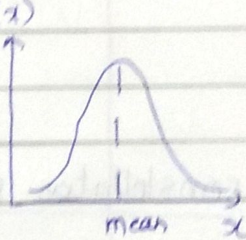
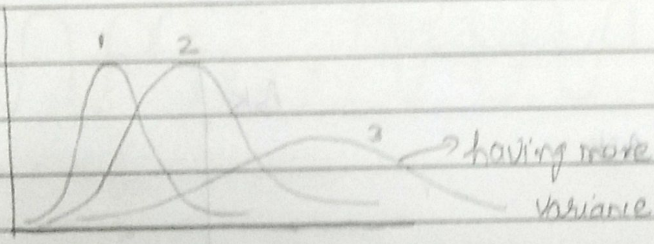
- for multiply two signals, we are using MOSFET.
- 2Kps → 1KHz BW coz $\frac{2Kbps}{2} = 1KHz$
- BW of analog TV channel = 7 MHz
- every pixel requires = 3 bits
- 120 - Horizontal 720 - Vertical

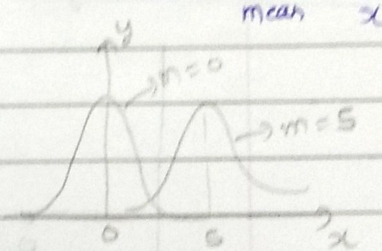
  $120 \times 720 \times \underset{\downarrow \text{RGB}}{(8\times3)} \times 8 \rightarrow$ no. of bits required in one second for transmitting the signal pixels.

Gaussion Random variable :

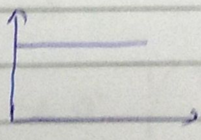
$$\boxed{P(x) = N(m, \sigma^2) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-(x-m)^2/2\sigma^2}}$$







- AWGN Noise (mean = 0
  PSD = ∞



- area under the gaussion curve = 1
- at mean prob. is max. & far away from mean point Prob. is decreases
- gaussion curve symmetric about its mean value.

Digital Modulation :

① ASK (amplitude shift key) : amp. is shifted to H to L & L to H.
② FSK (freq. shift key)
③ PSK (Phase shift key)

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- 120 - Horizontal 720 - Vertical

  120 × 720 × (8×3) × 8 → no. of bits required in one second for transmitting the signal Pixels.

  (8×3) ↓ RGB

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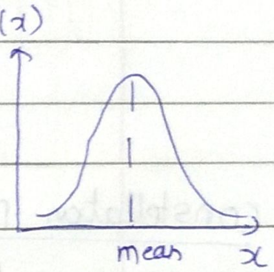
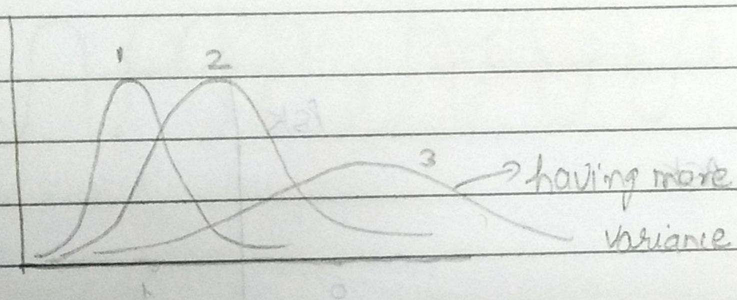
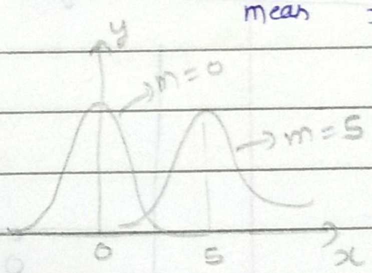
$$\boxed{P(x) = N(m, \sigma^2) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-(x-m)^2/2\sigma^2}}$$







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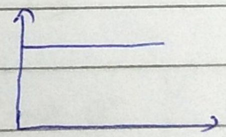

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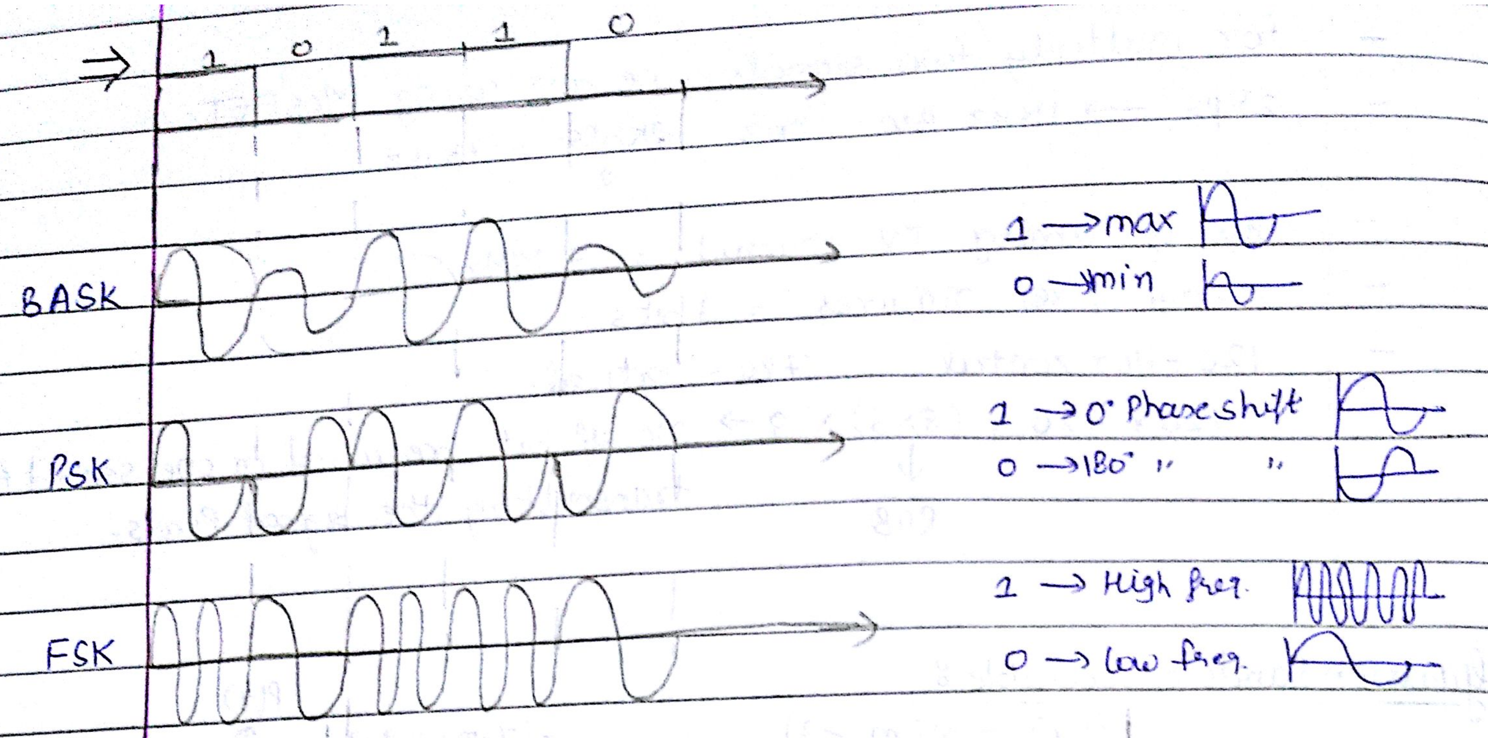
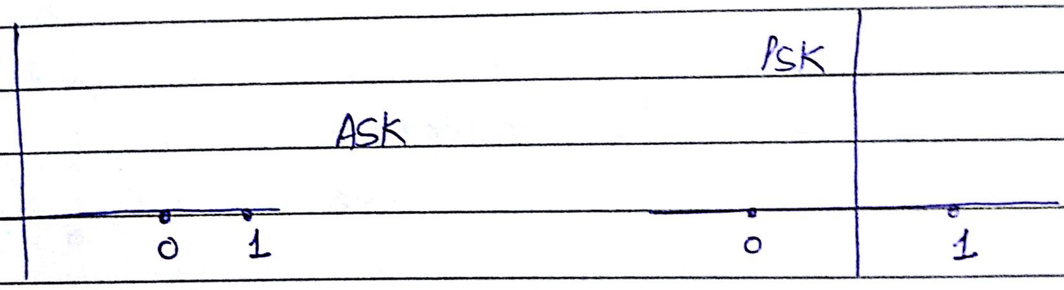
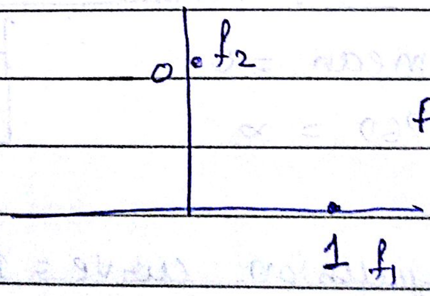
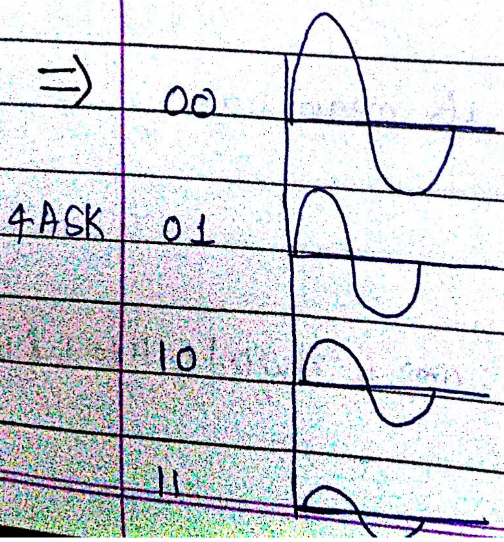


