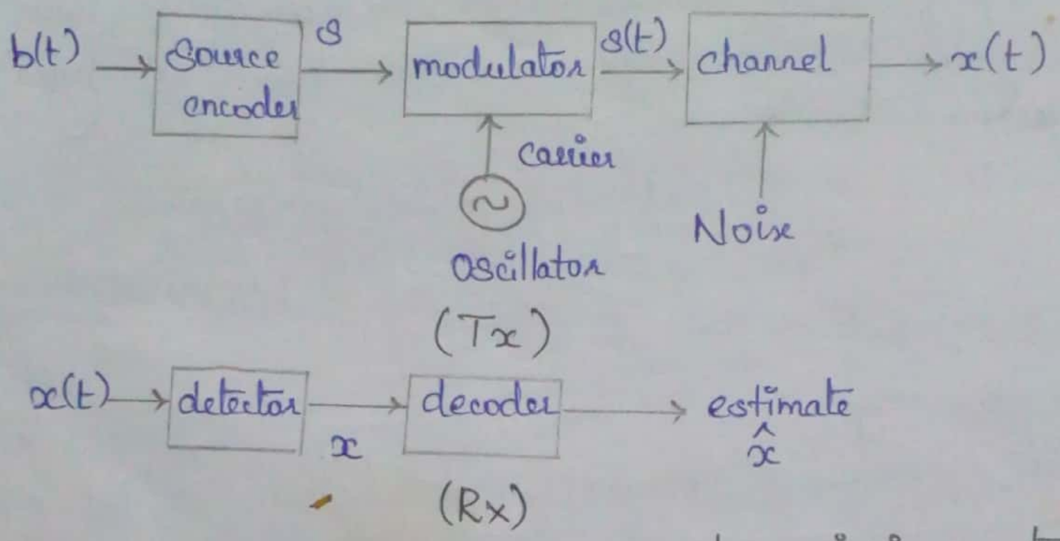
UNIT-4 DIGITAL MODULATION SCHEME

1) What is the need of digital modulations in digital communication? (or) State the advantages of digital carrier comm. over baseband digital transmission.

Passband Transmission Model.



Model of passband transmission system.

1) Digital data → is in the form of bits / bytes.

2) Source encoder → produces the vector s_i.

3) Modulator → constructs the modulated carrier signal $s_i(t)$.

4) Channel → modulated signal is transmitted over the channel. channel noise is to be white Gaussian of 0 mean & $N_0/2$ psd.

5) Detector → demodulates the received signal & estimates the signal vector.

6) Decoder → obtains the estimate of symbol back from the signal.

Digital modulation Schemes.

- → PSK (Phase Shift keying) → digital data modulates phase of the carrier
- → FSK (Frequency Shift keying) → digital data modulates frequency of the carrier.
- → ASK (Amplitude Shift keying) → digital data modulates amplitude of the carrier.

Types of Passband Transmission.

- → Coherent (Synchronous) detection → the local carrier generated at the receiver is phase locked with the carrier at the transmitter.
- → Non-coherent (Envelope) detection → the receiver need not be phase locked at the transmitted carrier.

Advantages of Passband Transmission.

→ Uses high carrier frequencies. Signals are transmitted over long distance with the help of cables, radio channels or fiber optic cables.

→ Signals generated are analog in nature. Hence all types of analog channels are used for transmission.

→ Bandwidth is conserved by this modulation techniques.

→ Mainly suffers from ISI and crosstalk in baseband txn, these problems are absent in this modulation.

→ Needs fiber optic / coaxial cables to carry the signals in baseband transmission whereas in passband signals are transmitted on radio channels.

Disadvantages of Passband Transmission.

→ Complex system.

→ Not suitable for short distance communication.

2) Explain Geometric Representation of Signals (or) How to represent the signals to be orthogonal to each other?

Geometric Representation of Signals.

Messages are transmitted over the carrier form a signal space that used to study the

→ Probability of error

→ Seperation between the individual messages.

Vector space representation → characteristic of every digital modulation technique.

Let M be the no of energy signals form the i/p

ie $y_i(t) = \{y_1(t)\ y_2(t) \dots y_M(t)\}$

interms of N no of orthonormal basis fn be

$\phi_j(t) = \{\phi_1(t)\ \phi_2(t) \dots \phi_N(t)\}$

the linear relationship between $s_i(t)$ & $\phi_j(t)$ be

$$y_i(t) = \sum_{j=1}^{N} y_{ij}\, \phi_j(t)$$

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coefficients $y_{ij} = \int_0^T y_i(t)\,\phi_j(t)\,dt$

Orthonormal basis fn be $\int_0^T \phi_i(t)\,\phi_j(t)\,dt = \begin{cases} 1 & i=j \\ 0 & i\neq j \end{cases}$

$$\int_0^T \phi_i(t)\,\phi_i(t)\,dt = \int_0^T \phi_i^2(t)\,dt = 1 \quad (\because i=j)$$

$$\int_0^T \phi_i(t)\,\phi_j(t)\,dt = 0 \quad (\because i\neq j)$$

i.e. the basis fn $\phi_1(t)\,\phi_2(t)\ldots\phi_N(t)$ are orthogonal to each other over the interval $0-T$.

Norm of the Vector.

