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Principles of Communication Systems

Chapter 4 (Part 3): Line Coding

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By the end of this class you should be able to:

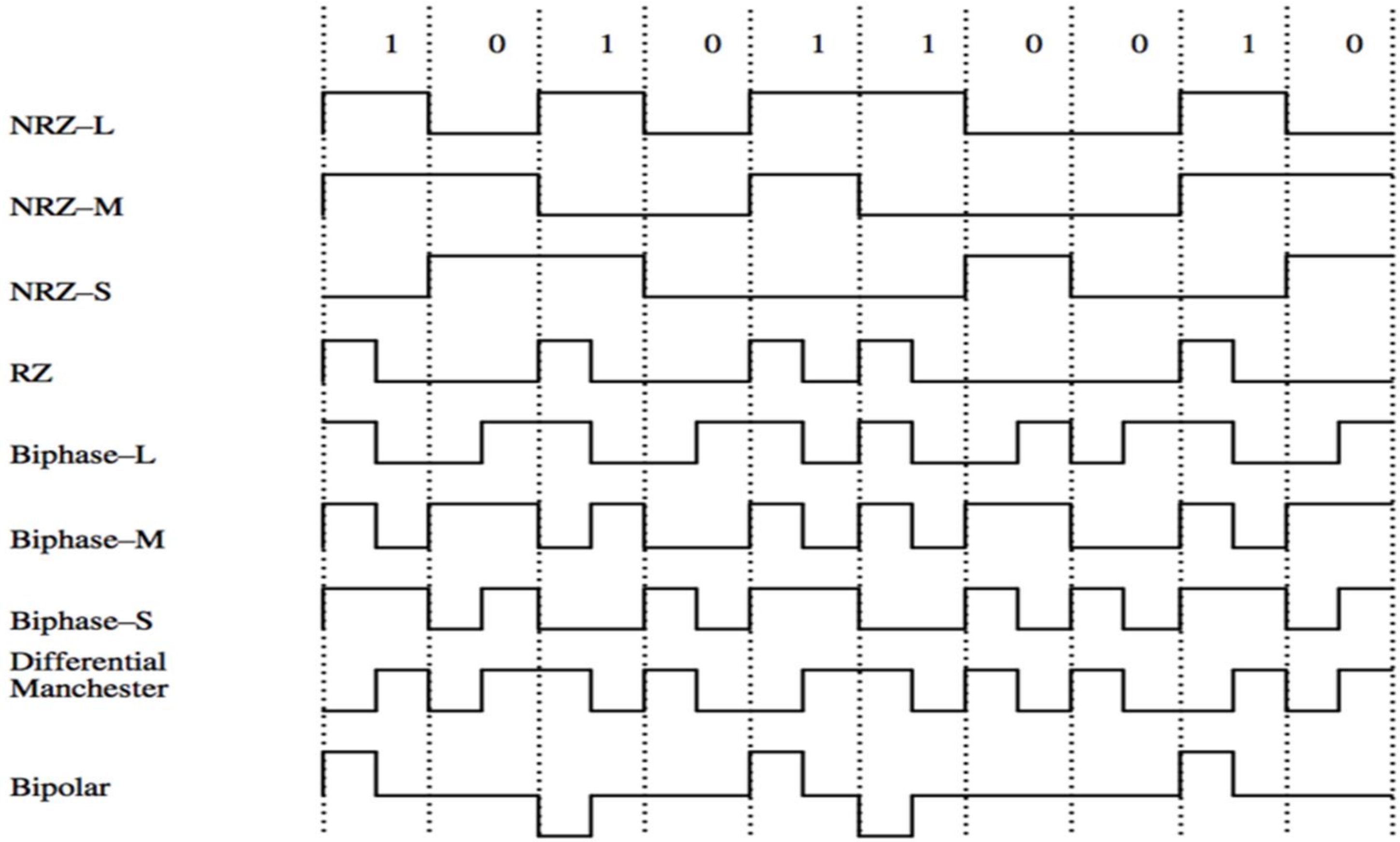
- Explain the concept of different types of line coding
- Solve problems involving line coding

What is Line coding?

- Process of converting binary data (sequence of bits) to a digital signal
- The pattern of voltage, current or photons is modified to represent the digital data on a transmission link.
- Ex. Binary “1” maps to +5V square pulse;

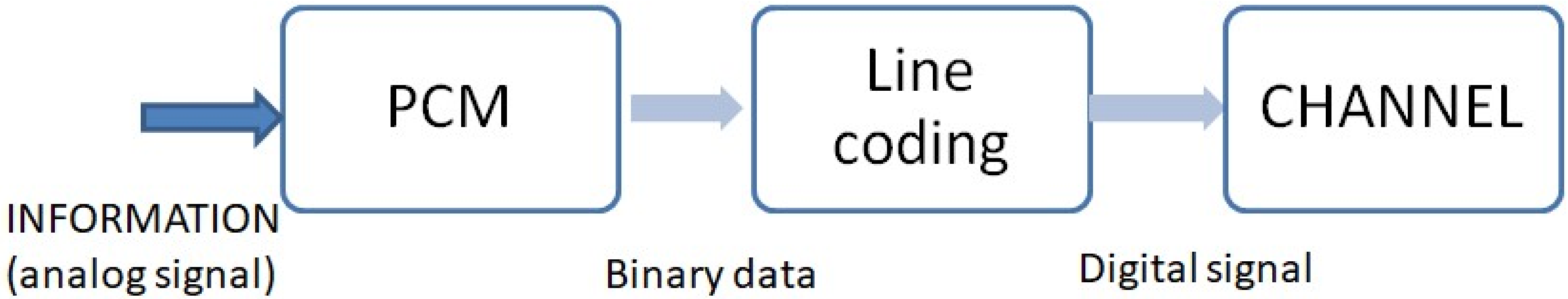
  Binary “0” to –5V pulse

Line Coding



Source: https://commons.wikimedia.org/wiki/File:Binary_Line_Code_Waveforms.png

Why we need Line Coding ?



- The purpose of line coding is to match the digital data output with the channel before transmission could take place.
- Line coding also allow the following processed to be done to the digital data:

1. **Synchronization**
2. **Error detection**
3. **Error correction**

Elements of line coding

Data element:

- number of values or levels used to represent data (either binary 0 or 1)

Data rate, (bits per second)

- the rate at which data elements are transmitted.

