Digital Modulation

- The input is discrete signals
    - Time sequence of pulses or symbols
- Offers many advantages
    - Robustness to channel impairments
    - Easier multiplexing of variuous sources of information: voice, data, video.
    - Can accommodate digital error-control codes
    - Enables encryption of the transferred signals
        - More secure link

Factors that Influence Choice of Digital Modulation Techniques

- A desired modulation scheme
  - Provides low bit-error rates at low SNRs
    - Power efficiency
  - Performs well in multipath and fading conditions
  - Occupies minimum RF channel bandwidth
    - Bandwidth efficiency
  - Is easy and cost-effective to implement
- Depending on the demands of a particular system or application, tradeoffs are made when selecting a digital modulation scheme.

Power Efficiency of Modulation

- Power efficiency is the ability of the modulation technique to preserve fidelity of the message at low power levels.
- Usually in order to obtain good fidelity, the signal power needs to be increased.
  - Tradeoff between fidelity and signal power
  - Power efficiency describes how efficient this tradeoff is made

- Eb: signal energy per bit
- N0: noise power spectral density
- PER: probability of error

Bandwidth Efficiency of Modulation

- Ability of a modulation scheme to accommodate data within a limited bandwidth.
- Bandwidth efficiency reflect how efficiently the allocated bandwidth is utilized

R: the data rate (bps)
B: bandwidth occupied by the modulated RF signal

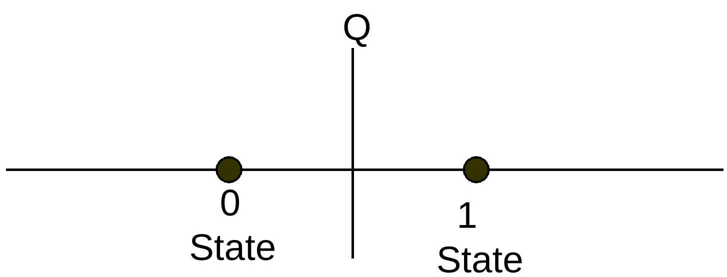
Linear Modulation Techniques

- Classify digital modulation techniques as:
  - Linear
    - The amplitude of the transmitted signal varies linearly with the modulating digital signal, m(t).
    - They usually do not have constant envelope.
    - More spectral efficient.
    - Poor power efficiency
    - Example: QPSK.
  - Non-linear

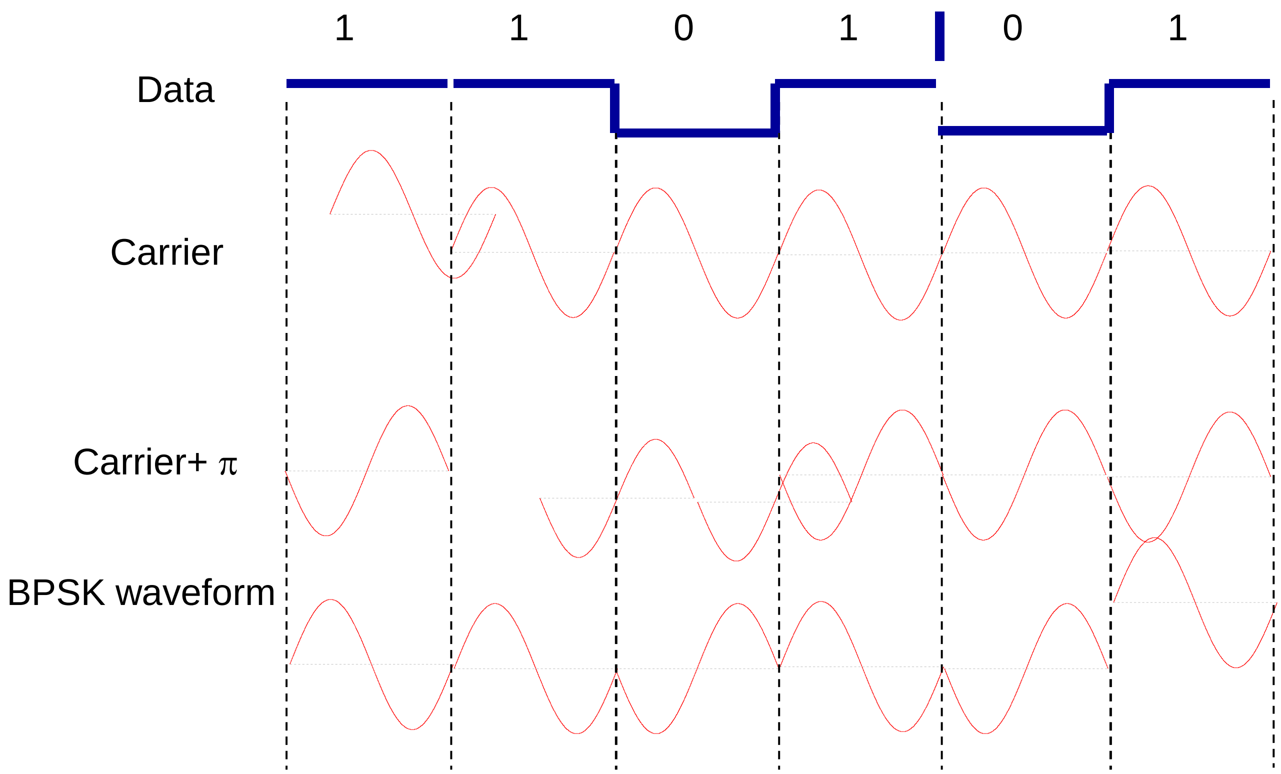
Binary Phase Shift Keying

- Use alternative sine wave phase to encode bits
  - Phases are separated by 180 degrees.
  - Simple to implement, inefficient use of bandwidth.
  - Very robust, used extensively in satellite communication.

