Data Communications

-Analog Transmission-

Digital Data → Analog Signal
analog → analog
라디오 (AM, FM)

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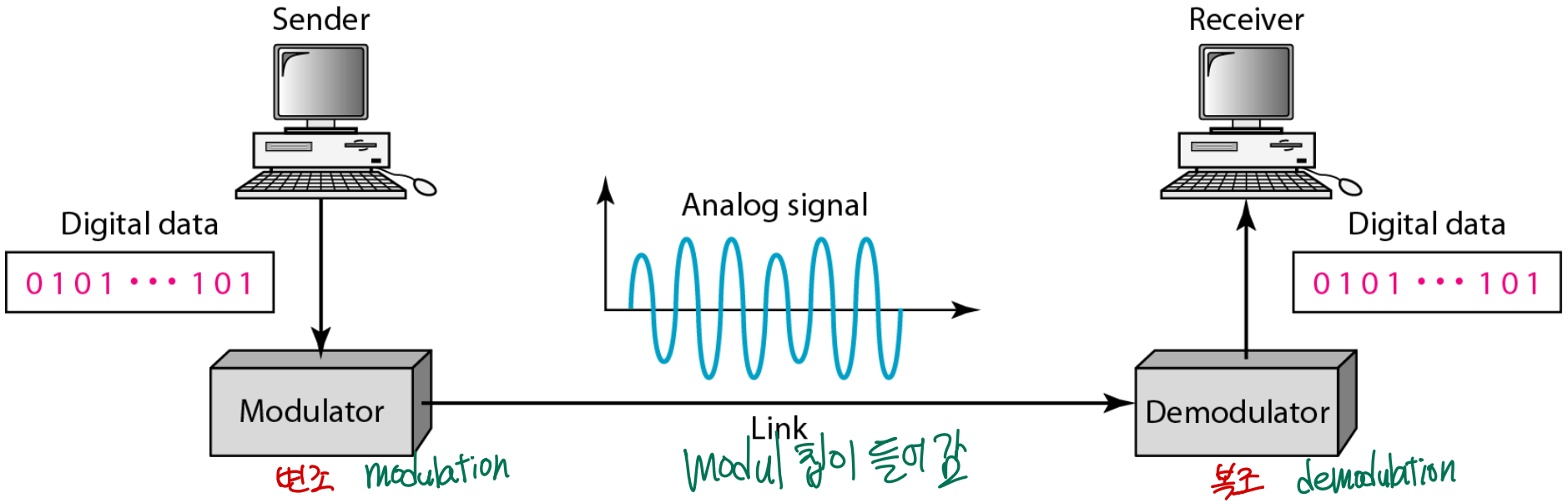
Digital Data to Analog Signal

디지털을 아날로그 신호로

- Main usage
  - PC 통신 (90년대)
  - Wireless communications
    - Wi-Fi, Zigbee (무선 통신), LTE (4G), NR (5G), etc.



Yeungnam University

Bitrate and Baud Rate

- Bit rate, N, is the number of bits per second (bps)
- Baud rate is the number of signal elements per second (bauds)
- In the analog transmission of digital data, the signal or baud rate is less than or equal to the bit rate

초당 비트 수 / 초당 발생하는 시그널 심볼 갯수 / 신호 변화의 속도 / bit rate 보다 많을 수 없다

signal baud rate < bit rate

$\text{bit rate} = \frac{\text{baud rate}}{r}$

Baud rate = bit rate × r 하나의 심볼이 보내는 데이터수

- S=Nx1/r bauds
  - Where r is the number of data bits per signal element.