Constellation Diagram:

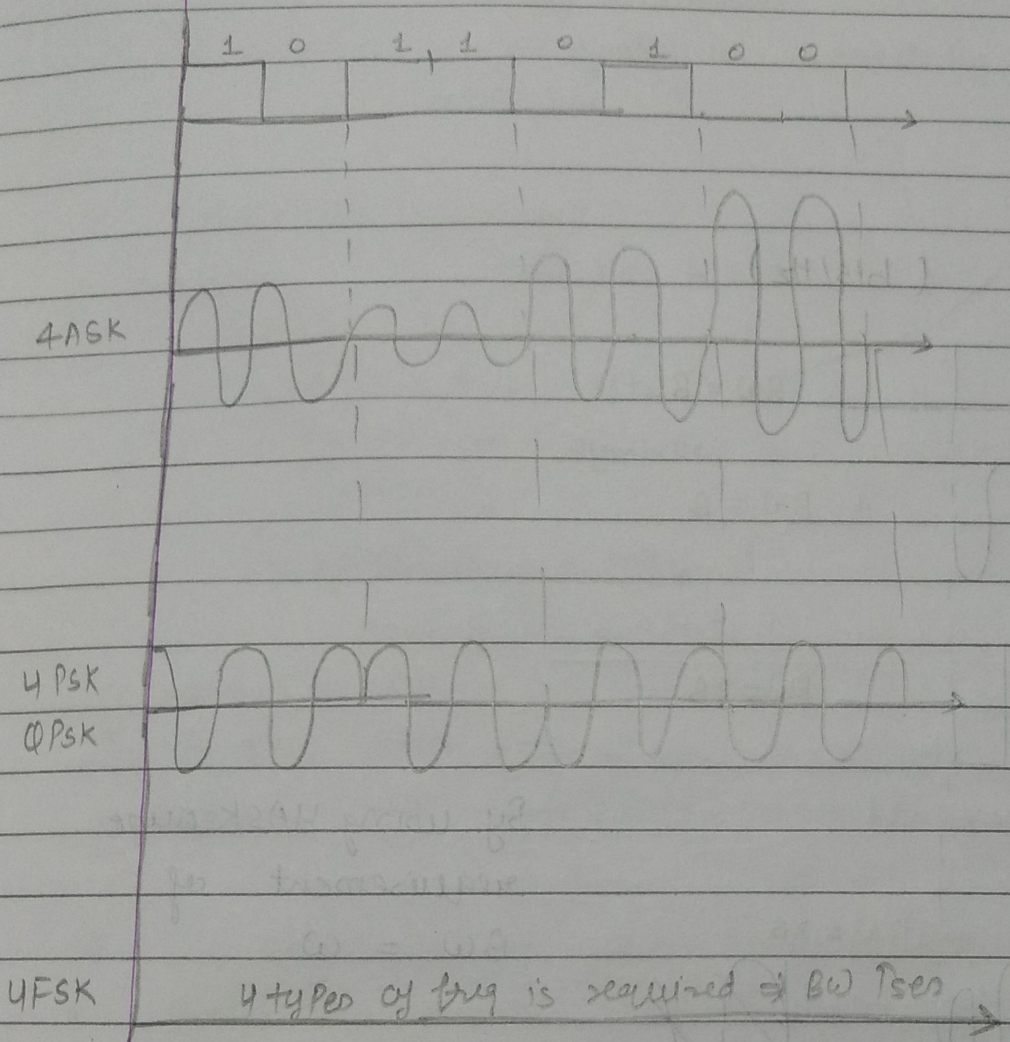


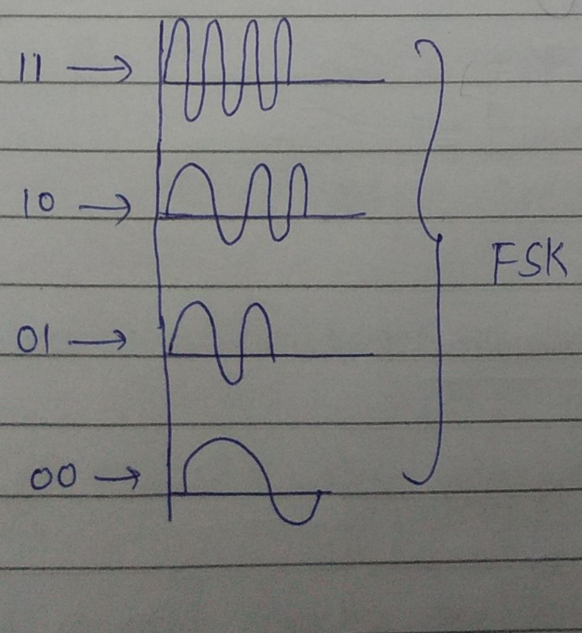


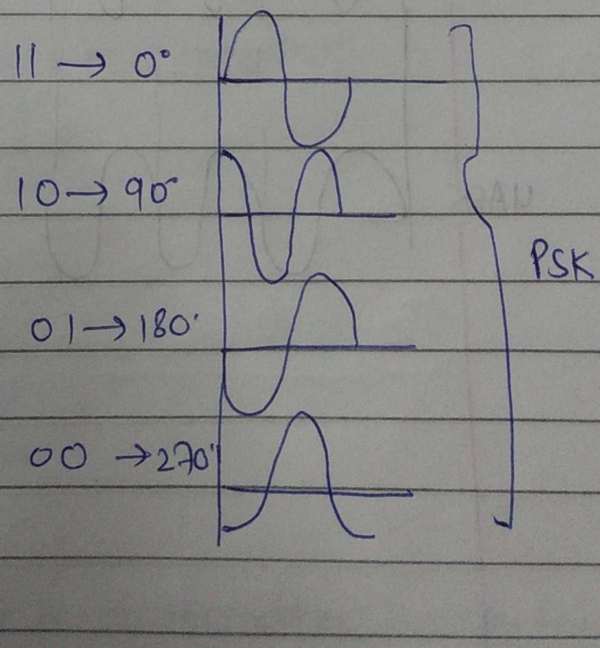


not used for ASK because noise is effected to amplitude very high. so feasible for FSK & PSK.

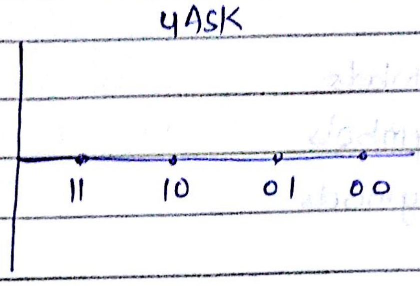
BASK $\longrightarrow$ 1 bits $\longrightarrow$ 2 symbols
4ASK $\longrightarrow$ 2 bits $\longrightarrow$ 4 symbols
8 ASK $\longrightarrow$ 3 bits $\longrightarrow$ 8 symbols

