NEW CHAPTER

⇒ **WIRELESS PLANNING SYSTEM**

→ We have a spectrum given, by TRAI we should/ can use the given B·W of spectrum.

→ cluster of cells are formed

• **Early Mobile system:**

1st wireless gen

→ 1970's Bell Mobile System : NY city 1000 sq m² (10M) ~12 calls @ a time

was consumed as one antenna for 10m people.

→ "High power" → "same frequency can be re used" (single antenna was used)

also cause health issue

→ Large subscriber base : capacity

→ Efficient use of spectrum : spectral efficiency "η"

→ Nationwide compatibility : "Roaming"

→ Widespread availability : coverage

→ Adaptability to traffic density : capacity ↑

→ services to vehicle & portable : link budget (antenna size @ vehicle)

→ support : "group call" "dispatch".

→ Quality : "Wireless quality" MIMO

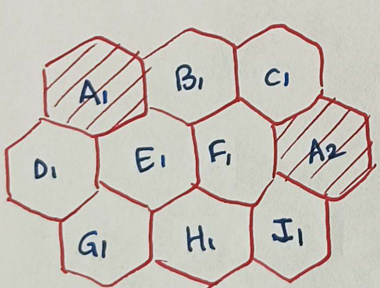
→ Affordable

this things were to be addressed after 1st gen generation

based on which a paper was published and implemented.

↓

cellular theory



cluster of cells (with orthogonal or non overlapping BW)

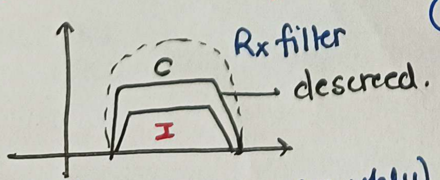
(if all cells operate at ~ BW/ frequency ↑ interference occurs.

∴ we need to check (contraints)

• **cochannel Interference** ①

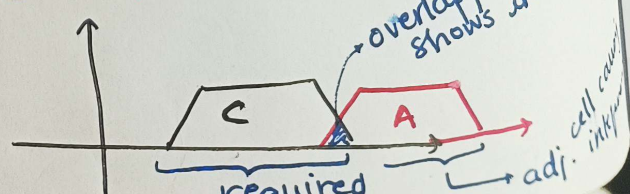
b/w cells.

happens when A1 & A2 have ~ B·W ∴ on passing thy LPF they come in same range but intensity of I is less than C



here $\frac{C}{I} > 10$ (roughly)

② **Adjacent channel interference.**



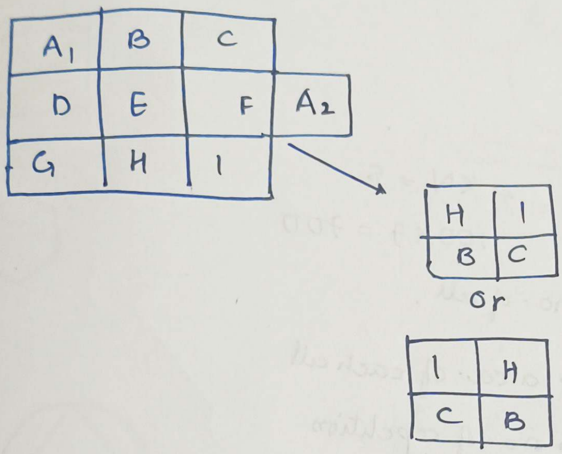
here we obtain ratio $\left[\frac{C}{A} > 10\right]$

• MacDonald Paper : premises,

essence of cell str. < freq. reuse / cell splitting

eg: BW = 36 MHz
each user is using 25 kHz < UL / DL } either

• cell splitting



→ Having more popular in a cell

⇒ splitting so we can accumulate more users

→ more filteram can't be done due to fading

can be any no. but less

→ 20 channels used by base stam

How many channels?

$$= \frac{36 MHz}{50 kHz} = 720$$

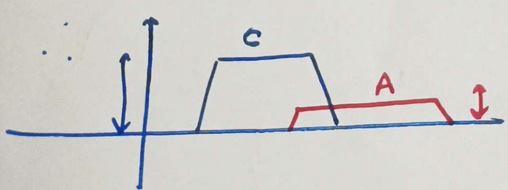
720 → 700 useful for traffic

UL = uplink
DL = downlink

singlex comm : 25 kH
duplex " : 50 kH.

20 : control
700 : Traffic

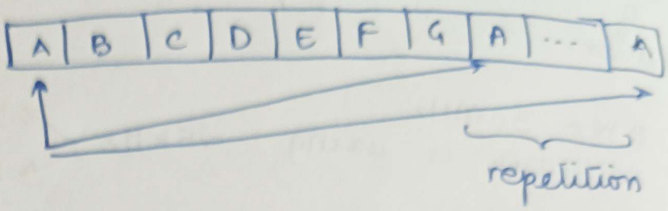
happens in adustre



} simple parameters like amplitudes taken for ratio

/ We can take acc. other parameter like power, etc.

assume
cluster size (N) = 7



for 100 channels/cell
(700 total)
capacity = 700

→ Total spectrum for traffic = $KN = S$
$100 \times 7 = 700$

→ area of coverage = MNA
- N → no. of cell.
- A → area of each cell
- M → no. of repetition

k = channel per cell

→ entire capacity = NS = MKN

→ Hexagonal Tessellation Patterns → Repetition of pattern

2nd chap. Rappaport.

