Transmission Fundamentals

W. Stallings, Chapter 2
Part 2

Data Communication Terms

- **Data** - entities that convey meaning, or information
- **Signals** - electric or electromagnetic representations of data
- **Transmission** - communication of data by the propagation and processing of signals

Examples of Analog and Digital Data

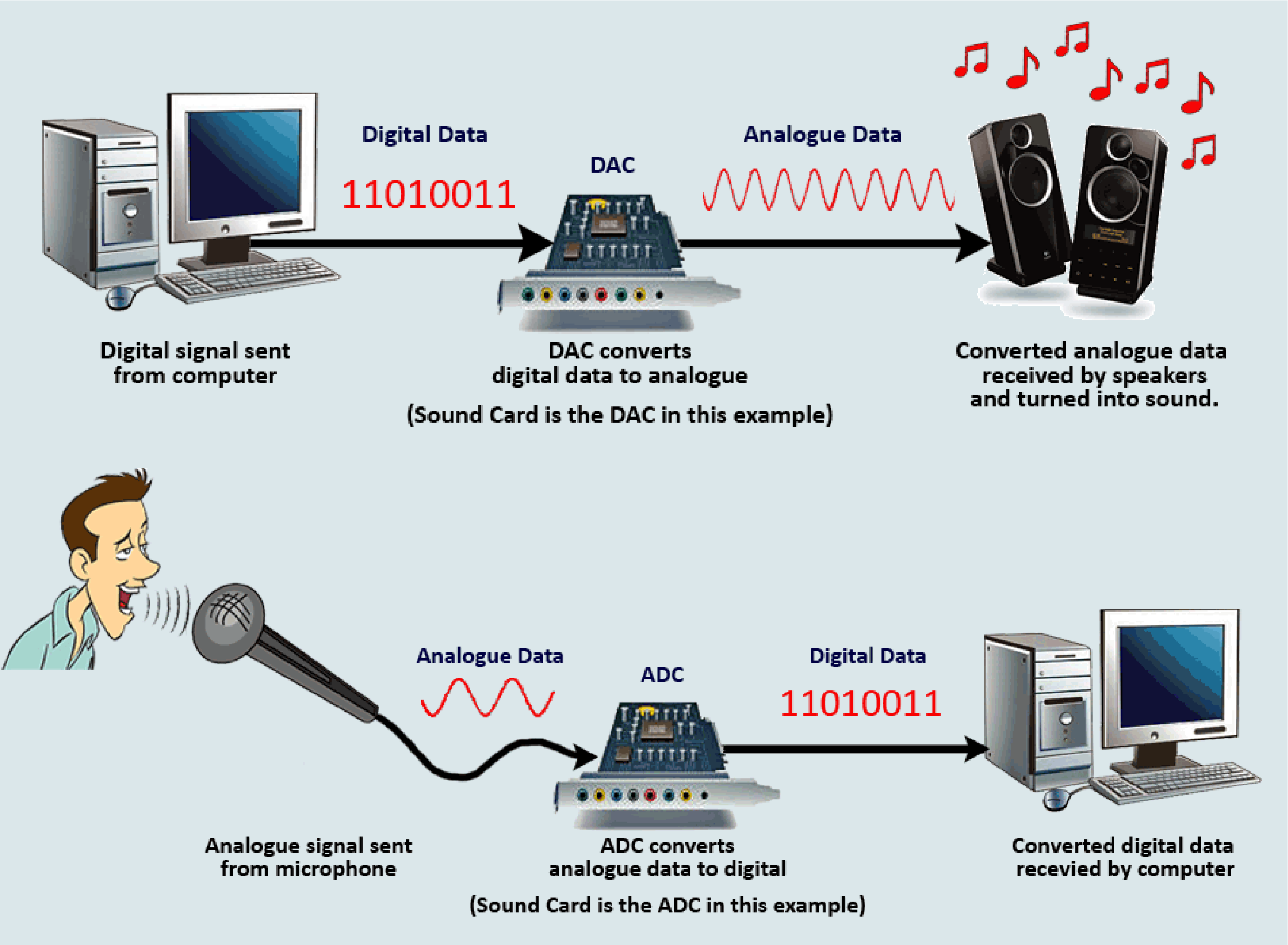
- Analog
  - Video
  - Audio
- Digital
  - Text
  - Integers

