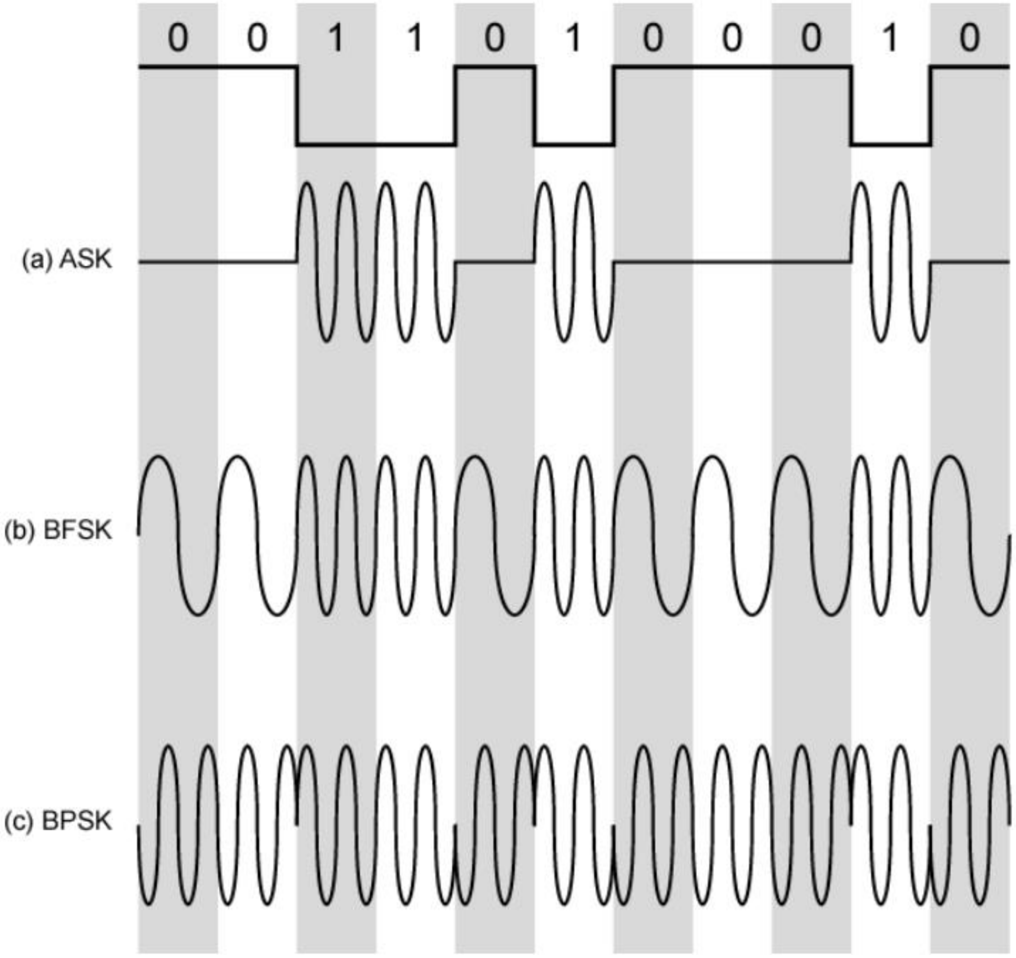
Computer Networks

Signal Encoding Techniques (Digital to Analog)

