Introduction to LAN/WAN

Physical Layer

Topics

- ☞ Introduction
- ☞ Theory
- ☞ Transmission Media

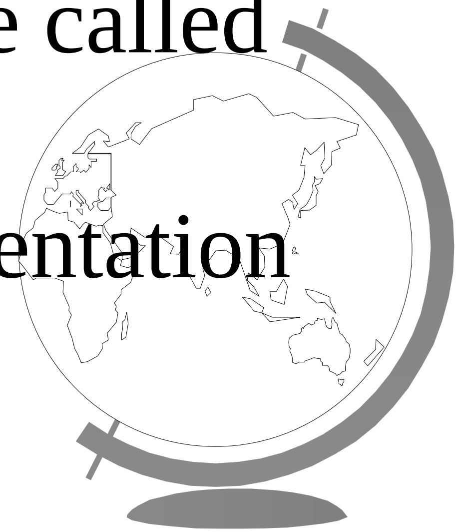
Purpose of Physical Layer

- ☞ Transport bits between machines
  - – How do we send 0's and 1's across a medium?
  - – Ans: vary physical property like voltage or current
- ☞ Representing the property as a function of time
  - – analyze it mathematically
- ☞ Does the receiver see the same signal generated by the sender?
  - – Why or why not?

Theoretical Basis

- 19th century: Fourier Analysis (eq 2-1)
- Any periodic function can be represented by a series of `sines` and `cosines`
- Treat bit pattern as periodic function

  ex - `01100010`
- co-efficients to summation terms are called *harmonics*
- More harmonics mean closer representation



Transmit

- Harmonics
  - *attenuate* (weaken)
  - *distortion* unevenly
  - *spectrum* (cutoff)
- Signal can have more than 1 bit
  - several volt levels
- Can calculate max. data rates based on channel parameters

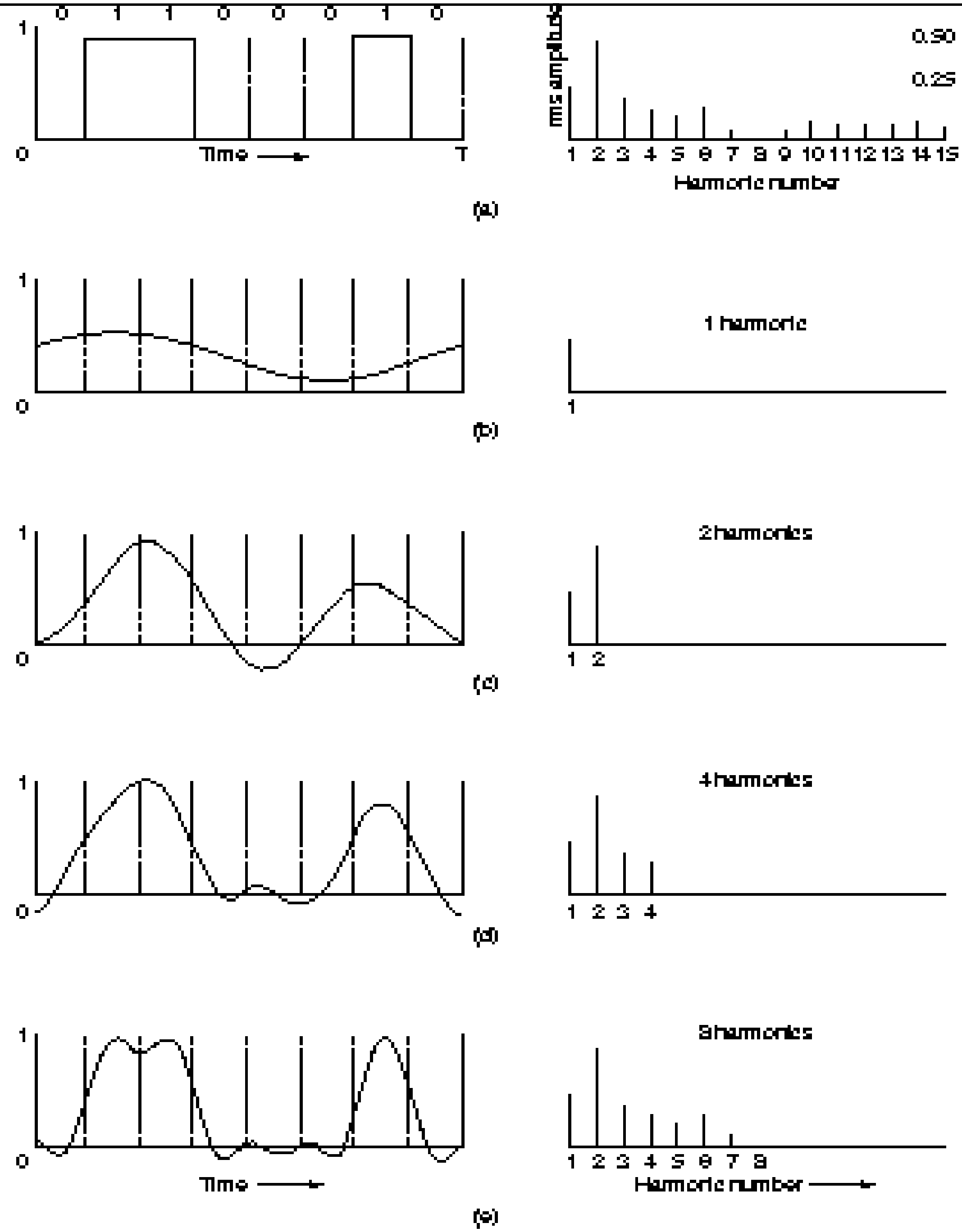


Fig. 2-1. (a) A binary signal and its root-mean-square Fourier amplitudes. (b)-(e) Successive approximations to the original signal.

