Introduction to Telecommunication Systems
Lecture 7

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Analog Transmission

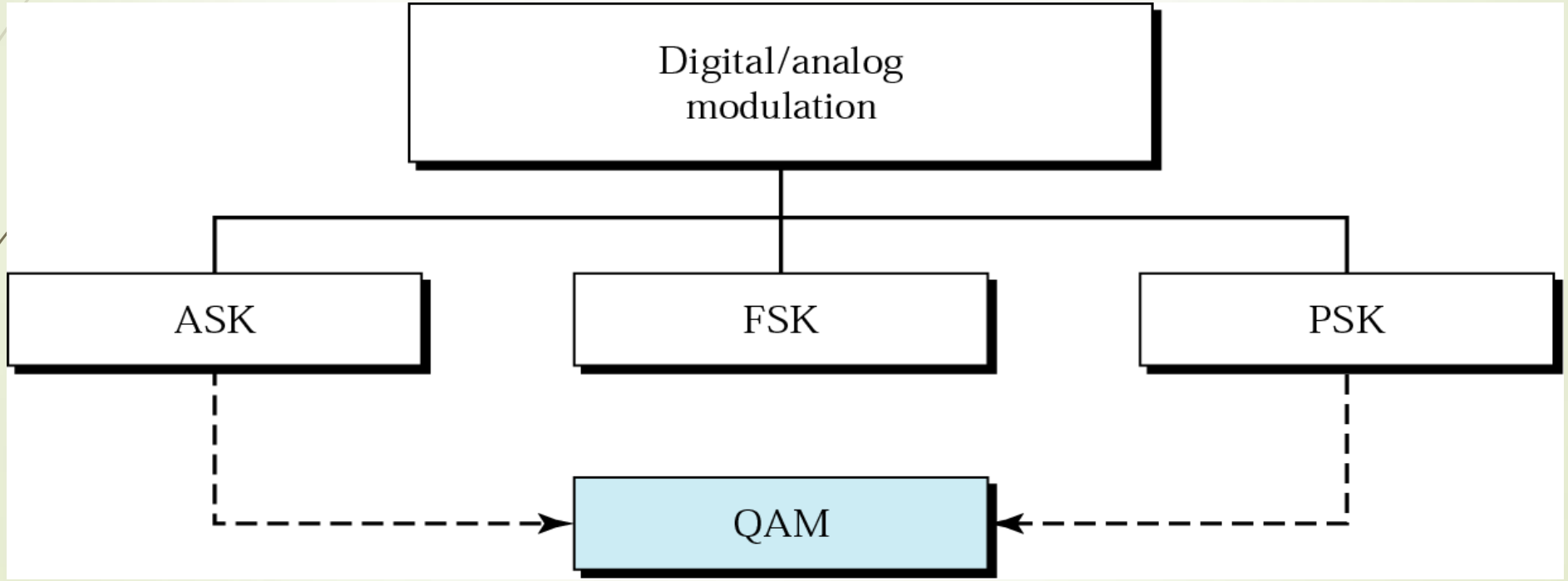
Digital Data, Analog Signal

- Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.
- Public telephone system
  - 300Hz to 3400Hz
  - Use modem (modulator-demodulator).

Modulation of Digital Signals

- We have therefore three mechanisms for modulating digital data into an analog signal:
  - Amplitude shift keying (ASK),
  - Frequency shift keying (FSK), and
  - Phase shift keying (PSK).
  - In addition, there is a fourth (and better) mechanism that combines changing both the amplitude and phase, called quadrature amplitude modulation (QAM).

Modulation of Digital Signals



Modulation of Digital Signals

- Bit rate
  - No. of bits transmitted per second
- Baud rate
  - No. of signal units per second that are required to represent those bits.
  - Baud rate refers to number of symbols transmitted per second. Since multiple bits can be encoded per symbol, Baud rate is less than or equal to the bit rate.
  - Bit rate = Baud Rate (symbols/second) x No. of bits/Symbol.

Modulation of Digital Signals

- **Example 1**
  - An analog signal carries 4-bit in each signal unit. If 1000 signal units are sent per second, find the baud rate and the bit rate?
  - Solution:
  - In this case, *r* = 4, S = 1000, and N(Bit rate) is unknown. We can find the value of N from
    - Baud rate = number of signal units per second = 1000 bauds/sec
    - Bit rate = baud rate x No. of bits per signal unit = 4000 bps

Modulation of Digital Signals

- **Example 2:**
  - The bit rate of a signal is 9600. If each signal unit carries 8-bits, what is the baud rate?
  - Solution:
    - Baud rate = bit rate/no. of bits per signal unit = 9600/8 = 1200 bauds

