Week 2 – Physical Layer (2)

COMP90007

Internet Technologies

Link Terminology

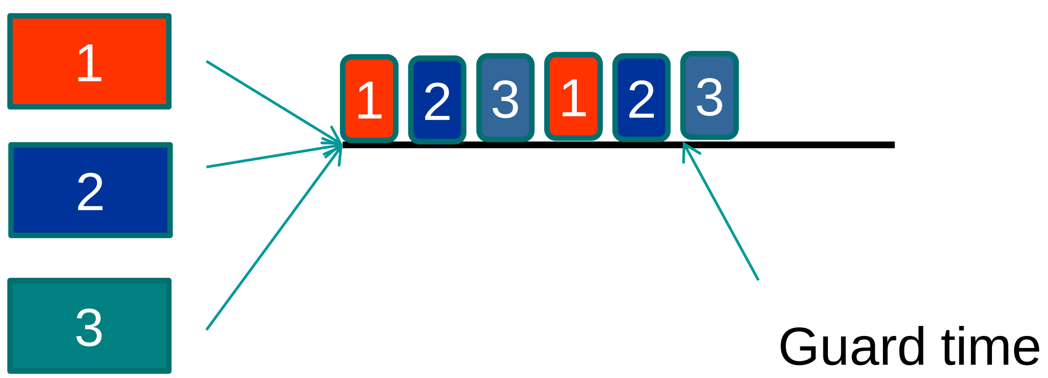
- Full-duplex link
  - Used for transmission in both directions at once
  - e.g., use different twisted pairs for each direction
- Half-duplex link
  - Both directions, but not at the same time
  - e.g., senders take turns on a wireless channel
- Simplex link
  - Only one fixed direction at all times; not common

Multiplexing

- When multiple sources want to access the medium
  - Time Division Multiplexing
  - Frequency Division Multiplexing
  - Statistical Multiplexing (for curious readers)
  - Code Division Multiple Access

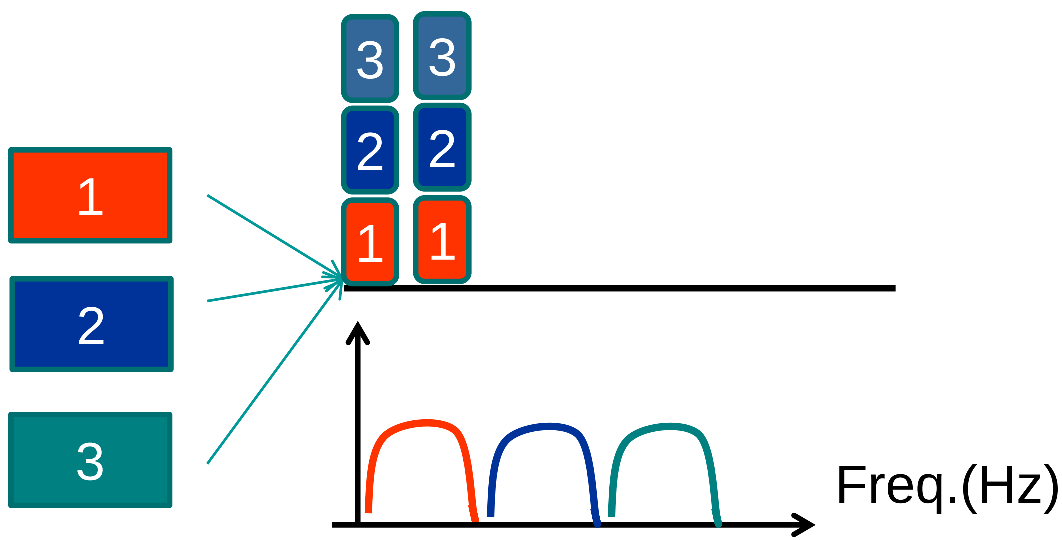
Time Division Multiplexing

- Users can send according to a fixed schedule
- Slotted access to the full speed of the media



Frequency Division Multiplexing

- Users can only use specific frequencies to send their data
- Continuous access with lower speed