Signal element:

- number of values or levels allowed in a particular signal

Signal rate or modulation rate,

- signal elements per second (baud), the rate at which signal elements are transmitted.

Data Rate versus Signal Rate

- **Data rate (bit rate)**
  - How much data is sent in 1 second.
  - The unit is bits per second (bps)

- **Signal rate (baud rate)**
  - How much signal element is sent in 1 second.
  - The unit is the **baud**

- **Relationship between data rate and signal rate:**

$$S = c \times N \times \frac{1}{r} \text{ baud}$$

- S: number of signal elements, c: the case factor, N: data rate (bps), r: data elements per signal elements

Six main properties of line coding

Transmission bandwidth : it should be as small as possible

Power efficiency : transmitted power should be as small as possible

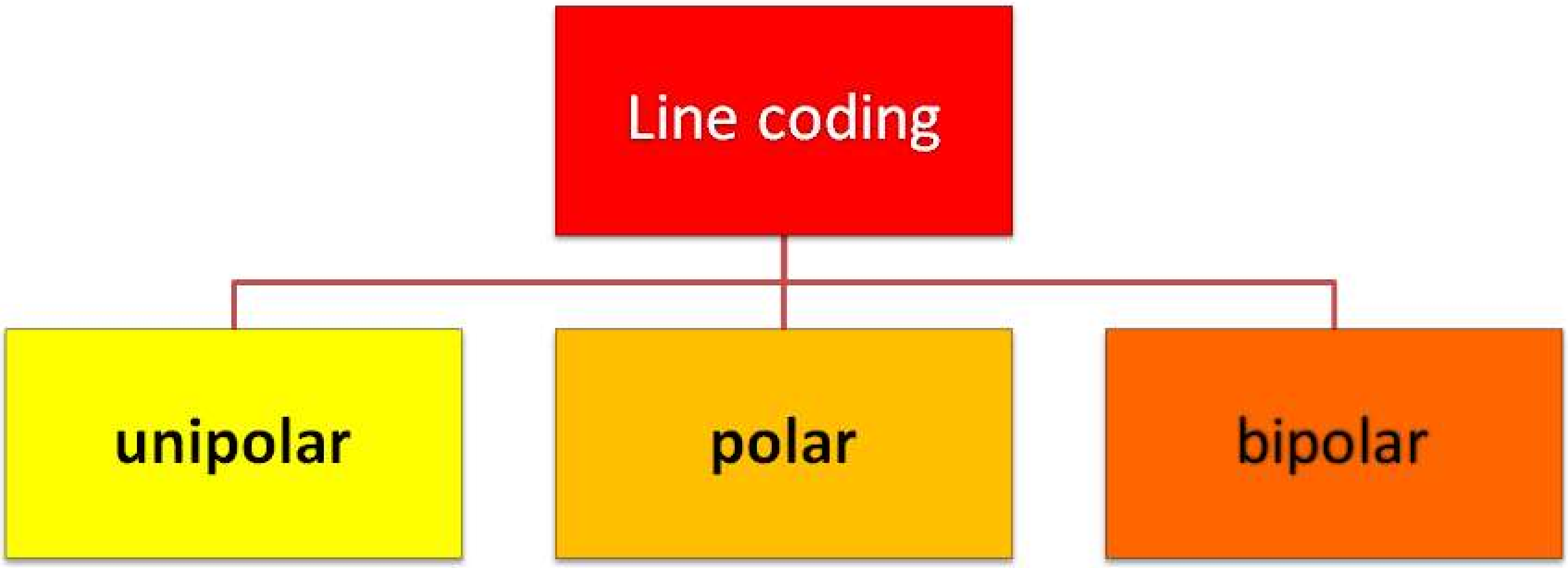
Error detection and correction capability: it should be possible to detect , and preferably correct, detection errors.

Transmission voltage and DC component

Adequate timing content : it should be possible to extract timing or clock information from the signal

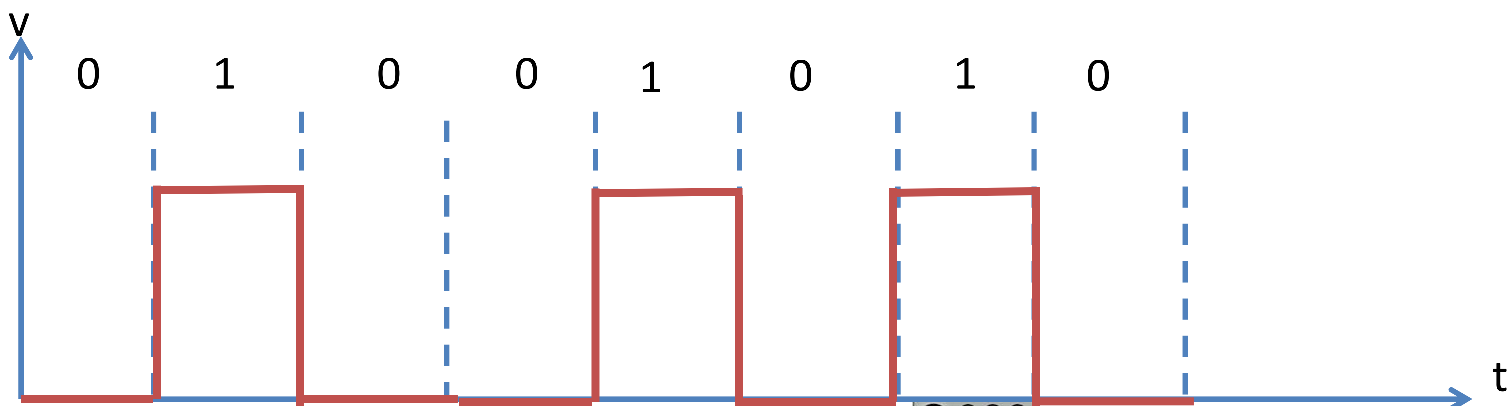
Transparency: it should be possible to transmit a digital signal correctly regardless of the pattern of 1's and 0's.

