Signal Encoding Techniques

CHAPTER 5

SIGNAL ENCODING TECHNIQUES

- Digital data, digital signal
- Analog data, digital signal
- Digital data, analog signal
- Analog data, analog signal

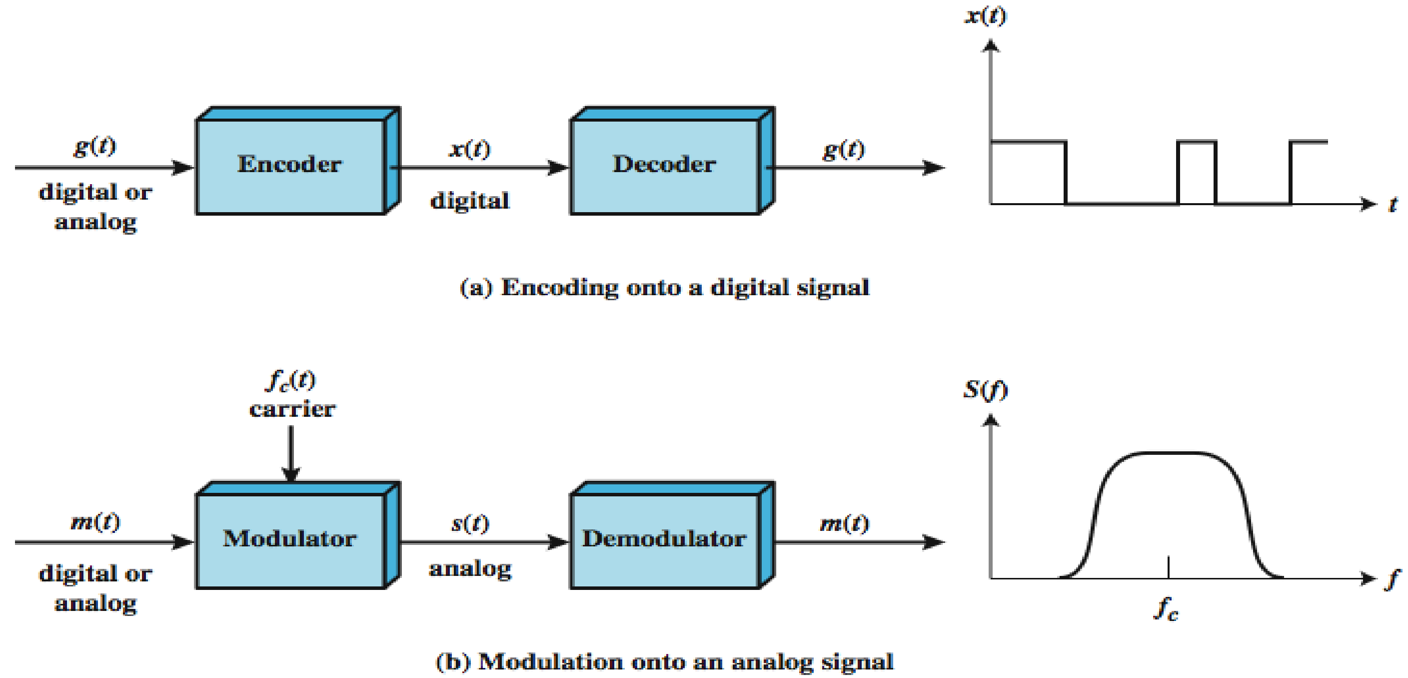


Figure 5.1 Encoding and Modulation Techniques

DIGITAL DATA, DIGITAL SIGNAL

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

LINE CODING

- **Data** as well as **signals** that represents data can either be digital or analog.

- **Line coding** is the process of converting **digital data to digital signals**. By below mention techniques we converts a sequence of bits to a digital signal.

- At the sender side digital data are encoded into a digital signal and at the receiver side the digital data are recreated by decoding the digital signal.

- We can roughly divide line coding schemes into five categories:
  1. Unipolar (eg. NRZ scheme).
  2. Polar (eg. NRZ-L, NRZ-I, RZ, and Biphase – Manchester and differential Manchester).
  3. Bipolar (eg. AMI and Pseudoternary).
  4. Multilevel
  5. Multitransition

SOME TERMS

- **Unipolar** - signal elements have the same sign
- **Polar** - One logic state represented by positive voltage, other by negative
- **Data Signaling or Data rate**
  - Rate of data transmission measured in bps: bits per second
- **duration or length of a bit**
  - Time taken for transmitter to emit the bit
- **modulation rate:**
  - Rate at which the signal level changes
  - Measured in baud: signal elements per second
- **mark and space**

INTERPRETING DIGITAL SIGNALS

- Receiver needs 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 – affects performance

