16.10.2025

Communication Engineering

Exam Note

1.1

Data: Data is a collection of discrete or continuous values that convey information describing the quantity, quality, fact, statistics, other basic units of meaning or simply sequence of symbols that may be further interpreted formally.

Data Communication: are exchange of data between two devices through some form of transmission medium.

Fundamental characteristics: The effectiveness of data commu.. depends on four :-

1. **Delivery:** The system must deliever data to the correct destination. Data must be received by the intended device or user only.

2. **Accuracy:** Must deliever the data accurately. Data that have been altered in transmission and left uncorrected are unusable.

3. Timeliness: Must deliever data in a timely manner. Data delivered late is useless. It means delieverying data as the data are produced. It is called real time transmission.

4. Jitter: It refers to the variation in the packet arrival time. It means uneven delievery of audio or video packet.

Five component of Data Communication:

1. Message: The information to be communicated.
2. Sender: Is the device that send the data.
3. Receiver: Is the device that receives the message.
4. Transmission Medium: Is the physical path by which a message travel from sender to receiver.
5. Protocol: Is a set of rules that govern data communication. It represents an agreement between the communicating devices. Without it, two devices may be connected but not communicating.

Network: A network is the interconnection of a set of devices capable of communication.

Network criteria is -

1. **Performance:** It is measured with transmit time and response time.

Transmit time: Is the amount of time required for a message to travel from one device to another.

Response time: Is the ~~time~~ elapsed time between an inquiry and a response.

Performence is also evaluated by two networking matrics-

1. **Throughput:** It is the rate of successfully transmitted data from sender to receiver.

2. **Delay:** Is the time taken for a data packet to travel from the source to destination.

2. Reliability:

i) accuracy of delivery.

ii) frequency of failure.

iii) time it takes a link to recover from failure.

iv) the network robustness in a catastrophe.

3. Security:

- Protecting data from unauthorized access.
- Protecting data from damage
- Development and implement policies and procedures for recovery from breaches and data losses.

Physical Structure of Network:

→ Type of connection → point to point
→ multi point

→ Physical topology → refers to the way in which a network is laid out physically.

3.2

Signal: refers to any time-varying voltage, current or electromagnetic wave that carries information

Periodic signal: completes a pattern in time frame and repeats that pattern over subsequent identical periods.

Non-periodic signal: changes without exhibiting a pattern or cycle that repeats over time

Periodic signal can be simple or composite-

→ A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals

→ A composite periodic analog signal is composed of multiple sine waves.

→ we use periodic analog and non-periodoc digital signal.

Sine wave: is a geometric waveform that oscilates periodically and defined by the function $y=\sin x$

It is S shaped and smooth.

It can represented by three parameters-

1. Peak Amplitude: is the absolute value of its highest intensity, proportional to the energy it carries. It measured in volts.

2. Frequency: refers to the number of periods in 1s.

3. Phase: describes the position of the waveform related to time 0. Measured in radian

$360° \rightarrow 2\pi$ rad

Time Domain: It express amplitude and times

Frequency Domain: It express ~~frequency~~ amplitude and ~~freq~~.

It is usefull when we deal with more than one sine wave. show relation between amplitude and frequency.

- Pure sine wave is used for energy carry or signal of danger.

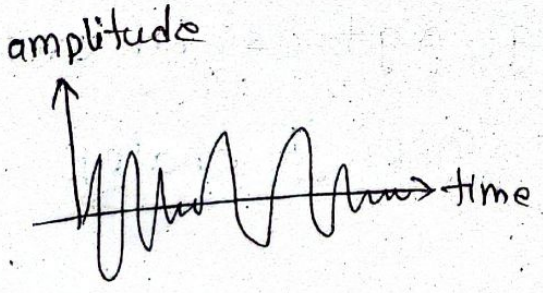
2.3

Jean Baptiste Fourier showed that any composite signal is actually a combination of simple sine waves with different frequencies amplitude and phases.

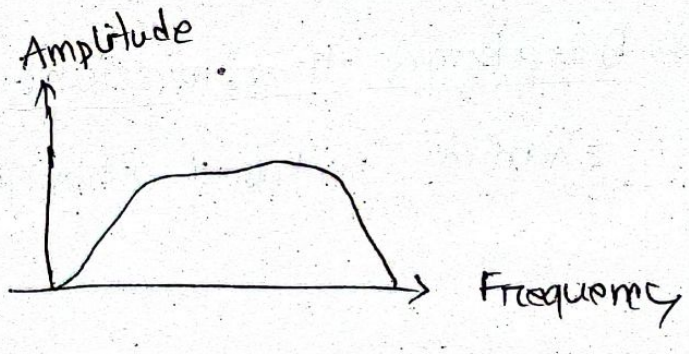
⇒ If periodic composite signal is decomposed they are discrete. If non-periodic the frequency is continuous.

First Harmonic: is the lowest frequency component of a periodic signal, having the same frequency as the signal itself. It is also called fundamental frequency.

Non-periodic composite signal:

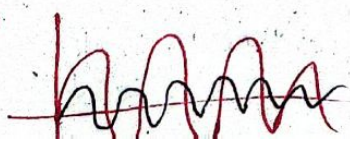


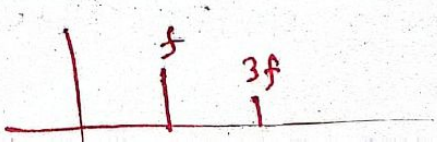
a. Time Domain



b. Frequency domain

(Periodic)





Bandwidth: The range of frequencies contained in a composite signal is its bandwidth.

Bit Rate: Numbers of bits send in 1 second.

If a signal has L levels, we can sent $\log_2^L$ bits.

Digital signal: is a composite analog signal with infinite bandwidth.

→ Vertical line in time domain means a infinite frequency, Suddenly change in time.