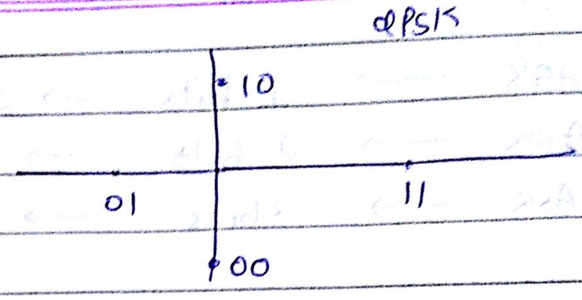




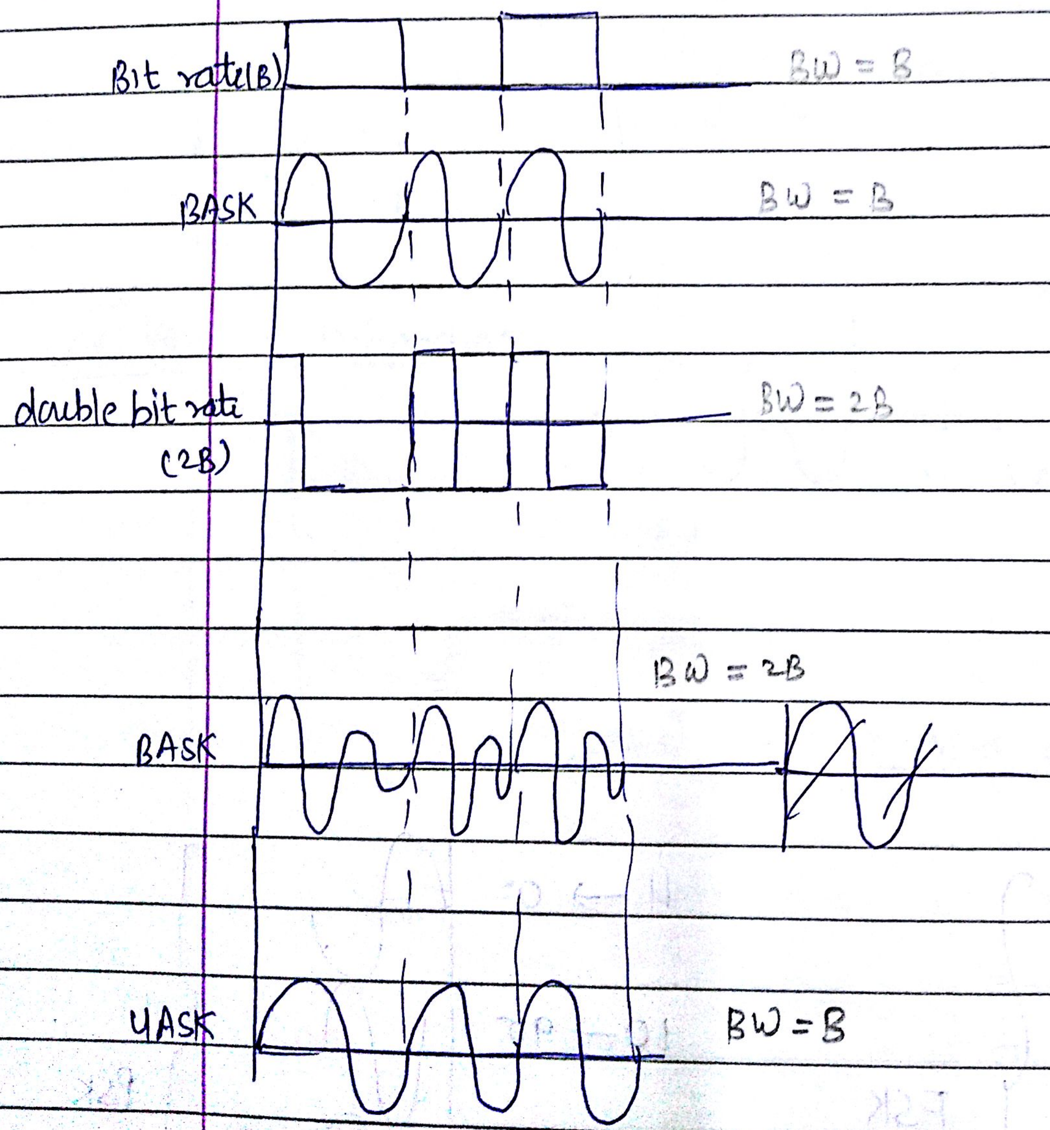


<u>constellation diagram:</u>





Bandwidth efficiency : (b/s/Hz)



By using 4ASK our requirement of BW = W

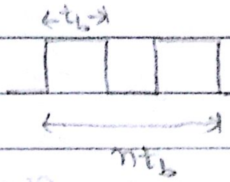
M-ary Modulation:

if one symbol is represents by the many bits (n). then its equal to $2^n = M$
M-ary modulation

for example: if One symbol is represents by 4 bits then its 16-array modulation.

Bandwidth efficiency:

Unit is b/s/Hz



Bit duration t_b, $1/t_b$

n-bits $\longrightarrow$ 1 symbols

2^n no $= M$

symbol duration $= nt_b$

Bandwidth $= 1/nt_b$

$\Rightarrow$ BW is reduced

* in BPSK $\longrightarrow$ 1 symbol loss $\rightarrow$ 1 bit loss

- But in 16PSK $\rightarrow$ 1 symbol loss $\rightarrow$ 4 bit information loss

* In cable channel we used 64-PSK, 16-PSK

* Satelite, we used QPSK (which affected by noise less)

1L G GPRS (upgraded version of binary FSK)

1L E edge (8PSK)

- Gaussian Noise (thermal noise)

Coherent & Non coherent:

- if receiver having the Knowledge of transmitter carrier freq., Phase, bit rate then it will detect the signal easily. then its Known as coherent.
- and if receiver not having the Knowledge, that means its non coherent.

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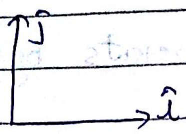
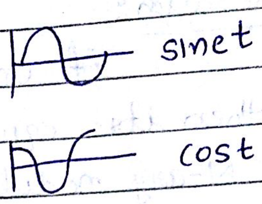
Vector & Signal Vector:





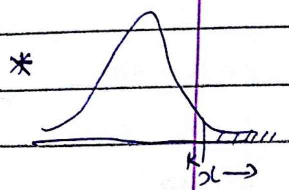
Orthogonal

$A \cdot B = 0$

orthogonal

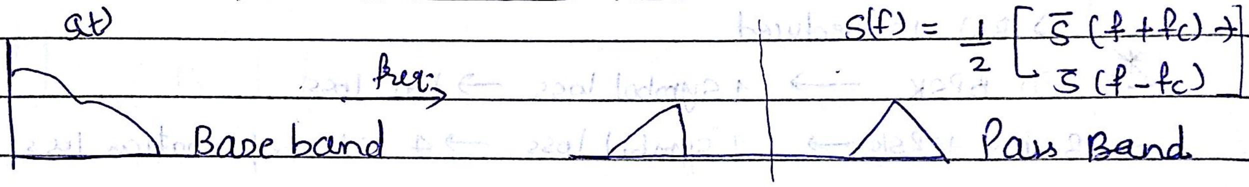
$$\int_0^T s_1(t)\, s_2(t) = 0$$

- sint & cost
- cosft & cos2ft   cos nft



$$P(x>K) = \int_K^{\infty} N(m, \sigma^2)\, dx$$

Base Band Signal / Band Pass Signal:



$$S(f) = \frac{1}{2}\left[\begin{array}{l}\tilde{S}(f+f_c) + \\ \tilde{S}(f-f_c)\end{array}\right]$$

Base Band Signal: $\tilde{s}(t) = x(t) + j\, y(t)$ BB

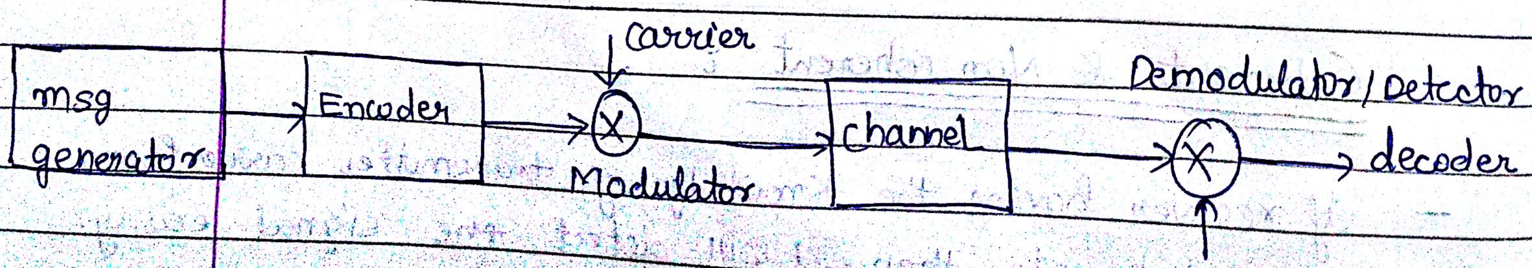
Pass Band Signal: $s(t) = x(t)\cos 2\pi ft - y(t)\sin 2\pi ft$

$$= Re[\ \tilde{s}(t)\, e^{j2\pi ft}\ ]$$

Proof: $\tilde{s}(t)\, e^{j2\pi ft} = [x(t) + j\, y(t)]\ [\cos 2\pi ft + j \sin 2\pi ft]$

$$= Re[\tilde{s}(t)\, e^{j2\pi ft}] = s(t)$$

Pass Band Signal Tx Model:



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Coherent Binary Phase Shift Keying : (BPSK)

$$1 \rightarrow S_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$

$$0 \rightarrow S_2(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi)$$

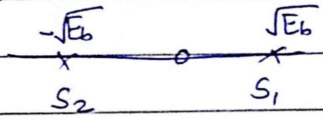
$T_b \rightarrow$ bit duration

$E_b \rightarrow$ energy per bit

$$= -\sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$

Basis Vector : orthogonal and Unit Magnitude

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



(One basis func required in BPSK that's case)

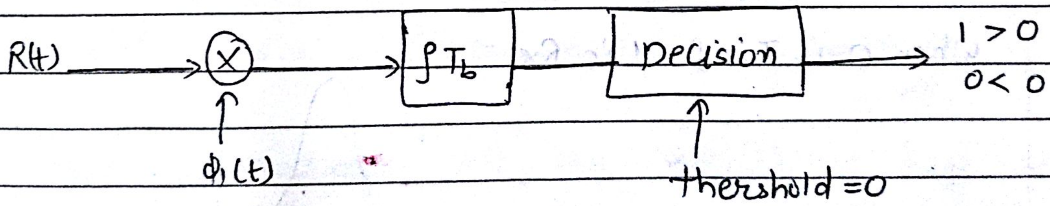
So $S_1 = \sqrt{E_b}\, \phi_1(t)$

$S_2 = -\sqrt{E_b}\, \phi_2(t)$

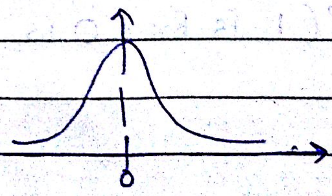
$$\int_0^{T_b} R(t)\phi_1(t)\, dt \quad > 0 \quad = 1$$

$$< 0 \quad = 0$$

Block Diagram of Reciver for BPSK :

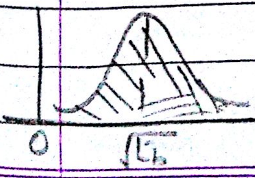


↳ 0 Mean ; $\frac{N_0}{2}$ = PSD ; AWGN



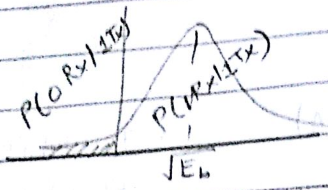
↳ P(1 is transmitted / 1 is receiving) = P (1 is Rx / 1 is Tx)

$$= N\left(\sqrt{E_b}, \frac{N_0}{2}\right)$$



$$= \int_0^{\infty} \frac{1}{\sqrt{2\pi N_0/2}}\, e^{-\frac{(x-\sqrt{E_b})^2}{2 N_0/2}}$$

$\hookrightarrow \quad P(0 \text{ is } Rx / 1 \text{ is } Tx) = \int_{-\infty}^{0} \frac{1}{\sqrt{\pi N_0}} e^{-(x-\sqrt{E_b})^2/N_0}$



