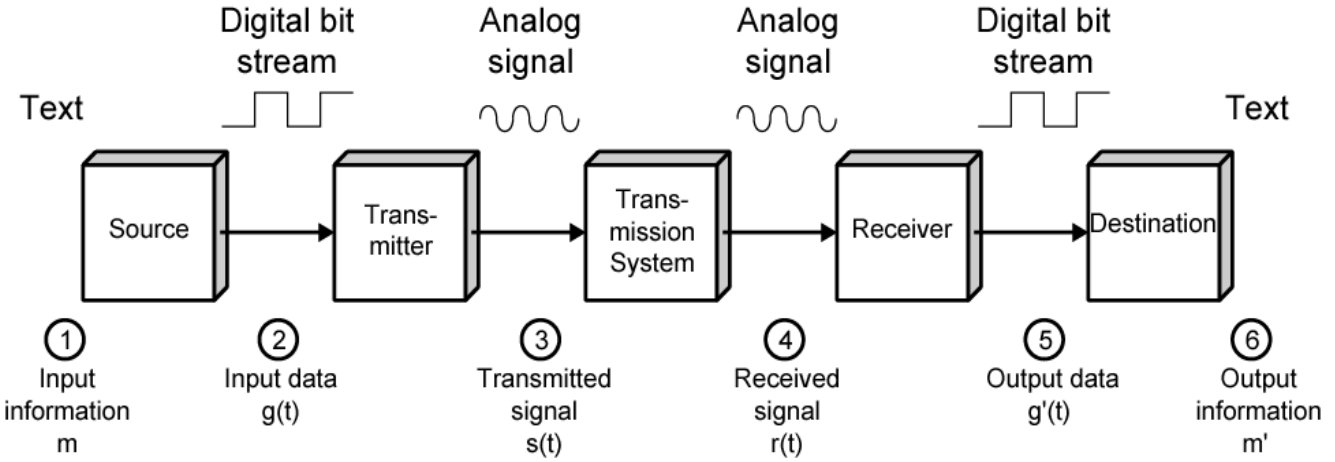
Data Communications
Introduction to Physical Layer

Communications Model

- Source
  - generates data to be transmitted
- Transmitter
  - converts data into transmittable signals
- Transmission System
  - carries data from source to destination
- Receiver
  - converts received signal into data
- Destination
  - takes incoming data

