Chapter 5 – Signal Encoding Techniques

Signal Encoding Techniques

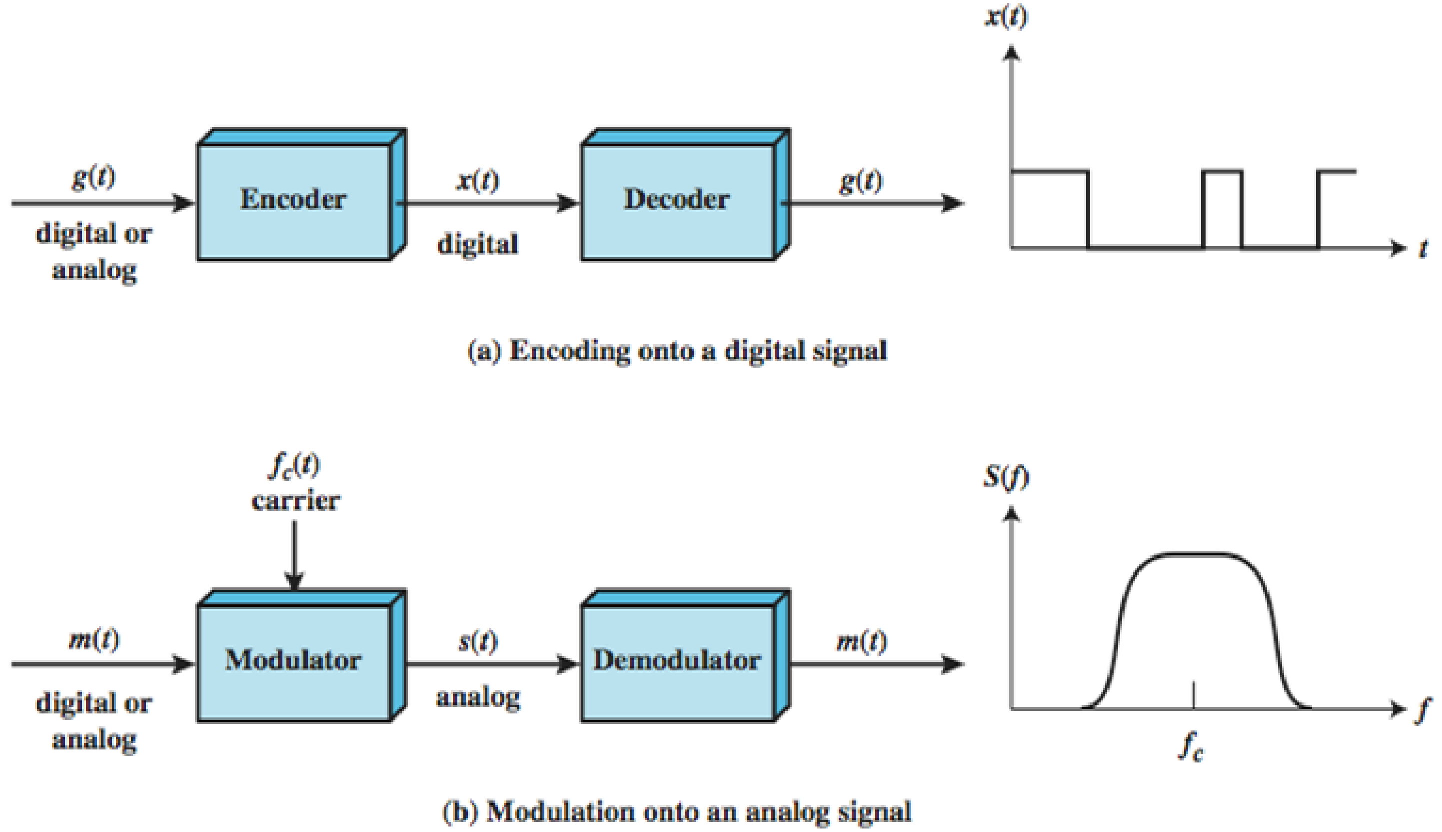
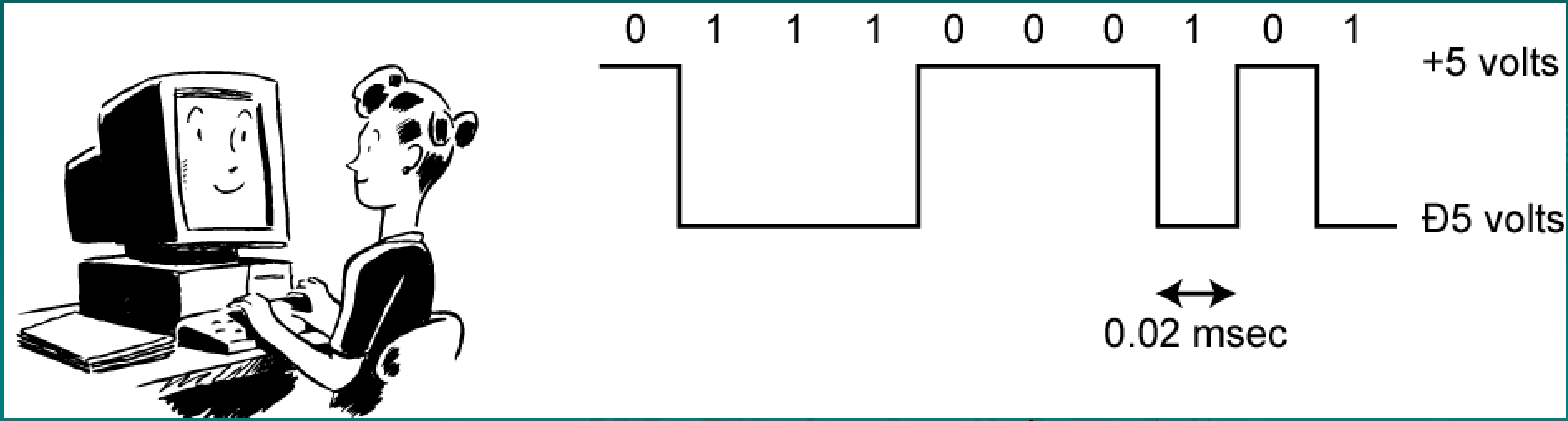


