(*) We have a channel with 4KHz bandwidth. If we want to send data at 100 Kbps, what is the minimum SNRdB?

⇒ Bandwidth (B) = 4 KHz
Bit rate (N) = 100 Kbps

We know: $N = B * SNR_{dB}/3$

$\Rightarrow 100*10^3 = 4*10^3 * SNR_{dB}/3$

$\Rightarrow 100*3/4 = SNR_{dB}$

$\Rightarrow SNR_{dB} = 75$

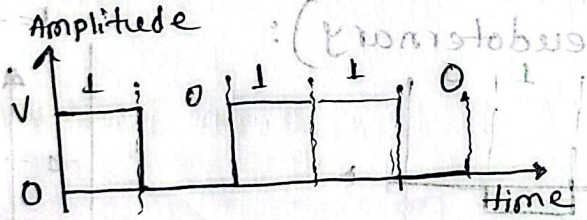
(*) Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be

Bitrate = $2 * 3000 * \log_2 2$

= 6000 bps.

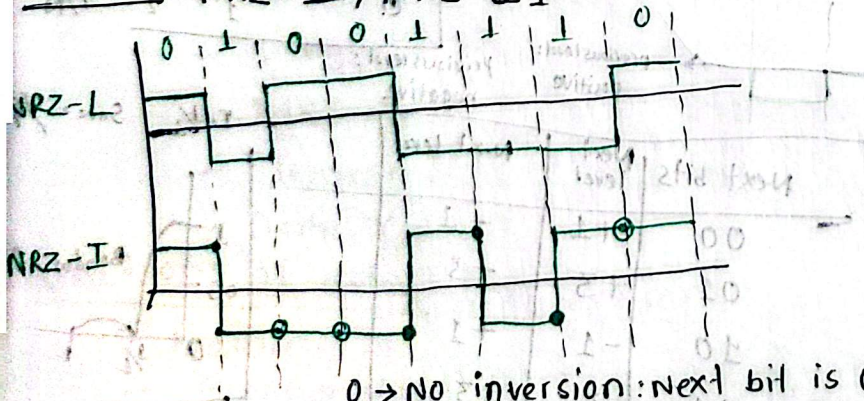
- Line coding
  - Unipolar: NRZ
  - polar: NRZ, RZ and biphase (Manchester, and differential Manchester)
  - Bipolar: AMI and pseudoternary
  - Multilevel: 2B/1Q, 8B/6T, and 4D-PAM5
  - Multitransition: MLT-3

Unipolar NRZ:

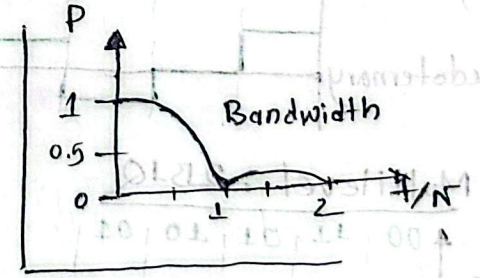


$\frac{1}{2} V^2 + \frac{1}{2}(0)^2 = \frac{1}{2} V^2$

Polar: NRZ-L, NRZ-I



r = 1 Save = N/2



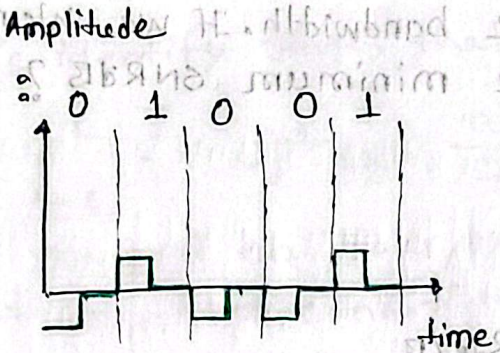
0 → No inversion: Next bit is 0
1 → Inversion: Next bit is 1

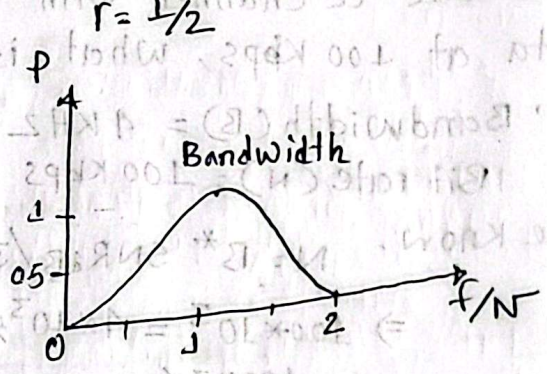
NRZ: L: 0 = positive, 1 = negative.

NRZ-I:
0 = no transition
1 = transition

Save = N

Polar RZ :

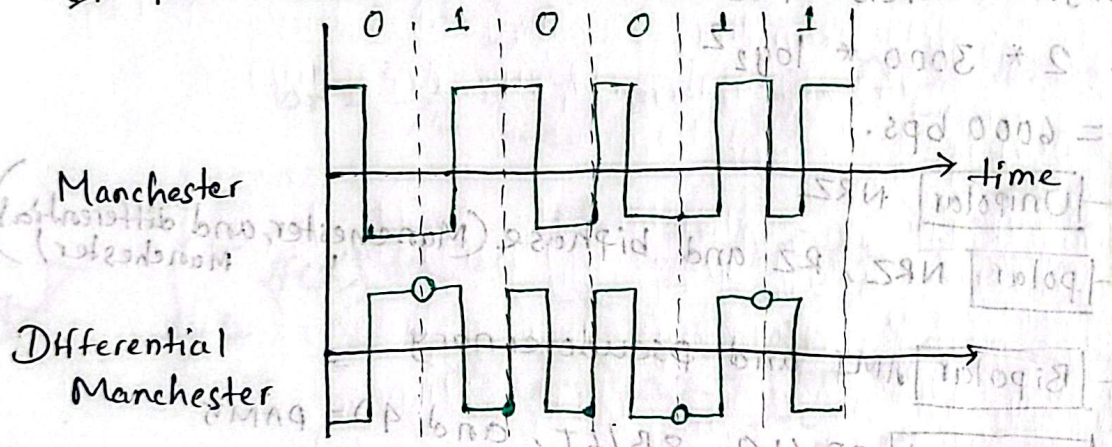


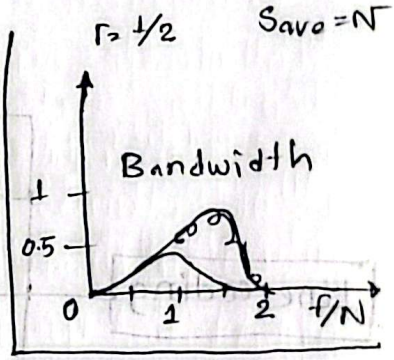


0 = positive to zero

1 = negative to zero

polar biphase : Manchester & differential manchester.