$$s_1(t) = A_c \cos(2\pi f_c + \theta_c) \qquad \text{binary } 1$$
$$s_2(t) = A_c \cos(2\pi f_c + \theta_c + \pi) \quad \text{binary } 0$$

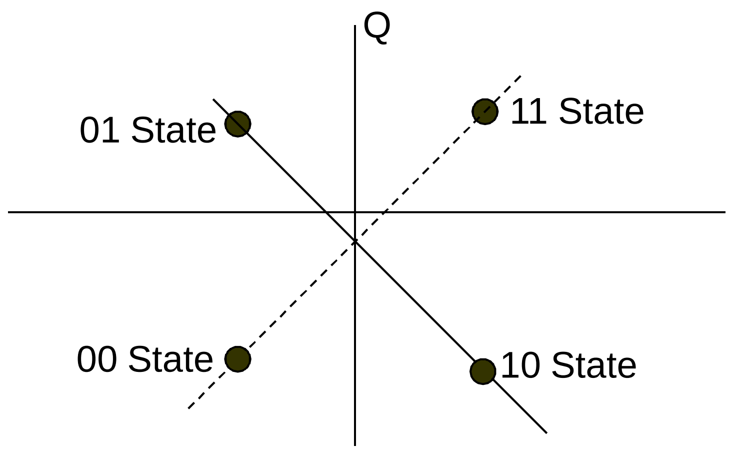


BPSK Example



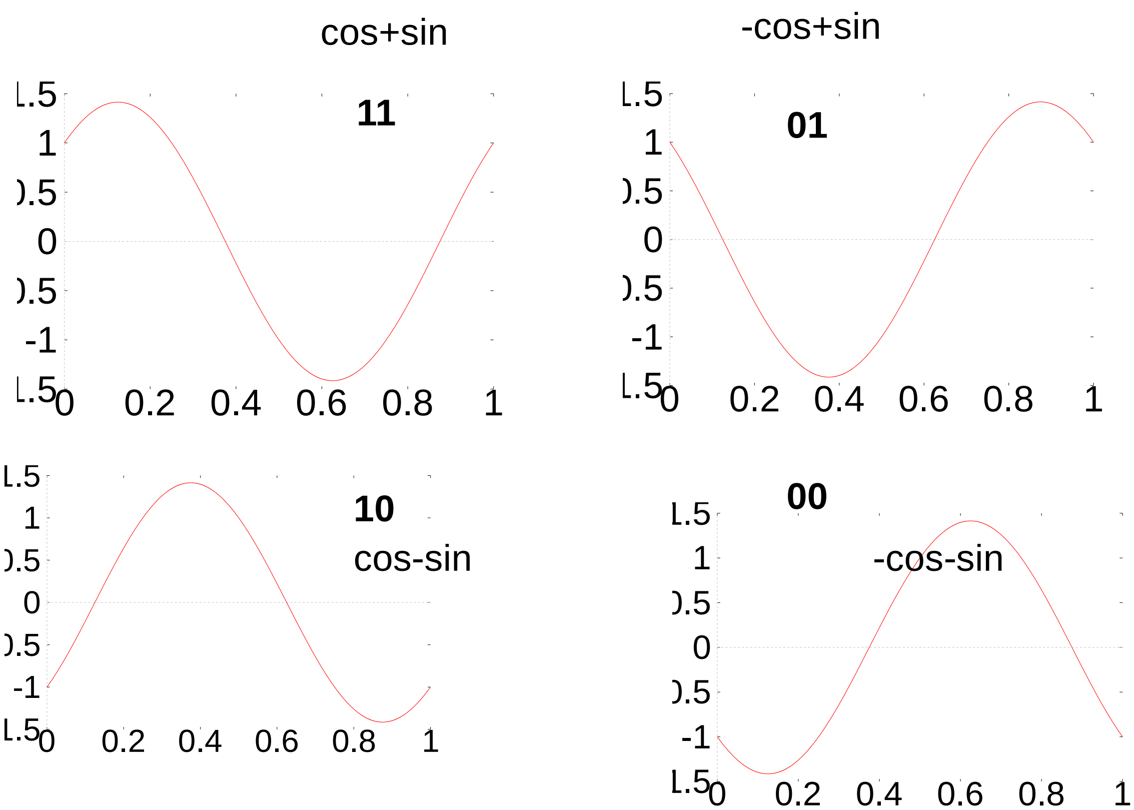
Quadrature Phase Shift Keying

- Multilevel Modulation Technique: 2 bits per symbol
- More spectrally efficient, more complex receiver.
- Two times more bandwidth efficient than BPSK



Phase of Carrier: $\pi/4$, $2\pi/4$, $5\pi/4$, $7\pi/4$

4 different waveforms



Constant Envelope Modulation

- Amplitude of the carrier is constant, regardless of the variation in the modulating signal
  - Better immunity to fluctuations due to fading.
  - Better random noise immunity
  - Power efficient
- They occupy larger bandwidth