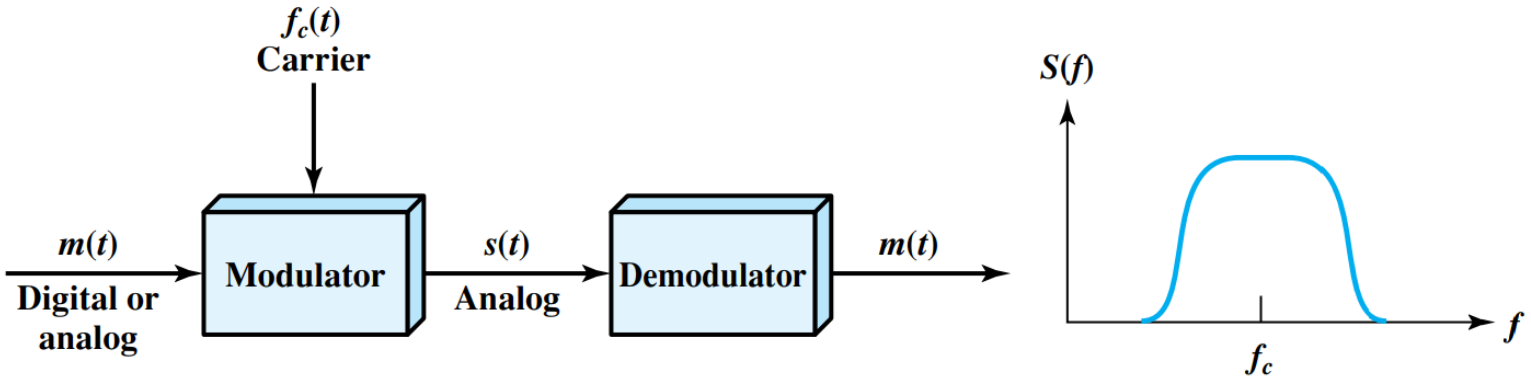
Computer Networks I

Signal Modulation Techniques (Digital to Analog)

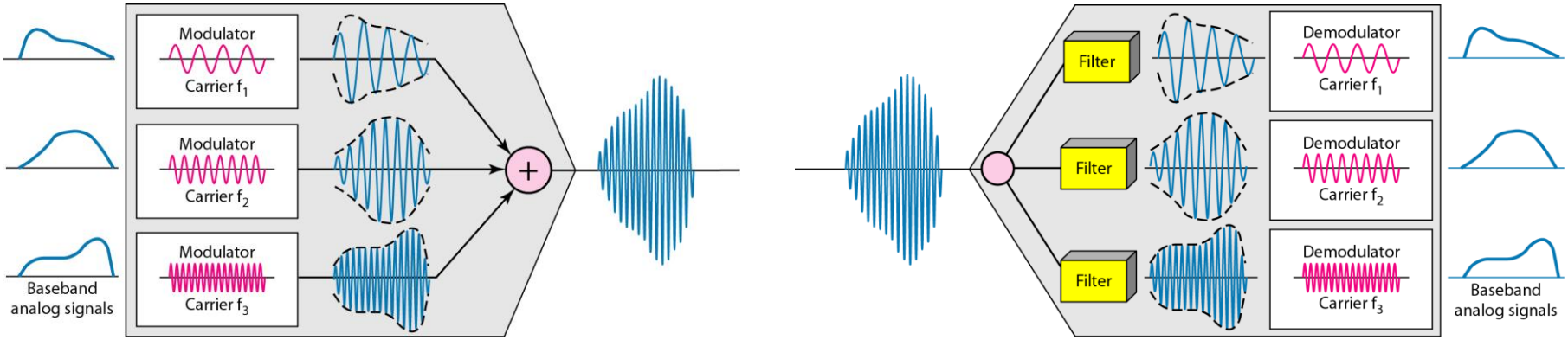
Amitangshu Pal
Computer Science and Engineering
IIT Kanpur

Modulation Basics

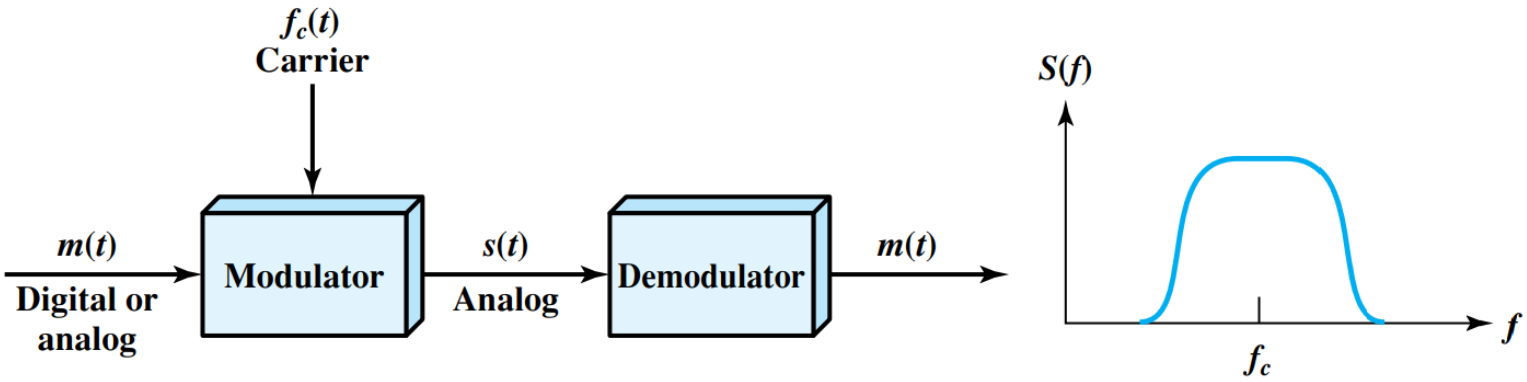


Why Modulation?