10/4/23

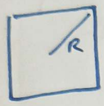
• **Cellular Geometry**

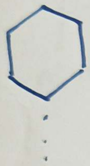
→ Design (for frequency planning) (reusing freq)

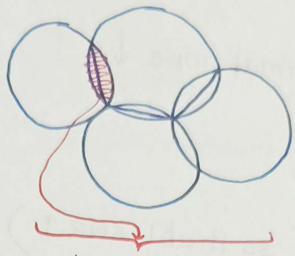
→ $\left(\frac{C}{I}\right)_{min}$ " To avoid fading"

→ capacity (meet demand of growing populatⁿ)

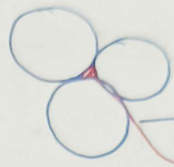
1) 

2) 

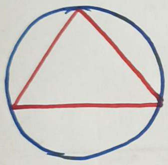
3) 

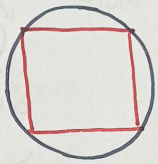


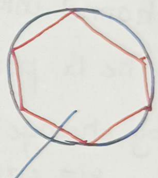
here coverage gap in ↑ (i.e not int in △ or other)



circle not a good choice of this

i] △ 

ii] 

iii] 

hexagon has larger area that it can match with a circle

(↑ order polynomials have ↑ complexity ∴ analysis becomes difficult).

∴ hexagon used.

* Why hexagon?

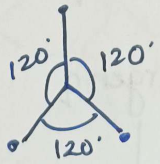
→ omnidirection antenna @ base station → can → 100W signals

(∵ if p↑ then it can destroy fauna & flora)

→ Directional antenna

↓

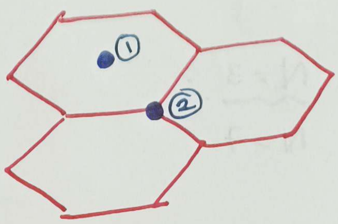
can transmit @ 500W } → covers ↑ area but it can destroy env.t.

→ When we choose  } 3 antenna str. (like fan) → and place it in the hexagonal str.

↓

on the centre ①

or at corner ②



here max area is covered in this situatⁿ & also there's no need of ↑ power

→ 2 reasons for hexagonal str: , & has max area, ↓ coverage

i) it closely resembles the circle str.
space

ii) it can bestly accomodate {⅄} str. of antenna to cover
max area & ↓ power of transmission can be used.

→ Frequency Reuse → can be done by TDM
↳ special domain
↓
cellular geometry method.

Tx Power ↑ → Thermal noise ↓

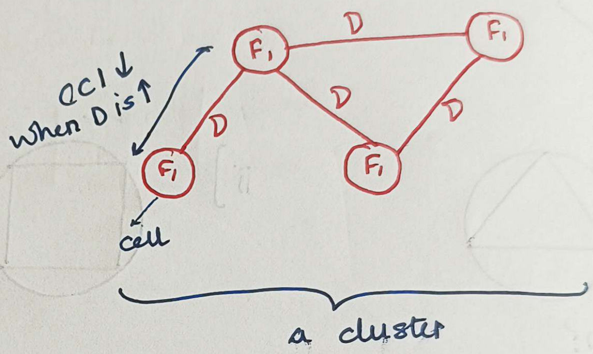
~~CCI ≠ f(Tx power)~~

→ Why Tx power ↑ (so that SNR ↑)
(& Themal noise ↓)

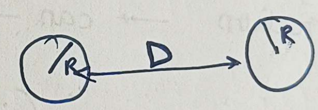
→ CCI doesn't depend on
cochannel interference
the Tx power.

(by change in Tx power
we can't ↑ or ↓ CCI)

∴ CCI ≠ f(Tx power)



→ CCI occures when R↑ & D↓
(or ↑).



∴ CCI = f(R, D)
↑ ↓

→ ∴ for ↑ frequency reuse D↑ R↓

frequency reuse factor

* q = ratio = $\frac{D}{R}$ = $\sqrt{3N}$ → smaller q means → means ↓N, ∴ K↑
∴ channel ↑ ∴ cap ↑
∴ CCI ↑

↓↑
$S = NK$ $N = \{3, 7, 12 \ldots\}$
capacity ↑ CCI ↑

→ larger q → large q means N↑, ∴ K↓
∴ CCI↓ ∴ cap↓

no. of cells in a cluster

* $\{N = i^2 + ij + j^2\}$ *

@ $i = 1$, $j = 1$ $N = 3$

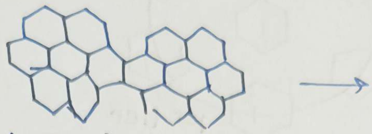
@ $i = 1$ $j = 2$ $N = 7$

10/8/24.

Actual cellular design

from geometry only certain values of K are possible if replicating cluster without gaps

eg: $K = 7$



$\underbrace{}_{K=7}$ → str. repeated

$i = 1, j = 2$

cochannel neighbors of a cell

↓

along a chain of hexagons

↓

to cal. we move i cells along any hexagon turn 60° counterclockwise and move j cells

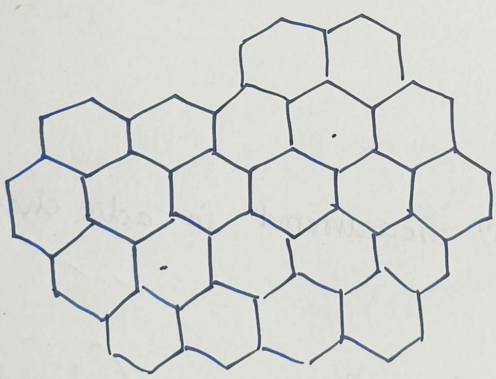
(eg: $i = 2$, $j = 2$, $K = 12$)