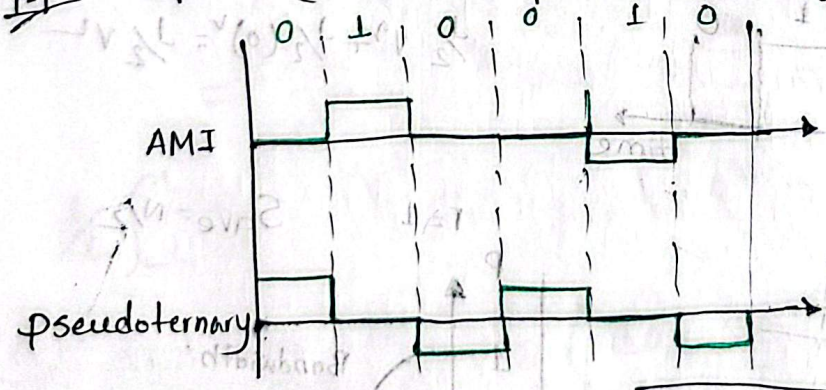


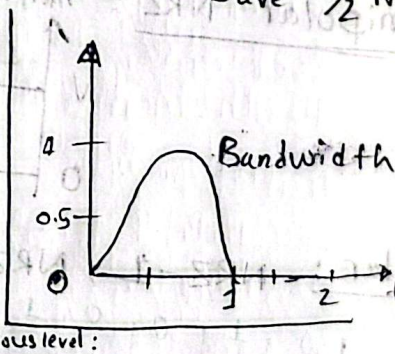


0 → No inversion : Next bit is 1

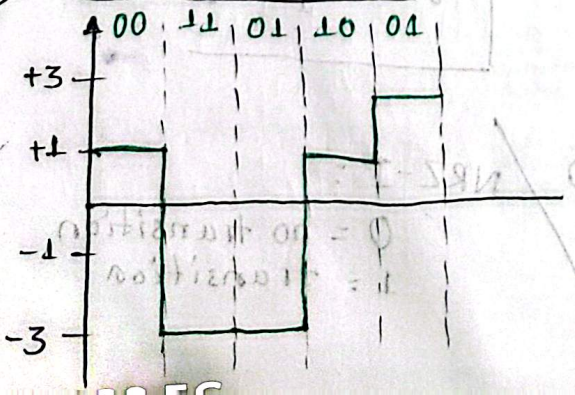
1 → inversion : Next bit is 0

Bipolar (AMI and pseudoternary) :

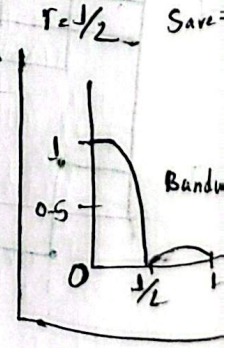




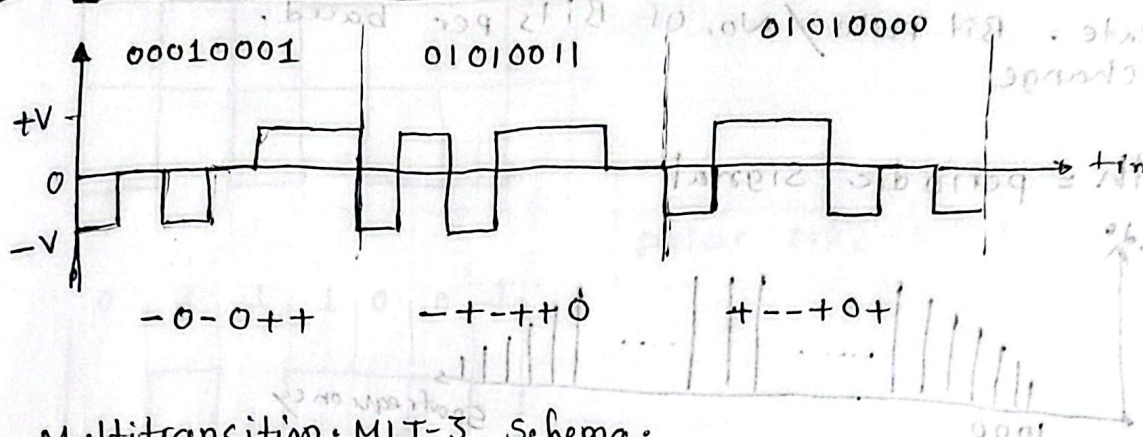
Multilevel : 2B1Q



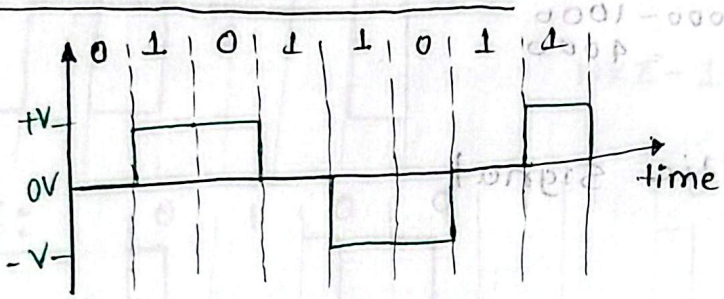
Next bits	Next level	Next level
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3



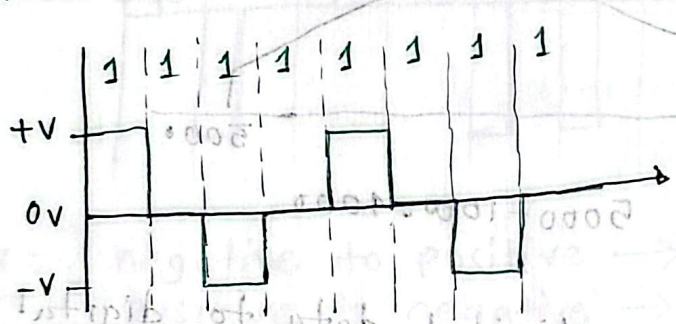
Multilevel : 8B6T schema:



Multitransition: MLT-3 schema:



: typical case



: Worst case

Functions of physical layer:

- Bit by bit transmission
- Encoding and decoding
- Siragnal transmission
- Modulation and demodulation
- Transmission modes.
- Data control

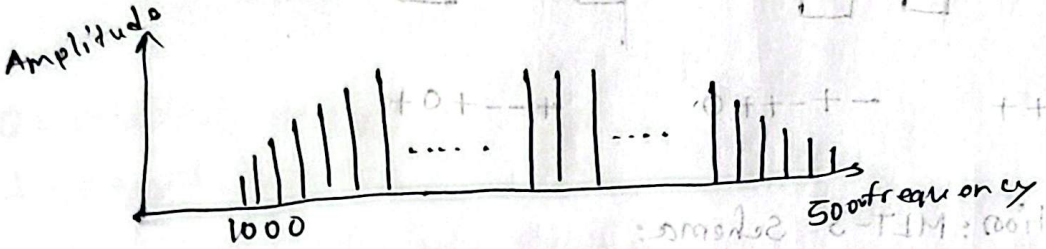
Functions of data link layer:

- Framing
- error detection - parity check
- error detection - checksum
- error detection - CRC
- error correction
- flow control
- addressing.

Bits → Bit rate = Baud Rate × no. of Bits per baud.

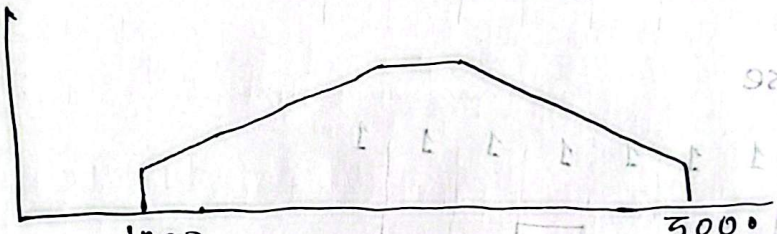
Baud Rate = Bit rate / No. of Bits per baud.
└ Signal change

Bandwidth = periodic signal



5000 − 1000
= 4000

Bandwidth = non periodic signal



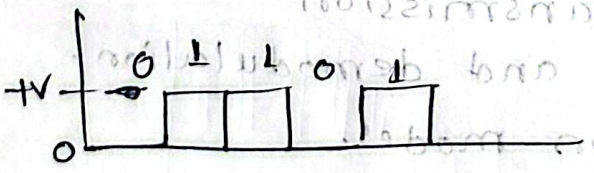
5000 − 1000 = 4000

Line coding: converting digital data to digital signal

- unipolar
- polar
- bipolar

→ three different type of line coding.

