COLLATE

Digital Communcation

Notes

Unit 4

Syllabus

UNIT – IV

Coherent Binary Schemes: ASK, FSK, PSK, QPSK, MSK, G-MSK.
Coherent M-ary Schemes, Incoherent
Schemes (DPSK and DEPSK), Calculation of average probability of error for different modulation schemes,
Power spectra of digitally modulated signals, Performance comparison of different digital modulation schemes.
Review of 2 Latest Research Paper.

Digital Modulation Technique UNIT-4 D.Com (1)

MEDHA MAAM DCOM CSE 5th sem

① In baseband Comm., signals are transmitted without any freq shift. ② In Base band pulse transmission; input data is in the form of discrete PAM signal (line codes).

③ Baseband Comm. is suitable only for transmission over short distance using ~~wire~~ connections over a lowpass channel. ④ baseband signal have adequately large power at lowfreq ~~signal~~ so they can transmitted over a pair of wires.

③ for long distance digital transmission it is necessary to generate band pass signals suited to the transmission medium.

band pass → channel bandwidth

⑤ But it is not possible to transmit the base band signal over RF/satellite bcz at low freq. high antenna is required large. Hence spectrum of msg signal is shifted to higher freq.

⇒ ASK (Amplitude Shift Keying) Digital ~~comm.~~ modulation Technique

① Used in wireless Telegraphy.

② In ASK 1 → Transmitting a sinusoidal carrier wave of fixed amplitude (A_c) and fixed freq. f_c for the bit duration T_b sec.

0 → switching off the carrier for T_b seconds

③ Means that turning the carrier on and off for the prescribed periods indicated by the modulating pulse train.

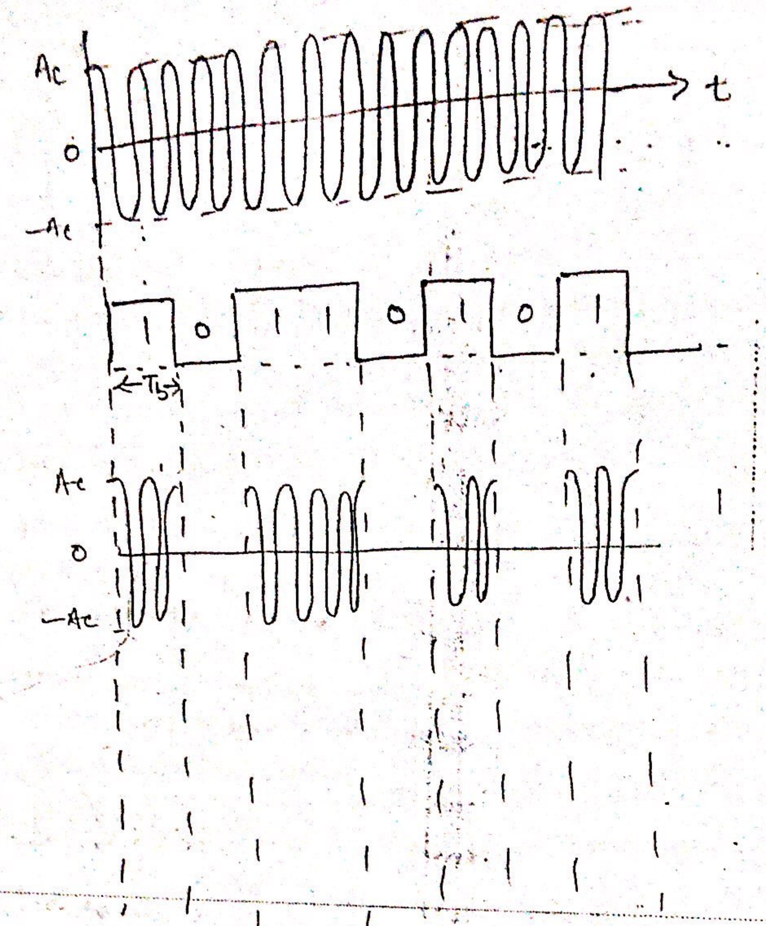
Also known as on-off keying (OOK)

Let carrier wave

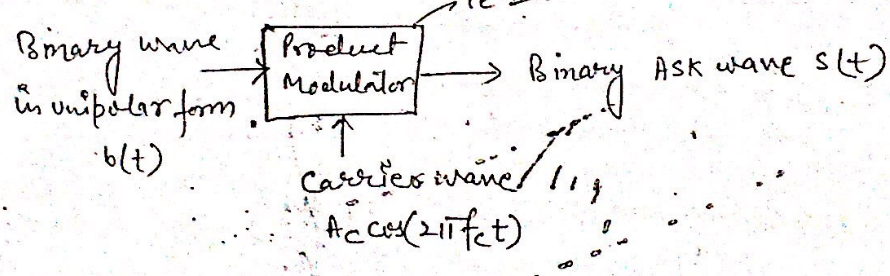
$$\left[e_c(t) = A_c \cos(2\pi f_c t)\right]$$

Then binary ASK signal $s(t)$ is given by

$$s(t) = A_c \cos(2\pi f_c t), \quad \text{symbol } 1$$
$$= 0 \quad \text{symbol } 0$$



Generation of ASK signal



① ASK signal which is product of binary sequence and carrier signal has a power spectrum density (PSD) same as baseband on-off signal but shifted in the freq. domain by $\pm f_c$.

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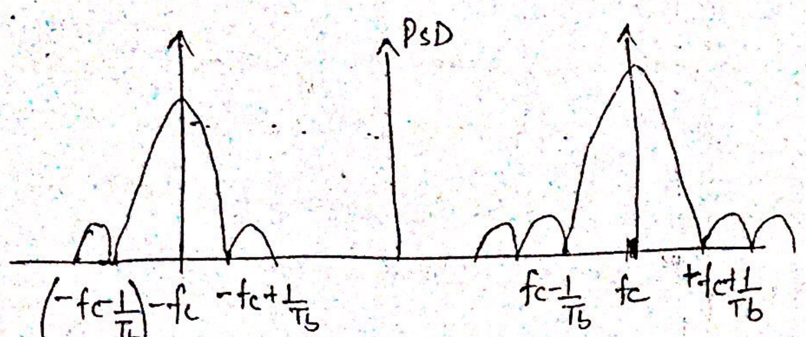
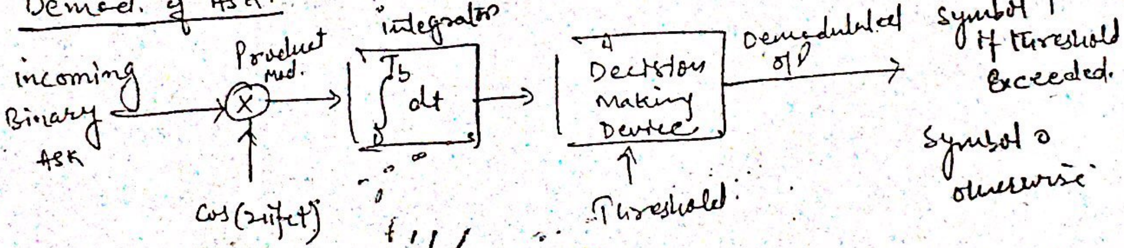


(4) Spectrum of ASK shows that it has infinite bandwidth.

(5) But practically bandwidth defined as bandwidth of an ideal band pass filter centered at f_c whose o/p contains 95% of the total average power content of the ASK signal.

(6) Bandwidth of ASK can be reduced by using smoothed version of the pulse waveform instead of rectangular pulse waveform.

Demod. of ASK.



(1) o/p of prod. mod. is goes to integrator. The integrator operates on the o/p of multiplier for successive bit interval and essentially performs a low pass filtering action.

(2) Now Decision making device compares the o/p of the integrator with a present threshold.

(3) It makes decision in favour of symbol 1 when threshold is exceeded and favour of symbol 0 otherwise

(4) The coherent detection makes the use of linear operation.

(5) we assumed that

(1) local carrier is in perfect synchronisation with the carrier used in the transmitter.

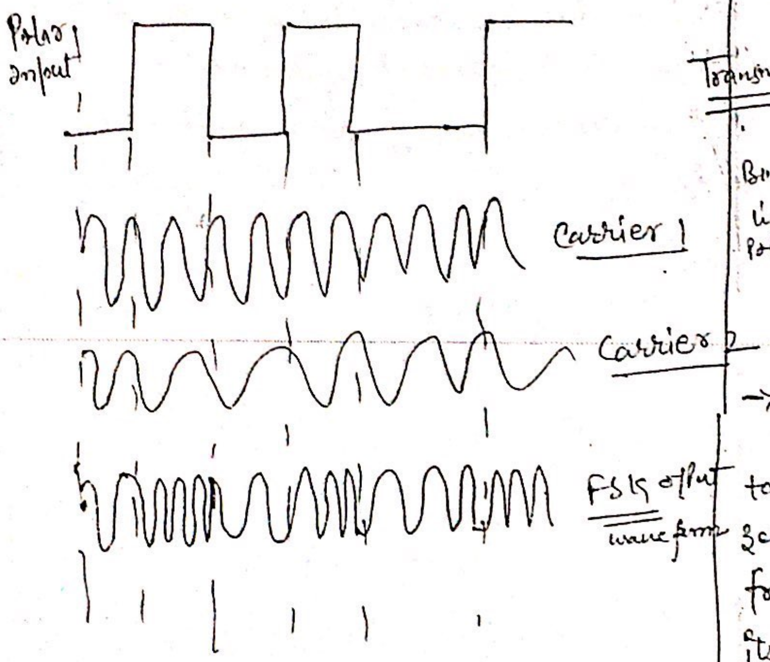
(2) Means freq. and phase of the locally generated carrier is same as those of the carriers used in the transmitter.