Line coding schemes



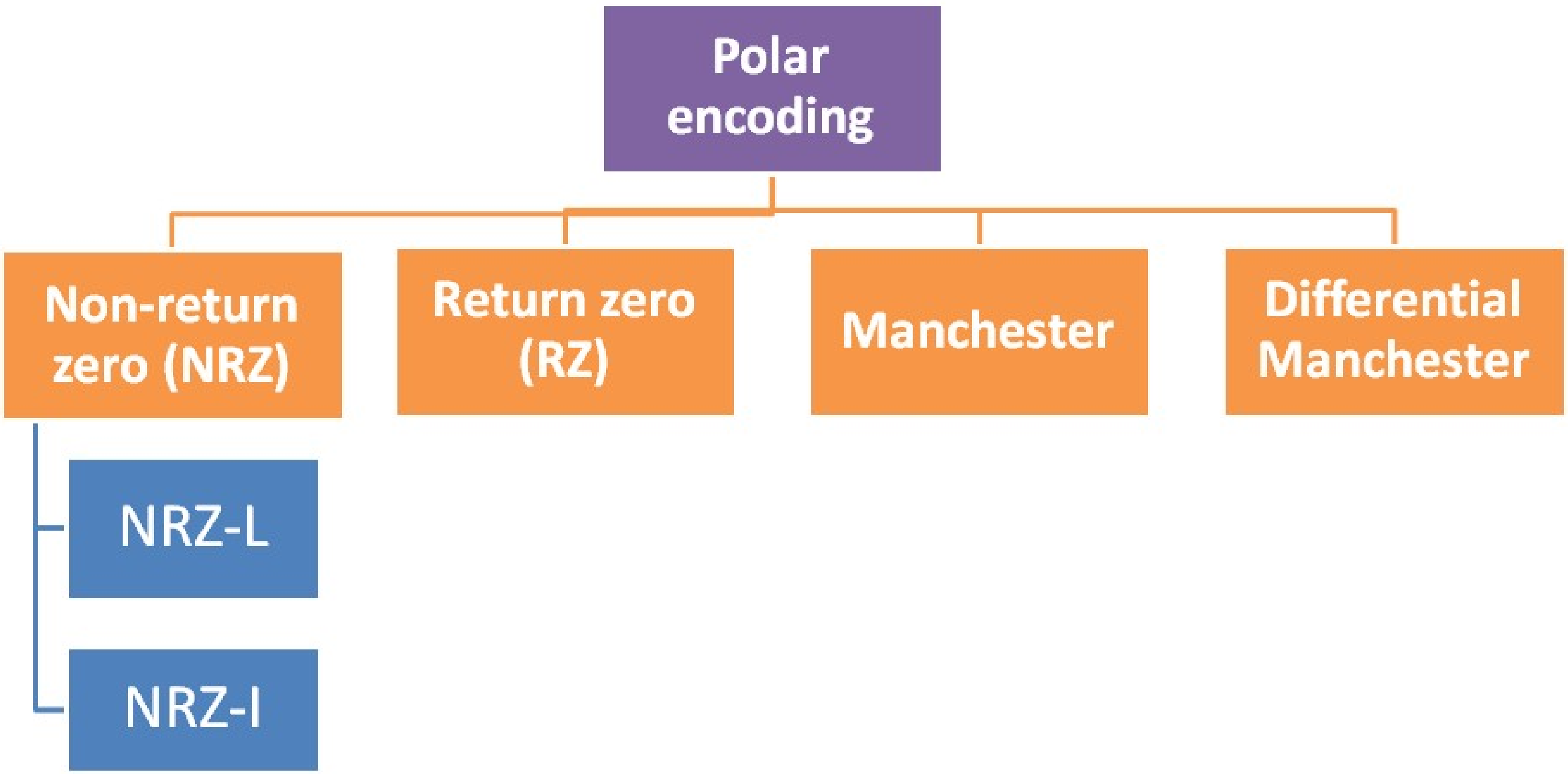
Unipolar Encoding

- ***Uses only one voltage level.***
- A positive voltage represents a binary 1
- Zero volts indicates a binary 0.
- It is the simplest line code
- drawbacks: not self-clocking



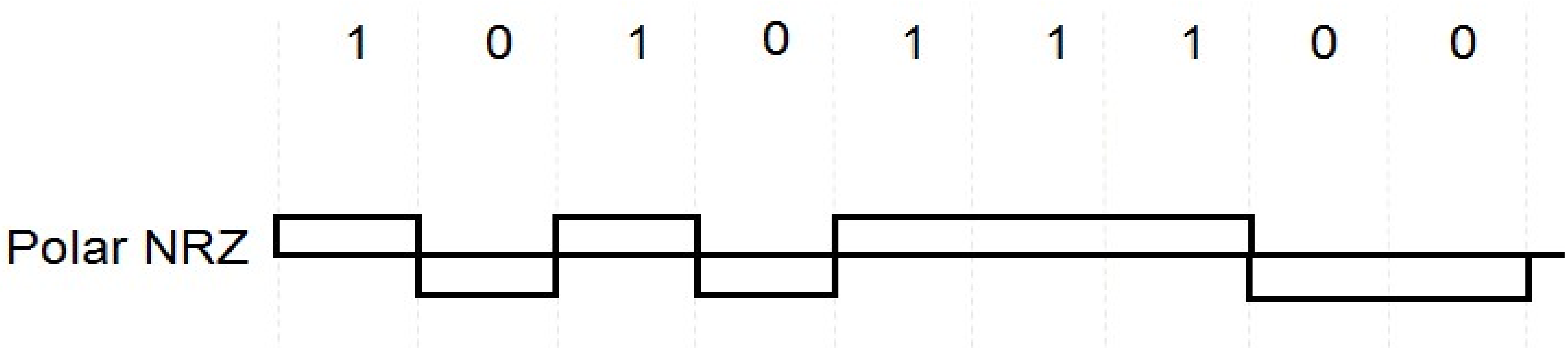
Polar encoding

- Uses two voltage levels (positive and negative).

