EEE 367
Telecommunication Engineering

Digital Transmission

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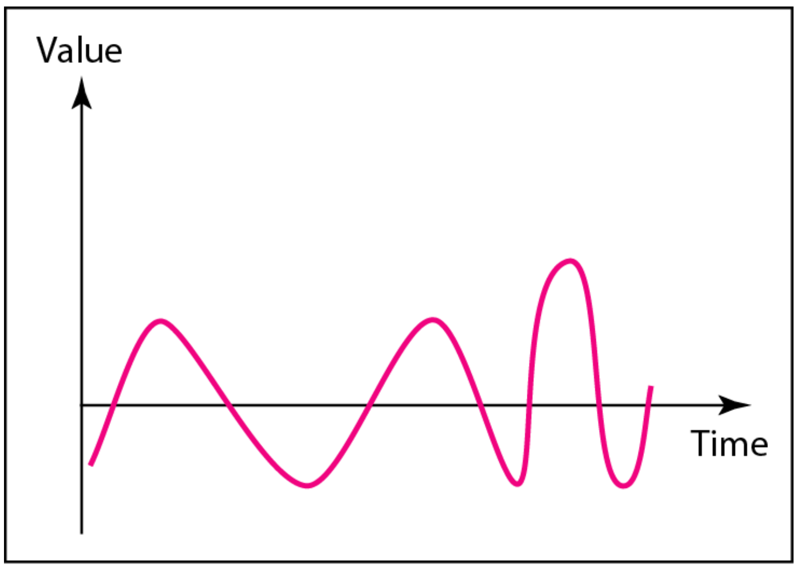
Data and Signals

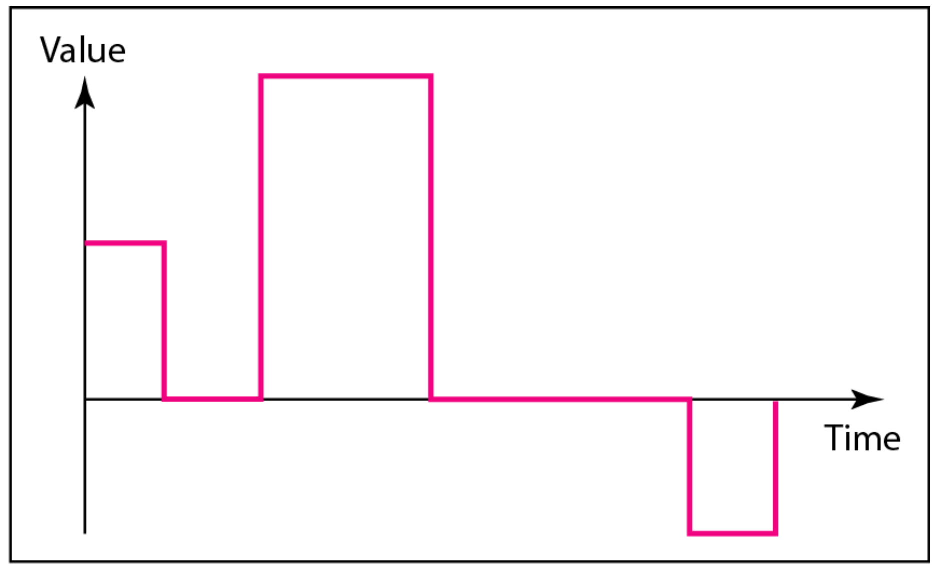
- Data are entities that convey meaning (computer file, music on CD, results from a blood gas analysis machine)
- Signals are the electric or electromagnetic encoding of data (telephone conversation, web page download)
- Computer networks and data/voice communication systems transmit signals
- Data and signals can be analog or digital

Analog vs. Digital Signals

- Signals can be interpreted as either analog or digital
- In reality, all signals are analog
- Analog signals are continuous, non-discrete
- Digital signals are non-continuous, discrete
- Digital signals lend themselves more nicely to noise reduction techniques



a. Analog signal



b. Digital signal

Digital Transmission

- *Digital transmission* is the transmission of digital signals between two or more points in a communication system. The signals can be binary or any other form of discrete-level digital pulses.
- The original source information may be in digital form or it could be analog signals that have been converted to digital pulses prior to transmission and converted to analog signals in the receiver.

