Com 2
Notebook

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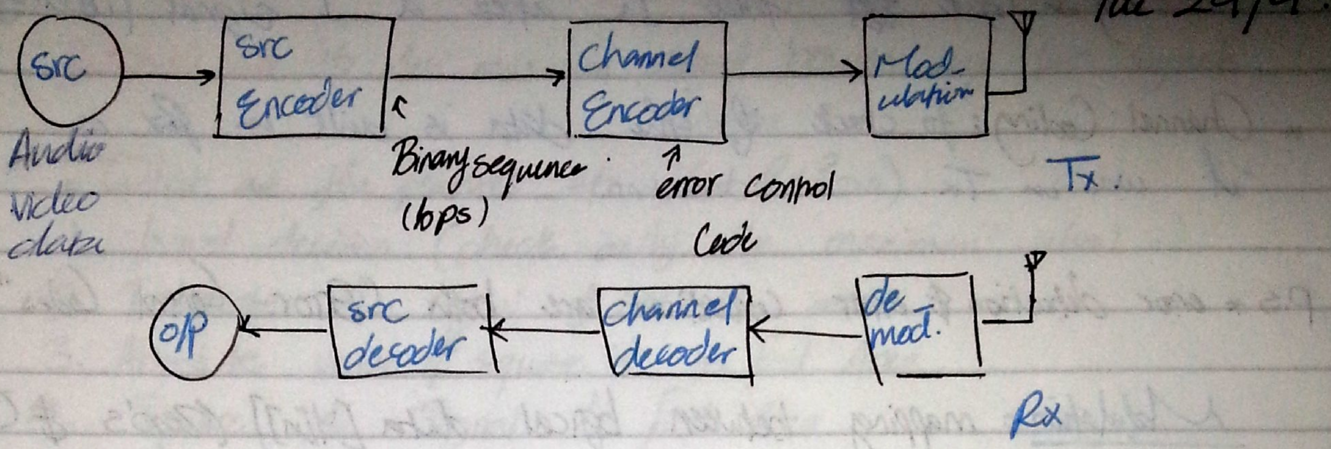
lecture #1
Tue 29/9.



src Encoder: takes the Analog Signal & Passes it through a certain Condition " Conditioning cct that limits the Amp & freq of a signal ".

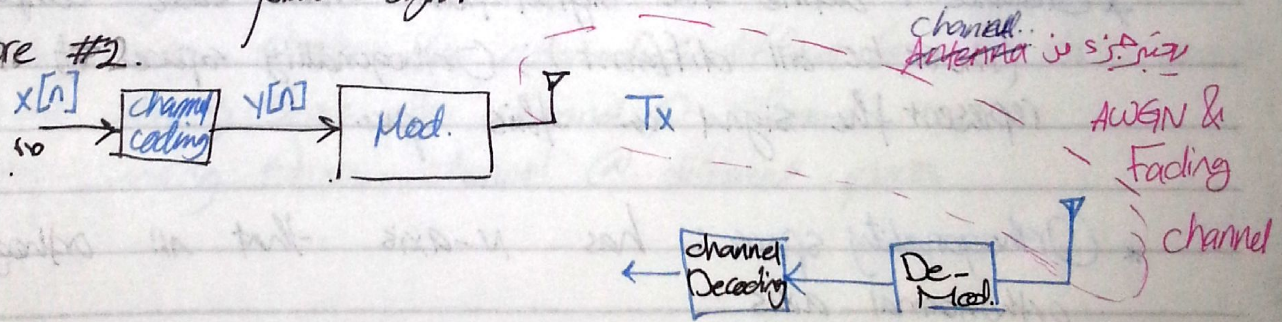
$$\hat{s}(t) = \alpha s(t) + n(t) .$$

are both a R.V / R.process as a function of time

P.S #1 : Periodic signal doesn't have any information

P.S #2 : Aperiodic signal does have information (Energy Signal) "Random Signal".

lecture #2.



- * x[n] , Y[n] → represented in Binary Serial & has a certain bit rate (r_b) in bPs.
- * Antenna is part of channel so if we want to make the signal stronger we change it
- * Add a Gaussian Noise ← channel (simpliest type of the channel

* to Save the signal from error; we make different things:
e.g → Give three 1s after a "1" signal (coding).

* Channel Coding: to check if the data is built in Rx as it was in Tx. (error detection).

p.s * error detection & error correction are both "Error Control Codes".

Modulation: mapping between logical data [Y[n]] (Zero's & One's) into physical waveforms (Energy signal) such that it can pass through the channel with minimum errors.

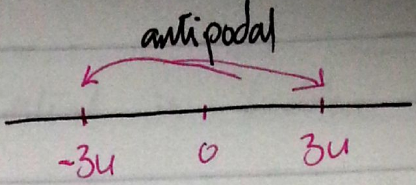
→ Square Integrable "mechanical motion": have energy (after square it & integrate it

* 1 & 0 must have a very far distance between their waveforms to make it easy to notice the difference between them.

* distance: define the signal from their basic components (must be all different); Orthogonality space & then represent the signal in this space

* Orthogonality space: has N-axis that all orthogonal / orthonormal axis.

*p.s * N-axis → a $x_1(t)$, a $x_2(t)$, ...
↳ they are all function of time (must be waveforms).



Antipodal ⇒ is the maximum ~~Signal~~ distance between any two signals.

* What are the features at the Rx?
1. hard decision (check only the maximum value).
2. Integrate the signal & see the areas
3. Absolute value & square it to find Area.
4. Square the Signal to find Area.

* distance means energy
* The best way to Find the distance is the way that give
the simplest implementation of the signal
"Soft (manipulation) information from all points /many point
(i.e ⇒ Samples ⇒ Integration)

* distance happen on the Rx
* for Cost effective we Choose the Optimal Choices.
* Sharing types:
  - Frequency Sharing: share the channel @ different freq. that doesn't ove
  - time sharing: Share the channel @ different times.
  - Space sharing: share channel @ different places.

lecture 3

Sun 4/10.

Orthogonality :

if we have S_1 & S_2 ~~then~~ , if $\langle S_1, S_2 \rangle = 0$ then they are Orthogonal .

let $X = S_1 + S_2$ & S_1, S_2 are Orthogonal . Then :
$\langle S_1, X \rangle = |S_1|^2$

* p.s *

$$\langle S_1, S_2 \rangle = \int S_1 * S_2^* \, dt .$$

$$\langle X, S_1 \rangle = \int x . S_1 \, dt = \int S_1 S_1^* \, dt + \underbrace{\int \cancel{S_1 S_2^*}}_{0} \, dt = |S_1|^2$$

↓ if this part ~~#~~ ≠0 then it is an interferance

p.s We can detect the signal according to SNR "Signal to noise ratio"
↳ the nature behavior of any Rx .

* p.s * if two signals weren't orthogonal , we couldn't detect the signal unless there is no interferance.

p.s In Digital Modulation we have a certain threshold. so we can detect the signal more correctly.

* SNR $\propto \beta$ (square).
* Noise effect is nonlinear .

→ ; The effect on signal detect by SNR is non-linear.

P.S * The information content is hidden inside the physical signal.

↳

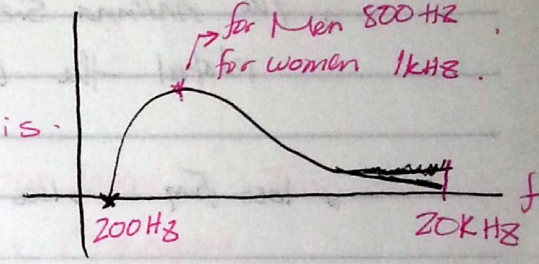
* Static → Audibable Noise → noise as voice (hearable).

* Fourier Series is important because it is the simpliest harmonic motion (e^{jwt}). [sin & cos] and because i can see it ON oscillator. ; Asin(wt) constant → easy to be generated.

* ~~We can generate it.~~

* Random Signal has a PSD → Auto correction then I transfer it to freq to have PSD.

* Y- axis is the mirror.
* Maximum Freq. for human error is: 20 KHZ.
* Toll quality is in 4KHZ.



PSD for Audio Signal.

Lecture #4 Tue 6/10

Channel: - Guided (limited). (wired, wave Guides).
- Un-Guided (wireless Communication).

* we can do ~~Antenna~~ ~~can~~ ~~be~~ Radiation on Antenna

* Radiation → Omnidirection.
↳ point to point.

* The best property in digital communication sys. is that we can manipulate the signal.

* The Characteristic we care about in Channel. (Guided):

- Bandwidth. $\left(\frac{1}{2\pi\sqrt{LC}}\right)$
- Attenuation $\propto$?!
- Interference.
- Characteristic Impedance. $\left(\sqrt{\frac{L}{C}}\right)$. → per unit capacitance (H/m, F/m)
  ↳ as function of length.
- Speed $= \frac{1}{2\pi\sqrt{LC}}$ → The speed of the signal in the channel.

* The Antenna Size is the most important thing in the system. related the Carrier frequency.

* less freq → less size of the Component.

* limited Freq. → limited BW → limited Data bit Rate.

* In Wireless Communication:-

- Multi user. (I must be able to seperate these Signals).
  ↑ Orthogonal Signals
- higher Data bit Rate.

* We are interested in Making ~~to~~ the signals seprable. at the Rx side. (different Orthogonal axis).

N-D Space.

Orthogonality defenition.

$$\begin{cases} \langle S_1, S_2 \rangle = 0. \\ \langle a\,x(t)_i, a\,x(t)_j \rangle = \delta_{ij}. \end{cases}$$

$$= \int_{-\infty}^{\infty} a\,x(t)_i \cdot a\,x(t)_j^{*}\, dt.$$

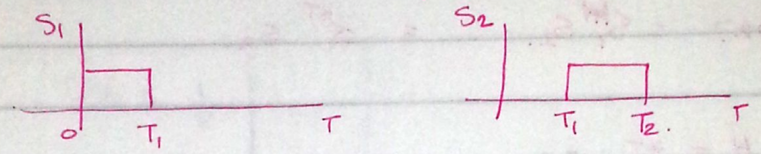
the answer must be finite. (0 OR 1).
"Square Integrable" (finite period signal).

* We choose finite signals in ~~thiere~~ thier BW & Magnitude.
↑ finite duration

* two axis for the same user. (parallel channels).
create parallel transmition using Orthogonal axises &
↳ increase the transmition data speed.
* axis ∝ carriers, Basis function $(ax_1(t) \text{ ---- } ax_j(t))$.
↳ abstract math.

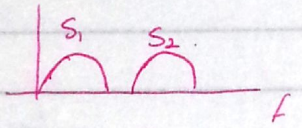
P.S. * Non-Overlapped signals in any domain are Orthogonal.

Time domain



S_1 & S_2 are both Orthogonal. $(S_1 \perp S_2)$.

In frequency domain.



$S_1 \perp S_2$

definitly aren't over-lapped in Time domain because they are Orthogonal.

$$\int_T = \int_f$$

$$\int_{-\infty}^{\infty} ax(f)_i \; ax(f)_j^* \; df = \int_{-\infty}^{\infty} ax(t)_i \; ax(t)_j \; dt.$$

\/

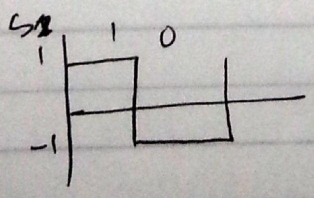
linear transformation

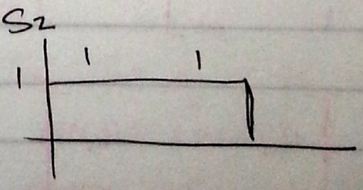
* Any linear transformation won't change the characteristic of the signal.

* Phase shift = time delay ; if (90°) Orthogonal. (code).

$S_1 \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

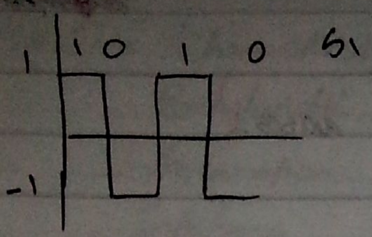
$S_2 \begin{bmatrix} 1 \\ 1 \end{bmatrix}$



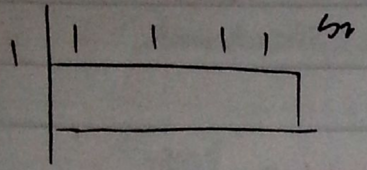


$S_1 \perp S_2$?.

$\langle S_1^{*T}, S_2 \rangle = 0$ code domain : represent the signal in Code.



$S_1 = \begin{bmatrix}1\\0\\1\\0\end{bmatrix} = \begin{bmatrix}1\\-1\\1\\-1\end{bmatrix}$



$S_2 = \begin{bmatrix}1\\1\\1\\1\end{bmatrix}$

(hermechian).

$< S_1 , S_2 > = S_1^{H} \cdot S_2 = S_1^{*T} \cdot S_2 .$

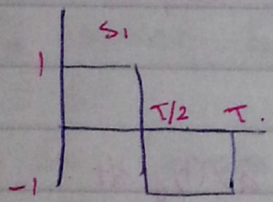
** $H = *T$ **

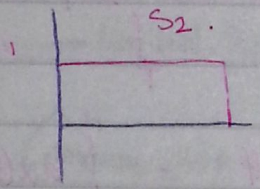
$H = \begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$

*how to create Orthogonal Signal ? Google it

lecture #5

Thr. 8/10.





$S_1 = \begin{bmatrix}1\\-1\end{bmatrix}$ $S_2 = \begin{bmatrix}1\\1\end{bmatrix}$ $S_1^{H} S_2 = 0 .$

W- H

$H_2 = \begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$

$H_{2N} = \begin{bmatrix}H_N & H_N\\H_N & -H_N\end{bmatrix}$

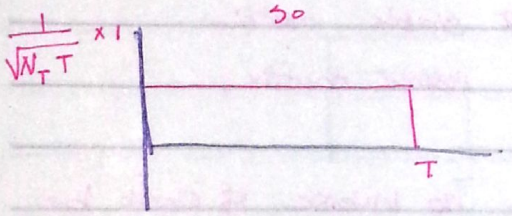
$$H4 = \frac{1}{\sqrt{4}}\left[\begin{array}{cc|c} \overset{H_2}{\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}} & \overset{H_2}{\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}} & \begin{array}{l} S_0 \\ S_1 \end{array} \\ \underset{H_2}{\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}} & \underset{-H_2}{\begin{bmatrix}-1 & -1\\ -1 & 1\end{bmatrix}} & \begin{array}{l} S_2 \\ S_3 \end{array} \end{array}\right]$$

thus:

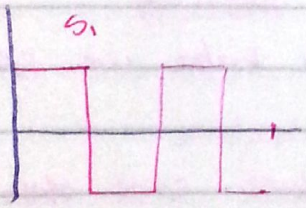
$$S_0 = \frac{1}{2}\begin{bmatrix}1\\1\\1\\1\end{bmatrix} \qquad S_1 = \frac{1}{2}\begin{bmatrix}1\\-1\\1\\-1\end{bmatrix} \qquad S_2 = \frac{1}{2}\begin{bmatrix}1\\1\\-1\\-1\end{bmatrix} \quad \&$$

$$S_3 = \frac{1}{2}\begin{bmatrix}1\\-1\\-1\\1\end{bmatrix}.$$

thus:-



$\frac{1}{\sqrt{N}}$ (to normalize).



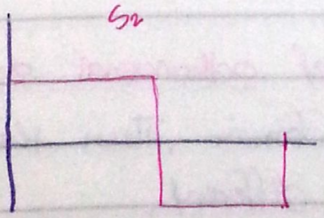
$$1 = \overset{\text{energy}}{\mathcal{E}} = \int_0^T |S_0|^2\, dt = N_T T \cdot * |S_0|^2$$

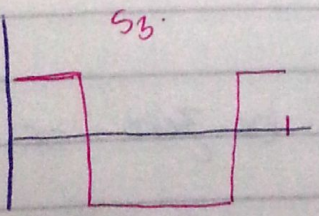
$$\cancel{N_T T} * \frac{1}{\cancel{N_T T}}$$

we want the energy to be 1

* then we scale the Amplitude by $\frac{1}{\sqrt{N_T T}}$

N_T ← total $\underline{N}$.





r_b (bps).

then $T \leq T_b = \frac{1}{r_b}$. (we will change this later to (equality) for some cases).

* Can I produce [illegible] signal [illegible] time of [illegible] T_b ?

↳ No problem. ⇒ $T \leq T_b = \frac{1}{r_b}$.

* A is a full Rank Matrix (all the raws or coloum are independent)
↳ have an inverse
all eigen values are nonzero & different.

→ $\Phi = eig(A) = [\Phi_1 \ \Phi_2 \ \cdots \ \Phi_N]$. those are eigen vectors

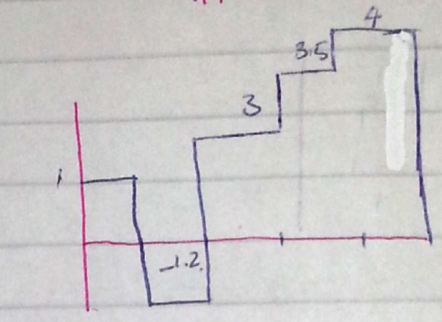
→ $\Phi_i^H \Phi_j = \delta_{ij}$. (orthonormal space)

$(A - \lambda I) = 0$.

