Introduction to Telecommunication Systems
Lecture 8

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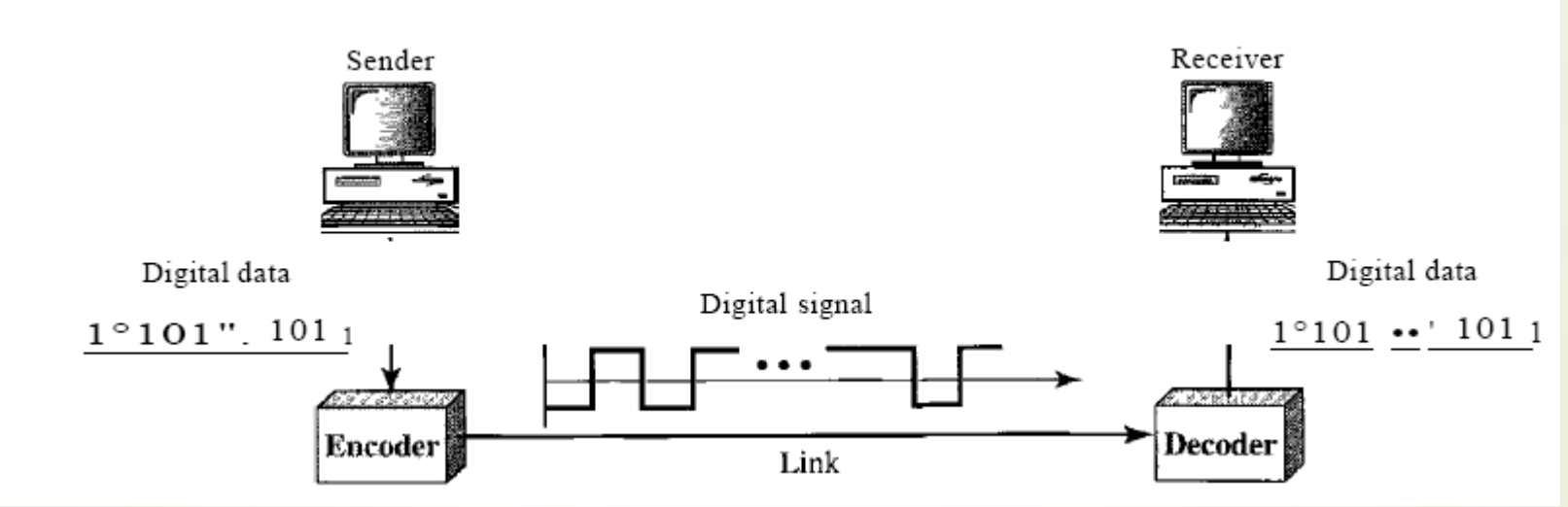
Digital Transmission

Digital Data, Digital Signal

- Line coding is the process of converting digital data to digital signals.
- Line coding converts a sequence of bits to a digital signal.
- At the sender, digital data are encoded into a digital signal; at the receiver, the digital data are recreated by decoding the digital signal.