Maximum Data Rate of Channel

- Nyquist's Theorem:

  max data rate = $2H\log_2 V$ bits/sec
  - H is filter bandwidth
  - V discrete levels
- example: noiseless 3000 Hz line (phone)
  - 6000 bps max, with 2 levels
- only need to sample at $2H$, to get all
- noise on channel?

Noise on Channel

- Every channel has background noise
  - *Thermal noise* from agitation of electrons in a conductor. Uniform. “White noise.”
  - *Intermodulation noise* different frequencies share the same medium
  - *Crosstalk noise* results from coupling signal paths
    - Ex: Other conversation (faintly) on a telephone
  - *Impulse noise* from sharp, short-lived disturbances
    - Ex: from lightning
- Measure (or quantify) background noise?

Max Data Rate with Noise

- *signal-to-noise* ratio (S/N)
  - use $10 \log_{10}$ S/N (*decibels*, *dB*)
  - ex: S/N = 100 then 20 dB
- Shannon's theorem:

  max data rate = $H\log_2(1+S/N)$ bits/sec
  - ex: 3000 Hz, 30 dB noise (typical phone)
  - max is 30 Kbps!
- Modems use compression

Summary

- ☞ Nyquist gives upper bound on sampling
- ☞ Nyquist gives max data rate for noiseless channel
  - – can always increase by increasing signal levels
- ☞ Shannon gives max data rate for channels with noise
  - – independent of signal levels!

Transmission Media

- Two types:
  - Guided (a physical path)
  - Unguided (waves propagated, but not in a directed manner)

Magnetic Media

☞ Put files on tape, floppy disks, …

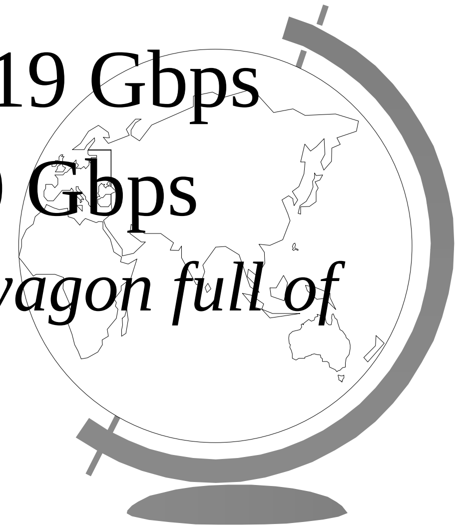
☞ Physically carry ("Sneaker Net")

☞ Example

- Ultrium tape holds 200 gigabytes (Gb)
- 1 byte = 8 bits
- Assuming a box holds 1000 tapes
- 24 hour delivery via FedEx
- = 1000 x 200 Gb * 8 / (24 * 3600) = 19 Gbps
- If delivered in hour, bandwidth = 400 Gbps

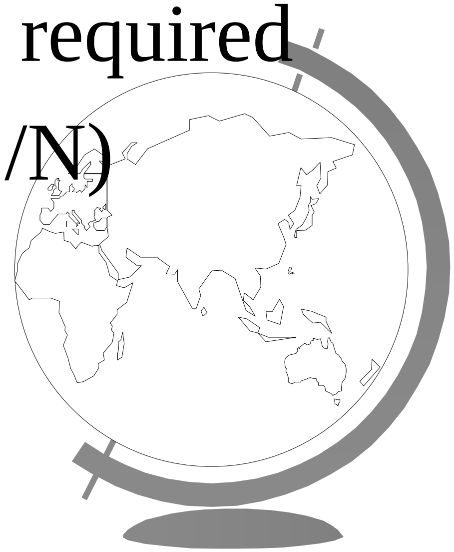
Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway

☞ High delay in accessing data



Twisted Pair

- ☞ Two copper wires are strung between sites
- ☞ “Twisted" to reduce interference
- ☞ Can carry analog or digital signals
- ☞ Distances of several kilometers
- ☞ Data rates of several Mbps common
  - – attenuation occurs so repeaters may be required
  - – shielding to eliminate noise (impacts S/N)
- ☞ Good, low-cost communication
  - – existing phone lines!



Coaxial Cable

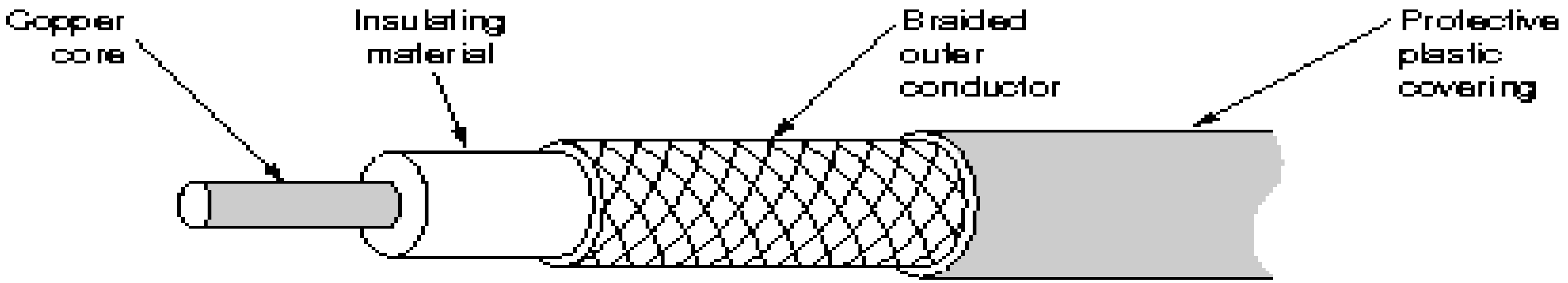


Fig. 2-3. A coaxial cable.