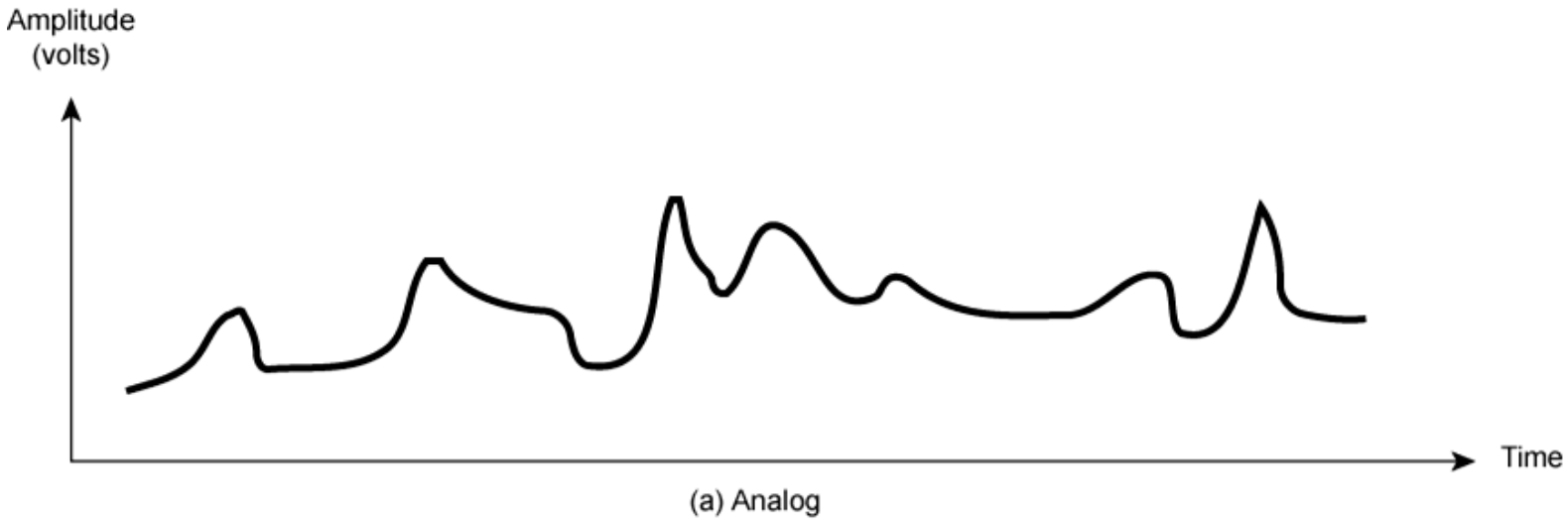


Frequency, Spectrum and Bandwidth

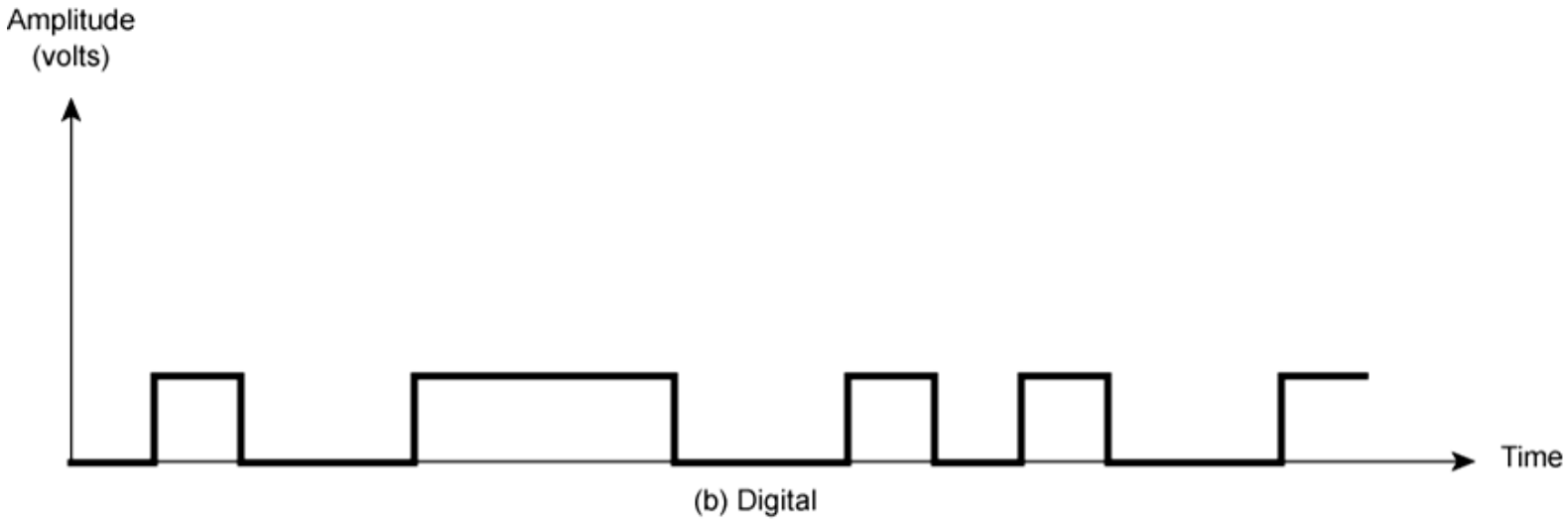
Time Domain Concepts

- **analog signal**
  - signal intensity varies smoothly with no breaks
- **digital signal**
  - signal intensity maintains a constant level and then abruptly changes to another level
- **periodic signal**
  - signal pattern repeats over time
- **aperiodic signal**
  - pattern not repeated over time