Analog Signals

- A continuously varying electromagnetic wave that may be propagated over a variety of media, depending on frequency
- Examples of media:
  - Copper wire media (twisted pair and coaxial cable)
  - Fiber optic cable
  - Atmosphere or space propagation
- Analog signals can propagate analog and digital data

Digital Signals

- A sequence of voltage pulses that may be transmitted over a copper wire medium
- Advantages of digital signals
  - Generally cheaper than analog signaling
  - Less susceptible to noise interference
  - Suffer more from attenuation
- Digital signals can propagate analog and digital data



Reasons for Choosing Data and Signal Combinations

- Analog data, analog signal
  - Analog data easily converted to analog signal
- Digital data, analog signal
  - Some transmission media will only propagate analog signals
  - Examples include optical fiber and satellite
- Digital data, digital signal
  - Equipment for encoding is less expensive than digital-to-analog equipment
- Analog data, digital signal
  - Conversion permits use of modern digital transmission and switching equipment

Channel Capacity

-How fast data can be transmitted

- Impairments, such as noise, limit data rate that can be achieved
- **Channel Capacity C** – the maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions

Concepts Related to Channel Capacity

- **Data rate -** rate at which data can be communicated (bps)
- **Bandwidth -** the bandwidth of the transmitted signal as constrained by the transmitter and the nature of the transmission medium (Hertz)
- **Noise -** average level of noise over the communications path (different definitions exists)
- **Error rate -** rate at which errors occur
  - Error = transmit 1 and receive 0; transmit 0 and receive 1
- We **want** to achieve as high data rate as possible for a given error rate, bandwidth and noise level

Nyquist Bandwidth (noise free channel)

- Given a bandwidth of signal (two levels) with frequency at B (Hz), the highest rate of transmission is 2B (bps).
  - $C = 2B$
- For signals with M levels (each signal element can present more than 1 bit)
  - $C = 2B \log_2 M$
    - M = number of discrete signal or voltage levels
- Data rate in noise free channel is limited by the bandwidth of the signals.

Example of Nyquist

- How many signaling levels are required?

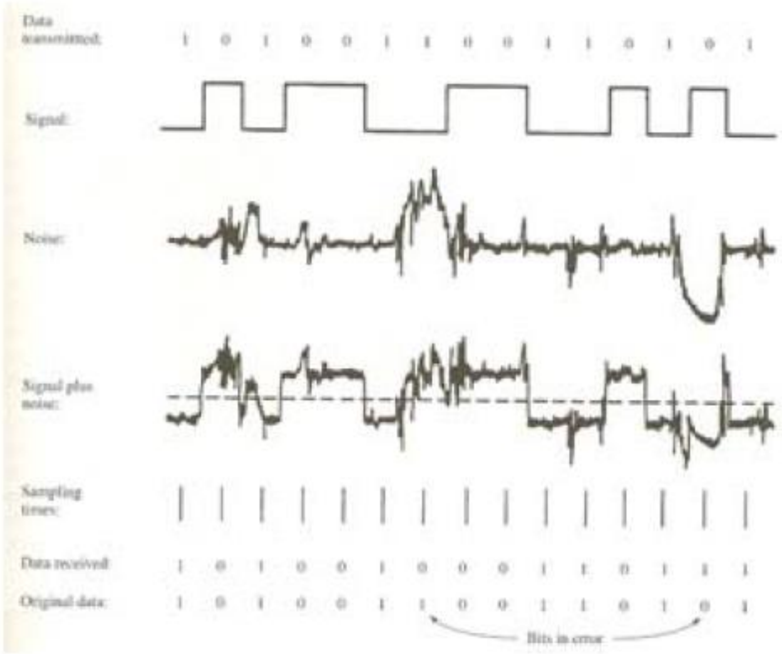
$$C = 2B \log_2 M$$

$$8 \times 10^6 = 2 \times \left(10^6\right) \times \log_2 M$$

$$4 = \log_2 M$$

$$M = 16$$

Signal-to-Noise Ratio



Signal-to-Noise Ratio

- Ratio of the power in a signal to the power contained in the noise that's present at a particular point in the transmission (often measured at a receiver)
- Signal-to-noise ratio (SNR, or S/N)

$$(SNR)_{\text{dB}} = 10\log_{10}\frac{\text{signal power}}{\text{noise power}}$$