P.S we can get any nember of space.

<u>example</u> :

$$\Phi_1 = \begin{bmatrix} 1 \\ -1.2 \\ 3 \\ 3.5 \\ 4 \end{bmatrix} \updownarrow T \Rightarrow$$



* Condition Num: $= \dfrac{\lambda_{max}}{\lambda_{min}}$

$\simeq 1$ most stable matrix.
> 1 less stable matrix.

→ if CN >> 1 (single matrix; have no inverse & can't be used as a space).

→ so we measure the condition number before we create a sys.

→ if non_Full Rank matrix ⇒ we will loose some data.

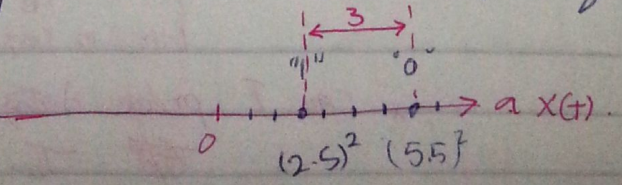
* We can design using the concept of orthonormal axis.
* If signals don't overlapped in frequency domain, Then the center frequency for each signal is different.

* Base_Band comm (Transmission):

→ Binary Transmission: The data may be zero or one.

distance = 3 ⇒

avg. energy = $\dfrac{(5.5)^2 - (2.5)^2}{2}$



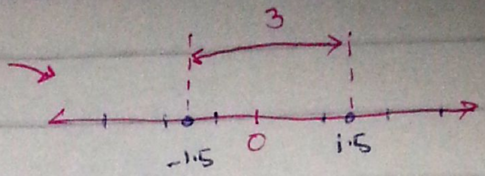
← One dimensional axis. (1-D)

* We need to maximize signals under condition of minimum average energy.

max distance avg. energy antipodal.

* Best Performance under minimum cost *

$E_{av} = (1.5)^2$.

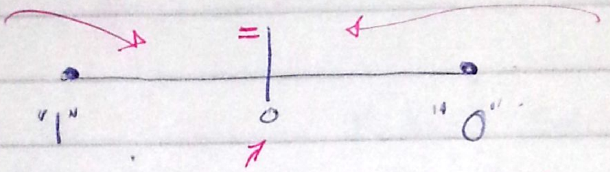


better than the previous sys.

best bit error rate. (تكلفة تشغيل أحسن).

* The Performance is set only by the distance between the point
the absolute value of energy doesn't directly effect the performance

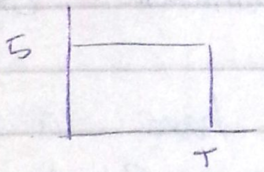
" Constellation "

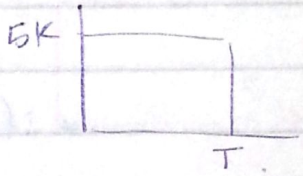


"signal Space diagram"

best thing to make the zero in between of both signals / points.

Signal space represent amplitude / voltage.





Bandwidth depends on the freq axis (differential $\frac{dv}{dt}$).

antipodal → different point oppisite in axis through origin.

Lecture #6.
Sun 11/10.

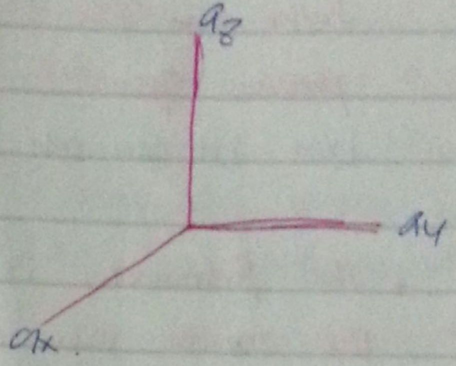
*Baseband → signal to be centered at zero ~~Fr~~ Hz

Ex

$a_x(t)$

$a_y(t)$

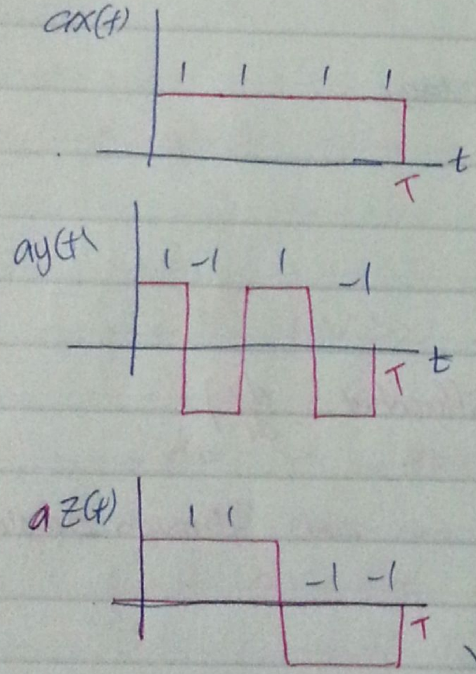
$a_z(t)$.



let,

$$H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

thus.



* axis is used to carry info.

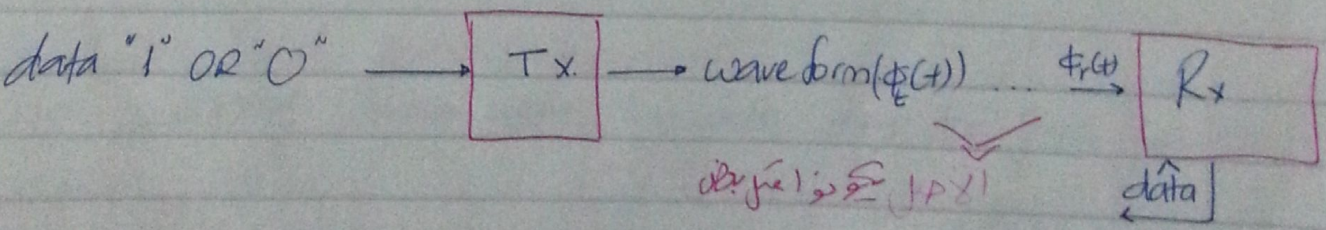
* assume ideal channel (no atten. no limitation on BW).

* if we have a Binary signal
↳ Binary Baseband.

* In Binary Baseband we care about:
r_b.

→ T must be less than or equal to 100 µs. to transfer "1" or "0".

let r_b = 10 Kbps.
thus T_b = 100 µs.



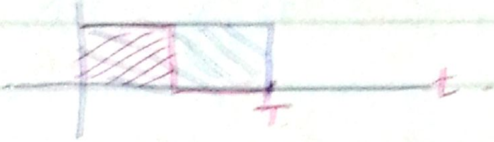
الاهم يكونوا غير بعض

* we need two signal to send 1 & 0.
* Num of signals = Num of differencies.

thus

$$\phi(t) = \begin{cases} S_0(t) & ; \text{"0"} \\ S_1(t) & ; \text{"1"} \end{cases}$$

as Every $S_0(t)$ & $S_1(t)$ will occupy (T) ; it can fill it or use part of it



* for 1-D sol.

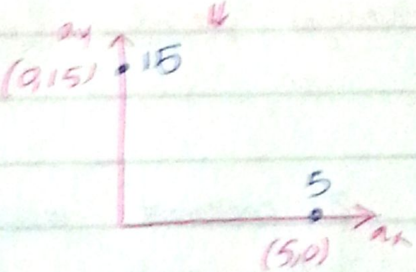
$S_0 = 5a_x$.

$S_1 = -5a_x$.

* 2-D sol.

$S_0 = 5a_x$.

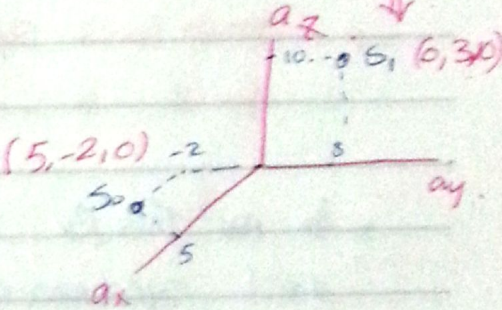
$S_1 = 15a_y$.



* 3-D sol.

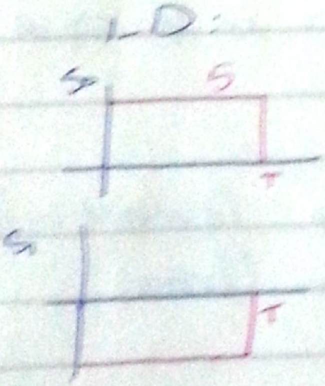
$S_0 = 5a_x - 2a_y$

$S_1 = 3a_y + 10a_z$.

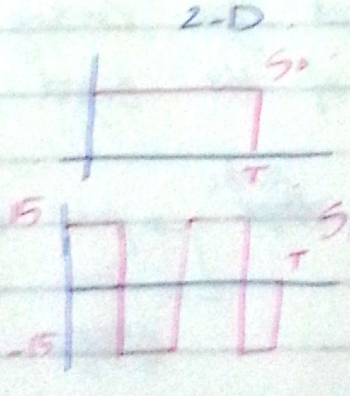


as a function of time (wave form) :-

1-D:

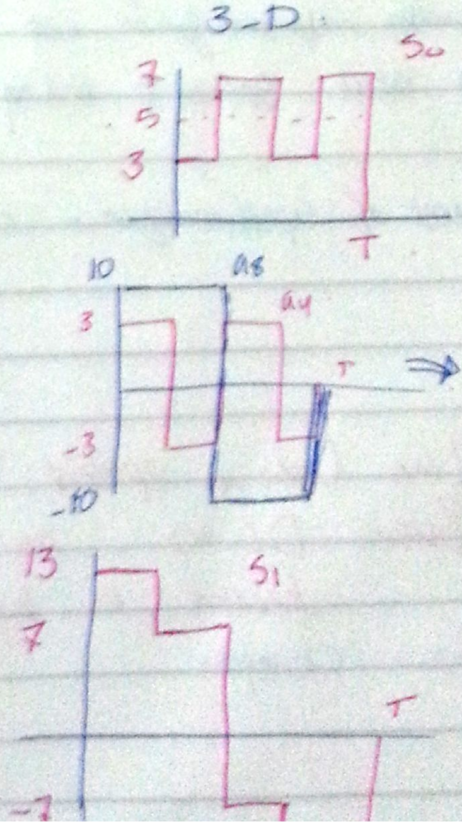


2-D.



* S0 & S1 out of transmitter goes to Rx.

3-D:



* the Rx makes an inner product. with the axis ; measuring device.

$\langle \phi_r(t), axis \rangle = ?$.

let intermediate variable called v in ~~from~~ Rx

→ for 1-D:

$$v = \langle \phi_r(t), axis \rangle = \langle \phi_r(t), a_x(t) \rangle = \begin{cases} \int s_0(t) a_x dt = \int 5 a_x a_x dt = 5 \\ \int s_1(t) a_x dt = \int -5 a_x a_x dt = -5 \end{cases}$$

intermediate measured variable (decision variable) to know what the data.

5 if and only if "0" was Transmitted.

-5 if only if "1" was transmitted.

→ it should be a synchronized procedure (repeat ax In parallel sync with the signal recieved)

* This Rx is a coonerant reciever since it to be generate ax(t) synchronously. ; This needs a synchronization cct at Rx to detect the starting point of the relieved signal each "T" (period) (signaling Interval).

Usually synchronization cct need zero crossing points in the signal to detect starting & ending of the signal.

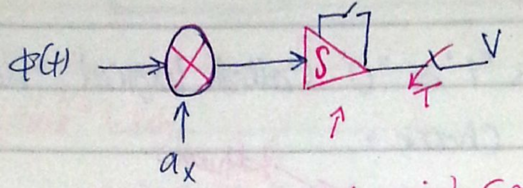
most of synchronization cct ~~detect~~ make → peak detection (it might be flat)
↳ zero detection (better).

* Line Codes → represent "1" & "0" with synchronized
1 * Better DC = 0 no average at the signal. (can't be detected or hard to detect).
2 * have changes.

* more changes → more BW.

*if the channel has over a 9x The BW of the signal make it Good to detect & observe the signal.

* Review Line Code in Comm (1).



each period (Reset) & start over to integrate.
& then we read the o/p voltage (give a wave form).

hard desicion → at "1" then check which is closer to S_0, S_1. using a certain Algorithim.
(# of point → more accurate).

Lecture #3
Sun 18/10/2015

* Channel:

* Wire channel , Baseband Tx.

→ Noise.

→ BW (Band limited signal , unlimited signal).

→ fading.

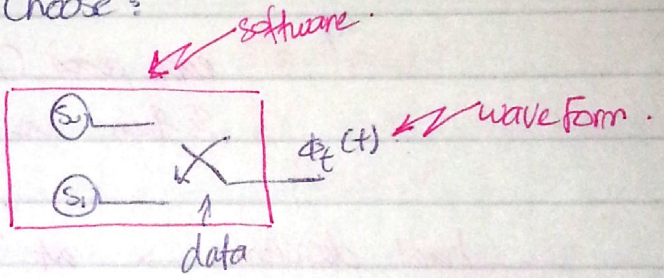
* The data come to transmitter as "1" or "0" Called (logical data).

* ~~How to choose~~ How the Tx Choose :

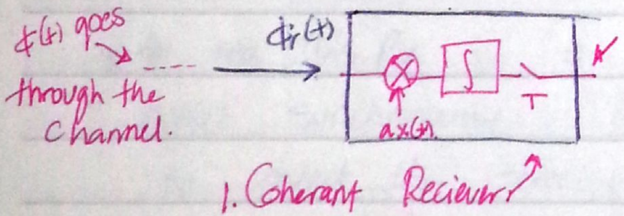
e.g Tx select :

S_0 if "0" at input

S_1 if "1" at input.



* At the Reciever:



1. Coherant Reciever

decision Variable.

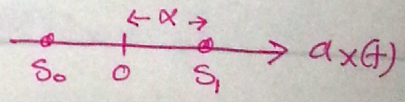
$$V_{out} = \int_0^T a\,x(t) \cdot \phi_r(t)\, dt.$$

~~[illegible]~~ thus:

$$V_{out} = \int_0^T a\,x(t) \cdot (-\alpha\, x(t))\, dt.$$

$$= -\alpha \underbrace{\int_0^T |a\,x(t)|^2\, dt}_{E_{ax}=1}.$$

$= -\alpha$ (~~[illegible]~~ if & only if S_0 is to be transmitted).



$S_0 = -S_1$.

$S_0 = (-\alpha\, a\,x(t))$.

thus:

$S_1 = \alpha\, a\,x(t)$.

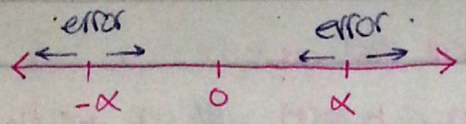
* if & only if S_1 is transmitted:

$V_{out} = +\alpha$

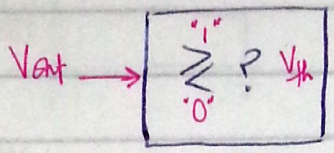
* V_{out} here is called → (decision Variable).

Luma♥

[redacted]



thus the decision goes like:-



it take to the closer one.

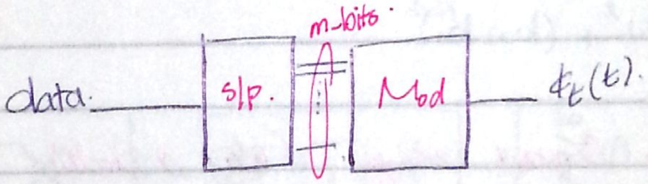
thus: $V_{th} = \dfrac{\alpha + (-\alpha)}{2} \neq 0$

ML Decision. (most likely).

[illegible]

what the probability of a continuous Random ~~[illegible]~~ Variable? 0 → that's why there's no equality.

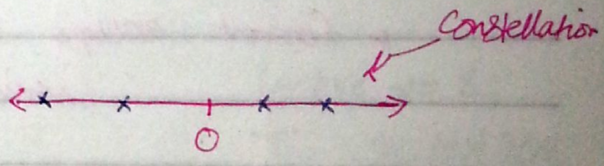
* each possible value is represented by one point on the axis.



$M = 2^m$. (called M-ary mod.).

when $m = 1$ → Binary.

example (1-D) →



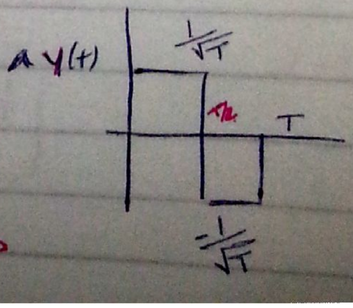
4-ary.

