SRM INSTITUTE OF SCIENCE & TECHNOLOGY (Deemed to be University u/s 3 of UGC Act, 1956)

SRM Institute of Science and Technology
College of Engineering and Technology
DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamilnadu

Academic Year: 2024-2025 (Even)

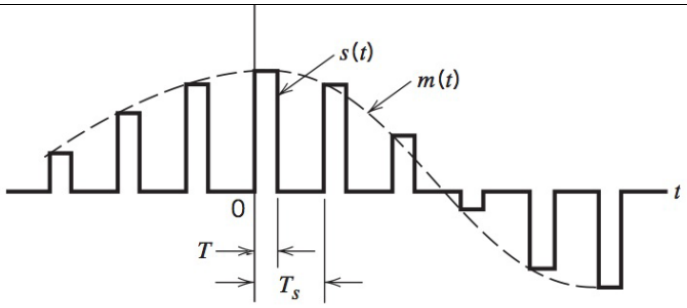
Batch 2 Set D

Test: FT- III **Date: 03.04.2025**
Course Code / Title:21ECC302T/ Analog and Digital Communication **Duration:12.30 – 2.15PM**
Year & Sem:III&VI **Max. Marks:50**
Course Articulation Matrix:

	21ECC302T/ Analog and Digital Communication	PROGRAM OUTCOMES (PO)												PROGRAM SPECIFIC OUTCOMES		
S.NO	COURSE OUTCOMES	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	Explain the Various Analog Modulation Techniques	3	-	-	-	-	-	-	-	-	-	-	2	2	-	-
2	Analyze the Noise performance of Radio transmitters and Receivers	3	3	-	-	-	-	-	-	-	-	-	2	-	3	-
3	Demonstrate the demodulation and detection of received digital data	3	2	-	-	-	-	-	-	-	-	-	-	-	-	3
4	Apply the suitable passband techniques for real time applications	3	-	-	-	3	-	-	-	-	-	-	-	-	-	2
5	Exposed to the concepts of information theory and channel capacity	3	-	3	-	-	-	-	-	-	-	-	-	3	-	-

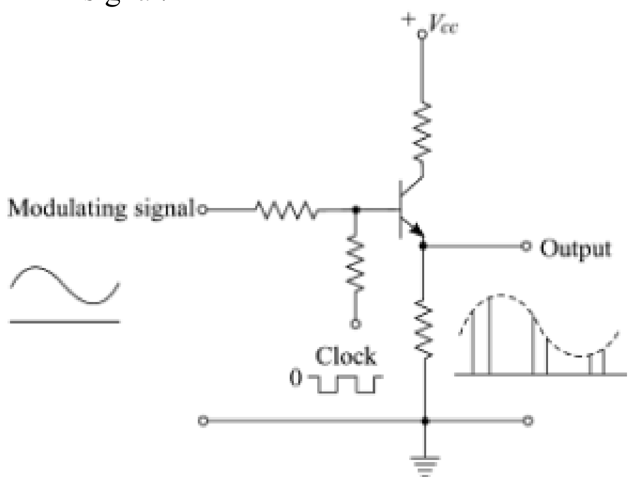
Q. No	Part A (11x1=11 Marks) Answer ALL the question	Marks	BL	CO
1	If a PCM system uses 8 bits per sample and has a sampling rate of 8 kHz, what is the bit rate? **a) 64 kbps** b) 32 kbps c) 16 kbps d) 128 kbps	1	2	3
2	A PCM system has a maximum input voltage of 5V and a minimum voltage of -5V. It uses 8-bit quantization. What is the step size of the quantizer? a) 0.02 V **b) 0.04 V** c) 0.08 V d) 0.1 V	1	2	3
3	The main purpose of a matched filter in a communication system is to: a) Reduce noise in the channel. **b) Maximize the signal-to-noise ratio (SNR).** c) Minimize the bit error rate. d) Amplify weak signals.	1	1	3
4	Inter Symbol Interference (ISI) occurs due to: a) Channel noise **b) Overlapping of successive symbols** c) Insufficient quantization levels d) Low sampling rates	1	1	3
5	A major drawback of Delta Modulation (DM) is: a) Quantization noise **b) Slope overload distortion** c) High complexity d) Low bandwidth efficiency	1	1	3
6	If a BPSK signal has a carrier frequency of 100 MHz and a data rate of 5 Mbps, what is the spectral bandwidth of the BPSK signal? a) 2.5 MHz **b) 5 MHz** c) 10 MHz d) 20 MHz	1	2	4
7	The probability of error in Quadrature Phase Shift Keying (QPSK) is given by: **a)** $P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$ b) $P_e = \frac{1}{2} erfc\left(\sqrt{\frac{2E_b}{N_0}}\right)$	1	2	4

	c) $P_e = erfc(\sqrt{\frac{2E_b}{N_0}})$ d) $P_e = \frac{1}{2} erfc(\sqrt{\frac{E_b}{2N_0}})$			
8	Which of the following has the highest bandwidth efficiency? a) BPSK b) QPSK c) 8-PSK **d) 16-PSK**	**1**	**1**	**4**
9	_________is a passband modulation technique a) Pulse Amplitude Modulation (PAM) **b) Frequency Shift Keying (FSK)** c) Pulse Code Modulation (PCM) d) Delta Modulation (DM)	**1**	**1**	**4**
10	A 16-QAM system has how many distinct symbols? a) 4 b) 8 **c) 16** d) 32	**1**	**2**	**4**
11	Which modulation scheme has the lowest bit error rate (BER) for a given signal-to-noise ratio (SNR)? **a) BPSK** b) QPSK c) 16-PSK d) BFSK	**1**	**1**	**4**
	Part B (3x8=24 Marks) Answer ALL the question			
12. a.	Explain Pulse Amplitude Modulation (PAM) and describe how a PAM signal is generated and demodulated, including the necessary waveforms. **Answer:** **(Explanation of PAM with diagram 2 Marks)** • In *pulse-amplitude modulation* (PAM), *the amplitudes of regularly spaced pulses are varied in proportion to the corresponding sample values of a continuous message signal*; the pulses can be of a rectangular form or some other appropriate shape. • Pulse-amplitude modulation as defined here is somewhat similar to natural sampling, where the message signal is multiplied by a periodic train of rectangular pulses. However, in natural sampling the top of each modulated rectangular pulse varies with the message signal, whereas in PAM it is maintained flat • The waveform of a PAM signal is illustrated in Figure 3.1. The dashed curve in this figure depicts the waveform of a message signal *m(t),* and the sequence of amplitude modulated rectangular pulses shown as solid lines represents the corresponding PAM signal *s(t)* • For transmission of digital data is discrete pulse amplitude modulation(PAM). In discrete PAM, the amplitude of the pulse varies in discrete manner according to the input binary data. • The discrete PAM can have only two amplitude levels corresponding to binary '1' and '0'. Successive binary bits can be combined into symbols. There can be multiple amplitude levels corresponding to these symbols. They generate discrete PAM signals. • These signals can be transmitted (without any modulation) over the channel in baseband transmission. • In PAM, amplitude of pulses is varied in accordance with instantaneous value of modulating signal.	**8**	**3**	**3**