Figure 5.1 Encoding and Modulation Techniques

Digital Data, Digital Signal

- digital signal
  - discrete, discontinuous voltage pulses
  - each pulse is a signal element
  - binary data encoded into signal elements



Terminology

- **unipolar** – all signal elements have the same sign
- **polar** – one logic state represented by positive voltage and the other by negative voltage
- **data rate** – rate of data (R) transmission in bits per second
- **duration or length of a bit** – time taken for transmitter to emit the bit (1/R)
- **modulation rate** – rate at which the signal level changes, measured in baud = signal elements per second.

Interpreting Signals

need to know:

- timing of bits - when they start and end
- signal levels

factors affecting signal interpretation:

- signal to noise ratio
- data rate
- bandwidth
- encoding scheme

Encoding Schemes

signal spectrum

- good signal design should concentrate the transmitted power in the middle of the transmission bandwidth

clocking

- need to synchronize transmitter and receiver either with an external clock or sync mechanism

error detection

- responsibility of a layer of logic above the signaling level that is known as data link control

signal interference and noise immunity

- certain codes perform better in the presence of noise
- cost and complexity
- the higher the signaling rate the greater the cost

Nonreturn to Zero-Level (NRZ-L)

- easiest way to transmit digital signals is to use two different voltages for 0 and 1 bits
- voltage constant during bit interval
  - no transition (no return to zero voltage)
  - absence of voltage for 0, constant positive voltage for 1
  - more often, a negative voltage represents one value and a positive voltage represents the other(NRZ-L)