Amitangshu Pal
Computer Science and Engineering
IIT Kanpur

Digital Data → Analog Signals

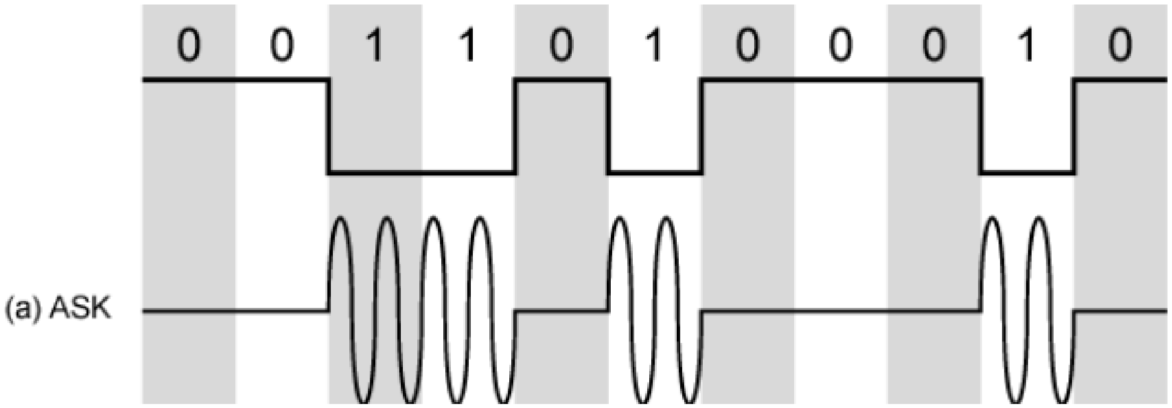
Modulation Techniques



Amplitude Shift Keying

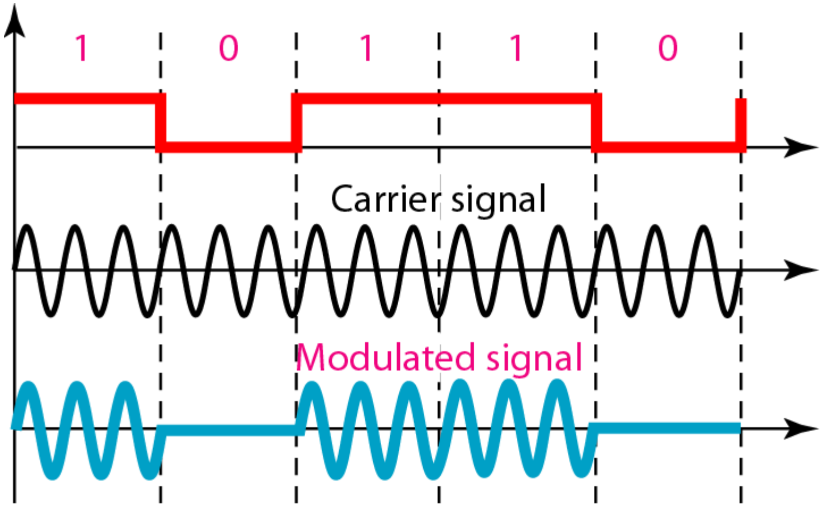
- Encode 0/1 by different carrier amplitudes
  - Usually have one amplitude zero

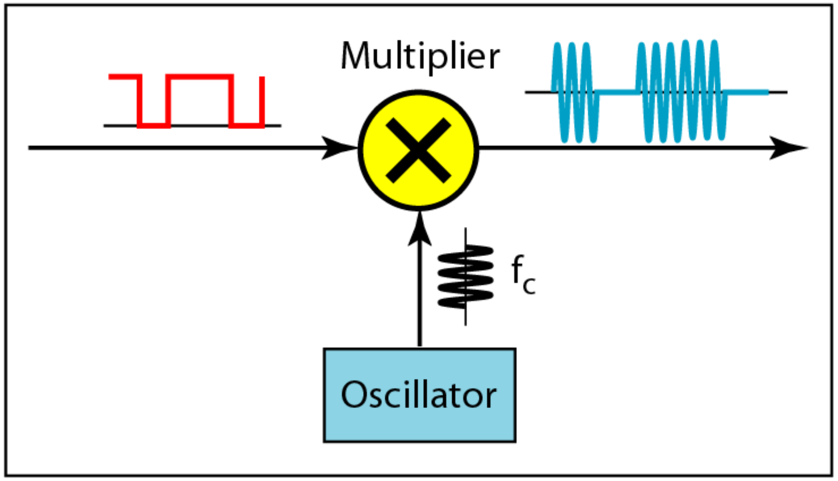
$$
\begin{aligned}
s(t) &= \begin{cases} A_1 \cos(2\pi f_c t) & \text{binary } 1 \\ A_2 \cos(2\pi f_c t) & \text{binary } 0 \end{cases} \\
&= \begin{cases} A \cos(2\pi f_c t) & \text{binary } 1 \\ 0 & \text{binary } 0 \end{cases}
\end{aligned}
$$