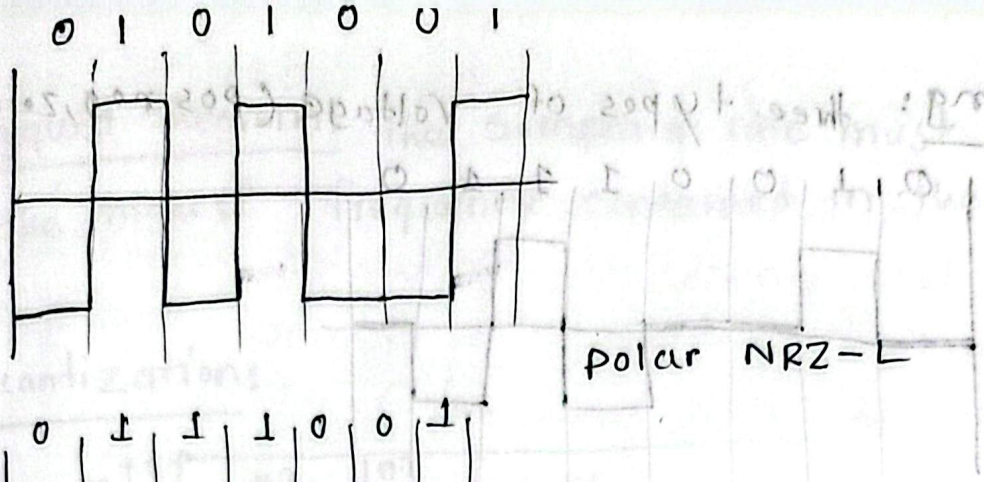
(*) Unipolar: 1 represent positive voltage and 0 represent 0 voltage.

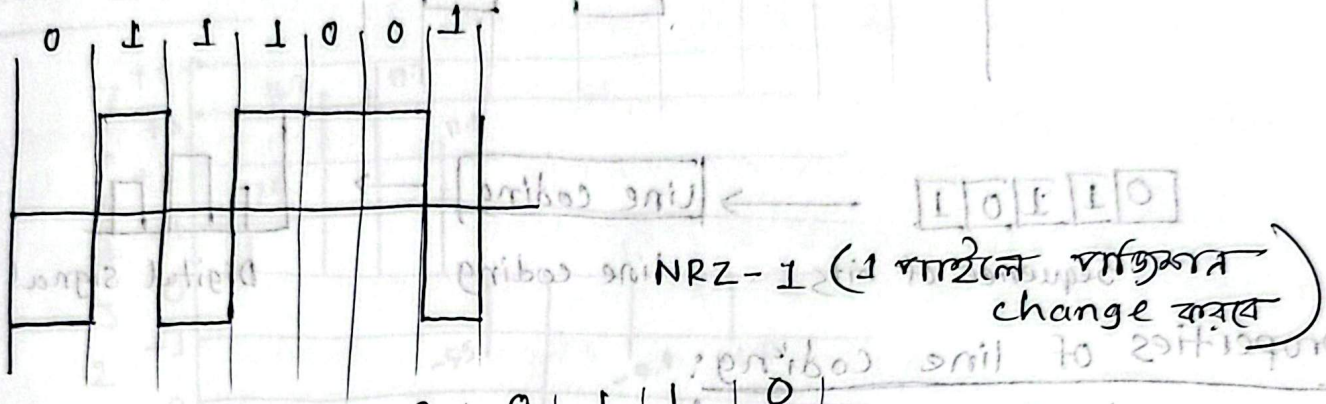


(*) polar:

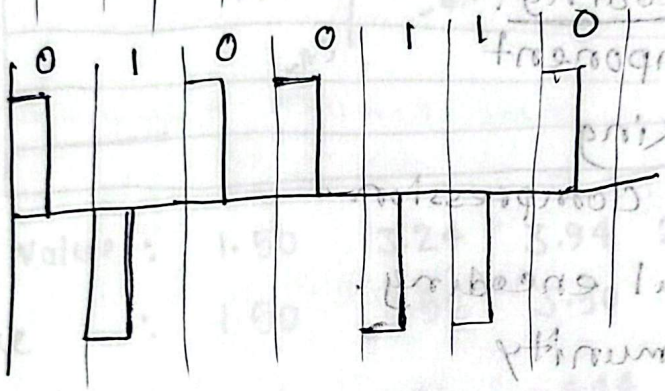
(*) polar NRZ: positive → 1
negative → 0

two types
- NRZ-L
- NRZ-I

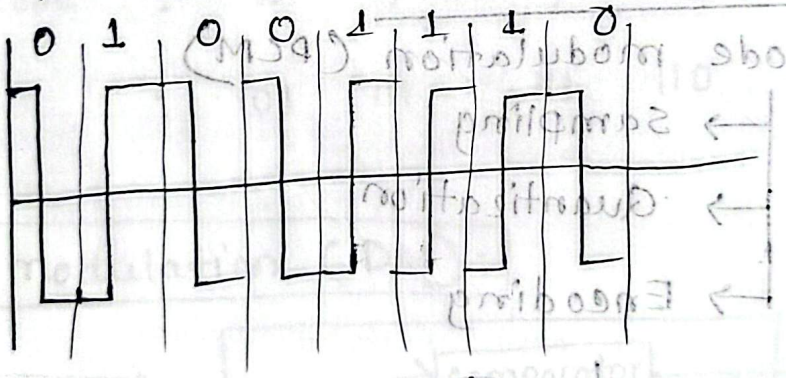




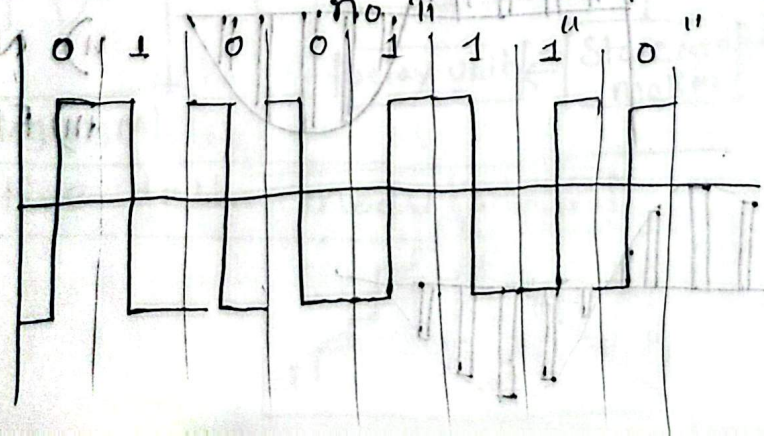
Polar RZ:



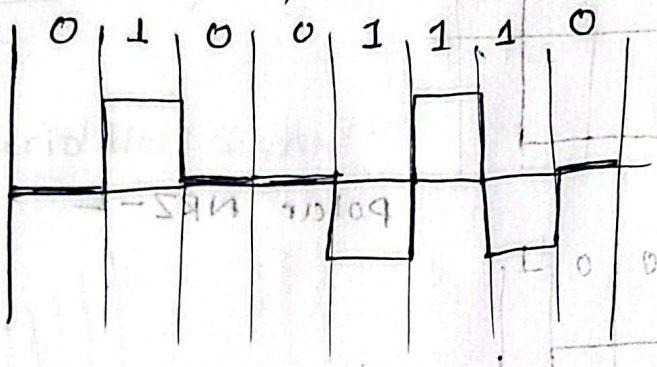
Manchester: negative to positive → 1
positive to negative → 0