Advantages of Digital Transmission

- Digital signals are inherently **less susceptible than analog signals to interference caused by the noise** because with digital signals it is not necessary to evaluate the precise amplitude, frequency or phase to ascertain its logic condition.
- Digital signals are also **better suited than analog signals for** processing and combining using a technique called **multiplexing**.
- It is much **simpler to store digital signals** than analog signals and the **transmission rate of digital signals can be easily changed** to adapt to different environments and to interface with different types of equipment.

Advantages of Digital Transmission

- Digital signals can be **transported longer distances** than analog signals.
- Digital signals are **simpler to measure and evaluate** than analog signals.

Disadvantages of Digital Transmission

- The transmission of digitally encoded analog signals **requires significantly more bandwidth** than simply transmitting the original analog signal.
- Analog signals must be converted to digital pulses prior to transmission and converted back to their original analog signal from the receiver. Therefore, **needs additional encoding and decoding circuitry**.
- Digital signals **requires precise time synchronization** between the clocks in the transmitter and the receivers.
- Digital transmission systems are **incompatible with older analog transmission signals**.

DIGITAL~TO~DIGITAL CONVERSION

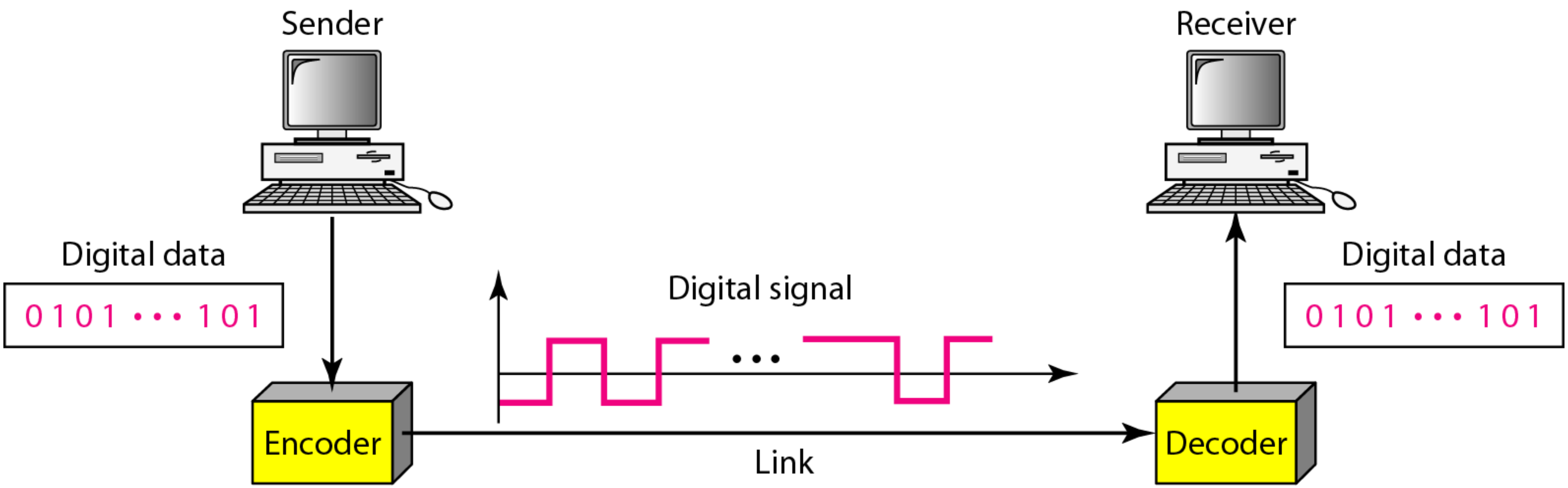
- The conversion involves three techniques:

1. line coding,
2. block coding
3. scrambling.

- Line coding is always needed~ block coding and scrambling mayor may not be needed.

Line Coding

Line coding is the process of converting digital data to digital signals. We assume that data, in the form of text, numbers, graphical images, audio, or video, are stored in computer memory as sequences of bits. 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.



Relationship between data rate and signal rate

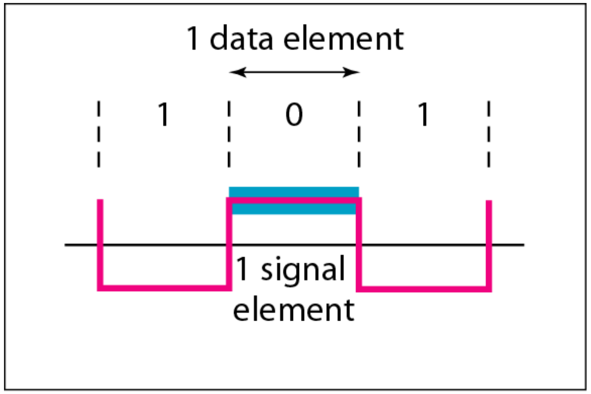
- The data rate defines the number of bits sent per sec - bps. It is often referred to the bit rate.
- The signal rate is the number of signal elements sent in a second and is measured in bauds. It is also referred to as the modulation rate.
- Goal is to increase the data rate whilst reducing the baud rate.