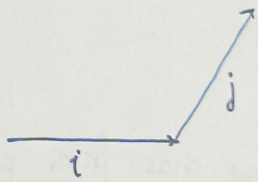
here $K = i^2 + ij + j^2$

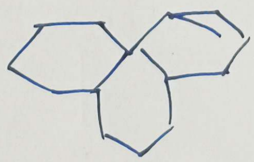
$(K = N)$

here

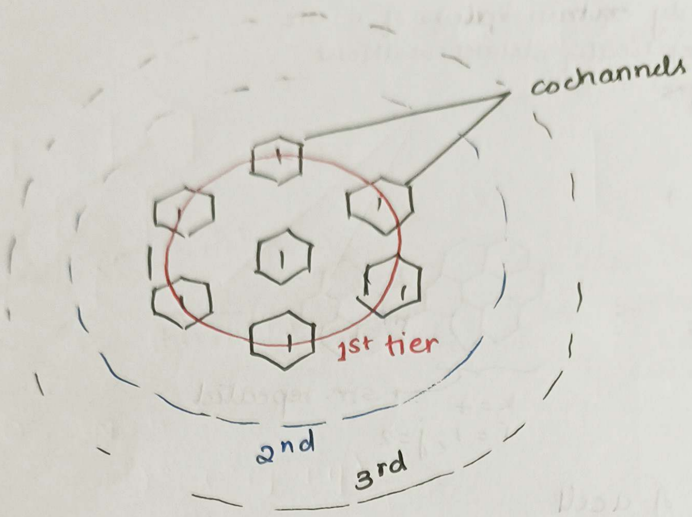
→ we move center to center.







DO PPT



$q = \frac{D}{R}$

$D = f\left(K_I , \frac{S}{I}\right)$

K_I → cochannel interfering cells of 1st tier

S → recevied carrier

$\frac{S}{I}$ → signal to interference ratio

→ We know that from propagation measurement in radio channels

avg. recieved signal strength

$$P_r = P_0 \left(\frac{d}{d_0}\right)^{-n}$$

(by the fact that its power gets attenuated by $\frac{1}{r^n}$ factor) for dist 'r'.

Q

$\frac{S}{I} = \frac{(\sqrt{3N})^n}{i_0(D)}$

~~IS~~ = $(\sqrt{3N})$

practically S/I should be 18 dB for proper communication

$$\frac{S}{I} = \frac{(\sqrt{3N})^{n \to 4}}{i_0}$$

eg: example: given path loss exponent $n = 3, 4$ find q & cluster size
S/N ratio = 15dB , $i_0 = 6$.

i) ($n=4$) if 7 cell reuse pattern

$N = 7$

$Q = D/R = \sqrt{3N} = \sqrt{21} = 4.58.$

$$\frac{S}{I}\Big|_{dB} = \frac{(\sqrt{3N})^n}{i_0}\Big|_{dB} = \frac{(4.58)^4}{6} = 18.66\text{dB}.$$

10log(73)

$\therefore$ N can be selected as 7. (no. of clusters).

ii) ($n=3$) assume $N=7$

$$\frac{S}{I} = \frac{(4.58)^3}{6} = 12.05\text{dB} < 15\text{dB}$$ Not possible

$N = 12$

$$\frac{D}{R} = 6$$

$$\frac{S}{I} = \frac{6^3}{6} = 36$$ $\therefore$ in dB 15.56dB $\therefore$ N = 12 can be selected.

eg: 2 compare interference from 1st tier of 6 interferers with that from 12 ($\underbrace{}_{}$ 1st tier + 2nd.) interferers.

1st tier $\Rightarrow \frac{2\pi D}{D} \approx 6$ (assume $n=4$) & $a_1 = \frac{D_1}{R_1} = \sqrt{3N}$

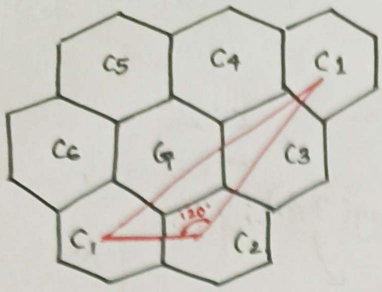
$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{6} I_i} = \frac{R_1^{-4}}{6 D_1^{-4}} = \frac{a_1^4}{6} = \frac{(\sqrt{3\times 6})^4}{6}$$

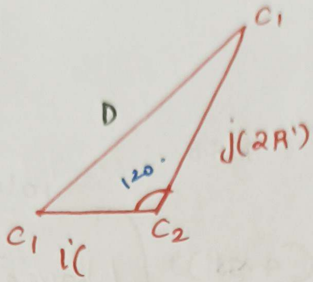
1st & 2nd combined.

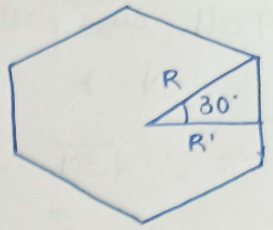
$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{6} (I_{1i} + I_{2i})} = \frac{1}{6(a_1^{-4} + a_2^{-4})}$$

21|3|24

* imp for exam 10 marks







$\frac{R'}{R} = \cos 30°$

$R' = R\cos 30°$

$D^2 = 3N * R^2$

$= (2R')^2 (i^2 + j^2 + ij)$

Reuse dist = D
$= \sqrt{3N} * R$

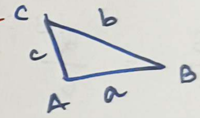
$\Rightarrow (2R')^2 = 3R^2$ (dist b/w adj channel cell $= \sqrt{3} * R/2$

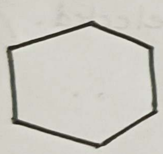
$N * 3 * R^2 = 3 * R^2 (i^2 + j^2 + ij)$

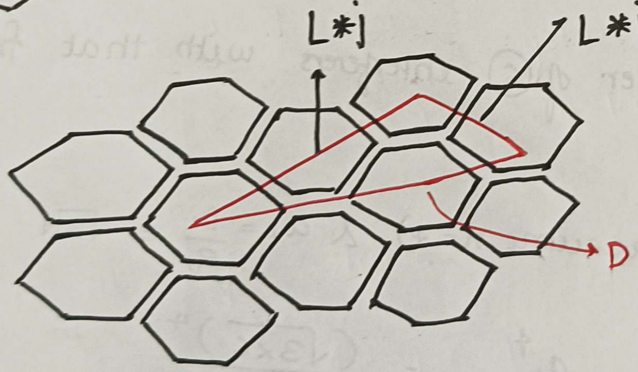
derivatn important [$N = i^2 + j^2 + ij$ → derive.