Amplitude Shift Keying

- Used for:
  - Up to 1200bps on voice grade lines
  - Optical fiber





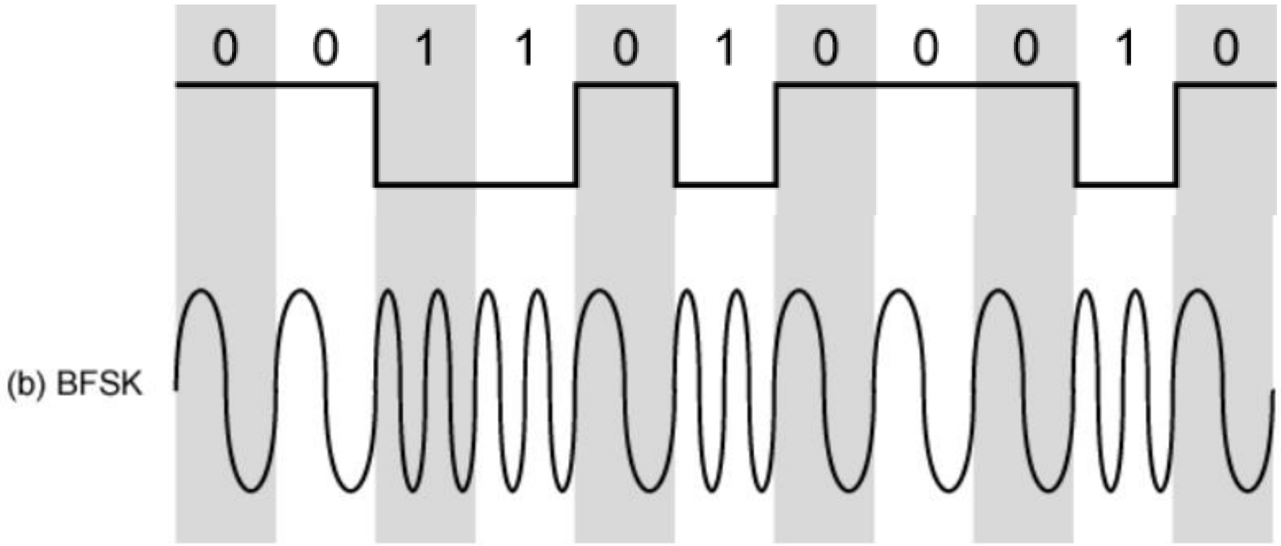
Frequency Shift Keying

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

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

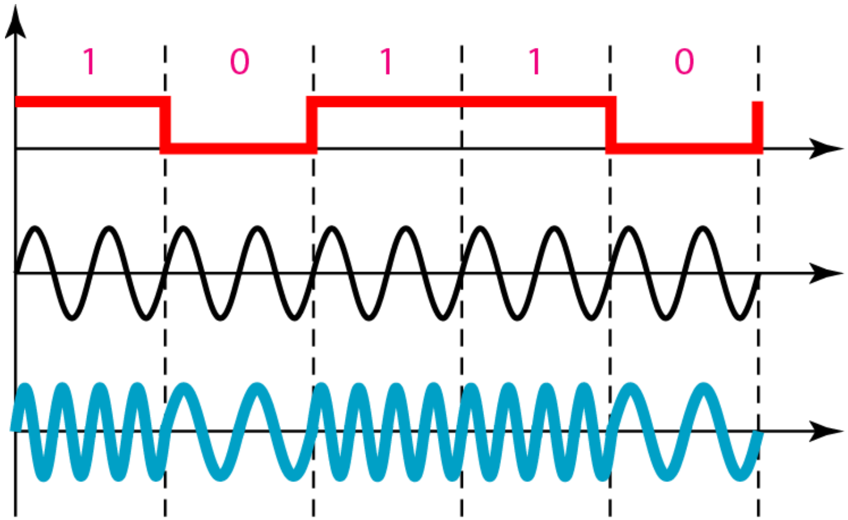
- MFSK:

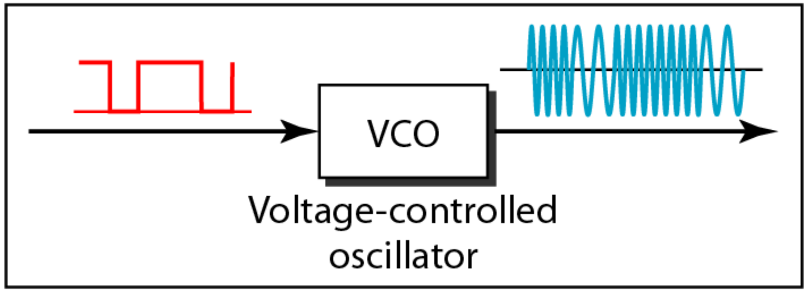
$$f_i = f_c + (2i - 1 - M) f_d$$



Frequency Shift Keying

- Most common is binary FSK (BFSK)
- Two binary values represented by two different frequencies
- Used in:
  - Upto 1200 bps on voice-graded lines
  - High frequency radio
  - LANs that use coaxial cable



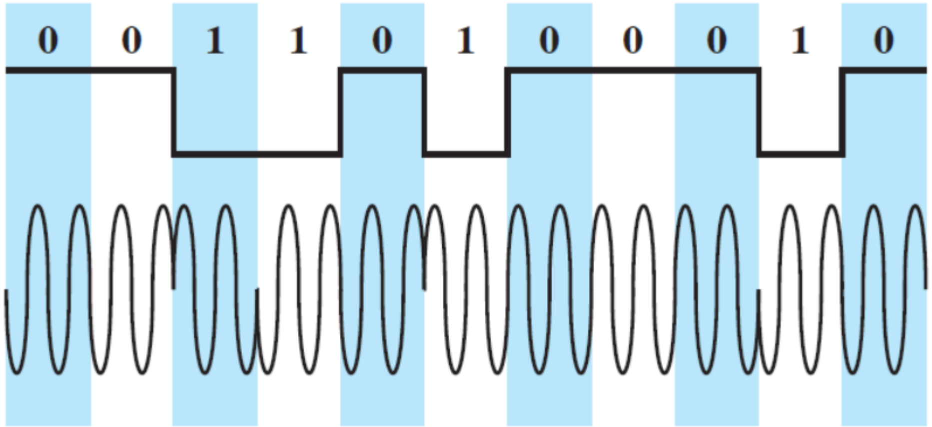


Phase Shift Keying

- Phase of carrier signal is shifted to represent data
- Binary PSK
  - Two phases represent two binary digits