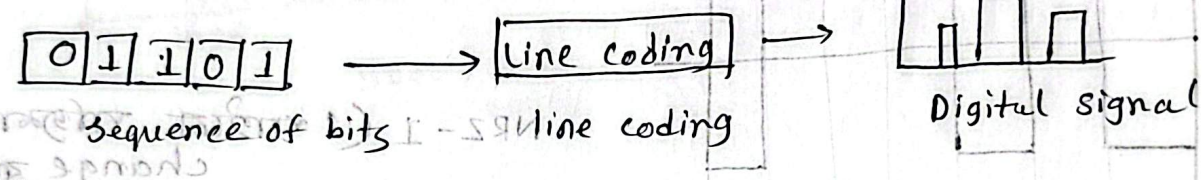


Differential Manchester: transition is represented by → 0
no " " " → 1



Bipolar encoding: three types of voltage (pos, neg, zero)





Sequence of bits → line coding

properties of line coding:

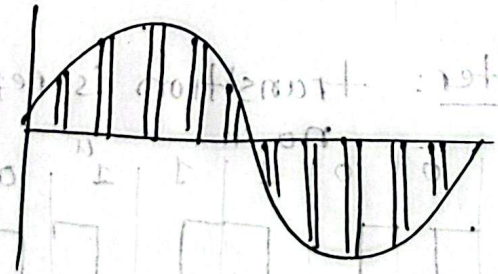
- No DC component
- self clocking
- Bandwidth compression
- Differential encoding.
- Noise immunity
- Minimum crosswalk.

Analog to digital conversion:

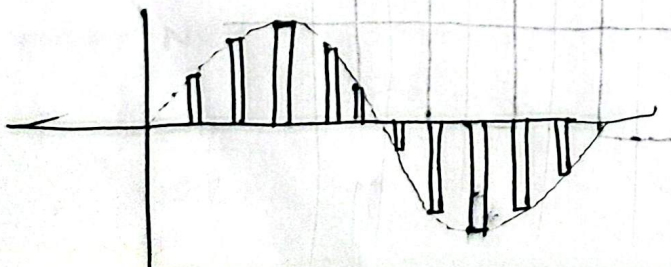
- pulse code modulation (PCM)

process → Sampling
→ Quantization
→ Encoding

Sampling:

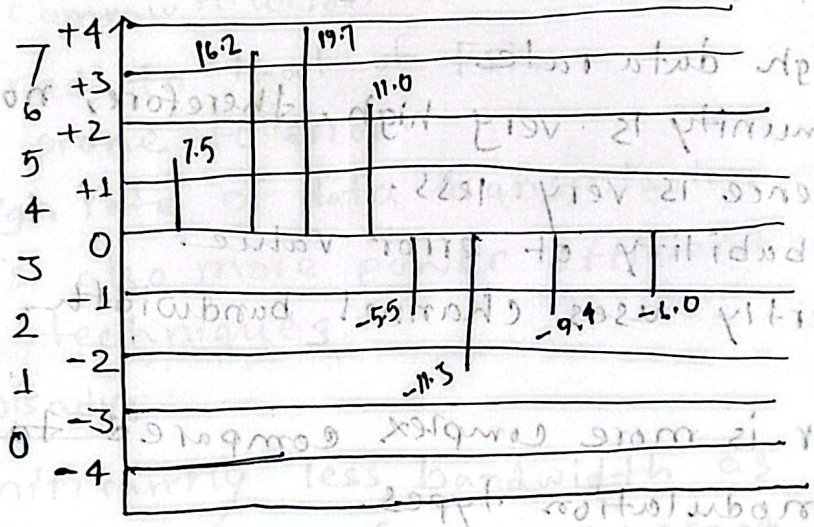


i) Ideal / Idle sampling
ii) Natural "
iii) Flat top "



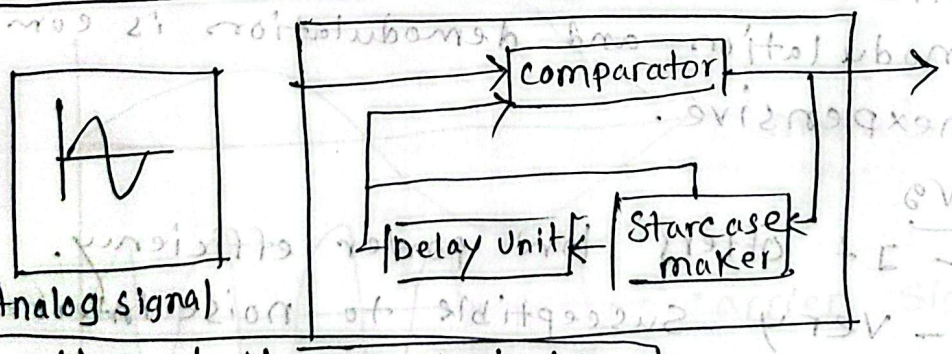
Nyquist theorem: the sampling rate must be at least 2 times the highest frequency contained in the signal.

- Quantization:

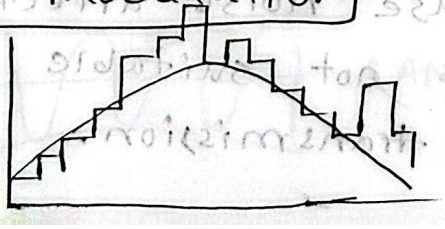


Normalized PAM value	:	1.50	3.24	3.94	2.20	-1.10	2.24	-1.88	-1.20
Quantized value	:	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	:	0	0.26	-0.44	0.30	-0.40	-0.24	0.38	-0.30
Quantization code	:	5	7	7	6	2	1	2	2
Encoded words	:	101	111	111	110	010	001	010	010

- Delta modulation (DM):



- Adaptive delta modulation:



Quadrature Amplitude Modulation: (QAM)

define as a modulation technique that can be use to combine two amplitude modulated waves into a single channel to increase the channel bandwidth.

- combination of (ASK and PSK).

Adv:
- support high data rate
- Noise immunity is very high, therefore, noise & interference is very less.
- Low probability of error value
- It expertly uses channel bandwidth.

disadv:
- the receiver is more complex compared to receive of other modulation types.

Amplitude Shift Keying (ASK):

Amplitude change but frequency and phase remain constant.

adv:
- it offers high bandwidth efficiency
- Simple receiver design.
- Can be used to transmit digital data over optic fiber.
- modulation and demodulation is comparatively inexpensive.

Disadvs
- It offers low power efficiency.
- Very susceptible to noise interference because noise affects the amplitude.
- It is not suitable for high bit rate data transmission.

Phase Shift Keying (PSK):

conveys data by changing the phase of a constant frequency reference signal.

adv:

- it allows information to be transmitted in radio communication in a more efficient way as compared to that of FSK.
- less prone to error.
- A high rate of data transmission is achieved.
- It is also more power efficient as compared to other techniques.

