

Data Communication (2017-18)

1. a) What is OSI Model? Difference between OSI and IOS model;

→ The OSI (Open Systems Interconnection) model is a conceptual framework used to understand and implement networking protocols in seven distinct layers. Each layer serves a specific process of moving data across a network.

- i. Application layer: Provides network services directly to user applications, like web-browser & email clients. Protocol include HTTP, FTP, SMTP etc.
- ii. Presentation: Translates data between the application layer and the network format, handling encryption, compression and data encoding (Syntax layer - SSL, SSH, FTP, JP EG)
- iii. Session: Manages sessions or connections between applications. It establishes, manages and terminates sessions.

(sync & send to port, API's, sockets, WinSock)

iv. Transport: Provides reliable data transfer across a network. It ensures complete data transfer with error checking & flow control. Protocols include TCP & UDP. (End to End connections, TCP-UDP)

v. Network layer: Handles data routing, addressing, and packet forwarding between networks. Protocols include IP, ICMP & ARP.

vi. Data link layer: Ensures reliable data transfer across the physical network by handling error detection and correction.

It's divided into two sublayers: MAC (Media Access Control) and LLC (Logical Link Control). (Ethernet, PPP, Switch, Bridge)

vii. Physical: Deals with the physical connection between devices, including cables, switches, & the electrical signals.

used to transmit data, (mechanical, electrical and functional interface)

ISO stands for International Standards organization. It is an organization for agreement on international standards of network communication worldwide. On the other hand OSI is a model for understanding & designing a network architecture.

OSI

i. OSI is a specific model created by ISO for standardizing the function of a telecommunication or computing system without regard to its underlying internal structure & technology.

ISO

i. ISO is an international standard setting body that develops and publishes various international standards across a wide range of industries, including technology, healthcare, manufacturing.

ii. focused on networking & communication between systems, providing a framework for how data should be transmitted btw different system

ii. ISO covers a ~~very~~ broad spectrum of standards not limited to networking or communication sys.

iii. The OSI model defines how different network protocols should interact to ensure data is transmitted accurately & efficiently across a network.

iii. ISO develops standards to ensure quality, safety, efficiency, & interoperability of products & services.

* iv. deals with networking standards, is responsible for developing standard for computer network

iv. responsible for developing international standards for all industries

✓ It is a reference model
for how applications can
communicate with each
other over a network.

b) Briefly describe the layers of OSI model.

c) Explain the components of a data communication system.

Data communication is the process of transferring data from one place to another or between two place locations. It allows electronic & digital data move btw two networks. It may be text, video, audio, image etc type data for communication.

Encode: process that converts data from sender into signals suitable for transmission over the communication medium. Convert digital data into analog signals into binary form.

Decode: It reverse the encoding process. The process that converts the received signals back into a form that the receiver can understand.

- Transmission mode: The method used to transmit data btw the sender & receiver. (Simplex, half duplex & full duplex)

Functions that a protocol perform -
Data sequencing, data routing, flow control, error control, order of transmission.

Advantages

fast & efficient transfer of information, global connectivity, resource sharing, cost savings, improve decision making, Scalability, Storage capacity (hard disk).

1) Match the following to one or more layers of the OSI model.

- A Communicates directly ^{interacts} with ^{end} user's application program
- B Error correction & retransmission
- C Mechanical, electrical & functional interface
- D Responsibility for carrying frames between adjacent nodes.

Ans:

- A Application layer (provides networking service to them)
- B Data link layer & transport layer
(connection detection frame level) (ensure reliable data transfer btw devices)
- C Physical layer ()
- D Data link layer (transferring frames btw adj network nodes, ensure they reach the next directly connected device).

2. a) Define Noise, we have a channel with 4 kHz bandwidth. If we want to send data at 1000 kbps, what is the minimum SNR is?

Noise in a data communication system refers to any unwanted signal that interferes with the transmission & reception of the intended data. Noise can distort or corrupt the signals being transmitted, leading to errors in the received data.

Common types of noise include thermal noise, electro magnetic interference & crosstalk.

Can originate from various sources (electrical equipment, environmental factors, other communication signals).

Can lead data corruption, requiring error correction or retransmission.

C = channel capacity in bps

B = bandwidth of the channel in Hz

SNR_{dB} = signal to noise ratio in decibels

Shannon-Hartley's Theorem

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

$$\Rightarrow SNR = 10^{SNR_{dB}/10}$$

Formula: $C = B \log_2(1 + SNR)$

$$\Rightarrow 100 \times 10^3 \geq 4 \times 10^3 \log_2(1 + SNR)$$

$$\Rightarrow \log_2(1 + SNR) = 25$$

$$\Rightarrow (1 + SNR) = 2^{25}$$

$$\Rightarrow SNR = 2^{25} - 1 = 33,554,931$$

Given,

$$C = 100 \text{ kbps}$$

$$= 100 \times 10^3 \text{ bps}$$

$$B = 4 \text{ kHz}$$

$$= 4 \times 10^3$$

So, $SNR_{dB} = 10 \log_{10} 33,554,931$

$$= 65.257 \text{ dB} \approx 75.26 \text{ dB}$$

minimum

$$SNR_{dB} = 10 \log_{10} \left(\frac{R}{B} \right) \quad (\text{Ans})$$
$$= 10 \log_{10} (5)$$

b) Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. Calculate the max bit rate.

Nyquist formula —

$$\begin{aligned} \text{Max Bit Rate} &= 2 \times B \times \log_2(L) \\ &= 2 \times 3000 \times \log_2(2) \\ &= 6000 \text{ bps (bits/sec)} \end{aligned}$$

B = bandwidth of the channel Hz
 L = num. of signal levels

c) What are the main causes of transmission impairment? Explain with proper diagram.

Transmission impairment in communication system refers to the degradation of the quality of the signal as it travels from the transmitter to the receiver.

Signals travel through transmission media which are not perfect. This means

that the signal at the beginning of the medium is not the same as the signal at the end of the medium. Three causes of impairment are

- attenuation
- distortion
- noise

Attenuation:

- Attenuation means a loss of energy

- When a signal, simple or complex, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire

- carrying electric signals gets warm

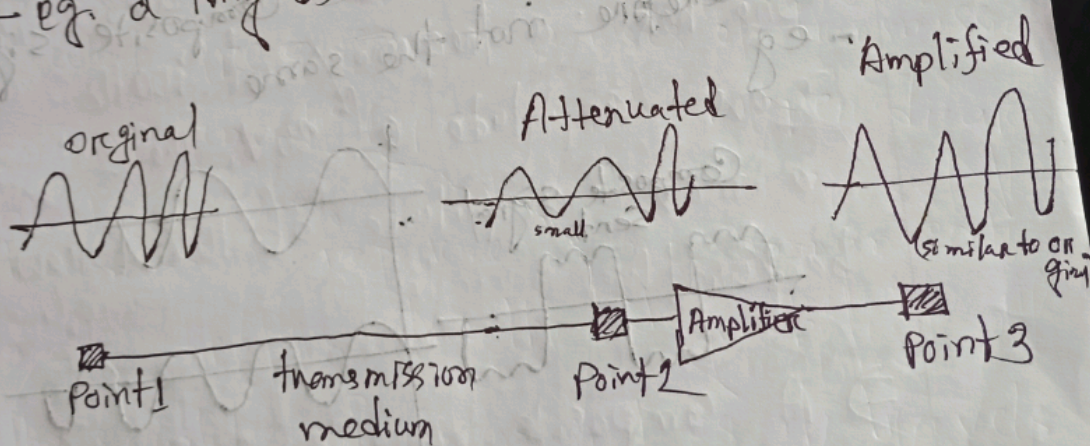
- To compensate for this loss, amplifiers are used to amplify the signal.