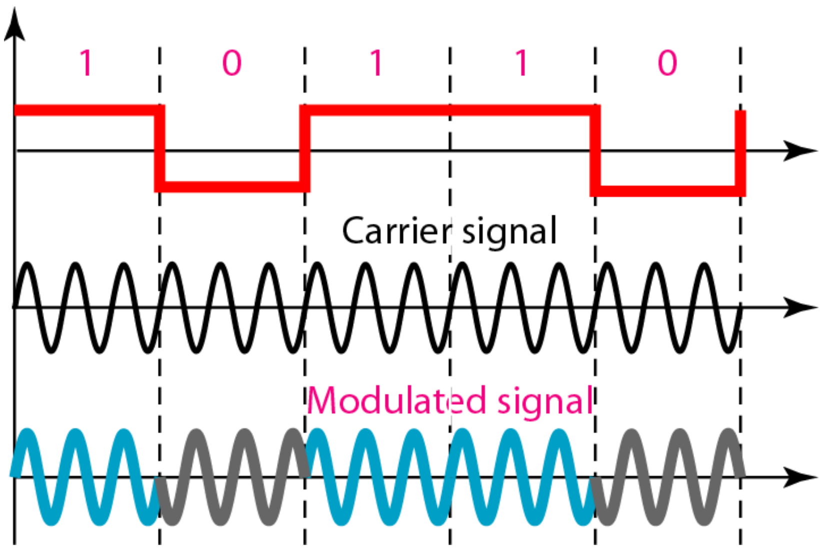
$$s(t) = \begin{cases} A\cos(2\pi f_c t + \pi) & \text{binary } 1 \\ A\cos(2\pi f_c t) & \text{binary } 0 \end{cases}$$

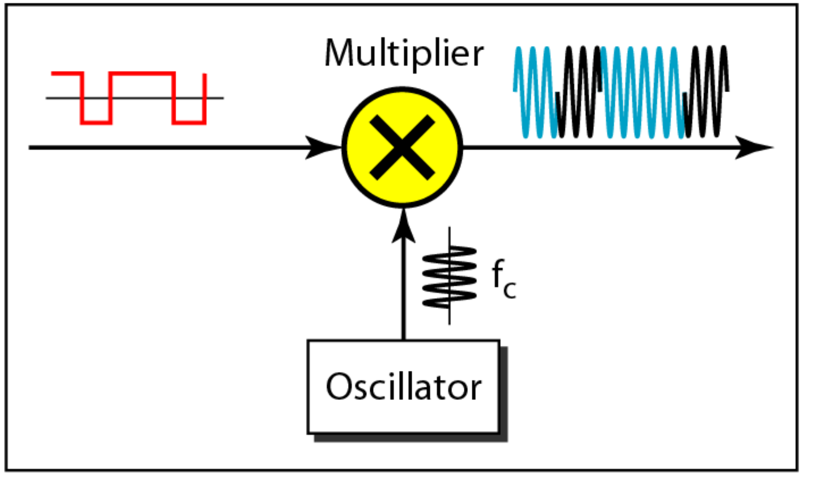
- Differential PSK
  - Phase shifted relative to previous transmission rather than some



Binary Phase Shift Keying

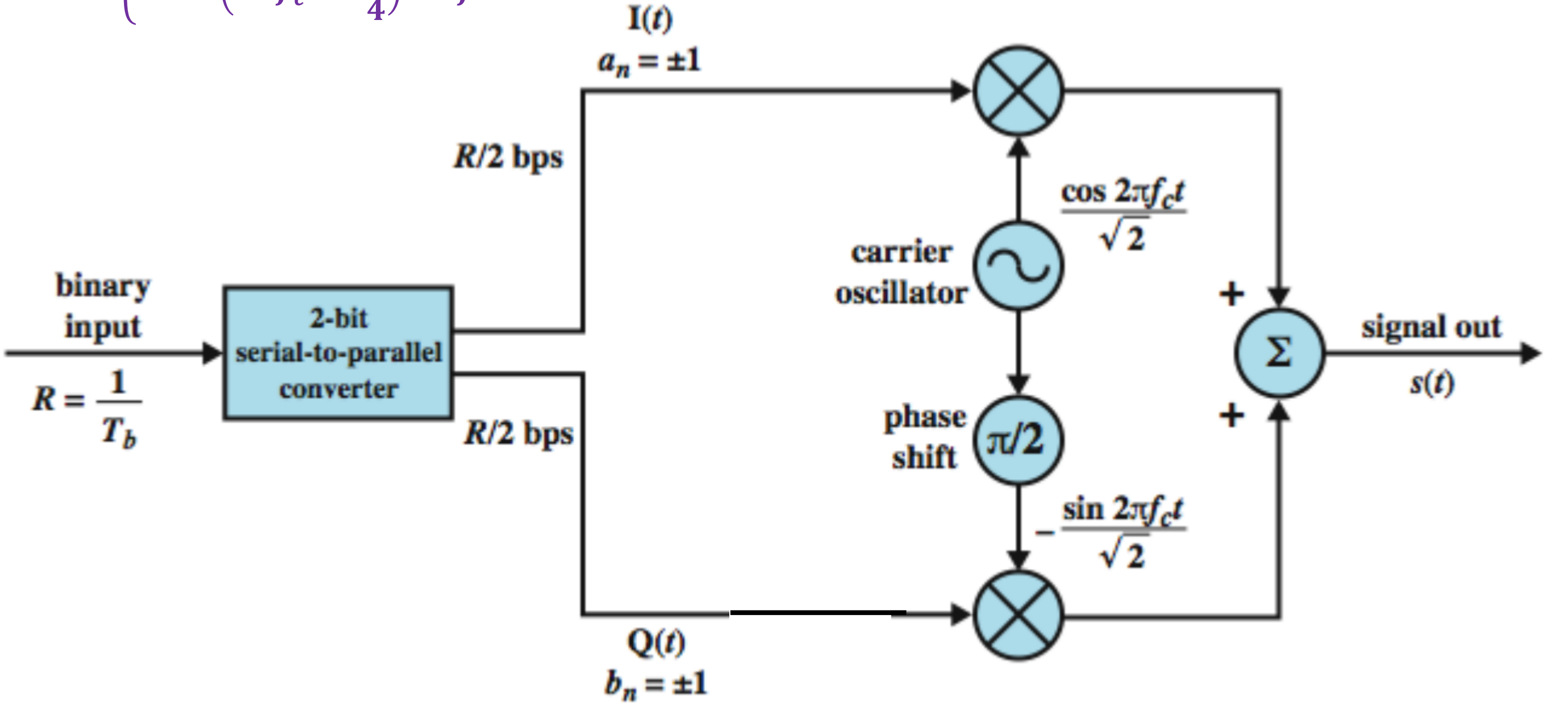
$$s(t) = \begin{cases} A\cos(2\pi f_c t + \pi) & \text{binary 1} \\ A\cos(2\pi f_c t) & \text{binary 0} \end{cases}$$





