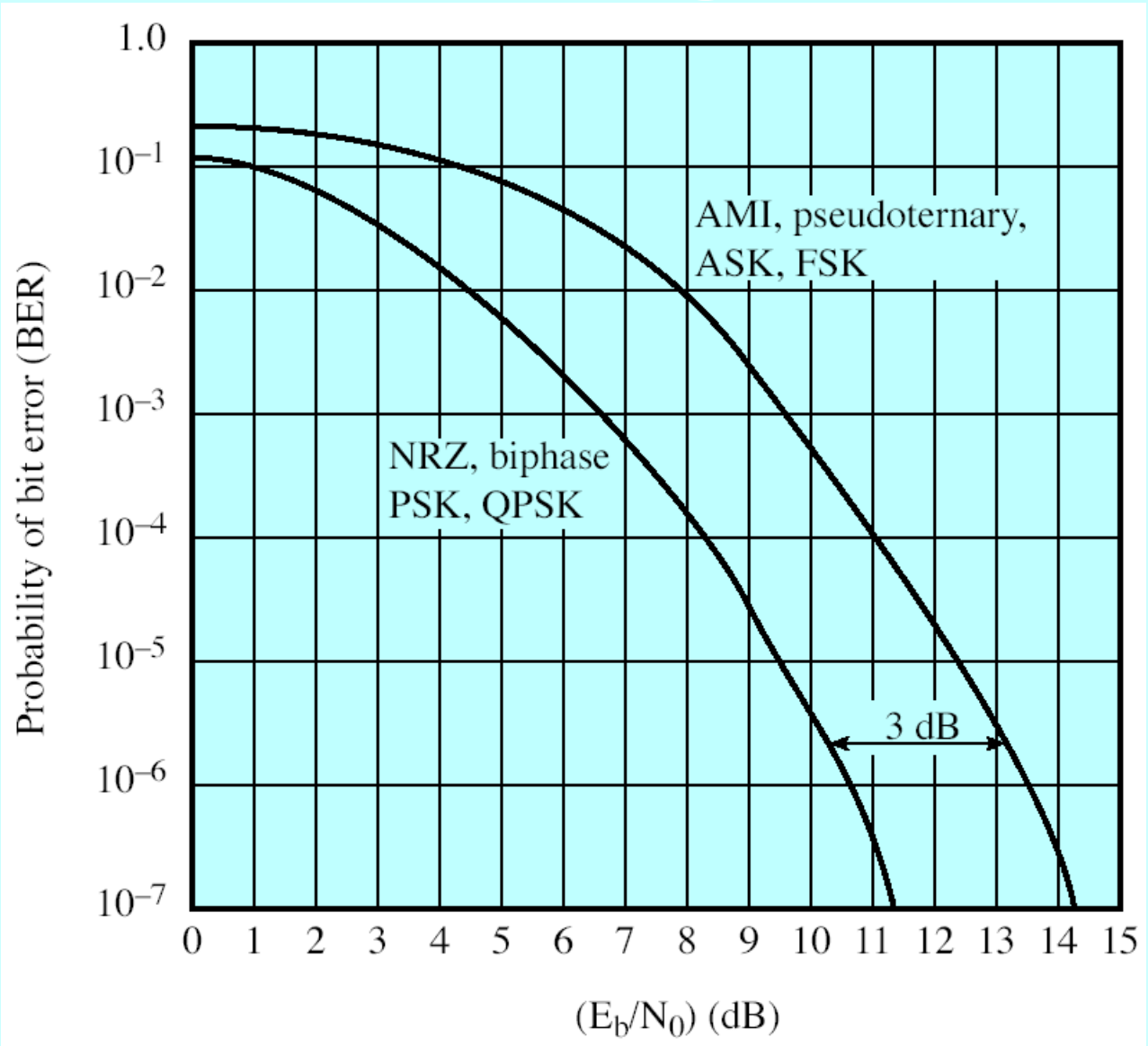
Multilevel Binary
Pseudoternary

- Binary one represented by absence of line signal
- Binary zero represented by alternating positive and negative pulses
- No advantage or disadvantage over bipolar-AMI
- Each used in some applications

