



CSE 320/EEE361

Data Communications

Digital Transmission

Chapter 4



Recap Previous Lecture

- Digital data
 - Digital Signal
 - Analog Signal
- Analog data
 - Digital Signal
 - Analog Signal



Encoding Techniques

- **Digital Data, Digital Signal**
 - Less expensive and less complex than digital to analog modulation.
- **Digital Data, Analog Signals**
 - Some transmission media, such as optical fiber and unguided media , will only propagate analog signals.

Digital Data □ Digital Signal

Signal Encoding Techniques:

- Line Coding

 - *Diffrent Line Coding Schemes*

- Block Coding

- Scrambling

Line coding is always needed; block coding and scrambling may or may not be needed.

Digital Data, Digital Signal

- Digital signal
 - Discrete, discontinuous voltage pulses
 - Each pulse is a signal element
 - Binary data encoded into signal elements

Data
transmitted:

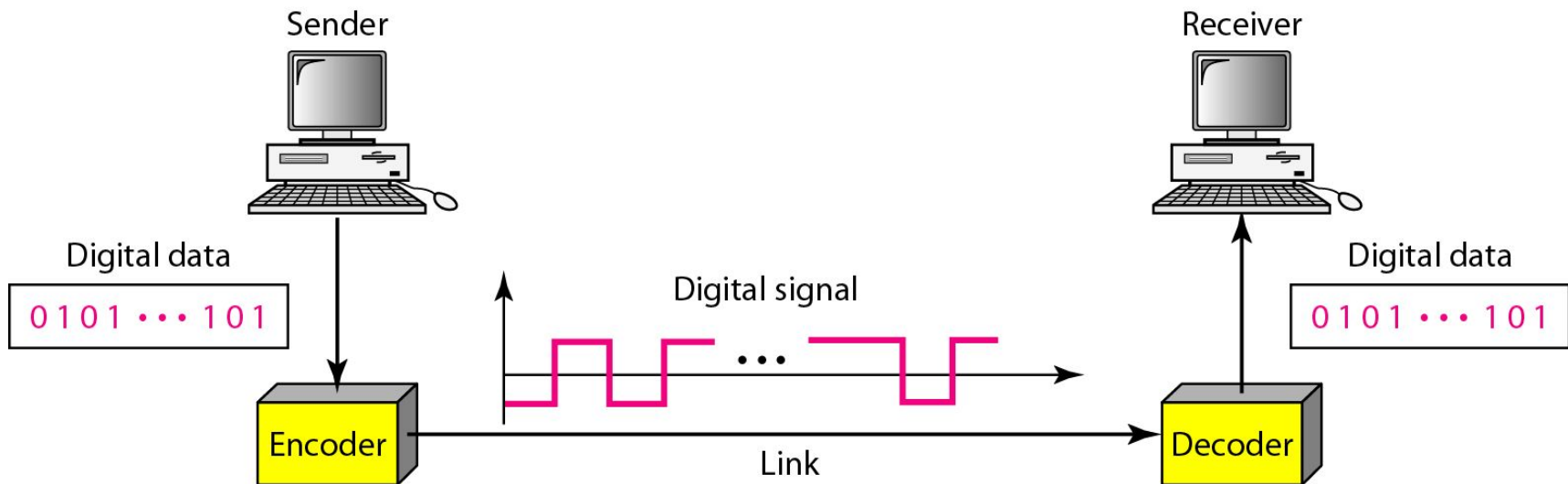
0 1 0 1 1 0 0 1 1 0 0 1 0 1 0

Signal:

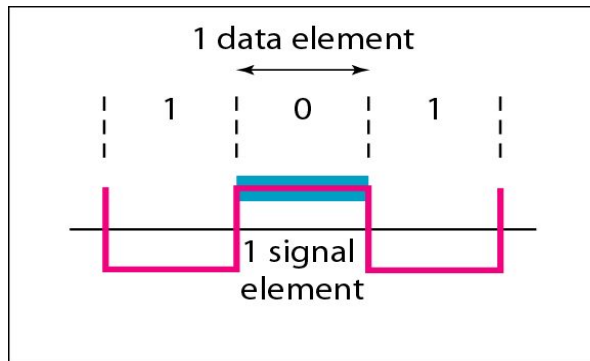


Line Coding

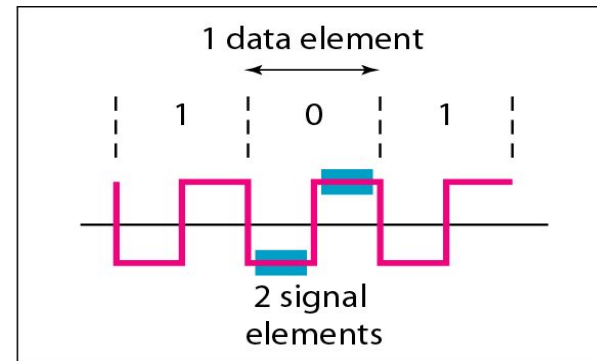
Line coding is the process of converting binary data, a sequence of bits, to a digital signal.



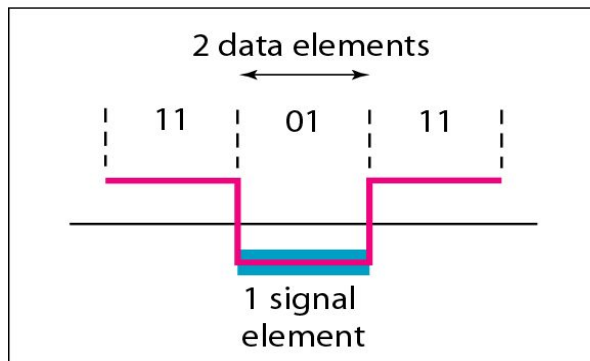
Signal Vs Data Element



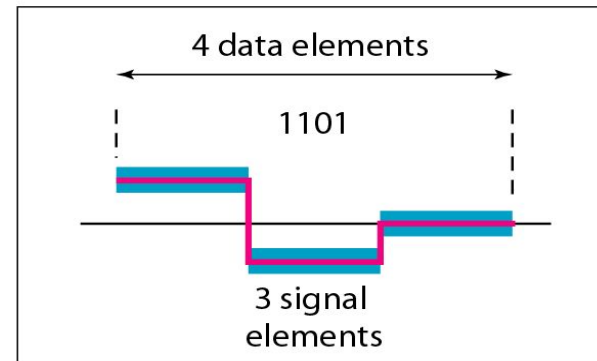
a. One data element per one signal element ($r = 1$)