초당 비트개수 × 1/r 초당 신호변화 횟수

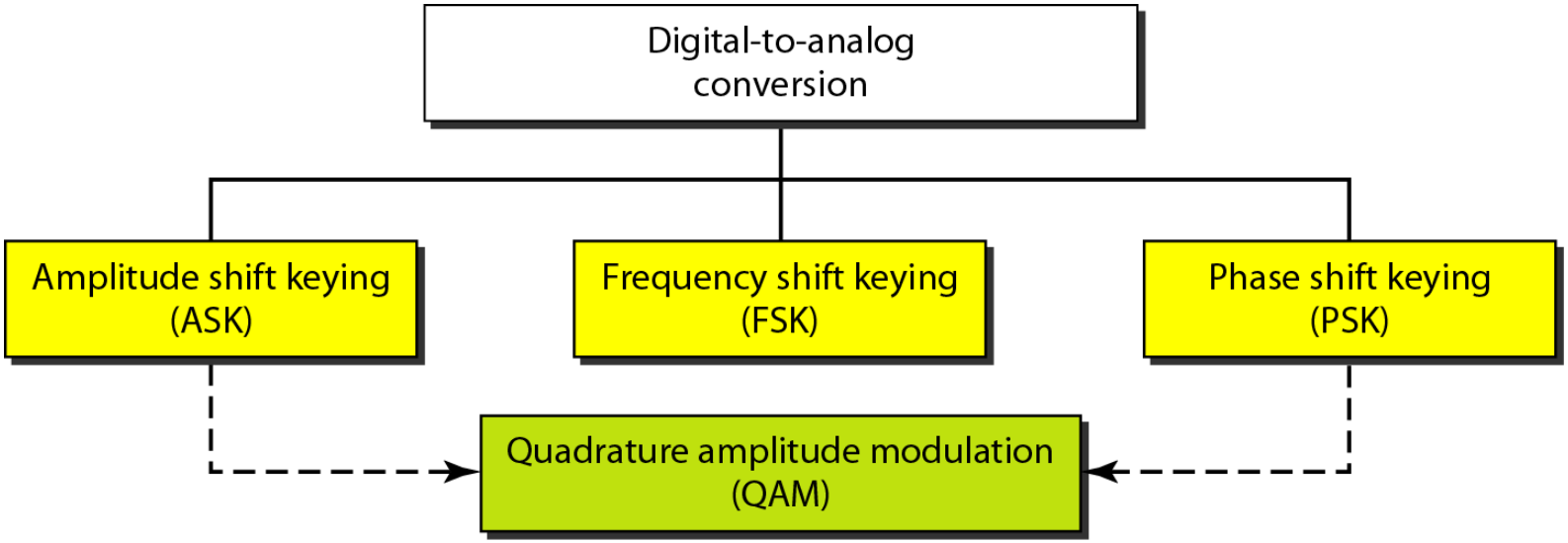
- Example
  - An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

bit rate 초당 신호수 / r 초당 시그널

$$S = N \times \frac{1}{r} \quad \text{or} \quad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$

Digital Data to Analog Signal

- Amplitude Shift Keying (ASK/OOK)
- Frequency Shift Keying (FSK)
- Phase Shift Keying (PSK)
- Quadrature Amplitude Modulation (QAM)



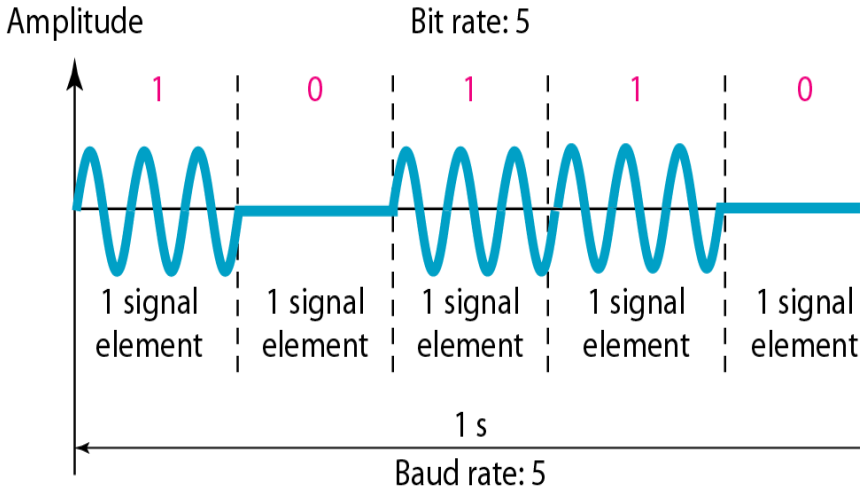
Amplitude Shift Keying (ASK) (On-off keying, OOK)