Consider the vector $y_i = \begin{bmatrix} y_{i1} \\ y_{i2} \\ \vdots \\ y_{iN} \end{bmatrix}$ and the product $\|y_i\|^2$ be $y_i^T y_i$

$$\|y_i\|^2 = \sum_{j=1}^{N} y_{ij}^2 \longrightarrow \text{absolute value of a vector}$$

↓

basically length of the vector

Relationship b/w signal energy & its vector

We know the signal energy be $E_i = \int_0^T y_i^2(t)\,dt$

$$E_i = \int_0^T \left[\sum_{j=1}^{N} y_{ij}\,\phi_j(t)\right]\left[\sum_{k=1}^{N} y_{ik}\,\phi_k(t)\right]dt$$

$$= \sum_{j=1}^{N}\sum_{k=1}^{N} y_{ij}\,y_{ik}\int_0^T \phi_j(t)\,\phi_k(t)\,dt$$

$$\int_0^T \phi_j(t)\,\phi_k(t)\,dt = \begin{cases} 1 & j=k \\ 0 & j\neq k \end{cases}$$

$$\therefore E_i = \begin{cases} \sum_{j=1}^{N}\sum_{k=1}^{N} y_{ij}\,y_{ik} & j=k \\ 0 & j\neq k \end{cases}$$

$$E_i = \sum_{j=1}^{N} y_{ij}^2 \qquad i=j$$

$$= \|y_i\|^2 = \boxed{y_i^T y_i = E_i} \rightarrow$$ the energy signal is equal to the squared length of the signal vector.

Euclidean distance.

Euclidean distance between y_i & y_k be

$$d_{ik} = \|y_i - y_k\|$$

Squared euclidean distance $\|y_i - y_k\|^2 = \sum_{i=1}^{N} (y_{ij} - y_{kj})^2$

ie $E_i = \int_0^T y_i^2(t)\, dt = \|y_i\|^2$

$$\|y_i - y_k\|^2 = \int_0^T [y_i(t) - y_k(t)]^2 dt$$

angle θ_{ik} be $\cos\theta_{ik} = \dfrac{y_i^T y_k}{\|y_i\|\|y_k\|}$

$y_i^T y_k = 0 \longrightarrow$ 2 vectors are orthogonal & perpendicular to each other.

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3) Explain the Gram Schmidt Orthogonalization Procedure (or) Derive the expressions for the procedure of Gram Schmidt Orthogonalization.

Gram Schmidt Orthogonalization Procedure.

↳ a tool to obtain the orthonormal basis fn $\phi_i(t)$.

① To derive $\phi_i(t)$

the set of M energy signals $y_1(t) y_2(t) \ldots y_M(t)$ for $y_1(t)$ the basis fn be

$$\phi_1(t) = y_1(t) / \sqrt{E_1}$$

E_1 is the energy of $y_1(t)$ is $y_1(t) = \sqrt{E_1}\, \phi_1(t)$

$N=1 \longrightarrow y_1(t) = y_{11} \phi_1(t)$

coeff $y_{21} = \int_0^T y_2(t)\, \phi_1(t)\, dt$

let a new fn be $g_2(t) = y_2(t) - y_{21}\phi_1(t)$
the fn is orthogonal to $\phi_1(t)$ over the interval 0-T then

$$\phi_2(t) = g_2(t)/\sqrt{E_{g_2}}$$

here $\sqrt{E_{g_2}} = \int_0^T g_2^2(t)\,dt \longrightarrow$ energy of $g_2(t)$.

(2) To prove $\phi_2(t)$ has unit energy

Energy of $\phi_2(t)$ is $\int_0^T \phi_2^2(t)dt = \frac{1}{E_{g_2}}\int_0^T g_2^2(t)\,dt$

$$= \frac{1}{E_{g_2}} \cdot E_{g_2} = 1.$$

Thus $\phi_2(t)$ has unit energy.

(3) To prove $\phi_1(t)$ & $\phi_2(t)$ are orthonormal.

Consider $\int_0^T \phi_1(t)\,\phi_2(t)\,dt = \int_0^T \frac{y_1(t)}{\sqrt{E_1}} \cdot \frac{g_2(t)}{\sqrt{E_{g_2}}}\,dt$

$$= \frac{1}{\sqrt{E_1}\sqrt{E_{g_2}}}\int_0^T y_1(t)g_2(t)\,dt$$

$$= \frac{1}{\sqrt{E_1}\sqrt{E_{g_2}}}\int_0^T y_1(t)\left[y_2(t) - y_{21}\phi_1(t)\right]dt$$

$$= \frac{1}{\sqrt{E_1 E_{g_2}}}\left[\int_0^T y_1(t)y_2(t)\,dt - \int_0^T y_2(t)\phi_1(t)y_1(t)\,\phi_1(t)\,dt\right]$$

$\therefore \int_0^T \phi_1(t)\,\phi_2(t)\,dt = 0 \longrightarrow$ thus the 2 basis fn are orthonormal

(4) Gen eqn for orthonormal basis fn.

$\phi_i(t) = g_i(t)/\sqrt{E_{g_i}}$ $i = 1, 2 \ldots N \longrightarrow$ orthonormal basis fn

where $g_i(t) = y_i(t) - \sum_{j=1}^{i-1} y_{ij}\,\phi_j(t)$

$y_{ij} = \int^T y_i(t)\,\phi_j(t)\,dt \longrightarrow$ contd.

4) Explain the maximum likelihood detection & obtain the decision rule. Prove that ML detector reduces to min. dist detector for white gaussian noise channel.

Maximum Likelihood decoding.

Let $x \longrightarrow$ Observation vector, decision be $\hat{m} = m_i$ & avg prob of error

$$P_e(m_i, x) = P(m_i \text{ not sent} | x) = 1 - P(m_i \text{ sent} | x)$$

Optimum decision rule is $\hat{m} = m_i$ if $P(m_i \text{ sent}|x) \geq P(m_k \text{ sent}|x)$ for all $k \neq i$

Let R is N dim space of all vectors x and this region is divided M decision regions then the decision rule be $R_i = \ln[f_x(x|m_k)]$ is max for $k = i$.