Multilevel Binary Issues

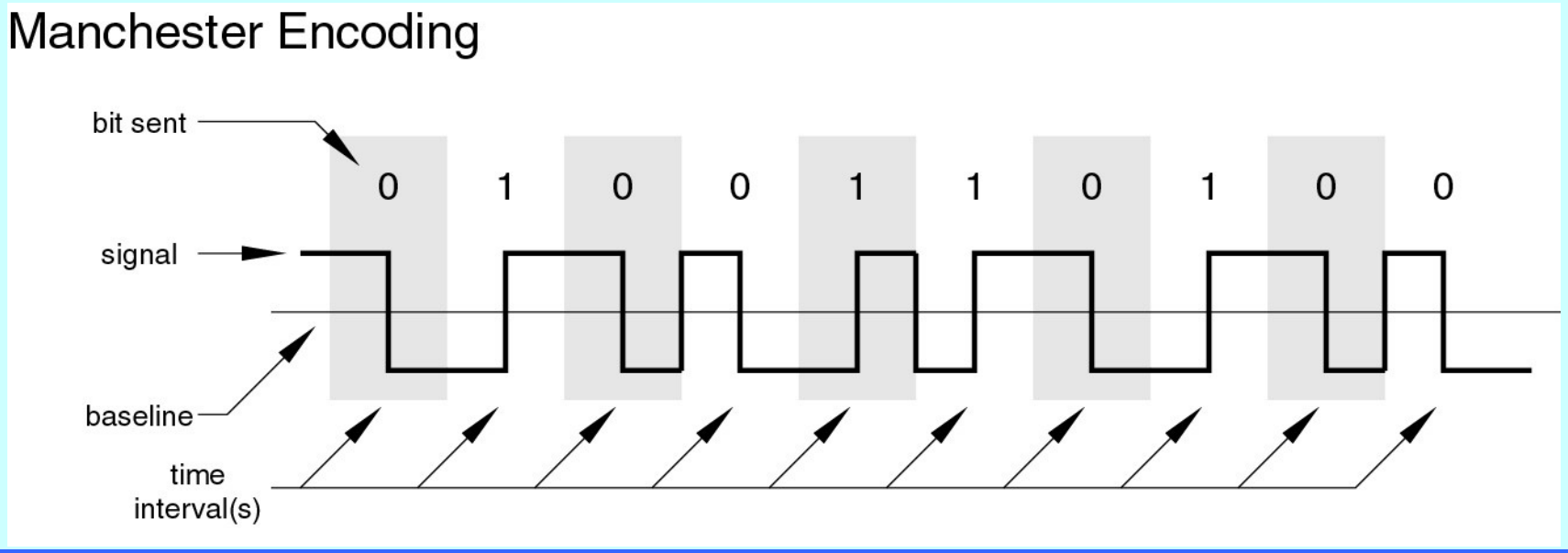
- Advantages:
  - No loss of synchronization if a long string of 1's occurs, each introduce a transition, and the receiver can resynchronize on that transition
  - No net dc component, as the 1 signal alternate in voltage from negative to positive
  - Less bandwidth than NRZ
  - Pulse alternating provides a simple mean for error detection
- Disadvantages
  - receiver distinguishes between three levels: +A, -A, 0
  - a 3 level system could represent $\log_2 3 = 1.58$ bits
  - requires approx. 3dB more signal power for same probability of bit error

Theoretical Bit Error Rate (BER) For Various Encoding Schemes



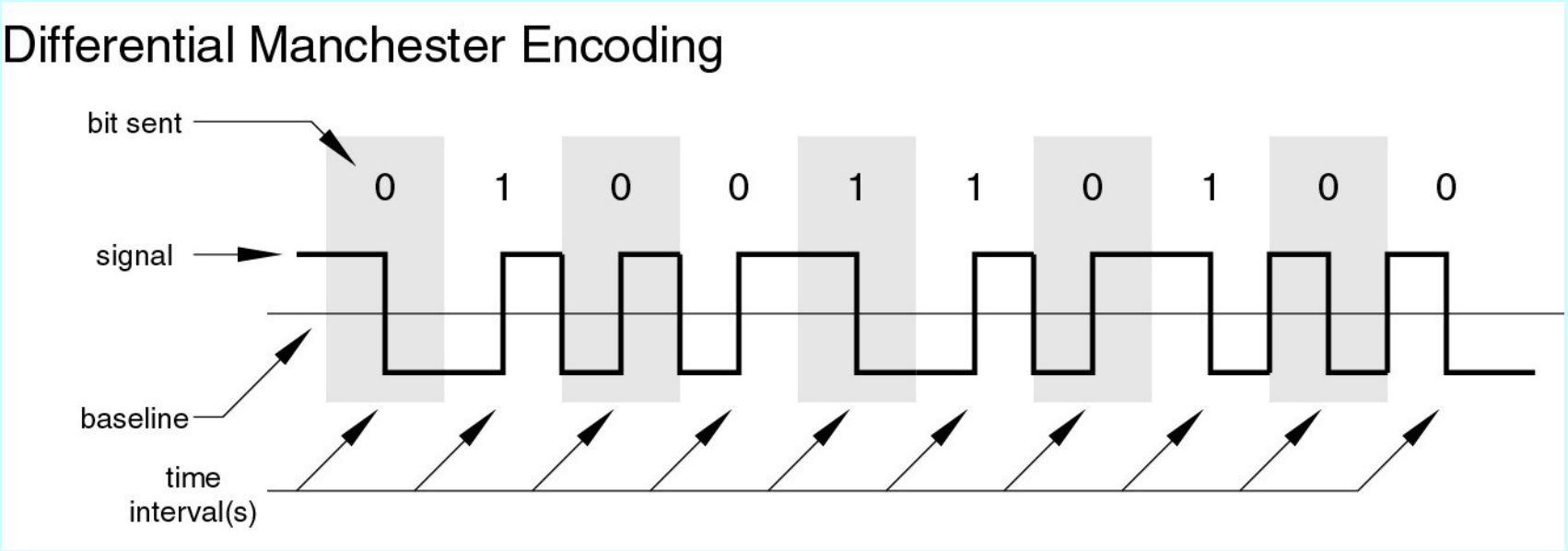
Manchester Encoding

- has transition in middle of each bit period
- low to high represents binary one
- transition serves as clock and data
- high to low represents binary zero
- used by IEEE 802.3 (Ethernet) LAN standard



Differential Manchester Encoding

- midbit transition is clocking only
- transition at start of bit period representing binary 0
- no transition at start of bit period representing binary 1
- used by IEEE 802.5 token ring LAN



Advantages and disadvantages of Manchester Encoding

- Disadvantages
  - at least one transition per bit time and possibly two
  - maximum modulation rate is twice NRZ

$$D = \frac{R}{L}$$

D : $Modulation\ \ rate, [baud]$

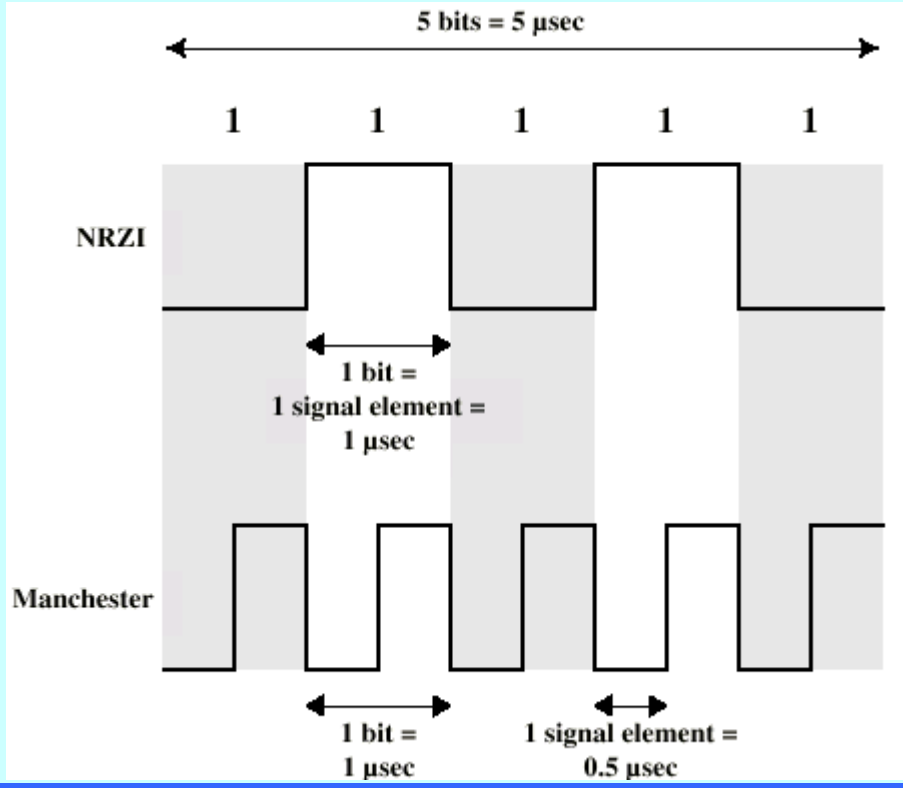
R : $Data\ \ Rate, \ [bps]$

L : $number\ of\ \ bits\ \ per\ \ signal\ \ elements$

  - requires more bandwidth
- Advantages
  - synchronization on mid bit transition (self clocking codes)
  - has no dc component
  - has error detection capability (the absence of an expected transition can be used to detect errors)

Modulation Rate versus Data Rate

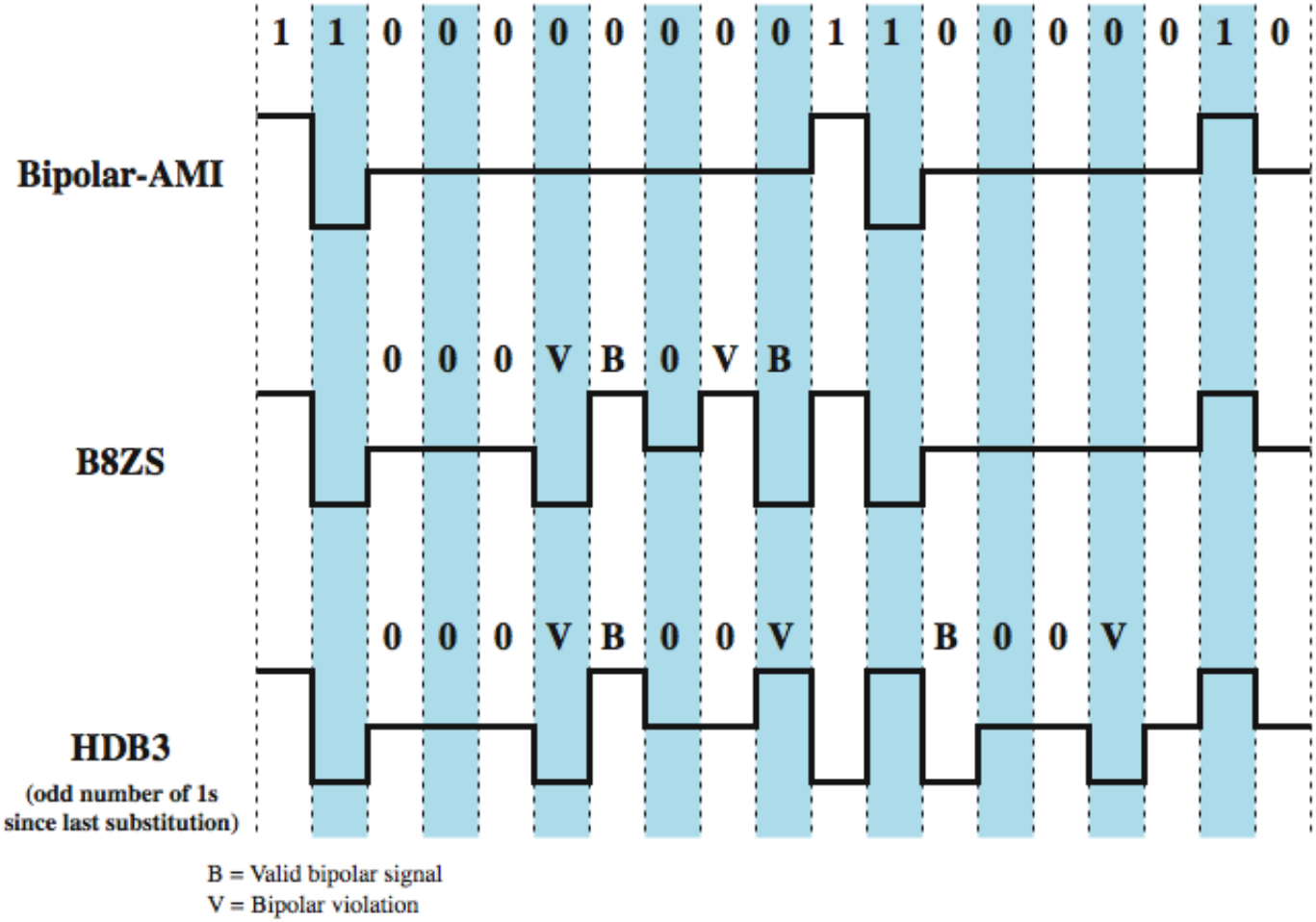
- Data rate (expressed in bps)
  - Data rate or bit rate $R=1/T_b=1/1\mu s=1Mbps$
- Modulation Rate (expressed in baud) is the rate at which signal elements are generated
  - Maximum modulation rate for Manchester is $D=1/(0.5T_b)=2/1\mu s=2Mbaud$



Scrambling

- Use scrambling to replace sequences that would produce constant voltage
- These filling sequences must
  - produce enough transitions to maintain synchronization
  - be recognized by receiver & replaced with original
  - be same length as original
- Design goals
  - have no dc component
  - have no long sequences of zero level line signal
  - have no reduction in data rate
  - give error detection capability

B8ZS and HDB3



Bipolar with 8-Zero Substitution (B8ZS)

- To overcome the drawback of the AMI code that a long string of zeros may result in loss of synchronization, the encoding is amended with the following rules:
  - If 8 zeros occurs and the last voltage pulse was positive, then the 8 zeros are encoded as 000+–0–+
  - If zeros occurs and the last voltage pulse was negative, then the 8 zeros are encoded as 000–+0+–

High Density Bipolar-3 zeros (HDB3)

- The scheme replaces strings with 4 zeros by sequences containing one or two pulses
- In each case, the fourth zero is replaced with a code violation (V)
- successive violations are of alternate polarity

Table 5.4 HDB3 Substitution Rules

	Number of Bipolar Pulses (ones) since Last Substitution	
Polarity of Preceding Pulse	**Odd**	**Even**
–	000–	+00+
+	000+	–00–

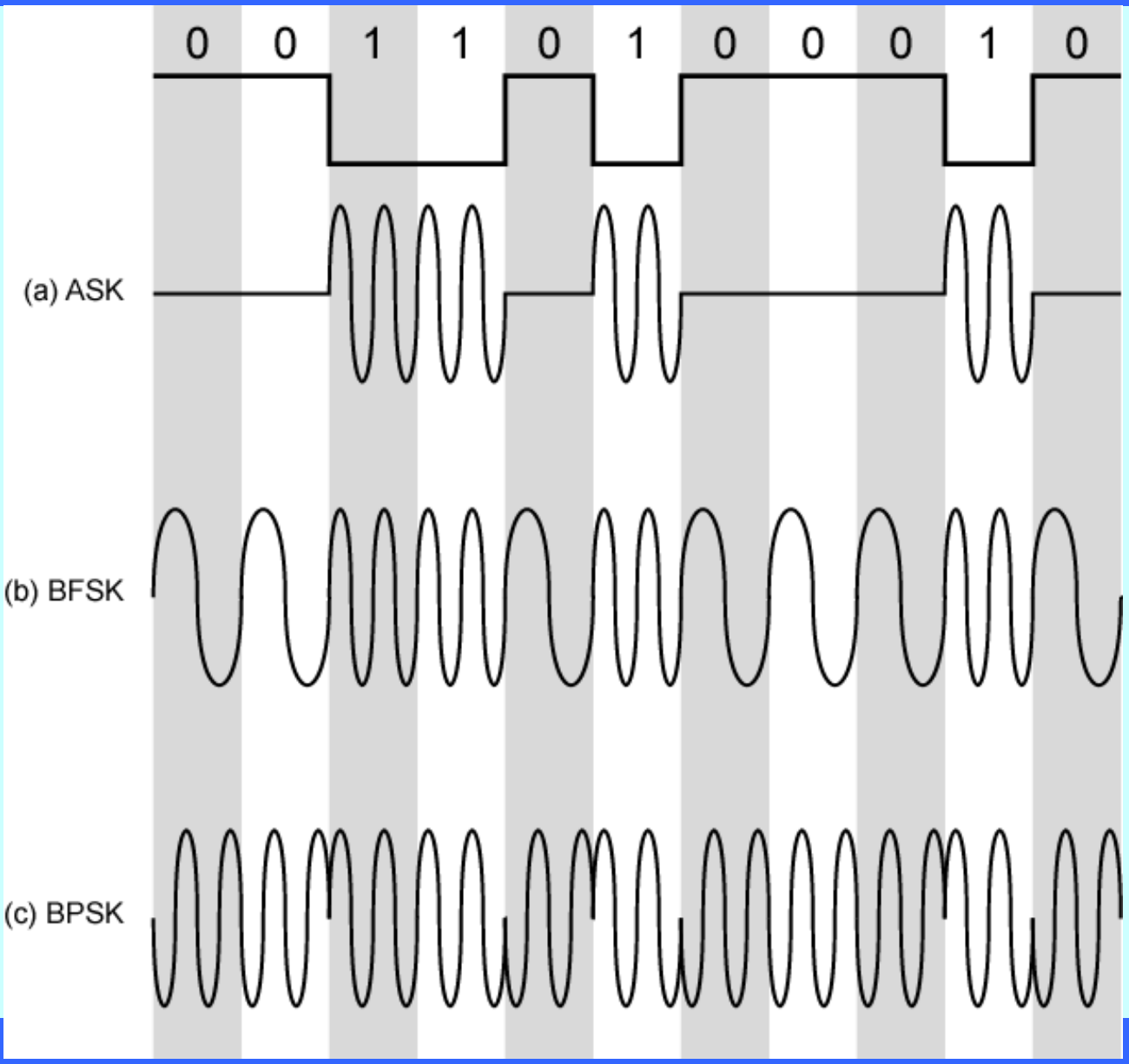
Digital Data, Analog Signal

- Main use is public telephone system
  - has freq range of 300Hz to 3400Hz
  - use modem (modulator-demodulator)
- The digital data modulates the amplitude A, frequency f_c, or phase θ of a carrier signal

$$A\cos(2\pi f_c t + \theta)$$

- Modulation techniques
  - Amplitude Shift Keying (ASK)
  - Frequency Shift Keying (FSK)
  - Phase Shift Keying (PSK)

