CIS 375
CHAPTER 3

Physical Layer

Outline

- Circuits
- Communication Media
- Data Types
- Data Transmission & Transmission Flaws
- Structured Cabling
- Implications for Cyber Security

Circuits

- What is a circuit?

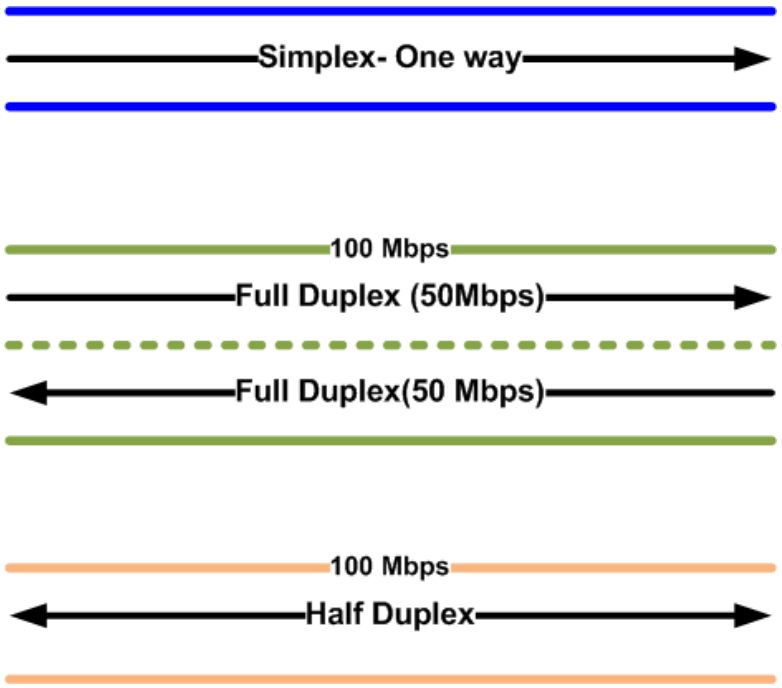
- The word “circuit” can refer to 2 different things:
  - Logical
  - Physical

- Dedicated Circuit
  - Point-to-Point

- Shared Circuit
  - Multipoint

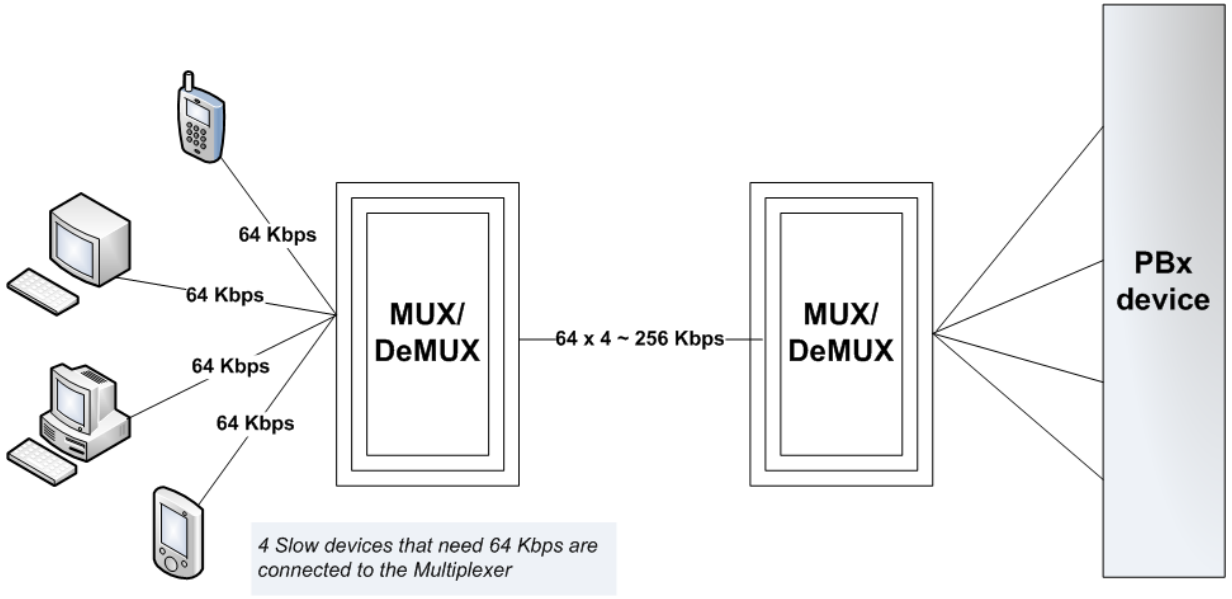
Data Flow

- Simplex
- Half Duplex
- Full Duplex



Multiplexing (MUX)

- Multiplexing = break one high-speed physical circuit into several lower-speed logical circuits

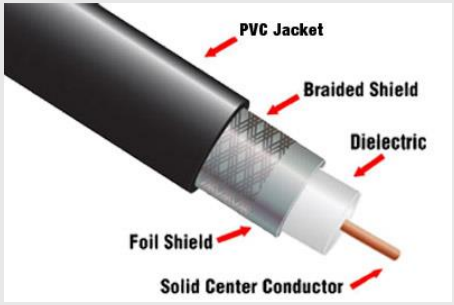
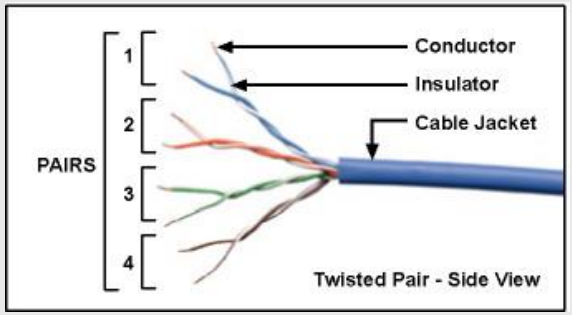
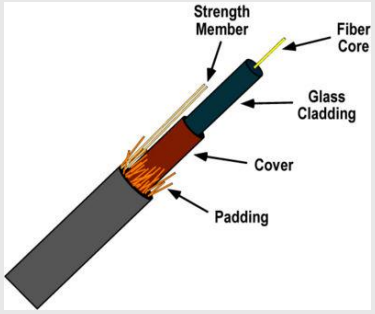


- Categories of Multiplexing
  - Frequency/Wavelength Division
  - Time Division

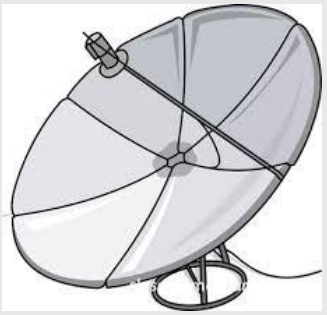
Communication Media

- Media
  - Guided Media
  - Wireless
- Common media characteristics:
  - Throughput
  - Cost
  - Noise immunity
  - Size & scalability
- Types