$\longrightarrow \ln[f_x(x|m_k)]$ is the likelihood f^n which results when symbol m_k is transmitted called max. likelihood and their detector called max. likelihood detector.

decision rule $\longrightarrow$ x lies in R_1 if $\|x - s_k\|$ is min for $k = i$.

Detection Process.

Let define $P(x_1)$ = Prob of rx symbol x_1

$P(x_2)$ = Prob of rx symbol x_2

$f_x(v|x_1)$ = pdf of rx voltage v when x_1 is sent

$f_x(v|x_2)$ = pdf of rx voltage v when x_2 is sent

λ = decision threshold.

when $v > \lambda \longrightarrow x_1$ selected and $v < \lambda \longrightarrow x_2$ selected.

Error Prob $P_e = P(x_1) \int_{v<\lambda} f_x(v|x_1)\,dv + P(x_2) \int_{v>\lambda} f_x(v|x_2)\,dv$

sym 1 $\longrightarrow \int_{v>\lambda} f_x(v|x_1)\,dv + \int_{v<\lambda} f_x(v|x_1)\,dv = 1 \quad \left(\because \int_{-\infty}^{\infty} f_x(x)\,dx = 1\right)$

$$\int_{v<\lambda} f_x(v|x_1)\,dv = 1 - \int_{v>\lambda} f_x(v|x_1)\,dv$$

$$P_e = P(x_1) + \int_{v>\lambda} P(x_2) f_x(v|x_2) - P(x_1) f_x(v|x_1)\,dv$$

$v > \lambda \longrightarrow \dfrac{P(v|x_1)}{P(v|x_2)} > \dfrac{P(x_2)}{P(x_1)} \longrightarrow$ max likelihood detector.

$\dfrac{P(v|x_1)}{P(v|x_2)} \underset{s_2}{\overset{s_1}{\gtrless}} \dfrac{P(x_2)}{P(x_1)} \longrightarrow$ max error probability.

5) Explain ASK (or) OOK in detail.

ASK (Amplitude Shift keying / OOK On-Off keying).

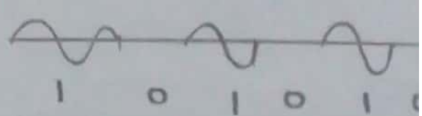
→ Simplest digital modulation technique.

→ there is only one unit energy carrier & it is switched ON/OFF depending upon the i/p.

ASK Waveform : $s(t) = \sqrt{2P_s} \cos(2\pi f_0 t)$

sym 0 → $s(t) = 0$ → no signal is transmitted.

sym 1 → $s(t) = 1$ → signal is transmitted.



ASK Waveform

Signal Space Diagram.

symbol 1 → $s(t) = \sqrt{P_s T_b}\sqrt{2/T_b}\cos(2\pi f_0 t)$

$= \sqrt{P_s T_b}\,\phi_1(t)$

(0) (1) → $\phi_1(t)$

0 $\sqrt{P_s T_b}$

→ Only one carrier freq. Signal space has 2 pt, one at 0 and other at $\sqrt{P_s T_b}$. dist b/w 2 signal pt be $d = \sqrt{E_b}$.

Coherent detector.

→ i/p binary sequence is applied to the product modulator that modulates the amplitude of the sine carrier.

$b(t)$ → Product modulator → $s(t)$

↑ carrier Generator.

→ { passes carrier → i/p 1
  { blocks carrier → i/p 0.

→ decision { $\lambda > 1 \rightarrow 1$.
  { $\lambda < 1 \rightarrow 0$.

Correlator

$s(t)$ → ⊗ → $\int$ → decision device → $b(t)$

↑ carrier ↑ λ

Detector.

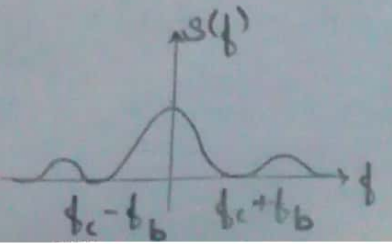
Non coherent Detection.

$s(t)$ → BPF → env. detector $\xrightarrow{y(t)}$ decision device → $b(t)$ { $y(t) > \lambda \rightarrow 1$
  { $y(t) < \lambda \rightarrow 0$

↑ λ

Power Spectral Density.

$S_{ASK}(f) = \frac{T_b}{4}\,\mathrm{sinc}^2(f T_b) + \frac{1}{4}\delta(f)$



b) Derive an expression for the error probability of BFSK system. (or) Explain the operation of BFSK Tx and Rx (or) Describe the generation & detection of coherent binary FSK and explain P_e

Binary Frequency Shift Keying (BFSK).

Principle:

In FSK, the frequency of the carrier is shifted according to the binary symbol. In this sym 0 & sym 1 are distinguished from each other by transmitting one of the 2 sine waves that differs in frequency.

$$S_i(t) = \begin{cases} \sqrt{2E_b/T_b}\cos(2\pi f_i t) & 0 \le t \le T_b \\ 0 & \text{otherwise} \end{cases}$$

$\therefore$ $S_1(t) \longrightarrow$ sym 1 and $S_2(t) \longrightarrow$ sym 0

Energy:

Orthonormal basis fn $\phi_j(t) = \begin{cases} \sqrt{2/T_b}\cos(2\pi f_i t) & 0 \le t \le T_b \\ 0 & \text{otherwise} \end{cases}$

coeff $\quad S_{ij} = \int_0^T S_{ij}(t)\,\phi_j(t)\,dt = \begin{cases} \sqrt{E_b} & i = j \\ 0 & i \ne j \end{cases}$

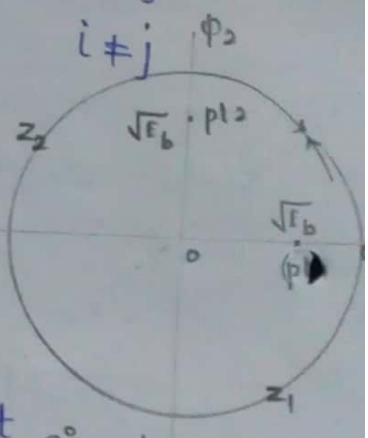
Geometrical Representation:

→ characterized by having single space ie $N = 2$, $M = 2$.