Data Communication using Signals

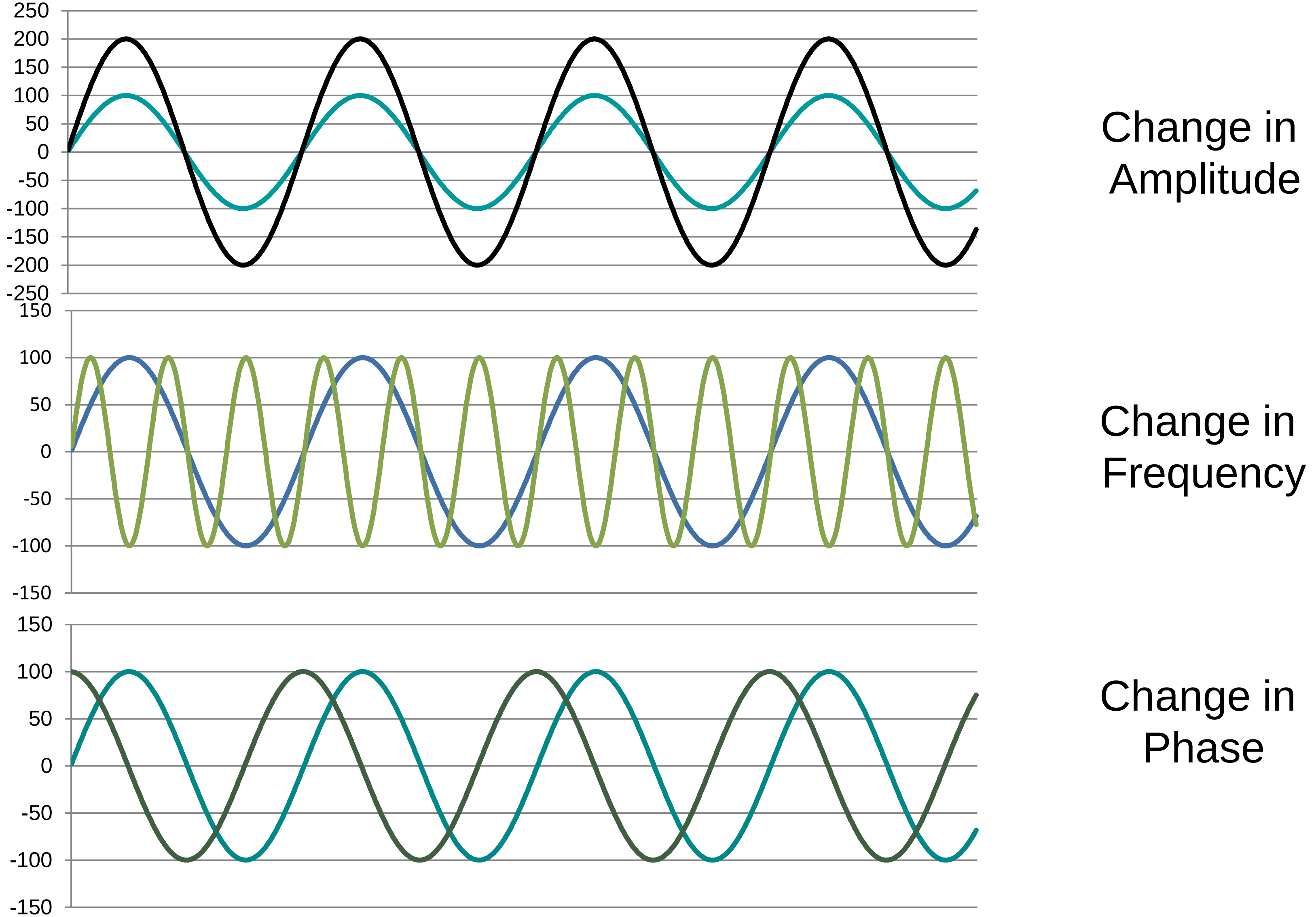
- Information is transmitted by varying a physical property e.g. voltage, current
- How to transform continuous signals into digital values? Sampling the amplitude values of the signal
- For a periodic function:

  e.g. Sine function: $c * \sin(a * t + b)$

  c: Amplitude, a/(2π):Frequency and b:Phase

  can change the behaviour of the function.

Change in Amplitude, Frequency, & Phase



Digital Modulation

Modulation schemes send bits as signals

Baseband Transmission

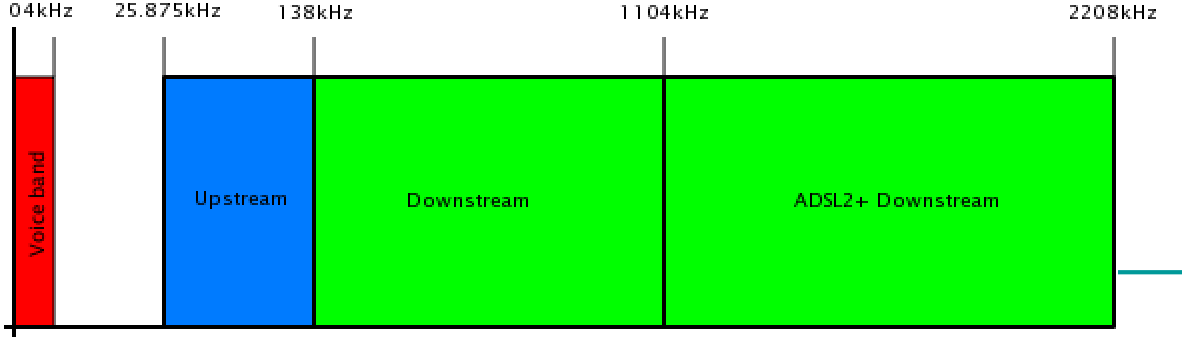
- Signal that run from 0 up to a maximum frequency
- E.g., Telephone system: 0 ~ 4kHz

