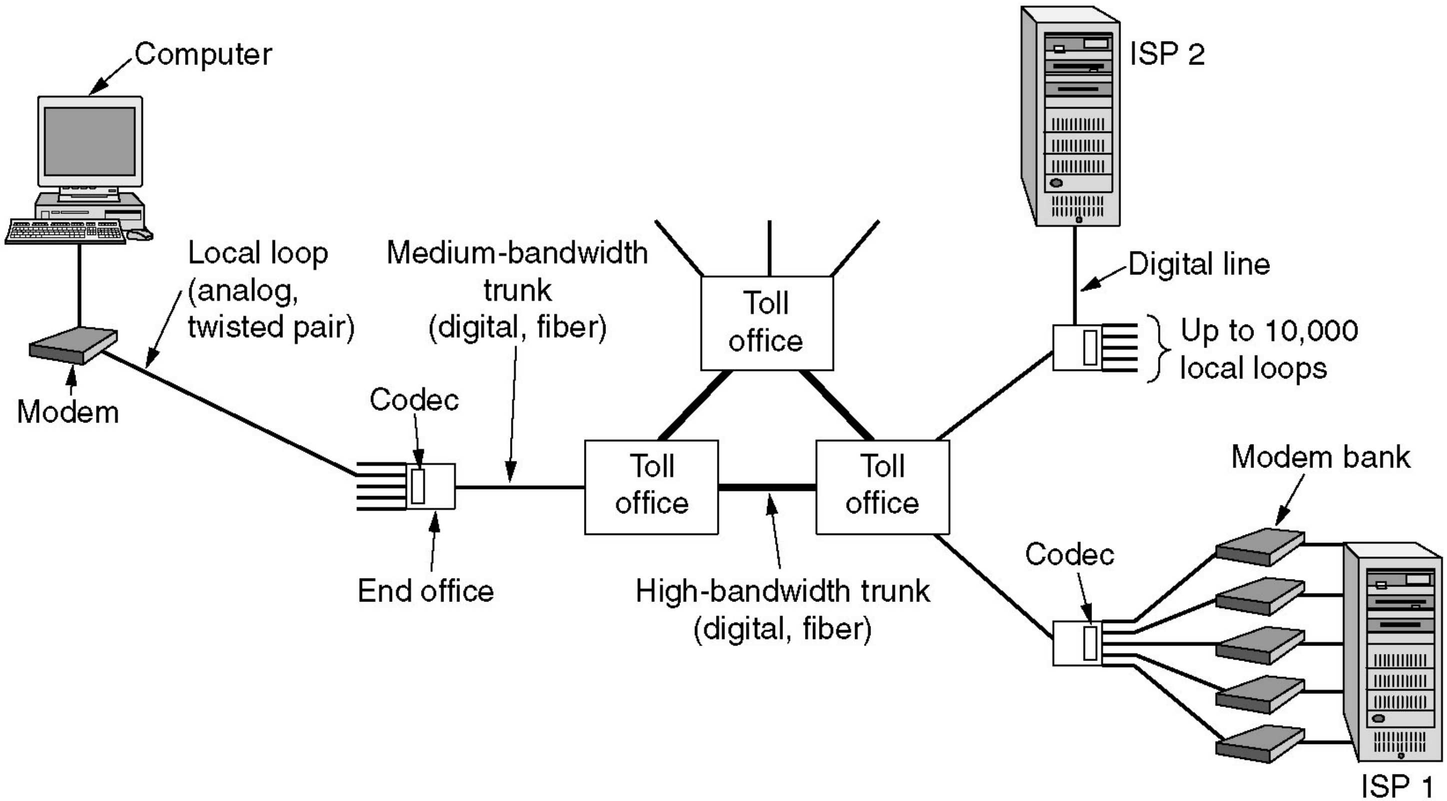
References:

*Data and Computer Communications*, William Stallings, Pearson-Prentice Hall, 9th Edition, 2010.

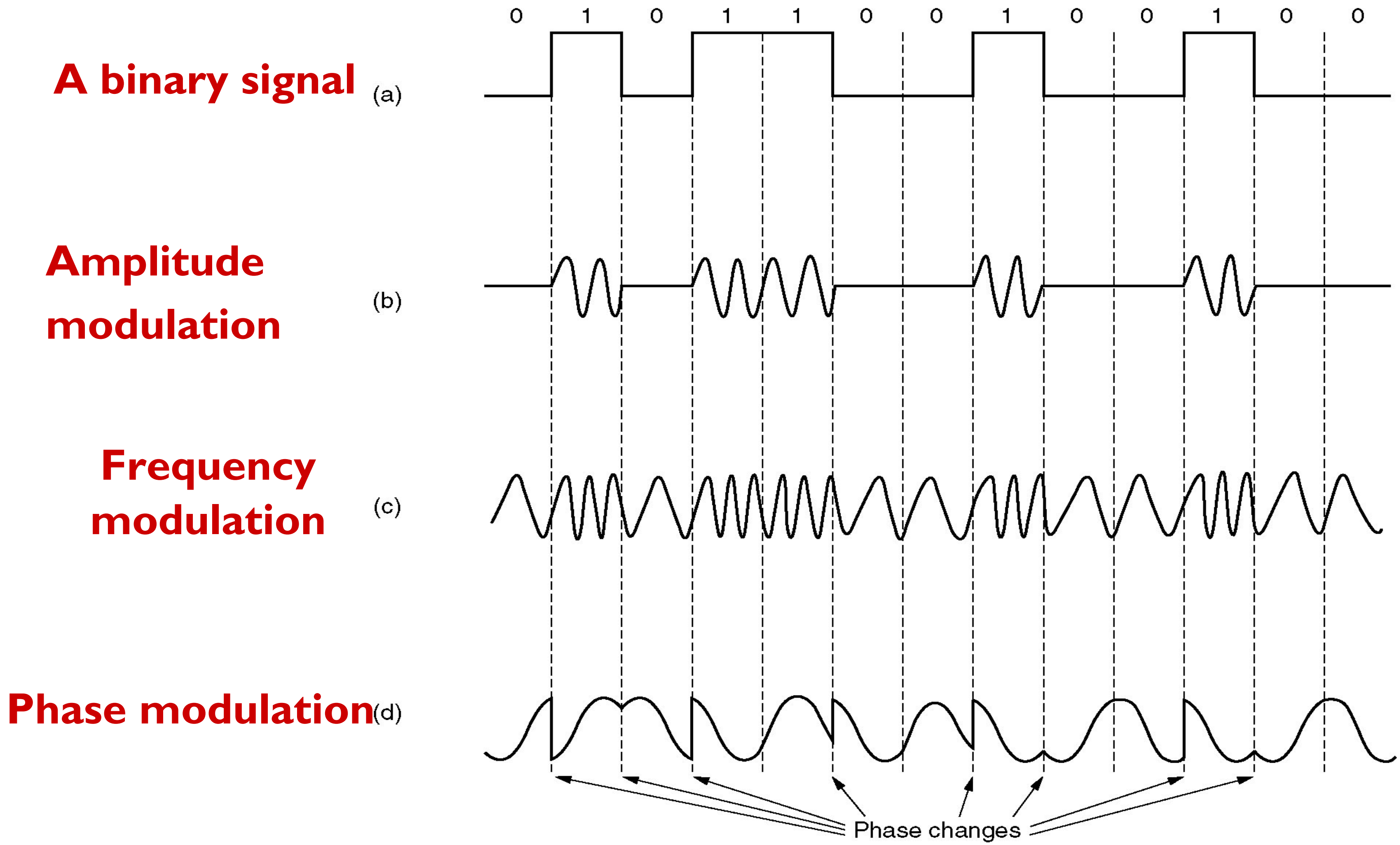
-*Computer Networking, A Top-Down Approach Featuring the Internet*, James F.Kurose, Keith W.Ross, Pearson-Addison Wesley, 6th Edition, 2012.

-Google!