③

FSK Freq. shift keying

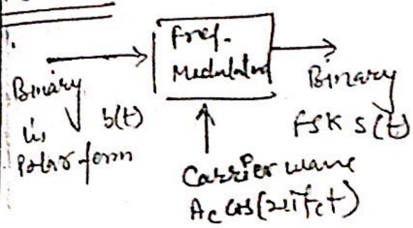
① Two sinusoidal carrier waves of the same amp. A_c but different frequencies f_{c_1} and f_{c_2} are used to represent binary symbol 1 and 0.

$$\begin{bmatrix} s(t) = A_c \cos(2\pi f_{c_1} t), & \text{symbol } 1 \\ \quad\; = A_c \cos(2\pi f_{c_2} t), & \text{symbol } 0 \end{bmatrix}$$



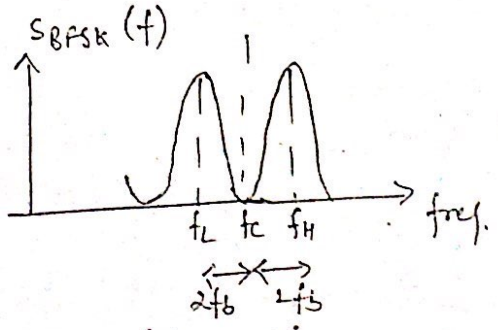
Modulator (Tr)
Generation.

Transmitter



→ As modulating voltage change from one level to another (both non zero being polar) the freq. mod. o/p change its freq in the corresponding fashion.

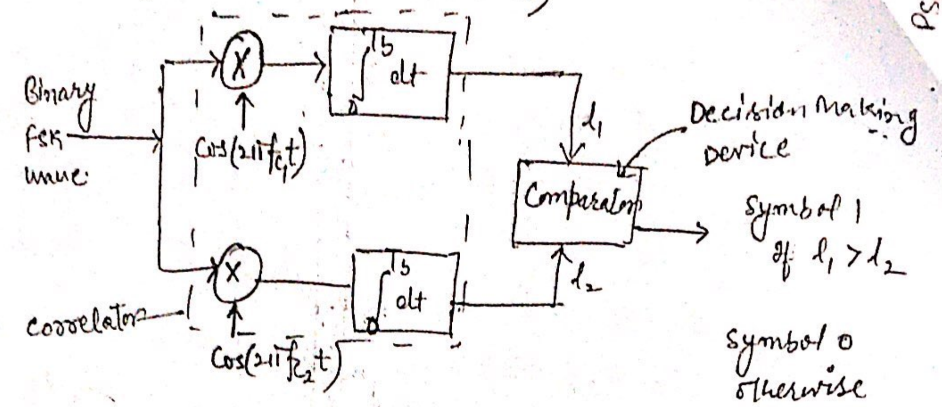
PSD, Power Spectral Density



Band width $= 2f_b + 2f_b$

$\boxed{BW = 4f_b}$

Receiver of FSK (Coherent Receiver)



① Rx Consist of two correlators that are individually tuned to two different carrier frequencies to represent symbol 0 and 1.

② Integrator o/p is feed decision making device and after comparision of l_1 and l_2 symbol 0 and 1 is received.

PSK or BPSK (Binary Phase Shift Keying)

→ used for high bit rates.

→ A bipolar NRZ signal is used to represent the digital data coming from the digital source.

→ Expression

Binary symbol 1 and 0 modulate the phase of the carrier $s(t)$.

$$s(t) = A\cos(2\pi f_c t)$$

↑ Peak value

for 1Ω load resistor, Power dissipated

$$P = \frac{1}{2}A^2 \quad \text{or} \quad 2P = A^2$$

$$A = \sqrt{2P}$$

when symbol is changed then ϕ of the carrier will also be changed by $180°$ (π radian).

for symbol '1'

$$s_1(t) = \sqrt{2P}\cos(2\pi f_c t)$$

if next symbol is '0'

$$s_2(t) = \sqrt{2P}\cos(2\pi f_c t + \pi)$$

Now $\cos(\theta + \pi) = -\cos\theta$

$\therefore$

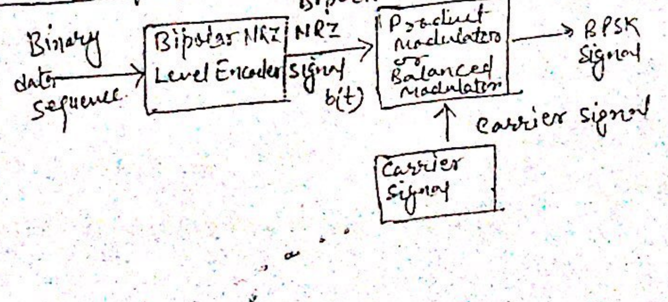
$$s_2(t) = -\sqrt{2P}\cos(2\pi f_c t)$$

or

$$s(t) = (\pm 1)\sqrt{2P}\cos(2\pi f_c t)$$

$b(t)$ = +1 when 1 is transmitted
−1 when 0 is transmitted.

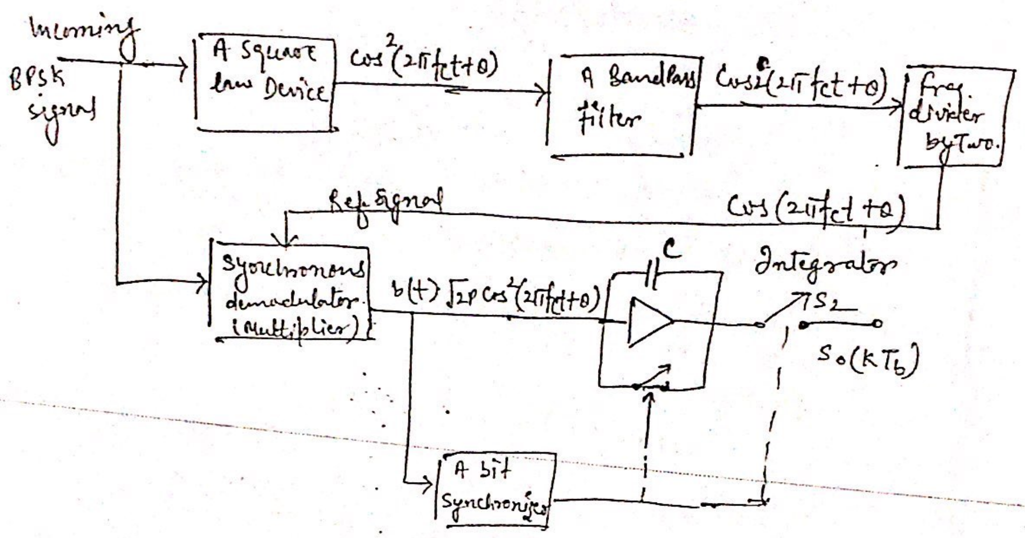
Generation of BPSK



Input digital Signal	Bipolar NRZ Signal b(t)	BPSK o/p Signal
Binary 0	$b(t) = -1$	$-\sqrt{2P}\cos\omega_c t$
Binary 1	$b(t) = +1$	$+\sqrt{2P}\cos\omega_c t$

$P = \frac{E_b}{T_b}$ $E_b \rightarrow$ Signal Energy, $T_b \rightarrow$ bit duration

Reception of BPSK Signal (Coherent)



$\Rightarrow$ $s(t) = b(t)\sqrt{2P}\cos(2\pi f_c t)$

(1) This signal undergoes the phase change depending upon the time delay from tr. to receiver end.

(2) This phase shift is usually a fixed phase shift in the transmitted signal.

Let phase shift $= \theta$

Now signal at input of receiver is

$$\left[s(t) = b(t)\sqrt{2P}\cos(2\pi f_c t+\theta)\right]$$

(3) carrier is separated through a square law device

o/p of square law device

$\Rightarrow$ $\cos^2(2\pi f_c t+\theta)$

Note – Neglected amplitude, carrier of the signal interested in

$\therefore \cos^2\theta = \frac{1+\cos 2\theta}{2}$

Therefore $\cos^2(2\pi f_c t+\theta) = \frac{1+\cos 2(2\pi f_c t+\theta)}{2} = \frac{1}{2} + \frac{1}{2}\cos 2(2\pi f_c t+\theta)$

$\frac{1}{2}$ represents a DC level.

This signal is pass through a BPF, whose band pass is centered around $2f_c$.

Band pass filter removes the DC level of $\frac{1}{2}$ and o/p will be

$$\left[\cos 2(2\pi f_c t+\theta)\right]$$

This signal having freq $2f_c$. Hence it is pass through a freq. divider by two.

At the o/p of freq divider get carrier whose freq is f_c

ie $\cos(2\pi f_c t+\theta)$

Synchronous demodulator → multiplies the input signal and the recovered carrier.

$$b(t)\sqrt{2P}\cos(2\pi f_c t+\theta) \times \cos(2\pi f_c t+\theta) = b(t)\sqrt{2P}\cos^2(2\pi f_c t+\theta)$$

$$= b(t)\sqrt{2P} \times \frac{1}{2}\left[1+\cos 2(2\pi f_c t+\theta)\right]$$

$$= b(t)\sqrt{\frac{2P}{4_2}}\left[1+\cos 2(2\pi f_c t+\theta)\right]$$

$$= b(t)\sqrt{\frac{P}{2}}\left[1+\cos 2(2\pi f_c t+\theta)\right]$$

Now integrator integrates the signal over one bit period. and Bit Synchronizer takes care of starting and ending times of a bit.