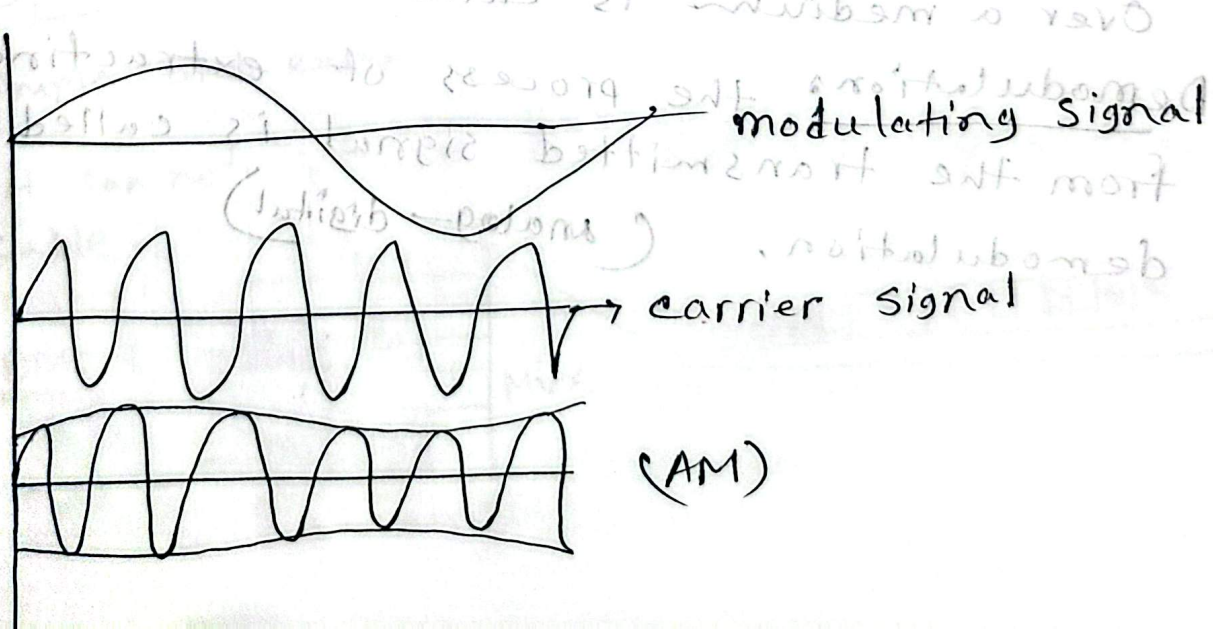
Disadv:

- Significantly less bandwidth as compared to ASK.
- It is a type of non-coherent reference signal.
- extremely difficult algorithms are used in decoding the binary information which is transmitted during PSK.

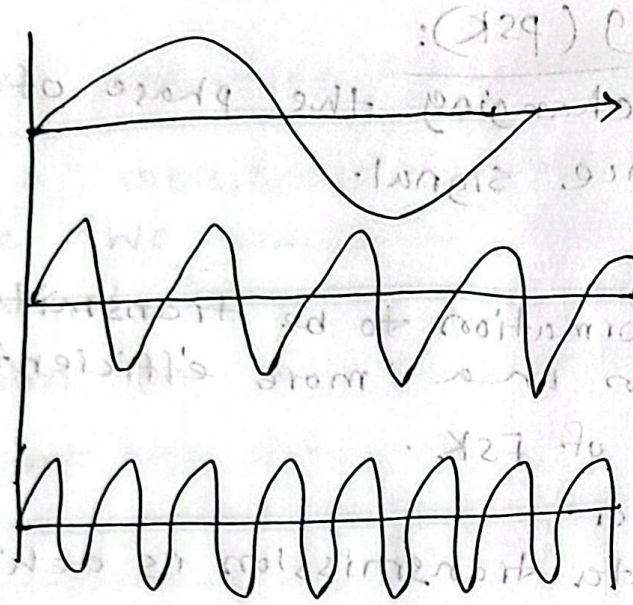
Analog to Analog conversion:

- Amplitude Modulation (AM)
- Frequency " (FM)
- phase " (PM)

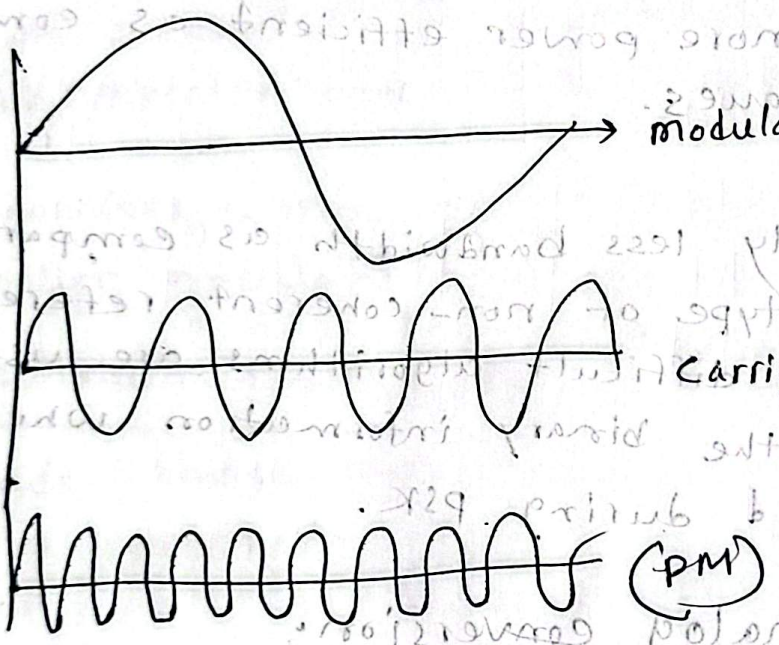
AM:



FM:



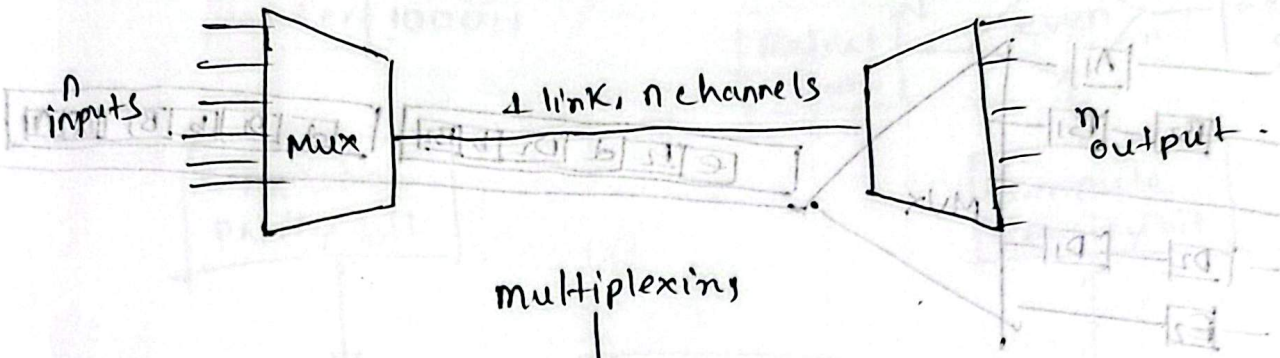
PM:



Modulation: the process by which data is converted into electrical/digital signal varies continuously ~~like a sine wave~~, for transferring that sign over a medium is called modulation (digital-anal

Demodulation: the process of extracting data from the transmitted signal is called demodulation. (analog-digital)

