Signal Encoding Techniques

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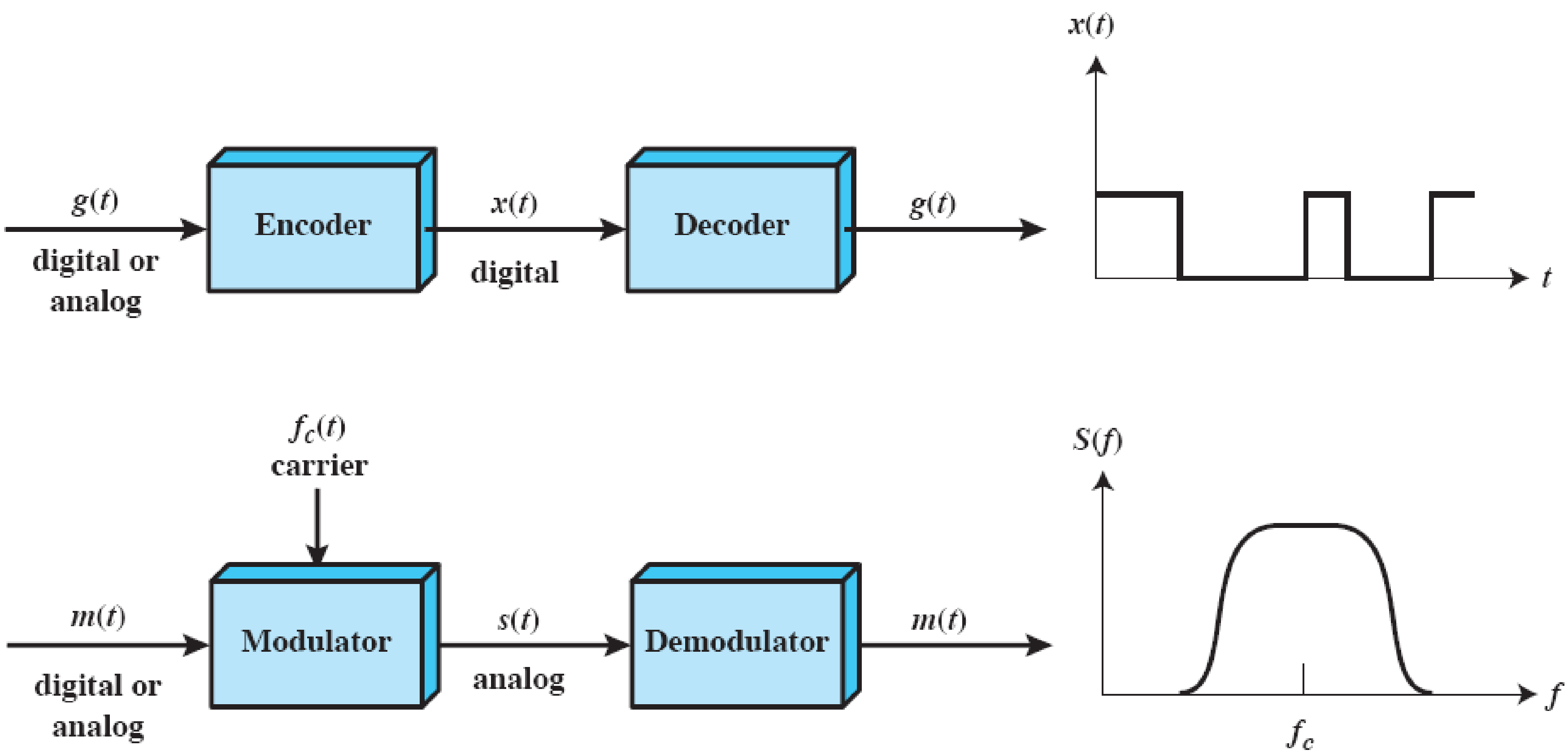
Signal Encoding Techniques

