Analog Transmission

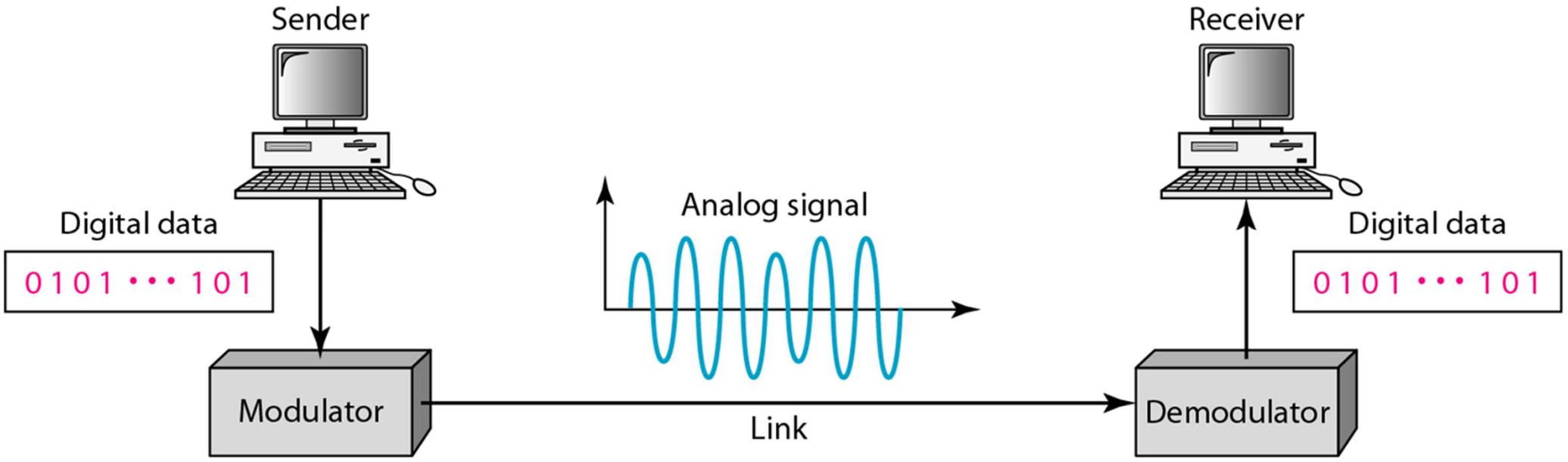
Topics covered in this topic

- Digital-to-Analog Conversion
- Analog Signal Modulation

Digital-to-Analog Conversion

Data Communication Model

- Digital → Analog – (send) – Analog → Digital



Reason for Converting to Analog Signal

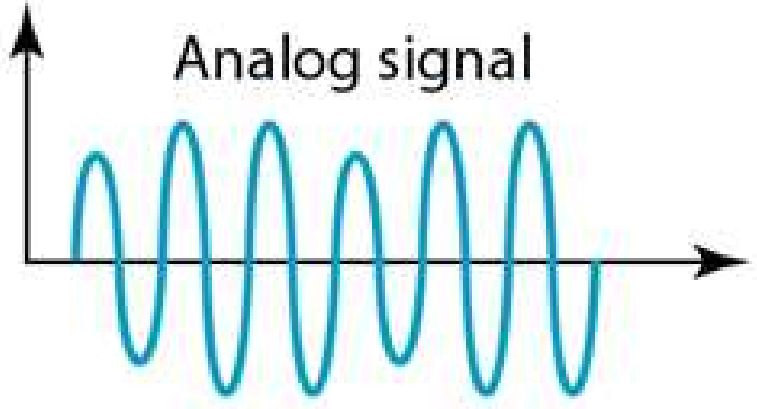
In other words, a low-pass channel is designed to transmit or pass signals that have frequencies lower than a specified frequency, while attenuating or filtering out signals that have frequencies higher than the specified frequency.

- To transmit digital signal, we need a low-pass channel with large bandwidth
- Broadcasting services such as TV and radio allocates different frequency bands to different channels
- Different frequency bands are allocated to cell phone users for simultaneous calls

Analog Signal

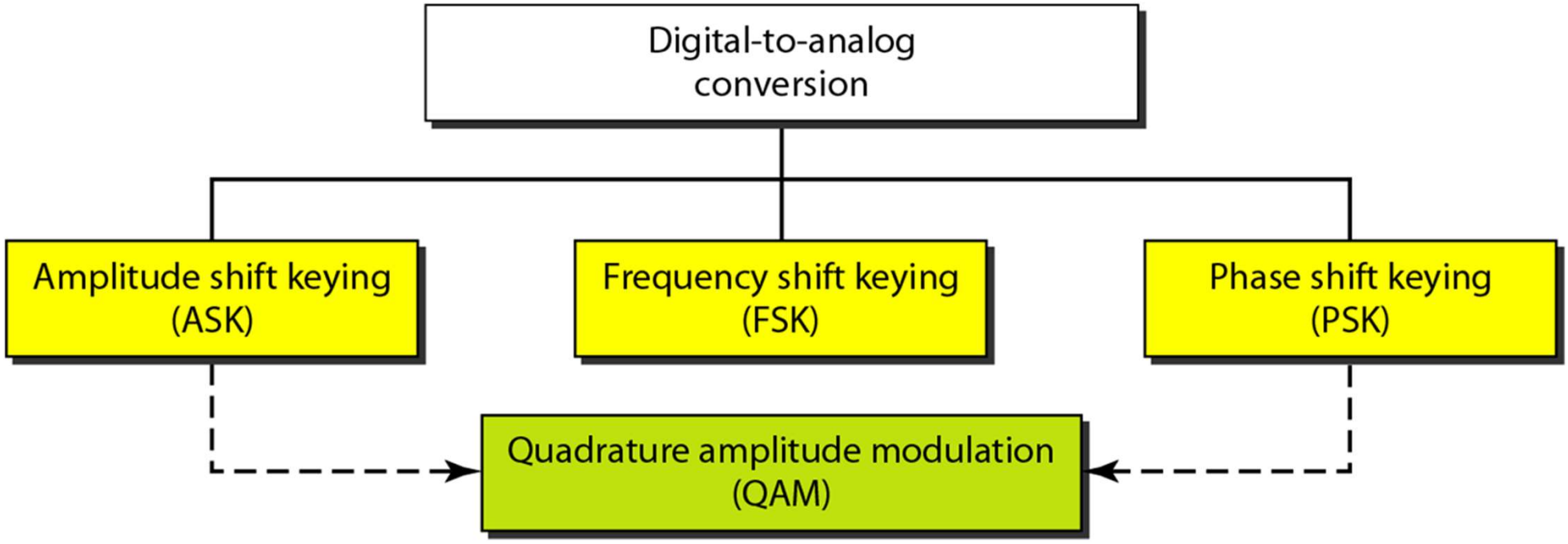
- Amplitude
- Frequency
- Phase

- Digital data can be “encoded” using these 3 characteristics



Types of Digital-to-Analog Conversion

0,1을 이 세가지를 이용해서 표현

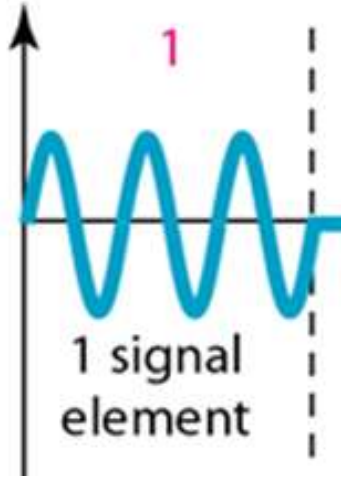


Data and Signal Elements in Analog

- Data element: bit
- Signal element: the smallest unit of signal

- Signal element in digital signal
  - The smallest unit of signal which has a constant level

- Signal element in analog signal
  - The smallest unit of signal that represents one or more bits
  - In analog, always bit rate ≥ baud rate



Data Element and Signal Element

- N: Data transmission rate (bit rate)
- S: Signal transmission rate (baud rate)

$$S = N \times \frac{1}{r}$$

Example

- An analog signal carries 4 bits of data per signal element. If baud rate is 1000 baud, what is the data transmission rate?

