Data Communication

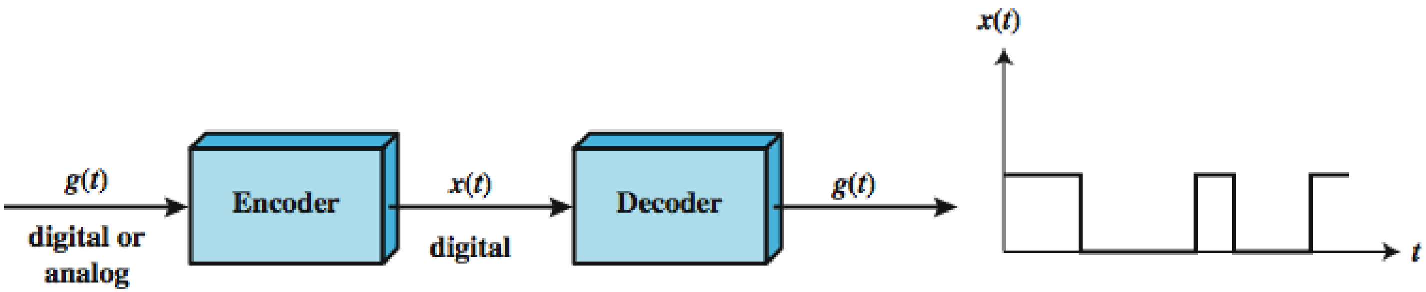
SİGNAL ENCODİNG TECHNİQUES

Signal Encoding Techniques

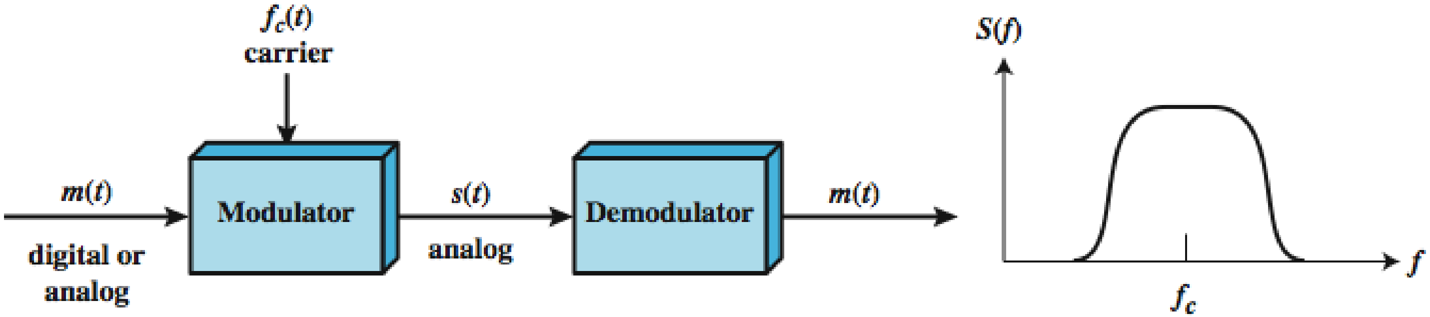
- Digital Communication
  - Digital Data, Digital Signal
  - Analog Data, Digital Signal

- Analog Communication
  - Digital Data, Analog Signal
  - Analog Data, Analog Signal

Signal Encoding Techniques



(a) Encoding onto a digital signal

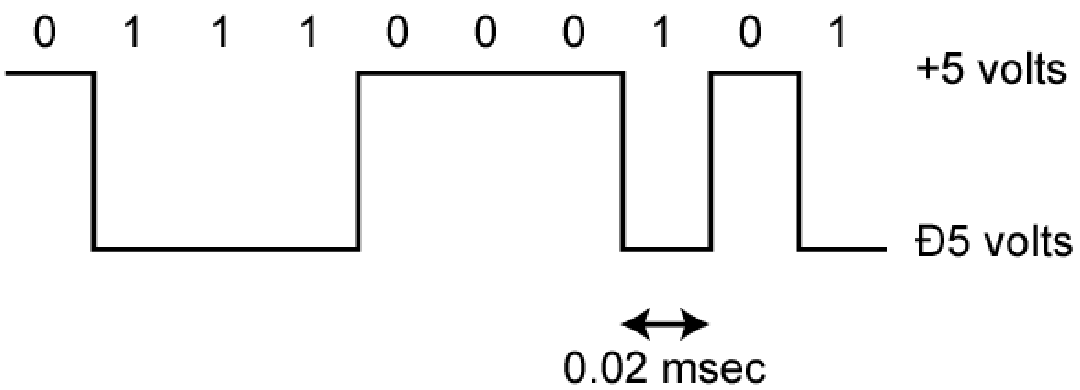


(b) Modulation onto an analog signal

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 (digital) encoded into signal elements

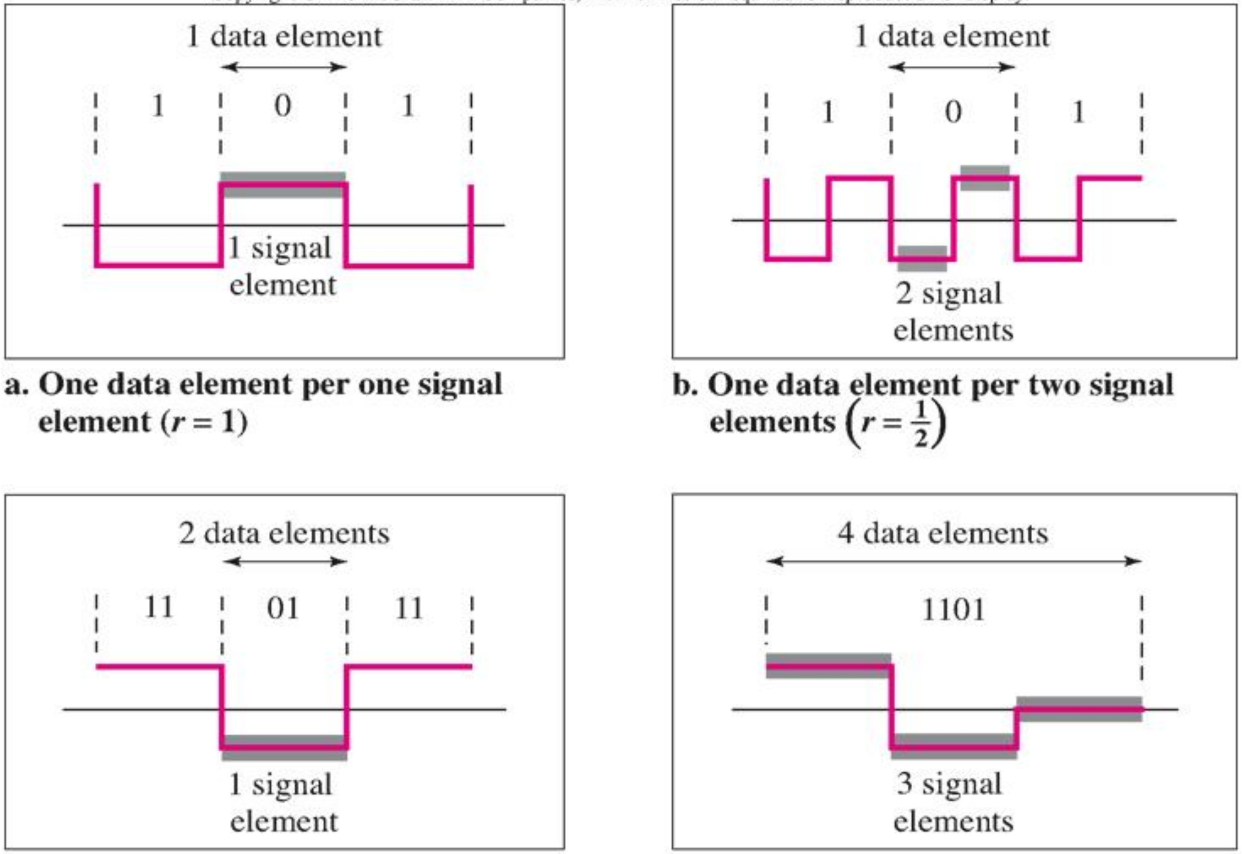


Bitrate and Baudrate

- **r,** represents the transmitted data bit counts by one signal

- **Nyquist bitrate**
  - **N = 2B $\log_2$L**
  - **N= 2 x B x r**

- **Baudrate (digital transmission)**
  - **S=1/2 x N x 1/r**



a. One data element per one signal element ($r = 1$)

b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$

c. Two data elements per one signal element ($r = 2$)

d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Some Terms

- Unipolar, *All signal elements have the same sign*
- Polar, *One logic state represented by positive voltage the other by negative voltage*
- data rate, (R) *transmission in bits per second*
- duration or length of a bit, *(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*
- mark and space

Interpreting Signals

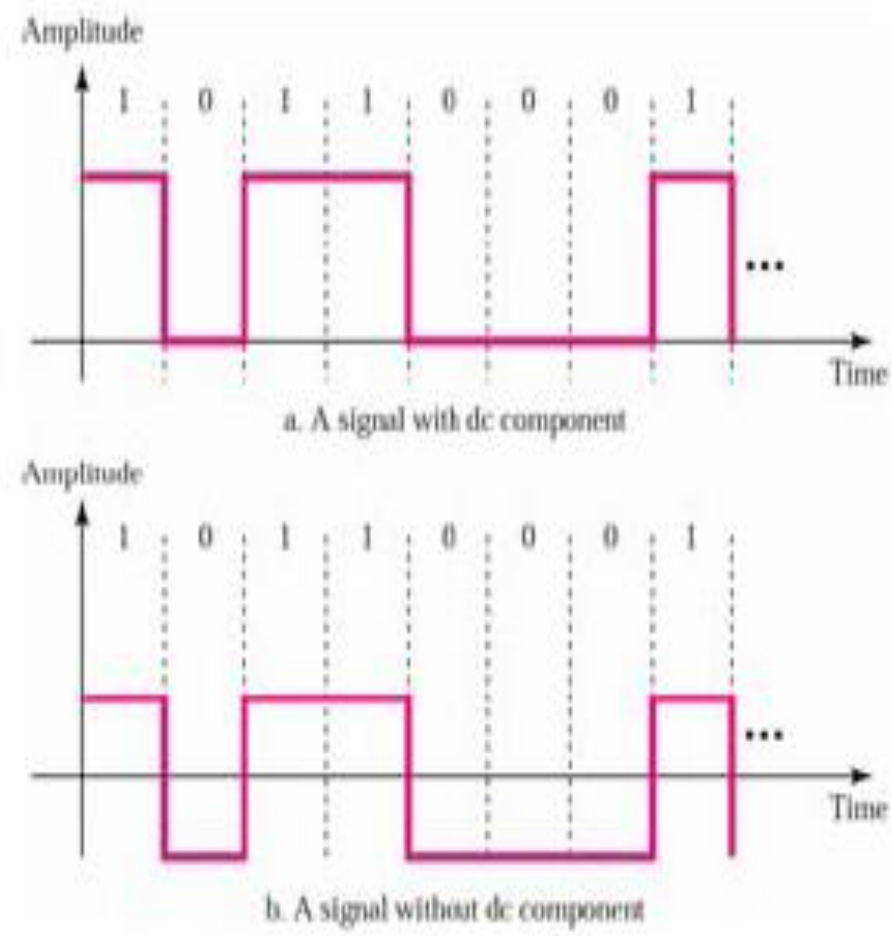
- need to know
  - timing of bits - when they start and end
  - signal levels
- factors affecting signal interpretation
  - signal to noise ratio
  - data rate
  - bandwidth
  - encoding scheme

Comparison of Encoding Schemes

- signal spectrum,
- Clocking, for synchronizing transmitter and receiver.
- error detection, useful if can be built
- signal interference and noise immunity
- cost and complexity