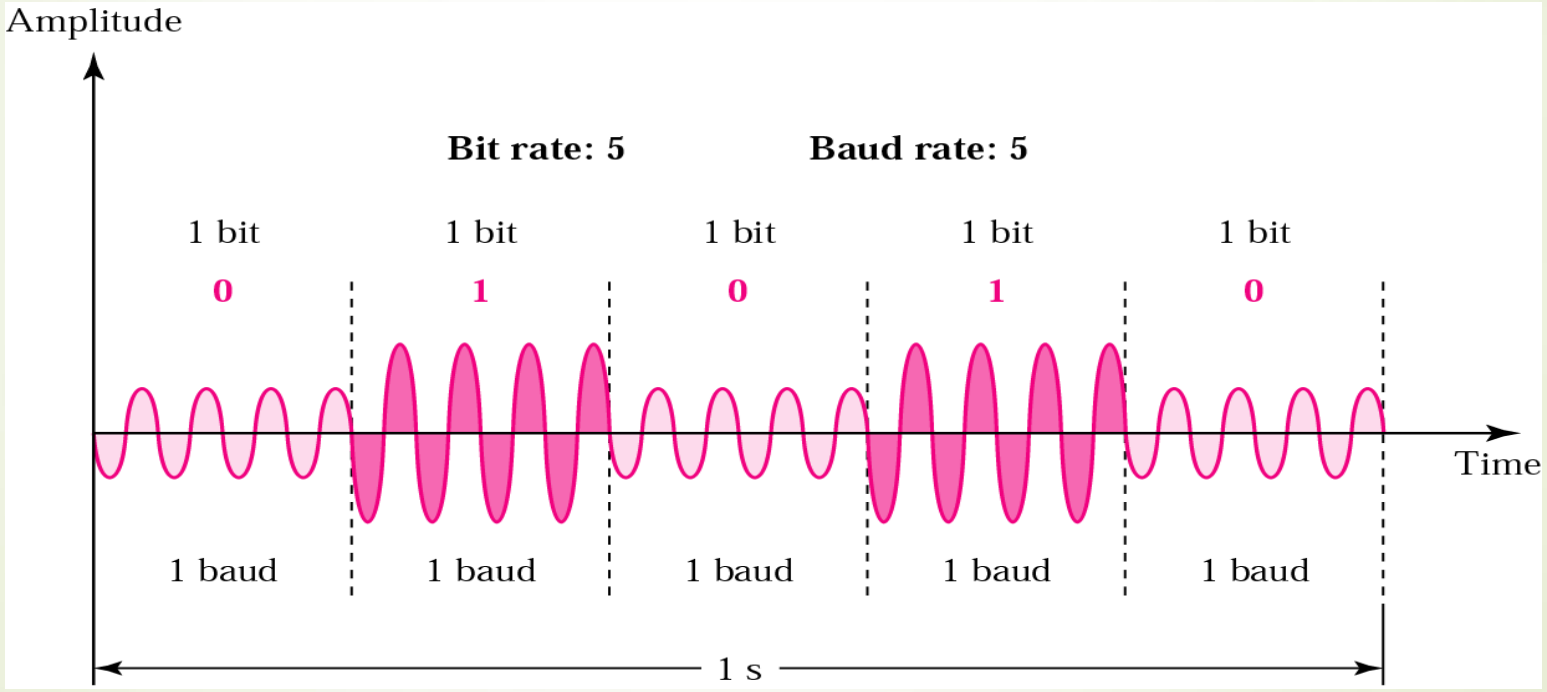
Modulation of Digital Signals

- Carrier Signal:
  - In analog transmission, the sending device produces a high-frequency signal that acts as a base for the information signal. This base signal is called the carrier signal or carrier frequency.
  - Digital information then changes the carrier signal by modifying one or more of its characteristics (amplitude, frequency, or phase). This kind of modification is called modulation (shift keying).

Amplitude Shift Keying

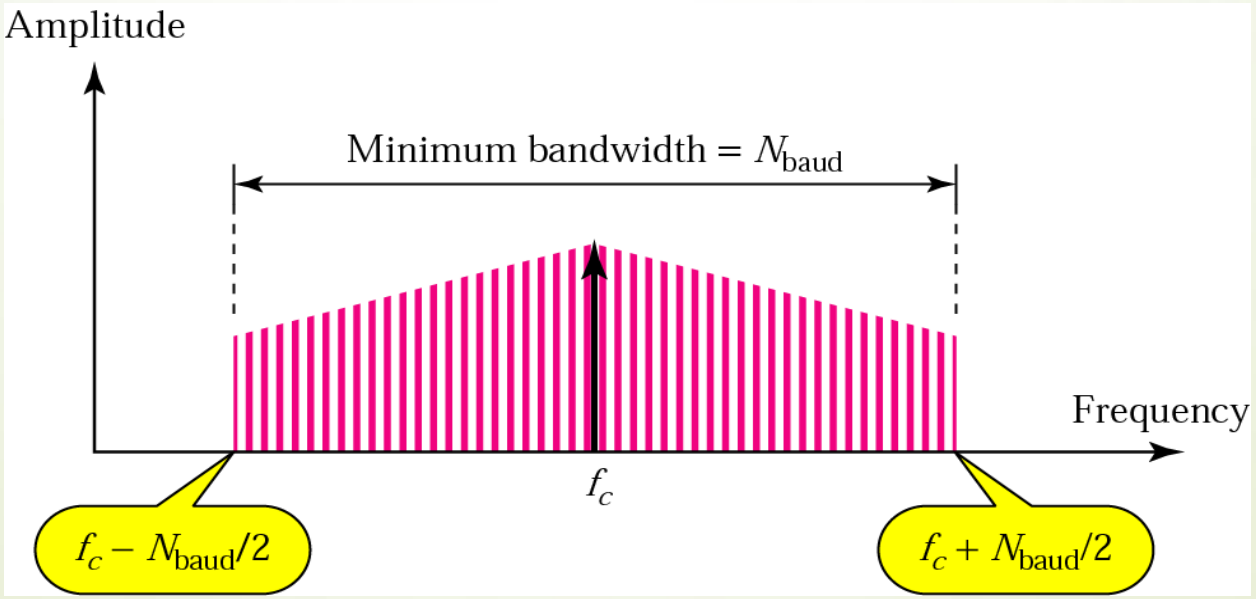
- In amplitude shift keying, the amplitude of the carrier signal is varied to create signal elements.
- The two binary values are represented by two different amplitudes of the carrier frequency.
  - 1 – higher magnitude
  - 0 – smaller magnitude
- Frequency & Phase remains constant .