- To show that a signal has lost or gained strength, engineers use the unit of the decibel (dB)

- The decibel (dB) measures the relative strengths of two signals or one signal at two different points.

- The decibel is negative if a signal is attenuated and positive if a signal is amplified.

- eg. a long distance fiber optic cable



Distortion:

- Distortion means that the signal changes its form or shape

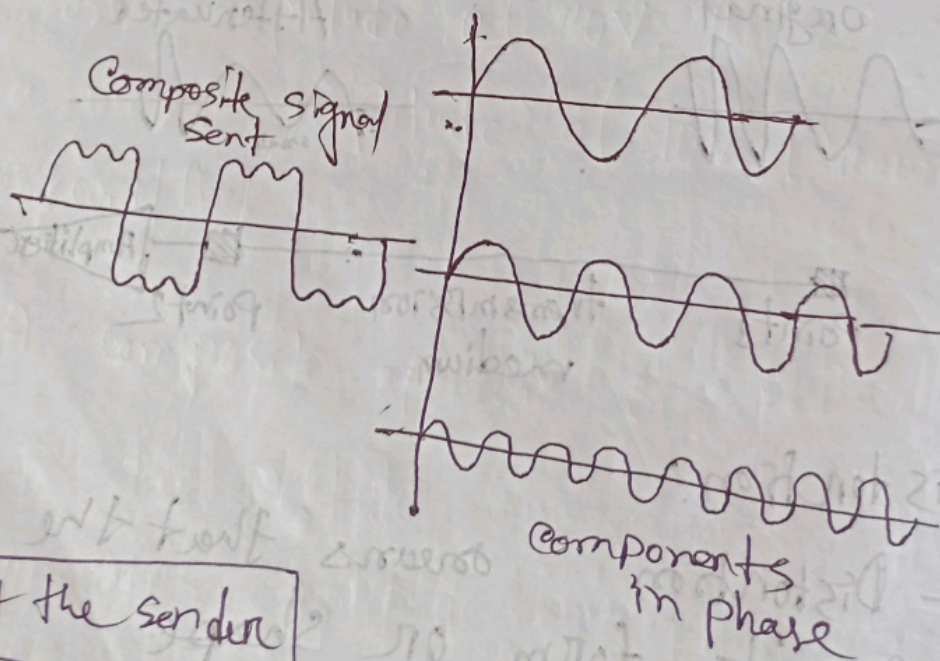
→ Distortion can occur in a composite signal made of different frequencies.

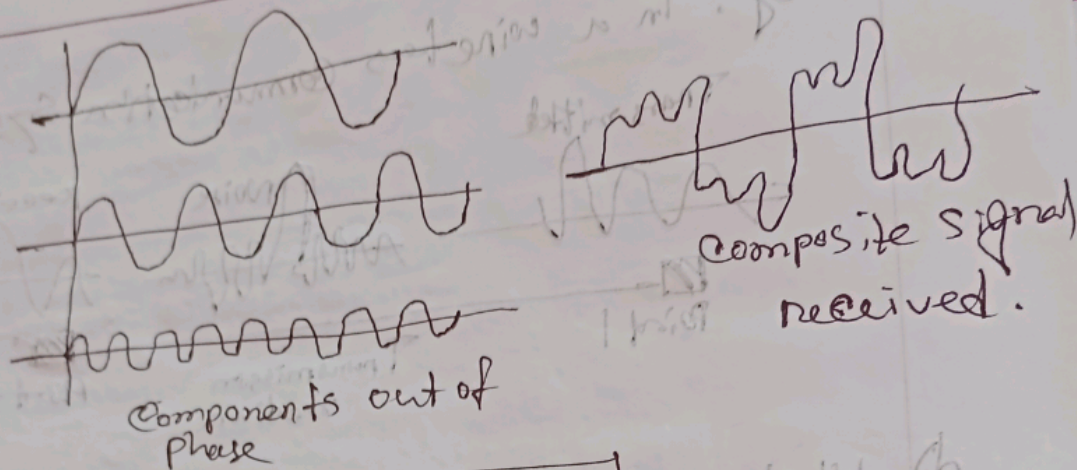
- Each signal component has its own propagation speed through a medium and, therefore, its own delay in arriving at the final destination. Differences in delay may create a difference in phase.

- Amplitude distortion, phase distortion & delay distortion

- The shape of the composite signal is therefore not the same

- eg

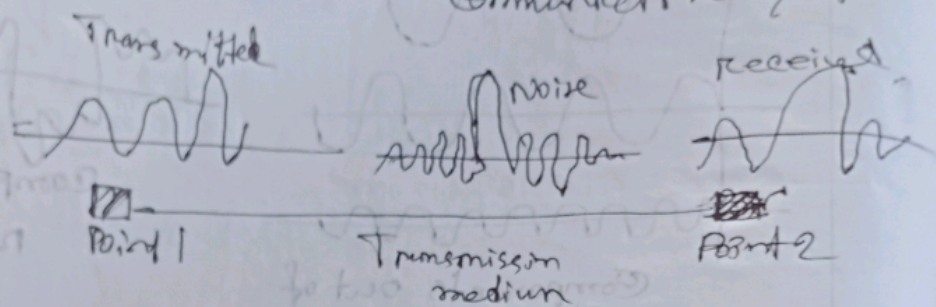




At the receiver

- Noise: Noise is another cause of impairment.
- Several types of noise, such as thermal noise, induced noise, cross-talk, and impulse noise, may corrupt the signal.
 - Noise refers to unwanted signals that get added to the original signal during transmission.
 - Can disturb the signal, making it difficult to distinguish b/w the original data.

and the noise.
-eg. In a wire less communication system



d) What is a composite periodic signal? A periodic composite signal with a bandwidth of 300 Hz is composed of two sine waves. The first one has a frequency of 100 Hz with a max amplitude of 30 V . The 2nd one has a max amplitude of 10 V . Draw the bandwidth.

⇒ A composite periodic signal is a signal composed of multiple sine waves with different frequencies, amplitude, and phases. These sine waves are added together to form the

Composite signal. The resulting signal is periodic if each of the individual sine waves is periodic and their frequencies are harmonically related (i.e. integer multiples of a fundamental frequency).