→ Horizontal line in time domain mean zero frequency, No change

Digital signal can transfer in two ways:

1. **Baseband transmission:** sending digita signal over channel without changing the digital to analog.

2. **Broadband Transmission:** sending digital signal as analog signal over a bandpass channel that support multiple frequency range, allowing several signal to travel simultaneously.

Frequency of analog signal is half of the bit rate

Ex: Data 1010

$N = 4$

$\therefore f = \frac{4}{2} = 2Hz$

Bit Per baud = $\log_2^{(L)}$ $\quad L \rightarrow$ signal level

1.4

Signal Impirement : During transmission through medium which ament perf signal causes impirement. 3-causes are-

1. Attenuation means a loss of energy.

It measures with decibal (dB)

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$P_2 \rightarrow$ End signal

$P_1 \rightarrow$ start signal

If signal is impiremout it is negative if it amplified impiremout is positive.

2. Distortion means that the signal changes its form or shape.

3. Noise: is another cause of impairment.

- Thermal Noise → Is the random motion of electrons in a wire, which create extra signal.
- Induced noise → comes from sources such as motors and appliances.
- Crosstalk → is the effect of one wire on the other.
- Impulse noise → is a spike that comes from power lines, lightning and so on.

SNR (Signal to Noise Ratio)

$$SNR = \frac{\text{average signal power}}{\text{average noise power}}$$

→ High SNR means signal is less corrupted.

→ Low SNR means the signal is more corrupted by noise.

$$SNR_{dB} = 10 \log_{10} SNR$$

For a noiseless channel, $SNR = \frac{\text{signal power}}{0} = \infty$ $SNR_{dB} = \infty$

Data Rate depends on three factor:

1. The bandwidth available.
2. The level of signal we use.
3. The quality of channel (the level of noise)

Two theoretical formula develop to calculate data rate.

→ Nyquist for a noiseless channel.

→ Shannon for a noisy channel.

Nyquist BitRate = $2 \times \text{bandwidth} \times \log_2 L$ $L \rightarrow$ number of signal level.

or theoritical maximum bit rate

$$\text{Shannon Capacity} = \text{bandwidth} \times \log_2(1 + \text{SNR})$$

- Shannon capacity gives us the upper transmit limit. And Nquist formula tells us how many signal levels we need for this shannon capacity.

2.1

Digital to Digital Conversion:

1. Line coding: converts a sequence of bit to a digital signal.

At Sender: Digital Data are encoded into digital signal

At Receiver: Digital data recreated by decoding the digital signal.

Data Element: is the smallest entity that can represent a piece of information.

Signal Element: is the shortest unite of a digital signal.

Data Element carried by signal element ratio-

$r =$

→ Data rate defines the number of data elements sent in 1 second. Unite is bps.

→ Signal rate is the number of signal elemeed sent in 1 second. Unite is baud.

Bandwidth: (Usages)

i) Bandwidth in hertz refers to the range of frequency

ii) Bandwidth in bps, refers the speed of transmission

Baseline wandering (Drifting): In decoding a digital signal, the receiver calculates a running average of the received signal power, it is called baseline.

→ A long string of zero or one can cause drift in the baseline and make hard to decode correctly.

Line coding →
- Unipolar — NRZ
- Polar — NRZ, RZ, Biphase
- Bipolar — AMI, Pseudoternary
- Multilevel — 2B1Q, 8B/6T, 4D-PAM5
- Multitransition — MLT-3

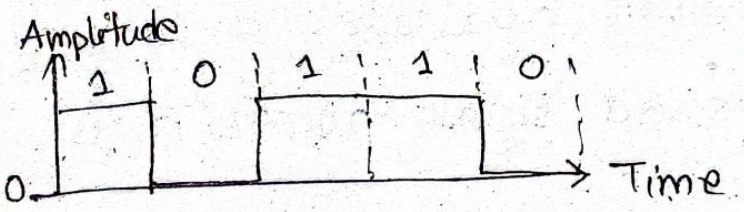
Unipolar: All the signal level are on one side of the time axis, either above or below.

Positive, Zero.

NRZ (Non-Return to Zero) the signal doesnot return to zero at the middle of the bit.

Polar : Voltages are one both side of the time axis Positive, Negative.

Unipolar NRZ:



Polar (NRZ-level and Invert)