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



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



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



Pulse /Modulation /Signal/ Baud Rate versus Bit Rate

- The pulse rate defines the number of pulses/signals sent in one second. Also known as **Baud Rate**.
- The bit rate defines the number of bits per second.

$$\text{BitRate} = \text{PulseRate} \times \log_2 L$$

L = Number of data levels



Digital Data □ Digital Signal

- Receiver needs to know
 - Timing of bits
 - Signal levels
- Factors affecting successful interpretation of signals
 - Baseline Wandering
 - DC Components
 - Self-synchronization
 - Built in Error Detection
 - Immunity to Noise and Interference
 - Complexity



BaseLine Wandering

- Receiver calculates the running average of received signal power.
- Average = baseline
- A long strings of 0's and 1's can cause a drift in the baseline making it difficult for the receiver to decode properly.



DC Components

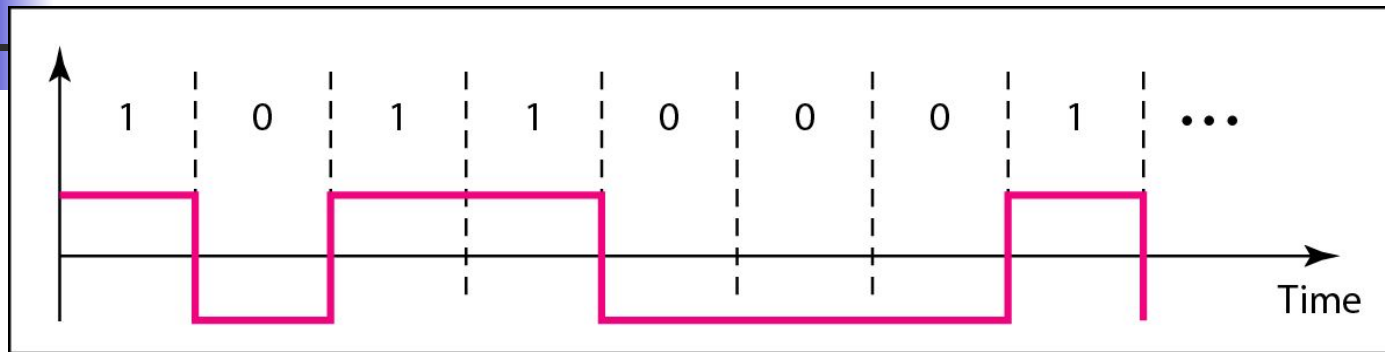
- When the voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies (results of Fourier analysis).
- If the signal is to pass through a system (such as a transformer) that does not allow the passage of a dc component, the signal is distorted and may create errors in the output.
- This component is extra energy residing on the line and is useless.



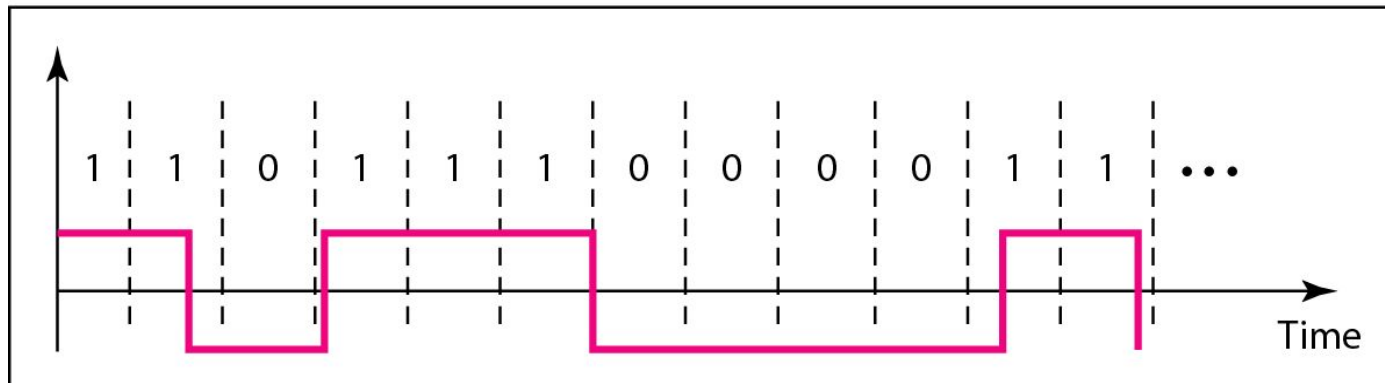
Self-Synchronization

- The receiver's bit intervals must correspond exactly to the senders bit intervals.
- If the receiver clock is faster or slower, the bit intervals are not matched and the receiver might misinterpret the signals.
-

Figure 4.3 *Effect of lack of synchronization*



a. Sent



b. Received



Self-Synchronization

- A self-synchronizing digital signal includes timing information in the data being transmitted.
- This can be achieved if there are transitions in the signal that alert the receiver to the beginning, middle, or end of the pulse.
- If the receiver's clock is out of synchronization, these points can reset the clock.