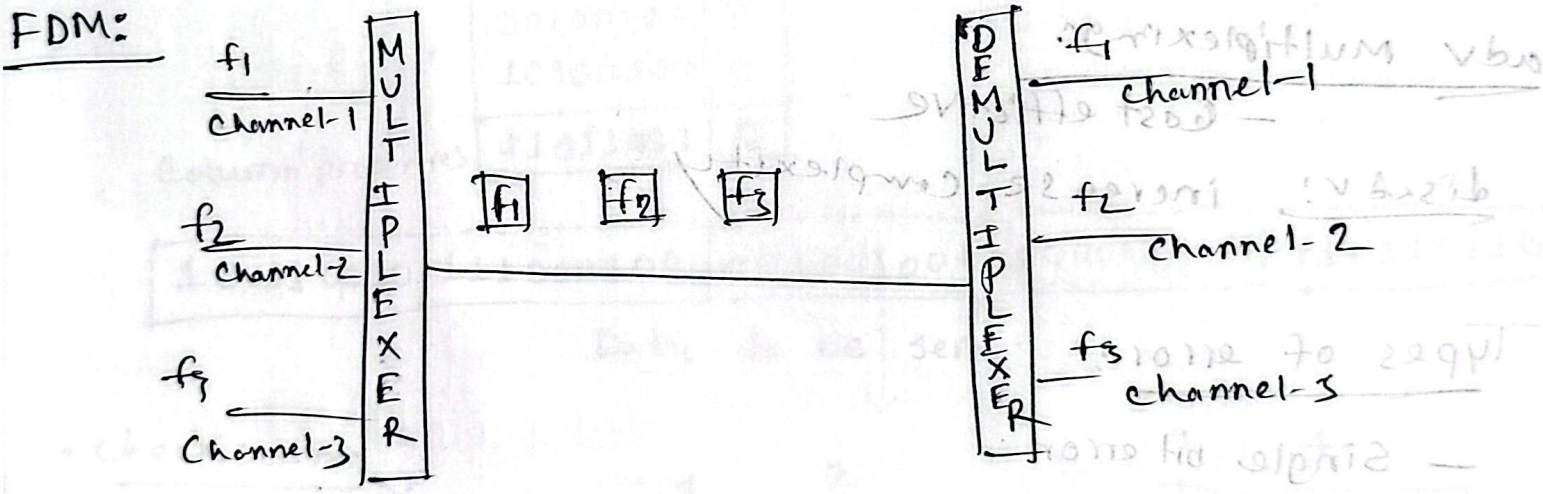
Multiplexing:



Multiplexing

- Frequency Division multiplexing (FDM)
- Time-Division multiplexing (TDM)
  - Synchronous TDM
  - Statistical TDM
- Wavelength Division multiplexing (WDM)

FDM:

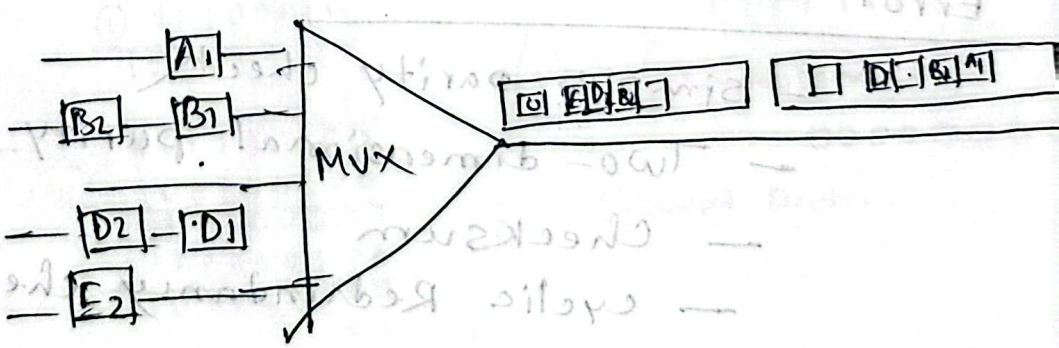


adv: simple and easy

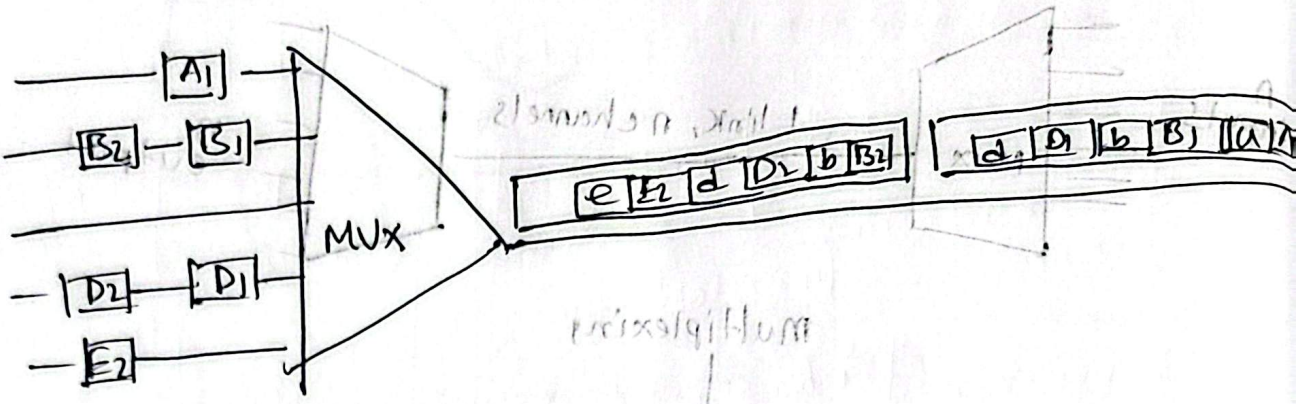
disadv: it can not utilize the full capacity of the cable.

TDM:

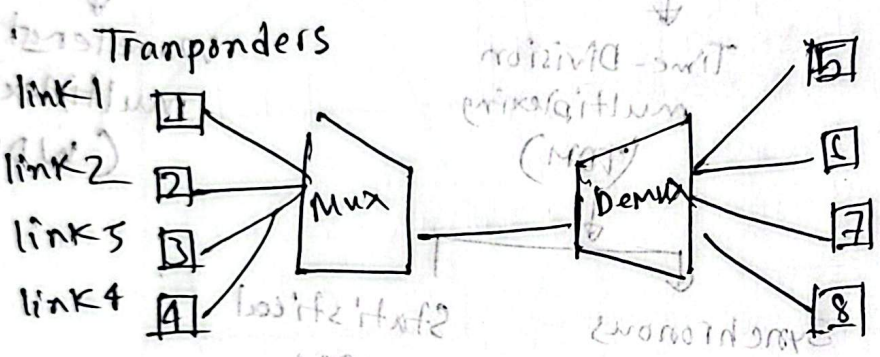
STDM:



Statistic TDM:



WDM:



adv Multiplexing:

- Cost effective

disadv: increase complexity

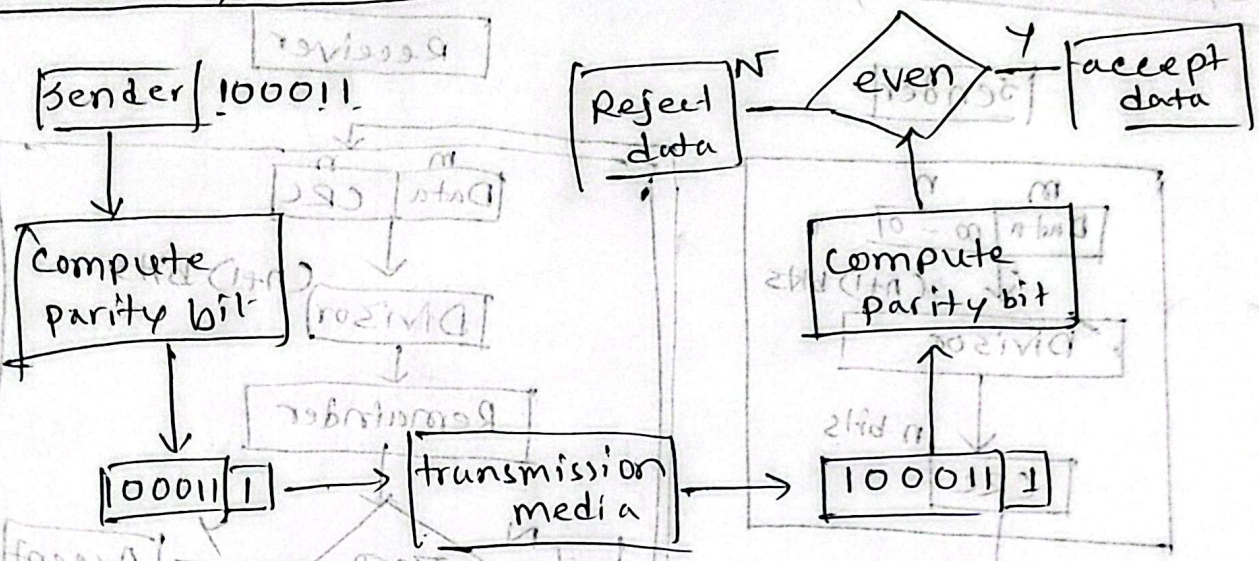
Types of error:

- Single bit error:
- Multiple " "
- Burst error: Several consequtive bits are flipp

Error detection method:

- simple parity check
- Two-dimensional purity check
- Checksum
- cyclic Redundancy check (CRC)

- **Simple parity check:**



- **Two-dimensional parity check:**

Original data: 10011001 | 11100010 | 00100100 | 10000100

Row parities

10011001	0
11100010	0
00100100	0
10000100	0
11011011	0

Column properties

10011 0010 | 111000100 | 00100100 0 | 100001000 | 110110110

Data to be sent.

- **Checksum:**

Original Data: 10011001 | 11100010 | 00100100 | 10000100

K=4, m=8

Sender

1 10011001
2 11100010
10 1111 011
+1
10111100
00100100
10100000
10000100
10010 0100
+1
00100101

Receiver

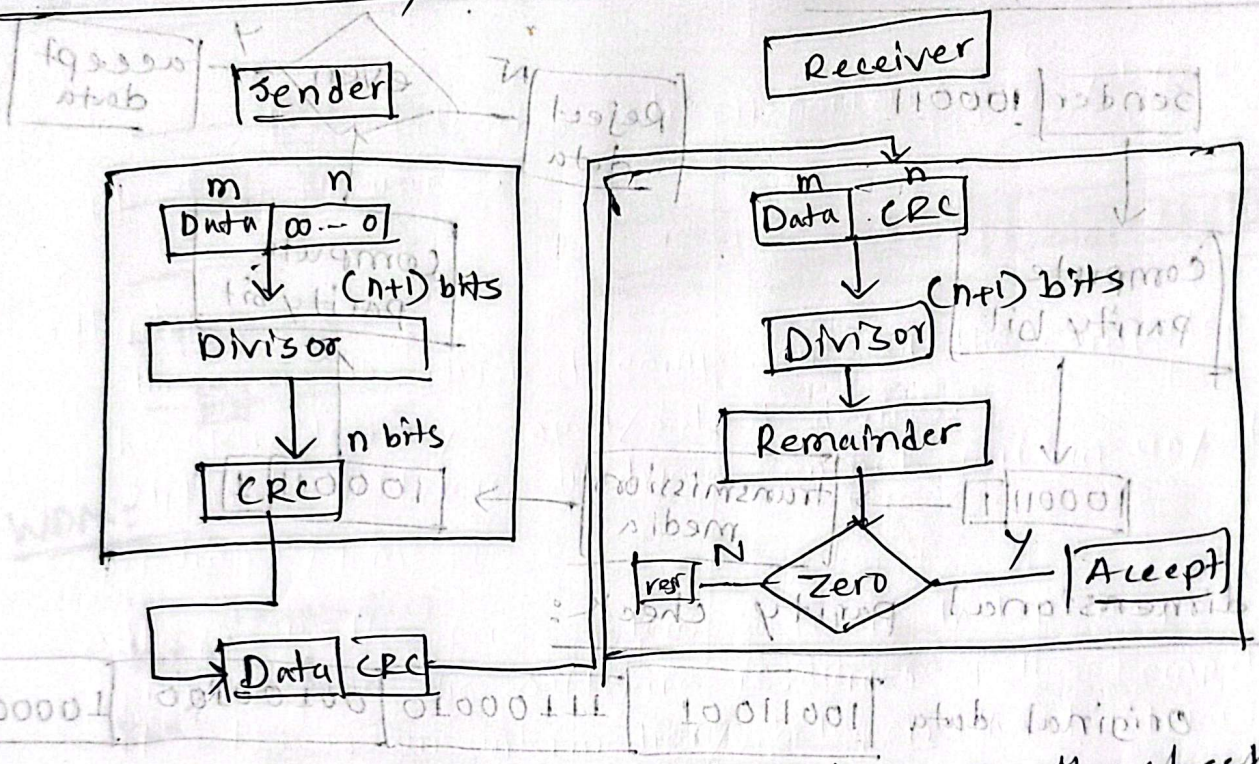
① 10011001
② 11100010
101111011
+1
01111100
00100100
10100000
10000100
10010 0100
+1
00100101