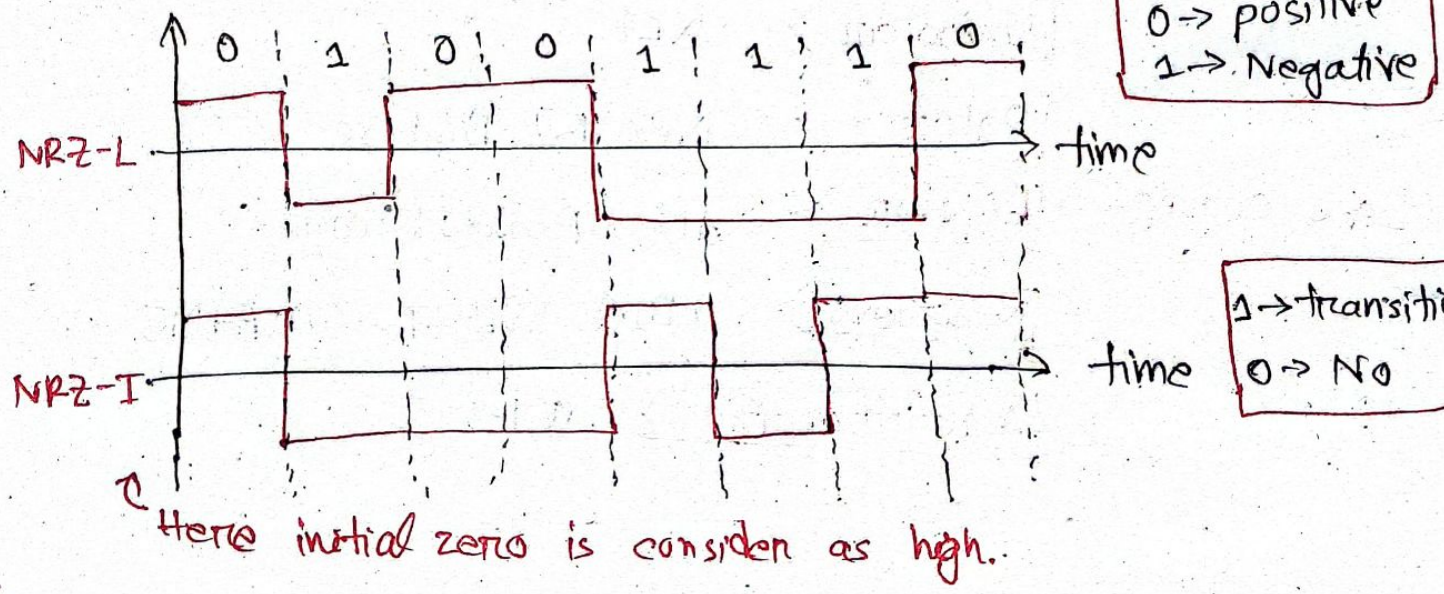


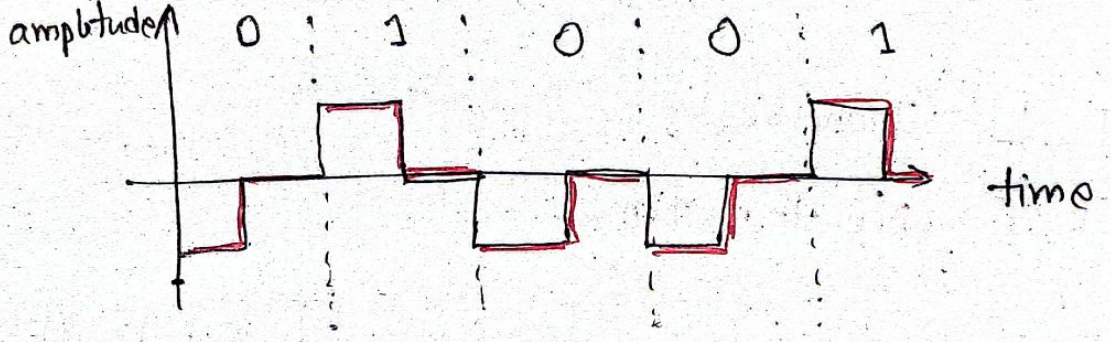
Diagram থেকে Decode করতে বলে যদি 1 পাই তবে 1 আর যদি 0 হবে।

বিন্দু যদি এমন রেখা থাকে যার শুরুতে 0 নেই। সেখানে 0 যোগ করে নিবো।

10011 → 010011

RZ(Return to Zero): It solve the problem of sender and receiver not synchronized. The signal goes to zero in the middle of each bit and remain there until the begining of the next bit.

→ main disadvantages that it requires two signal changes to encode a bit and therefore take large bandwidth.

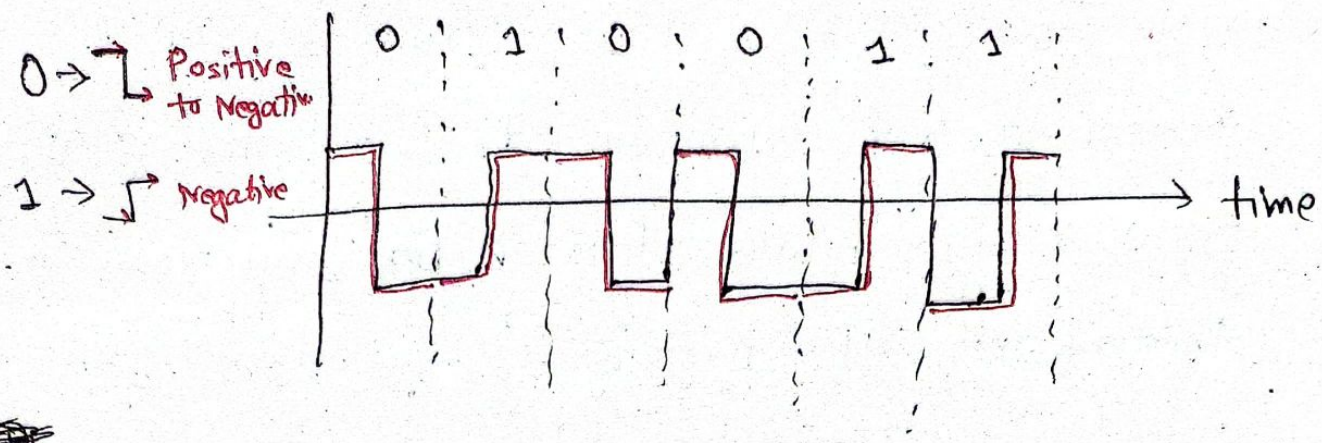


0 → Negative to Zero

1 → Positive to Zero.

Biphase: (Manchester) IEEE Here the RZ and NRZ-L are combines.

- The duration of bit is divided into two levels.
- voltage remains at one level at first half and move to other level in the second half
- The transition at the middle provides synchronization.



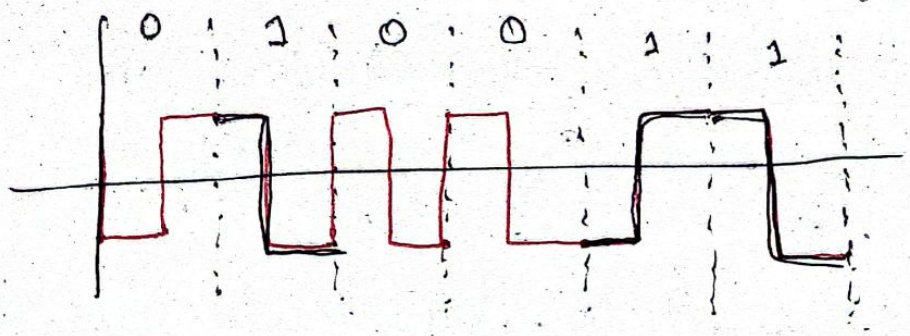
Biphase (Differential Manchester): It combine RZ and NRZ-I

- there is always transition at the middle.