- Copper core, insulating material ("coax")
- *Baseband* means in the voice range
- *Broadband* means move to much higher frequencies by introducing a carrier
  - telephone folks mean wider than 4 kHz
- To connect, need to touch core:
  - *vampire taps* or *T junction*
- 10 Mbps is typical

Evaluation of Broadband vs. Baseband

- Which is better, broadband or baseband?
- Baseband:
  - simple to install
  - interfaces are inexpensive
  - short range
- Broadband:
  - more complicated
  - more expensive
  - more services (can carry audio and video)

Fiber Optics

- ☞ Hair-width silicon or glass
- ☞ Signals are pulses of light (digital)
  - – Ex: pulse means “1”, no pulse means “0”
- ☞ Glass “leaks” light?

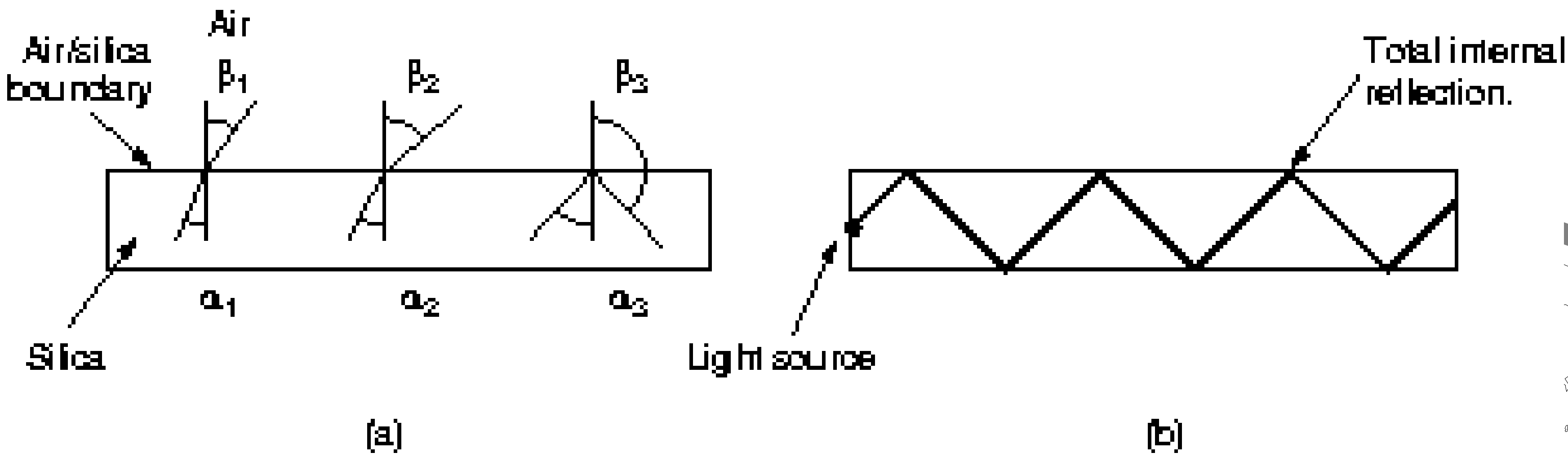
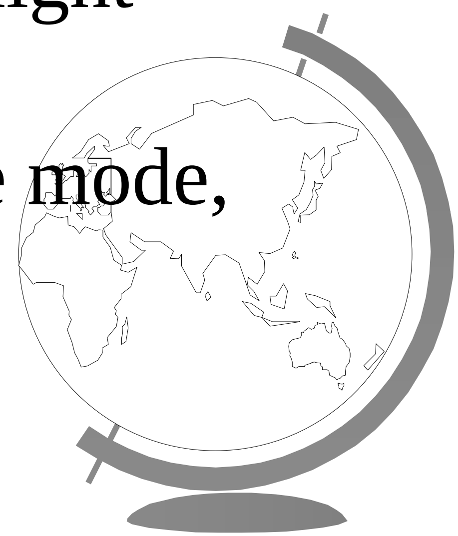


Fig. 2-5. (a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles. (b) Light trapped by total internal reflection.

