Encoding and Modulation Techniques

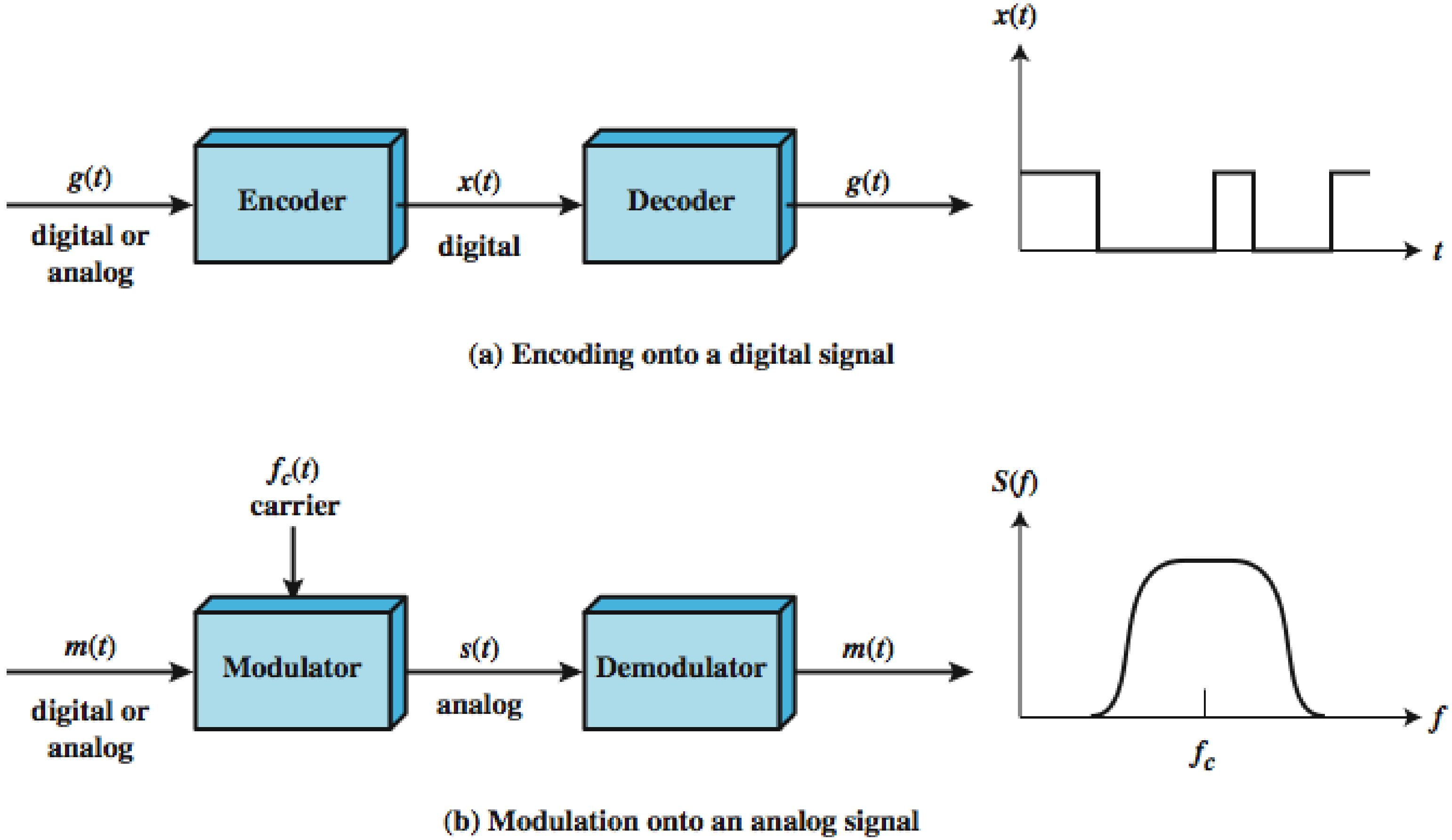


Figure 5.1 Encoding and Modulation Techniques

Digital Signaling Versus Analog Signaling

Digital signaling

- **Digital or analog data** is encoded into a digital signal
- Encoding may be chosen to conserve bandwidth or to minimize error

Analog Signaling

- **Digital or analog data** modulates analog carrier signal
- The frequency of the carrier fc is chosen to be compatible with the transmission medium used
- Modulation: the amplitude, frequency or phase of the carrier signal is varied in accordance with the modulating data signal
- by using different carrier frequencies, multiple data signals (users) can share the same transmission medium

Digital Signaling

Digital data, digital signal

- Simplest encoding scheme: assign one voltage level to binary one and another voltage level to binary zero
- More complex encoding schemes: are used to improve performance (reduce transmission bandwidth and minimize errors).
- Examples are NRZ-L, NRZI, Manchester, etc.