- Frequency reuse and multiplexing
  - Multiple stations can simultaneously transmit at different frequencies
- Reducing antenna length
  - Antenna length $\propto \lambda$



Digital Data → Analog Signals



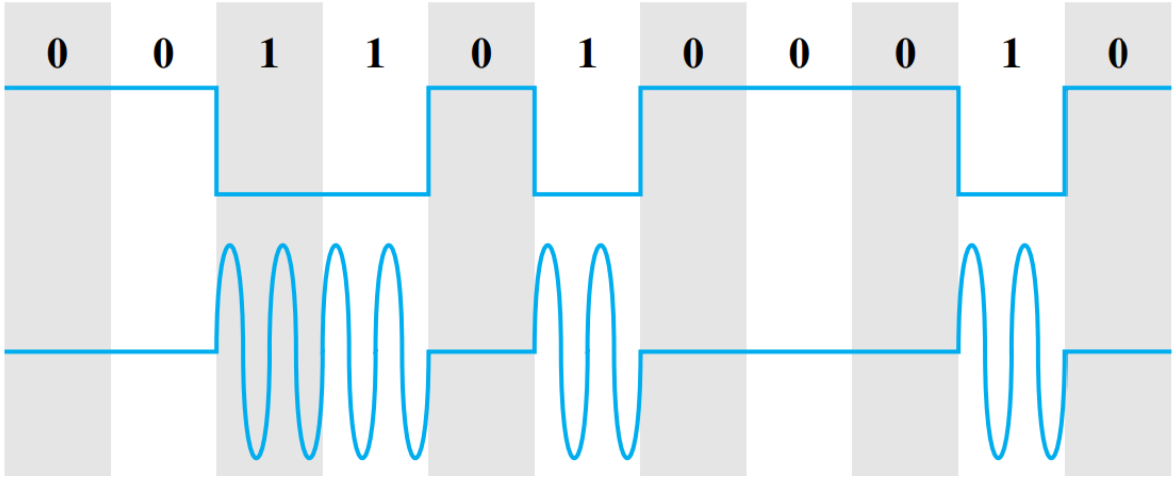
- Three principle techniques:
  - Amplitude shift keying (ASK)
  - Frequency shift keying (FSK)
  - Phase shift keying (PSK)

$$s(t) = A\sin(2\pi ft + \phi)$$

Amplitude Shift Keying

- Encode 0/1 by different carrier amplitudes
  - Usually have one amplitude zero

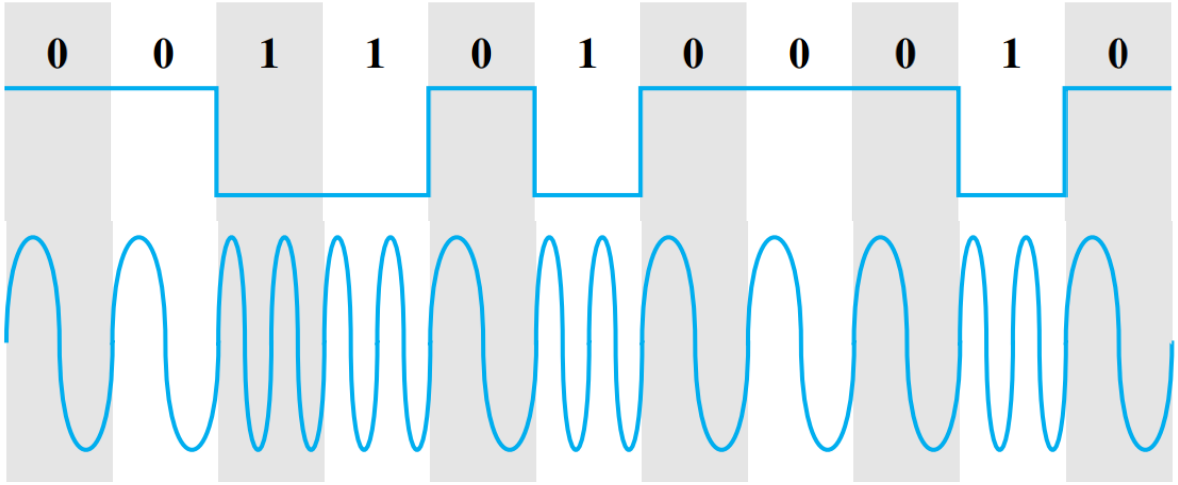
$$s(t) = \begin{cases} A_1 \cos(2\pi f_c t) & \text{binary 1} \\ A_2 \cos(2\pi f_c t) & \text{binary 0} \end{cases} = \begin{cases} A \cos(2\pi f_c t) & \text{binary 1} \\ 0 & \text{binary 0} \end{cases}$$



Frequency Shift Keying

- Most common is binary FSK (BFSK)
- Two binary values represented by two different frequencies

$$s(t) = \begin{cases} A\cos(2\pi f_1 t) & \text{binary 1} \\ A\cos(2\pi f_2 t) & \text{binary 0} \end{cases}$$



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- MFSK: $f_i = f_c + (2i - 1 - M)f_d$

M-ary FSK (MFSK):

MFSK extends the concept of FSK to more than two frequencies.
Each symbol in the digital data is represented by a unique frequency

f_i is the frequency of the i_th symbol.
f_c is the carrier frequency.
f_d is the frequency deviation, which is the difference between adjacent frequencies.