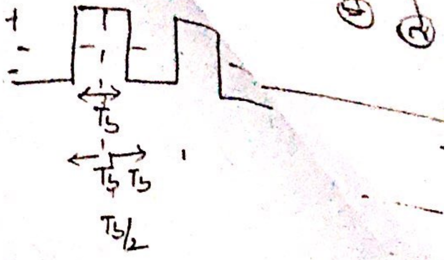
At the end of bit duration T_b bit synchronizer close the switch S_2

this connects the o/p of an integrator to the decision devices

It is equivallent to sampling the o/p of integrator.

Spectrum of BPSK Signal

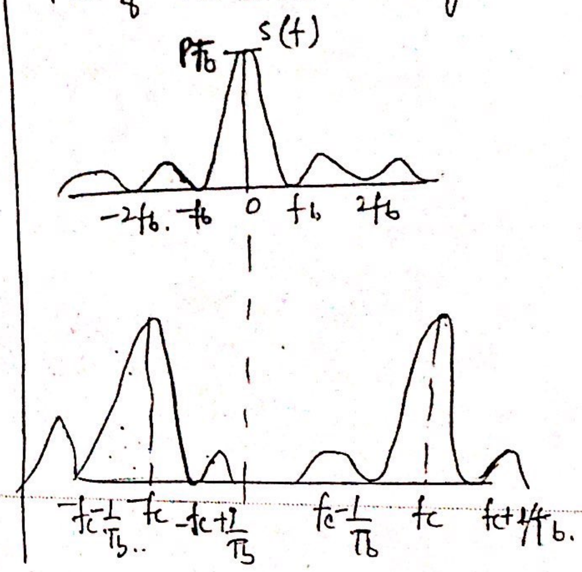
Pulse is $\pm \frac{T_b}{2}$ around its centre



then it becomes easy to find F. Transform of such Pulse.

$$X(f) = V_1 T_b \frac{\sin(\pi f T_b)}{(\pi f T_b)}$$

PSD of NRZ baseband signal



$$B.W = \left(f_c + \frac{1}{T_b}\right) - \left(f_c - \frac{1}{T_b}\right)$$

$$\cancel{f_c} + \frac{1}{T_b} - \cancel{f_c} + \frac{1}{T_b}$$

$$BW = \boxed{\frac{2}{T_b}}$$

Min. B.W of BPSK Signal is equal to twice of the highest freq. contained in base band signal.

DPSK (Differential Phase Shift keying) ①

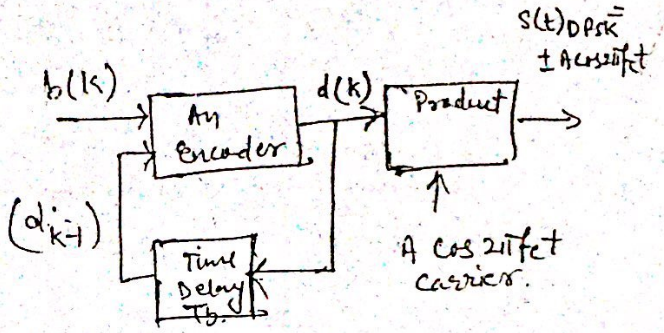
① → DPSK is view as non coherent version of PSK.

② → Does not need carrier at the demodulator.

③ → Input sequence of binary bits is modified such that the next bit depends upon the previous bit.

④ → Means the previous received bits are used to detect the present bit.

Generation of DPSK



Encoding Technique

① → In order to eliminate carrier need for phase syn: so ~~of~~ we use DPSK.

② → The symbol 0 may be used to represent transition in ~~it~~ a given binary sequence (with respect to previous encoded bit) and symbol 1 to indicate no transition.

③ → New signaling technique which combines differential encoding with ~~DPSK~~ PSK is known as DPSK.

Schematic diagram.

① b(t) is applied to the input of Encoder.

② 2nd input to Encoder is d_{K-1}.

③ EXNOR o/p of d_K is given to Product modulator and time delay ckt.

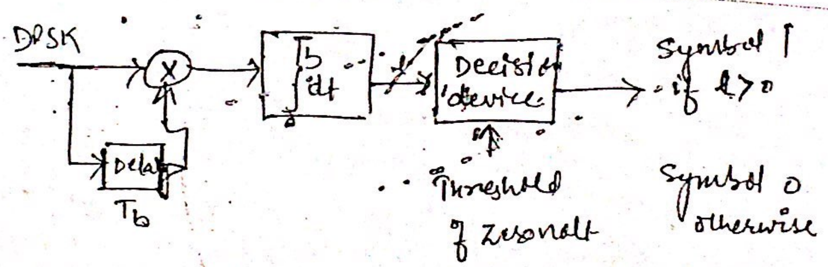
④ Carrier is applied at product modulator.

⑤ o/p of Product modulator is DPSK.

Binary data		0	0	1	0	0	1	0	0	1	1
Diff $d(k)$ Encoded data	1*	0	1	1	0	1	1	0	1	1	1
Phase of DPSK	0	π	0	0	π	0	0	π	0	0	0
d_{K-1}		1	0	1	1	0	1	1	0	1	1
Phase of shifted DPSK		0	π	0	0	π	0	0	π	0	0
Phase comparision o/p.		−	−	+	−	−	+	−	−	+	+
Detected binary sequence		0	0	1	0	0	1	0	0	1	1

* Arbitrary starting ref. bit

Detection of DPSK



① Received DPSK signal is applied to one input of the multiplier.
② other input of of the multiplier a delayed version of the received DPSK signal by time interval T_b is applied.
③ o/put of the difference is proportion to $\cos(\phi)$ where ϕ is difference b/w. the carrier phase angle of received DPSK signal and its delayed version, measured in the same bit interval

Digital Modulation Technique — 2 Categories — Coherent / Non Coherent] Depending ② upon Rx having phase recovery ckt or not.

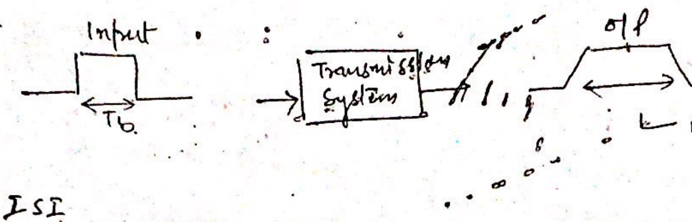
Coherent	Non Coherent
① use a phase synchronized carrier to be generated at the receiver to recover the information signal.	① No phase synchronized local carrier is needed at the receiver.
② Freq. and phase of this carrier produced at the receiver should be synchronised with that at the transmitter	② These Techniques are less complex.
③ coherent techniques are complex but with better performance.	③ Performance is inferior to that of coherent techniques.
	④ Error probability increase.

ISI

① when data is being transmitted in the form of pulses or bits, the o/put produced at the receiver due to other bits or symbol interferes with the o/p produced by the desired bits

Factor Responsible for ISI

ISI (Intersymbol interference)

- Arise due to imperfection in the overall freq response of the system
- when a pulse T_b second is transmitted through a bandlimited system then the freq components in the input pulse are differentially attenuated and differentially delayed by the system.
- 

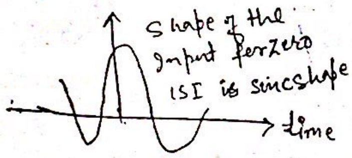
Effect of ISI

- Introduce error at the receiver o/put for decision making whether it has received a logic 1 or logic 0.

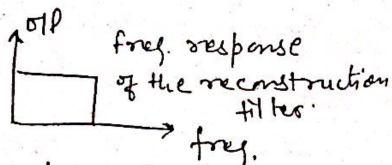
Remedy

① fx which has zero ISI is sinc fx. Hence instead of a rectangular pulse if we transmit a sinc pulse then the ISI can be reduced to zero.

② This is known as Nyquist pulse shaping.



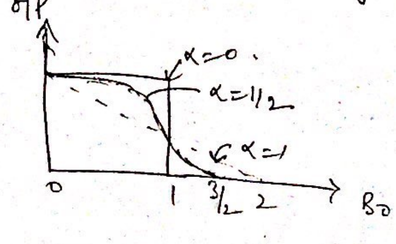
Ideal pulse shape for zero ISI



But practically not possible.

③ Fourier Trf fx of a sinc fx is Rectangular fx.

④ ~~Hence~~ To preserve all the freq components, freq response of the filter must be exactly flat in the pass band and zero in the attenuation band.



QPSK (Quadrature PSK)

① Keep the baud rate same and increase the bit rate by using multilevel modulation technique.

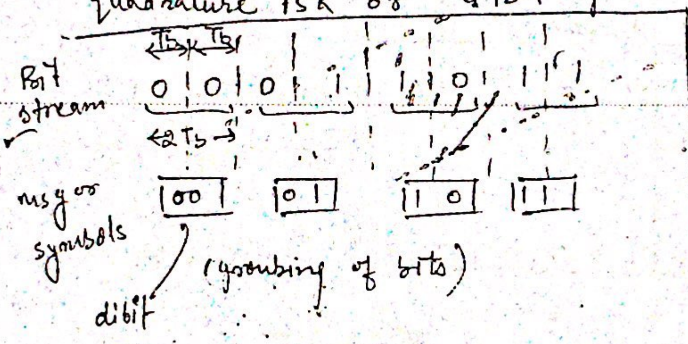
② Data groups are divided into groups of two or more bits and each group of bits is represented by a specific value of phase of the carrier. (dibit)

③ Each symbol or message contains two bits hence symbol duration

$$\boxed{T_s = 2T_b}$$

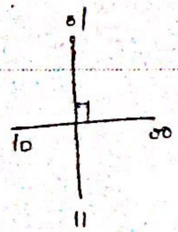
④ These symbols are transmitted by transmitting the same carrier at four different phase shifts.