# Analog and Digital Transmissions

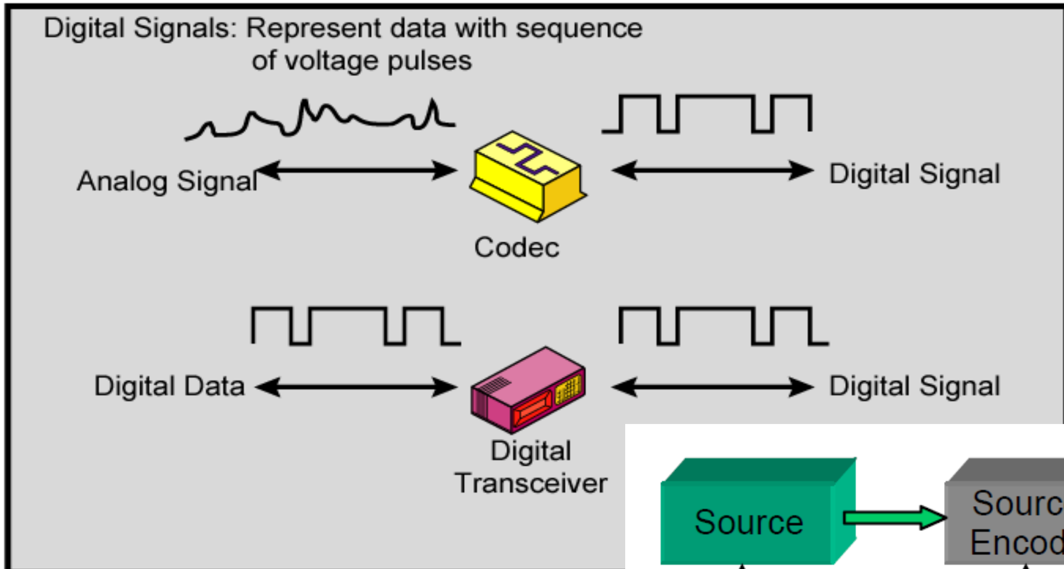


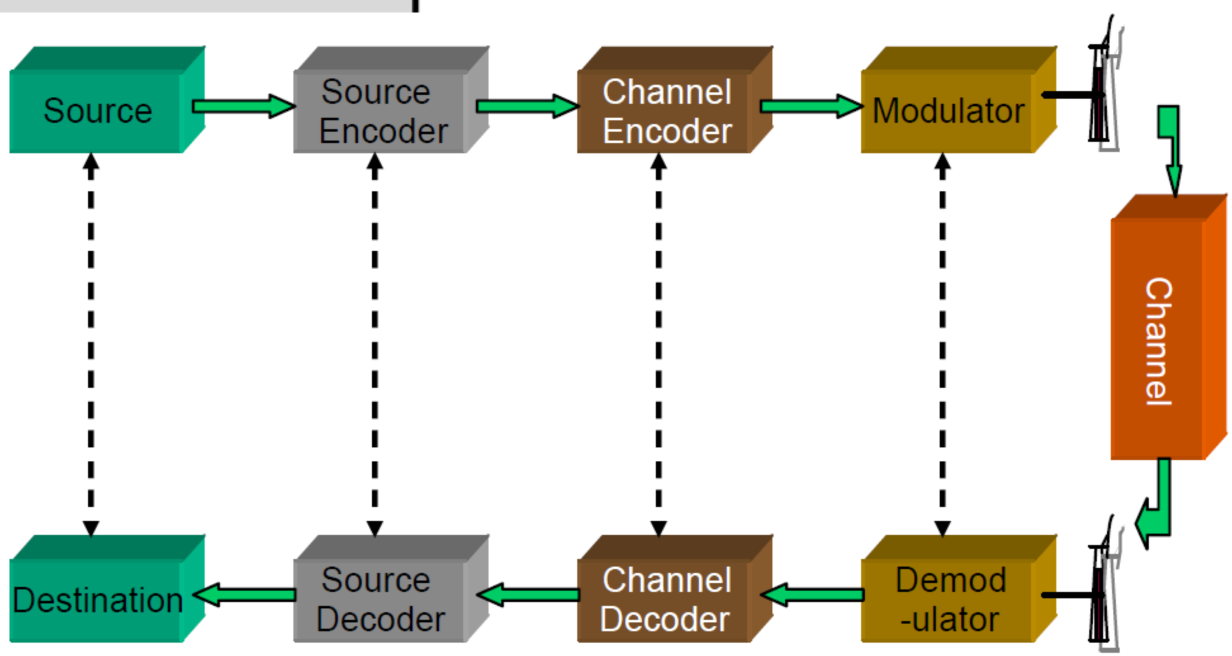

The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modems and codecs.



A binary signal
Amplitude modulation
Frequency modulation
Phase modulation
(a)
(b)
(c)
(d)
0 1 0 1 1 0 0 1 0 0 1 0 0
Phase changes

# Digital Signals Carrying Analog and Digital Data



# Encoding Schemes

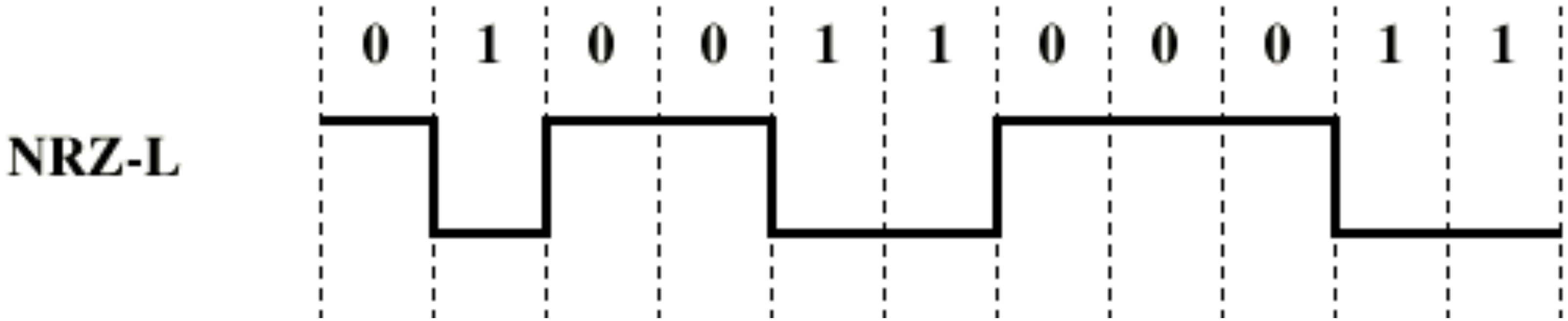
- Nonreturn to Zero-Level (NRZ-L)

- Manchester

# NonReturn to Zero (NRZ-L)

- NRZ-L (Level)
  - Two different voltages for 0 and 1 bits
  - Voltage constant during bit interval
    - no transition, i.e., no return to zero voltage
  - e.g. Absence of voltage for zero, constant positive voltage for one
  - Negative voltage for one value and positive for the other