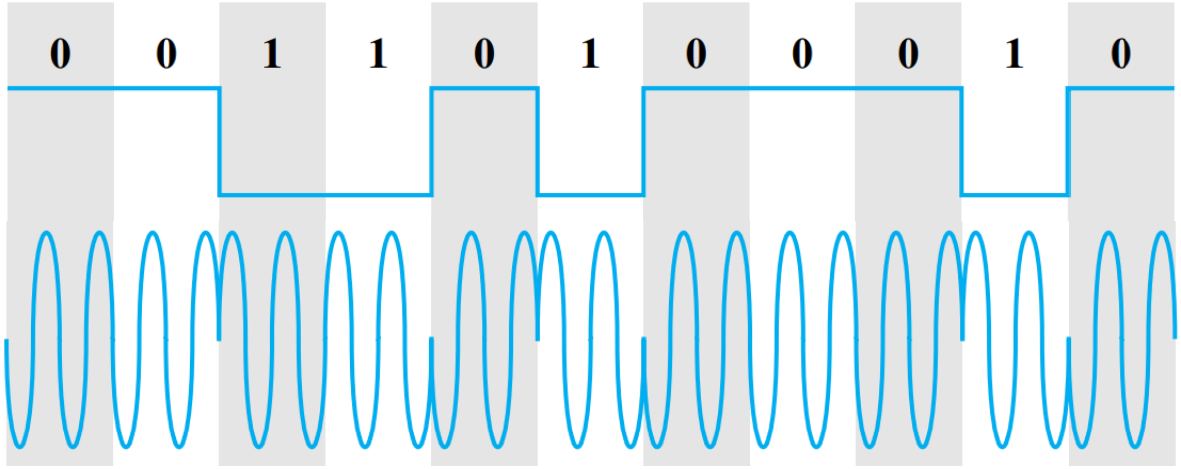
M is the number of frequencies (symbols).

Phase Shift Keying

- Phase of carrier signal is shifted to represent data

$$s(t) = \begin{cases} A\cos(2\pi f_c t + \pi) & \text{binary 1} \\ A\cos(2\pi f_c t) & \text{binary 0} \end{cases}$$

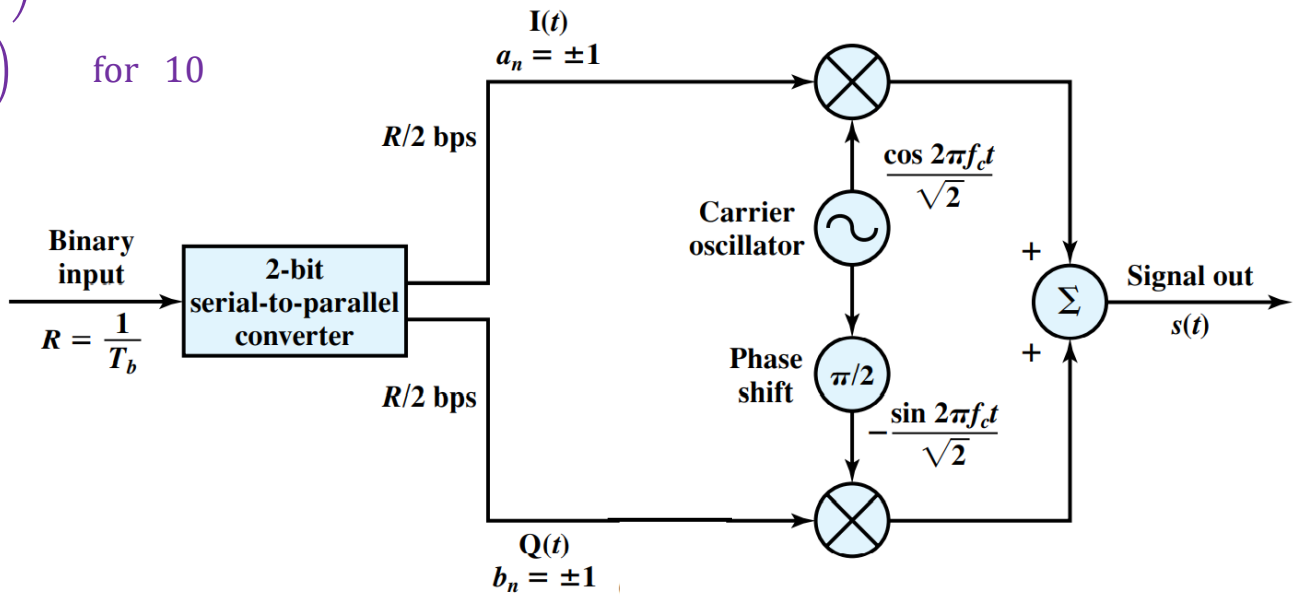
- Binary PSK
  - Two phases represent two binary digits