시그널 element가 1초에 1000개
4000bps

Example

- An analog signal transmits at 1000 baud and its bit rate is 8000 bps. How many bits are carried in a single signal element? bit : signal element = 8 : 1

  8

- How many <u>different signal elements</u> must be used?

  하나의 signal element에 8개의 비트를 표현해야 하니까 2^8

Amplitude Shift Keying (ASK)

- Change amplitude of the carrier signal to encode data

- Carrier signal: the analog signal that carries the data

- Carrier frequency: frequency of the carrier signal (typically, the central frequency)

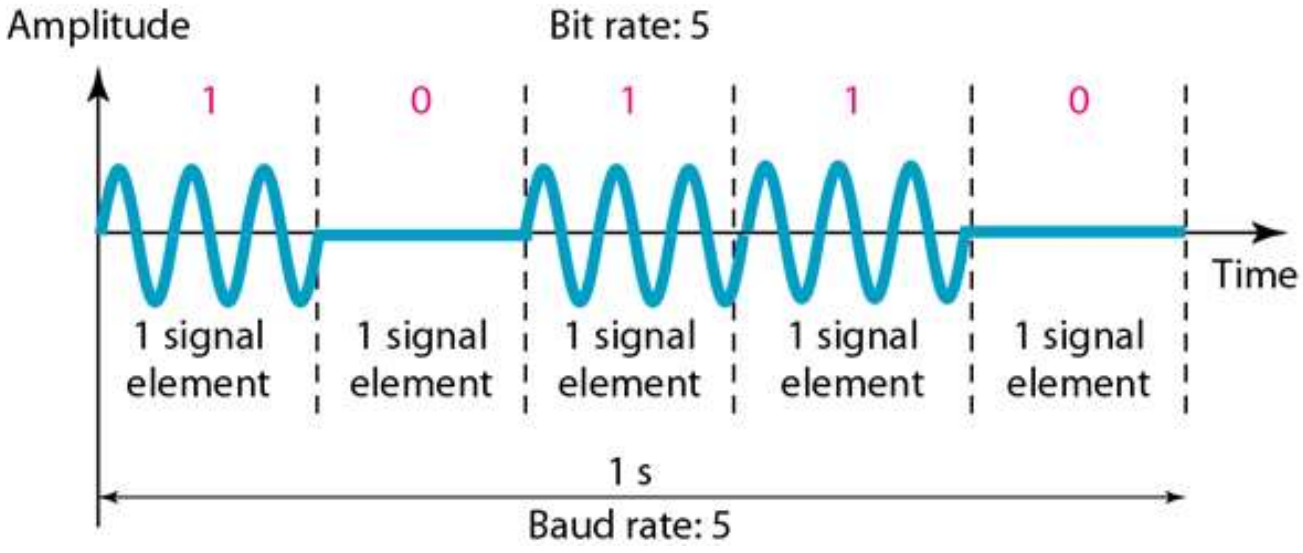
carrier frequency가 다르면 동시에 전송해도 구별할 수 있다

carrier frequency - 데이터를 보내는 기준 주파수
bandwidth - carrier frequency 전 후로 추가적으로 사용하는 대역

ASK

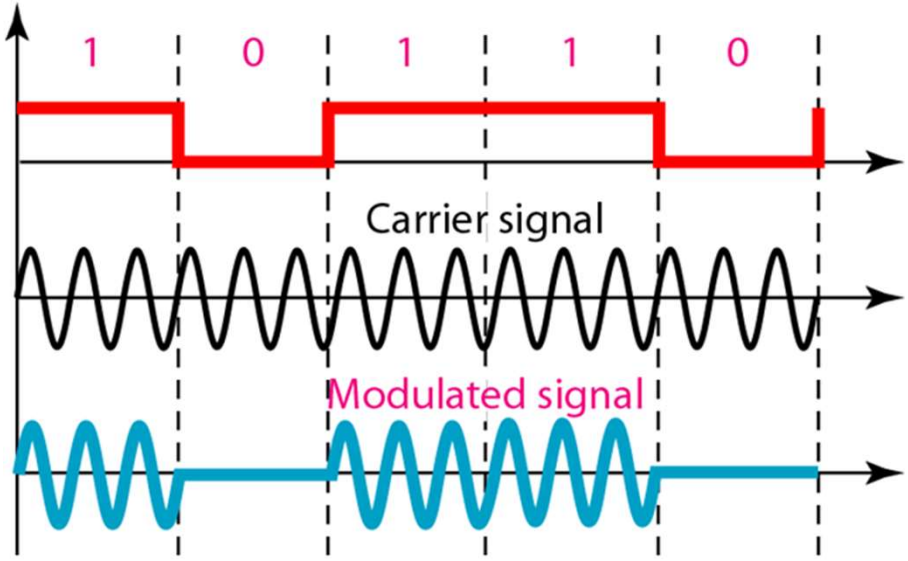
- Change amplitude of the carrier signal to encode data