0 → ⊓, ⊔ (Transition)

1 → ⌐ ⌙ (No transition)

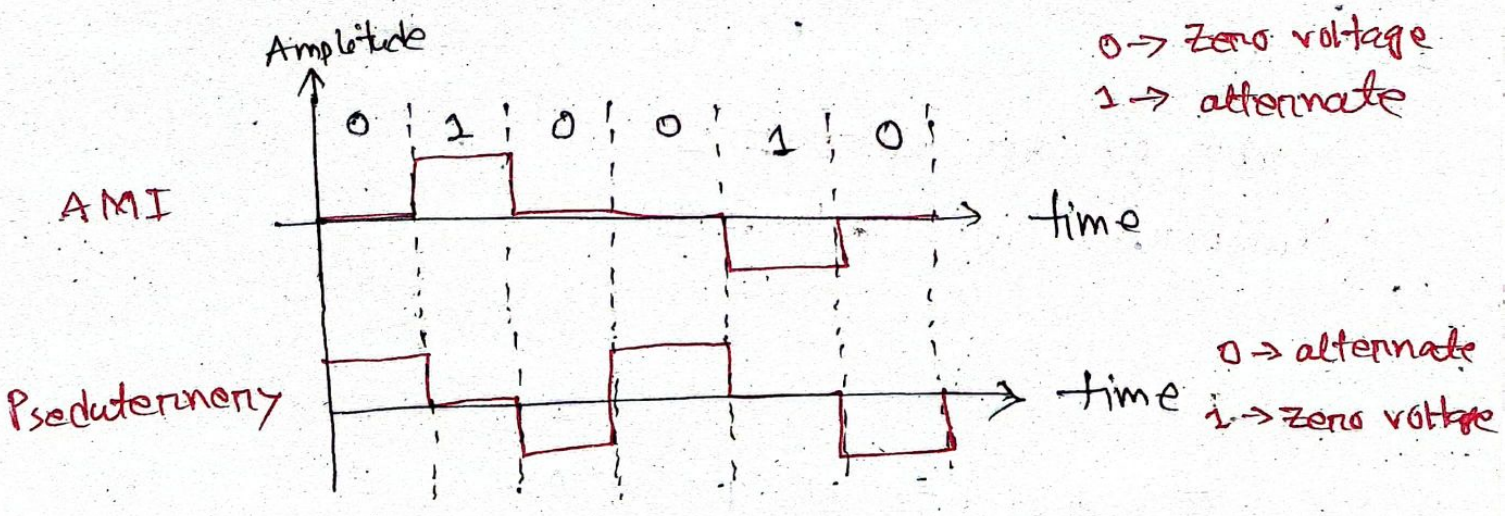
If first input is 0 then start with ⊔ and if first input is 1 then start with ⌙. Always need to match.



Bipolar Schemes: Bipolar encoding or multilevel binary there are three voltages level. Negative, Positive and Zero.

- The voltages level for one data element is zero, while the voltages for othe level alternate between positive and negative.

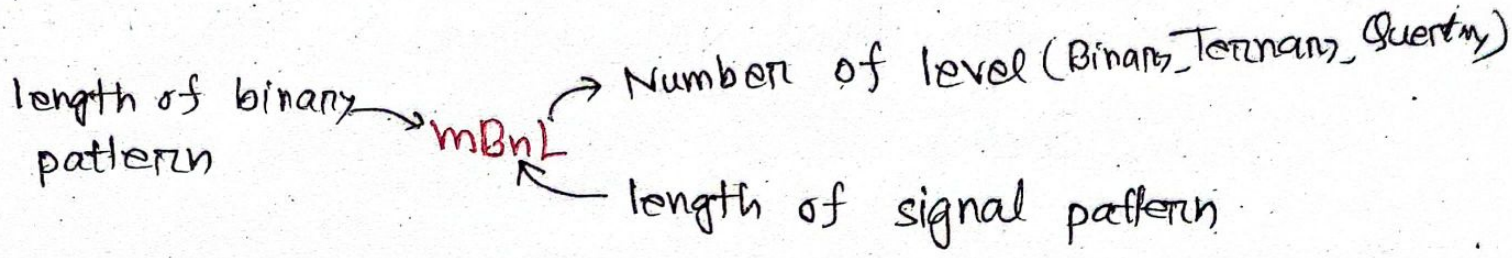
Alternate Mark Inversion (AMI) (Pseudoternary)



→ Mind it; alternate to the immediate previous same state.

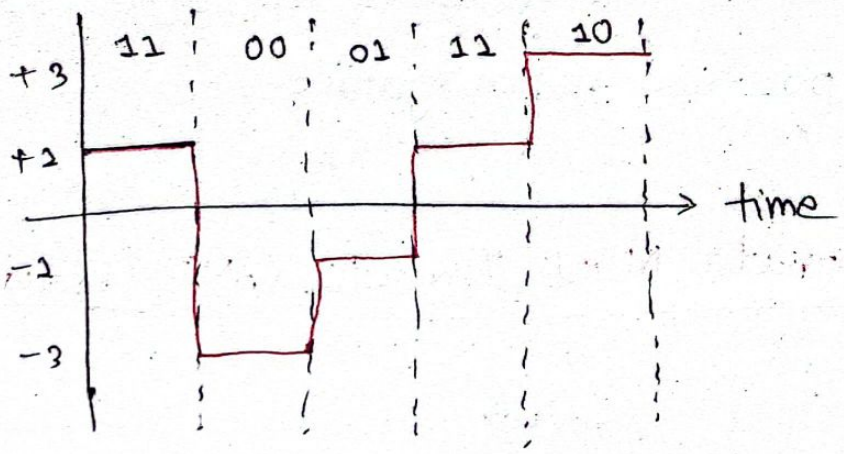
2.2

Multilevel Scheme: 2B1Q, 8B6T, 4D-PAM5



Assume positive as original level

00 → -3
01 → -1
10 → +3
11 → +1



Number of data pattern = 2^m

Number of signal pattern = L^n

Bit rate: Number of bits sent per second.

