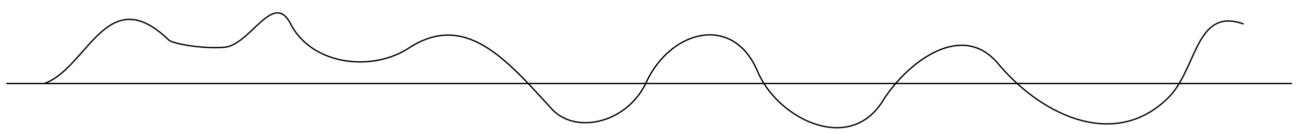
CSE and EE 461
Lecture 5

Spring Quarter 1998

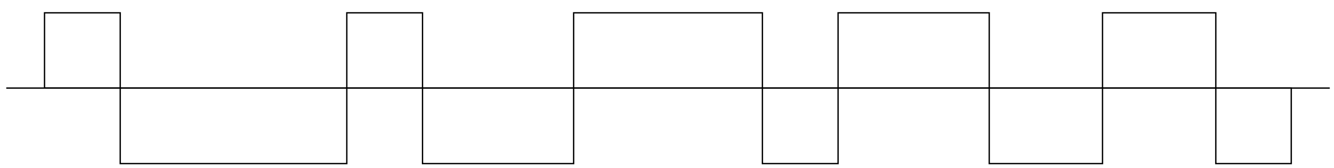
Data Rate vs. Frequency

- Data Rate is measured in bits per second (bps)
- Signals of all kinds are measured in cycles per second or frequency (Hertz, Hz)

Analog Signal -



Digital Signal -



Nyquist's Equation

$$B = 2H\log_2 V$$

B = bit rate
H = max fequency
V = discrete levels

- Nyquist tells us if we are limited in frequency we are limited in bit rate
- Noiseless best possible because sampling at a faster rate than 2H gives no additional information about the signal.
- Example. Telephone line supports upto 3,000 Hz. What is the best pure bit rate this can support with two discrete levels.

$$2 \cdot 3000 \cdot \log_2 2 = 6000 bps$$

Shannon's Equation

$$B = H\log_2\left(1 + \frac{S}{N}\right)$$

B = bits per second
H = max frequency
S/N = signal to noise ratio

- Shannon says the best you can do in the presence of noise.
- S/N is measured in decibels (dB):

  SNR = 10 $\log_{10}$ (S/N)   or   S/N = $10^{SNR/10}$

- Example: 3,000 Hz and SNR = 30 dB

$$3000 \cdot \log_2(1 + 10^{30/10}) = 29,900 bps$$

Transmission Media

Media

- Magnetic tape
- Twisted Pair
- Coaxial Cable
- Fiber Optics
- Infrared
- Microwave
- Radio

Modulation

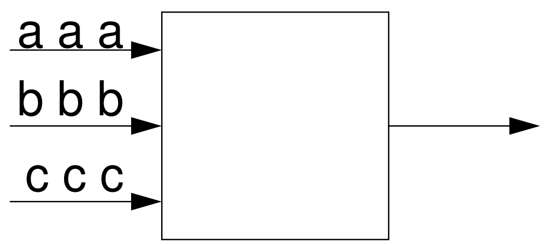
- Amplitude
- Frequency
- Phase
- Combination

QAM uses amplitude and phase

Quadrature Amplitude Modulation used in the highest speed modems

Multiplexing

- Multiplexing is using a single carrier for multiple channels



- **Frequency Division Multiplexing (FDM)**- Each channel uses a different frequency band.
- **Time Division Multiplexing (TDM)**- Each channel uses a different time slot in a round robin fashion
- Both FDM and TDM may not utilize the carrier well. Neither is appropriate for data communications.

Asynchronous Time Division Multiplexing

- Like TDM but time slots are not allocated in round robin fashion.

- For an ATDM to work there must be a policy for managing the incoming data.

Issues in Multiplexing

- Quality of service

  - Do the incoming channels receive their fair share of the outgoing bandwidth?
  - Is the data from one channel unduly delayed?

- Bandwidth allocation -
- Buffer control -