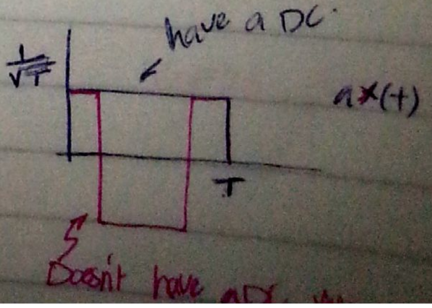
* example (2D modulation): $a_x(t)$, $a_y(t)$

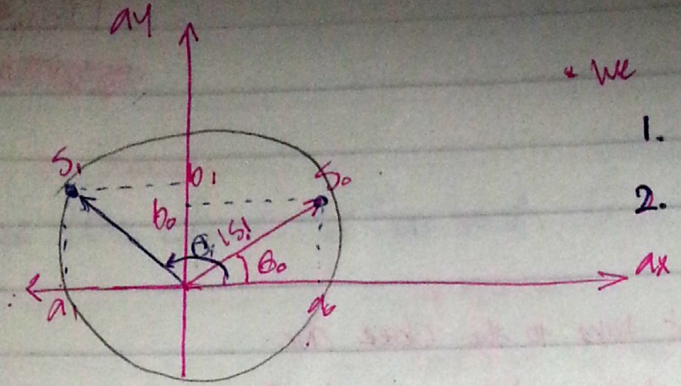
P.S { * Modulation Dimensionality → # of points.
└ * Constellation Dimensionality → # of axis.

* $a_x(t)$, $a_y(t)$ are both orthogonal & have zero DC value.

→







* We can represent S_0 as:

1. $S_0 = a_0\, x(t) + b_0\, y(t)$
2. (a_0, b_0)
3. $|S_0| \angle \theta_0$
4. $a_0 + j\, b_0$

↑ means 90° phase shift.

→ to know the Angle between S_0 & S_1:(say θ).

1. $E_0 = |S_0|^2 = a_0^2 + b_0^2$ ← x & y are Orthogonal.

$E_1 = |S_1|^2 = a_1^2 + b_1^2$

$$E_{av} = \frac{E_0 + E_1}{2} = P(0)\cdot E_0 + P(1)\cdot E_1$$

2. to know the distance between S_0 & S_1. (say d_{01}):

$$d_{01} = \sqrt{(a_0 - a_1)^2 + (b_0 - b_1)^2}$$

→ at a certain energy → Constant energy (like a circle).

Maximum distance → antipodal

* Constant envelope signals → When all Signals are in a circle.
"Certain Energy).

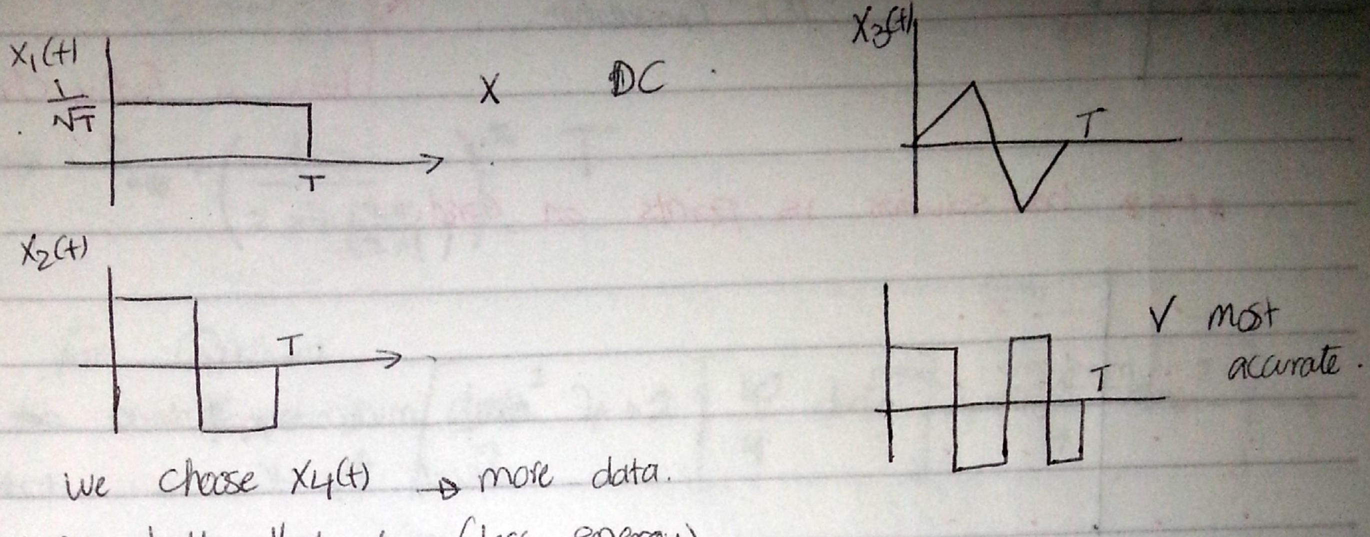
<u>H.w</u> :

$$Y = \sum_{i=1}^{I} \alpha_i^2$$; find the Optimal Values of α's ?!.

→ Once α is all equal are the Optimal solution & Once the multiplexing between ~~ea~~ the probability of any two α's are equal.

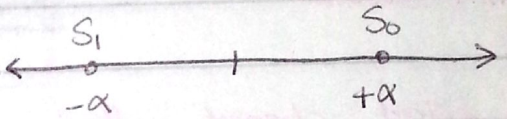
* For a 10 Kbps data design a one Dimension Tx and

the available wave forms are :

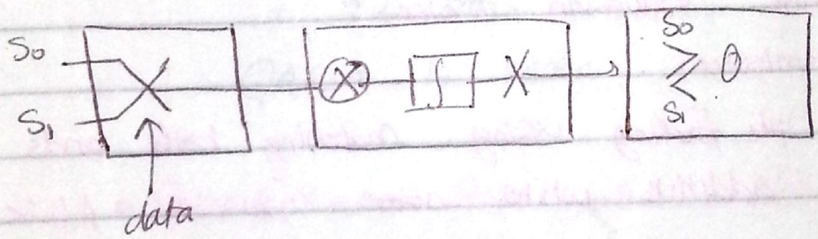


sol we chose $x_4(t)$ → more data.

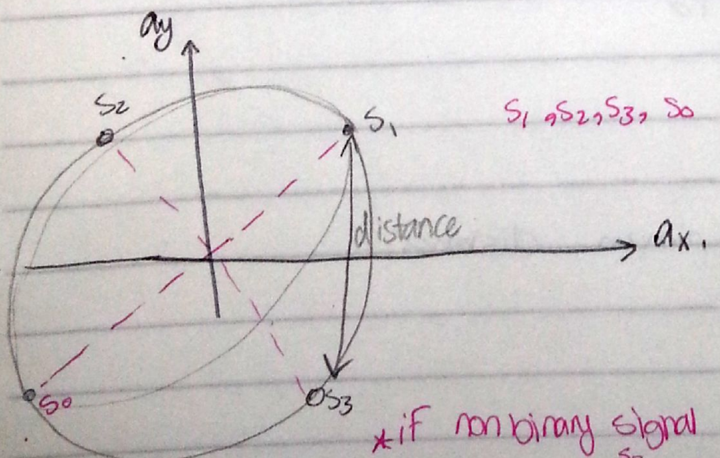
$x_2(t)$ better that x_3 (less energy) .



why antipodal ?!.
easier synchronization

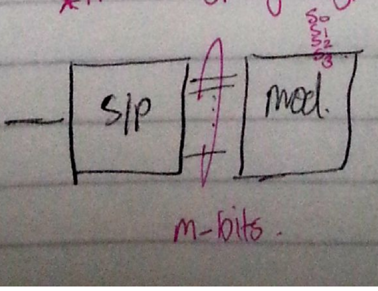


lecture # 8.
Tue . 20/10/2015

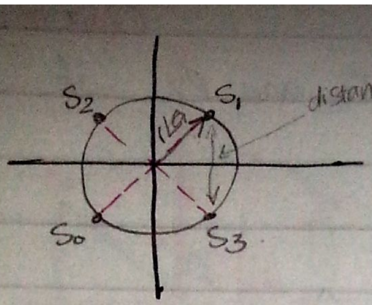


S_1, S_2, S_3, S_0 are equal energy signals.

*if non binary signal



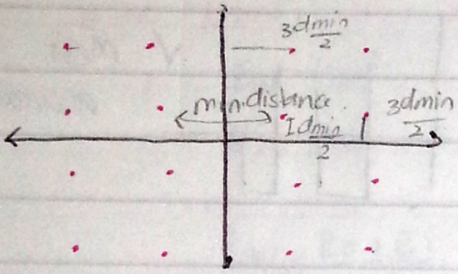
$M = 2^m$ symbols. (waveform)



looks like phase shift keying constellation
"PSK" Constellation.

better in fading channel

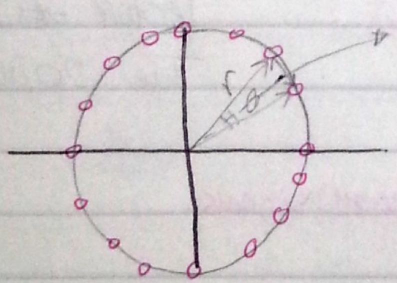
P.S best solution is. points on Grid:-



* if the minimum distance ~~are~~ is equal → the we take the min. avg energy

looks like QAM constellation.

* In baseband, wired channel there's no fading & the channel only additive white Gaussian Noise.
* In Wired Transmission :-
we can control the fading using matching both ends of the wires & only additive white ~~noise~~ Gaussian Noise.
(Thermal Noise).



$\theta = \frac{2\pi}{M} = \frac{2\pi}{16}$

$E_{av} = r^2 t$.

For PSK. r as fn. of minimum distance:

$$\frac{d_{min}}{2} = r \sin\left(\frac{2\pi}{M}\right)$$

↑ # of points.

Thus :

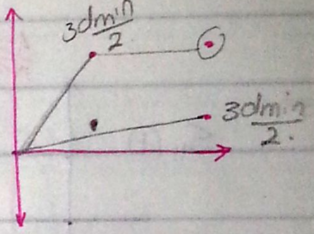
$$r = \frac{d_{min}}{2 \sin\left(\frac{2\pi}{2M}\right)}$$

$$\Rightarrow E_{avg} = \left(\frac{d_{min}}{2 \sin\left(\frac{2\pi}{2M}\right)}\right)^2 T$$

For QAM:

$$E_{av} = \frac{1}{4}\left[\frac{d_{min}^2}{2} + 2\left[\frac{10}{4} d_{min}^2\right] + \frac{18}{4} d_{min}^2\right]$$

$$\boxed{E_{av} = \frac{40\, d_{min}^2 T}{16}}$$

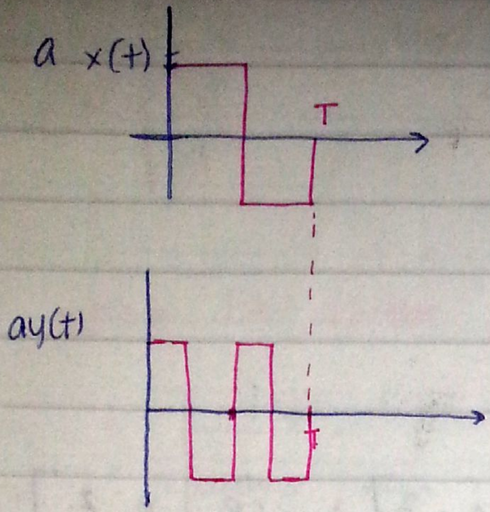


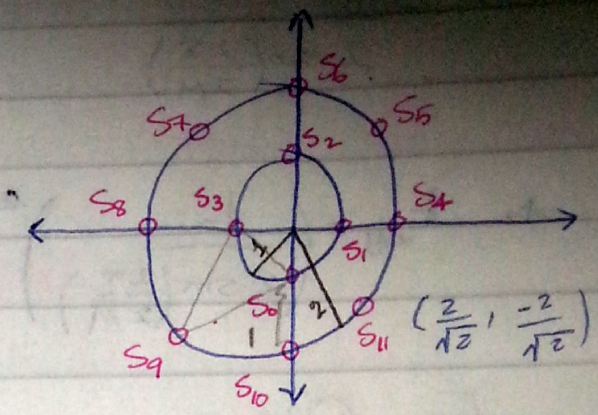
$$= 2.5\, d_{min}^2 T$$

QAM is better.

* Peak to Average Power ratio → (PAPR).

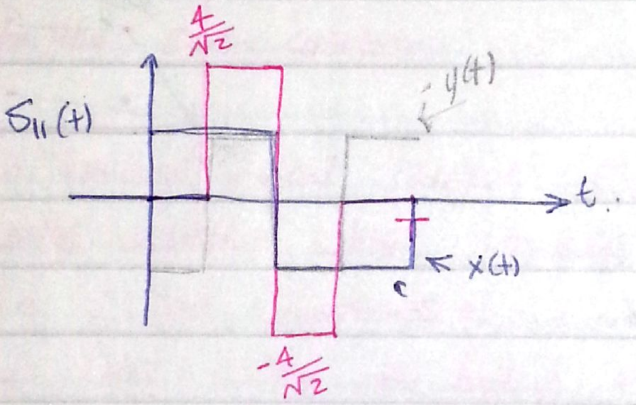
↳ we need it as small as possible.



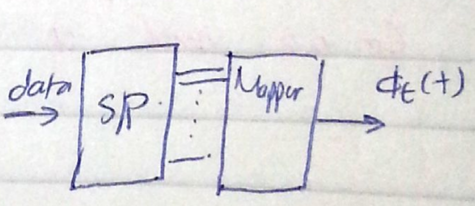


APSK "Amplitude, phase Shift Keying".

$$S_{11}(t) = \frac{2}{\sqrt{2}}\, a\, x(t) - \frac{2}{\sqrt{2}}\, a y(t)$$



Tx



* Designing Criteria.

- Minimum energy, Maximum distance.
- More decision variable → increase the ability to notice the difference. (increase the probability of detection).

Mapper.

data	S_i
000	S_0
001	S_5
⋮	⋮

* Gray Code :- every adjacent symbols differs in only 1 bit.

* Gray Code

differs in one bit.

0 0 1

0 0 0 ← as a Mirror.

0 1 0

0 1 1

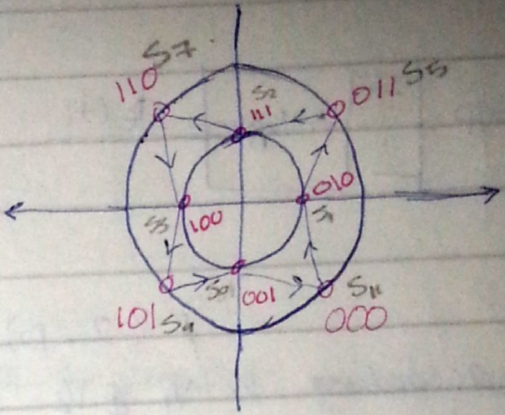
1 1 1

1 1 0

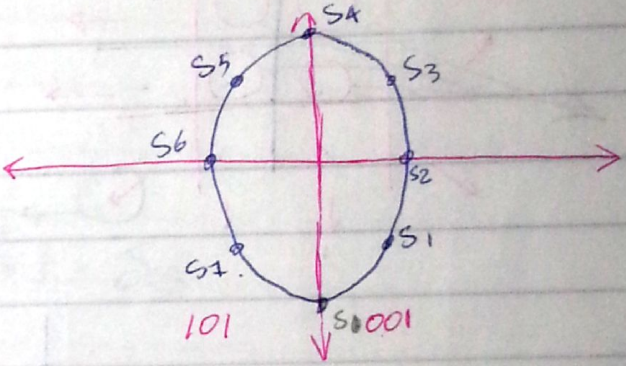
1 0 0

1 0 1

is A



if the 8-points on 1 circle it becomes like



* ~~En~~ all mapping techniques use Gray Code :- minimize error to only 1 bit.

*mapping: توزيع "0" و "1" على ال constellation.

* Usually we can ~~enhance~~ improve enhancement using if-Statement. (correlated).

* One-One → full response Signaling (Memory less)

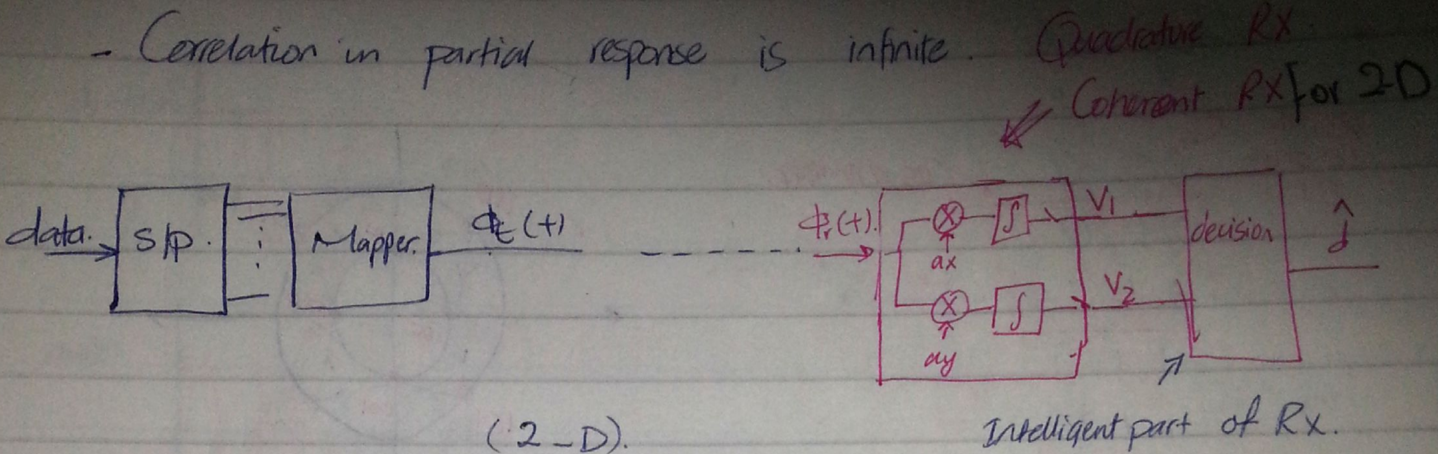
* Memory → Partial response Signaling.