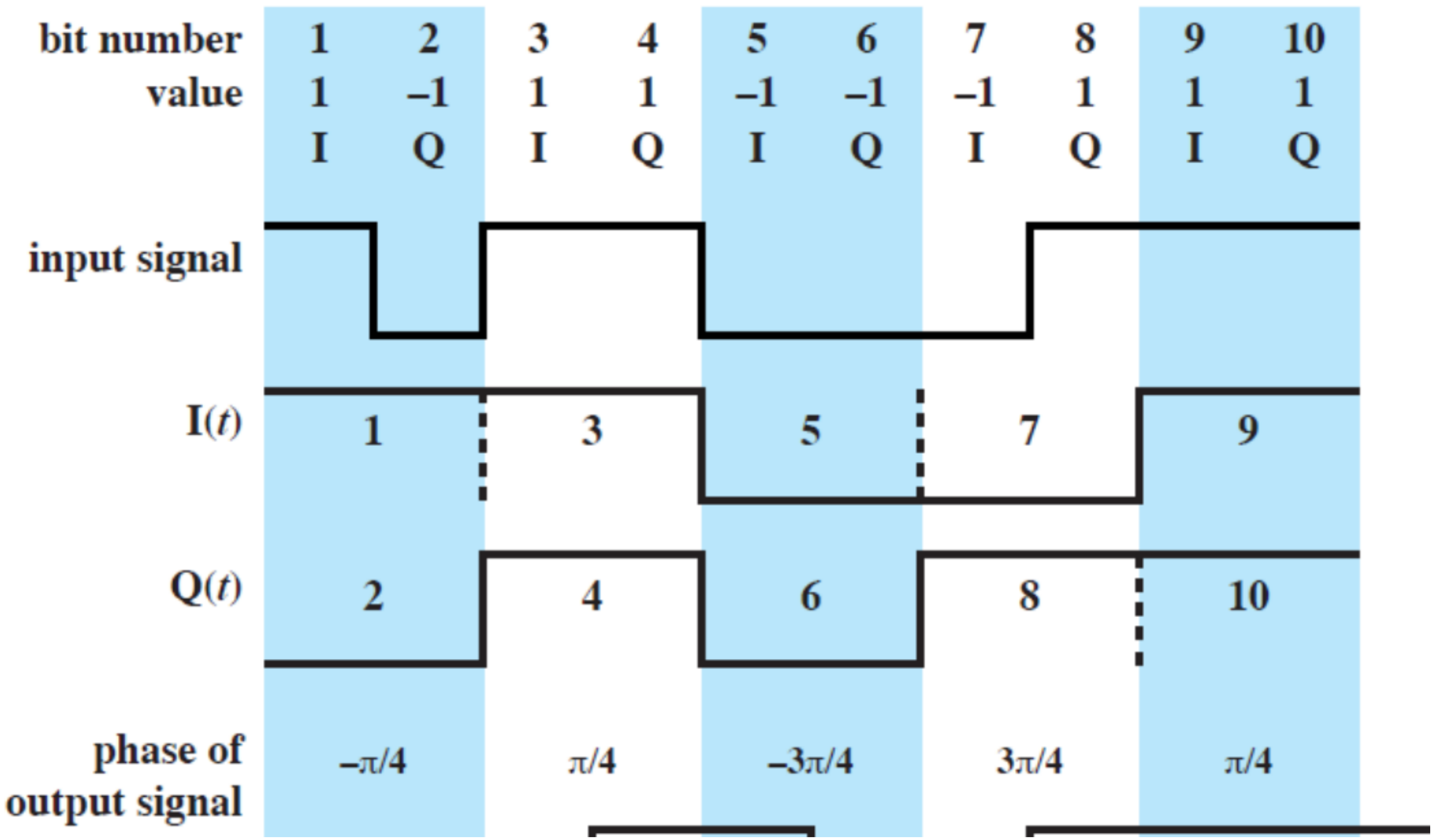
Quadrature Phase Shift Keying

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



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