2 msg pts are defined as $S_1 = \begin{pmatrix} \sqrt{E_b} \\ 0 \end{pmatrix}$ $S_2 = \begin{pmatrix} 0 \\ \sqrt{E_b} \end{pmatrix}$

Observation vector has 2 elements $x_1 = \int_0^{T_b} x(t)\phi_1(t)\,dt$

$$x_2 = \int_0^{T_b} x(t)\phi_2(t)\,dt$$



Signal space rep.

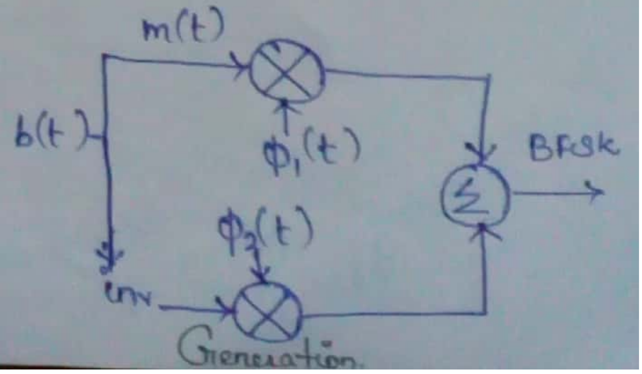
sym 1 $\longrightarrow x(t) = S_1(t) + w(t) \longrightarrow$ x falls inside Z_1 when $x_1 > x_2$

sym 0 $\longrightarrow x(t) = S_2(t) + w(t) \longrightarrow$ x falls inside Z_2 when $x_1 < x_2$

decision boundary $x_1 = x_2$ and distance $d = \sqrt{2E_b}$

Coherent BFSK.

$\longrightarrow b(t) \longrightarrow \begin{cases} \sqrt{E_b} & \text{sym 1} \\ 0 & \text{sym 0} \end{cases}$



Generation.

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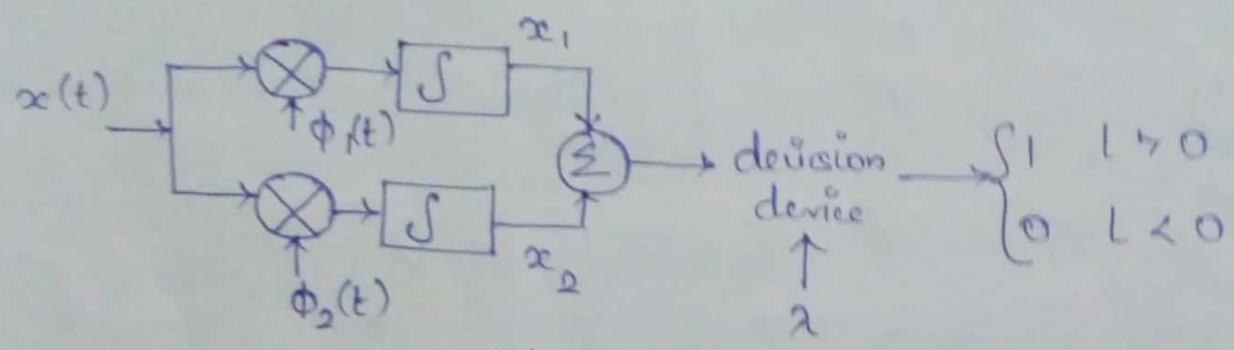
inverter → sym 1 → oscillator with f_1 in upper channel ON, f_2 in lower channel OFF

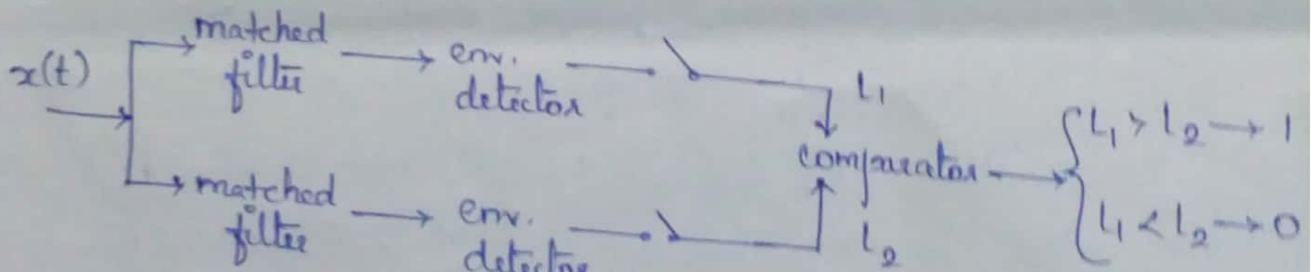
inverter → sym 0 → oscillator with f_1 in upper channel OFF, f_2 in lower channel ON

Receiver.



Detection

Non-coherent Rx.