- SNR sets upper bound on achievable data rate

Shannon Capacity Formula

- Equation:

$$C = B\log_2(1+\text{SNR})$$

- Represents **theoretical maximum rate** that can be achieved
- In practice, only much lower rates achieved
  - Formula assumes white noise (thermal noise)
  - Impulse noise, attenuation distortion or delay distortion not accounted for
- Note that C increases, when signal power S increases for a given noise power level

Example

- Spectrum of a channel between 3 MHz and 4 MHz; $\text{SNR}_{\text{dB}} = 24$ dB

$$B = 4\ \text{MHz} - 3\ \text{MHz} = 1\ \text{MHz}$$

$$\text{SNR}_{\text{dB}} = 24\ \text{dB} = 10\log_{10}(\text{SNR})$$

$$\text{SNR} = 251$$

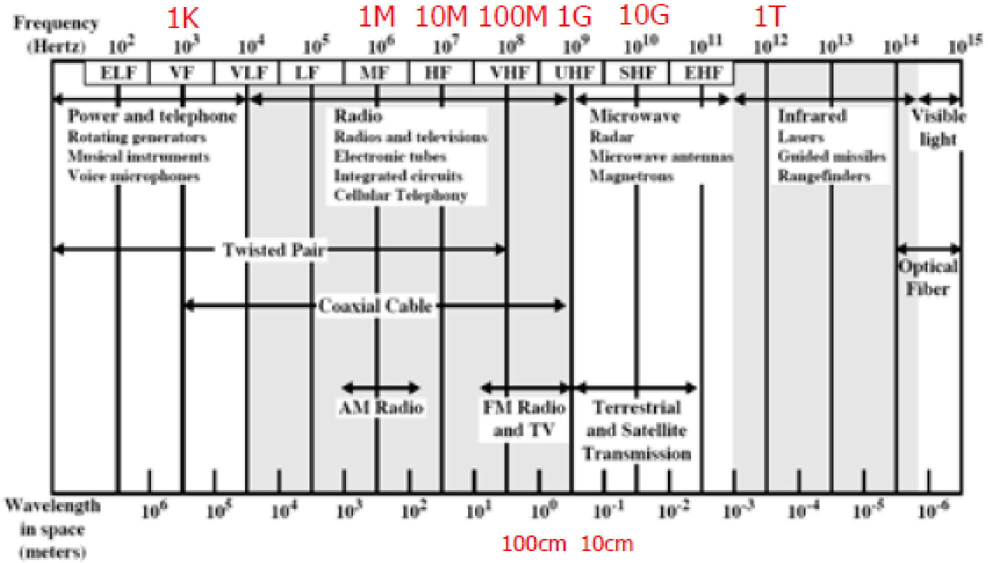
- Using Shannon's formula

$$C = 10^6 \times \log_2(1+251) \approx 10^6 \times 8 = 8\text{Mbps}$$

Classifications of Transmission Media

- Transmission Medium
  - Physical path between transmitter and receiver
- Guided Media
  - Waves are guided along a solid medium
  - E.g., copper twisted pair, copper coaxial cable, optical fiber
- Unguided Media
  - Provides means of transmission but does not guide electromagnetic signals
  - Usually referred to as wireless transmission
  - E.g., atmosphere, outer space
  - Transmission and reception are achieved by means of an antenna
    - Directional
    - Omnidirectional