Passband Transmission

- Signals that are shifted to occupy a higher range of frequencies

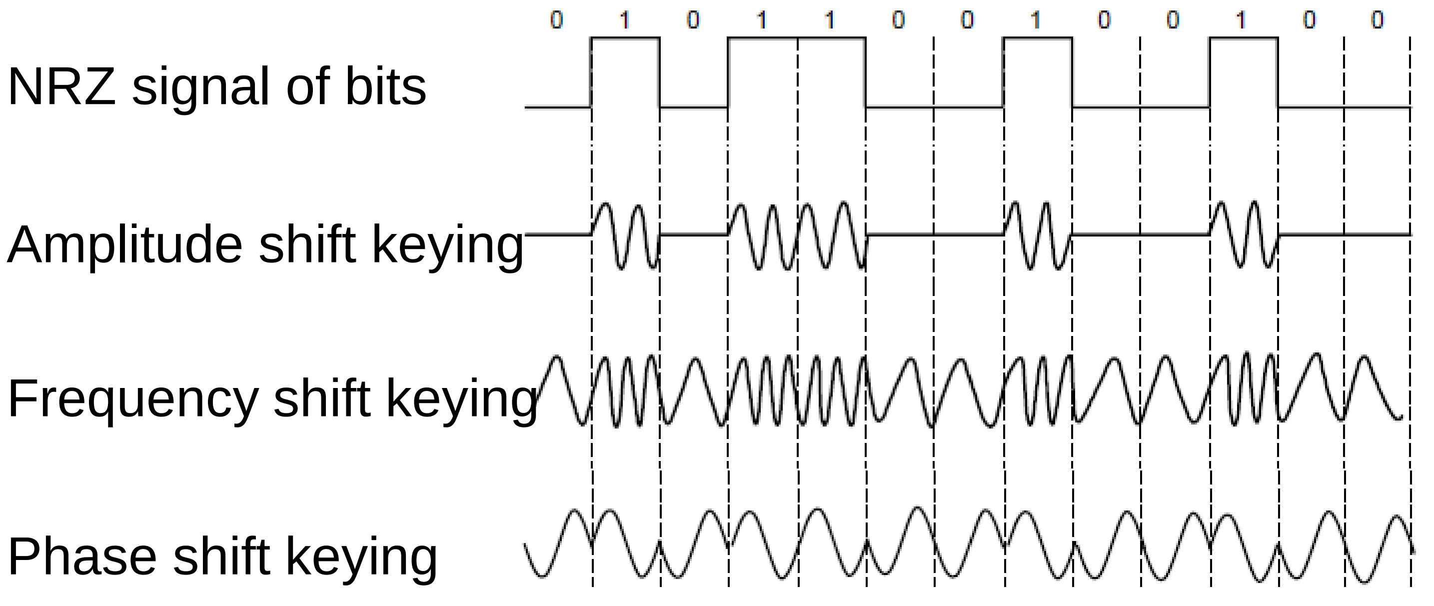
ADSL

Example



Modulation Types

- Modulating the amplitude, frequency/phase of a carrier signal sends bits in a (non-zero) frequency range



Symbol Rate

- One symbol (signal element) can represent multiple bits (data elements)
- Symbol Rate (Baud Rate): number of signal changes per second

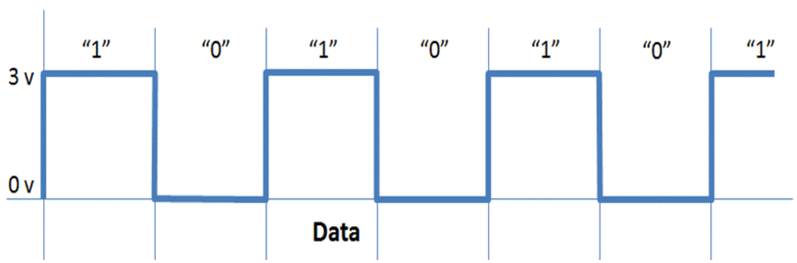


Figure 1. Data bits where logical "0" and "1" are represented by 0 volts and 3 volts respectively