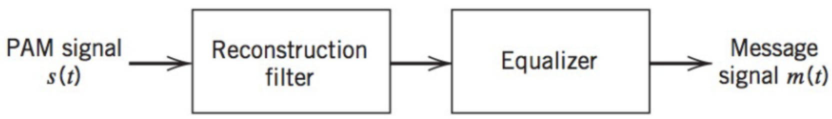


PAM Generation (Explanation- 1 Mark ; diagram 2 Marks)

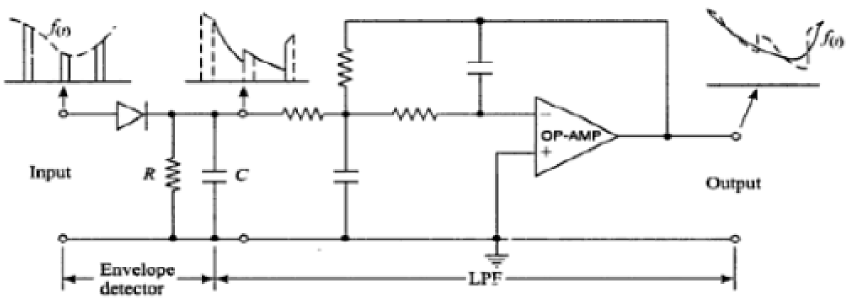
- The circuit is simple emitter follower., In the absence of the clock signal, the output follows input.The modulating signal is applied as the input signal. Another input to the base of the transistor is the clock signal. The frequency of the clock signal is made equal to the desired carrier pulse train frequency.
- The amplitude of the clock signal is chosen the high level is at ground level(0v) and low level at some negative voltage sufficient to bring the transistor in cutoff region.
- When clock is high, circuit operates as emitter follower and the output follows in the input modulating signal. When clock signal is low, transistor is cutoff and output is zero. Thus the output is the desired PAM signal.



PAM Demodulation (Explanation- 1 Mark ; diagram 2 Marks)



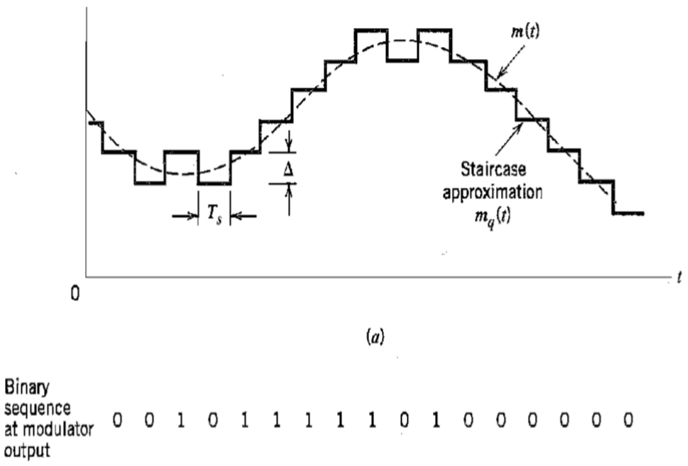
Reconstruction of pulse signal



PAM demodulator

- A PAM (Pulse Amplitude Modulation) demodulator recovers the original message signal from a modulated waveform.

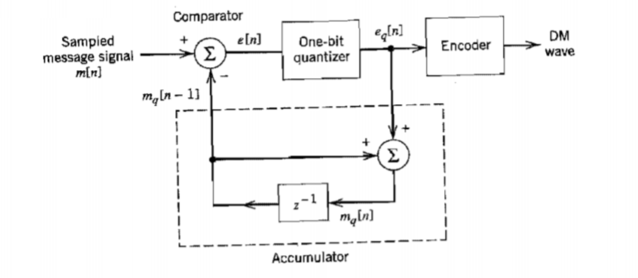
	• It consists of an envelope detector and a second-order op-amp low pass filter. • The envelope detector, made using a diode, capacitor, and resistor, tracks the amplitude variations of the PAM pulses and converts the amplitude information into a continuous signal. • The second-order low pass filter, designed using an operational amplifier, provides sharper roll-off and better high-frequency noise attenuation. • It effectively removes the sampling frequency and residual carrier components. • Compared to a first-order filter, the second-order filter is more effective in noise reduction. • This ensures accurate retrieval of the original message signal. • PAM demodulators are widely used in analog communication systems, data transmission, and audio signal processing. • Combining an envelope detector and a second-order filter enhances demodulation performance, making it reliable for various practical applications. **(OR)** With neat diagram, explain the working of Delta modulation. **Answer:** **Delta modulation Concept (2 Marks)** The delta modulation is a special case of DPCM. DM is 1-bit version of DPCM. In DM, an incoming message signal is oversampled to increase the correlation between adjacent samples of the signal. It provides the staircase approximation to the oversampled version of the message signal. The difference between the input and the approximation is quantized into only two levels $\pm\Delta$, corresponding to positive and negative differences. If the approximation falls below the signal at any sampling epoch, it is increased by Δ If the approximation lies above the signal ,it is decreased by Δ If there is no rapid change from sample to sample, then the stair-case approximation remains within $\pm\Delta$ of the input signal. The staircase approximation mq(t) follows variations in the input signal m(t).			
12. b.		**8**	**2**	**3**



(Diagram 1 Mark)

(Transmitter Diagram 1 Mark: Expression with Explanation 2 Marks)

Transmitter



- Let m(t) – input message signal ,$m_q(t)$ – its staircase approximation
  m[n] –sequence of samples
  m[n] T_s - sample of m[t] taken at time t=n T_s , where T_s is sampling period.
  we have,

$$m[n] = m(nT_s), \qquad n = 0, \pm 1, \pm 2, \ldots$$
$$e[n] = m[n] - m_q[n-1]$$
$$e_q = \Delta \operatorname{sgn}(e[n])$$
$$m_q[n] = m_q[n-1] + e_q[n]$$

where

e[n] – error signal representing the difference between the present sample m[n] of input signal and the latest approximation m_q[n-1]

$e_q[n]$ – quantized version of e(n)

sgn(.) –signum function

The quantizer output $m_q[n]$ is coded to produce the DM signal.

The rate of information transmission is equal to the sampling rate f_s =1/ T_s.

The delta modulated wave is generated by applying the sampled version of the incoming message signal to a modulator that involves a comparator , quantizer and accumulator.

z^{-1} is unit delay.

The comparator computes the difference between its two inputs . The quantizer consists of hard limiter with an input-output relation that is scaled version of the signum function . Then the quantizer output is applied to the accumulator, producing the result,

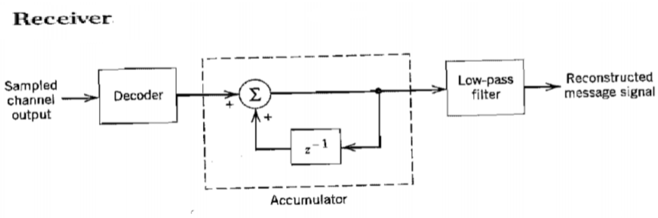
$$m_q[n] = \Delta \sum_{i=1}^{n} \operatorname{sgn}(e[i])$$
$$= \sum_{i=1}^{n} e_q[i]$$

Thus, at the sampling instant n T_s, the accumulator increments the approximation by a step Δ in a positive or negative direction, depending on the sign of the error signal e[n].

If the input sample m[n] is greater than the most recent approximation m_q[n] , a positive increment + Δ applied to the approximation.

If the input sample is smaller, a negative increment - Δ applied to the approximation.

(Receiver Diagram 1 Mar;kExplanation 1 Mark)

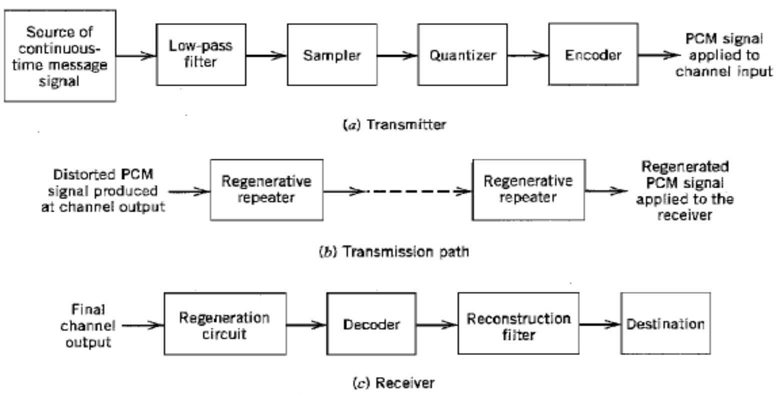


In the receiver, the staircase approximation m_q(t) is reconstructed by passing the sequence of positive and negative pulses, produced at the decoder output, through the accumulator. The quantization noise in staircase waveform m_q(t) is rejected by passing it through a LPF.

13. a. | **4** | **2** | **3**

i. Explain the operations of Pulse Code Modulation (PCM) with the help of a block diagram.

Answer:
(Block Diagram 2 Marks; Explanation 2 Marks)



Block diagram of Pulse Code Modulation (PCM)

- **Sampling:**
  - The message signal is sampled using narrow pulses to approximate instantaneous values.
  - Sampling rate must exceed twice the highest frequency component for accurate reconstruction.
- **Quantization:**
  - Converts sampled values to discrete levels using non-uniform quantization (e.g., μ-law, A-law).
- **Encoding:**
  - Maps quantized values to codewords using a specific coding scheme.
- **Regeneration:**
  - Regenerative repeaters correct distortions and noise through equalization, timing adjustment, and decision-making.
  - They restore the original signal apart from minor errors due to noise and jitter.

- **Decoding:**
  - Converts codewords back to quantized values, forming a Pulse Amplitude Modulated (PAM) signal.
- **Filtering:**
  - A low-pass filter with a cutoff at the message bandwidth reconstructs the original signal.

	ii. A Television signal with a bandwidth of 4.2 MHz is transmitted using binary PCM. The number of quantization levels is 512. Calculate, (a) Code word length **(1 Mark)**, (b)Final bit rate **(2 Marks)** and Transmission bandwidth **(1 Mark)**	**4**	**3**	**3**

Answer:

$$W = 4.2 \text{ MHz}$$

Quantization levels $q = 512$

i) Number of bits and quantization levels are related in binary PCM as,

$$q = 2^v$$

.e. $$512 = 2^v$$

$$\log 512 = v \log 2$$

$$v = \frac{\log 512}{\log 2} = 9 \text{ bits}$$

code word length is 9 bits. **(1 Mark)**

The final bit rate will equal to signaling rate. The signaling rate is given as,

$$r = v f_s$$

Sampling frequency $f_s \geq 2W$ by sampling theorem.

$\therefore$ $$f_s \geq 2 \times 4.2 \text{ MHz} \quad \text{since} \quad W = 4.2 \text{ MHz}$$

$\therefore$ $$f_s \geq 8.4 \text{ MHz}$$

Putting this value of 'f_s' in equation for signaling rate,

$$r = 9 \times 8.4 \times 10^6 = 75.6 \times 10^6 \text{ bits/sec}$$

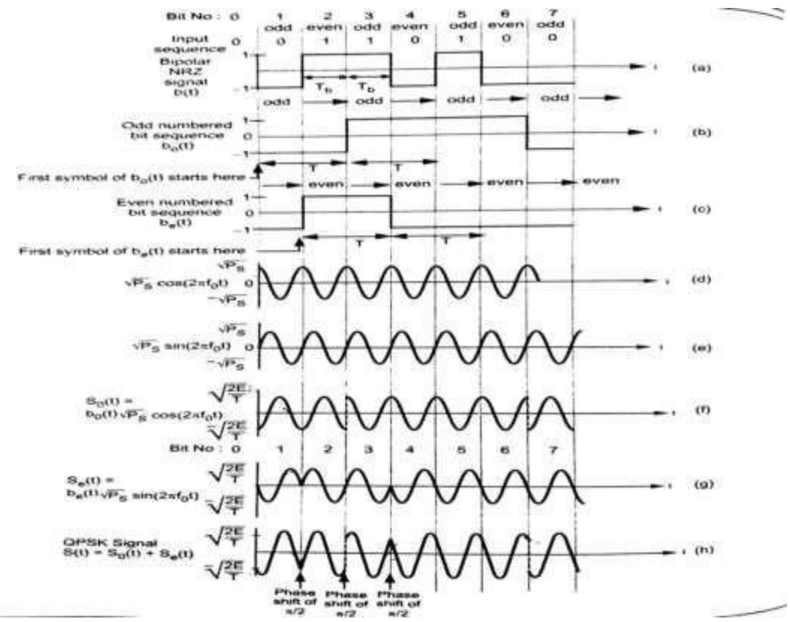
(2 Marks)

The transmission bandwidth is obtained as,

$$B_T \geq \frac{1}{2} r \geq \frac{1}{2} \times 75.6 \times 10^6 \quad \text{bits/sec}$$

$$B_T \geq 37.8 \text{ MHz}$$ **(1 Mark)**

(OR)

<table>
<tr>
<td>13. b.</td>
<td>
Draw the waveforms for a binary sequence 0110100 modulated under QPSK.
Answer:


(8 Marks)
</td>
<td>8</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>14. a.</td>
<td>
i. With neat diagrams, explain the concept of M-ary PSK transmitter and receiver.

Answer:
In M-ary PSK, the carrier phase takes on one of the M possible values, namely $q_i = 2 * (i - 1)p / M$ where i = 1, 2, 3, …..M.
The modulated waveform can be expressed as

$$S_i(t) = \sqrt{\frac{2E_s}{T_s}}\cos\left(2\pi f_c t + \boxed{\frac{2\pi}{M}(i-1)}\right),\ 0 \le t \le T_s \quad i = 1, 2, ..., M$$

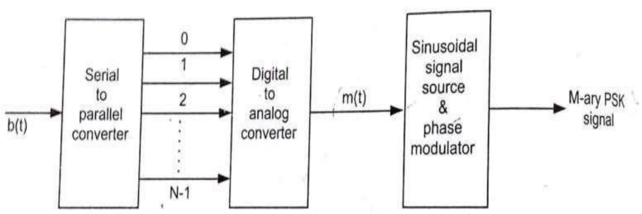
where E_s is energy per symbol = $(\log_2 M)\, E_b$
T_s is symbol period = $(\log_2 M)\, T_b$.
The above equation in the Quadrature form is

$$S_i(t) = \sqrt{\frac{2E_s}{T_s}}\cos\left[(i-1)\frac{2\pi}{M}\right]\cos(2\pi f_c t) - \sqrt{\frac{2E_s}{T_s}}\sin\left[(i-1)\frac{2\pi}{M}\right]\sin(2\pi f_c t) \qquad i = 1, 2, ..., M$$

By choosing orthogonal basis signals

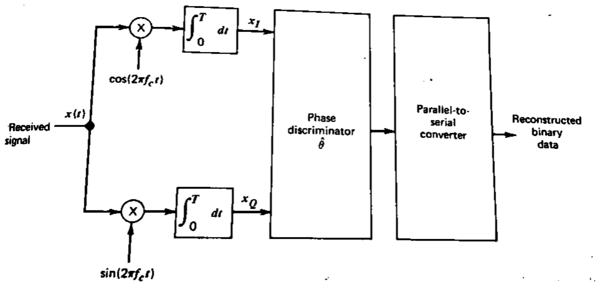
$$\phi_1(t) = \sqrt{\frac{2}{T_s}}\cos(2\pi f_c t),$$

$$\phi_2(t) = \sqrt{\frac{2}{T_s}}\sin(2\pi f_c t)$$

M-ARY PSK Transmitter (Diagram 1 Mark; Explanation 1 Mark)


</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
</table>

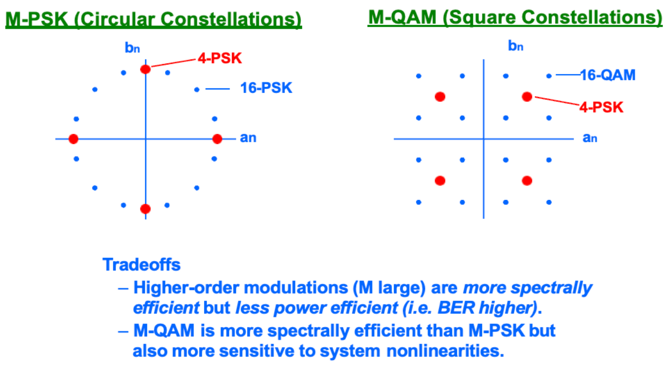
Input Binary Data (b(t)):
The input is a stream of binary data (0s and 1s).
Serial to Parallel Converter:
This block converts the incoming serial bit stream into **N parallel bit streams**.
Digital to Analog Converter (DAC):
The parallel data is converted into an analog signal that represents a unique value or symbol. Each unique symbol corresponds to a specific phase in the constellation diagram.
Sinusoidal Signal Source and Phase Modulator:
A carrier wave (sinusoidal signal) is generated. The phase modulator shifts the phase of the carrier wave based on the analog signal.This results in an **M-ary PSK modulated signal**.
Output M-ary PSK Signal:
The modulated signal is transmitted over the communication channel. Each symbol carries $\log_2 M$ bits of information, providing efficient data transmission.
M-ARY PSK Receiver (Diagram 1 Mark; Explanation 1 Mark)



Uses a reference carrier signal that is phase-aligned with the transmitted signal.
I/Q Demodulation: Separates the signal into in-phase and quadrature components for accurate detection.
Phase Discrimination: Determines the most likely transmitted symbol based on phase shifts.
Efficient for M-PSK: Works for BPSK (M=2), QPSK (M=4), 8-PSK (M=8), and higher-order PSK.
This receiver efficiently demodulates M-PSK signals by **extracting phase information** from the received signal.

ii. Explain the difference between M-PSK and M-QAM in terms of constellation diagrams.