Signal vs. Data

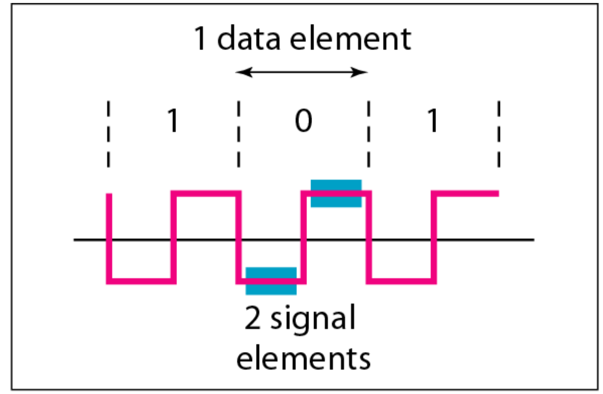
Data Element: What we need to send (is being carried)
Signal element: What we can send (it is a carrier)

Data rate defines the number of data elements (bits) sent in 1 second (bps).
The signal rate is number of signal elements sent in 1 second (Pulse rate, modulation rate, baud rate).

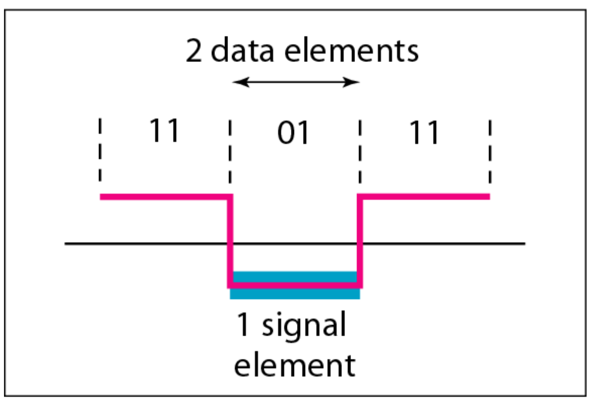
Signal level vs. Data level



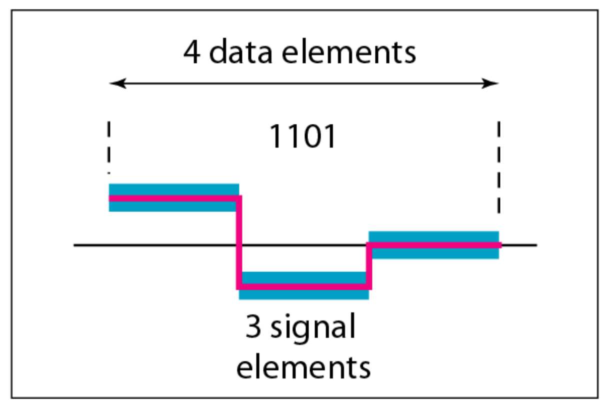
a. One data element per one signal element (r = 1)



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 $\left(r = \frac{4}{3}\right)$

Data rate and Baud rate

- The baud or signal rate can be expressed as:

$$S = c \times N \times 1/r \text{ bauds}$$

where N is data rate

c is the case factor (worst, best & avg.)