단거리

- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal

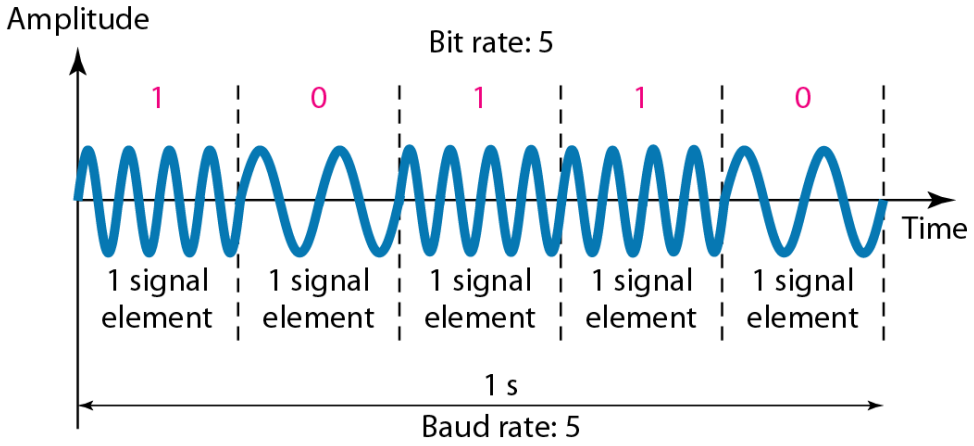
원거리의 정보를 실어 보내기 위한 신호 변조 과정

- A digital "1" could not affect the signal, whereas a digital "0" would, by making it zero



Frequency Shift Keying (FSK)

- The digital data stream changes the frequency of the carrier signal, f_c
- Example
  - a "1" could be represented by $f_1 = f_c + \Delta f$
  - a "0" could be represented by $f_2 = f_c - \Delta f$



Phase Shift Keying (PSK)

장거리

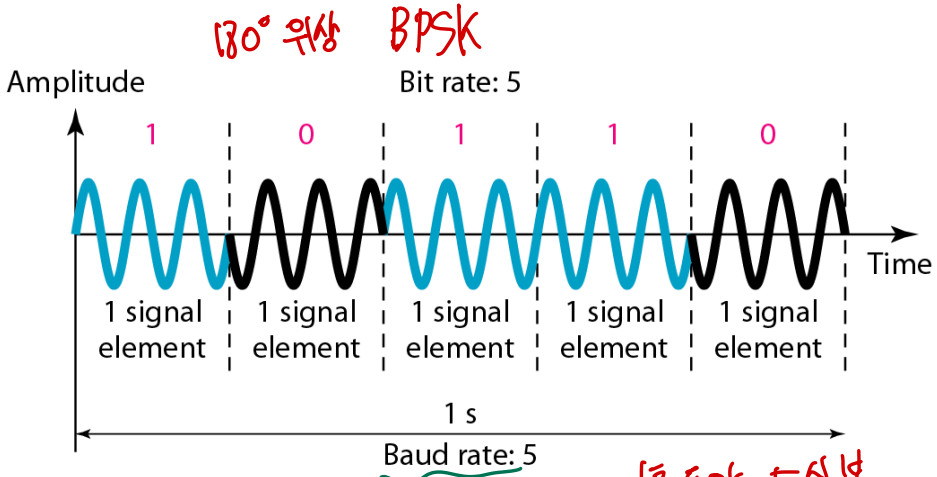
- We can vary the phase shift of the carrier signal to represent digital data