↳ Full response → One bit input one bit output (System is fully response for a time).

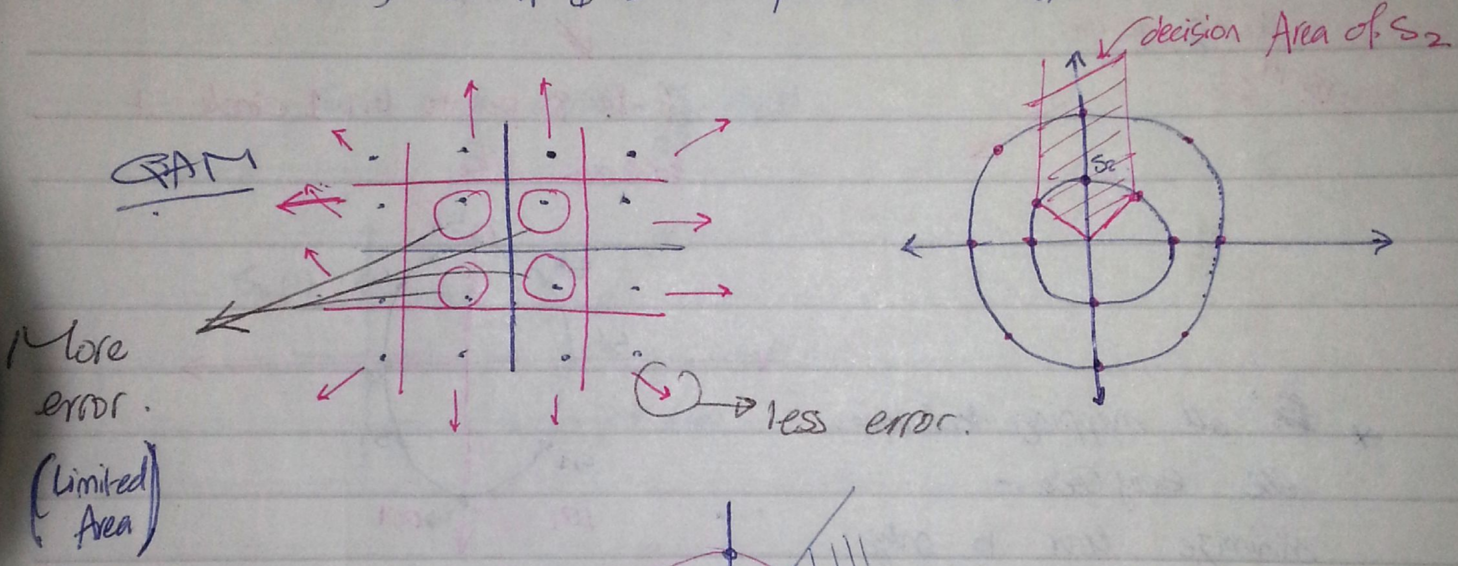
↳ partial response → responding to the current and previous data. (data is sent many times)

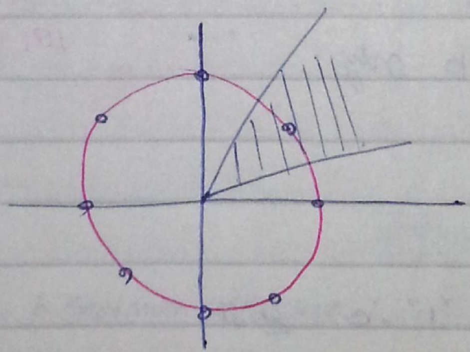
better performance

- Correlation in partial response is infinite.



according to V_1 & V_2 we put it onto constellation.

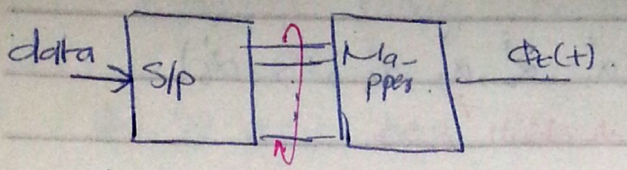




* Non linear functions ⟹ We Get Gain.
Linear functions ⟹ No Gain.

* Coherent Rx → has synchronization.

* to Get ~~Pea~~ less Peak to Avg Power we should Get rid of the ~~[illegible]~~ points that have a ~~un~~ - limited Areas.



$r_b = 30$ kbps

$r_s = \frac{r_b}{m} = 10$ kbps

$T_s = m T_b$ "Convert data to parallel transmission"

Lecture #10

Sun 25/10

Multi-Dimensional Tx:

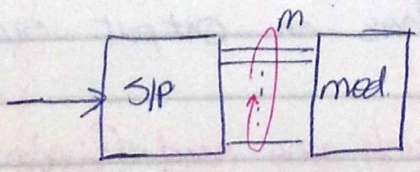
N-D Modulation

N-axis:

$$\left.\begin{matrix} a\, x_1(t) \\ \vdots \\ a\, x_N(t) \end{matrix}\right\} \quad \langle a x_i , a x_j \rangle = \delta_{ij}$$

$\overset{\nearrow}{\# M}$ doesn't relate to $\overset{\nearrow}{N}$

# of constillation points. # of axis.



$M = 2^m$

Example: $m = 4 \longrightarrow M = 16$

16-ary mod

$N = 6$ dimension

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \rightarrow H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

$$H_8 = \begin{array}{l} \left[\begin{array}{cccccccc} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{array}\right] \end{array} \begin{array}{l} x \leftarrow dc. \\ ax_1 \\ ax_2 \\ ax_3 \\ ax_4 \\ ax_5 \\ ax_6 \\ - \end{array}$$

- $P_i = (\alpha_1^i, \alpha_2^i, \overset{\nearrow}{\alpha_3^i}, \alpha_4^i, \alpha_5^i, \alpha_6^i)$

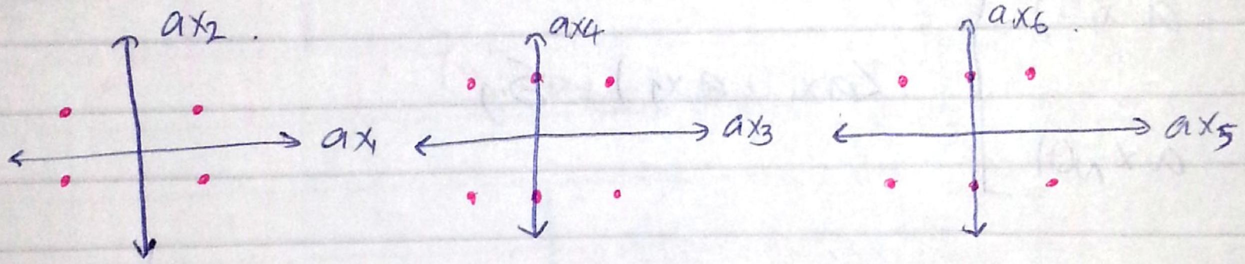
مسقط النقطة على الـ axis

- each 2-axis can be represented as a plane (3-planes For this example)

- take One Point For example:
  $P_5 = (1, -2, -1, 0, 1, 0)$

- 16 points in 4 planes are better than two planes; more dimensionality of the space → less peak to average ratio.

- let's distribute the 16 points on the three planes.

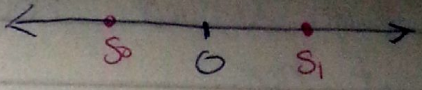


- modulator → do the mapping.
- One-One mapping For full response (modulator); every input compenation has an output symbol.

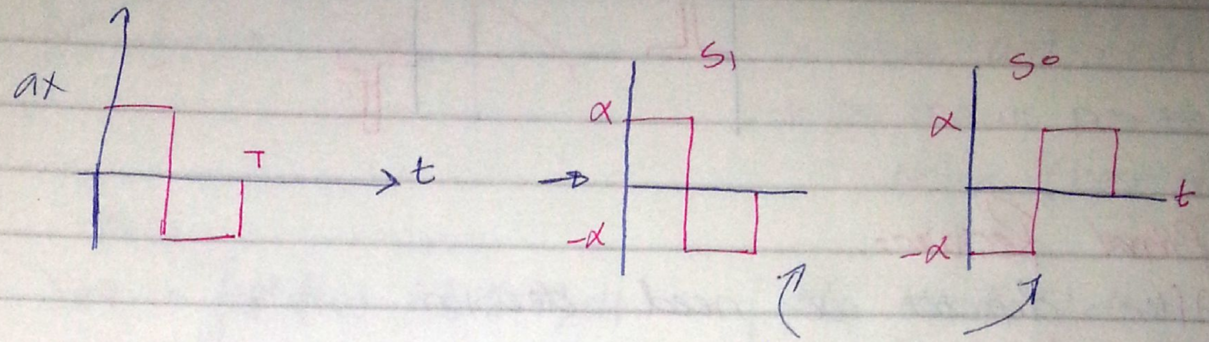
- more axis → more complexity → each axis need Quadrature modulator → more cost from implementation point of view. → more # of decision variables.

- Non Coherant Rx: doesn't have to be preciese.

Example: Binary Tx (S_0 , S_1).



A. let $ax(t)$ be:

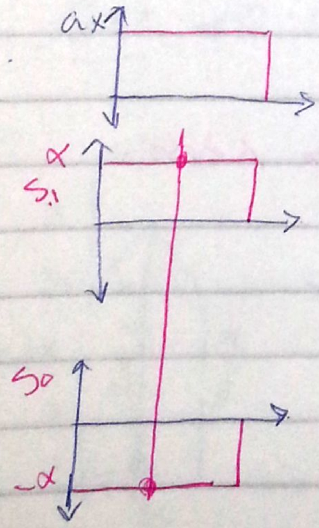


do samples in the Period
↳ using Voltage without synchronization

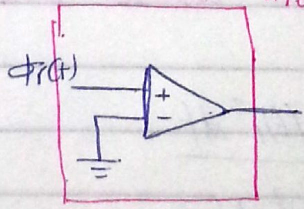
3_types of synchronization:

1. Carrier Synchronization (not enough to read data)
2. bit degree synchronization
3. Frame degree synchronization [must be verified].

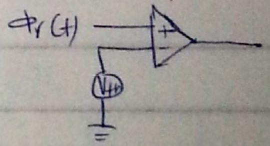
B. let $ax(t)$ be:



*level detector.

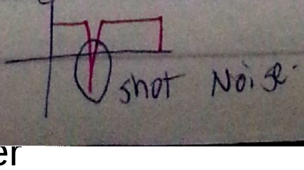


* if the threshold ≠ 0 we use $V_{threshold}$ instead of ground.

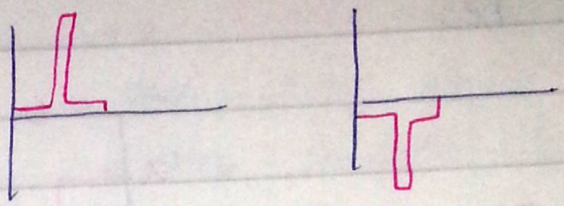


* to eleminate DC value → $P_r(0) = P_r(1)$ statistical features of Data.

P.S 1. used for Asynchronous.
2. Rx → simple but only depends on Amplitude.
3. we use a small length of frame to not loose synch.
↳ if a shot noise happened → error in reading data.

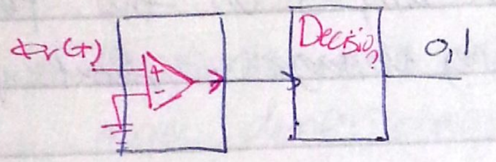


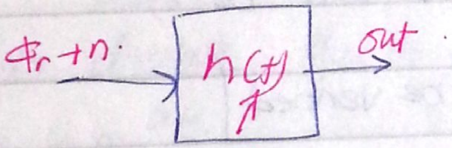
4. High Amplitude isn't required because we need high-valued source regardless to the min. energy it has.



Optimal Reciever:

After detection we need decision.





filter with SNR value to be maximum.

$$SNR = \frac{|\Phi_r * h(t)|^2}{\int \underset{\uparrow}{S_{nn}(f)} \cdot |H(f)|^2\, df}$$

$\frac{\eta_0}{2}$; for additive white Gaussian Noise.

$$SNR = \frac{\int |\Phi_r(f)\, H(f)|^2\, df}{\frac{\eta_0}{2} \int |H(f)|^2\, df}$$

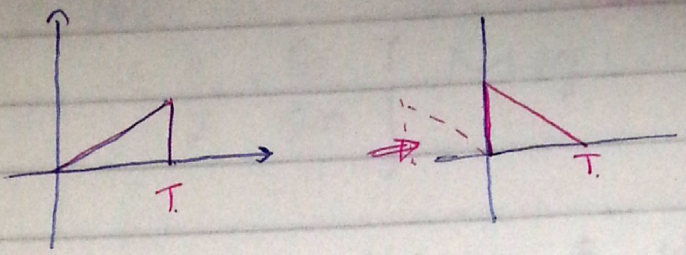
thus:

$$\int |\Phi(f) \cdot H(f)|^2 df \leq \int |\Phi(f)|^2 df \cdot \int |H(f)|^2 df$$

*** the equality happened when $\Phi(f) = H^*(-f)$.

In time domain → $h(t) = \Phi^*(T-t)$

if .



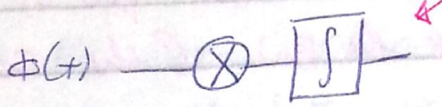
→ rotate and shift by T

→ as min as possible of Noise. (best decision)

thus:

$$V_{out} = \int \phi(t)\, h(\tau - t)\, dt = \int \phi(t)\, \phi(t + \underset{\text{constant.}}{T} + \underset{\text{variable.}}{\tau})\, dt$$

$$\rightarrow V_{out}(u) = \int \phi(t)\, \phi(t+u)\, dt$$



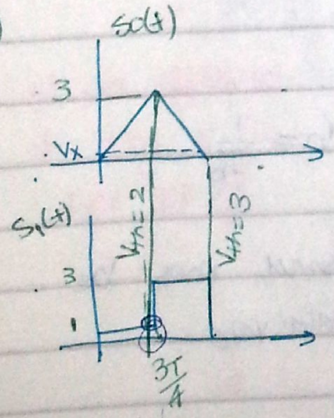
Correlator Rx.

* Correlator Rx is the Optimal Rx.

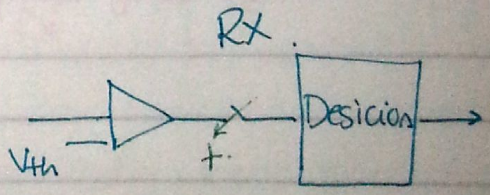
Quiz #2 :

Tue. 27/10

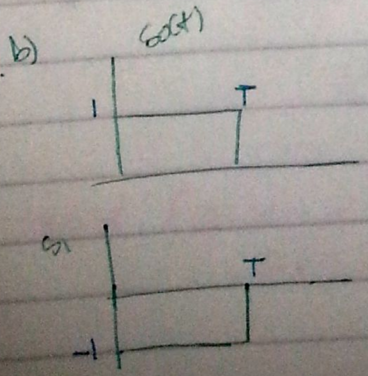
a)



$$V_{th} = \frac{3 + V_x}{2}$$

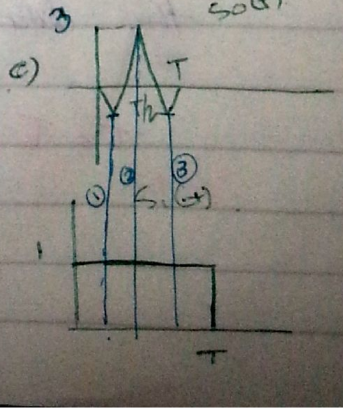


b)



$V_{th} = 0$, timing any where $0 < t < T$

c)



From synchronization point of view V_{th_2} is the best choice.

$V_{th_1} = 0$

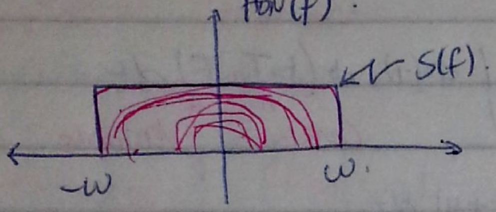
$V_{th_2} = 2$

$V_{th_3} = 3$

Tue 2/10

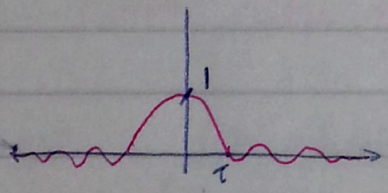
Tx	Rx
* No DC	* More Data (Vth >>)
* More Data	* time (better)
* Maximum Distance	
* Minimum energy	

Band_Limited channels:



Soft limitation of bandwidth → limit the BW of the transmitted signal no matter what the BW of the channel.