Given:

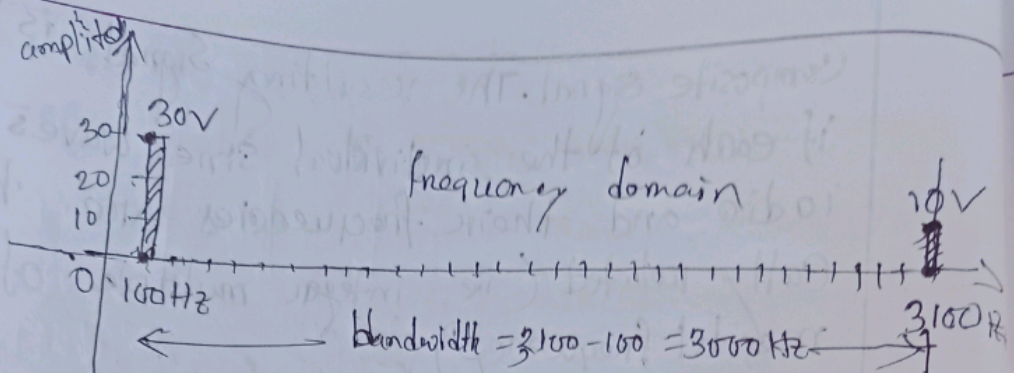
- Bandwidth of the composite signal 3000 Hz

- First sine wave:
frequency 100 Hz
Max amplitude 30 V

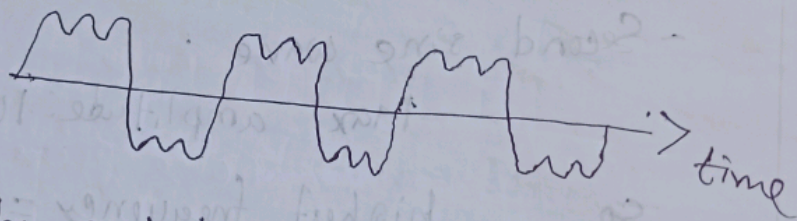
- Second sine wave:
Max amplitude: 10 V

So highest frequency $= 100 + 3000 = 3100\text{ Hz}$

(1st frequency $= 100\text{ Hz}$ & total bandwidth is 3000 Hz , and the bandwidth typically represents the difference btw the highest & lowest frequencies in the signal)



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



It can be periodic or non periodic.

(non periodic - decomposed into a combination of an infinite num of simple sine waves with continuous frequencies).

3. a) Draw the graph of the NRZ-L scheme using each of the following data streams, assuming that the last signal level has been positive. From the graphs, guess the bandwidth for this scheme using the average num. of changes in the signal level.

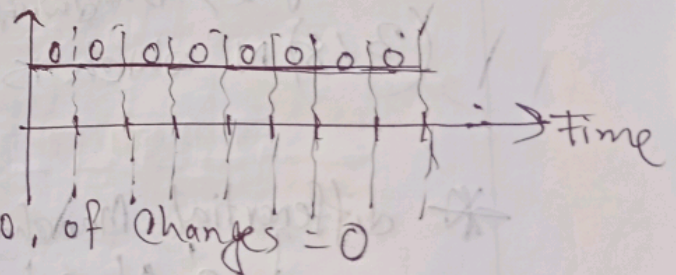
(a) 00000000

(b) 11111111

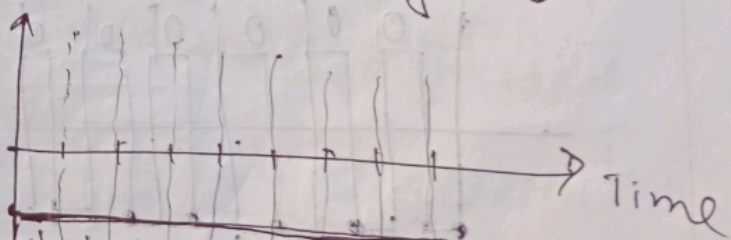
(c) 01010101

(d) 00110011

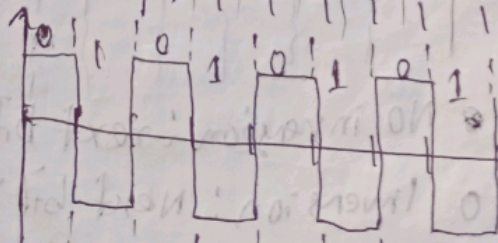
(a) 00000000
NRZ-L



(b) NRZ-L

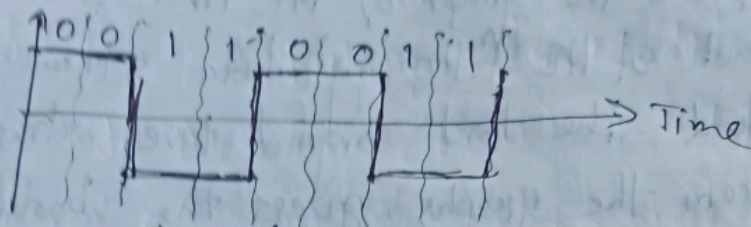


(c) NRZ-L



No. of changes = 8

① NRZ-L



No. of changes = 4

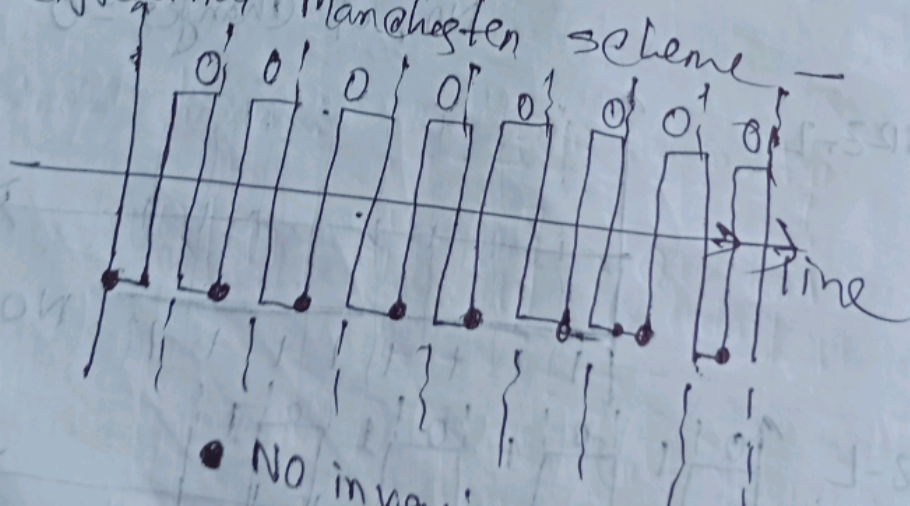
Now, Avg num of changes = $(0+0+8+4)/4$

The data Rate (N) defines the num of data elements, Here it has given 8 data strings

Thus, $N=8$.

Therefore, Bandwidth B is proportional to $(3/8)N$ which is range $B=0$ to N .