Amplitude Shift Keying



Amplitude Shift Keying

- Bandwidth of ASK
  - BW = (1 +d) * Nbaud
    - Where d: modulation factor, Nbaud = baud rate
    - If d = 0, BW = Nbaud
  - Bit rate = baud rate

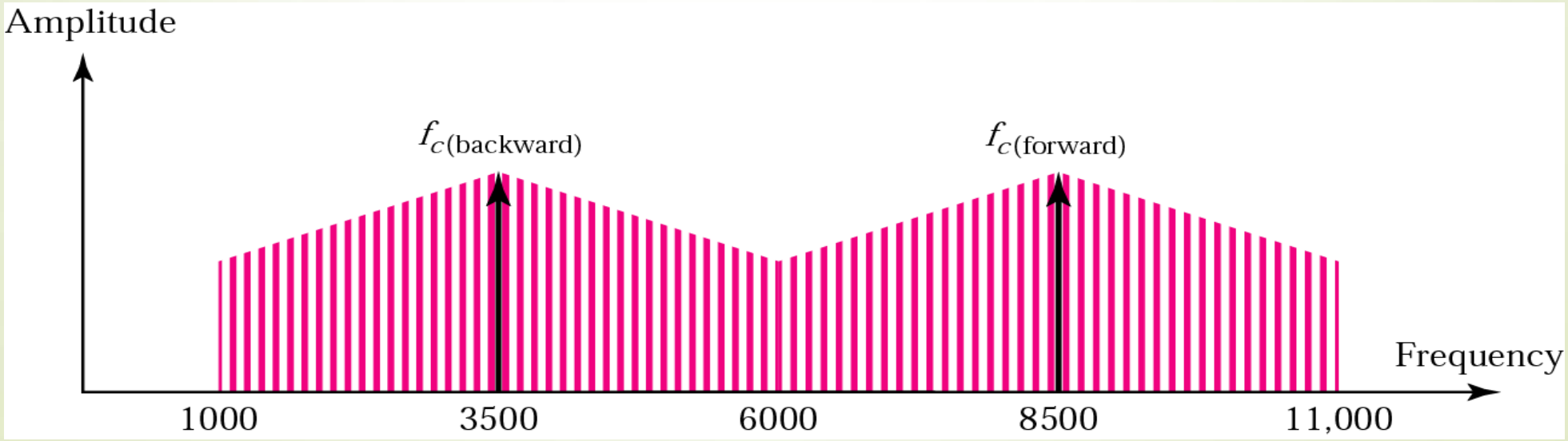


Amplitude Shift Keying

- Example 3
  - Find the min BW for an ASK signal transmitting at 2000 bps. The transmission mode is half-duplex.
  - Ans: BW = Nbaud = 2000 Hz
- Example 4
  - Given a bandwidth of 5000 Hz for an ASK signal, what are the baud rate and bit rate?
  - Ans: In ASK, Bit rate = Baud rate = 5000 bps

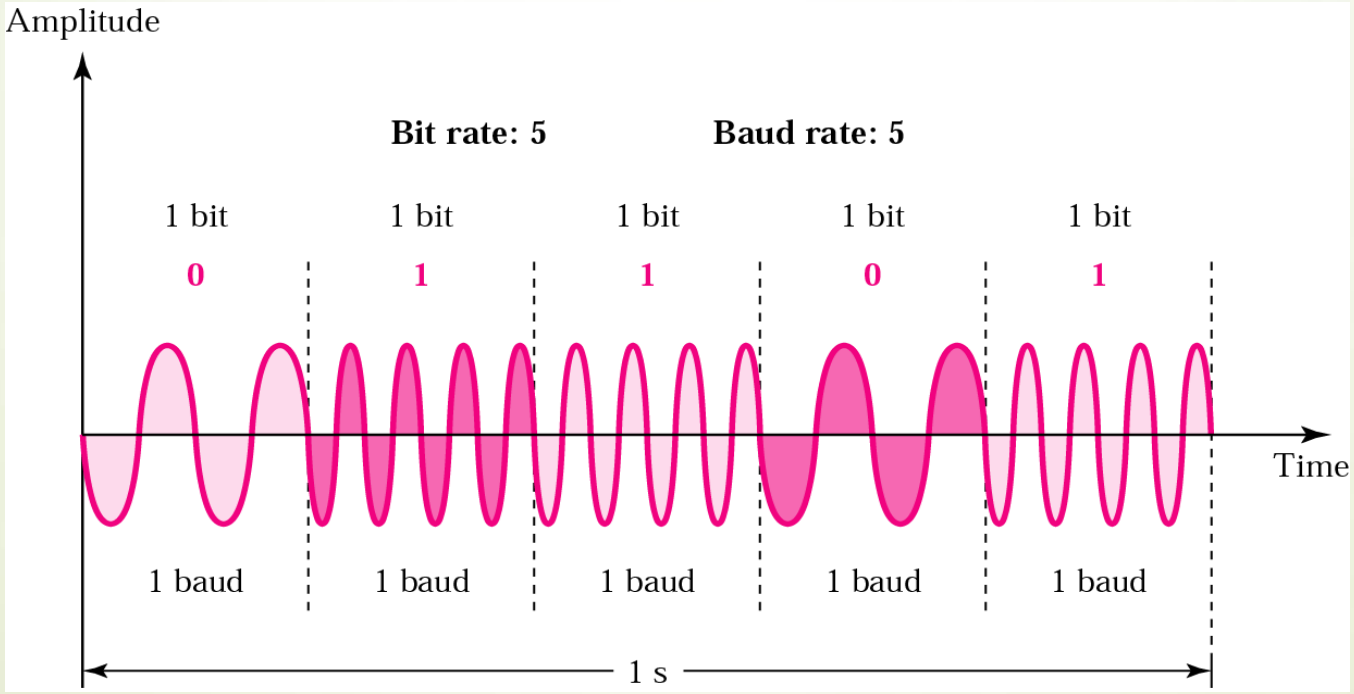
Amplitude Shift Keying

- Example 5
  - Given a BW of 10,000 Hz (1000 to 11,000 Hz), draw the full-duplex ASK diagram of the system. Find the carriers and the BWs in each direction. Assume there is no gap between bands in the two directions.
  - Ans:
    - BW = 10,000/2 = 5000 Hz
    - Carrier Frequency 1 = 1000 + 5000/2 = 3500 Hz
    - Carrier Frequency 2 = 11000 – 5000/2 = 8500Hz