* S(f) is a Sinc in time domain.



$$\boxed{\omega = \frac{1}{2\tau}}$$

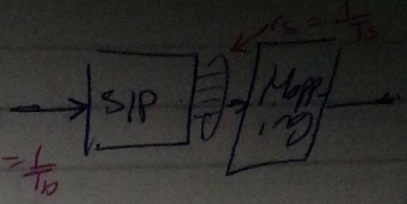
if $\tau = T_b$ (period) & ~~then~~ $r_b = \frac{1}{T_b}$.

For Binary → $\{ \omega = \frac{r_b}{2}$. ↖ the BW of the channel must be half the used data rate.

if Binary Transmission can pass the double value of the data rate.

$\tau = T_s \Rightarrow W = \frac{r_s}{2}$.

$T_s = m T_b$.



thus.

$$w = \frac{r_s}{2} = \frac{r_b}{2m} \Big\} \text{ M-ary.}$$

* if $r_b = 160$ kbps. & $w = 20$ kHz. Can it be transmitted?

Sol. $w = \frac{r_b}{2m} \Rightarrow m = \frac{160k}{2 \times 20k} = 4$.

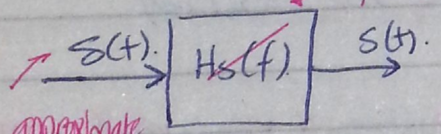
base band (2).
Band Pass (No 2).

* At the same channel at the same time I can transmit 4 bits in parallel.

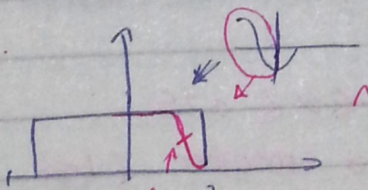
* The most expensive part of communication [illegible] is the BW

* Data rate → consumer requirement.

*



we can approximate it using a thin unit step



α: (roll off factor)

$n(R, L, C) \propto \frac{\Delta H}{\Delta f} = \infty$ (∞ # of components)

*

$w = (1 + \alpha) f_m$.

RCα = wave form shapping filter.

raised Cosine ∝ Simple to implement & causal.
↳ sub optimal

lecture #12.
Thr 29/10

Ex $w = \frac{r_b}{2m}(1+\alpha)$.

* One more time: in bandpass there's no $\boxed{2}$.

*3 types of BW:
1- 3dB BW ($\frac{1}{2}$ power).
2- null to null Bandwidth.
3- Percentage of Power Bandwidth.

Example: r_b = 1Mbps. Design a system:
BW = 20KHz.

Sol $20k = \frac{1M}{2m}(1+\alpha)$

$m = \frac{1*10^6}{40\times10^3}(1+\alpha)$ => $m = 25(1+\alpha)$

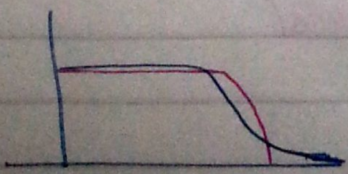
→ α mustn't be zero; α = 0 ideal and there's no ideal system.

→ Practically: $0.12 \leq \alpha \leq 0.25$.

* bigger value of α → smoother. (less ~~data rate~~ BW)

* BW related to the bit rate linearly. *

→ α is too small, but must be bigger than zero, the design of raised cosine filter is more complicated. thats why we select α between (0.12 - 0.25) for acceptable BW.



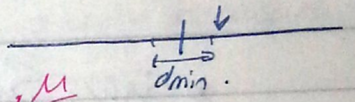
if $m = 26 \rightarrow \alpha = 0.04$ → ⊛.

* show that you understand what are you doing in the exam. =P *.

↳ let $\alpha = 0.15$ → thus $m = 25 * 1.15 =$ ~~28.75~~. 28. bits.

* more bits → more error. → increase the peak to avg ratio (not preferred).

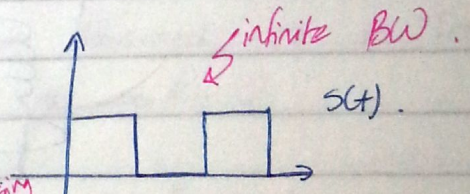
* ~~chas~~ choose the bigger value by one integer value than it is when $\alpha = 0$.
then you find α ; if $\alpha < 0.12$ you say: valid but not optimal (more complixity system).
then you take $\boxed{\alpha = 0.12}$. to find the Optimal value of $\boxed{m}$.



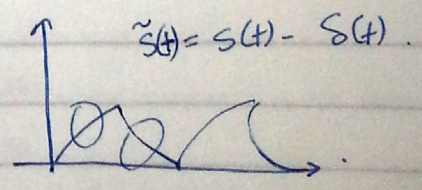
* $S_i = d_{min}\left(\frac{2i-1}{2}\right)$, $i = -\frac{M}{2}, \frac{M}{2}$.

Find the average energy for this example → as a function of dmin and M.

* Intersymbol interference [ISI].



after crossing filter.



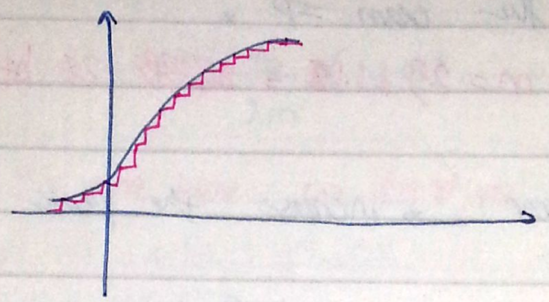
after crossing a channel that has less BW than the signal. ←

$\tilde{s}(t)$: Signal with distortion.

$ISI = \sum_{i=1}^{\infty} S_i(t)$
↑ practically.

$|S_i(t)|$ → can be two sided (-ve & +ve)
↳ $(S_{min} \leq |S_i(t)| \leq S_{max})$.

* Δ Modulation : Quantization (either +1 or −1) .



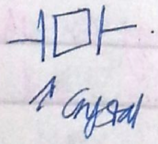
* Central limit theorem: Σ RU = Gaussian (RU) .

thus :

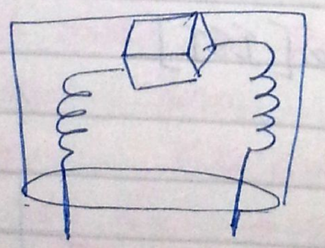
* ISI is a gaussian Random Variable (additive white Gaussian Noise) .

* $\Phi_t(t) \longrightarrow \underset{n(t)}{\uparrow} \longrightarrow \Phi_r(t) = \Phi_t(t) + n(t)$.

* SAW : Surface Acostic wave filter .



size $\alpha^{-1} f$.



* Wed ⇒ 24/11/2015.

Lecture #13
Sun 8/11

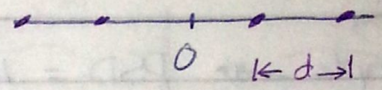
* Performance:-

$$* \; BW = \frac{r_b}{2m}(1+\alpha)$$

raised cosine.

$$\Phi_t(t) = a_i \underbrace{RC_\alpha(t)}_{p(t)}$$

$$= a_i \, p(t).$$



will define the performance.

* quality of service ⇒ has a parameter of quality of signals (RX) (based on the system parameter).

* We usually count the avg error (bit error rate) [BER]. which is the way to descripe the quality measure of a Recieved signal. (Performance measure).

BER ⇒ expectation of errors $E\{error\}$.

	Tx	Rx	
	1	0	$Pr(0 \mid 1)$
or	0	1	$Pr(1 \mid 0)$.

error event : conditional event when we transmit a 1 and Recieved 0 or Transmit 0 ~~1~~ ⇒ Rx 0.

$$V_o = \int_0^T \Phi_R \, p(t) \, dt = \hat{a}_i$$

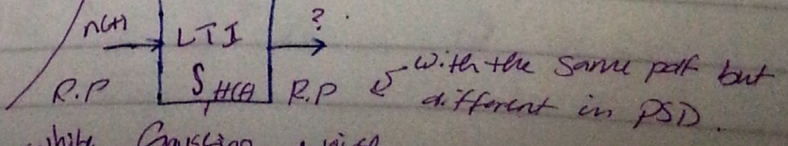
; ~~if there's a noise~~.

↑ for clean signal with no noise

↑ * in RC $(-\infty, \infty)$ *

$$V_o = \int_0^T \Phi_R \, P(t) \, dt + \int n(t) p(t) dt$$

← with noise.



with the same pdf but different in PSD.

additive white Gaussian Noise.

* if the PSD for the input = $\frac{n}{2}$. then the PSD for the O/P will be..

$$S^o_{nn}(f) = \int_{-w}^{w} S^i_{nn}(f) \cdot |H(f)|^2 \, df = \frac{n_o}{2} \int_{-w}^{w} |H(f)|^2 \, df = \boxed{\eta_o \cdot w} = \sigma_{n_o}^2$$

if raised cosine

⊛ example → $PSD_i = 10^{-5}$ W/Hz ⇒ $\boxed{\frac{n_o}{2}}$

$PSD_o = 10^{-5} * 2 * BW$.

* Total Power of a process = Variance = $\sigma_{n_o}^2$.

* $$f_{n_o}(n_o) = \frac{1}{\sqrt{2\pi \sigma_{n_o}^2}} e^{-\frac{1}{2\sigma_{n_o}^2}(n_o - \mu_{n_o})^2}$$ ⇒ For Gaussian.

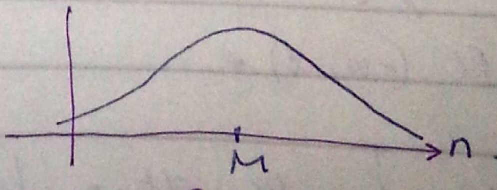
→ thus:

$$V_o = \int_0^T a_r \, p(t) \, dt + \int n(t) \cdot p(t) \, dt.$$

$= a_i + \underline{\underline{n_o}}$ ← Random Variable. (Gaussian) $N(\overset{\text{Zero mean}}{0}, \overset{\text{variance.}}{\sigma_{n_o}^2})$.

* White → PSD exist on all frequencies.

* if the noise took the shape of the filter → Colour Gaussian noise. (diffrent PSD).



$$Pr(n \le \beta) = \int_{-\infty}^{\beta} f_n(n) \, dn.$$

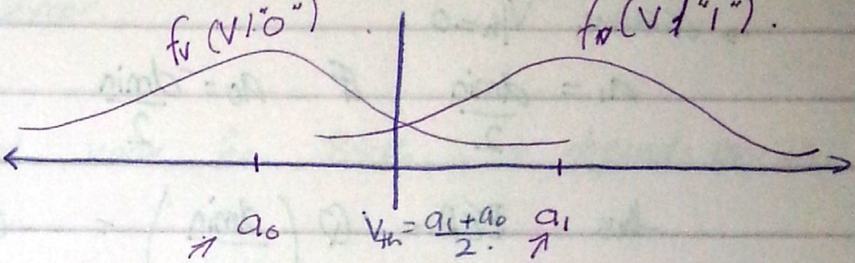
[illegible] $V = a_i + n_o \xrightarrow{} N(0, \sigma_{n_o}^2)$

$\downarrow$ — constant shift.

$N(a_i, \sigma_{n_o}^2)$

conditional PDF function based on $\boxed{a_i}$.

* Binary Tx. Case:



Gaussian Centered around a_0

we will recieved. a Gaussian centered around a_1.

$Pr(0|1) = \int_{-\infty}^{V_{th}} N(a_1, \sigma_{n_o}^2)\, dn$.

less than Vthreshold

cuz we transmit a (1).

Same Area. (as quantity)

$Pr(1|0) = \int_{V_{th}}^{\infty} N(a_0, \sigma_{n_o}^2)\, dn$.

higher than Vthreshold

* $BER = Pr(1|0) * P(0) + P(0|1)\, P(1)$. ← total Probability.

if $P(0) = P(1) \Rightarrow \therefore$ [illegible] $= Pr(0|1) = P(1|0)$. ← check if they are equal to BER ?!.

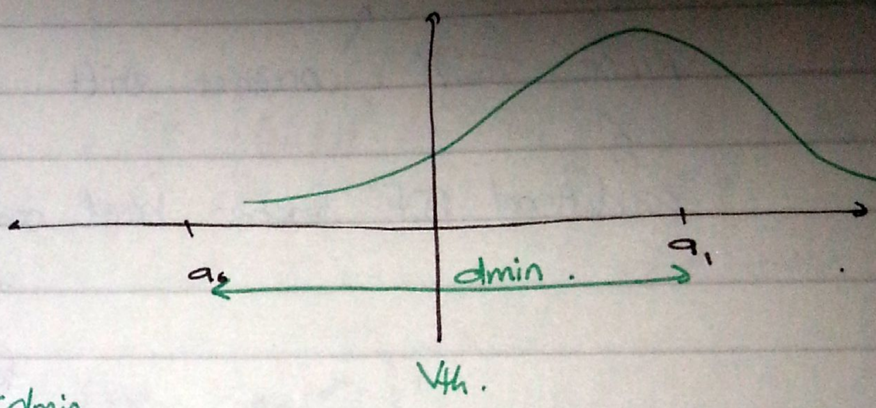
$$= \int_{-\infty}^{V_{th}} \frac{1}{\sigma_{n_o}\sqrt{2\pi}}\, e^{-\frac{1}{2\sigma_{n_o}^2}(n_o - a_1)^2}\, dn_o.$$

* $Q(t) = \frac{1}{\sqrt{2\pi}} \int_{t}^{\infty} e^{-t^2/2}\, dt$

let $x = \frac{n_o - a}{\sigma_{n_o}} \Rightarrow dx = \frac{dn_o}{\sigma_{n_o}}$

thus it becomes: $\int_{-\infty}^{\frac{V_{th}-a_1}{\sigma_{n_o}}} \frac{1}{\sqrt{2\pi}}\, e^{-x^2/2}\, dx = Q\left(\frac{-V_{th} + a_1}{\sigma_{n_o}}\right)$

* $BER = Q\left(\frac{-V_{th} + a_1}{\sigma_{no}}\right)$



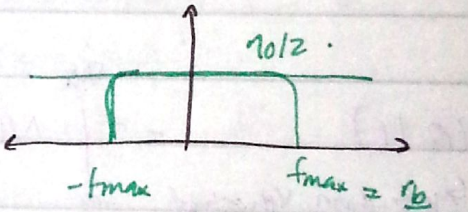
$$Q = \int_u^\infty N(0,1)\,dt.$$

→ assume $V_{th} = 0$

$a_1 = \frac{dmin}{2}$ & $a_0 = -\frac{dmin}{2}$

thus $BER = Q\left(\frac{dmin}{2\sigma_{no}}\right) = Q\left(\sqrt{\frac{dmin^2}{4\sigma_{no}^2}}\right).$

→ But $\sigma_{no}^2 = \eta_0 \frac{r_b}{2}.$



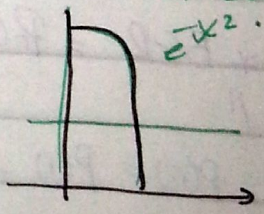
$\sigma_{no}^2 = \eta_0 f_{max}$

thus:

$$Q = \left(\sqrt{\frac{dmin^2}{2\eta_0 r_b}}\right) = Q\left(\sqrt{\frac{dmin^2 T_b}{2\eta_0}}\right).$$

↑ if this increase → Q decrease.

* more dmin → decrease BER.



$V_{rms} = \sqrt{4KTB}$ ← Bandwidth.

↑ temprature.

noise True RMS value (voltage) for (1 Ω) Resistance

$$\sigma_{no}^2 = \frac{V_{rms}^2}{1(R)(\Omega)} = \underbrace{4KT}_{\frac{\eta_0}{2}}B$$

Example :

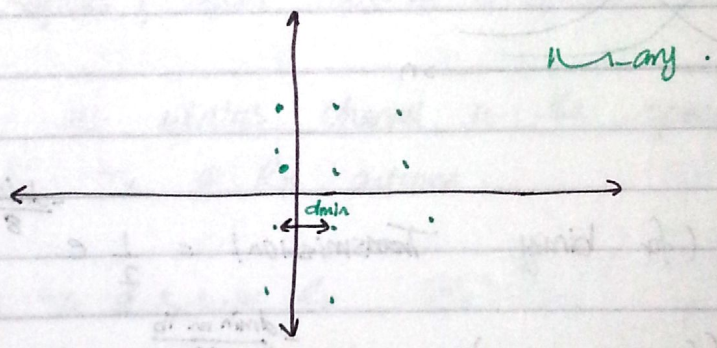
$BER = 10^{-4}$ (Probability of detecting the signal in any Tx with error).

-1- Transmit the signal in packets (1000 bit instead of 10000) thus the propability to have an error is $\frac{1}{100000}$ thus ; can resend the packet if there's any error. (Packet switching).