* [cosine law =

$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$] *







In this case : j = 2 i = 1

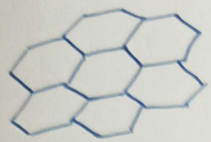
$D^2 = (L*i)^2 + (L*j)^2 - 2(L \cdot j)(L \cdot$

$= L^2 i^2 + L^2 j^2 - 2L^2 ij(-0.5)$

$= L^2 (i^2 + j^2 + ij)$

$D/r = \sqrt{3(i^2 + j^2 + ij} = \sqrt{3N}$

→ Evolving deployement

a)  early stage

b)  → intermediate stage

d)  final stage

* str. evolution with ↑ subscriber.

• Worsts case CCI

→ CCI is one of the prime limitatⁿ on system capacity. We use the propagation model to calculate CCI.

→ There are 6 1st tier, co-channel BSs, two each @ (approx) distance of D-R, D, and R+D and the worst case (average) carrier to (co-channel) interference is

$$\left[\Lambda = \frac{1}{2} \frac{R^{-\beta}}{(D-R)^{-\beta} + D^{-\beta} + (D+R)^{-\beta}} \right] *$$

$\beta = n$
large scale fading coeff.

diagram on ppt

[Worst case CCI on the forward channel]

⟹ WIRELESS SYSTEM PLANNING

26/03/24.

→ affect when a signal passes through free space.
(attenuatn occurs)
intensity ↓ by $\propto \frac{1}{r^2}$ r = distance.

Large scale propagation model:

↳ We use this model @ the reciever, to predict the (mean) signal strength.

↳ a) Free space prop. model:
"unobstructed path"

* Friis equation:

$$\left\{ P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \right\} *$$

P_t : power transmitted
G_t : transmitted antenna gain
G_r : recieved " "
L : system los factor
λ = wavelength : $\frac{c}{f_c}$

Let P_0 at a ref. distance at d_0

$$P_0 = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d_0^2 L}$$

this causes ↑ attenuatn

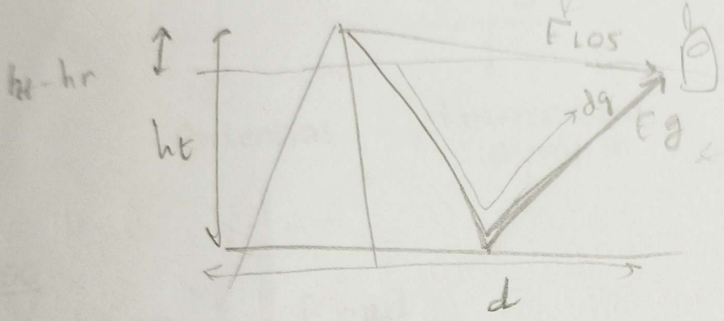
power $\propto \frac{1}{d^4}$

ground reflectn scena → path changes & phase, by 180'

→ this ish k.a as large scale propagatn

n = 4 here

total signal strength = $\underbrace{E_{LOS}}_{\text{direct component}} + \underbrace{E_g}_{\text{ground refl}} = E_{TOT}$



$E_{LOS} = \frac{E_0 d_0}{d_{LOS}} e^{j 2\pi f_c \left(t - \frac{d_{LOS}}{c}\right)}$ — phase lag or delay

assume $d_{LOS} \approx d$ "large scale path loss"

$$E_{LOS} = \frac{E_0 d_0}{d} e^{j 2\pi f_c \left(t - \frac{d_{LOS}}{c}\right)} \quad eq. (1)$$

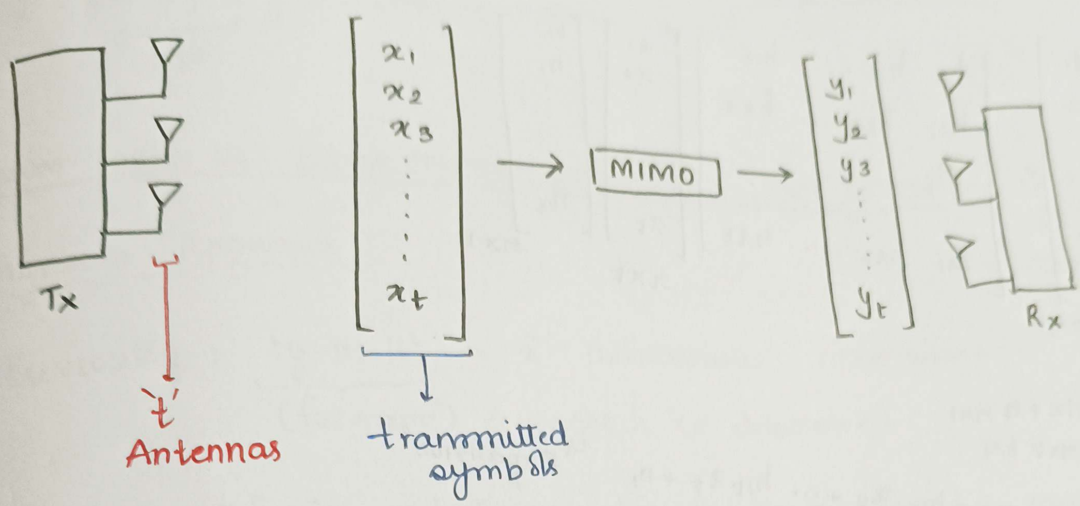
$\approx ly$

→ has 2 models
- → okumura model
- → Hata model.

} by Japan. → gives 2 values..

Handover method do self study.

3/4/24 ⇒ MIMO SYSTEMS



a) SISO

$y = hx + n$ " Model"

$\hat{x} : y/h = \frac{hx}{h} + \frac{n}{h}$ } → "zero forcing" estimated value of message signal calc. by div by 'h' @ noise ≈ 0 we get x.