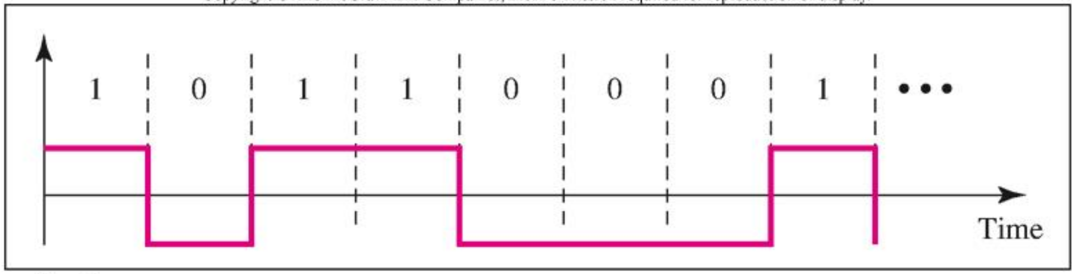
Digital Data Digital Signal Problems

- Long bit string of ones and zeros is a problem for sensing.
- If the duration of a signal is constant for a long time, it causes DC component. It is a problem for systems that don’t transmit low frequencies (Ex. Telephone lines don’t transmit frequencies below 200 Hz
- Coding Schemes must capable by these problems

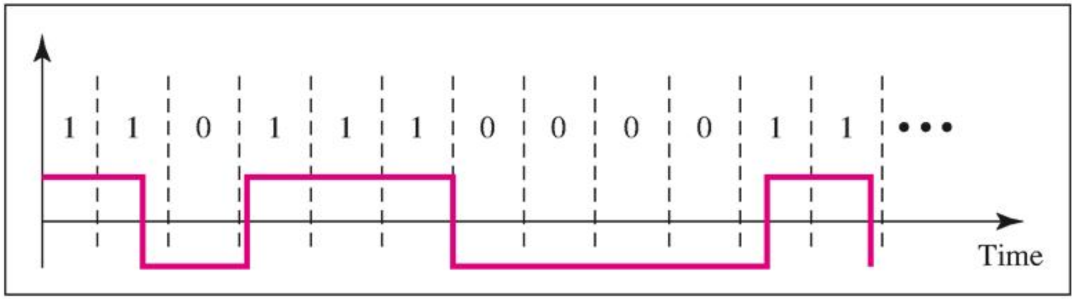


Digital Data Digital Signal Problems - 2

- Both sides must have same bit interval time (bitrate)
- Synchronization
  - Start and end delimeter problem (11111111)
  - It causes additional bits
    - 1111→11111
  - A new line or entegrated signal coding can solve this problem.

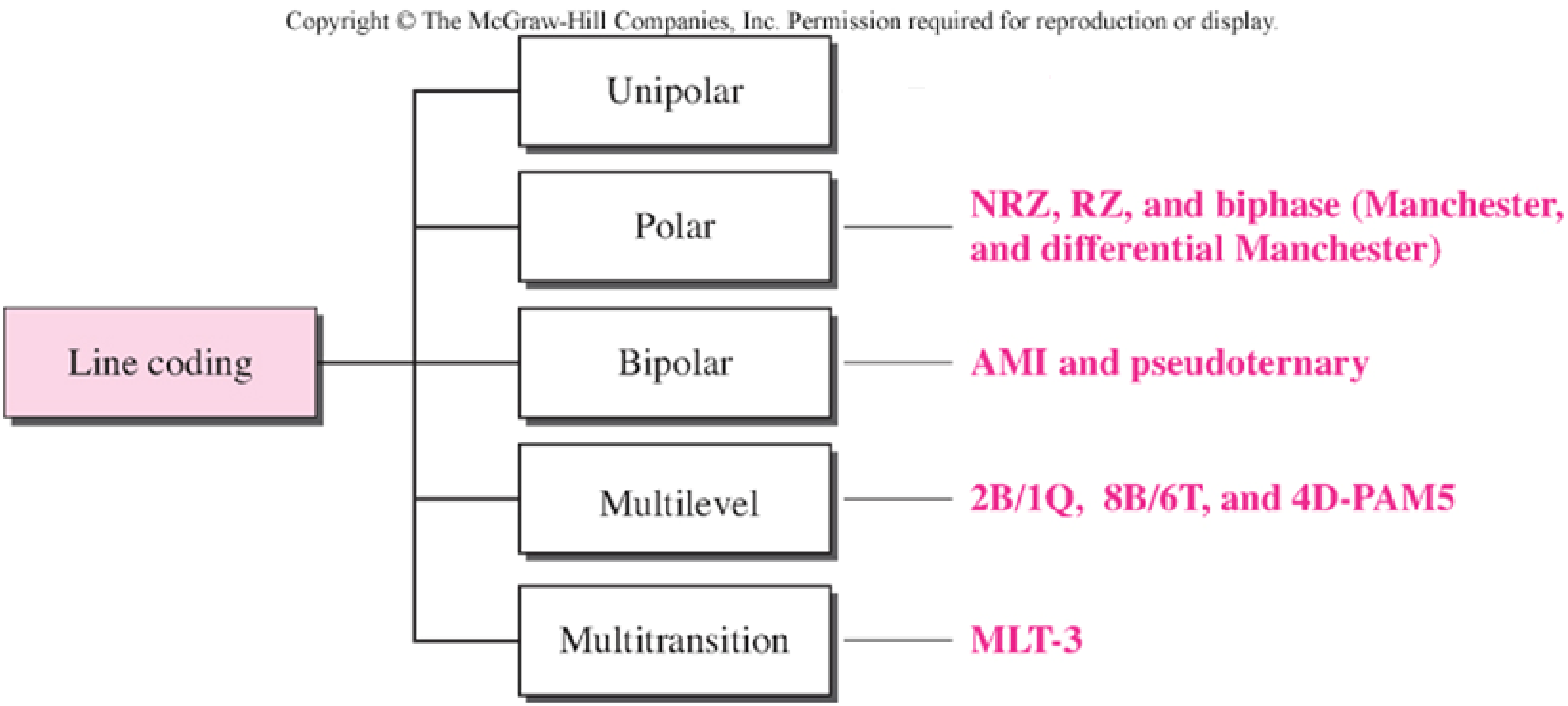


a. Sent



b. Received

Line Coding



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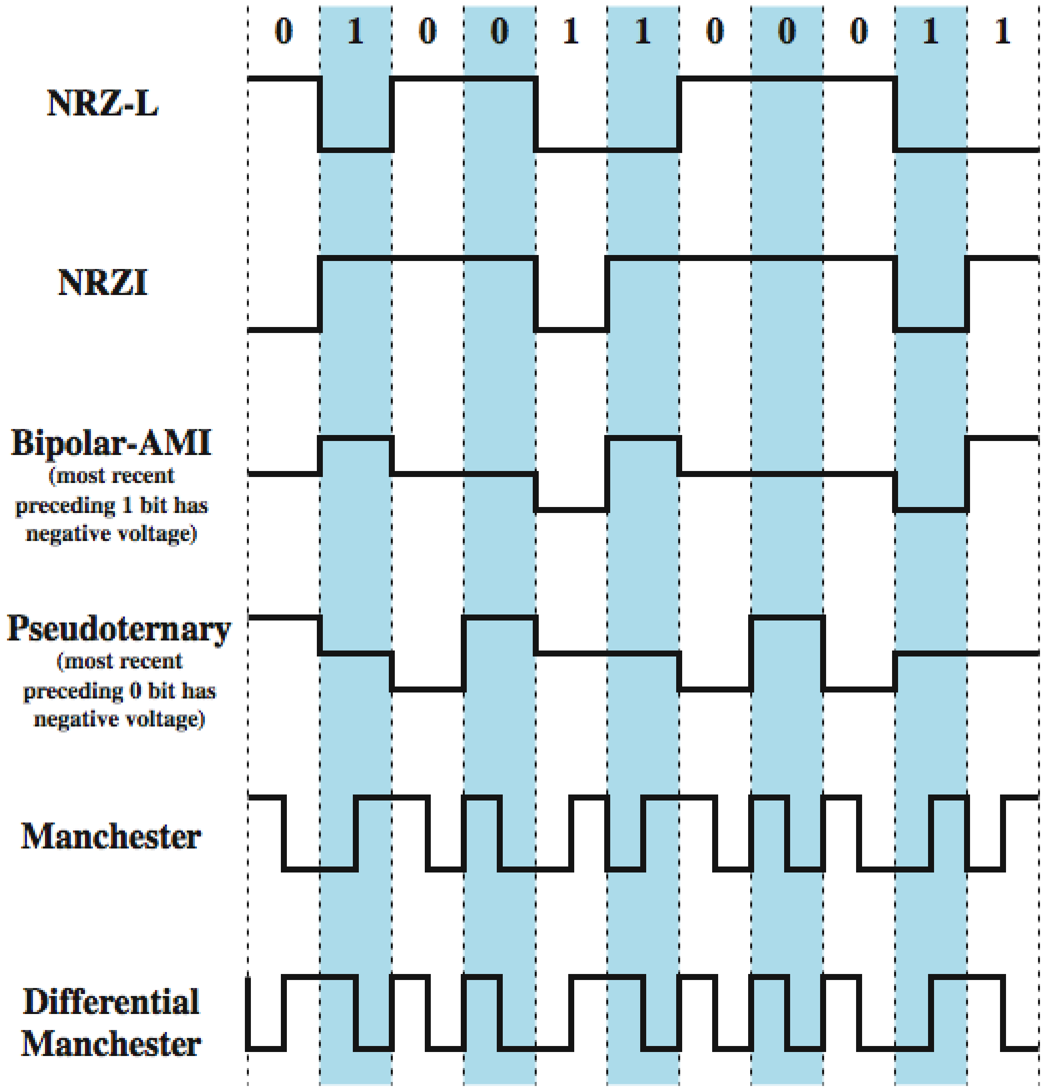
Line coding
Unipolar
Polar
Bipolar
Multilevel
Multitransition
NRZ, RZ, and biphase (Manchester, and differential Manchester)
AMI and pseudoternary
2B/1Q, 8B/6T, and 4D-PAM5
MLT-3

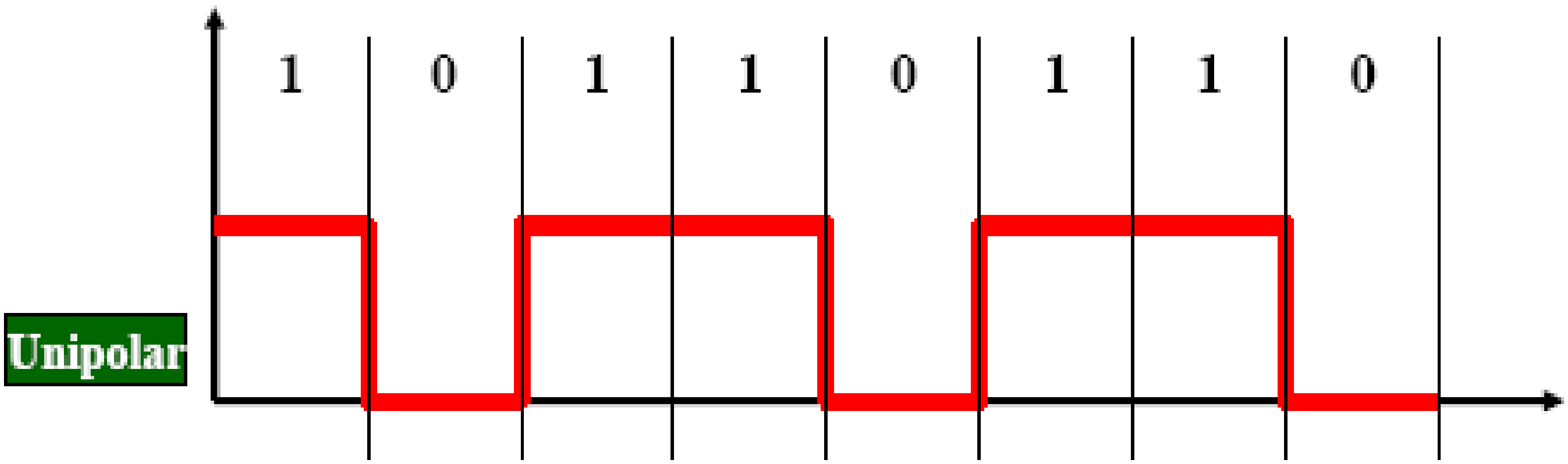
Encoding Schemes



- Nonreturn to Zero-Level (NRZ-L)
- Nonreturn to Zero Inverted (NRZI)
- Bipolar –AMI
- Pseudoternary
- Manchester
- Differential Manchester
- B8ZS
- HDB3

Unipolar Coding

- Single level.
- Bit 1 is positive voltage level
- Bit 0 is no voltage
- Very simpel



NRZ Coding Scheme

- is a level based coding scheme. Data are shown by levels
- has a DC component
- has a problem of synchronization
- NRZ-L and NRZ-I types are present.