Digital Transmission



Line coding and decoding

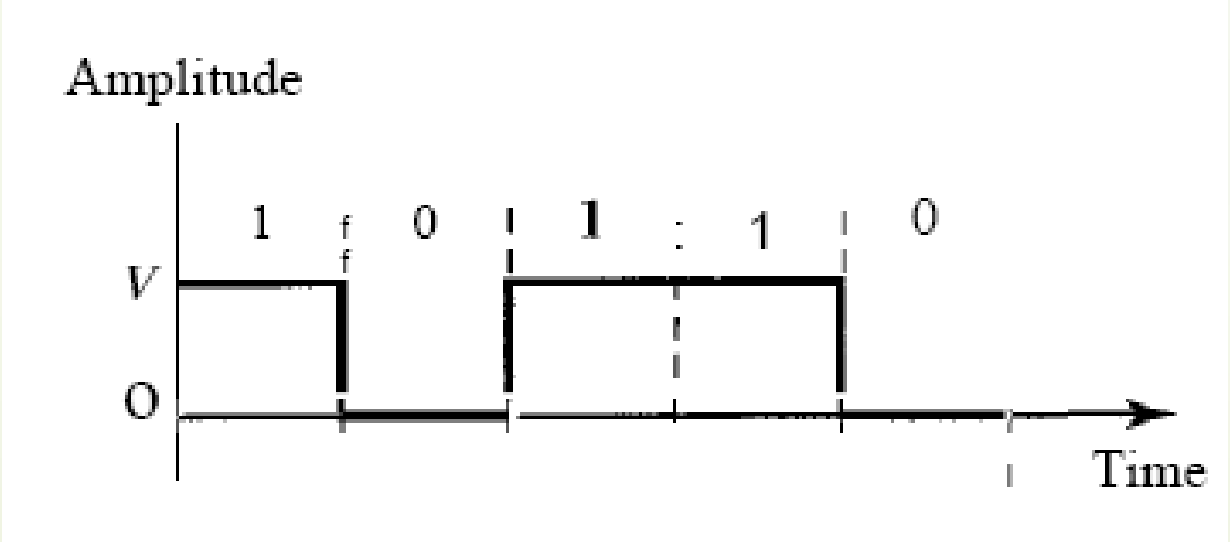
Line Encoding Schemes

- Unipolar: NRZ Scheme
- Polar Scheme: Nonreturn to Zero-Level (NRZ-L), Nonreturn to Zero Inverted (NRZI)
- Multilevel Binary: Bipolar –AMI
- Bi-phase Encoding : Bi-phase Manchester and Differential Manchester
- Block Coding: B8ZS and HDB3

Unipolar NRZ Scheme

- In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.
- NRZ (Non-Return-to-Zero): Traditionally, a unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0.
- It is called NRZ because the signal does not return to zero at the middle of the bit.
- Figure show a unipolar NRZ scheme.

Unipolar NRZ Scheme



Polar Schemes

- In polar schemes, the voltages are on the both sides of the time axis.
- For example, the voltage level for 0 can be positive.
- The voltage level for 1 can be negative.
  - Nonreturn to Zero-Level (NRZ-L)
  - Nonreturn to Zero Inverted (NRZ-I)

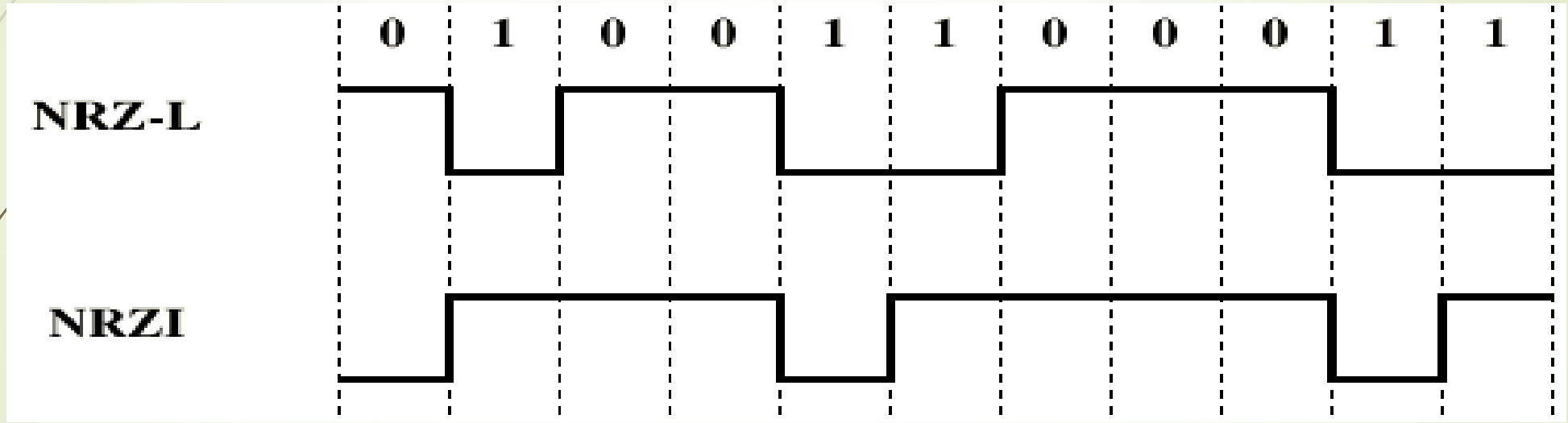
Nonreturn to Zero-Level (NRZ-L)

- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - no transition i.e. no return to zero voltage
- e.g. Absence of voltage for zero, constant positive voltage for one
- More often, negative voltage for one value and positive for the other.
- This is NRZ-L

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 a binary 1
- No transition denotes binary 0
- An example of differential encoding

NRZ



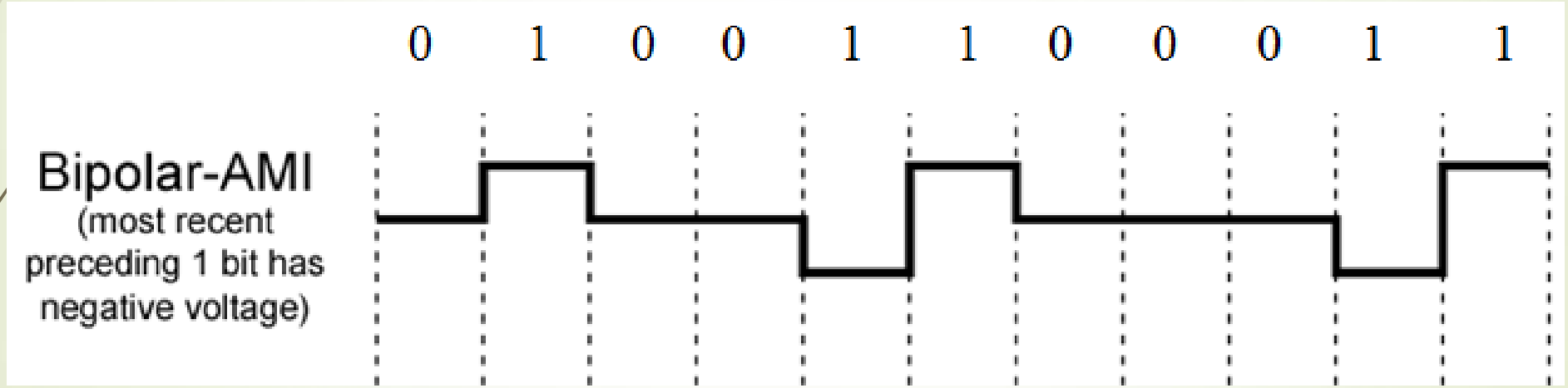
NRZ Pros and Cons

- Pros
  - Easy to engineer
  - Make good use of bandwidth
- Cons
  - DC Component
  - The synchronization of the transmitter clock with the receiver clock gets completely disturbed, when there is a string of **1s** and **0s**. Hence, a separate clock line needs to be provided.
  - It becomes difficult for the receiver to differentiate between 0 and 1.

Multilevel Binary

- 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 (zeros still a problem)
  - No net dc component
  - Lower bandwidth
  - Easy error detection

Bipolar-AMI


0 1 0 0 1 1 0 0 0 1 1
Bipolar-AMI
(most recent preceding 1 bit has negative voltage)

Bi-phase Encoding

- Modulation rate twice that of NRZ and bandwidth correspondingly greater. (Modulation is the rate at which signal level is changed).
- Because there is predictable transition during each bit time, the receiver can synchronize on that transition i.e. clock is extracted from the signal itself.
- Since there can be transition at the beginning as well as in the middle of the bit interval the clock operates at twice the data transfer rate.
- The bandwidth required for this coding is greater.
- There are two types of Bi-phase Encoding.
  - Bi-phase Manchester
  - Differential Manchester