$P(\text{total}) = P(0\,Tx)\,P(1\,Rx/0\,Tx) + P(1\,Tx)\,P(0\,Rx/1\,Tx)$

$P_e = \frac{1}{2}[\quad] + \frac{1}{2}[\quad]$

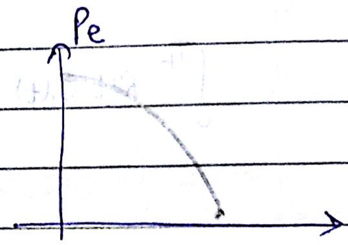
$= \frac{1}{2}\,\text{erc}\left(\frac{\sqrt{E_b}}{\sqrt{N_0}}\right)$

$\Rightarrow \int_0^{T_b} R(t)\,\phi_1(t)\,dt$

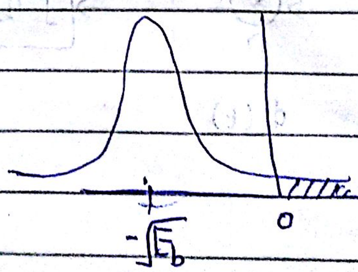
when 0 is Tx $\quad R = s_2 + \eta$

$= \int_0^{T_b} [s_2(t)\,\phi_1(t) + \eta\,\phi_1(t)]\,dt$

$= -\sqrt{E_b} + \int \eta\,\phi_1(t)\,dt$



$\hookrightarrow$ When 0 is Tx & 1 is Rx



$P(-\sqrt{E_b}, \frac{N_0}{2}) = P(1 \text{ is } Rx / 0 \text{ is } Tx) = \int_0^{\infty} \frac{1}{\sqrt{2\pi N_0/2}} e^{-\frac{(x+\sqrt{E_b})^2}{2N_0/2}}\,dx$

$= \int_0^{\infty} \frac{1}{\sqrt{\pi N_0}} e^{-(x+\sqrt{E_b})^2/N_0}\,dx$

Let assume $\frac{x+\sqrt{E_b}}{\sqrt{N_0}} = z$

$\because N(m, \sigma^2) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-(x-m)^2/2\sigma^2}$

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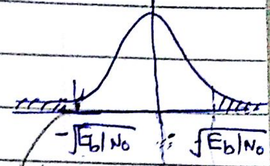
$dx = \sqrt{\frac{N_0}{E}}\, dz$

So $P(1 \text{ is Rx} / 0 \text{ is Tx}) = \frac{1}{\sqrt{\pi N_0}} \int_{\sqrt{E_b/N_0}}^{\infty} e^{-z^2} dz \cdot (\sqrt{N_0})$

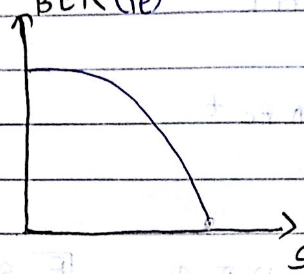
$= \frac{1}{\sqrt{\pi}} \int_{\sqrt{E_b/N_0}}^{\infty} e^{-z^2} dz$



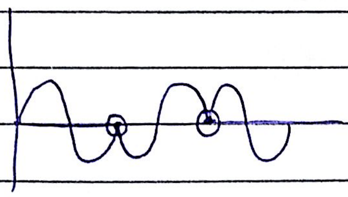
P(0 Rx/1 Tx)

P(1 Rx/0 Tx)

$= \frac{1}{2} \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$



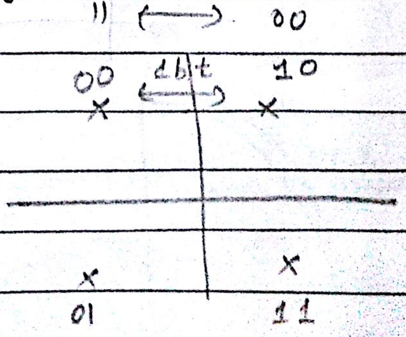
⇒ Problems with BPSK :

① 

due to phase discontinuity harmonics occurs and if we remove harmonics information may be lost.

② due to harmonics BW requirement is high. so BW ↑ses

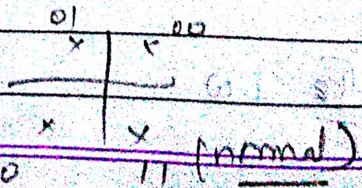
QPSK :



– Grey coding required.
00 & 10 → 1 bit difference

So error is 1-bit diff

but if 00 & 11 → more than 1 bit difference



(normal)

So error is more

$$S_i(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + (2i-1)\frac{\pi}{4}\right]$$

where $i = 1, 2, 3, 4$

* [two basis fun^n are required in QPSK, thats cos & sin]

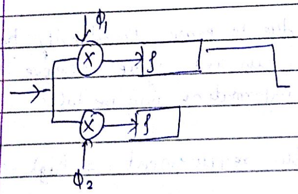
$$= \sqrt{\frac{2E}{T}} \left[\cos 2\pi f_c t \cos (2i-1)\frac{\pi}{4} - \sin 2\pi f_c t \sin\left(2i-1\right)\frac{\pi}{4}\right]$$

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

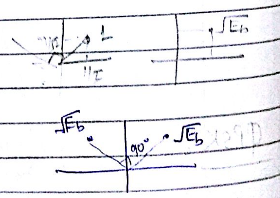
$$\phi_2(t) = \sqrt{\frac{2}{T}} \sin 2\pi f_c t$$

So; $S_i(t) = \sqrt{E} \cos(2i-1)\frac{\pi}{4} \phi_1 - \sqrt{E} \sin(2i-1)\frac{\pi}{4} \phi_2$ — (A)

* we required two correlators



$r = s_i(t) + \omega$



$\hookrightarrow \int^T s_i(t)\phi_1(t) + \omega \phi_1(t)$

$= \pm \frac{\sqrt{E_b}}{\sqrt{2}} + \omega$

$\hookrightarrow \int_0^T s_i(t)\phi_2(t) + \omega$

$= \pm \frac{\sqrt{E_b}}{\sqrt{2}} + \omega$

probability of error is QPSK:

By comparing with PSK; energy $= 2E_b = E$ (bit energy)

in QPSK energy $= E_b/2$

So error in PSK $P_e' = \frac{1}{2} \operatorname{erc}\left(\sqrt{\frac{E_b/2}{N_0}}\right)$

symbol error in QPSK;

$P_e = 1 - P_c$

$= 1 - (1-P')(1-P')$

1st BPSK No error, 2nd BPSK No error

$= 1 - (1 + P'^2 - 2P')$

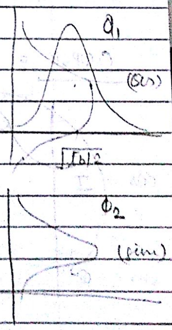
$= 2P' - P'^2 \rightarrow$ ignored

$= 2P'$

symbol error; (QPSK) $P_e = 2 \times \frac{1}{2} \operatorname{erc}\left(\sqrt{\frac{E_b/2}{N_0}}\right)$

$= \operatorname{erc}\left(\sqrt{\frac{E/2}{N_0}}\right)$

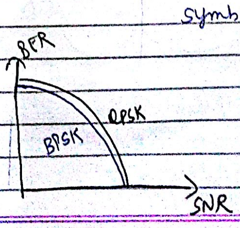
$= \operatorname{erc}\left(\sqrt{\frac{E_b}{N_0}}\right)$ $(\because E = 2E_b)$



bit error; (QPSK) $BER = \frac{1}{2} SER = \frac{1}{2} \operatorname{erc}\left(\sqrt{\frac{E_b}{N_0}}\right)$

(bit error rate) $BER = \frac{1}{2} SER$ (symbol error rate)

symbol is represent $\rightarrow$ 2 bit



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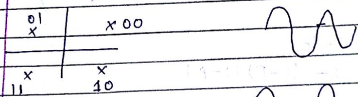
Advantage / Disadvantage
- data rate will increase
- phase shift is 90°, one bit differ

  00 ⟷ 01, 10   11 ⟷ 10, 01

phase shift is 180°, both bits are differs 00 ⟷ 11



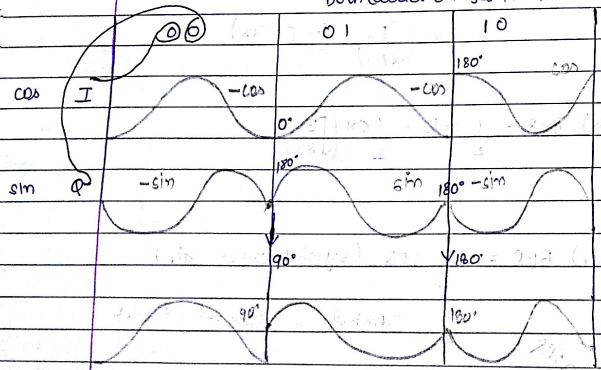
90° phase shift
less harmonics

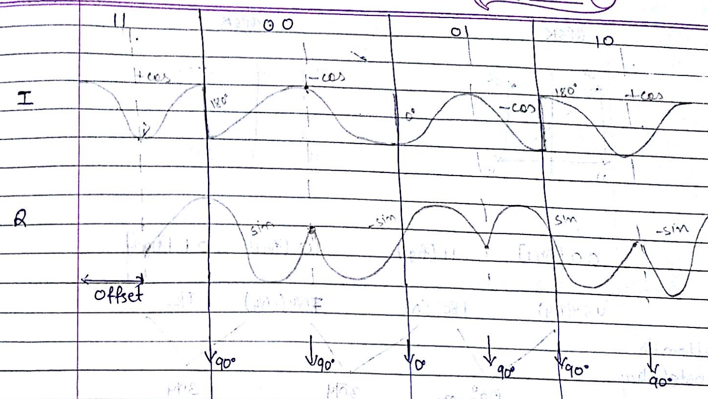
180° Phase shift
Higher harmonics

wireless → because of harmonics, QPSK not suitable
if harmonics removed then information may loss.