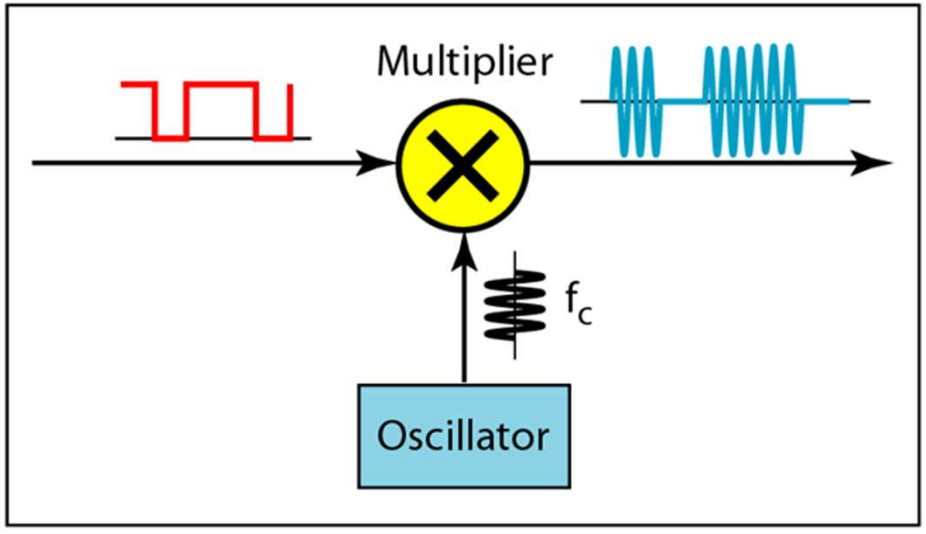
진폭이 큰게 1, 없는게 0으로 표현하고 있음



ASK

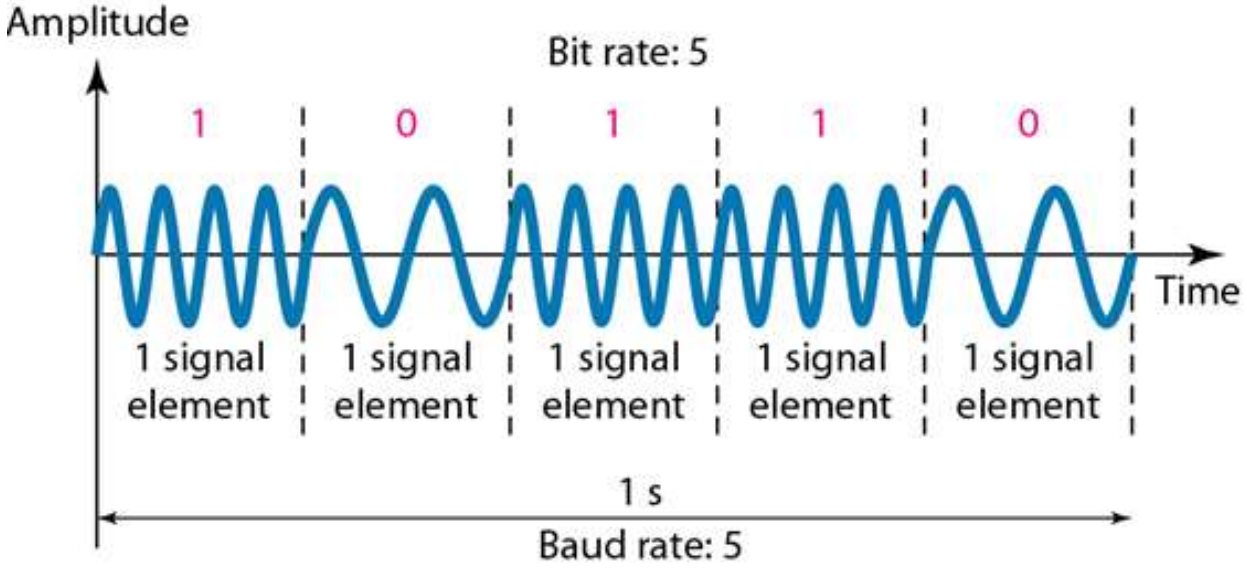
- Signal generation





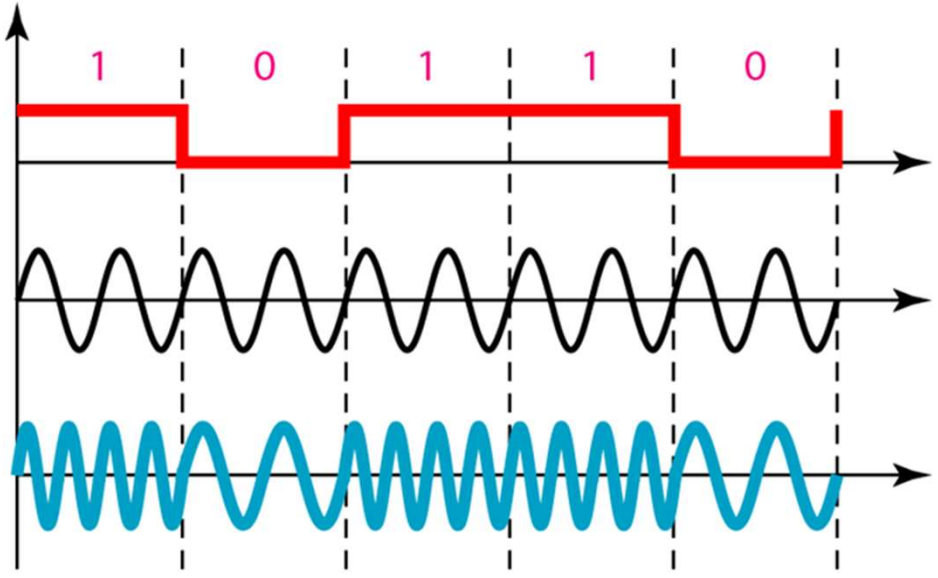
Frequency Shift Keying (FSK)

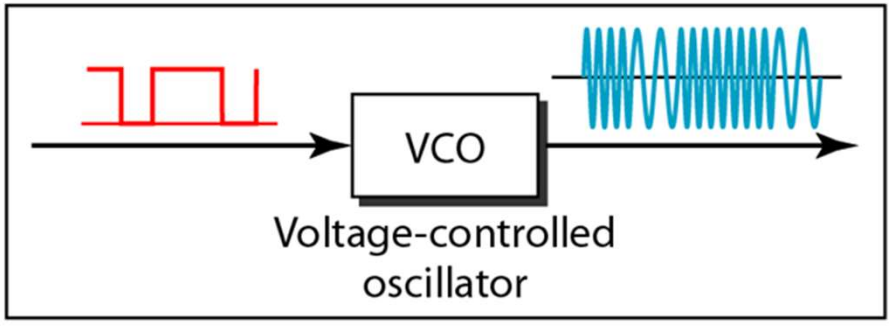
- Change frequency of the carrier signal to encode data



FSK

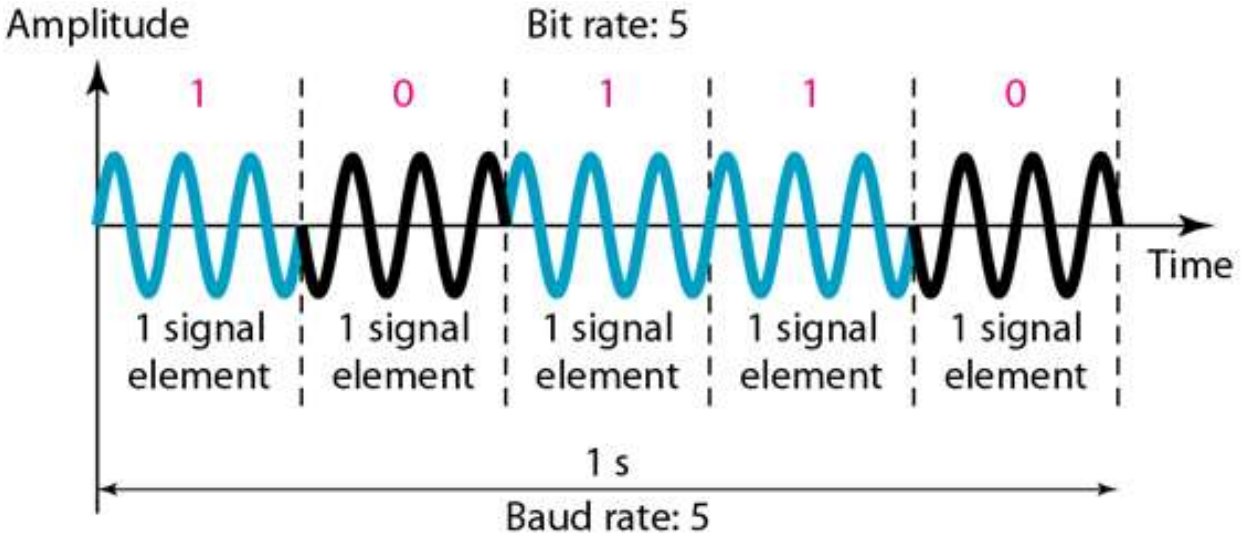
- Signal generation





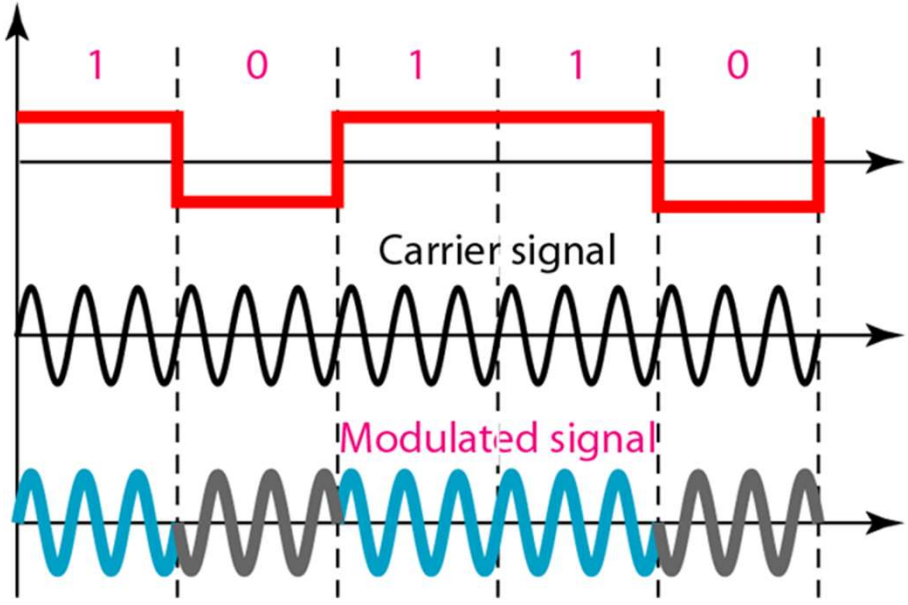
Phase Shift Keying (PSK)