Guided Media

Characteristic	Coaxial Cable	Twisted Pair	Fiber Optic Cable
Description	1970s LAN	4 color coded pairs of wire TIA/EIA 568 B STP or UTP	Glass, plastic cladding Reflects LASER/LED Multimode/singlemode
Connectors	BNC	RJ-45	ST, SC, LC, HT-RJ
Throughput	10 Mbps	10 Mbps, 100 Mbps, 1 Gbps	> 1 Gbps
Cost	$0.2 / foot	$0.1 - $0.2 / foot	$36 - $50 / foot
Noise immunity	Highly resistant to noise	STP better than UTP	Unaffected by EMI
Size & Scalability	10 Base 2 thin-net 200m 10 Base 5 thick-net 500m	100m	10 Base F 200m Others 150m – 4km
Image			

Radiated Media

Characteristic	Wireless	Microwave	Satellite	Infrared
Description	Radio LAN; 2.46 & 5 GHz	WAN; 3.5 & 4GHz	WAN; 10 GHz	WAN; 30 THz
Throughput	Up to 200 Mbps	Up to 70 Mbps	1 Mbps	115 Kbps, 1.15 Mbps, 4 Mbps
Cost	Low	Moderate	High	Low
Noise immunity /Problems	Security	Atmospheric/ obstacle interference	Significant delay in data transmission	Obstacle interference
Size & Scalability	Up to 100m	25-30 mile radius	500 miles	Short
Image				

Media

- Physical matter used to carry voice or data transmissions
- **Guided media** – transmission flows along physical medium
- **Wireless (Radiated) media** - transmission flows through the air

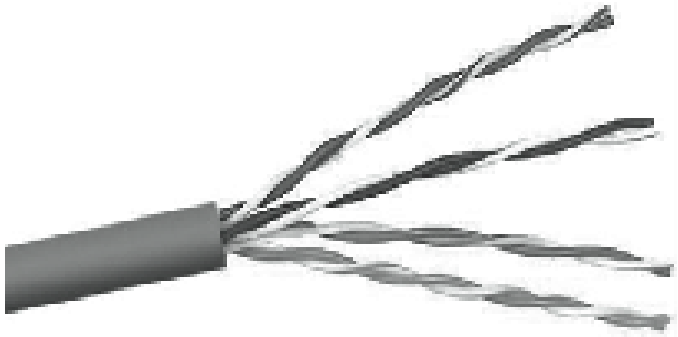
Guided Media

- Twisted-pair (TP) cable
  - Insulated pairs of wires bundled together
  - Wires twisted to reduce electromagnetic interference
  - Some times use additional shielding (STP)
  - Commonly used for telephones, LANs
  - Characteristics
    - Price – inexpensive
    - Distance – typically up to 100m
    - Use - Telephones, LANs

FIGURE 3-5

Category 5e twisted pair wire

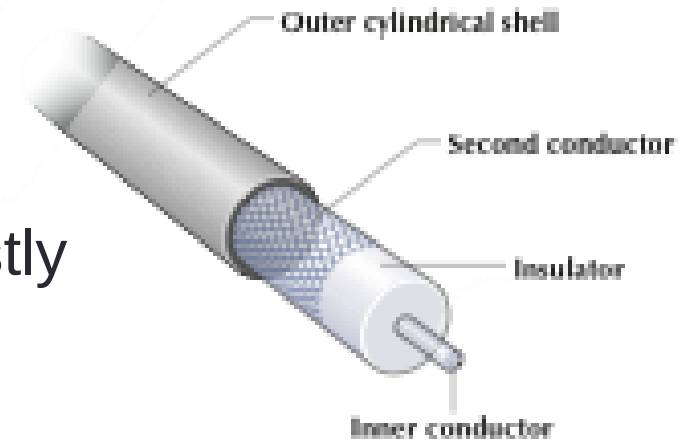
Source: Courtesy of Belkin International, Inc.



Guided Media

- Coax cable
  - Has a single copper core, plus outer insulation, shielding, and inner insulation
  - Less prone to interference
  - Characteristics
    - Price - inexpensive (but more costly than TP)
    - Distance - up to 2 km (1.2 miles)
    - Use: Cable TV / Internet

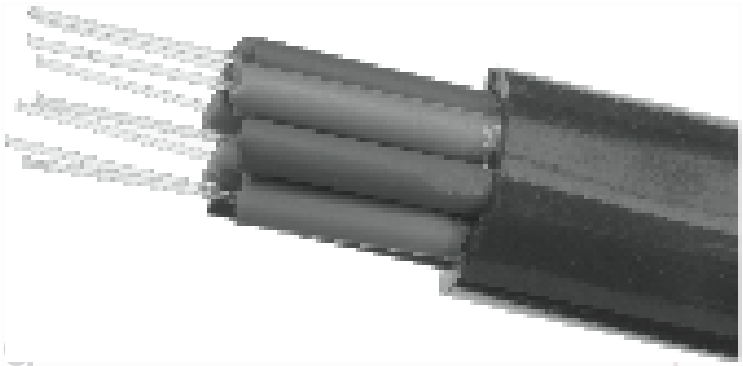
Source: Courtesy of Tim Kloske



Guided Media

- Fiber optic cable
  - Optical core made of glass or plastic
  - Data transmitted using light from lasers or LEDs
  - Resistant to interference and corrosion
  - Extremely fast data rates
  - Characteristics
    - Price: Expensive
    - Distance: 500m – 100km
    - Use: Trunk line / Backbone, long distance circuits (e.g., undersea cables)

Source: © Hugh Threlfall/Alamy



Guided Media

- Fiber optics
  - Multimode (about 50 micron core)
  - Graded index multimode
  - Single mode (about 5 micron core)