Analog and Digital Signals

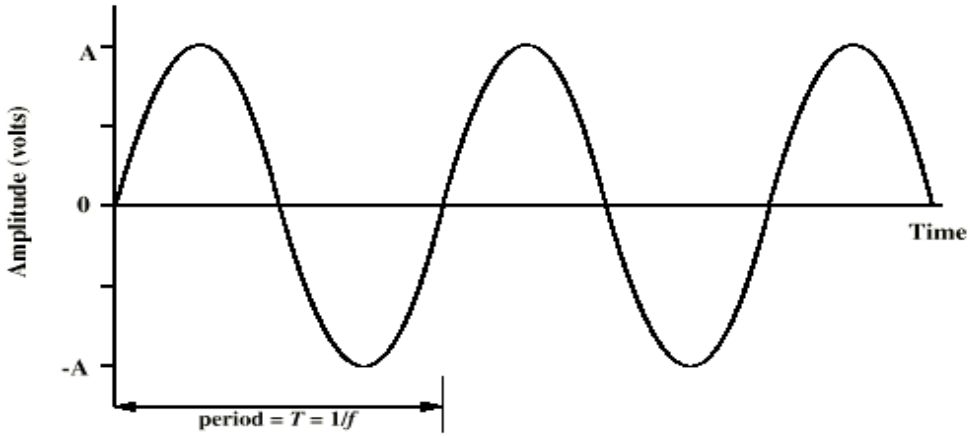


(a) Analog

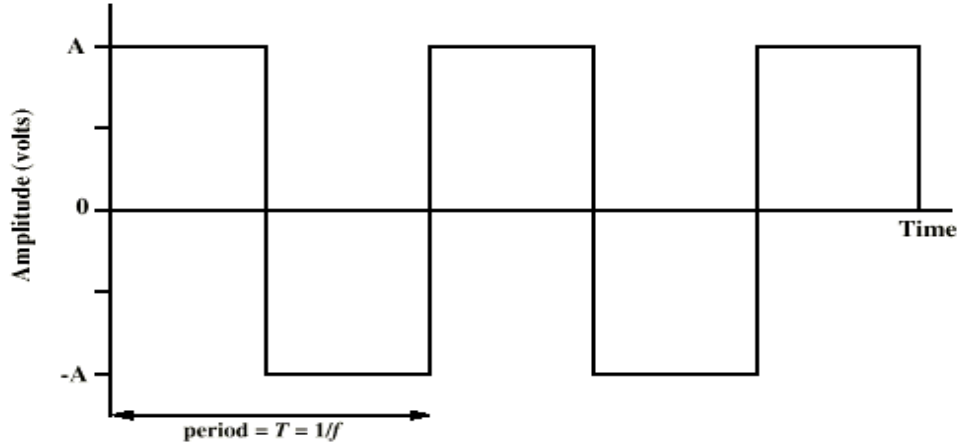


(b) Digital

Periodic Signals

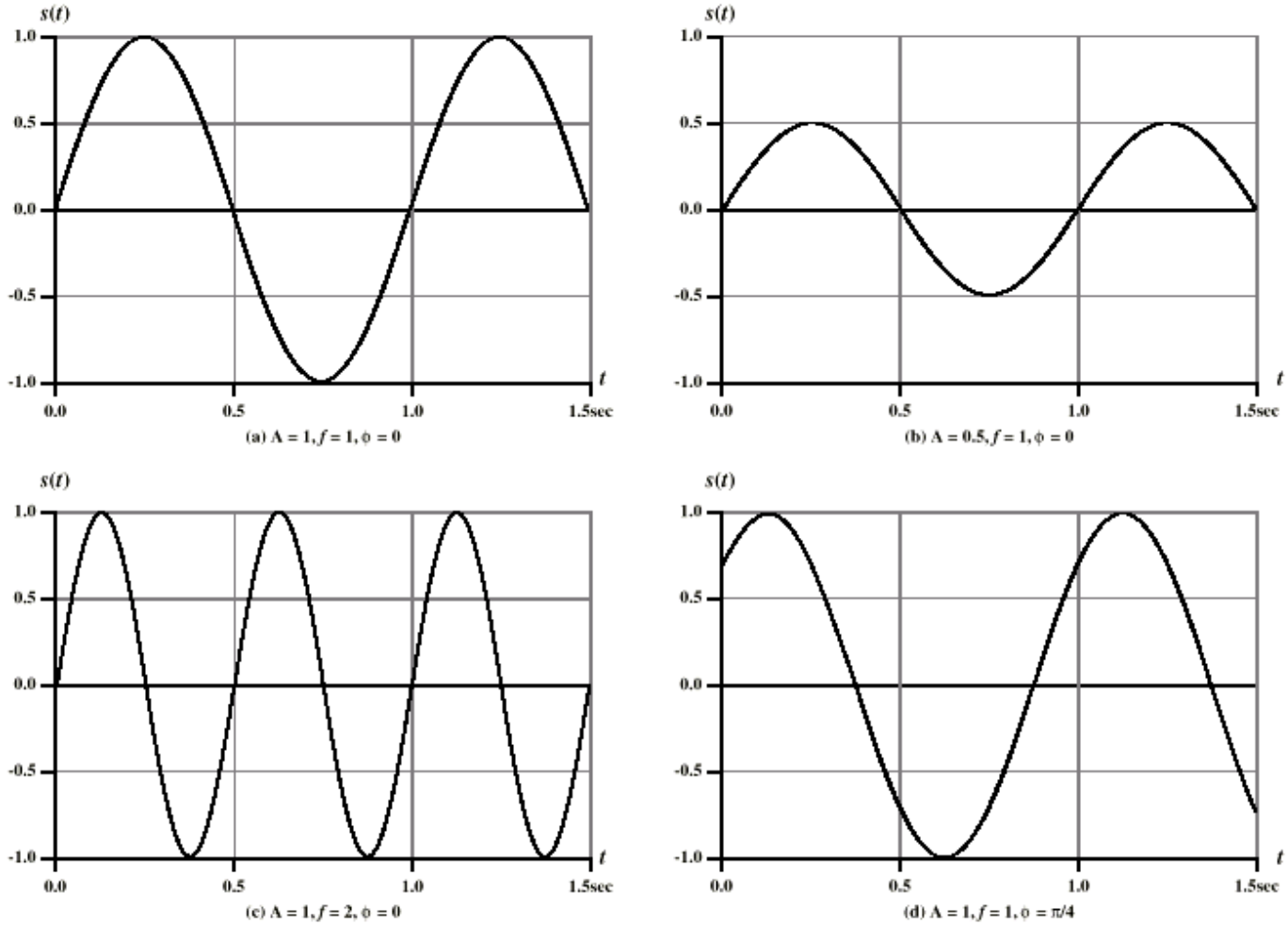


(a) Sine wave



(b) Square wave