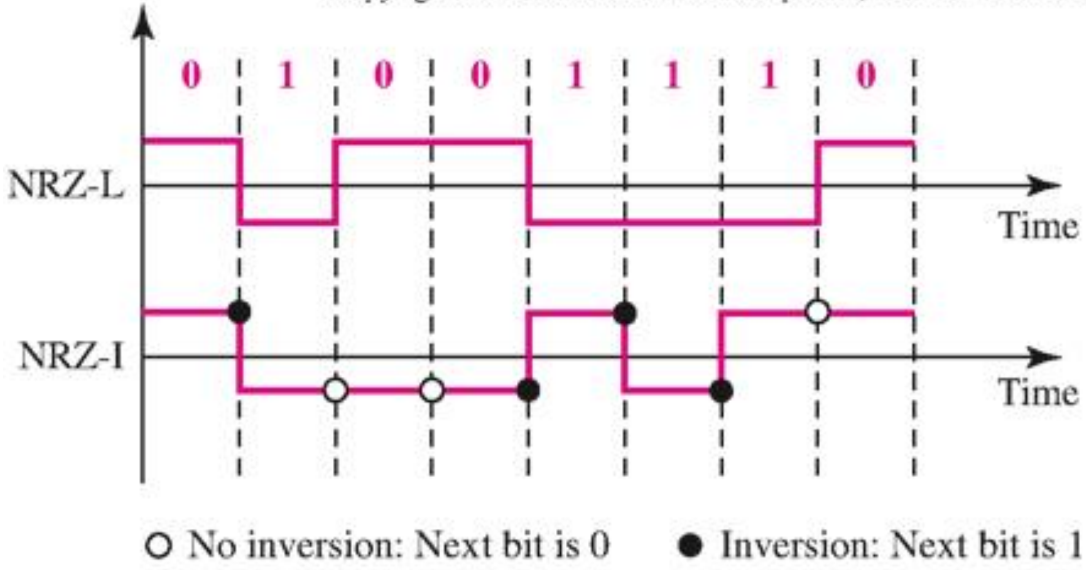
Nonreturn to Zero-Level (NRZ-L)

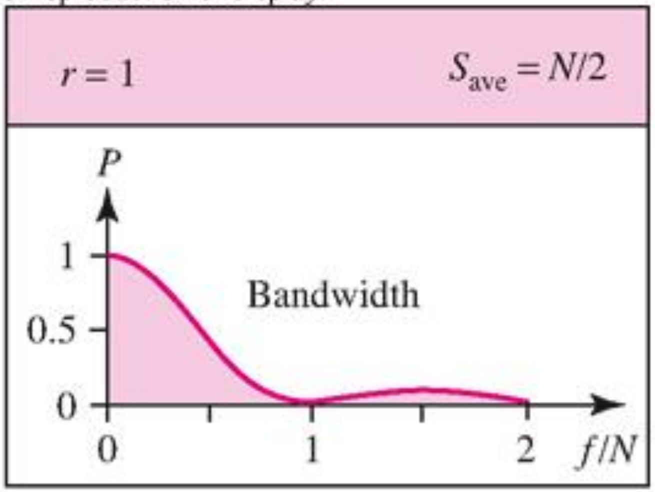
- two different voltages for 0 and 1 bits
- voltage constant during bit interval
  - no transition I.e. no return to zero voltage
  - such as absence of voltage for zero, constant positive voltage for one
  - more often, negative voltage for one value and positive for the other
  - Used for short connections, e.g. PC-Ex.Modem

NRZ-I, Nonreturn to Zero Inverted

- 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
  - easy to lose sense of polarity