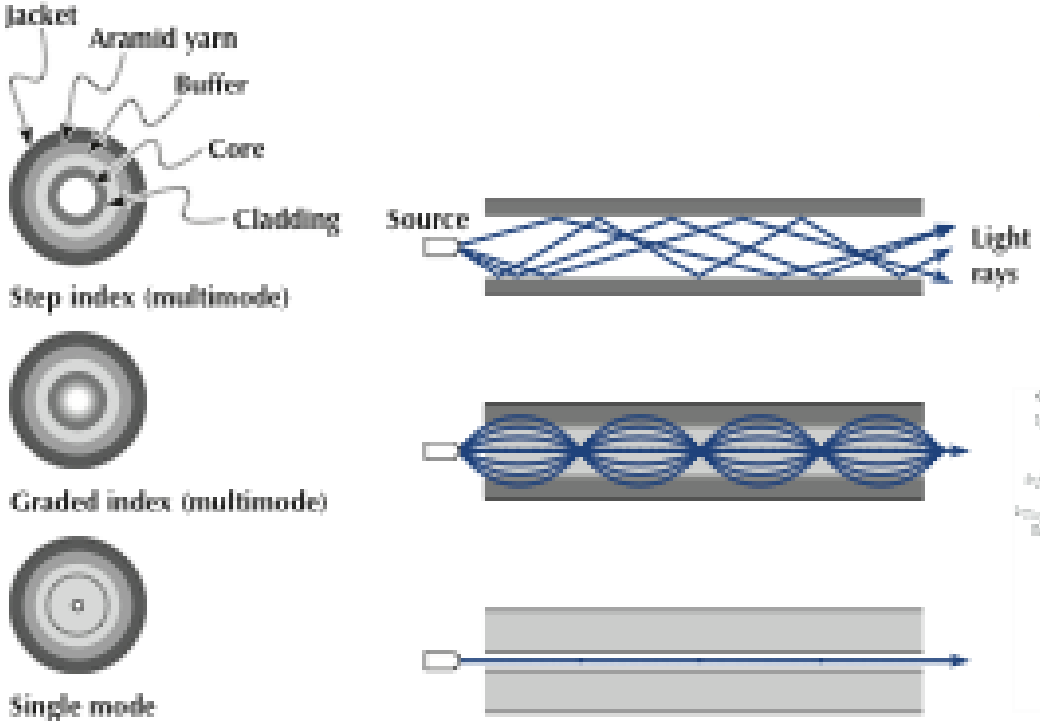
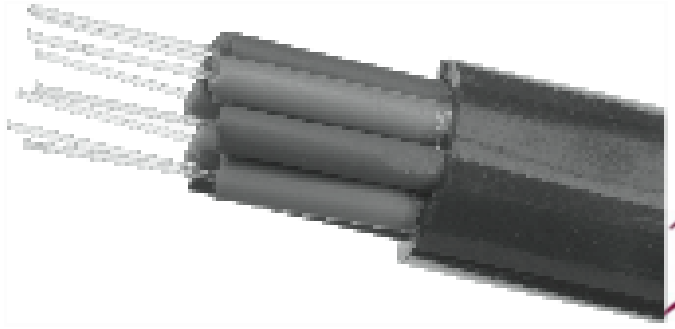


FIGURE 3-7 Fiber-optic cable

Source: © Hugh Threlfall/Alamy



Wireless Media

- Radio
  - Wireless transmission of electrical waves through air
  - Each device on network has a radio transceiver operating at a specific frequency range
  - Enables mobile network communication
  - Characteristics
    - Distance: depends on frequency and power
    - Use: Wireless LANs, cellular and cordless phones, baby monitors

Wireless Media

- Microwave
  - High-frequency radio communication
  - Requires line of sight which may require large antennas and towers
  - Affected by weather
  - Characteristics
    - Distance: ~60 km (due to curvature of earth
    - Use: Trunk line / Backbone, long distance
- Satellite
  - Special form of microwave communication
  - Long distance leads to propagation delays

FIGURE 3-8
A microwave tower. The round antennas are microwave antennas and the straight antennas are cell phone antennas
Source: © Matej Pribelsky / iStockphoto

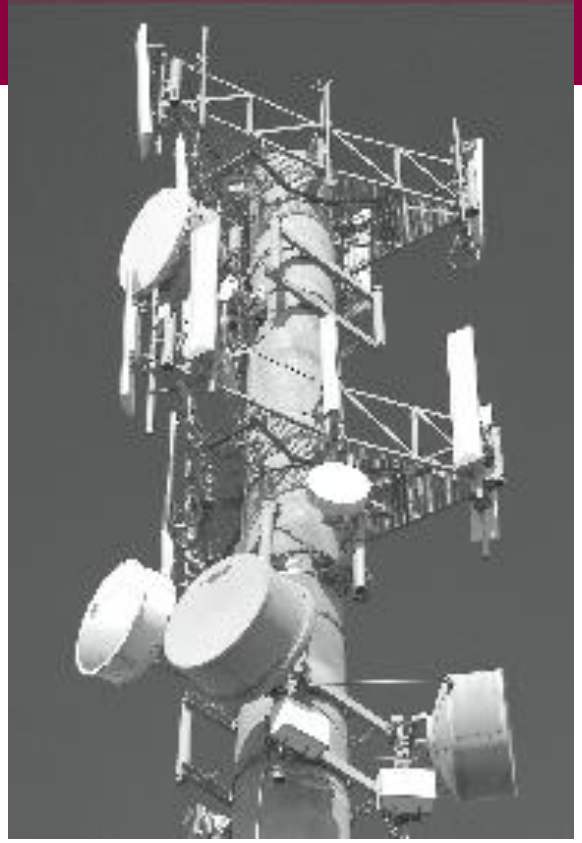
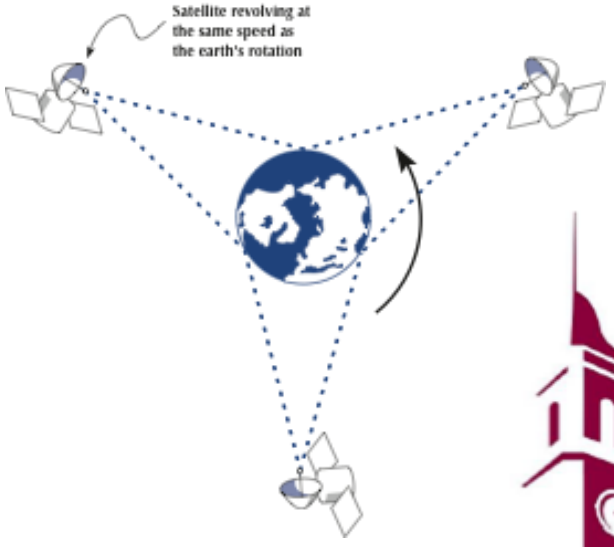


FIGURE 3-9
Satellites in operation



Media

- Factors to consider in media selection
  - Type of network
  - Cost
  - Transmission distance
  - Security
  - Error rates
  - Transmission speeds

Data Transmission & Transmission Flaws

- **Digital transmission of Digital data**
  - Unipolar
  - Bipolar
- **Analog transmission of Digital data**
  - Amplitude Modulation (AM)
  - Phase Modulation (PM)
  - Frequency Modulation (FM)
  - Combination techniques
- **Digital transmission of Analog data**
  - Pulse Core Modulation

Closer Look: Binary to Decimal Conversion

Binary Positional Value	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decimal Value								

Convert the following binary numbers to decimal:

00000000 =

11111111 =

10101010 =

01110111 =

Convert the following decimal numbers to binary:

60 =

182 =

192 =

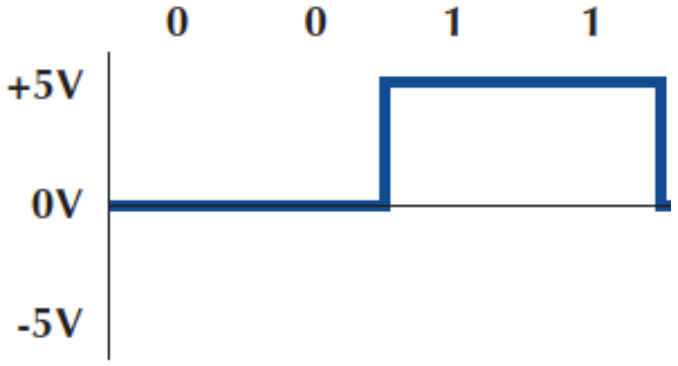
200 =

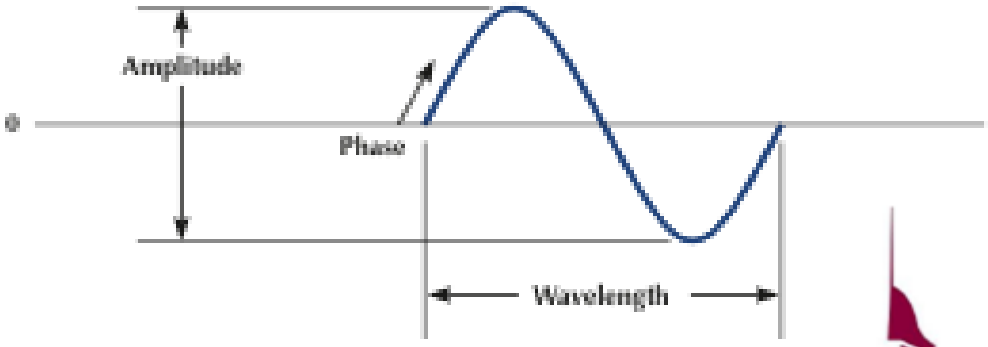
Transmission Flaws

- **Noise**
  - Any undesirable influence degrading or distorting signal
- **Types of noise**
  - EMI (electromagnetic interference)
  - Cross talk
    - NEXT (near end cross talk)
    - Potential cause: improper termination
  - Environmental influences
  - Attenuation
  - Latency
  - Echo

Digital vs. Analog Data

- **Digital** transmission involves discrete binary values (i.e., 0 or 1)
- **Analog** transmission involves continuous waves





Digital Transmission of Digital Data

- Coding scheme needed to ensure sender and receiver understand messages (e.g., ASCII, Unicode, etc.)
- A character is represented by a group of bits

Character	ASCII
A	01000001
B	01000010
C	01000011
D	01000100
E	01000101
a	01100001
b	01100010
c	01100011
d	01100100
e	01100101
1	00110001
2	00110010
3	00110011
4	00110100
!	00100001
$	00100100

FIGURE 3-10
Binary numbers used to represent different characters using ASCII

Digital Transmission of Digital Data

- Transmission modes
  1. **Parallel:** multiple bits transmitted simultaneously

Digital Transmission of Digital Data

- Transmission modes
  2. **Serial:** bits are transferred sequentially, one at a time

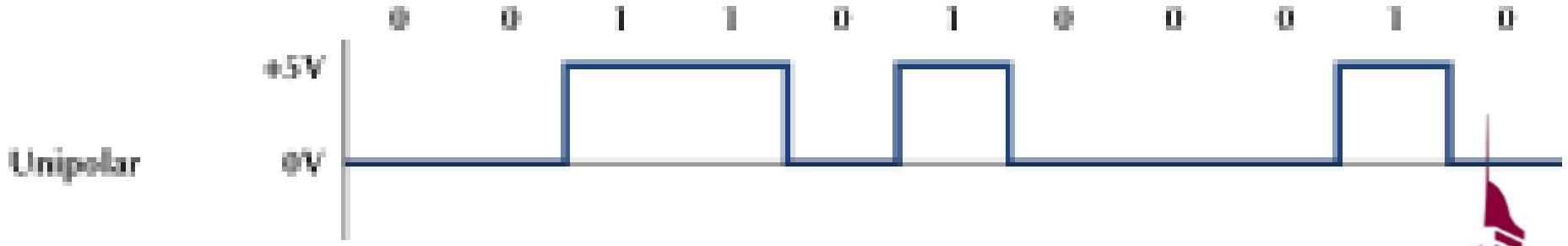
Digital Transmission of Digital Data

- Sender and receiver must agree upon:
  - **Set of symbols**
    - How bits are encoded as voltages or light pulses
    - e.g., +5V might be encodes as a “1”
  - **Symbol rate**
    - How often symbols are sent
    - e.g., with a symbol rate of 64 kilohertz (kHz), a symbol is sent every 1/64,000 of a second

Digital Transmission of Digital Data

- Five types of signaling techniques
  1. **Unipolar -** voltage is 0 or positive representing binary bits (in some circuits, 0 and negative voltage could be used)

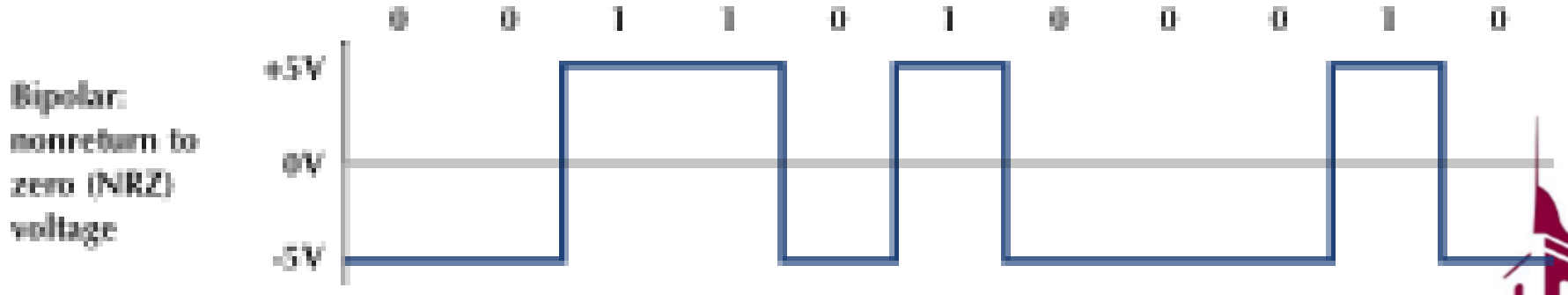
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  2. **Bipolar NRZ -** voltage is positive or negative, but not zero
     - Fewer errors than unipolar because signals are more distinct

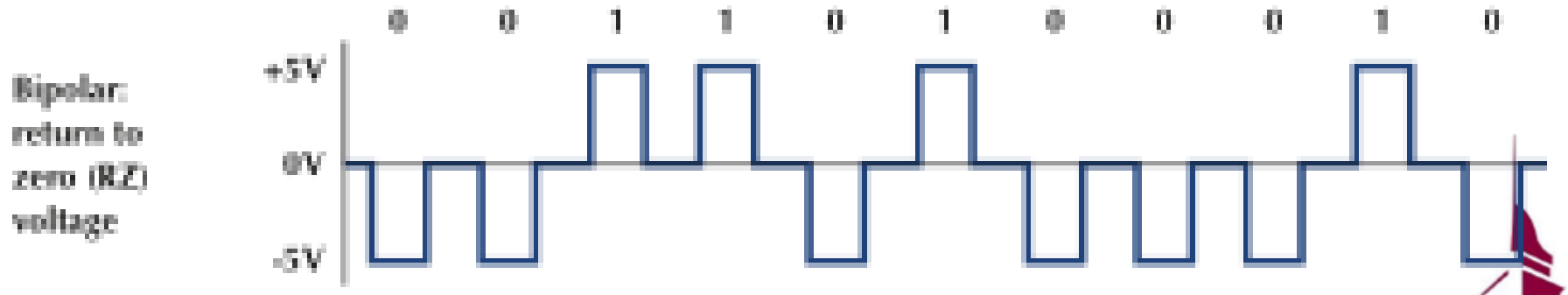
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  3. **Bipolar RZ -** voltage is positive or negative, returning to zero between each bit
     - Fewer synchronization errors than bipolar NRZ