Bit Duration: Inverse of bit rate.

Block coding: Block coding changes a block of m-bits into a block of n bits where n is larger than m. mB/nB

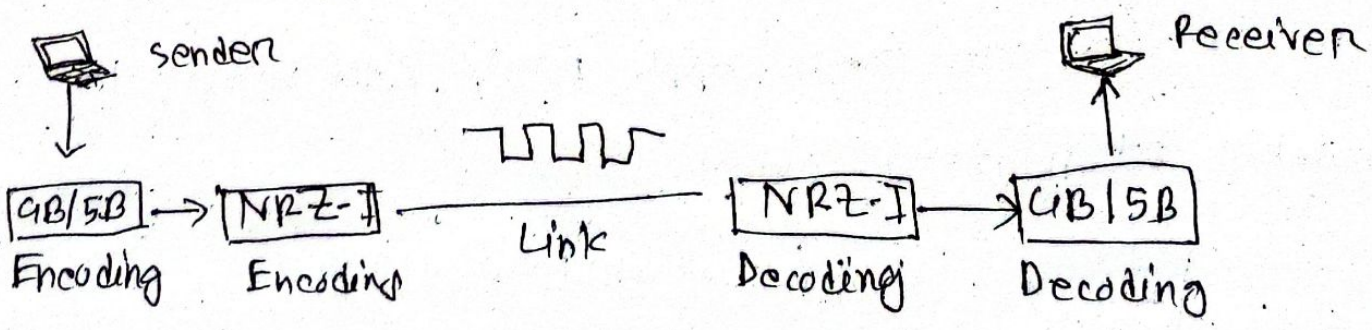
- Block coading is used to make redundeud code as more redundent code help to error dirtection and synchronization.

Step: Division
substitution
combination

4B/5B (Four binary/Five binary)

- Here no more than one leading zero in left bit and no more than two trailing zeros in right side.

→ control bit = 8 bit



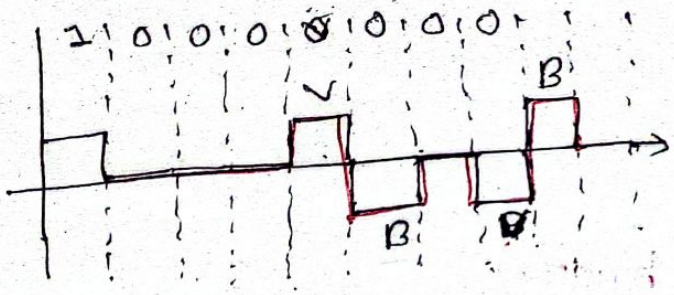
Scrambling: is a technique that does not increase the number of bits but provide synchronization.

B8ZS → Bipolar with 8 Zero Substitution → It substitute eight consecutive zeros with 000VB0VB

V (Violation) → same as last non-zero level.

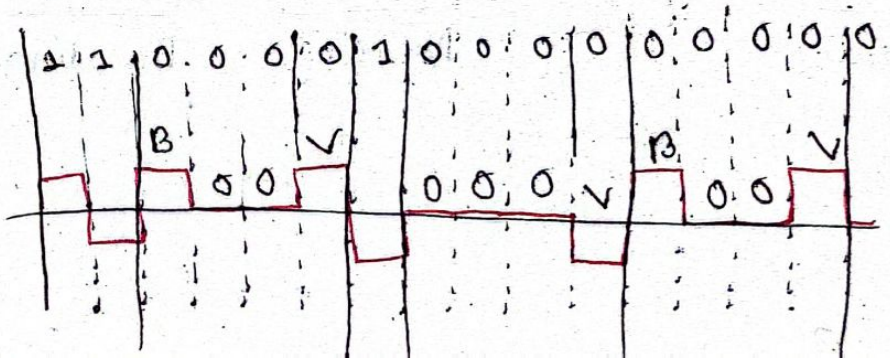
B (Bipolar) → opposite to last nonzero level.

It is the improve version of AMI



HDB3 (High Density Bipolar 3-zero) Four consequtive zero level are replaced with 000V or B00V

→ If last totall nonzero pulse is odd then replace with 000V and if they are even apply B00V. Both make totall number of nonzero even.



2.3

Analog to Digital Conversion: Most common technique is called pulse code modulation.

A PCM encoder has three process:-

1. Analog signal is sampled.
2. Sampled signal is quantized.
3. The quantized values are encoded as streams of bits.

Sampling Frequency: Analog signal is sampled in every Ts sec.

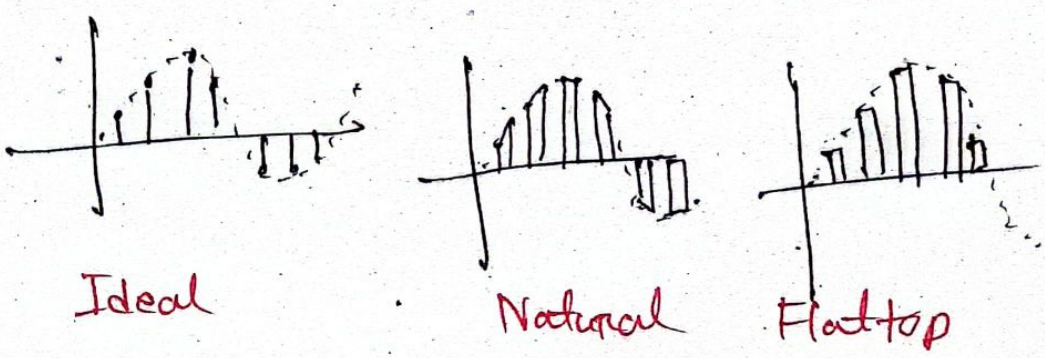
It is sample interval or period.

