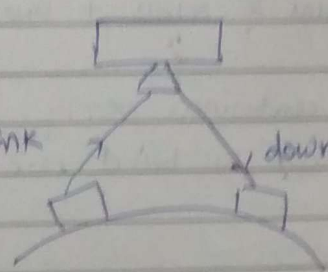
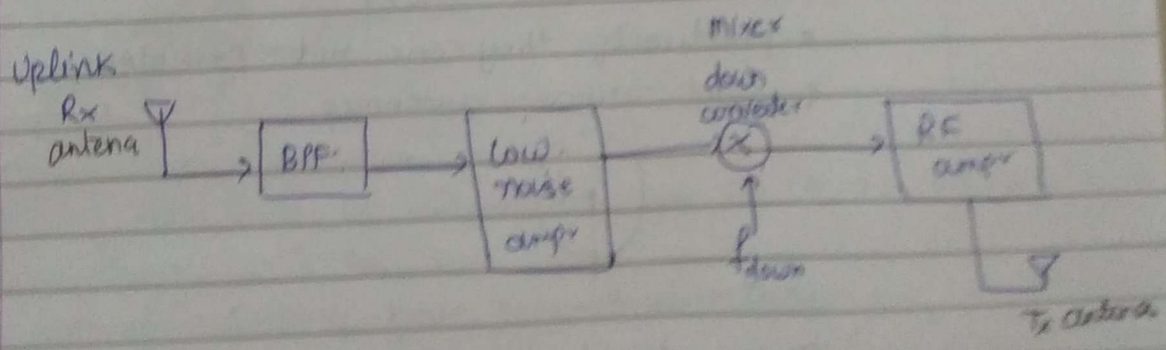
22-Aug

SATELLITE COMMUNICATION

- line of sight communication
- No problem by reflected signals as delay is very less.
- Its an AGWN noise channel
- higher the antenna ⇒ larger distance covered in other comm sls while in satellite commⁿ area covered by satellites are very large.
  3 satellites can cover the whole earth.
- launching cost of satellites is high.
- age of satellite is 2-15 yrs acc to amount of fuel present in it
- distance b/w earth & satellite is large ⇒ delay occurs (ms)

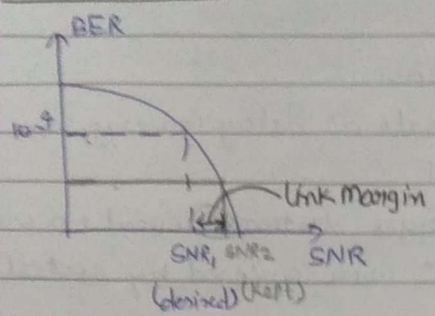


- Uplink & downlink commⁿ frequencies are different
  f(uplink) > f(downlink)
  bcoz power availability at satellite is limited while base-station can provide high power to signal and as $f \propto$ power.



- satellite commⁿ depends on weather. So we keep a margin to get signal properly.

Link Margin :



for transmission of signal in channel having low parameters and when channel parameters vary so SNR is kept high than what is needed.

SNR(chossen) = M SNR(required)

M, is mostly in 3 or 6 dB

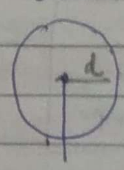
⇒ SNRchossen in 3 dB or 6 dB higher than SNR(req)

SNR choosen (dB) = MdB + SNR req. (dB)

- f ↑ ⇒ smaller antennas req.
  So c band or KU band are used.

ANTENNA :

- converts electrical signal to electro-magnetic waves or vice-versa. radiates into free space in desired direction
- Isotopic Antenna: → radiates signal in all direction in uniform / equal power.
  - practically they are not possible.
  - point square antennas



power density for isotropic antennas

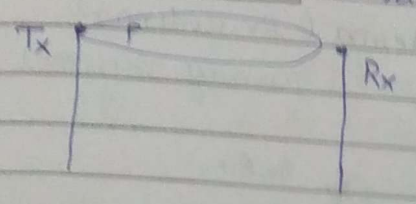
$$= \frac{P}{4\pi d^2}$$

P → Power
d → distance

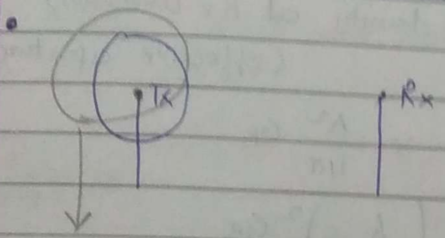
(spherical coordinates are considered here)

- $d\uparrow \Rightarrow$ Power density ↓ses $\Rightarrow$ signal power ↓ses and vice versa.