Detector

Tx signal $s_i(t) = \begin{cases} \sqrt{2E_b/T_b}\cos(2\pi f_i t) & 0 \le t \le T_b \\ 0 & \text{other} \end{cases}$

$f_1 \rightarrow$ sym 1 and $f_2 \rightarrow$ sym 0.

avg prob of error $P_e = \frac{1}{2}\exp\left(-E_b/2N_0\right)$

Bandwidth $B/W = 4f_b$, Baud rate $= f_b/N$.

PSD of BFSK. $S_B(f) = \frac{E_b}{2T_b}\left[\delta\left(f - \frac{1}{2T_b}\right) + \delta\left(f + \frac{1}{2T_b}\right)\right] + \frac{8E_b\cos^2(\pi f T_b)}{\pi^2(4T_b^2 f^2 - 1)^2}$.

Error Prob $P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{E_b/2N_0}$.

Advantages.
Better noise immunity
simple

Disadvantages.
Doubles the B/W
Poor error performance.

4) Explain the generation & detection of coherent BPSK and derive the PSD of BPSK (or) Derive the PSD of binary PSK signal (or) Calculate BER of BPSK

BPSK (Binary Phase Shift keying).

Principle.

In PSK, the phase of the carrier signal is varied according to the binary i/p. The carrier phase is changed between 0° & 180° based on the binary i/p. The pair of signals $S_1(t)$ & $S_2(t)$ used to represent sym 1 & 0.

$$\text{Sym } 1 \longrightarrow S_1(t) = \sqrt{2E_b/T_b}\cos(2\pi f_c t)$$

$$\text{Sym } 0 \longrightarrow S_2(t) = -\sqrt{2E_b/T_b}\cos(2\pi f_c t)$$

Energy.

→ There is only one basis fn of unit energy

$$\phi_1(t) = \sqrt{2/T_b}\cos(2\pi f_c t) \qquad 0 \le t \le T_b.$$

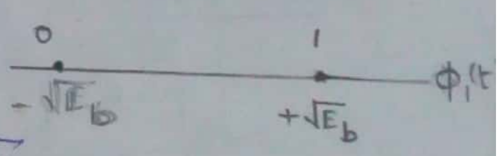
ie $S_1(t) = \sqrt{E_b}\,\phi_1(t)$ and $S_2(t) = -\sqrt{E_b}\,\phi_2(t)$.

Geometric Representation.

→ $N = 1$ and $M = 2$ the coordinates of msg pt be

$$S_{11} = \int_0^{T_b} S_1(t)\,\phi_1(t)\,dt = +\sqrt{E_b}$$

$$S_{21} = \int_0^{T_b} S_2(t)\,\phi_1(t)\,dt = -\sqrt{E_b}$$



distance $\quad d = +\sqrt{E_b} - (-\sqrt{E_b}) = 2\sqrt{E_b}.$

Generation.

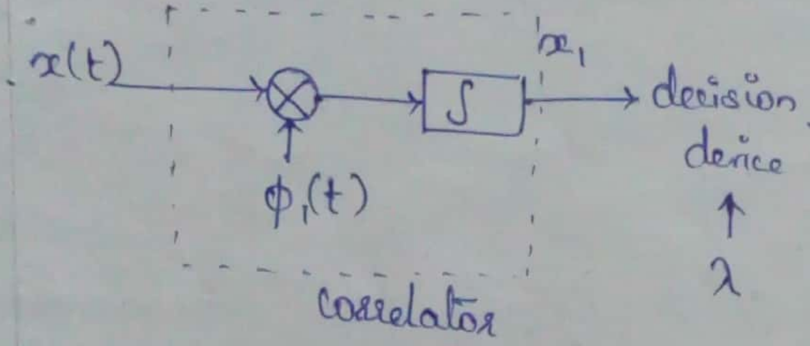
$b(t) \longrightarrow$ Bipolar NRZ $\xrightarrow{b(t)}$ balanced modulator $\longrightarrow$ BPSK wave.

$\begin{cases} 1 \longrightarrow +\sqrt{E_b} \\ 0 \longrightarrow -\sqrt{E_b} \end{cases}$

↑ Carrier $\phi_1(t)$

Transmitter

Detection.



$\longrightarrow \begin{cases} 1 & x_1 > 0 \\ 0 & x_1 < 0 \end{cases}$ | $x_1 = 0 \longrightarrow 1/0$

Receiver.

Bandwidth $BW = 2f_b \longrightarrow f_b = 1/T_b$

max BW is equal to twice the highest frequency contained in baseband signal.

Baudrate : Baudrate $= f_b$

PSD of BPSK be $S_B(f) = 2E_b \, sinc^2(fT_b)$

Error Prob. $P_e = \frac{1}{2} erfc \sqrt{\frac{E_b}{N_0}}$

Advantages.
- → min error probability
- → very good noise immunity
- → lower BW

Disadvantages.
- → Complex
- → ambiguity in o/p signal.

8) Derive an expression of probability of error of QPSK signal (or) Explain QPSK TX & Rx with suitable block d/g and relevant expressions.

QPSK (Quadrature Phase Shift Keying).

Goal:

the 2 important goals of the design of a digital communication system are
- → Very low error probability
- → Efficient utilization of BW.

Principle:

In QPSK, 2 successive bit in data sequences are grouped together to form symbols. This reduces the bit rate and reduces the channel BW. The phase of the carrier be $\pi/4$, $3\pi/4$, $5\pi/4$ & $7\pi/4$.

$$s_i(t) = \begin{cases} \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + (2i-1)\frac{\pi}{4}\right] & 0 \le t \le T \\ 0 & \text{other} \end{cases}$$

$$= \begin{cases} \sqrt{\frac{2E}{T}} \cos\left((2i-1)\frac{\pi}{4}\right)\cos(2\pi f_c t) - \sqrt{\frac{2E}{T}} \sin\left((2i-1)\frac{\pi}{4}\right)\sin(2\pi f_c t) & 0 \le t \le T \\ 0 & \text{other} \end{cases}$$

Signal space representation.