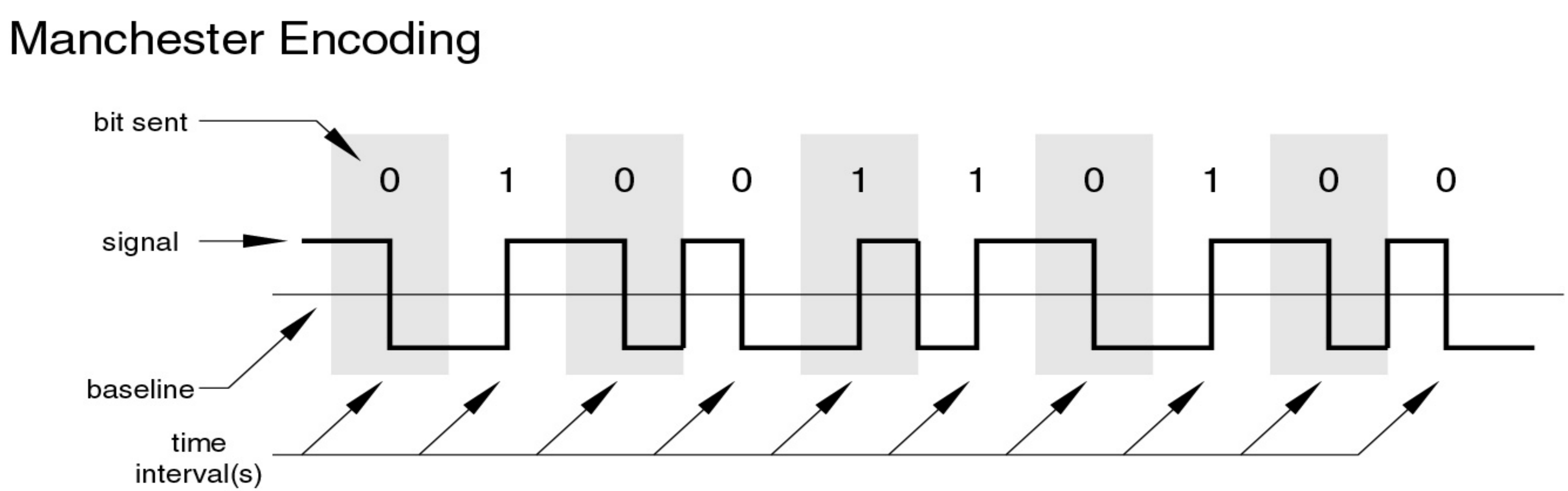
# NRZ



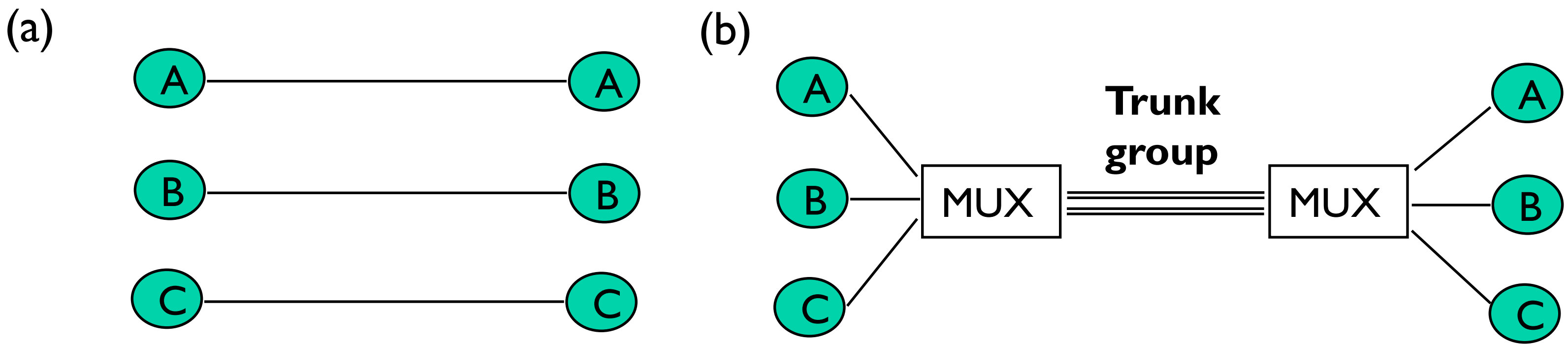
# Manchester Encoding

- Manchester
  - Transition in middle of each bit period
  - Transition serves as clock and data
  - Low to high represents one
  - High to low represents zero
  - Used by IEEE 802.3

To represent bits, wait till middle of period!