NRZ Pros & Cons

Pros

- easy to engineer
- make efficient use of bandwidth

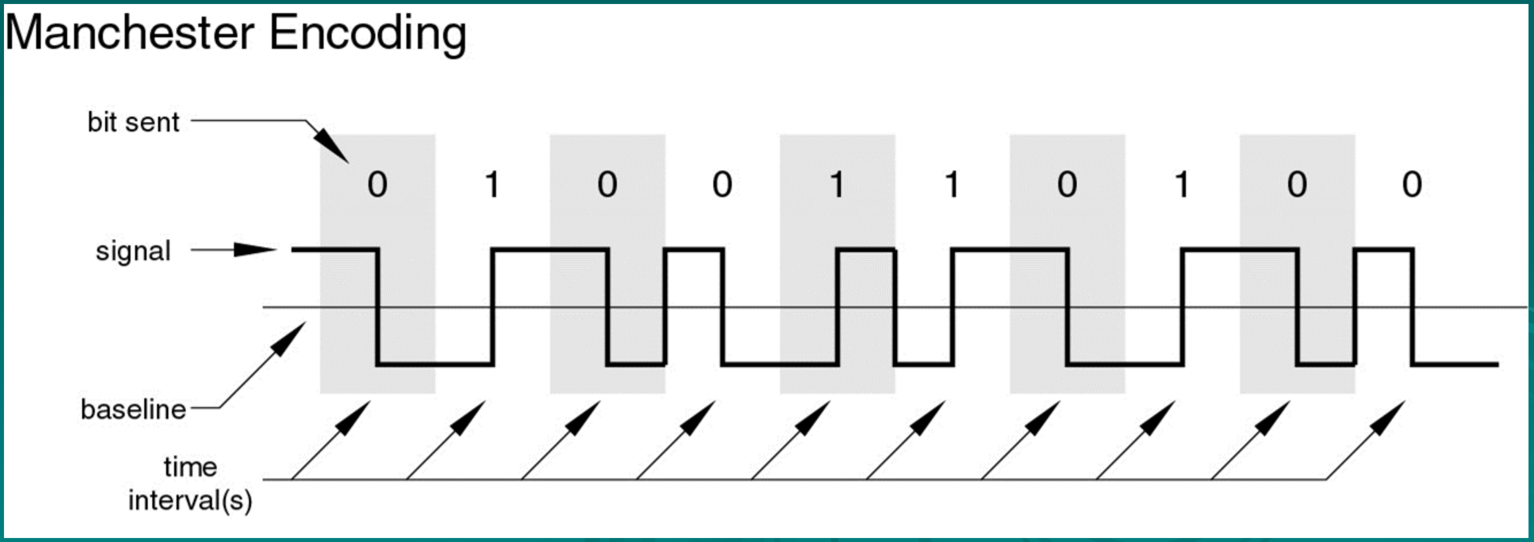
Cons

- presence of a dc component
- lack of synchronization capability

- used for magnetic recording
- not often used for signal transmission

Manchester Encoding

- transition in middle of each bit period
- midbit transition serves as clock and data
- low to high transition represents a 1
- high to low transition represents a 0
- used by IEEE 802.3