⑤ Due to four phase shifts involved this system is called quadrature PSK or 4 PSK system.

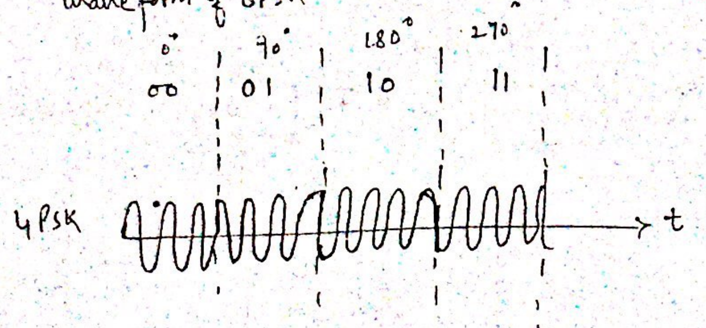


Phase shift in QPSK

Symbol	Phase
00	0
01	90
10	180
11	270



waveform of QPSK



baud rate $= \frac{1}{T_s}$ (symbols per second), T_s → symbol duration

No of possible signal (M)

$M = 2^n$ → grouping of bits, an integer

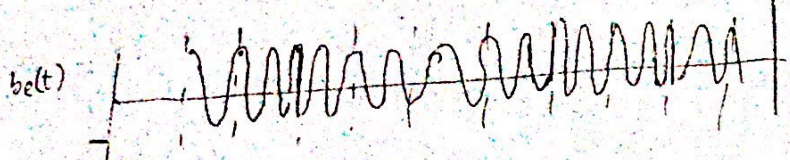
$T = nT_b$

$M = 2^2$

$M = 4$

One of four possible signal is transmitted during each signaling interval.

⑥ Each signal uniquely related to a dibit.



QPSK signal mathematically representation

$$S(t) \text{ or } V_{QPSK}(t) = \sqrt{2P_s}\cos\left[w_c t + \underbrace{(2m+1)\frac{\pi}{4}}_{\phi(t)}\right] \quad m = 0,1,2,3$$

$P_s = \frac{E}{T}$ E → Symbol Energy, T → Symbol time duration

for m = 0

$$S_1 = \sqrt{2P_s}\cos\left[w_c t + \frac{\pi}{4}\right]$$

m = 1

$$S_2 = \sqrt{2P_s}\cos\left[w_c t + \left(3\frac{\pi}{4}\right)\right]$$

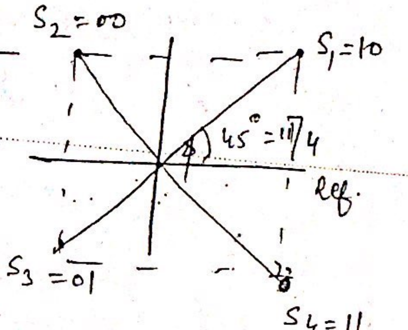
m = 2

$$S_3 = \sqrt{2P_s}\cos\left[w_c t + \left(5\frac{\pi}{4}\right)\right]$$

m = 3

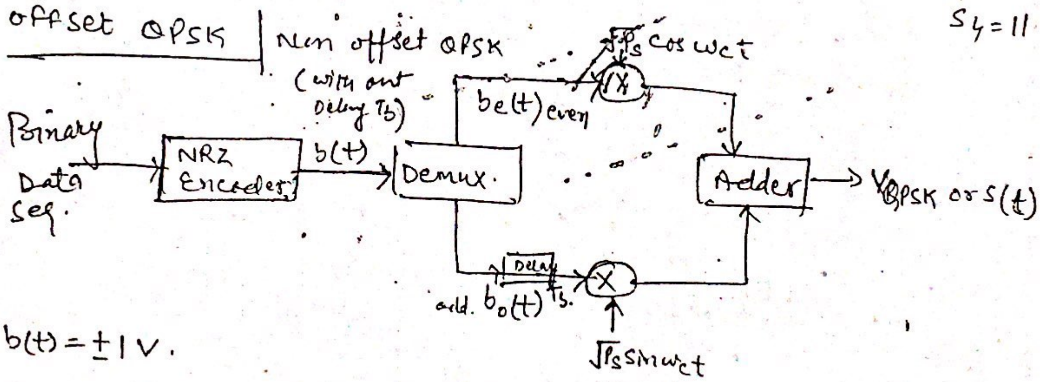
$$S_4 = \sqrt{2P_s}\cos\left[w_c t + \left(\frac{7\pi}{4}\right)\right]$$

Symbol	Input A	Input B	Phase shift in Carrier
S_1	1	0	$\pi/4$
S_2	0	0	$3\pi/4$
S_3	0	1	$5\pi/4$
S_4	1	1	$7\pi/4$



Transmitter

offset QPSK | Non offset QPSK (without Delay T_b)



① $b(t) = \pm 1V$.

② Demux divide b(t) into two separate bit stream $b_o(t)$ and $b_e(t)$
$b_e(t)$ consist of even numbered ie 2, 4, 6 ---
$b_o(t)$ " " odd number ie 1, 3, 5

③ Each bit in even or odd bit streams will be for $2T_b$ seconds. This duration is known as symbol duration T_s.

Means that every symbol contains two bits.

4. First 'odd bit' (1 bit) occur before the first even bit (bit 2). Hence even bit $b_e(t)$ start with a delay of one bit period after the first odd bit.

5. This delay is equal to one bit period T_b.

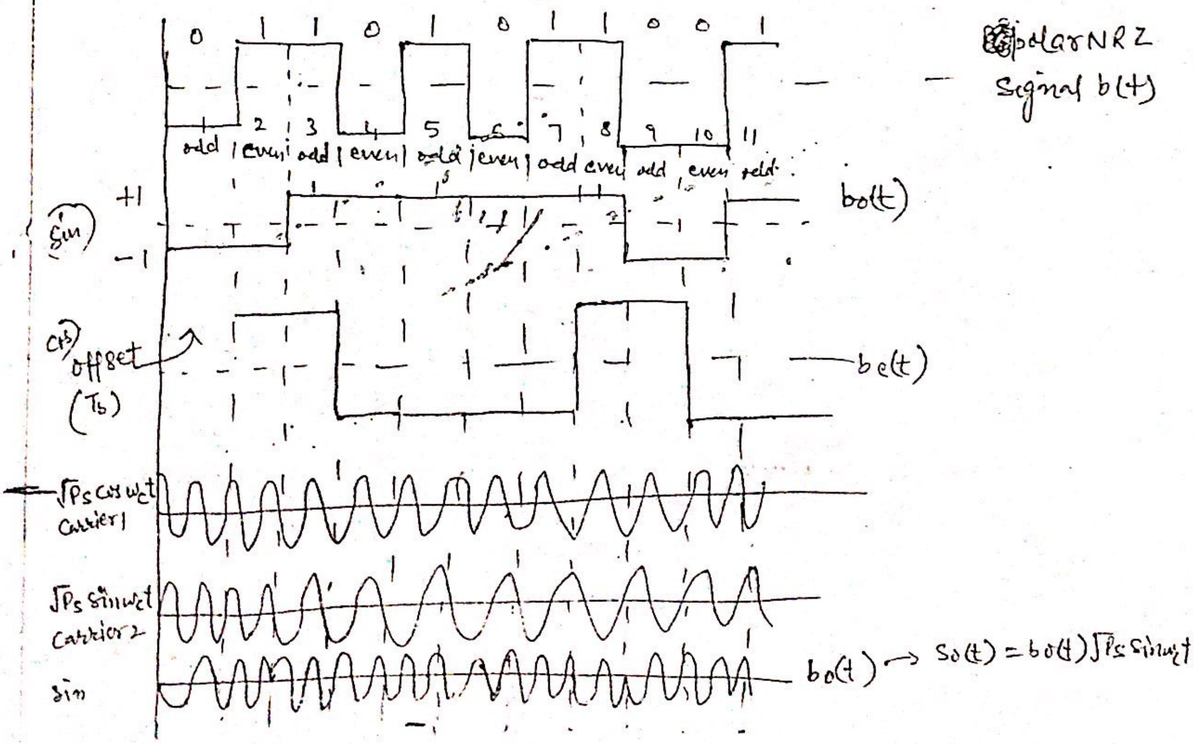
6. This delay is called as offset.

7. Due to offset $b_o(t)$ and $b_e(t)$ can not change their level at the same instant of time.

8. $b_o(t)$ is superimposed on $\sqrt{P_s}\cos\omega_c t$ and $b_e(t)$ is " " $\sqrt{P_s}\sin\omega_c t$ by the use of two multiplier. (Bal. Modulator) to generate $s_e(t)$ and $s_o(t)$.