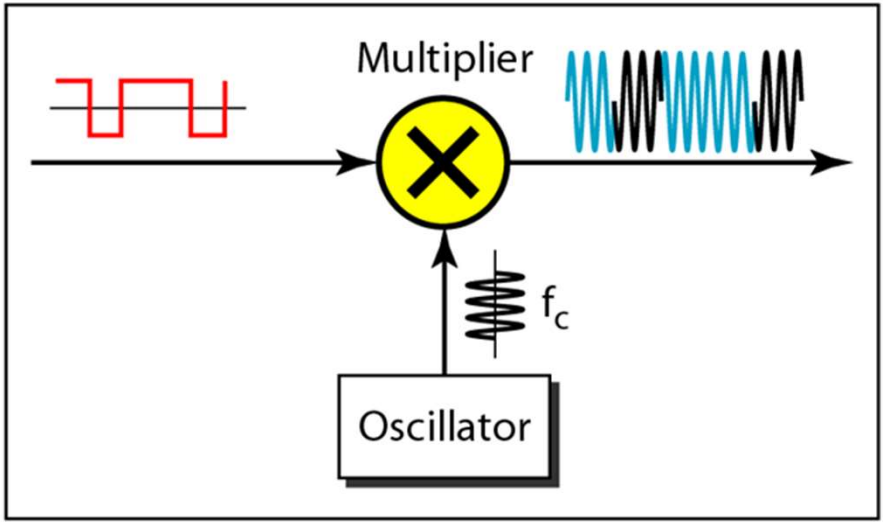
- Change phase of the carrier signal to encode data



PSK

- Signal generation





binary

BPSK vs. QPSK

- BPSK (Binary PSK): use 2 different phases to encode 0 and 1

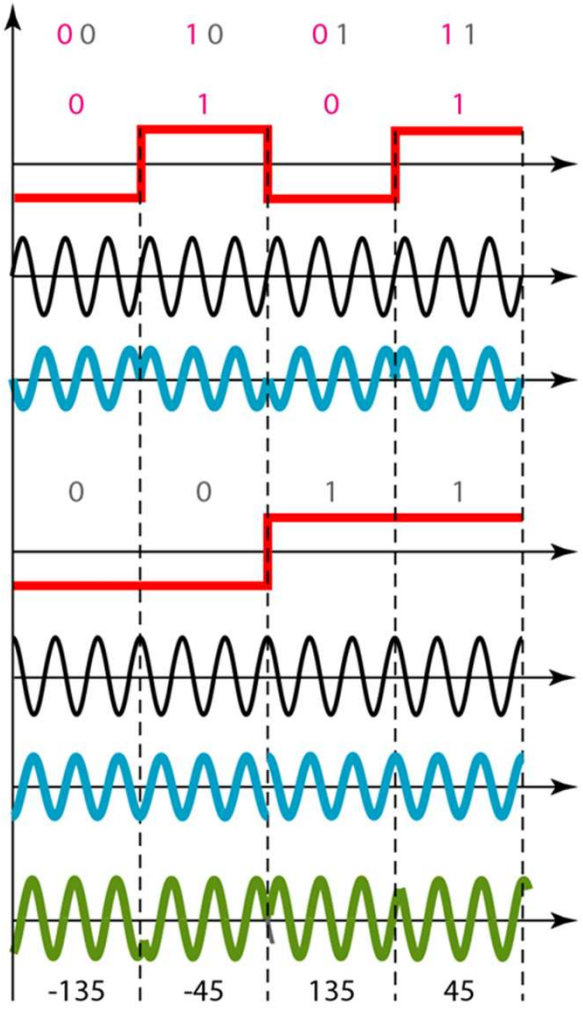
두 가지 signal element를 사용

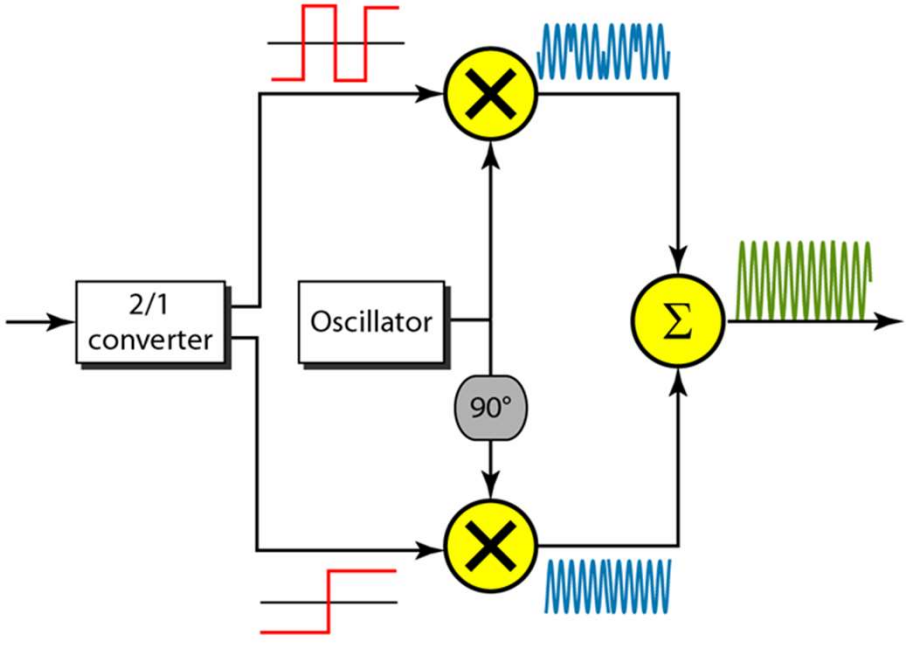
  - 0° , 180°

- QPSK (Quadrature PSK): use 4 different phases to encode 00, 01, 10, 11 (2 bits per signal element)
  - 45° , 135° , -45° , -135°

QPSK

- Signal generation





Example

- Data was transmitted at 12Mbps using QPSK modulation. What is the baud rate?