반송파 신호

- PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal

강력V

PSK > ASK 버티는 힘이 더 있다 노이즈가 더 강하다

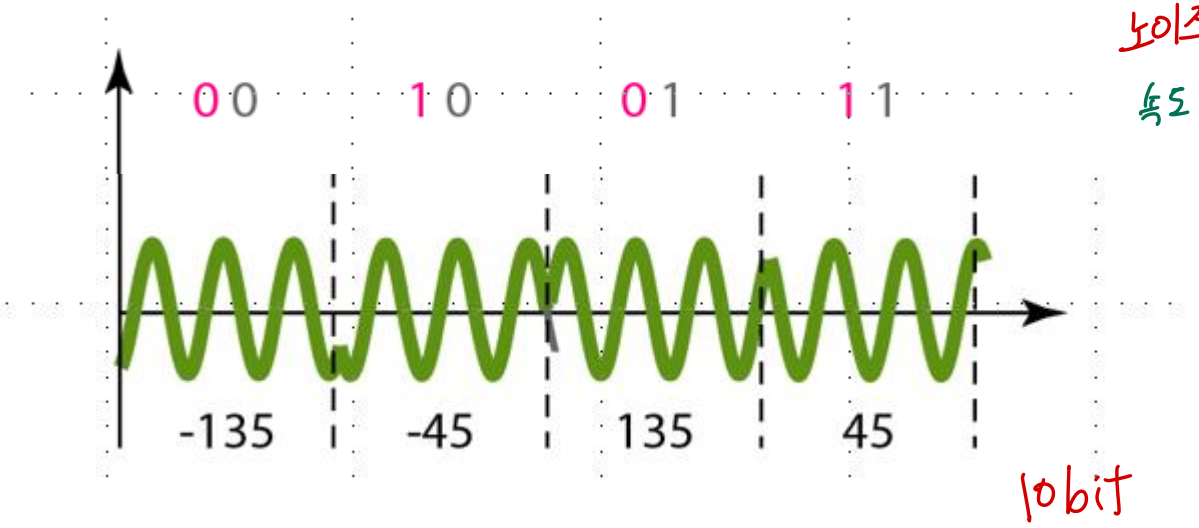


Analog ① A
② F
③ P

Quadrature PSK (QPSK)

- To increase the bit rate, we can code two or more bits onto one signal element

- One carrier frequency is phase shifted 90° from the other



Constellation Diagrams

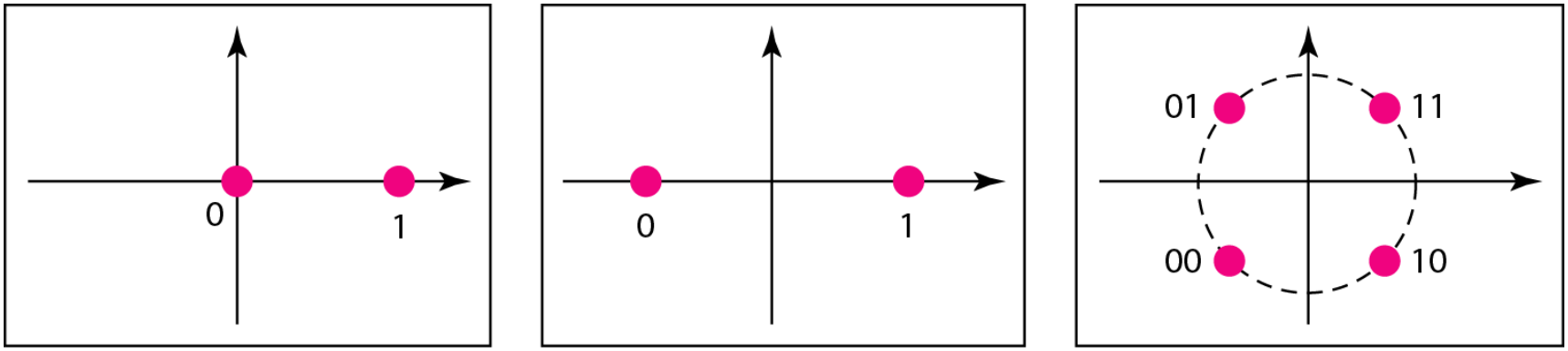
성좌도 다이어그램

- A constellation diagram helps us to define the amplitude and phase of a signal

bit error 발생 수

180°

90°



a. ASK (OOK)