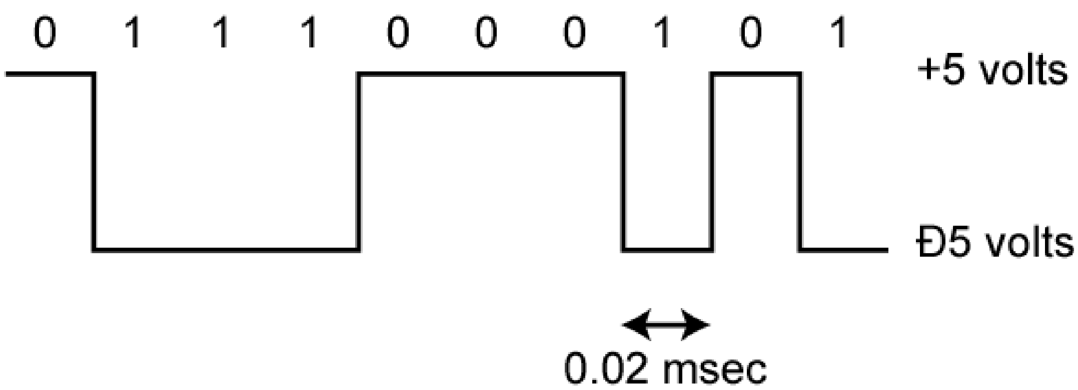


Four Different Options

	Analog Signal	Digital Signal
Analog Data	Two alternatives: (1) signal occupies the same spectrum as the analog data; (2) analog data are encoded to occupy a different portion of spectrum.	Analog data are encoded using a codec to produce a digital bit stream.
Digital Data	Digital data are encoded using a modem to produce analog signal.	Two alternatives: (1) signal consists of two voltage levels to represent the two binary values; (2) digital data are encoded to produce a digital signal with desired properties.

Digital Data, Digital Signal

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

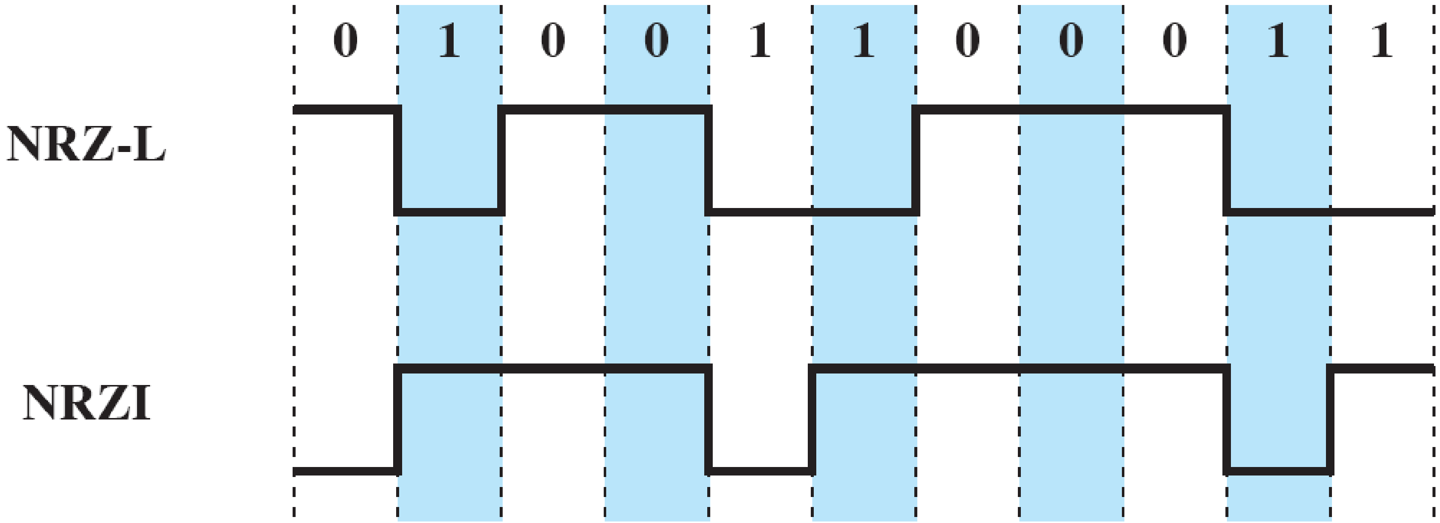


Interpreting Signals

- A receiver needs to know
  - Timing of bits – when does the bit start and end?
  - Signal levels – when is it a 0 or 1?
- Factors affecting signal interpretation
  - Signal to noise ratio (SNR)
  - Data rate
  - Bandwidth
  - Encoding scheme
- Encoding Schemes:
  - Define the sequence of high and low signals to transmit 0’s and 1’s. Why?
    - Can shape the output spectrum to be more efficient
    - Detect errors
    - Avoid errors due to noise
    - Simplify digital circuits (hence lower cost)
  - Examples: Non-return to Zero (NRZ); Alternate Mark Inversion (AMI); Manchester; B8ZS; HDB3; …