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

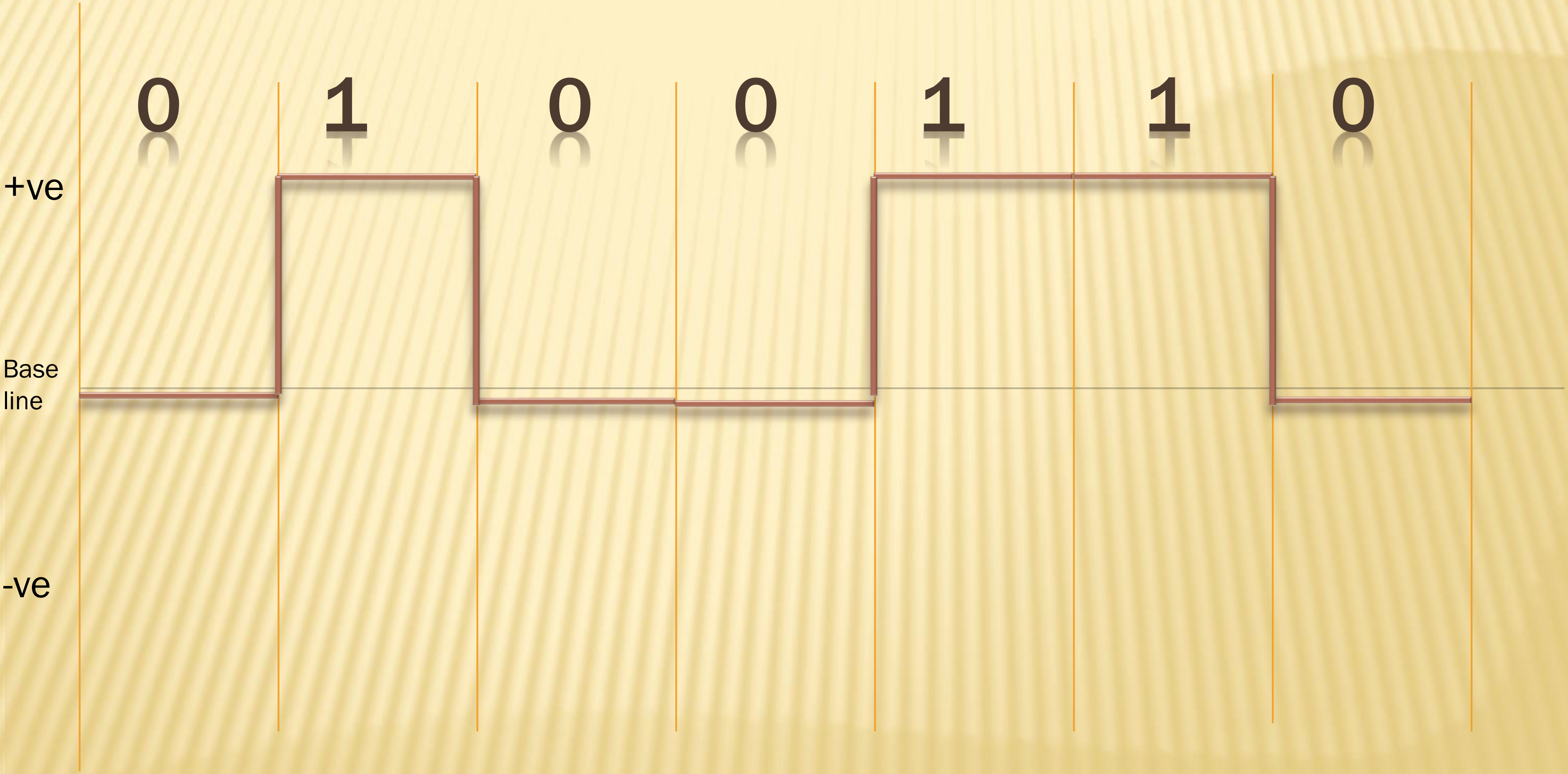
HDB3

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

COMPARISON OF ENCODING SCHEMES

- signal spectrum
- clocking
- error detection
- signal interference and noise immunity
- cost and complexity

Unipolar

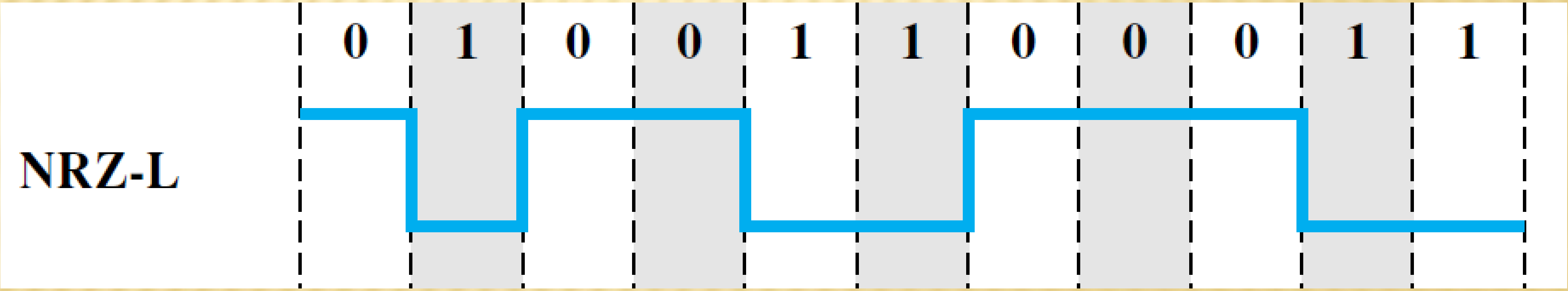


ENCODING SCHEMES

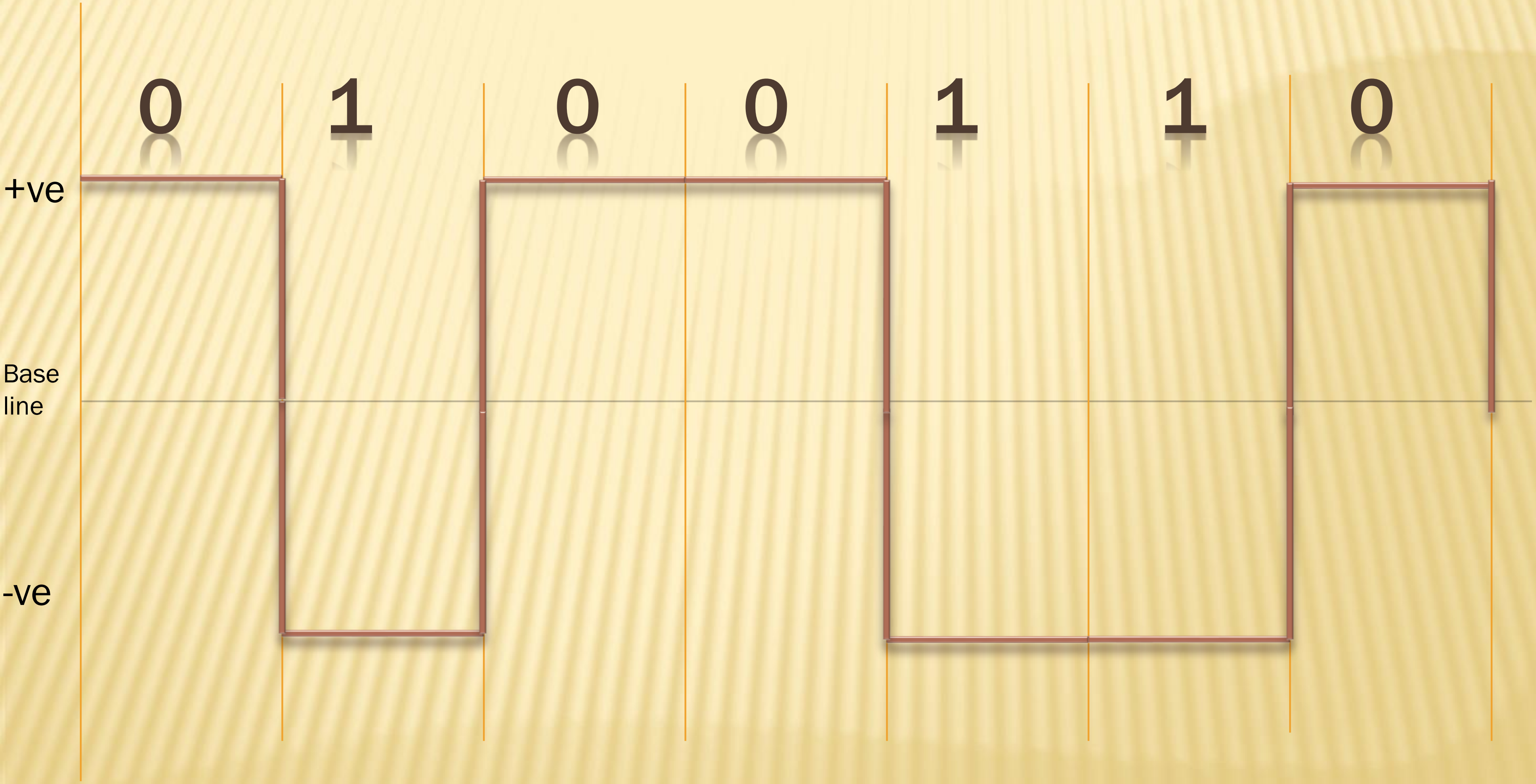
- **Nonreturn to Zero (NRZ)**
  - Nonreturn to Zero-Level (NRZ-L)
  - Nonreturn to Zero Inverted (NRZI)
- **Multilevel Binary**
  - Bipolar-AMI
  - Pseudoternary
- **Biphase**
  - Manchester
  - Differential Manchester
- **Scrambling techniques**
  - B8ZS
  - HDB3