Different Line Encoding Schemes

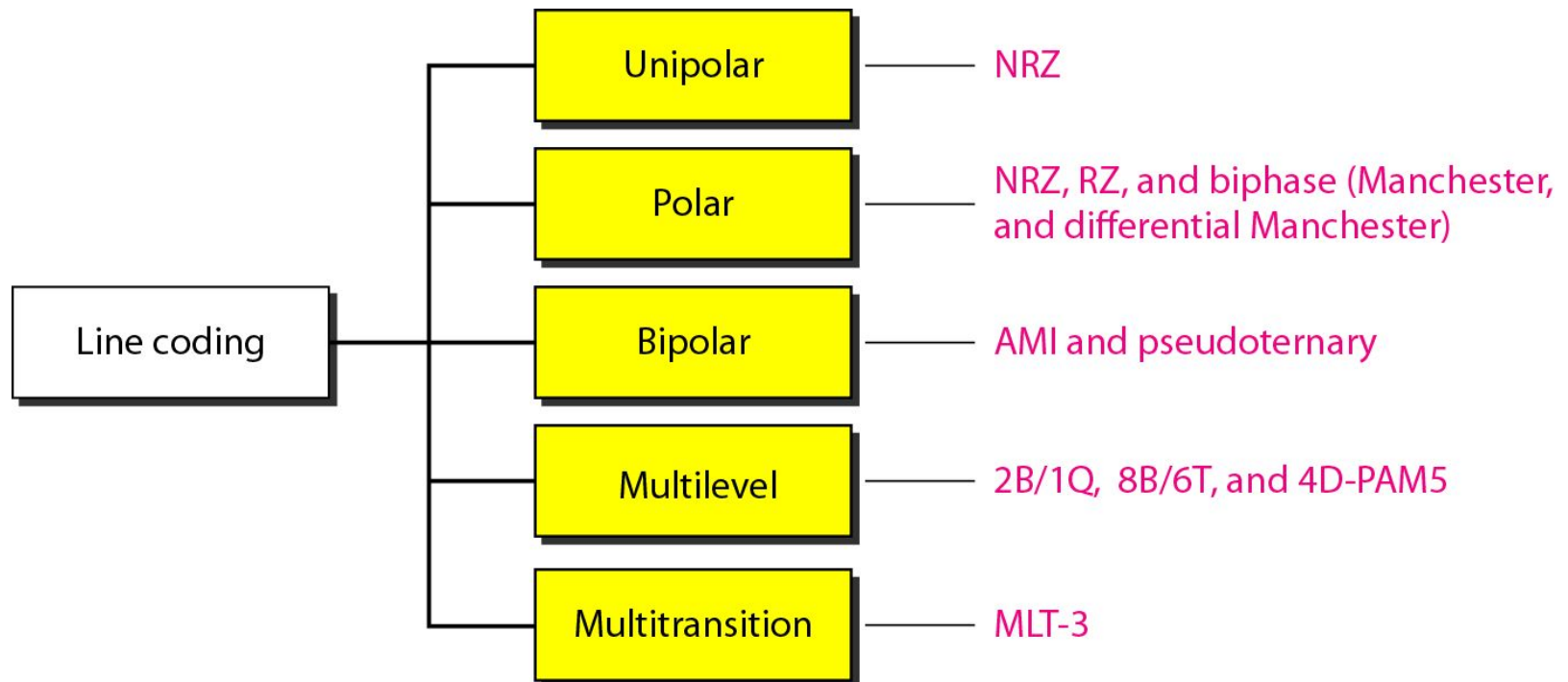
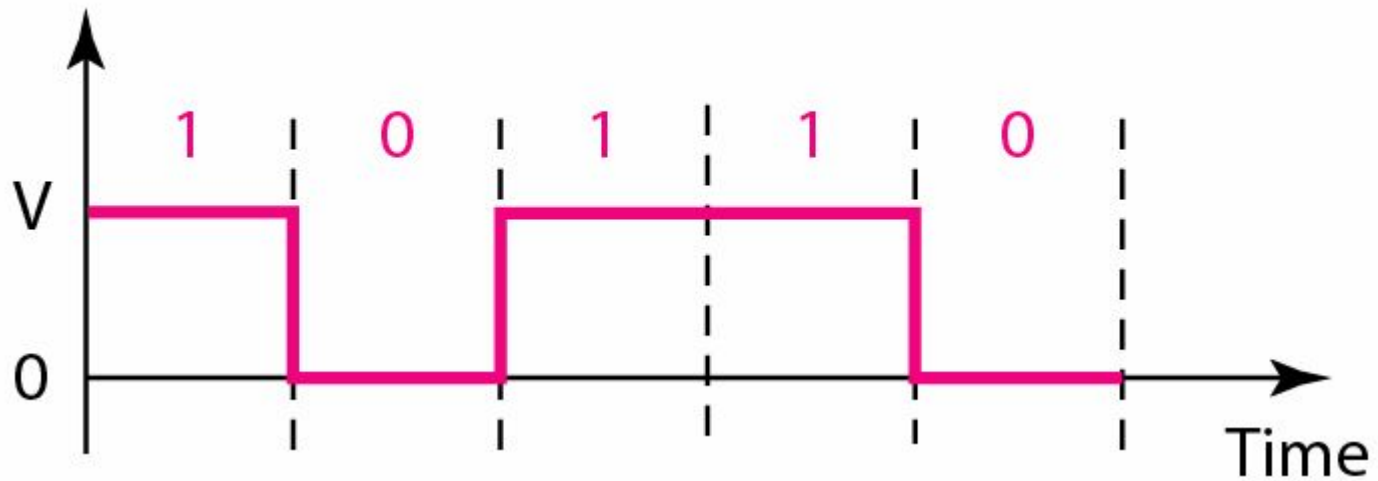