<u>OQPSK</u> : Offset QPSK

- both carrier changes then Phase shift = 180°



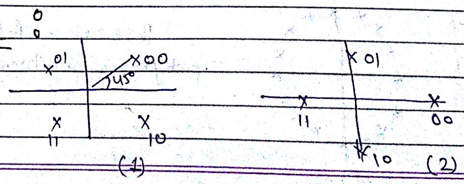


* 180° Phase shift in QPSK = two 90° Phase shift in OQPSK

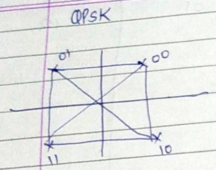
- Class-C Power Ampr is non-linear, more efficient
  Class-A is linear, less efficient

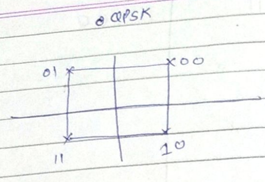
- in OQPSK ; less harmonics
- non-linearity in phase shift
  [Non-linearity would decreases ⇒ we can use non-linear amplifier. Hence less power loss.]

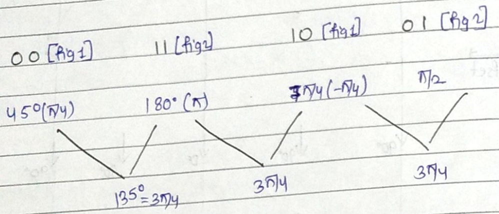
$\frac{\pi}{4}$ - QPSK



Date 21-july





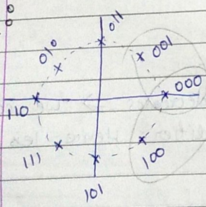


alternate constellation

- linearity in phase shift

  Phase shift = 135° → less harmonic
- can be used in non-coherent
- less harmonic power loss

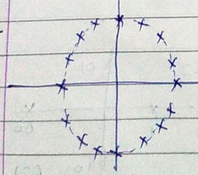
8-PSK :



- Grey coding
- 3 bit
- difference between two symbols is less, so noise interference can effect more

$P_e(8PSK) > P_e(QPSK)$

16-PSK :



$P_e(16PSK) > P_e(8PSK)$

prob of error will increases.

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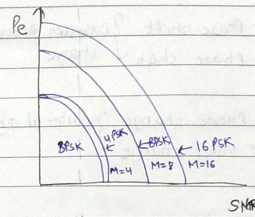
$$P_e = erc\left(\sqrt{\frac{E}{N_o}}\ \sin\frac{\pi}{M}\right)$$

$$S_i(t) = \sqrt{\frac{2E}{T}}\ \cos\left[2\pi f_c t + \frac{2\pi}{M}(i-1)\right] \qquad i = 1, 2, \dots M$$

for 8 PSK ; M = 8

16 PSK ; M = 16

$P_e(BPSK) < P_e(4PSK) < P_e(8PSK) < P_e(16PSK)$



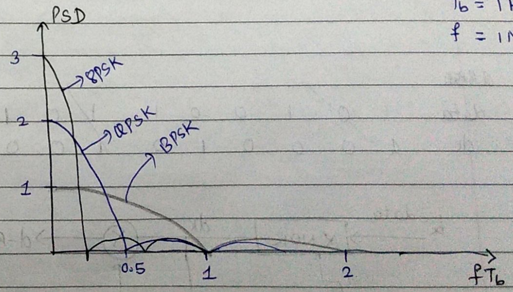
- In wired communication → coaxial wires, we can used higher order PSK
- wireless → we can not used higher order PSK because more signal power is used & Pe ↑
- video & audio transmission where less error is req. higher order PSK is not used.

data rate = 1Mbps

$T_b = 1\ \mu s$

$f = 1\ MHz$

PSD of M-PSK :



in QPSK ; 1 symbol = 2 bit

in 8PSK ; 1 symbol = 3 bit

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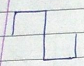
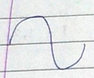


→ high freq. components more → PSD



→ high freq. components less → PSD graph smooth
- interface will occur.

Differential-BPSK :

in BPSK
$0 \rightarrow 180°$ Phase shift } carrier phase change
$1 \rightarrow 0°$ Phase shift }

in D-BPSK
$1 \rightarrow$ no Phase change } original signal
$0 \rightarrow 180°$ Phase change }

Ex: 0 0 1 0 1 1 0 1 $\quad$ $1 \rightarrow$ no change; $0 \rightarrow$ change

DPSK π 0 0 π π π 0 0

non coherent

Ex data 1 0 0 1 0 0 1 1

XNOR

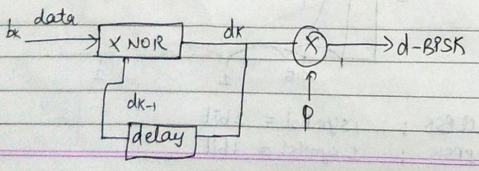
1 1 1; 0 0 1

dk 1 1 0 1 1 0 1 1 1

d-BPSK

Ex data : 0 1 0 0 1 1 0 1

dk 1 0 0 0 1 0 1 0 0



Date 25-july

data 0 1 0 0 1 1 0 1

dk 1 0 0 1 0 0 0 1 1

↓BPSK ↓BPSK

XNOR

D-BPSK

d-BPSK 0 π π 0 π π π 0 0

π π 0 π π π 0 0

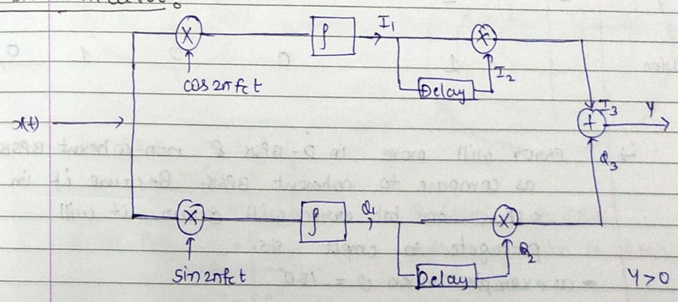
D-BPSK

Differential-QPSK :

data $\underbrace{0\ 1}_{\pi/2}$ $\underbrace{0\ 0}_{3\pi/2}$ $\underbrace{1\ 0}_{\pi\ (3\pi)}$ $\underbrace{1\ 1}_{\pi}$ $\underbrace{0\ 0}_{0\ (2\pi)}$

$11 \rightarrow 0°$
$01 \rightarrow \pi/2$
$00 \rightarrow \pi$
$11 \rightarrow 3\pi/2$

D-BPSK Receiver :



$y > 0$; 1
$y < 0$; 0

data (b_k) 1 0 0 1 0 —— (1)

dk 1 1 0 1 1 0

BPSK → Tx $\cos\omega t$ $\cos\omega t$ $-\cos\omega t$ $\cos\omega t$ $\cos\omega t$ $-\cos\omega t$

↓ basic fun^n is cos

$S - S = 2CS$

Rx	$\cos(\omega t+\theta)$	$\cos(\omega t+\theta)$	$-\cos(\omega t+\theta)$	$\cos(\omega t+\theta)$	$\cos(\omega t+\theta)$	$-\cos(\omega t+\theta)$
I_1	$\cos\theta$	$\cos\theta$	$-\cos\theta$	$\cos\theta$	$\cos\theta$	$-\cos\theta$
I_2	–	$\cos\theta$	$\cos\theta$	$-\cos\theta$	$\cos\theta$	$\cos\theta$
I_3	–	$\cos^2\theta$	$-\cos^2\theta$	$-\cos^2\theta$	$\cos^2\theta$	$-\cos^2\theta$
Q_1	$-\sin\theta$	$-\sin\theta$	$\sin\theta$	$-\sin\theta$	$-\sin\theta$	$\sin\theta$
Q_2 (delay)	–	$-\sin\theta$	$-\sin\theta$	$\sin\theta$	$-\sin\theta$	$-\sin\theta$
Q_3	–	$\sin^2\theta$	$-\sin^2\theta$	$-\sin^2\theta$	$\sin^2\theta$	$-\sin^2\theta$

for $Q_1 \rightarrow \cos(\omega t+\theta)\sin 2\pi f_c t$

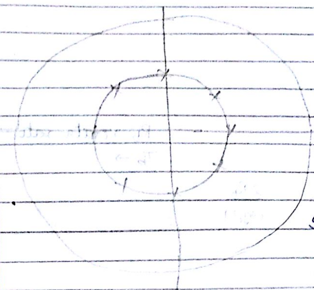
$$= \frac{1}{2}\left[\underbrace{\sin(\omega t+\theta+2\pi f_c)}_{LPF} \bullet \sin(\theta)\right]$$

y	–	1	-1	-1	1	-1
decision		1	0	0	1	0

↳ error will more in D-BPSK & non-coherent BPSK as compare to coherent BPSK. Because if in D-BPSK one bit error will occur, it will propagate to cmplt s/s.

- as exemple when $\theta = 180°$

QAM : Quadrature Amplitude Modulation



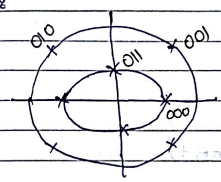
by ↑sing the distance between two symbols power ↑se, SNR will ↑se also. but BER ↓ses

- But we required more power to propagate the symbols.

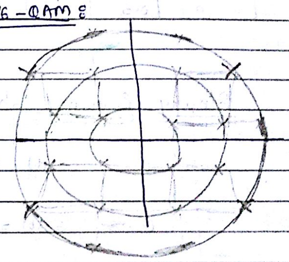
$$S_k(t) = \sqrt{\frac{2E}{T}}\left[a_k \cos(2\pi f_c t) - b_k \sin(2\pi f_c t)\right]$$

- So overcome from this we used QAM which is combination of PSK & ASK.