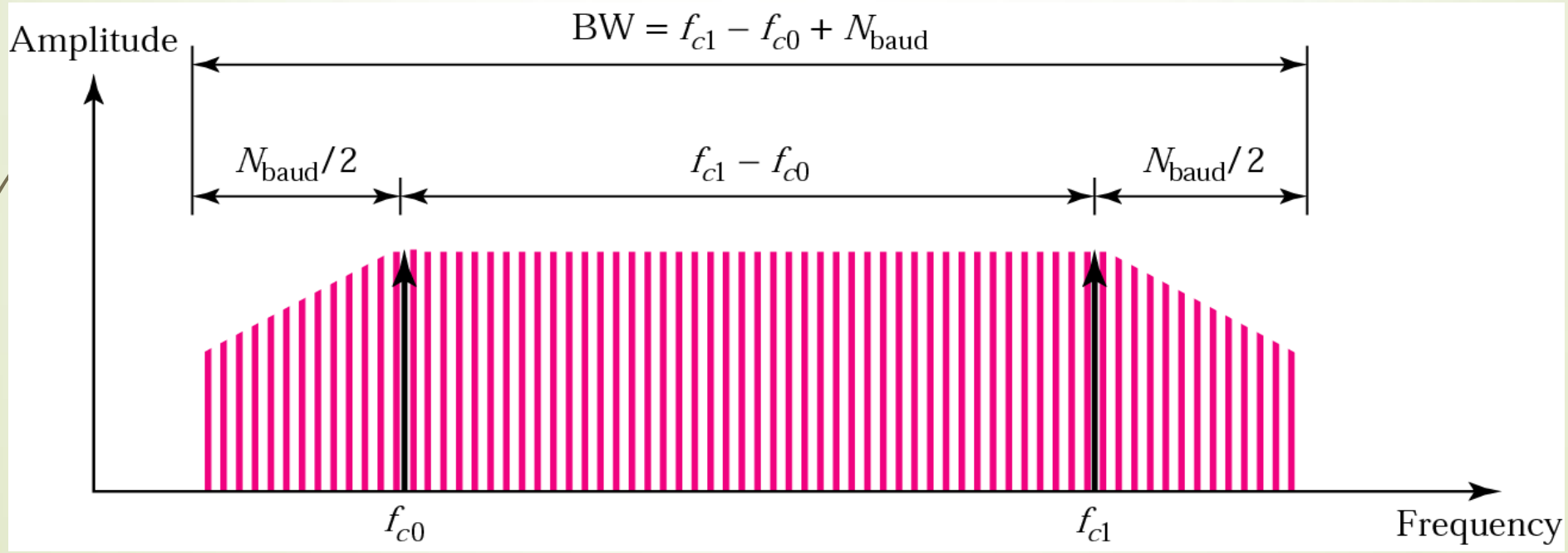
Frequency Shift Keying (FSK)

- Varying frequency of carrier signal to represent 1 or 0.
- Amplitude and phase remain constant.



Frequency Shift Keying (FSK)

- Bandwidth = Fc1 – Fc0 + Nbaud



Frequency Shift Keying (FSK)

- Example 6: Find the min BW for an FSK signal transmitting at 2000 bps. Transmission is in half-duplex mode, and the carriers are separated by 3000 Hz.
  - Ans:

    BW = Nbaud + Fc1 – Fc0 = 2000 + 3000 = 5000 Hz
- Example 7: Find the maximum bit rates for an FSK signal if the BW of the medium is 12kHz and difference between the two carriers is 2000 Hz. Transmission is in full-duplex mode.
  - Ans:

    BW = baud rate + Fc1 – Fc0

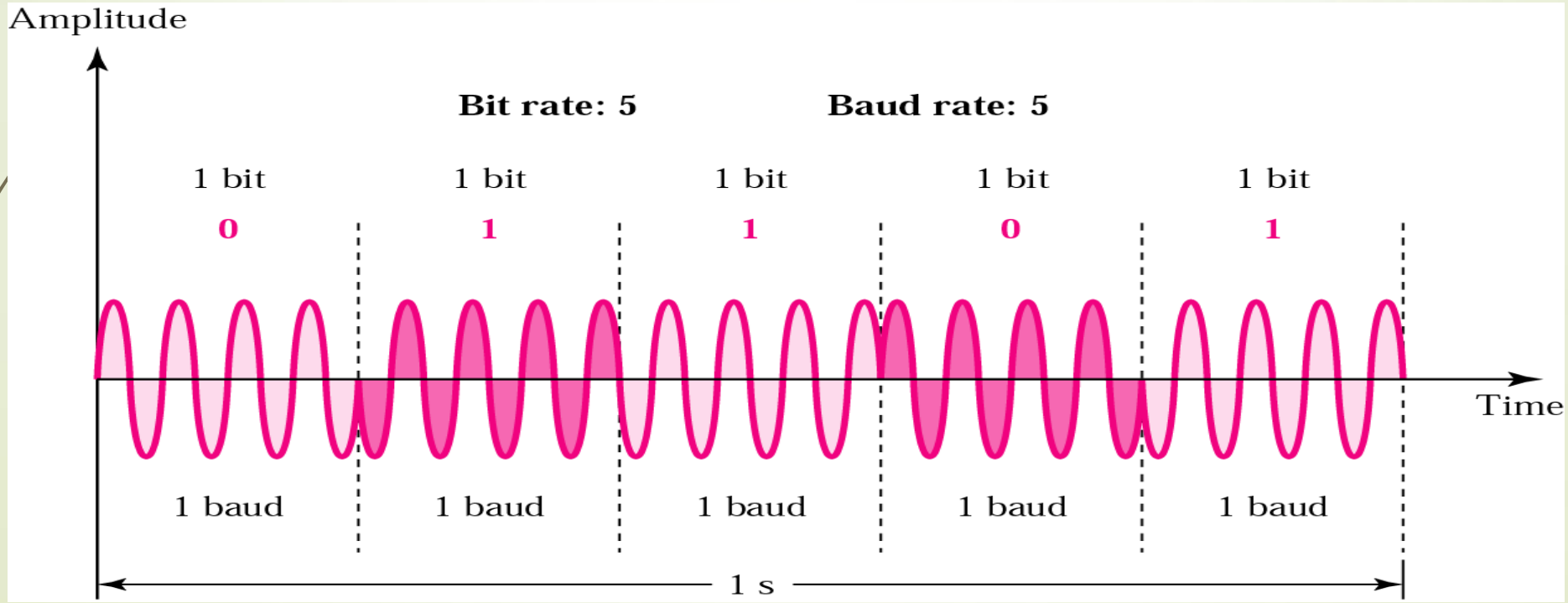
    Baud rate = BW – (Fc1 – Fc0) = 6000 – 2000 = 4000 bps

Constellation Diagram

- A constellation diagram can help us define the amplitude and phase of a signal element, particularly when we are using two carriers.
- The diagram is useful when we are dealing with multilevel ASK, PSK, or QAM.
- In a constellation diagram, a signal element type is represented as a dot.
- The diagram has two axes.
- The horizontal X axis is related to the in-phase carrier and is represented by I.
- The vertical Y axis is related to the quadrature carrier and is represented by Q.

Phase Shift Keying (PSK)

- Varying phase of the carrier to represent 1 or 0.
- 0 degree = 0, 180 degree = 1

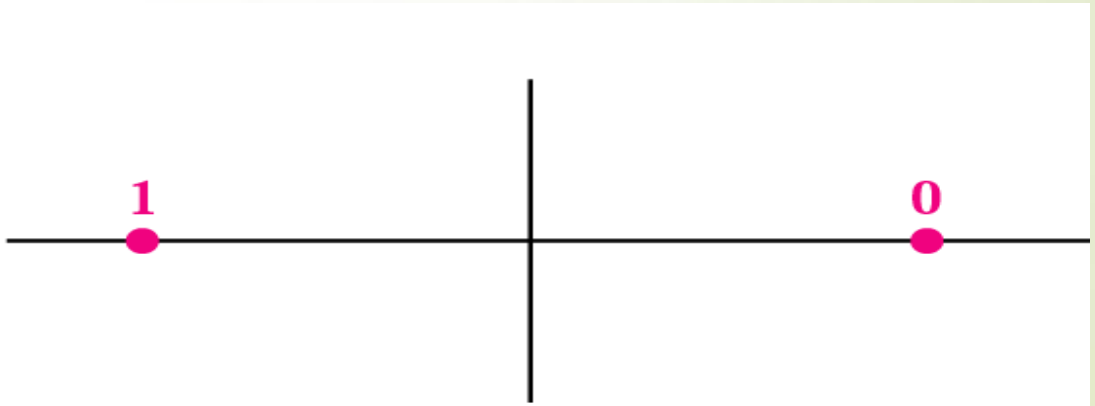


PSK Constellation

- Not susceptible to the noise degradation (ASK)
- No bandwidth limitation (FSK)
- 1 –bit: two variations (0 and 180)