Answer:



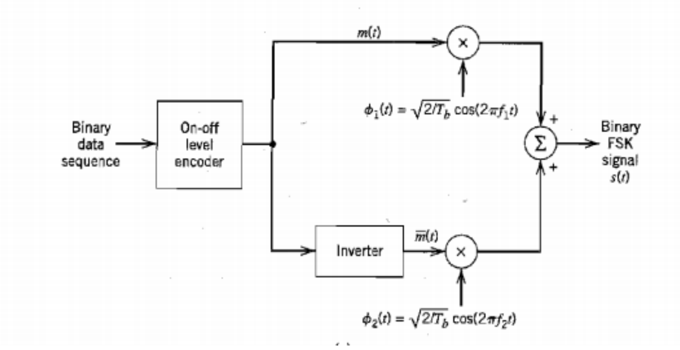
Constellation Diagram for M-PSK (1 ½ Marks)and M-QAM (1 ½ Marks)
Any two differences 1 Mark (½ Mark for each)

4 | 3 | 3

14. b.	**(OR)** Describe the generation and detection of binary FSK signal with necessary diagram and equation.	8	2	4

Answer:

Generation of FSK (2 Marks – Diagram; 2 Marks - Explanation with Expressions)



In a binary FSK system symbol ‘1’ and ‘0’ are transmitted as

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}}\, Cos 2\pi f_1 t \quad \text{for symbol 1}$$

$$S_2(t) = \sqrt{\frac{2E_b}{T_b}}\, Cos 2\pi f_2 t \quad \text{for symbol 0}$$

Frequency $f_i = \frac{n_c + i}{T_b}$ for some fixed integer nc and i=1, 2

The basic functions are given by

$$\phi_1(t) = \sqrt{\frac{2}{T_b}}\, Cos 2\pi f_1 t \qquad for \quad 0 \le t \le T_b$$

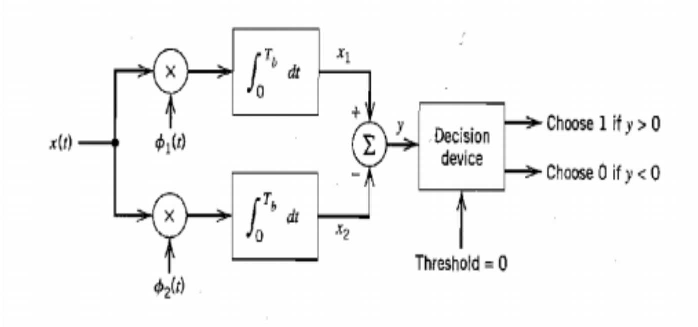
$$\phi_2(t) = \sqrt{\frac{2}{T_b}}\, Cos 2\pi f_2 t \qquad Zero\ \ Otherwise$$

Therefore FSK is characterized by two dimensional signal space with two message points i.e. N=2 and m=2.

The two message points are defined by the signal vector $S_1 = \begin{bmatrix} \sqrt{E_b} \\ 0 \end{bmatrix}$ and $S_2 = \begin{bmatrix} 0 \\ \sqrt{E_b} \end{bmatrix}$

- The incoming binary data sequence is applied to on-off level encoder.
- The output of encoder is $\sqrt{Eb}$ volts for symbol 1 and 0 volts for symbol ‘0’.
- When we have symbol 1 the upper channel is switched on with oscillator frequency f1, for symbol ‘0’, because of inverter the lower channel is switched on with oscillator frequency f2.
- These two frequencies are combined using an adder circuit and then transmitted.

	DETECTION OF FSK (2 Marks – Diagram: 2 Marks- Explanation)			



- The detector consists of two correlators.
- The incoming noisy BFSK signal x(t) is common to both correlator.
- The Coherent reference signal $\Phi_1(t)$ *and* $\Phi_2(t)$ are supplied to upper and lower correlators respectively.
- The correlator outputs are then subtracted one from the other and resulting a random vector ‘l’ (l=x1 - x2).
- The output ‘l’ is compared with threshold of zero volts.
- If l > 0, the receiver decides in favor of symbol 1.
- l < 0, the receiver decides in favor of symbol 0.

Part C (1x15=15 Marks) Answer ALL the question

15. a.	Derive the expression for the error probability of matched filter.	**15**	**4**	**3**

Answer:

Prob. error of Matched filter

Consider a PCM sys/: based on NRZ signalling -

NRZ → 1 +ve, 0 −ve and channel noise as AWGN

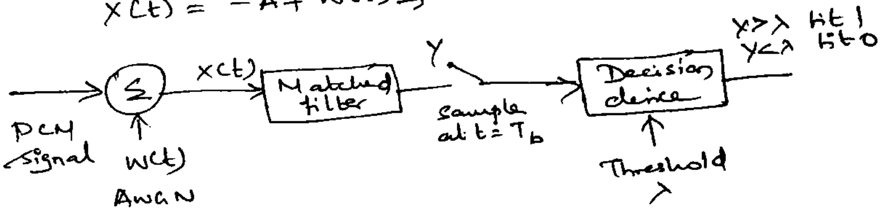
denoted by w(t)

The rxd. signal is written as follows (ie)

i/p signal to Rxr is

$x(t) = +A + w(t) \rightarrow$ symbol 1 is txd

$x(t) = -A + w(t) \rightarrow$ " 0 is txd



(upto this 2 Marks)

2 possible Bit errors are

i) chosing bit 1 when 0 was txd.

ii) " " 0 " 1 " "

Case i) symbol 0 was txd

then rxd. signal is $x(t) = -A + w(t)$

rectangular i/p '$-A$' to matched filter can be replaced by integrator and dump circuit.

$$\therefore \; y = \int_0^{T_b} x(t)\, dt$$

The integrator computes the area under the rectangular pulse

$$y = \frac{1}{T_b} \int_0^{T_b} [-A + w(t)]\, dt$$

$$y = \frac{1}{T_b}\left[\int_0^{T_b} -A\, dt + \int_0^{T_b} w(t)\, dt\right]$$

$$= \frac{1}{T_b}\left[[-At]_0^{T_b} + \int_0^{T_b} w(t)\, dt\right]$$

$$= \frac{1}{\cancel{T_b}} - A\cancel{T_b} + \frac{1}{T_b}\int_0^{T_b} w(t)\, dt$$

$$y = -A + \frac{1}{T_b}\int_0^{T_b} w(t)\, dt \rightarrow (1)$$

$$\therefore \; y + A = \frac{1}{T_b}\int_0^{T_b} w(t)\, dt \rightarrow (2)$$

random variable y is gaussian distributed with u '$-A$'. The variance of y is written as

$$\sigma_y^2 = E[y - \bar{y}]^2$$

$$= E[y - (-A)]^2 = E[y + A]^2$$

Using (2)

$$\sigma_y^2 = E\left[\frac{1}{T_b}\int_0^{T_b} w(t)\, dt\right]^2$$

$$= E\left[\frac{1}{T_b^2}\int_0^{T_b}\int_0^{T_b} w(t)\, w(u)\, dt\, du\right]$$

$$= \frac{1}{T_b^2}\int_0^{T_b}\int_0^{T_b} E[w(t)\, w(u)]\, dt\, du$$

Can be written as

$$\sigma_y^2 = \frac{1}{T_b^2}\int_0^{T_b}\int_0^{T_b} R_w(t,u)\, dt\, du \rightarrow (3)$$