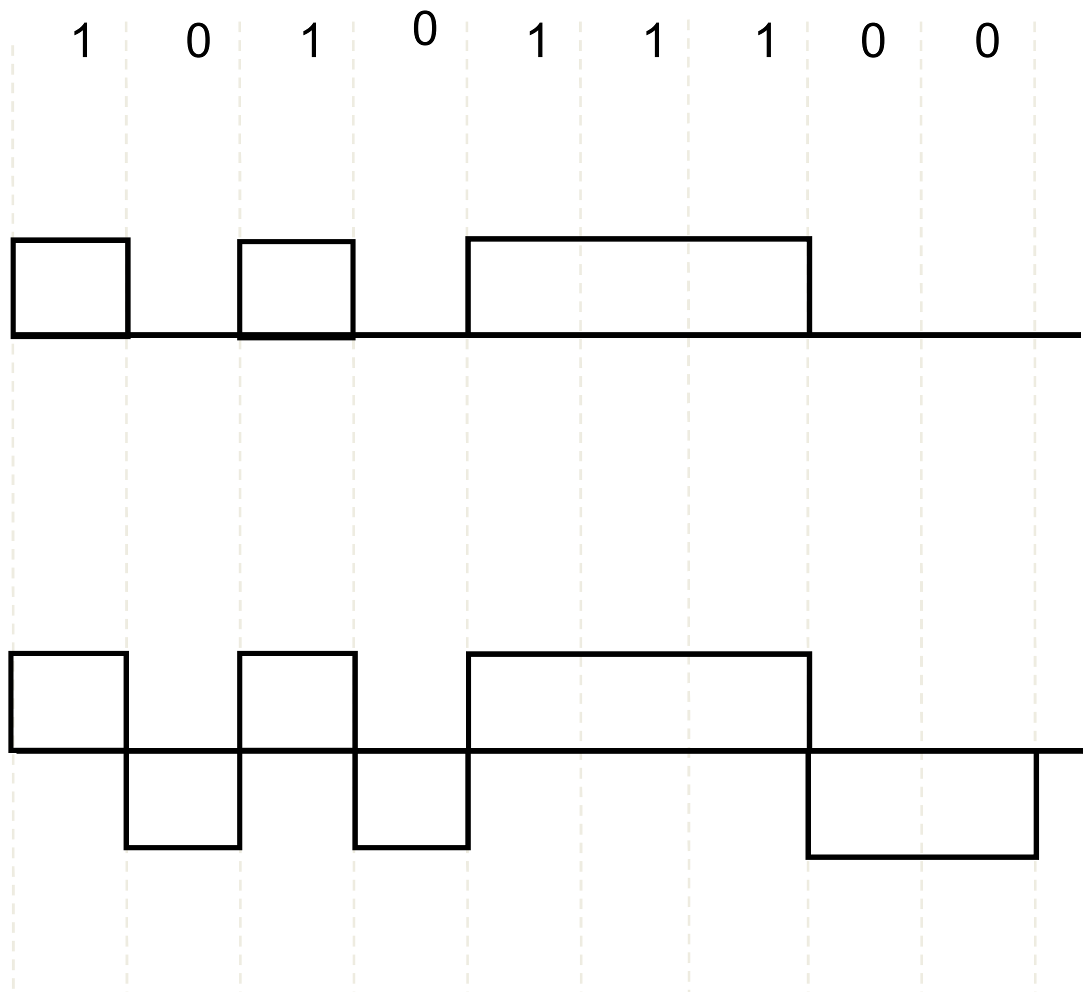


Polar Non-Return-to-Zero-Level (NRZ-L)

- Easy
- signal never returns to zero, and the voltage during a bit transmission is level (1 or 0)
- No synchronization. Can use 'start bit' for synchronization purposes



Unipolar & Polar Non-Return-to-Zero-level (NRZL)



Unipolar NRZ-L

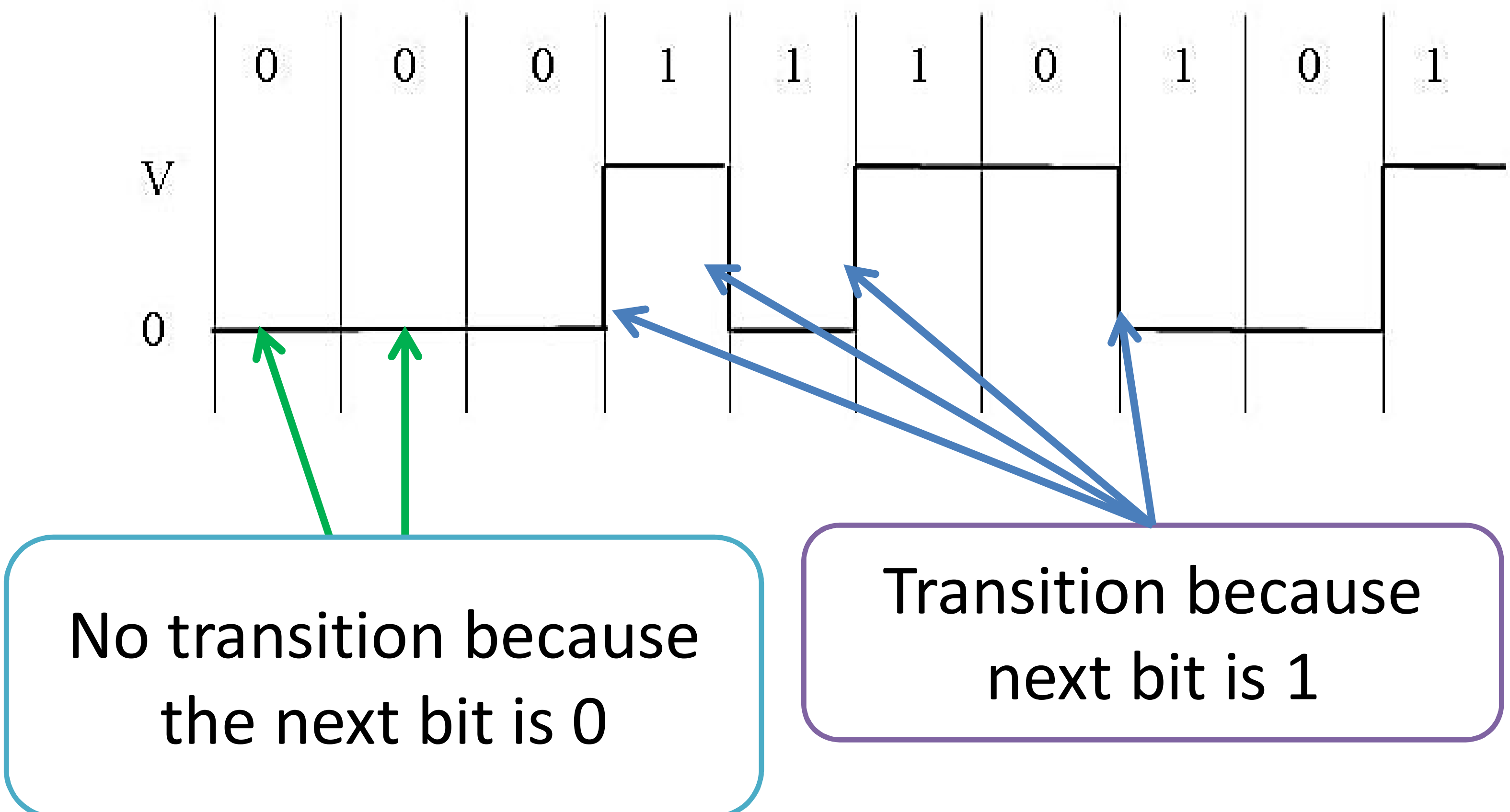
- Binary 1 maps to +A V
- Binary 0 maps to 0 V
- Long strings of A or 0
  - Poor timing
  - Low-frequency content