Bit	Phase
0	0
1	180

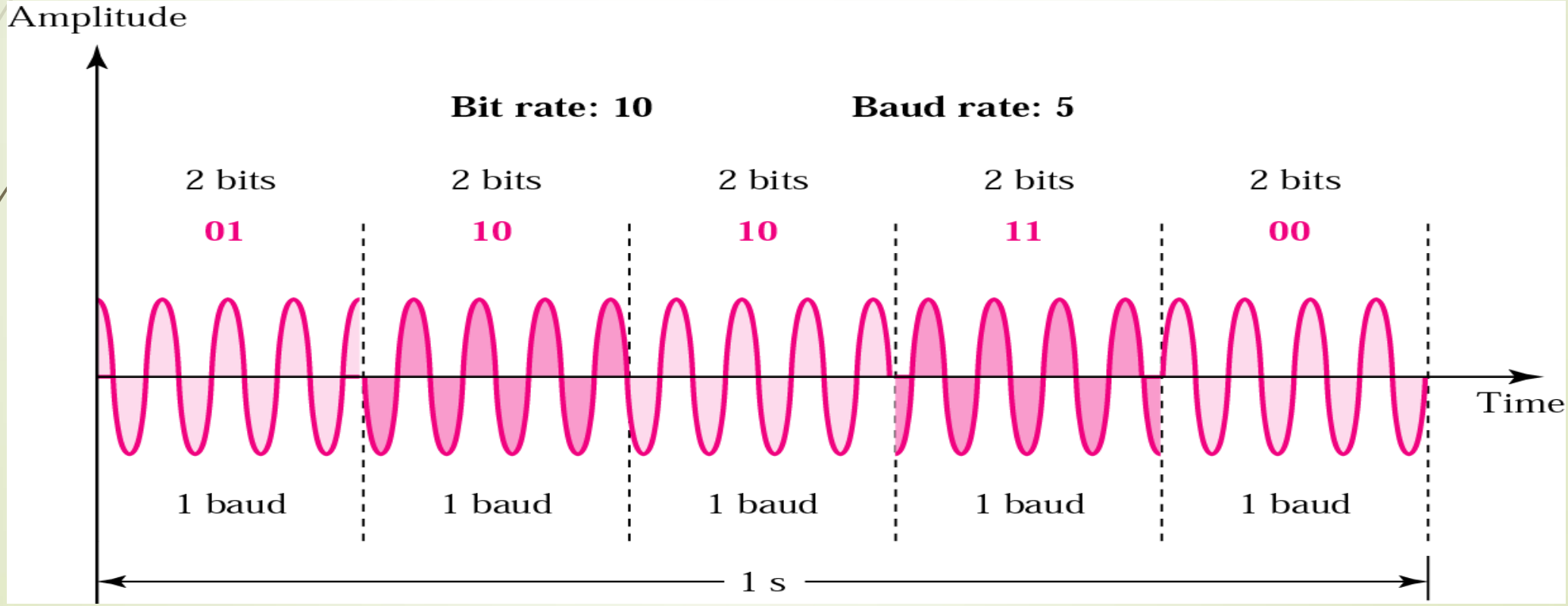
Bits



Constellation diagram

PSK Constellation

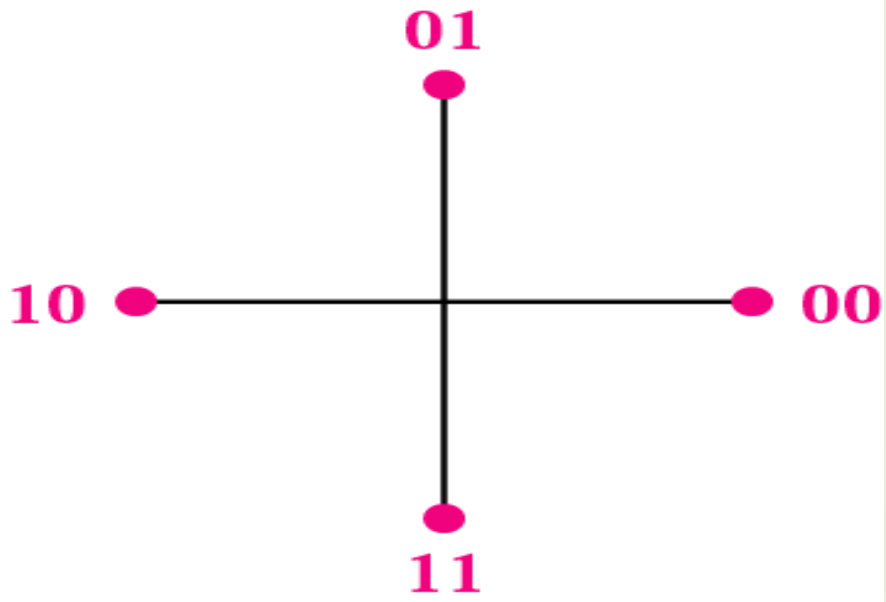
- The 4 PSK or Q-PSK method
- 2-bit variation of 4 phases: 00 – 0 deg.; 01 – 90 deg.; 10 – 180 deg.; 11 – 270 deg.



PSK Constellation

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit
(2 bits)