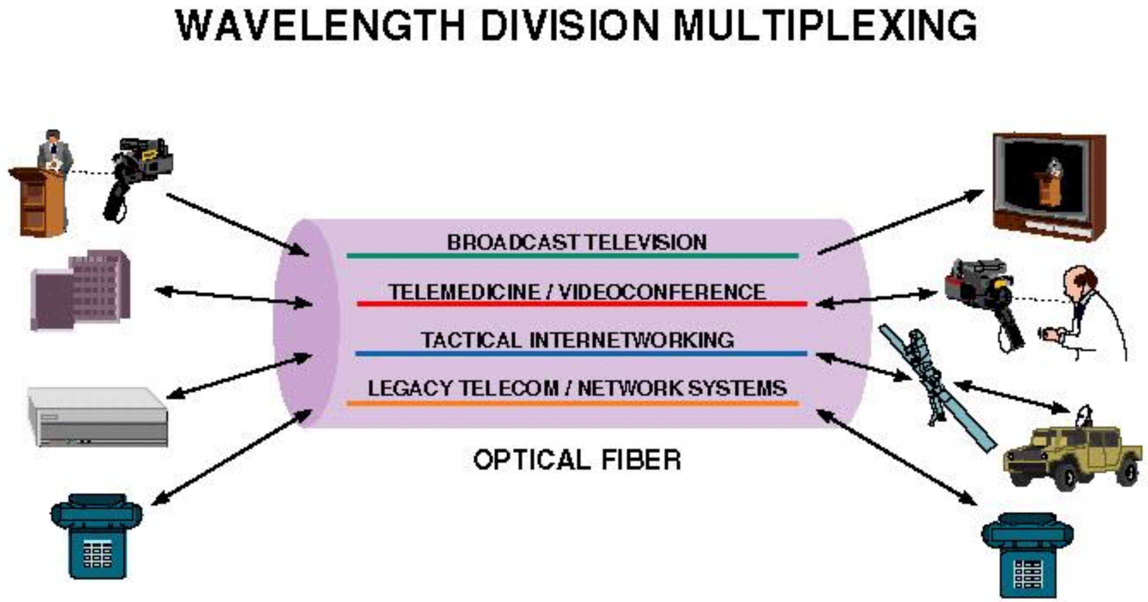
Electromagnetic specturm



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

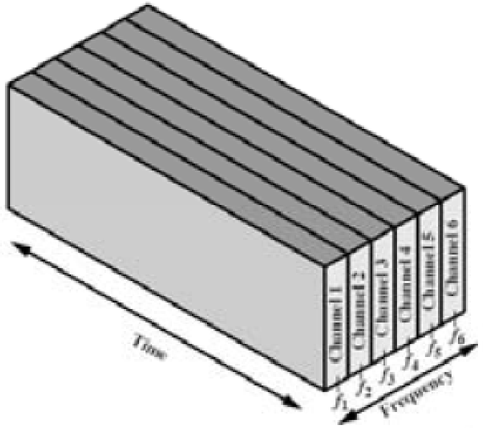
Multiplexing

- Multiplexing - carrying multiple signals on a single medium
  - More efficient use of transmission medium