Quadrature Phase Shift Keying



Constellation Diagram

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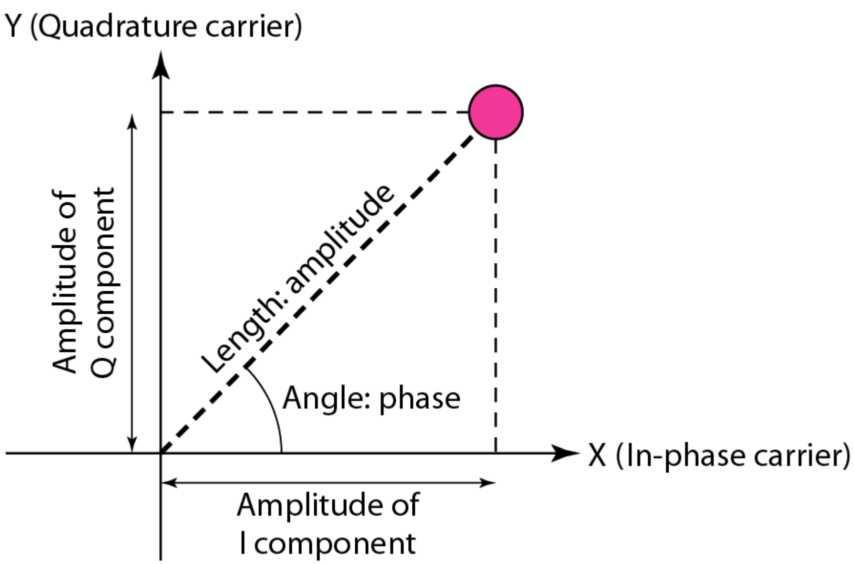
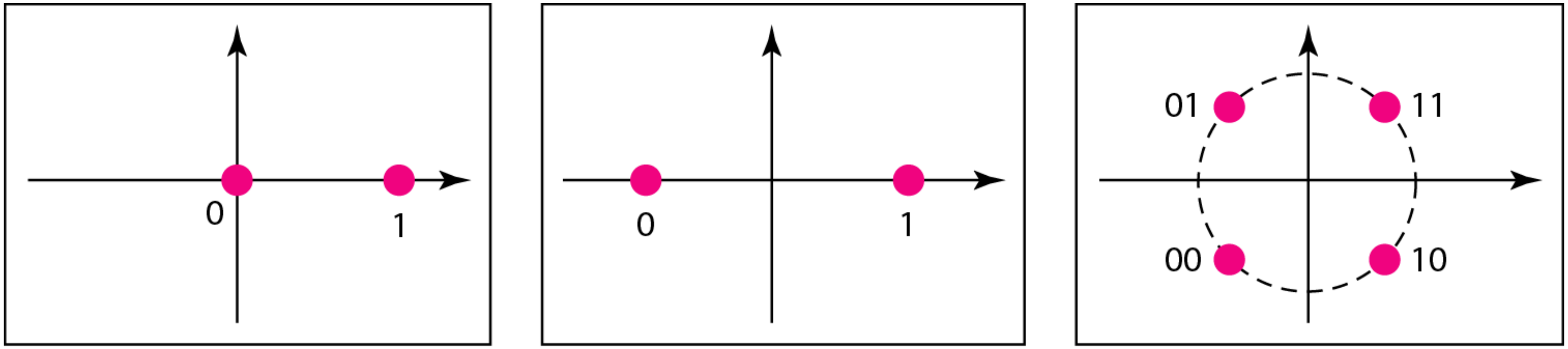