r is the ratio between data element & signal element

Example

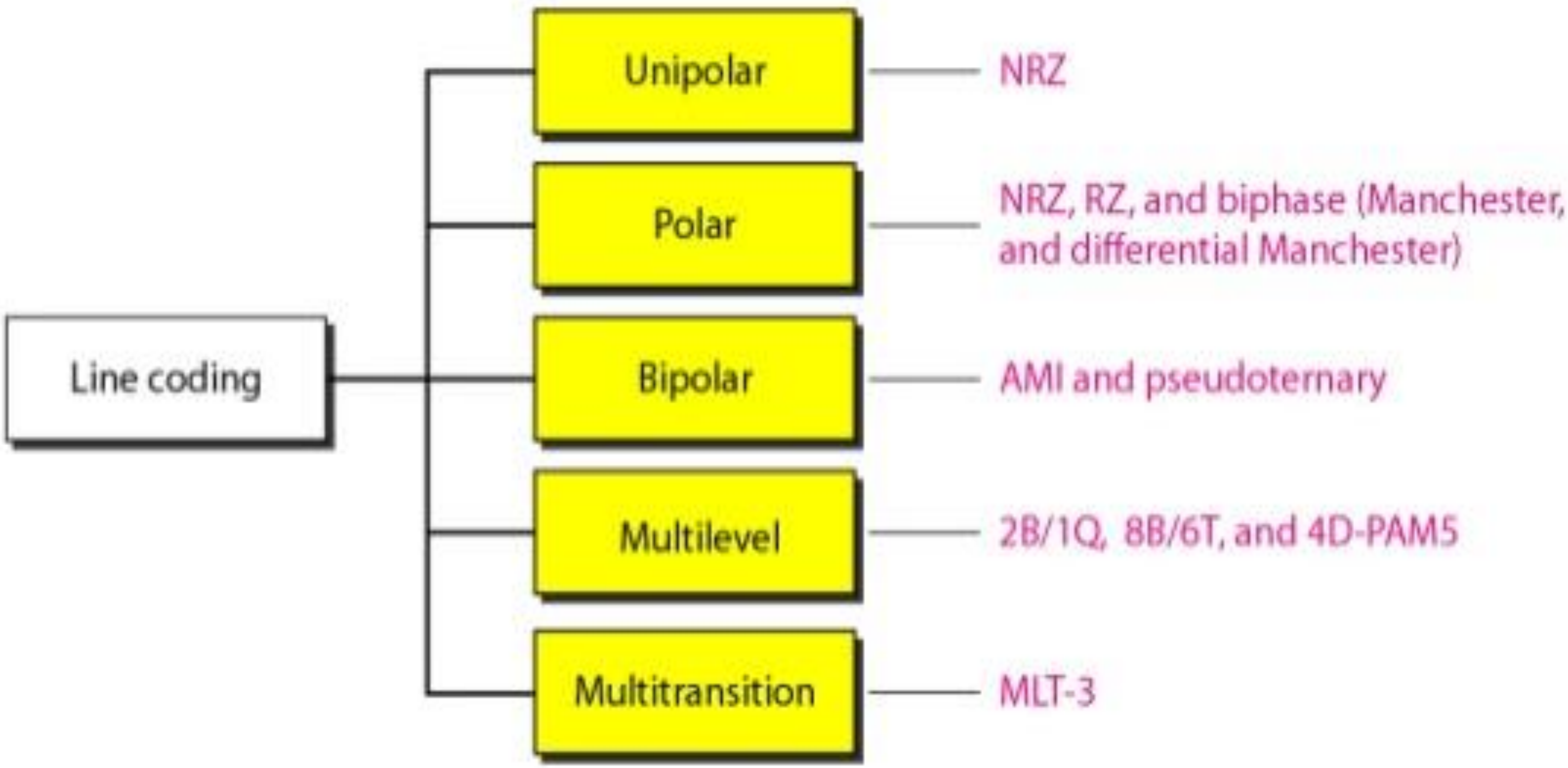
- ***A signal is carrying data in which one data element is encoded as one signal element (r = 1). If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and 1?***