9. These two signal are BPSK and then added to generate QPSK o/put.

$$s(t)\ V_{QPSK}(t) = \sqrt{P_s}\ b_o(t)\sin\omega_c t + \sqrt{P_s}\ b_e(t)\cos\omega_c t$$



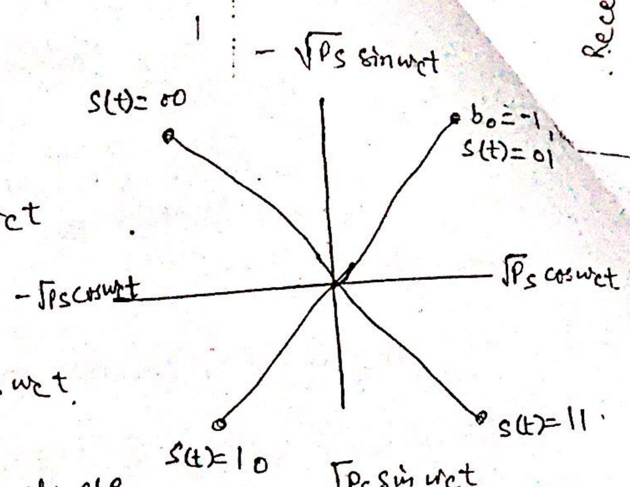
Now

∴ $b_o(t) = 1$, $S_o(t) = \sqrt{P_s} \sin w_c t$

$b_o(t) = 0$, $S_o(t) = -\sqrt{P_s} \sin w_c t$

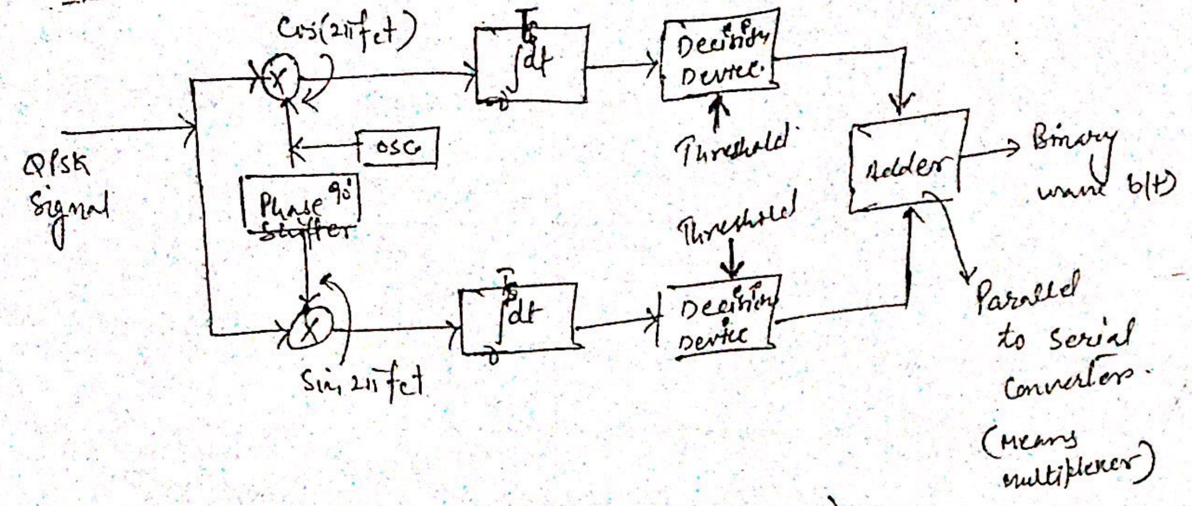
Similarly

$b_e(t) = \pm 1$, $S_o(t) = \pm \sqrt{P_s} \cos w_c t$

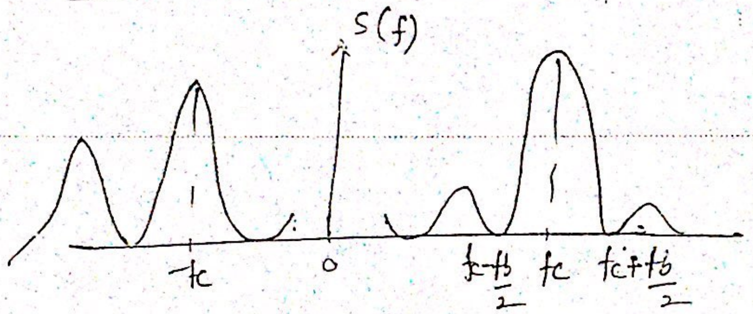


These 4 possible o/p ~~sx~~ signals are equal in amp. $\sqrt{2P_s}$ and in quadrature in phase.

Receiver of QPSK (Coherent) ③



Spectrum of QPSK (Power spectral Density PSD)

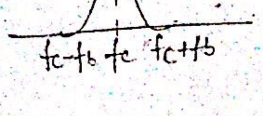


$$B.W = \cancel{f_c} + \frac{f_b}{2} - \cancel{f_c} + \frac{f_b}{2}$$

$$B.W = \frac{\cancel{2} f_b}{\cancel{2}}$$

$$\boxed{B.W = f_b}$$

B.w of QPSK is half of the B.w of BPSK.



$\cancel{f_c} + f_b - \cancel{f_c} + f_b$

$B.W = \boxed{2 f_b}$

erfc - Comp. error fx.

Error probablity of QPSK

$$P_e = \frac{1}{2} \text{erfc} \sqrt{E_b/N_0}$$

P_e of QPSK is same as BPSK. so Performance in presence of noise is Equivalent to BPSK.

Advantages

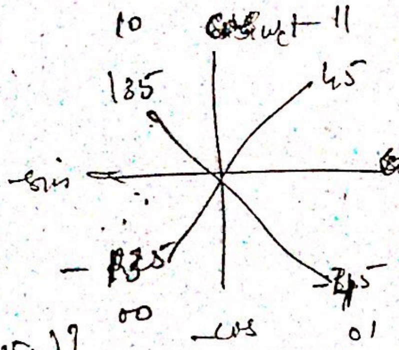
① Baud rate is half the bit rate so more effective utilization of B.W of Tr. channel.

② used for high bit data transmission. (low error prob.)

Drawbacks

Tr./Rx is quite complex.

QPSK



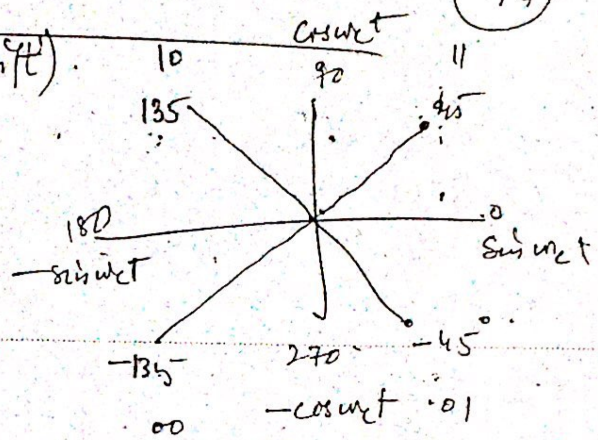
135
90
22.5
90
315

$v_{QPSK}(t) = A\cos\left[\omega_c t + (2m+1)\pi/4\right]$

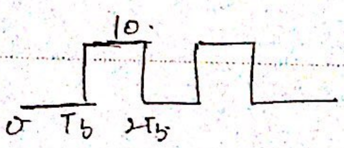
$m = 0, 1, 2, 3, 4.$

$180/4$

$\boxed{QPSK}$ (quadrature ϕ shift) Keying



10|10|11|00



Baud rate $= \frac{1}{t_s}$ symbol duration
$t_s \rightarrow$ timing

$\boxed{T_s = 2T_b}$

$4\overline{)1260}(315$ — 135, 235, 315

$s(t) = A\cos\left[\omega_c t + (2m+1)\pi/4\right)$

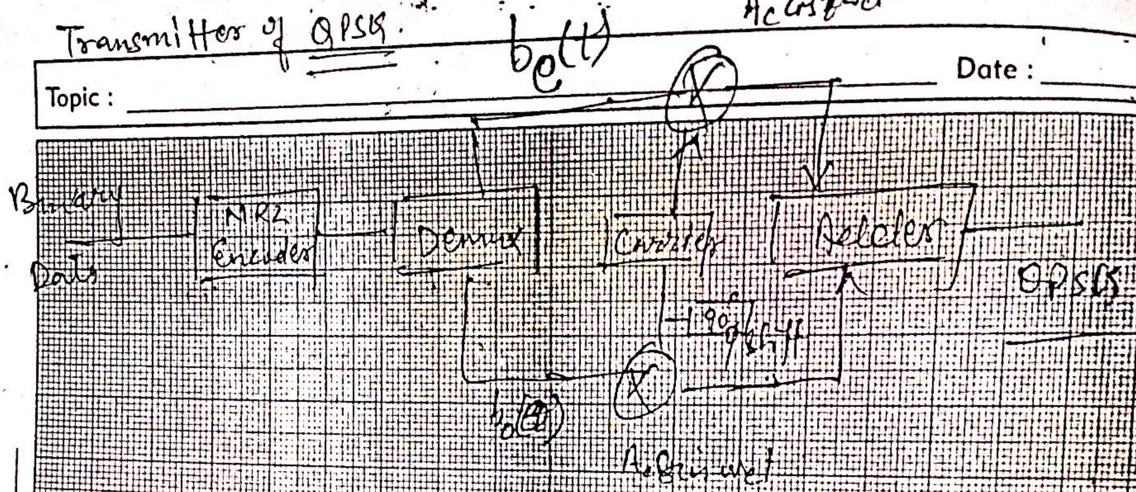
$m = 0, 1, 2, 3$

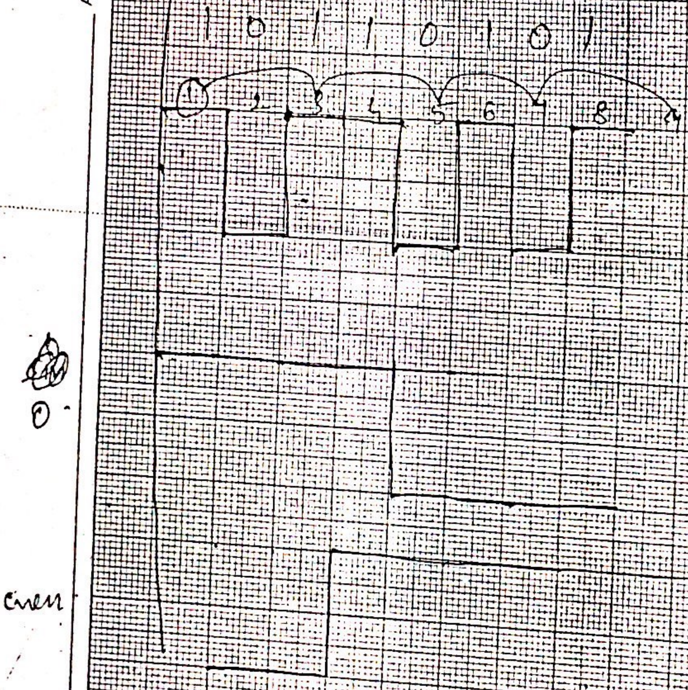
$= \begin{bmatrix} \pi/4 \\ 3\pi/4 \\ 5\pi/4 \\ 7\pi/4 \end{bmatrix}$ —