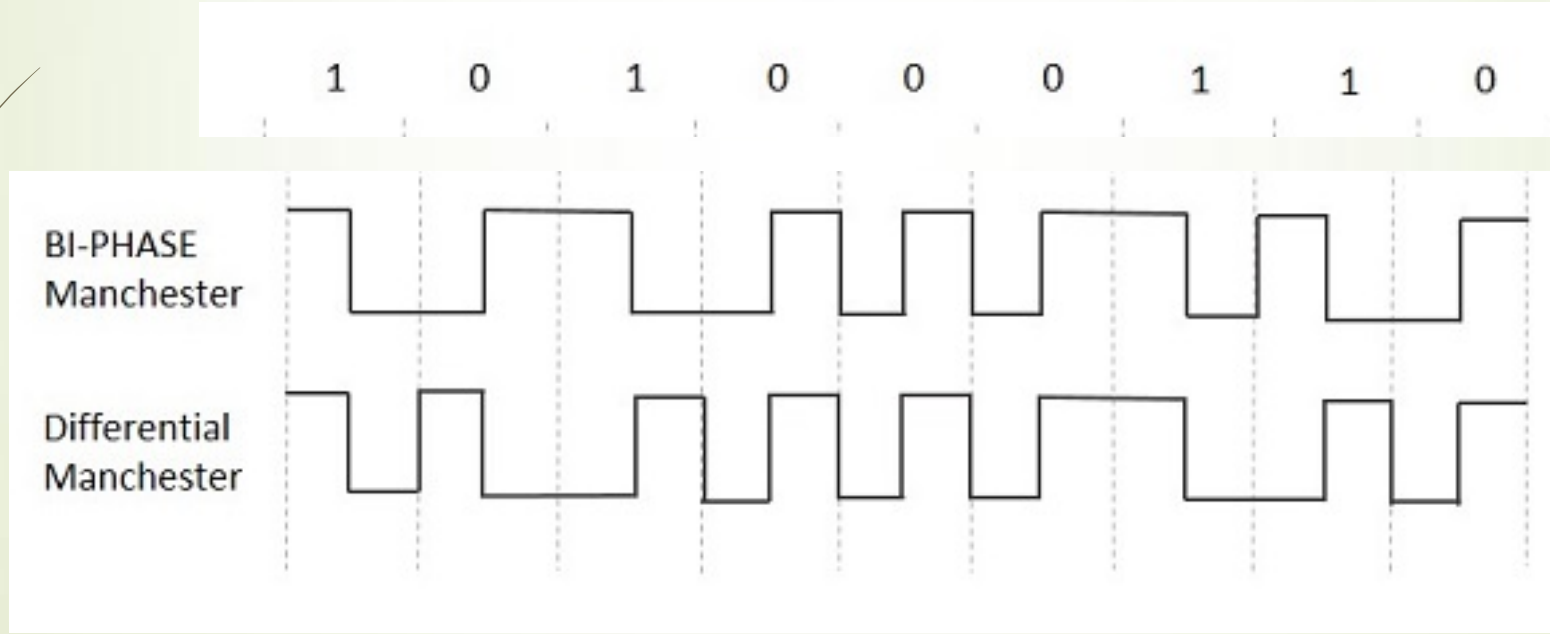
Bi-phase Manchester

- In this type of coding, the transition is done at the middle of the bit-interval.
- The transition for the resultant pulse is from High to Low in the middle of the interval, for the input bit 1.
- While the transition is from Low to High for the input bit **0**.

Differential Manchester

- In this type of coding, there always occurs a transition in the middle of the bit interval.
- If there occurs a transition at the beginning of the bit interval, then the input bit is **0**.
- If no transition occurs at the beginning of the bit interval, then the input bit is **1**.