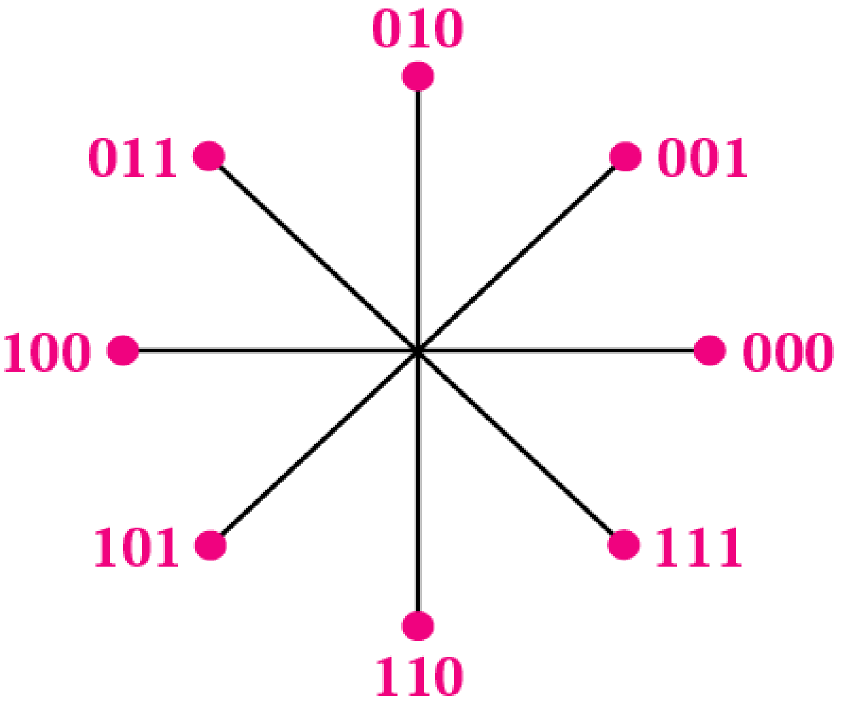


a. ASK (OOK) b. BPSK c. QPSK

Constellation Diagram

Tribit	Phase
000	0
001	45
010	90
011	135
100	180
101	225
110	270
111	315

Tribits
(3 bits)

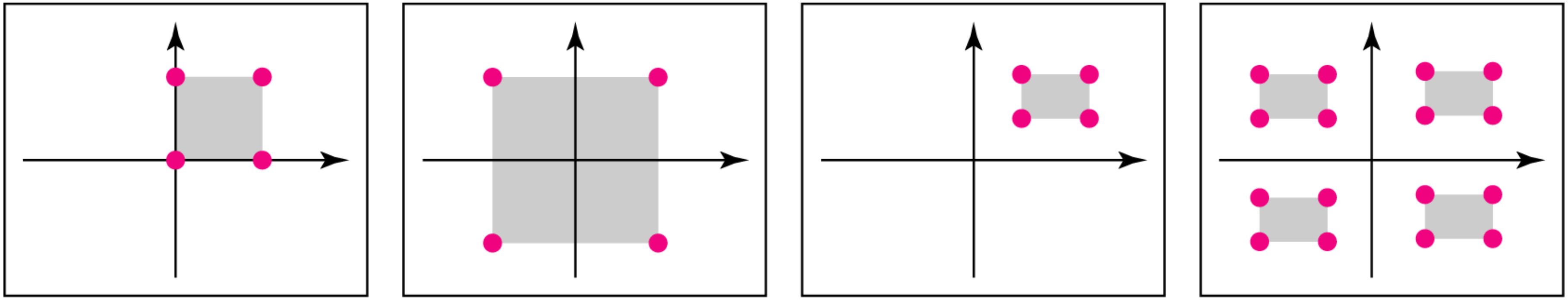


Constellation diagram

Quadrature Amplitude Modulation

- QAM used on asymmetric digital subscriber line (ADSL) and some wireless

Quadrature amplitude modulation is a combination of ASK and PSK.



a. 4-QAM b. 4-QAM c. 4-QAM d. 16-QAM

Quadrature Amplitude Modulation

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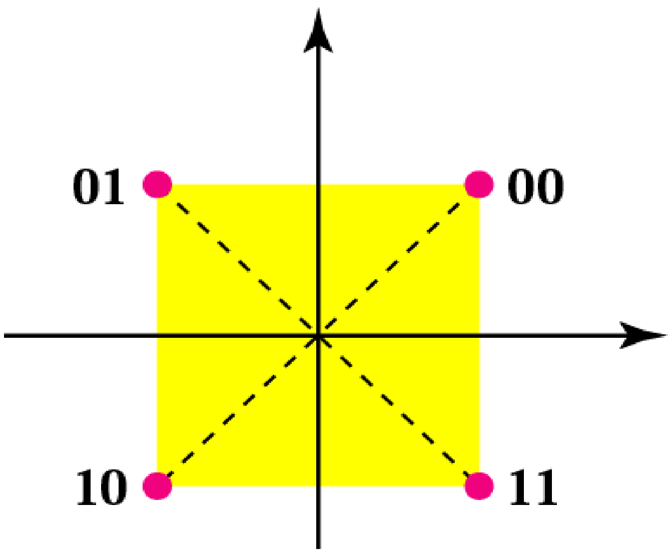
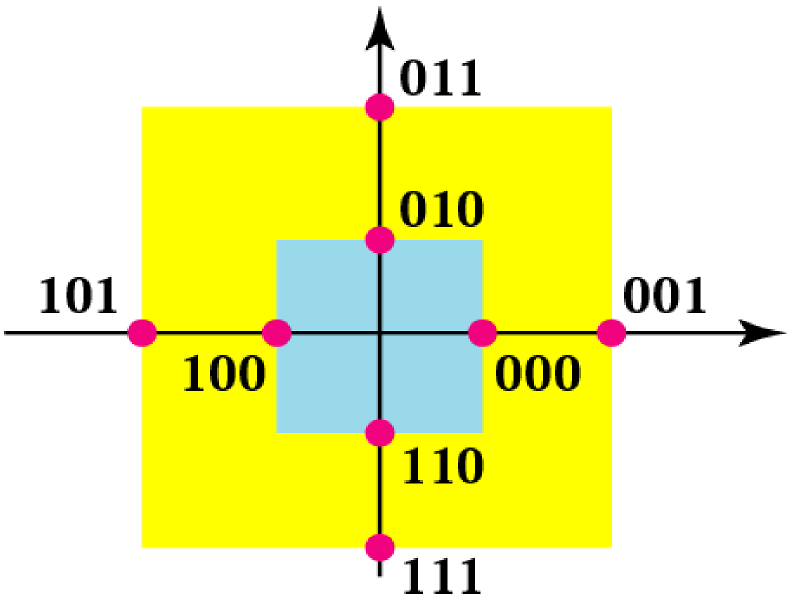
Quadrature amplitude modulation is a combination of ASK and PSK.