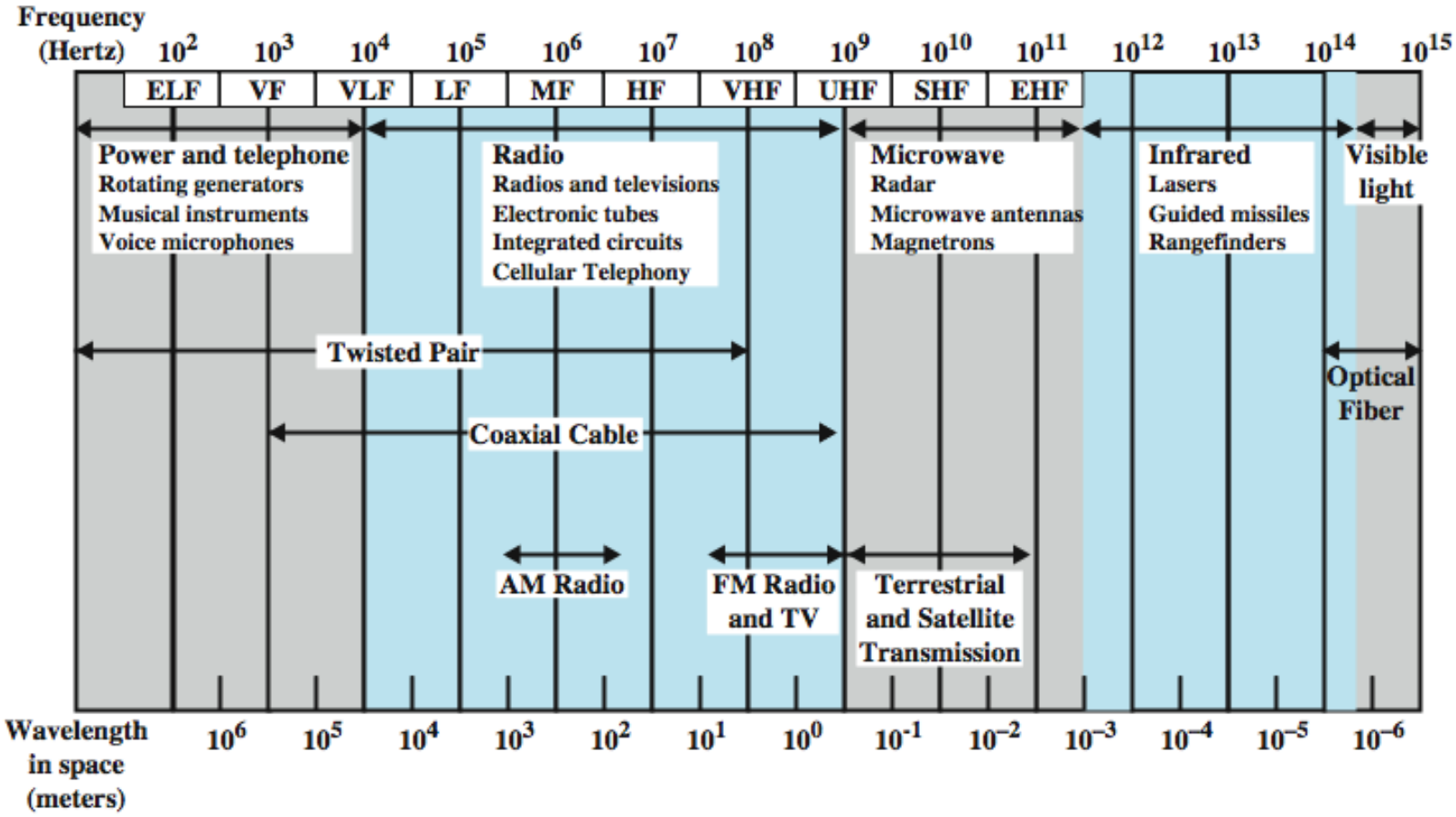
Varying Sine Waves
$s(t) = A \sin(2\pi ft + \Phi)$



Spectrum & Bandwidth

- spectrum
  - range of frequencies contained in signal
- bandwidth
  - width of spectrum
  - narrow band of frequencies containing most energy