Fiber Optics

- Three components required:
  - Fiber medium: 100s miles, no signal loss
  - Light source: Light Emitting Diode (LED), laser diode
    - current generates a pulse of light
  - Photo diode light detector: converts light to electrical signals
- Wide fiber = many diff. Wavelengths of light (multimode fiber)
- Narrow fiber = only 1 wavelength (single mode, better)



Fiber Optics

- Advantages
  - Huge data rate (1 Gbps), low error rate
  - Hard to tap (leak light), so secure (hard w/coax)
  - Thinner (per logical phone line) than coax
  - No electrical noise (lightning) or corrosion (rust)
- Disadvantages
  - Difficult to tap, really point-to-point technology
    - training or expensive tools or parts are required
  - One way channel
    - Two fibers needed for *full duplex* communication

Fiber Uses

- ☞ long-haul trunks--increasingly common in telephone network (Sprint ads)
- ☞ metropolitan trunks--without repeaters (have 8 miles in length)
- ☞ rural exchange trunks--link towns and villages
- ☞ local loops--direct from central exchange to a subscriber (business or home)
- ☞ local area networks--100Mbps ring networks

Wireless Transmission

- ☞ 1870's: moving electrons produce waves
  - – *frequency* and *wavelength*
- ☞ Attach antenna to electrical circuit to send

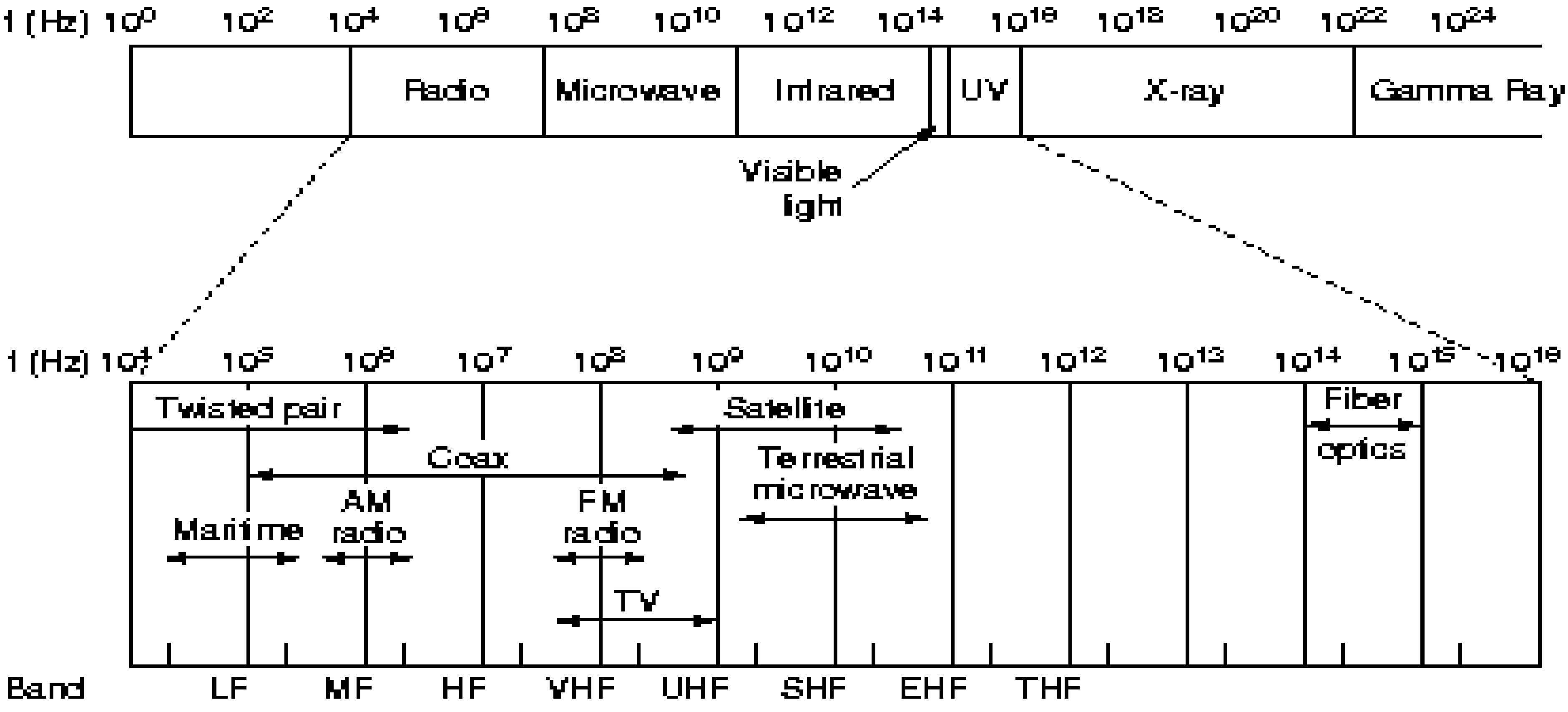


Fig. 2-11. The electromagnetic spectrum and its uses for communication.

Radio Waves

- Easy to generate, travel far, through walls
- Low bandwidth
- Low radio freqs follow earth
- High freqs travel in straight lines, bounce off obstacles
- Restricted use by regulation

