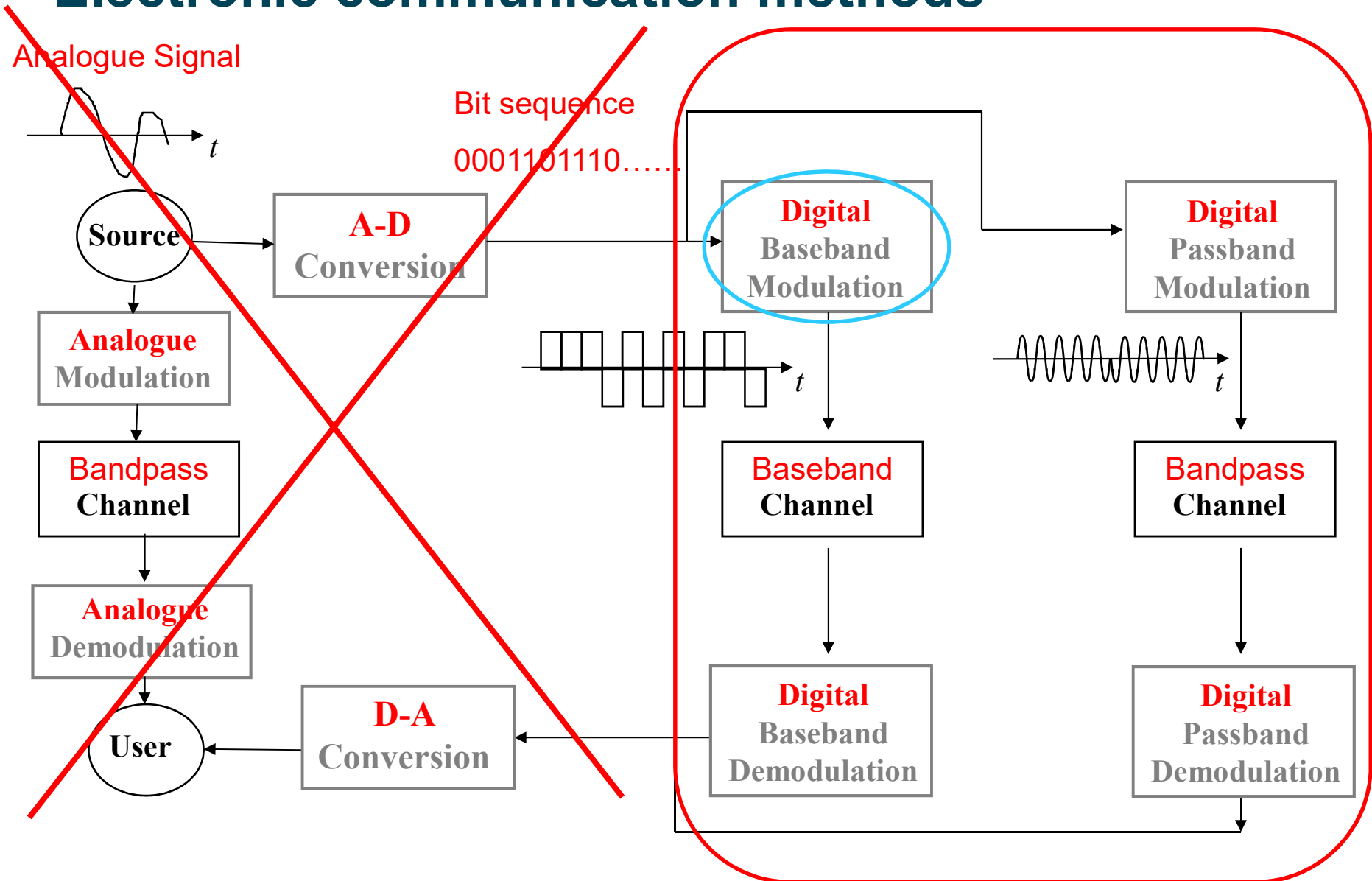


# **Wireless Communications Principles**

Digital Baseband Transmission (line coding)

# Electronic communication methods



# Line Codes

- Symbol sequences and pulse shapes constrained to enhance the properties of a signal
- This is known as line coding
- For example, by forbidding certain symbol sequences:
  - The spectral shape can be changed (e.g. no low frequency transitions)
  - DC components can be removed
  - Clock recovery can be assisted (e.g. by embedding a clock tone in the signal)
- Commonly used code is the 8b/10b code
  - Ensures DC balance
  - Implementations vary
  - Pros and cons?