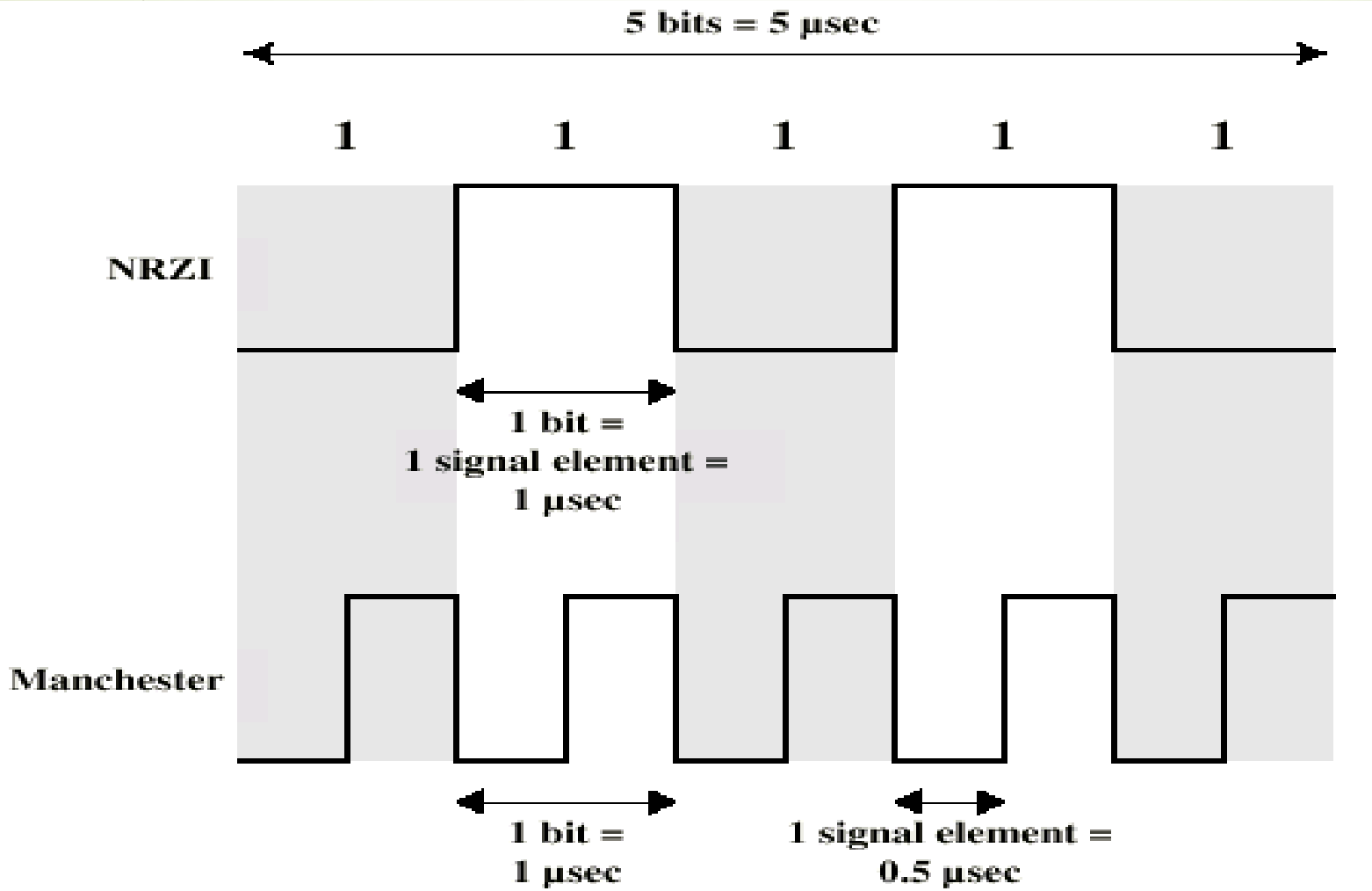
Bi-phase Encoding



Bi-phase Pros and Cons

- Pros
  - Self-clocking: Because there is a predictable transition during each bit time, the receiver can synchronize on that transition.
  - No dc component
  - Error detection: the absence of an expected transition can be used to detect errors
- Cons
  - Requires at least one transition per bit time and may have as many as two transitions, thus, the maximum modulation rate is twice that for NRZ.
  - Requires more bandwidth.