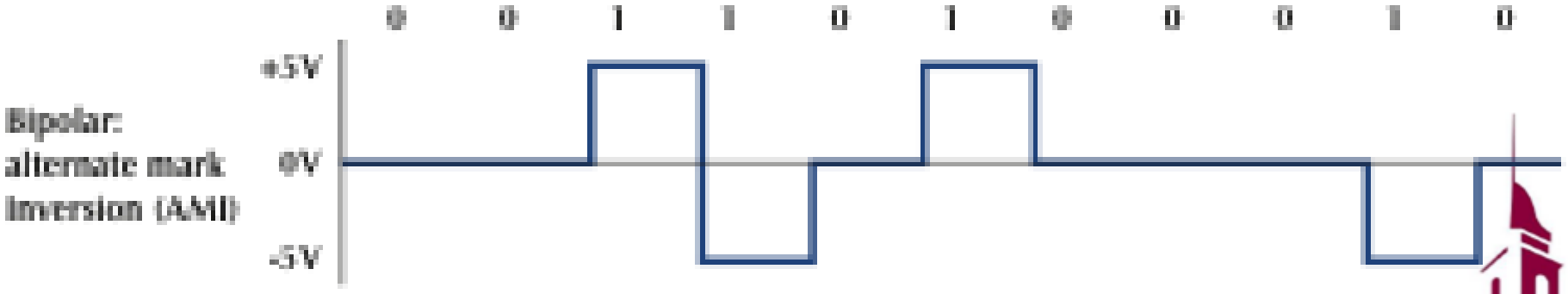
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
    4. **Bipolar AMI -** voltage is 0, positive, or negative, returns to zero between each bit, and alternates between positive and negative voltage

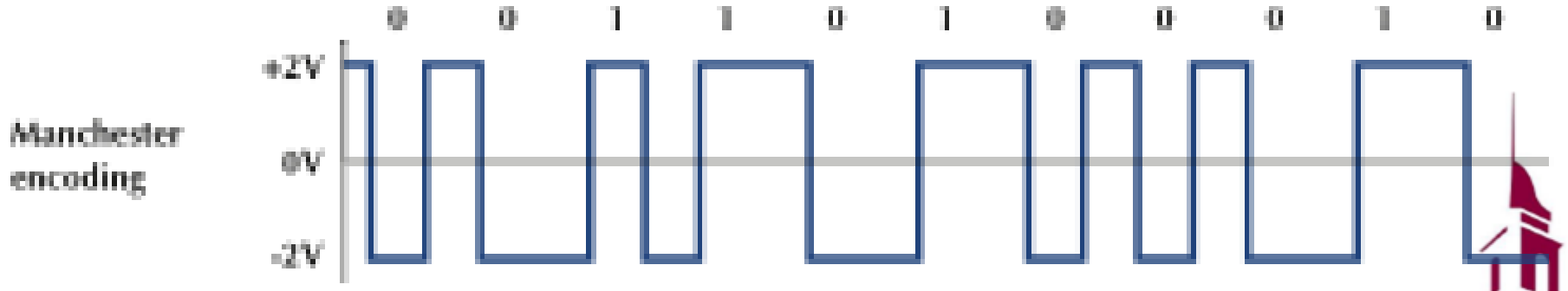
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  5. **Manchester -** voltage is positive or negative and bits are indicated by a mid-bit transition

FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Analog Transmission of Digital Data

- Telephone system built for analog data
  - Electrical signals mimic sound waves (i.e., voice)
  - Analog transmissions take on range of values (vs. discrete values of digital transmissions)
  - Need a **modem** (modulator/demodulator) to convert from analog to digital and vice versa

Analog Transmission of Digital Data

- Three characteristics of waves
  1. **Amplitude:** height of wave (decibels)
  2. **Frequency:** waves per second (hertz)
     - **Wavelength** is the inverse of frequency
  3. **Phase:** wave direction (degrees) or the point at which the wave begins