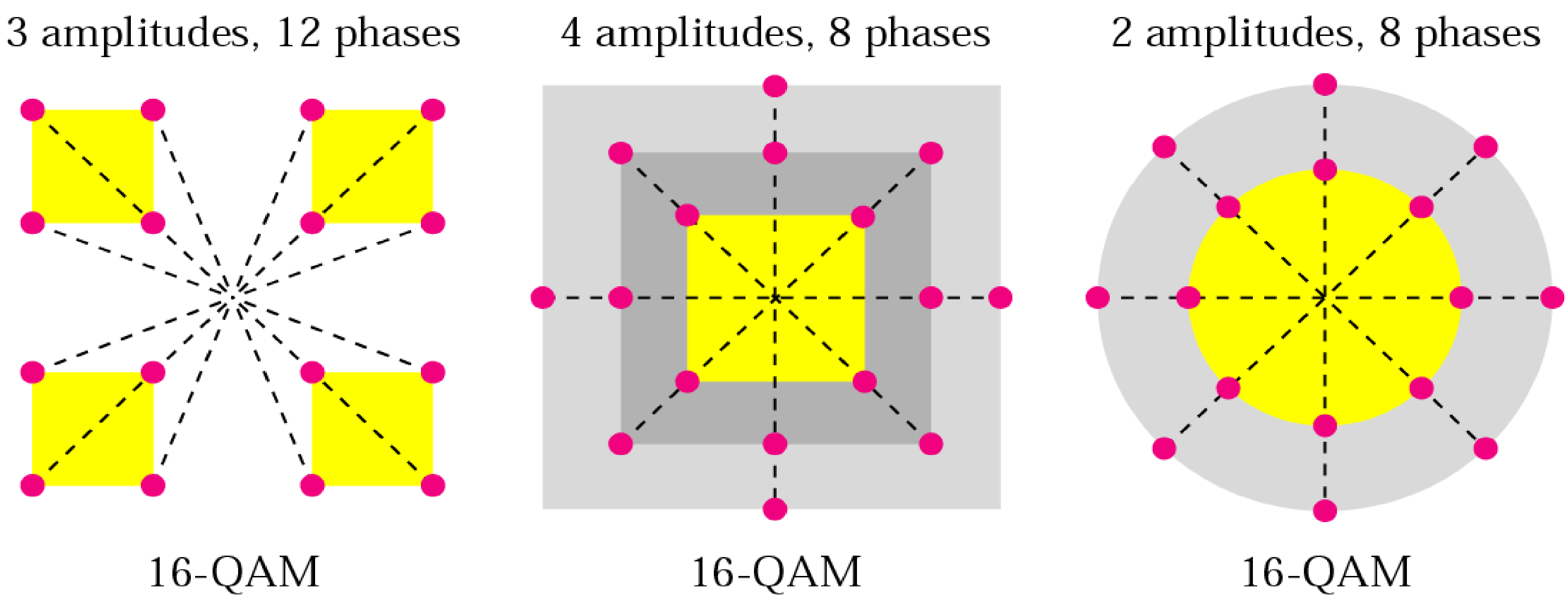
4-QAM
1 amplitude, 4 phases



8-QAM
2 amplitudes, 4 phases

Quadrature Amplitude Modulation

Quadrature amplitude modulation is a combination of ASK and PSK.



Bit and Baud Rate Comparison

Modulation	Units	Bits/Baud	Baud rate	Bit Rate
ASK, FSK, 2-PSK	Bit	1	N	N
4-PSK, 4-QAM	Dibit	2	N	2N
8-PSK, 8-QAM	Tribit	3	N	3N
16-QAM	Quadbit	4	N	4N
32-QAM	Pentabit	5	N	5N
64-QAM	Hexabit	6	N	6N
128-QAM	Septabit	7	N	7N
256-QAM	Octabit	8	N	8N

THANK YOU

QUESTIONS???