- Directive antennas :- → radiates signal in a single direction

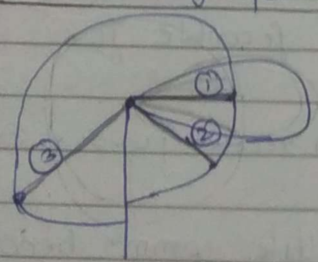


- Power density in single direction is higher in directive antennas than isotropic antennas.



Power is wasted in isotropic antenna when we req. to transmit in single direction.

* Directivity Gain :- $= \dfrac{\text{Radiation intensity at } (\theta, \phi)}{\text{Radiation intensity of isotropic source}}$



$G(1) \rightarrow$ max
$G(2) \rightarrow$ less
$G(3) = 0$

directivity of antenna depends on (θ, ϕ) of direction in which it is Tx.
max of directivity gain is ⟶ directivity.

* EIRP (effective (equivalent) isotropic radiated Power) :- at Tx antenna
it is amount of Power that theoritical isotropic antenna would emit to produce peak power density

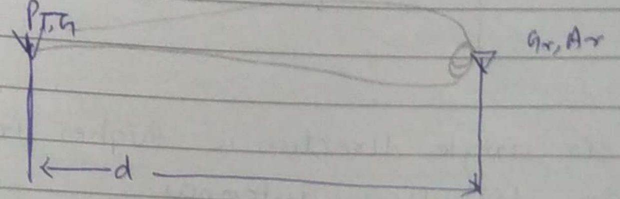
observed in direction of the max. antenna power gain.

$EIRP = $ (total Power transmitted) (total Gain)

$= P_T G_T$

* Effective apparture of antenna (Rx antenna)

$$A = \frac{\lambda^2}{4\pi} \cdot G_R \longrightarrow \text{(gain of receiver)}$$



(received power) P_R = (Power density at Rx antenna) x (effective aparture)

Friss Free space eqn :

$$= \frac{EIRP}{4\pi d^2} \times \frac{\lambda^2}{4\pi} G_R$$

$$= P_T G_T \left(\frac{\lambda}{4\pi d}\right)^2 G_R$$

$P_T \rightarrow$ can't be increased as not feasible

$G_T \rightarrow$ Can be ↑sed } should be high

$G_R \rightarrow$ Can be ↑sed

$\lambda \rightarrow$ should be high but due to this frequency reduces, which is not feasible for transmission.

$d \rightarrow$ larger the distance ⇒ recieve power ↓ses exponentially

∴ bcoz of this satellite commn becomes challenging.

Thus, size of Tx and Rx antenna should be large.

path loss $= \frac{P_t}{P_R}$ → (transmitted Power) / → (received Power)

P_R = Power density × EA

$= \frac{EIRP}{4\pi d^2} \times \frac{\lambda^2}{4\pi} \times G_R$

$P_R = P_T \cdot G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$

$\frac{P_R}{P_T} = G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$

So; path loss $= 10 \log \left(\frac{4\pi d}{\lambda}\right)^2 + 10 \log \left(\frac{1}{G_R G_T}\right)$

Noise figure:

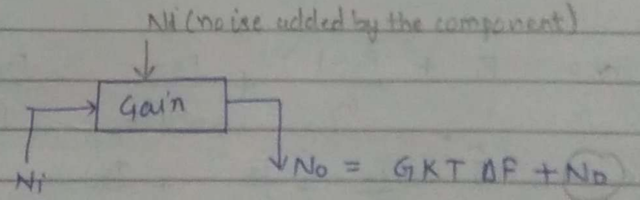
$F = \frac{\text{i/p SNR}}{\text{o/p SNR}}$

→ i/p signal power
→ i/p noise power

$= \frac{S_i / N_i}{S_o / N_o} = \frac{N_o}{N_i (S_o/S_i)}$

$= \frac{N_o}{N_i \cdot G}$ → (Gain = o/p Power / i/p Power)

Noise temperature:



$N_o = GKT\Delta f + N_d$ → noise generated by component

$N_i = KT\Delta f$ → Bandwidth

$N_d = GKT_e\Delta f$ → equivalent noise temp

— all tempr which are generated, they are thermal noise

K → boltzman constant

T → tempr (outside/ environment) Noise

Te → equivalent noise by components (tempr)