Table 4.1 *Summary of line coding schemes*

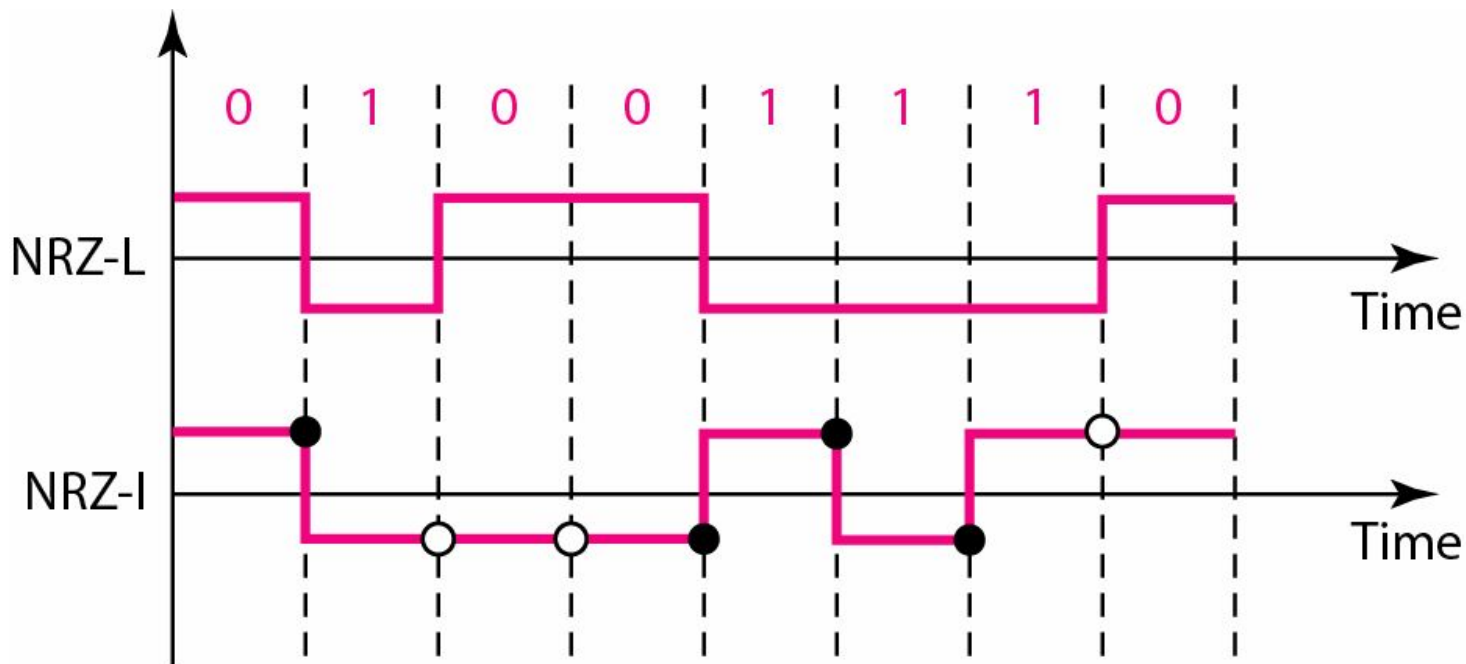
<i>Category</i>	<i>Scheme</i>	<i>Bandwidth (average)</i>	<i>Characteristics</i>
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Unipolar	NRZ-L	$B = N/2$	No self-synchronization if long 0s or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long 0s, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = N/2$	No self-synchronization for long 0s, DC
Multilevel	2B1Q	$B = N/4$	No self-synchronization for long same double bits
	8B6T	$B = 3N/4$	Self-synchronization, no DC
	4D-PAM5	$B = N/8$	Self-synchronization, no DC
Multiline	MLT-3	$B = N/3$	No self-synchronization for long 0s

Unipolar

Amplitude



NRZ-L & NRZ-I (Bipolar)



○ No inversion: Next bit is 0

● Inversion: Next bit is 1



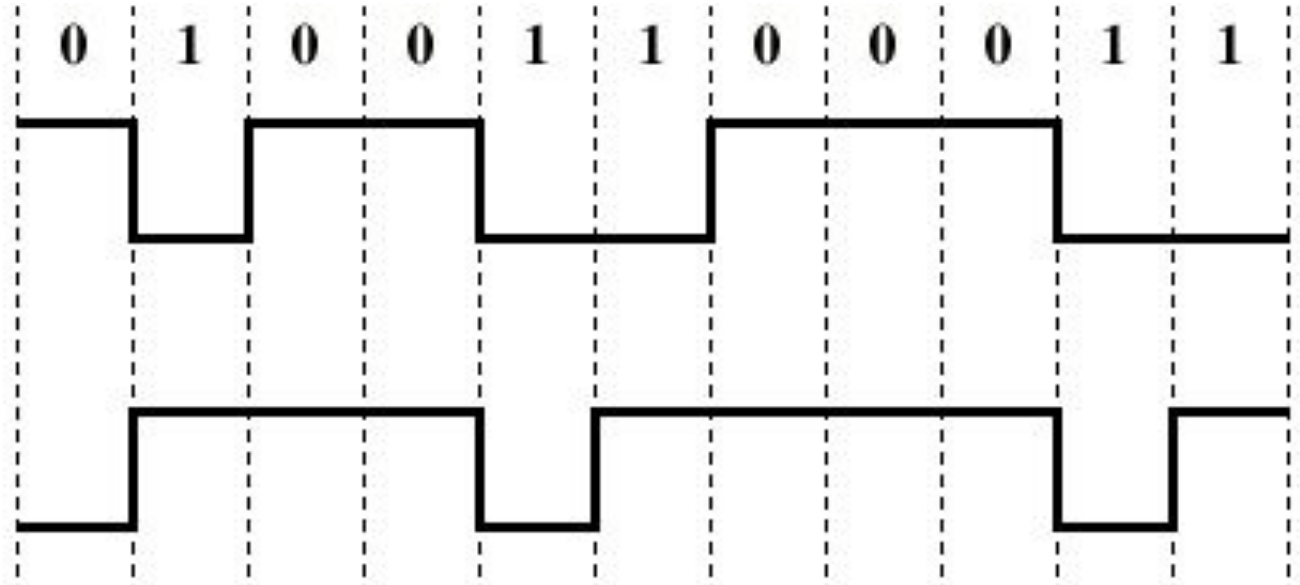
Nonreturn to Zero (NRZ)