→ 2 orthonormal basis fn $\phi_1(t)$ & $\phi_2(t)$ are

$$\phi_1(t) = \sqrt{\frac{2}{T}} \cos(2\pi f_c t) \quad \text{and} \quad \phi_2(t) = \sqrt{\frac{2}{T}} \sin(2\pi f_c t)$$

→ 4 msg pt.

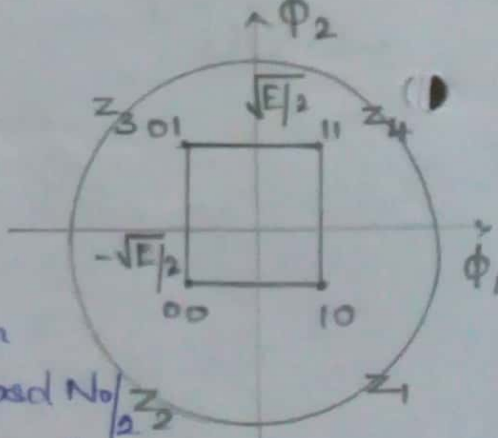
$$s_i = \begin{cases} \sqrt{E} \cos\left[(2i-1)\frac{\pi}{4}\right] \\ -\sqrt{E} \sin\left[(2i-1)\frac{\pi}{4}\right] \end{cases}$$

Geometrical Representation.

→ $N = 2$, $M = 4$.

rx signal $x(t) = s_i(t) + w(t) \quad 0 \le t \le T$

└→ white gaussian noise of mean 0 & psd $N_0/2$



→ 2 elements ⇒ $x_1 = \int_0^T x(t)\phi_1(t)\,dt = \sqrt{E}\cos\left((2i-1)\pi/4\right) + w_1$

$$x_2 = \int_0^T x(t)\phi_2(t)\,dt = -\sqrt{E}\sin\left((2i-1)\pi/4\right) + w_2$$

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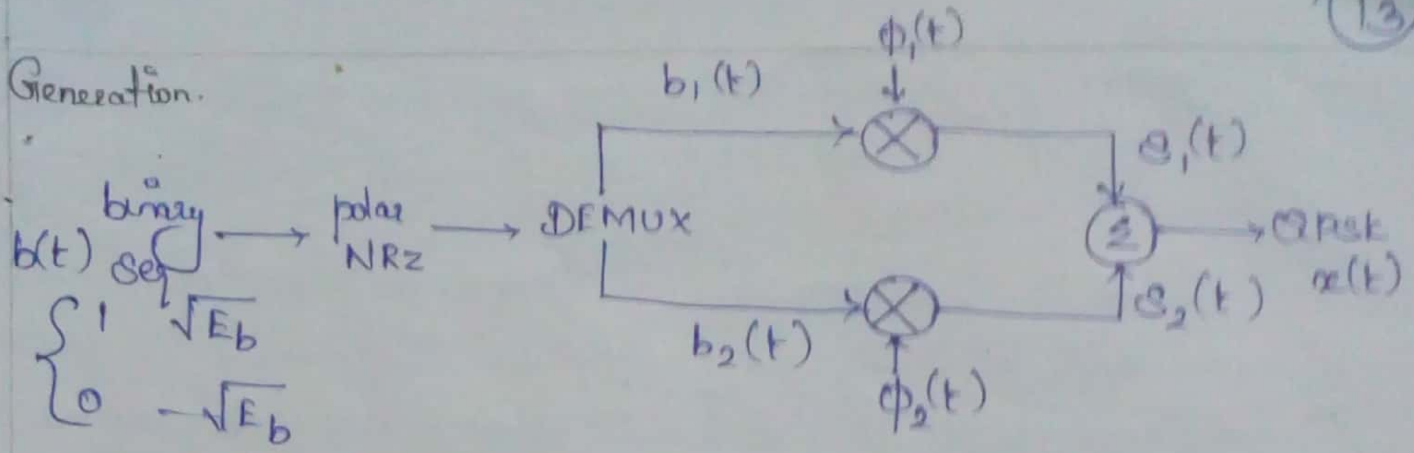
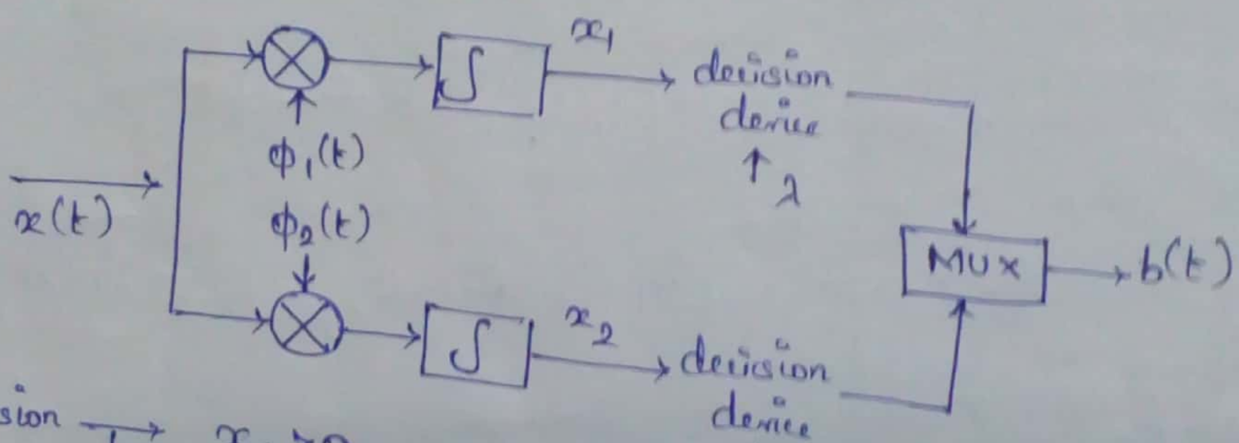
Generation.