Solution

We assume that the average value of c is 1/2 . The baud rate is then

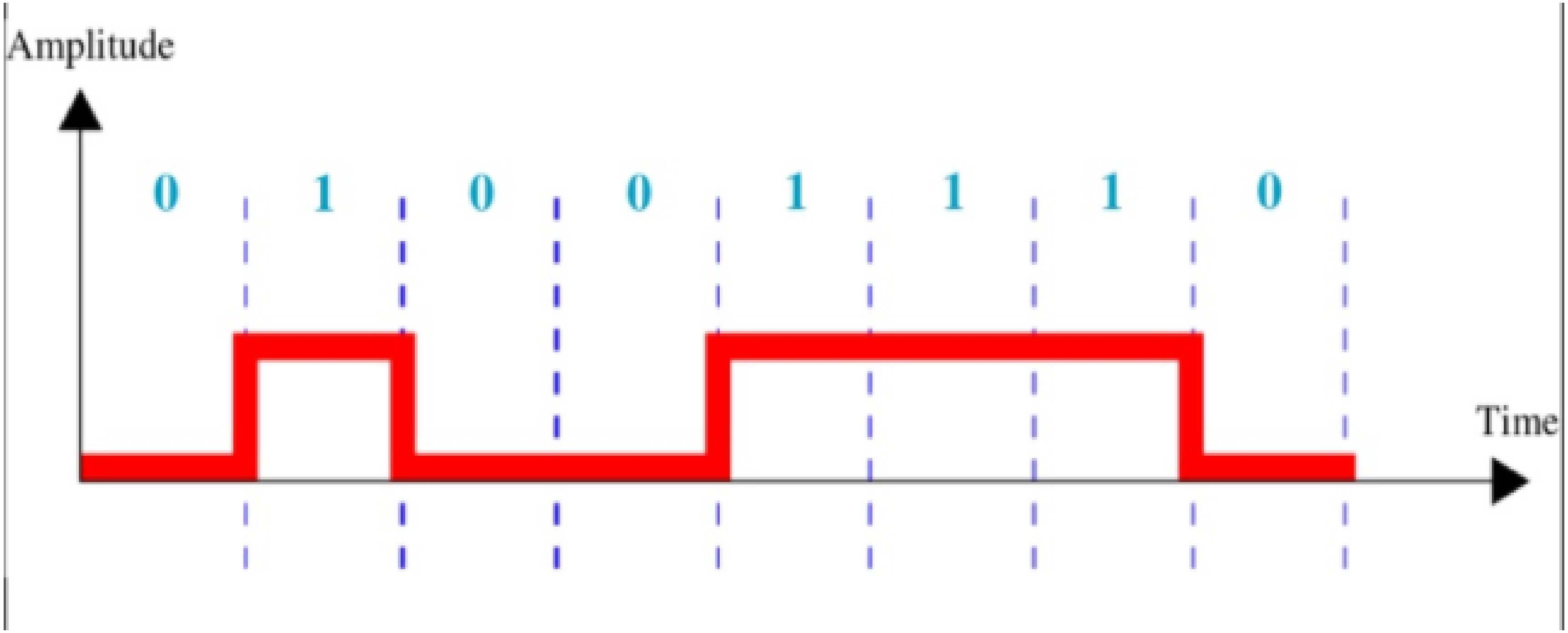
$$S = c \times N \times \frac{1}{r} = \frac{1}{2} \times 100{,}000 \times \frac{1}{1} = 50{,}000 = 50 \text{ kbaud}$$

Line Coding



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

Unipolar Encoding

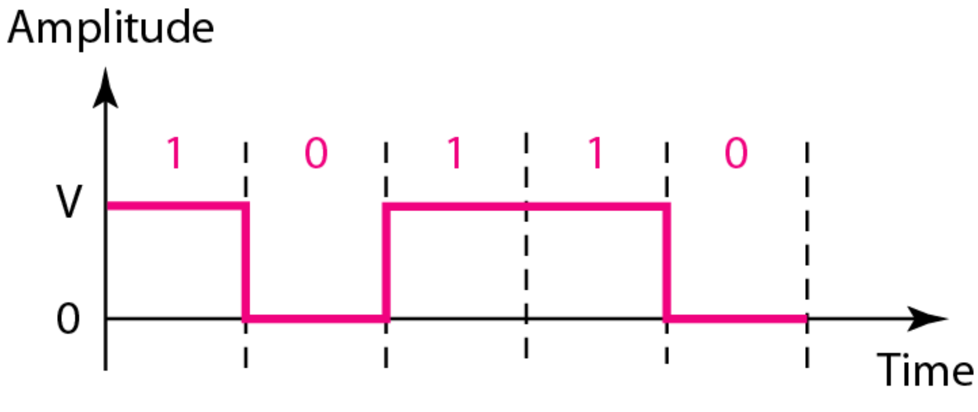


In a unipolar scheme, all the signal levels are on one side of the time axis, either above or below.