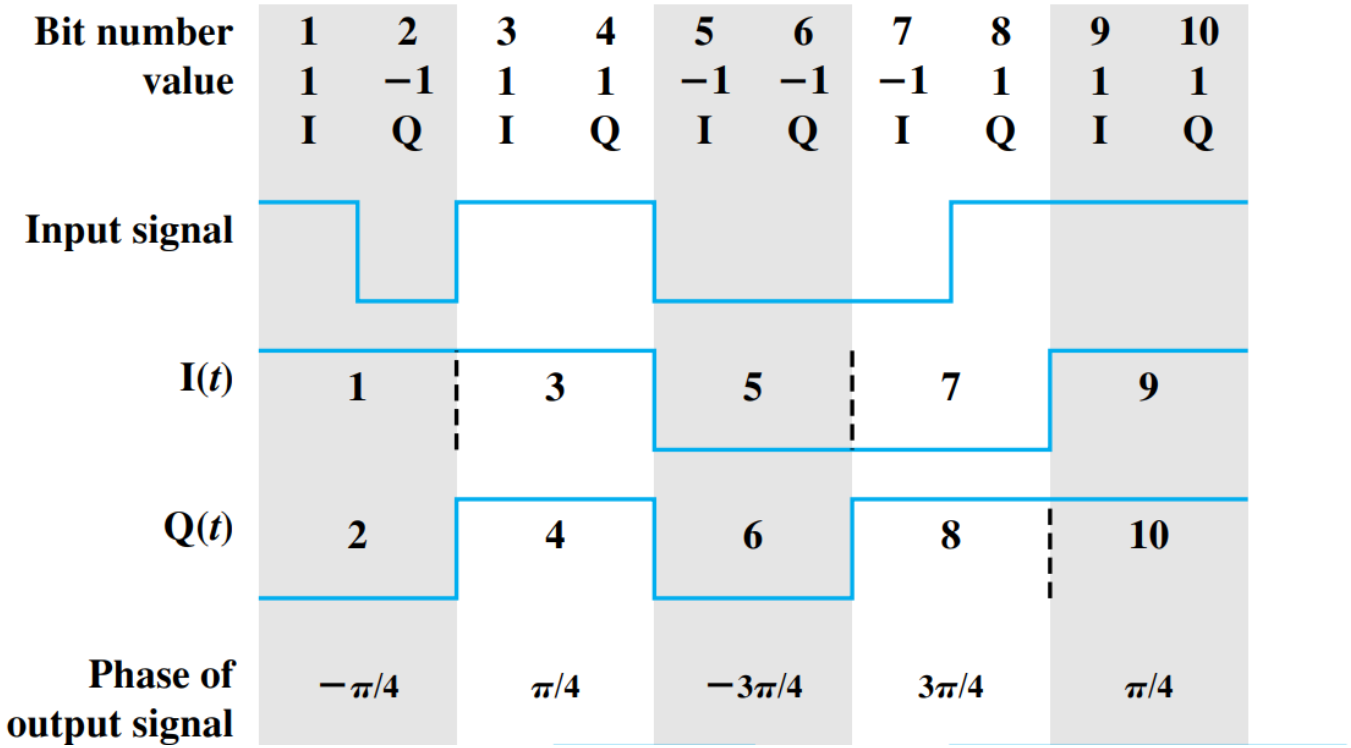
Quadrature Phase Shift Keying

$$s(t) = \begin{cases} A\cos\left(2\pi f_c t + \frac{\pi}{4}\right) & \text{for } 11 \\ A\cos\left(2\pi f_c t + \frac{3\pi}{4}\right) & \text{for } 01 \\ A\cos\left(2\pi f_c t - \frac{3\pi}{4}\right) & \text{for } 00 \\ A\cos\left(2\pi f_c t - \frac{\pi}{4}\right) & \text{for } 10 \end{cases}$$

$$\mathbf{s(t) = \frac{1}{\sqrt{2}} I(t)\cos 2\pi f_c t - \frac{1}{\sqrt{2}} Q(t)\sin 2\pi f_c t}$$