	0	1	0	0	1	1	0	0	0	1	1
NRZ-L											
NRZI											

NRZ

NRZ-L

NRZI





NRZ – Pros and Cons

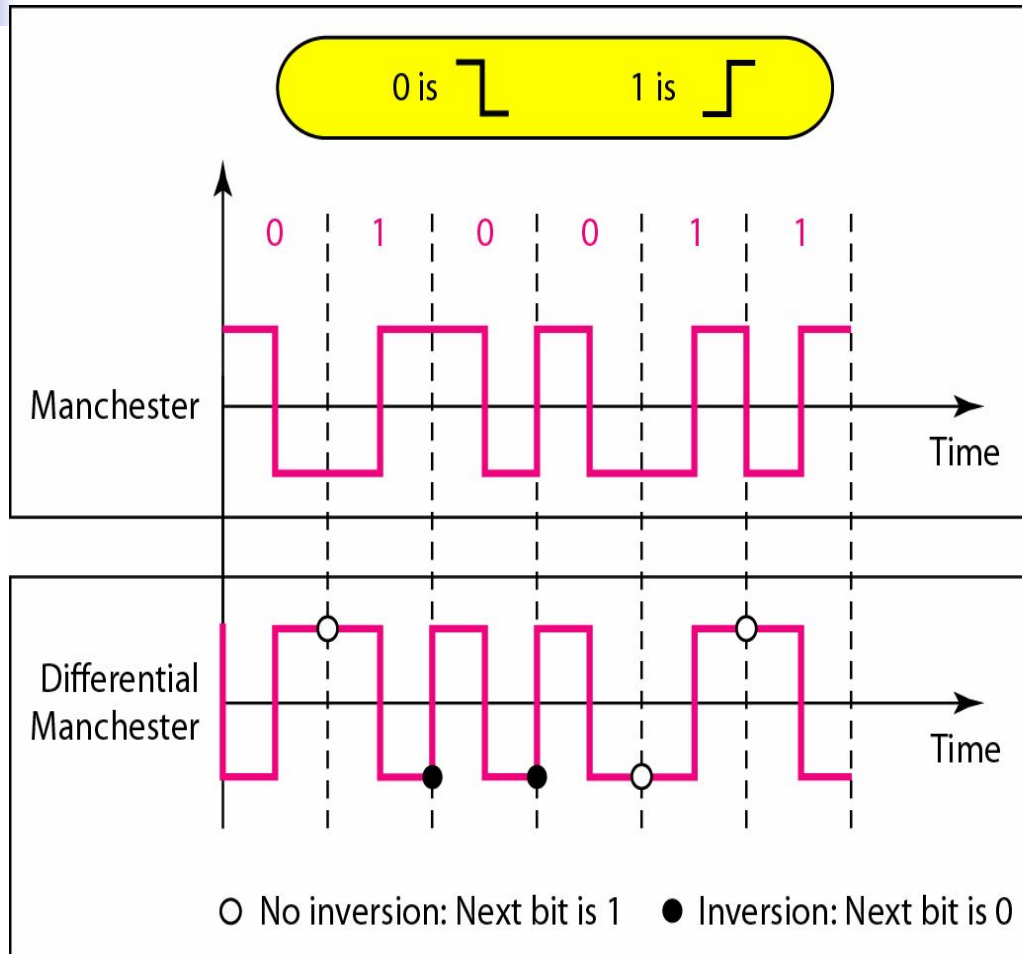
- Pros
 - Easy to engineer
 - Make good use of bandwidth
- Cons
 - DC component
 - Lack of synchronization capability
- Used for magnetic recording
- Not often used for signal transmission



Differential Encoding

- In complex transmission layouts, it is easy to lose sense of polarity
- Therefore
 - Data represented by changes (i.e., transitions) rather than levels
 - More reliable detection of transition rather than level

Manchester Encoding & Differential Manchester Encoding





Biphase (Manchester and D-Manchester)

	0	1	0	0	1	1	0	0	0	1	1
Man											
D-Man											



Biphase -- Pros and Cons

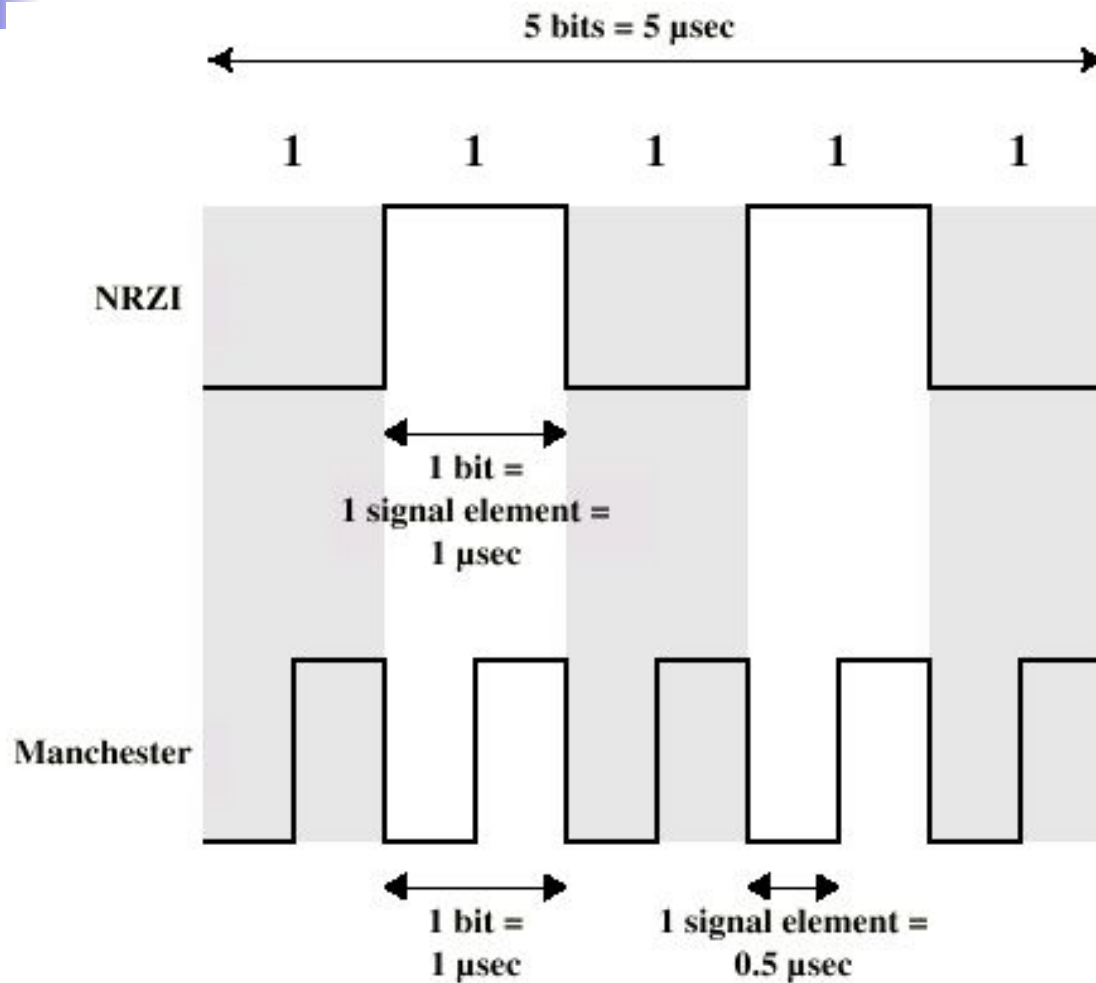
- Pros

- Synchronization on mid bit transition (self clocking)
- No dc component
- Error detection
 - Absence of expected transition