Symbol		Angle
0	0	-135
0	1	-45
1	0	$+135$
1	1	$+45$

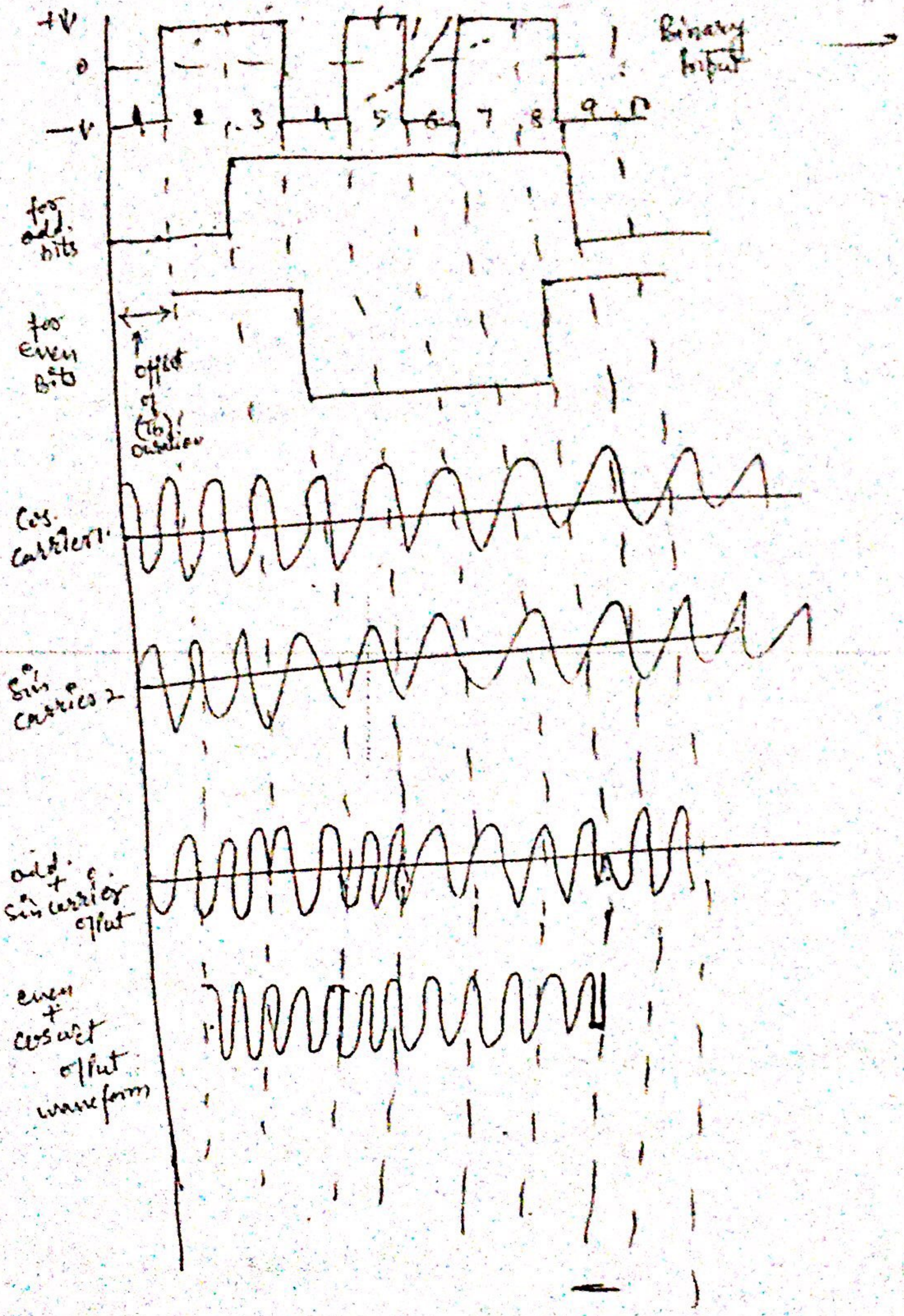
Transmitter of QPSK.

Topic : Date :





QPSK waveform.



M-Ary Modulation Techniques.

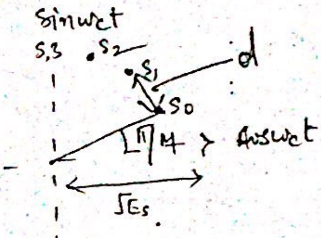
M-ary-PSK
M-ary-QAM
M-ary-FSK

⇒ **M-ary PSK** (M-ary Phase Shift Keying)

(i) Group N bits together to form N-bit symbols.

(ii) These symbols will extend over a period of NT_b where T_b is the duration of one bit.

(iii) Due to grouping of N bits per symbol $2^N = M$ Possible symbols.



Mathematically Representation

$$S(t) \text{ or } V_{mary\ PSK} = A \cos(w_c t + \phi_m)$$

$m = 0, 1, \ldots M-1$

$$\boxed{\phi_m = (2m+1)\pi/M}$$

$$S(t) = A \cos\left(w_c t + (2m+1)\frac{\pi}{M}\right) \quad \sin w_c t$$

when $m=0$ $\quad A \cos\left(w_c t + \frac{\pi}{M}\right)$

$m=1$ $\quad A \cos w_c t + \frac{3\pi}{M}$

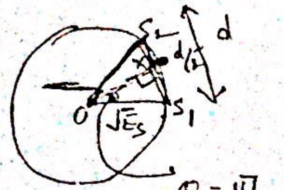
$m=2$ $\quad A \cos w_c t + \frac{5\pi}{M}$

⋮

M ary PSK represented by dots in signal space diagram in which coordinate axis are formed by orthogonal waveform A cos wct and A sin wct.

(iv) 'd' is Euclidean distance.

(v) Prob. of error ↓ing with ↑es in 'd'.



Let Right angle triangle

$$\sin\theta \text{ or } \sin \pi/M = \frac{\text{Distance } S_1 - X}{\text{Distance } O - S_1} = \frac{d/2}{\sqrt{E_s}} \Rightarrow d = 2\sqrt{E_s}\sin(\pi/M)$$

B.W

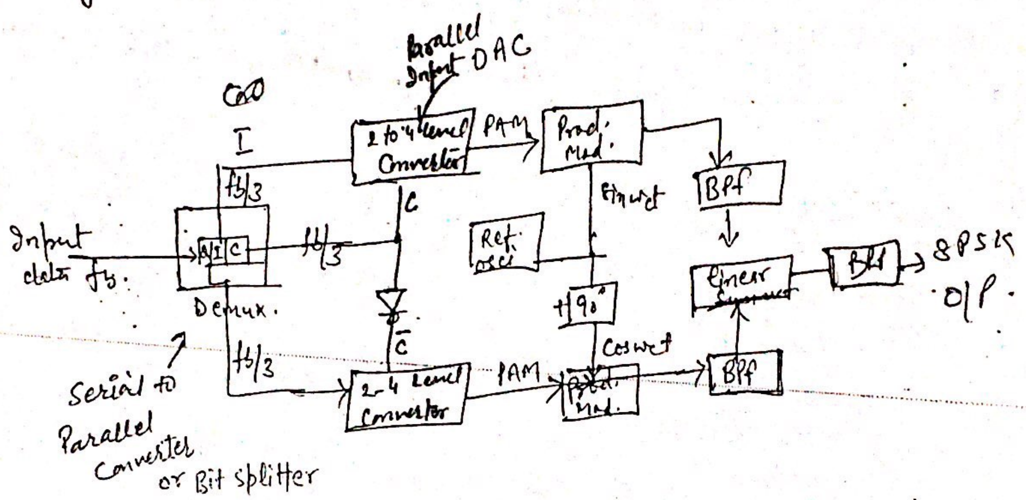
In PSK B.W = $2f_b$

QPSK B.W = $\frac{2f_b}{2} = f_b$

In Mary PSK = $\boxed{\frac{2f_b}{N}}$ ← B.W

Means that with ↑es no. of bits per msg B.W ↓es.

M-ary ~~PSK~~ Transmitter. (8 PSK).



① Incoming serial bit converted to parallel 3 channels

I, – In phase channel

Q – quadrature "

C – control channel

② Bit rate of each of 3 channels is $f_b/3$.

③ I and C channels enters in I (2 to 4) level converter.