Non-Return to Zero (NRZ)

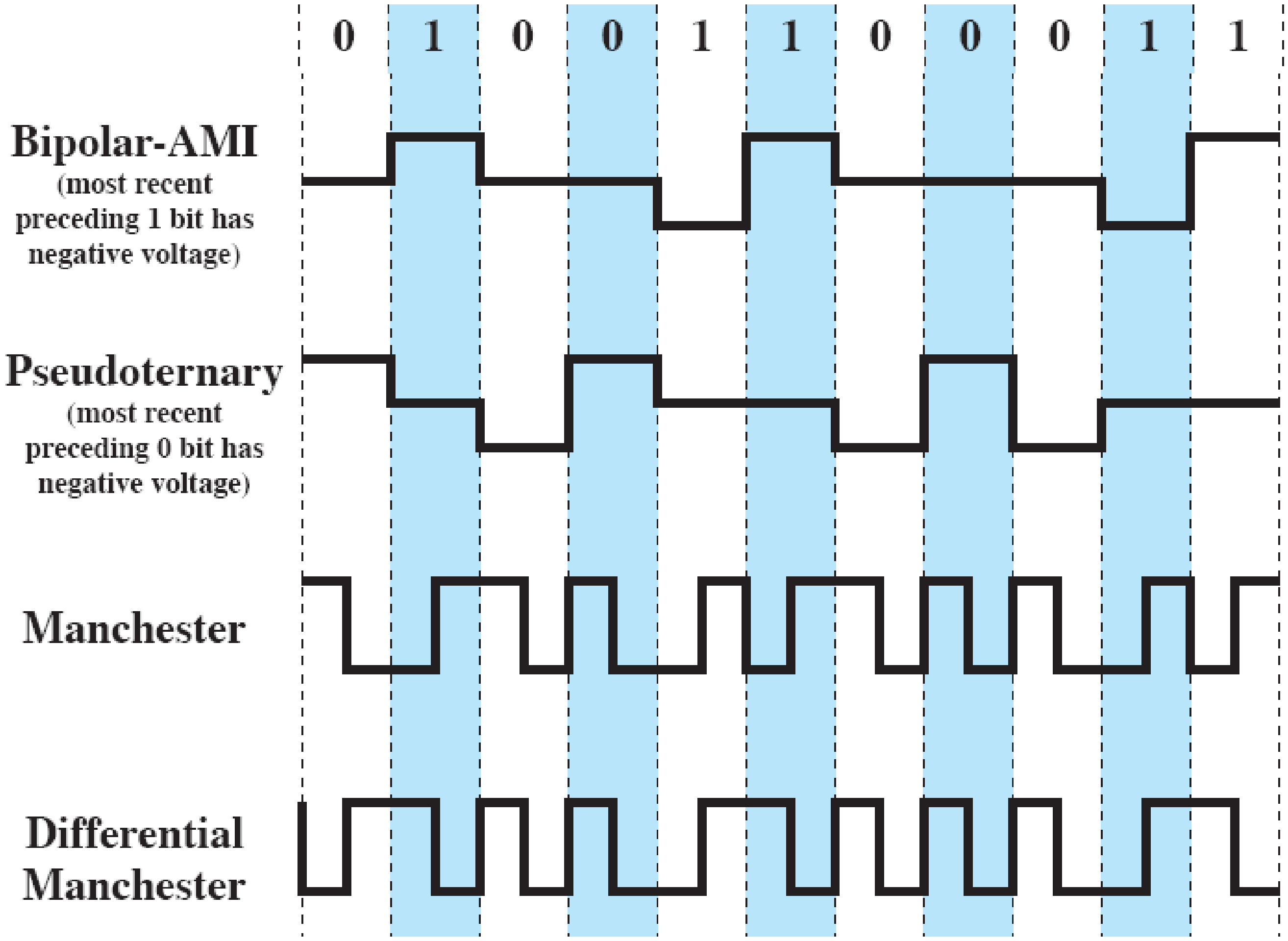
- Non-Return to Zero Level (NRZ-L)
  - Negative voltage represents binary 1
  - Positive voltage represents binary 0
    - (or other way around)
- A variant: NRZ Invert on ones (NRZI)
  - A transition (from high to low or low to high) represents binary 1
  - No transition represents binary 0