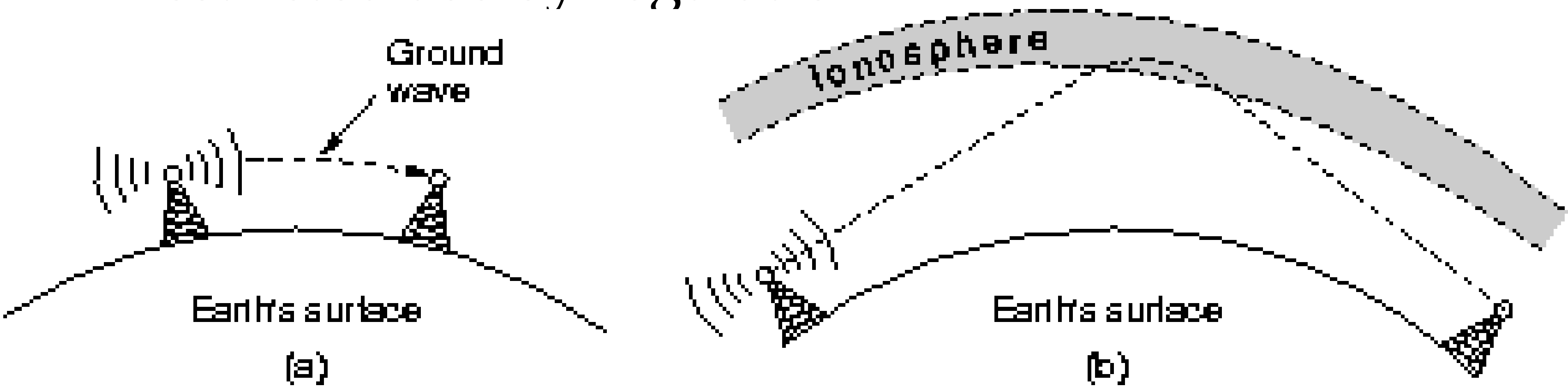
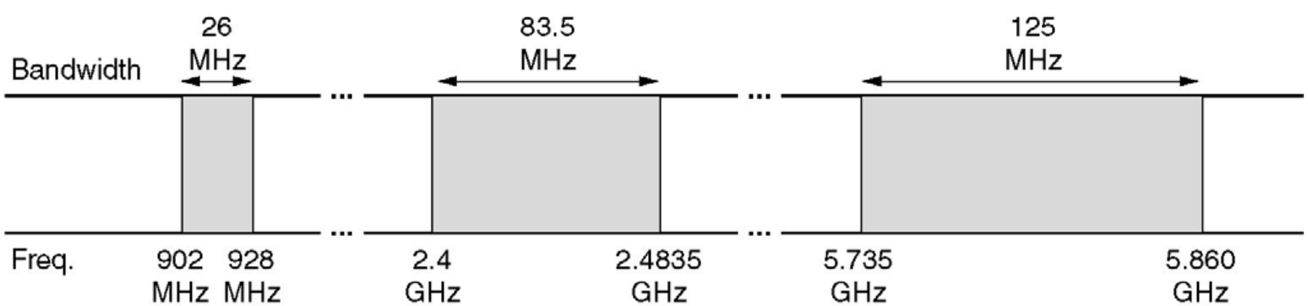
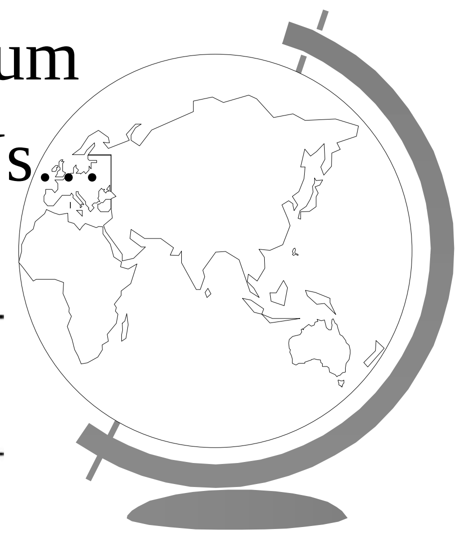


Fig. 2-12. (a) In the VLF, VF, and MF bands, radio waves follow the curvature of the earth. (b) In the HF they bounce off the ionosphere.

Microwave Transmission

- Tight beam, (dish plus transmitter)
- Blocked by walls, absorbed by water (rain)
- Need repeaters (earth’s curvature)
- Inexpensive (buy land and voila! MCI)
- Used extensively: phones, TV …
  - shortage of spectrum!
- Industrial/Scientific/Medical bands
  - not govt regulated but must use spread spectrum
  - cordless phones, garage doors, Wireless LANs…





Infrared Transmission

- ☞ Short range
- ☞ Cheap
- ☞ Line-of-Sight: Not through objects
- ☞ Used for remote controls (VCR …)
- ☞ Maybe indoor LANS, but not outdoors