-2- error Correction : if there's an error we resend the data until we have a zero error.

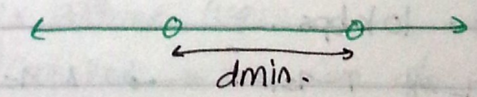
p.s* There's no good or bad value for BER ; it depends on the System itself.

Consider the following Constellation



Closer points might have more error.

Worst case scenareo → the points with min distance have the biggest BER / $\overset{\text{Symbol}}{SER}$, any two points will have less BER.



thus:

$$SER \simeq Q\left(\sqrt{\frac{d_{min}^2 T_s}{2\eta_0}}\right) ;$$

$$BER = \frac{1}{m} SER \quad \text{(For Gray Coded)}$$

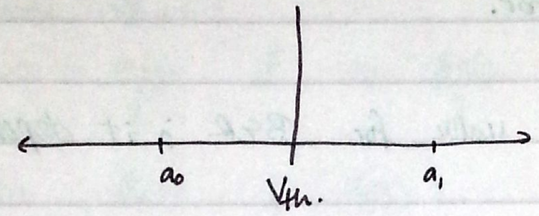
Only for Coherent Rx.

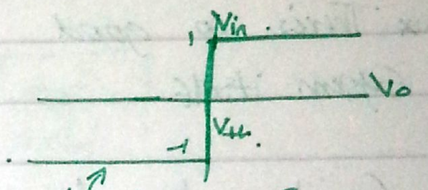
$$BER = \frac{1}{m} Q\left(\sqrt{\frac{d_{min}^2 \, m T_b}{2\eta_0}}\right)$$ ← approximation type for any modulation for Coherent Rx.

$$Q(x) \simeq \left[\frac{1}{(1-a)x + a\sqrt{x^2+b}} \right] \frac{e^{-x^2/2}}{\sqrt{2\pi}} \; ;$$

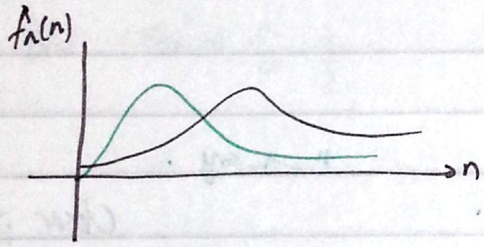
where $a = \frac{1}{\pi}$ & $b = 2\pi$.

- for Non-Coherent Reciever: (level detector).





*. Vfn is not Gaussian *



⊛ BER (for binary Transmission) $= \frac{1}{2} e^{-\frac{d_{min} T_b}{8\eta_0}}$

⊛ B.ER (for M-ary) $\simeq \frac{1}{2m} e^{-\frac{d_{min}\, m T_b}{8\eta_0}}$.

Example:

$r_b = 10$ kbps.

M-ary $M=16$. → $M = 2^m$ → $m = 4$.

$\eta_0 = 10^{-4}$

$d_{min} = 2$ Volts.

Coherent Rx:

$$BER = \frac{1}{4} Q\left(\sqrt{\frac{4*4}{2}}\right) = \frac{1}{4} Q(\sqrt{8}).$$

level Detector:

$$BER = \frac{1}{8} e^{-1}$$

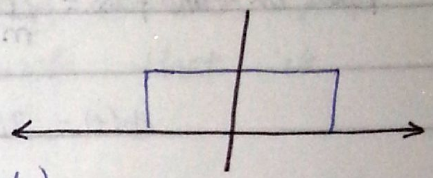
P.S
If we were Given
PSD = 10^{-4}
then η_0 = PSD * 2
$\eta_0 = 2 * 10^{-4}$

* AutoCorrelation fn. of noise = $5\Delta\tau$ PSD = $\mathcal{F}\{(\text{Auto Correlation})\}$.
thus PSD = 5

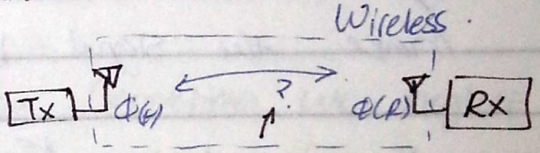
* PSD = $\sin(\omega\tau)$ is stationary or not stationary → not stationary because it isn't symmetric around the origin.

lecture #15
Thr. 12/11.

* Band Pass: (applied in wireless channels)
  - ↳ we don't have an infinite bandwidth.
  - * We care about orthogonality in order to detect the signals (signals must be orthogonals).



→ physically the wireless channel is the space ∴
* We need Tx & Rx antenna.



make a difference in Φ_t (according to the channel).

* Multi Tx & Multi Rx
  - use the same channel
  - at the same time so the best way to detect them is to make them in different freq.

↳ Multiple axis → ① Controlled → we can do TDM. (orthogonality in t domain).
↳ ② un controlled (different systems) → Regulation

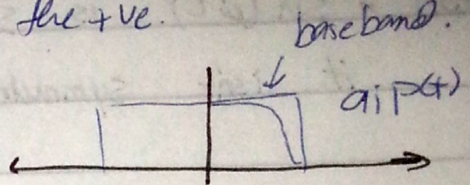
each system works in different freq.

soft limitation of the bandwidth (Band limited systems).

* The most expensive part in the system is the spectrum (freq).

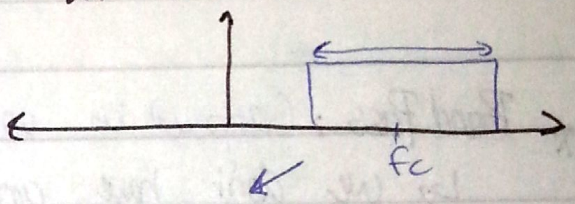
* BW in the baseband was: $\frac{r_b}{2m}(1+\alpha)$. ← using RC α.

* the -ve is a mirror image of the +ve.



p(t) → Raised cosine.

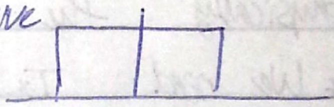
* translate to Band Pass *
in band Pass.



BW in Band Pass = $\frac{r_b}{m}(1+\alpha)$ ←

$\phi(t) = a_i\, a\, x(t)$ ← $a_i \underbrace{p(t)\cos(\omega_c t)}_{a\,x(t)}$.

P.S if we have ~~ano ther~~ another signal: $b_i p(t)$ and transmitt it on the same channel it will have ~~the~~ interference so if we make the signal: $b_i \underbrace{p(t)\sin(\omega t)}_{a\,y(t)}$

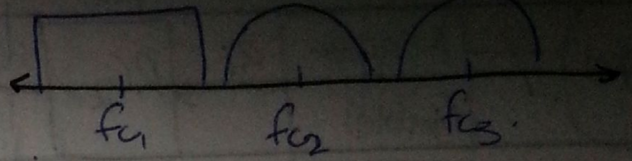


- Is $a_i\, a\, x(t)$ & $b_i\, y(t)$ are orthogonal ?!.

We can't decide according to p(t) which can make them not orthogonal ;
so the affect of p(t) & the amplitude must be constant for the same period.
thus the max. freq of p(t) must be less than the freq. of the carrier. $f_m \ll f_c$. to make the two signal orthogonal.

↳ two Dimension modulation
for multi Dimension Modulation we change ω

define an axis ⇐



⇒ We change ω in the way that it wont overlap with other signals.

→ Inside the channel we want the signal ~~to~~ be orthogonal to not overlap or SNR acceptable if the interferance happen with a little amount

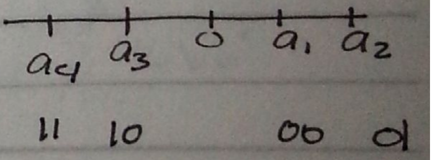
→ Band Pass trans. ~~realize~~ realize band limited, One Dimension, two Dimenssion Modulation by selecting different freq. (using cos & sine for 1 D) . such that it garantee to not ~~over lap.~~ overlap.

→ axis now is ($P(t)$ cos $\omega_c t$)
↗ wave form shapping filter.

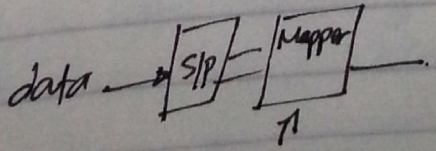
→ BW (Band Pass) = 2 BW(~~B~~ base band).

* 1-D → the change in Carrier (sometimes we neglect $P(t)$) we only have Cosine or Sine with a factor (~~and~~ a_1).
a_i ≡ constellation (Amplitude).

& then we put the binary. (Gray Coded) ⇒ BER. (best).

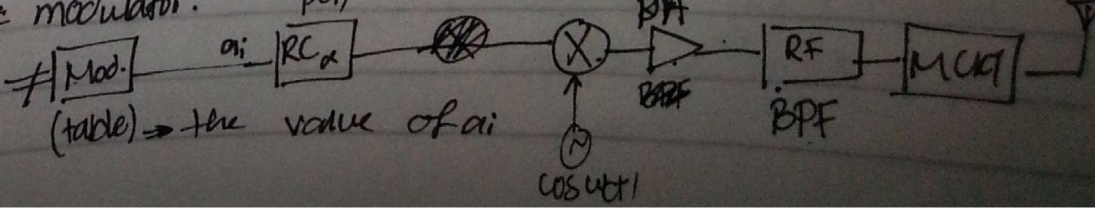


* AT TX:

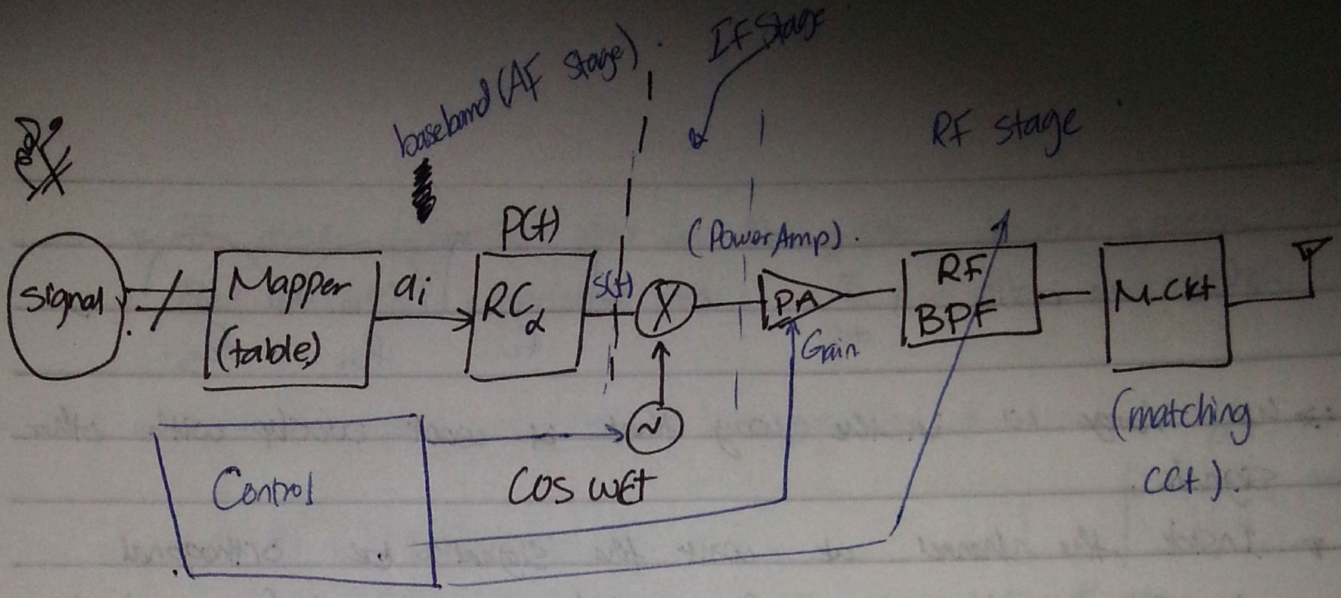


$a_i\, p(t) \cos(\omega_c t)$

⊛ Mapper ≡ modulator.

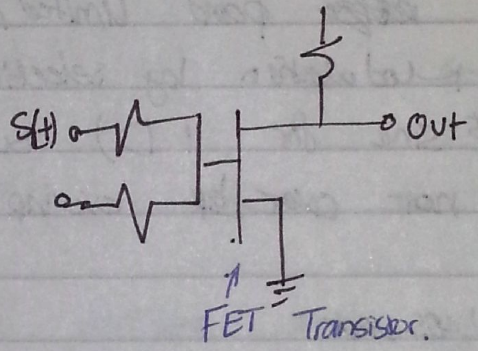


(table) → the value of ai



each antenna must be matched.

Mixer →



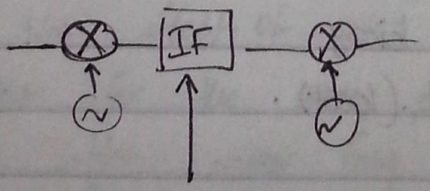
$$\rightarrow k\,(s(t)+\cos(\omega_c t))^2$$

$$= s(t)^2 + \cos^2(\omega_c t) + 2s(t)\cos(\omega_c t)$$

(FET) $V_o \propto V_{in}^2$ (2nd Order).

we put on the (out) of the FET a band Pass filter centered around ω_c so we pass → $s(t)\cos(\omega_c t)$

* We do mixing in Multistage.



choose the freq. we need.

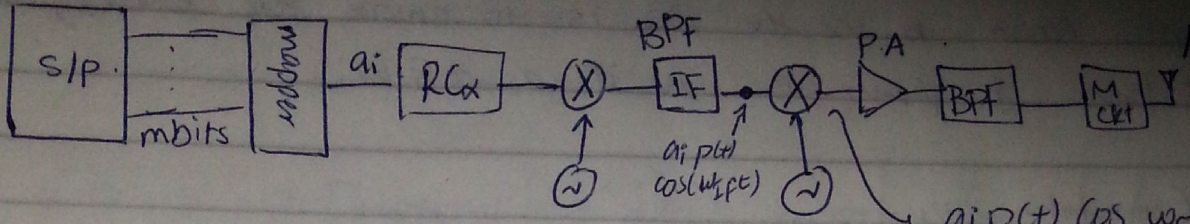
(just like the sattelite).

TP → (12–14) G

15/11/2015

lecture # 16.

for 1-D :-



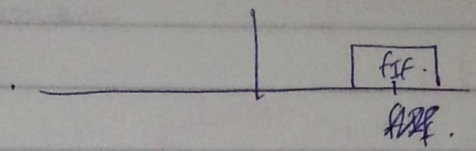
→ $a_i p(t) \cos \omega_c t$)

$\cos(\omega_1 t)$, $\cos \omega_2(t)$

$\Downarrow$

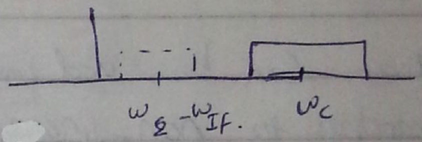
$\omega_c = \omega_2 \underset{\uparrow}{\boxed{\pm}} \omega_{IF}$.

determined by BPF.



thus $f_1 = f_{IF}$.

If $\omega_c = \omega_2 + \omega_{IF}$.

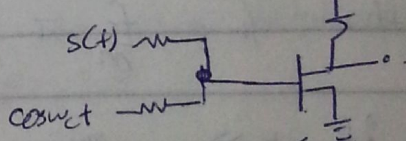


the image is far away from the Original (No Problem)

* Linear or second order mixer. is needed to simplify the mixer. ; thus we assume that all the mixers are Linear region.

* Mixer Order:-

I_{max} - 1 .



$V_{out} = \sum_{i=1}^{I_{max}} k_i V_{in}^i$.

assume we have a 2nd order mixer: thus $I_{max} = 3$ thus.

$V_{out} = k_1 V_{in} + k_2 V_{in}^2 + k_3 V_{in}^3$.

thus; when assuming $V_{in} = \cos(\omega_c t) + S(t)$.

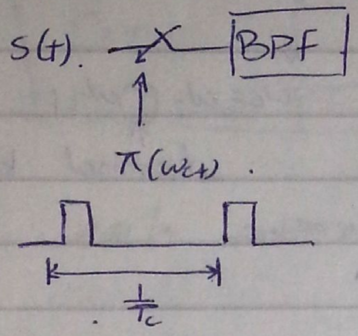
~~thus~~ then $V_{out} = S(t) + \cos(\omega_c t) + ((S(t))^2 + \cos^2(\omega_c t) + S(t) \cos \omega_c t)$

$+ \cdots + S(t)^2 \cos(\omega_c t) + \cdots$.

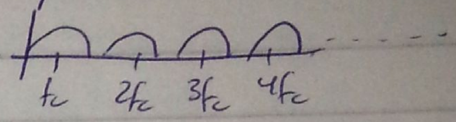
centered around the same Freq. (distortion come from the (non) linearity of the mixer)

*// The main reason to use the RCx is to remove the intersymbol interference & then we use it as a Filter.

*// Commutator ckt :.



* before the BPF the Spectrum is repeated



*// Mixer Can be used as Commutator.