Digital Signal Encoding Formats

- Nonreturn to Zero-Level (NRZ-L)
  - 0 = high level
  - 1 = low level
- Nonreturn to Zero Inverted (NRZI)
  - 0 = no transition at beginning of interval (one bit time)
  - 1 = transition at beginning of interval
- Bipolar-AMI
  - 0 = no line signal
  - 1 = positive or negative level, alternating for successive ones
- Pseudoternary
  - 0 = positive or negative level, alternating for successive zeros
  - 1 = no line signal
- Manchester
  - 0 = transition from high to low in middle of interval
  - 1 = transition from low to high in middle of interval
- Differential Manchester
  - Always a transition in middle of interval
  - 0 = transition at beginning of interval
  - 1 = no transition at beginning of interval
- B8ZS
  - Same as bipolar AMI, except that any string of 8 zeros is replaced by a string with two code violations
- HDB3
  - Same as bipolar AMI, except that any string of 4 zeros is replaced by a string with one code violation

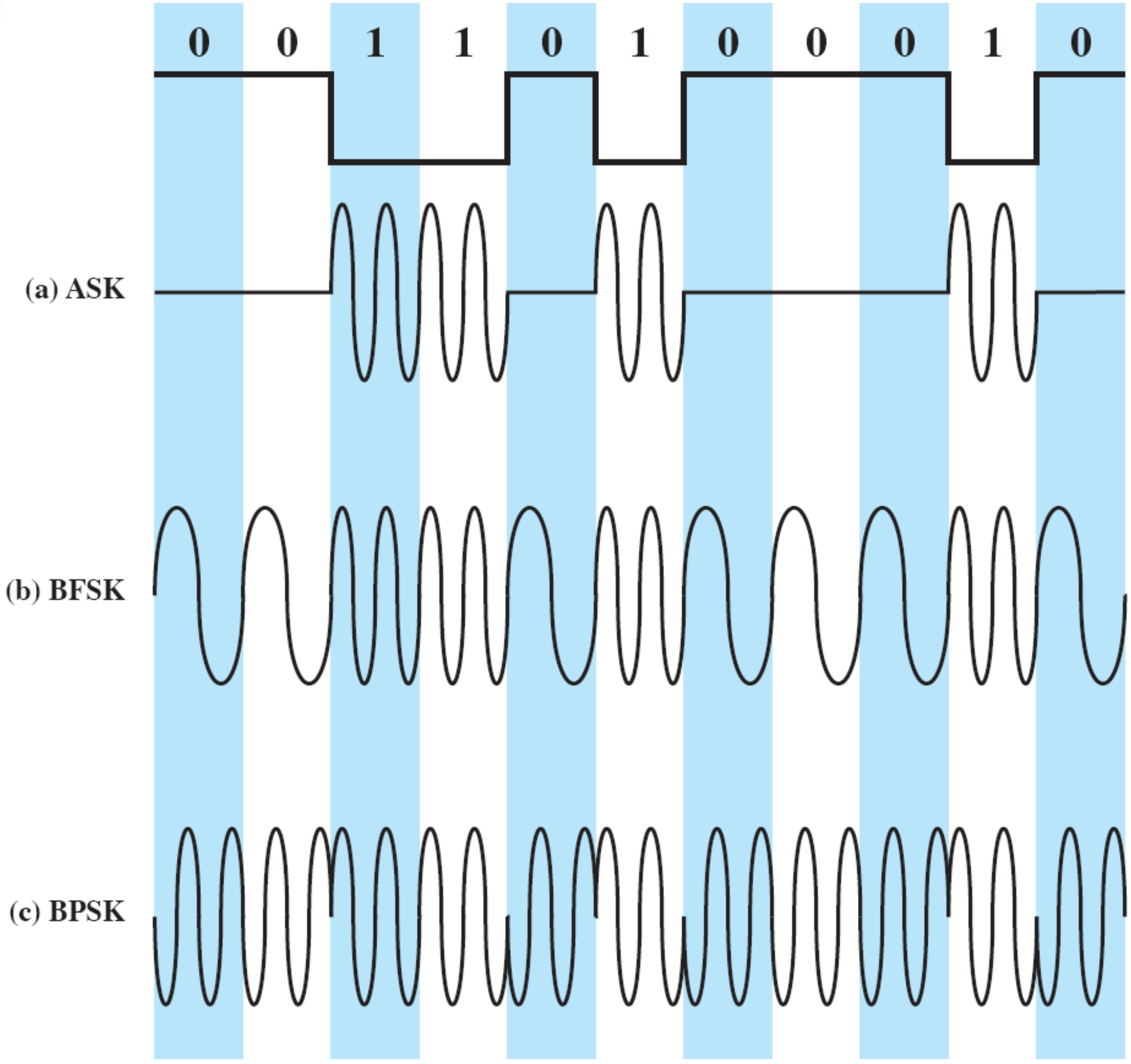