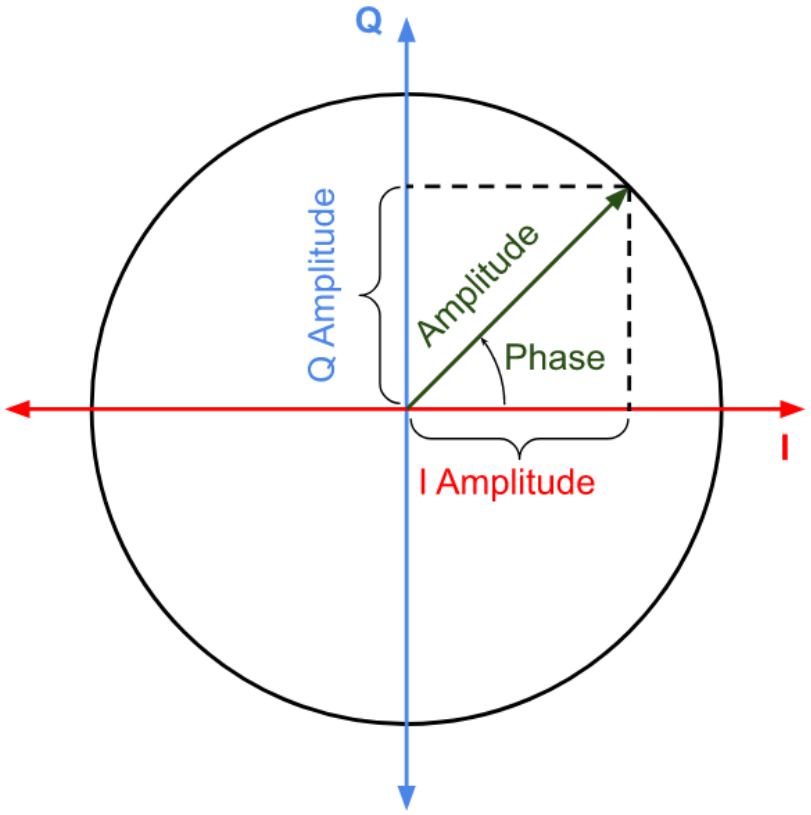


Quadrature Phase Shift Keying



Constellation Diagram

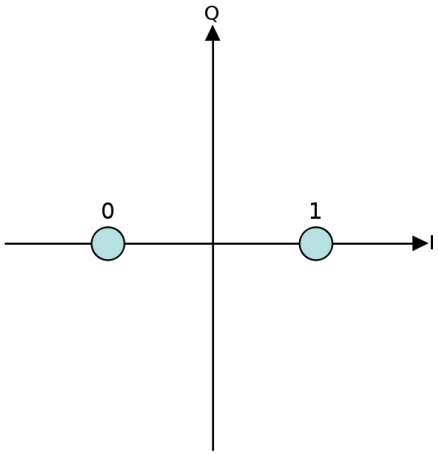
- Representation of a digital modulated signal as a two-dimensional scatter diagram