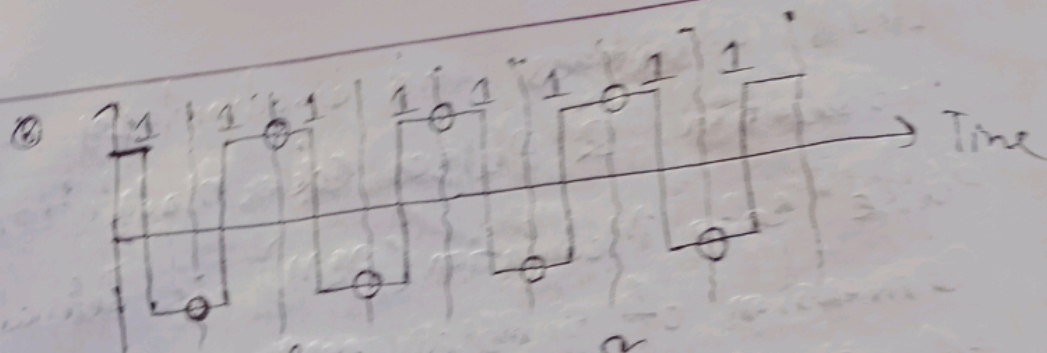
* Differential Manchester scheme -



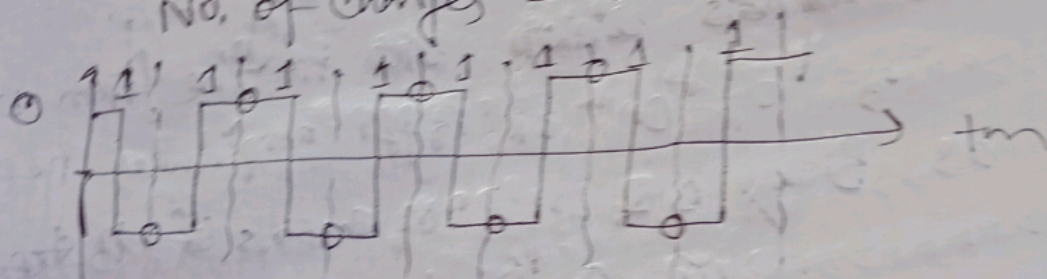
• No inversion: next bit is 0

• Inversion: Next bit is 1

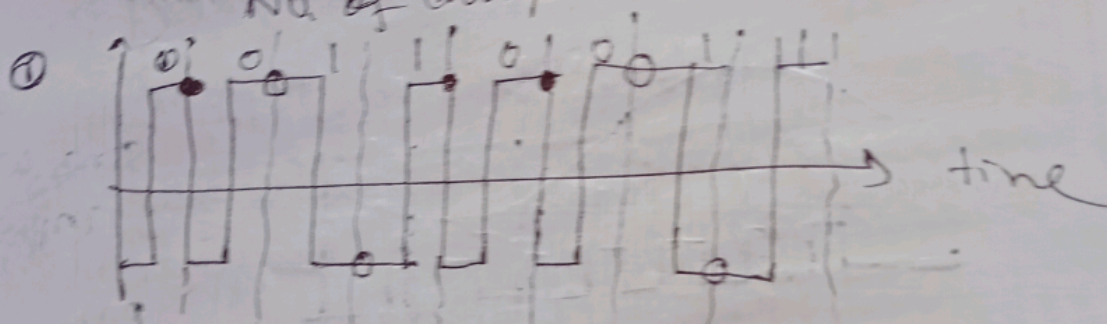
No. of changes = 8. 16.



No. of changes = 8



No. of change = 12



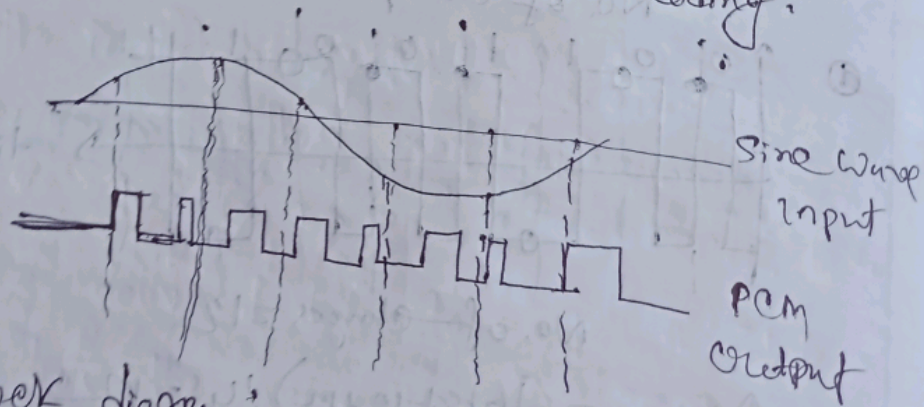
No. of changes = 12

$$\text{Avg} = (16 + 12 + 12) / 4 = 12$$

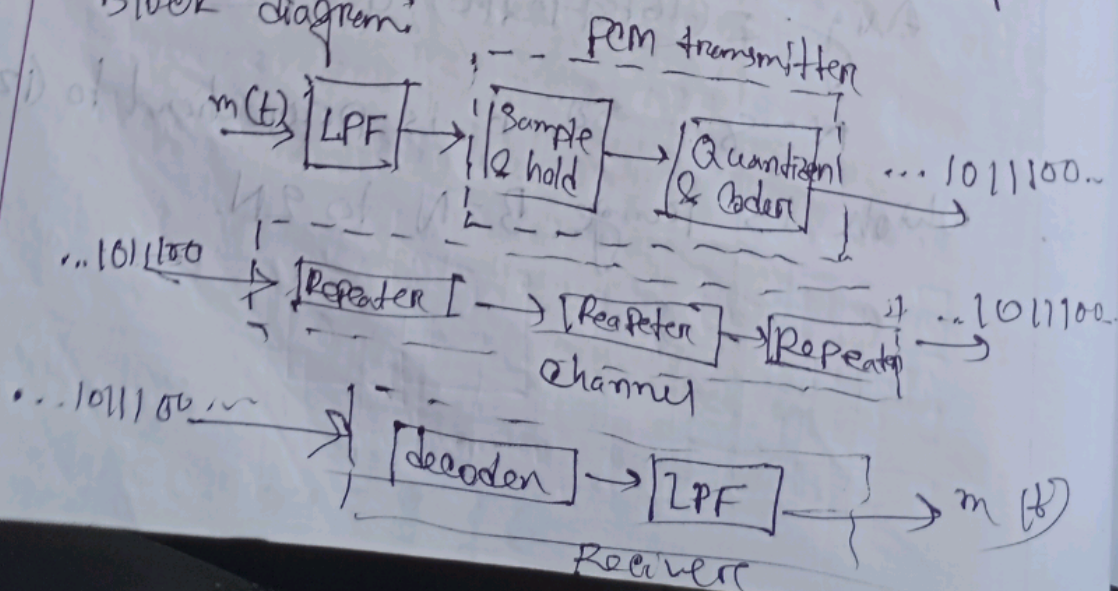
$N = 8$. So, B is proportional to $(12/8)$
 which is range $B = N$ to $2N$.

b) Listed advantages and disadvantages of delta modulation & Pulse code modulation.

