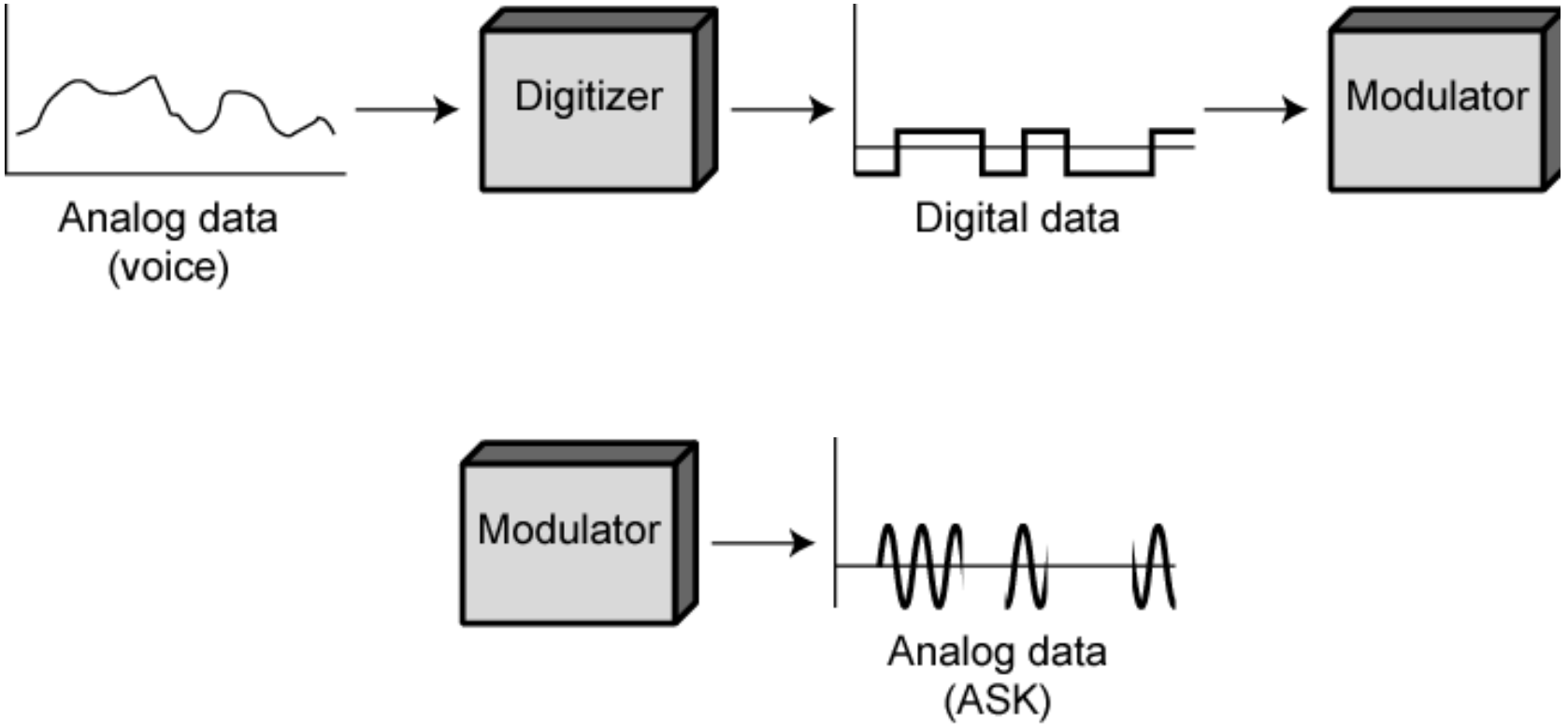
Data Communication

SİGNAL ENCODİNG TECHNİQUES

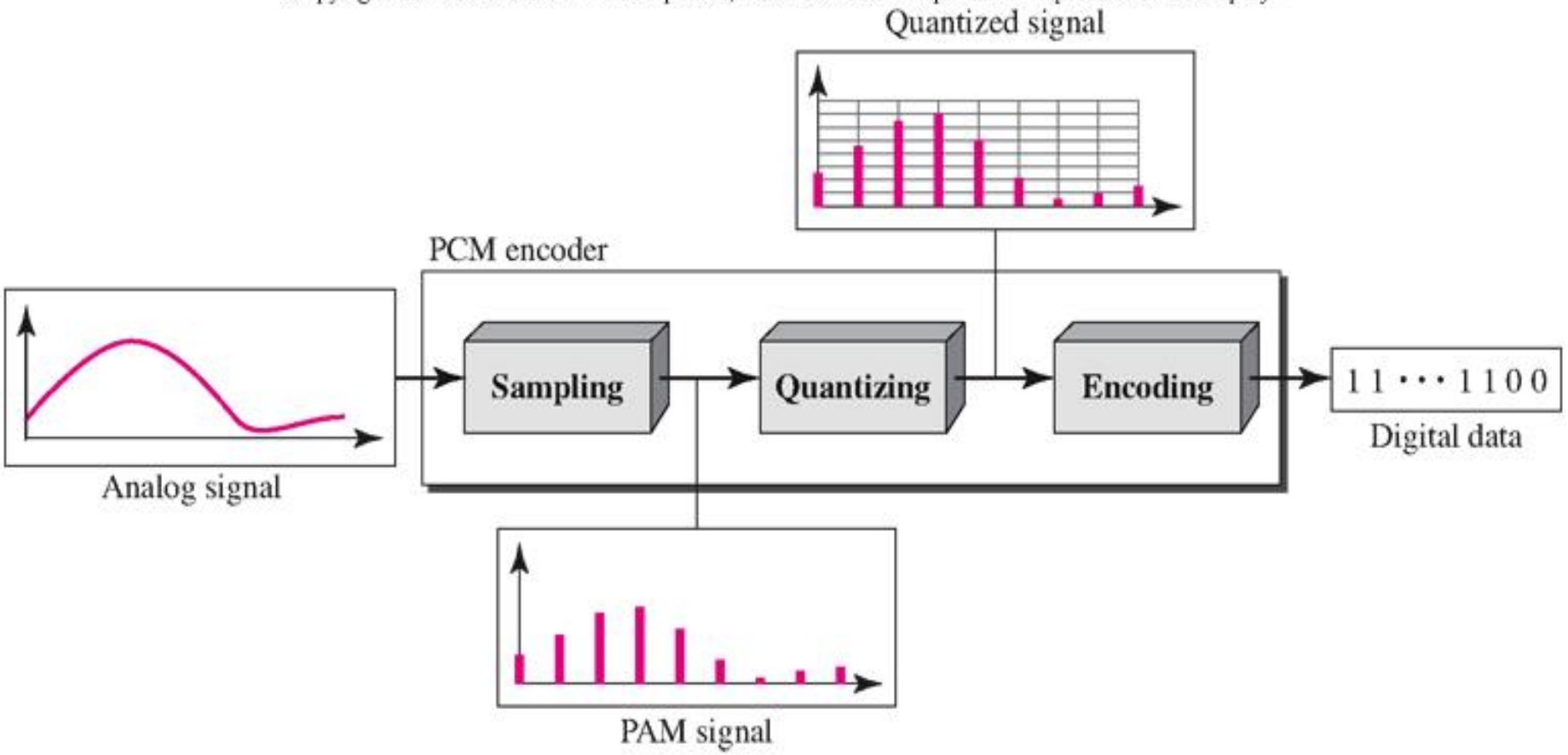
Signal Encoding Techniques

- Digital Communication
  - Digital Data, Digital Signal
  - Analog Data, Digital Signal
- Analog Communication
  - Digital Data, Analog Signal
  - Analog Data, Analog Signal

Digitizing Analog Data



Block Diagram of PCM

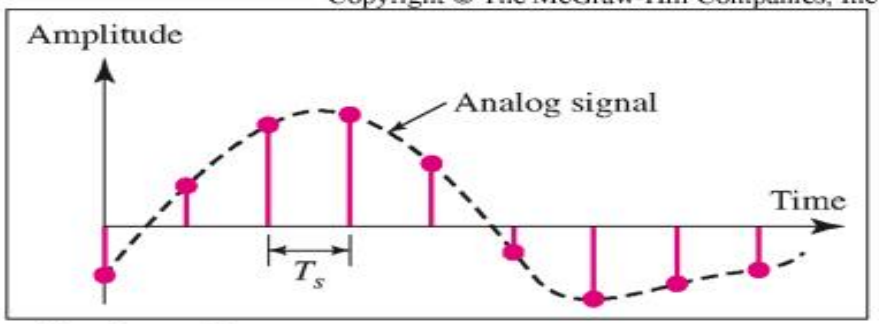


Pulse Code Modulation (PCM)

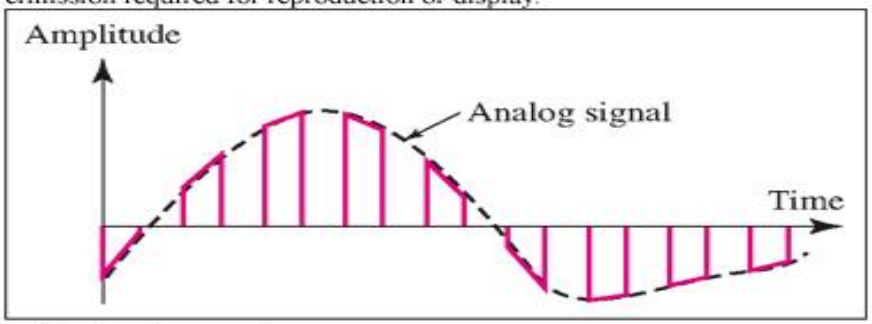
- sampling theorem:
  - "If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all information in original signal"
  - eg. 4000Hz voice data, requires 8000 sample per sec
- strictly have analog samples
  - Pulse Amplitude Modulation (PAM)
- so assign each a digital value

Sampling

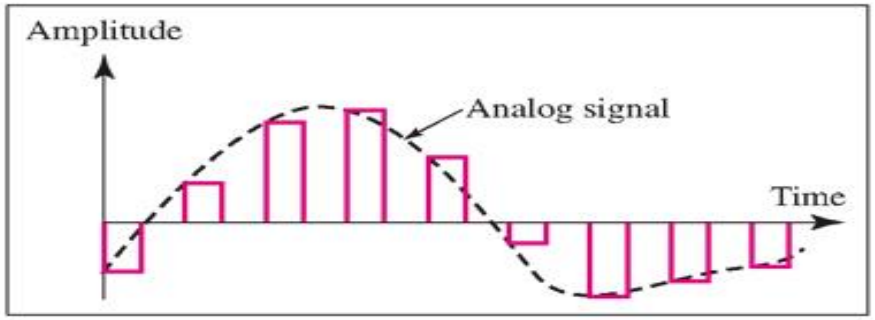
- First stage of PCM
- Take a sample for each T_s period. And also this taken sample has a digital value
- Three types of sampling



