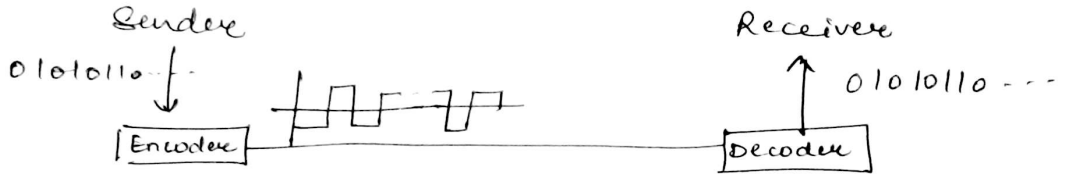
Chapter - 4

Digital Transmission

Digital to Digital Conversion

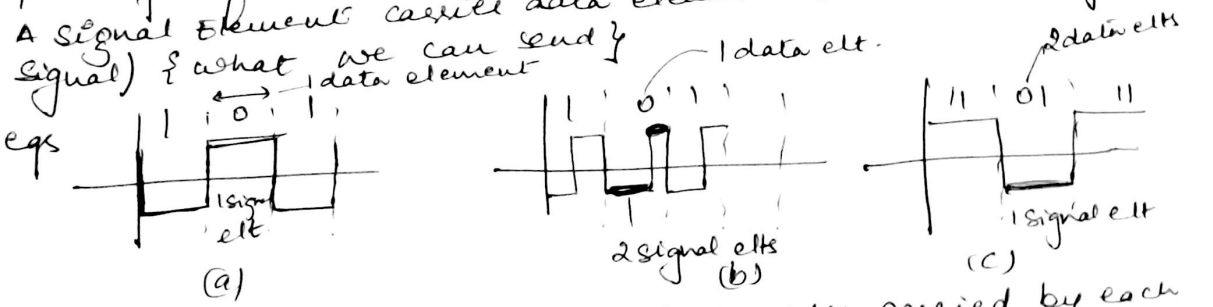
→ How we can represent digital data by using digital signals.
- This conversion involves 3 techniques:-
  a) line coding b) block coding c) scrambling

A **line coding :-** It is the process of converting digital data to digital signals. Data is stored in computer memory as sequence of bits. line coding converts a sequence of bits to a digital signal.



Signal Element Versus Data Element

Data Element is the smallest entity that can represent a piece of information. (what we need to send)
A signal Element carries data elements. (Shortest unit of digital signal) & what we can send }



- A ratio r is the no. of data elts carried by each signal element.

(a) $r = 1$ (b) $r = \frac{1}{2}$ (c) $r = \frac{2}{1}$

Data rate or bit rate defines the no. of data elements sent in 1s.
Its unit is bps.
Signal " " " " " signal " " " " ".
Its unit is baud. It is also called baud rate, pulse rate, modulation rate.

- Our goal is to increase data rate ≈ speed of transmission
  decrease signal rate ≈ ↓ bandwidth req.
- Relationship b/w data rate & signal rate is represented as:-

$$S = c \times N \times \frac{1}{e}$$

(Data rate; e — ratio of data elt to signal elt; S — no. of signal elts; c — coefficient factor)

Qus A signal is carrying data in which one data element is encoded as one signal element. If bit rate is 100 kbps. What is the average value of baud rate if c is b/w 0 & 1?

Sol $c = \frac{1}{1} = 1$

$c = \frac{0+1}{2} = \frac{1}{2}$

$S = c \times N \times \frac{1}{e}$

$= \frac{1}{2} \times 100 \times \frac{1}{1} = \frac{1}{2} \times 100000 \times 1 = 50,000$ baud.

- Baudrate determines the bandwidth required.
- Bandwidth reflects the range of frequencies.
- " is proportional to the signal rate.

$B_{min} = c \times N \times \frac{1}{e}$

↓ Minimum Bandwidth

$N_{max} = c \times N \times \frac{1}{e}$

↓ maximum data rate

Ques The max data rate of a channel is $N_{max} = 2 \times B \times \log_2 L$. Does this agree with older formula for N_{max}.

$$N_{max} = \frac{1}{C} \times B \times \ell$$

if $C = \frac{1}{L}$ then $N_{max} = \frac{1}{\frac{1}{L}} \times B \times \ell$

$$N_{max} = 2 \times B \times \ell$$

A signal with L levels carry $\log_2 L$ bits per level if each level corresponds to 1 signal elt then

$$N_{max} = 2 \times B \times \log_2 L$$

Baseline Wandering

Sender → encoder ——→ decoder → Receiver

In decoding a digital signal, the receiver calculates a running average of the received signal power. This average is called baseline. ~~wandering~~. The incoming signal power is evaluated against this baseline to determine the value of the data element. A long sequence of 0's & 1's can cause drift in the baseline & make it difficult for receiver to decode.

DC Component

When a voltage level in a digital signal is constant for a while the spectrum voltage creates very low frequencies. These frequencies around zero called DC direct current components.

Self Synchronization

If the receiver bit interval must match with sender's bit interval otherwise signals are misinterpreted.