The inverse of the sampling interval is called sampling rate or sampling frequency denoted by f_s.

$$f_s = \frac{1}{T_s}.$$

Three Sampling Method:

1. Ideal
2. Natural
3. Flat-top



Restrictions on T_s.

1. A signal with infinite bandwidth cannot be sampled.
2. Sampling rate must be at least two times of highest frequency.

Quantization: steps in Quantization

1. We assume that the original analog signal has amplitude between V_{min} and V_{max}
2. Divide the range into L zones, each of height Δ

$$\Delta = \frac{V_{max} - V_{min}}{L}$$

3. We assign quatized values of 0 to L-1 to the mid point of each zone.
4. We approximate the value of the sample amplitude to the quantized values.

(2) First row is the normalized value for each sample

$$\frac{\text{actual amplitude}}{\Delta}$$

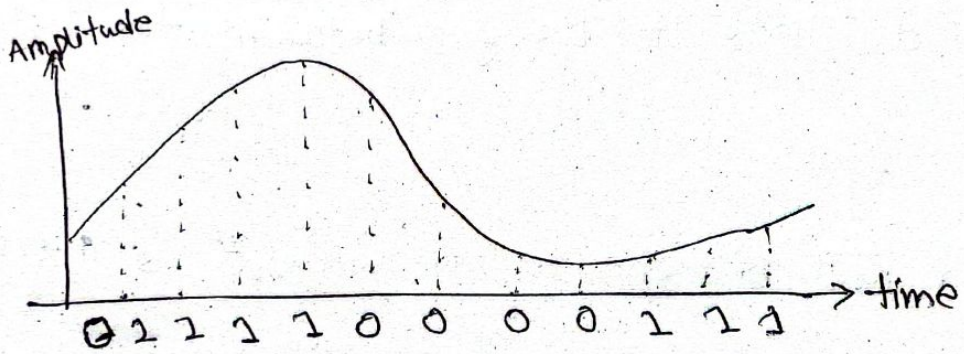
Original Signal Recovery:

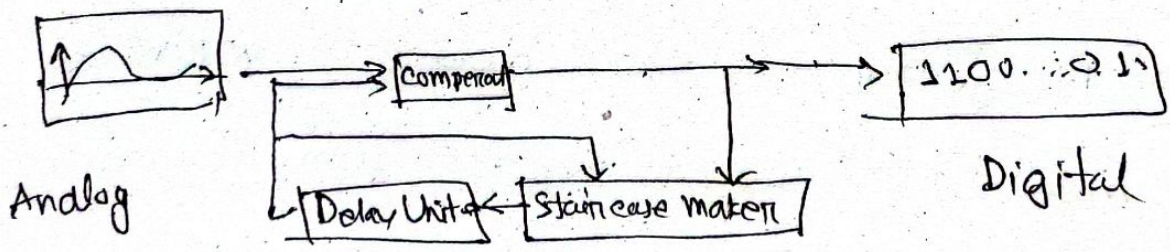
Delta Modulation: Finds the change from previous sample.

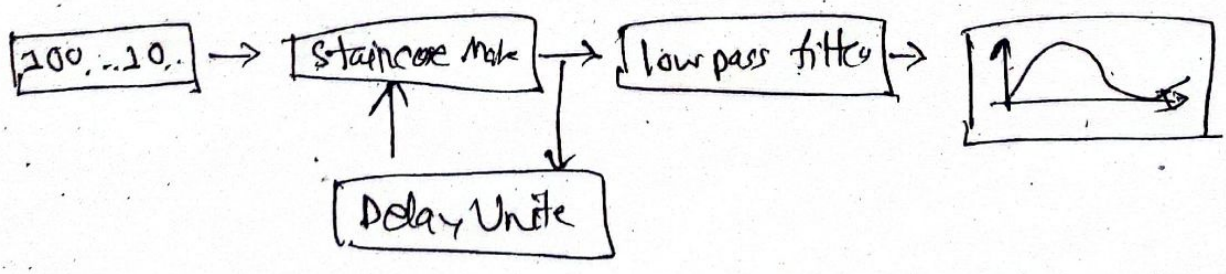
→ modulator create a stream of bits. from analog signal at sender site. &

→ It records small positive or negative changes called delta

→ If delta is positive, it is 1. If delta is negative it is 0.







Transmission Mode:

Parallel: Multiple bits are send together at a time with bit number wire.

Serial: ↓ Bits are sent one after another with single wire.

Asynchronous: Sent start bit at beginning and stop bit at end. There maybe gap between the bytes.

Synchronous: We sent bit one after without start-end bit or gaps. Receiver grops bit using synchronizati with the senden.

Isochronous: It guarientees that data are arrive at a fixed rate. Time interval is same for each data.

3.1

Digital to Analog Conversion:

is the process of changing one of the characteristics of an analog signal based on the info in digital data.