Pulse code Modulation (PCM) is defined as the conversion of sampled analog signals into digital signals, which are in the form of a series of 'on' or 'off' amplitudes represented as Binary 0 & 1. PCM consists of 3 steps which are sampling, quantization & coding.



Block diagram



Pulse Code Modulation

1. The samples can use 4, 8 or 16 bits per sampled data.

2. Pulse Code Modulation requiring the highest transmitter bandwidth.

3. Pulse Code Modulation is Complex

4. It has a good signal to noise ratio

5. The signal requires an encoder & decoder on both sides.

6. It is mostly used in video & audio telephony.

Advantages (PCM)

- i. It has a good noise to signal ratio
- ii. It has an efficient method
- iii. The efficiency of the transmitter is high.
- iv. It is used in transmitting telephone, TV, and audio signals (broadcast station, television sets), Satellite Communication.

Delta Modulation

only one bit is used per sample

requiring the lowest transmitter bandwidth.

It is simple.

It has a poor signal to noise ratio.

Signal can modulate & demodulate.

It is mostly used for speeches & images.

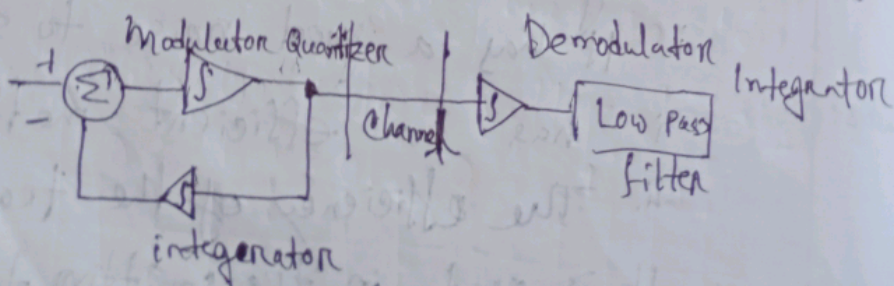
disadvantages:

i. the bandwidth required is high and it is costly.

ii. It is complex process as it requires a lot of steps like sampling, quantizing, encoding & decoding.

iii. Higher bit rate & more power consumption

Delta modulation: Delta modulation (DM) is a signal conversion method used for speech communication when quality is not a concern. It reduces the delivered data to a 1-bit data stream. It has the transmitter circuit of a delta modulation system is made up of a Modulator, channel & demodulator.



Advantages:

- i. It is a high performance approach.
- ii. This technique is utilized when extreme circuit simplicity is critical & the usage of a high bit rate permissible.
- iii. This technology gets rid of the need for correcting circuits in radio design and error identification.
- iv. The dynamic range is large because the different step size covers such a variation.
- v. Delta modulation is effective with narrower channel bandwidths.
- vi. There is no indication of granular or slope overload.
- vii. Slope error is reduced to a lesser degree.
- viii. Simple, lower bit rate, efficient for slowly varying signals.



Disadvantages:

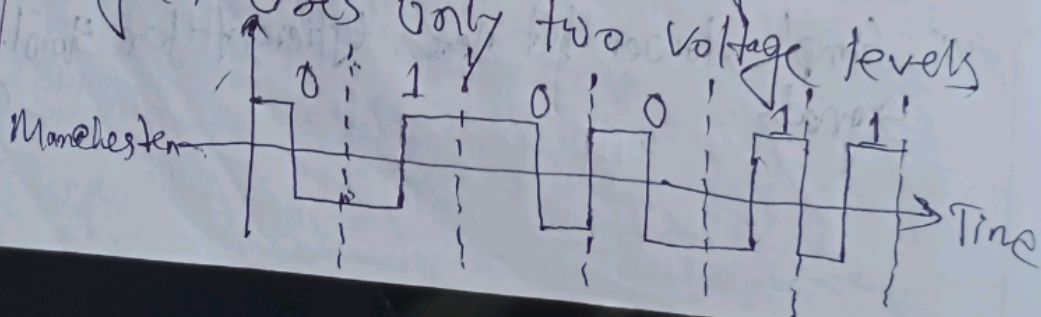
- i. Slope overload Distortion
- ii. Granular Noise
- iii. lower Signal-to-Noise Ratio (SNR)
- iv. Signal vary at a faster rate

c) Write down basic properties of the following line coding schemes with proper signal scheme?

- i. Manchester
- ii. MLT-3
- iii. 2B1Q

⇒ Manchester: coding consists of combining the NRZ-L (Non-Return-to-zero Level) and RZ (Return Zero) schemes.

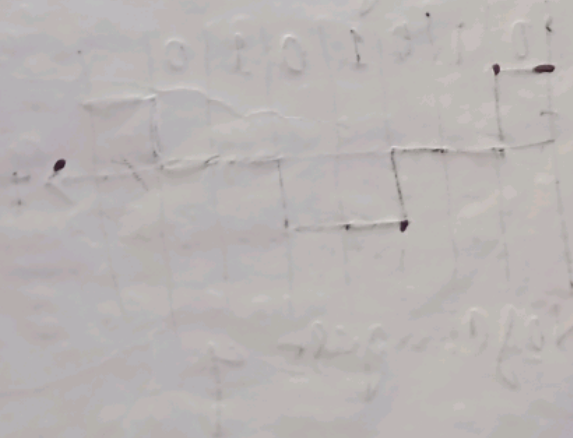
Every symbol has a level transition in the middle; from high to low to high. Uses only two voltage levels.



0 is $\downarrow$ 1 is $\uparrow$

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

- In Manchester encoding, the transition at the middle of the bit is used for synchronization.
- The minimum bandwidth of Manchester is 2 times that of NRZ.
- No DC component & no baseline wandering
- None of these codes has error detection