Lightwave Transmission

- not good in rain or fog
- Heat can affect transmission
- need very tight focus

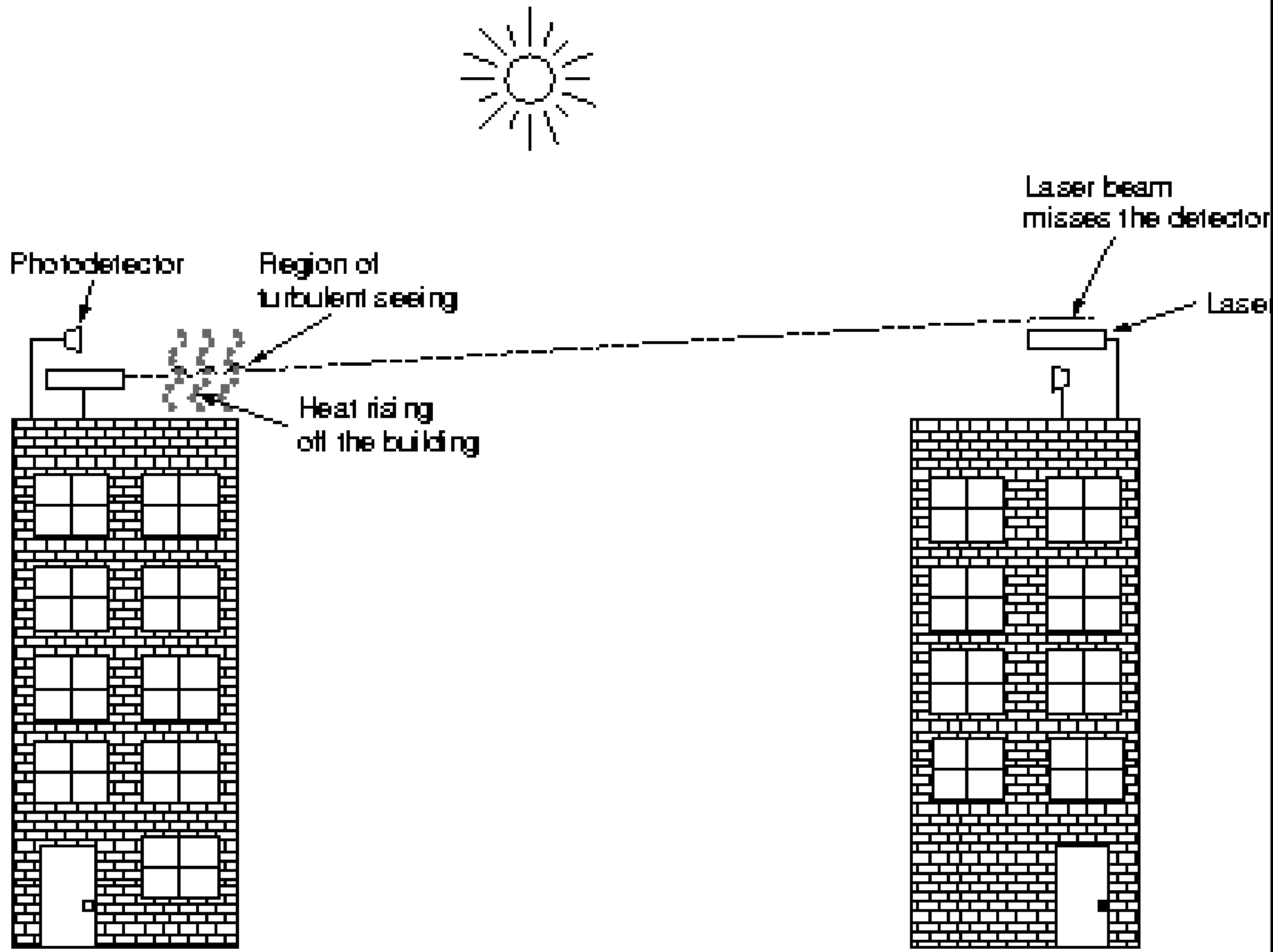


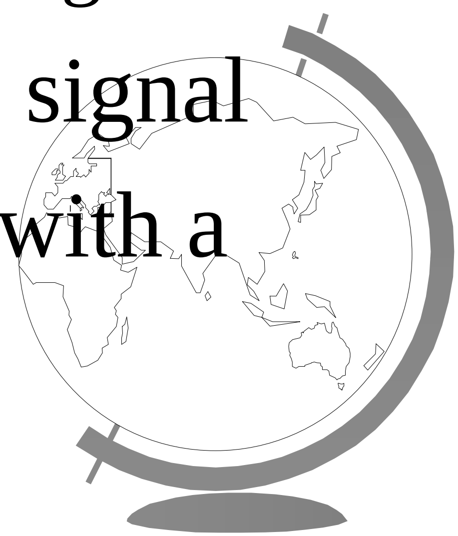
Fig. 2-13. Convection currents can interfere with laser communication systems. A bidirectional system, with two lasers, is pictured here.

Satellites

- ☞ Satellite typically in geosynchronous orbit
  - – 36,000 km above earth;
  - – satellite never "moves" (Geostationary)
  - – 2 deg. separation at equator: only about 180 are possible
- ☞ Satellite typically a repeater
- ☞ Satellite broadcasts to area of earth
- ☞ International agreements on use (ITU)
- ☞ Weather effects certain frequencies
- ☞ One-way delay of 250ms !
- ☞ VSATs: new development

Comparison of Satellite and Fiber

- Propagation delay very high
- One of few alternatives to phone companies for long distances
- Uses broadcast technology over a wide area
  - everyone on earth could receive a message!
- Easy to place unauthorized taps into signal
- Fiber tough to building, but anyone with a roof can lease a satellite channel.