Unipolar encoding: 1s encoded as positive, 0s encoded as the zero voltage

Unipolar NRZ Scheme

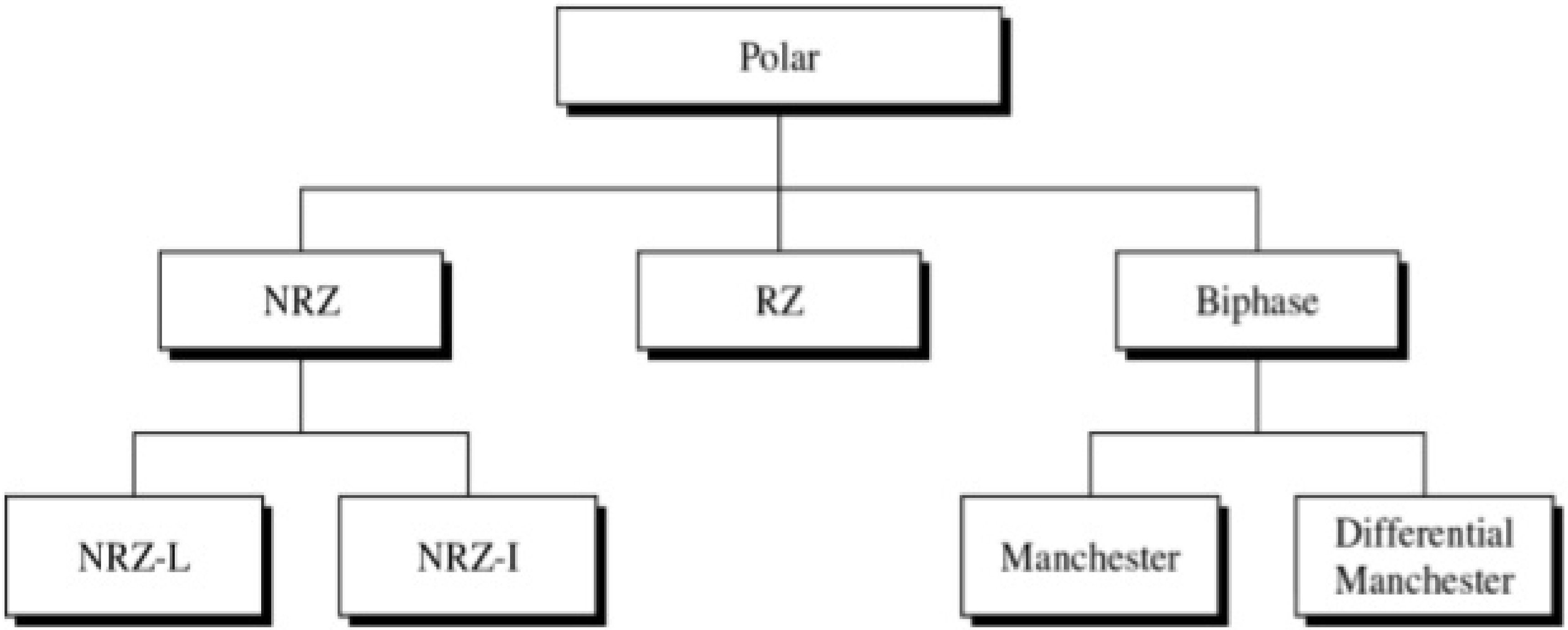
- NRZ (Non-Return-to-Zero) Traditionally, a unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit 1 and the zero voltage defines bit 0. It is called NRZ because the signal does not return to zero at the middle of the bit.