NRZ-L and NRZ-I



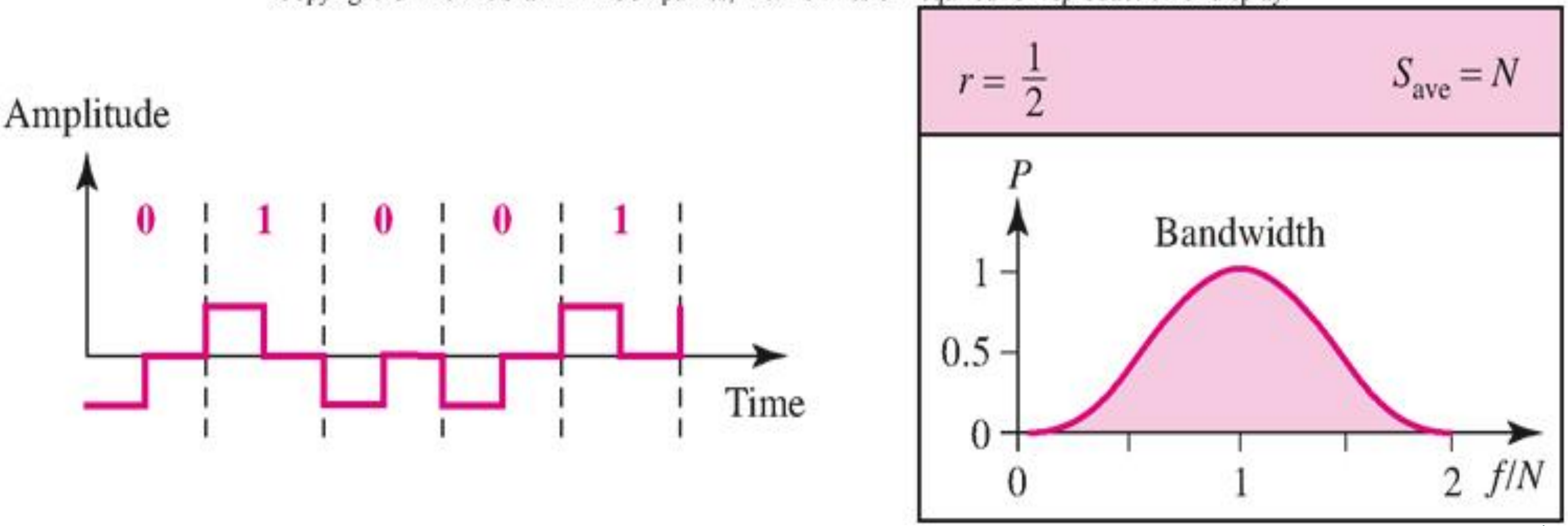


NRZ Pros & Cons

- 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

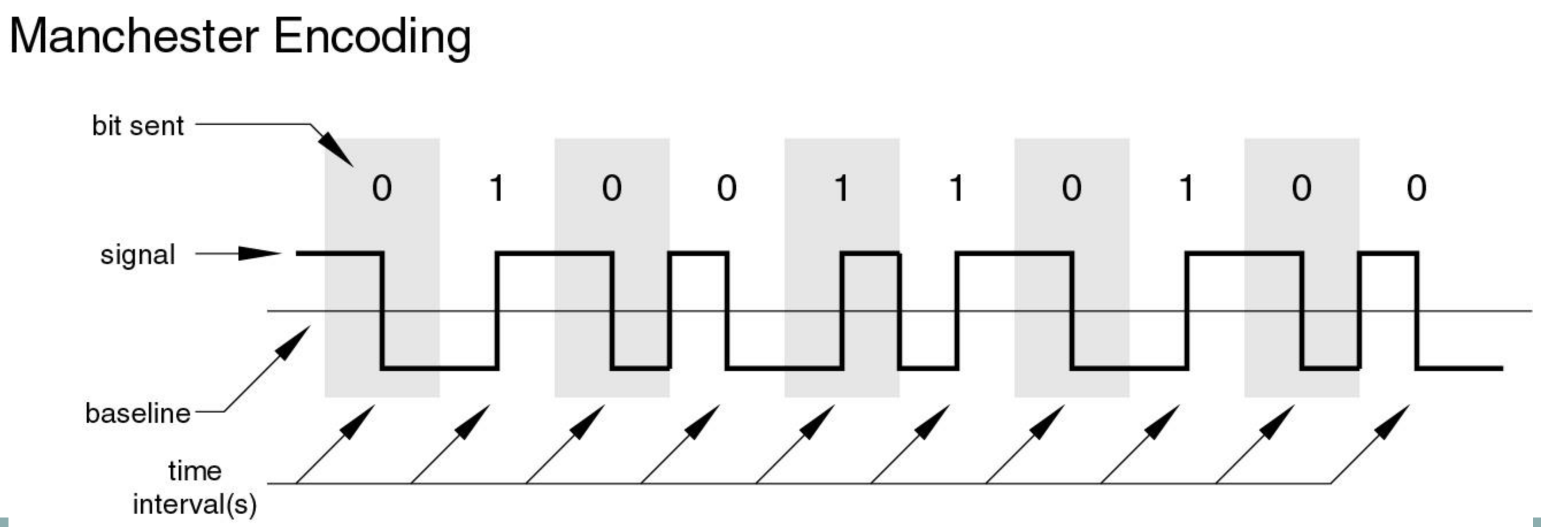
RZ- Return to Zero

- Three level (+V, -V, 0)
- Two signal per bit

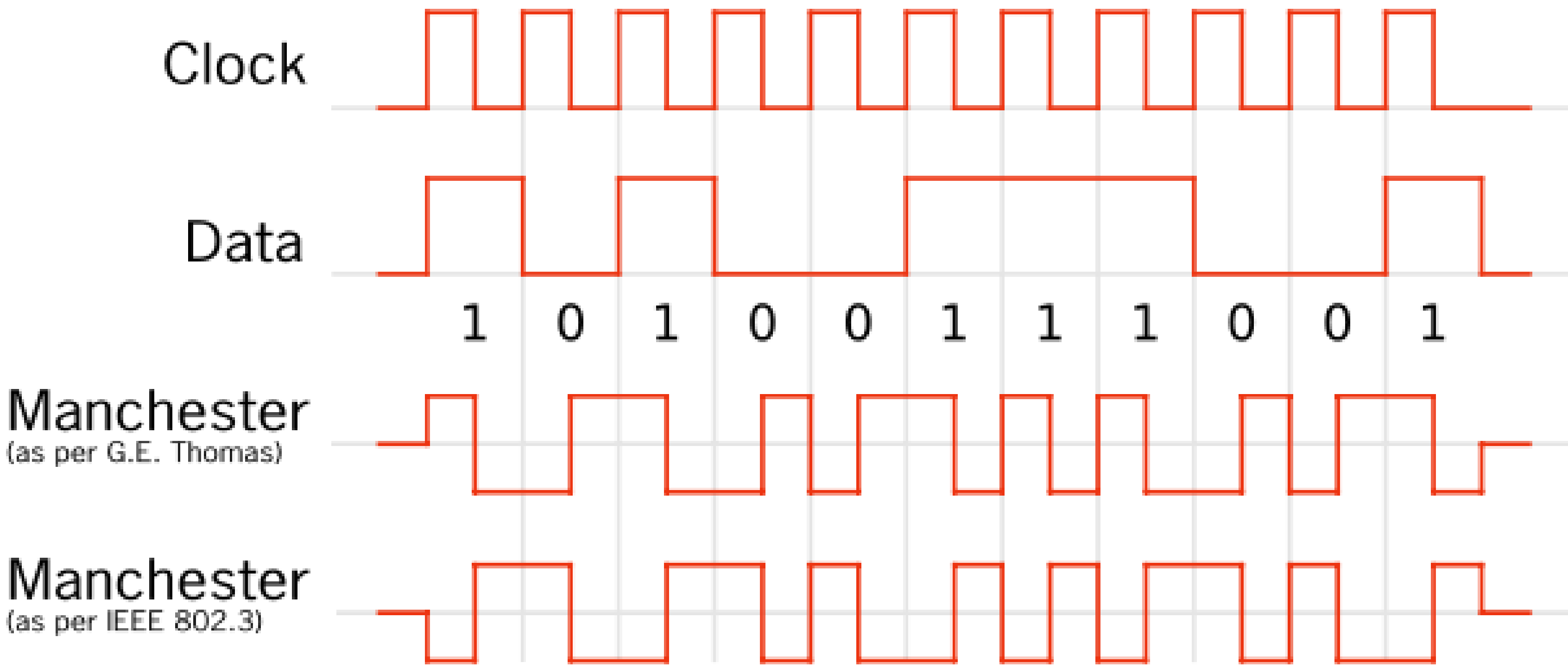


Manchester Encoding

- has transition in 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



Manchester Encoding



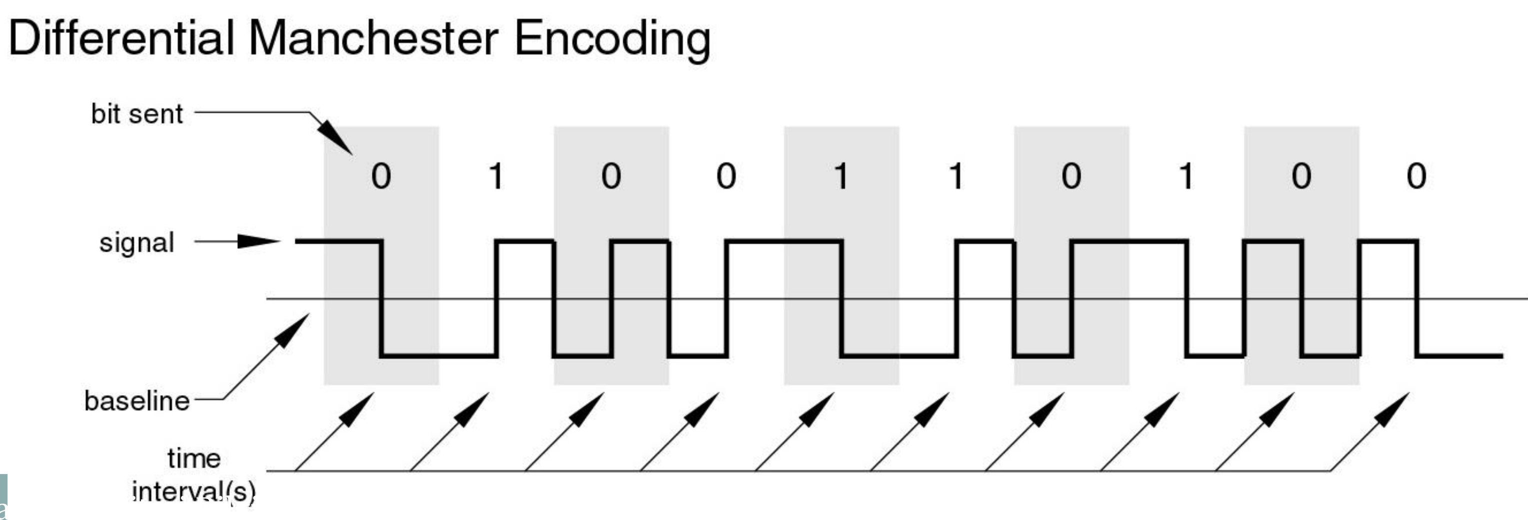
Manchester Encoding

- Extracting the original data from the received encoded bit (from Manchester as per 802.3)

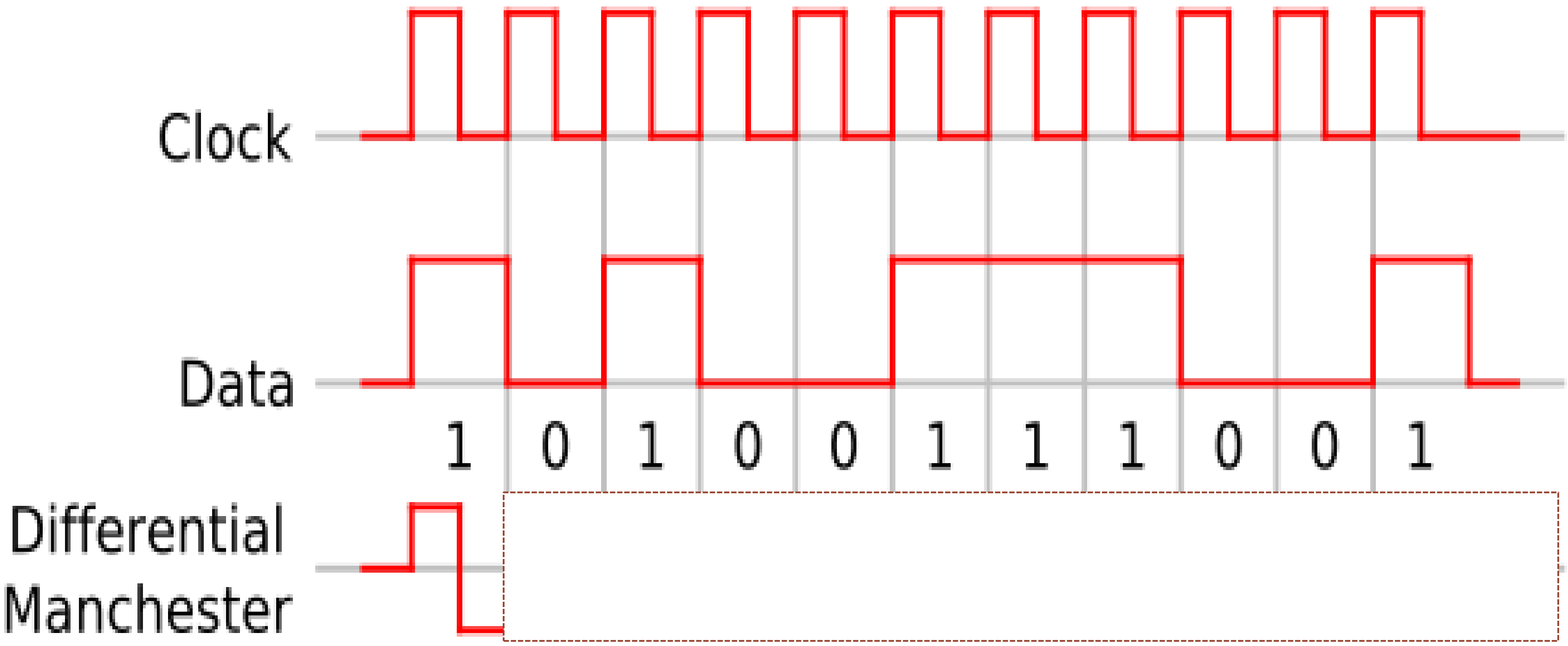
original data	= clock XOR	Manchester value
0	0	0
0	1	1
1	0	1
1	1	0

Differential Manchester Encoding

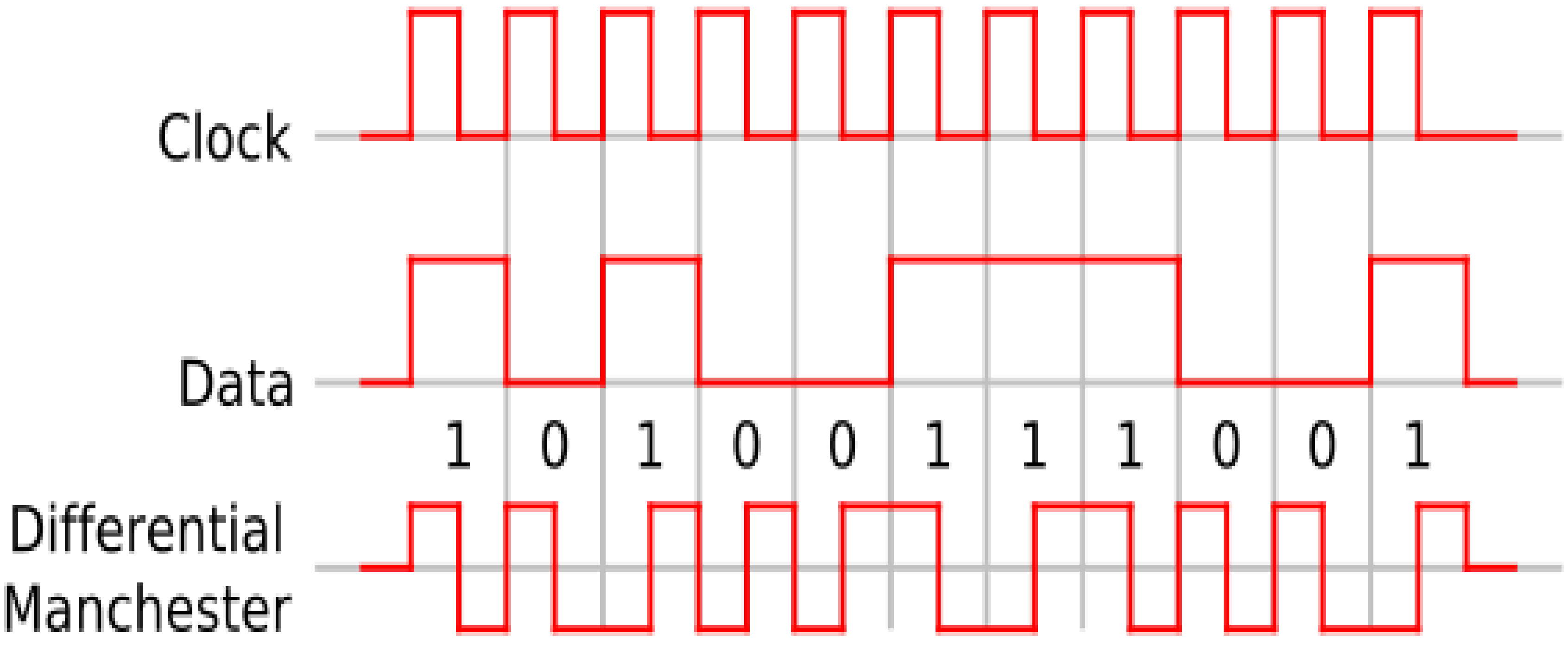
- midbit transition is clocking only
- transition at start of bit period representing 0
- no transition at start of bit period representing 1
  - this is a differential encoding scheme
- used by IEEE 802.5



Differential Manchester Encoding



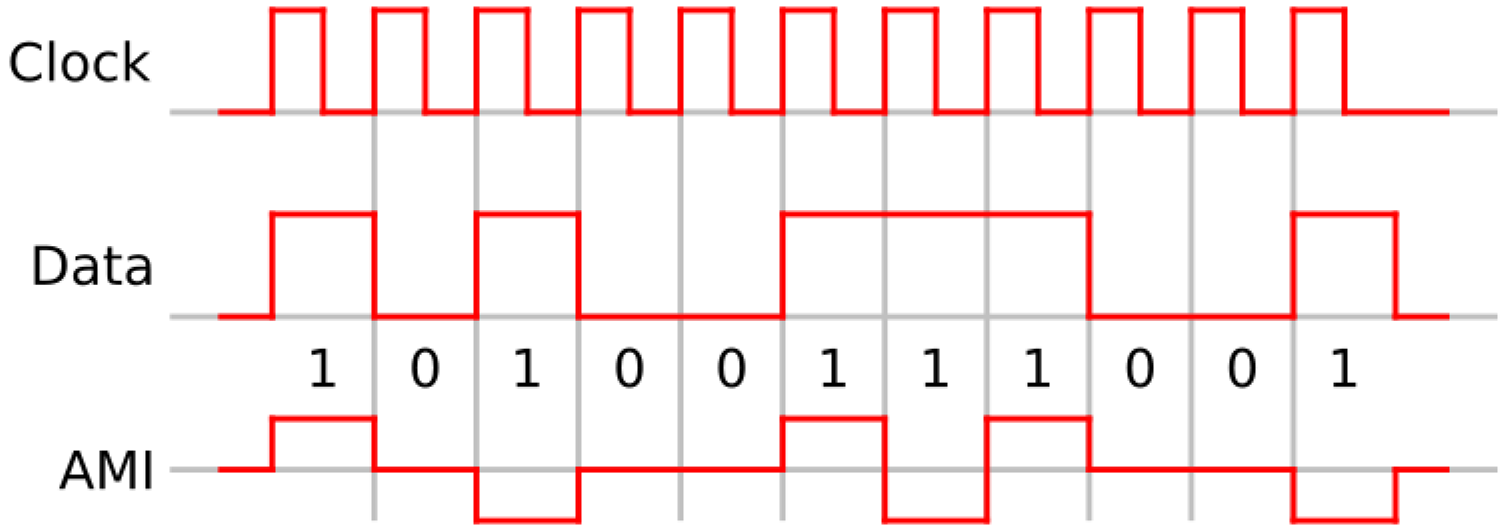
Differential Manchester Encoding



Multilevel Binary Bipolar-AMI

- Alternate Mark Inversion
- Use more than two levels
- 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