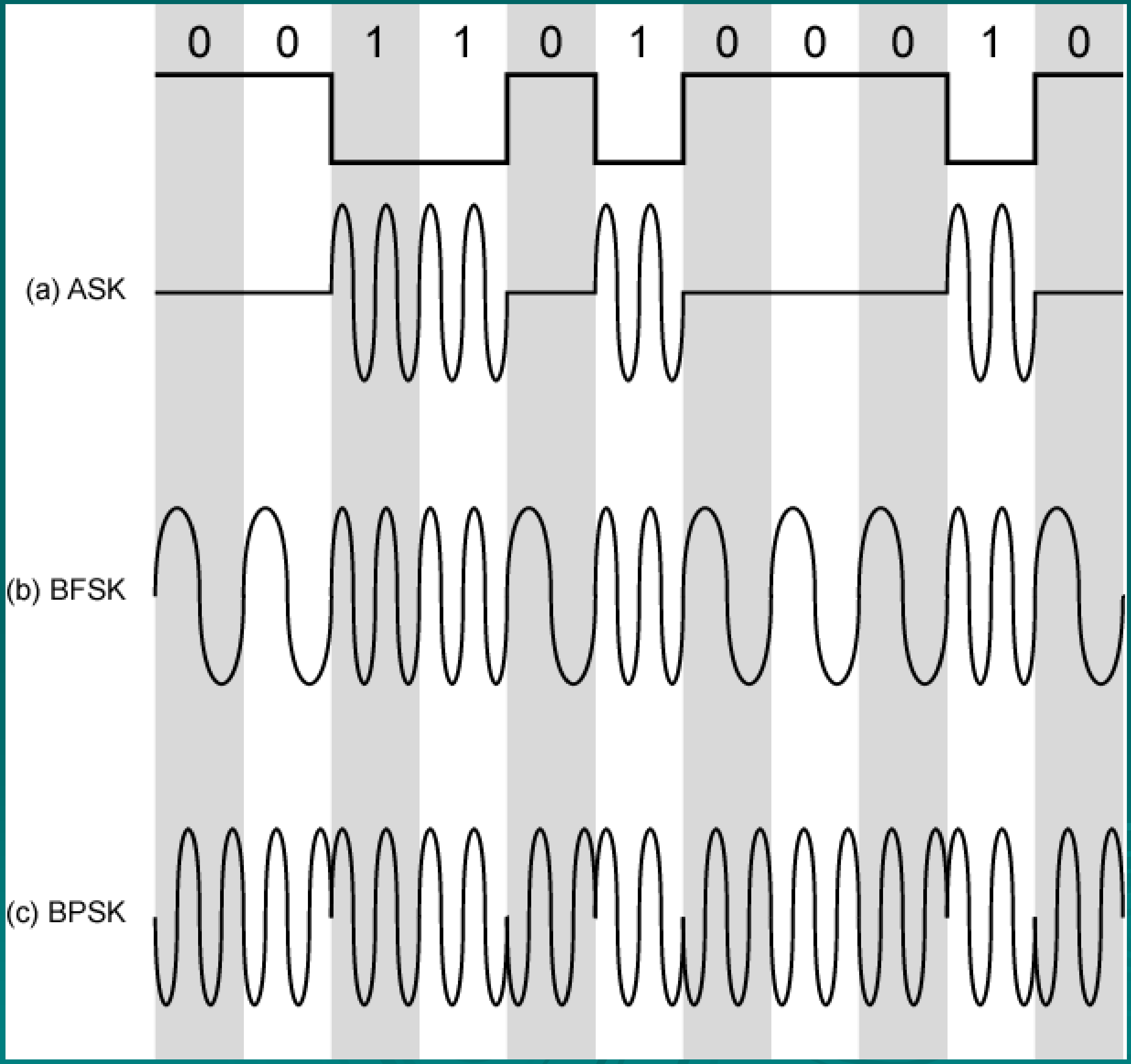
Digital Data, Analog Signal

Encoding Techniques

Amplitude shift keying (ASK)	Frequency shift keying (FSK)	Phase shift keying (PK)
• used to transmit digital data over optical fiber	• most common form is binary FSK (BFSK)	• phase of carrier signal is shifted to represent data

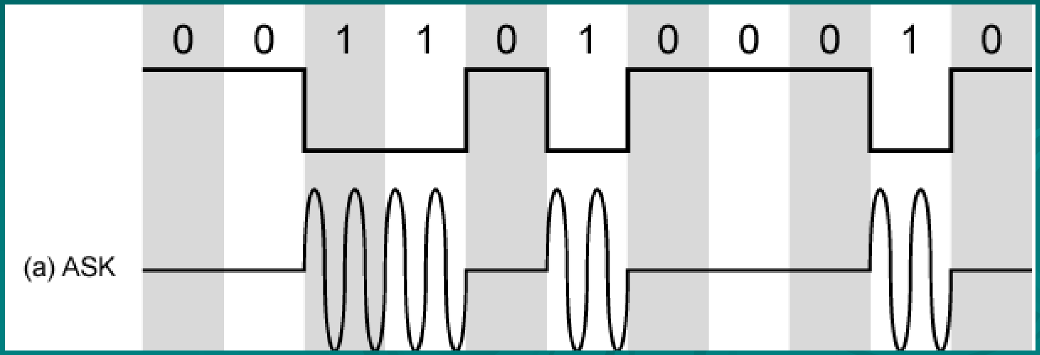
- main use is public telephone system
  - has frequency range of 300Hz to 3400Hz
  - uses modem (modulator-demodulator)