Digital Signal Encoding Formats



Digital Data, Analog Signal

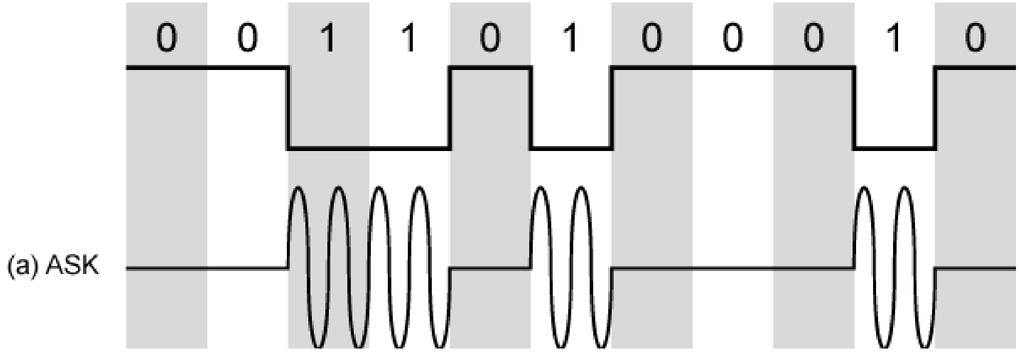
- Main use is public telephone system
  - Has frequency range of 300Hz to 3400Hz
  - Use modem (modulator-demodulator)
- Encoding techniques
  - Amplitude Shift Keying (ASK)
  - Frequency Shift Keying (FSK)
  - Phase Shift Keying (PSK)

Modulation Techniques



Amplitude Shift Keying

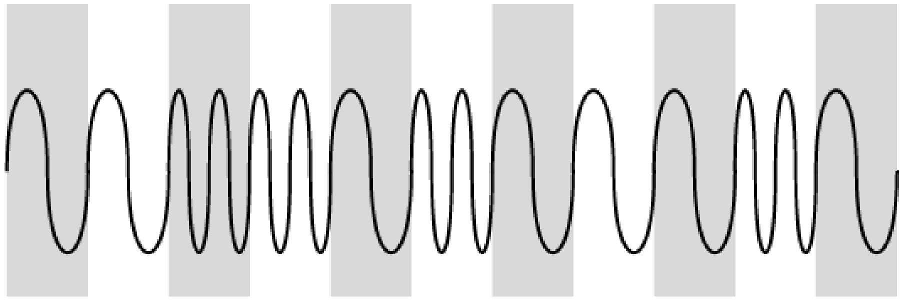
- Encode 0/1 by different carrier amplitudes
  - Usually have one amplitude zero
- Susceptible to sudden gain changes
- Inefficient
- Used for
  - up to 1200bps on voice grade lines
  - very high speeds over optical fiber



Binary Frequency Shift Keying

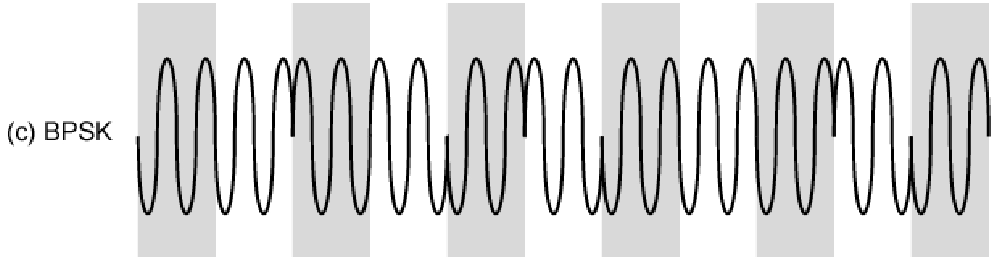
- Most common is binary FSK (BFSK)
- Two binary values represented by two different frequencies (near carrier)
- Less susceptible to error than ASK
- used for
  - up to 1200bps on voice grade lines
  - high frequency radio
  - even higher frequency on LANs using co-ax