$R_w(t,u)$ → auto correlation function of white noise

$$R_w(t,u) = \frac{N_0}{2}\,\delta(t-u) \rightarrow (4)$$

Using ②

$$\sigma^2_Y = E\left[\frac{1}{T_b}\int_0^{T_b} w(t)\,dt\right]^2$$

$$= E\left[\frac{1}{T_b^2}\int_0^{T_b}\int_0^{T_b} w(t)\,w(u)\,dt\,du\right]$$

$$= \frac{1}{T_b^2}\int_0^{T_b}\int_0^{T_b} E\left[w(t)\,w(u)\right]dt\,du$$

Can be written as

$$\sigma^2_Y = \frac{1}{T_b^2}\int_0^{T_b}\int_0^{T_b} \underbrace{R_w(t,u)}_{\text{auto correlation function of white noise}}\,dt\,du \rightarrow ③$$

$$R_w(t,u) = \frac{N_0}{2}\,\delta(t-u) \rightarrow ④$$

$$\frac{1}{T_b}$$

Conditional pdf (When bit '0' was sent) P_{10}

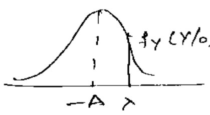
$$f_Y(Y/0) = \frac{1}{\sqrt{2\pi\sigma^2_Y}}\exp\left[\frac{-(x-\bar{x})^2}{2\sigma^2_Y}\right]$$

$$f_Y(Y/0) = \frac{1}{\sqrt{\cancel{2}\pi\frac{1}{T_b}\frac{N_0}{\cancel{2}}}}\exp\left[\frac{-(y+A)^2}{\cancel{2}\frac{1}{T_b}\frac{N_0}{\cancel{2}}}\right]$$

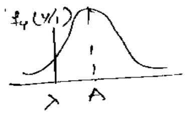
$$f_Y(Y/0) = \frac{1}{\sqrt{\frac{\pi N_0}{T_b}}}\exp\left[\frac{-(y+A)^2}{N_0/T_b}\right]$$

Let P_{10} be the conditional pdf when 0 was txd.

$$P_{10} = \int_{\lambda}^{\infty} f_Y(Y/0)\,dy = \int_{\lambda}^{\infty}\frac{1}{\sqrt{\frac{\pi N_0}{T_b}}}\exp\left[\frac{-(y+A)^2}{\frac{N_0}{T_b}}\right]dy \rightarrow ⑥$$



IIIrly.



The integral in eq ⑥ can be replaced with complementary error fun / erfc

$$\operatorname{erfc}(u) = \frac{2}{\sqrt{\pi}}\int_u^{\infty}\exp(-z^2)\,dz$$

Let $z = \dfrac{y+A}{\sqrt{\frac{N_0}{T_b}}}$ $\quad\therefore\; dz = \dfrac{1}{\sqrt{N_0/T_b}}\,dy$ $\quad$ limits $z\to u$, $y\to\lambda$, $u = \dfrac{A+\lambda}{\sqrt{N_0/T_b}}$; $z\to\infty$, $y\to\infty$ $\therefore\infty$

In eq ⑥

$$\therefore P_{10} = \int_{\frac{A+\lambda}{\sqrt{N_0/T_b}}}^{\infty}\frac{1}{\sqrt{\frac{\pi \cancel{N_0}}{\cancel{T_b}}}}\exp(-z^2)\sqrt{\cancel{N_0/T_b}}\,dz$$

$$= \int_{\frac{A+\lambda}{\sqrt{N_0/T_b}}}^{\infty}\frac{1}{\sqrt{\pi}}\exp(-z^2)\,dz = \frac{1}{2}\operatorname{erfc}(u)$$

$$\therefore P_{10} = \frac{1}{2}\operatorname{erfc}\left[\frac{A+\lambda}{\sqrt{N_0/T_b}}\right] - ⑦$$

III^{rly} for case(ii) when bit 1 was txd.

$$f_Y(y/_1) = \frac{1}{\sqrt{\frac{\pi N_0}{T_b}}} \exp\left[\frac{-(y-A)^2}{N_0/T_b}\right]$$

$$P_{01} = \frac{1}{2}\,\text{erfc}\left(\frac{A-\lambda}{\sqrt{N_0/T_b}}\right)$$

· Avg. Prob. of symbol error

$$P_e = P_0 P_{10} + P_1 P_{01}$$

$$\boxed{P_e = P_0 \frac{1}{2}\,\text{erfc}\left[\frac{A+\lambda}{\sqrt{N_0/T_b}}\right] + P_1 \frac{1}{2}\,\text{erfc}\left[\frac{A-\lambda}{\sqrt{N_0/T_b}}\right]} \rightarrow (8)$$

(upto Average probability of symbol error 8 Marks)

For optimum threshold:

Using Leibnitz rule

$$\frac{d}{du}\int_{a(u)}^{b(u)} f(z,u)\,dz = f(b(u),u)\frac{db(u)}{du} - f(a(u),u)\frac{da(u)}{du} + \int_{a(u)}^{b(u)} \frac{\partial f(z,u)}{\partial u}\,dz$$

Considering $f(z,u) = \frac{2}{\sqrt{\pi}}\exp(-z^2)$

$$a(u) = u \quad ; \quad b(u) = \infty$$

$$\boxed{\frac{d}{du}\,\text{erfc}(u) = -\frac{1}{\sqrt{\pi}}\exp(-u^2)} \rightarrow (9)$$

differentiating eq (8) using (9) and equating to zero we get the optimum threshold value.

$\hat{\lambda} \rightarrow$ optimum threshold

From eq (8)

$$P_e = P_0 \frac{1}{2}\,\text{erfc}\left[\frac{A+\lambda}{\sqrt{N_0/T_b}}\right] + P_1 \frac{1}{2}\,\text{erfc}\left[\frac{A-\lambda}{\sqrt{N_0/T_b}}\right]$$

Using eq (9) & equating to zero.

$$0 = \frac{P_0}{2}\left[-\frac{1}{\sqrt{\pi}}\exp^{-}\left(\frac{A+\lambda}{\sqrt{N_0/T_b}}\right)^2\right] + \frac{P_1}{2}\left[-\frac{1}{\sqrt{\pi}}\exp^{-}\left(\frac{A-\lambda}{\sqrt{N_0/T_b}}\right)^2\right]$$

$$P_0\left[\cancel{-}\exp^{-}\left(\frac{A+\lambda}{\sqrt{N_0/T_b}}\right)^2\right] = -P_1\left[\cancel{-}\exp^{-}\left(\frac{A-\lambda}{\sqrt{N_0/T_b}}\right)^2\right]$$

$$\therefore \frac{P_0}{P_1} = \frac{\exp\left[-\left(\frac{A-\lambda}{\sqrt{N_0/T_b}}\right)^2\right]}{\exp\left[-\left(\frac{A+\lambda}{\sqrt{N_0/T_b}}\right)^2\right]}$$