# Line Codes – Digital Baseband Modulation

## Classification of Line Codes (I)

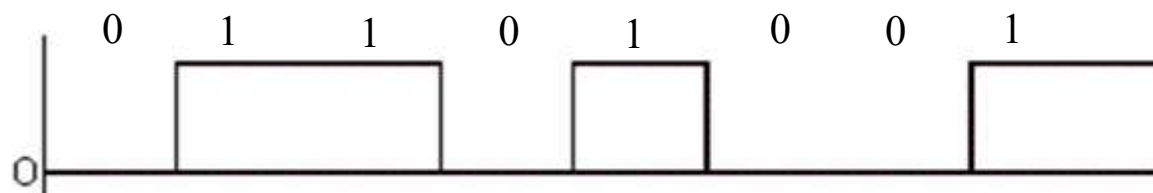
- ❖ **Unipolar**: Only nonnegative voltage levels are used for signalling.
- ❖ **Bipolar**: Both positive and negative voltage levels are used for signalling.

## Classification of Line Codes (II)

- ❖ **Non-return-to-zero (NRZ) codes**: Level remains constant within a bit duration and does not **return** to zero (**pulse duration=bit duration**).
- ❖ **Return-to-zero (RZ) codes**: Level (for bit 1) **returns** to zero during bit interval (**pulse duration<bit duration**, usually pulse duration=1/2 bit duration).

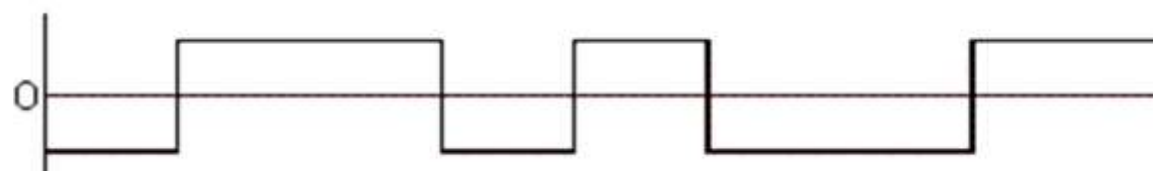
NRZ and RZ can be combined with Unipolar and Bipolar.

### Unipolar NRZ



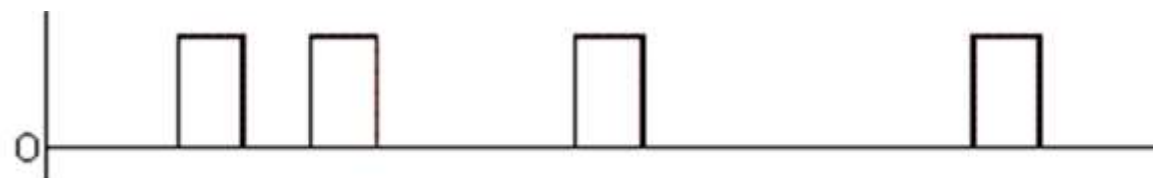
(DC component wastes power. Wander in receiver.)

### Bipolar NRZ



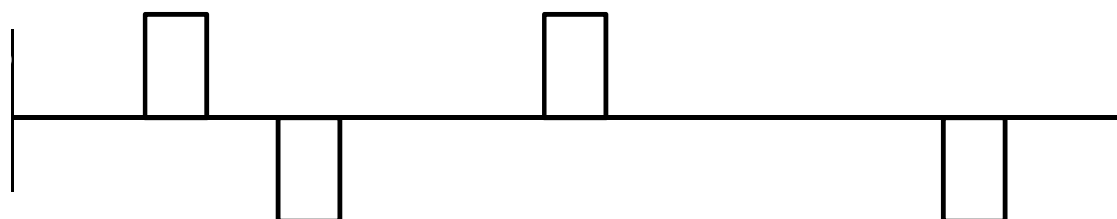
(Power efficiency is better than unipolar NRZ. Cannot be used for bit-timing recovery at the receiver)

### Unipolar RZ



(Used for bit-timing recovery at the receiver. Not power efficient. Wander in receiver.)