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so; $N_o = G N_i + N_d$

$$= G K \Delta f T + G K T_e \Delta f$$

$$N_o = G K \Delta f (T + T_e) \Rightarrow \frac{N_o}{G N_i} = (T + T_e)$$

– noise figure $F = \dfrac{N_o}{N_i G}$

$$\cancel{F = T + T_e}$$

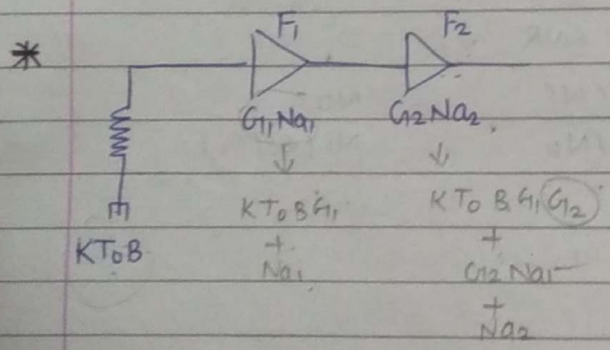
$$= \frac{\text{total o/p noise Power}}{\text{o/p noise generated due to i/p}}$$

$$= \frac{N_o}{N_o - N_d}$$

$$\boxed{F = \frac{T + T_e}{T}}$$

$$\therefore T_e = T(F - 1)$$

*

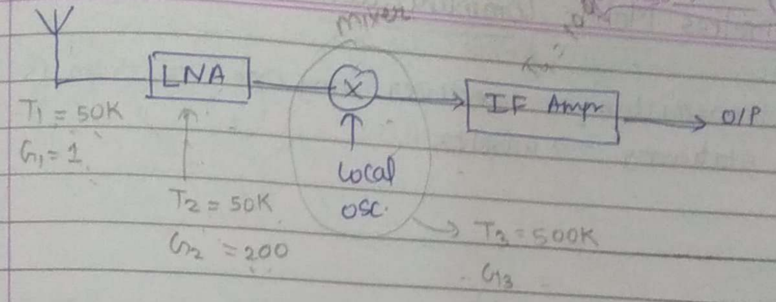


$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \cdots \rightarrow \text{cascade connect}$$

$$T_e = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \frac{T_4}{G_1 G_2 G_3}$$

Example 3 $T_{antenna} = 50K$; $T_{RF} = 50K$; $T_{mixer} = 500K$ (written over "middle")
$T_{IF} = 1000K$; Gain RF ampr = 200
there is earth terminal device calculate
i) Noise tempr ii) Noise figure

2018



$$T_{eq} = T_{ant} + \frac{T_{RF}}{G_1} + \frac{T_{mixer}}{g_1 g_2} + \frac{T_{IF}}{g_1 g_2}$$

$$= 50 + \frac{50}{1} + \frac{500}{200} + \frac{1000}{200}$$

$$= 107.5 \quad \underline{\text{Ans.}}$$

Link Budget Analysis:

- Link margin
- Signal to noise ratio
- Power loss

$EIRP = 46.5\ dBW$ (Per 1 watt)

$G/T = 24.7\ dB/K$

free space loss $= -206\ dB$

$C/N_0 = 93.8\ dB\text{-}Hz$ (carrier to noise ratio)

G_R (?)

⇒ Receiver sensitivity $\log S_i$

$$N_0 = (NF)\,N_1 \cdot G$$

$$S_0 \times \frac{N_0}{} = (NF) \cdot KT\Delta f \cdot G \times S_0$$

$\frac{S_0}{N_0} \rightarrow$ SNR required

$$S_0 = (NF)KT\Delta F \cdot G \times SNR_{req.}$$

$\frac{S_0}{G} = S_i$

$$S_i = (NF)\,(KT\Delta F)\,(SNR_{req.})$$

So sensitivity of $Rx = 10\log(NF) + 10\log\left(\frac{KT\Delta f}{10^{-3}}\right)$

$$+ 10\log(SNR_{req.})$$

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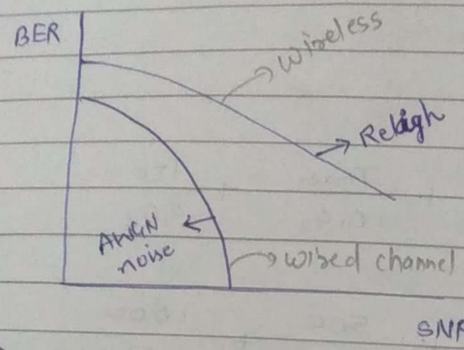
(529) Wireless (Mobile) Communication

- transmitter or receiver, any one of them is not stationary → wireless



- for wireless, its performance is very bad and its difficult to implement because every time channel is changed due to moving Tx or Rx.