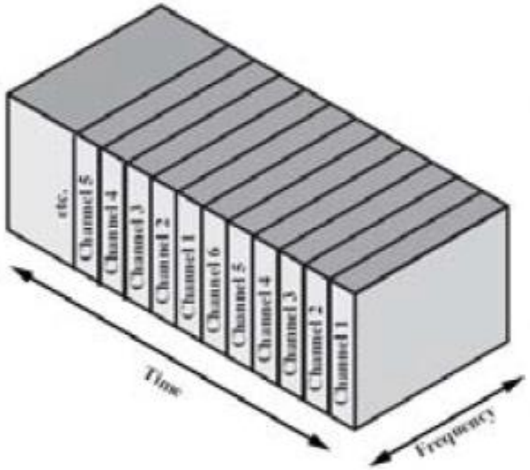
Frequency-division Multiplexing

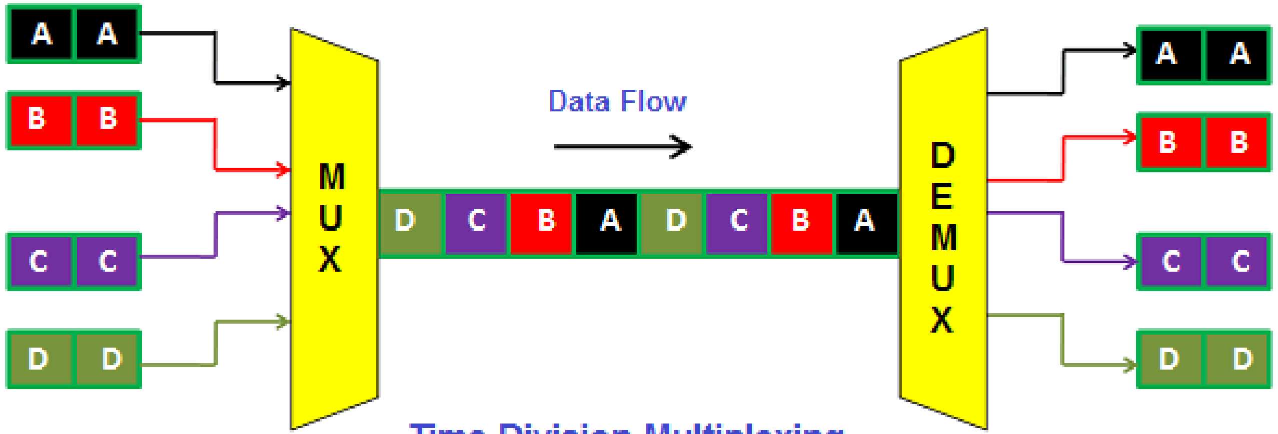
- Takes advantage of the fact that the useful bandwidth of the medium exceeds the required bandwidth of a given signal
- Example:
  AM broadcast
  FM broadcast



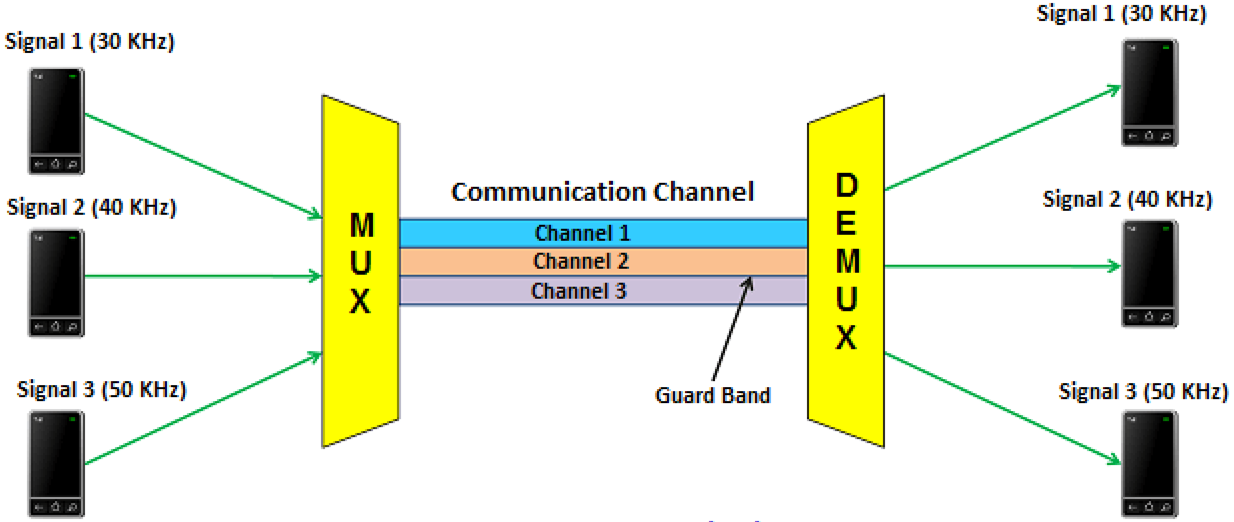
Time-division Multiplexing (TDM)

- Takes advantage of the fact that the achievable bit rate of the medium exceeds the required data rate of a digital signal.
- Example: GSM 1990
  TDMA/FDD
  Spectrum 935-960MHz
  Channel BW 200kHz
  8 voice users per carrier
  Ch. Speed 270.833Kbps
- Example: AT&T standard in P. 37





Time Division Multiplexing



Frequency Division Multiplexing

Appendix 2A dBW and dBm

- dBW refers to an absolute level of power in decibels.
  - It is easy to calculate gains and losses.
  - 1 W is selected as a reference and defined to be 0 dBW.

$$Power_{dBW} = 10Log_{10} \frac{P_W}{1W}$$

- dBm (decibel-milliWatt) uses 1mW as the reference.

$$Power_{dBm} = 10Log_{10} \frac{P_{mW}}{1mW}$$

Thank You