Electromagnetic Spectrum

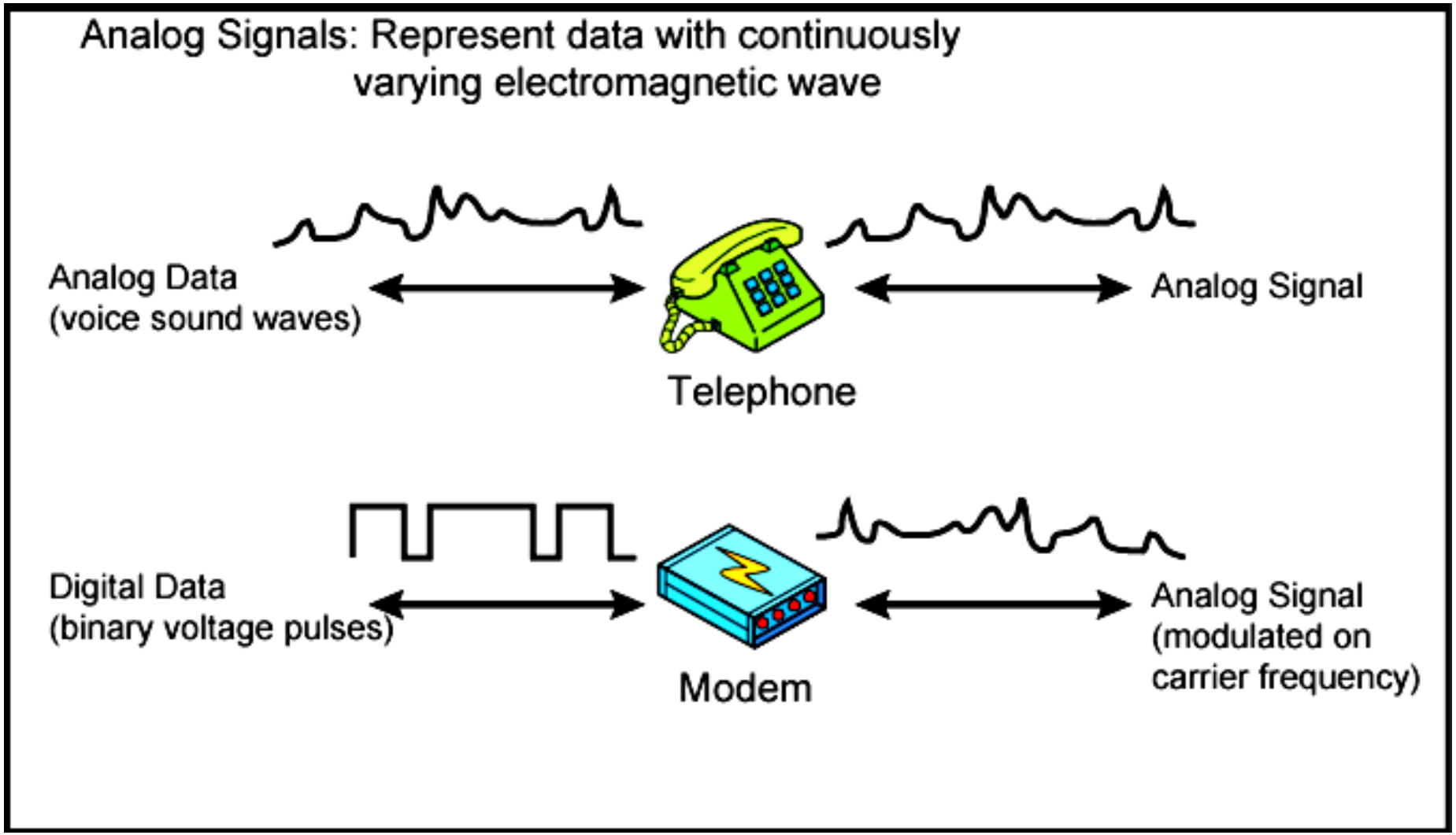


ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

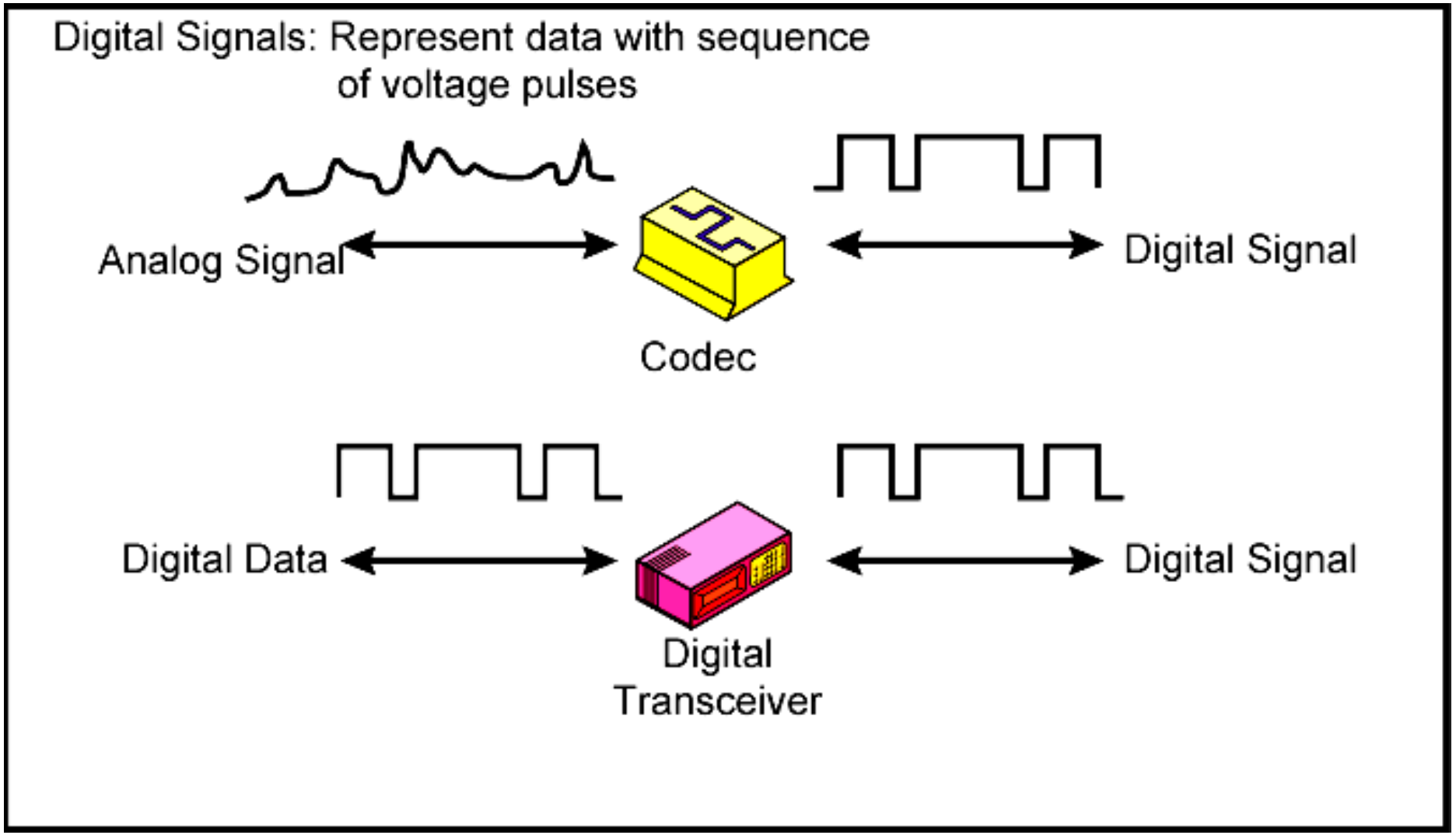
Analog and Digital Signals

- Analog Signal
  - Continuous electromagnetic waves transmitted through various medium
- Digital Signal
  - sequence of voltage pulses that may be transmitted over a wire medium
  - for example, a constant positive voltage level may represent binary 0 and a constant negative voltage level may represent binary 1

Analog Signals



Digital Signals



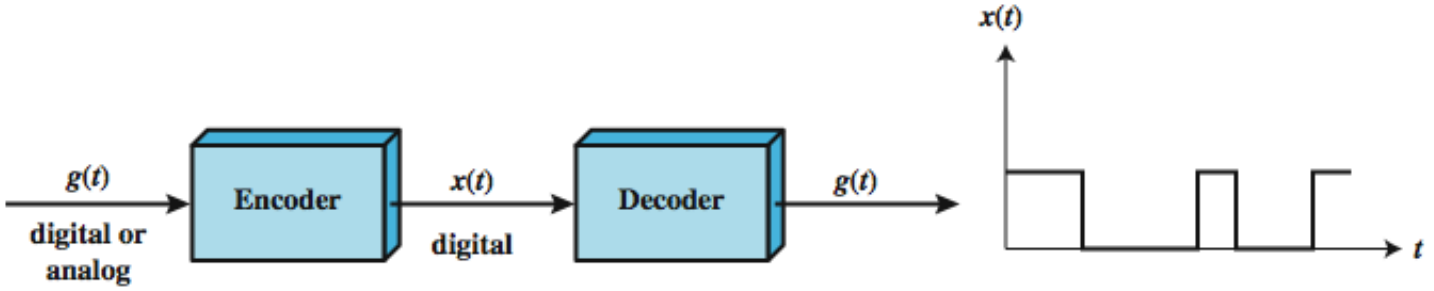
Transmission Impairments