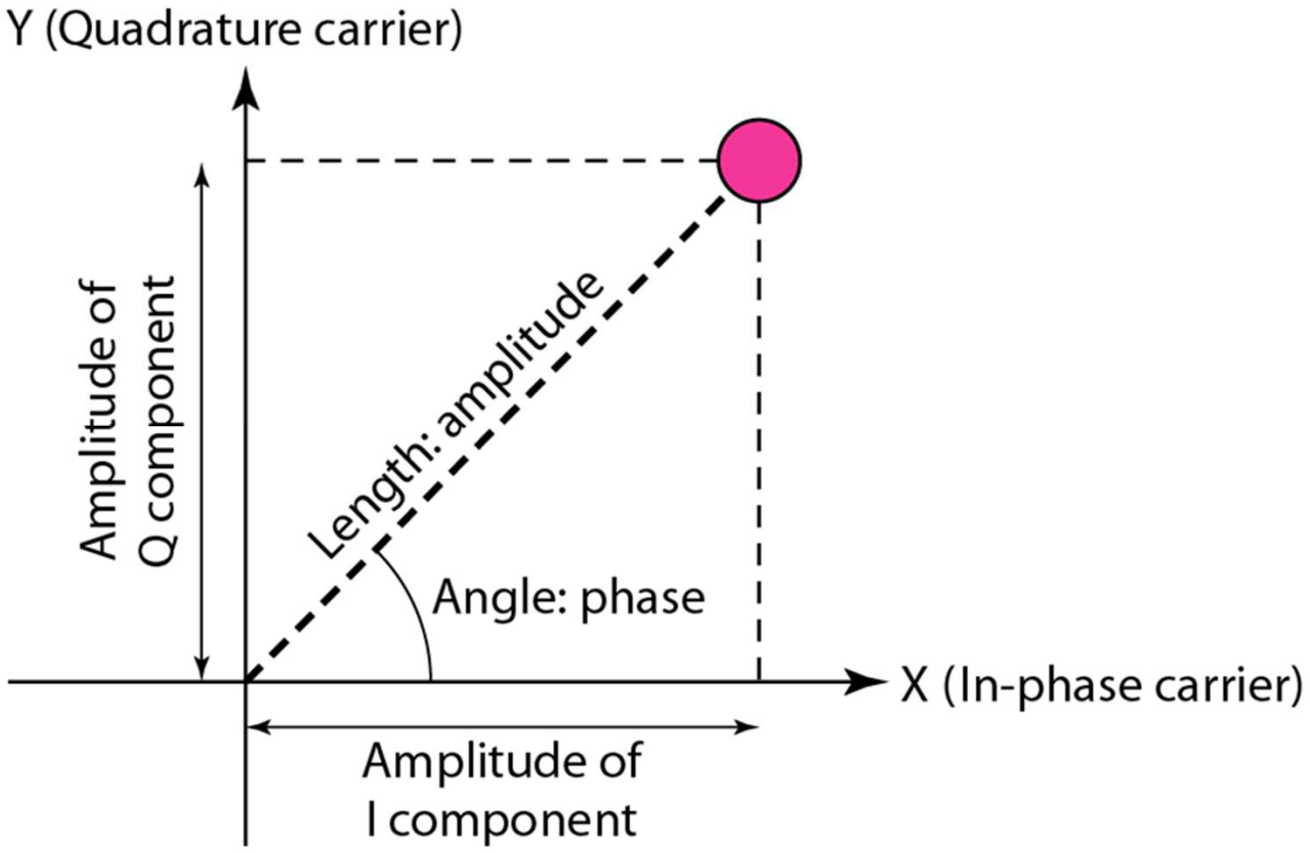
디지털을 아날로그로 바꾸는 거

초당 몇 개의 시그널 엘리먼트
12 / 2 = 6Mhz

설명:
12,000,000 bps로 전송되고 있음.
QPSK는 4개의 위상을 사용하고, 각 위상은 2개의 비트를 표현함. 즉 하나의 signal element가 2개의 비트를 표현
12,000,000 / 2 : baud rate

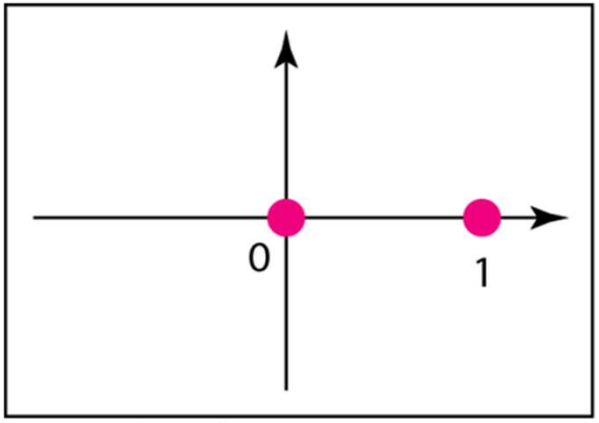
Constellation Diagram

- A diagram to represent amplitude and phase of a signal 송신자가 어떤 인코딩을 써서 데이터를 전달하는지 그림으로 표현



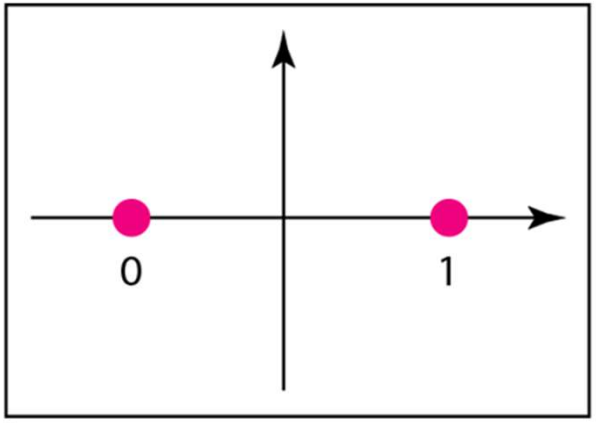
Constellation Diagram

- ASK, BPSK, QPSK



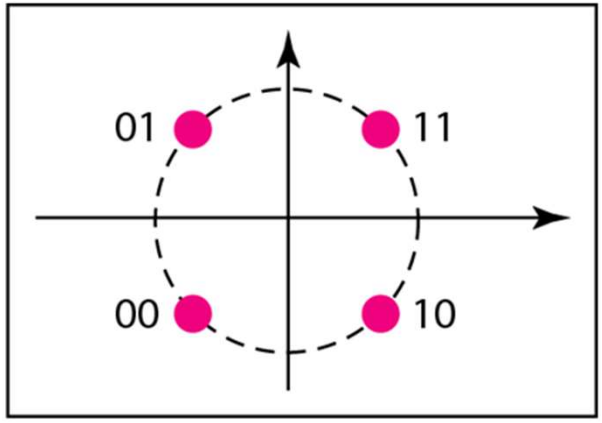
a. ASK (OOK)

0을 표현할 때는 아무것도 없음
1을 표현할 때는 0의 위상, 1의 진폭



b. BPSK

0과 1의 진폭은 같고 위상이 반대



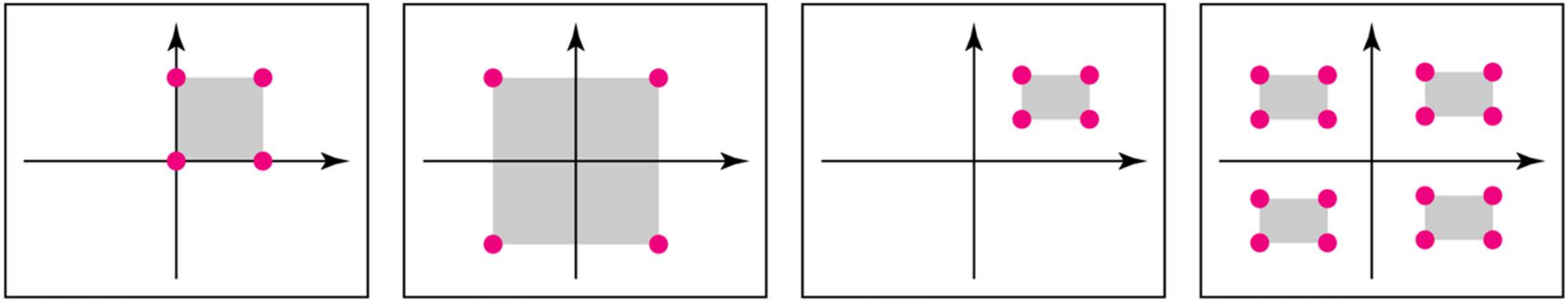
c. QPSK

Quadrature Amplitude Modulation

- QAM = QPSK + ASK
  - Use both amplitude shift and phase shift on carrier signal to encode data