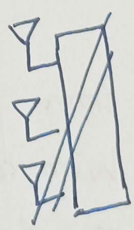
b) SIMO

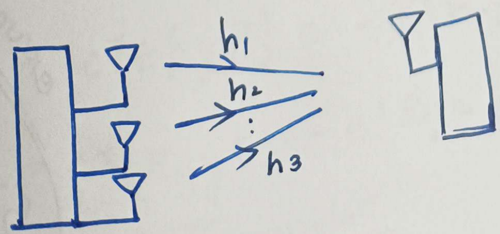
" Multiple Recieve antenna system"

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_r \end{bmatrix} = \begin{bmatrix} h_1 \\ h_2 \\ \vdots \\ h_r \end{bmatrix} x + \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_r \end{bmatrix}$$

c) MISO

$$y = [h_1, h_2 \dots h_t] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_t \end{bmatrix} + n$$





MIMO model

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_r \end{bmatrix}_{r\times 1} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1t} \\ h_{21} & h_{22} & \cdots & h_{2t} \\ \vdots & & & \vdots \\ h_{r1} & h_{r2} & \cdots & h_{rt} \end{bmatrix}_{r\times t} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_t \end{bmatrix} \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_r \end{bmatrix}_{r\times 1}$$

$$\underset{r\times 1}{y} = \underset{r\times t}{H}\,\underset{t\times 1}{x} + \underset{r\times 1}{n}$$

$$y_1 = h_{11}x_1 + h_{12}x_2 + \ldots h_{1t}x_t + n_1 \quad \text{"Expansion"}$$
$$\vdots$$

→ **zero forcing (ZF) RECEIVER**

$$\hat{x} = H^{-1}y$$

$$f(x) = \|y - Hx\|^2$$ (from $y = Hx + n$) → we can obtain $\hat{x}$

(error which is to be minimized)
↓
so that we get optimized $\hat{x}$ value @ least error.

$$*\left[\hat{x} = \arg\min_x f(x)\right]*$$

$$\hat{x} = \underbrace{(H^H H)^{-1} H^H}_{} y$$

$$*\left[\hat{x} = F_{ZF}\,y\right]*$$

→ we can obtain $\hat{x}$ from $y = Hx + n$ by $\hat{x} = H^{-1}y$ ~~but we~~ but we need to find optimized $\hat{x}$ with minimized error ∴ for that we minimize $f(x) = \|y - Hx\|^2$ (error) and then we use that instead of H^{-1}

∴ we get $\hat{x} = (H^H H)^{-1} H^H y$

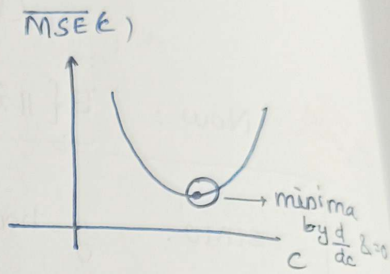
$$\hat{x} = F_{ZF}\,y.$$

to get the value (optimal) of 'c' diff w.r.t c & equate to 0

$$\frac{\partial \overline{MSE}(c)}{\partial c} = 0$$

$$\frac{\partial \left(c^T R_{yy} c - 2c^T R_{yx} + R_{xx}\right)}{\partial c} = 0$$

$$\underbrace{\frac{\partial}{\partial c}\left(c^T R_{yy} c\right)} - 2\frac{\partial \left(c^T R_{yx}\right)}{\partial c} + \frac{\partial (R_{xx})}{\partial c} = 0$$



$R_{yy}c + (c^T R_{yy})^T$

$= R_{yy}c + R_{yy}c$

$= 2R_{yy}c \quad - \quad 2R_{yx} + 0 = 0$

$\cancel{2}R_{yy}c = \cancel{2}R_{yx}$

$$c = \frac{R_{yx}}{R_{yy}}$$

OR

$$* \left[c = R_{yy}^{-1} R_{yx} \right] *$$

autocovarience matrix ~~b/w~~

cross covarience matrix

when 'c' is complex

We can also write $\hat{x} = c^H y$

$$R_{yy} = E\{yy^H\} = E\{(Hx+n)(Hx+n)^T\}$$

$$= E\{Hxx^H H^H + Hx\,n^H + n x^H H^H + nn^H\}$$

$$= HE\{xx^H\}H^H + E\{\cancel{xn^H}\} + E\{\cancel{nx^H}\}H^H$$

$$+ E\{nn^H\}$$

$$= H R_{xx} H^H + \underbrace{R_{nn}}_{\text{noise}} \quad \text{——} (1)$$

initially ; for SIMO , $y = Cx + n$ (y: $r \times 1$, C: $r \times 1$, n: $r \times 1$)

now ; for MIMO, $y = Hx + n$ (y: $r \times 1$, H: $r \times t$, n: $r \times 1$)

$$R_{xx} = E\{xx^H\}$$

$$= E\left\{ \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_t \end{bmatrix} [x_1^*, x_2^*, x_3^* \cdots x_t^*] \right\}$$

$$= \begin{bmatrix} E\{|x_1|^2\} & E\{x_1x_2^*\} & \cdots & E\{x_1x_t^*\} \\ E\{x_2x_1^*\} & E\{|x_2|^2\} & \cdots & E\{x_2x_t^*\} \\ \vdots & & \ddots & \vdots \\ E\{x_tx_1^*\} & E\{x_tx_2^*\} & \cdots & E\{|x_t|^2\} \end{bmatrix}$$

→ here all the values are zero except the diagonal that are varience

$$= P\, I_t$$

I_t → identity matrix of $t \times t$

P → diagonal matrix of variences

$$\therefore \boxed{R_{xx} = P I_t} \; * \qquad \left(\text{Where } P = \sigma_n^2 \right)$$

$$R_{yy} = E\{yy^H\} = E\{(Hx+n)(Hx+n)^T\}$$

$$= H R_{xx} H^H + R_{nn}$$

$$R_{yy} = \underbrace{PHH^H I_t}_{\text{We need to make it } r\times r} + \sigma_n^2 I_r$$

$(r \times r)$

(∵ noise has dimension of r)