* According to non-linearity of the mixer then a distortion of $s(t)^2 \cos(w_ct)$ is shown at the same Center freq.. but if k_3 is small it can be negligable (for the output of BPF is $k_2 s(t) \cos(w_ct) + s(t)^2 \cos(w_ct)$))

*// for Kth order mixer:

s(t) → @ f_1

Carrier → @ f_2.

thus: $f_o = \frac{f_c}{m} \mp \frac{n}{m} f_1$ $n, m \leq K$.

→ if k >> ~~even~~ m>> then there's a fractions of s(t) so ~~its~~ we need a narrower BPF "problem".

→ In Order to reduce the complexity of RF BPF. we <u>must</u> use linear mixers (1st order Mixers)

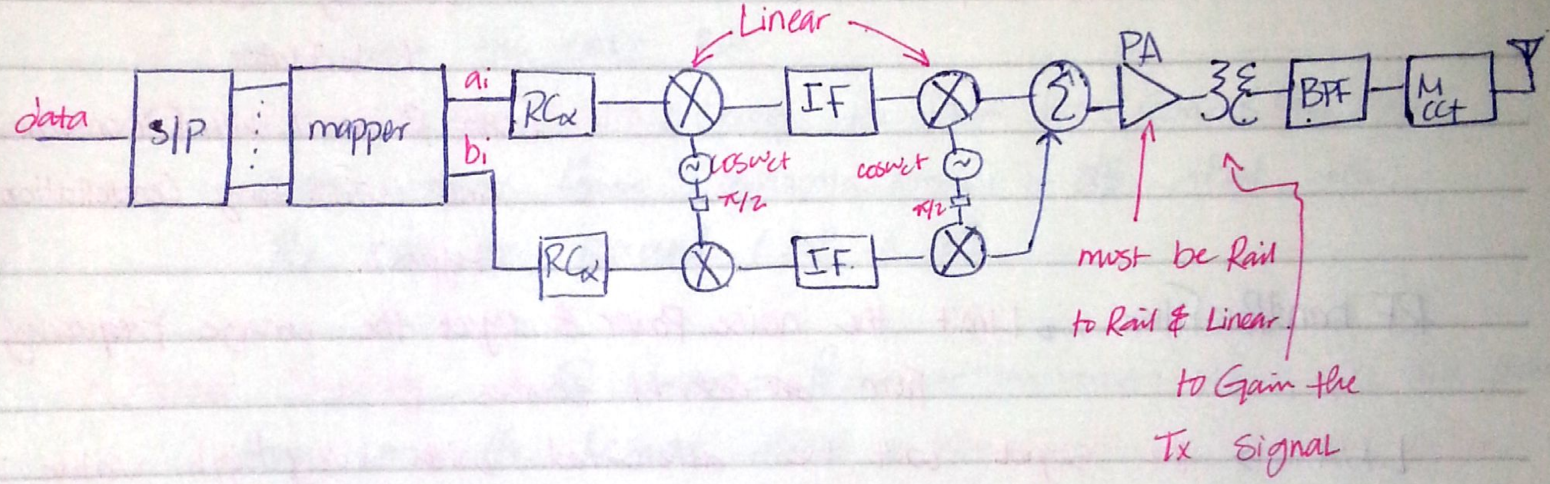
→ And we need to have P.A is to be Rail to Rail linear P.A.

↑

show the o/p exactly for the range of the power suppy.

* If we add a transformer with a gain then we can maximize the output. which is $Ga_i p(t) \cos\omega_c t$ which is $\phi(t)$.

* For a 2-Dimensional 2 outputs to show from the mapper but with phase shift of the carrier equal to $\frac{\pi}{2}$ which make the system QAM modulator.

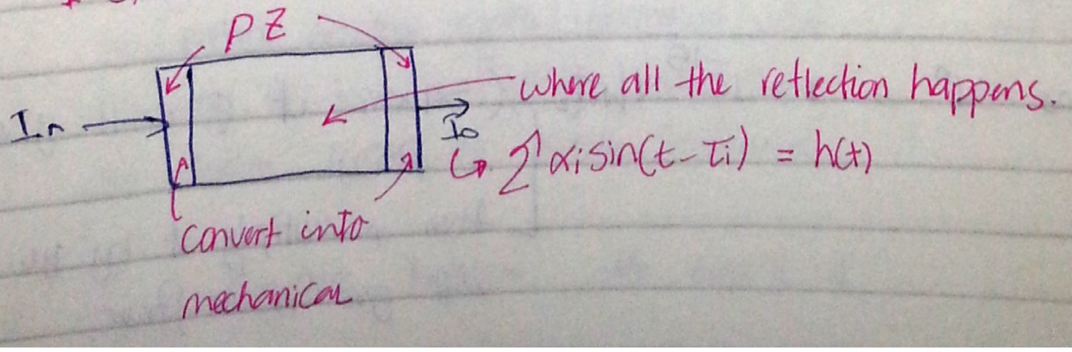


"QAM" :- $\phi_T(t) = Ga_i p(t) \cos\omega_c t + Gb_i p(t) \sin\omega_c t$

* BPF → RLC but inductance in high Frequency is a problem so we use an insulating system (costy design).

* Adjacent channel interference : Inter the power between the signals (Signals Power ~~Interfer~~ Interference).

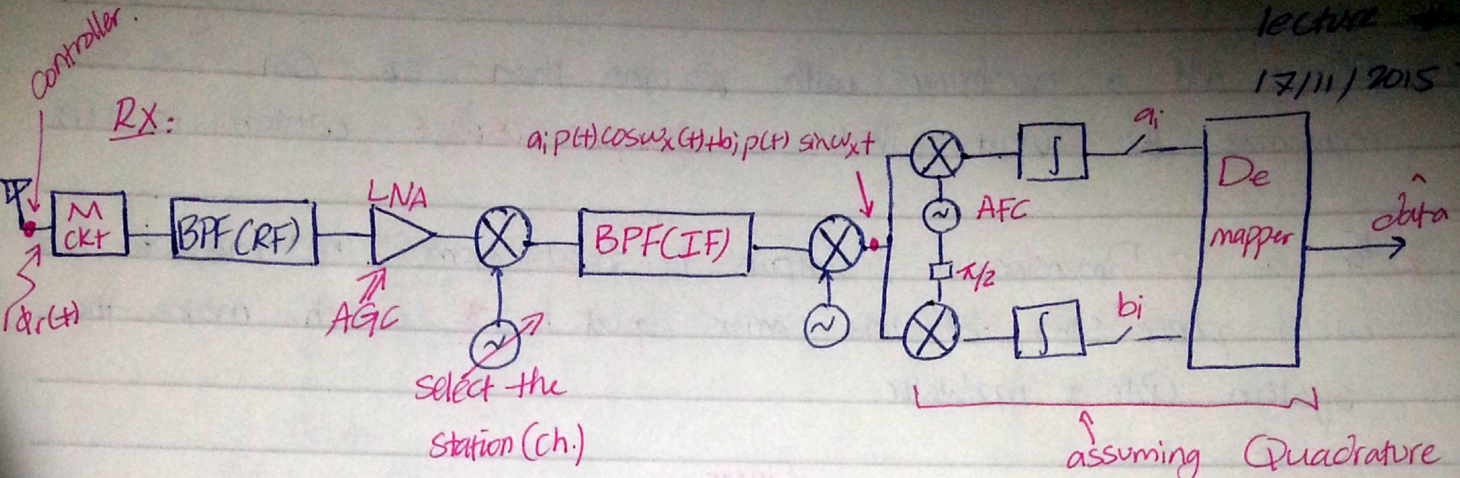
* SAW Filter is to be used as BPF.



lecture

17/11/2015 Tu.

Rx:



assuming Quadrature Modulator.
(can Recieve Multi Dimensions and with any Constellation types).

RF bandPassFilter → Limit the noise Power & reject the image Frequency from ~~ex~~ external sources.

LNA → the signal will be attenuated with a very high value; (both internal noise and noise from air). thus the noise Generated or $\underline{\text{added from Rx}}$ is a very small noise.
↑ noise Figure

→ $P_r = \frac{V_{rms}^2}{R_{in}}$ (Recieved Power & R_{in} to be 50Ω)

Usually $P_r = -100\,dBm = 10^{-10}\,mW = 0.1\,pW$.

→ For Internal noise ⇒
$V_{rms}^{n} = \sqrt{4KTB}$

→ assume $V^n = 1 * 10^{-15}\,V/\sqrt{Hz}$ → (square it & will give PSD).
→ then Multiply it by BW will give noise Power.

* if we put a wire (in antenna design) to be $(\frac{\lambda}{4})$ gives internal impedance = $53 - j72$, so we can reduce $-j72$ to be zero by:

- 1. Adding $+j72$ 2. reduces the length by 75%.

the resistance can't be reduce so we build the whole system according to it.

* M-ckt : used to Match the impedance.

IF : to Limit the exact BW

AGC : Automatic gain control ; change the Gain from $G_{min} \leq G \leq G_{max}$.

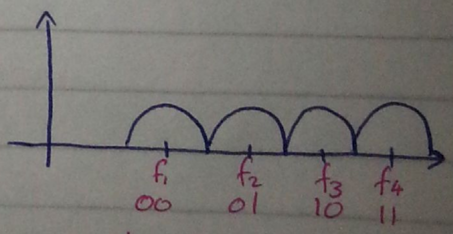
$\Delta G = G_{max} - G_{min}$ (dynamic range) in dB that the Rx can be recieved (ΔP_r in dB).

* Reciever Sensitivity → @ G_{max} = $P_{r\,min}$ ← minimum value of the power that can the Reciever detect ; usually to be measured after [the antenna, Matching ckt & BPF] ; why?!.

we put the controller before the matching ckt to determine the power that can be detected , so if we Recieve smaller value we can: 1. ~~choose~~ change the gain of the Antenna (best)

2. change the length.

* M-D (multi_Dimension) : according to the data we choose the Frequency (FSK)



they all have the same distance of the origin (why we don't use Gray Code)

* Constant envelope signals : information isn't in the Amp, it's in the frequency ; we can use either Filters or Multi_frequencies.

* we Compare between the signal & Zero.

$\phi_{FSK}(t) = a\, p(t) \cos(\omega t)$

↑ depend on Freq.

* Rx is called a Voter

lecture #18.
Thr. 19/11

M-D FSK.

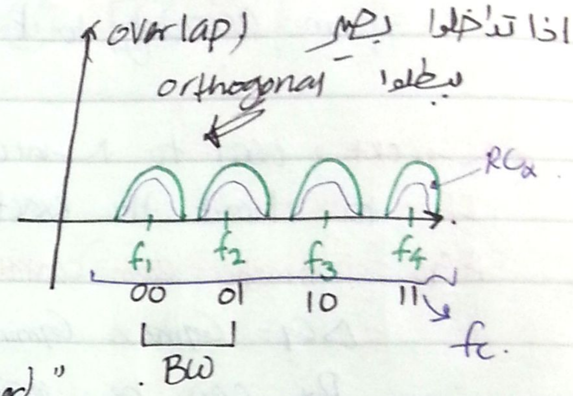
$\phi(t) = \underbrace{a\,G}_{A}\, p(t) \cos(\omega_c t)$

constant value.

* Mapping Table:

00	f_1
01	f_2
10	f_3
11	f_4

* $\frac{r_b}{m} = r_s \Rightarrow \frac{1}{r_s} = T_s$.



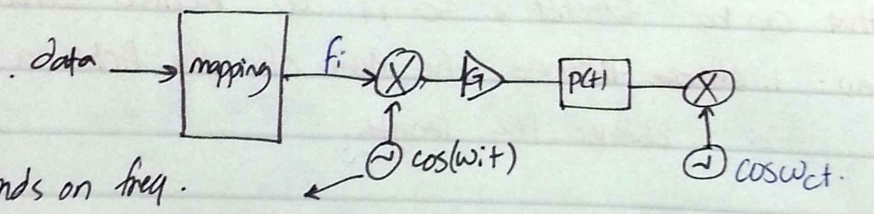
اذا تداخلوا بصير overlap) بطلوا orthogonal

$BW = M \frac{r_b}{m}(1+\alpha)$. "Wide band mod."

FSK > M-PSK ,ASK.

P.S We don't use Gray Code in M-D because they are equal distance

* Narrow Band ⇒ Min. BW. (from implementation point of view and from modulation point of view).

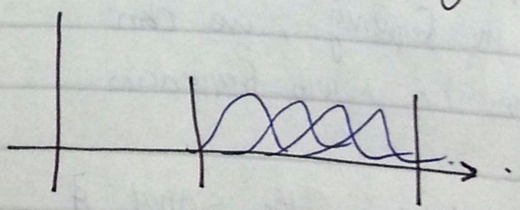


depends on freq.

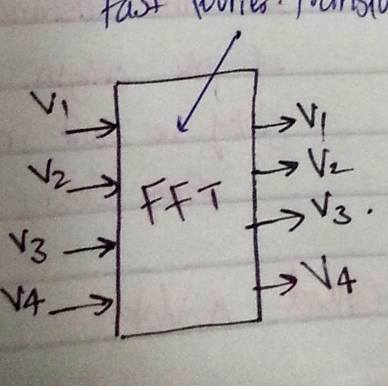
ICI → intercarring interference
GB ⇒ Guide Band

FSK best (modulation against fading)
PSK
ASK

* We need to Compress the BW but keeping all the signals orthogonal.

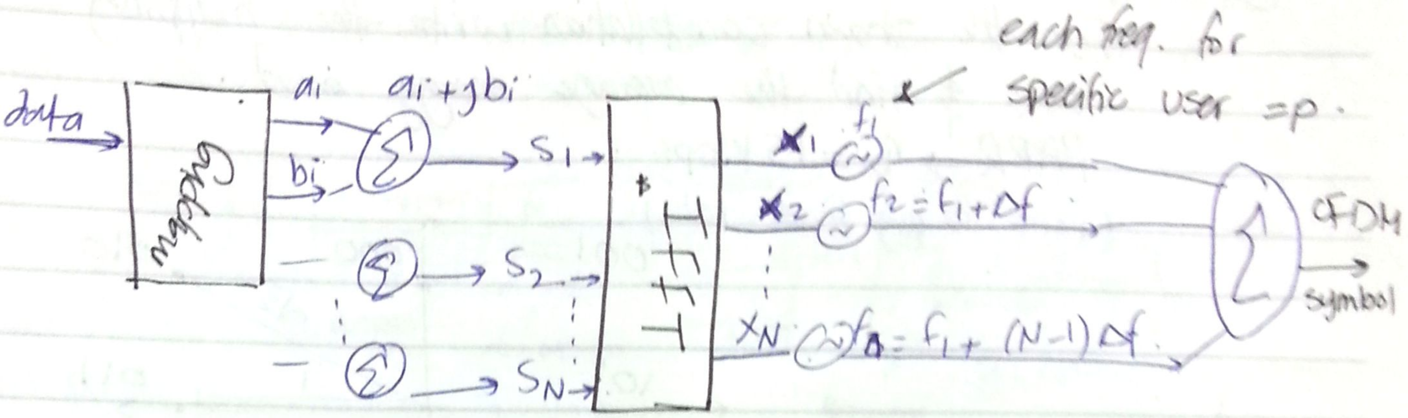


fast fourier transform



$\Delta f = \frac{f_s}{n}$ (frequency resolution increase when # of points increase)

OFDM. (take the data & Compress it):



p.s x_1, x_2 & x_N are all Orthogonal.

we use OFDM → to get the channel for Multi user. (more than One user share the same channel).

$$X = W s.$$

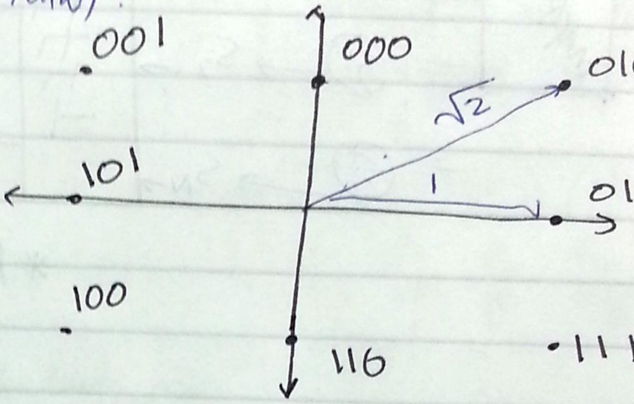
$$w = e^{j\frac{nk2\pi}{N}} \qquad n,k = 0, \dots, N.$$

OFDM is a Compressed FSK.

Quiz #3:

For the shown constellation write the mapping table & Find the average energy and PAPR → $r_b = 15$ Kbps.

(Peak to avg Power ratio).



sol/

$E_{avg} = 1.5\, T_s$

$= \frac{1.5}{5}$ mJ.

$PAPR = \frac{2}{1.5}$

$r_s = \frac{r_b}{m}$.