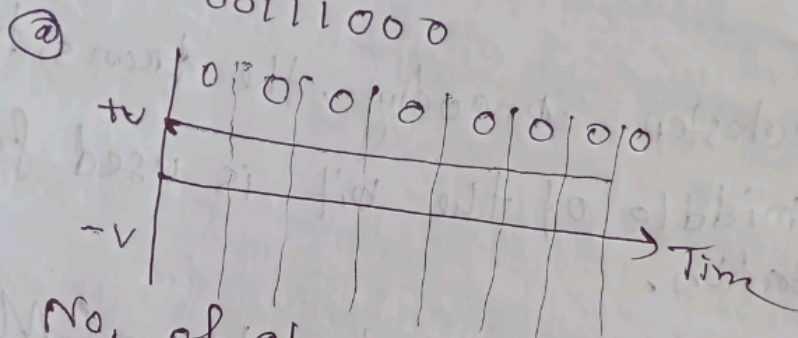
* Extra: MLT-3 scheme -

① 0000 0000

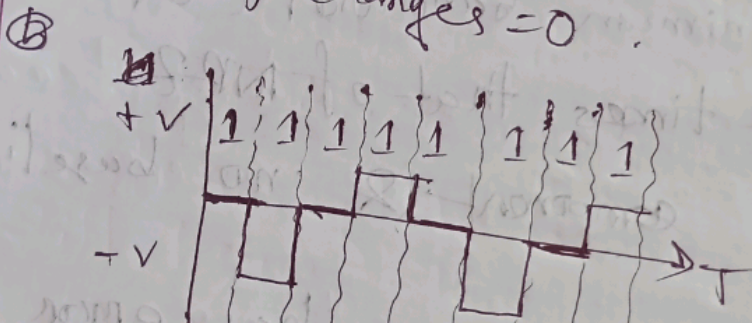
② 1111 111

③ 01010101

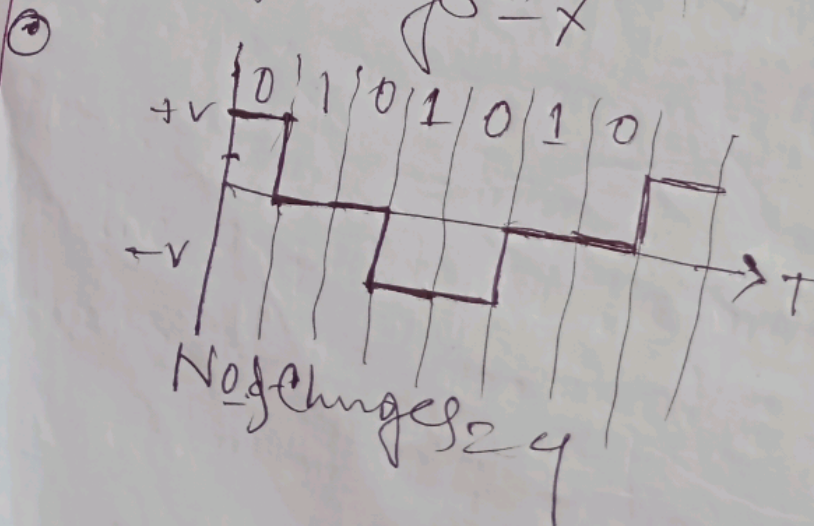
④ 000111000



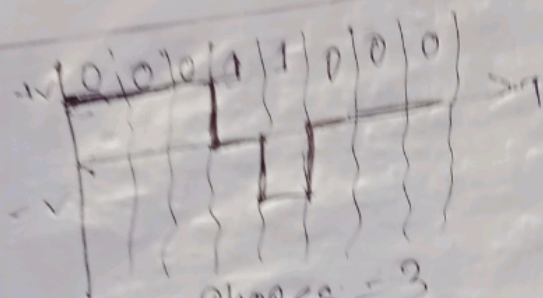
No. of changes = 0



No. of changes = 0



No. of changes = 4



changes = 3

$$\text{Avg No. of chgs} = (0 + 1 + 4 + 3) / 4 = 3.5$$

$N=8$. Bandwidth B is proportional to $(3.5/8)N$
 which is Range $B=0$ to $N/2$

Q. a) which of the four digital-to-analog conversion techniques (ASK, FSK, PSK or QAM) is the most susceptible to noise? Define your answer.

Digital to analog conversion techniques are used to convert digital signals into analog signals. There are four common techniques used for this purpose: ASK, FSK, PSK & QAM. Among these techniques, the most susceptible to noise is ASK (Amplitude Shift Keying). This is because ASK uses amplitude variations to represent digital data. Any noise or interference in the transmission medium can cause changes in the amplitude of the signal, leading to errors in the received data. In contrast, FSK (Frequency Shift Keying), PSK (Phase Shift Keying) & QAM (Quadrature Amplitude Modulation) use frequency or phase variations to

b)

represent digital data. These techniques are less susceptible to noise because changes in frequency or phase are less affected by noise or interference.

- * Signal Amplitude Dependency
- * Lack of Robustness
- * Sensitivity to channel conditions
- * Lower Signal to Noise Ratio (SNR)

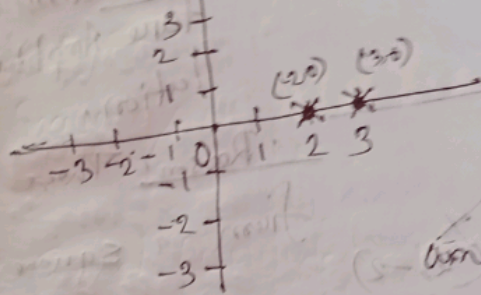
3 parameters:— ASK is changing amplitude value of the carrier signal, therefore ASK conversion is potentially more infected by noise than other conversions & has higher bit error rate (BER).

- b) Draw the constellation diagram for the following cases. Find the peak amplitude value for each case and define the type of modulation (ASK, FSK, PSK or QAM). The number a in parentheses define the values of I and Q respectively.

- a) Two points at $(2, 0)$ and $(3, 0)$
- b) Two points at $(3, 0)$ & $(-3, 0)$
- c) Four points at $(3, 2)$, $(-2, 2)$, $(-2, -2)$ & $(2, -2)$
- d) Two points at $(0, 2)$ & $(0, -2)$

(2, -2)

a) Constellation Diagram: Type of Modulation: ASK (Amplitude Shift Keying)



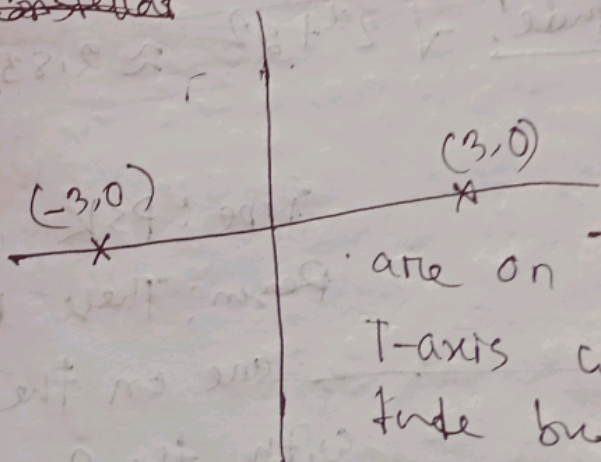
Reason: Since both lie on the I-axis (in phase component) with different amplitudes and no Q-component

(quadrature component), this represents ASK, where data is encoded by varying the amplitude of the signal.

Peak amplitude: is the largest distance from the origin which is 3.