$\sigma_n^2 I_r$ = I of $r \times r$ dimension

Note

$y = Hx + n$

y → $r\times1$, Hx → $t\times1$, n → $r\times1$

$$R_{yx} = E\{yx^H\}$$

$$= E\{(Hx+n)x^H\}$$

$$= E\{Hxx^H + nx^H\}$$

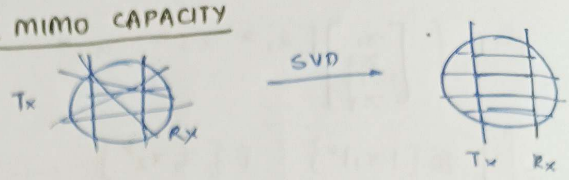
$$= H\,E\{xx^H\} + \cancel{E\{nx^H\}}^{\,0}$$

$$= PHI_t$$

16/4/24

⇒ SINGULAR VALUE DECOMPOSITION & MIMO CAPACITY

→ achieve spatial multiplexing
→ Parallel channels



SVD ——————→ we decompose a sq. matrix into 3 matrices U, Σ, V
→ this is to have Σ with a diagonal matrix with eigen values
can rept. a class of data

$H = U\Sigma V^H$

channel matrix

$y = Hx + n$ (mimo model)

$y = U\Sigma V^H x + n$ (subs. H acc. to SVD.)

all done for identification purpose.

$U^H y = U^H U \Sigma V^H x + U^H n$ (multi U^H both sides).

$\tilde{y} = \Sigma V^H x + \tilde{n}$

$x = V\tilde{x}$

modified noise

$\tilde{y} = \Sigma \tilde{x} + \tilde{n}$

$$R_{\tilde{n}} = E\{\tilde{n}\tilde{n}^H\}$$
$$= E\{U^H n (U^H n)^H\}$$
$$= E\{U^H n n^H U\}$$
$$= U^H E\{nn^H\} U$$
$$= U^H \sigma_n^2 I U$$
$$= \sigma_n^2 I_t$$

$$\begin{bmatrix} \tilde{y}_1 \\ \tilde{y}_2 \\ \tilde{y}_3 \\ \vdots \\ \tilde{y}_t \end{bmatrix} = \begin{bmatrix} \sigma_1 & 0 & 0 & 0 & \cdots \\ 0 & \sigma_2 & & & \vdots \\ 0 & & \sigma_3 & & \vdots \\ \vdots & & & \ddots & \\ 0 & - & - & - & \sigma_t \end{bmatrix} \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \vdots \\ \tilde{x}_t \end{bmatrix} + \begin{bmatrix} \tilde{n}_1 \\ \tilde{n}_2 \\ \tilde{n}_3 \\ \vdots \\ \tilde{n}_t \end{bmatrix}$$

* power allocat^n is done to each symbol.

$\tilde{y}_1 = \sigma_1 \tilde{x}_1 + \tilde{n}_1$

$\vdots$

$\tilde{y}_t = \sigma_t \tilde{x}_t + \tilde{n}_t$] → capacity of this each channel. (given by shannon capacity.

capacity of channel can be enhanced only when channel can be written as (SVD here is applied).

→ Shannon capacity

$$* \left[C_i = B\log_2(1+SNR) = \log_2\left(1+\frac{P_i\sigma_i^2}{\sigma_n^2}\right) \right] *$$

↳ unit = b/s/Hz

we net to maximize $\left\{ C_{net} = \sum_{i=1}^{t} C_i \right\}$ subjected to the constraint that power should not exceed P_i (Total power)

$$\left\{ \sum_{i=1}^{t} P_i \le P \right\}$$

↳ for this we : Lagrangian optimization

$$\text{cost } f^n \quad f(P,\lambda) = C_{net} + \lambda\left(P - \sum_{i=1}^{t} P_i\right)$$

↳ λ = regularisar parameter

~~w~~ we need to maximise this

if $C_{net} = \max$ then @ $C_{net} = \max$ $\lambda\left(P - \sum_{i=1}^{t} P_i\right)$ is min or very less.

∴ we solve $f(P,\lambda)$ as a convex problem.

$$\frac{\partial f(P,\lambda)}{\partial P_i} = 0$$

$$f(P,\lambda) = \underbrace{C_{net}} + \lambda\left(P - \sum_{i=1}^{t} P_i\right)$$

$$= \sum_{i=1}^{t} C_i + \lambda\left(P - \sum_{i=1}^{t} P_i\right)$$

$$= \sum_{i=1}^{t} \log_2\left[1 + \frac{P_i\sigma_i^2}{\sigma_n^2}\right] + \lambda\left[P - \sum_{i=1}^{t} P_i\right]$$

$$\therefore \frac{\partial f(P,\lambda)}{\partial P_i} = \frac{\sigma_i^2/\sigma_n^2}{1 + \frac{P_i\sigma_i^2}{\sigma_n^2}} - \lambda = 0$$

$$P_i = \left[1/\lambda - \frac{\sigma_n^2}{\sigma_i^2} \right]^+$$

} is said to be +ve if -ve then '0' power is allocated

∴ ⇒ no power is sent with symbol.

* try how SVD occurs for 2x2 / 3x3 / 3x4 / 4x4 ***

exam = 15 marks SVD question

eg: $H = \begin{bmatrix} 2 & -6 & 0 \\ 3 & 4 & 0 \\ 0 & 0 & 2 \end{bmatrix}_{3\times3}$ (here column vector usually = orthogonal)

3x3 ant

(column = orthogonal) (diagonal eigen values should be ↓)

$T_x : P = -1.25\text{dB} = 0.75$

$\sigma_n^2 = 3\text{dB} = 2$

$\sigma_1^2 = 52$

$\sigma_2^2 = 13$

$\sigma_3^2 = 4$

$$c = \log_2\left[1 + \frac{P_1\sigma_1^2}{\sigma_n^2}\right] + \log_2\left[1 + \frac{P_2\sigma_2^2}{\sigma_n^2}\right] + \log_2\left[\frac{1+P_3\sigma_3^2}{\sigma_n^2}\right]$$

$P_1 + P_2 + P_3 = 0.75$

$$\left[P_i = \frac{1}{\lambda} - \frac{\sigma_n^2}{\sigma_i^2}\right]$$

1st iteration ⇒

$$\left[\frac{1}{\lambda} - \frac{2}{52}\right] + \left[\frac{1}{\lambda} - \frac{2}{13}\right] + \left[\frac{1}{\lambda} - \frac{2}{4}\right] = 0.75$$

$1/\lambda = \frac{1}{2.48} = 0.48$

~~$\lambda = 0.48$~~.