a. Ideal sampling



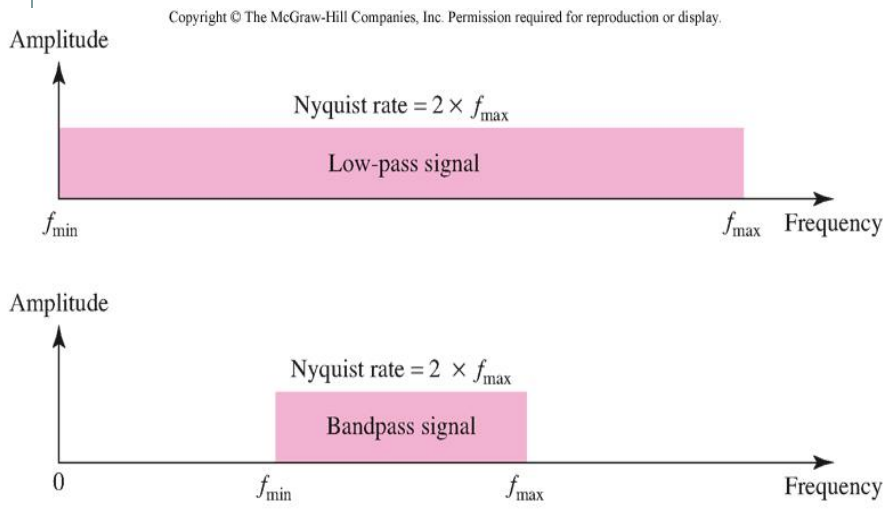
b. Natural sampling

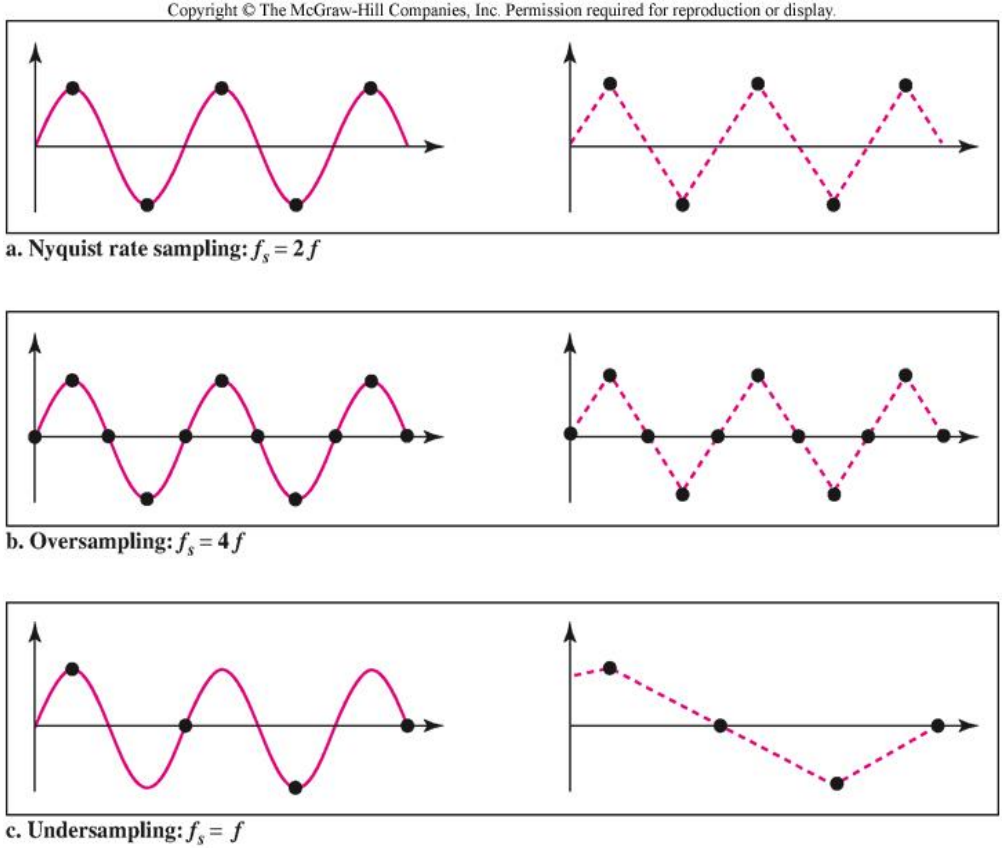


c. Flat-top sampling

Sampling – Nyquist Teorem

- If a signal is sampled with the twiced frequency of maximum frequency of signal, the samples hold all of the data.





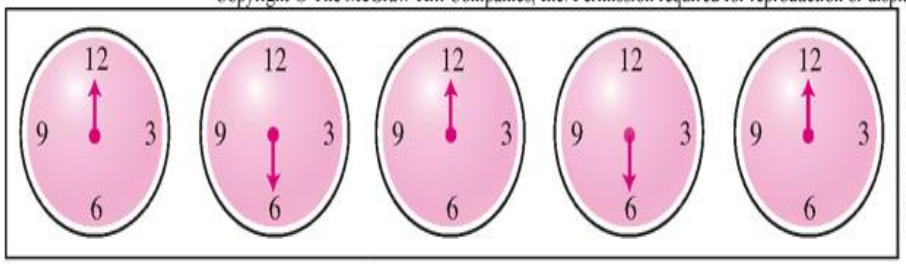
a. Nyquist rate sampling: $f_s = 2f$

b. Oversampling: $f_s = 4f$

c. Undersampling: $f_s = f$

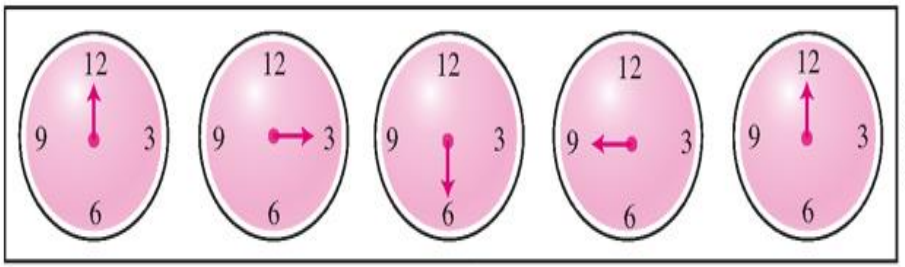
Sampling Rate

- Let's digitize human voice. What is the bitrate if we encode each sample with 8 bit?
- Ans: Human voice has a frequency of 0-4000 Hz (for telephone line)
  - Sampling rate:
  - 4000 x 2 = 8000 sample/sec
  - Bitrate = sampling rate x encoding bit numbers per sample = 8000 x 8 = 64000 bps = 64 kbps



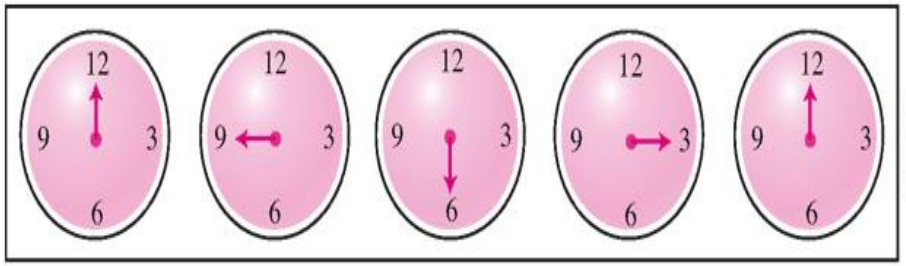
Samples can mean that the clock is moving either forward or backward. (12-6-12-6-12)

a. Sampling at Nyquist rate: $T_s = \frac{1}{2}T$



Samples show clock is moving forward. (12-3-6-9-12)

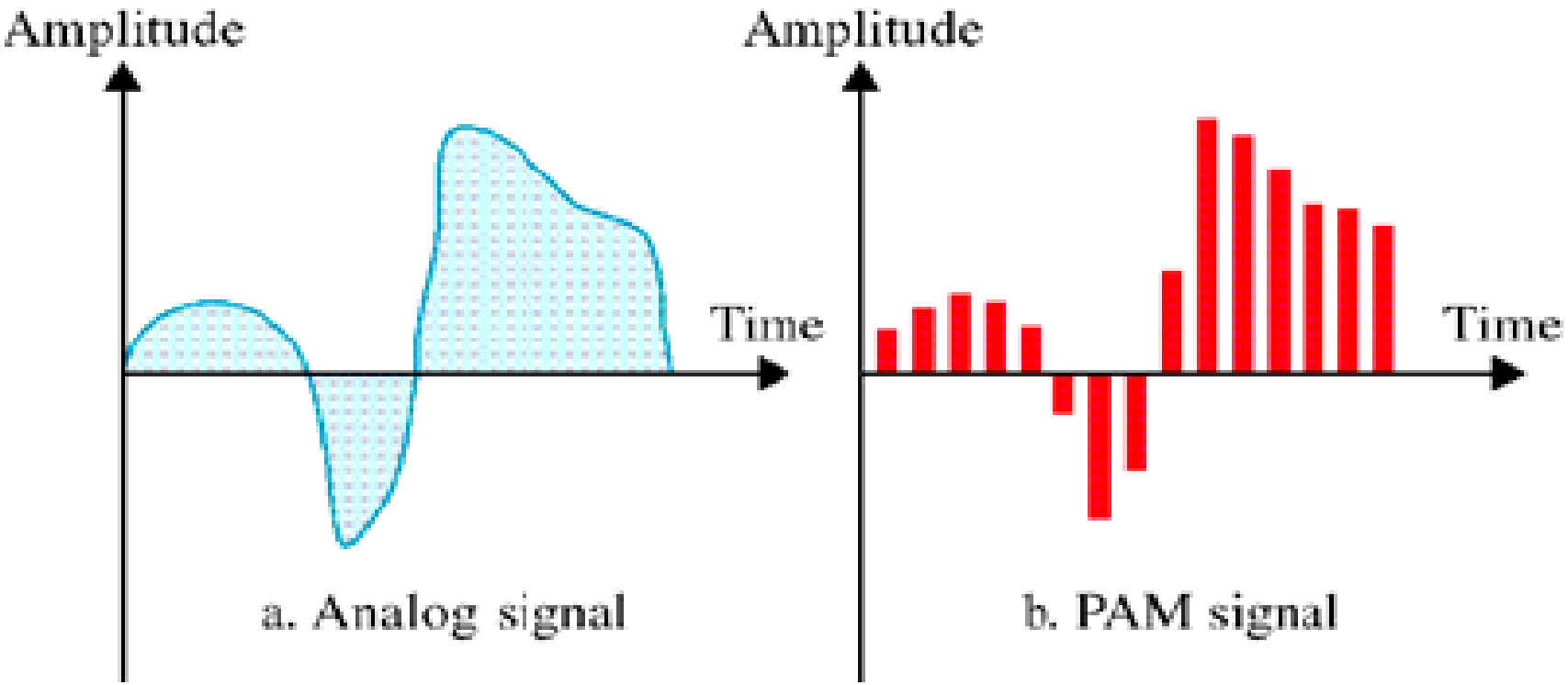
b. Oversampling (above Nyquist rate): $T_s = \frac{1}{4}T$



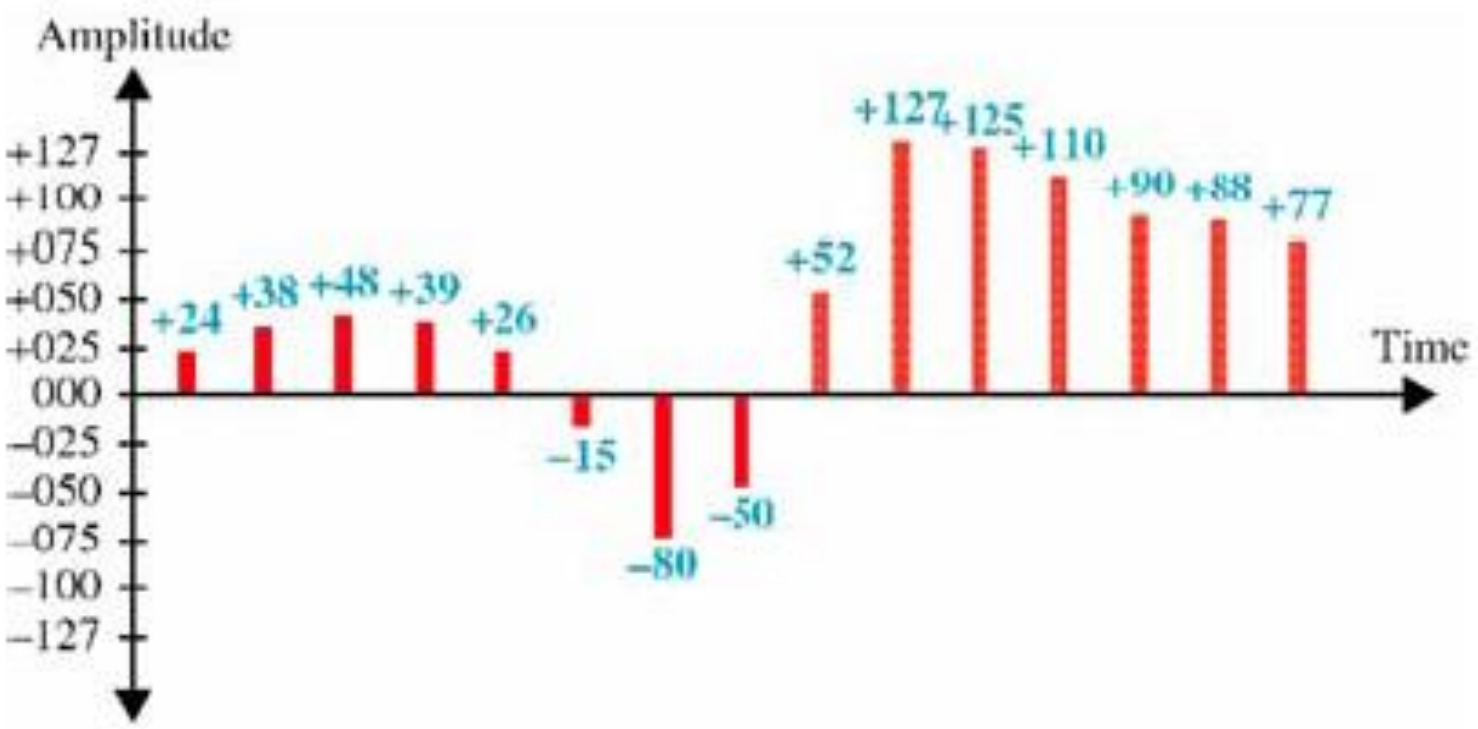
Samples show clock is moving backward. (12-9-6-3-12)