- Cons

- At least one transition per bit time and possibly two
- Maximum modulation rate is twice NRZ
- Requires more bandwidth

Modulation Rate

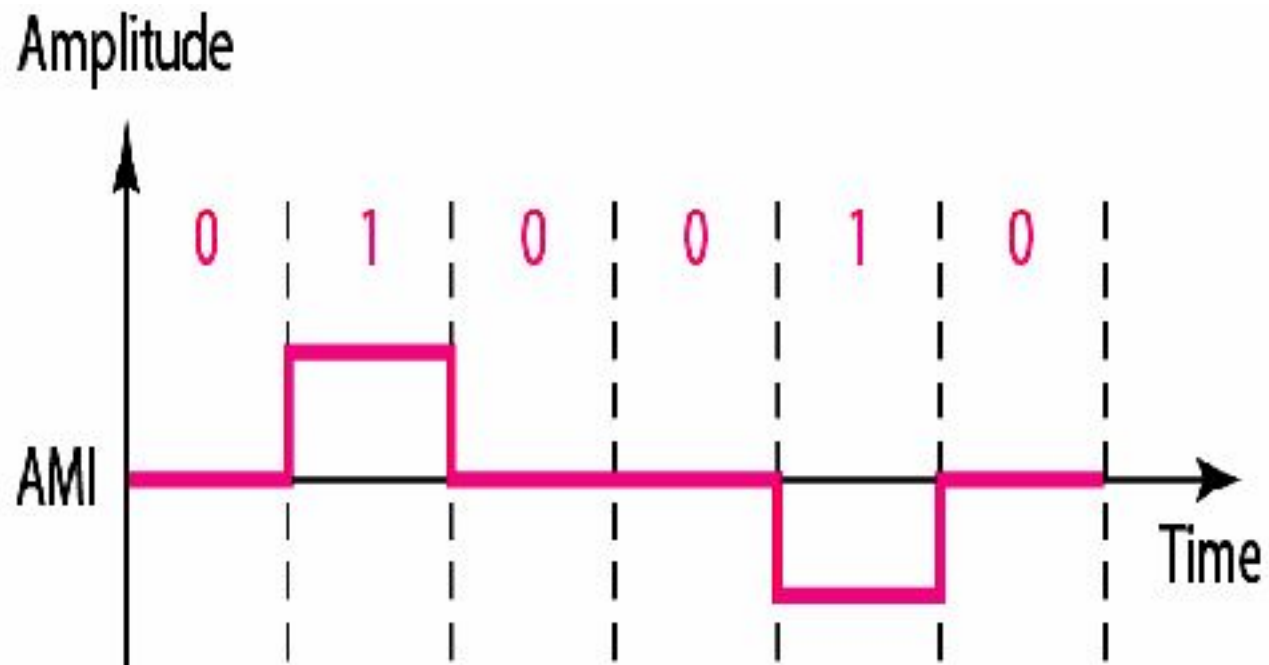




Multilevel Binary

- Use more than two levels
- Bipolar-AMI
 - zero represented by no line signal
 - one represented by positive or negative pulse
 - No loss of sync if a long string of ones (zeros still a problem)
 - Lower bandwidth

Bipolar-AMI

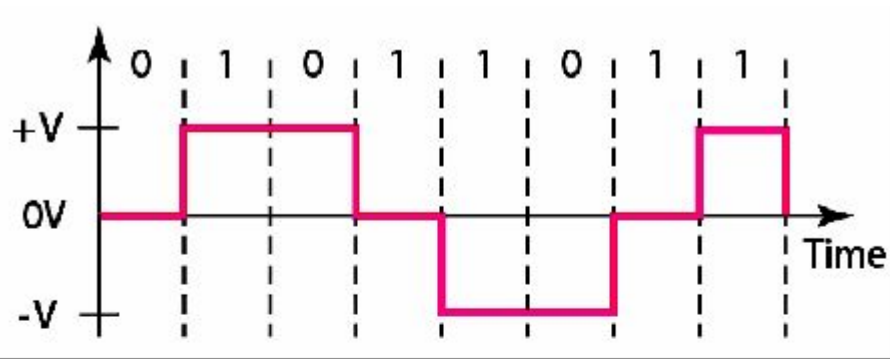




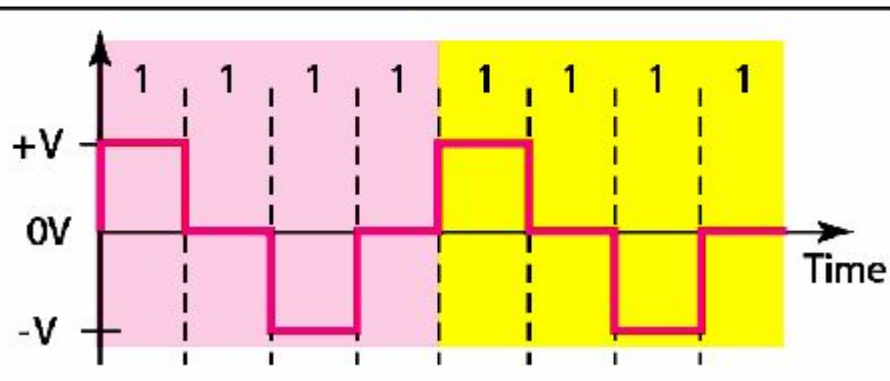
Multilevel Transition, three level- MLT-3,

- There is no transition at the beginning of a 0 bit.
- The signal transitions from one level to the next at the beginning of a 1 bit
- Transition occurs using three levels of signals (+1, 0, -1).

MLT-3



a. Typical case



b. Worse case



Bipolar AMI and MLT-3 Example

	0	1	0	0	1	1	1	0	0	1	1
Bipolar AMI											
MLT-3											

Bipolar
AMI

MLT-3



Block Coding



Block Coding/Scrambling

- NRZ, Bipolar AMI, MLT-3 all has a common problem.
- Long sequence of 0 can make the receiver lose synchronization
- **Solutions:**
 - Change the bit stream before encoding with NRZ-I so that there is no long streams of 0s.