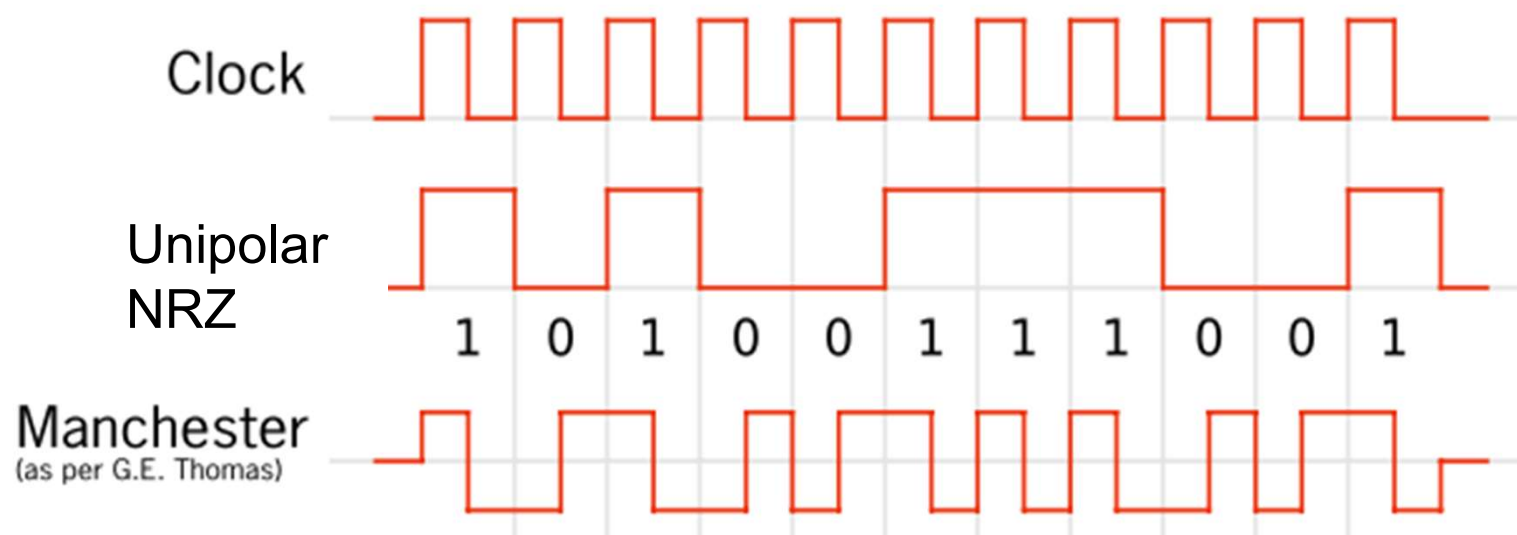
### Bipolar RZ



(Power efficient. Used for bit-timing recovery at the receiver. However, the bit-timing information may be lost when there is a long sequence of zeros).

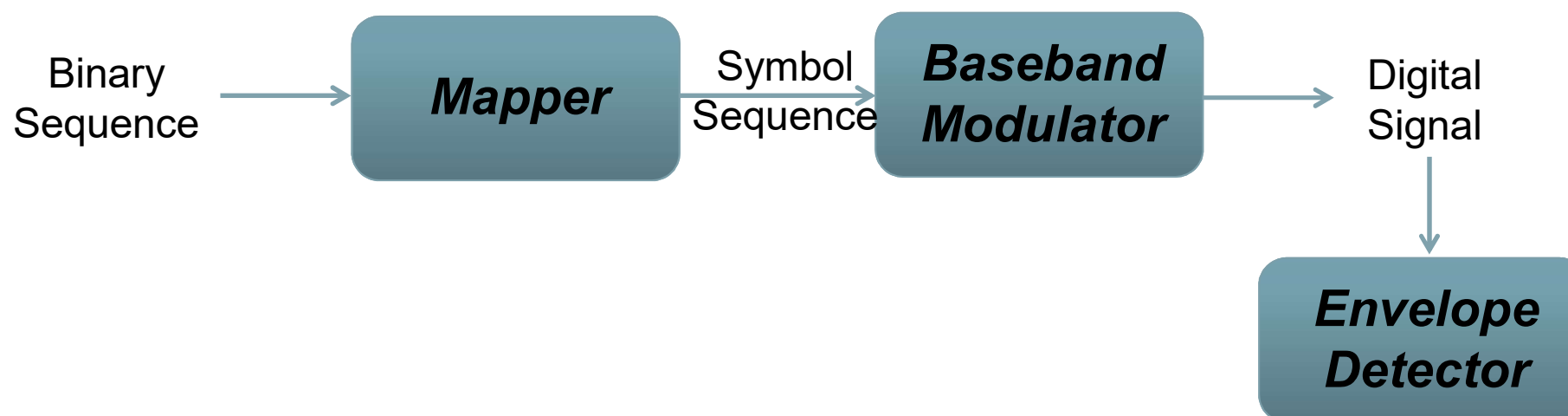
# Manchester Code

- **A bi-phase or split-phase code**
- **Clock recovery**: Frequent transitions at clock rate allow for clock recovery through use of **phase-locked loop (PLL)**.