Modulation Rate



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

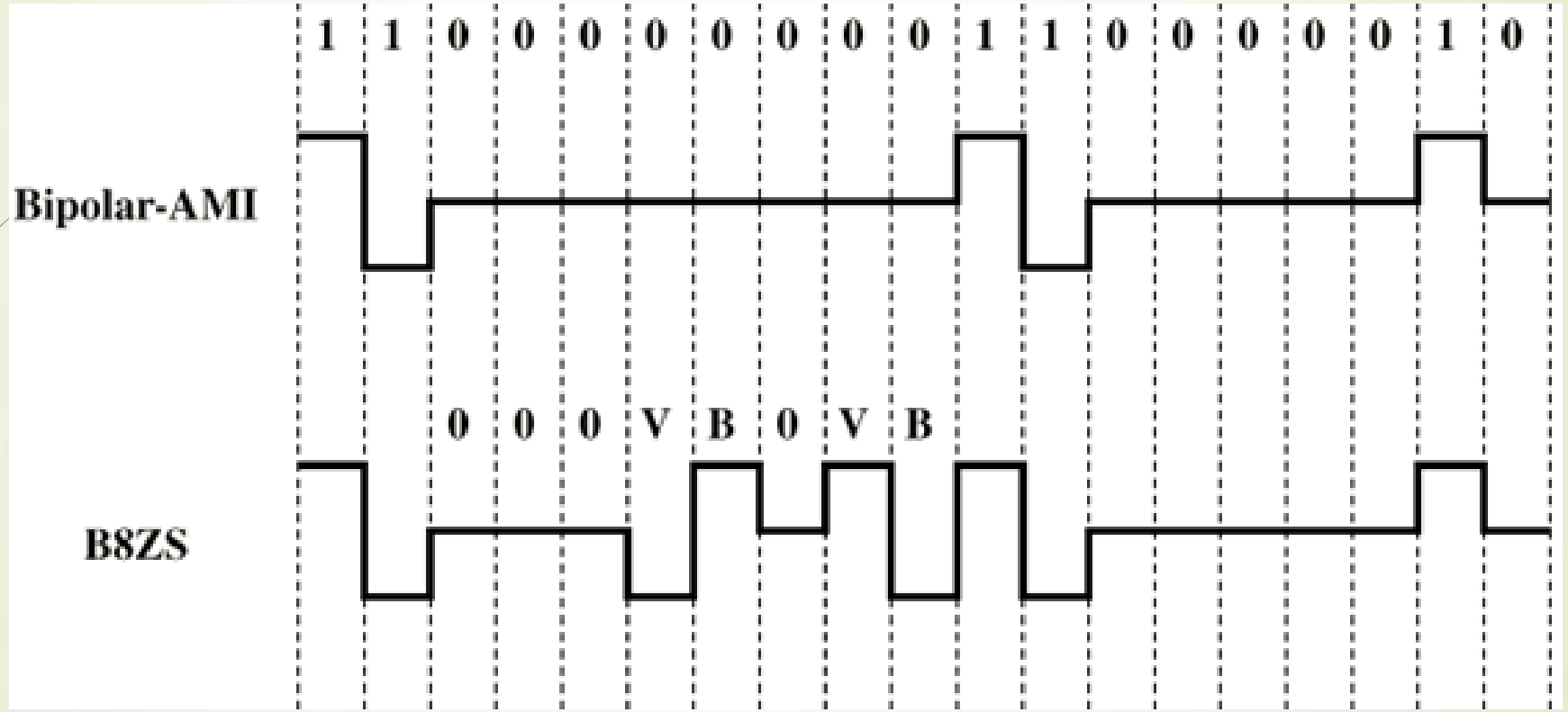
B8ZS

- Bipolar With 8 Zeros Substitution
- Based on bipolar-AMI.
- In this technique, eight consecutive zero-level voltages are replaced by the sequence OOOVBOVB.
- The V in the sequence denotes *violation;* this is a nonzero voltage that breaks an AMI rule of encoding (opposite polarity from the previous).