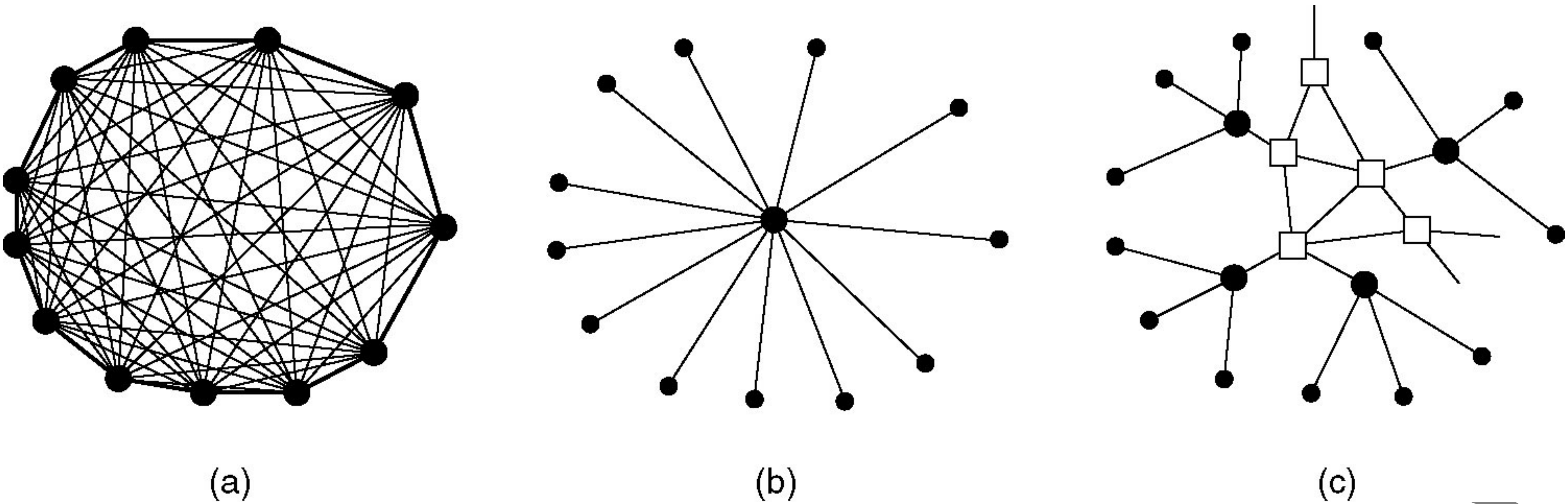
Analog vs. Digital Transmission

- Compare at three levels:
  - Data--continuous (audio) vs. discrete (text)
  - Signaling--continuously varying electromagnetic wave vs. sequence of voltage pulses.
  - Transmission--transmit without regard to signal content vs. being concerned with signal content.

Shift towards digital transmission

- ☞ improving digital technology
- ☞ data integrity.
- ☞ easier to multiplex
- ☞ easy to apply encryption to digital data
- ☞ better integration :voice, video and digital data.

Structure of the Telephone System



(a) Fully-interconnected network.
(b) Centralized switch.
(c) Two-level hierarchy.

Major Components of the Telephone System

- Local loops
  - Analog twisted pairs going to houses and businesses
- Trunks
  - Digital fiber optics connecting the switching offices
- Switching offices
  - Where calls are moved from one trunk to another

Analog Transmission

- Phone System
  - Local phones are connected to a central office over a 2-wire circuit, called local-loop
  - Today analog signal is transmitted in local-loop

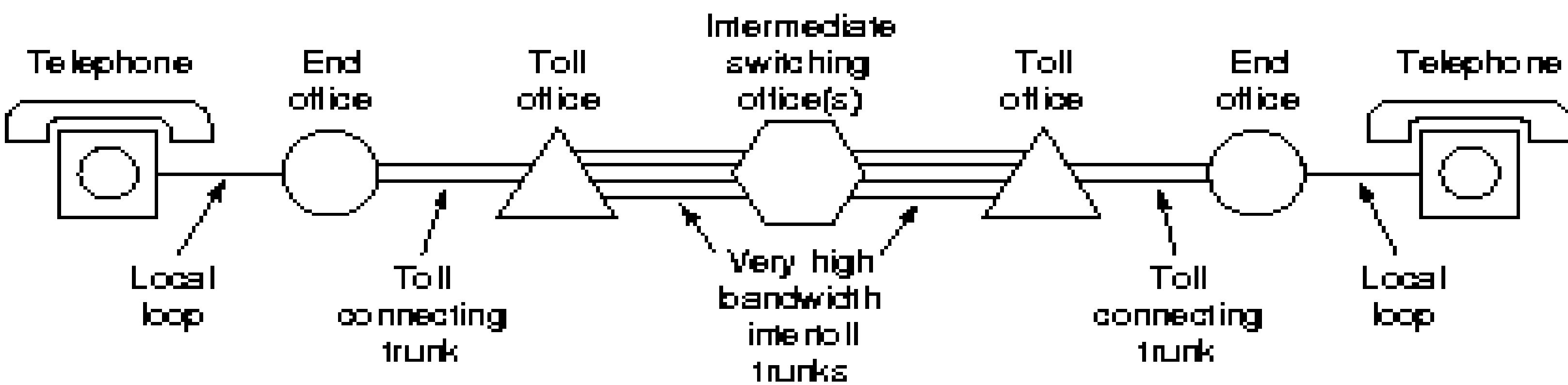
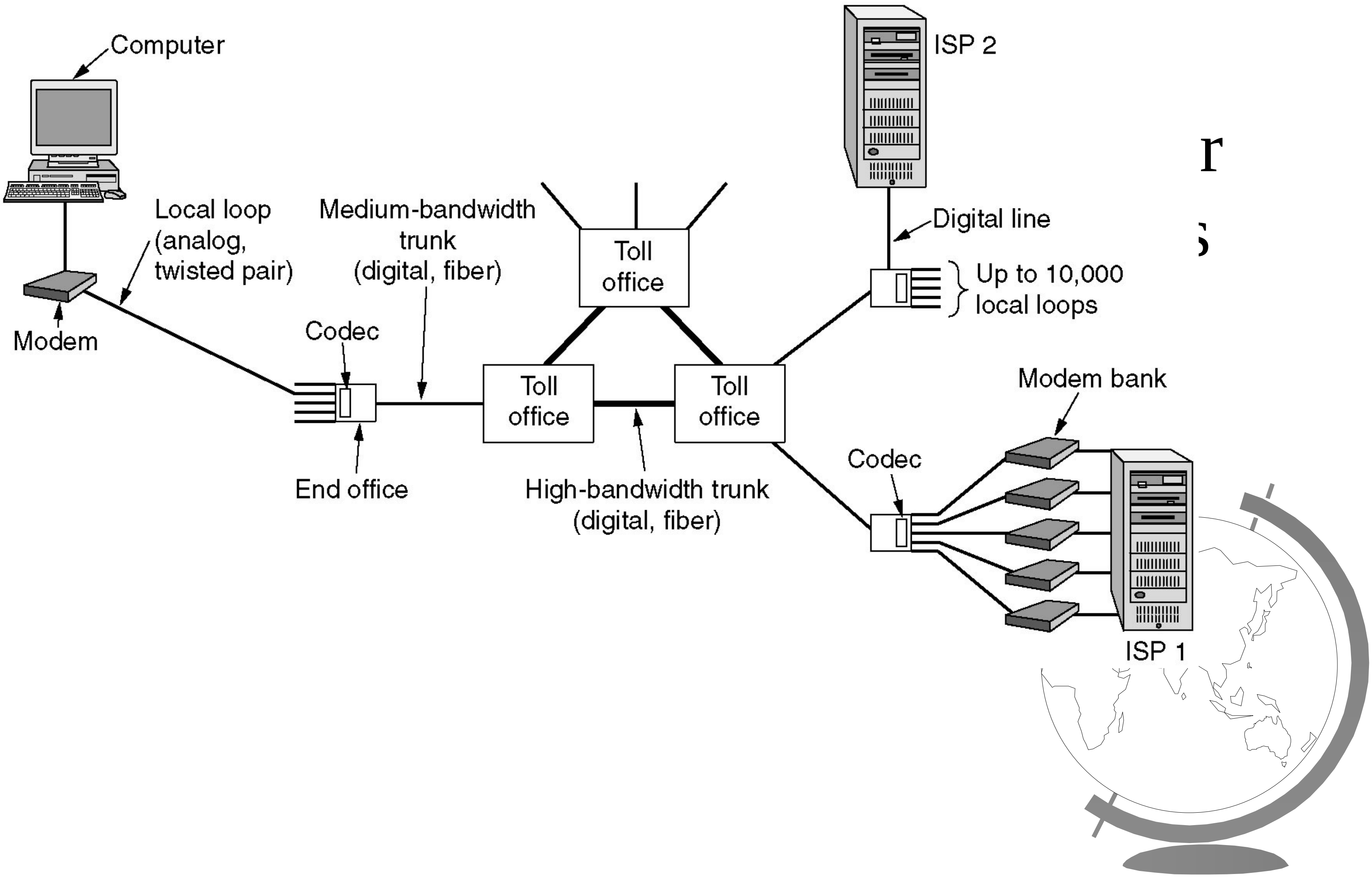