Amplitude Shift Keying

b. BPSK

Binaray Phase Shift Keying

c. QPSK

< 노이즈 더 취약

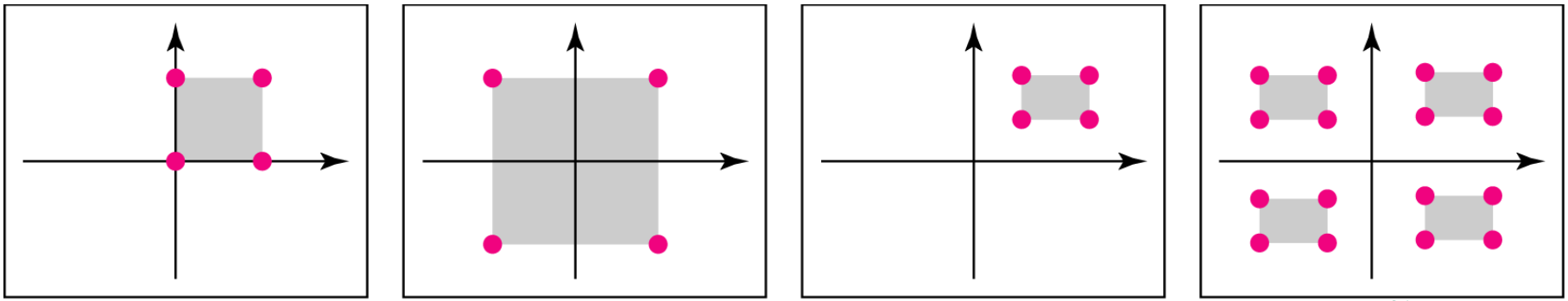
Quadrature Amplitude Modulation (QAM)

Wi-Fi 속도 향상의 핵심

직교 진폭 변조

- QAM is a combination of ASK and PSK
- Logical extension of QPSK

phase ≠ amplitude



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

= QPSK

4개

단거리

16 = 4bit

256 = 8bit

Modulation Schemes in Wi-Fi (802.11n)

안테나 개수 MIMO

MCS Index	Spatial Streams	Modulation Type	Coding Rate	Data Rate Mb/s			
				20 MHz 채널		40 MHz 채널	
				800ns GI	400ns GI	800ns GI	400ns GI
0	1	BPSK	1/2	6.50	7.20	13.50	15.00
1	1	QPSK	1/2	13.00	14.40	27.00	30.00
2	1	QPSK	3/4	19.50	21.70	40.50	45.00
3	1	16-QAM	1/2	26.00	28.90	54.00	60.00
4	1	16-QAM	3/4	39.00	43.30	81.00	90.00
5	1	64-QAM	2/3	52.00	57.80	108.00	120.00
6	1	64-QAM	3/4	58.50	65.00	121.50	135.00
7	1	64-QAM	5/6	65.00	72.20	135.00	150.00
8	2	BPSK	1/2	13.00	14.40	27.00	30.00
9	2	QPSK	1/2	26.00	28.90	54.00	60.00
10	2	QPSK	3/4	39.00	43.30	81.00	90.00
11	2	16-QAM	1/2	52.00	57.80	108.00	120.00
12	2	16-QAM	3/4	78.00	86.70	162.00	180.00
13	2	64-QAM	2/3	104.00	115.60	216.00	240.00
14	2	64-QAM	3/4	117.00	130.00	243.00	270.00
15	2	64-QAM	5/6	130.00	144.40	270.00	300.00
...	3	...	...	...	...	...	...
23	3	64-QAM	5/6	195.00	216.60	405.00	450.00
...	4	...	...	...	...	...	...
31	4	64-QAM	5/6	260.00	288.90	540.00	600.00

bit rate

느리지만 안전하게

노이즈 취약

시험X

Data rate Adaptation