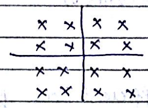
8-QAM :



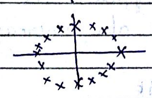
16-QAM :



- in QAM



& in PSK



Pe (QAM) < Pe (PSK)

- prob. of error is ↓ses in QAM.
- But in QAM amplitude is also a symbol. so performance is also affect.
- non-linearity of amplitude is also occur in QAM

- So we can't used QAM in noise channel (because of amplitude)
- Digital TV transmission – 16, 32 QAM efficiency used.

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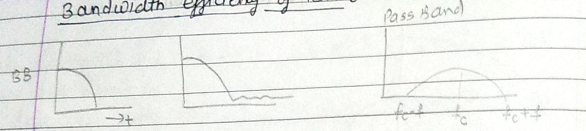
Bandwidth efficiency of PSK :



$R_b \rightarrow$ data rate

$T_b \rightarrow$

$$BW = \frac{2}{T}$$

$$BW = \frac{2}{\log_2 M\, T_b} = \frac{2R_b}{\log_2 M}$$

BW efficiency; $\rho = \frac{R_b}{BW}$

$$\rho = \frac{R_b}{(2R_b/\log_2 M)} = \frac{\log_2 M}{2}$$

when M	2	4	8	16
ρ	0.5	1	1.5	2

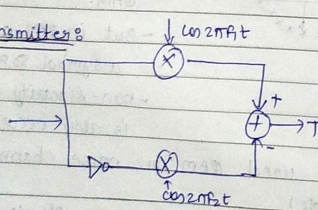
Binary frequency shift keying :

$$1 - \quad s_1(t) = \sqrt{\frac{E_b}{T_b}}\cos(2\pi f_1 t)$$

$$0 - \quad s_2(t) = \sqrt{\frac{E_b}{T_b}}\cos(2\pi f_2 t)$$

FSK → not bandwidth efficient as frequencies increase, bandwidth could also increase.

BFSK Transmitter :



~~coherent~~
" Coherent "

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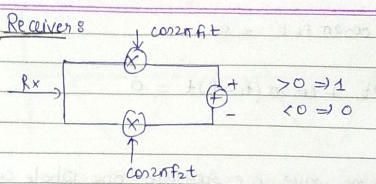
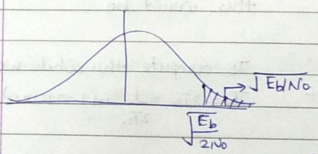
Receiver :



BPSK : $\quad P(e) = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E}{N_0}}\right)$

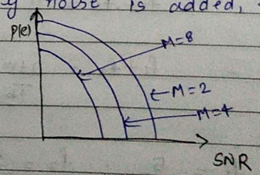
BFSK : $\quad P(e) = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E}{2N_0}}\right)$

and error is nothing but the area under Gaussian tail



∴ more the area under tail (shaded) more the error.
Hence performance of BPSK is better BFSK. but as the M ↑ses (as in 4FSK, 8FSK etc.) no. of frequencies ↑ses whereas in case of PSK, even if M ↑ses, only 2 frequencies 0 and 1 is used (its various combinat
Hence PSK is more bandwidth efficient than FSK.

→ Hence on ↑ing M; the probability of error in FSK ↓ses because;
- ↳ freq. are orthogonal to each other.
- ↳ noise only affects phase and amplitude. So even on increasing freq., if noise is added, its effect can't be shown.

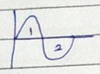


How to check whether two freq. are orthogonal to each other or not?

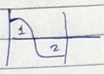
$\int_0^{T_b} \cos 2\pi f_1 t \cdot \cos 2\pi f_2 t = 0$

$= \int_0^{T_b} \cos 2\pi (f_1+f_2)t + \cos 2\pi (f_1 - f_2)t = 0$

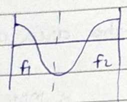
*

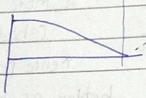


in sine wave, we require one whole cycle to make the area under curve 0.



in case of cos wave, we just need half the cycle to make area under the curve $= 0$

$f_1 + f_2 =$  → area under curve for this would be

$f_1 - f_2 =$  To compute this whole wave, $T_b = 2T_b = \frac{1}{2T_b}$ in (n times)

$= \int_0^{T_b} \cos 2\pi (f_1+f_2)t + \cos(2\pi)(f_1 - f_2)t = 0$

$= \int_0^{T_b} 0 + \cos 2\pi \left(\frac{1}{T_b} \cdot n\right) = 0$

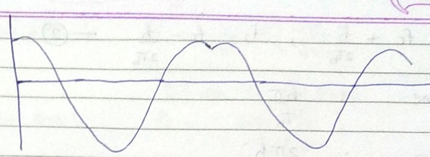
- So to check whether the given frequencies are orthogonal; it should satisfy following two conditions

↳ $f_1 - f_2 = \frac{n}{2T_b}$

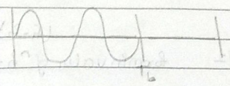
$f_1 + f_2 = \frac{n+m}{T_b}$

Que: $f_1 = \frac{5}{4T_b}$; $f_2 = \frac{3}{4T_b}$ check if orthogonal.

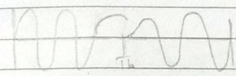
$f_1 - f_2 = \frac{2(T_b^{-1})}{4} = \frac{1(T_b^{-1})}{2}$ $\therefore n = 1$ Orthogonal



discontinuity → Produces harmonics



continuous (integer no. of symbols)



discontinuous

- We required minimum distance between f_1 & f_2. So we used M-FSK.

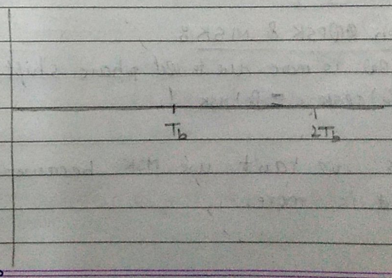
MSK:

$S_1 = \sqrt{\frac{2E}{T_b}} \cos[2\pi f_{1c} t + \theta(0)]$

$S_2 = \sqrt{\frac{2E}{T_b}} \cos(2\pi f_{2c} t + \theta(0)]$

general form: $S = \cos(2\pi f_c t + \theta(t)]$ —— (1)

$\begin{cases} f_1 = f_c + \Delta f \\ f_2 = f_c - \Delta f \end{cases}$



if $T_b \rightarrow h\pi$ (Phase

$t \rightarrow \frac{h\pi}{T_b} t$ (Phase shift)

$\theta(t) = \theta(0) \pm \frac{h\pi}{T_b}$

$1/2T_b$

$\hookrightarrow f_1 = f_c + \frac{h}{2T_b}$; $f_2 = f_c - \frac{h}{2T_b}$ — (2)

phase : $\frac{h\pi}{T_b}$

in freq : $\frac{2\pi h}{2T_b}$

By eqⁿ (2) ; $f_c = \frac{f_1 + f_2}{2}$ if

$(f_1 - f_2) = 1/2T_b$

$f_1 - f_2 = \frac{h \to 1/2}{T_b}$ for min value of $h = 1/2$

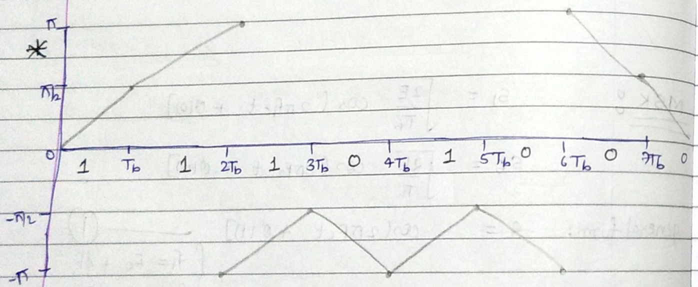
$\hookrightarrow \theta(T_b) - \theta(0) = \pm \pi/2$

$\because \theta(t) = \theta(0) \pm \frac{h\pi}{T_b}$

when $1 \to \pi/2$

$0 \to -\pi/2$

*



Similarity between QPSK & MSK:

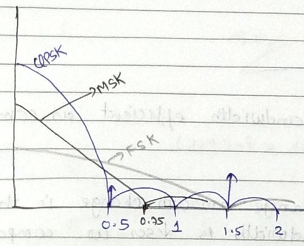
- m QPSK BW is more due to 180° phase shift
- $P_e)_{QPSK} \approx P_e)_{MSK}$

In wireless, we can't use MSK because of BW requirement is more.

for MSK : $P_e = \frac{1}{2} \operatorname{erf}\left(\sqrt{\frac{E_b}{N_0}}\right)$

$P_e)_{MSK} < P_e(FSK)$

for FSK : $P_e = \frac{1}{2} \operatorname{erf}\left(\sqrt{\frac{E_b}{2N_0}}\right)$



advantages:

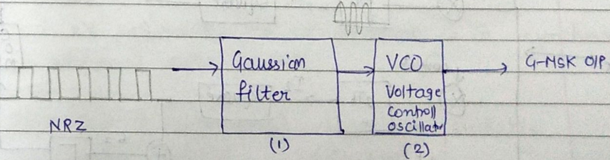
- error performance is good.
- Bandwidth requirement is less as compare to FSK

disadvantages:

- BW is more as compare QPSK.

GMSK :

By Pulse shaping we can reduce the bandwidth.



By passing through (1) → we get the shaping signal in which high freq. components are removed. So BW uses.