Analog data, Digital signal

- Analog data, such as voice and video
- Often digitized to be able to use digital transmission facility
- Example: Pulse Code Modulation (PCM), which involves **sampling** the analog data periodically and **quantizing** the samples

Analog Signaling

Digital data, Analog Signal

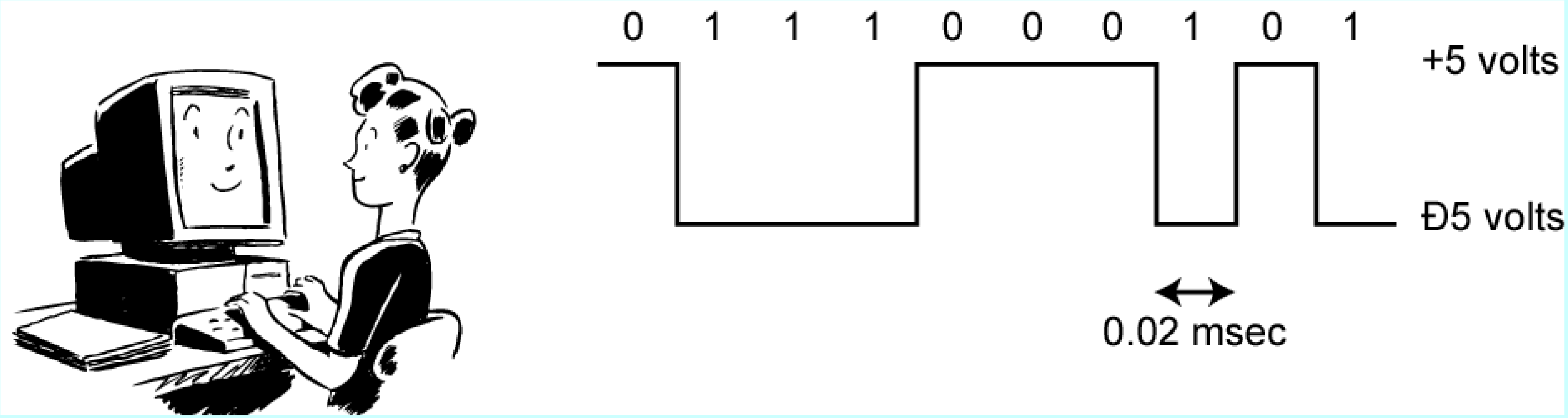
- A modem converts digital data to an analog signal so that it can be transmitted over an analog line
- The digital data modulates the amplitude, frequency, or phase of a carrier analog signal
- Examples: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK)

Analog data, Analog Signal

- Analog data, such as voice and video modulate the amplitude, frequency, or phase of a carrier signal to produce an analog signal in a different frequency band
- Examples: Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM)

Digital Data, Digital Signal

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



Periodic signals

- **Data element:** a single binary 1 or 0
- **Signal element:** a voltage pulse of constant amplitude
- **Unipolar:** All signal elements have the same sign
- **Polar:** One logic state represented by positive voltage 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 (T_b=1/R)
- **Modulation rate:** Rate at which the signal level changes, measured in baud = signal elements per second. Depends on type of digital encoding used.

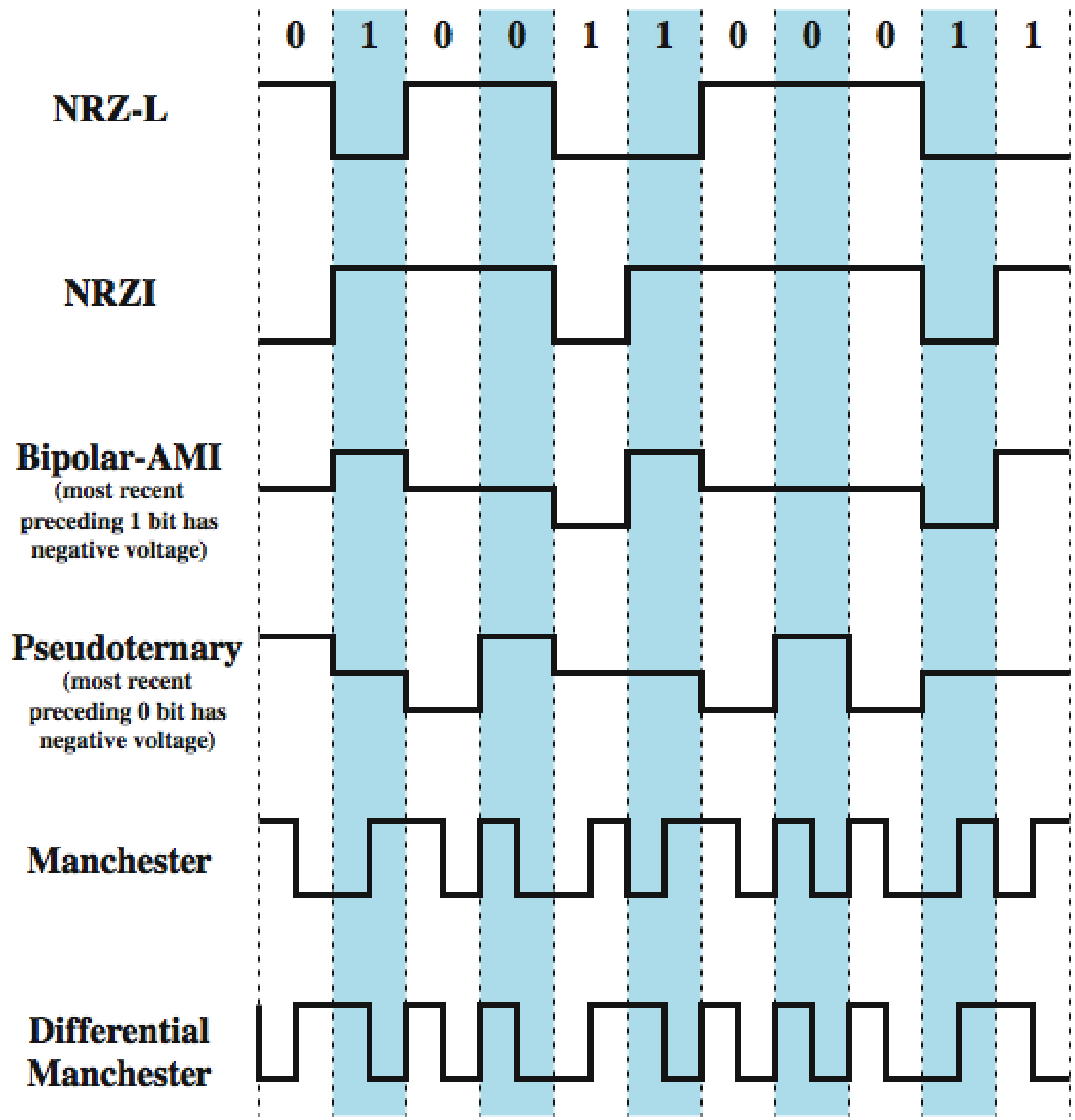
Interpreting Signals

- Need to know
  - timing of bits: when they start and end
  - signal levels: high or low
- factors affecting signal interpretation
  - Data rate: increase data rate increases Bit Error Rate (BER)
  - Signal to Noise Ratio (SNR): increase SNR decrease BER
  - Bandwidth: increase bandwidth increase data rate
  - encoding scheme: mapping from data bits to signal elements

Comparison of Encoding Schemes

- signal spectrum
  - Lack of high frequencies reduces required bandwidth,
  - lack of dc component allows ac coupling via transformer, providing isolation,
  - should concentrate power in the middle of the bandwidth
- Clocking
  - synchronizing transmitter and receiver with a sync mechanism based on suitable encoding
- error detection
  - useful if can be built in to signal encoding
- signal interference and noise immunity
- cost and complexity: increases when increases data rate

Encoding Schemes



Positive level (+5V)

Negative level (-5V)

Positive level (+5V)
No line signal (0V)
Negative level (-5V)

Table 5.2 Definition of 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 eight zeros is replaced by a string with two code violations

HDB3
Same as bipolar AMI, except that any string of four zeros is replaced by a string with one code violation

NonReturn to Zero-Level (NRZ-L)

- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - no transition, i.e. no return to zero voltage
  - more often, negative voltage for binary one and positive voltage for binary zero

NonReturn to Zero INVERTED (NRZI)