Qus In a digital transmission, receiver clock is 0.1 faster than the sender clock. How many extra bits per second does the receiver receive if the data rate is 1kbps? How many if data rate is 1Mbps?

Sol At 1kbps

$\frac{0.1}{1000} \times 1000 = 1$

At 1Mbps

$\frac{0.1}{1000} \times 1000000 = 1000$

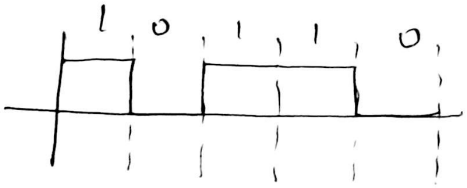
Line Coding Schemes

(1) Unipolar — NRZ
(2) Polar - NRZ, RZ & biphase
Manchester — Diff Manchester
(3) Bipolar — AMI & pseudoternary
(4) Multilevel — 2B/1Q, 8B/6T
(5) Multitransition - MLT-3

Unipolar

- all signals should be on one side of time axis.

NRZ (Non Return-to zero) :- +ve voltage = 1
-ve voltage = 0



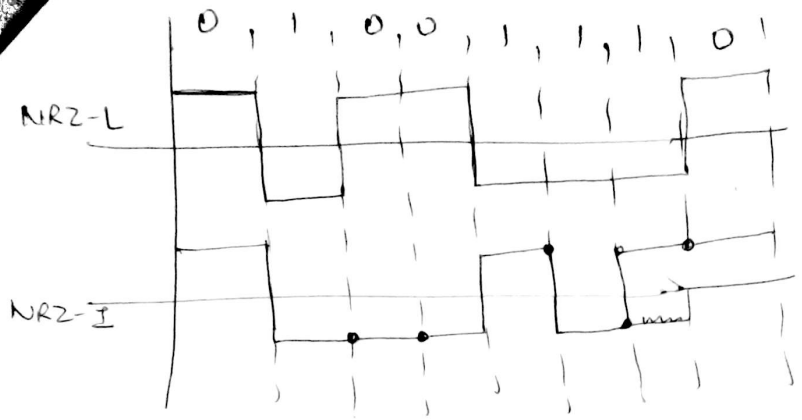
Polar

- voltages are on both sides of the time axis

NRZ
- Avg signal rate is N/2 baud

NRZ-L NRZ-I

NRZ-L :- level of the voltage determines bit value.
NRZ-I :- the change in the level determines bit value, ~~not~~ if no change bit value is 0 (4) if change bit value is 1.



0 = +ve
1 = -ve

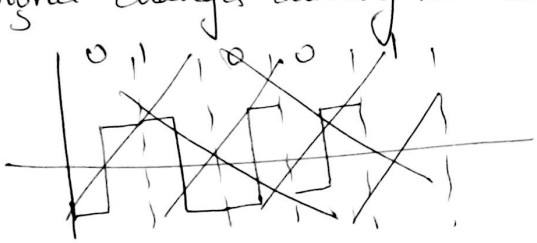
if 0 no change
if 1 change

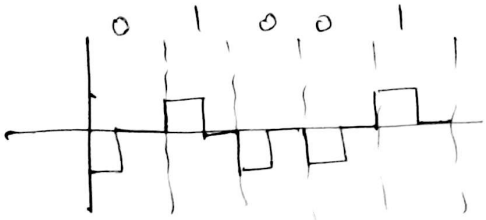
Problems with NRZ-L & I

- Baseline wandering :- long sequence of 0's & 1's
- DC component problem

RZ (Return to zero)

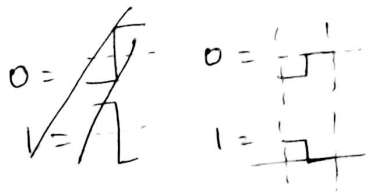
- It uses 3 values positive, negative & zero
- Signal changes during the bit.