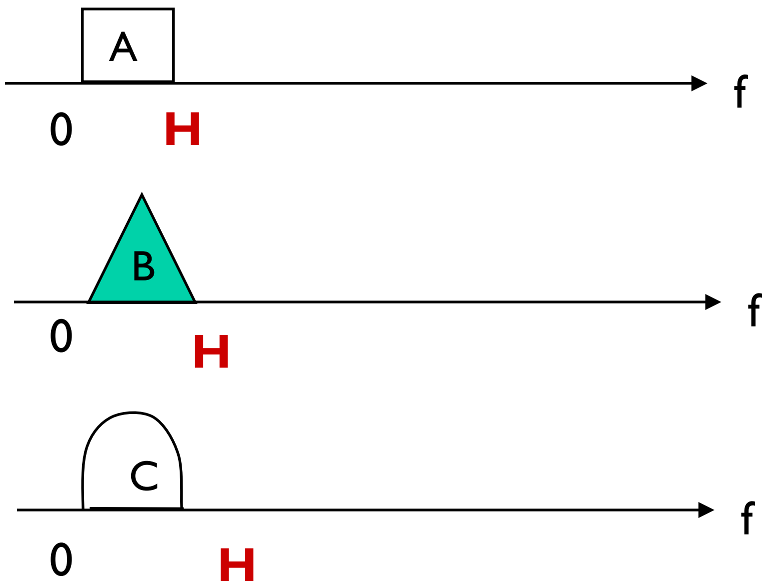


# Multiplexing

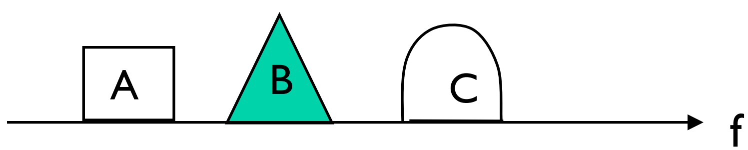


# Frequency-division Multiplexing

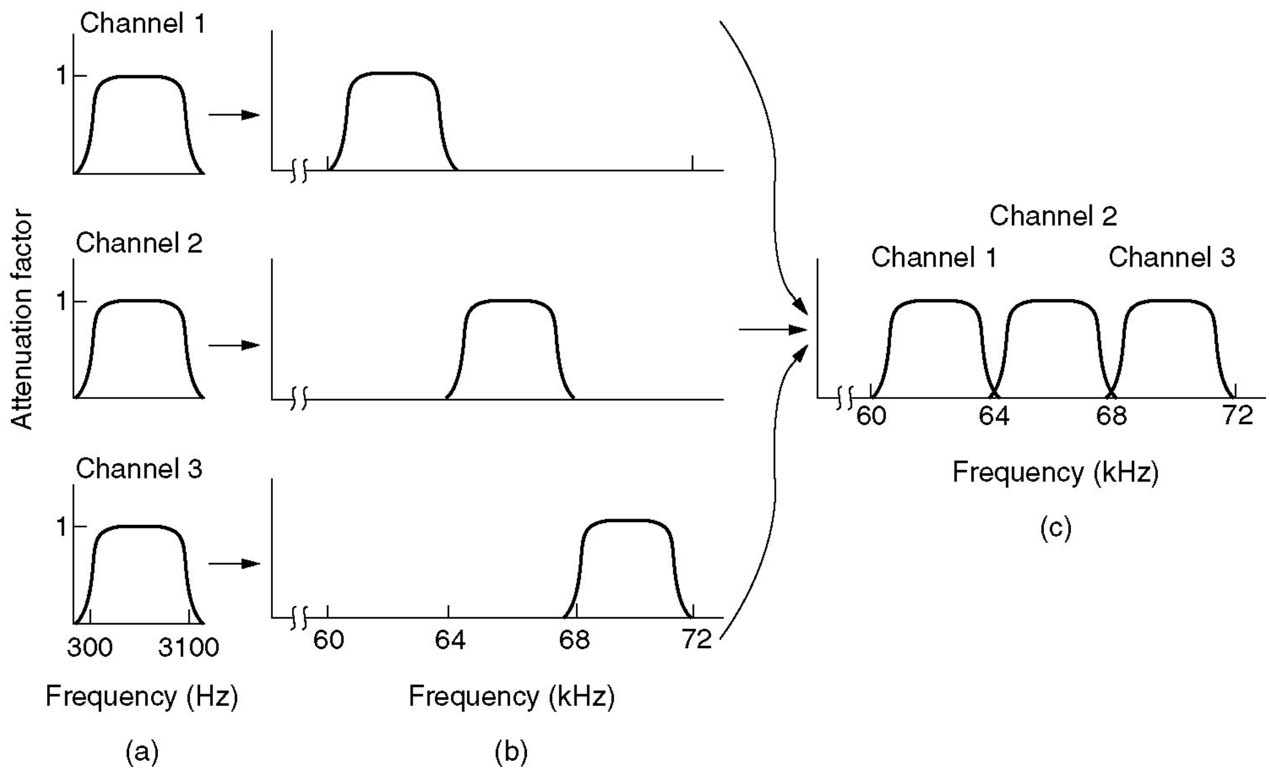
(a) Individual signals occupy **H** Hz




(b) Combined signal fits into channel bandwidth

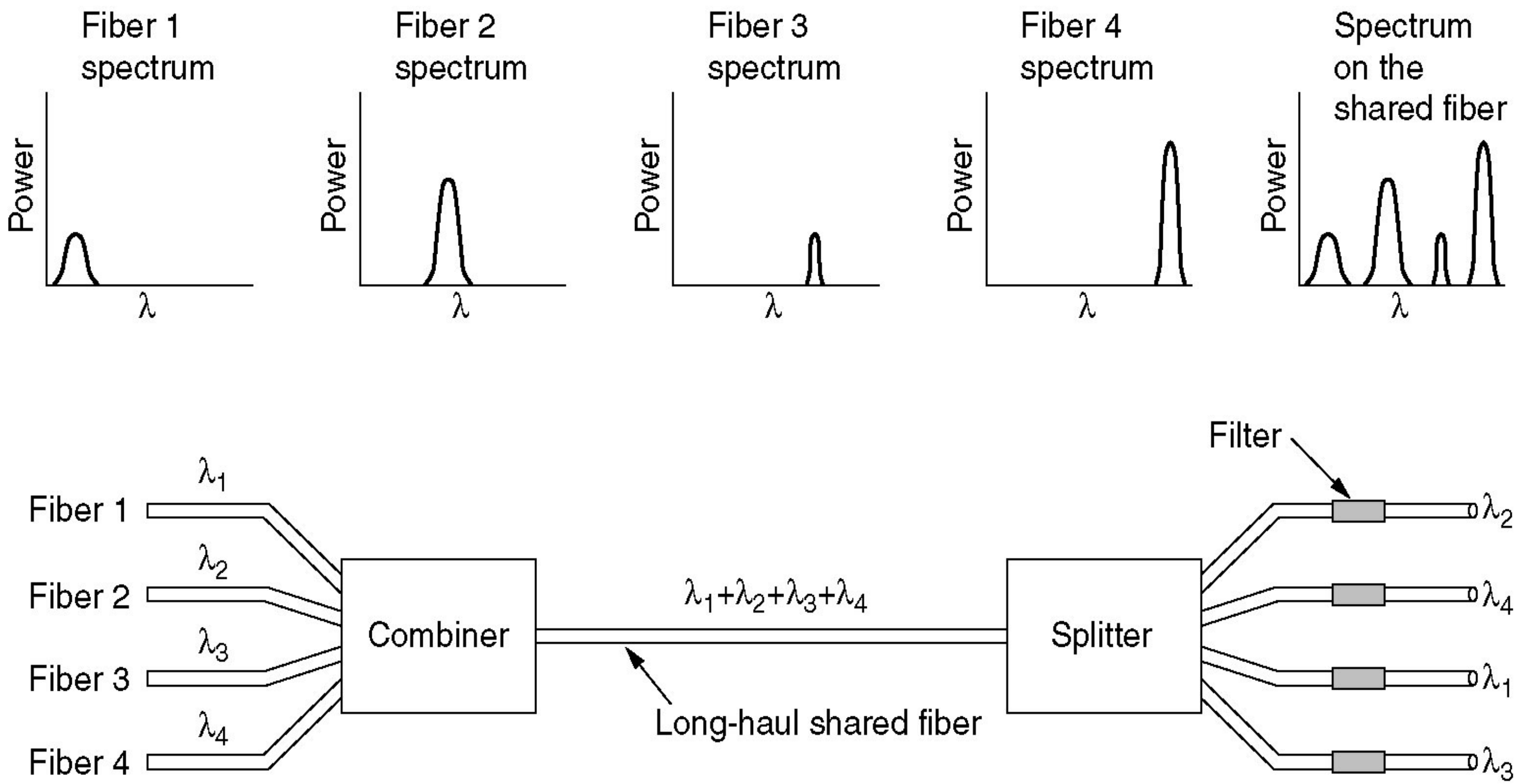


# Frequency-division Multiplexing



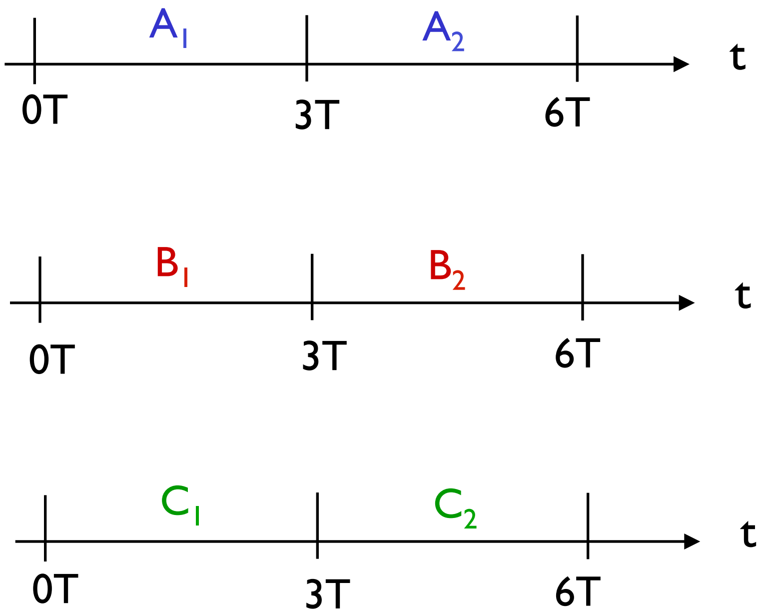

(a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

# Wavelength Division Multiplexing

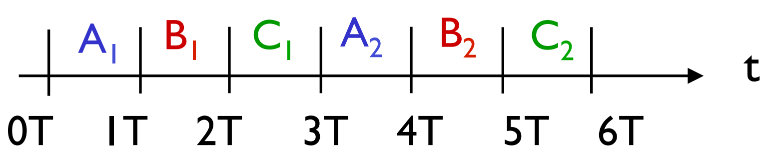


# Time-division Multiplexing

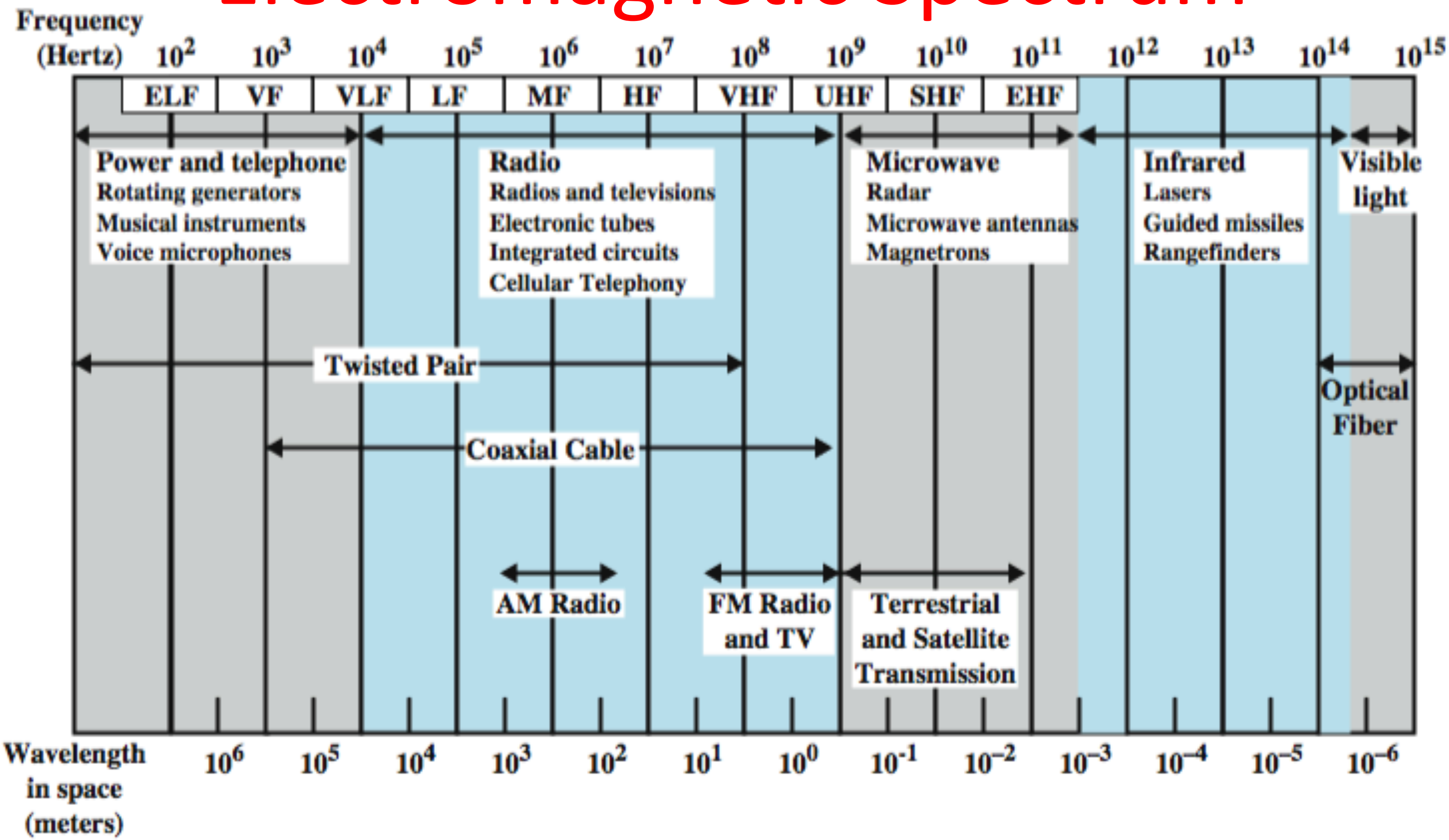
(a) Each signal transmits 1 unit every 3*T* seconds