- Nonreturn to zero inverted on ones
- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at beginning of bit time
  - transition (low to high or high to low) denotes binary 1
  - no transition denotes binary 0
- Example of differential encoding since have
  - data represented by changes rather than levels
  - more reliable detection of transition rather than level

Advantages and disadvantages of NRZ-L, NRZI

- Advantages
  - easy to engineer
  - good use of bandwidth
- Disadvantages
  - dc component
  - lack of synchronization capability

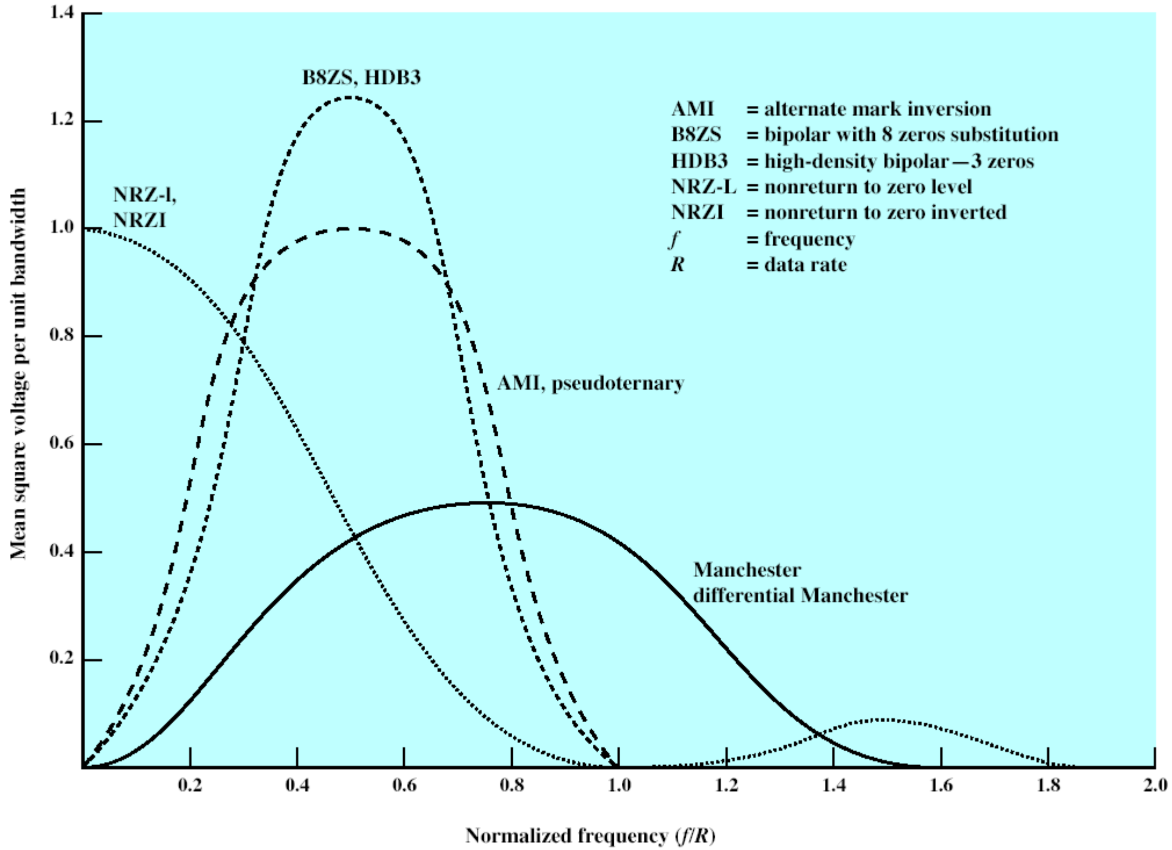


Figure 5.3 Spectral Density of Various Signal Encoding Schemes

- Unattractive for signal transmission applications

Multilevel Binary
Bipolar Alternate Mark Inversion (AMI)

- Use more than two levels (three levels, positive, negative and no line signal)
- Bipolar-AMI
  - zero represented by no line signal
  - one represented by positive or negative pulse
  - one pulses alternate in polarity
  - no loss of sync if a long string of ones
  - long runs of zeros still a problem
  - no net dc component
  - lower bandwidth
  - easy error detection

QAM Variants

- Two level ASK (two different amplitude levels)
  - each of two streams in one of two states
  - four state system
  - essentially QPSK
- Four level ASK (four different amplitude levels)
  - combined stream in one of 16 states
- Have 64 and 256 state systems
- Improved data rate for given bandwidth
  - but increased potential error rate