- → Amplitude Shift Keying (ASK)
- → Frequency Shift Keying (FSK)
- → Phase Shift Keying (PSK)

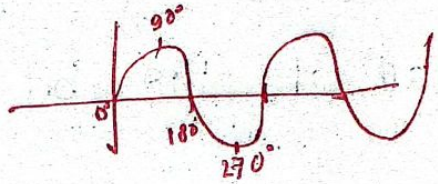
→ Quadrature Amplitude Modulation (QAM)

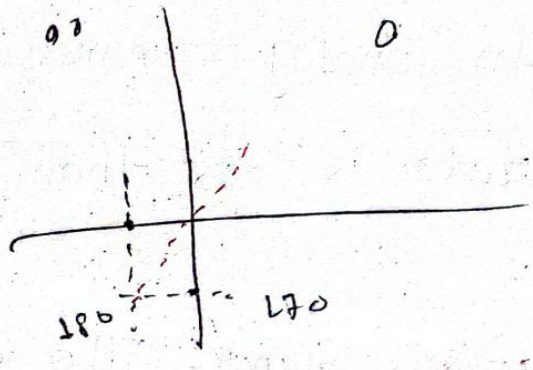
- In analog transmission of digital data, the baud rate is less than or equall to the bit rate.

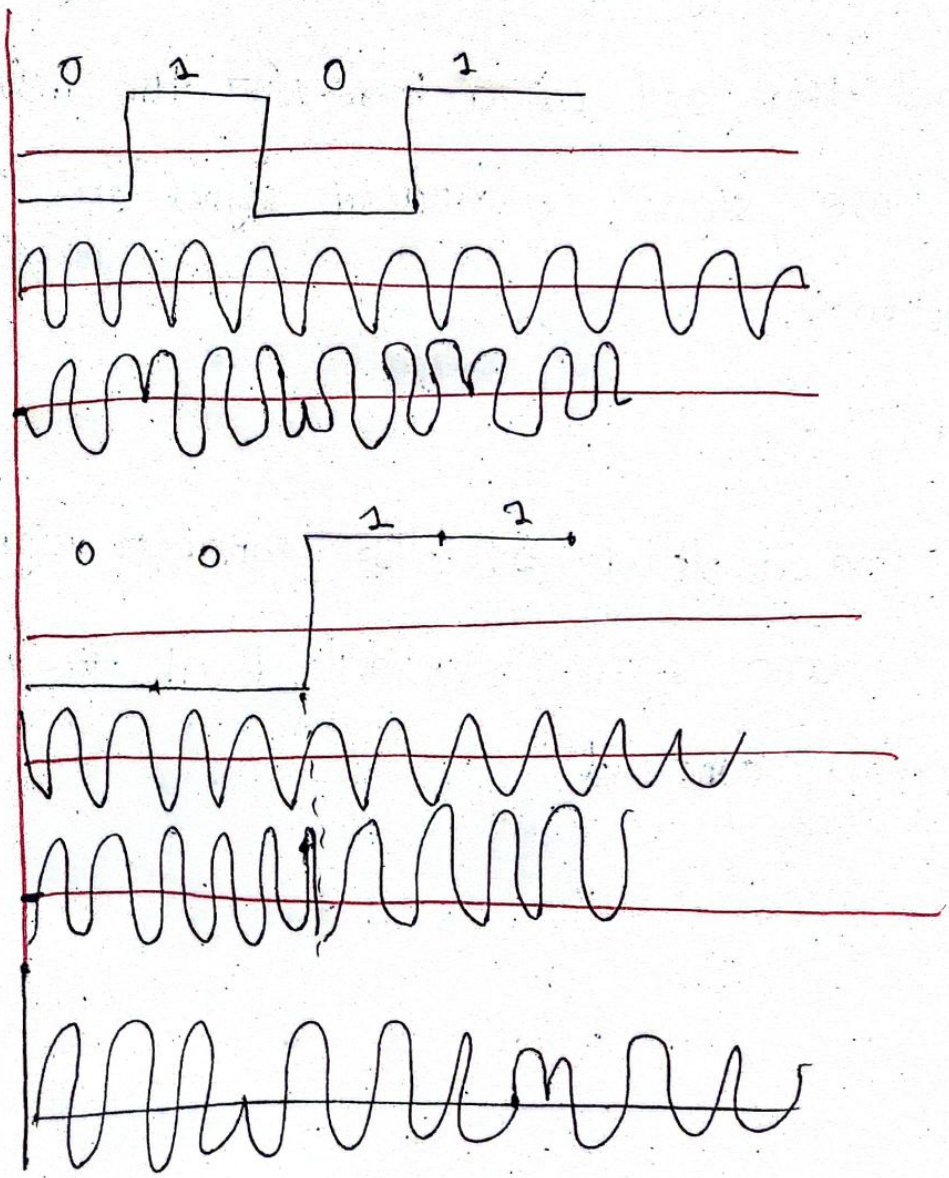
Carrier Signal: The sending device produce a high frequency signal that act as a base for the information signal, this base signal is carrier signal or carrier frequency.

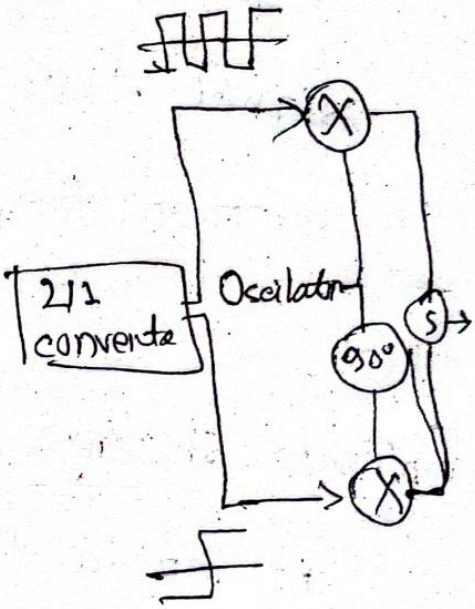
Amplitude Shifting: The amplitude of the carrier signal is varied to create signal elements. Both frequency and phase remain constant.

QPSK (Quadrature Phase Shift Keying) It is a form of PSK where two bit are modulated at once. It decrease the baud rate and send data twich faster.