c. Undersampling (below Nyquist rate): $T_s = \frac{3}{4}T$

Quantizing



Quantized Signal

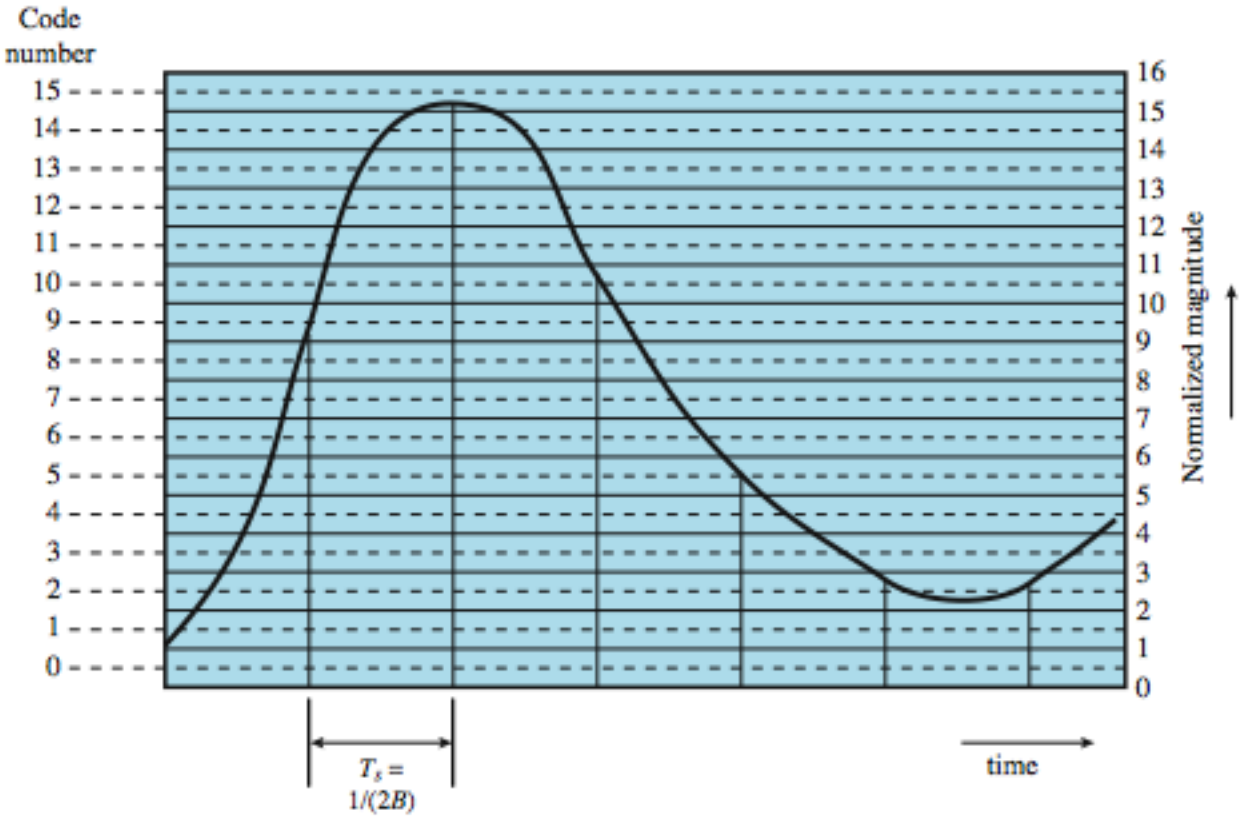


Encoding

+024	00011000	−015	10001111	+125	01111101
+038	00100110	−080	11010000	+110	01101110
+048	00110000	−050	10110010	+090	01011010
+039	00100111	+052	00110110	+088	01011000
+026	00011010	+127	01111111	+077	01001101