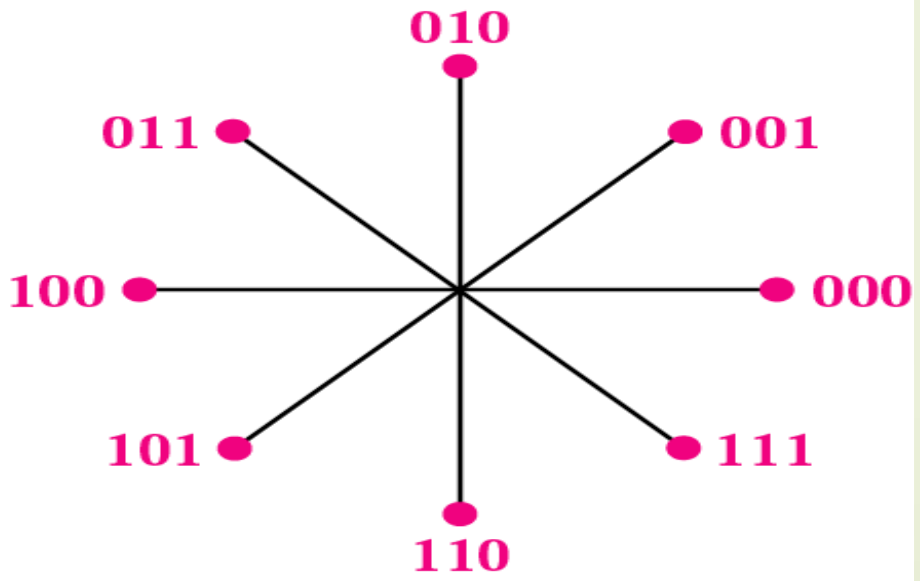


Constellation diagram

8 PSK Constellation

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

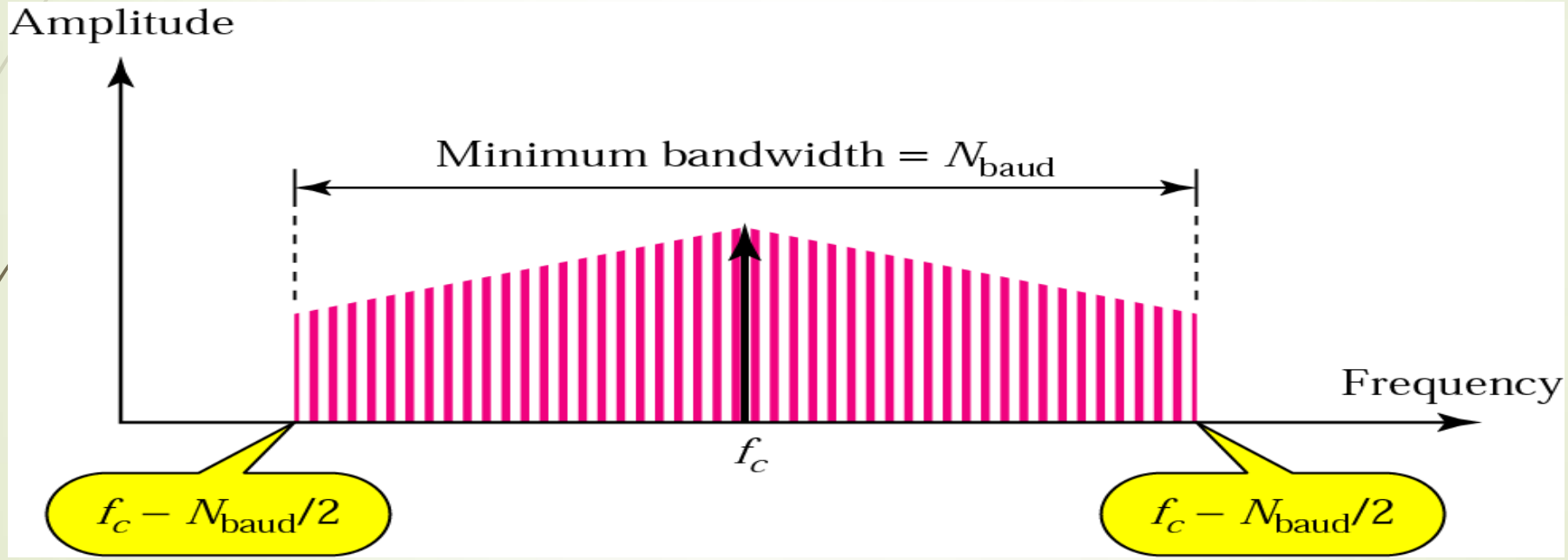
Tribits
(3 bits)



Constellation diagram

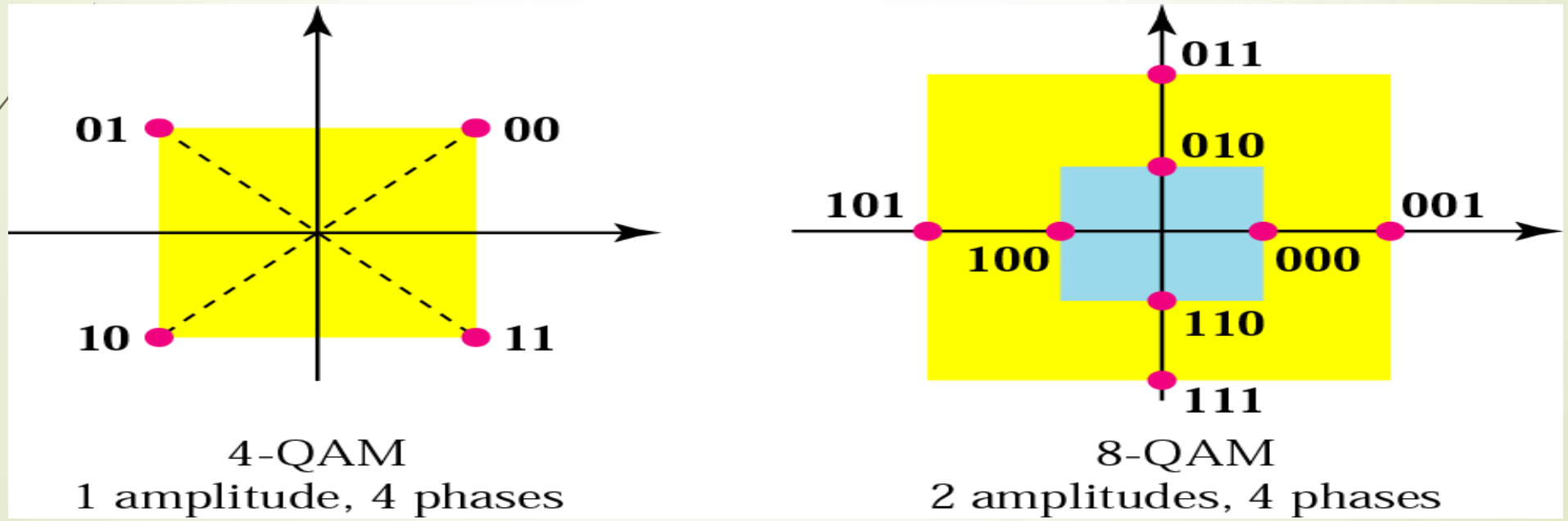
BW of PSK

- BW = Baud rate

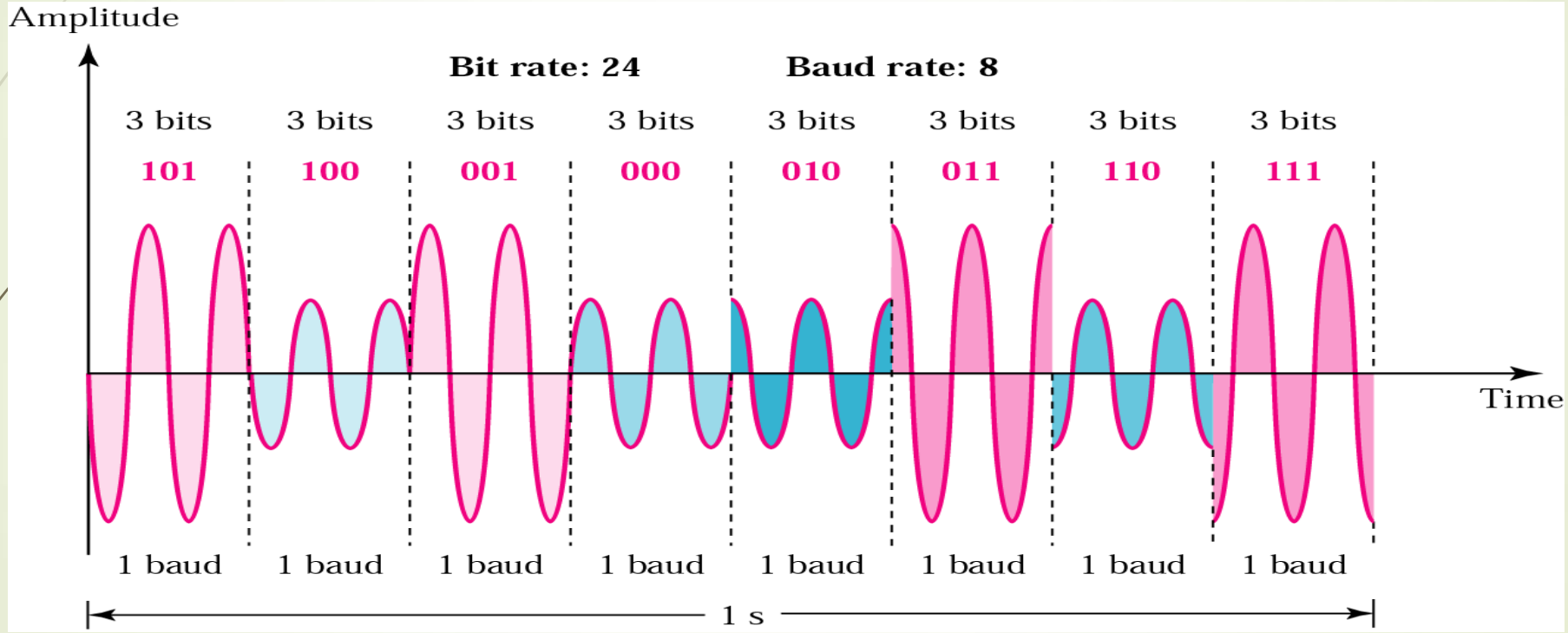


Quadrature Amplitude Modulation

- QAM - combining both ASK and PSK; same BW as ASK or PSK
- 4-QAM – 1 amplitude, 4 phases; 8-QAM – 2 amplitude, 4 phases



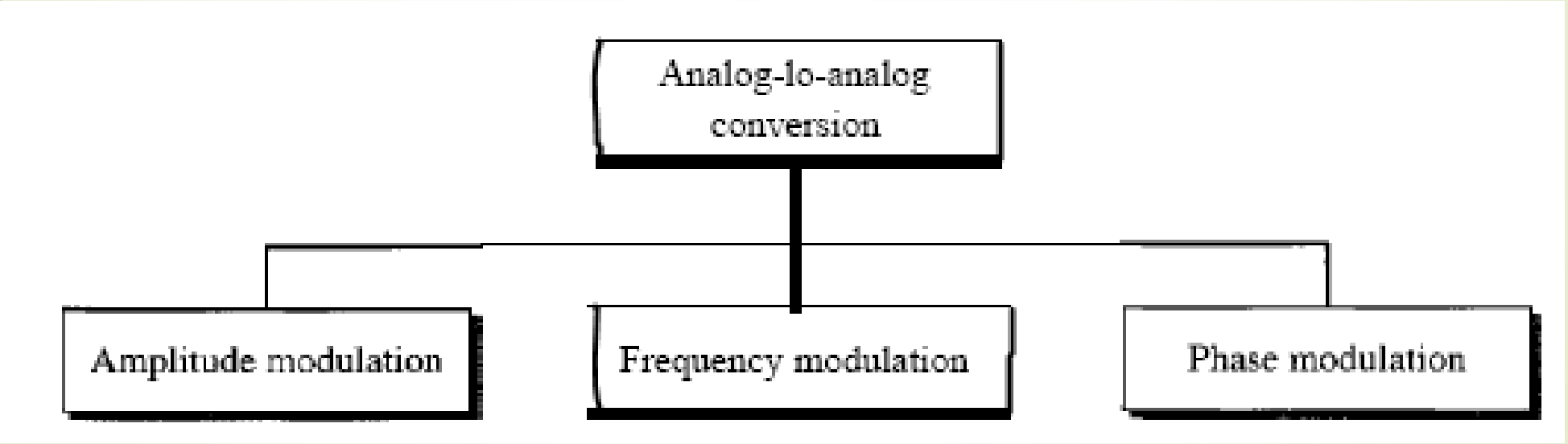
Time Domain Signal for 8-QAM



Analog Data, Analog Signals

- Why modulate analog signals?
  - Higher frequency can give more efficient transmission
  - Permits frequency division multiplexing
- Types of modulation
  - Amplitude
  - Frequency
  - Phase

Analog Data, Analog Signals



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