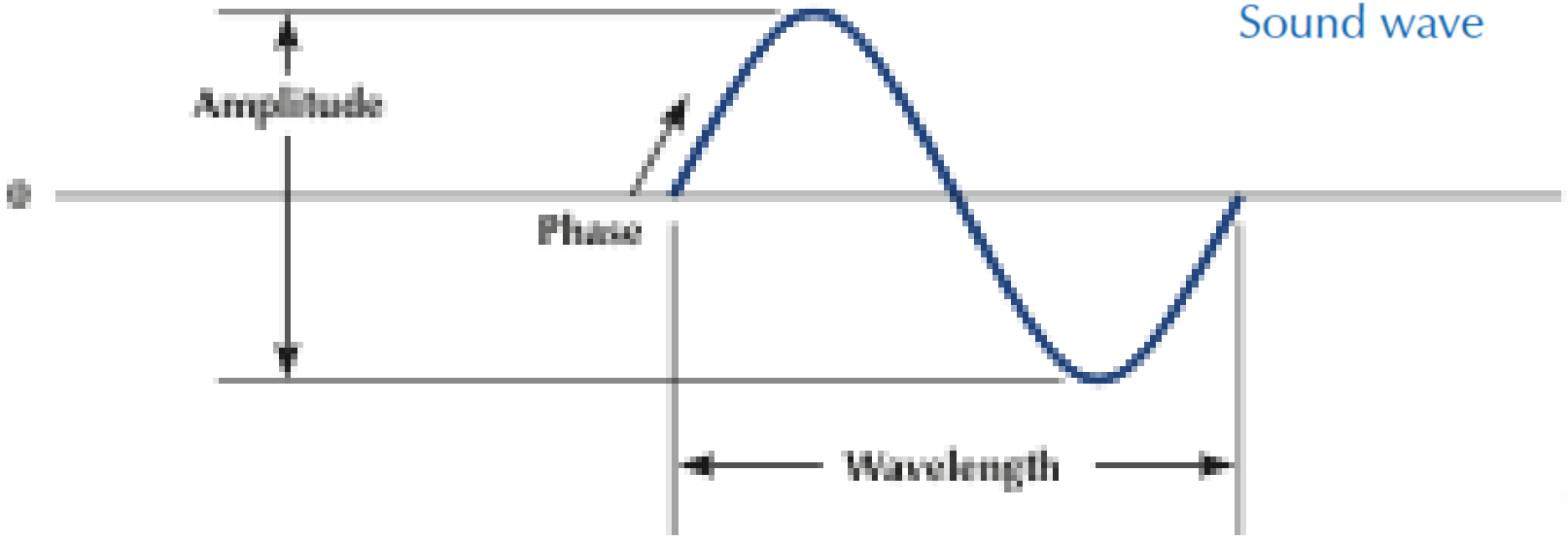


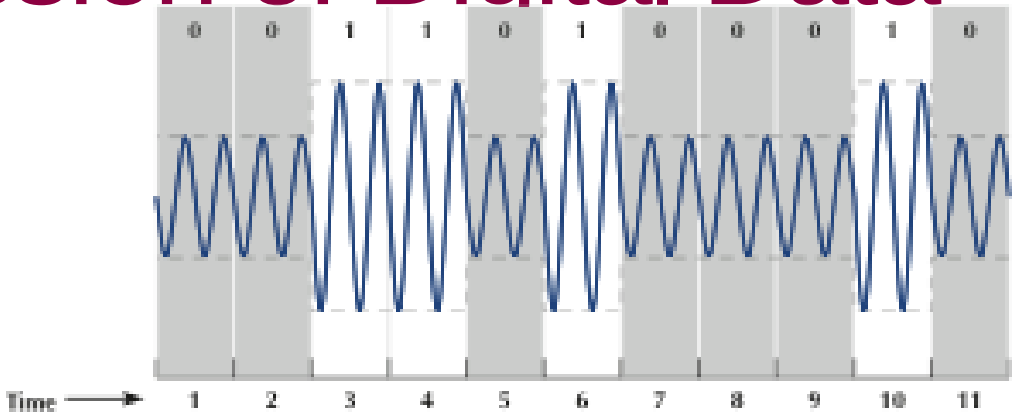
FIGURE 3-14
Sound wave

Analog Transmission of Digital Data

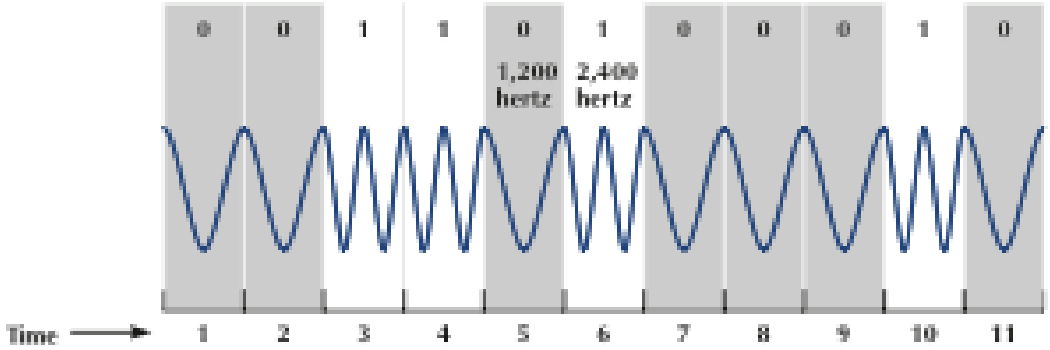
- **Carrier wave** is basic wave transmitted through a circuit
- **Modulation** is the modification of a carrier wave's fundamental characteristics in order to encode information
- Three ways to modulate a carrier wave:
  1. **Amplitude Modulation (AM)** or Amplitude Shift Keying (ASK)
  2. **Frequency Modulation (FM**) or Frequency Shift Keying (FSK)
  3. **Phase Modulation (PM)** or Phase Shift Keying (PSK)