B8ZS

- The B in the sequence denotes *bipolm;* which means a nonzero level voltage in accordance with the AMI rule.
- Unlikely to occur as a result of noise.
- Receiver detects and interprets as octet of all zeros.

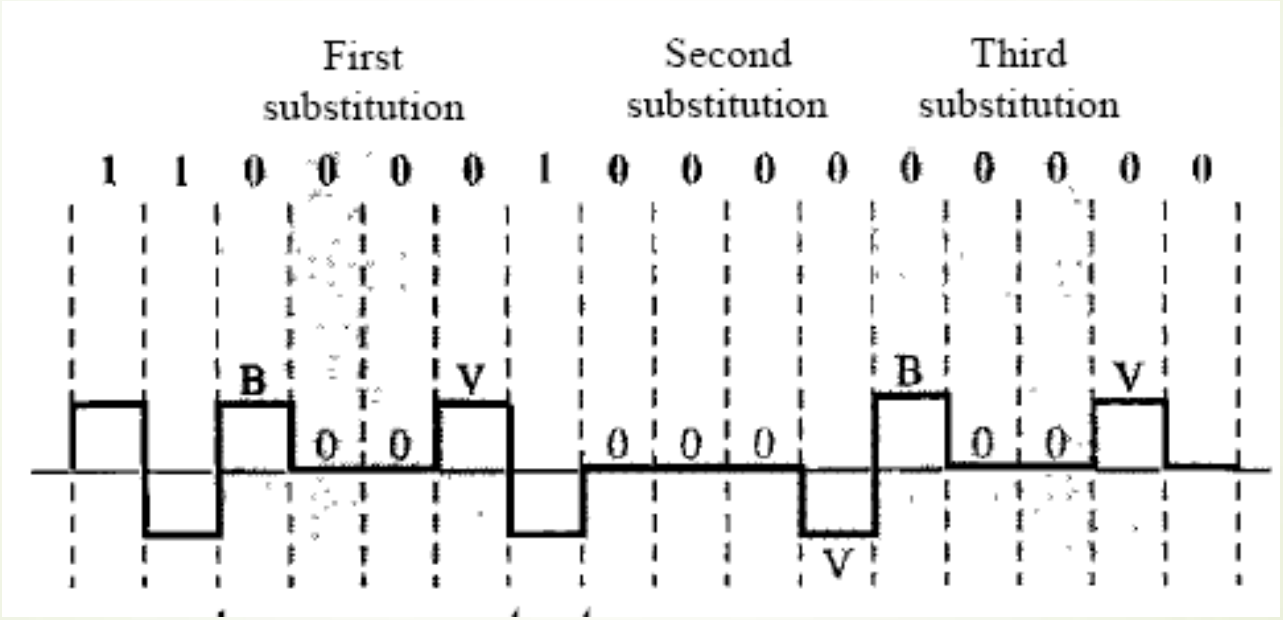
B8ZS



HDB3

- High Density Bipolar 3 Zeros
- Based on bipolar-AMI
- String of four zeros replaced with one or two pulses.
- HDB3 Substitution Rules:
- If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be OOOV, which makes the total number of nonzero pulses even.
- If the number of nonzero pulses after the last substitution is even, the substitution pattern will be BOOV, which makes the total number of nonzero pulses even.

HDB3


First substitution
Second substitution
Third substitution
1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0
B
V
B
V
0 0
0 0 0
0 0
V

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