Power efficient. Little low-frequency component, regardless of the signal statistics.  
 Timing information can be easily recovered.  
 Used in older Ethernet, RFID...

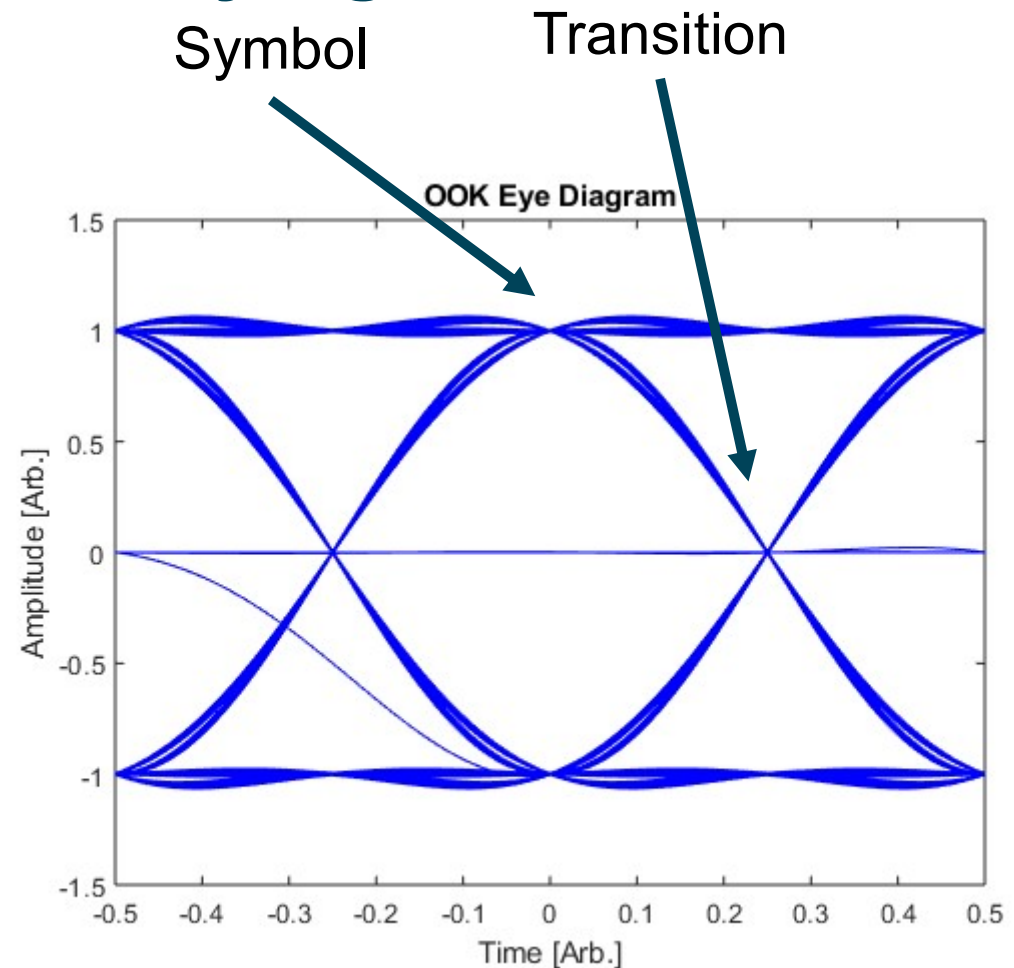
# Visualisation...



- An envelope detector just measures the amplitude of a signal:
$$A_k = |x_k|^2$$
- If this is measured synchronously with the signal, and persistently shown on an oscilloscope, this generates an **eye diagram**

# Eye Diagram: on-off keying

- A **measurement** over multiple symbol periods
- Overlay symbol periods to obtain eye diagram
- ‘Eye’ opening an indicator of **signal quality**





## Self-assessment

- What is the advantage of using a polar line code compared to a unipolar one?
- What is the advantage of using Manchester code compared to a return-to-zero (RZ) code.
- Discuss the advantages/disadvantages of using an 8B10B code rather than the Manchester line code?
- Lines codes such as 8B10B use “non-data symbols” for special purposes, such as synchronization. What do you think is meant by a “non-data symbol”?