$R = \frac{1}{2}$

$S = N$



Biphase

Manchester

0 = ⎤⎦ 1 = ⎣⎡

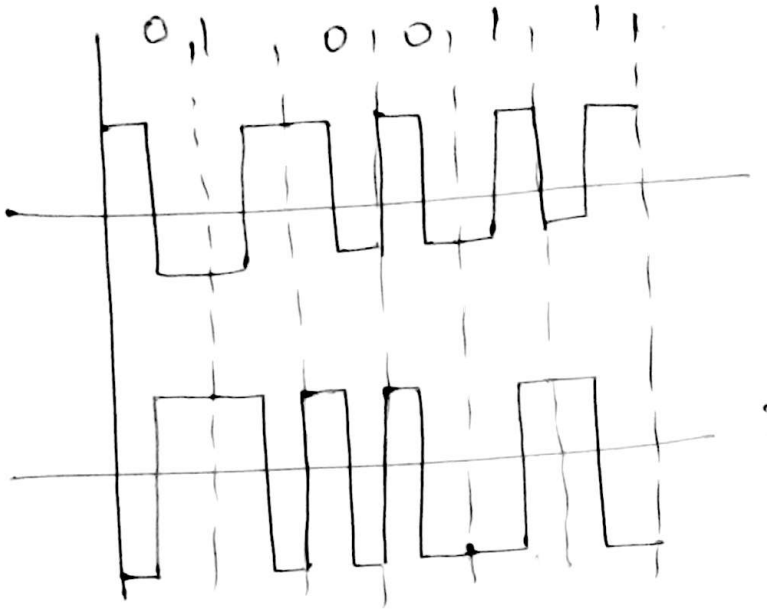
RZ + NRZ-L

Diff. Manchester

RZ + NRZ-I 0 ⎤⎦

if 0 invert 1 ⎣⎡

if 1 no inversion



Manchester

Diff. Manchester

$S = N$

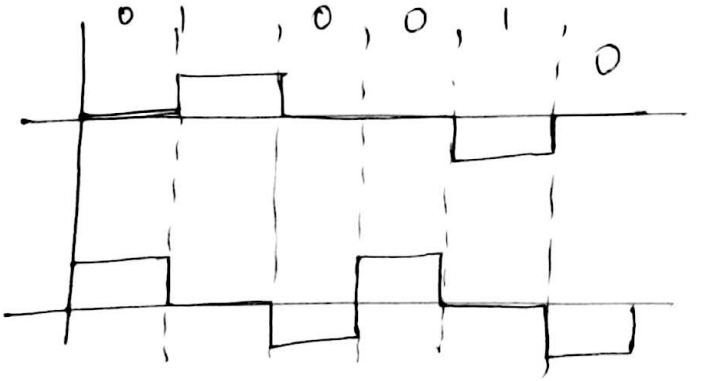
Bipolar

- 3 voltage levels +ve, -ve, 0

AMI
Alternate Mark Inversion

0 = 0 voltage
1 = alternate b/w +ve & -ve

Pseudoternary
1 = 0 voltage
0 = alternate +ve/-ve



AMI $S = \frac{N}{2}$

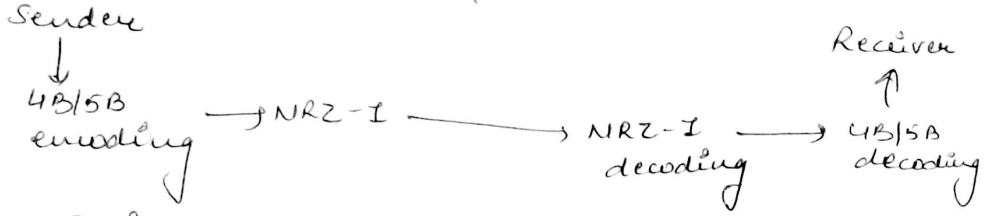
Pseudoternary

B Block Coding

- It changes the block of n bits into a block of n bits where $n > m$.
- Also called mB/nB encoding technique.
- It involves 3 steps : a Division
  b substitution
  c Combination

First we divide the original bit sequence into group of m bits. Then we substitute an n bit group for an m-bit group. Finally all n bit groups are combined together.

eg 4B/5B



- The 5 bits that replace 4 bits should not contain more than 1 zero on left & 2 zero's on right.
- So when these groups are combined no more than 3 consecutive 0's are there.
- 4 Bits = 2^4 = 16 combinations
  5 Bits = 2^5 = 32 combinations
  32
  − 16
  16 → unused combinations may be used for control purpose/error detection

Qus We need to send data at 1Mbps rate. What is the minimum required bandwidth using a combination of 4B/5B and NRZ-I or Manchester coding?

Sol $\frac{1000000}{4 \text{ bits}}$ = 2,50,000 blocks of 4 bits each

Total = 1000000 + 250000 = 1250000 bps

$= \frac{1250000}{1000000} = 1.25$ Mbps

Minimum Bandwidth $= \frac{N}{2}$

$= \frac{1250000}{2} = 625000 = 625$ kHz

8B/10B

- 8B/10B = 5B/6B + 3B/4B

2^8 | | $_{10}$

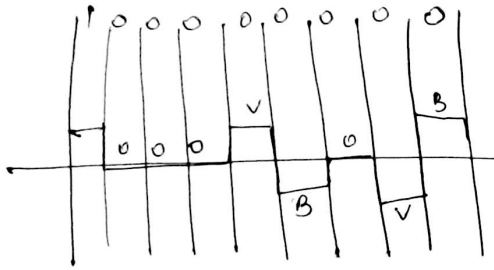
$2^{10} - 2^8$ = unused combinations

Scrambling

B8ZS — HDB3

Bipolar with 8 zero Substitution

- 8 consecutive zero level voltages are replaced by sequence of 000VB0VB
- V denotes violation & is a nonzero voltage that breaks AMI ie same polarity as previous non zero pulse
- B denotes bipolar, opposite of previous non zero



High density Bipolar 3-zero

- 4 consecutive zeros are replaced with 000V & B0V
- reason for 2 substitutions is to maintain a even no. of nonzero pulses after each substitution.
- 2 rules
  - i) if no of non zero pulse after last substitution is odd then substitution pattern will be 000V.
  - ii) if even then pattern is B0dV
- AMI