AMI- Alternate Mark Inversion



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

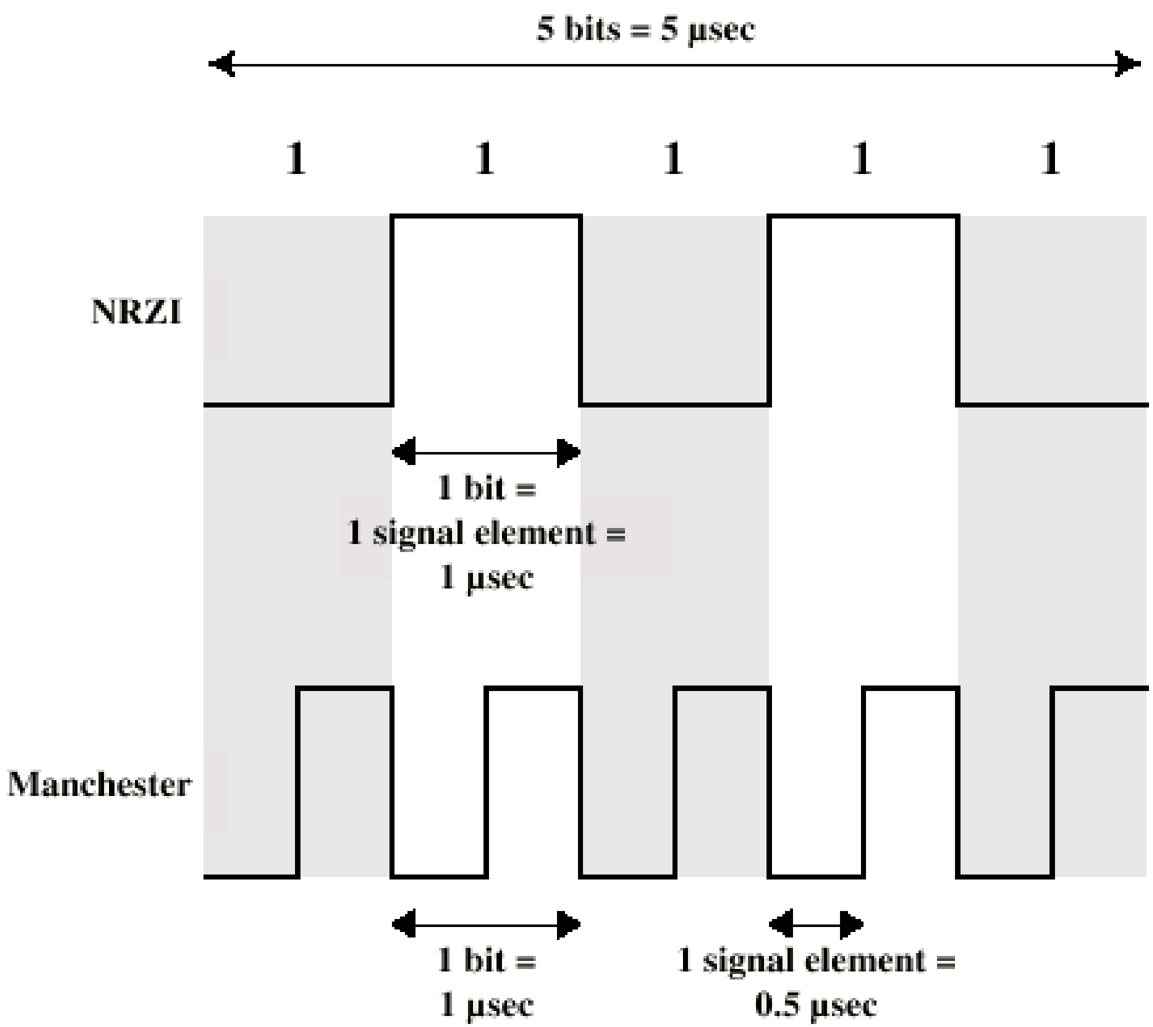
Multilevel Binary Issues

- synchronization with long runs of 0's or 1's
  - can insert additional bits, cf ISDN
  - scramble data (later)
- not as efficient as NRZ
  - 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
  - requires approx. 3dB more signal power for same probability of bit error

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



Scrambling

- use scrambling to replace sequences that would produce constant voltage
- these filling sequences must
  - produce enough transitions to sync
  - 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-Bipolar With 8 Zeros Substitution

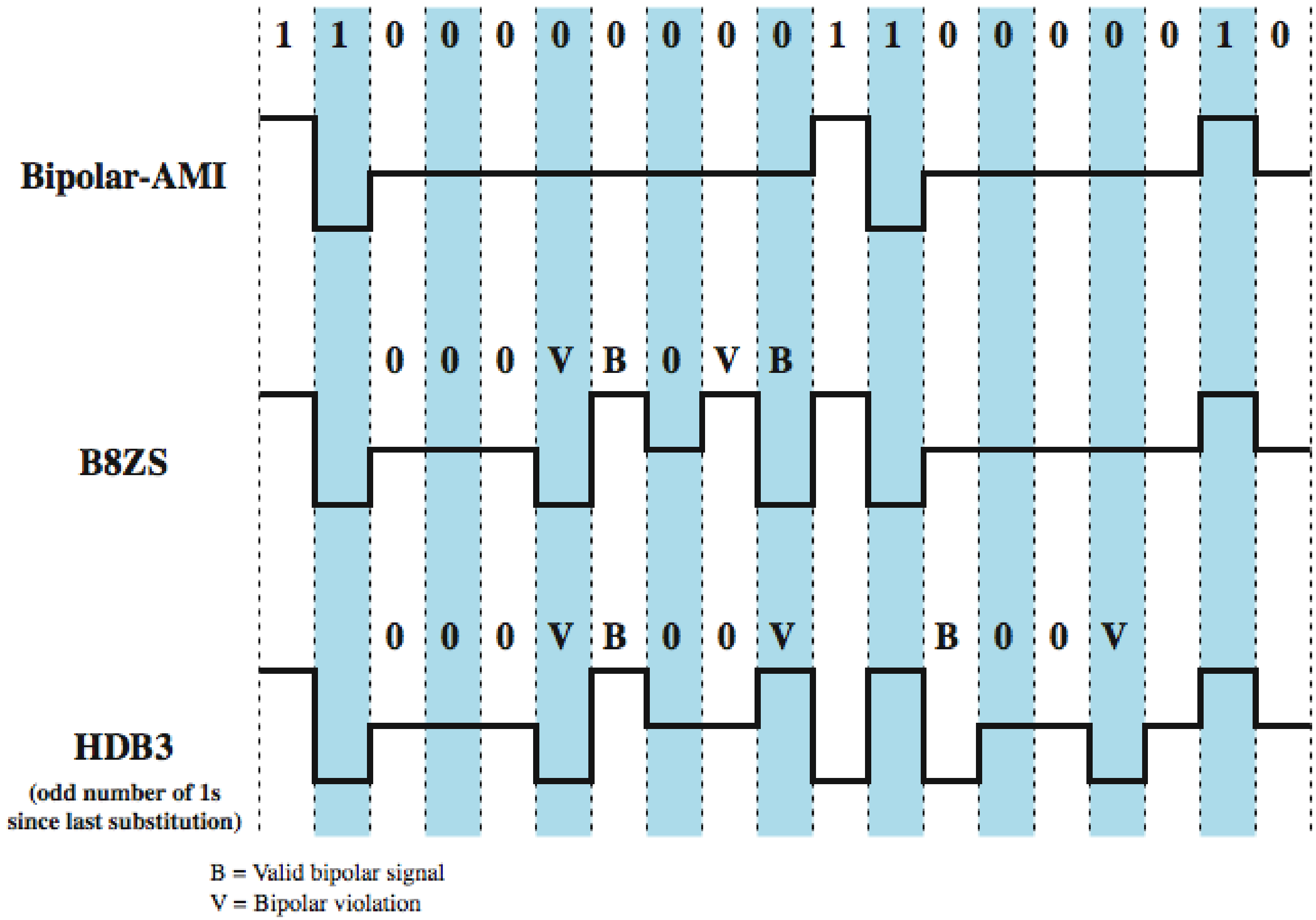
- Based on Bipolar AMI
- A coding scheme that is commonly used in North America
- If an octet of all zeros occurs and the last voltage pulse preceding this octet was positive, then the eight zeros of the octet are encoded as 000+–0–+
- If an octet of all zeros occurs and the last voltage pulse preceding this octet was negative, then the eight zeros of the octet are encoded as 000–+0+–

HDB3 – High Density Bipolar 3 Zeros

- A coding scheme that is commonly used in Europe and Japan
- After last violation (ihlal), we look to number of 1s (odd or even)
- If there is no 1 after last violation (e.g. After 0000 again 0000) the number of 1s is assumed as even
- Odd+ → 000+
- Odd – → 000-
- Even + → -00-
- Even – → +00+