Detection.



decision
$x_1 > 0 \longrightarrow 1$, $x_1 < 0 \longrightarrow 0$ $\}\longrightarrow$ upper channel

$x_2 > 0 \longrightarrow 1$, $x_2 < 0 \longrightarrow 0$ $\}\longrightarrow$ lower channel.

Bandwidth : $BW = f_b$

PSD $\longrightarrow$ Symbol shaping fn $g(t) = \begin{cases} \sqrt{E/T} & 0 \le t \le T \\ 0 & \text{other} \end{cases}$

$\longrightarrow$ inphase & quadrature component $S_B(f) = 4E_b \operatorname{sinc}^2(2T_b f)$.

Error Prob.

$$P_e = \operatorname{erfc}\sqrt{\frac{E_b}{N_0}}$$

Advantages.
- $\longrightarrow$ Reduced BW
- $\longrightarrow$ effective utilization of BW
- $\longrightarrow$ low prob of error

Disadvantages.
- $\longrightarrow$ interchannel interference is large
- $\longrightarrow$ Complex.

9) Explain QAM system with its Tx, Rx and signal space representation (or) Define Pe for QAM.

QAM (Quadrature Amplitude Modulation)

Principle:

In all PSK, inphase and quadrature components of the modulated signal are interrelated in such a way that the envelope is constrained to remain constant. If this constraint is removed and the inphase & quadrature components are permitted to be independent such modulation scheme called QAM.

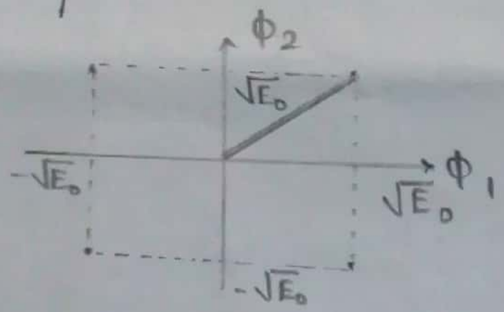
$$S_i(t) = \sqrt{\frac{2E_0}{T}}\, a_i \cos(2\pi f_c t) + \sqrt{\frac{2E_0}{T}}\, b_i \sin 2\pi f_c t \quad 0 \le t \le T$$

S_i interms of basis fn

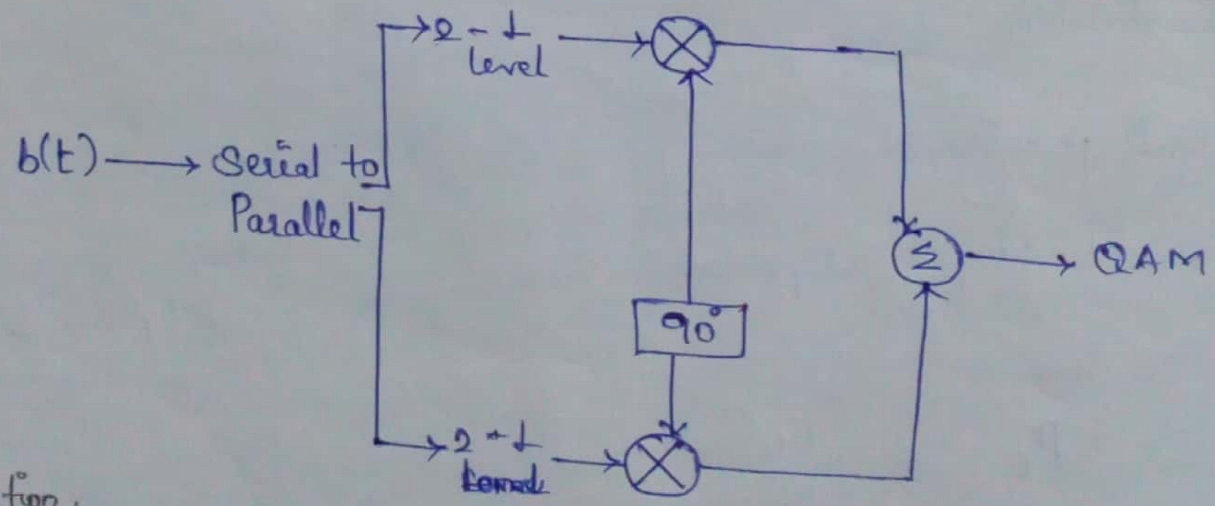
$$\phi_1(t) = \sqrt{\frac{2}{T}} \cos(2\pi f_c t) \text{ and } \phi_2(t) = \sqrt{\frac{2}{T}} \sin(2\pi f_c t)$$

Geometrical Representation

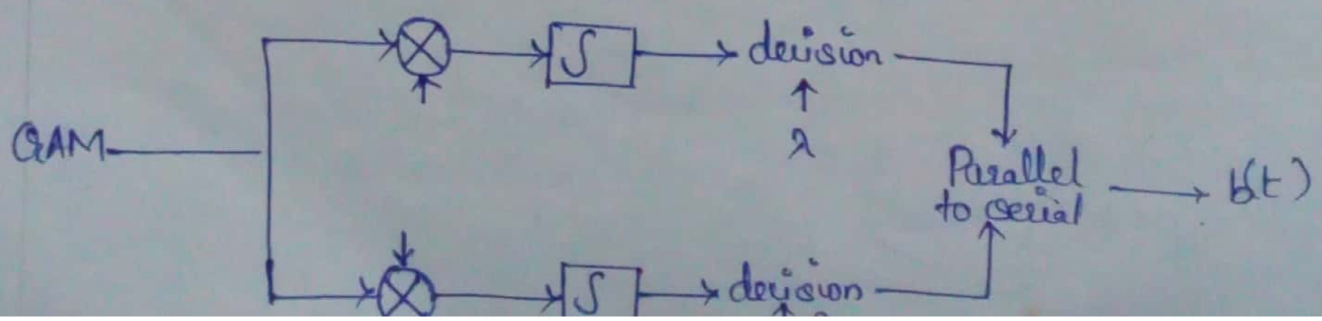
M = 4



Generation



Detection.