QAM

- n-QAM: use **n** points on the constellation diagram
  - use n signal elements to encode $\log_2 n$ bits



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

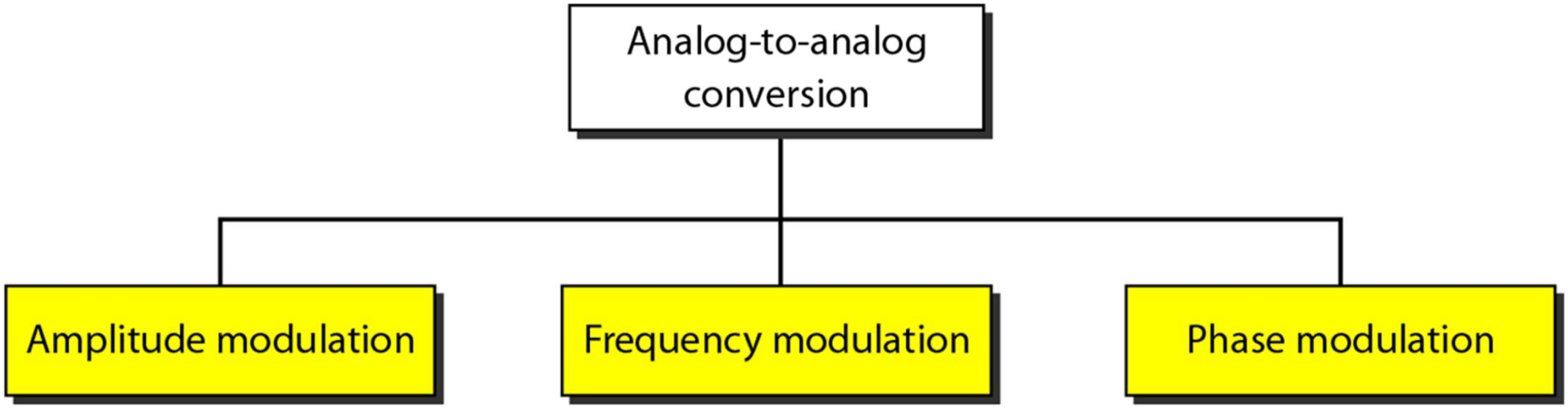
2^2 2bit 2^4 4bit

Analog-to-Analog Conversion

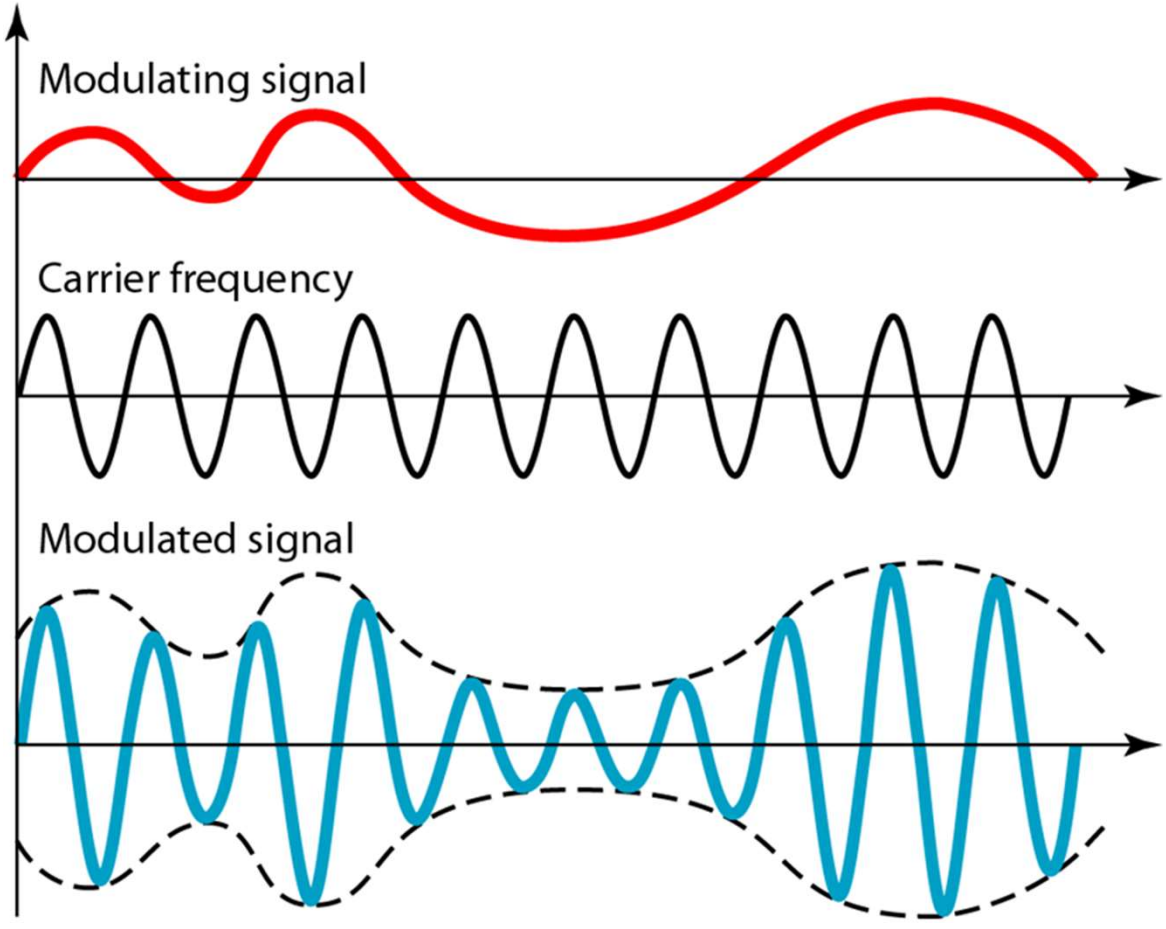
Analog-to-Analog Conversion

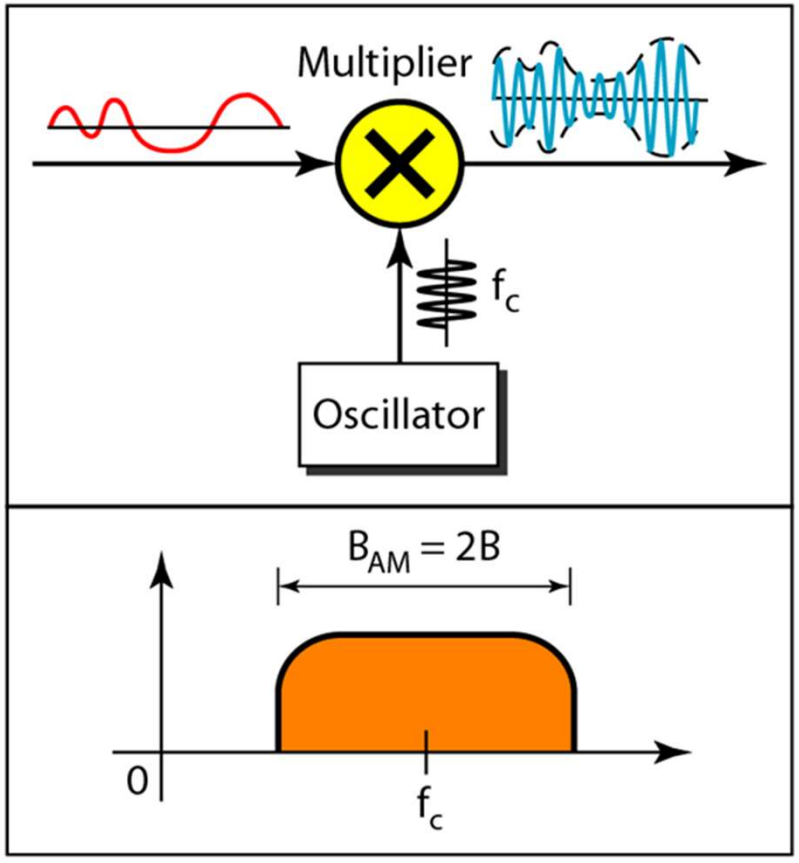
- Why convert?
  - To send analog data using carrier frequency
- Example: radio
  - Voice has a fixed frequency range (20 – 20000Hz)
  - But radio channel is on a different frequency band
    - 88 – 108 MHz
  - Thus, we need analog-to-analog conversion