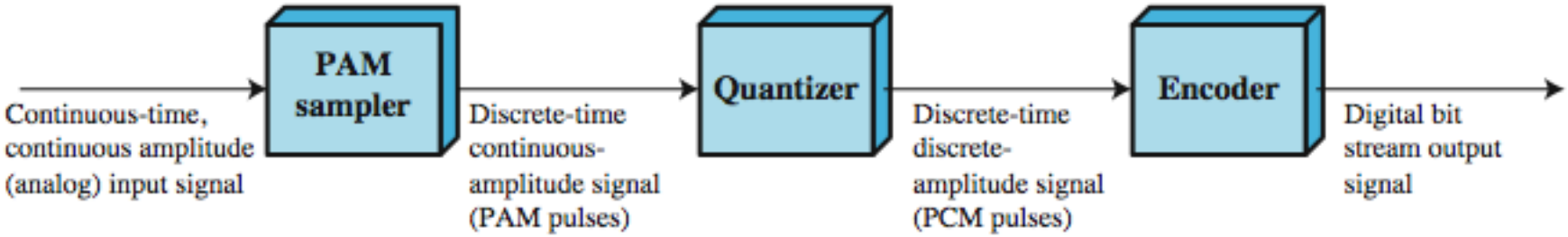
Sign bit
+ is 0 − is 1

PCM Example

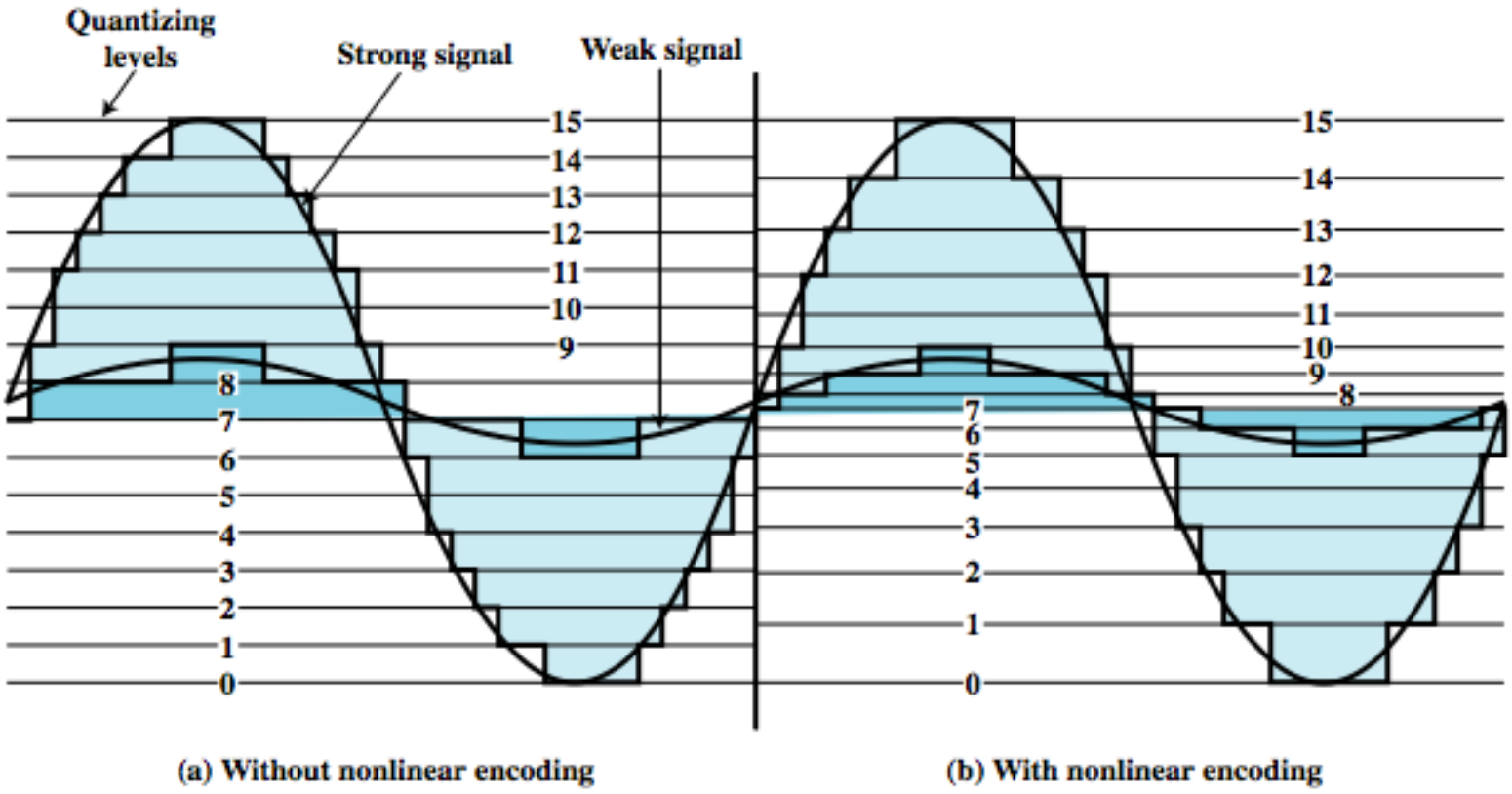


PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

PCM Block Diagram



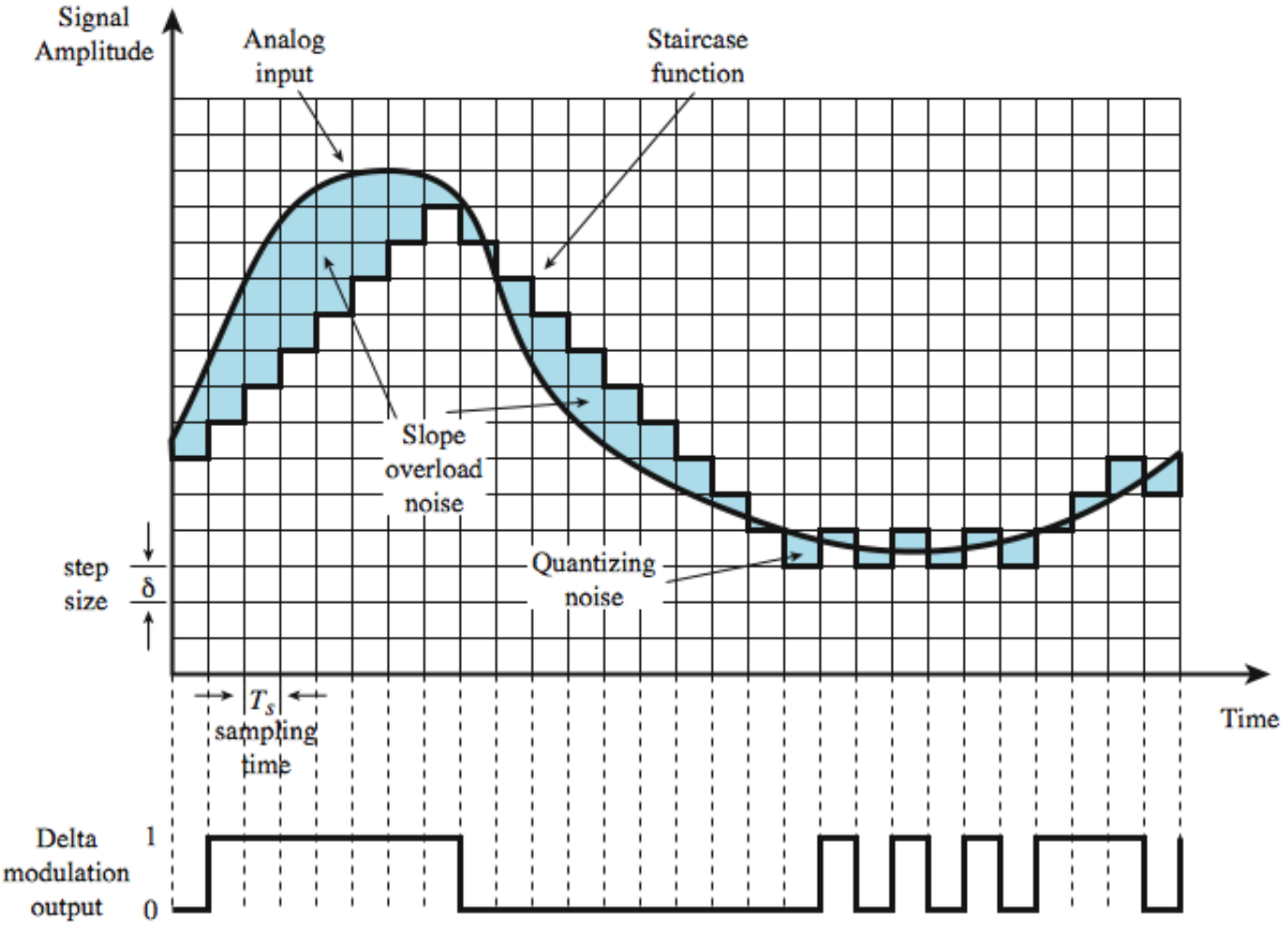
Non-Linear Coding



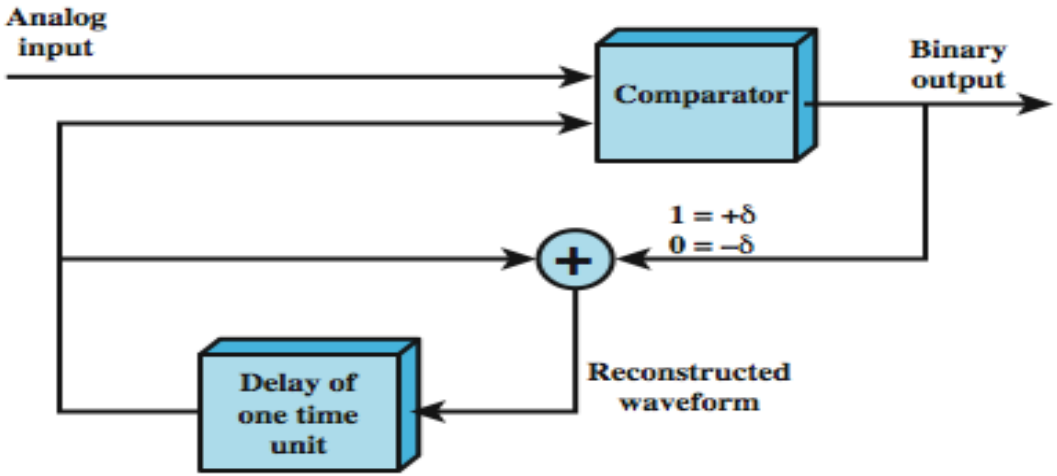
Delta Modulation

- analog input is approximated by a staircase function
  - can move up or down one level (δ) at each sample interval
- has binary behavior
  - since function only moves up or down at each sample interval
  - hence can encode each sample as single bit
  - 1 for up or 0 for down

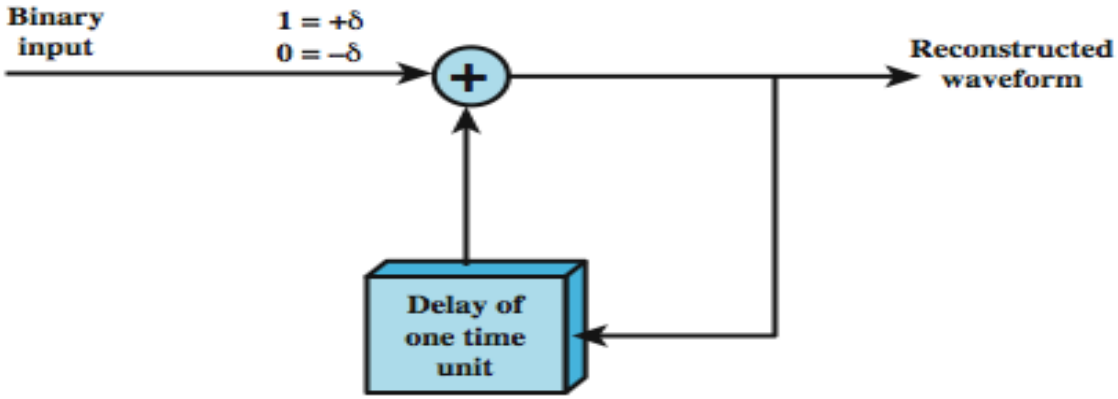
Delta Modulation Example



Delta Modulation Operation



(a) Transmission



(b) Reception

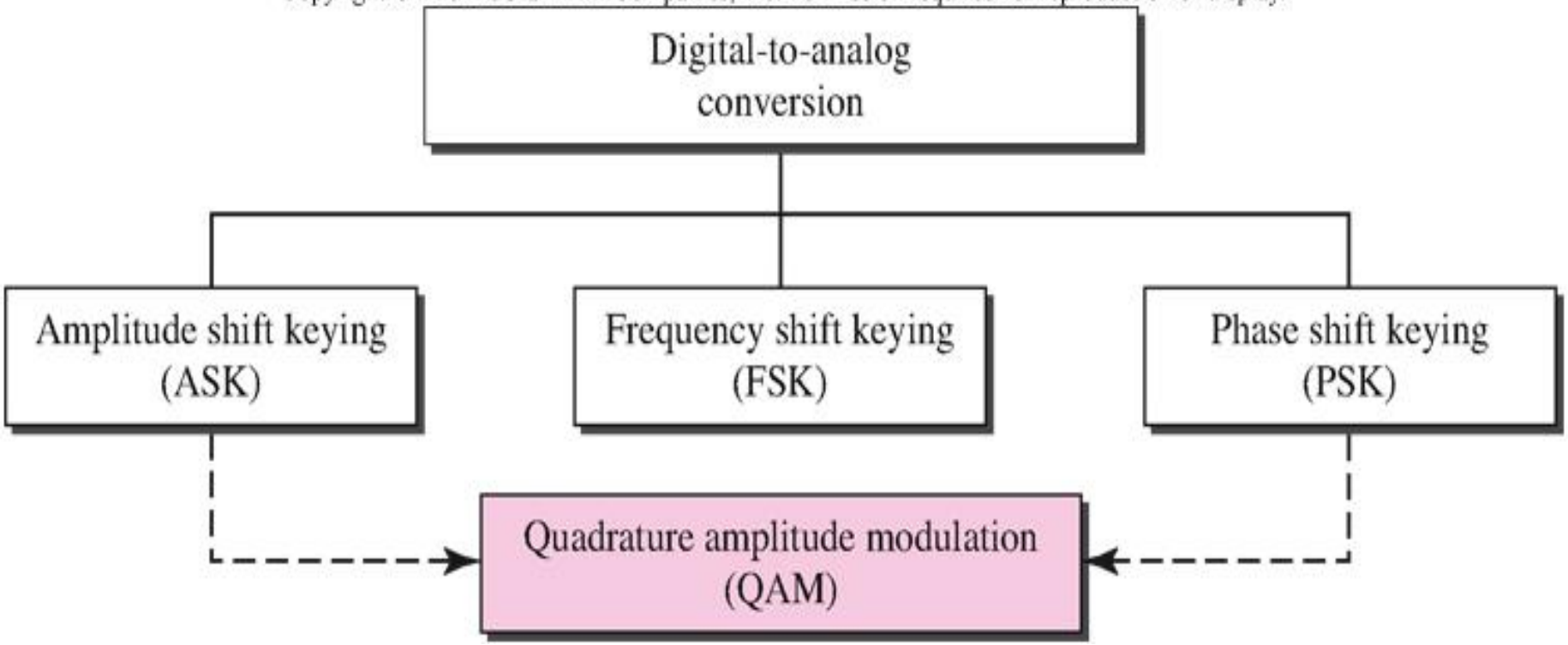
PCM verses Delta Modulation

- DM has simplicity compared to PCM
- but has worse SNR
- issue of bandwidth used
  - eg. for good voice reproduction with PCM
    - want 128 levels (7 bit) & voice bandwidth 4khz
    - need 8000 x 7 = 56kbps
- data compression can improve on this
- still growing demand for digital signals
  - use of repeaters, TDM, efficient switching
- PCM preferred to DM for analog signals

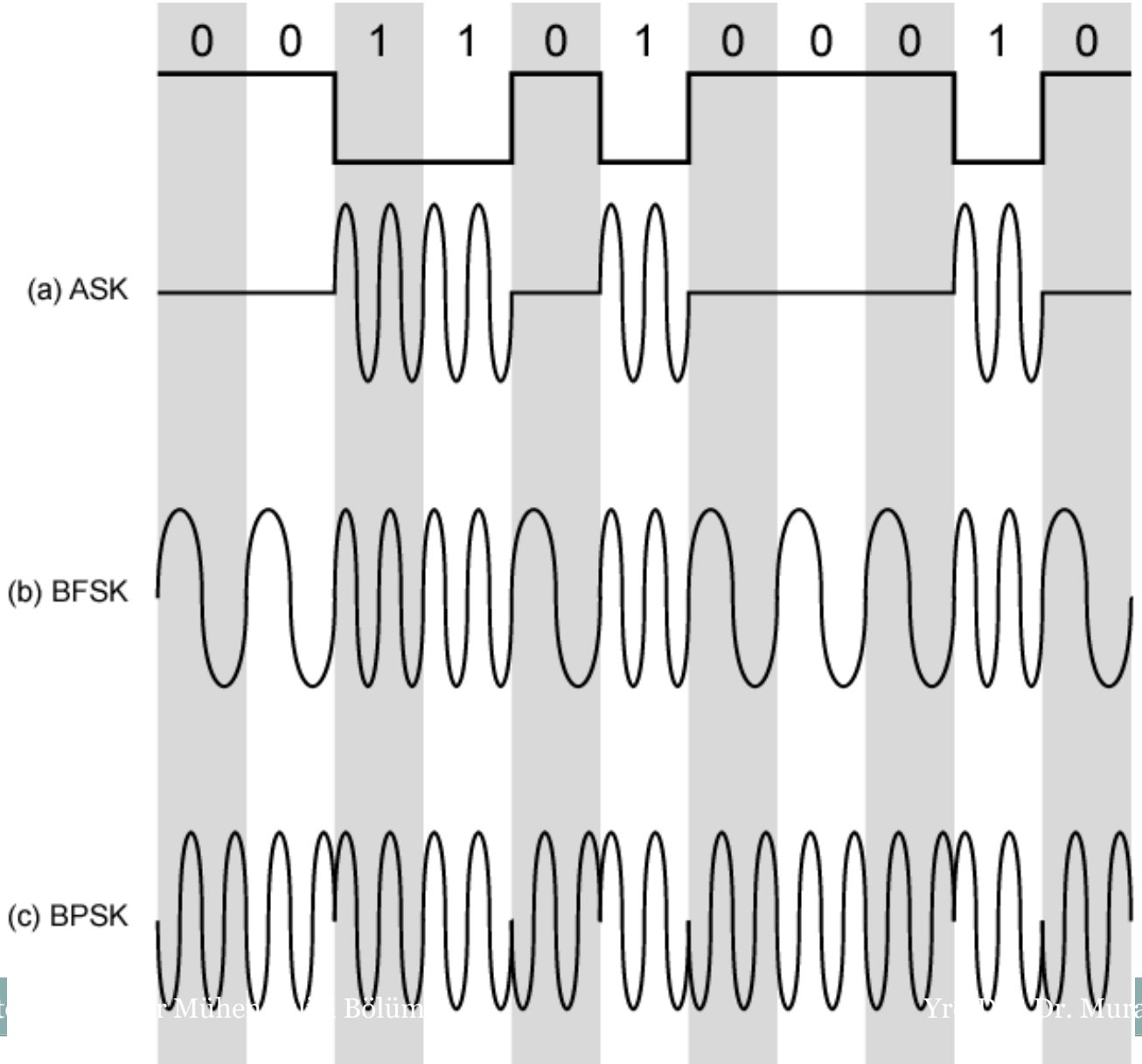
Analog Transmission

- Digital Data, Analog Signal
- main use is public telephone system
  - has freq range of 300Hz to 3400Hz
  - use modem (modulator-demodulator)
- encoding techniques
  - Amplitude shift keying (ASK)
  - Frequency shift keying (FSK)
  - Phase shift keying (PSK)