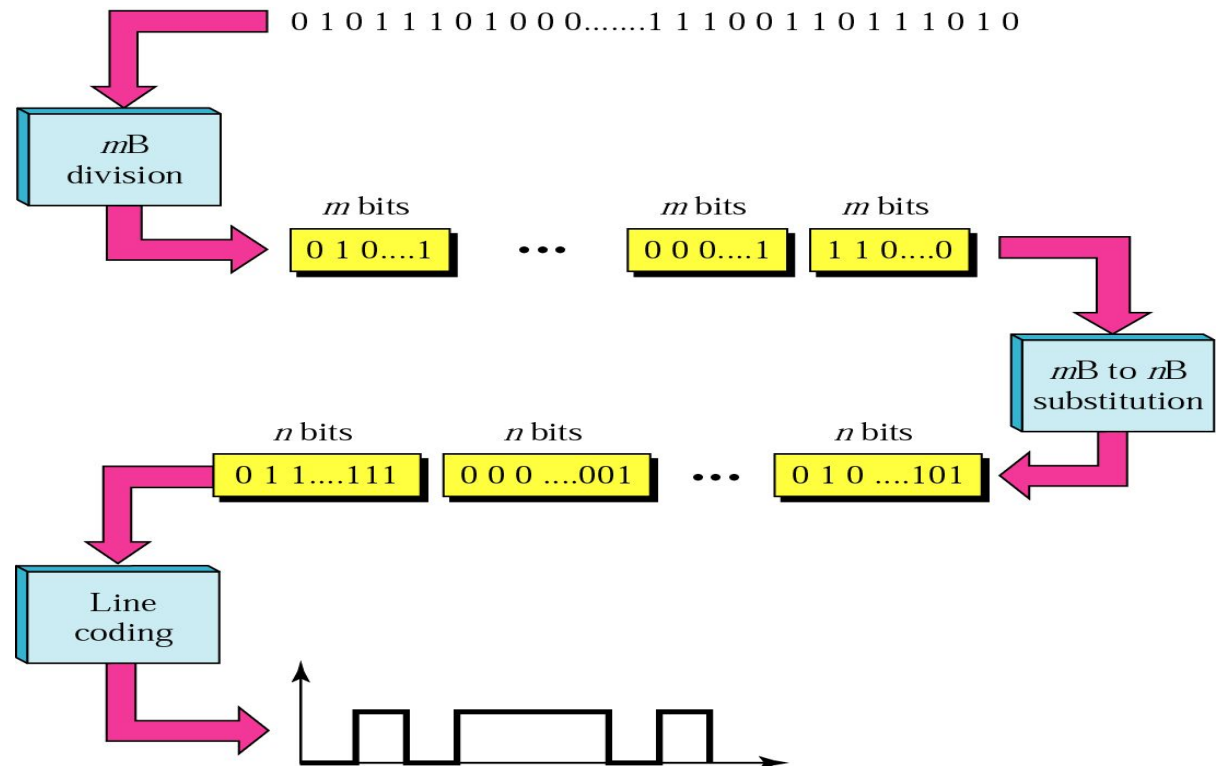
Solutions:

- Block Coding
- Scrambling
- Block Coding
 - Changes a block of m bits to a block of n bits.
 - Referred to as mB/nB encoding.

Block Coding

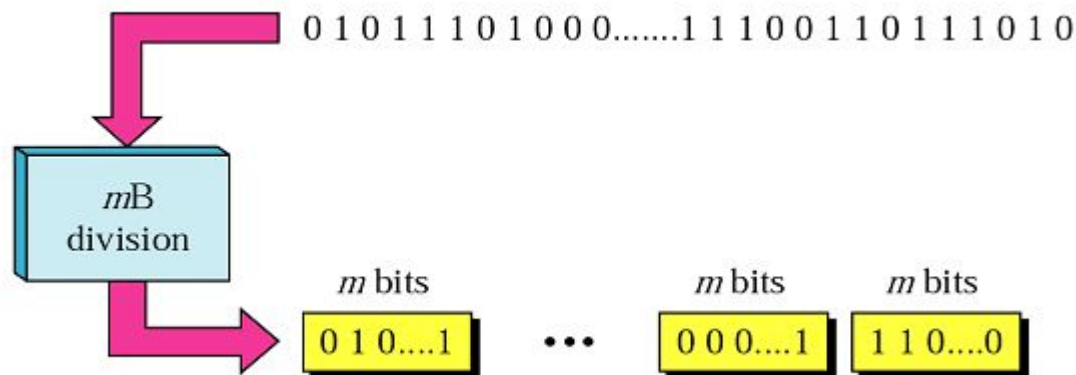
- Three Steps Process:

- Division
- Substitution
- Line Coding /Combination



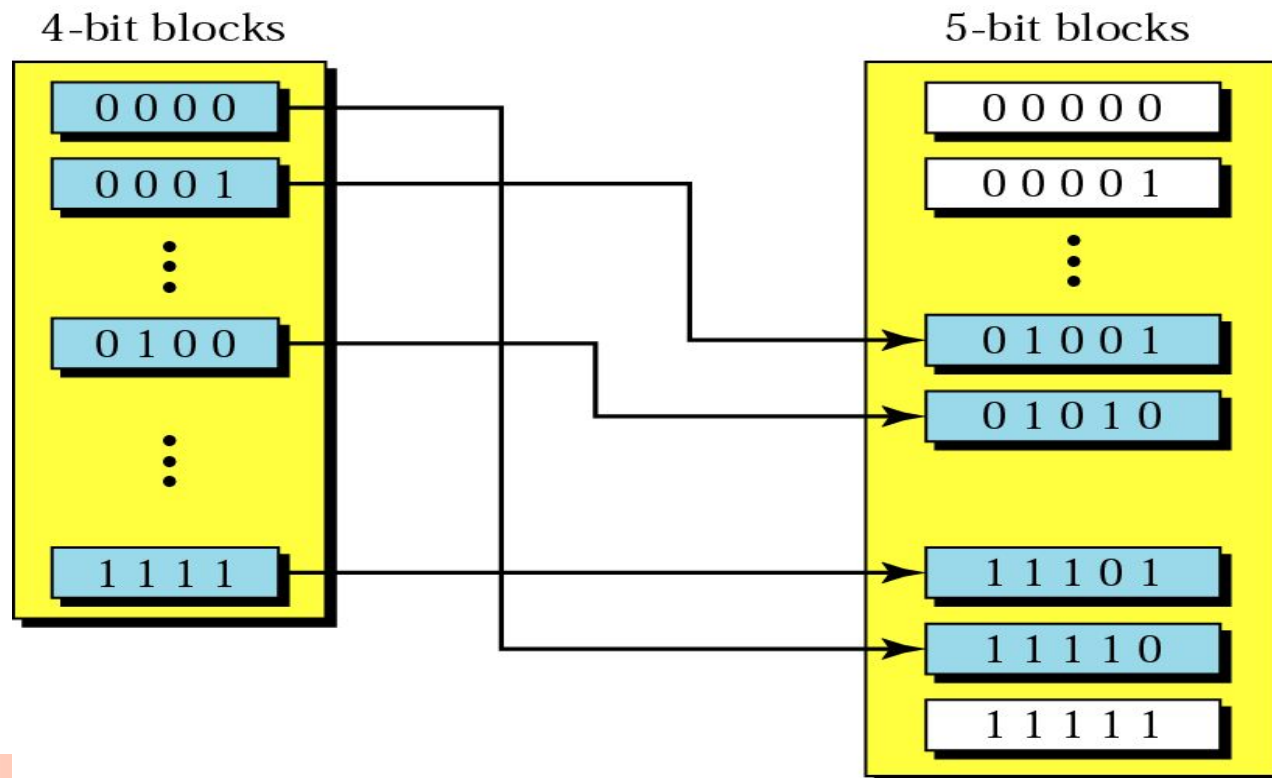
Step 1-Division

- The sequence of bits in data is divided into m Bits.
- For example in 4B/5B encoding, the original bit sequence is divided into 4-bit codes/sequence.



Step 2-Substitution

- Each m bits sequence is substituted for a n bit code.





4B/5B Block Coding

- 4-bit code == 16 different combinations
- 5-bit code == 32 possible combinations.
- So not all of 5-bit codes are required.
- Selection of the 5-bit code is such that each code contains no more than
 - “one leading 0 and no more than two trailing 0s.” (3 consecutive 0s)



Table : 4B/5B encoding

<i>Data Sequence</i>	<i>Encoded Sequence</i>	<i>Control Sequence</i>	<i>Encoded Sequence</i>
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		



Step 3: Line Coding

- After substitution, a line coding scheme, exp NRZ-I is chosen to create a signal.
- A very simple line coding scheme is chosen, because the block coding procedure provides
 - two desirable features (??) of complex line coding schemes.



Block Coding-Pros/Cons

- Solves the synchronization problem but not the DC component problem.
- If DC is unacceptable, use bipolar or biphase encoding.
- Increases the baud rate **by 20%**, still better than Manchester schemes.



Scrambling

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



Types of Scrambling:

- B8ZS

- Bipolar With 8 Zeros Substitution
- Commonly used US.

- HDB3

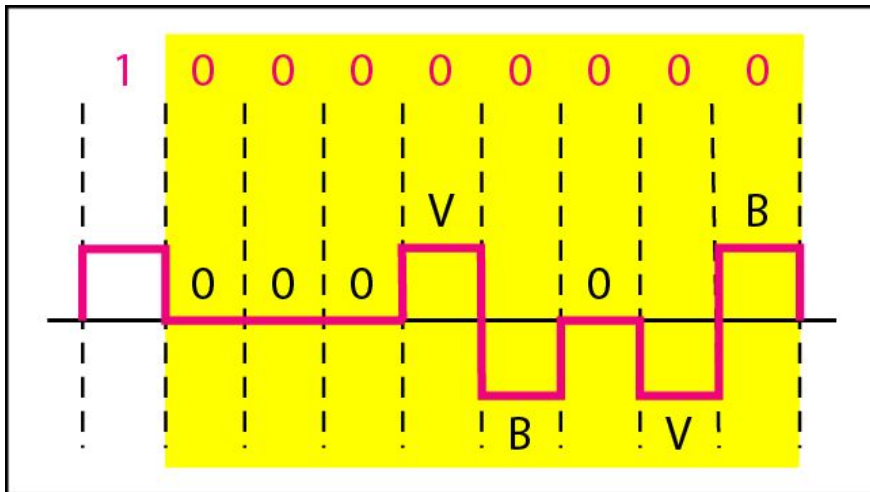
- High Density Bipolar 3 Zeros
- Based on Bipolar AMI
- Commonly used Europe and Japan.



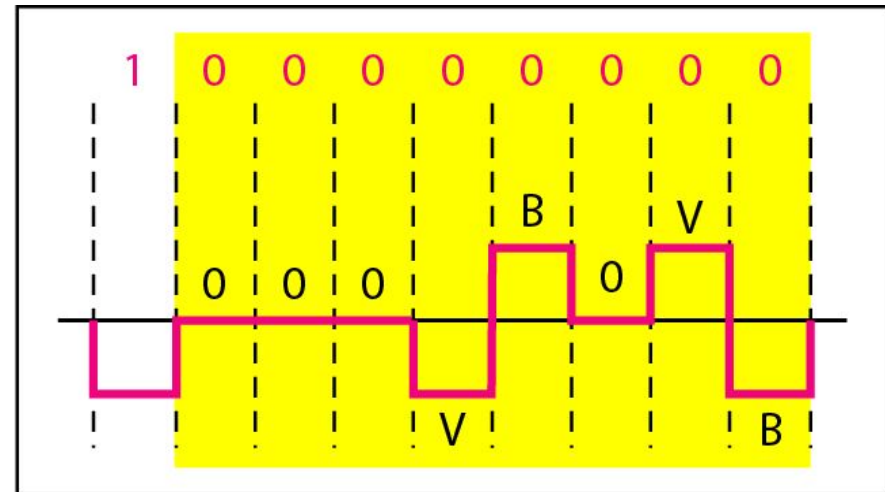
B8ZS

- 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

B8ZS



a. Previous level is positive.



b. Previous level is negative.



HDB3

- High Density Bipolar 3 Zeros
- Based on Bipolar AMI, Commonly used Europe and Japan.
- Based on bipolar-AMI
- String of four zeros replaced with one or two pulses



HDB3 Substitution Table

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

HDB3