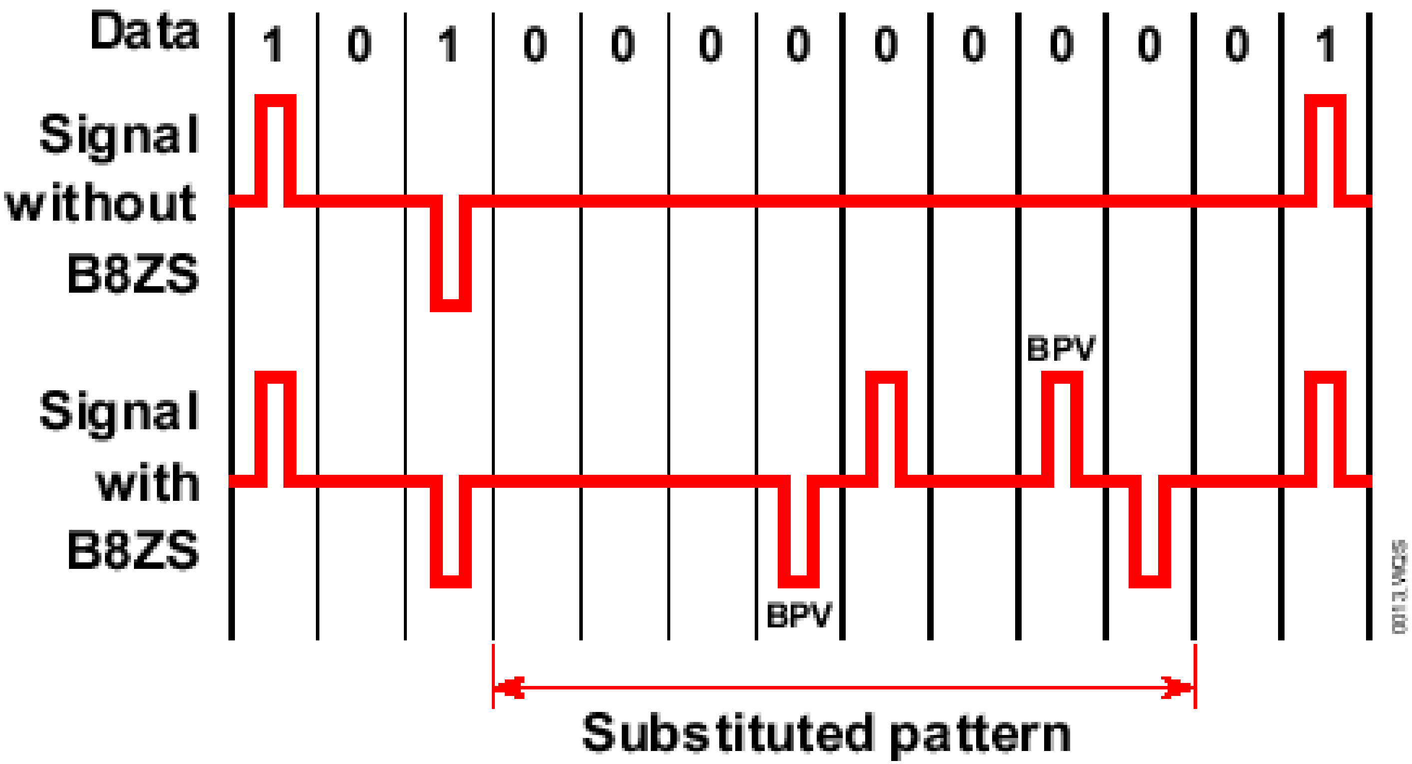
B8ZS and HDB3

B: Valid Bipolar Signal
V: Bipolar Violation



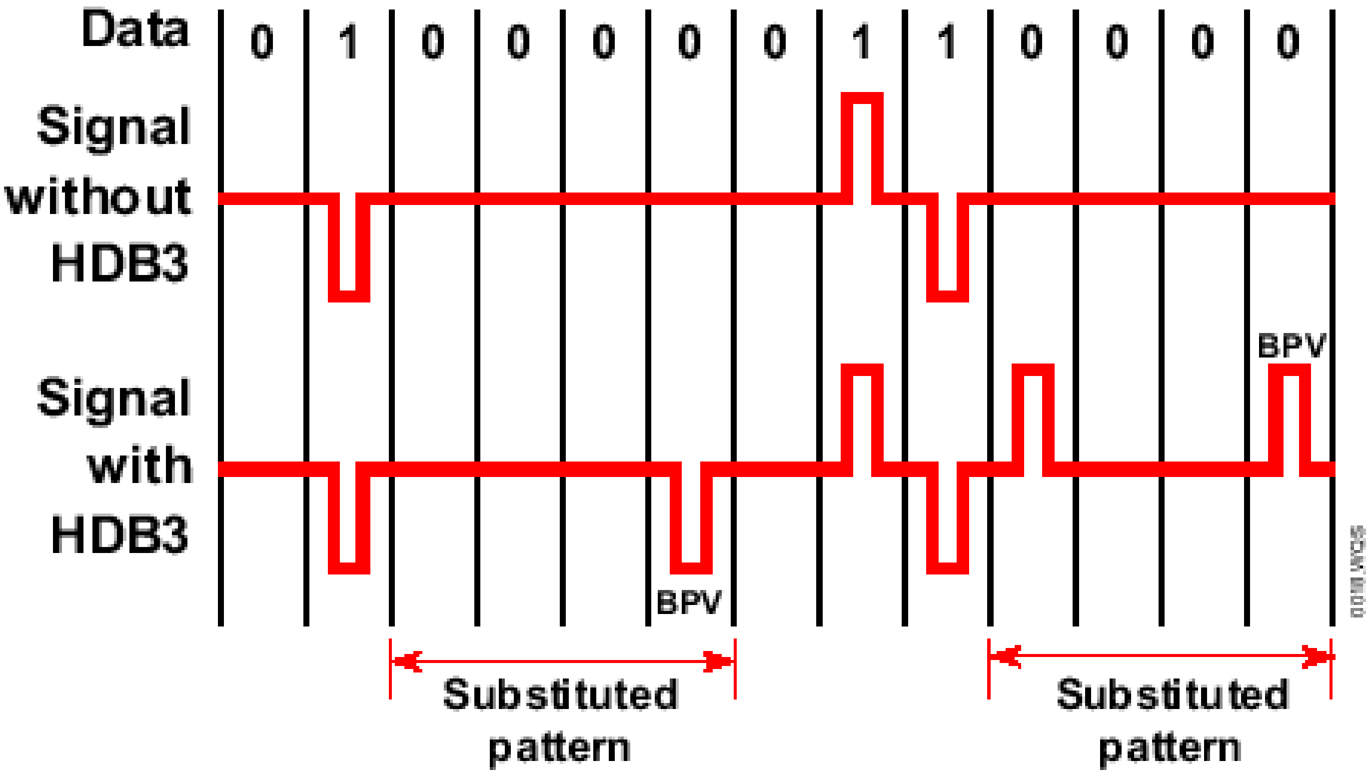
B8ZS-Example

Bipolar 8-zero substitution (B8ZS)—ones density enforcement on T1 lines

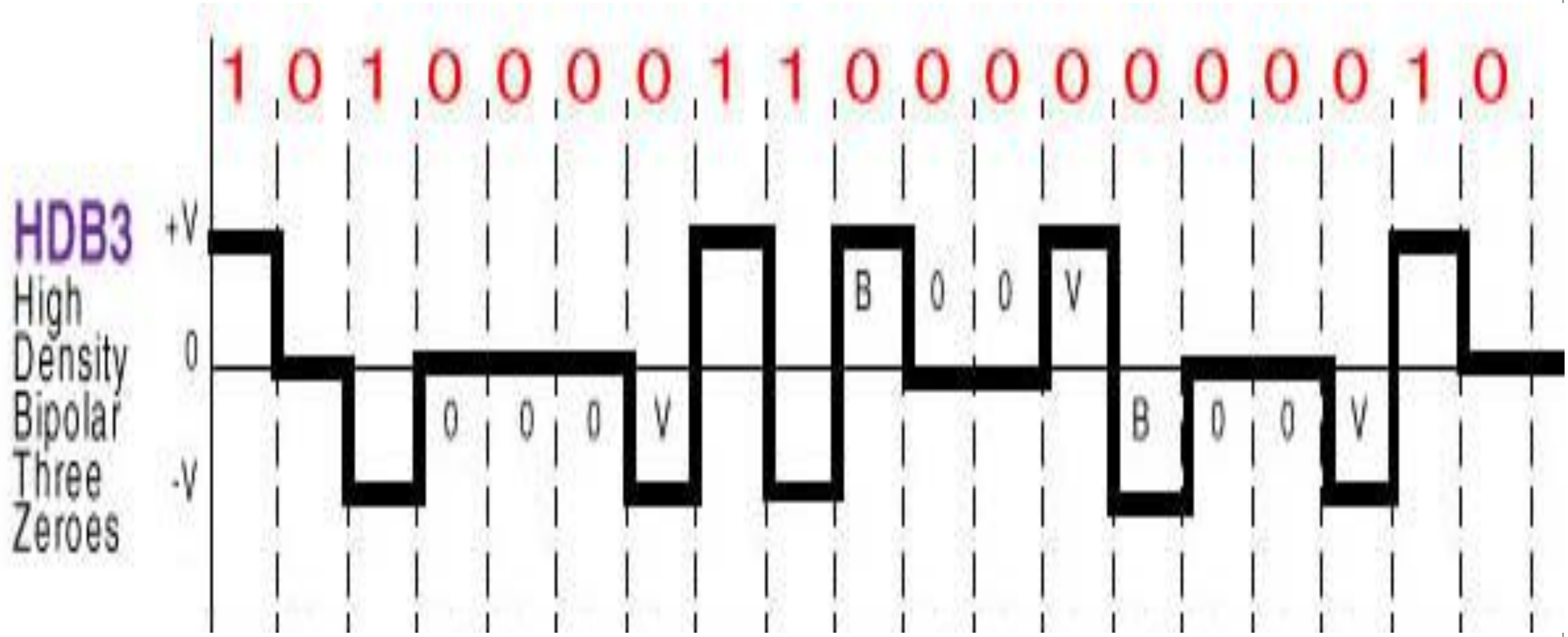


HDB3 - Example

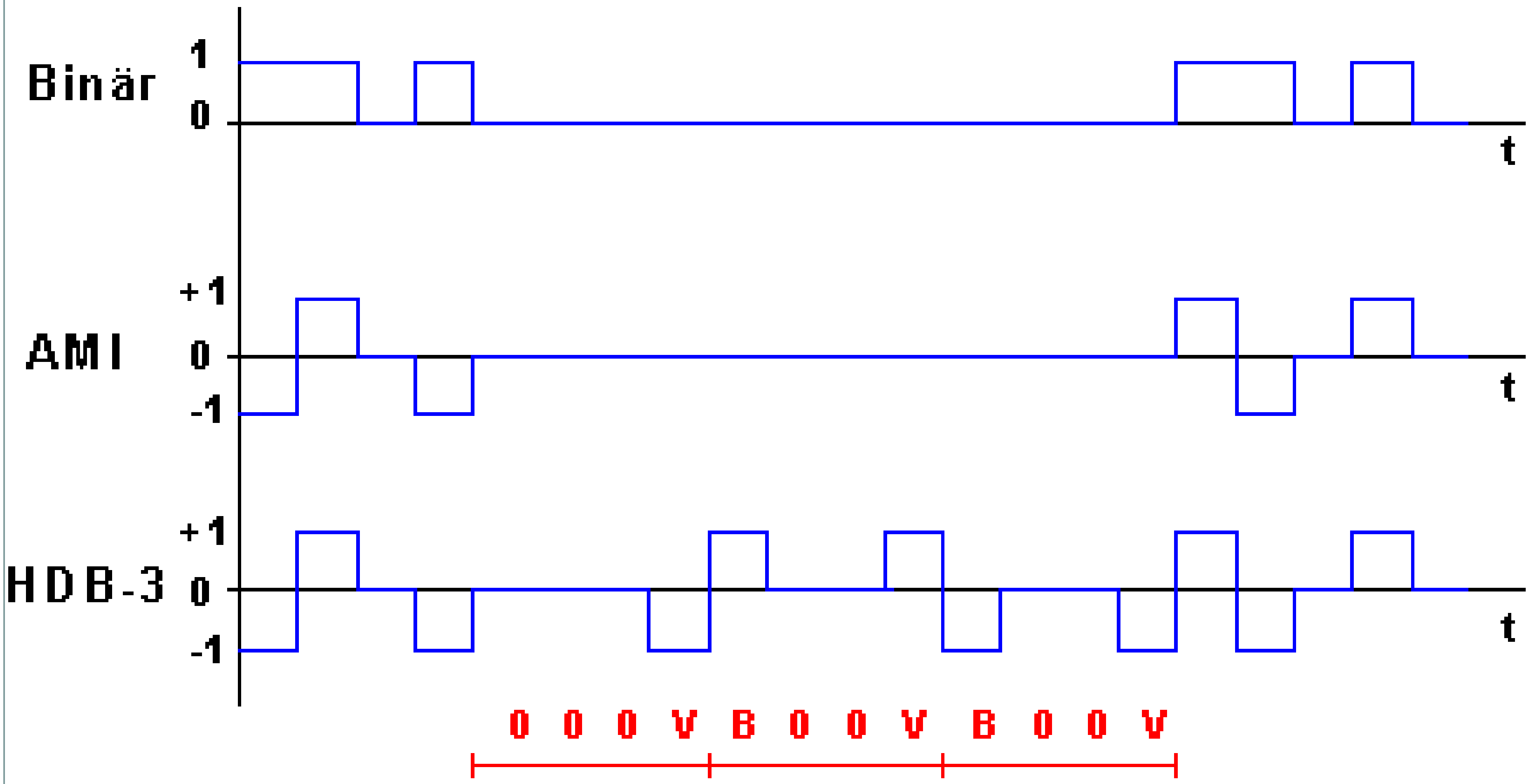
High-density bipolar 3 (HDB3)—ones density enforcement on E1 lines



HDB3 -Example



HDB3 - Example



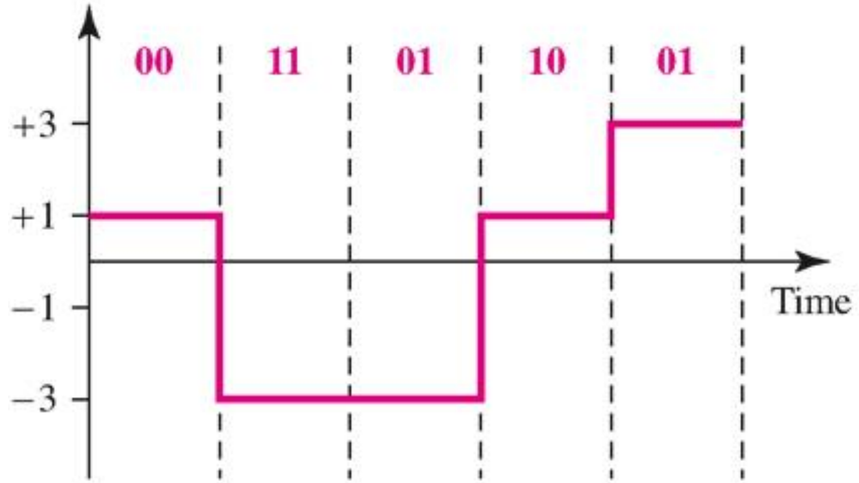
Other Digital Data Digital Signal Codings

- 2B1Q (Two Binary, One Quaternary)
- MLT-3 (Multiline Tx, three Level)