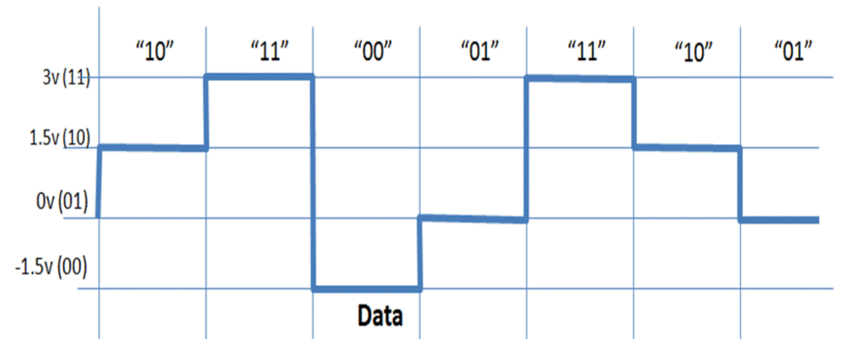


Figure 2. Four signaling levels per clock cycle can represent two data bits.

Source of figures: http://mason.gmu.edu/~rmorika2/Baud_Versus_Bits_per_second.htm

Harry Nyquist

- Early theoretical work on determining fundamental limits for the bandwidth required for communication-heralded digital revolution

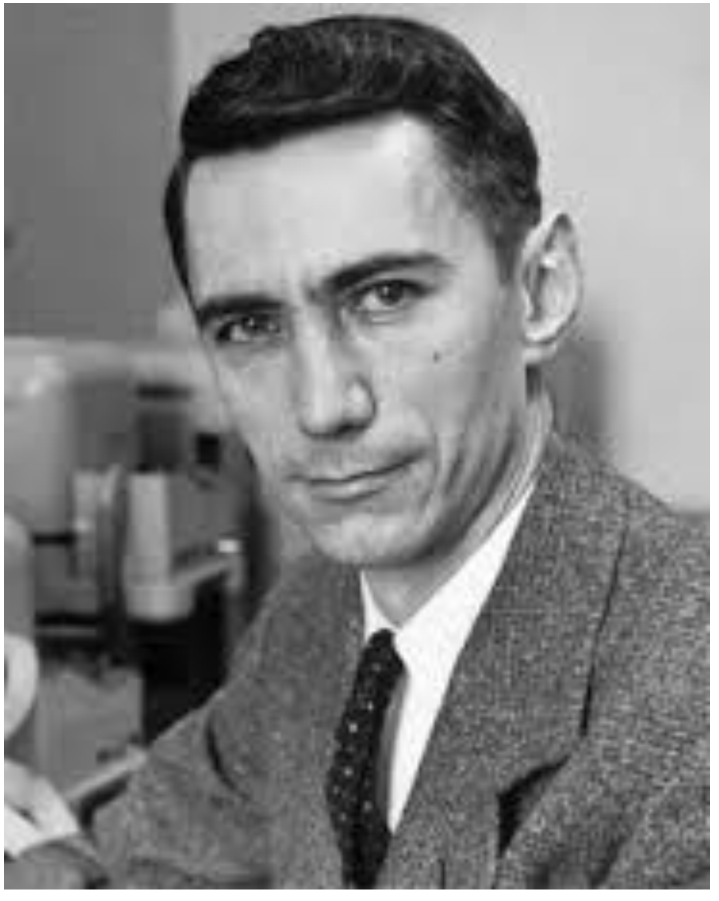
Maximum Data Rate of a Channel

- Nyquist's theorem relates the data rate to the bandwidth (B) and number of signal levels (V) (channel **without noise**):

$$\boxed{\text{Max. data rate} = 2B \log_2 V \text{ bits/sec}}$$

- Increase the bandwidth B can increase the data rate.
- If signal has V levels, each symbol can represent $\log_2 V$ bits.

Claude Shannon



- Father of Information theory.
- 1948 monograph – “The mathematical theory of communication” defined a new area;
- 1949 monograph- “Communication Theory of Secrecy Systems” is another foundational work on modern Cryptography

Maximum Data Rate of a Channel

- Shannon's theorem relates the data rate to the bandwidth (B) and signal strength (S) relative to the **noise** (N):

$$\boxed{\text{Max. data rate} = \underbrace{B}_{\text{How fast signal can change}} \log_2(1 + \underbrace{S/N}_{\text{How many levels can be seen}}) \text{ bits/sec}}$$

Example 1

Q: Given the signal-to-noise ratio (SNR) of 20 dB, and the bandwidth of 4kHz (telephone communications), what is the maximum data rate according to Shannon's theorem?

Ans:

Example 2

<u>Q</u>: If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?

<u>Ans</u>: