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Royal University of Phnom Penh

Data Communication I

Chapter 3.2 : Analog transmission

Lecturer: **CHHORN SYLUN**

Email: chhorn.sylun@rupp.edu.kh

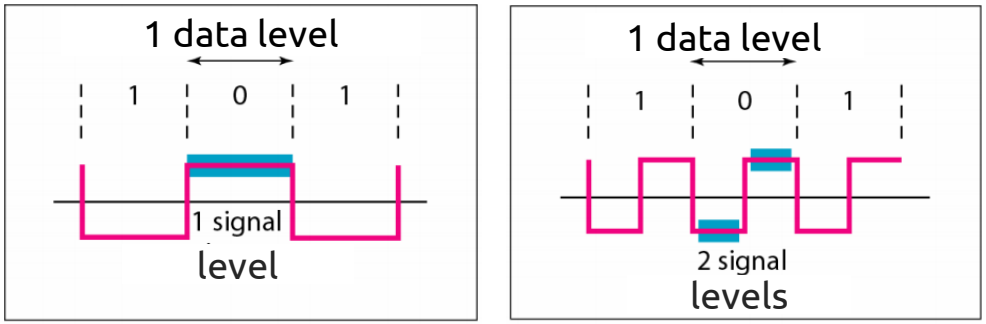
Room: 302, STEM Building, RUPP

Objective

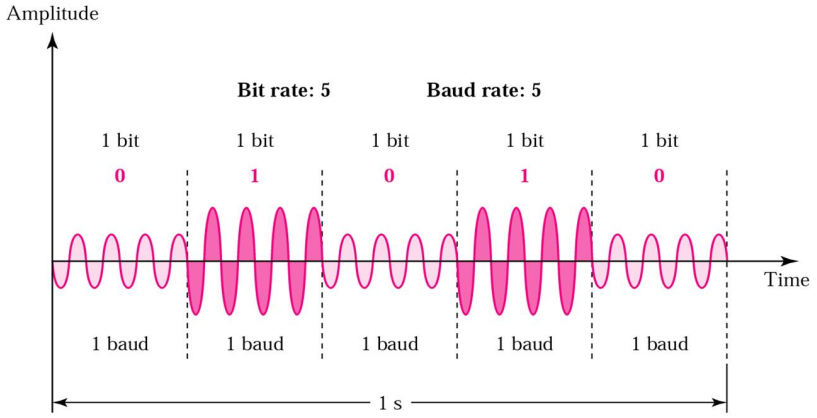
- What is analog transmission?
- Digital to Analog Conversion
- Bit rate vs Baud rate
- Amplitude Shift Keying (ASK)
- Frequency Shift Keying (FSK)
- Phase Shift Keying (PSK)
- Quadrature Amplitude Modulation
- Modem Standard

Baud Rate vs Pulse Rate

- **Baud Rate and Pulse rate are the same.**
- In *digital transmission*, we called Pulse Rate
- In *analog transmission*, we called Baud Rate



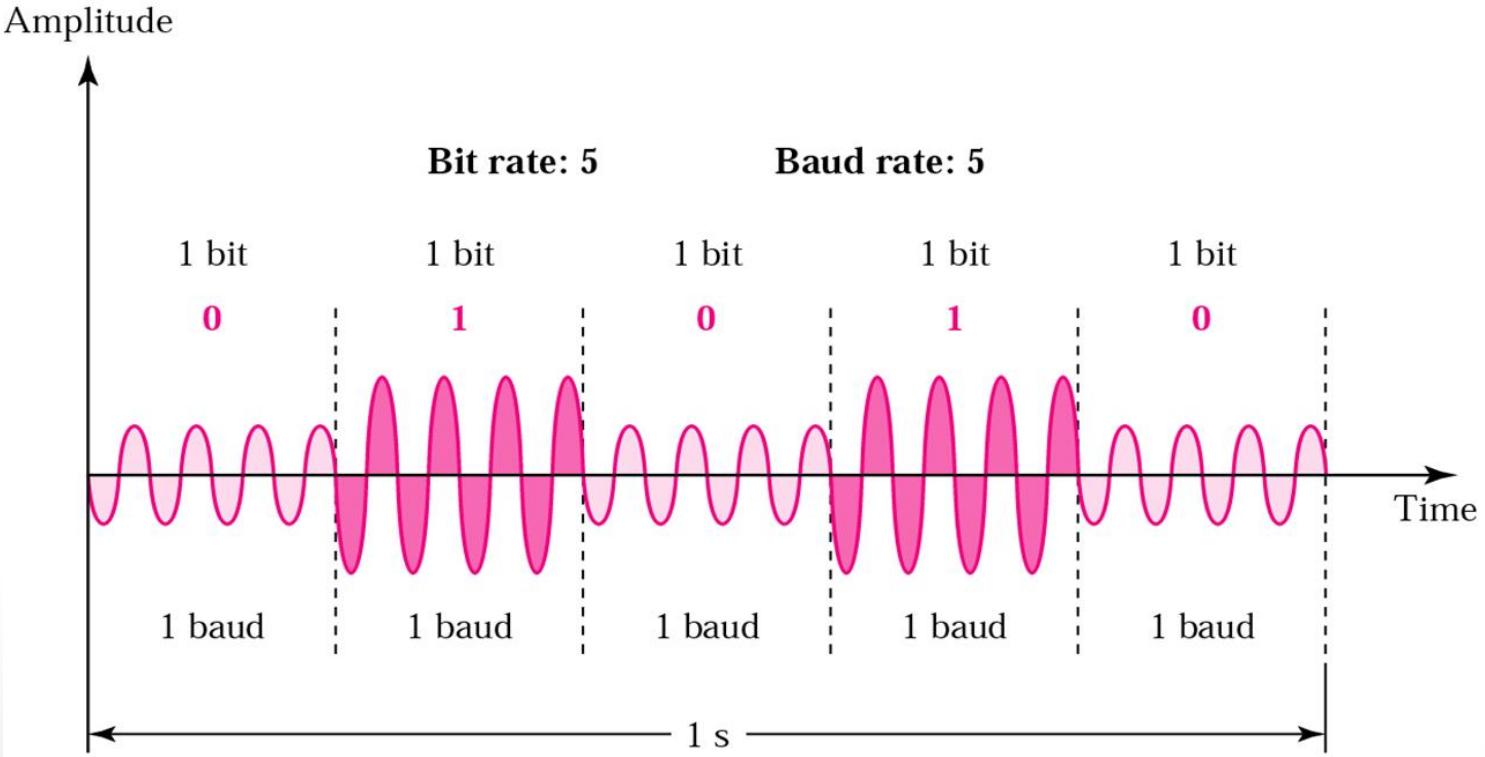
Pulse Rate



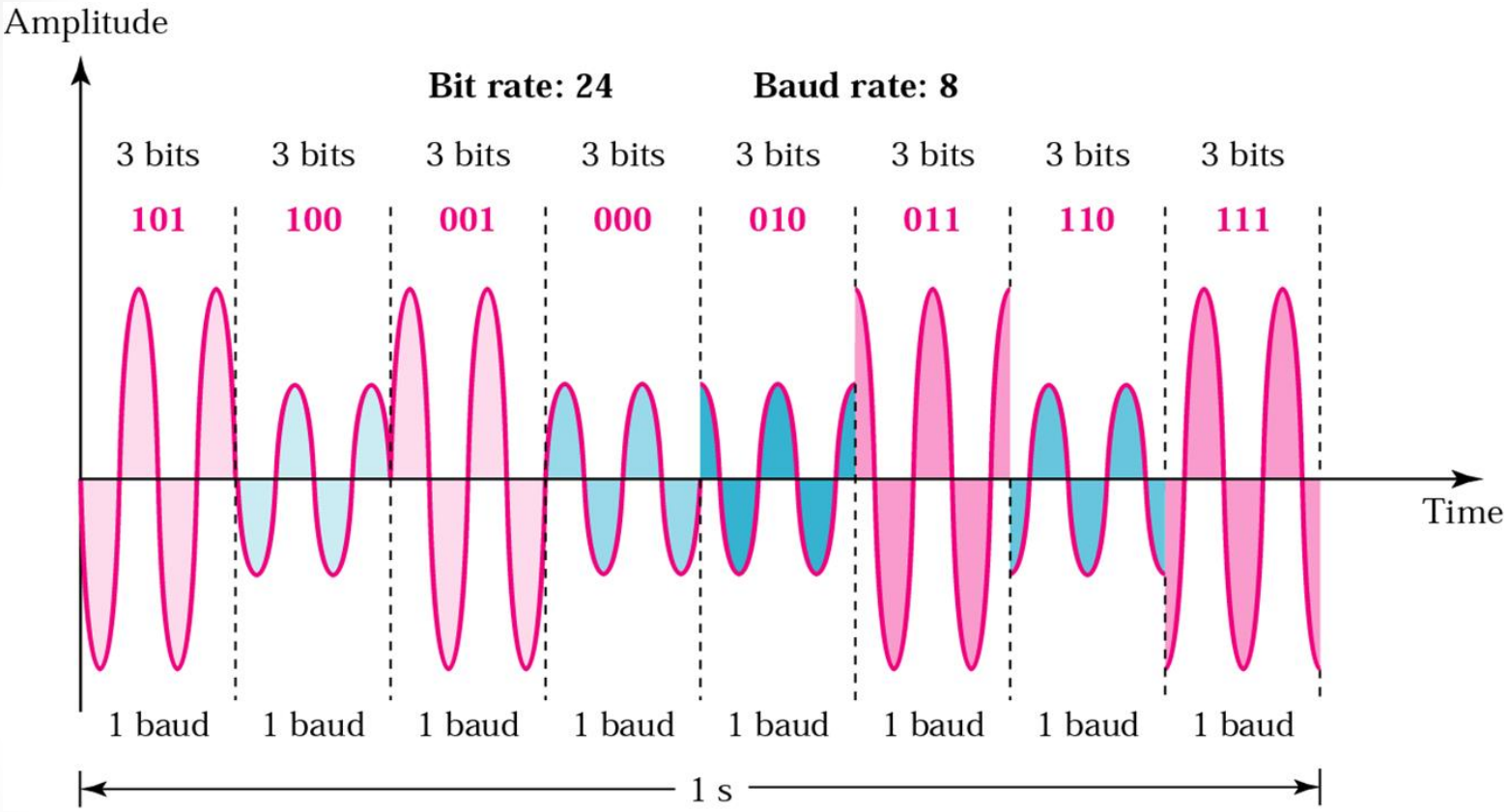
Baud Rate

Bit Rate vs Baud Rate

- **Bit rate (data rate)** is the number of bits per second.
- **Baud rate (signal rate)** is number of signal unit per second. Baud rate is less than or equal to the bit rate.



Bit Rate vs Baud Rate



Bit Rate vs Baud Rate

- We can define the data rate (bit rate) and the signal rate (baud rate) as we did for digital transmission. The relationship between them is:

$$S = N\ x \frac{1}{r} = N\ x\ \frac{1}{\log_2 L}$$

- Where S is signal rate or Baud Rate(baud)
- and N is data rate or bit rate(bps).
- r is number of data element carried in one signal element.
- The value of r in analog transmission is $r = \log_2 L$, where L is the number of different signal element

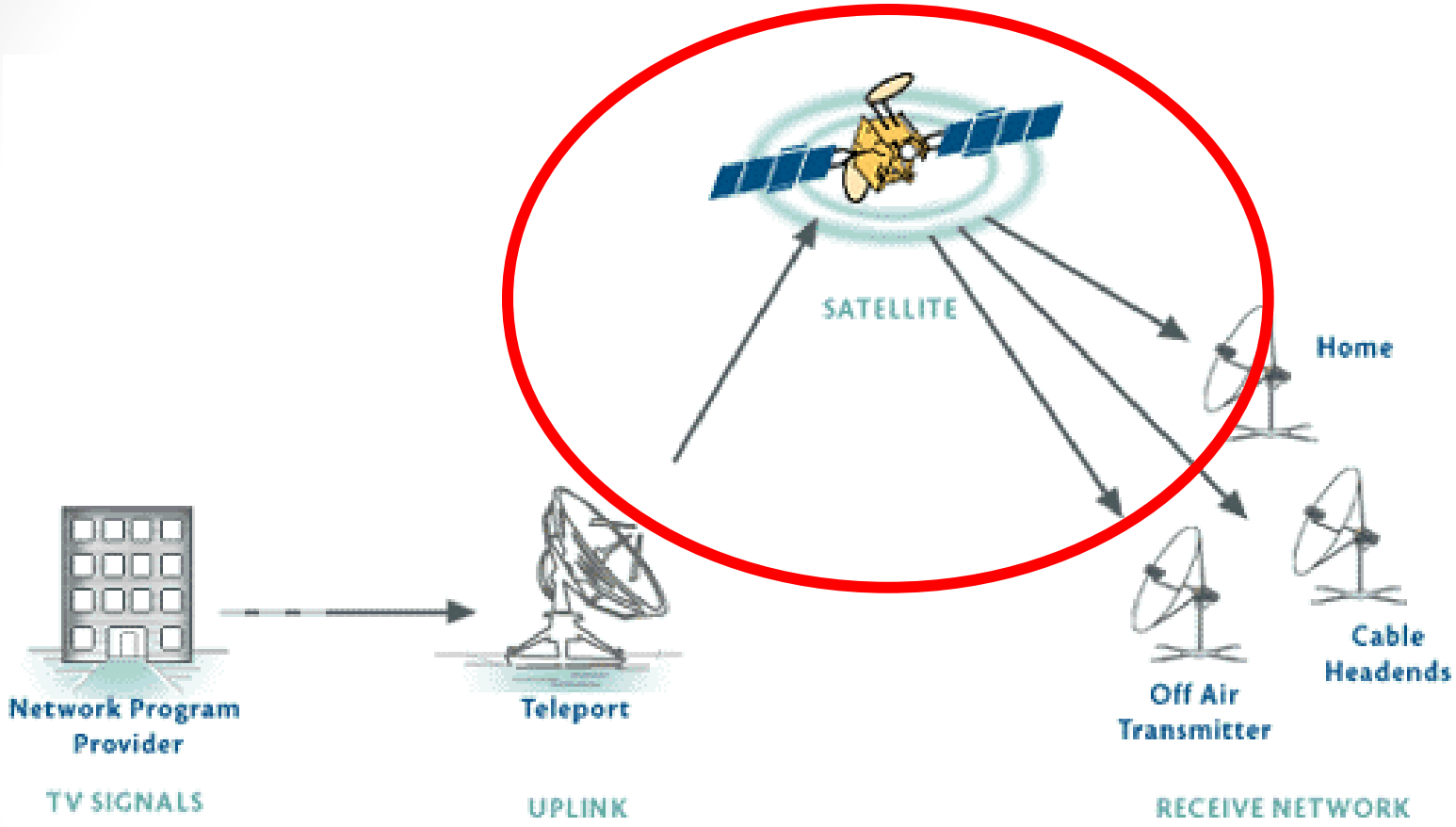
Bit Rate vs Baud Rate

- **Example 1:** An analog signal carries 4 bits in each signal unit. If 1000 signal units are sent per second, find the bit rate **N**?

Bit Rate vs Baud Rate

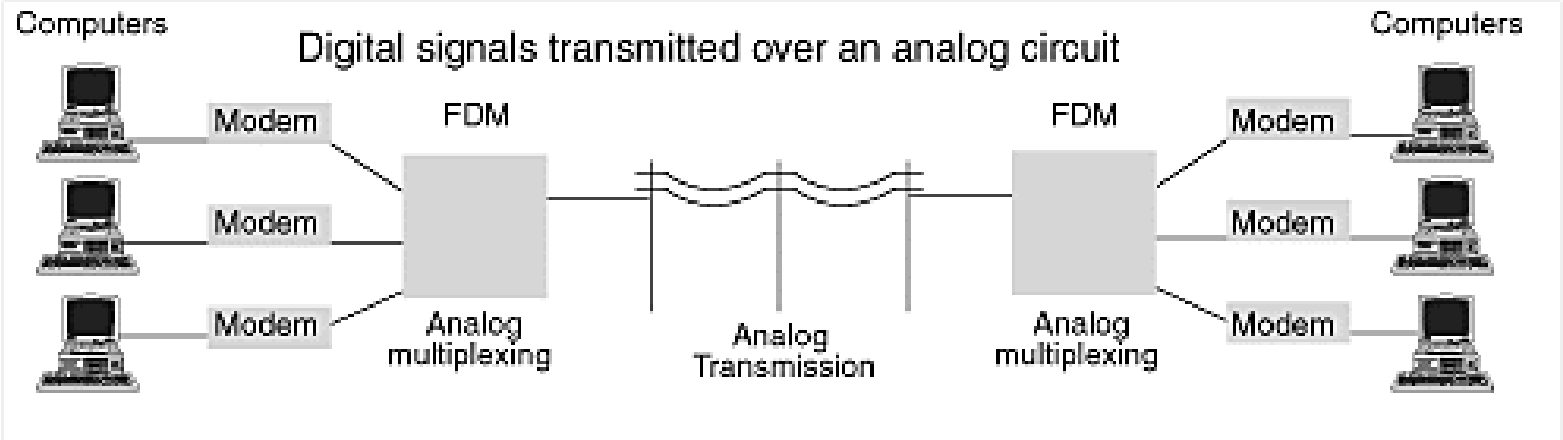
- **Example 3:** An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

Analog Transmission



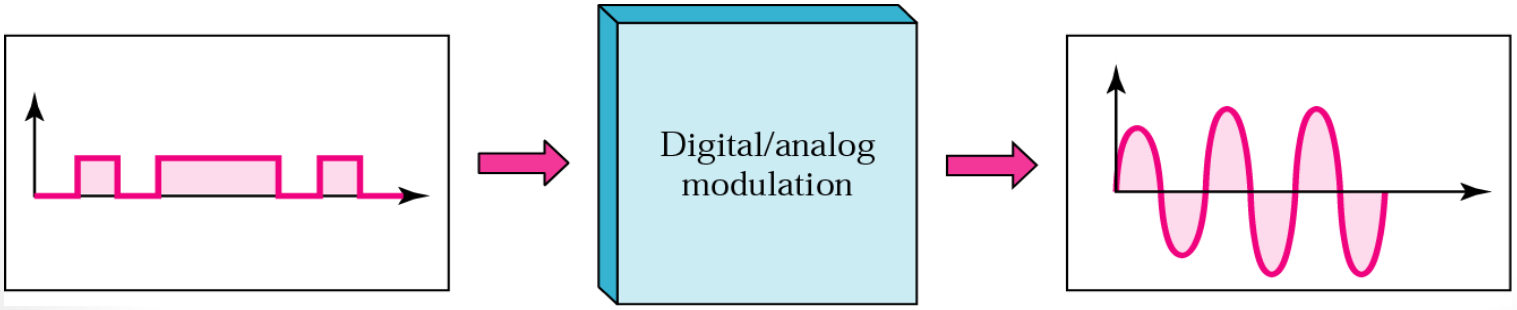
Analog Transmission

Analog transmission is a transmission method of conveying voice, data, image, signal or video information using a continuous signal which varies in amplitude, phase, or some other property in proportion to that of a variable.



Digital to Analog conversion

- Digital to Analog conversion is the process of changing one of the characteristics (amplitude, frequency, or phase) of an analog signal based on the information in a digital signal (0s and 1s).
- Example: To transmit digital data from one PC to another using a phone-line. Telephone line carries analog signal, so digital data must converted using process of Modulation.



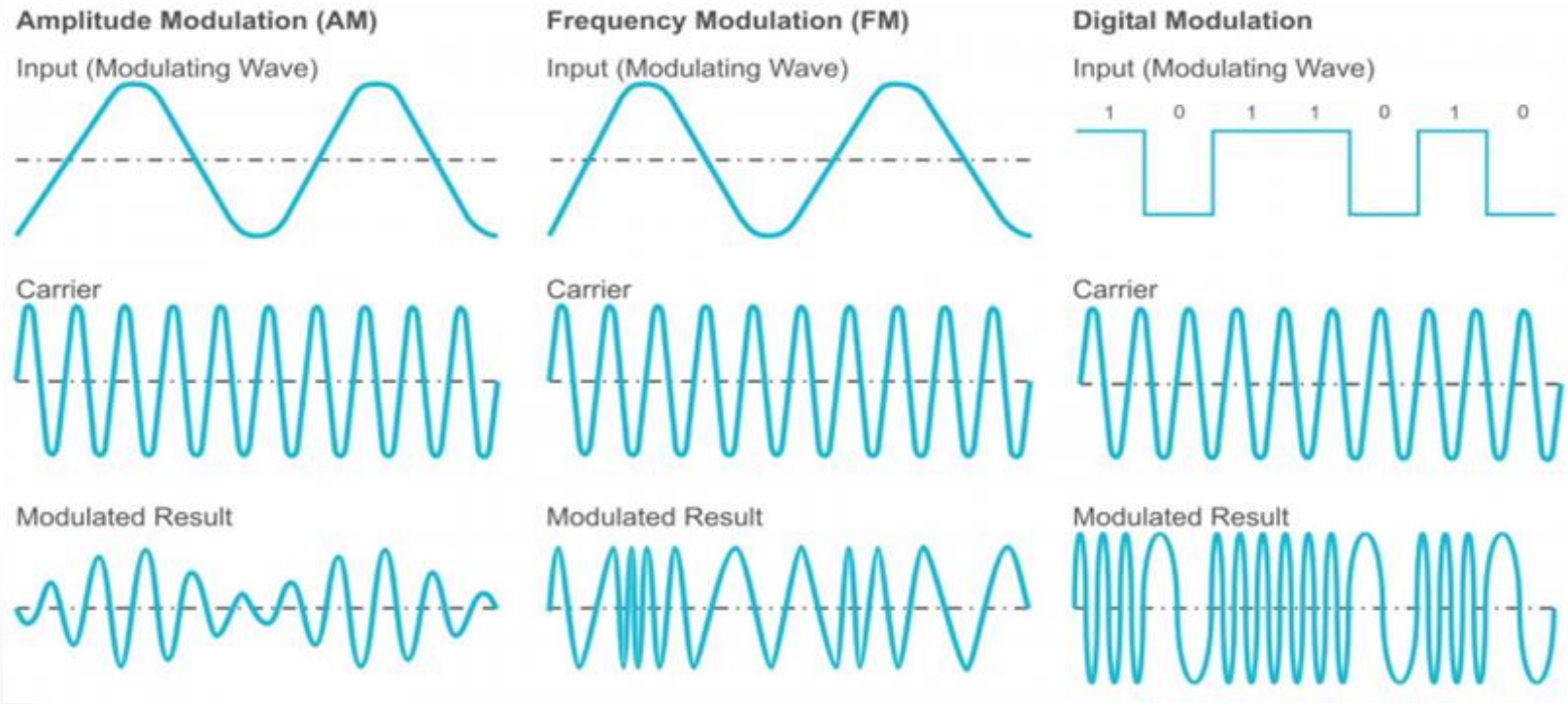
Digital to Analog conversion

What is Modulation?

DEMO

Digital to Analog conversion

What is Modulation?



Digital to Analog conversion

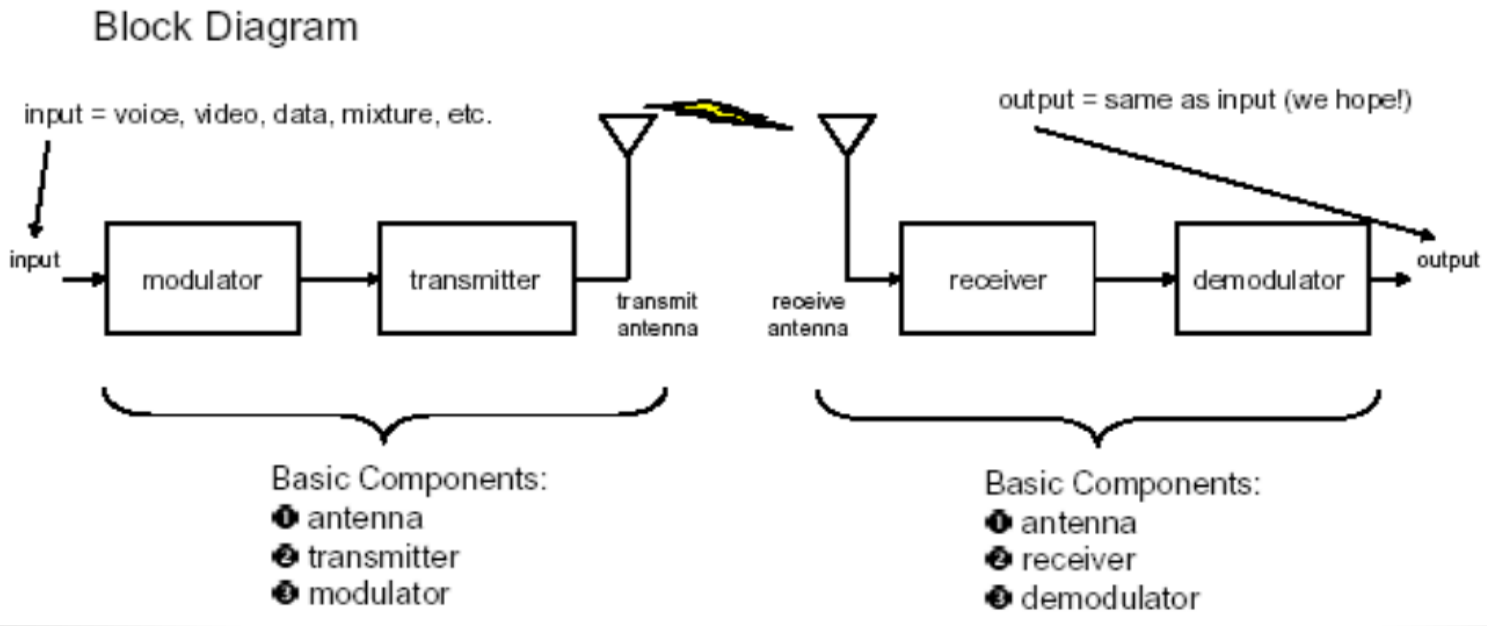
What is Modulation?

- A **carrier wave** is pure of constant frequency, a bit like a sine wave. It does not carry much information that we related to like speech or data.
- To include data or information, another wave needs to be imposed, called **input signal**, on the top of the carrier wave.
- The process of imposing or combine an input signal onto a carrier wave is called modulation.

Digital to Analog conversion

Why modulation?

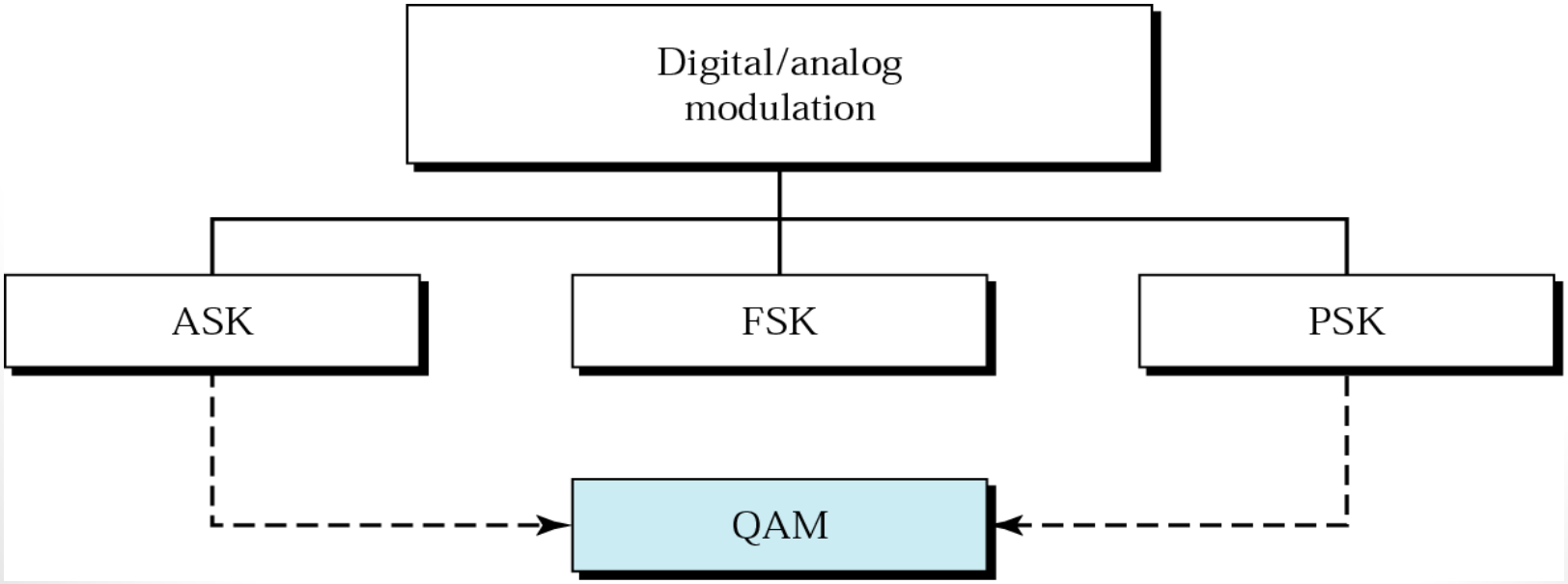
1. For allowing multiple signals to share a single physical channel.
2. Suitable for signal transmission (distance,..)
3. Stability and noise rejection



Digital to Analog conversion

Basic Digital Modulation Techniques:

1. Amplitude Shift Keying (ASK)
2. Frequency Shift Keying (FSK)
3. Phase Shift Keying (PSK)



Digital to Analog conversion

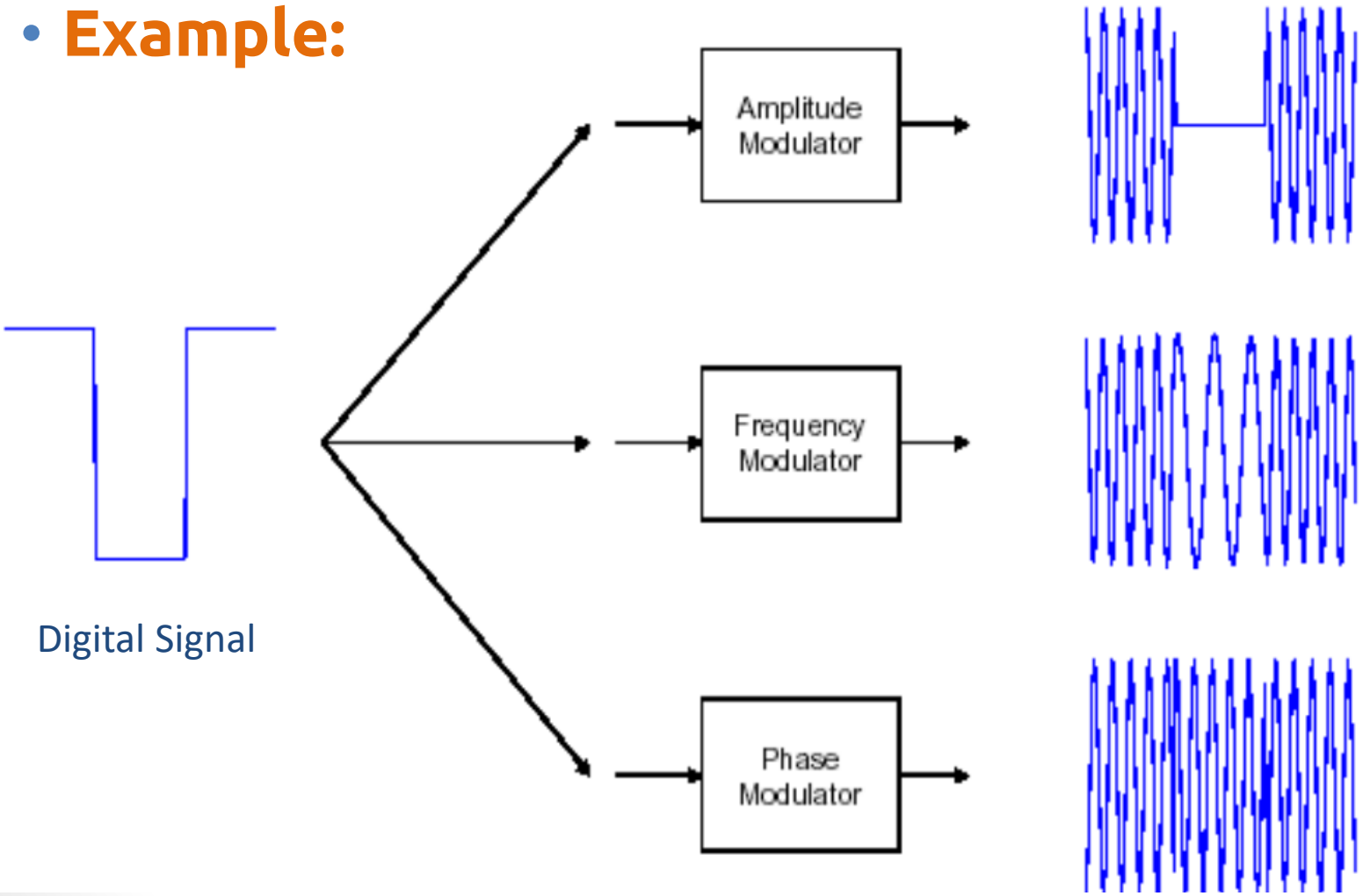
- **Amplitude Modulation (AM)** also known as amplitude shift keying: This method requires changing the amplitude of the carrier phase between 0 and 1 to encode the digital signal.

- **Frequency Modulation (FM)** also known as frequency shift keying. Must alter the frequency of the carrier to correspond to 0 or 1.

- **Phase Modulation (PM)** also know as phase shift keying. At each phase shift, the bit is flipped from 0 to 1 or vice versa.

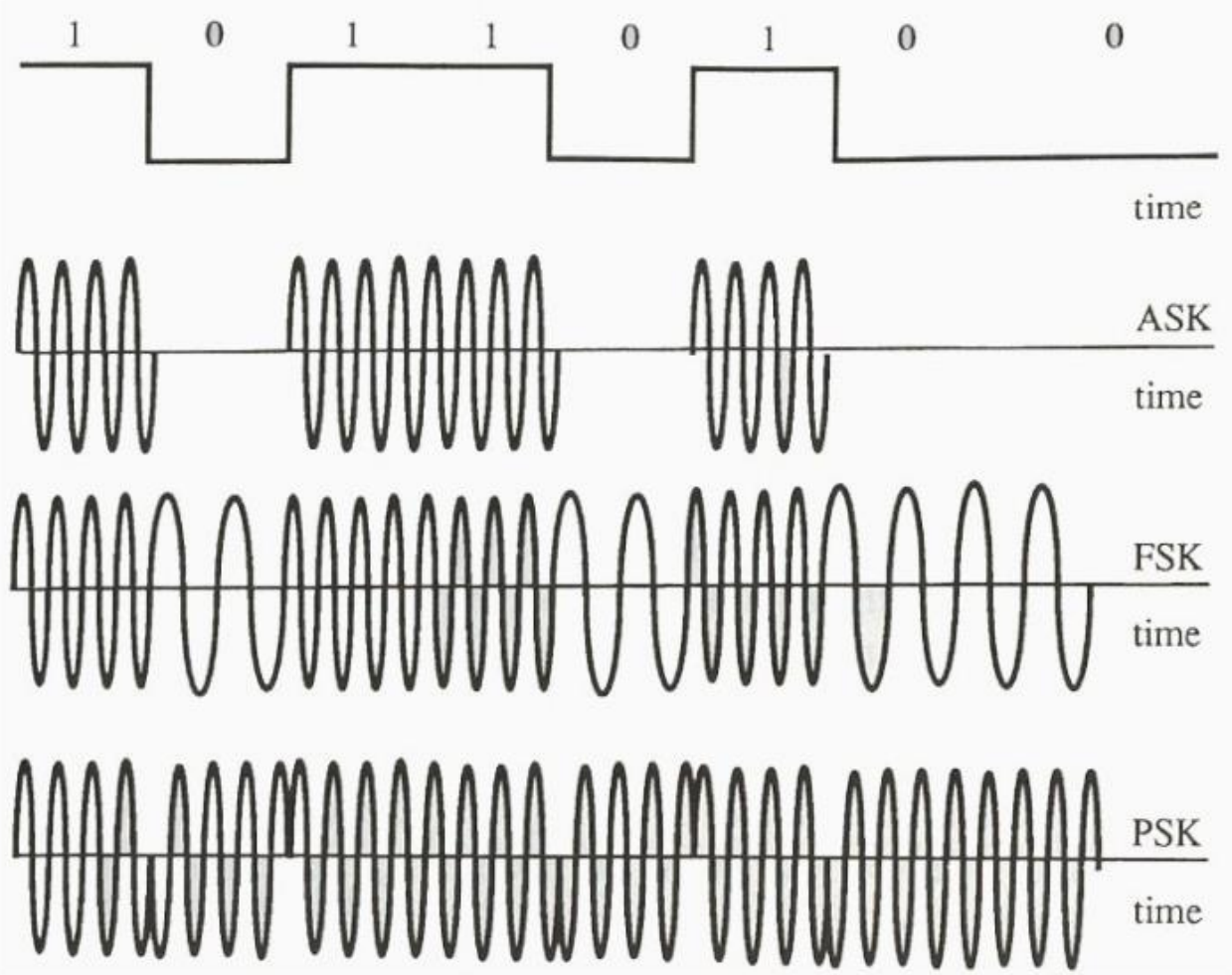
Digital to Analog conversion

- **Example:**

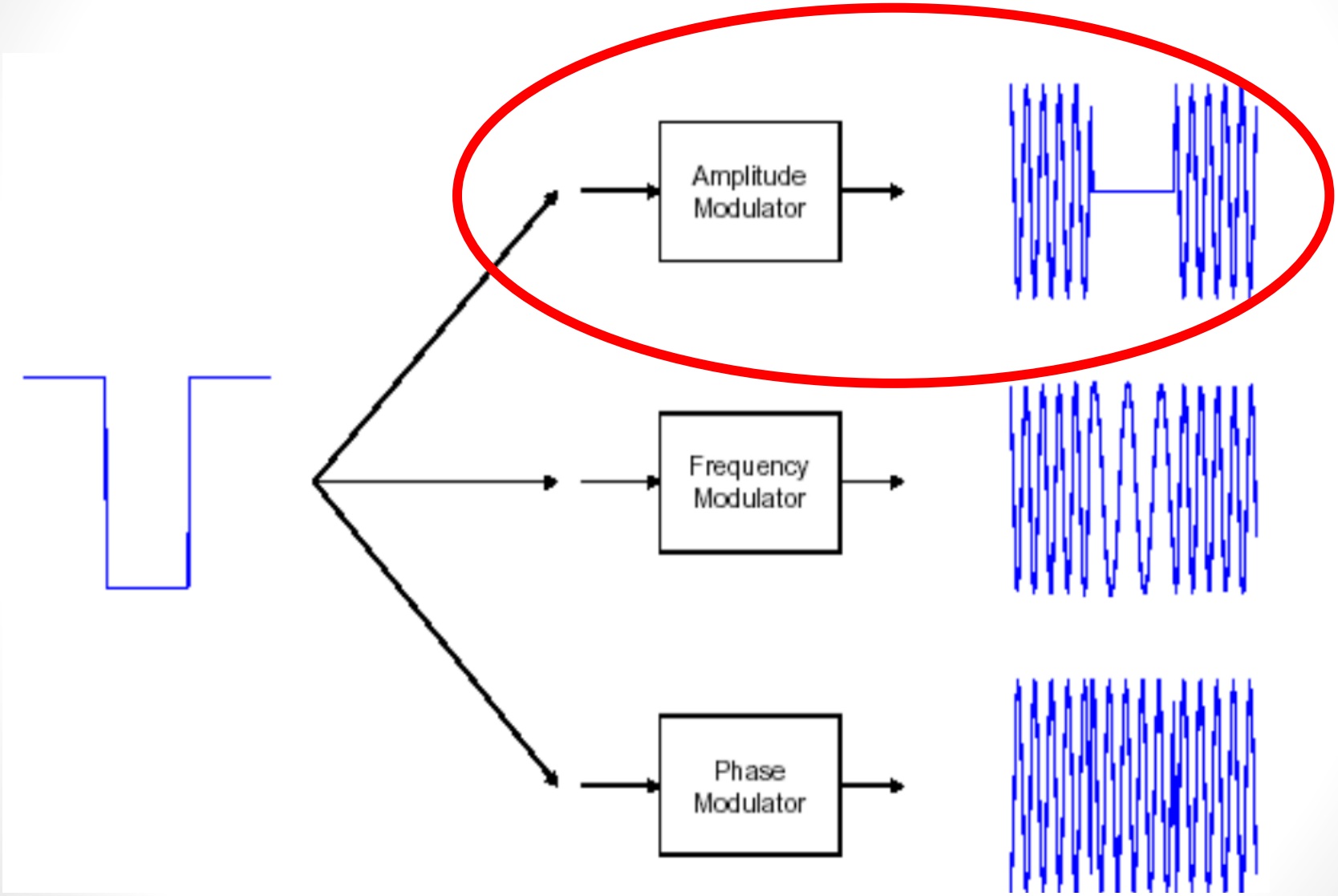


Digital to Analog conversion

- **Modulation Schematics:**



Amplitude Shift Keying



Amplitude Shift Keying

- **In ASK**, the amplitude of the carrier signal is varied to create signal elements. Both frequency and phase remain constant while the amplitude change.
- A popular techniques that used for ASK is called Binary Amplitude Shift Keying (BASK)
- In ASK, data rate is equal to baud rate

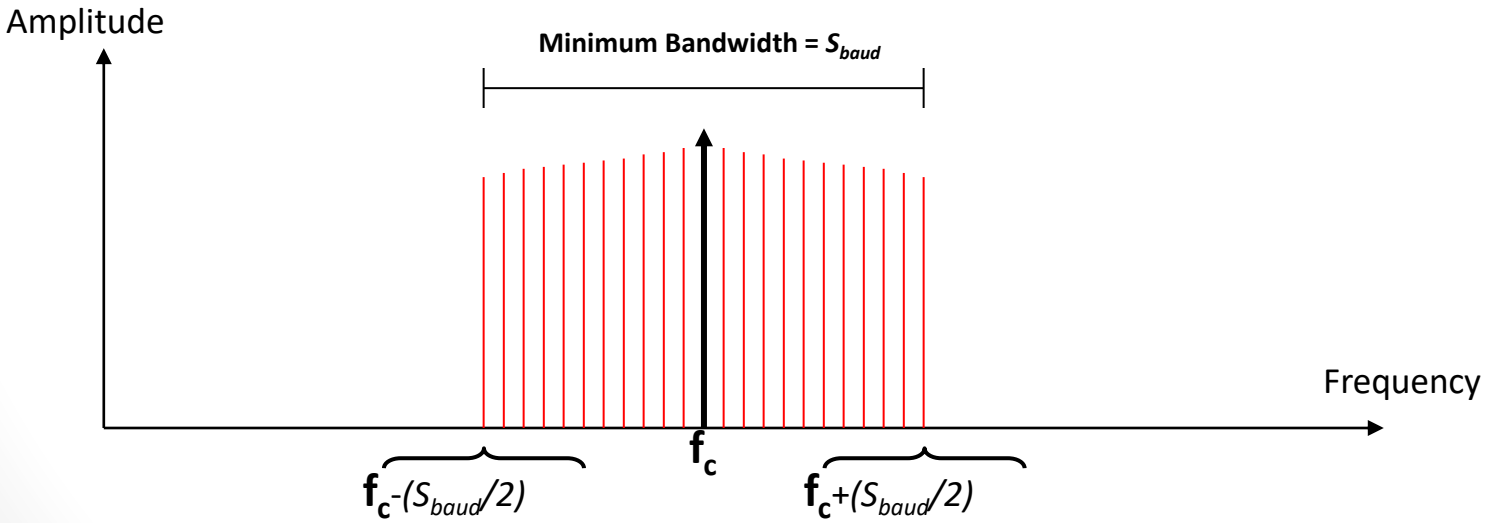
$S = N$ and number of data elements in one signal elements r=1

- The Bandwidth for ASK: B=(1+d) x N

Or B=(1+d) x S

Amplitude Shift Keying

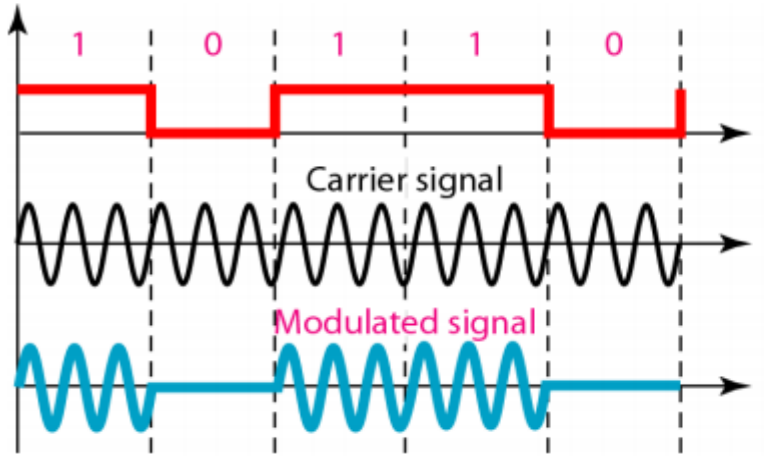
- The bandwidth is depending on signal rate and another factor d which depends on the modulation and filtering, $0 \leq d \leq 1$
- When d=0 → Minimum $B = (1 + d)S = S = N$
- When d=1 → Maximum $B = (1 + d)S = 2S = 2N$

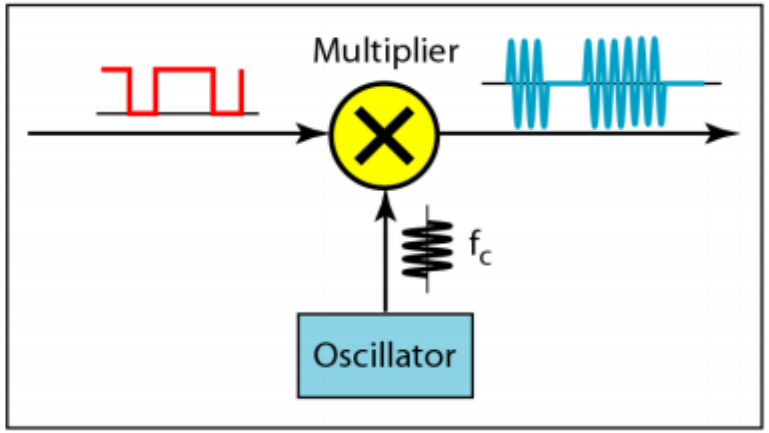


fc is carrier frequency

Amplitude Shift Keying

- **Implementation of Binary ASK**





Amplitude Shift Keying

- **Example 1:** we have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulate our data using ASK with d=1?

Amplitude Shift Keying

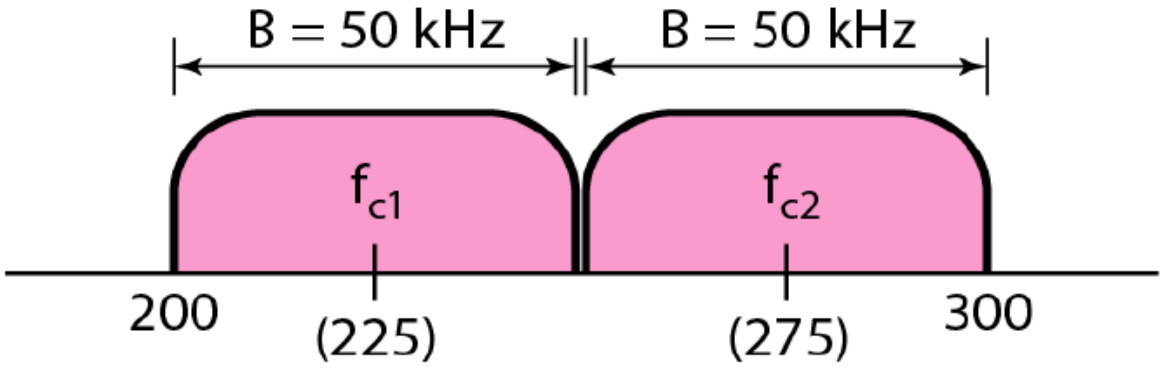
- **Implementation of Binary ASK**

✓In full duplex transmission, data has to be sent in both direction.

✓The available bandwidth is divided into two with 2 carried frequencies.

✓Example, the total bandwidth of **100kHz** is divided into 2 parts of **50kHz** each.

✓The available bandwidth for each direction is now **50kHz.**



Amplitude Shift Keying

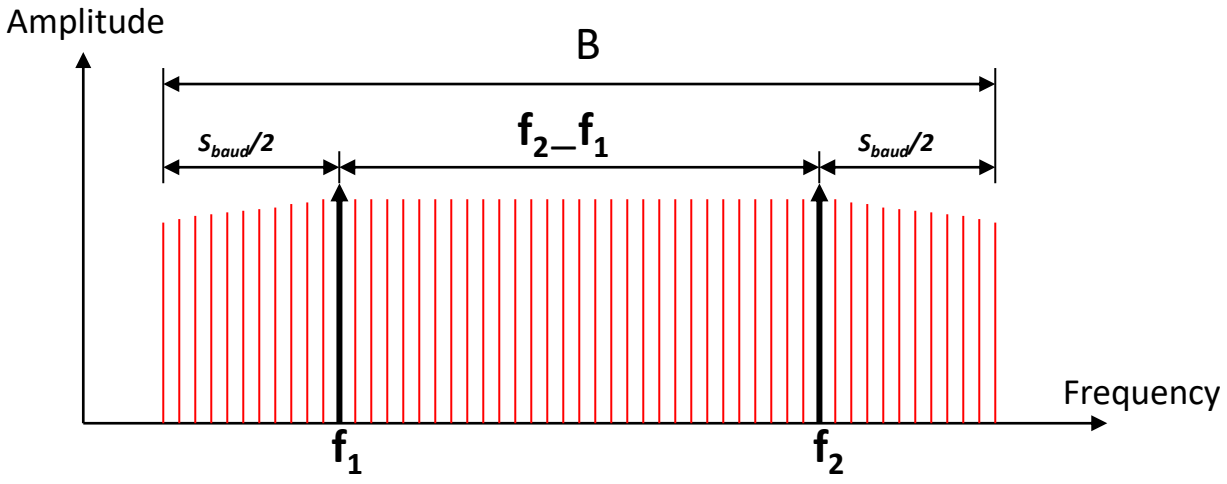
- **Example 2:** Find the minimum bandwidth for an ASK signal transmitting at 2000 bps. The transmission mode is half duplex.

Amplitude Shift Keying

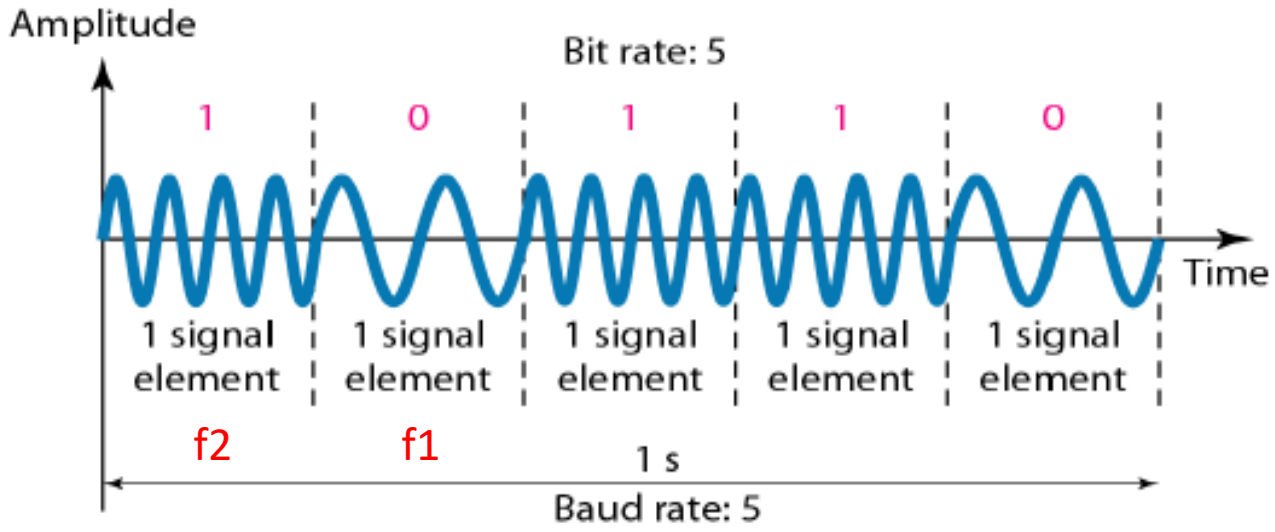
- **Example 3:** Given a bandwidth of 10kHz(1000Hz to 11kHz), draw the full duplex ASK diagram of the system. Find the carriers and the bandwidths in each direction?

Frequency Shift Keying

- **In FSK**, the frequency of the carrier is changed to represent the binary 1 and 0. For binary 0 the carrier frequency will be f_1 and for binary 1 the carrier frequency will be f_2.
- The Bandwidth for FSK: $B = f_2 - f_1 + S_{baud}$



Frequency Shift Keying



Frequency Shift Keying

- **Example 1:** Find the minimum bandwidth for an FSK signal transmitting at 2000 bps? The difference between the two carries are separated by 3000Hz.

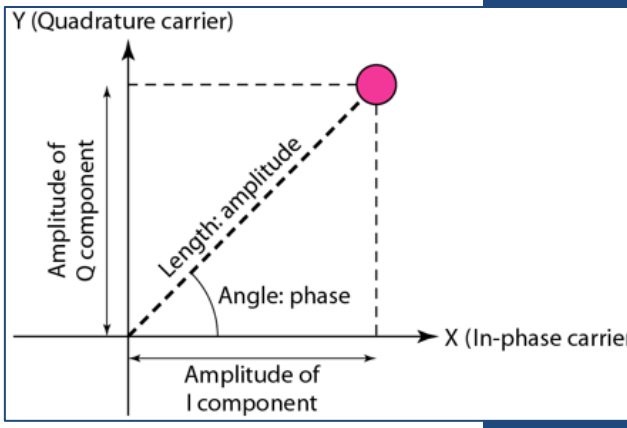
Phase Shift Keying

- **In PSK,** the phase of a transmitted signal is varied to convey information.
- The difference phase angles in the carrier signal are used to represent the binary states of **0 and 1.**
- The simplest PSK technique is called Binary PSK (**BPSK**), which uses two opposite signal phases (0 and 180 degrees).
- There are also more than two phases such as
  - Four(0, +90, -90 and 180 degrees)
  - Eight (0,+45,-45,+90,-90,+135,-135, and 180 degrees)
- In PSK, the Bandwidth= Baud rate

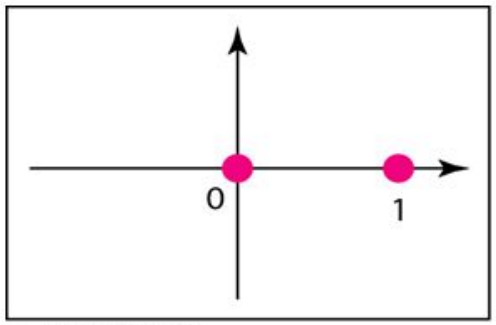
Phase Shift Keying

Constellation Diagram

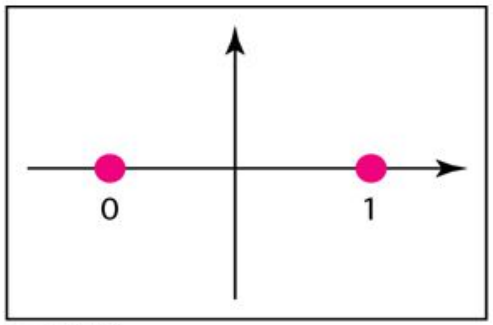
- A **constellation diagram** is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase shift keying.
- It displays the signal as a two dimensional scatter diagram in the complex plane at symbol sampling instant.



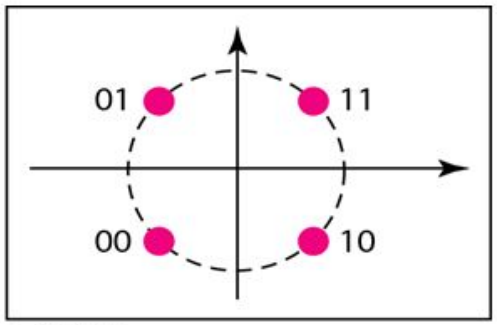
Example:



a. ASK (OOK)



b. BPSK



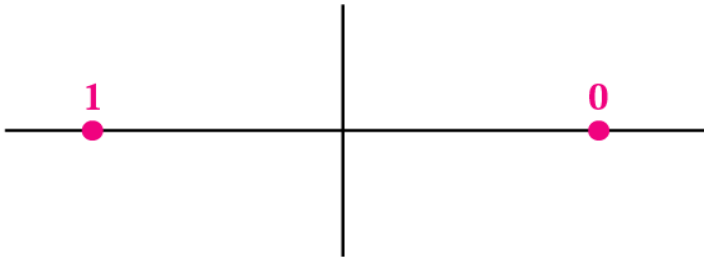
c. QPSK

Phase Shift Keying

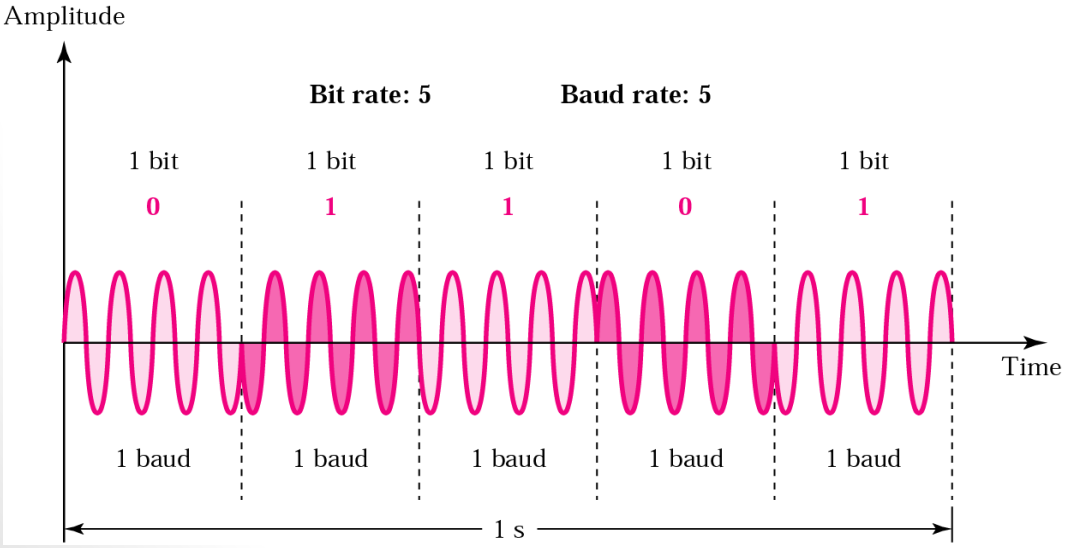
- **Binary-PSK** (BPSK)(2-PSK)

Bit	Phase
0	0
1	180

Bits



Constellation diagram



Bit rate=Baud Rate

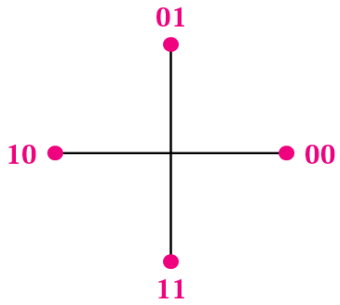
Bandwidth=Baud Rate

Phase Shift Keying

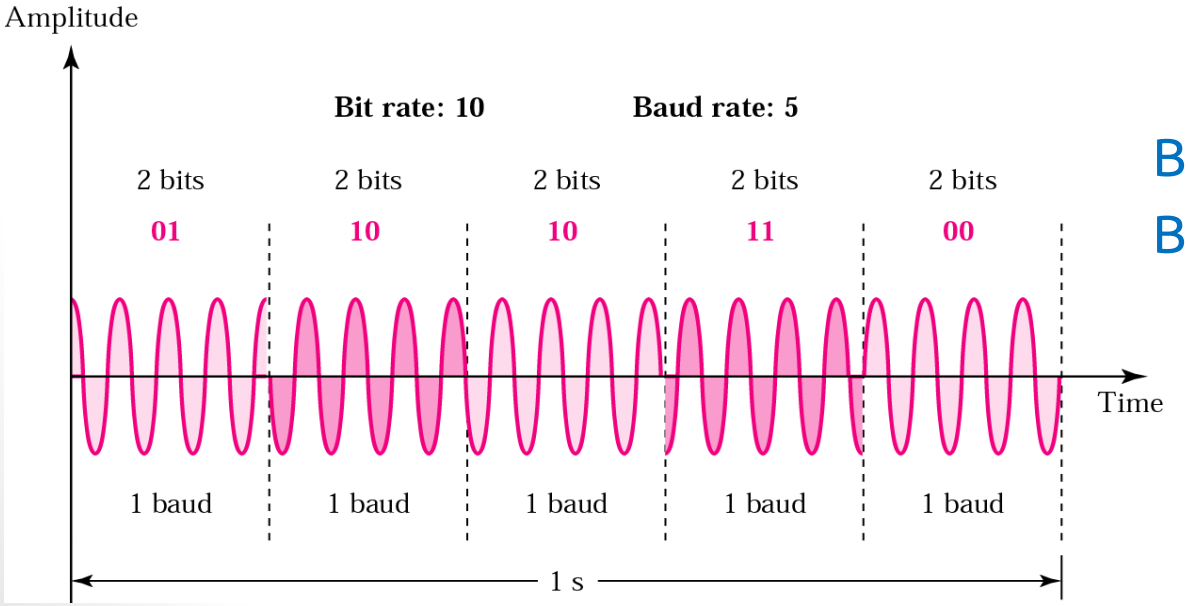
- **The 4-PSK (QPSK)**

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit
(2 bits)



Constellation diagram

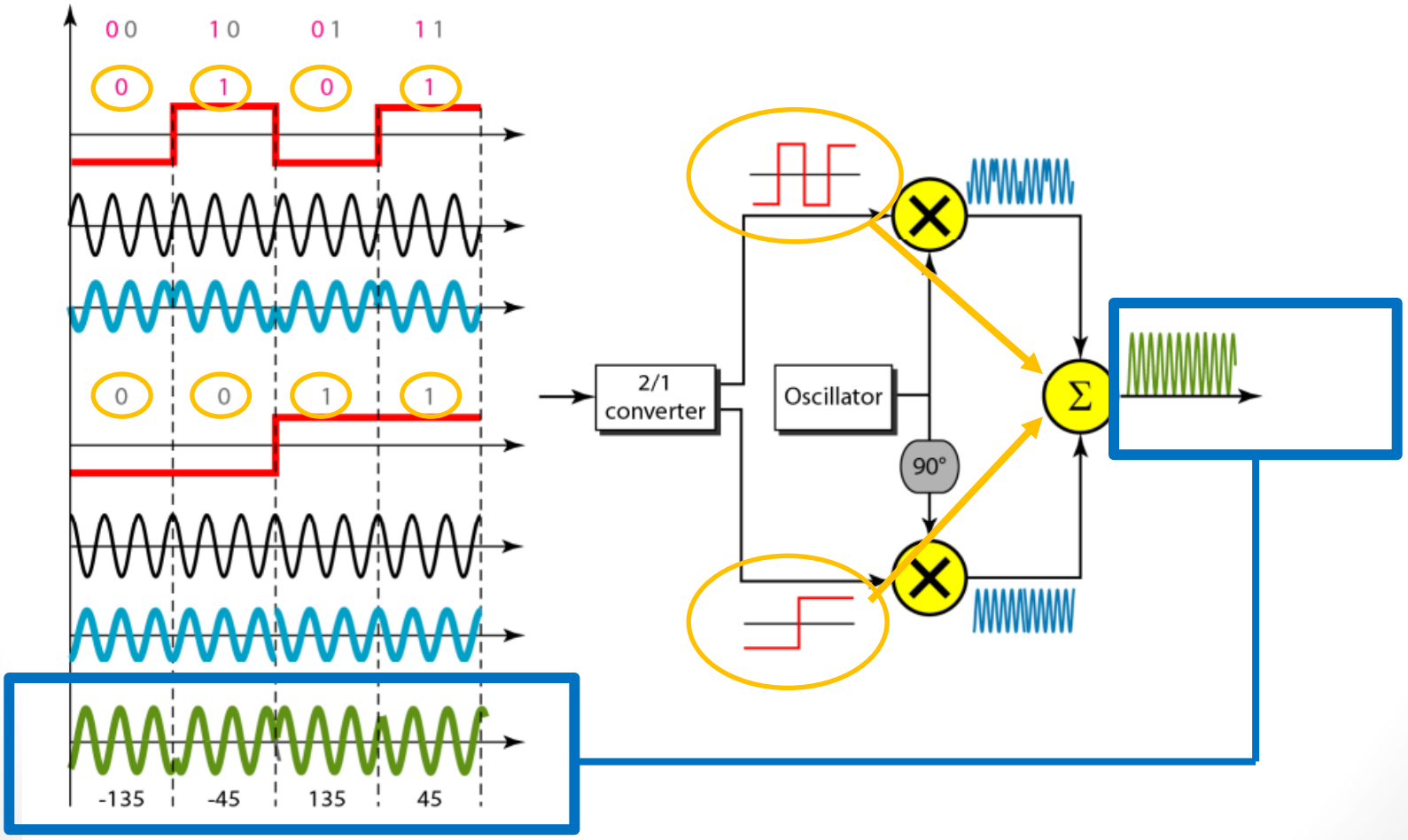


Bit rate=2xBaud Rate

Bandwidth=Baud Rate

Phase Shift Keying

- **The 4-PSK (QPSK) implementation**

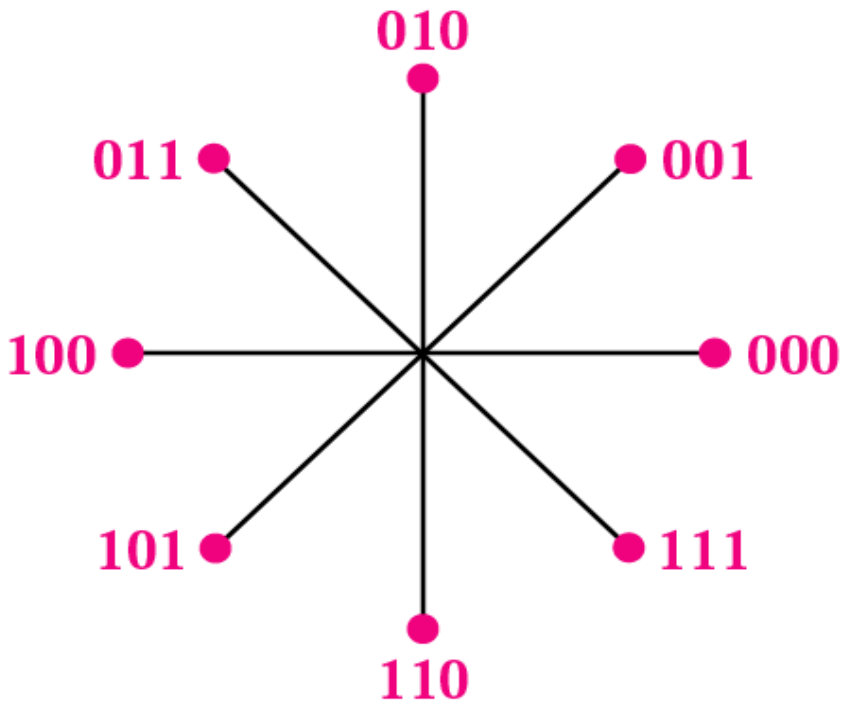


Phase Shift Keying

- **The 8-PSK**

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

Tribits
(3 bits)



Constellation diagram

Phase Shift Keying

- **Example 1:** Find the bandwidth for a 4-PSK transmitting at 2000 bps. Transmission is in half duplex mode.

Phase Shift Keying

- **Example 2:** Given a bandwidth of 5000Hz for an 8-PSK signal, what are the baud rate and bit rate?

Phase Shift Keying

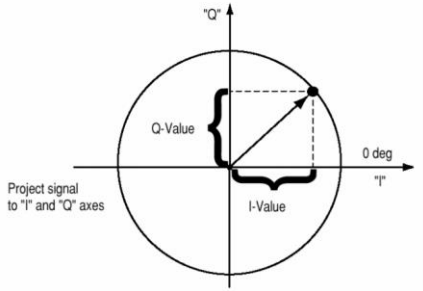
- **Example 3:** Find the bandwidth for a signal transmitting at 12 Mbps for QPSK? The value of d = 0.

Quadrature Amplitude Modulation(QAM)

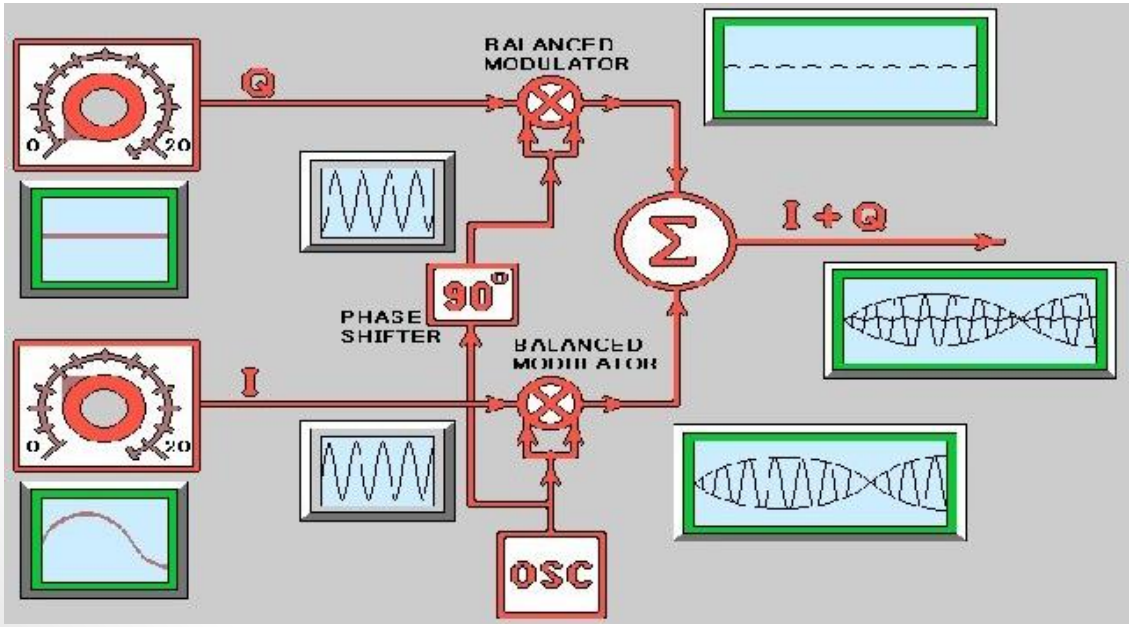
- In practice, the maximum number of bits can be sent with any one of ASK, PSK, FSK is five bits.
- In order to meet the limitations, we need to have other technique is called **QAM.**
- QAM is a combination of ASK and PSK .
- In QAM, the both Amplitude and Phase are varied.
- Quadrature = Sine Wave + Cosine Wave

Quadrature Amplitude Modulation(QAM)

- This technique combines two carries whose amplitudes are modulated independently with same frequency and phases are shifted by $90°$ with respect to each other.
- These carries are called:
  1. In-Phase Carries **(I)**
  2. Quadrature Carries **(Q)**

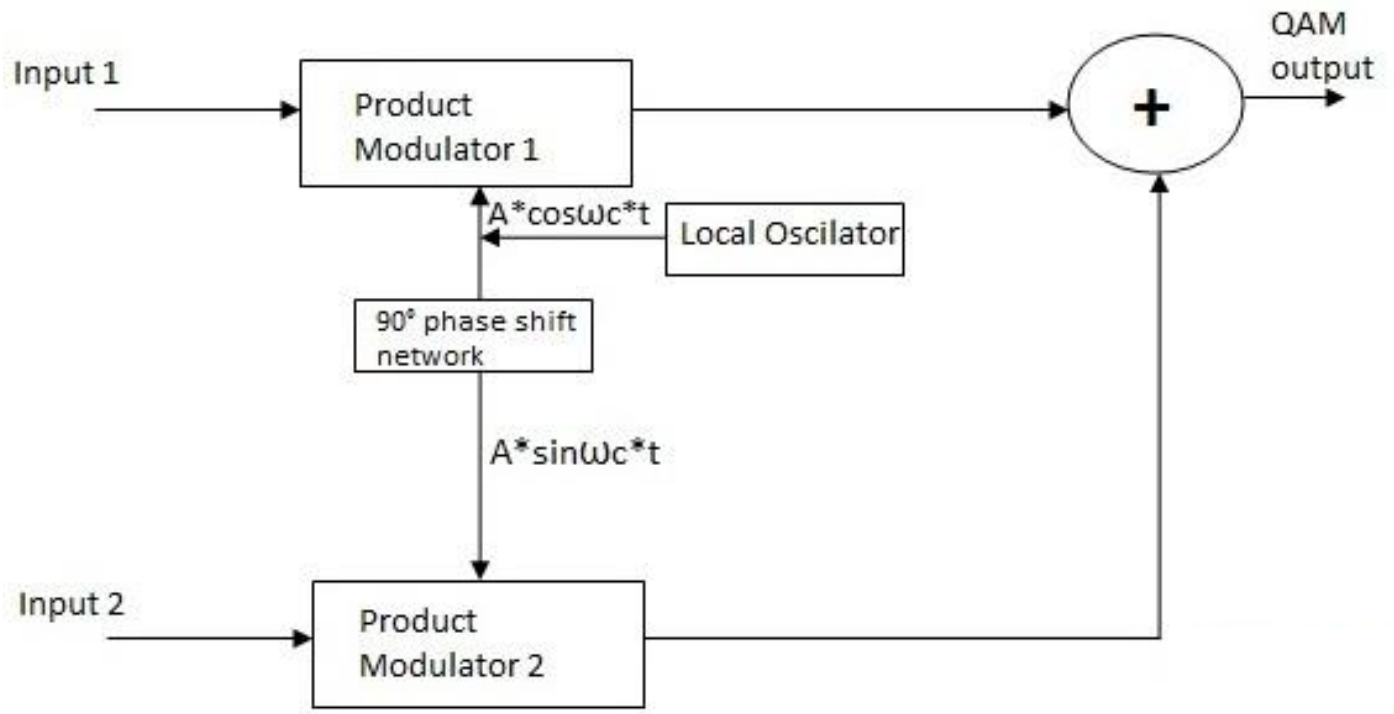


"I-Q" format—Polar to rectangular conversion



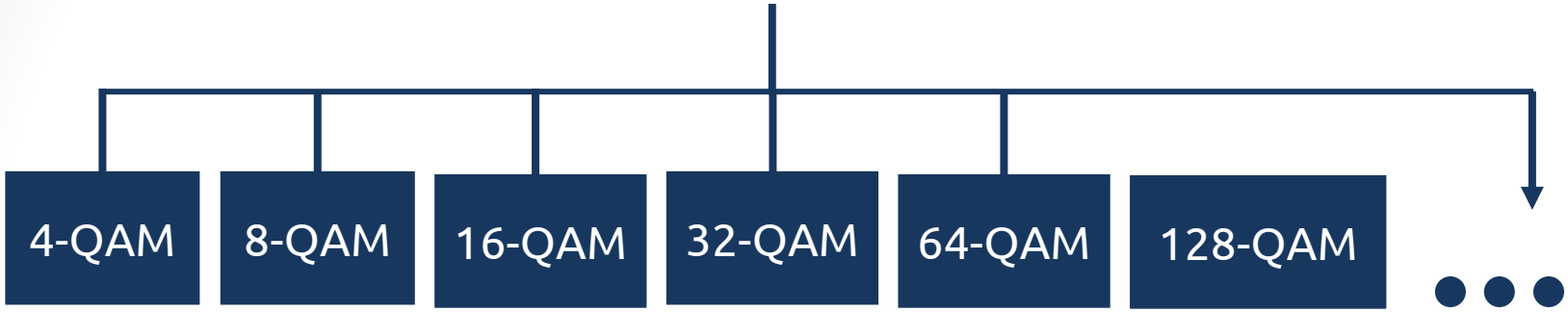
Quadrature Amplitude Modulation(QAM)

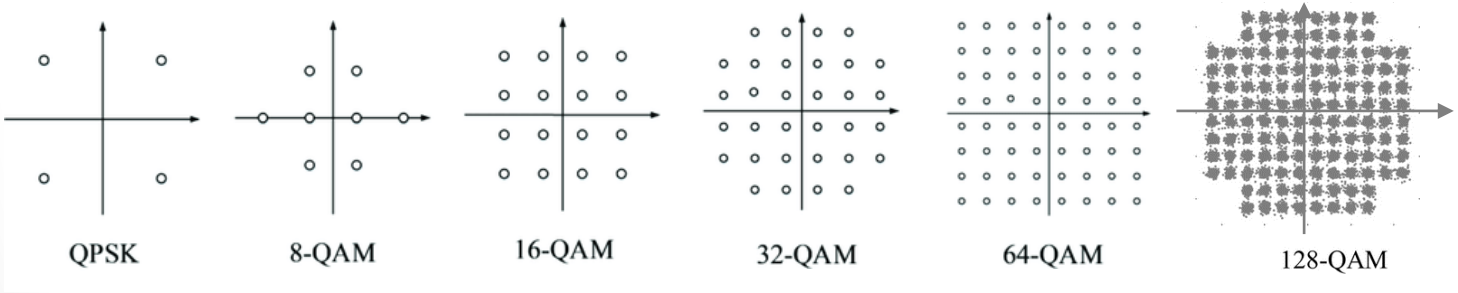
QAM Block Diagram



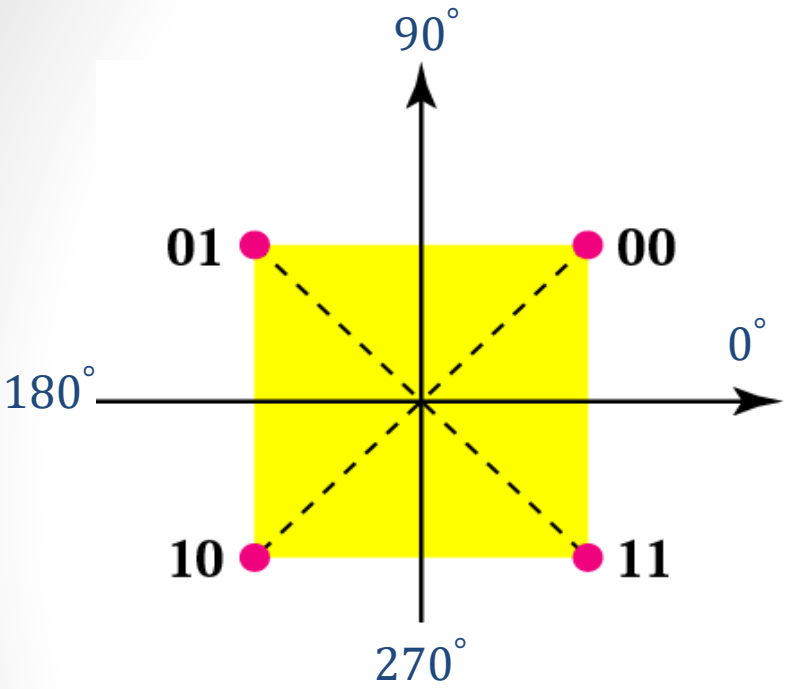
Quadrature Amplitude Modulation(QAM)

QAM Forms

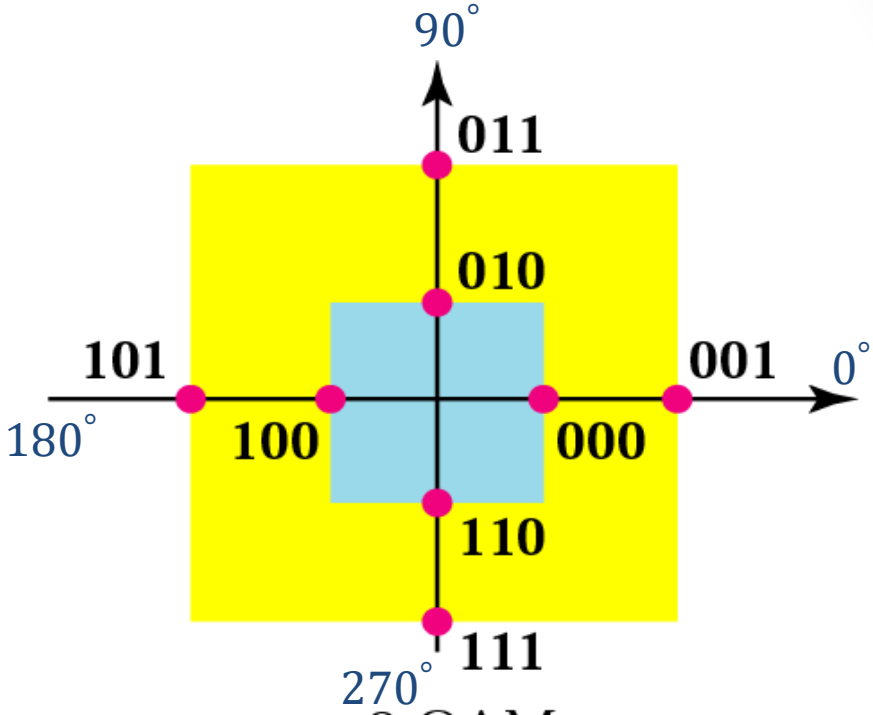




Quadrature Amplitude Modulation(QAM)

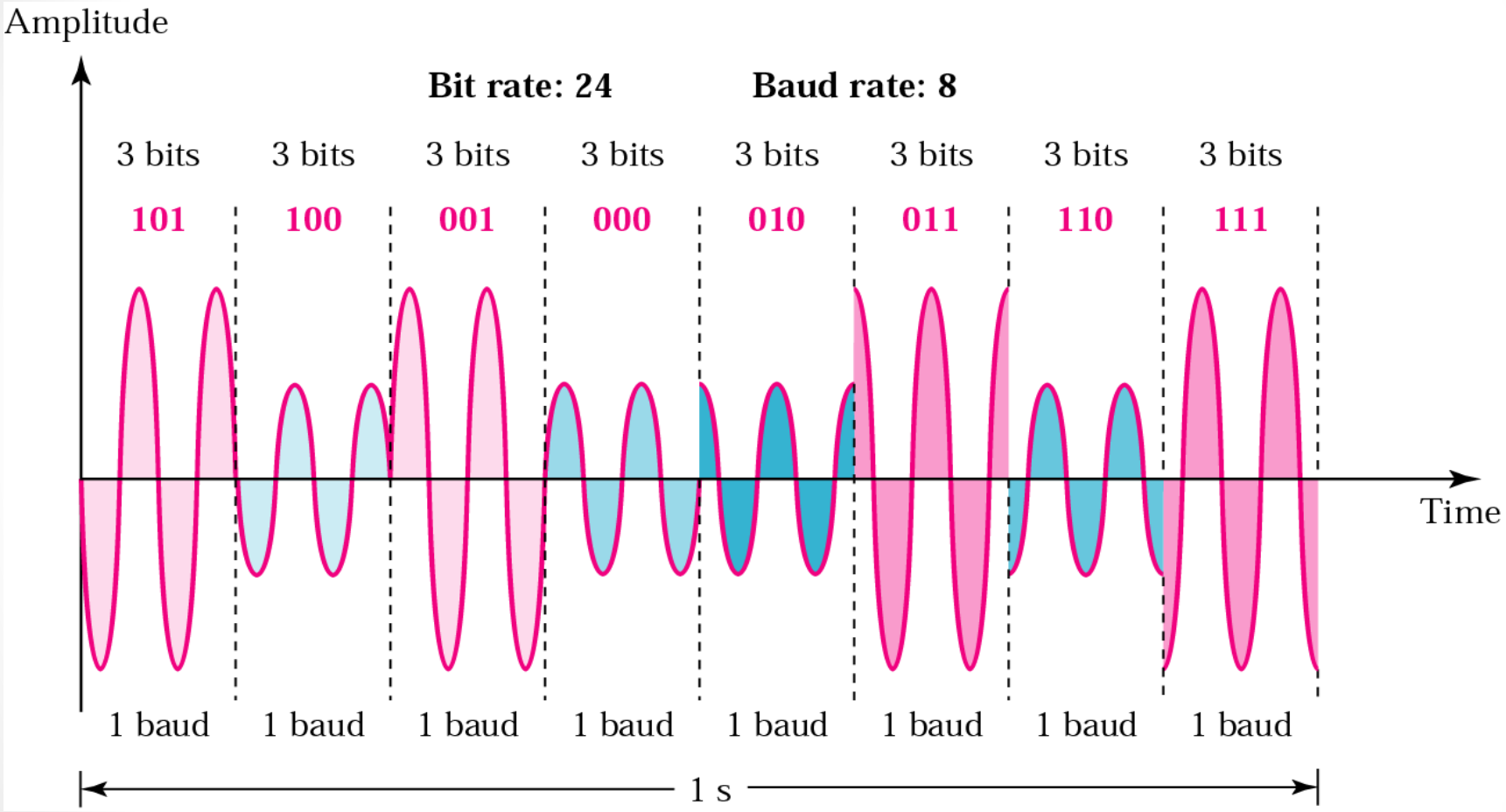


4-QAM
1 amplitude, 4 phases



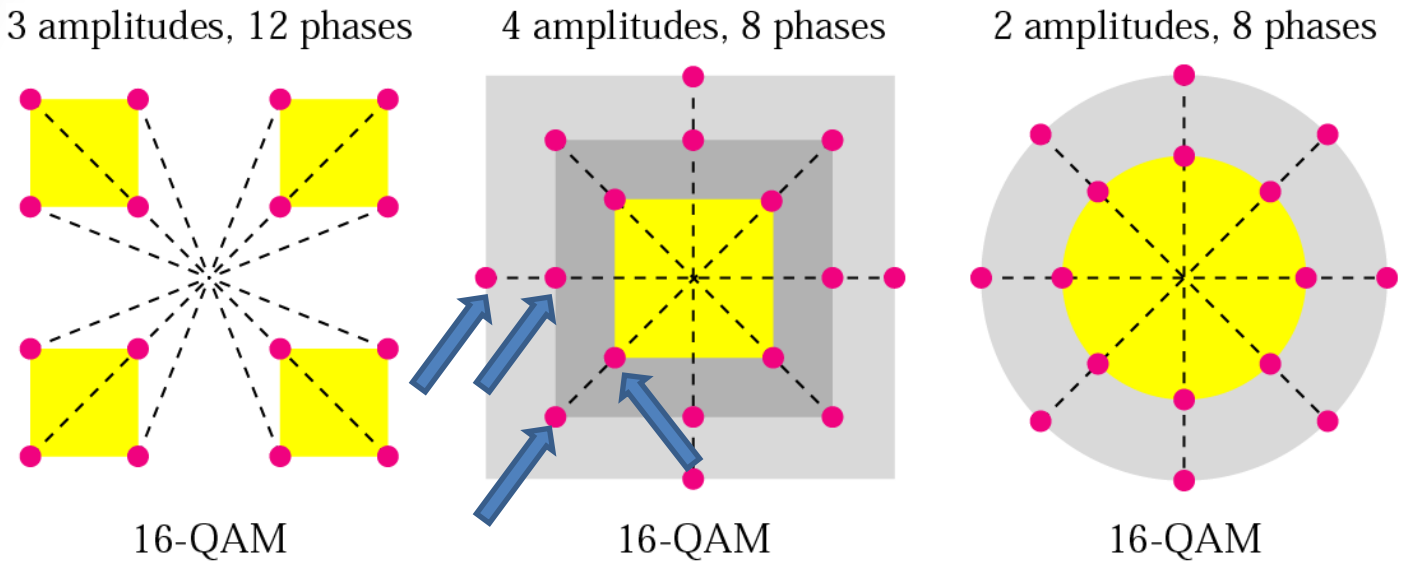
8-QAM
2 amplitudes, 4 phases

Quadrature Amplitude Modulation(QAM)

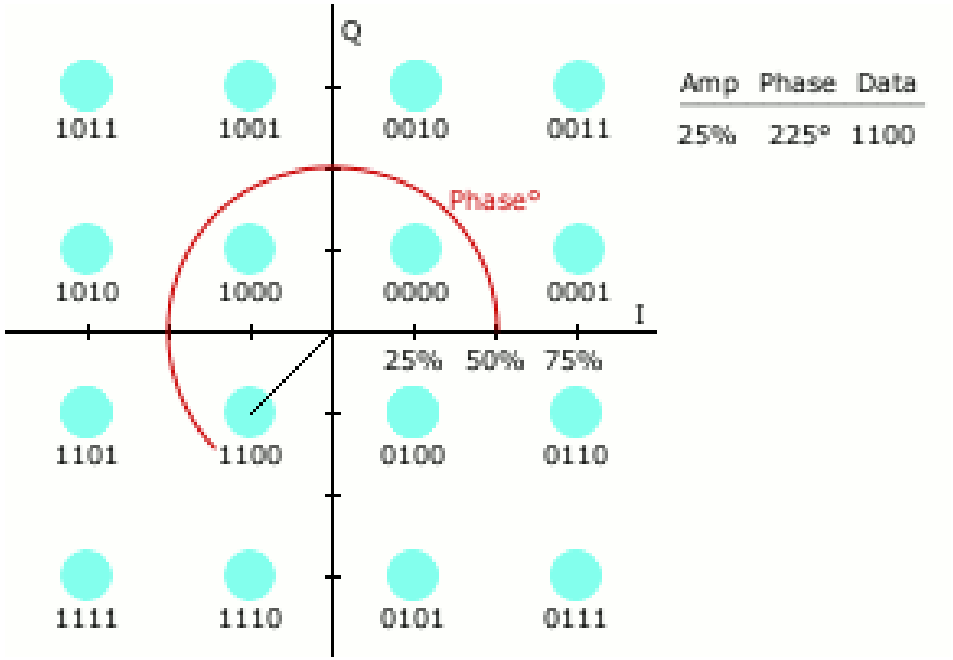


Example diagram of 8-QAM

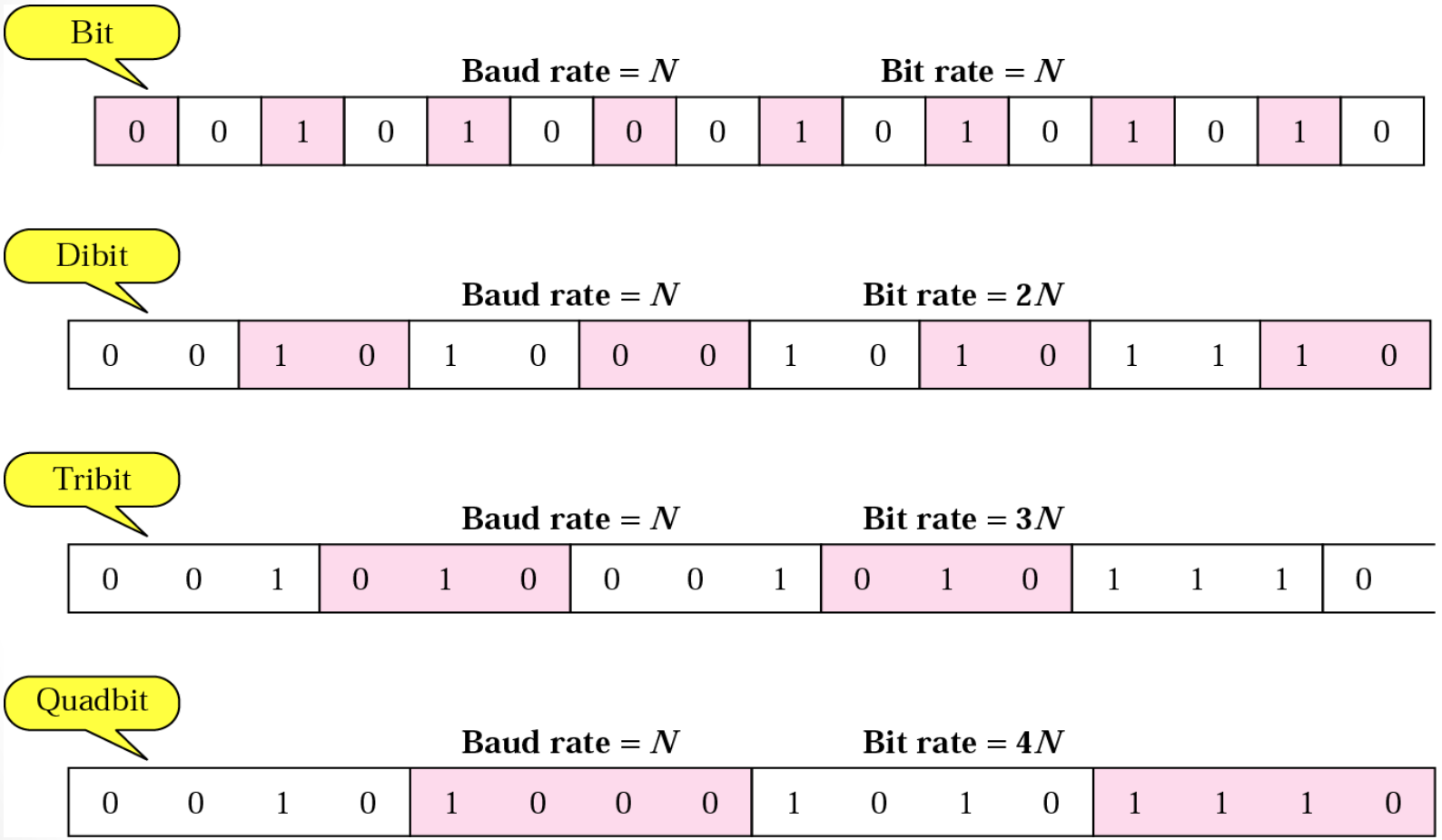
Quadrature Amplitude Modulation(QAM)



Quadrature Amplitude Modulation(QAM)



Quadrature Amplitude Modulation(QAM)



Bit and Baud Rate Scheme

Quadrature Amplitude Modulation(QAM)

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

Bit and Baud Rate Comparison

Quadrature Amplitude Modulation(QAM)

- **Example 1:** A constellation diagram consists of eight equally spaced points on a circle. If the bit rate is 4800 bps, what is the baud rate?

Quadrature Amplitude Modulation(QAM)

- **Example 2:** Compute the bit rate for a 1000-baud 16-QAM signal.

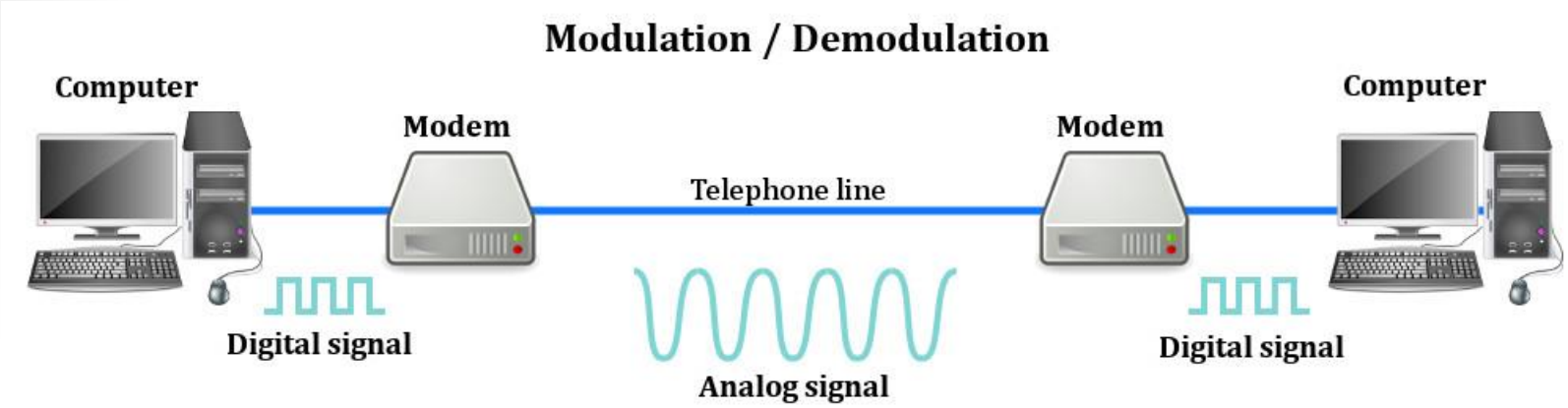
Quadrature Amplitude Modulation(QAM)

- **Example 3:** Compute the baud rate for a 72,000-bps 64-QAM signal.

Modem Standard

Difference types of modem

Modem Standard



Modem stands for Modulator-Demodulator is a device that modulates an analog carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information over the **telephone line.** So it is Data Conversion Equipment.

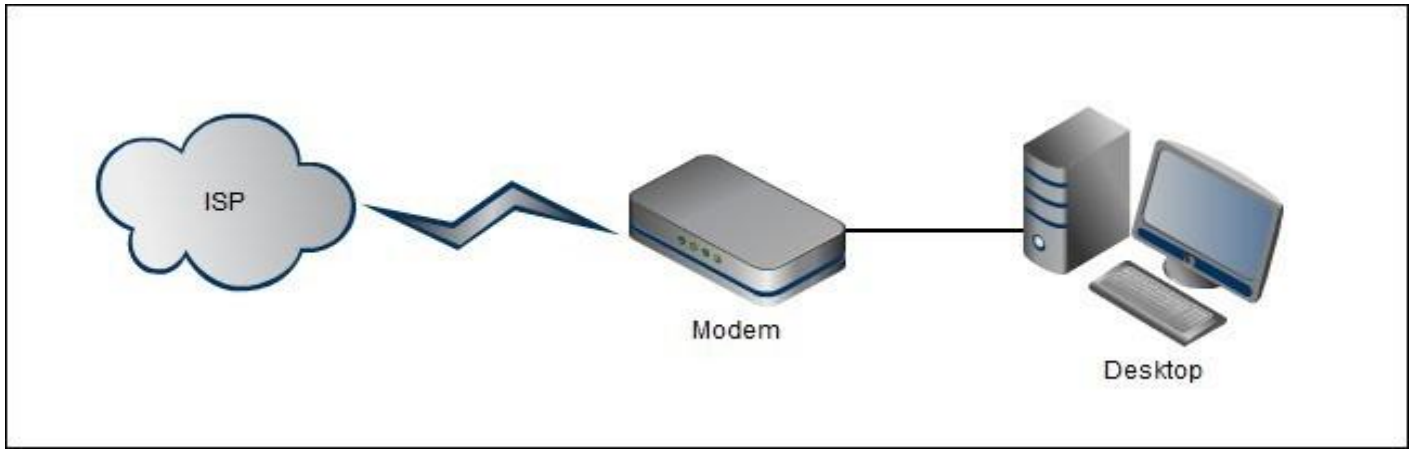
Modem Standard

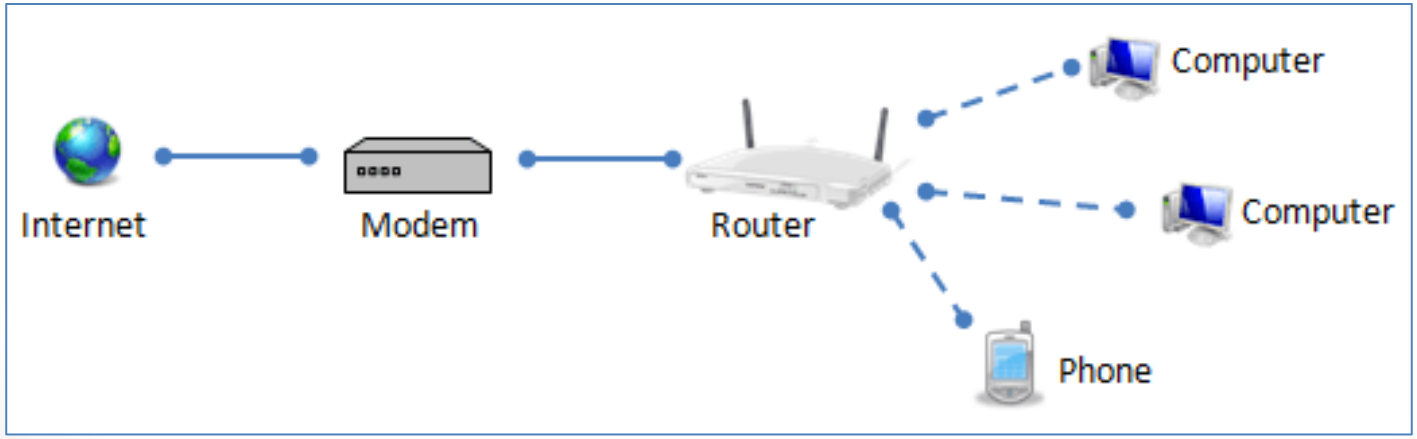
Modem vs Router

DEMO

Modem Standard

Modem vs Router





Repeater Access Point

New technology

Quiz

A constellation diagram can help us define the amplitude and

A. Frequency
B. Signal
C. Phase
D. QAM

In constellation diagram, a signal element type is represented as a

A. line
B. dot
C. X component
D. Y component
E. None of above

Quiz

In Binary Phase Shift Keying (BPSK), there are two values of phase i.e 0 degree and :

A. 180 degree
B. 90 degree
C. 360 degree
D. 45 degree

When Amplitude Shift Keying (ASK) is implemented using only two levels then it is called

A. Half duplex ASK
B. Multilevel ASK
C. Binary ASK
D. Duplex ASK
E. None of above

Homework

Read Book: Data communication and Networking, 4th Edition

1. Chapter 5: Analog Transmission
2. Page: 141-157
3. Try to answer question: 158-160