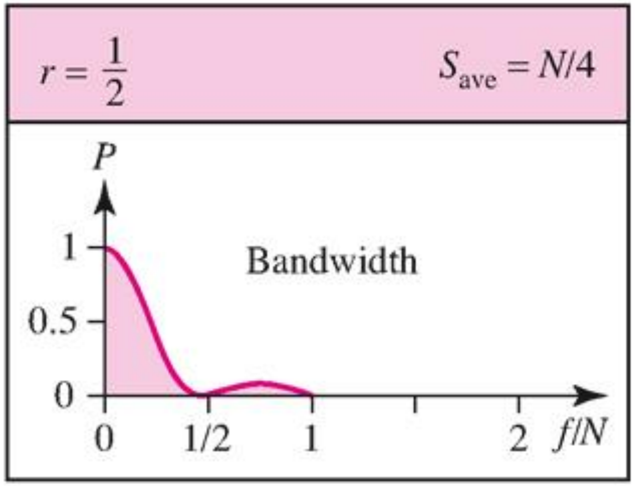
2B1Q – Two Binary One Quaternary

	Previous level: positive	Previous level: negative
Next bits	Next level	Next level
00	+1	−1
01	+3	−3
10	−1	+1
11	−3	+3

Transition table

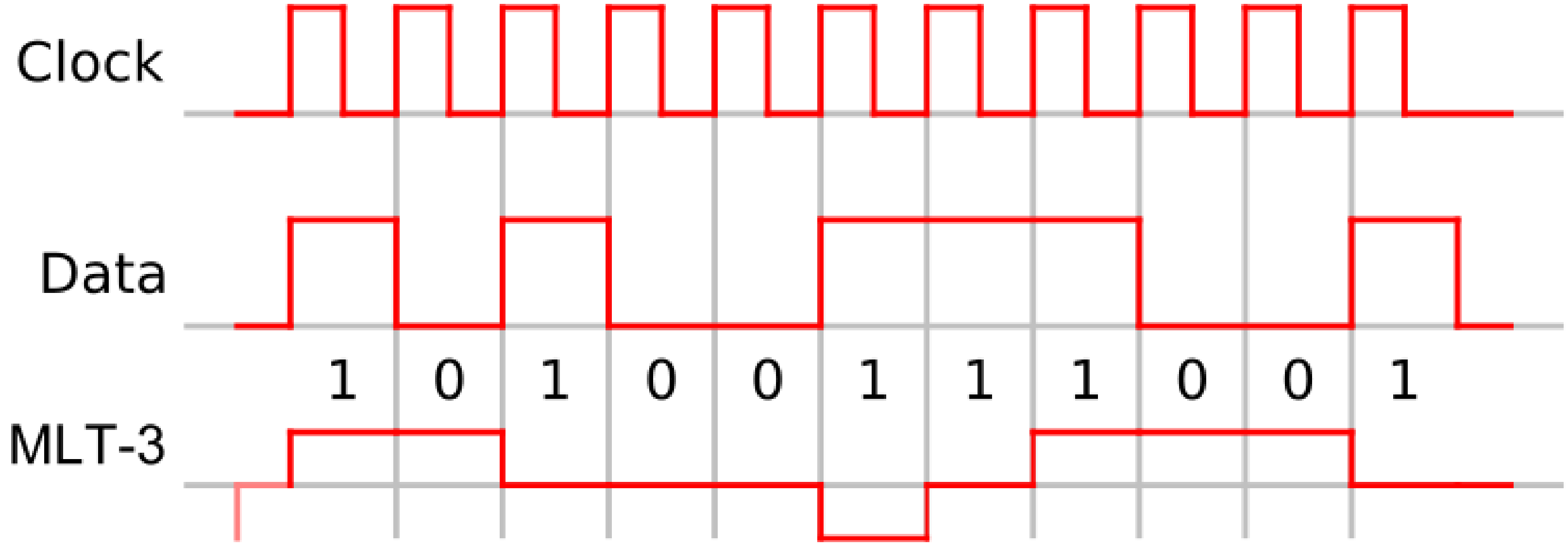


Assuming positive original level



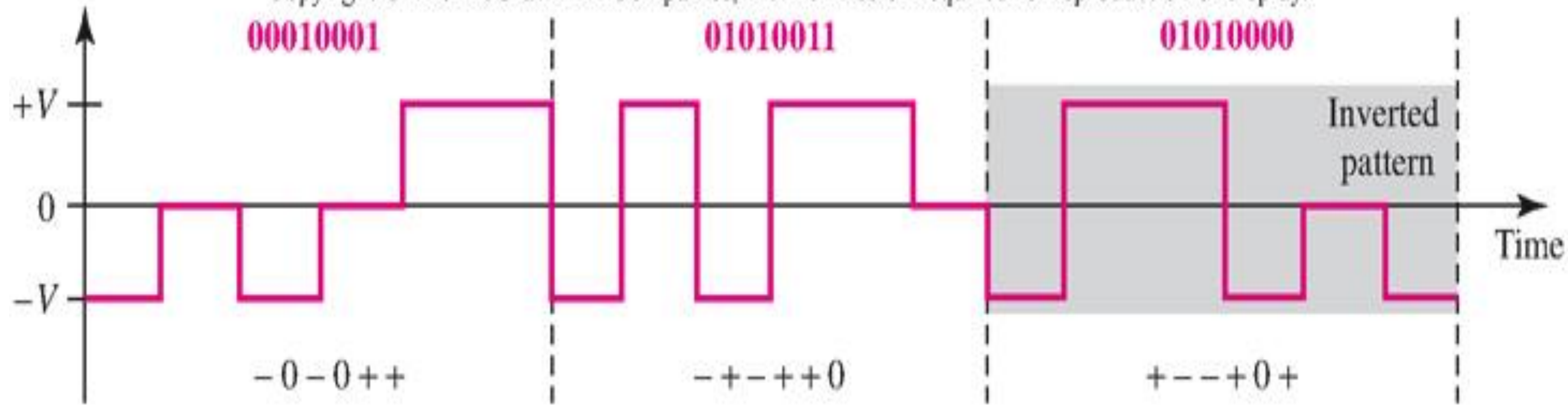
MLT-3

- Like NRZ-I.
- Use 3 signal level (+1, 0, -1)
- Transition at 1 bit, no transition at 0 bit.



8B6T

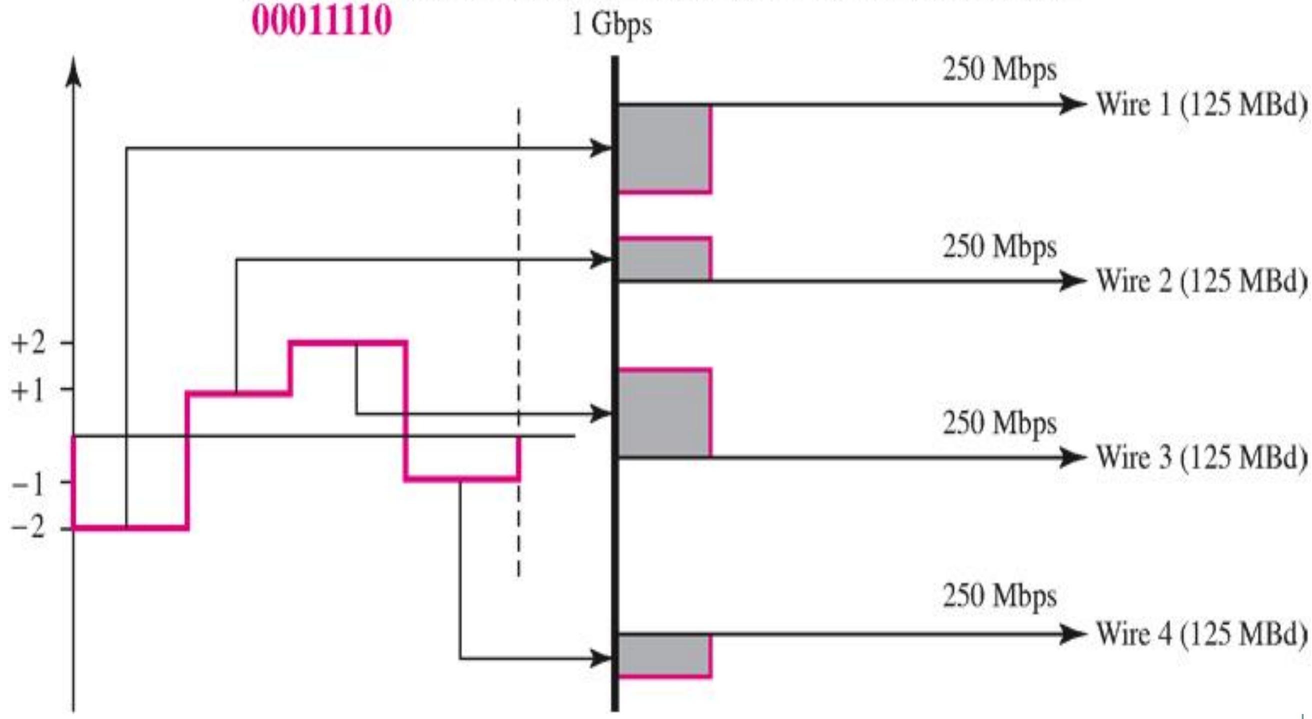
- 8B6T (Eight-binary-six-ternary) kodlamada 8 bit veri (m=8) 3 seviyeli (L=3) sinyalle gösterilir
- 2^8=256 farklı veri ve 3^6=729 farklı sinyal kullanılır
- Sinyallerin bir kısmı senkronizasyon ve hata denetimi için kullanılır
- Her bit grubu için kullanılacak sinyal grubu sabittir
- 100Base-T4 Ethernet çeşidinde 8B6T kodlama yöntemi kullanılır



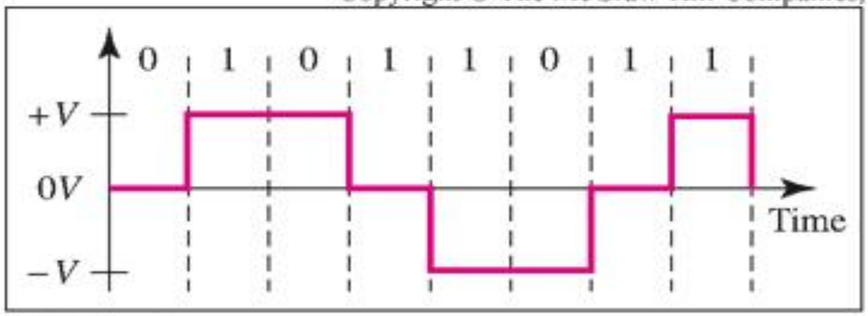
4D-PAM5

- 4D-PAM5 (Four-dimensional five-level pulse-amplitude-modulation) kodlamada 4D verinin 4 kablo ile iletildiğini gösterir
- 5 farklı sinyal seviyesi (-2, -1, 0, 1, 2) bulunur.