Fig. 2-15. Typical circuit route for a medium-distance call.

The Local Loop: Modems, ADSL, and Wireless



Digital Data/Analog Signals

- Local loop still analog
- Must convert digital data to analog signal before be transmitted
- Modem(Modulator & Demodulator) (Fig 2-17)

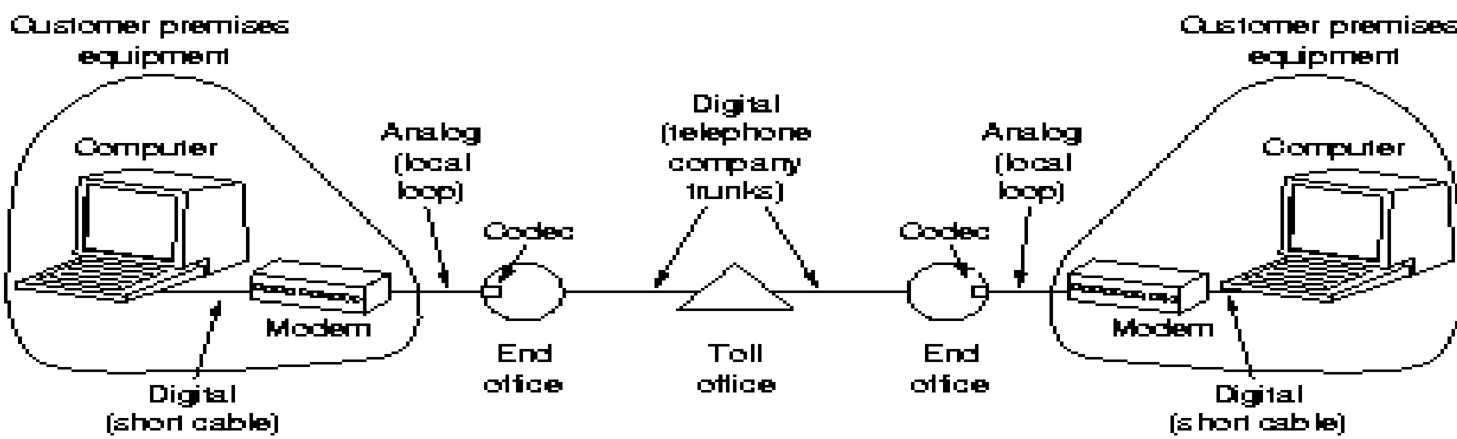


Fig. 2-17. The use of both analog and digital transmission for a computer to computer call. Conversion is done by the modems and codecs.