Types of Modulations

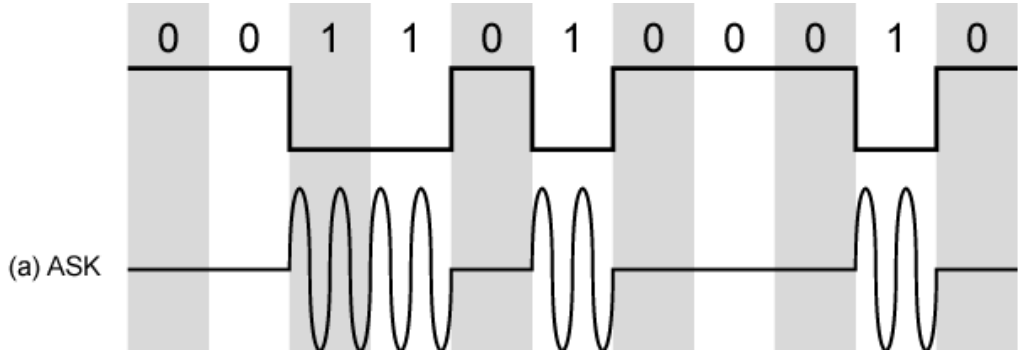


Modulation Techniques

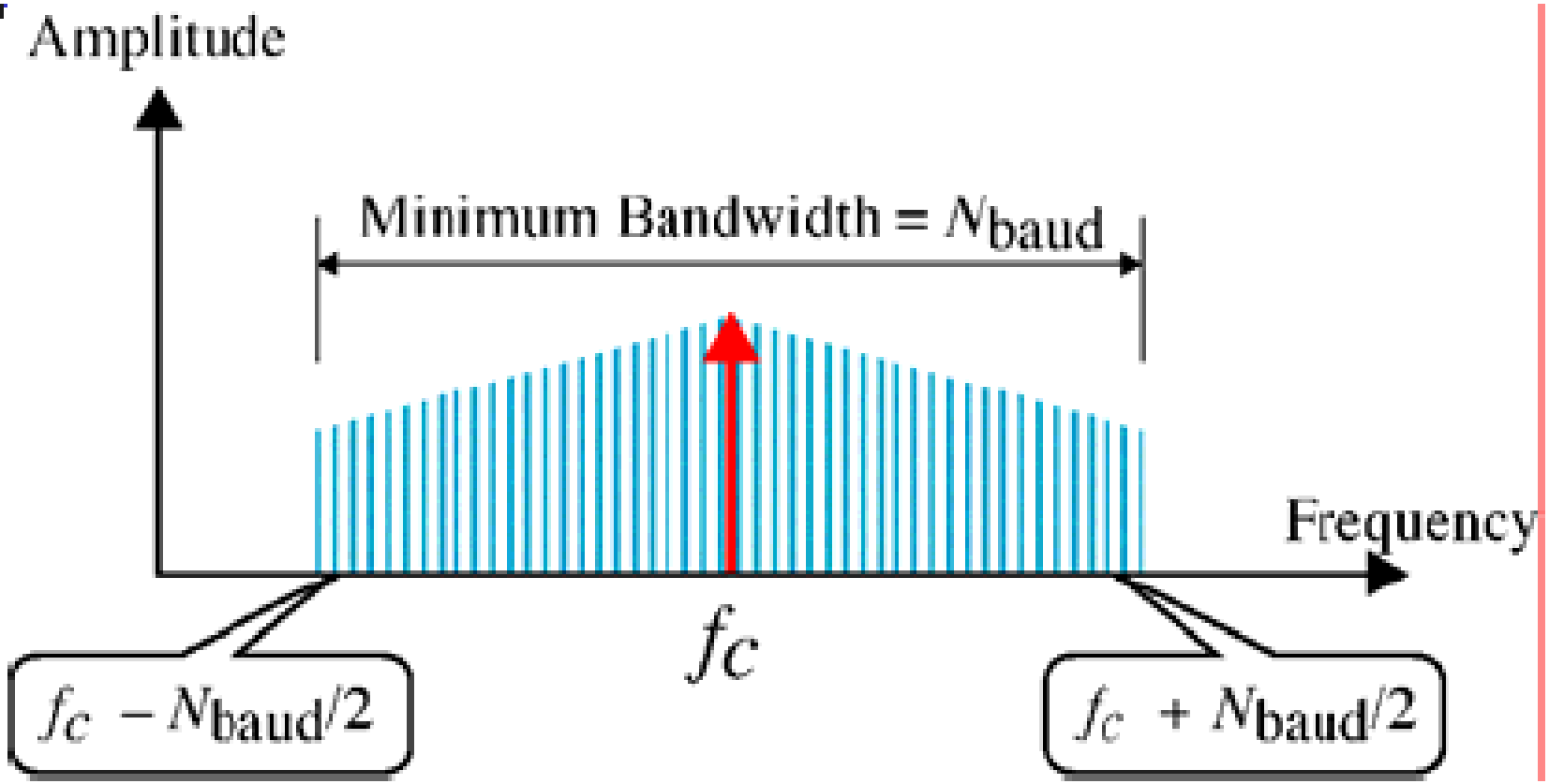


Amplitude Shift Keying

- encode 0/1 by different carrier amplitudes
  - usually have one amplitude zero
- susceptible to sudden gain changes
- inefficient
- used for
  - up to 1200bps on voice grade lines
  - very high speeds over optical fiber



Bandwidth for ASK



ASK Example

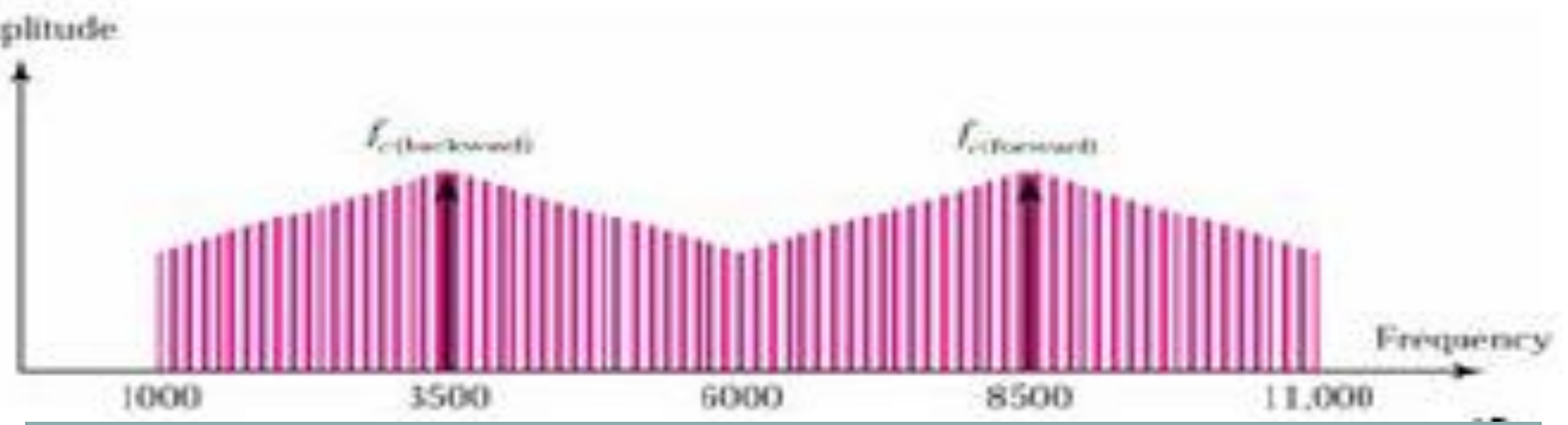
- For an ASK signal that has a 2000 bps transfer speed, what is the minimum bandwidth?

- Baudrate=Bitrate (for ASK)
- So minimum BW=2000 Hz

ASK Example-2

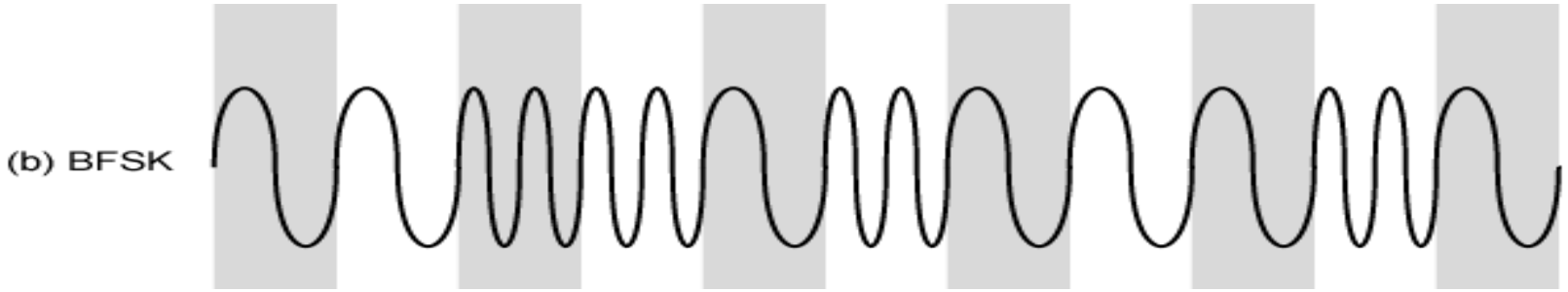
- For a 10000 Hz bandwidth (between 1000 Hz and 11000 Hz) draw the full-dublex ASK diagram. Find the carrier and bandwidth at both of two sides. Suppose that there is no gap.