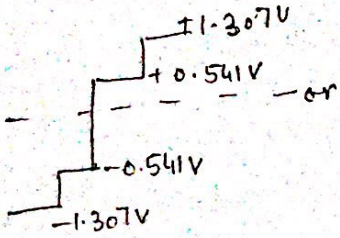
④ Q and $\bar{C}$ channels enters in Q (2 to 4) " " .

⑤ with two input 4 o/p is possible !

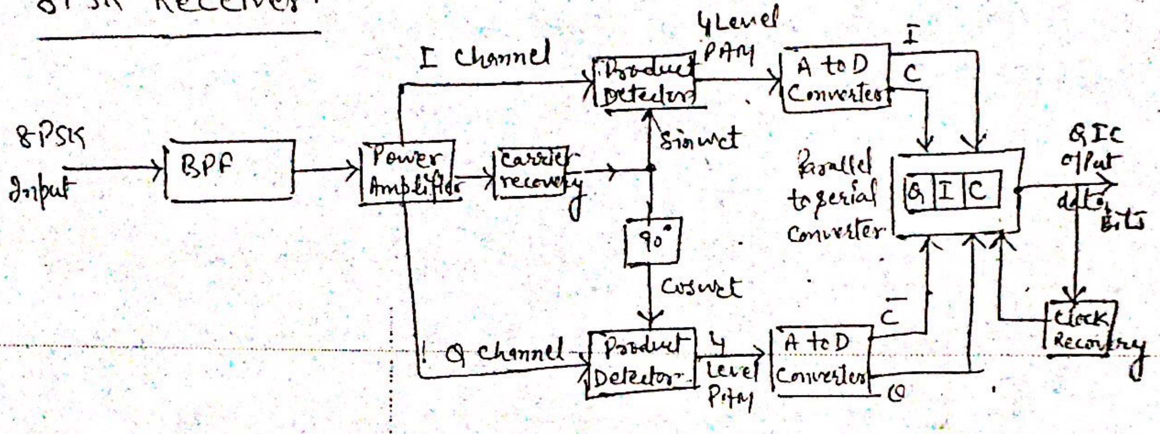
⑥ I and Q bit determine the polarity of the o/p analog signal – (logic 1 = +v, 0 = –v) where as C and $\bar{C}$ determines the magnitude

Logic 1 = 1.307 V
0 = 0.541 V

Two magnitude and two polarities, four different o/p. cond^n are possible.

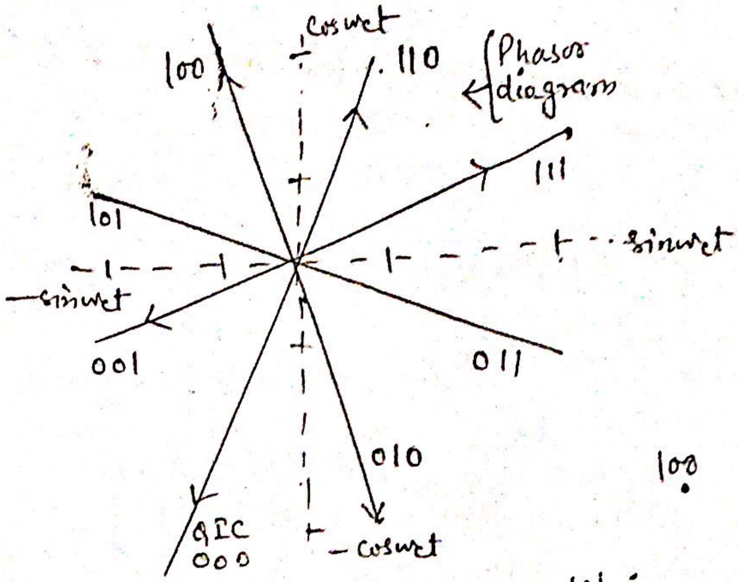


8PSK Receiver.

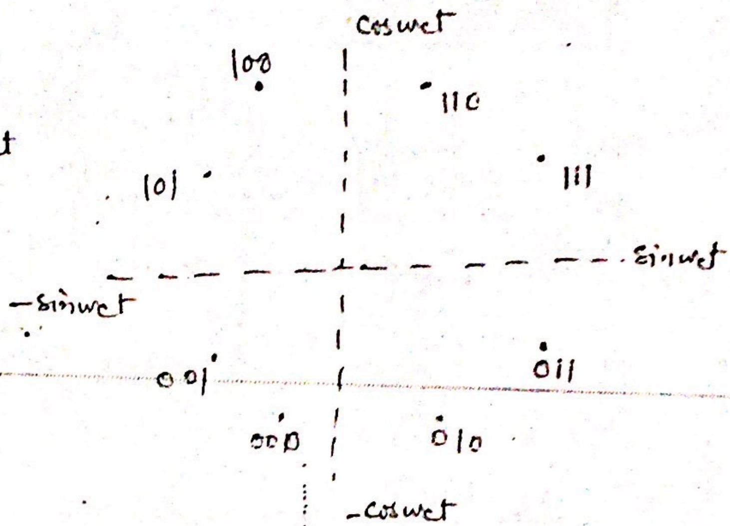


1. Carrier recovery ckt reproduces the origional reference oscillator ckt.
2. Input signal is mixed with the recovered carrier in I and Q product detector.
3. o/p of product detector is 4 level PAM signals that are feed to 4 to 2 level A to D converters.
4. o/p of A to D are I and C, $\bar{C}$ and Q bits.
5. Parallel to serial logic ckt converts the I/c and Q/$\bar{C}$ bit pairs to serial I, Q and C o/put data stream.

Constellation Diagram | Phasor diagram

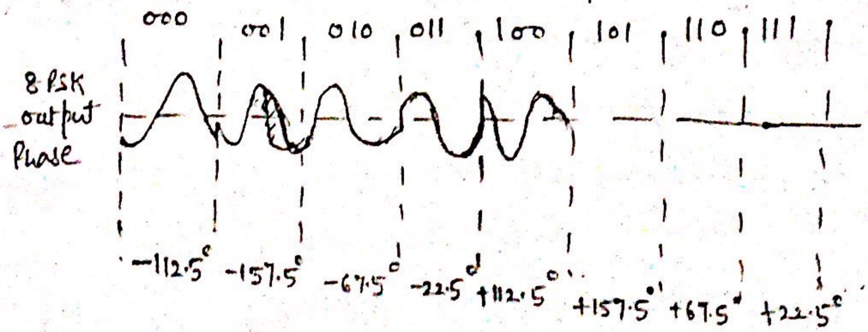


Binary input	8-PSK output Phase
Q I C	
0 0 0	$-112.5°$
0 0 1	$-157.5°$
0 1 0	$-67.5°$
0 1 1	$-22.5°$
1 0 0	$+112.5°$
1 0 1	$+157.5°$
1 1 0	$+67.5°$
1 1 1	$+22.5°$



[Constellation diagram]

O/P phase versus time relationship 8-PSK



QAM (Quadrature Amplitude modulation)

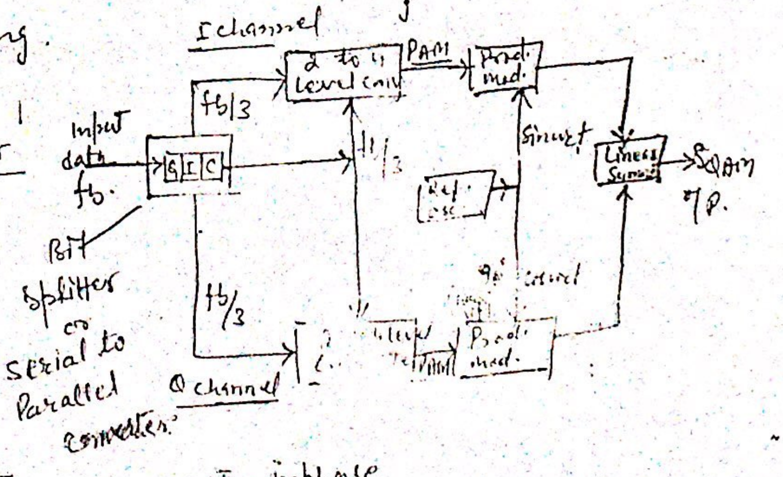
① Noise immunity will improve if the signal vector differ not only in phase but also in amplitude.

② Such a system is called amplitude and phase shift keying system.

③ Direct modulation of carrier in quadrature (cos wct and sin wct) is involved, therefore this system is called as Q.A.PSK or simply QAPSK or quadrature amplitude modulation (QAM).

④ Digital information is contained in both amp. and phase of transmitter carrier.

⑤ Phase and amp. are combined in such a way that the position of the signaling elements on the constellation diagram are optimized to achieve the greatest distance b/w elements thus reducing the liklihood of errors occuring.



8-QAM Transmitter

Tx.
$m = 8$

$2^3 = 8$

$\boxed{N = 3}$

I/Q	C	o/Put
0	0	−0.541 V
0	1	−1.307 V
1	0	+0.541 V
1	1	+1.307 V

I - inphase

Q - quadrature in phase

C - control

Scanned with CamScanner

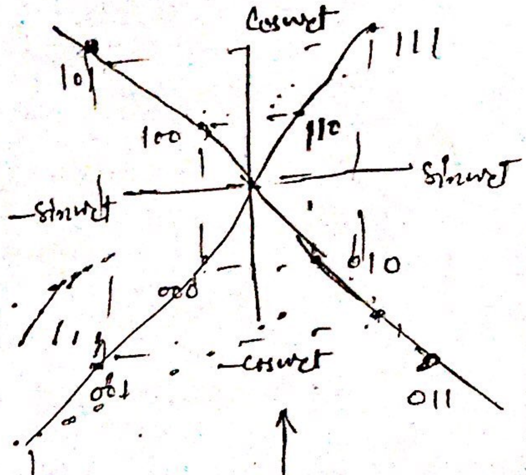
Band width of 8QAM

① same as 8PSK.