(b) Combined signal transmits 1 unit every T seconds



# 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

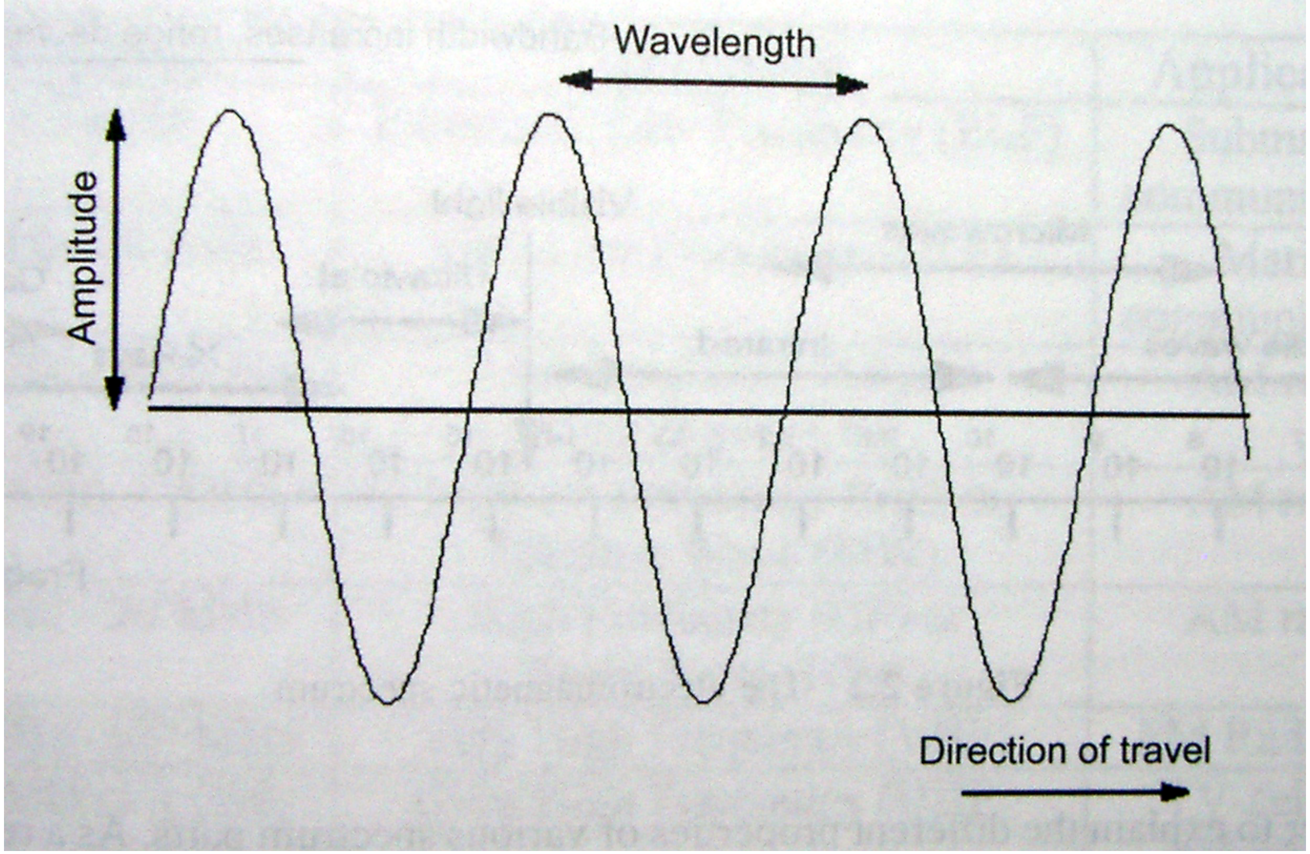
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

# Electromagnetic Waves

- Predicted by British physicist James Maxwell in 1865, and observed by German physicist Heinrich Hertz in 1887
- These waves are created by the movement of electrons and have the ability to propagate through space.
  - using appropriate antennas, transmission and reception of electromagnetic waves through space becomes feasible.
  - the speed of electron vibration determines the wave's frequency.
- Hertz: how many times the wave is repeated in 1 sec. (to honor Heinrich Hertz)

# Wavelength and Amplitude

- l = wavelength, f = frequency, c = speed of light

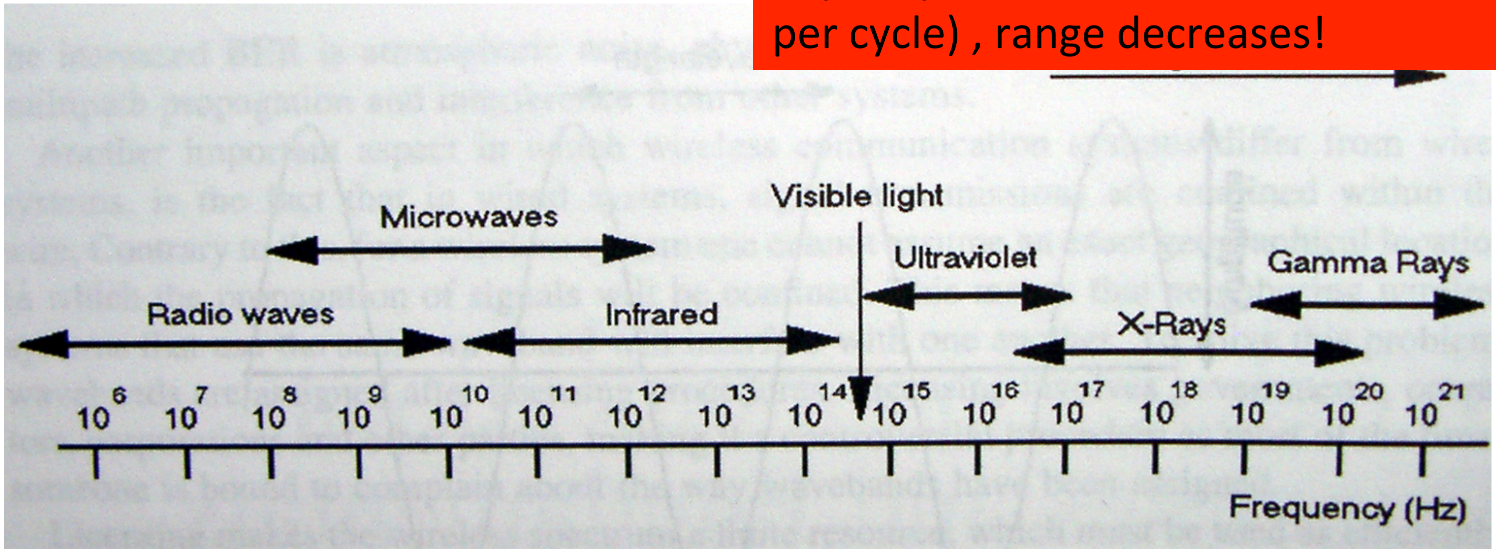



Wavelength and Amplitude of an Electromagnetic wave

# Electromagnetic Spectrum

- spectrum: range of electromagnetic radiation
- band: spectrum parts

Capacity increases (more data to carry per cycle) , range decreases!




The Electromagnetic Spectrum

# Radio and Micro Waves

| Frequency | Band name | Applications |
|---|---|---|
| < 3 KHz | Extremely Low Frequency (ELF) | Submarine communications |
| 3 KHz -30 KHz | Very Low Frequency (VLF) | Marine communications |
| 20 KHz -300 KHz | Low Frequency (LF)or Long Wave (LW) | AM radio |
| 300 KHz -3 MHz | Medium Frequency (MF) or Medium Wave (MW) | AM radio |
| 3 MHz - 30 MHz | High Frequency (HF) or Short Wave (HW) | AM radio |
| 30 MHz -300 MHz | Very High Frequency (VHF) | FM Radio-TV |
| 300 MHz - 3 GHz | Ultra High Frequency (UHF) | TV-cellular telephony |
| 3 GHz - 30 GHz | Super High Frequency (SHF) | Satellites |
| 30 GHz - 300 GHz | Extra High Frequency (EHF) | Satellites-radars |

The various radio bands and their common use

- HF band enables worldwide transmission:
  - HF signals are reflected off the ionosphere and thus can travel very large distances

# Microwaves

- small wavelengths compared to radio waves
- easily attenuated by objects

| Frequency | Band name | Applications |
|---|---|---|
| 0.4 GHz - 1.5 GHz | L | Broadcasting-cellular |
| 1.5 GHz - 5.2 GHz | S | Cellular |
| 3.9 GHz - 6.2 GHz | C | Satellites |
| 5.2 GHz - 10.9 GHz | X | Fixed wireless-satellite |
| 10.9 GHz - 36 GHz | K | Fixed wireless-satellite |
| 36 GHz - 46 GHz | Q | Fixed wireless |
| 46 GHz -56 GHz | V | Future satellite |
| 56 GHz -100 GHz | W | Future cellular |