Taking log on both sides

$$\log\frac{P_0}{P_1} = \log\left[\exp\left[-\left(\frac{A-\lambda}{\sqrt{N_0/T_b}}\right)^2\right]\right] + \log\left[\exp\left[-\left(\frac{A+\lambda}{\sqrt{N_0/T_b}}\right)^2\right]\right]$$

$$\log\frac{P_0}{P_1} = \left(\frac{A-\lambda}{\sqrt{N_0/T_b}}\right)^2 - \left(\frac{A+\lambda}{\sqrt{N_0/T_b}}\right)^2$$

$$\therefore \log P_0/P_1 = \frac{\cancel{A^2}+\cancel{\lambda^2}-2A\lambda - (\cancel{A^2}+\cancel{\lambda^2}+2A\lambda)}{N_0/T_b}$$

$$\log P_0/P_1 = \frac{-4A\lambda}{N_0/T_b}$$

$$\therefore \lambda = \lambda_{opt} = \frac{\log(P_1/P_0)\, N_0}{4AT_b}$$

$$\lambda_{opt} = \frac{N_0}{4AT_b}\log\frac{P_1}{P_0}$$

For spl. case P_0 & P_1 are equiprobable

$$\therefore P_0 = P_1 = \frac{1}{2} \rightarrow (10)$$

$$\text{Hence } \lambda_{opt} = \frac{N_0}{4AT_b}\log(1)$$

$$\therefore \lambda_{opt} = 0 \rightarrow (11)$$

Substitute (10) & (11) in eq (8)

$$P_e = \frac{1}{2}\cdot\frac{1}{2}\,\mathrm{erfc}\left[\frac{A+0}{\sqrt{N_0/T_b}}\right] + \frac{1}{2}\cdot\frac{1}{2}\,\mathrm{erfc}\left[\frac{A-0}{\sqrt{N_0/T_b}}\right]$$

$$= \frac{1}{4}\,\mathrm{erfc}\left[\frac{A}{\sqrt{N_0/T_b}}\right] + \frac{1}{4}\,\mathrm{erfc}\left[\frac{A}{\sqrt{N_0/T_b}}\right]$$

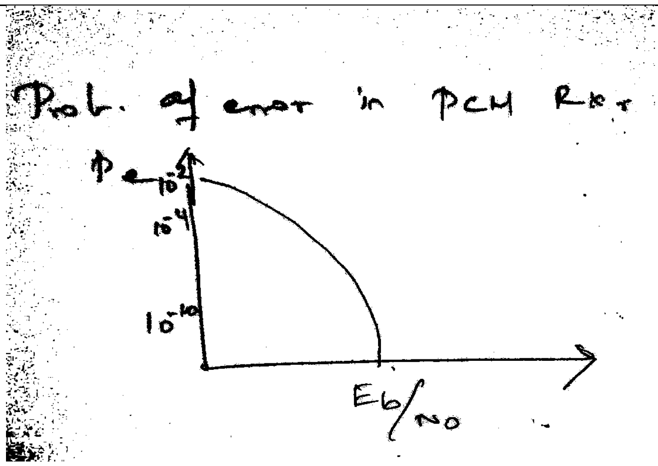
$$\boxed{P_e = \frac{1}{2}\,\mathrm{erfc}\left[\frac{A}{\sqrt{N_0/T_b}}\right]}$$

Let the txd. signal energy per bit is

$$E_b = A^2 T_b \quad \therefore A = \sqrt{E_b/T_b}$$

$$\boxed{P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{\frac{E_b}{N_0}}}$$

(4 Marks)



(1 Mark)

15. b.	(see below)	15	4	4

(OR)

(a) In digital CW communication system, the bit rate of NRZ data stream is 1 Mbps and carrier frequency is 100 MHz. Find the symbol rate of transmission and bandwidth requirement of the channel in the following cases of different techniques used. (1) BPSK system (2) QPSK system (3)16ary PSK system. **(6 Marks)**

Answer:

(1) BPSK system (2 Marks-> Symbol rate 1 Mark BW 1 Mark)
(2) QPSK system (2 Marks-> Symbol rate 1 Mark BW 1 Mark)
(3)16ary PSK system (2 Marks-> Symbol rate 1 Mark BW 1 Mark)

Sol. : Given data

The bit rate is, $f_b = 1 \text{ Mbps} = 1\times10^6$

Hence $T_b = \frac{1}{f_b} = \frac{1}{1\times10^6} = 1\times10^{-6}$ or 1 μs.

Carrier frequency $f_0 = 100$ MHz

(i) BPSK system

Bandwidth of BPSK system is given as,

$$BW = 2 f_b$$
$$= 2\times1\times10^6 = 2 \text{ MHz}$$

In BPSK, one bit is considered as one symbol.

Hence $T_s = T_b = 1\times10^{-6}$

$\therefore$ Symbol rate $= \frac{1}{T_s} = \frac{1}{1\times10^{-6}} = 1\times10^6$ symbols/sec.

Note that this rate is same as bits/sec.

(ii) QPSK system

Bandwidth of QPSK is given as,

$$BW = f_b = 1\times10^6 \text{ i.e. } 1 \text{ MHz}$$

In QPSK, $T_s = 2T_b$

$= 2\times1\times10^{-6}$ or 2 μsec

Hence, symbol rate $= \frac{1}{T_s}$

$$= \frac{1}{2\times10^{-6}} = 500\times10^3 \text{ symbols/sec}$$

(iii) 16-ary PSK system

Equation 3.6.13 gives the bandwidth of M-ary PSK as,

$$BW = \frac{2 f_b}{N}$$

Here 'N' is the number of bits used to make one symbol. Here there are total 16 sy