- Ex:- GSM ⇒ 2G signal → modulation is GMSK

$P_e = \frac{1}{2} \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$

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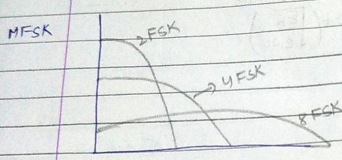
disadvantage : (G-MSK)

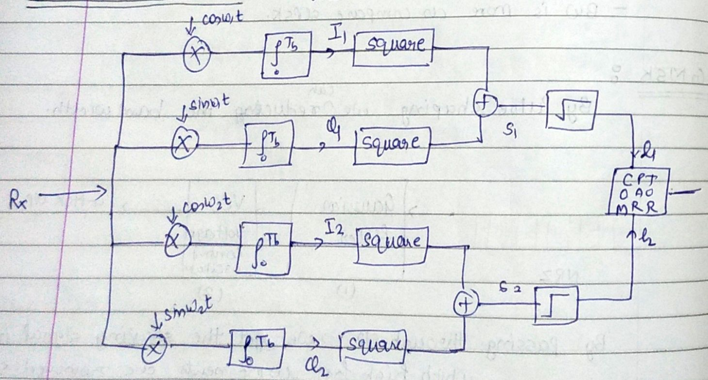
ISI (intersymbol interference)



8PSK is more bandwidth efficient as compare to 8FSK. and $P_e)_{8FSK} < P_e(8PSK)$

- instead of sharp change, smooth change is there in GMSK so its Bandwidth is ↓ses as compare to QPSK.

Non-coherent FSK : "Quadratic Receiver"



$l_1 > l_2 \Rightarrow 1$

$l_1 < l_2 \Rightarrow 0$

Rx	$\cos(\omega_1 t+\theta)$	$\cos(\omega_2 t+\theta)$
I_1	$\cos\theta$	0 (because ω_1 & ω_2 func are orthogonal)
Q_1	$-\sin\theta$	0
S_1	1	0
I_2	0	$\cos\theta$
Q_2	0	$-\sin\theta$
S_2	0	1
Decision	1 ($S_1 > S_2$)	0 ($S_1 < S_2$)

- in this we required four correlator, but in coherent FSK we required two correlator.

* non-coherent scheme is suitable for practically used because in coherent ; we required our carrier wave is in synchronize, which is not possible

Non coherent, orthogonal schemes are suitable.

⇒

	coherent	orthogonal
QPSK	C (Not gud)	O (gud)
FSK	NC	O
8 PSK	C	NO
QAM	C	NO
DBPSK	NC	NO

to find out coherent or not, at the receiver side if carrier wave is required to detect the data that's coherent.

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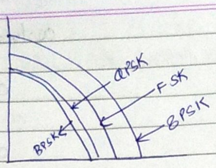
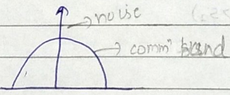
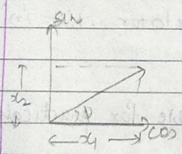


Receiver :
↳ Matched filter
↳ correlation Rx
↳ Quadratic Rx
- correlator Recivers are good because in this we have carrier information.

- it communication S/G band having some noise so we can't do communicate or communication will disturb.

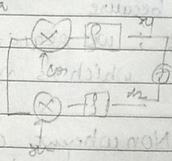


⇒



ϕ → which receiver's not known

by using two correlators, we can detect data



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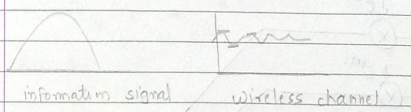
0001 0000
0000 1111
AND
OR 0001 1111

OFDM : Orthogonal freq. Division Multiplexer :



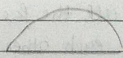
In wireless channel → Higher data rate, bit duration less then ISI will ↑se becuz of reflection
↳ less data rate,

* due to higher data rate in wireless channel
  - ISI ↑ses becuz of reflection
  - effect of noise (impulse)
  - channel LP → HF

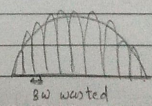
even ↑ing SNR will not solve problem beyond certain limit.

- wireless channel behave as LPF

1 MbPS → BPSK
BW = 1 MHz
T symbol = 1 μs
T_b = 1 μs



10 carriers
1 MbPs → BPSK
BW = 0.1 MHz
T symbol = 10 μsec

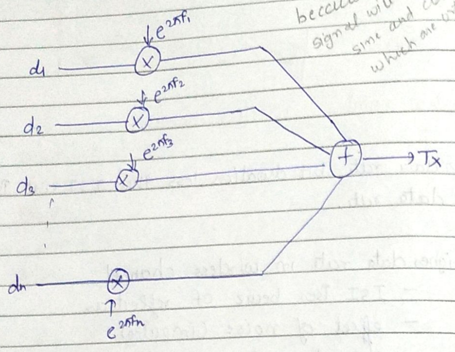


multiple carrier used instead of single carrier, we can remove ~~the~~ or overcome from the problems of High data rate. But
Hardware requirement is ↑ses because of carrier is ↑es
10 carriers ⟶ 10 Oscillators
⟶ 10 modulators

and also BW lost / waste is occur due to some space between two carrier is there.

So we keep the carrier orthogonal in multi carrier modulation $\longrightarrow$ "OFDM".

because all modulated signal will be in sine and cos which are orthogonal



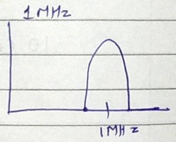
$$T_x = d_1 e^{2\pi f_1} + d_2 e^{2\pi f_2} + d_3 e^{2\pi f_3} + \ldots \ldots d_n e^{2\pi f_n}$$
$$= \sum_{i=1}^{N} d_i e^{2\pi f_i} \Rightarrow \text{IFFT}$$

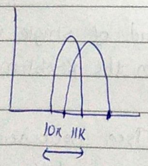
– all the frequencies $f_1, f_2 \ldots$ are orthogonal to each other. In this we required only IFFT; not 10 modulators, 10 oscillators for 10 carriers.

1 KbPS $\longrightarrow$ 1ms $= T_b$

$\frac{1}{2T_b}$

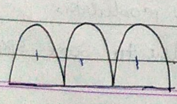
$= 0.5$ KHz



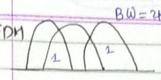


- BW lost is not occur in this
- BW utilization is there in OFDM
- even though spectrum's are overlapping, we can detect them without error because they are orthogonal.

*



- BW lost ; BW = 3KHz
- ~~BW~~ spectrum is high



- BW lost is not occur
- BW utilization is there
- spectrum of carrier is less
- high data rate

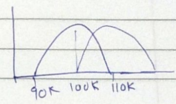
20 MbPS – for 4G n/w, BW is less & data rate is high $\rightarrow$ OFDM
2 MbPS 3G n/w, BW is high & data rate is less

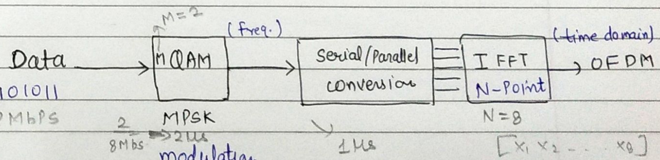
10 KbPS $\longrightarrow$ BPSK
BW = 10 KHz
20 KHz

$f_c = 100$ KHz

$f_1 - f_Q = \frac{1}{2T_b}$

$\hookrightarrow f_1 - f_c = 5$ KHz
100K
105K



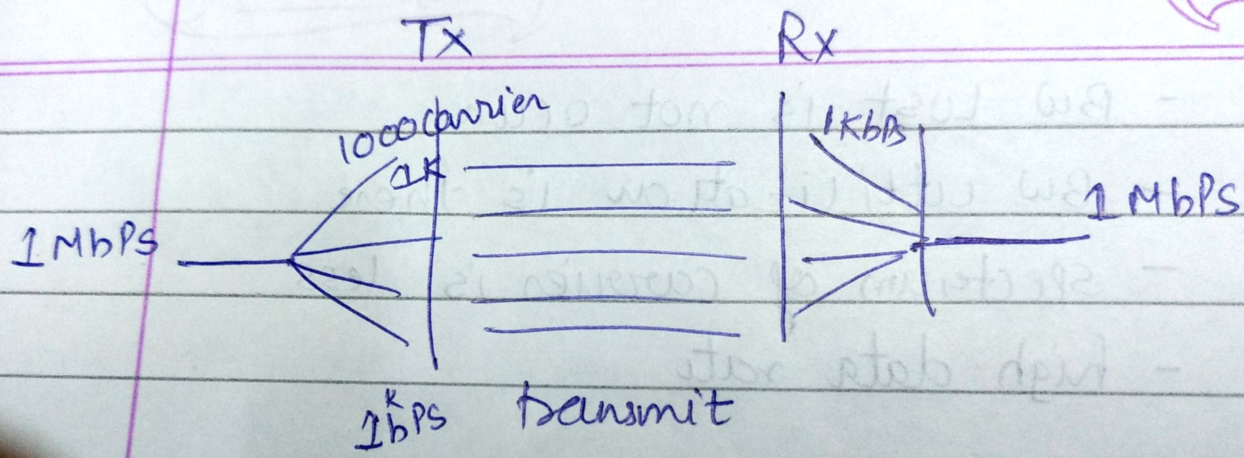


$\frac{2}{8 \text{Mbs}} \Rightarrow 2\mu s$

16-Point FFT $\xrightarrow{QPSK}$ 16 carriers
8-Point FFT $\longrightarrow$ 8 carriers
1 OFDM symbol = $8 \times 2 = 16$ bit