$= \frac{15}{3} = 5k$.

data.	a_i	b_i
001	-1	1
000	0	1
010	1	1
011	1	0
111	1	-1
110	0	-1
100	-1	-1
101	-1	0

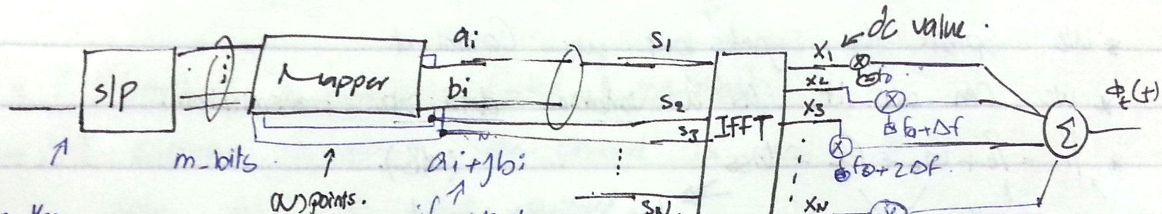
الرمضانية

Lecture # 19

Sat. 21/10.

OFDM:

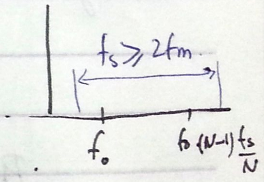
* OFDM → easy to use, effecient { BW ~~eff~~. , Can be used for single or Multi users.



increase the number of bits
"Convert from Binary Transmission to non-Binary Transmissio".

if we take (N) points

represented as Complex. at different frequencies.
$X = \omega_s$.

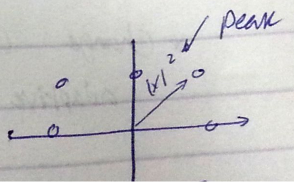


~~[illegible]~~ Constellation : 1. minimum Cost (min avg energy) at max dmin) (BER↓)

2. Peak to avg power ratio ≃ 1 (small).

أبعد نقطة (مسافة من الأصل)

معدل مسافات لكل النقاط



3. min BW. → T_b $(1+\alpha)$

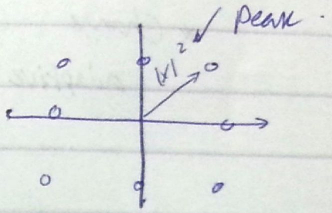
Binary Transmissio. $X = \omega s$. f_0 $f_0 (N-1)\frac{f_s}{N}$

Constellation : 1. minimum Cost (min avg energy) at max d_{min}) (BER↓)

2. Peak to avg power ratio $\simeq 1$ (small).

أبعد نقطة (مسافة من الأصل)

معدل مسافات لكل النقاط.



3. min BW. → $\frac{r_b}{m}(1+\alpha)$

for 1,2 Dimension. (ASK, PSK, QAM...).

(FSK) Multi Dimension → $\frac{M r_b}{m}(1+\alpha)$.

* BER → determine the quality of service (Performance).

$$X = \omega s \; ; \quad X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix}, \quad S = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_N \end{bmatrix}, \quad \omega = \begin{bmatrix} e^{-j2\pi\frac{nk}{N}} & \\ & \\ & \end{bmatrix}$$

$k, n = 0, 1, \ldots, N-1$.

$$\Downarrow$$

$$= \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & e^{j} & & \\ 1 & & & \\ 1 & & & \end{bmatrix}$$

$\Delta f = \frac{f_s}{N}$.. → we do a project (S) to a space ω.

- as band width of the signal

split the frequency to bank of smaller frequencies.

* Sub band Transformation. (wavlet transformation) → make the sub frequencies different from each other. (Δf, $2\Delta f$, $4\Delta f$ - - -)

* We Spread the signals but we Control it.
* we can use it as a variable data rate transmission.
* $P_r = P_t + G_t + G_r - \text{loss}$. (dB).

P_r ↑ reciever sensitivity.

P_t ↑ transmitter sensitivity

G_t, G_r ↘↙ Gain for the Antenna

loss ⟹ $\text{loss} \cong 10\,\gamma \log d$.

$2 \leq \gamma \leq 4$ (depends on fade).

$P_t + G_t = EIRP$.

* Modulation technique → 64 QAM → 16QAM → 4 QAM → 2 binary.

more distance. ⟶ max min distance

* Change Constellation Dimensionality according to the distance called. adaptive modulation → keep the same power & ~~quality~~. in a good quality.

" & same power to control the peak to avg power ratio (PAPR).

* I can manage the fading affect → to not send on the fading frequencies → In OFDM its good in fading channels (it convert freq. selective channels into flat fading channels) → fading select a frequency.

on the whole signal theres a fading.

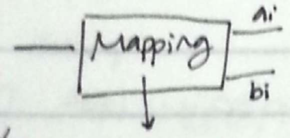
↳ fading goes to only one part of the channel.

⊛ each user has his own group of the signal.

* Channel estimation techniques: the key for successfull Communication

* Differential Modulation (Coded Modulation):

→ Full esponse signaling → the channel is used for T_s for only one data until it's being recieved.



Ex

data	out
00	out 1
00	out 2
01	out 3
11	out 4

previous ~~current~~ data (d_{n-1}) →

↑ the ~~previous~~ current data (d_n).

* depending on the previous current & previous data.

Asume.

Ex 0 1 0 11 0 1

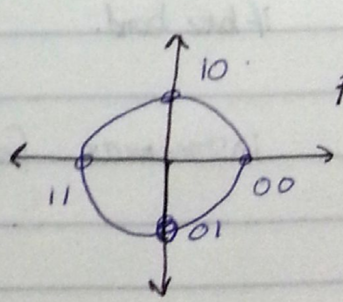
↑ IC ↳ version every signal to be transmitted we send ~~so~~ partial signaling (part of the current signal (symbol) and one from the previous).

01, 10, 01, 11, 10, 01 (this is how the signal transmit).

Partial response signaling * the response for current & previous data every signaling interval.

another technique:

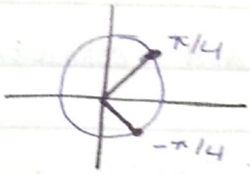
d_n	d_{n-1}	Δ phase.
0	0	π/4.
0	1	π/2
1	0	-π/4
1	1	-π/2.



PSK.

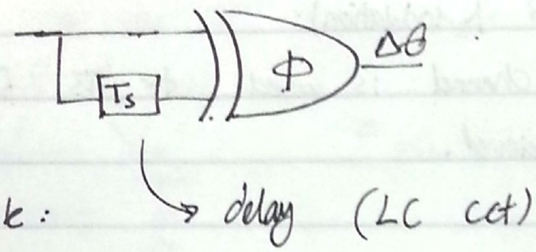
assume the following signal.

$\underline{0}\,1\,\underline{0}\,1\,\underline{1}\,\underline{0}\,1 \rightarrow Ap(t)\cos(\omega t + \theta i)$.



at 1 previous
0 current
(10)

at 0 previous
and 1 current.
(01)

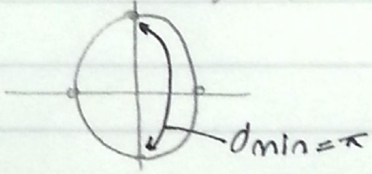


Example:

MSK.

MSK Same as PSK

difference in symbol ↳ d	Δθ
0	π/2
1	-π/2

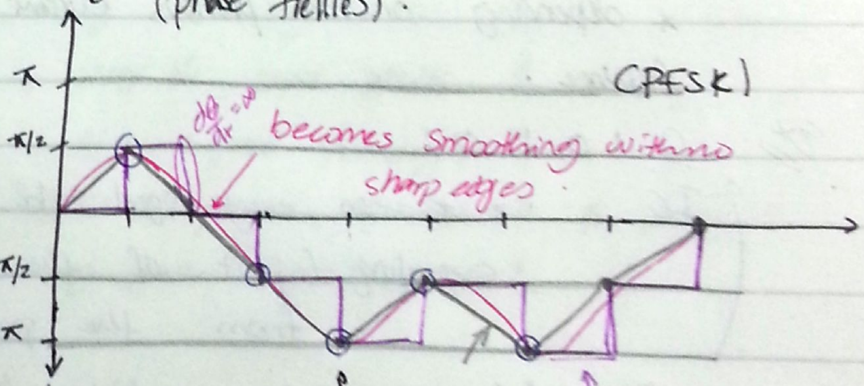


Change as a function of time.

$\Phi_t(t) = Ap(t)\cos(\omega t + \theta)$

data :	0	1	1	1	0	1	0	0
t →								
Δθ :	π/2	-π/2	-π/2	-π/2	π/2	-π/2	π/2	π/2
θ :	π/2	0	-π/2	-π	-π/2	-π	-π/2	0

θ (phase trellies).



smoothing for the sharp edges (by the RC).
Continuous phase.

why linear is better than unit step?

$BW = 2f_{max} + 2\Delta f$

f_{max} ↑ $\frac{\text{Bitrate}}{2}$ ↗ if base band.

Δf ↖ depends on the derivative of the phase. (frequency diviation)

instantaneous freq = $\omega + \dot{\Phi}(t)$

$\dot{\theta} = \frac{d\theta}{dt} = \frac{\Delta\theta}{\Delta t}$ → if linear (better) / → if step (∞).

CPFSK → cont. phase freq shift keying.

types of CPFSK : → 1. Multi-h signaling ← Change the phase continuously

2. MSK.

minimum shift keying (π/4 or −π/4).

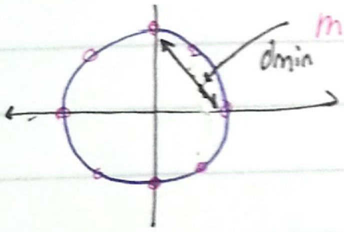
GMSK → gaussian shape & minimum shift keying FM Transmitter. (used in GSM).

Gausian filter.

example:

$\pi/4$ - QDPSK : (two bits at a time)

data	$\Delta\theta$
00	$\pi/4$
01	$-\pi/4$
10	$3\pi/4$
11	$-3\pi/4$

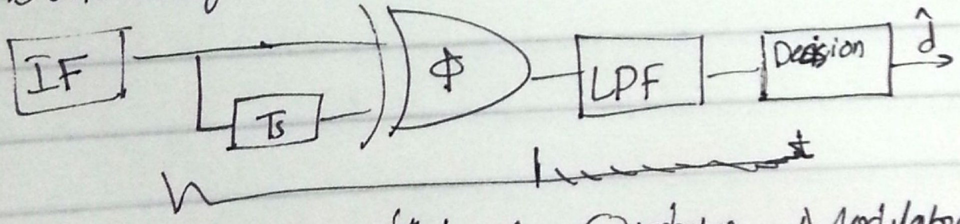


What is the min distance.

$d_{min} \equiv \min \Delta(\Delta\theta)$

~~what~~ we need to maximize the minimum distance.

Differentially Coherent Rx :

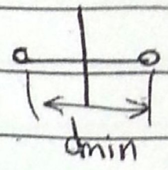


instead of Quadrature Modulator.

Sun.

lecture 20.

$$BER = \frac{1}{m} Q\left(\sqrt{\frac{d_{min}^2\, mT_b}{2\eta_0}}\right)$$



$$E_{av} = \frac{d_{min}^2}{4} \boxed{T_s} \equiv mT$$

$$E_b = \frac{d_{min}^2}{4} T_b$$

$$SNR \triangleq \gamma_b \triangleq \frac{E_b}{\eta_0}$$

~~B~~

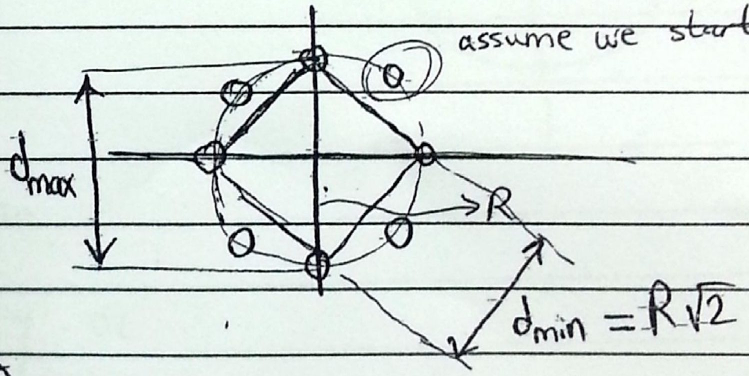
$$BER = \frac{1}{m} Q\left(\sqrt{2\gamma_b m}\right)$$

$\frac{\pi}{4}$-GDPSk :

data	$\Delta\theta = x$
00	$\pi/4$
01	$-\pi/4$
10	$3\pi/4$
11	$-3\pi/4$

d_{min} @ $\min(\Delta x)$

assume we start here



$$\underbrace{\Theta_{n}}_{\text{present}} = \underbrace{\Theta_{n-1}}_{\text{previous}} + \Delta\Theta$$

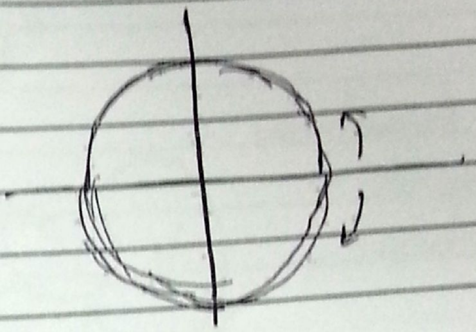
$$\phi_{PS}(t) = A\,p(t)\cos(\omega_c t + \Theta_n)$$

Why do we need d_{min}?

To measure the error probability (SER or BER) hence we compare possible outcomes neglecting our present state.

Ex III :

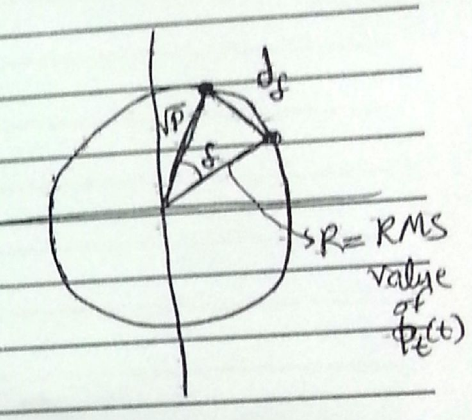
d	Δθ
0	π/5
1	π/3



Design involves ΔΘ values, observe how choosing ~~Const~~ ΔΘ affects the number of constellation points

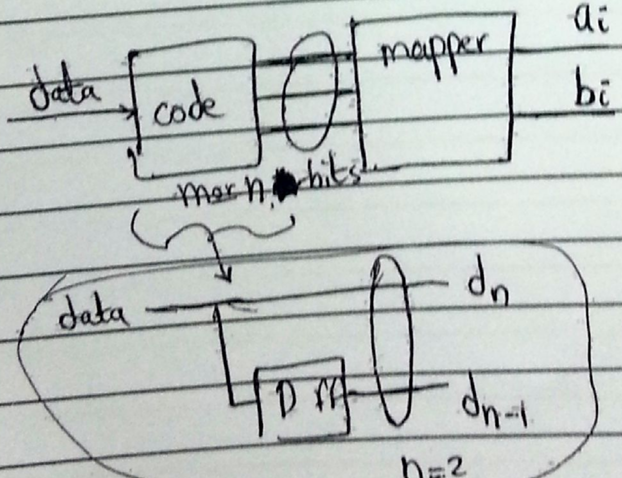
$$E_\phi = \frac{A^2}{2}T$$

$$d_\delta = \frac{2R}{\sin(\frac{\delta}{2})}$$

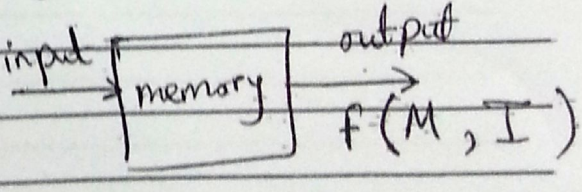


↑ Mid exam material ↑

coded modulation:-

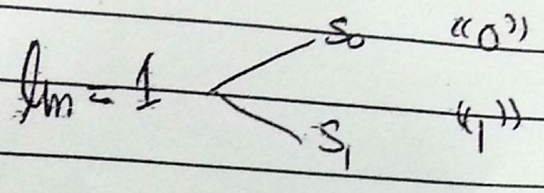


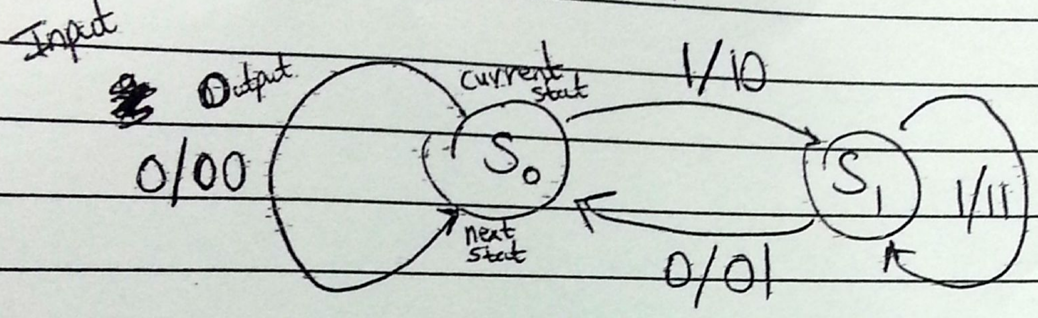
memory machine



memory content = state ≡ node on the graph

No





#outward arrows = # of possible inputs

State diagram