$$\therefore \quad N = \log_2 M$$

$$= \log_2 16 = \frac{\log_{10} 16}{\log_{10} 2} = 4$$

Thus 4 bits make 16 symbols. Hence bandwidth of the 16-ary PSK becomes,

$$BW = \frac{2 \times 1 \times 10^6}{4} = 500 \text{ kHz}$$

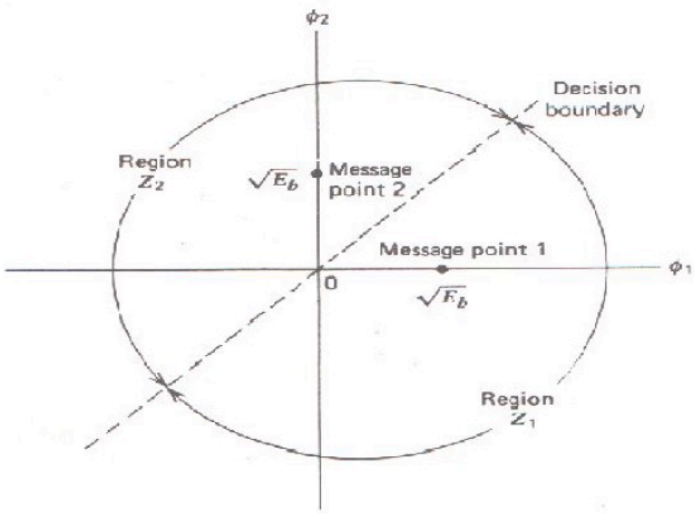
$$T_s = N T_b$$

$$= 4 \times 1 \times 10^{-6} = 4 \times 10^{-6}$$

$$\text{rate} = \frac{1}{T_s}$$

$$= \frac{1}{4 \times 10^{-6}} = 250 \times 10^3 \text{ symbols/sec}$$

(b) Draw the constellation diagram of FSK, PSK and QPSK. **(6 Marks)**



(2 Marks)

Fig. Signal Space diagram of Coherent binary FSK system.

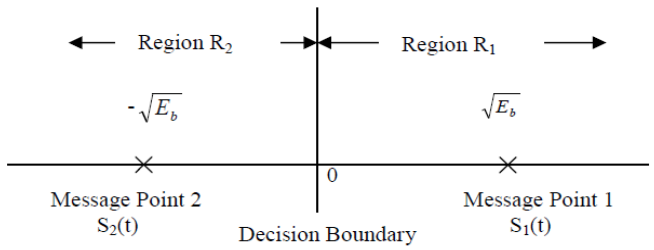


Fig. Signal Space Representation of BPSK

(2 Marks)

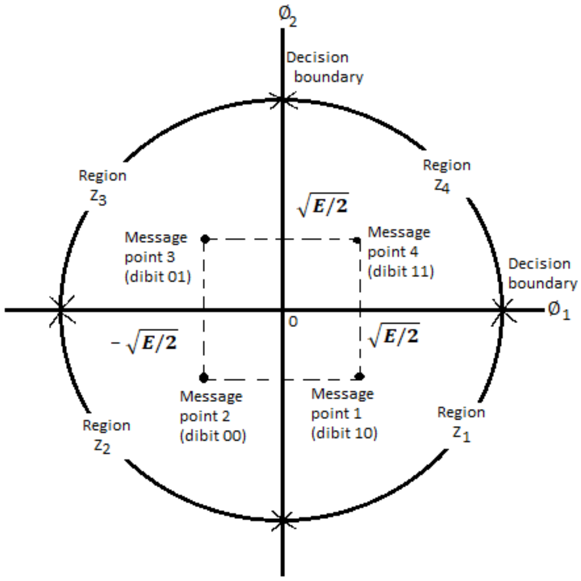


Fig. Signal Space Representation of QPSK **(2 Marks)**

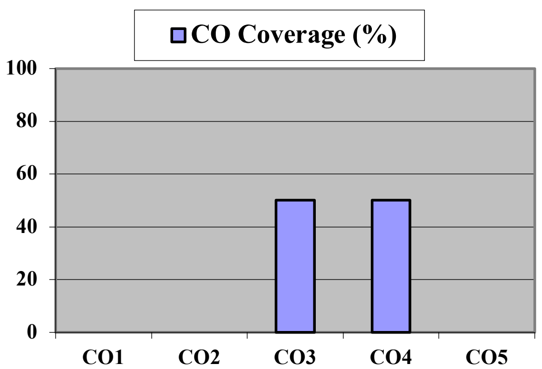
(c) Differentiate coherent and non-coherent detection. **(3 Marks)**

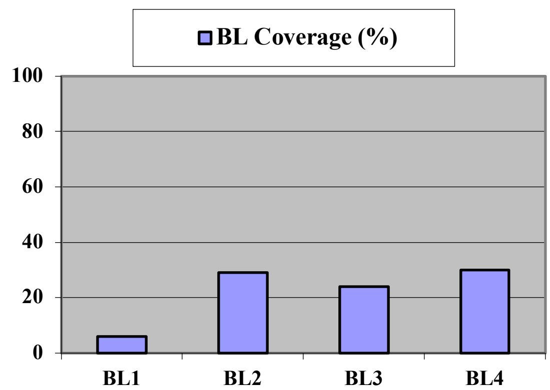
Coherent Detection and **Non-Coherent Detection**:

Aspect	**Coherent Detection**	**Non-Coherent Detection**
Synchronization	Requires carrier phase synchronization	No phase synchronization needed
Complexity	Higher due to synchronization circuits	Lower and simpler receiver design
Performance (BER)	Lower (better performance)	Higher (worse performance)
Spectral Efficiency	Higher	Lower
Noise Sensitivity	More sensitive to phase noise	Less sensitive to phase noise
Receiver Type	Requires coherent demodulator	Uses envelope or differential detector
Power Consumption	Higher	Lower
Examples	BPSK, QPSK, QAM	FSK, DPSK, ASK
Applications	High data rate systems (e.g., 5G)	Low complexity systems (e.g., Satellite Communication)
Cost	More expensive	More economical

Any 3 Difference 3 Marks

Course Outcome (CO) and Bloom's level (BL) Coverage in Questions





<u>**Evaluation Sheet**</u>

Name of the Student: **Register No.:**

Part- A (11x 1= 11 Marks)				
Q. No	**CO**	**Maximum Marks**	**Marks Obtained**	**Total**
1	3	1		
2	3	1		
3	3	1		
4	3	1		
5	3	1		
6	4	1		
7	4	1		
8	4	1		
9	4	1		
10	4	1		
11	4	1		
Part – B (3 x 8 = 24 Marks)				
12 a	3	8		
12 b	3	8		
13 a	3	8		
13 b	4	8		
14 a	4	8		
14 b	4	8		
Part - C (1 x 15 = 15 Marks)				
15 a	3	15		
15 b	4	15		

Consolidated Marks:

CO	Maximum Marks	Marks Obtained
3	**44**	
4	**45**	
Total	**89**	

Signature of Course Teacher

Signature of the Course Coordinator **Signature of the Academic Advisor**