Analog-to-Analog Conversion



Amplitude Modulation

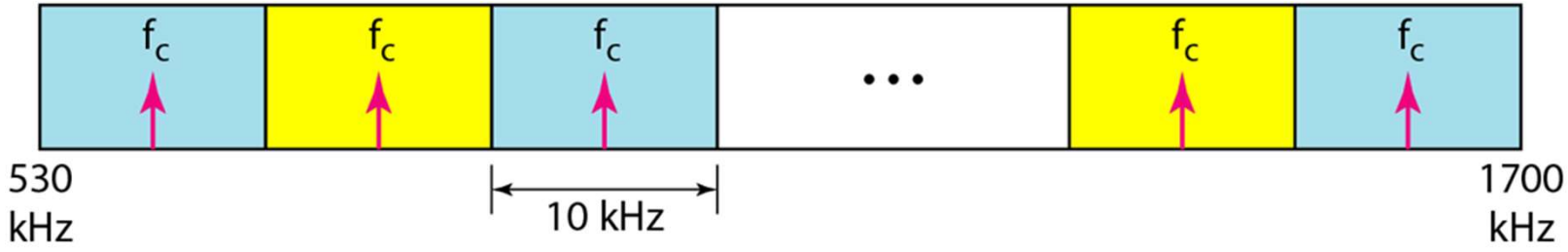




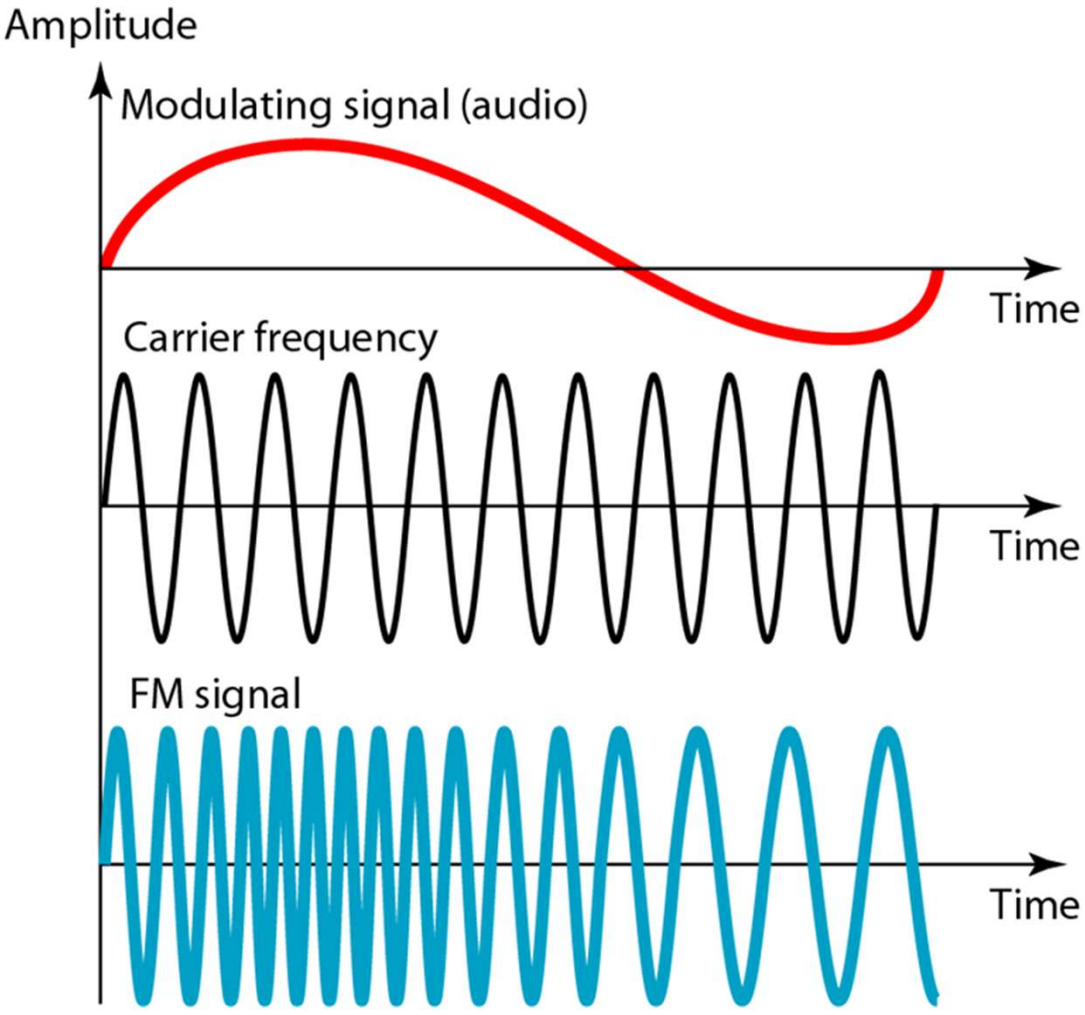
Amplitude Modulation

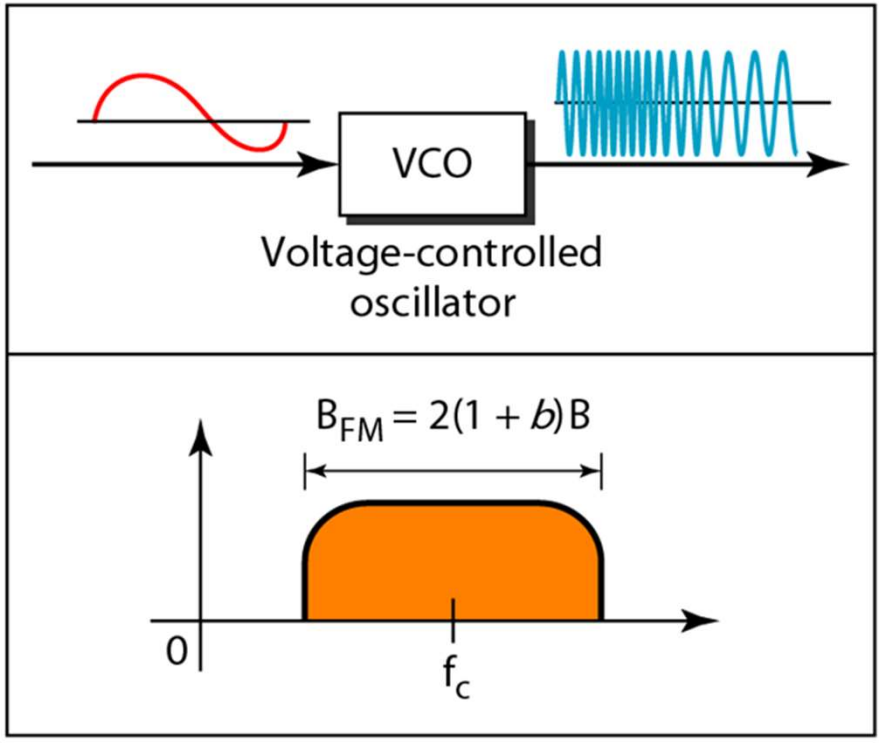
- AM Radio
  - 10kHz per channel
  - Carrier frequency: 530kHz ~ 1700kHz
  - Frequency gap between channels: at least 10kHz