00100101
11011010
11111111

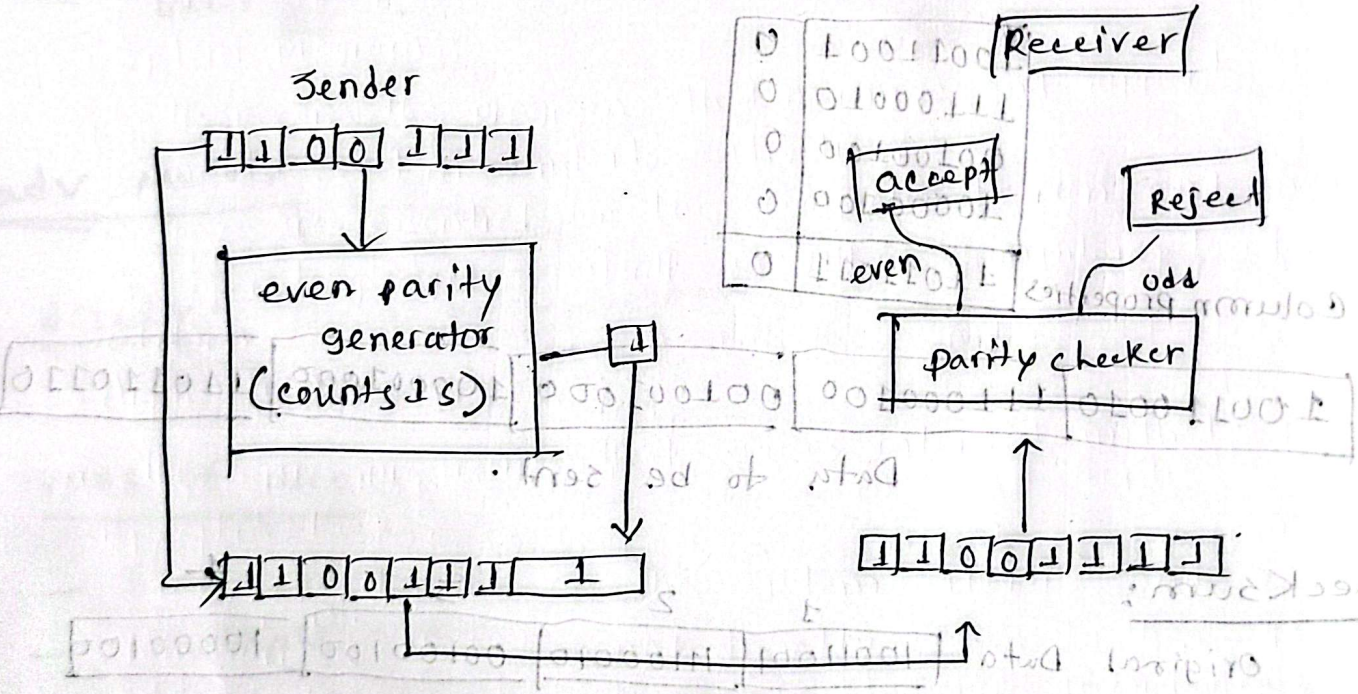
complement
00000000

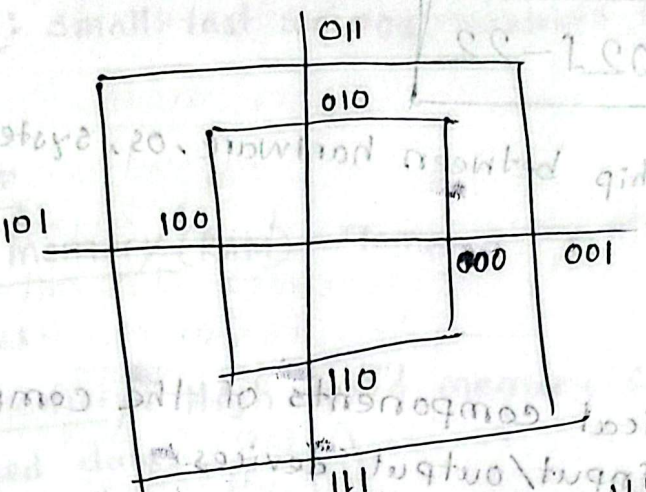
Accept Data.

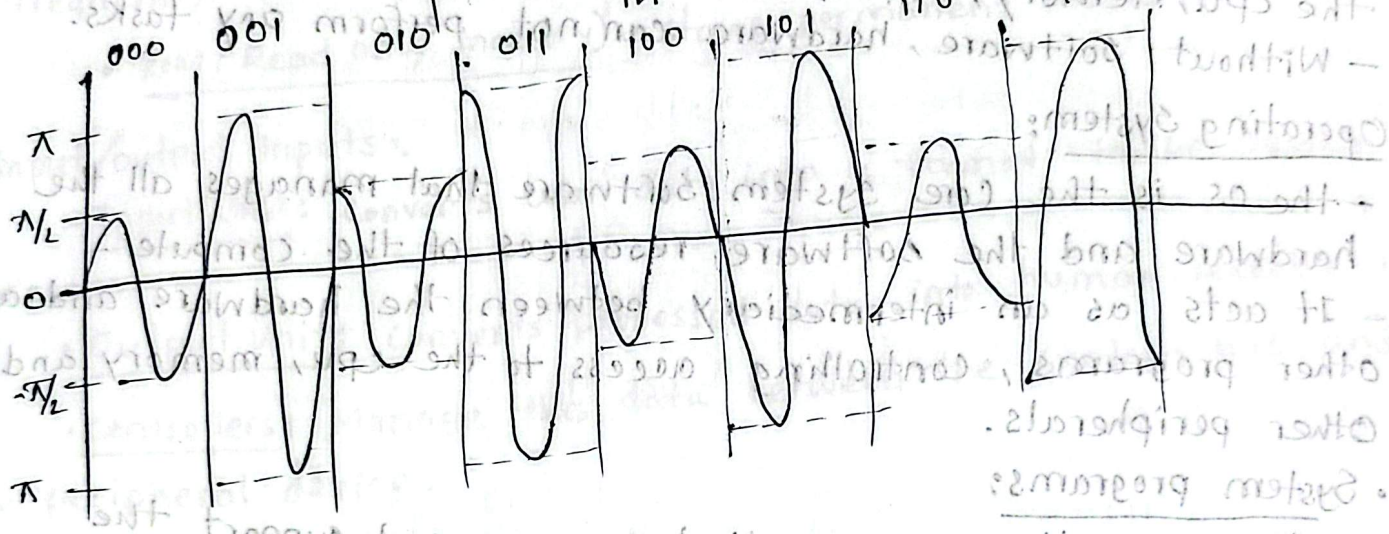
Cycle Redundancy check:

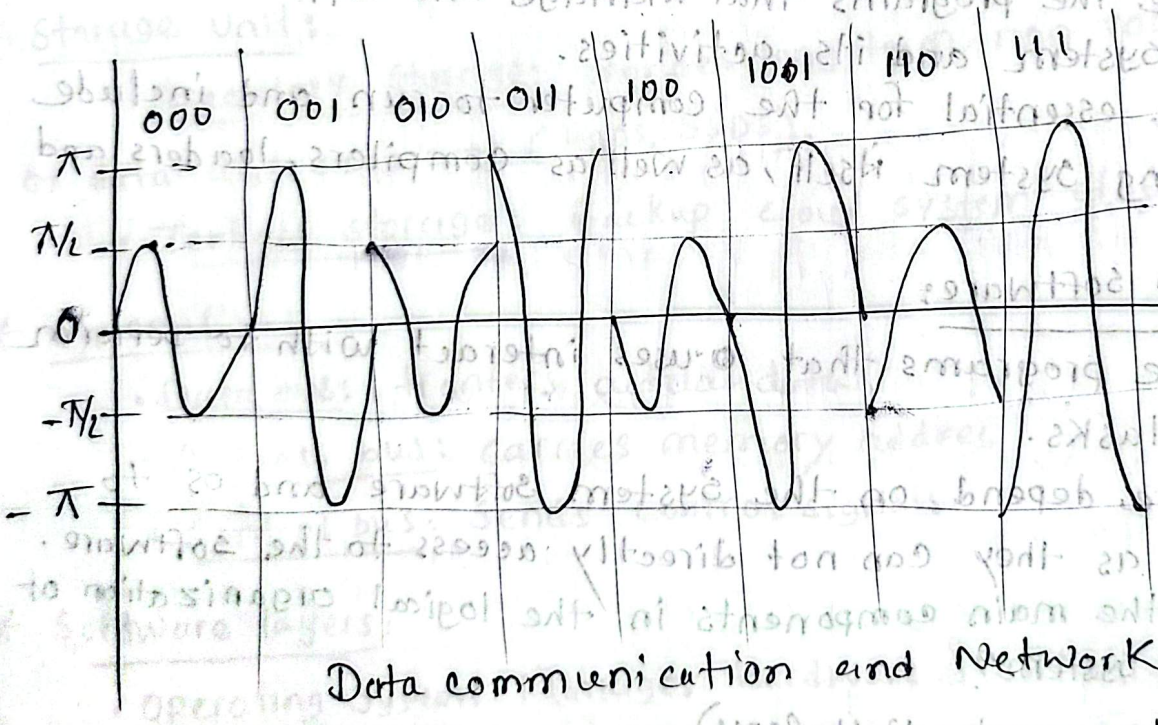


Vertical Redundancy check (VRC) or parity check:









Data communication and Networking

BEHROUZ A. FOROUZAN