(b) BFSK



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
  - Shift phase by 90 degrees; a signal represents two bits (00, 01, 10, 11) depending on phase shift (45°, 135°, 225°, 315°)
  - More efficient: carry more information (bits) per signal
- Quadrature Amplitude Modulation
  - Combines ASK and PSK

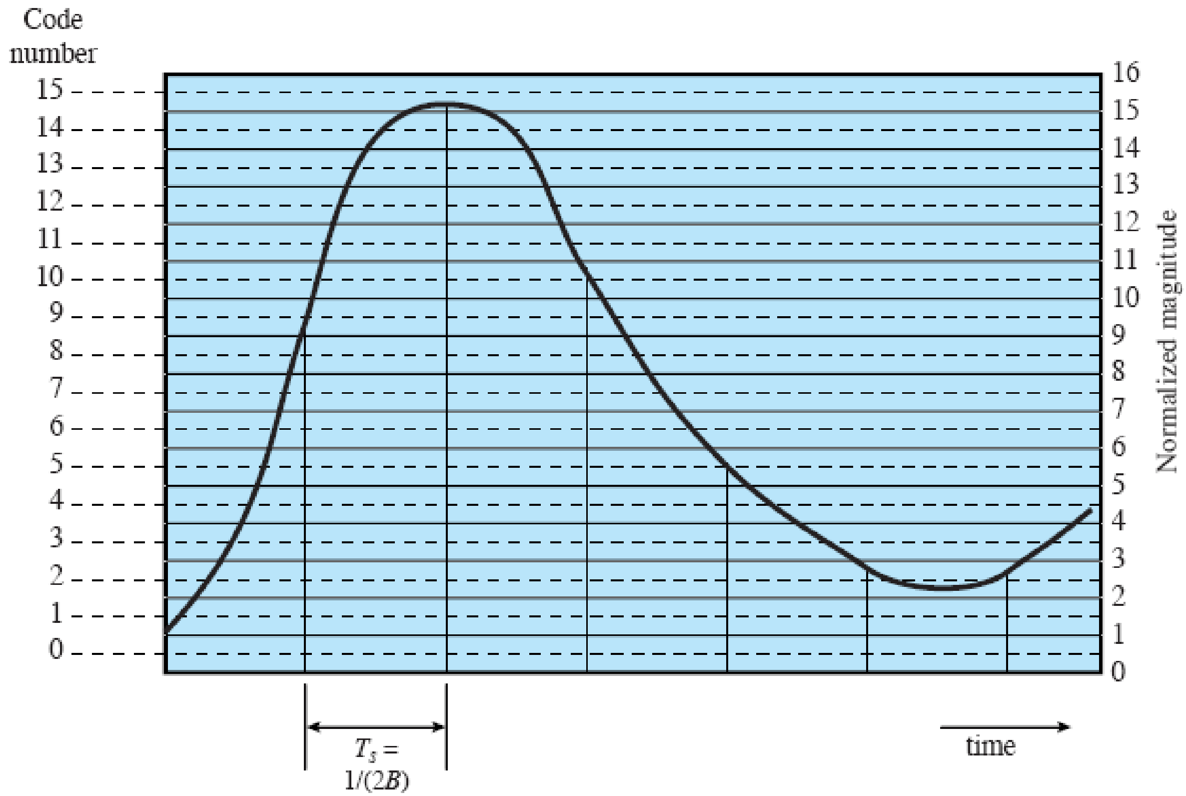
Analog Data, Digital Signal

- Involves *digitization* of analog signal
  - Convert analog data to digital data
  - Then send digital data using, for example:
    - NRZ-L or similar code
    - Or convert to analog signal and send
- Analog to digital conversion done using a codec
  - Pulse Code Modulation
  - Delta Modulation
    - Simpler than PCM, but not as good performance

Pulse Code Modulation (PCM)

- PCM is used to convert analog data to digital data
- 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 samples per sec
- Sampling an analog signal (data) creates Pulse Amplitude Modulation (PAM) samples
- Each PAM sample is assigned a code (Pulse Code Modulation)
- Performance:
  - Typically, good voice reproduction requires 128 levels or 7 bits, hence 56kb/s
    - Using Nyquist, requires 28kHz of bandwidth