The various microwave bands and their common use

# Antennas

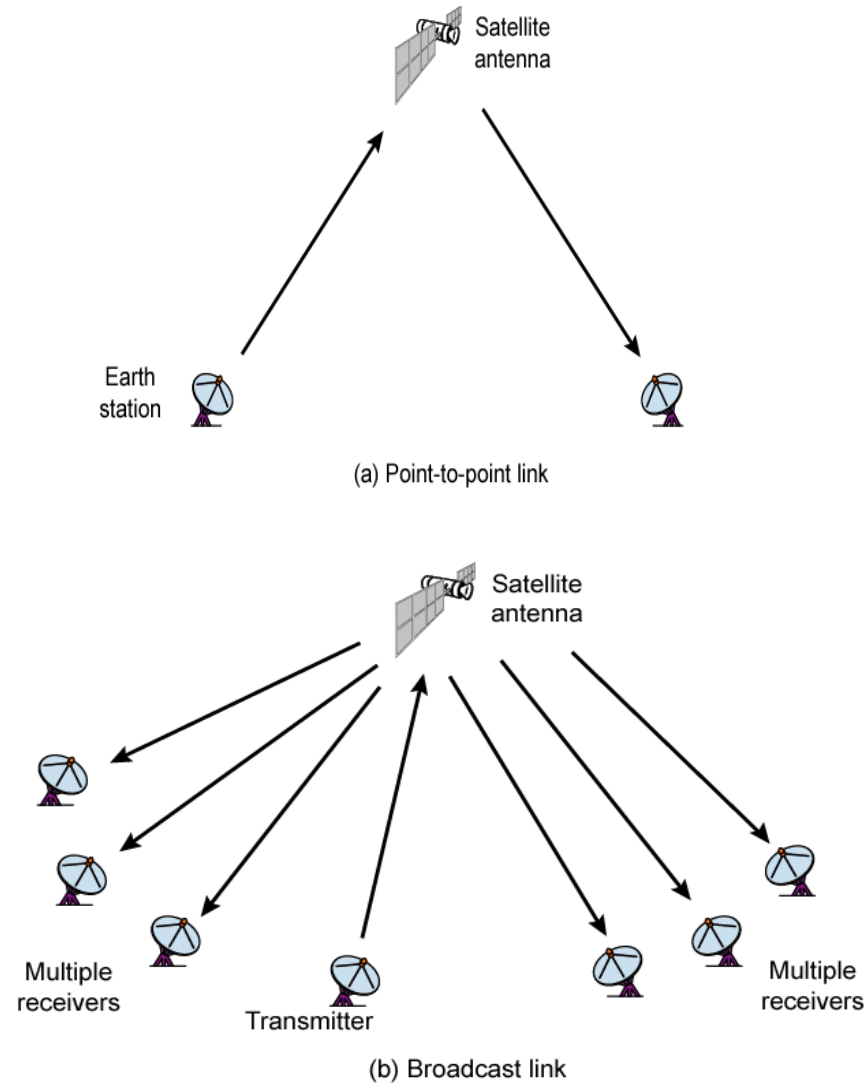
- Electrical conductor (or system of..) used to radiate electromagnetic energy or collect electromagnetic energy
- Transmission
  - Radio frequency energy from transmitter
  - Converted to electromagnetic energy
  - By antenna
  - Radiated into surrounding environment
- Reception
  - Electromagnetic energy impinging on antenna
  - Converted to radio frequency electrical energy
  - Fed to receiver
- Same antenna often used for both

# Terrestrial Microwave

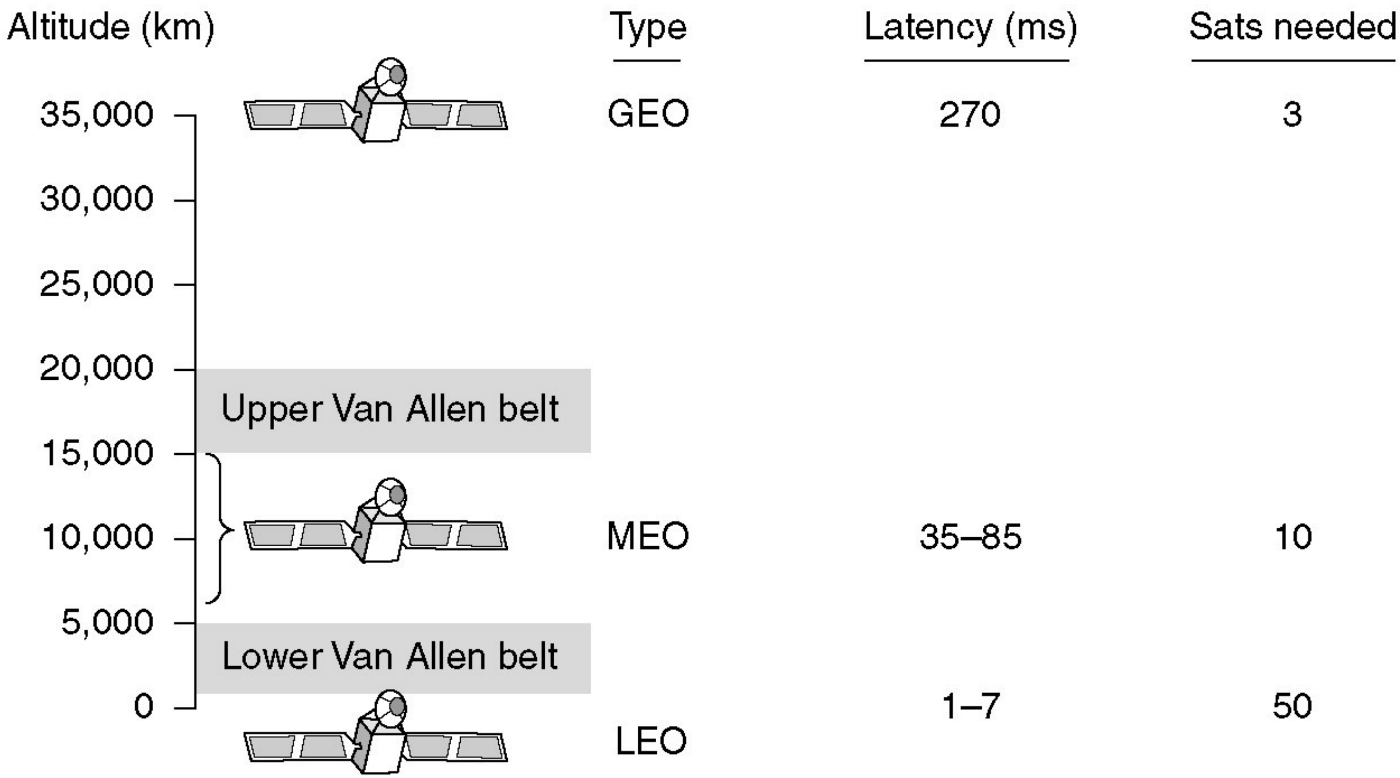
- Parabolic dish
- Focused beam
- Line of sight
- Long haul telecommunications
- Higher frequencies give higher data rates

# Satellite Microwave

- Satellite is relay station
- Satellite receives on one frequency, amplifies or repeats signal and transmits on another frequency
  - Television
  - Long distance telephone
  - Private business networks



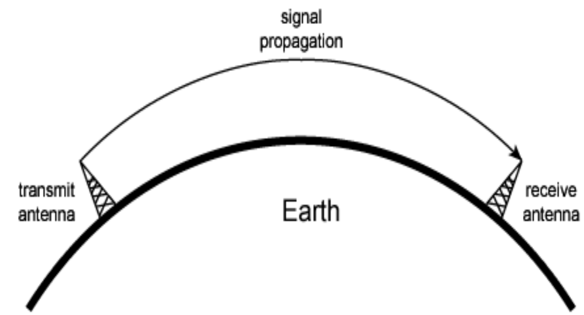
# Communication Satellites



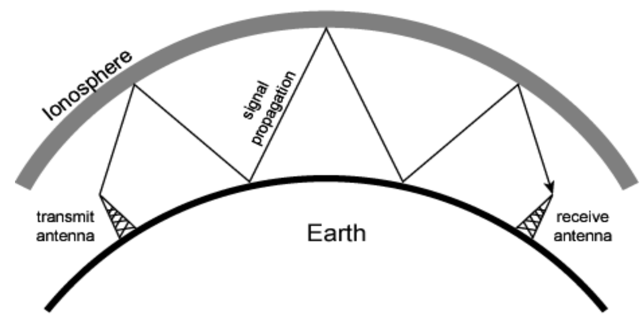

Communication satellites and some of their properties, including altitude above the earth, round-trip delay time and number of satellites needed for global coverage.