Analog Transmission of Digital Data

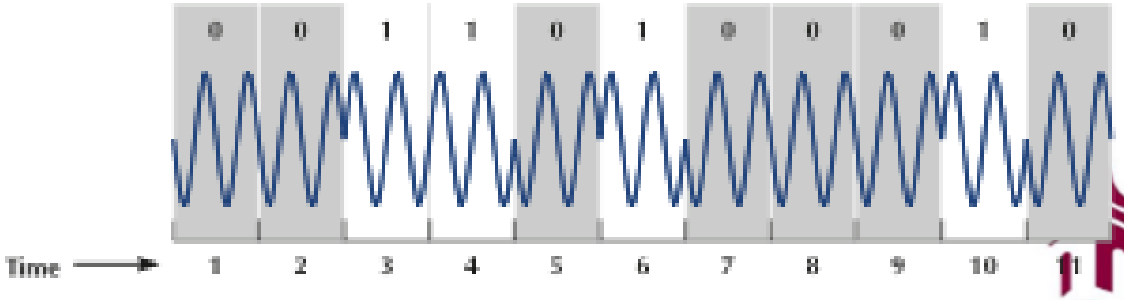
- Amplitude Modulation



- Frequency Modulation



- Phase Modulation



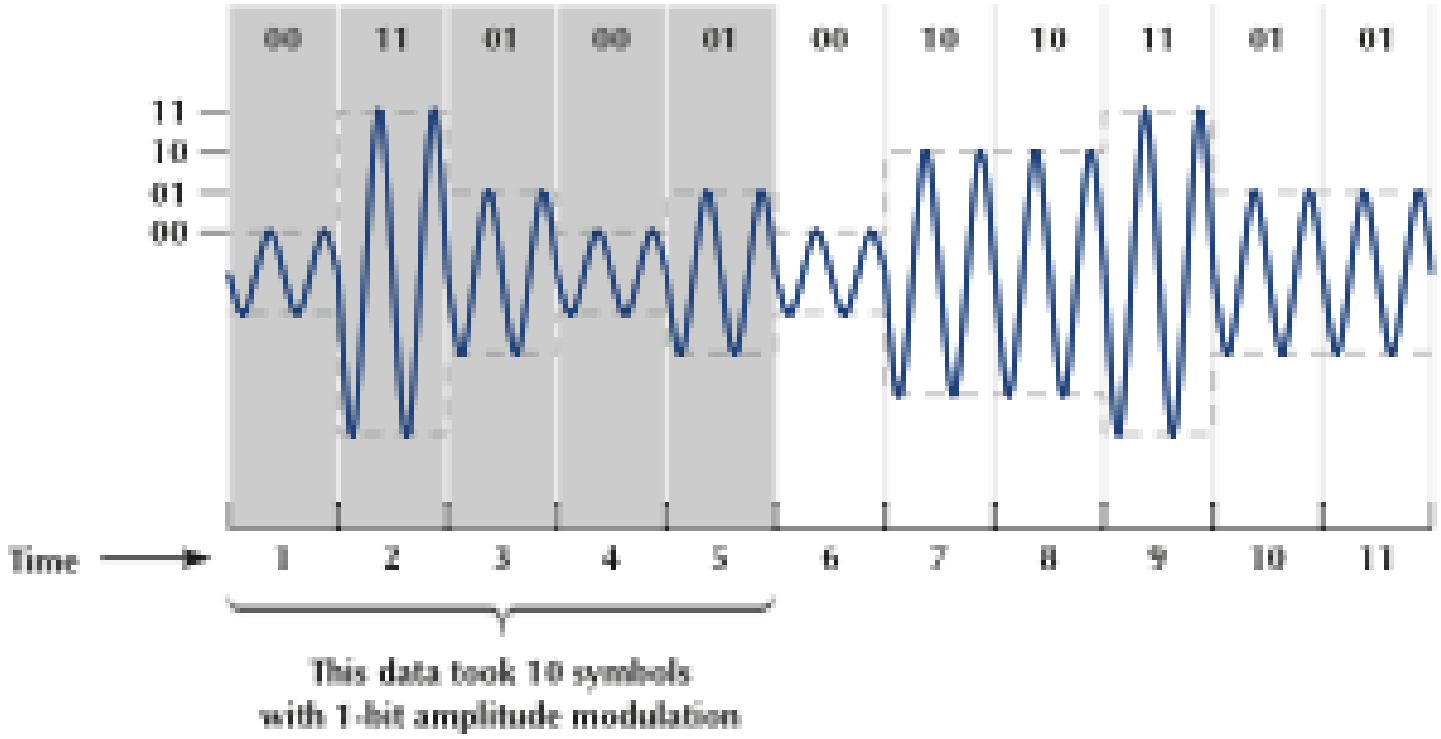
Analog Transmission of Digital Data

- **Symbol:** One or more modifications to a carrier wave used to encode data
- Can send 1 bit by defining two different symbols (e.g., amplitudes, frequencies, etc.)
- Can send multiple bits by defining more than two symbols
  - Need more complicated information coding schemes
  - 1 bit of information → 2 symbols
  - 2 bits of information → 4 symbols
  - 3 bits of information → 8 symbols
  - n bits of information → 2^n symbols

Analog Transmission of Digital Data

- Two-bit Amplitude Modulation
  - With 4 levels of amplitude defined as symbols, 2 bits can be transmitted per symbol

FIGURE 3-18
Two-bit amplitude modulation



Analog Transmission of Digital Data

- **Data rate (or bit rate)** is the number of bits transmitted per second
- **Symbol rate:** number of symbols transmitted per second

Data rate = symbol rate × (# bits/symbol)

- Example

  Symbol rate = 16,000 symbols/sec

  #bits/symbol = 4 bits/symbol

  Data rate = 16,000 symbols/sec × 4 bits/symbol

  = 64,000 bits/sec = 64Kbps

Digital Transmission of Analog Data

- **Codecs (COde, DECode)** is a device or software that converts an analog signal (e.g., voice) into digital form and the reverse
- **Pulse-Code Modulation (PCM)** converts analog to digital by:
  1. Sampling the analog signal at regular intervals
  2. Measuring the amplitude of each sample
  3. Encoding (quantizing) the amplitude as binary data
- **Quantizing Error** is the difference between the original analog signal and the approximated, digital signal
- Reducing quantizing error can be done by:
  - Sampling more frequently
  - Using more levels of amplitude in encoding

Digital Transmission of Analog Data

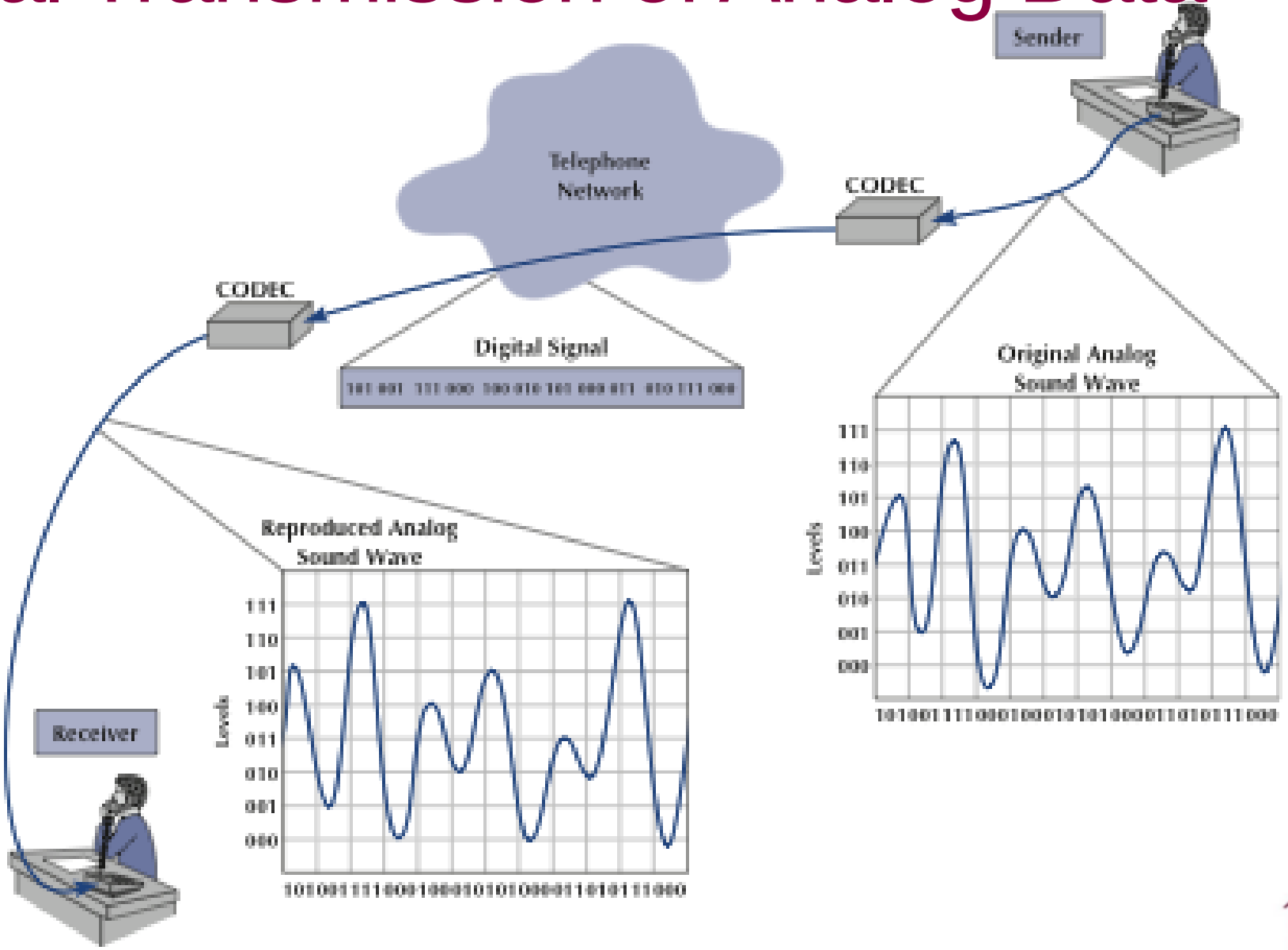
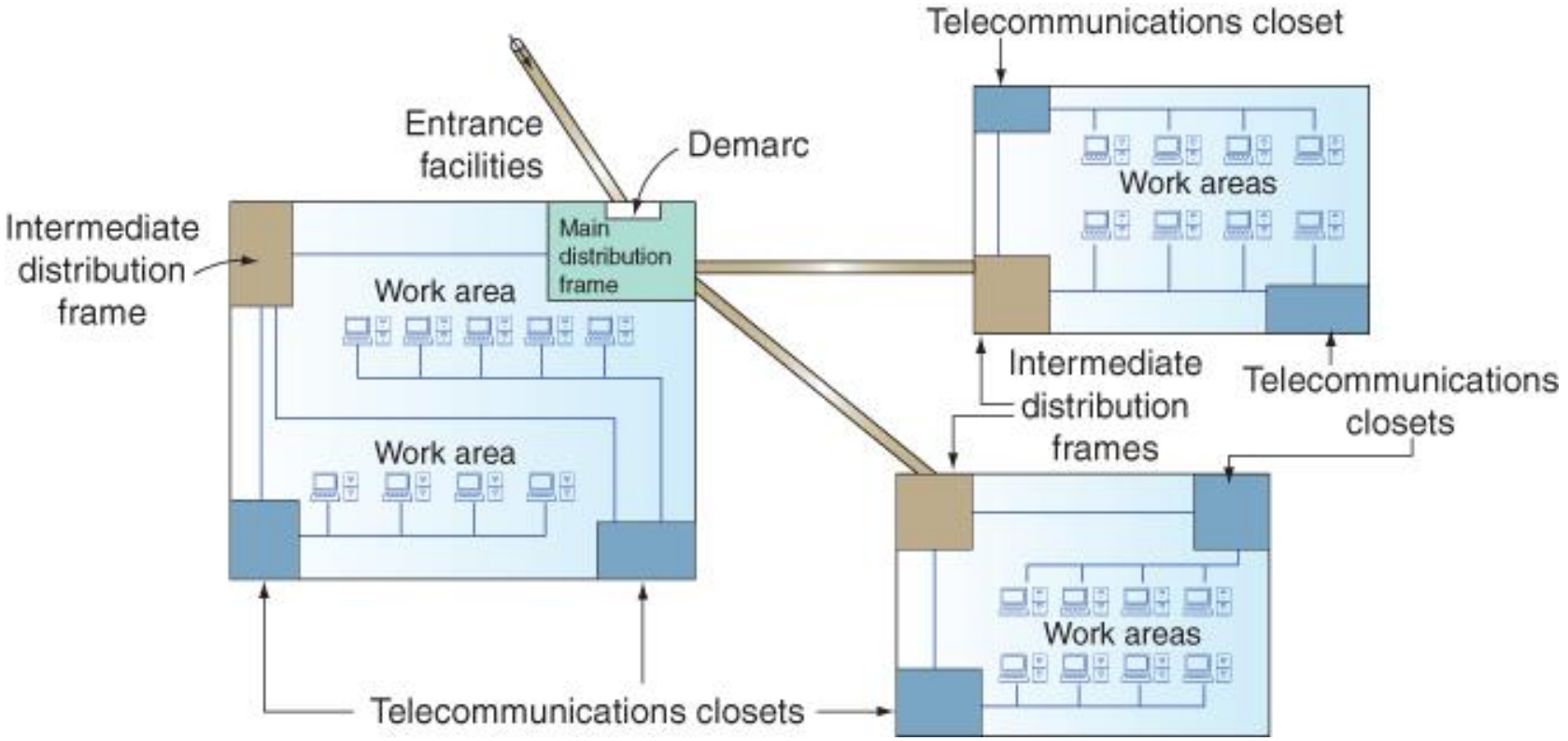