Polar NRZ-L

- Binary 1 maps to +A/2 V
- Binary 1 maps to –A/2 V
- Long strings of +A/2 or -A/2
  - Poor timing
  - Low-frequency content

NRZ-I encoding

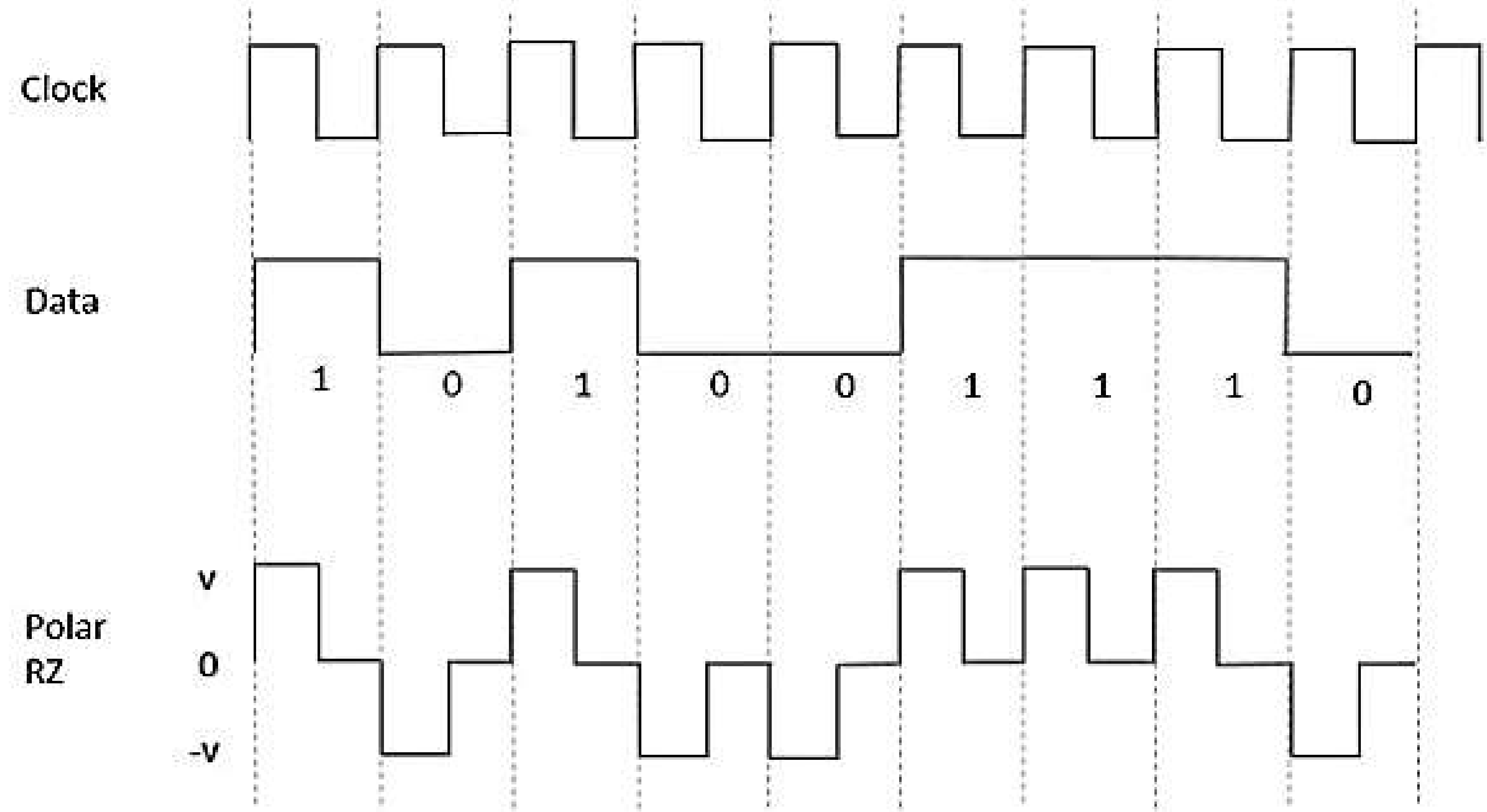
the signal is inverted if a 1 is encountered.