Modulation Techniques



Amplitude Shift Keying (ASK)

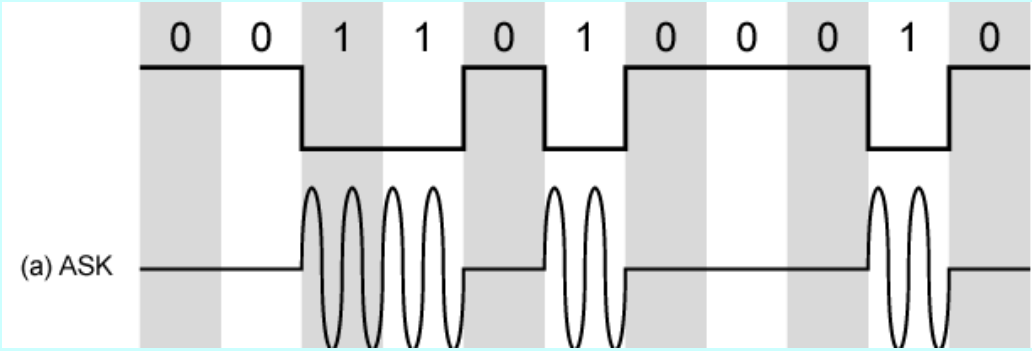
Binary Frequency Shift Keying (BFSK)

Binary Phase Shift Keying (BPSK)

Amplitude Shift Keying (ASK)

- In ASK, the two binary values are represented by to different amplitudes of the carrier frequency
- The resulting modulated signal for one bit time is

$$s(t) = \begin{cases} A\cos(2\pi f_c t), & binary\ 1 \\ 0, & binary\ 0 \end{cases}$$

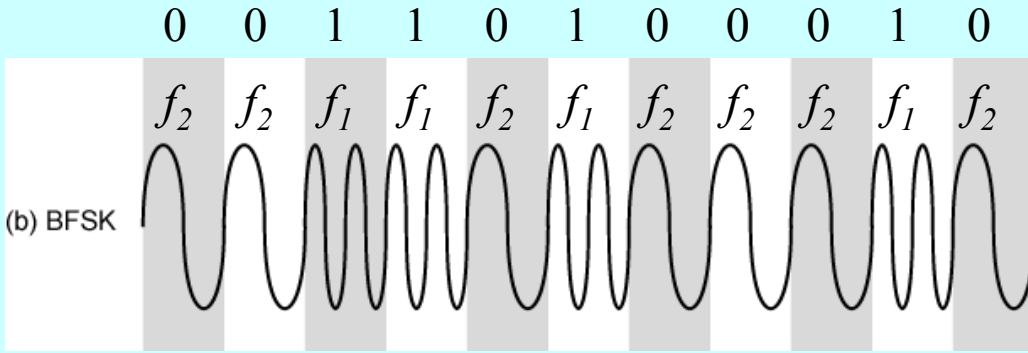


- Susceptible to noise
- Inefficient modulation technique
- used for
  - up to 1200bps on voice grade lines
  - very high speeds over optical fiber

Binary Frequency Shift Keying (BFSK)

- The most common form of FSK is Binary FSK (BFSK)
- Two binary values represented by two different frequencies (f_1 and f_2)

$$s(t) = \begin{cases} A\cos(2\pi f_1 t), & binary\ 1 \\ A\cos(2\pi f_2 t), & binary\ 0 \end{cases}$$



- less susceptible to noise than ASK
- used for
  - up to 1200bps on voice grade lines
  - high frequency radio (3 to 30MHz)
  - even higher frequency on LANs using coaxial cable