$$\frac{1}{2}V^2 + \frac{1}{2}(0)^2 = \frac{1}{2}V^2$$

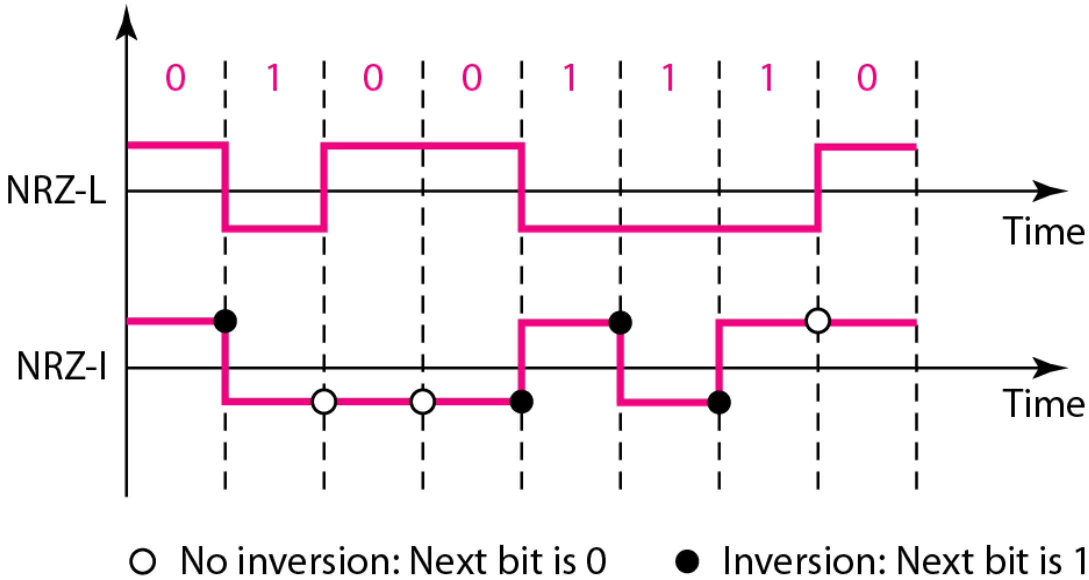
Normalized power

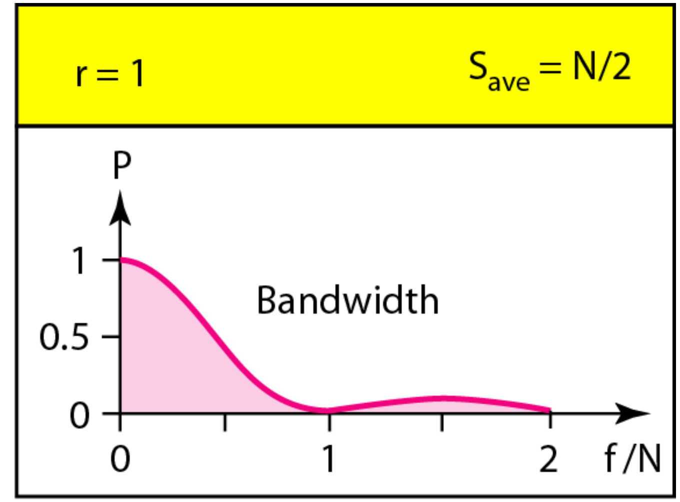
Types of Polar Encoding



- In polar schemes, the voltages are on the both sides of the time axis. For example, the voltage level for 0 can be positive and the voltage level for 1 can be negative.

NRZ-L and NRZ-I



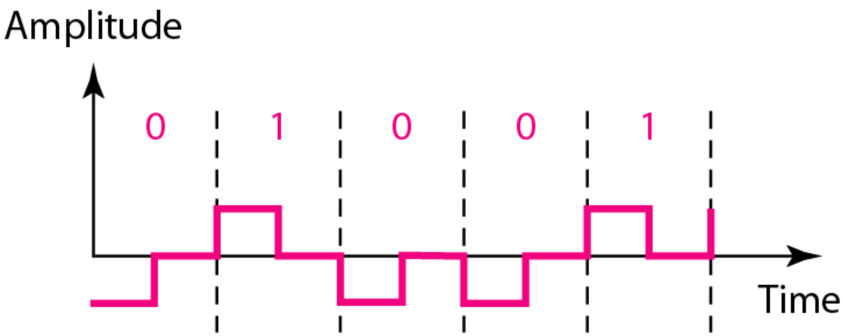


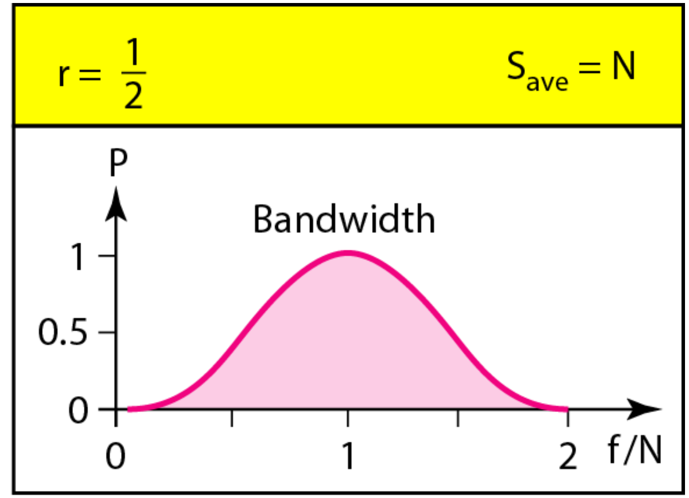
In polar NRZ encoding, we use two levels of voltage amplitude. We can have two versions of polar NRZ: NRZ-Land NRZ-I. In the first variation, NRZ-L (NRZ-Level), the level of the voltage determines the value of the bit. In the second variation, NRZ-I (NRZ-Invert), the change or lack of change in the level of the voltage determines the value of the bit. If there is no change, the bit is 0; if there is a change, the bit is 1.