방송마다 간격을 줘야 왜곡이 안일어남



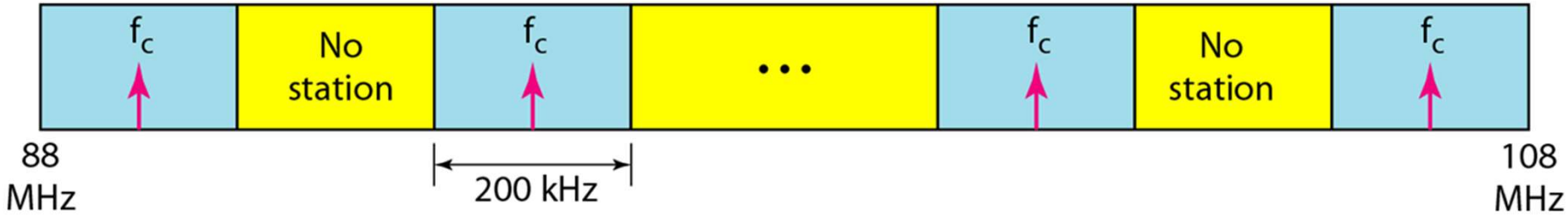
Frequency Modulation



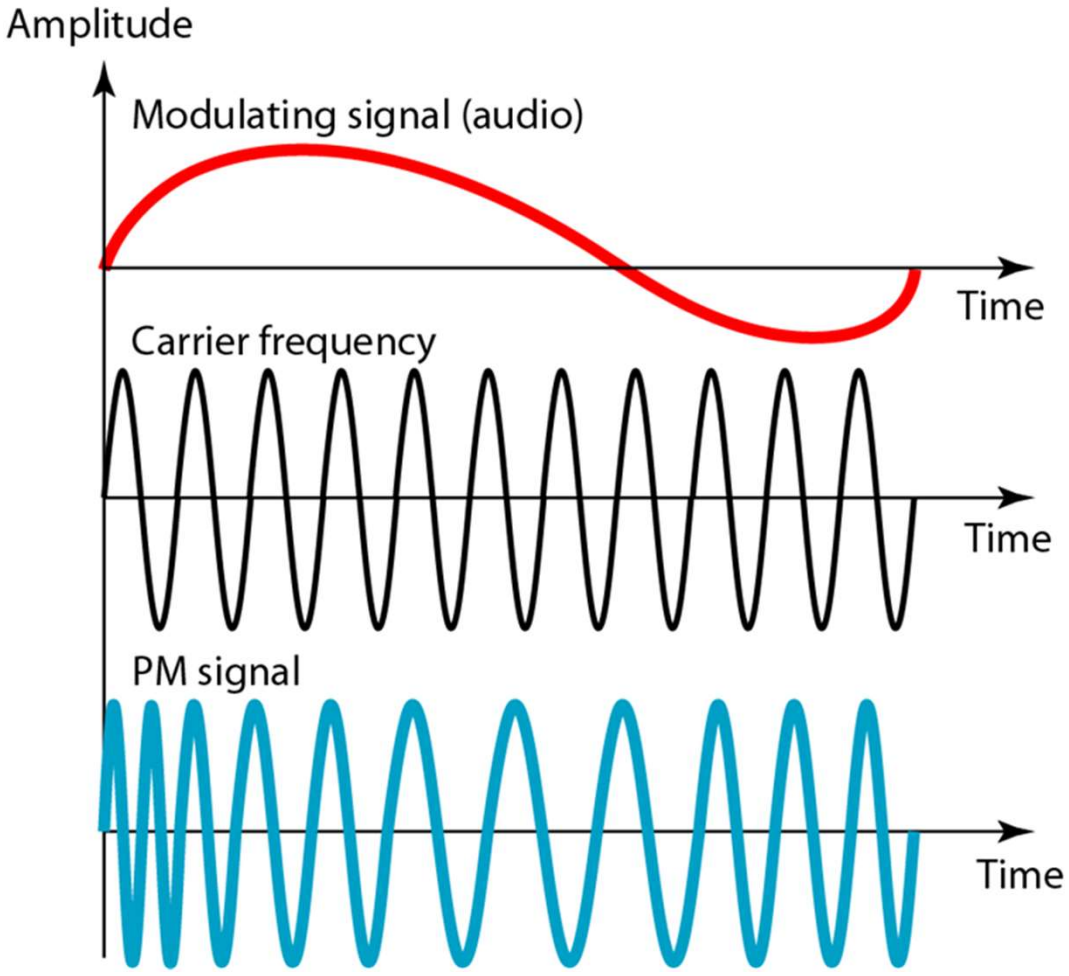


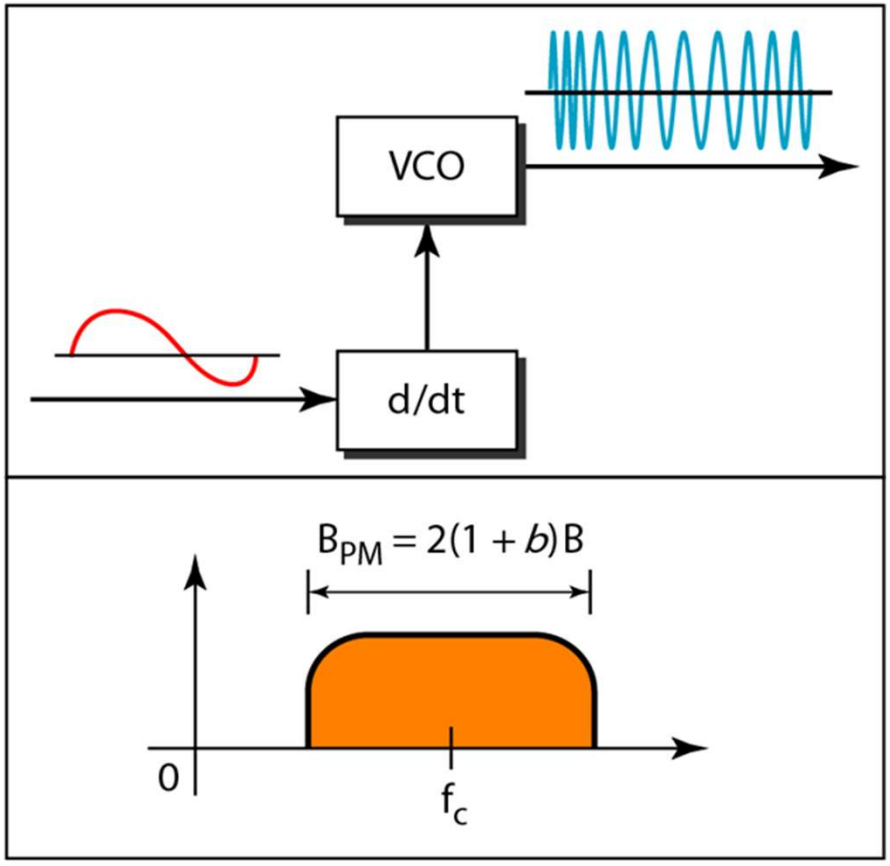
Frequency Modulation

- FM Radio
  - 200kHz per channel
  - Carrier frequency: 88MHz – 108MHz
  - Frequency gap between channels: at least 200kHz
  - In practice, channels are 400kHz apart (FCC regulation to avoid interference)



Phase Modulation





End of Chapter