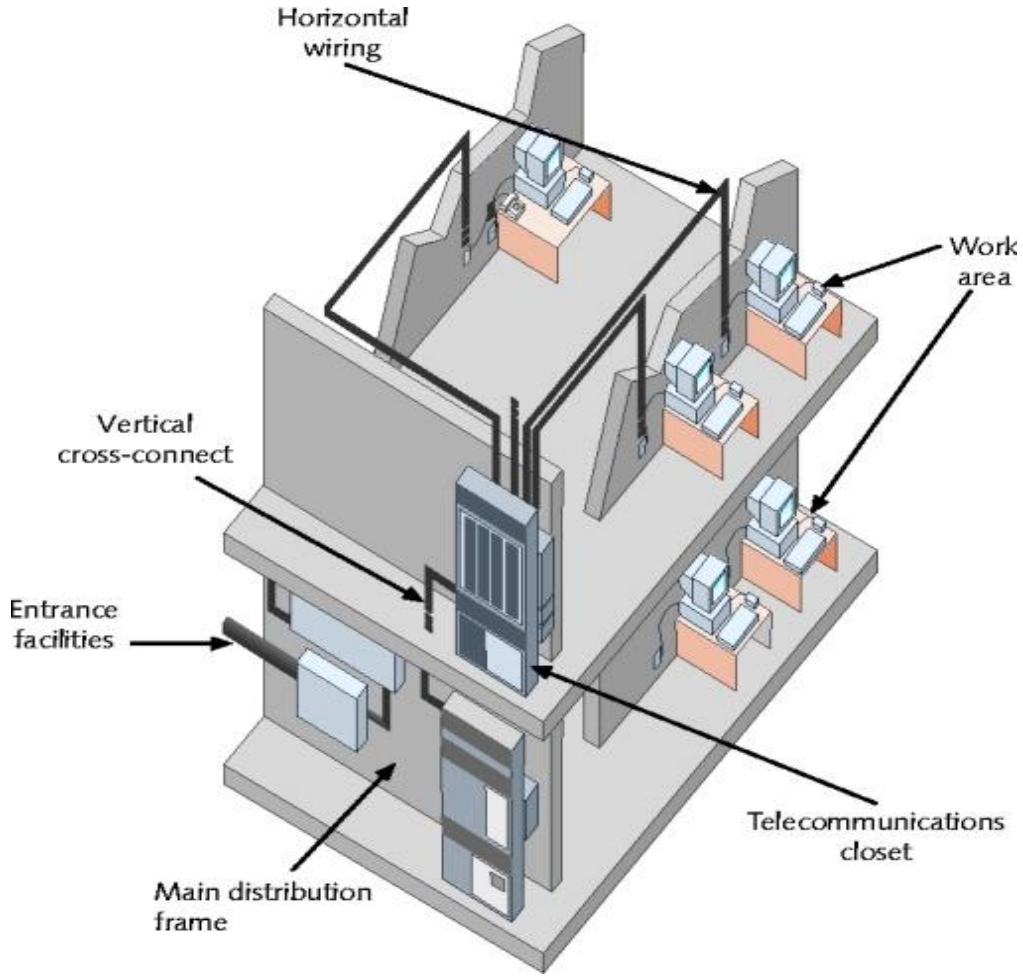
FIGURE 3-20 Pulse amplitude modulation (PAM)

Structured Cabling (TIA/EIA 568)



TIA/EIA structured cabling in an enterprise

Structured Cabling (Cont.)



TIA/EIA structured cabling in a building

Implications for Cyber Security

- How do we protect the physical layer? Should we protect it?
- Devices that leave the premises of enterprise campus
- Devices that never leave the premises of enterprise campus

Hands-On Activity 3C

- Patch Cable is …
- Order of wires according to the 568B standard is:
  - Orange/white
  - Orange
  - Green/white
  - Blue
  - Blue/white
  - Green
  - Brown/white
  - Brown
- Cross-over Cable is …