Polar RZ Encoding

- The signal returns to zero in between each pulse, regardless if its ‘0’ or ‘1’
- The signal is self-clocking

Polar RZ Encoding



Manchester Encoding
(IEEE 802.3 (Ethernet) standards)

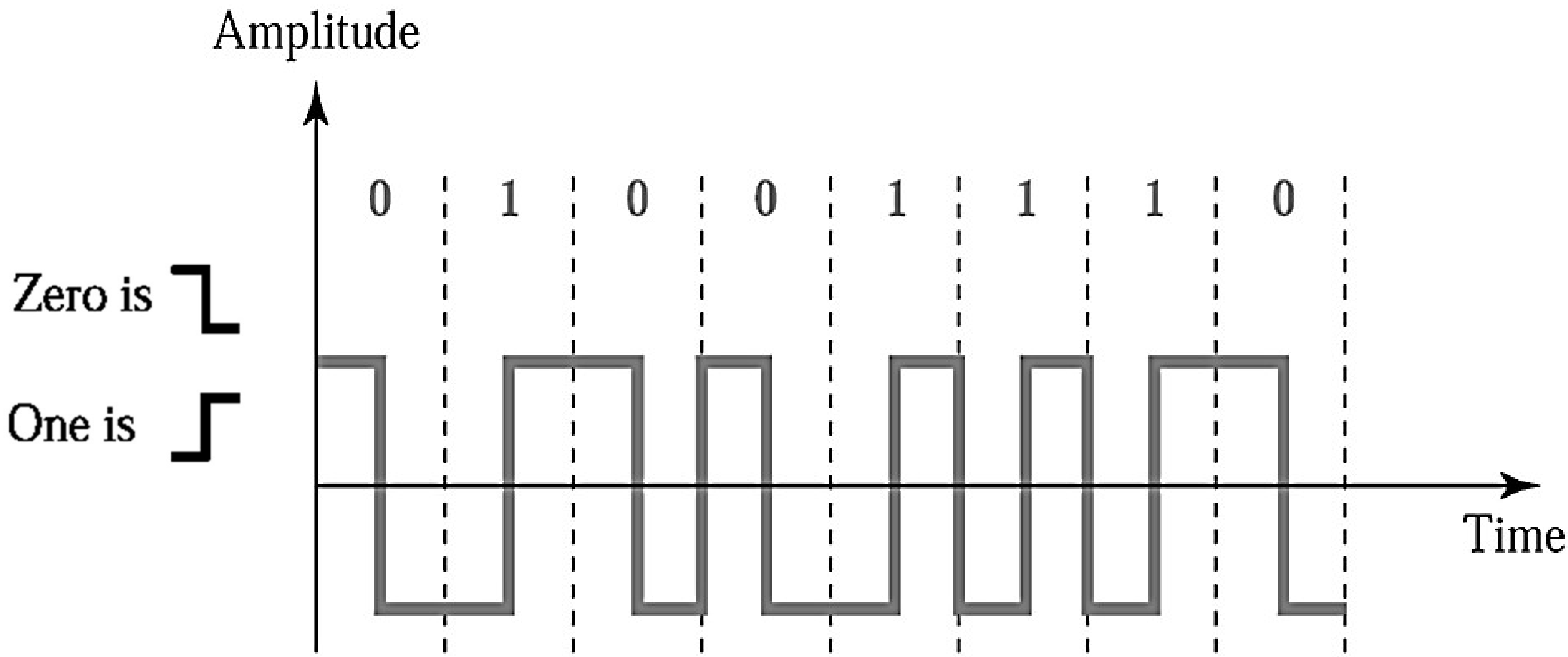
- In Manchester encoding, the signal is changed from a high to low (0) or low to high (1) in the middle of the signal.

Binary 1 => transition from LOW to HIGH at the middle

Binary 0 => transition from HIGH to LOW at the

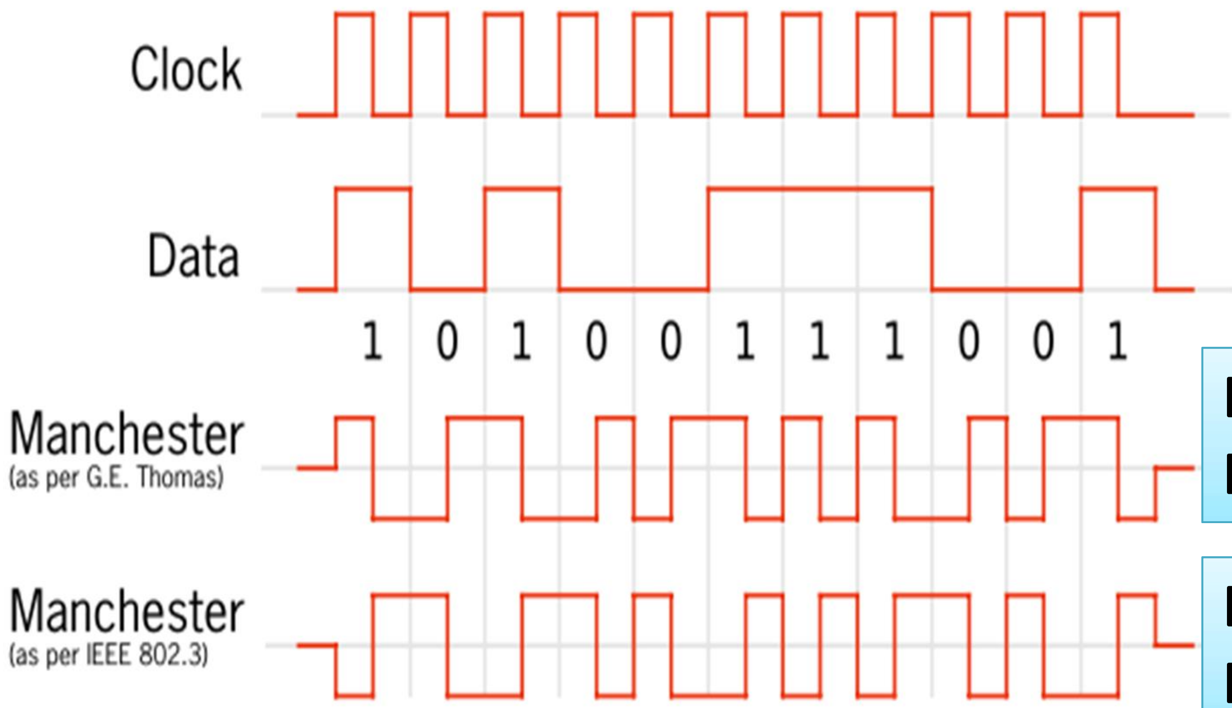
- More reliable when recovering signal

Manchester encoding
(IEEE 802.3 (Ethernet) standards)



The transition at the middle of the bit is used for both synchronization and bit representation.