- ATTENUATION
  - signal strength falls off with distance over any transmission medium
  - varies with frequency
- Noise
  - Unwanted signals inserted between transmitter and receiver
  - The major limiting factor in communications system performance

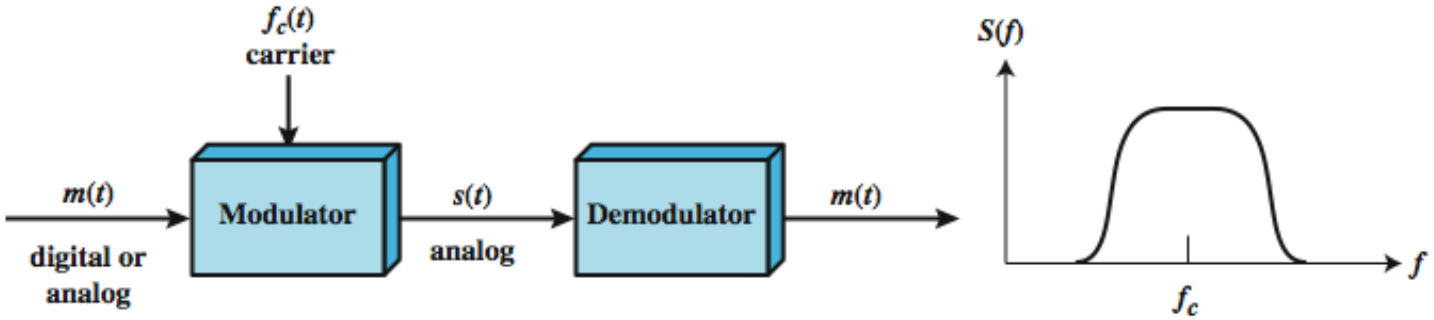
Shannon Capacity Formula

- considering the relation of data rate, noise and error rate
- Shannon developed formula relating these to signal to noise ratio
- SNR = (signal strength / noise strength)
- B: Bandwidth (Hz)
- capacity C = B log2(1+SNR)
  - theoretical maximum capacity
  - get much lower rates in practice