- For full-dublex BW=10000/2 = 5000 Hz
- Carrier frequencies are at the center of each band, so
- fc (forward) =1000+5000/2 =3500 Hz
- fc (backward)= 11000-5000/2=8500 Hz



Binary Frequency Shift Keying

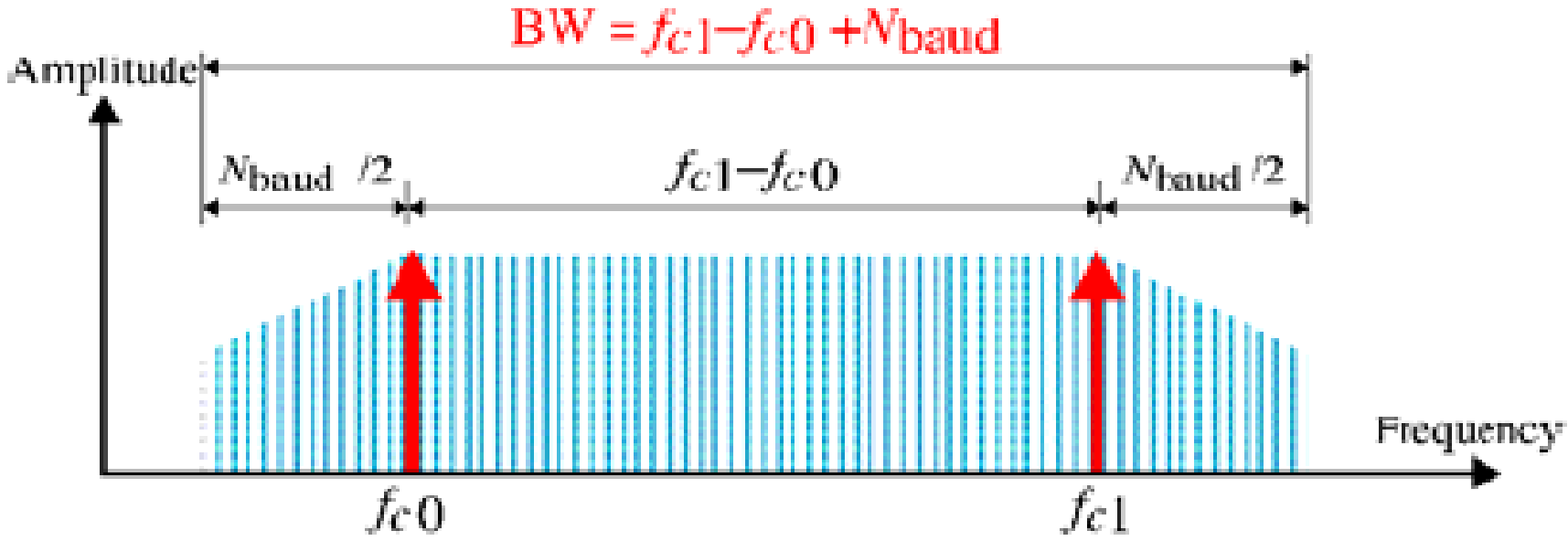
- most common is binary FSK (BFSK)
- two binary values represented by two different frequencies (near carrier)
- less susceptible to error than ASK
- used for
  - up to 1200bps on voice grade lines
  - high frequency radio
  - even higher frequency on LANs using co-ax



FSK Example

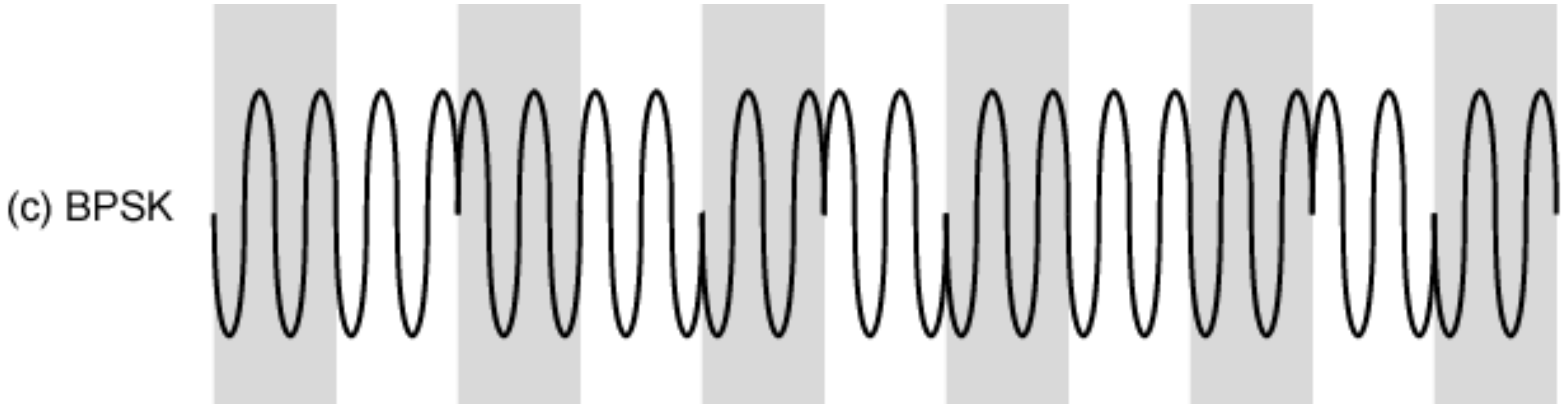
- For a FSK signal that transfer data at 1000 bps, what is the minimum bandwidth? Suppose that communication is half-dublex and carriers are seperated with 2000 Hz.

- BW=baudrate +fc1-fc0
- BW= bitrate+fc1-fc0= 1000+2000
- BW=3000 Hz



Phase Shift Keying

- phase of carrier signal is shifted to represent data
- binary PSK
  - two phases represent two binary digits
- differential PSK
  - phase shifted relative to previous transmission rather than some reference signal

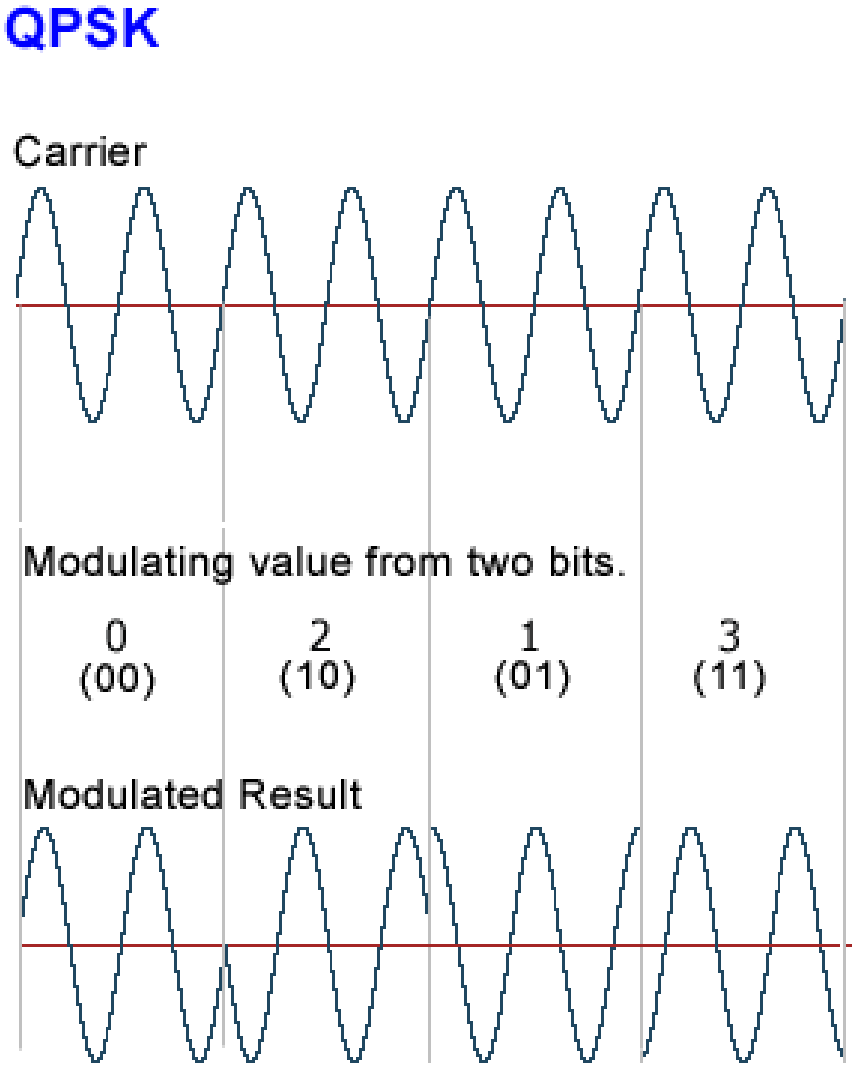


Quadrature PSK

- get more efficient use if each signal element represents more than one bit
  - eg. shifts of $\pi/2$ (90^0)
  - each element represents two bits
  - split input data stream in two & modulate onto carrier & phase shifted carrier
- can use 8 phase angles & more than one amplitude
  - 9600bps modem uses 12 angles, four of which have two amplitudes

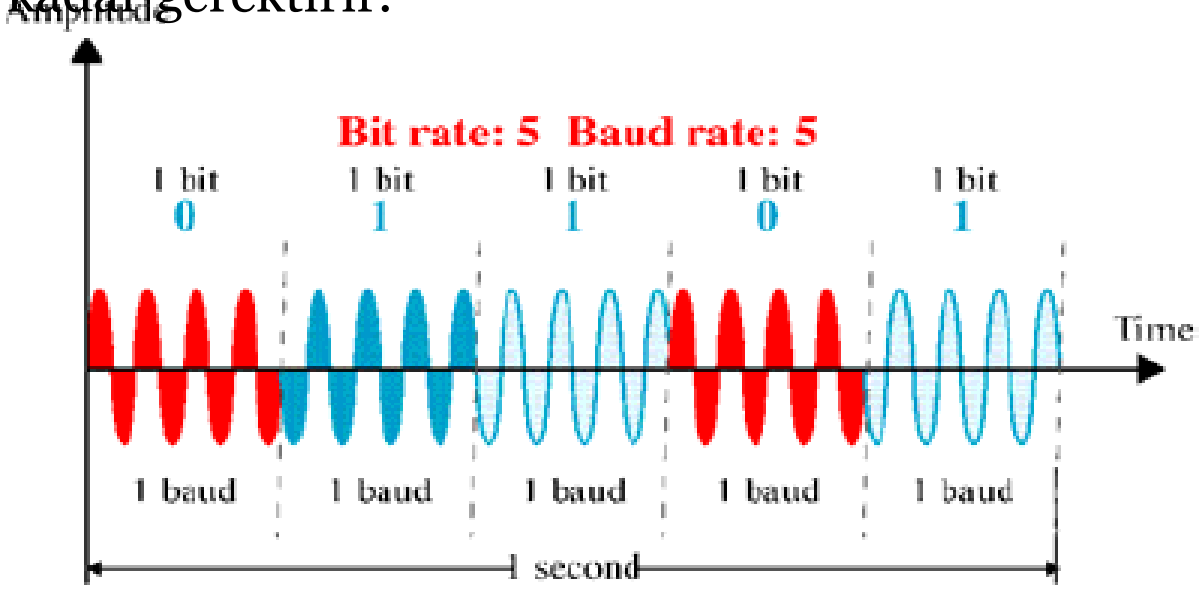
QPSK

- Quadrature PSK (QPSK) is like 4QAM without amplitude modulation. QPSK uses four phase angles to represent each two bits of input; however, the amplitude remains constant.



PSK – Phase Shift Keying

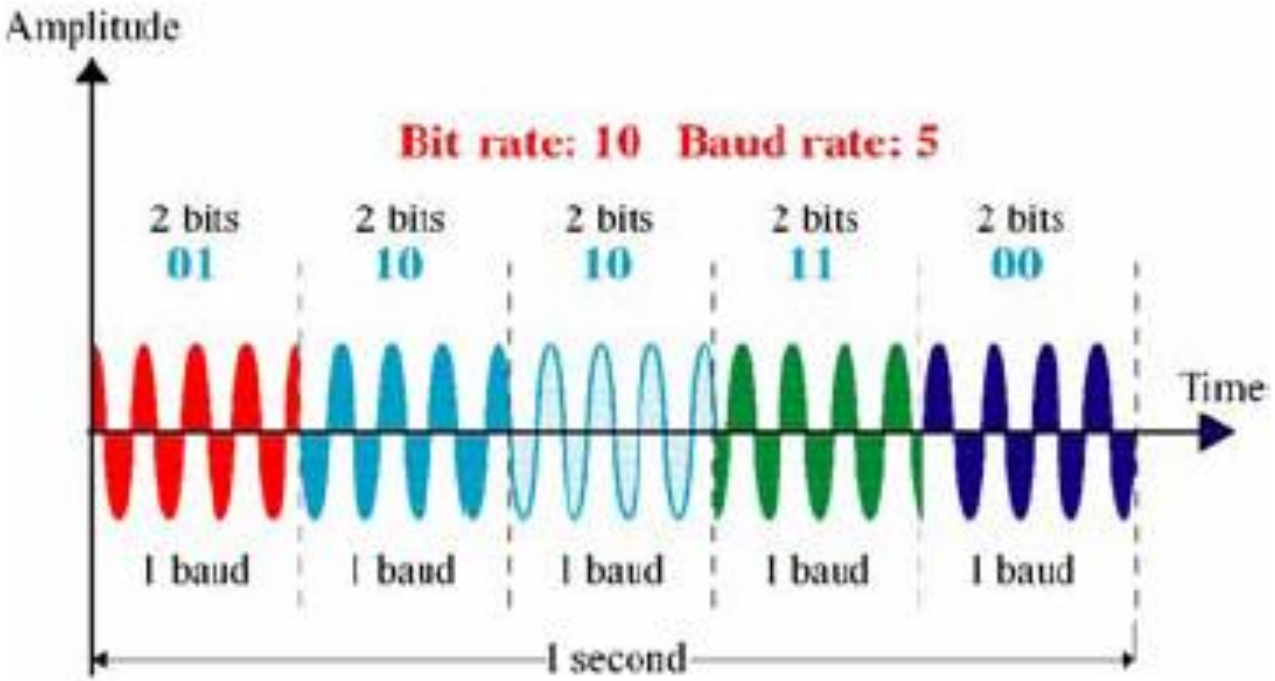
- Taşıyıcı sinyalin fazı değiştirilir
- Aşağıdaki şekilde 0° ve 180° faz farklı iki sinyal kullanılır. Bundan dolayı Binary PSK'da denir
- PSK sadece bir tane taşıyıcı frekans gerektirir, FSK seviye sayısı kadar gerektirir.