Modulation Techniques



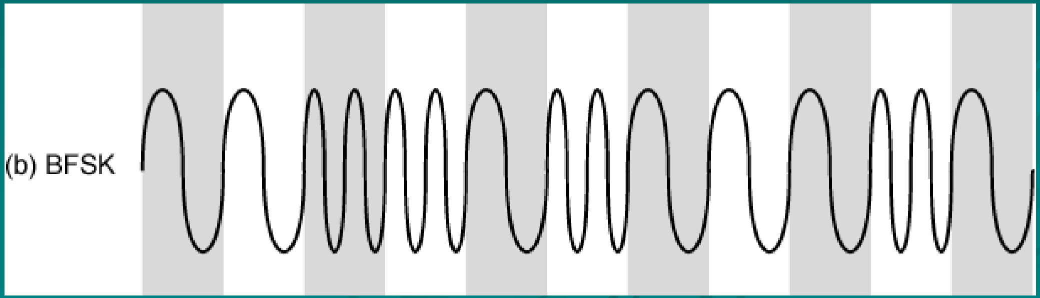
Amplitude Shift Keying

- 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



Binary Frequency Shift Keying

- 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 coaxial cable

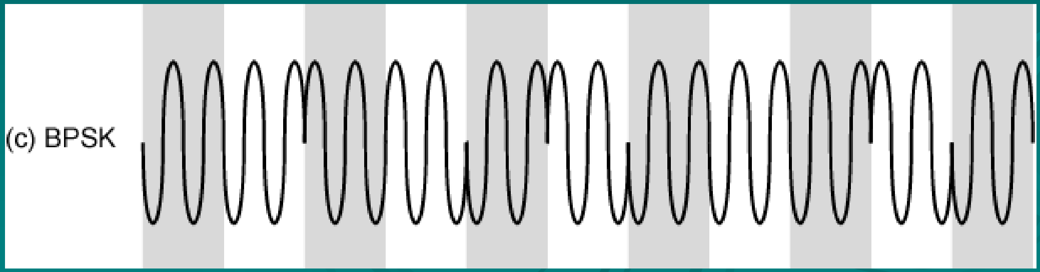


Multiple FSK

- each signalling element represents more than one bit
- more than two frequencies used
- more bandwidth efficient
- more prone to error