RZ Scheme

- The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit has ended and the next bit is starting. One solution is the return-to-zero (RZ) scheme, which uses three values: positive, negative, and zero. In RZ, the signal changes not between bits but during the bit.

Polar RZ Scheme



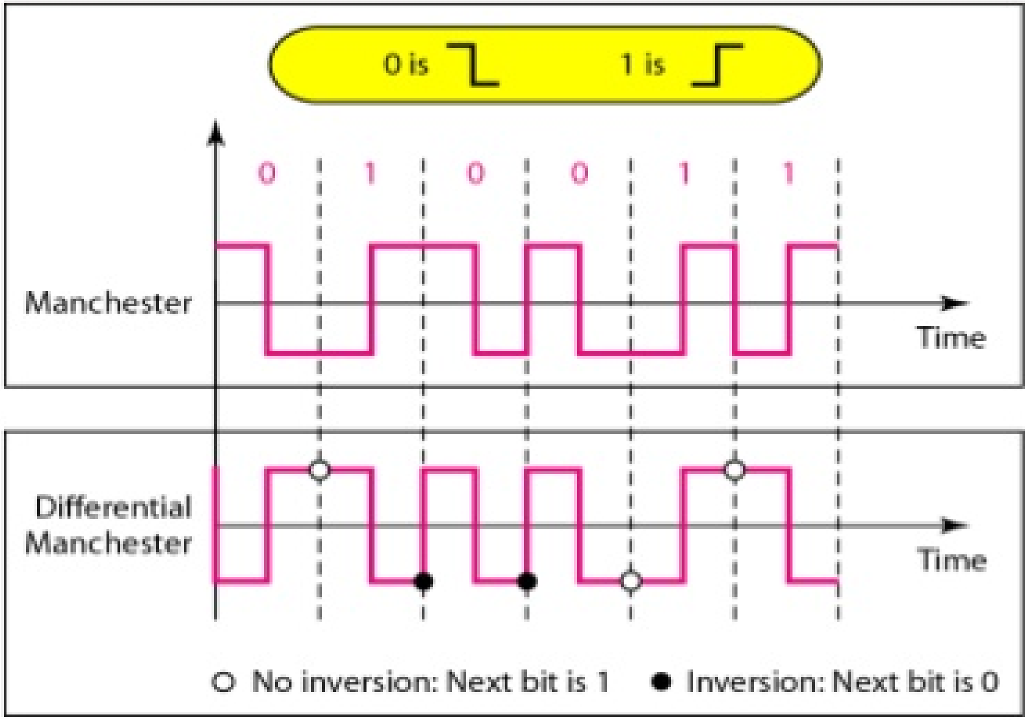


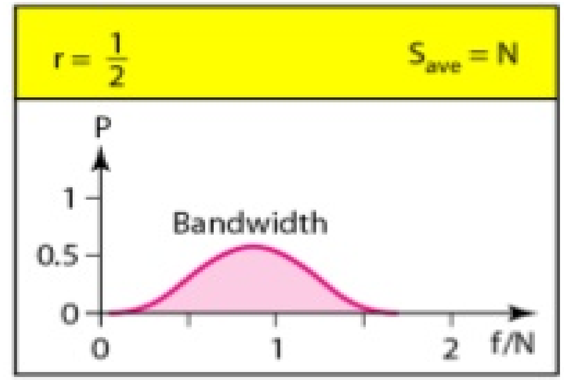
- The signal goes to 0 in the middle of each bit. It remains there until the beginning of the next bit. The main disadvantage of RZ encoding is that it requires two signal changes to encode a bit and therefore occupies greater bandwidth.
- Polar RZ scheme RZ (Return-to-Zero) – returns to zero in the middle of the bit and remains there until the next bit

Manchester and Differential Manchester

- The idea of RZ (Transition at the middle of the bit) and the idea of NRZ-L are combined into the Manchester scheme. In Manchester encoding, the duration of the bit is divided into two halves. The voltage remains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides synchronization. Differential Manchester, on the other hand, combines the ideas of RZ and NRZ-I. There is always a transition at the middle of the bit, but the bit values are determined at the beginning of the bit. If the next bit is 0, there is a transition; if the next bit is 1, there is none.

Polar biphase: Manchester and Differential Manchester





- In Manchester and differential Manchester encoding, the transition at the middle of the bit is used for synchronization.
- In bipolar encoding, we use three levels: positive, zero, and negative.


Thank you!