$P_3 = \left[1/\lambda - \frac{2}{4}\right] = 0.48 - 0.5 = -ve$] ⟶ as -ve we need to make it zero ∴ no power allocatn to it.

2nd iteration ⇒

$$\left[1/\lambda - \frac{2}{52}\right] + \left[1/\lambda - 2/13\right] = 0.75$$

$$2/\lambda - \frac{2+4(2)}{52} = 0.75$$

$$\frac{2}{\lambda} - 0.19 = 0.75$$

$$\frac{2}{\lambda} = 0.75 + 0.19$$

$$\frac{2}{\lambda} = 0.9423$$

$$1/\lambda = 0.471 \quad \cancel{20}$$

$\therefore P_1 = 0.4327 > 0$

$P_2 = 0.3174 > 0$

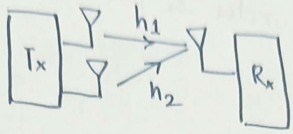
ALAMOUTI & SPACE TIME CODES:

Encoding scheme → superior performance of MIMO system (IMP.)

Aditya K J.

→ 1×2 system ($r \times t$)

→ channel matrix $[h_1, h_2]$



* this coding is done to boost overall SNR by encoding the symbols.

$$y = [h_1, h_2]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n$$

(y not a vector, x not a vector only 1 Rx is tnt)

∴ we need to Tx one symbol.

assume beamforming : $x \rightarrow Tx$ (assume we transmit only x symbol)

x_1 is generated as $\underbrace{\frac{h_1^*}{\|h\|}}\, x$ → optimal weight vector with x to get the data @ Rx

x_2 is generated as $\frac{h_2^*}{\|h\|}\, x$

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \underbrace{\begin{bmatrix} \frac{h_1^*}{\|h\|} \\ \frac{h_2^*}{\|h\|} \end{bmatrix}}_{} x \qquad w_{opt}^H\, x$$

$$y = [h_1, h_2]\begin{bmatrix} \frac{h_1^*}{\|h\|} \\ \frac{h_2^*}{\|h\|} \end{bmatrix} x + n = \left[\frac{|h_1|^2}{\|h\|} + \frac{|h_2|^2}{\|h\|}\right] x + n = \|h\| x + n$$

$$SNR = \frac{\|h\|^2 P}{\sigma_n^2}$$ similar to MRC for MRA.

→ here main prob: for getting 1 symbol, we transform x to x_1, & x_2 that requires knowledge of channel state info i.e h_1, h_2, ∴ we must know h_1, h_2 before sending symbol.

Note: space time codes a.k.a orthogonal ... OSTBC

→ achieving diversity of order 2 without CSI at Tx "no feedback required"

~~steps ① one antenna Tx : x_1~~
~~other " Tx : x_2~~

~~$y(1)$~~

step ① 1^{st} instance : ① one antenna Tx : x_1
other " Tx : x_2

Rx ; $y(1) = [h_1, h_2]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n(1)$

step ② 2nd instance : 1^{st} antenna Tx : $-x_2^*$
second " Tx $+x_1^*$

$$\therefore\ y(2) = [h_1\ h_2]\begin{bmatrix} -x_2^* \\ x_1^* \end{bmatrix} + n(2)$$

$$y^*(2) = [h_1^*\ h_2^*]\begin{bmatrix} -x_2 \\ x_1 \end{bmatrix} + n^*(2)$$

$$= [h_2^*\ \ -h_1^*]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n^*(2)$$

$$\begin{bmatrix} y(1) \\ y^*(2) \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n(1) \\ n^*(2) \end{bmatrix}$$

$$y = \overset{2\times 2}{H}\, x + n$$

vector

now sys becomes more complex

we need to extract data from here.

$$w_1 = \frac{1}{\|C_1\|} C_1$$

$$w_2 = \frac{1}{\|C_2\|} C_2$$

w_1 = Colum 1 of H
W_2 = column2 of H.

$\|c_1\|$ " assume beamforming with MRC

$$= \frac{1}{\|h\|}\begin{bmatrix} h_1 \\ h_2^* \end{bmatrix}$$

$$w_1^H y = \frac{1}{\|h\|}\begin{bmatrix} h \\ h^* \end{bmatrix}\begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + w_1^H n$$

$$= \begin{bmatrix} \|h\| & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \tilde{n}_1$$

$$w_1^H y = \|h\| x_1 + \tilde{n}_1$$

$$w_2^H y = \|h\| x_2 + \tilde{n}_1$$

→ SNR enhanced
→ without feedback.