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

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

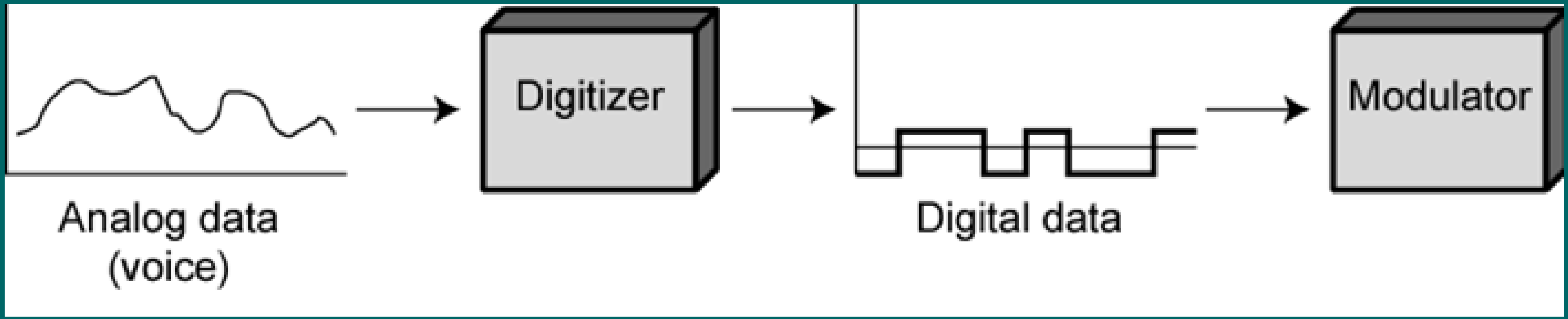
QAM Variants

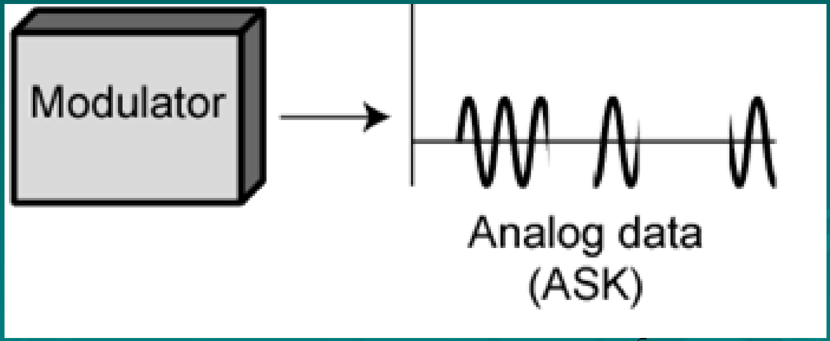
- two level ASK
  - each of two streams in one of two states
  - four state system
  - essentially QPSK
- four level ASK
  - combined stream in one of 16 states
- have 64 and 256 state systems
- improved data rate for given bandwidth
  - increased potential error rate

Analog Data, Digital Signal

- digitization is conversion of analog data into digital data which can then:
  - be transmitted using NRZ-L
  - be transmitted using code other than NRZ-L
  - be converted to analog signal
- analog to digital conversion done using a codec
  - pulse code modulation
  - delta modulation