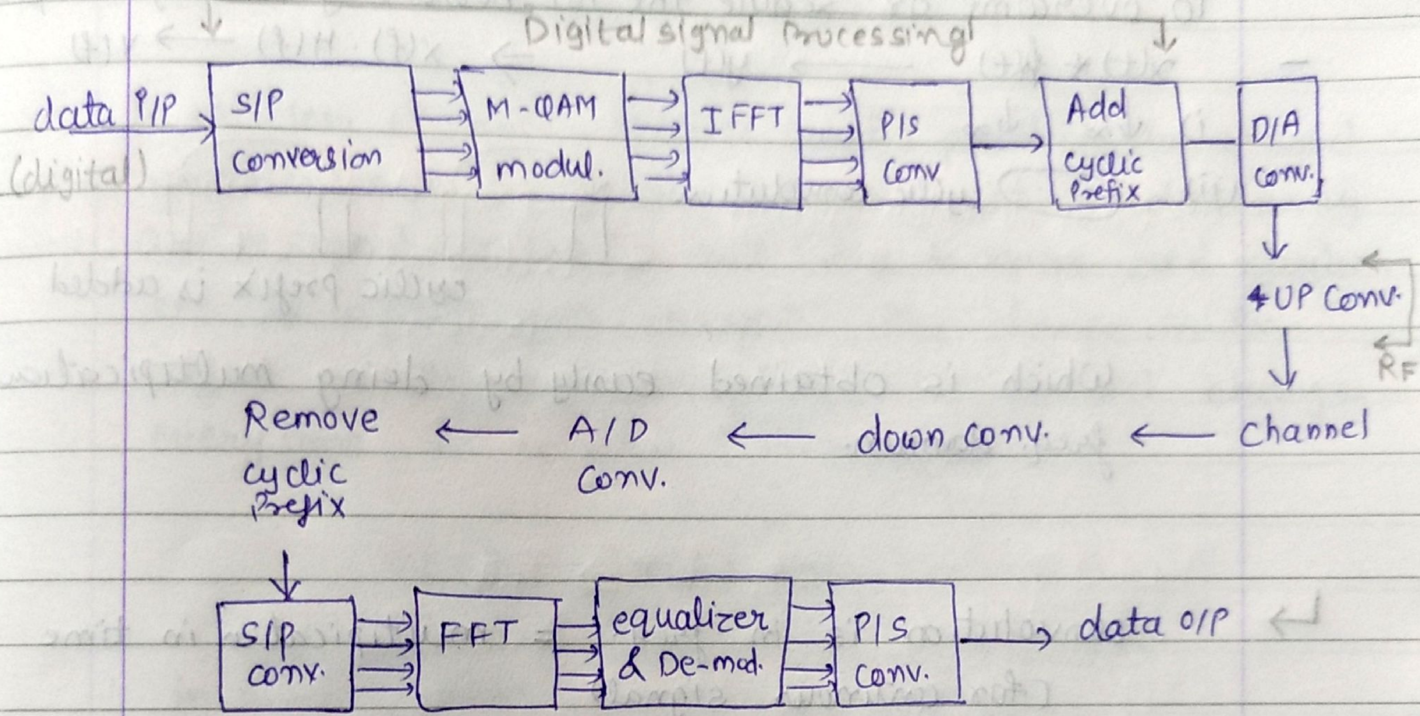
QPSK (1 symbol = 2 bits); N-point IFFT (N = 8); then 1 OFDM symbol having $2 \times 8 = 16$ bits.

$\Rightarrow$ 1 MbPS — 1000 1K carriers (S/P conversion)
By using OFDM, easily transform
P/S $\longrightarrow$ 1 MbPS

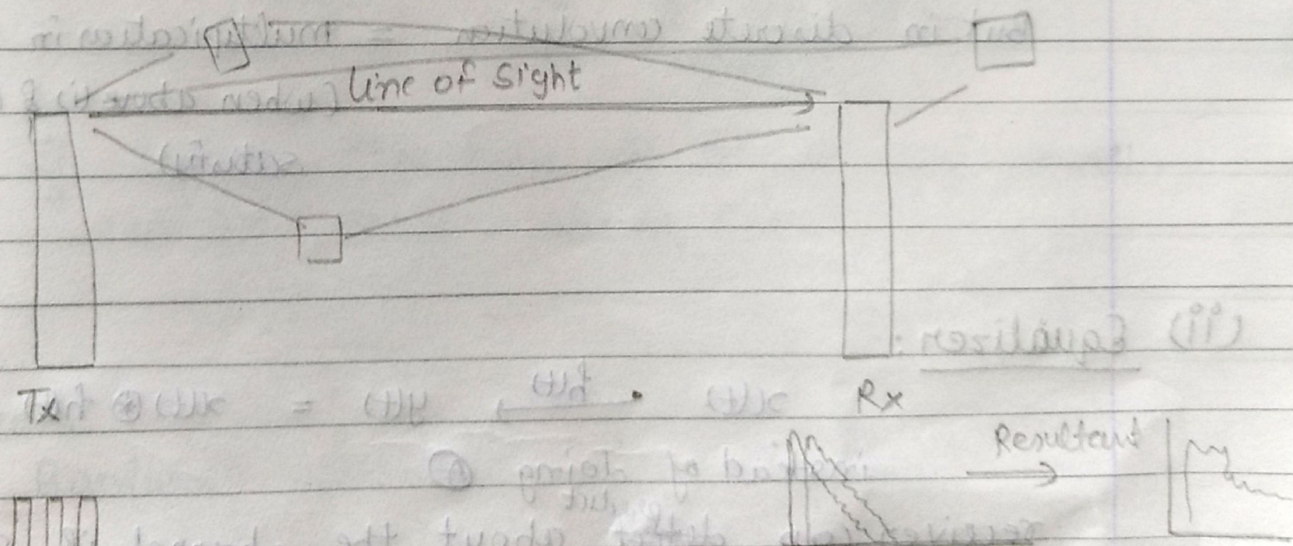

Tx
Rx
1000 carrier
1K
1KbPS
1 MbPS
1 MbPS
1 kbPS
transmit

DATE 4-Aug

B/D of OFDM :



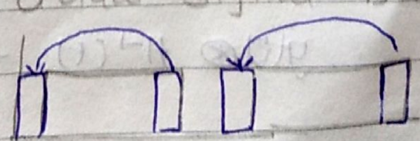
(i)



two signals are closer to each other. so we can't received actual signal back because of ISI, reflection

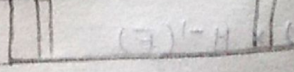
To avoid this :

(i)



adding the prefix

(ii)



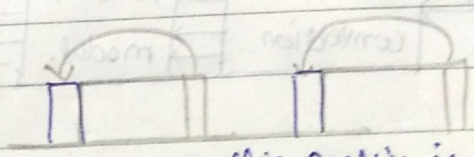
$\uparrow$ses the bit duration

To overcome or reduce the ISI noise, by adding the prefix

– $x(t) * h(t) \longrightarrow y(t) \Rightarrow X(f) \cdot H(f) \longrightarrow Y(f)$

i) $\downarrow \infty \quad \downarrow \infty$

(ii) cyclic convolution



cyclic prefix is added

Which is obtained easily by doing multiplication in freq. domain.

↳ convolution is in freq. = multiplication in time (for continous signal)

But in discrete convolution = multiplication in freq. (when above (i) & (ii) are satisfy)

(ii) **Equalizer:**

$x(t) \xrightarrow{h(t)} y(t) = x(t) \circledast h(t)$ — Ⓐ

instead of doing Ⓐ

receiver can ~~detect~~ predict about the channel if S/S knows what is i/p & o/p at receiver side.

But channel is time varying, so it will change, as time passes.

We done $y(t) \circledast H^{-1}(t) \longrightarrow x(t)$

$X(F) \longrightarrow Y(F) = X(F) \times H(F)$

↳ $Y(F) \times H^{-1}(F)$

Scanned by CamScanner

equalizer is nothing but the filter which inverse channel response.

- In wireless channel, receiver can't predict the channel response. But in wired channel, it predict easily
- as Tx signal is known but due to noise and reflection etc. Rx signal gets changed. The change in Rx signal is different everytime as channel changes everytime in wireless communication.

$$Y[F] = X(F)\,H(F) \quad \text{channel}$$

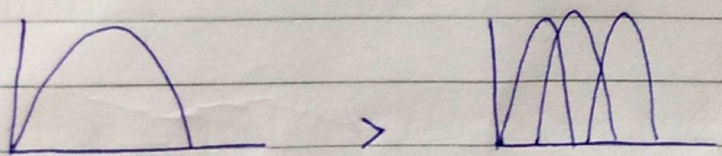
$$Y(F) \times H^{-1}(F) \quad \text{equilizer}$$

in wireless comm^n : $\underset{\text{o/p}}{y} = \underset{\text{response}}{h} \cdot \underset{\text{i/p}}{x} + \underset{\text{noise}}{n}$

if $h = -ve$ then even if n is very small, we get error at Rx side.

Advantages:

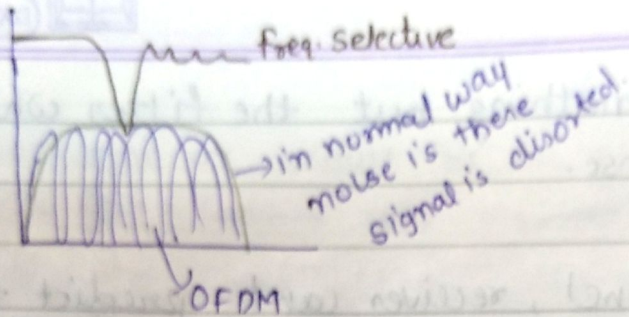
① Bandwidth efficient



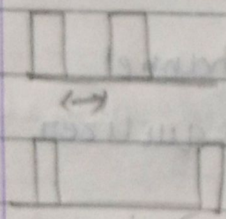
1MbPS

in less BW more signal is transmitted.

② frequency selective channel ⟶ flat channel



- error detection coding
- supressed the carrier at particular
- coding different for different carriers



$f\uparrow$, $BW\uparrow \Rightarrow T_b\downarrow$