Src: https://commons.wikimedia.org/wiki/File:IQ_phasor_diagram.svg

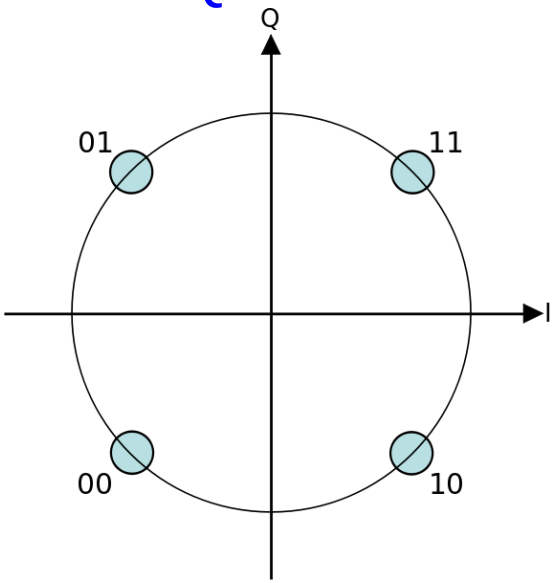
Constellation Diagram

BPSK



Src:https://commons.wikimedia.org/wiki/File:BPSK_Gray_Coded.svg

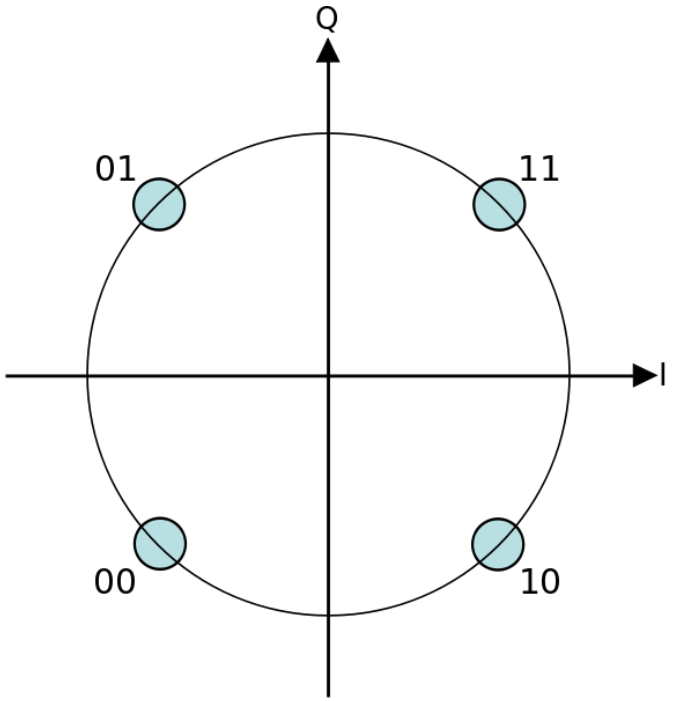
QPSK



Src:https://commons.wikimedia.org/wiki/File:QPSK_Gray_Coded.svg

Constellation Diagram

QPSK



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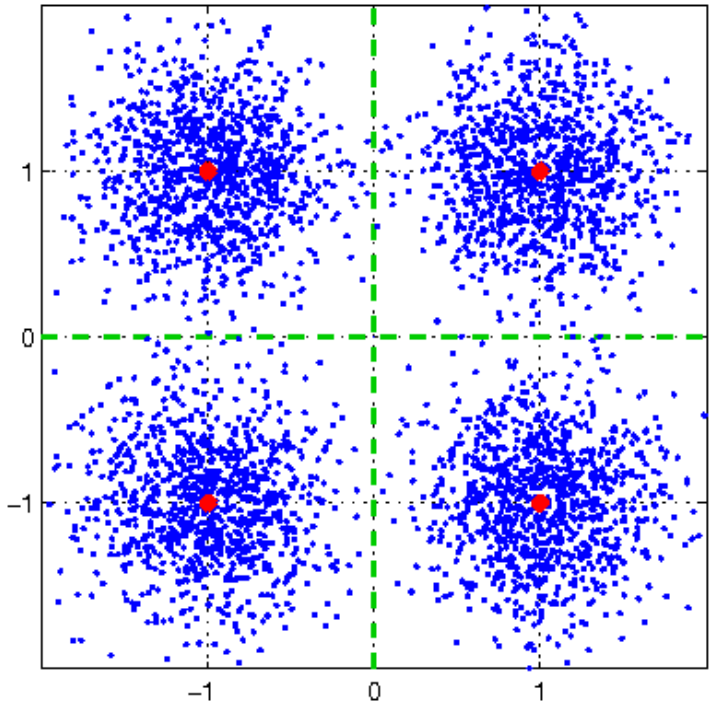
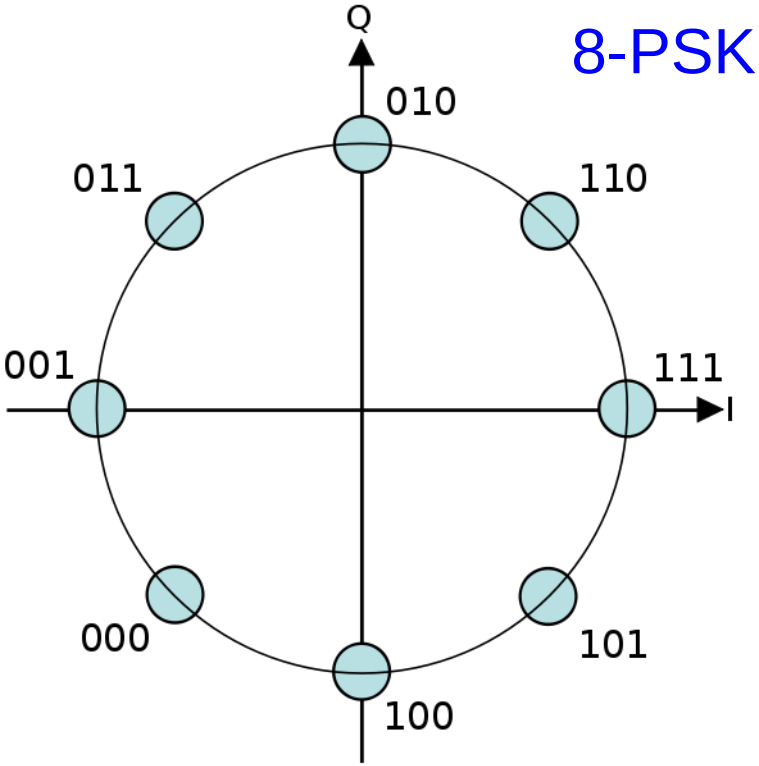


Src:https://commons.wikimedia.org/wiki/File:4qam_constellation_noisy_sigma025.png