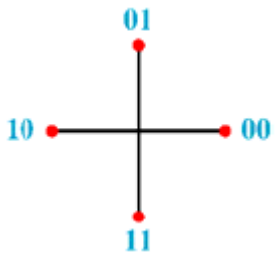
Bit	Phase
0	0
1	180

Bits

4 - PSK



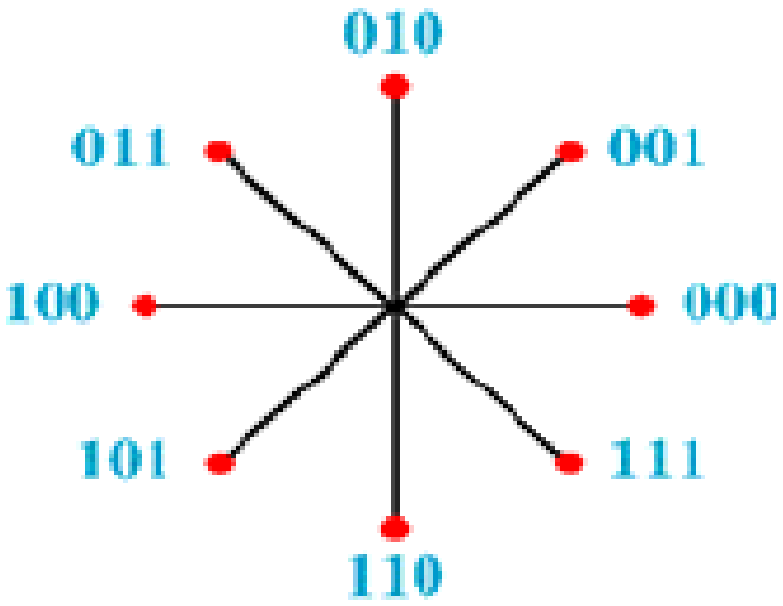
Dibit	Phase
00	0
01	90
10	180
11	270



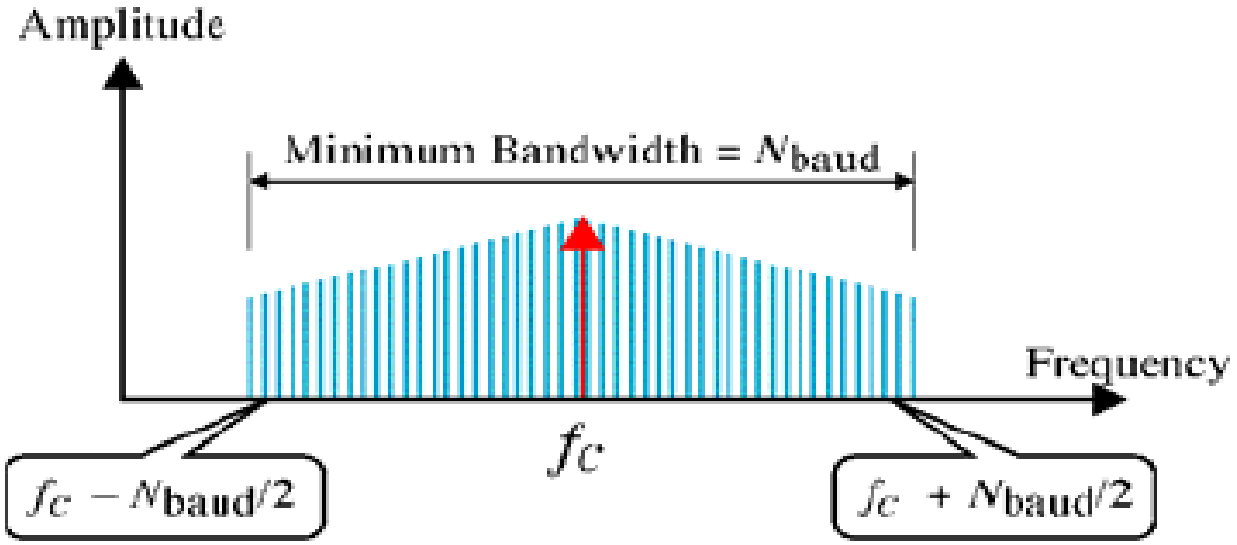
8 – PSK Yapısı

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

Tribits
(3 bits)



PSK İçin Bandgenişliği



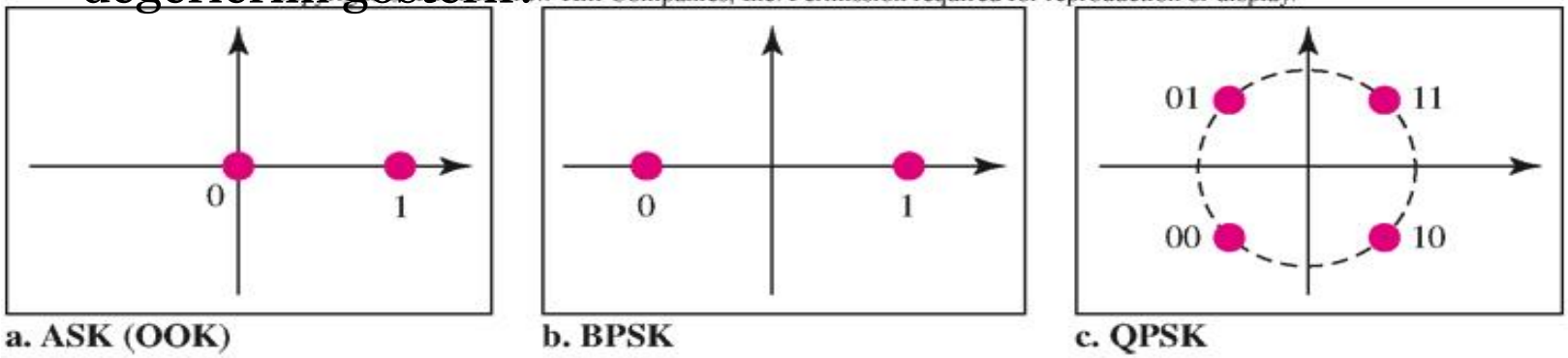
- Soru : Bir 8-PSK sinyalinin 4000 Hz'lik bir bandgenişliğinin olduğu kabul edilmektedir. Baud hızı ve bit hızı nedir?
- Cevap : PSK sinyali için baud rate = BW = 4000 Hz

  Bit Hızı baud hızının 3 katıdır

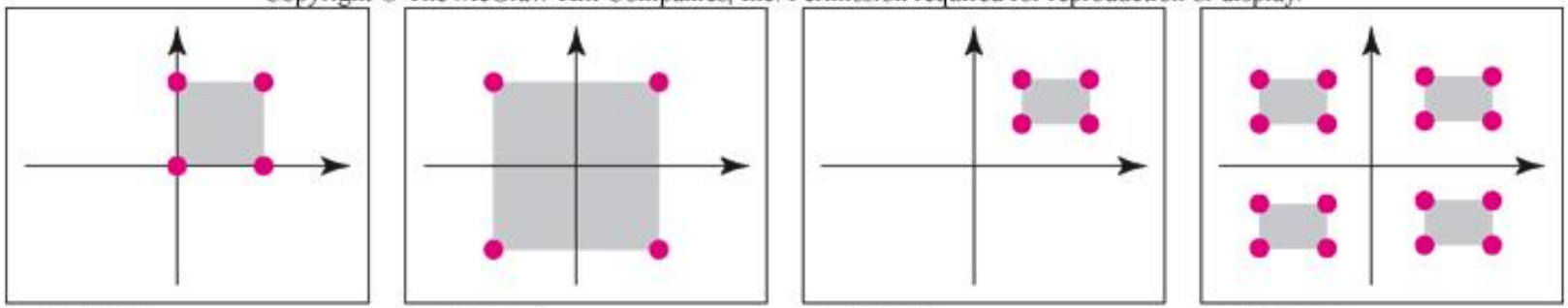
  Bit hızı = 4000 * 3 = 12000 bps

Takımyıldızı (Consellation) Diyagramı

- Sinyalin genlik ve faz değerlerini göstermek için kullanılır.
- ASK, PSK ve QAM için kullanılır. Her nokta faz ve genlik değerlerini gösterir.



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



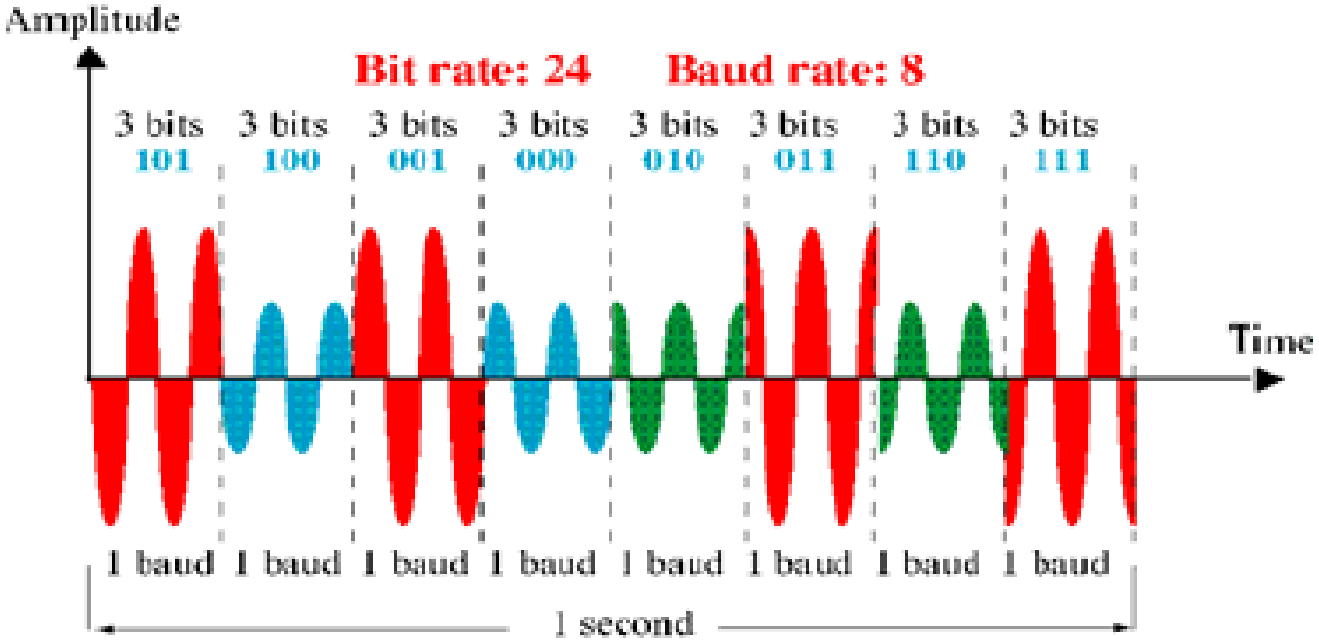
a. 4-QAM b. 4-QAM c. 4-QAM d. 16-QAM

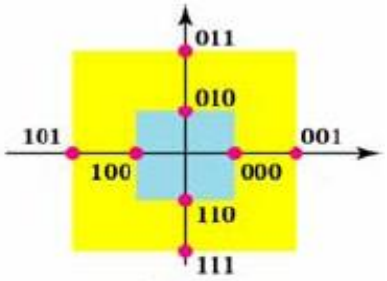
Quadrature Amplitude Modulation

- QAM used on asymmetric digital subscriber line (ADSL) and some wireless
- combination of ASK and PSK
- logical extension of QPSK
- send two different signals simultaneously on same carrier frequency
  - use two copies of carrier, one shifted 90°
  - each carrier is ASK modulated
  - two independent signals over same medium
  - demodulate and combine for original binary output