Digitizing Analog Data

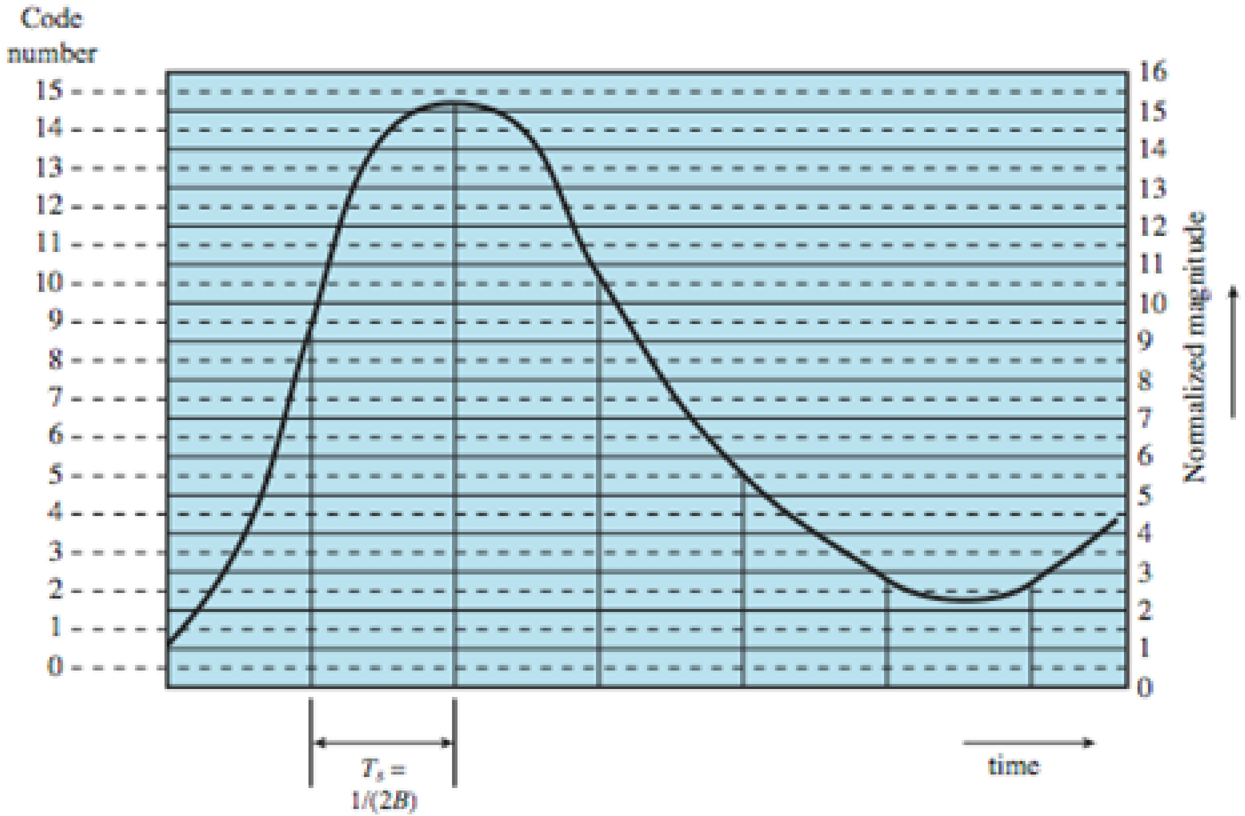




Pulse Code Modulation (PCM)

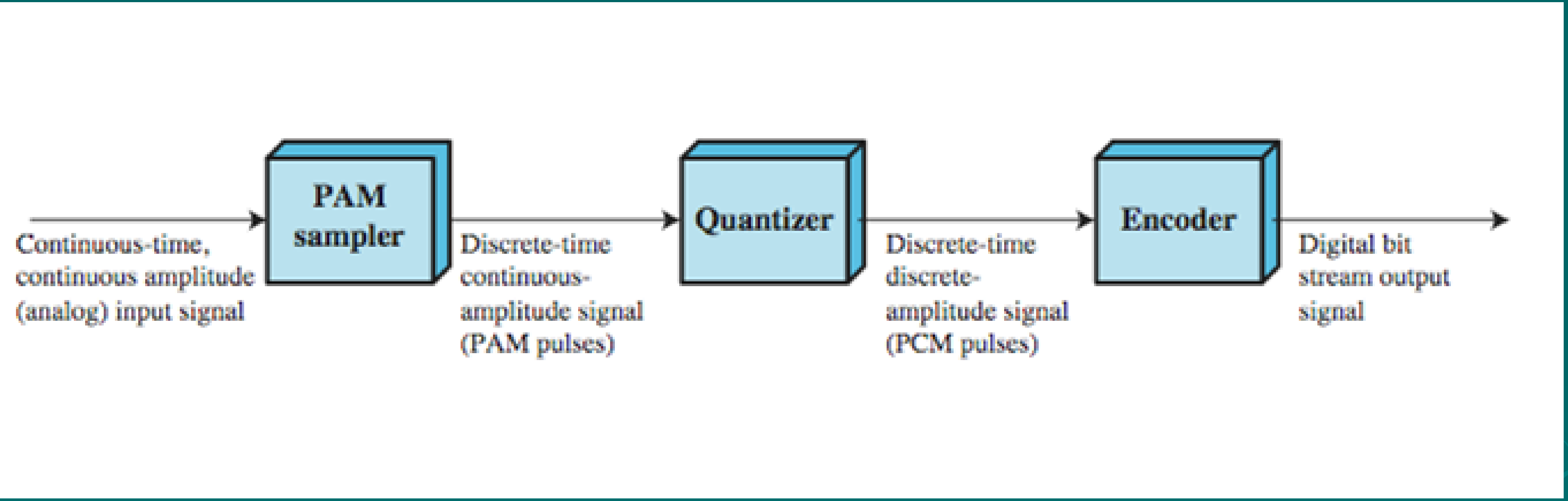
- sampling theorem:
  - “If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all information in original signal”
  - eg. 4000Hz voice data, requires 8000 sample per second
- strictly have analog samples
  - Pulse Amplitude Modulation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

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



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
- types of modulation:
  - Amplitude
  - Frequency
  - Phase

Analog Modulation Techniques

- Amplitude Modulation
- Frequency Modulation
- Phase Modulation