* 20m do example from tb.

do pdf
ask sir if pdf enough.

ground reflect → okumura Hata model.

ask for pdf/ppt

⇒ ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

→ used in 4G/5G → 4G LTE
→ objective: data rate ↑ BER ↓

→ Basis of 4G/5G
→ 4G "LTE" & "Wi MAX"
→ Data rate >100 Mbps
→ used in LAN std 802.11 a/g/n

* If ISI ↓ ⇒ then better Tx

• objective: • avoid oscillations, "Hardware"
• suppress OSI

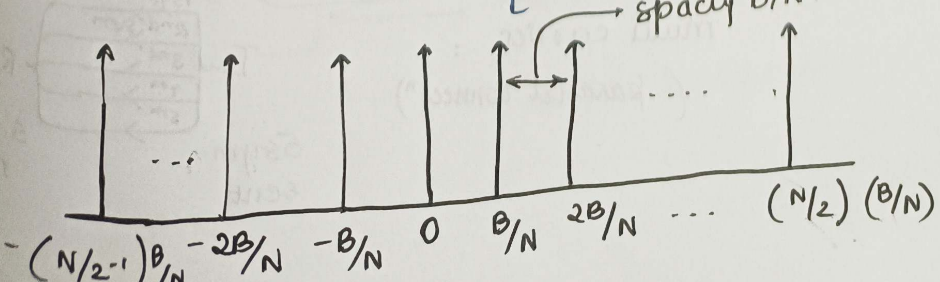
a) single carrier Transmission QAM maybe, If B = 1.024 MHz then ISI

If B.W = 1.024 MHz its > channel B.W (250 kHz)
∴ intersymbol SI happens.
can be avoided by

b) Multicarrier Tx ← i.e by using N-subcarriers.

serial data — N - subcarriers

spacing B/N.



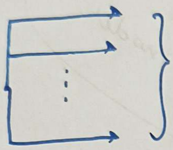
→ so if $N = 256$
& $B = 1024\,kHz$

$\therefore B/N = \frac{1024}{256} = \underline{4kHz}$ in the B.W range.

→ now $N = 256 \Rightarrow$ i.e 256 carrier required
↓
for which 256 oscillators req to generate carrier
↓
drawback.

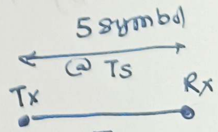
→ if 256 carriers are used then 256 bits are to be ~~recieved~~/ Tx.

serial data

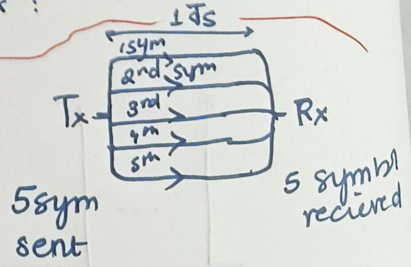


N subcarrier
↳ while Tx this we Tx it with some weight
↓
are summatⁿ of complex exponential signals / fⁿs
↓
nothing but F.T or D.F.T
↓
∴ ~~insteo~~
∴ instead of sending weights we send the inverse F.T so that 'N' carriers are not required.

→ in single carrier Tx & multi-carrier Tx, the symbol rate doesn't change
↳ this is ∵ for singlet - carrier Tx :



multi carrier :
(parallel connectⁿ)



- single carrier

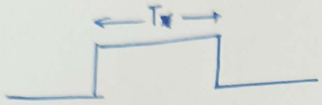
symbol time = T

one symbol in 1/B seconds

$\therefore$ In 1 second = B symbol

$\therefore$ rate = B symbol/sec.

- multiple carrier



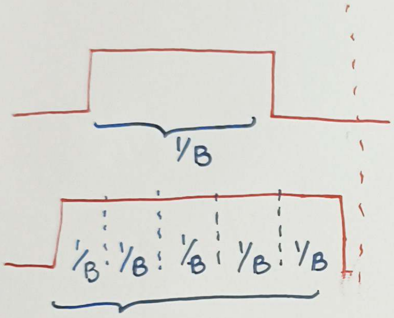
N-symbol in parallel are Tx now Tx BW = B/N.

$\therefore$ symbol time = N/B (1/(B/N))

symbol rate : B/N

(per subcarrier)

overall, symbol rate = (B/N) × N = B.



total = 5/B = N/B (N = no. of symbol.)

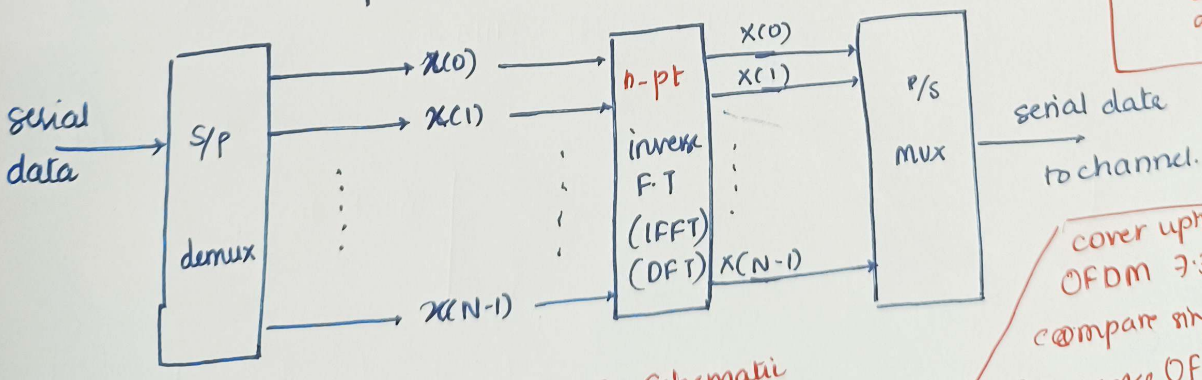
consider i^{th}, subcarrier with freq. $f_i = \frac{iB}{N}$; $-\left(\frac{N}{2}-1\right) \le i \le N/2$.

let x_i = data Tx on i^{th} subcarrier

then, $s_i(t) = x_i e^{j2\pi f_i t}$

$$s(t) = \sum_{i=1}^{N} s_i(t) = \sum_{\forall i} x_i e^{j2\pi f_i t}$$

$s(t) \xleftrightarrow[\text{pair}]{F.T} X$



OFDM Tx Schematic

20 CDMA

* how to get rid of ISI. (by adding bits)
* How many bits to be rep.
- carrier how many?
- 10% data to be added as prefix

cover upto 245.
OFDM 7.3 eg.
compare single multiple
20 marks OFDM
+ 2 page from Aditya K Jag
cyclic prefix

do · { fig 7.3, 7.2, 7.5