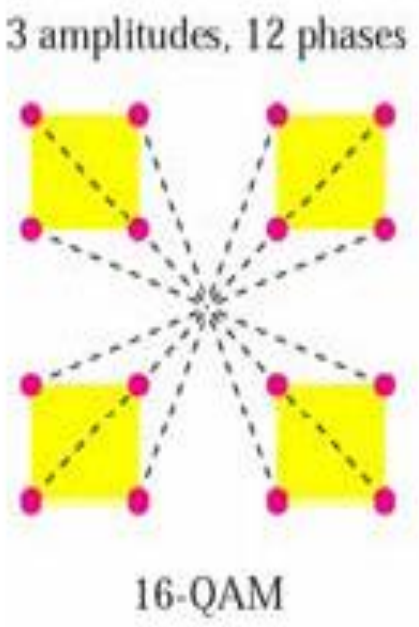
8 – QAM Sinyali

1 sinyal → 3 b

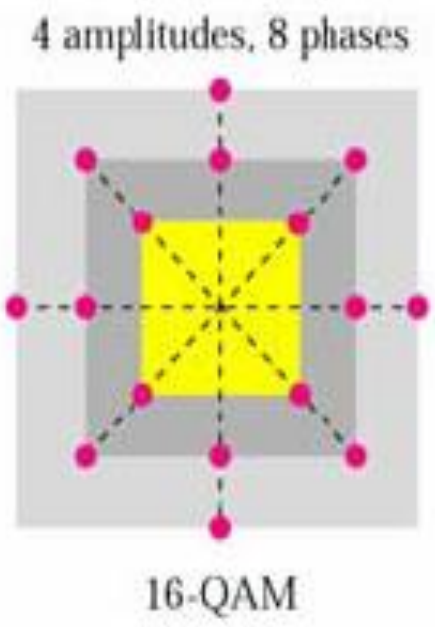




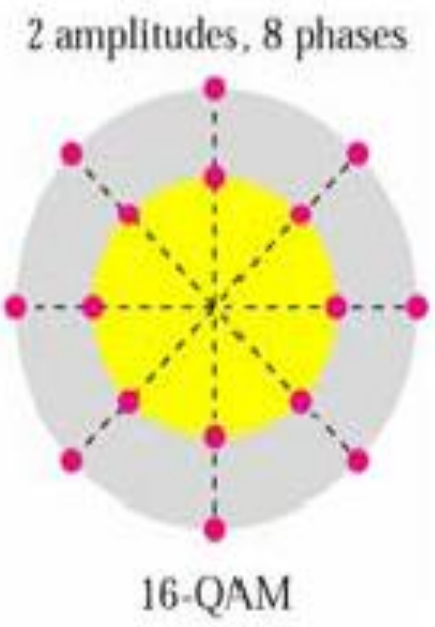
16 - QAM Yapısı



3 x 12 = 36 combinations
36 ➔ 2^4 (16)



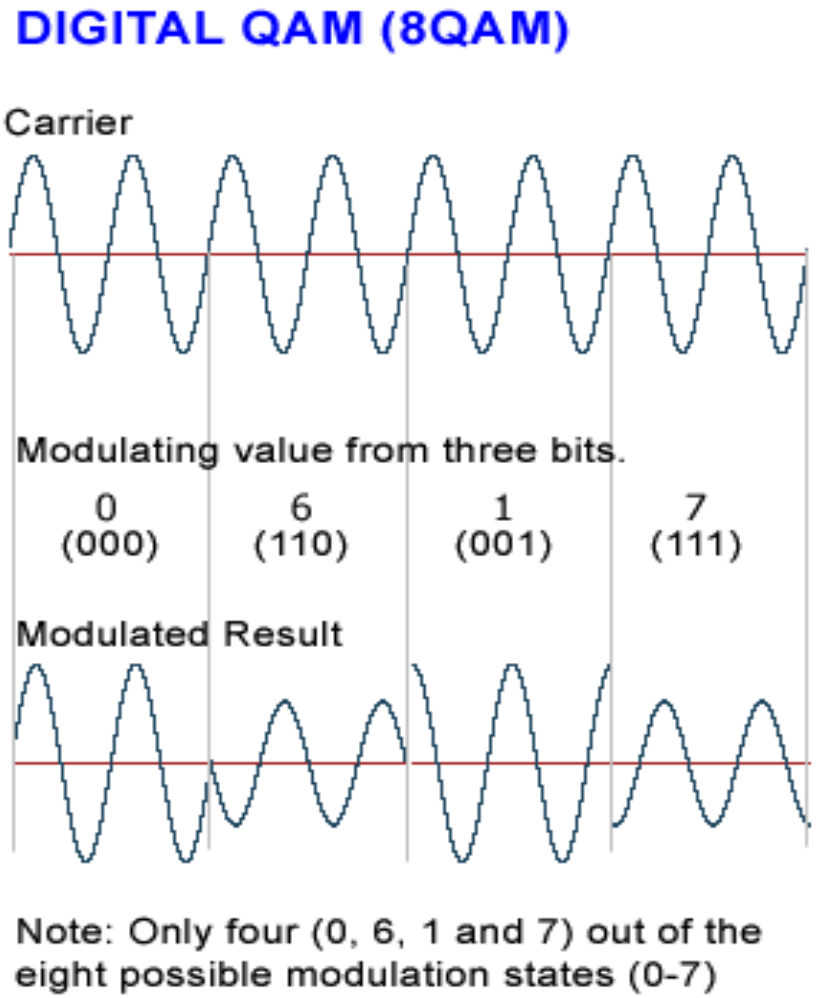
4 x 8 = 32 combinations
32 ➔ 2^4 (16)



2 x 8 = 16 combinations
16 ➔ 2^4 (16)

8-QAM

- In this 8QAM example, three bits of input generate eight different modulation states (0-7) using four phase angles on 90 degree boundaries and two amplitudes: one at 50% modulation; the other at 100% (4 phases X 2 amplitudes = 8 modulation states). QAM examples with more modulation states become extremely difficult to visualize



QAM Variants

- two level ASK
  - each of two streams in one of two states
  - four state system
  - essentially QPSK
- four level ASK
  - combined stream in one of 16 states
- have 64 and 256 state systems
- improved data rate for given bandwidth
  - but increased potential error rate

Baudrate and Bitrate Comparison

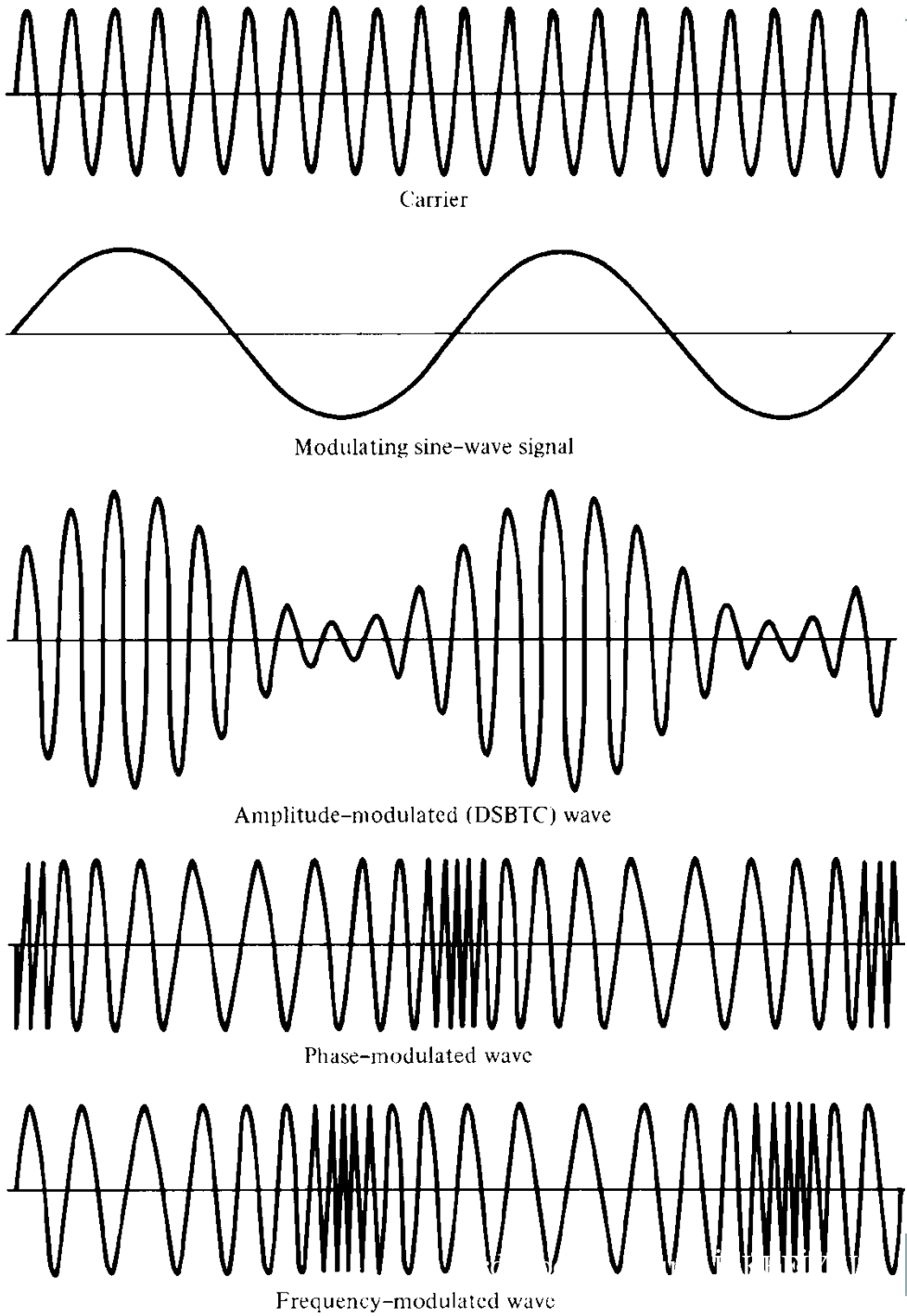
Modulation	Units	Bits/Baud	Baudrate	Bitrate
ASK, FSK, 2-FSK	Bit	1	N	N
4-PSK, 4-QAM	Dibit	2	N	2N
8-PSK, 8-QAM	Tribit	3	N	3N
16-QAM	Quadbit	4	N	4N
32-QAM	Pentabit	5	N	5N
64-QAM	Hexabit	6	N	6N
128-QAM	Septabit	7	N	7N
256-QAM	Octabit	8	N	8N

Analog Data, Analog Signals

- modulate carrier frequency with analog data
- why modulate analog signals?
  - higher frequency can give more efficient transmission
  - permits frequency division multiplexing (chapter 8)
- types of modulation
  - Amplitude
  - Frequency
  - Phase

Analog Modulation Techniques

- Amplitude Modulation
- Frequency Modulation
- Phase Modulation



Summary

- looked at signal encoding techniques
  - digital data, digital signal
  - analog data, digital signal
  - digital data, analog signal
  - analog data, analog signal