Constellation

b)



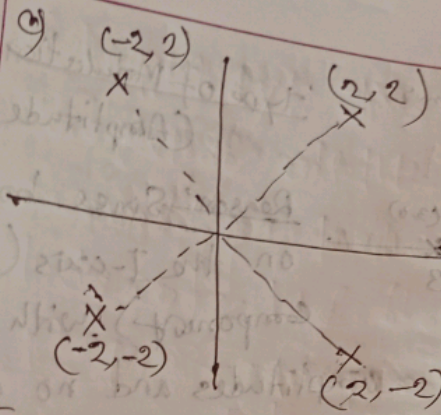
Type of Modulation:

PSK (Phase Shift Keying)

Reason: These points are on opposite sides of the I-axis with the same amplitude but opposite signs,

indicating a phase of 180° . This chart of Binary Phase Shift Keying (BPSK).

Peak amplitude: 3.

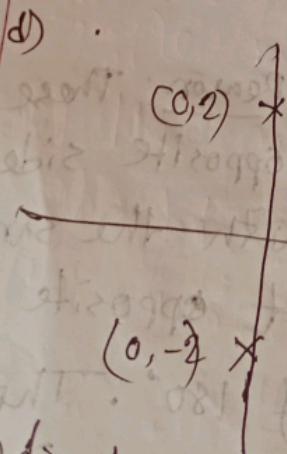


Type: QAM (Quadrature Amplitude Modulation).

Reason: These points form a square in the

I-Q plane, indicating both amplitude & phase are varied. This is characteristic of QAM, where each point represents a different combination of phase & amplitude.

Peak amplitude: $\sqrt{2^2 + 2^2} \approx 2.83$



Type: PSK

Reason: These points

are on the Q-axis with the same amplitude but opposite signs indicating a 180° phase shift. This is an

then, example of (BPSK), where the phase shift is 180° .

Peak amplitude: 2

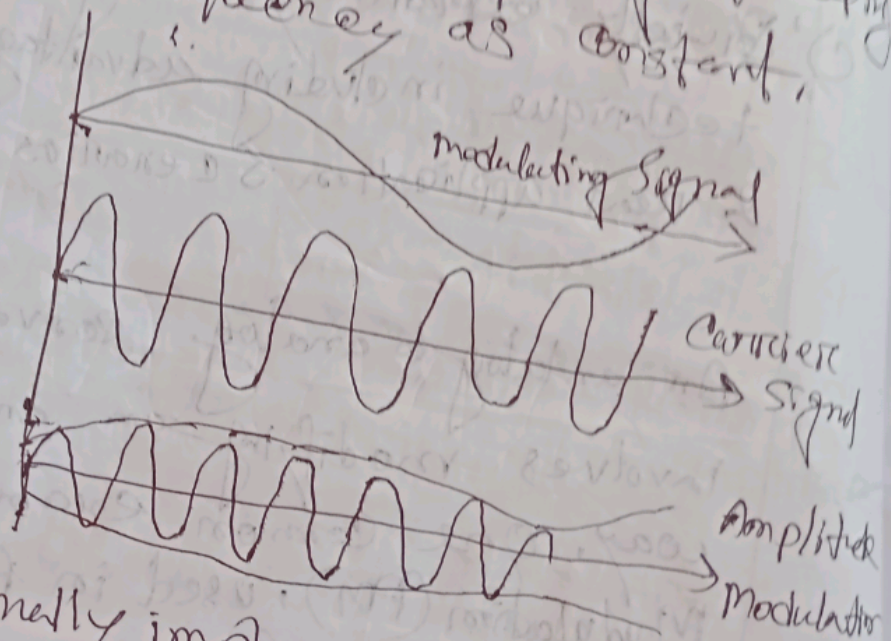
c) Briefly explain any analog to analog conversion technique including advantages, disadvantages & real application scenarios.

An analog to analog conversion technique involves modifying an analog signal in some way. One common example is Frequency Modulation (FM), used in FM radio broadcasting.

A to A, is the representation of Analog to analog information by an analog signal.

Analog to Analog Conversion can be done in three ways: i. Amplitude ii. Frequency & iii. Phase Modulation.

1. Amplitude: The modulation in which the amplitude of the carrier wave is according to the instantaneous amplitude of the modulating signal keeping phase & frequency as constant.



AM is normally implemented by using a simple multiplier because the amplitude of the carrier signal needs to be changed according to the amplitude of the modulating signal.

$\text{Bandwidth} = 2f_m$

Note:

i. @ media only screen and (min-width:) and (max-width:)
— Color and size change after zoom.

ii. inspect — ☒ — show padding

Advantages: — Simple to implement

— Efficient use to bandwidth

— Resistant to amplitude variations in the received signal

Disadvantages:

— Susceptible to noise interference

— Inefficient use of power

— Limited in terms of the number of channels that can be transmitted simultaneously.

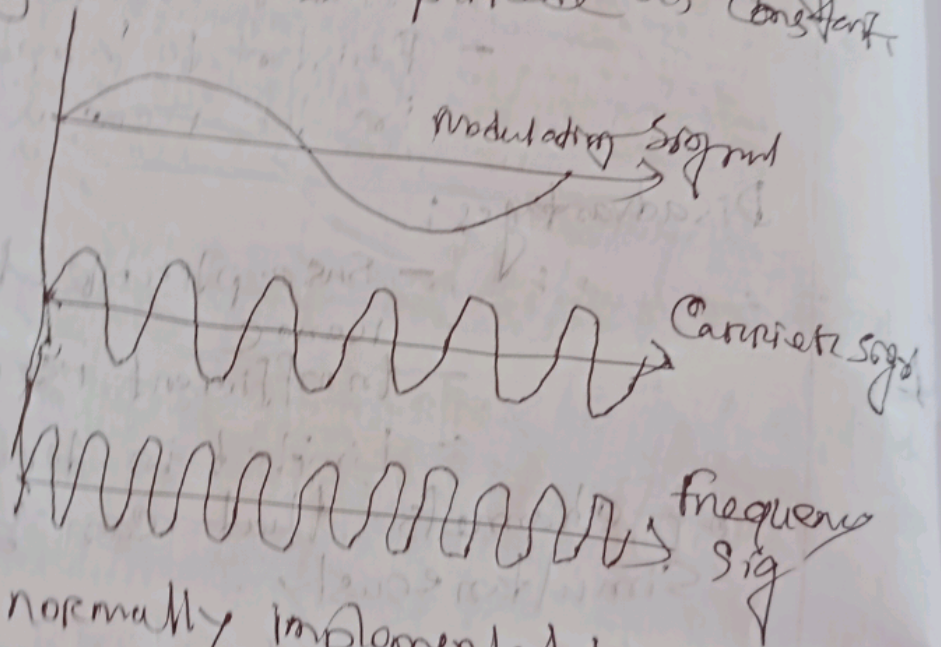
Real Application Scenarios:

— AM radio broadcasting

— Two-way radio communication

— Audio signal transmission in analog television

ii. Frequency: The modulation which the frequency of the carrier wave is varied according to, the instantaneous frequency of the modulating signal keeping phase & amplitude as constant.



FM is normally implemented by using a voltage controlled oscillator as with FSK.