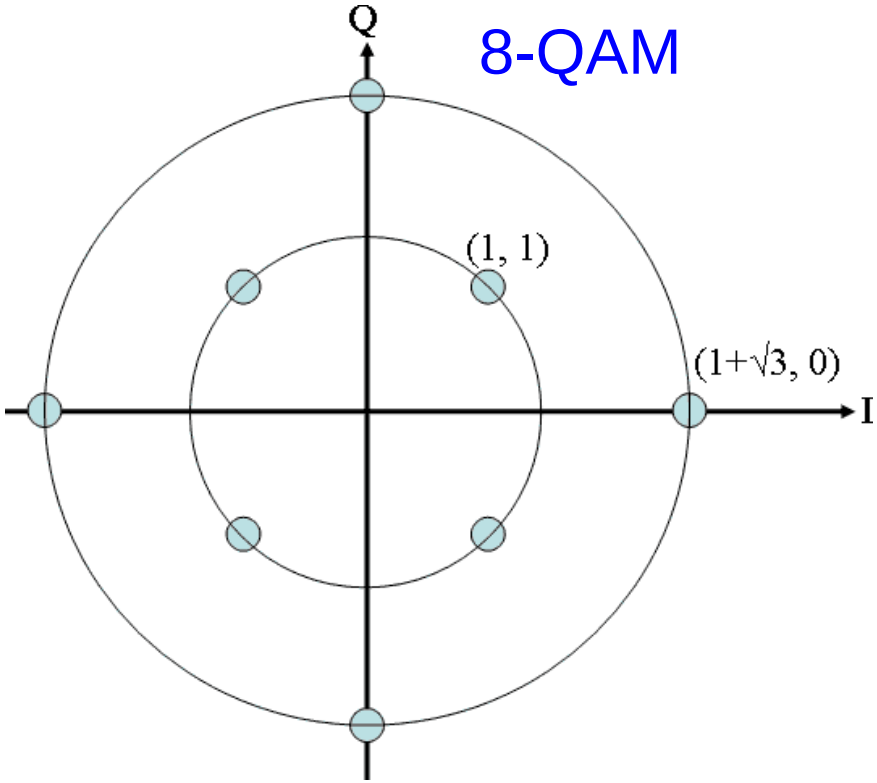
Constellation Diagram

8-PSK



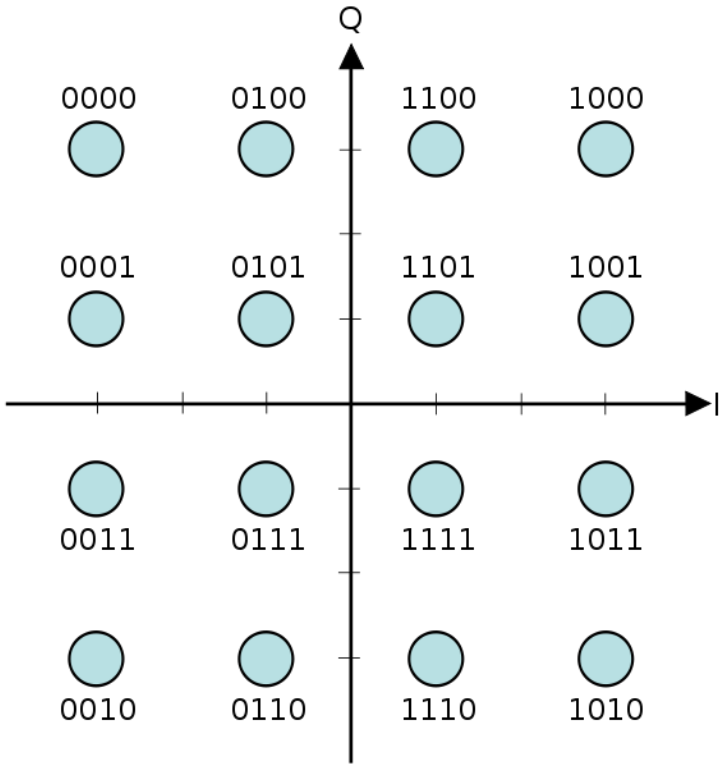
Src:https://commons.wikimedia.org/wiki/File:8PSK_Gray_Coded.svg

8-QAM



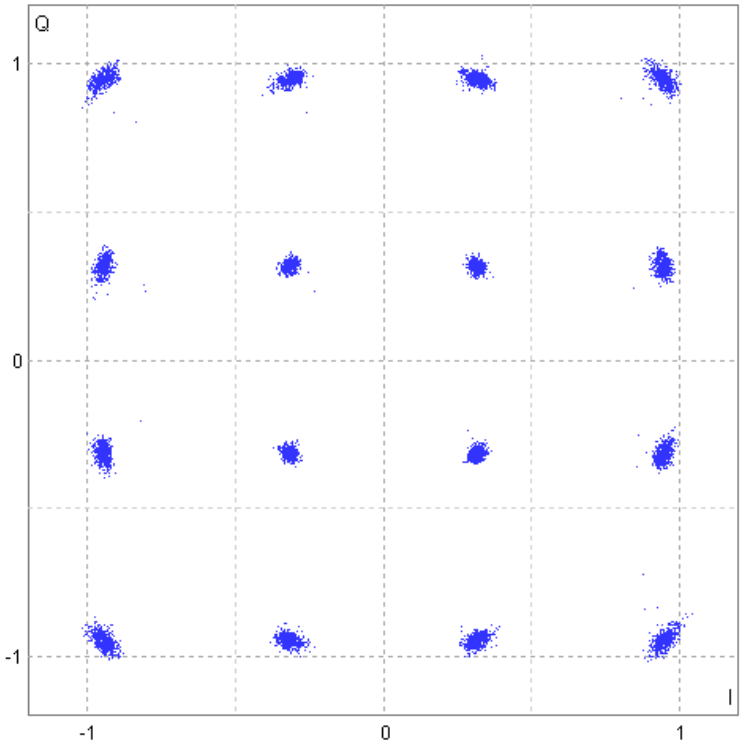
Src:https://commons.wikimedia.org/wiki/File:Circular_8QAM.png