# Wireless Propagation

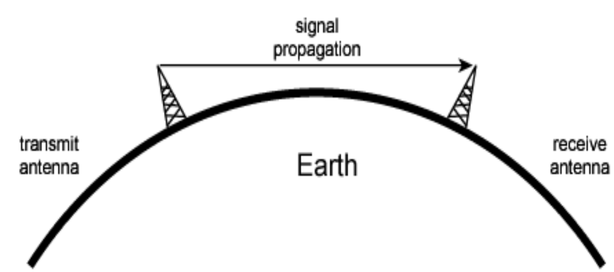
- Signal travels along three routes
  - **Ground wave**
    - Follows contour of earth
    - Up to 2MHz
    - AM radio
  - **Sky wave**
    - Amateur radio, BBC world service, Voice of America
    - Signal reflected from ionosphere layer of upper atmosphere
    - (Actually refracted)
  - **Line of sight**
    - Above 30Mhz
    - May be further than optical line of sight due to refraction




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




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



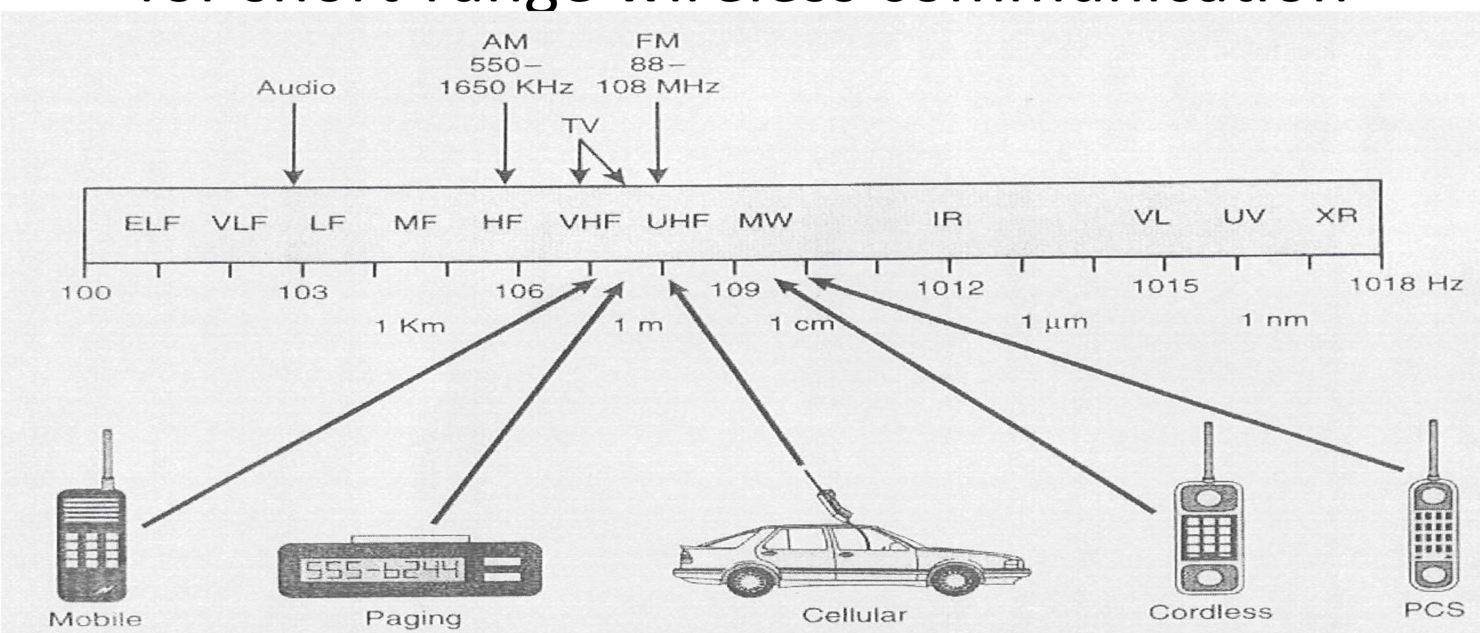

(c) Line-of-sight (LOS) propagation (above 30 MHz)

# Infrared

- emitted by very hot objects
  - such as human body (night vision applications)
  - frequency depends on the temperature of the emitting body
- line-of-sight, point-to-point
  - of no use outdoors (interfered by heat of sun)
- short-rang: 10 meters
- IrDA: Infrared Data Association

# Microwave and Infrared Bands

- Most wireless networking traffic is in the microwave frequency bands.
  - some licensed, some unlicensed
- Infrared:
  - for short-range wireless communication



# Spectrum Regulation

- ITU = Int'l Telecommunications Union
  - a worldwide spectrum regulation org.
  - the world is split into 3 parts:
    - American continent
    - Europe, Africa, and former Soviet union
    - rest of Asia and Oceania
- Rules of assigning spectrum
  - lottery
  - auction
  - comparative bidding
    - such as pricing, technology, etc.

# Licensed Microwave Band

- Examples: cellular, paging, PCS
- Use of a license is typically in an order of 10 years.
  - A company can't have the license and not use it.
  - Bandwidth is regarded as a resource that the public wants and needs.

# Unlicensed Microwave Band

- Also on the same microwave band, but no license required.
  - To avoid interfering primary (licensed) users, spreading spectrum is required.
- Also known as ISM band.
  - industrial, scientific, and medical
  - WiFi!

# Model of Wireless Propagation

Free space path loss

Slow/fast fading

# Shannon's Formula (Recap)

- an upper bound on the bit rate W of any channel of bandwidth H Hz:

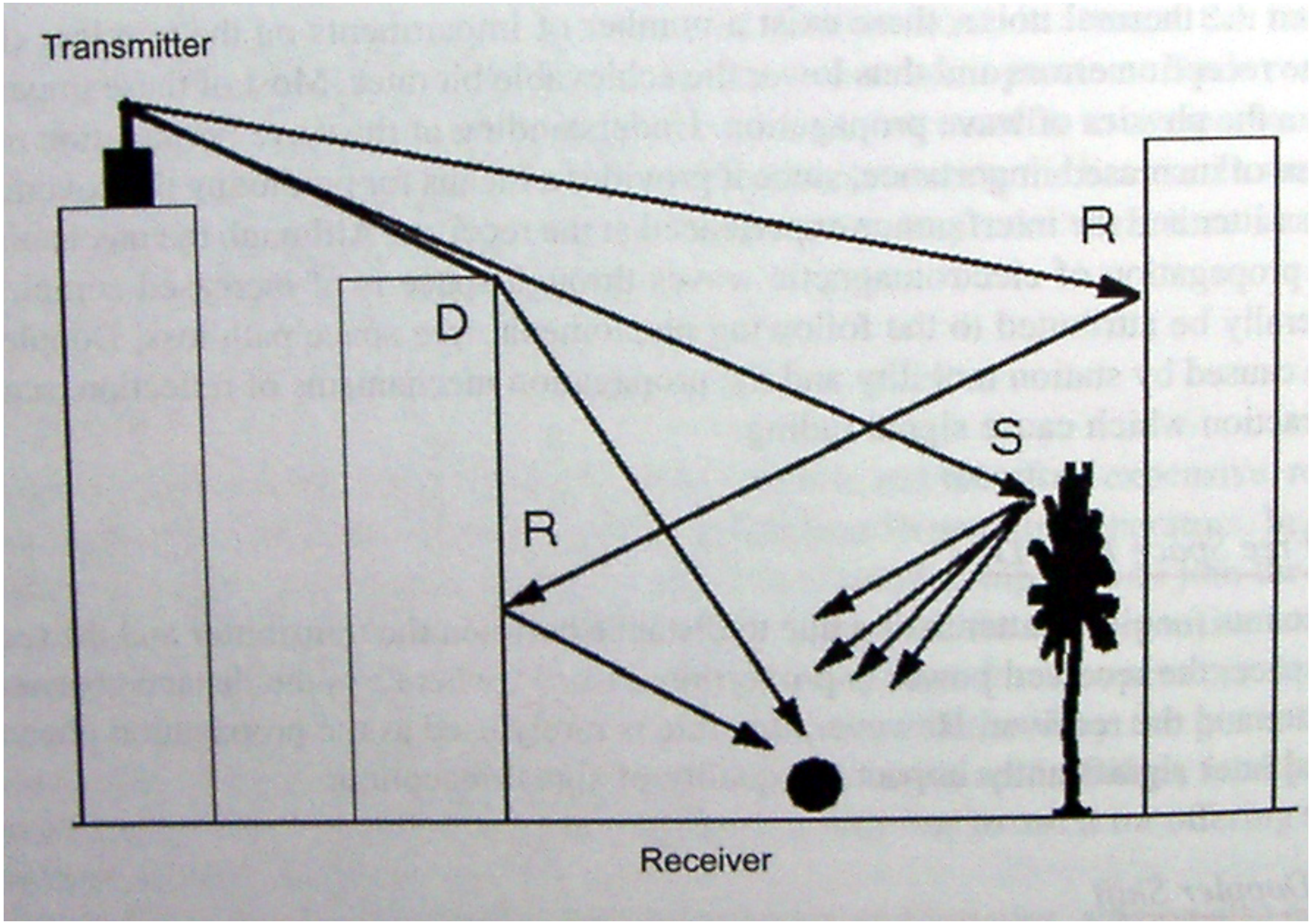
  $W = H \log_2(1 + S/N)$

  S/N = signal to thermal noise ratio
- However, in real world, the upper bound is difficult to achieve due to:
  - free space path loss
    - proportional to $r^{-2}$, where r is the distance between transmitter and receiver (sometimes at higher exponent)
  - Doppler shift
    - a signal transmitter and receiver are moving relative to one another
  - slow/fast fading