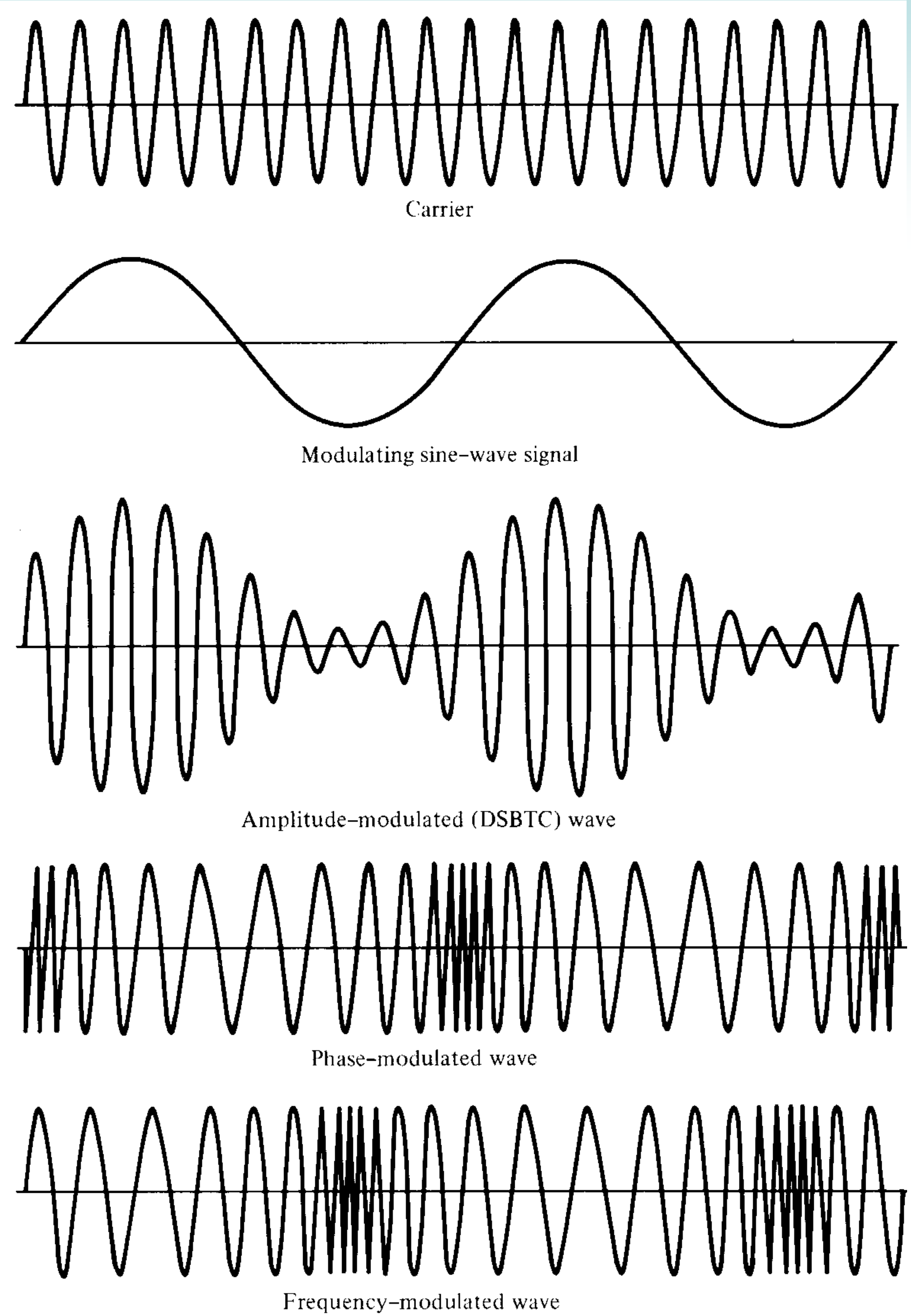
PCM Example



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

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 (covered later)
- Types of modulation
  - Amplitude (AM)
  - Frequency (FM)
  - Phase (PM)


Carrier
Modulating sine-wave signal
Amplitude-modulated (DSBTC) wave
Phase-modulated wave
Frequency-modulated wave