Manchester Coding problem: different convention for representation of data

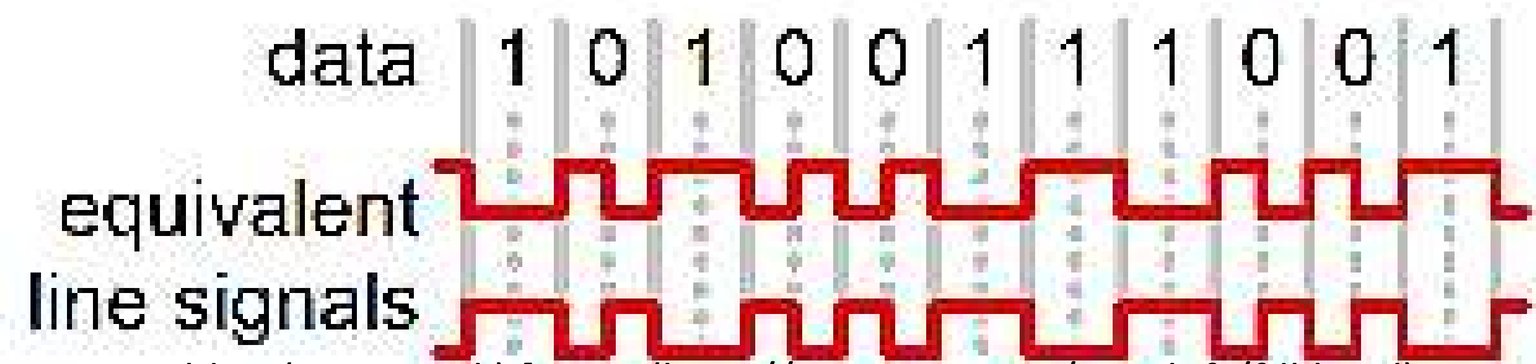


Binary 0: low-high
Binary 1:high-low.

Binary 0: high-low
Binary 1: low-high

Differential Manchester encoding IEEE 802.5 (Token ring)

- Transition at the middle of the bit is used only for synchronization.
- The bit representation is defined by the inversion or noninversion at the beginning of the bit.
  - Binary 1 mapped into no transition in signal level
  - Binary 0 mapped into transition in signal level



By Rainald62 (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html)]

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

Bipolar Encoding - Alternately Mark Inversion

Three levels are used: positive, zero, and negative.

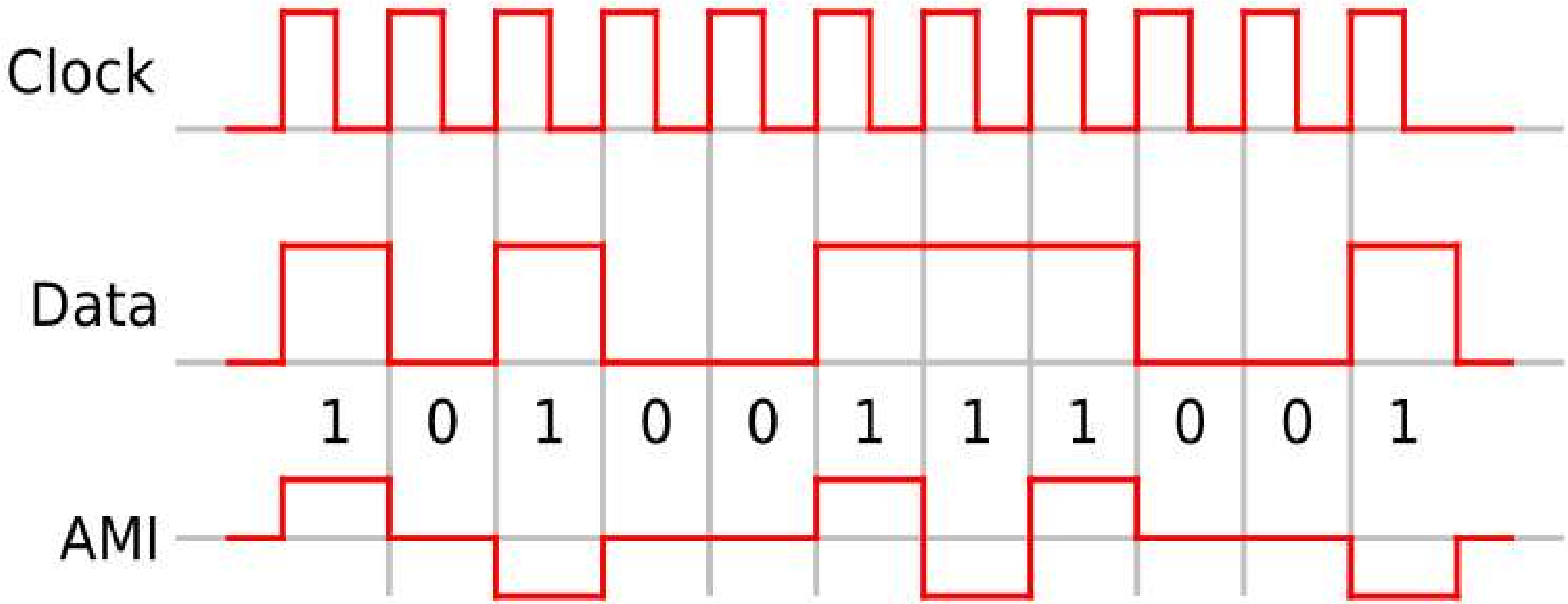
Binary 0 : no line signal

Binary 1 : positive or negative pulse – one pulses alternate in polarity

No loss of synchronization if a long string of ones (zeros still a problem)

RZ (AMI – Alternately Mark Inversion)

- **1 => Alternately +ve and -ve**
- **0 => Low level**



Source: https://en.wikipedia.org/wiki/File:Ami_encoding.svg

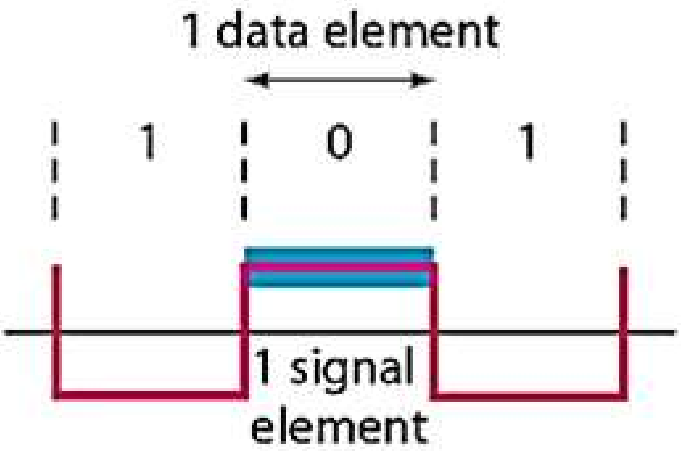
Data rate and Signal (Baud) rate for line coding:

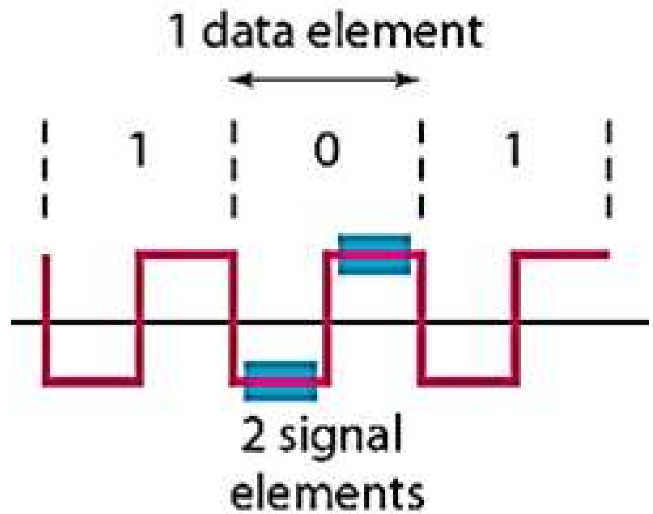
- Baud rate for line coding can be calculated by:

$$S = \frac{N}{r}$$

- Where N is the bit rate and
- R is number of data elements / number of signal elements

Example 1: Assume the data transfer rate as 2000bit/sec





$r = 1$

$S = \frac{N}{r}$

$= \frac{2000}{1}$

=2000 signal/sec

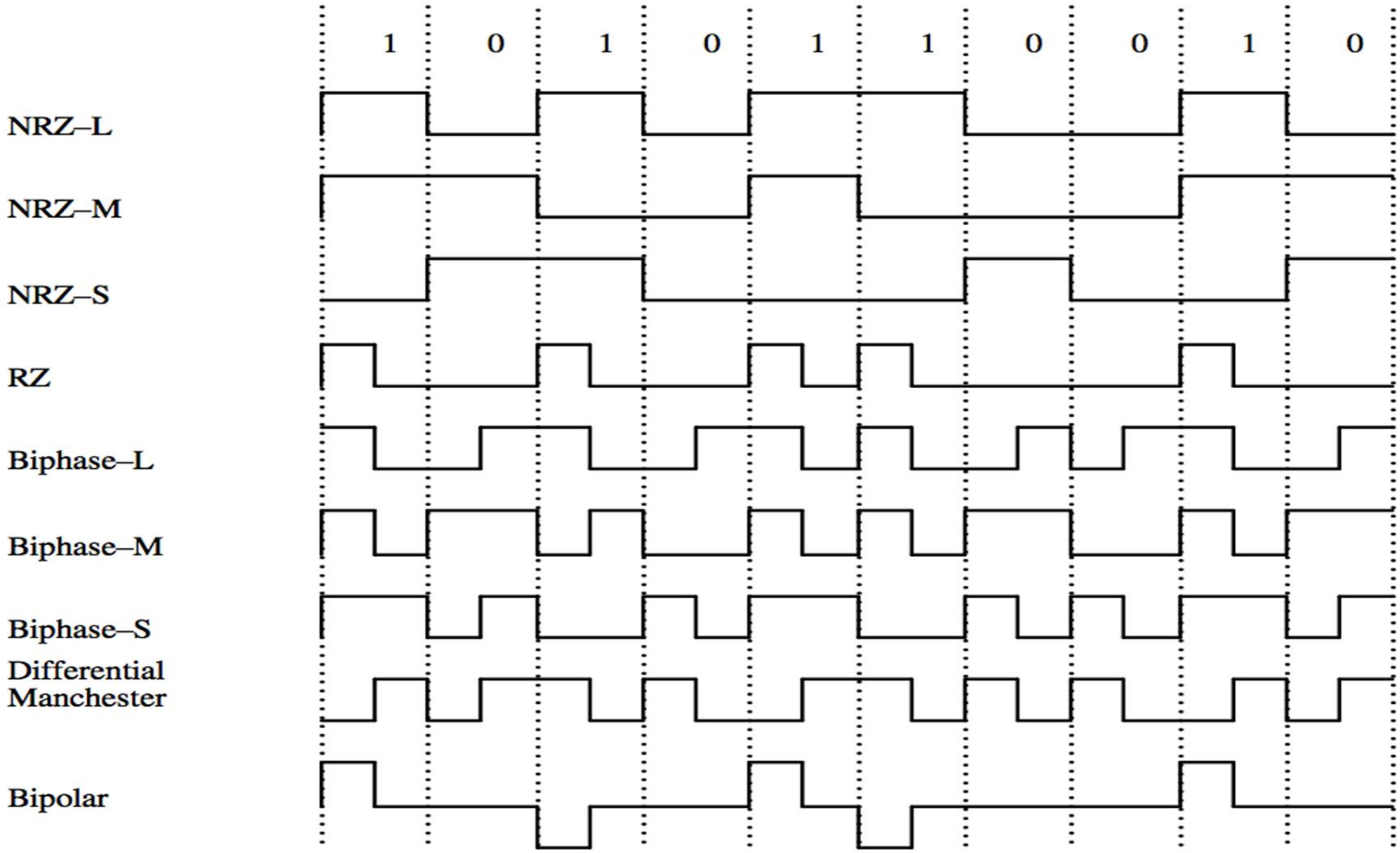
$r = 1/2$

$S = \frac{N}{r}$

$= \frac{2000}{1/2}$

=4000 signal/sec

Polar Encoding



Note:

- For long distance transmission
  - bandwidth efficiency is important
  - bipolar coding is used
- For short distance transmission like LAN,
  - bandwidth efficiency is less important than cost per station
  - in Ethernet LAN – Manchester encoding is used

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