# Definitions

- Reflection:
  - when an electromagnetic wave falls on an object with dimension <u>very large</u> compared to the wave's wavelength
- Scattering:
  - when obstructed by objects with dimensions <u>in the order of the wavelength</u>
- Diffraction (or shadowing):
  - when the wave falls on an <u>impenetrable object</u>
  - in which case, the <u>secondary waves</u> are formed behind the obstructing body

# Slow Fading




Reflection (R), Diffraction (D), Scattering (S)

# Fast Fading: Multipath Effect

- waves traveling along different paths may be completely out of phase when they reach the antenna (thereby canceling each other)

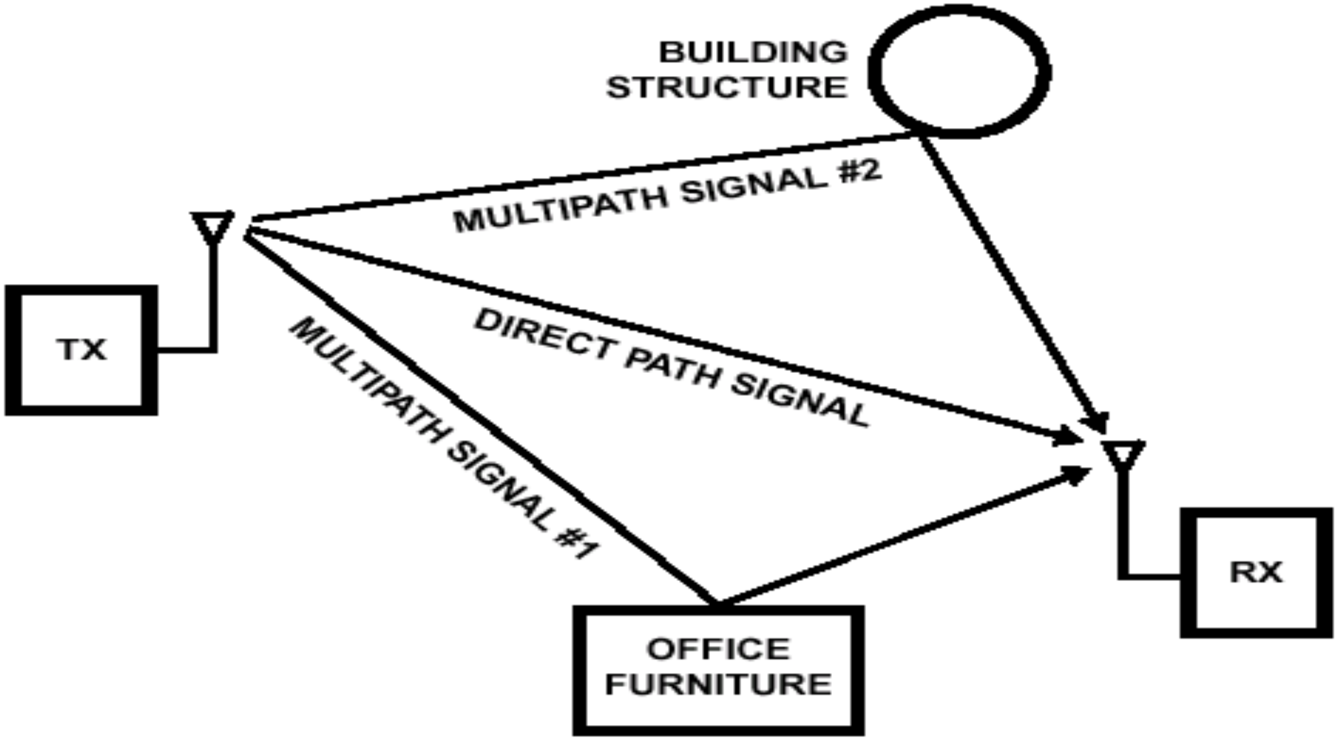
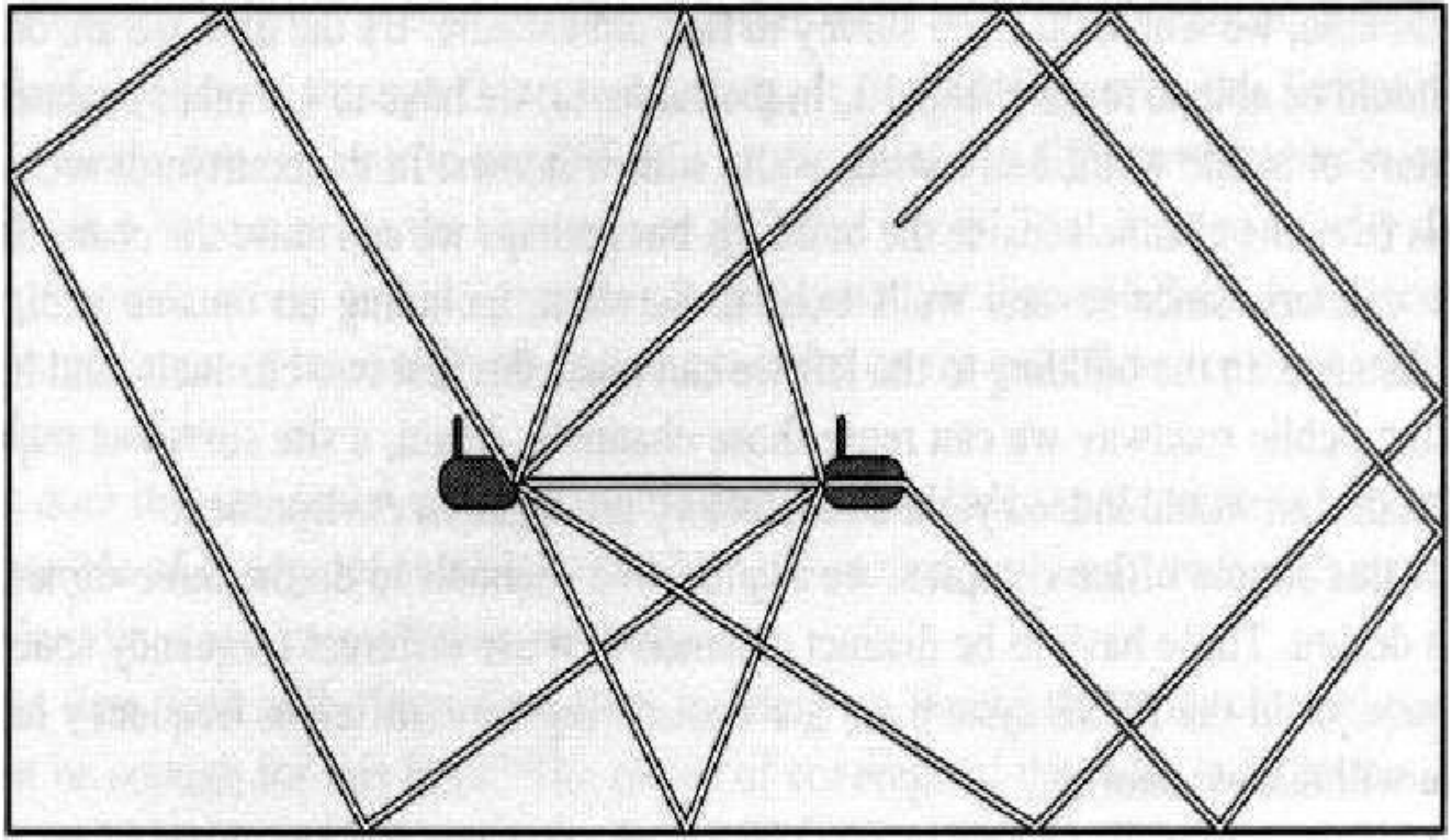



FIGURE 2.  MULTIPATH



Multipath example indoors.