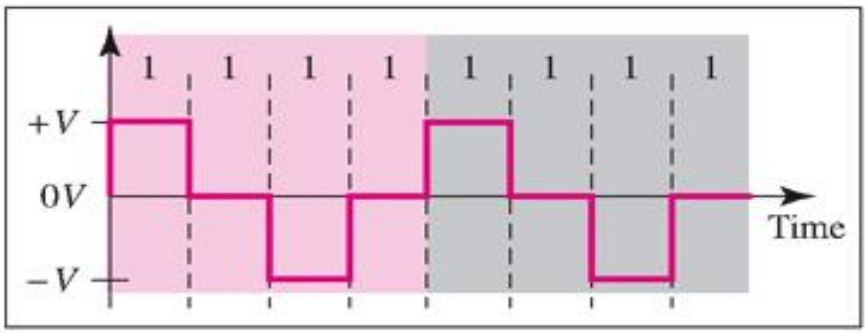
- Sinyal 4 parça ile gösterilir her parçası bir kablo üzerinden iletilir
- Gigabit-LAN ağlarında kullanılır



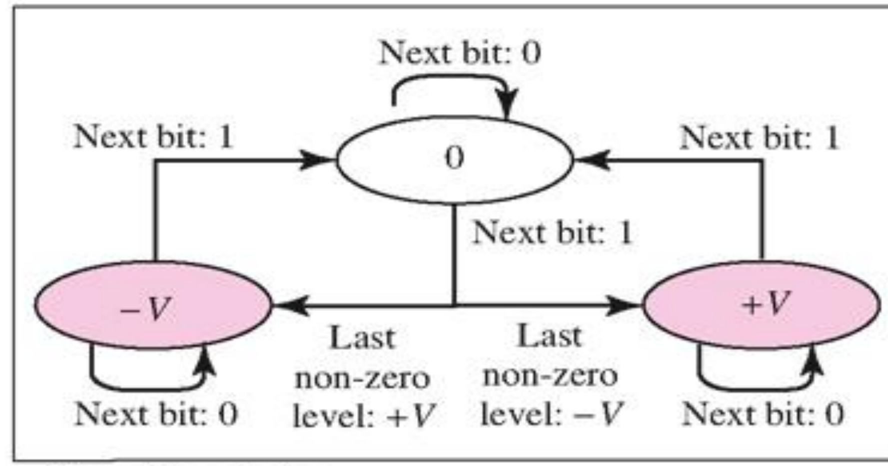
Multiline Kodlama - MLT-3



a. Typical case



b. Worse case

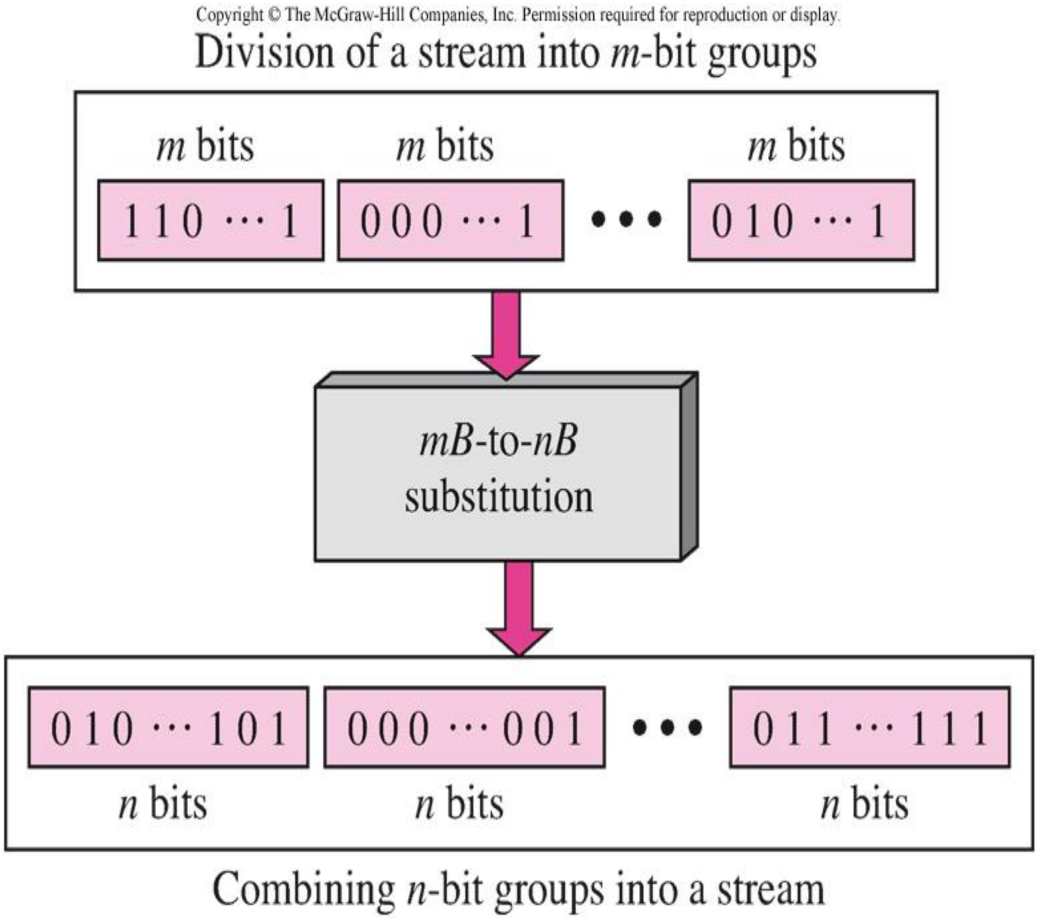


c. Transition states

- NRZ-I ve farksal manchester veriyi kodlarken iki geçiş yapar
- MLT-3 (Multiline Transmission, Three Level) kodlama 3 seviyeli geçiş yapar, yani 3 sinyal seviyesi kullanır (+V, 0, -V).

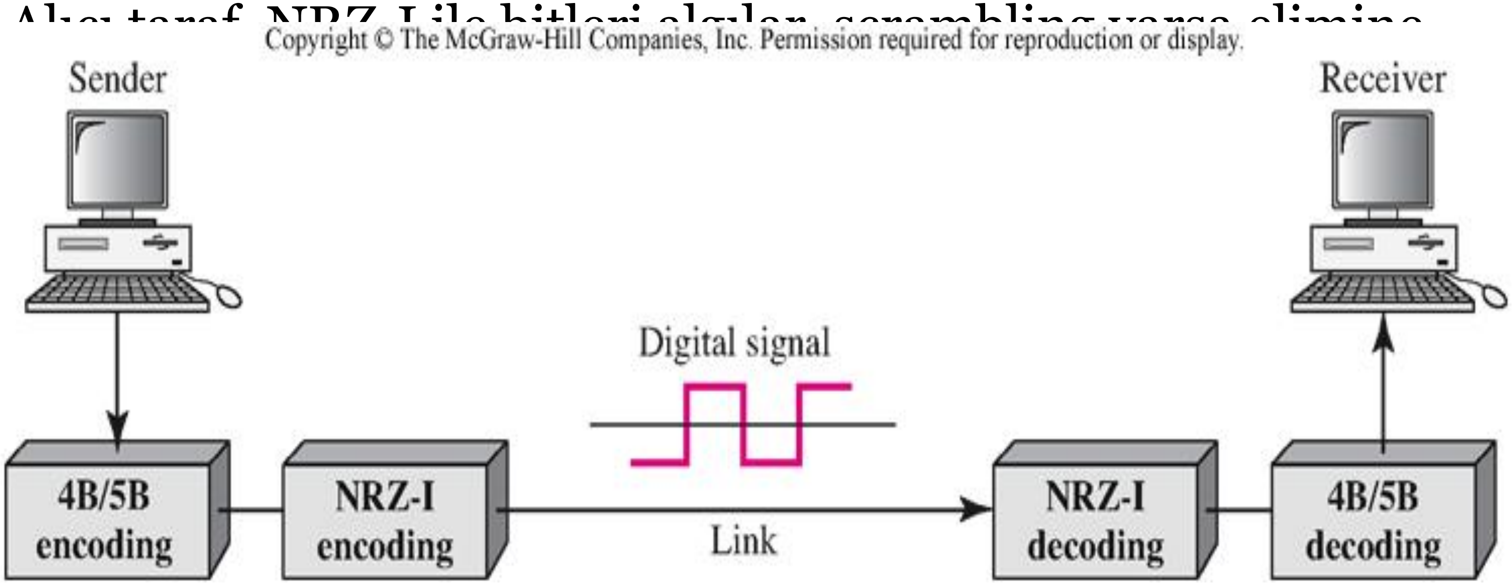
Blok Kodlama

- Senkronizasyonu ve hata sezimini sağlamak için ek bitlere ihtiyaç duyulur
- Blok kodlamada m adet bit n adet bit haline getirilir (mB/nB, n>m). Diğer bir deyişle m bit grubu n bit grubu yerine yerleştirilir. Örnek olarak 4B/5B'de orijinal bitler 4-bit gruplara ayrılır ve her 4 bitin yerine 5 bitlik karşılıkları yazılır
- "/" işareti blok kodlamayı multilevel kodlamadan ayırır



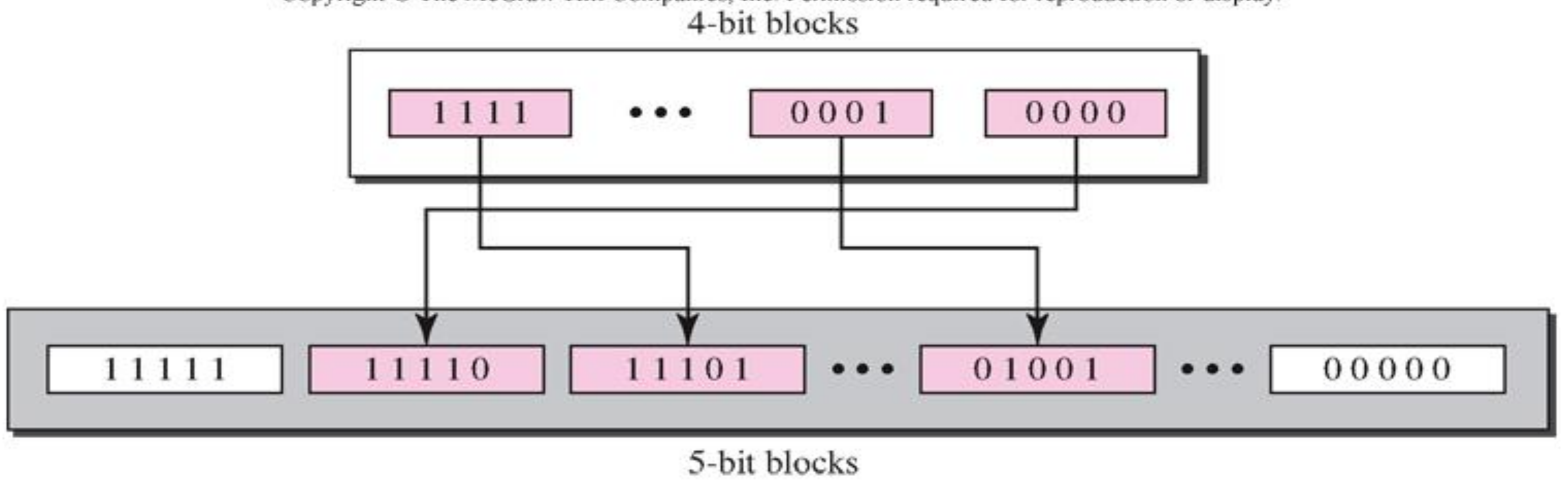
4B/5B Blok Kodlama

- 4B/5B (four binary/five binary) blok kodlama yöntemi NRZ-I ile birlikte kullanılır
- NRZ-I kodlama ardarda gelen uzun 0'larda senkronizasyon problemi oluşturur. Bundan dolayı kodlamadan önce uzun 0 olmayacak şekilde değişiklik gerekir.
- Alıcı taraf, NRZ-I ile bitleri algılar, scrambling varsa elimine



4B/5B Blok Kodlama

- Örnek: 1 Mbps hızında veri göndermek istiyoruz. 4B/5B + NRZ-I ve Manchester kodlama kullanıldığında gereken minimum bant genişliği nedir?
  - 4B/5B bit hızını 1.25 Mbps olarak aktarır
  - NRZ-I kodlama N/2 bantgenişliği gerektirdiğinden 625 KHz gerekir



4B/5B Blok Kodlama

Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

- 4B/5B blok [illegible] e kullanılır
- 4B/5B haricinde 6B/8B, 8B/10B ve 64B/66B blok kodlama yöntemleri bulunmaktadır

Hat Kodlama Yöntemleri – Özet Tablo

Kategori	Şema	Bant genişliği	Karakteristik
Unipolar	NRZ	BW = N/2	• Uzun 1 ve 0 larda senkronizasyon yoktur • DC bileşen vardır
Polar	NRZ-L	BW = N/2	• Uzun 1 ve 0 larda senkronizasyon yoktur • DC bileşen vardır
	NRZ-I	BW = N/2	• Uzun 0 larda senkronizasyon yoktur • DC bileşen vardır
	Biphase	BW = N	• Yüksek bant genişliği gerektirir • Senkronizasyon vardır • DC bileşen yoktur
Bipolar	AMI	BW = N/2	• Uzun 0 lar için senkronizasyon yoktur • DC bileşen yoktur
Multilevel	2B1Q	BW = N/4	• Uzun aynı bit çiftleri için senkronizasyon yoktur
	8B6T	BW = 3N/4	• Senkronizasyon vardır • DC bileşen yoktur
	4D-PAM5	BW = N/8	• Senkronizasyon vardır • DC bileşen yoktur
Multiline	MLT-3	BW = N/3	• Uzun 0 lar için senkronizasyon yoktur

- Bu tablo, Doç.Dr. M. Ali Akçayol un Veri İletişimi ders notlarından alınmıştır