NONRETURN TO ZERO-LEVEL (NRZ-L)

- two different voltages for 0 and 1 bits
- voltage constant during bit interval
  - negative voltage for one value and positive for the other

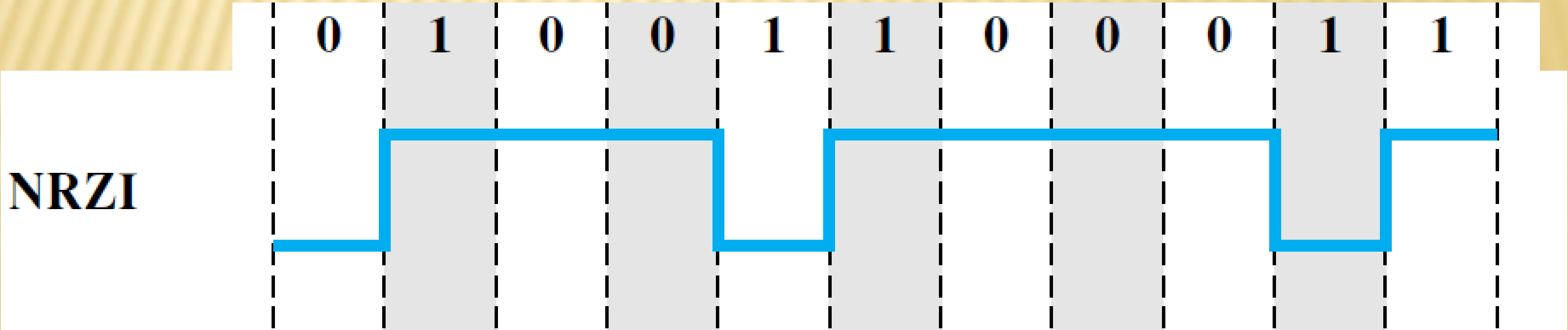


Nonreturn to Zero level (NRZ-L)

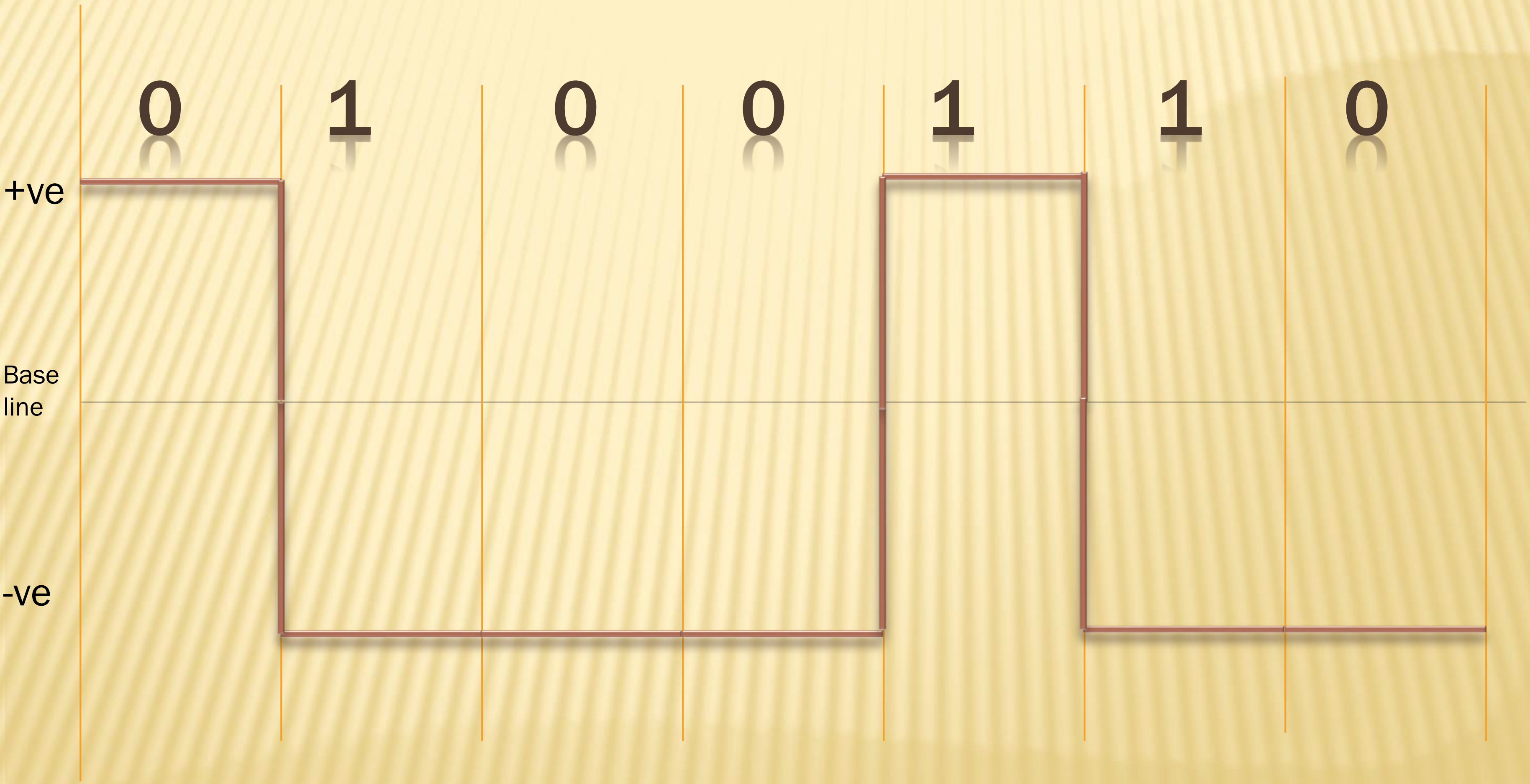


NONRETURN TO ZERO INVERTED

- Non-return 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
  - data is represented by changes rather than levels
  - more reliable detection of transition rather than level
  - easy to lose sense of polarity in twisted-pair line (for NRZ-L)



Nonreturn to Zero Inverted (NRZI)

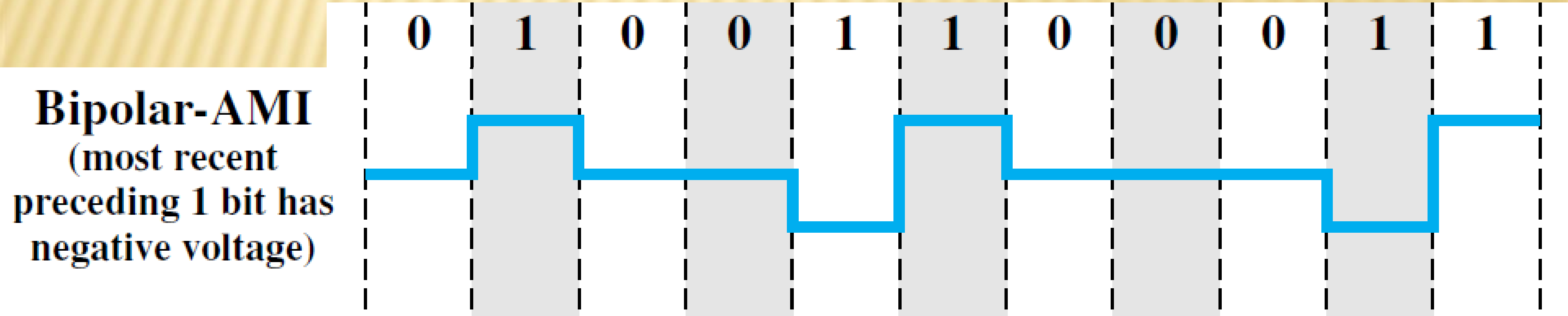


NRZ PROS & CONS

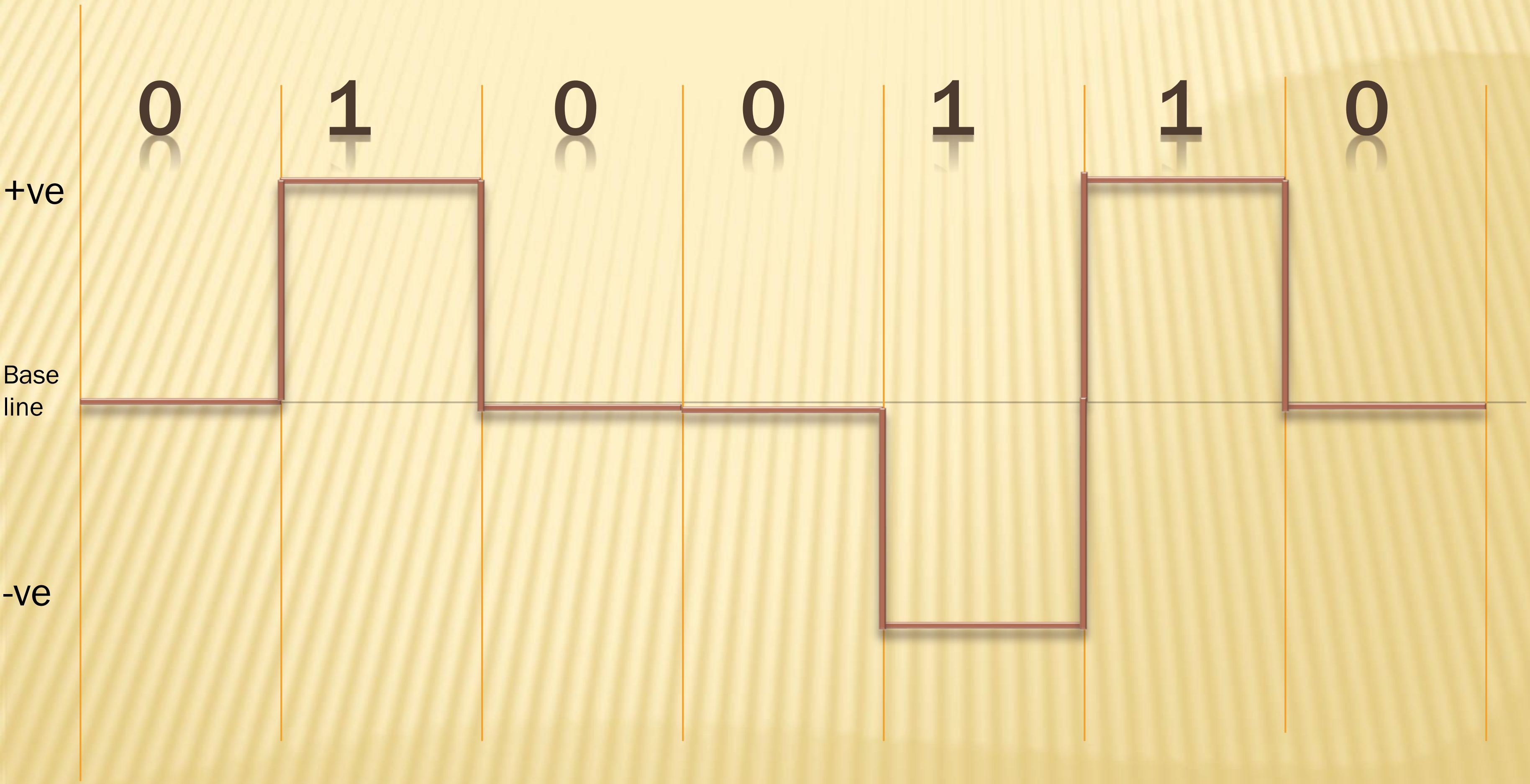
- Pros
  - easy to engineer
  - make good use of bandwidth
- Cons
  - dc component
  - lack of synchronization capability
- used for magnetic recording
- not often used for signal transmission

MULTILEVEL BINARY: BIPOLAR-AMI

- Use more than two levels
- Bipolar-AMI
  - zero represented by no line signal
  - one represented by positive or negative pulse
  - ‘One’ pulses alternately 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



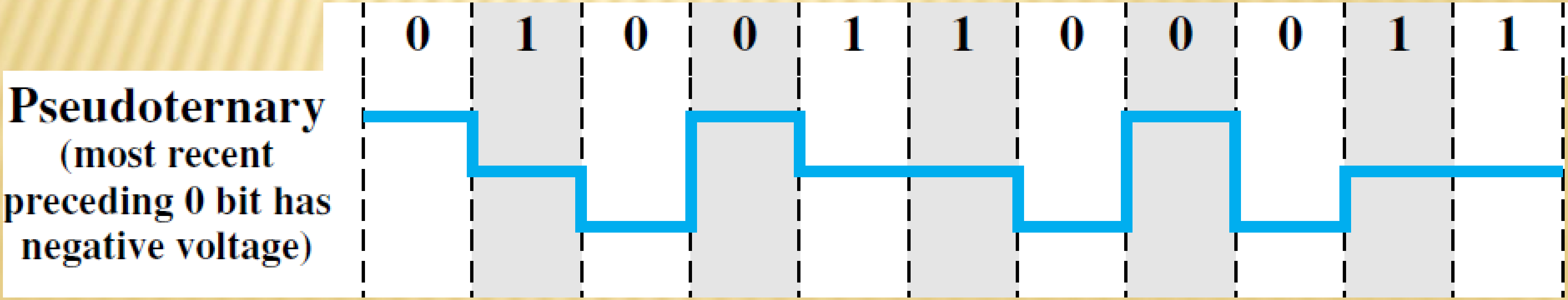
Bipolar(Alternate mark inversion (AMI))



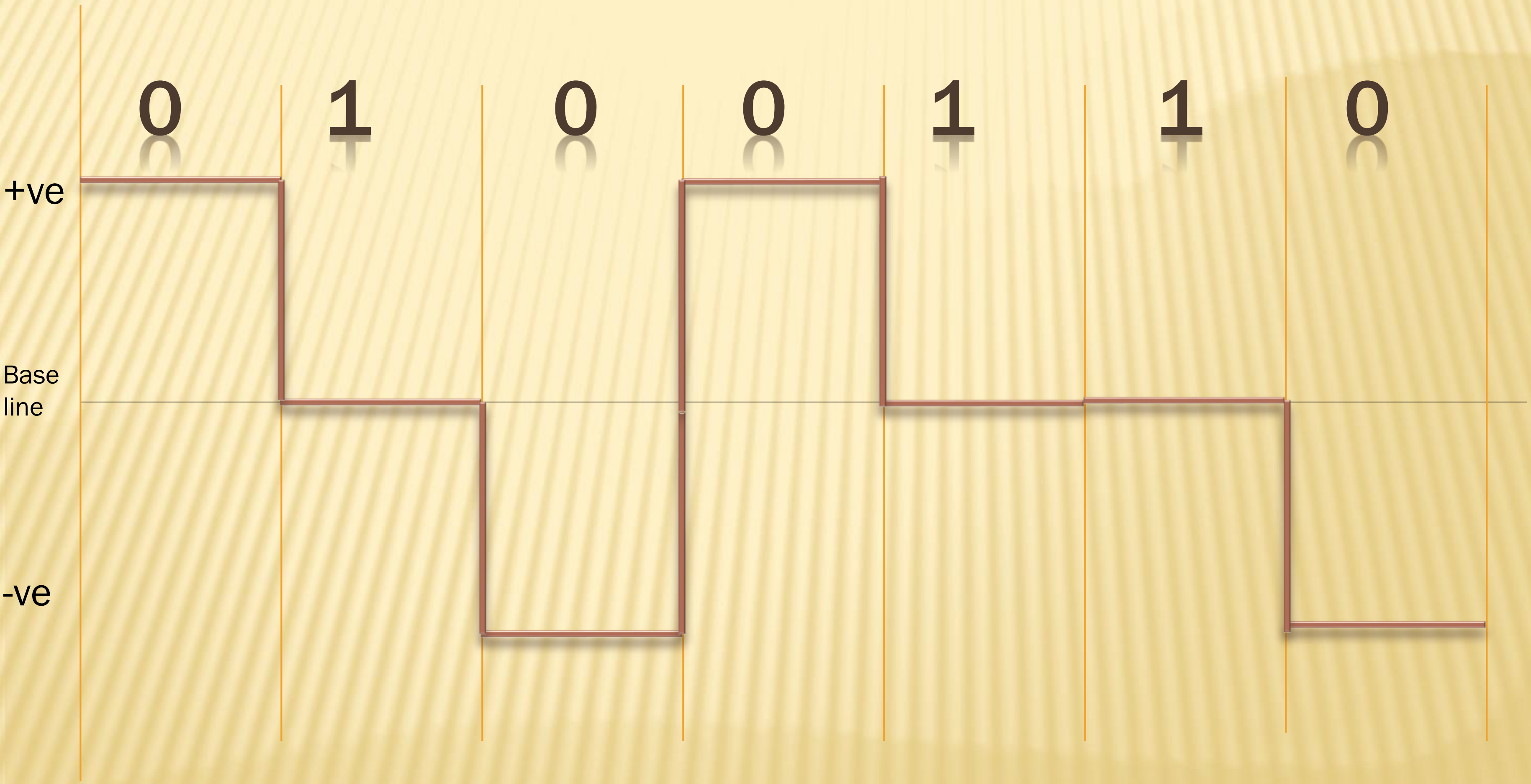
Most recent preceding 1 bit has negative Voltage

MULTILEVEL BINARY: PSEUDOTERNARY

- one represented by absence of line signal
- zero represented by alternating positive and negative
- no advantage or disadvantage over bipolar-AMI
- each used in some applications



Bipolar(Pseudo ternary)



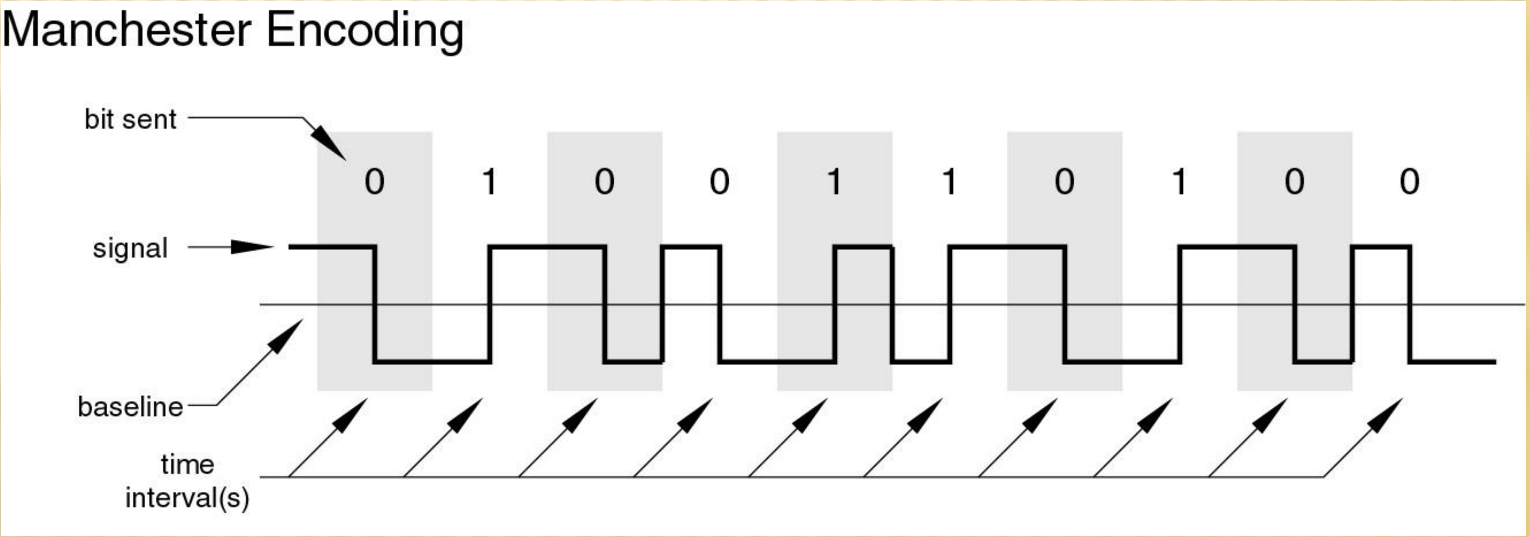
Most recent preceding 0 bit has negative Voltage

MULTILEVEL BINARY ISSUES

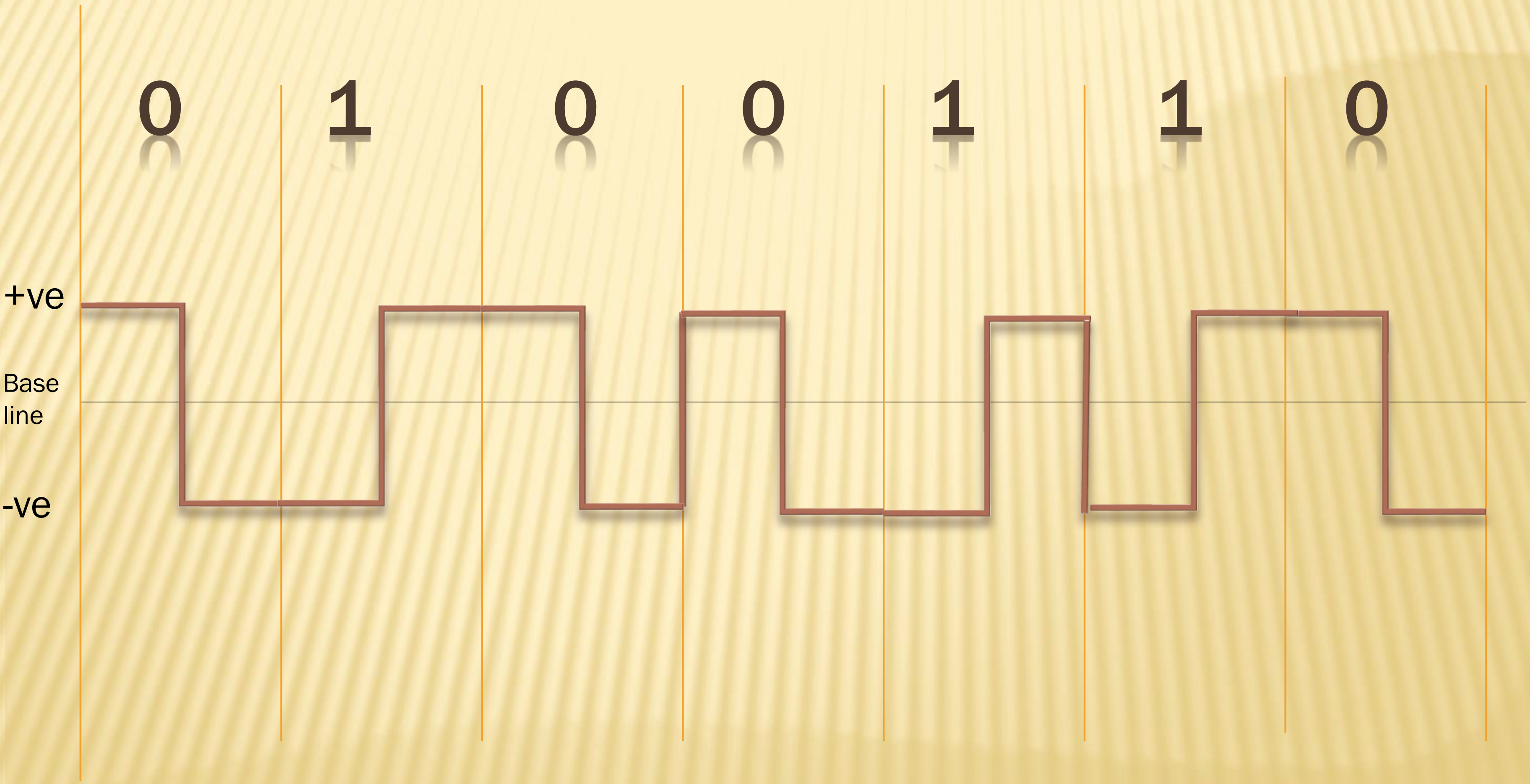
- not as efficient as NRZ because of the following:
  - each signal element only represents one bit
    - receiver distinguishes between three levels: +A, -A, 0
  - a 3 level system could represent $\log_2 3 = 1.58$ bits
- Bit error rate for NRZ at given SNR ratio is significantly less than multilevel binary.

BIPHASE: MANCHESTER ENCODING

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



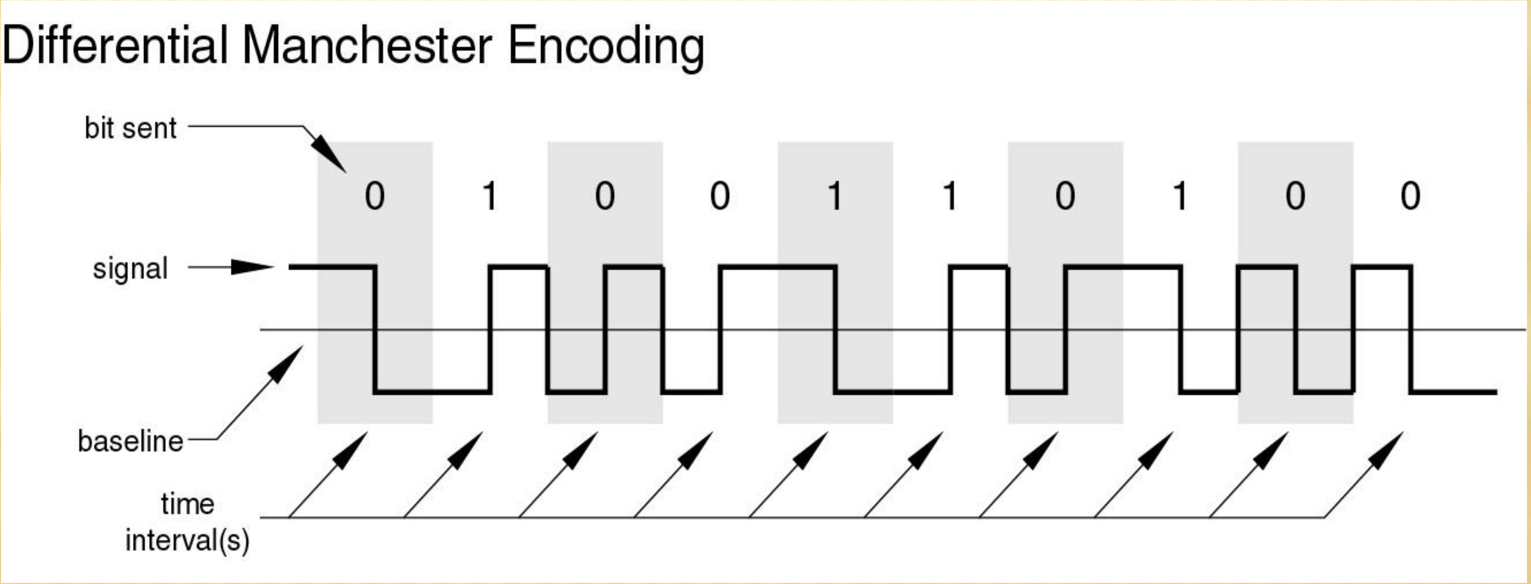
Manchester



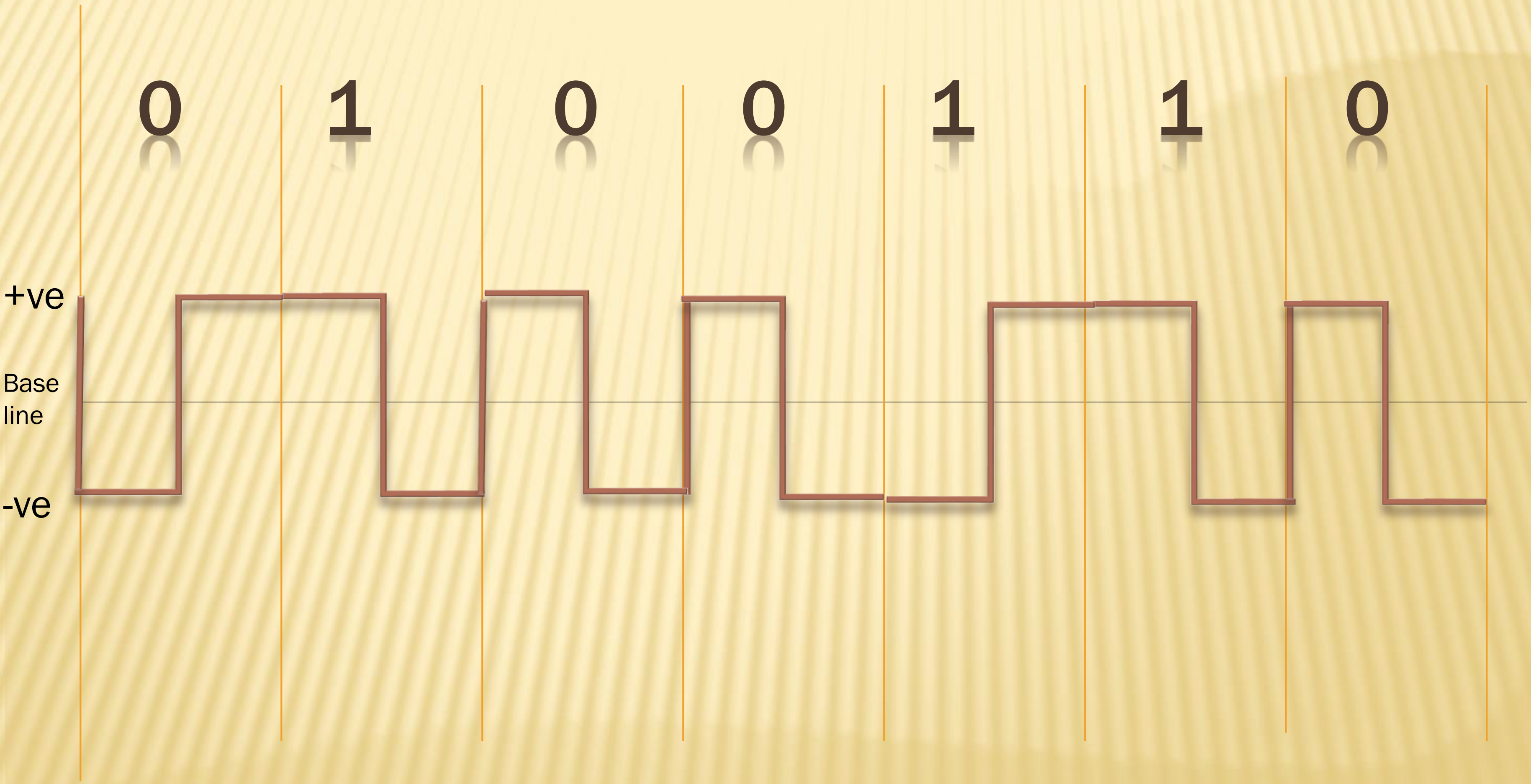
Voltage started from positive side

DIFFERENTIAL MANCHESTER ENCODING

- Mid-bit transition is clocking only
- transition at start of bit period representing 0
- no transition at start of bit period representing 1
  - this is a differential encoding scheme
- used by IEEE 802.5 (Token Ring LAN)