Signal Encoding Techniques



(a) Encoding onto a digital signal

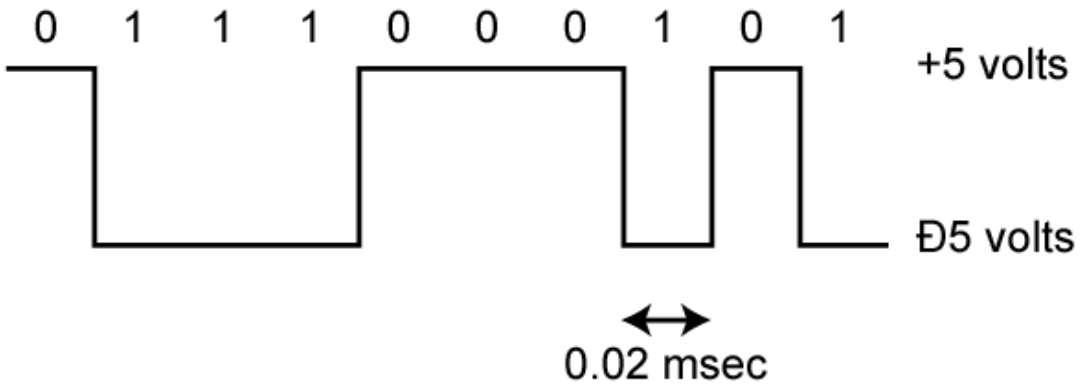


(b) Modulation onto an analog signal

Figure 5.1 Encoding and Modulation Techniques

Digital Data, Digital Signal

digital signal
- –discrete, discontinuous voltage pulses
- –each pulse is a signal element
- –binary data encoded into signal elements