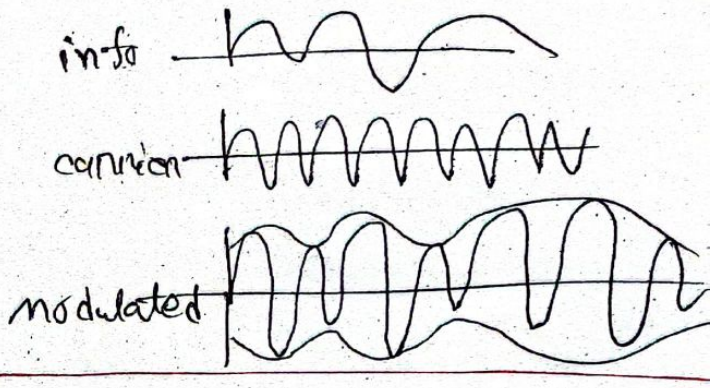
Analog to Analog Conversion: is the representation of analog information by analog signal.

Amplitude modulation:

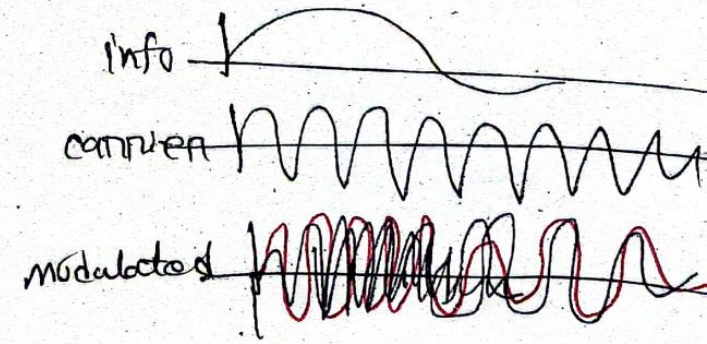
require bandwidth

$$B_{AM} = 2B$$

B → Bandwidth of audio signal



Frequency Modulation:



Phase Modulation:

[4.1]

Multiplexing: is the set of techniques that allow the simultanous transmission of multiple signals accross a single data link.

1. Frequency Division 2. Wavelength Division 3. Time Division (Digital)

Frequency Division: FDM is an analog technique that can be applied when the bandwidth of a link is greater than the combined bandwidths of the signals to be transmitted.

1. Each sources generates a signal of a similar frequency range.
2. Inside the multiplexure, the similar signal are modulate on attached different carrier frequency (f_1, f, f_i)
3. The resulting modulated signals are then combine into a single composite signal and sent over a link.

Demultiplexing:

1. The demultiplexure use a series of filter to decompose the multiplexed signal into its constituent componed signals.
2. The individual signals are then passed to a demodulator that seperate them from their carrier signal and passess them to the output line.

Wavelength Division Multiplexing: It is designed to use the high datarate capability fiber optic cable.

Time Division Multiplexing (TDM) It combine several low rate channels into high rate one.

Two different Scheme:

1. Synchronous: Eeach input connection has an allotmeed reserved cell in the output if it is not even sending data.

2. statistical: It improve synchronous process bandwidth by skipping these line cuhoes have no data. If give data in output cuho have meaningfull data.

Spread Spectrum: is a communication technique in which the transmitted signal bandwidth is intentionally spread over a much wider frequency range than the minimum require.

Frequency Hopping Spread Spectrum (FHSS) The signal jumps rapidly between different frequencies in a pattern known to both sender and receiver.

Direct Sequence Spread Spectrum (DSSS) Each bit of data is multiplied by a high speed chipping code to spread it across many frequencies.

Transmission Medium: can be broadly defined as any thing that can carry information from a sources to a destination.

Guided: which are those that provide a channel ~~one~~ from one device to another device.

Ex: Twisted pair cable, coaxial cable, fiber optic cable.

Twisted Pair Cable: One wire used to carry signal and other is used only as ground reference.

Coaxial Cable: It carries signals of higher frequency ranges than twisted pair cable.

Fiber Optic Cable: A glass or plastic core is surrounded by a cladding of less dense so that the ligut beam will reflected instead of refracted into it.

Propagation mode:

1. Singlemode
2. Multimode → Stepindex | Graded Index > Multiple beam sent

Advantages and Disadvantages of Optical Fiber:

Higher bandwidth: Dramatically higher bandwidth.

less signal attenuation: Transmission distance is greater.

Immunity to Electromagnetic interference: Have no effect

Resistance to corrosive materials:

Light weight:

Greater immunity to tapping:

Disadvantages:

Installation and Maintenance.

Unidirectional light propagation.

Cost:

Step Index: In multimode step index fiber, the density is constant from center to edge. The light beam is move through it by sharp reflect that is called step index. Sharp reflect create distortion.

Graded Index: Density is higher at the center and it decrease gradually to its lowest at the edge. Here distortion is reduced and index means the degree of refraction.

Single Mode Propagation: Manufactured very small diameter than multimode fiber and lower density cladding that increase critical angle upto 90°. As a result highly focuse source of light moves like closely horizontal.

Unguided (Wireless):

- Radio waves use omnidirectional radio antena that sent signal to all direction.
- It propagate in sky mode and can travel long distances. Low and Medium frequency can penetrate walls.
- But make problems with another close antena with same frequency and band.

- Microwave are used for unicast communication such as ~~de~~llular phones, satellite networks and wireless lans.
- It use parbolic dish antena or horn antena.
- Propagation is line of sight. Have problems, it need to align same line, world curve and obstacles are problems but have advantages to not overlap with other antena and higher wide band.

Satellite Network: An artificial body placed in orbit round th earth or moon or another planete in order to collect information or for communication

- A satellite network is a combination of nodes some of which are satellites, that provides communication from one point to another point on earth.
- Orbit is the path that a satellite takes around a planet or other star.

Keplan law of period = $c \times \text{distance}^{1.5}$

$= \frac{1}{100} \times \text{distance}^{1.5}$

MEO (Midium Earth Orbit): Its position is between two va Allen belts. Take 6 to 8 houre to circle the earth

- Used for GPS that take 24 active satellite.