Differential Manchester

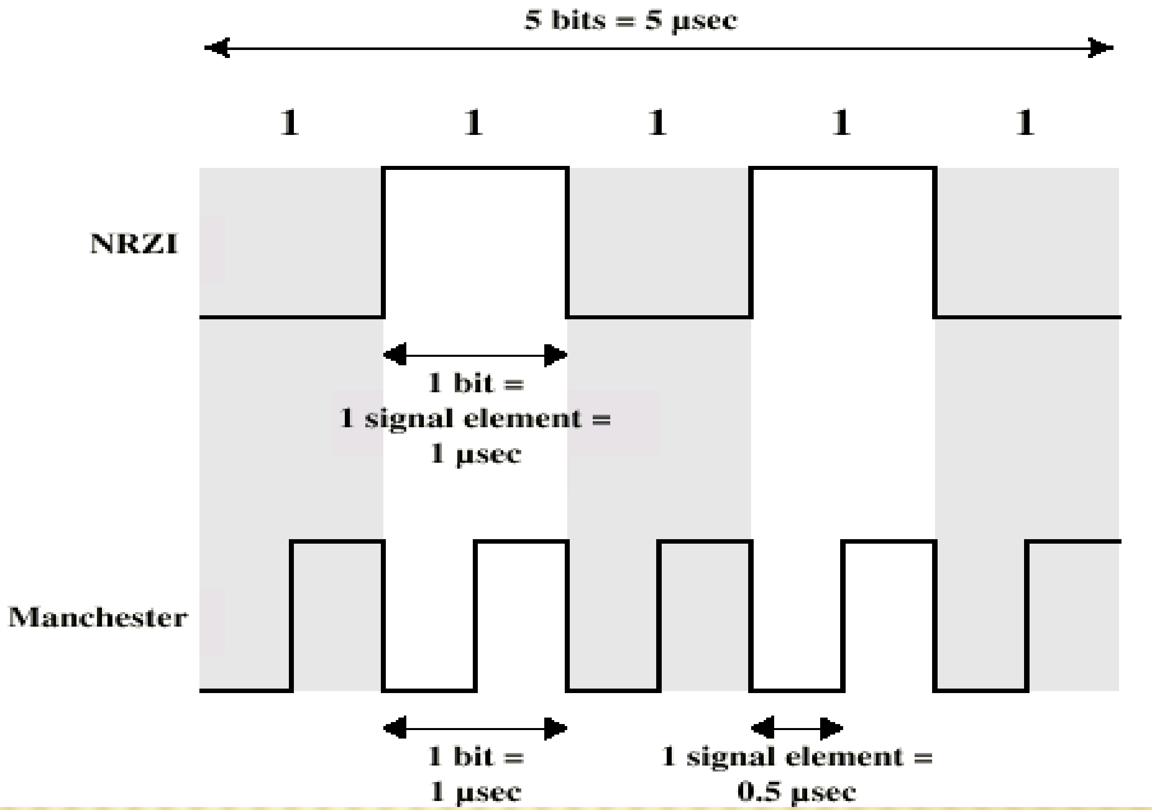


Voltage started from positive side

BIPHASE PROS AND CONS

- Con
  - at least one transition per bit time and possibly two
  - maximum modulation rate is twice NRZ
  - requires more bandwidth
- Pros
  - synchronization on mid bit transition (self clocking)
  - has no dc component
  - has error detection

MODULATION RATE



MODULATION RATE

$$D = \frac{R}{L} = \frac{R}{\log_2 M}$$

where

D = modulation rate, baud

R = data rate, bps

M = number of different signal elements = 2^L

L = number of bits per signal element

SCRAMBLING

- Use scrambling to replace sequences that would produce constant voltage
- Filling sequence
  - Must produce enough transitions to sync
  - Must be recognized by receiver and replace with original
  - Same length as original
- No dc component
- No long sequences of zero level line signal
- No reduction in data rate
- Error detection capability

B8ZS

- Bipolar With 8 Zeros Substitution
- Based on bipolar-AMI
- If octet of all zeros and last voltage pulse preceding was positive encode as 000+-0-+
- If octet of all zeros and last voltage pulse preceding was negative encode as 000-+0+-
- Causes two violations of AMI code
- Unlikely to occur as a result of noise
- Receiver detects and interprets as octet of all zeros

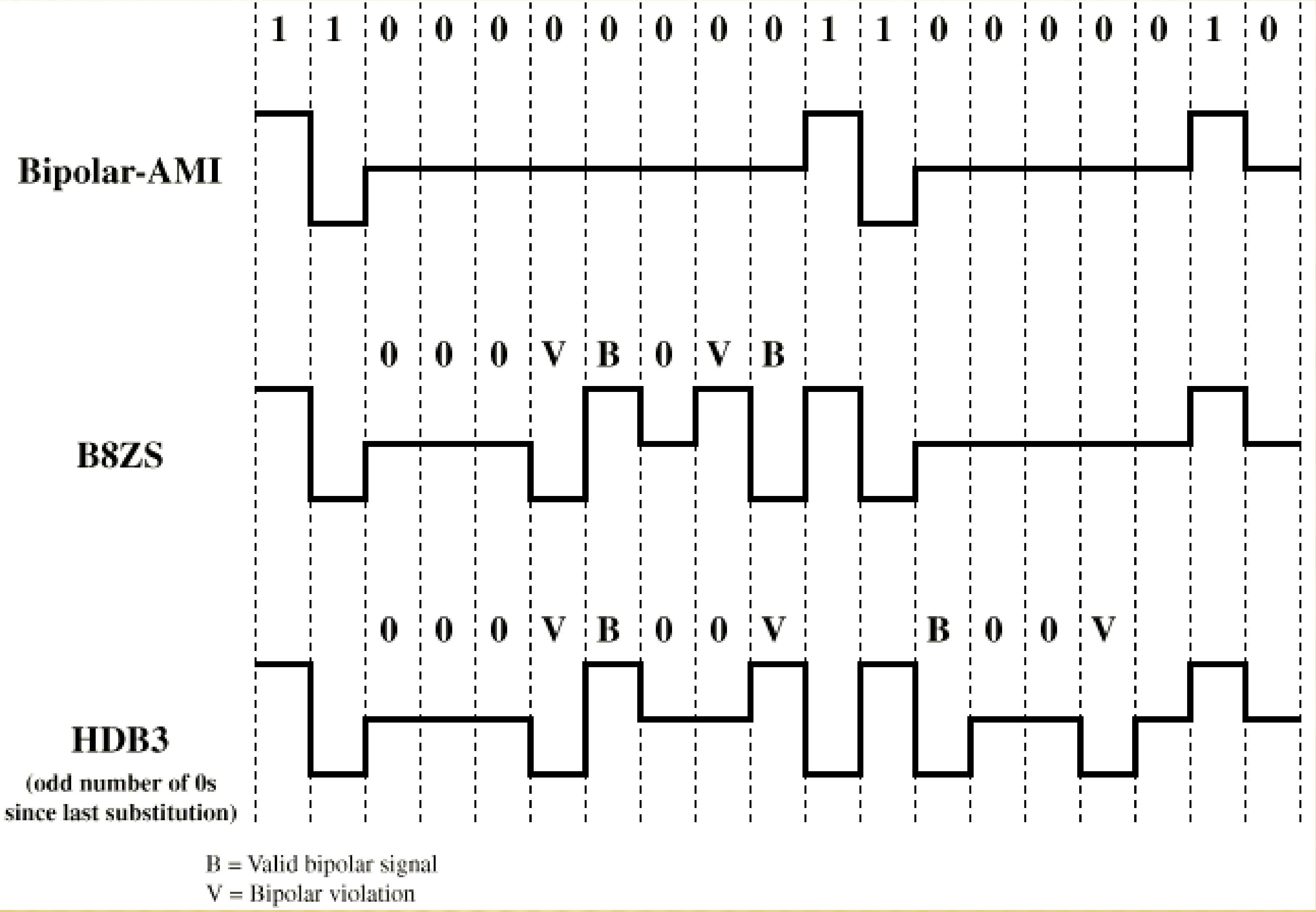
HDB3

- High Density Bipolar 3 Zeros
- Based on bipolar-AMI
- String of four zeros replaced with one or two pulses

HDB3 RULES

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

B8ZS AND HDB3



WHICH OF THE SIGNALS USE DIFFERENTIAL ENCODING?

For the bit stream 01001110, sketch the waveforms for each of the codes. Assume that the signal level for the preceding bit for NRZI was high; the most recent preceding 1 bit (AMI) has a negative voltage; and the most recent preceding 0 bit has a negative voltage (pseudoternary).