Quadrature Amplitude Modulation



Src:https://commons.wikimedia.org/wiki/File:16QAM_Gray_Coded.svg

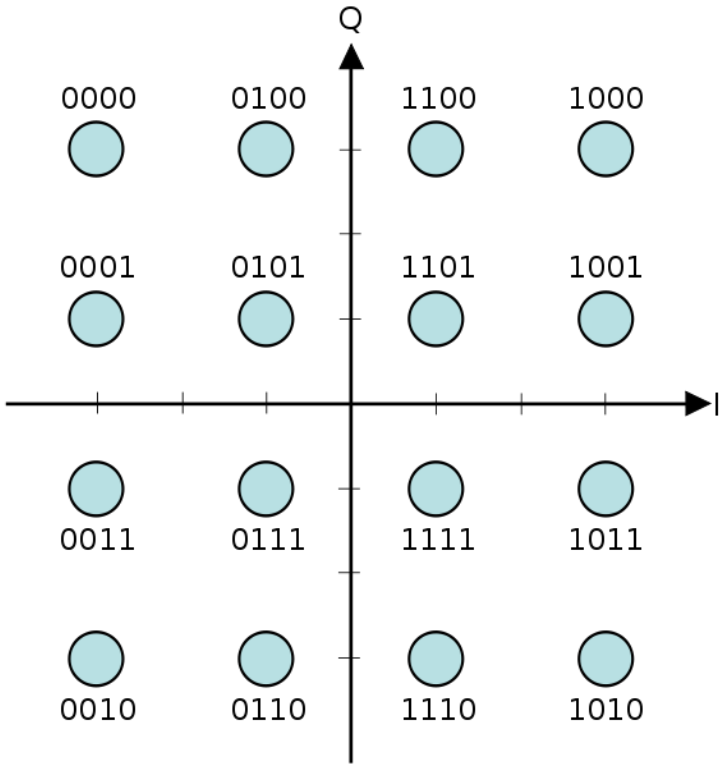
16-QAM



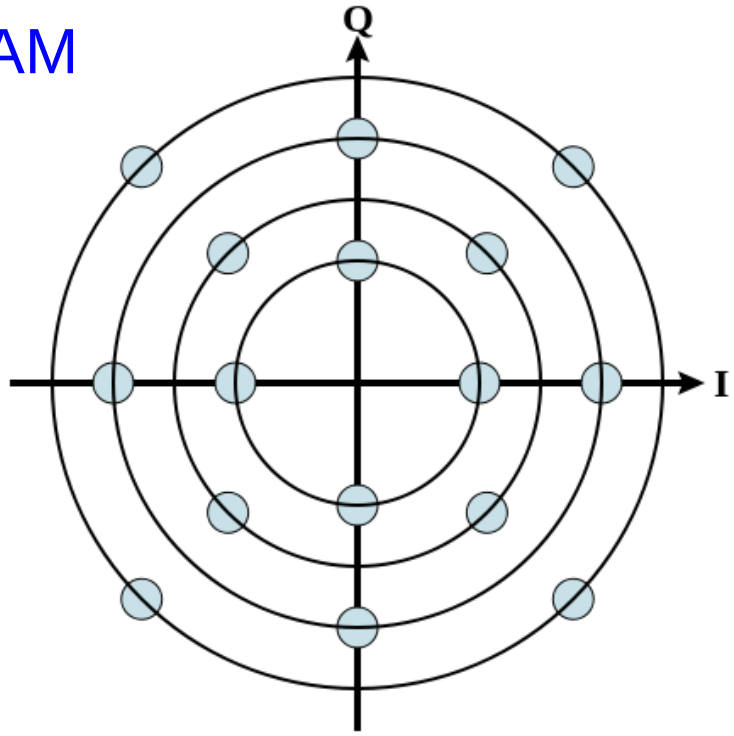
Src:https://commons.wikimedia.org/wiki/File:FDD_16-QAM.png

Quadrature Amplitude Modulation

16-QAM

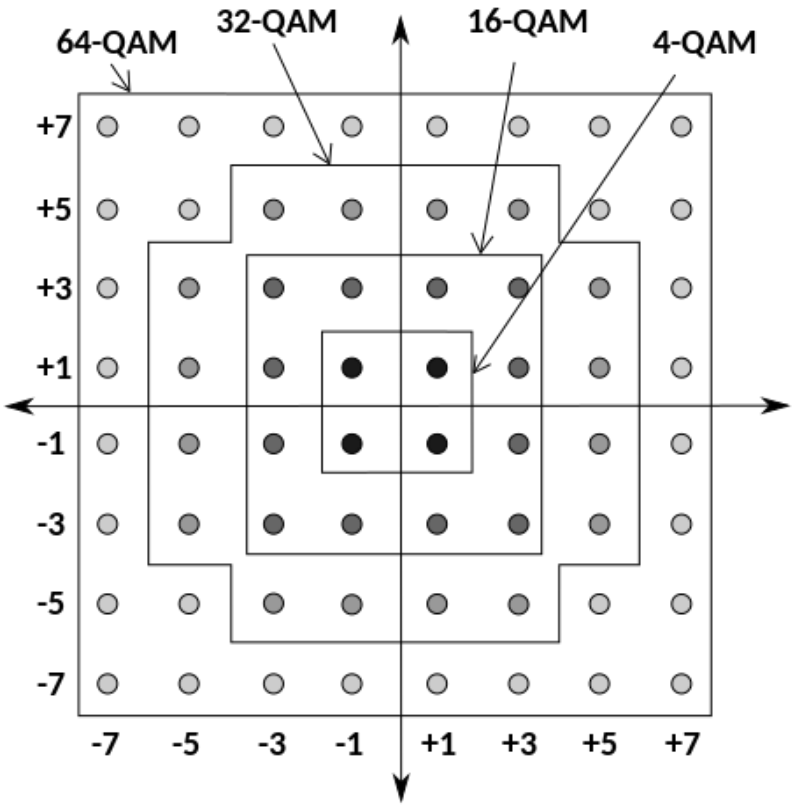


Src:https://commons.wikimedia.org/wiki/File:16QAM_Gray_Coded.svg



Src:https://commons.wikimedia.org/wiki/File:Circular_16QAM.svg

Quadrature Amplitude Modulation



Src:https://commons.wikimedia.org/wiki/File:Rectangular_constellation_for_QAM.svg

Bit and Baud Rate Comparison

Modulation	Bits/Baud	Baud rate	Bit Rate
ASK, FSK, 2-PSK	1	N	N
4-PSK, 4-QAM	2	N	2N
8-PSK, 8-QAM	3	N	3N
16-QAM	4	N	4N
32-QAM	5	N	5N
64-QAM	6	N	6N
128-QAM	7	N	7N
256-QAM	8	N	8N

Summary

- Modulation techniques (Digital data → Analog signals):
  - Different modulation techniques discussed
    - Amplitude Shift Keying
    - Frequency Shift Keying
    - Phase Shift Keying
  - Constellation diagram
  - Quadrature Amplitude Modulation