Advantages:

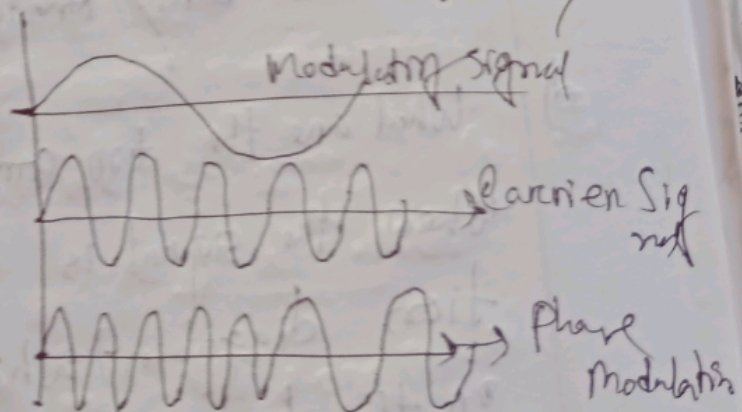
- i. Resilience to Noise / high noise immunity
- ii. Better Sound quality
- iii. Efficient use of power

discrete require more bandwidth
ii. Complexity in receivers

Application Scenarios:

- i. FM Radio Broadcasting
- ii. Two-way Radio Communication
- iii. Television Sound Transmission

iii. Phase: The modulation in which the phase of the carrier wave is varied according to the instantaneous p/n of the modulation signal keeping amplitude and frequency as constant.



Similar to frequency modulation but in phase modulation frequency of the carrier signal is not increased. implemented by using

a voltage controlled oscillator along with a derivative.

Adv:

- i. ~~can~~ High data transmission Rate
- ii. Resilience to Noise
- iii. Efficient ~~in~~ bandwidth

dis.

- i. Complexity in implementation
- ii. Difficult to Demodulate

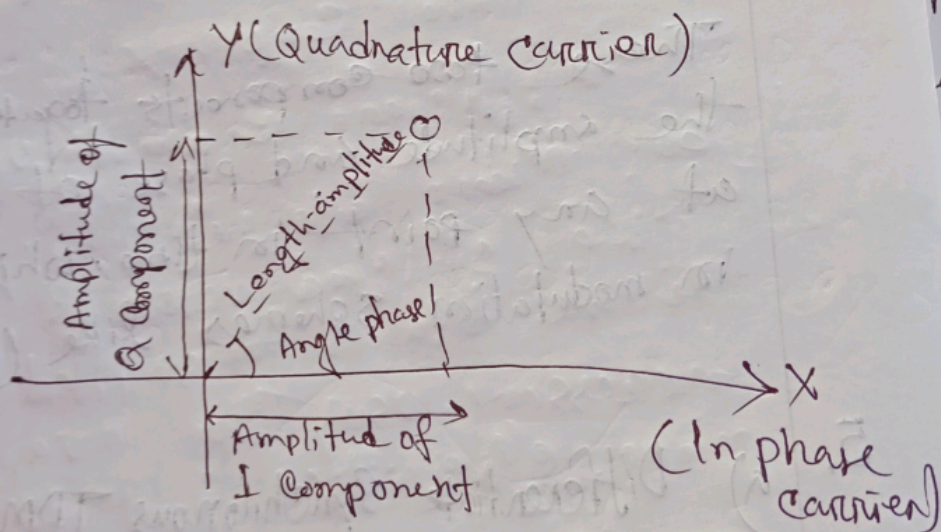
App

- i. Digital Communication system (Wireless)
- ii. Satellite Communication
- iii. Early Analog Telephone / Optical Comm.

Q) What are the two components of a signal when the signal is represented on a constellation diagram? Which component is shown on the horizontal axis? Which is shown on the vertical axis?

The two components of a signal are called I & Q. The I component, called inphase, is shown on the horizontal axis; the Q component, called quadrature, is shown on the vertical axis.

In phase:



Constellation diagram

In Phase Component (I): This component corresponds to the horizontal axis of the constellation diagram. It represents the part of the signal that is in phase with the

Reference signal.

ii. Quadrature Component (Q); This component corresponds to the vertical axis of the constellation diagram. It represents the part of the signal that is 90° out of phase (in quadrature) with the reference signal.

These two components together describe the amplitude and phase of the signal at any point in time, which is crucial in modulation schemes like QAM & PSK.

5. a) Differentiate Synchronous TDM & Statistical TDM.

Synchronous TDM (Time Division Multiplexing): each channel is allocated a fixed time slot in a repeating cycle, regardless of whether there is data to

transmit or not.

Characteristics -

- * Fixed time slots
- * Wasted Bandwidth
- * Simple implementation

Example: Traditional telephone networks, where each call is given a fixed time slot on a TDM line.

- In Synchronous TDM, the input lines mark speed is never more than the direction's value.
- There are n minimum time periods in the frame, in n input lines.

Adv: * Reduced transmission noise

- * Only input device with data to send are used for transmission

Dis: * ~~Dead~~

- * It's possible that a link's entire capacity won't be used.
- * The implementation is complex.

Statistical TDM In Statistical TDM, time slots are dynamically allocated based on demand. Only channels with data to transmit are given time slots.

Characteristics:

- * Dynamic time slots
- * Higher Complexity
- * Efficient Bandwidth Usage.

eg: Modern data networks, such as packet switched networks (Ethernet) where data is transmitted only when necessary, using the available bandwidth more efficiently.

Syn TDM

i.

Stat TDM

i.

6. a) What is the Hamming distance for each of the following code words.

a) $d(10000, 00000)$

b) $d(10101, 10000)$

c) $d(11111, 11111)$

d) $d(000, 000)$

⇒ The Hamming distance between two code words is the number of positions at which the corresponding bits are different.

a) $d(10000, 00000)$

Compare each bit:

1 vs 0 → diff (1 difference)

0 vs 0 → Same

0 vs 0 → "

0 vs 0 → "

0 vs 0 → "

Hamming distance = 1

b) 1 vs 1 → Same

0 vs 0 → Same

1 vs 0 → diff (1)

0 vs 0 → Same

1 vs 0 → diff (1)

Hamming distance = 2

③ 1 vs 1 → same

1 vs 1 → same

1 vs 1 → same

1 vs 1 → "

1 vs 1 → "

④ 0 vs 0 → same

0 vs 0 → same

0 vs 0 → "

Hamming distance = 0

Hamming distance = 0

The num of bit position at which the two code differs.

~~How~~ Minimum Hamming Distance: It is the smallest Hamming Distance between the all possible codes in the given encoding scheme

b) Apply the following operations on the corresponding polynomials.

a) $(x^3 + x^2 + x + 1) + (x^4 + x^2 + x + 1)$

b) $x^3 + x^2 + x + 1 - (x^4 + x^2 + x + 1)$

c) $(x^3 + x^2) \times (x^4 + x^2 + x + 1)$

d) $(x^3 + x^2 + x + 1) / (x^2 + 1)$