- Bandwidth $BW = 2f_b / N$.

- PSD $S(f) = \frac{P_s T_s}{2} \left[\frac{\sin(\pi f T_s)}{\pi f T_s}\right]^2$

Error Prob.

→ Probability of correct detection

$$P_c = (1 - P_e')^2$$

→ signal constellation

$$P_e' = \left(1 - \frac{1}{L}\right) \operatorname{erfc} \sqrt{\frac{E_b}{N_0}}$$

→ symbol error probability

$$P_e = 2\left(1 - \frac{1}{\sqrt{M}}\right) \operatorname{erfc} \sqrt{\frac{E_0}{N_0}}.$$

Transmitted energy.

$$E_{av} = 2\left[\frac{2E_0}{L} \sum_{i=1}^{L/2} (2i-1)^2\right]$$

$$E_{av} = \frac{2(M-1)E_0}{3}$$

Advantages.

→ better noise immunity

→ Easy to design

Disadvantages.

→ high error probability

→ complex.

10) Explain DPSK in detail (or) Write a short note on DPSK.

DPSK (Differential Phase shift keying).

→ Non coherent version of PSK. Eliminates the need for a coherent reference signal at the rx by combining 2 basic operations at the TX.

- → differential encoding
- → PSK.

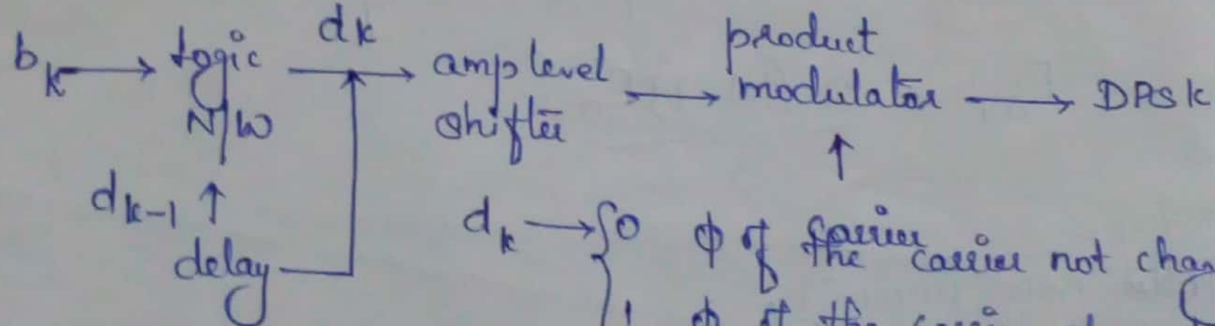
→ Sym 0 → phase advance the current signal by 180°.

→ Sym 1 → unchanged the phase.

TX signal sym 1 → $s_1(t) = \sqrt{\frac{E_b}{2T_b}} \cos(2\pi f_c t) \quad 0 \le t \le 2T_b$

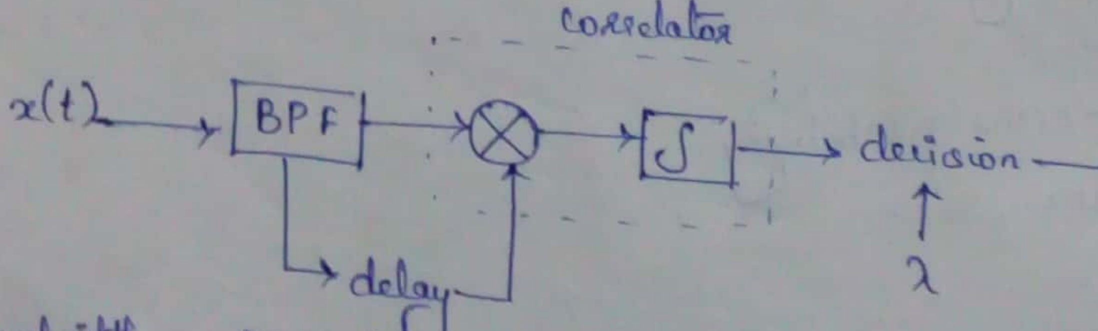
sym 0 → $s_2(t) = \begin{cases} \sqrt{\frac{E_b}{2T_b}} \cos(2\pi f_c t) & 0 \le t \le T_b \\ \sqrt{\frac{E_b}{2T_b}} \cos(2\pi f_c t + \pi) & T_b \le t \le 2T_b \end{cases}$

Generation.



$d_k \rightarrow \begin{cases} 0 & \phi \text{ of the carrier not changed} \\ 1 & \phi \text{ of the carrier changed by } \pi \end{cases}$

Detection.



$\begin{cases} 1 & l > 0 \\ 0 & l < 0 \end{cases}$

Bandwidth $BW = f_b$

Error Probability $P_e = \frac{1}{2} \exp\left(-\frac{E_b}{N_0}\right)$

Scanned with CamScanner