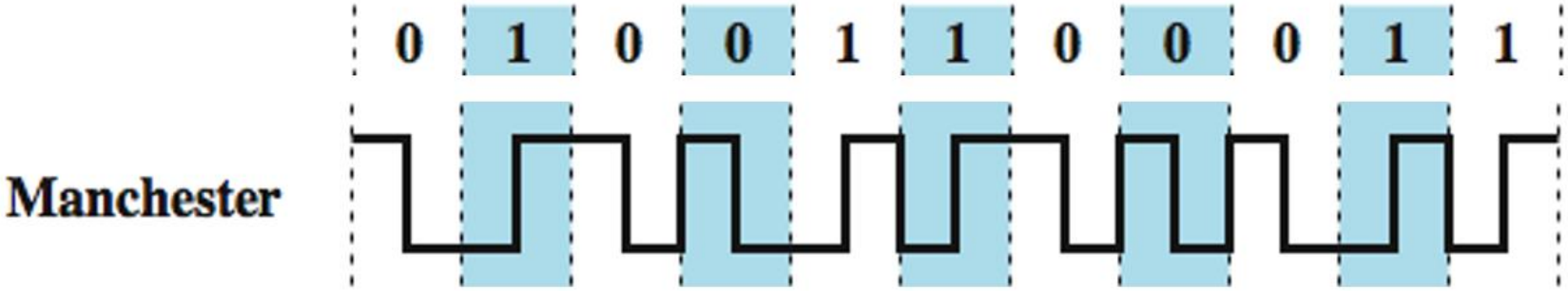
Digital Data, Digital Signal

Manchester Encoding

0: transition from high to low in the middle of interval

1: transition from low to high in the middle of interval

Used by Ethernet

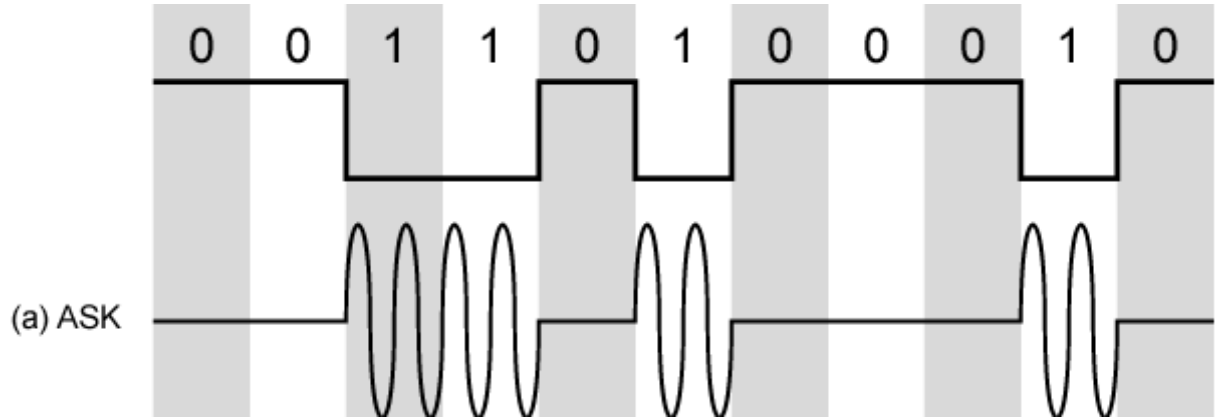


Digital Data, Analog Signal

Amplitude Shift Keying

encode 0/1 by different carrier amplitudes

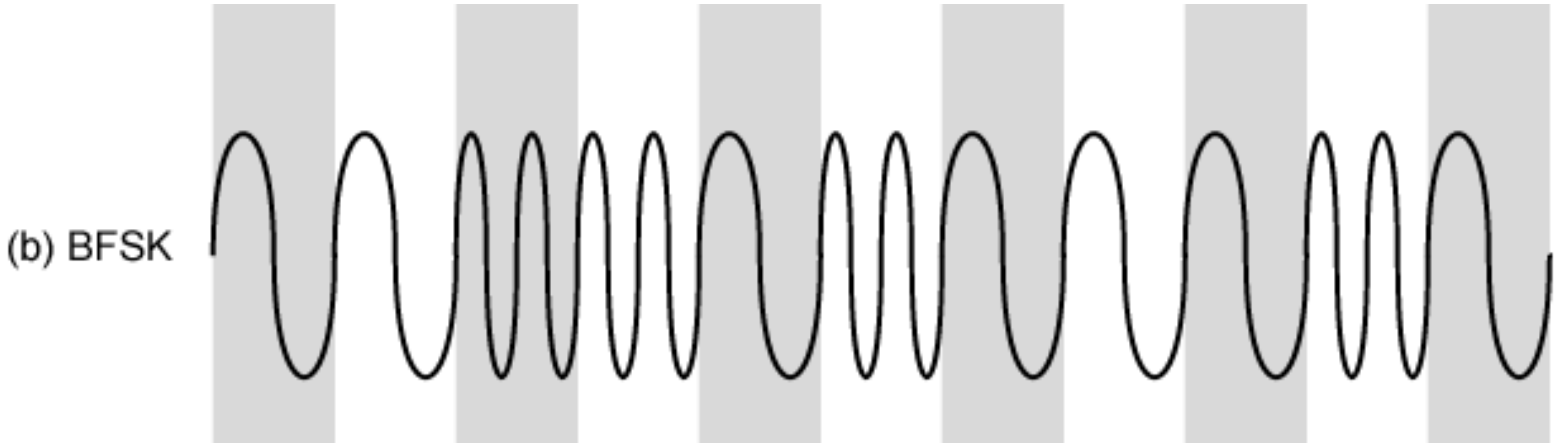
- –usually have one amplitude zero
- –susceptible to sudden gain changes
- –inefficient



Binary Frequency Shift Keying

two binary values represented by two different frequencies

less susceptible to error than ASK

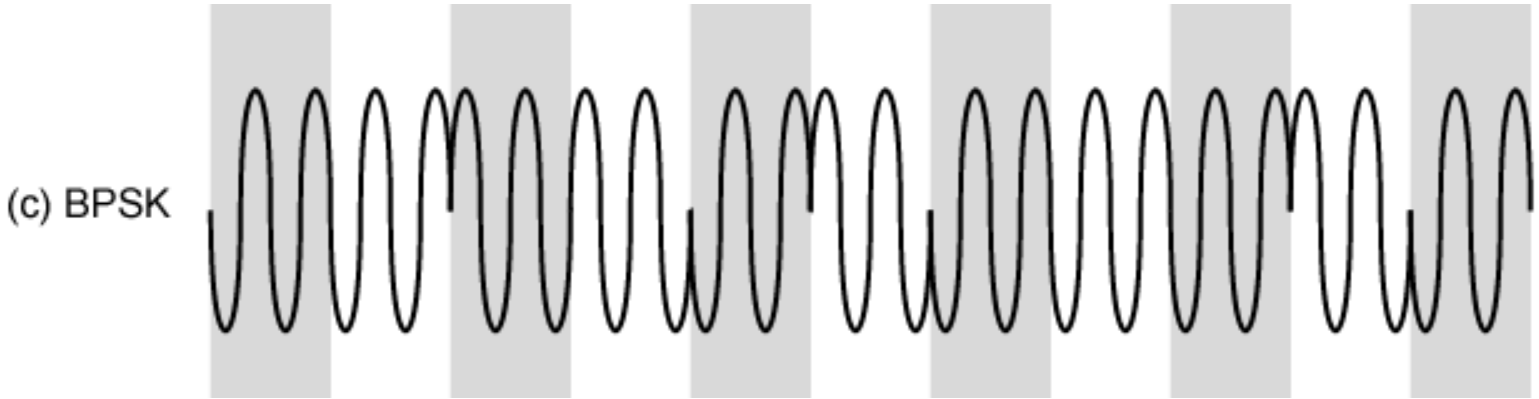


Multiple FSK

- each signalling element represents more than one bit
- more than two frequencies used
- more bandwidth efficient
- more prone to error

Phase Shift Keying

- phase of carrier signal is shifted to represent data
- binary PSK
  - two phases represent two binary digits



References

- Data and Computer Communications, Ninth Edition by William Stallings, (c) Pearson Education - Prentice Hall, 2011

- Computer Networking A Top-down Approach, 6th edition, J. F. Kurose et al, Pearson, 2012