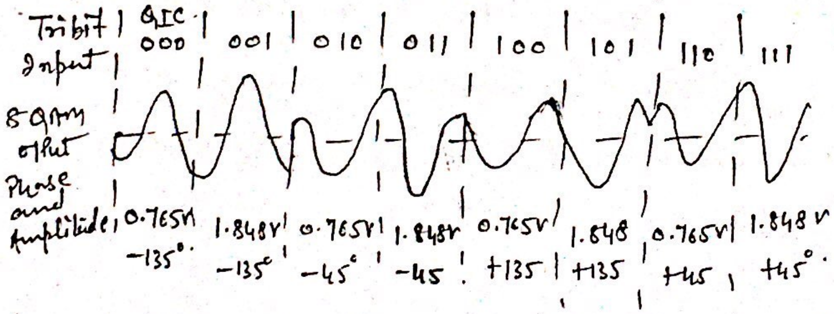
$\frac{2f_b}{3}$

Truth Table.

Binary input			8QAM o/put	
Q	I	C	Amplitude	Phase
0	0	0	0.765 V	−135°
0	0	1	1.848 V	−135
0	1	0	0.765 V	−45
0	1	1	1.848 V	−45
1	0	0	0.765	+135
1	0	1	1.848	+135
1	1	0	0.765	+45
1	1	1	1.848	+45

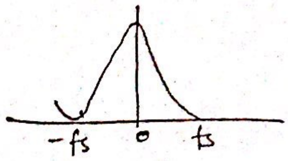


Phasor Diagrams
Constellation diagrams



Band width of 8QAM.

B.W is same as that of 8PSK.

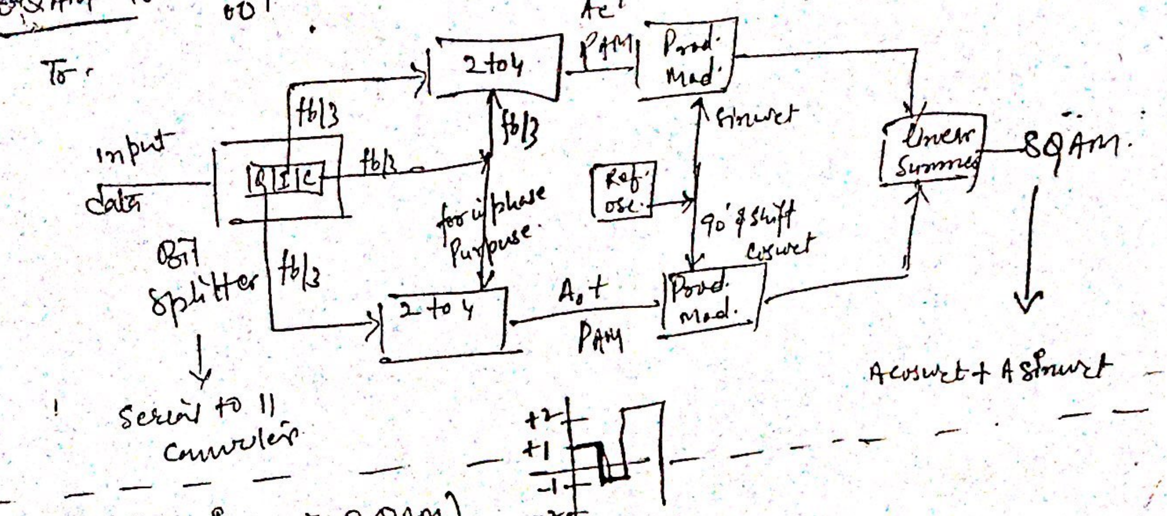


$B.W = f_s - (-f_s) = 2f_s$

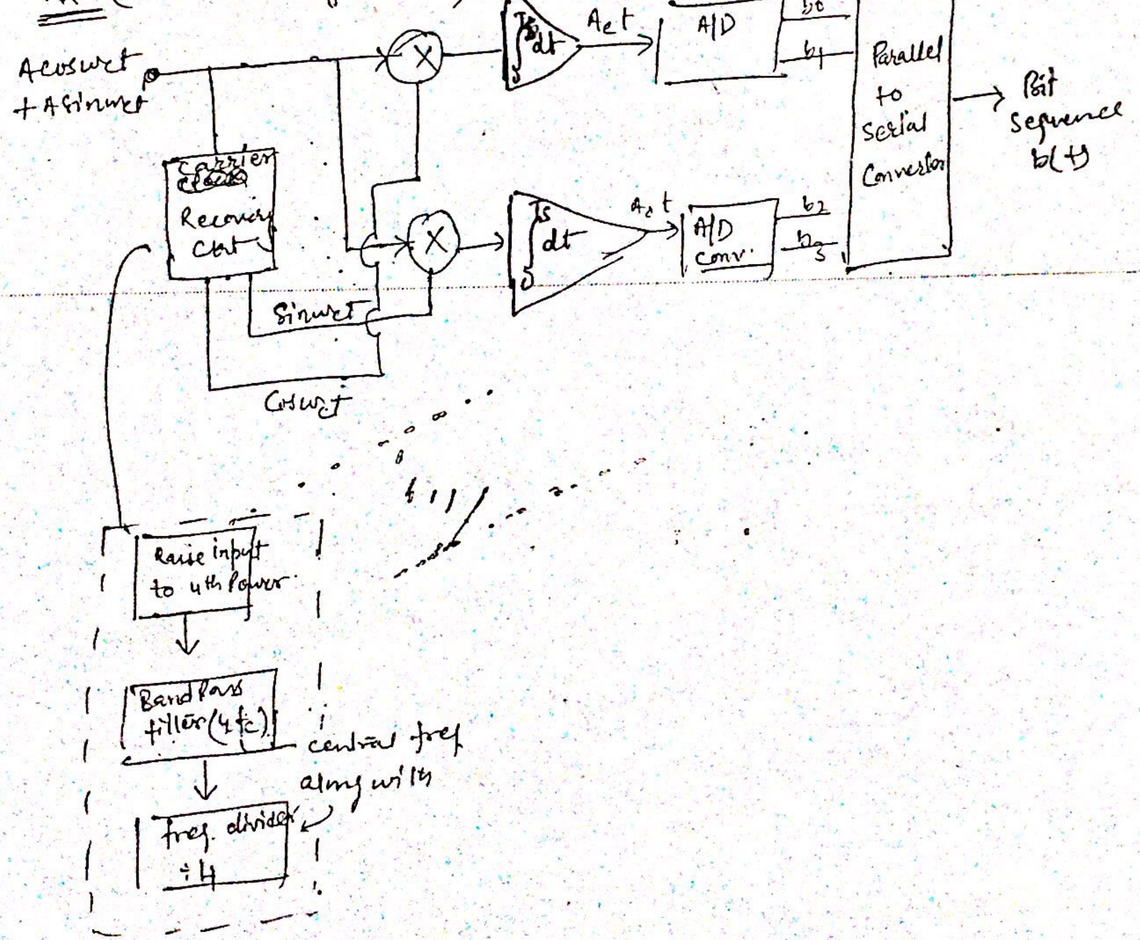
$B.W = \frac{2}{T_s} = \frac{2}{N \cdot T_b}$ $\therefore T_s = N T_b$

$B.W = \frac{2f_b}{N}$ $\because f_b = \frac{1}{T_b}$

8QAM Transmitter



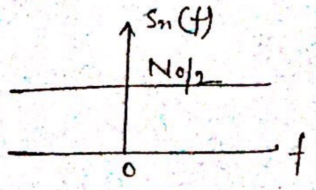
Rx (Receiver of 8-QAM)



White Gaussian Noise

(1) white noise is the noise whose power spectral density ~~or~~ is uniform over the entire frequency range of interest.

<u>Why white noise</u>



(1) white noise contains all the frequency components in equal proportion.

(2) This is analogous with white light which is a superposition of all visible spectral components

<u>Why Gaussian Noise</u>

white noise has a gaussian distribution.
Means PDF of white noise has the shape of gaussian PDF.

<u>PDF of white Noise</u>

$$S_n(f) = \frac{N_0}{2}$$

(1) This shows that PSD of white noise is independent of frequency.
As N_0 is constant, PSD is uniform over the entire frequency range including the positive as well as negative frequencies.

$N_0 = K T_e$ — equivalent noise temp of the system
$K \downarrow$ Boltzmann's Constant
N_0 in $\rightarrow$ watt/Hertz

(2) Idealized form of Noise.

$T_e \rightarrow$ Temp. at which a noisy resistor will have to be maintained such that if it is connected at the input of a noiseless system, will produce the same output as that produced by all the sources of noise.

(3) If noise process at the input of system is having BW > the system then it is treated as white noise.

4. Application of white noise is similar to that of impulse delta function.

5. Effect of impulse function is observed only after it is passed through that system, so it is with white noise, whose ~~effect~~ effect appears only after its occurance.

Information Capacity Theorem

→ Max. rate at which information may be transmitted without error through the channel.

unit - Bits / sec. (b/s.)

→ $C = B \log_2 (1 + SNR)$ b/s

C ↑ information capacity

B → Channel Band width

SNR → Received Signal to noise ratio

→ This theorem ideally relates B and SNR.

→ Shannon Capacity theorem deals with a continuous channel.

→ According to this theorem channel bandwidth and signal to noise ratio are exchangeable in the sense that we may trade off one for the other for a prescribed system performance

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