These are some elements which are required in mobile communication

Base station: mobile towers are known as base station. (BTS) interference between mobile subscriber and cellular radio s/s

Mobile station: mobile headset (MS)

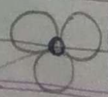
Base station controller: (BSC)

Main s/w center: (MSC) — interference between cellular radio s/s and public s/w telephone n/w; control of the mobile communication

Wireless (Mobile)	Wired (Landline)
- BW:- 15 to 20 Kbps	- BW:- 64 Kbps
- channel is not always availabe. (we have to sent the request for using the channel if we have enough balance then and only then we used it)	- channel is always available

* theoritaclly shape of cell (area or region which is covered by tower) is circle, but its not possible practically. ; so practically it will be hexagonal

To cover the whole area, shape is



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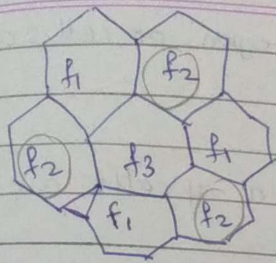


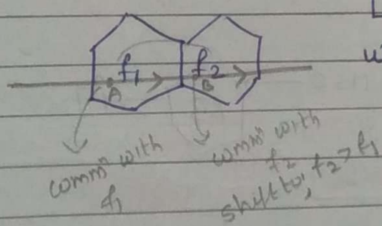
We are using different frequencies, because if we uses same then interference will occur.

if we are using only single frequency:
- High power radiations (which are harmful for human)
- physically not efficient (if we are using 100 or 200 users over a same freq. BW is also very high)
- places away from base station will not be able to commⁿ as power of signal ↓ses and reflects on ↑ses ⇒ if 1 freq. is used.

* in rural area, then area of cells are large, because there user are less as compared to Urban area's
in Urban area, area of cells is very smalls because poppulation is very high.

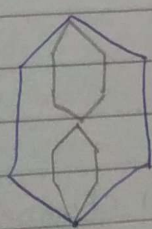
if three freq. is used then the distance b/w the region using same freq. is less so interferences [may occur. so no. of freq. used is ↑sed.]

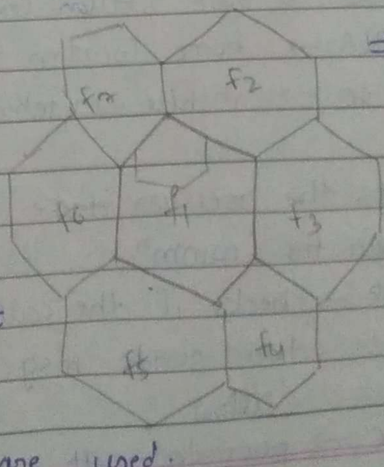
handoff:



we communicate with f1, only then when strength of freq. f1 signal is high compared to f2 signal.

Cell spliting:

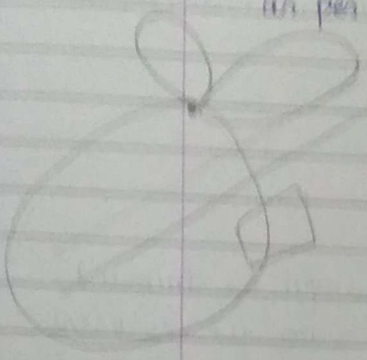




⇒ here no of users in f1 region has ↑sed so it is been splitted using other freq.

- cell spliting is used when no. of users in an area ↑ses which is not been able to be controlled by a tower.
- for these portable towers are used.

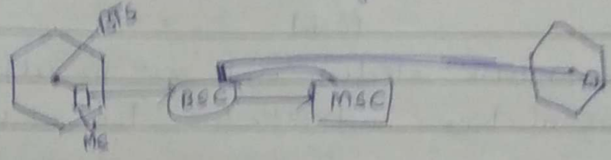
Sectioning: in this we are divided the region or cell/s area as per the requirements.



- By sectioning, area of cells are different
in mobile commⁿ we have three stations.

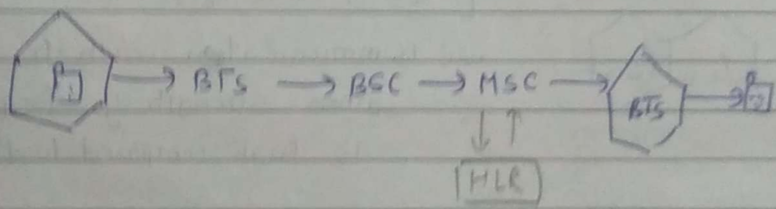
used when no of users in particular regions differ highly.

⇒



control channel → its requesting for the using the channel
Voice channel → its provided by the MS channel.

Path of commⁿ of mobile:



BTs → base station
BSC → base station control
HLR → home location register
MSC → mobile switching center

- Once, the reciver takes the call → channel is located given for commⁿ.
- HLR → checks if the caller has balance or not and then sends msg. to allow or not to allow.
- MSC → provides path and other parameters req. to

Date 31-Aug.

Know about where is the receiver's mobile.

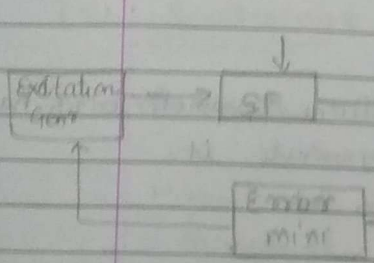
Source coding of speech in wireless channel:

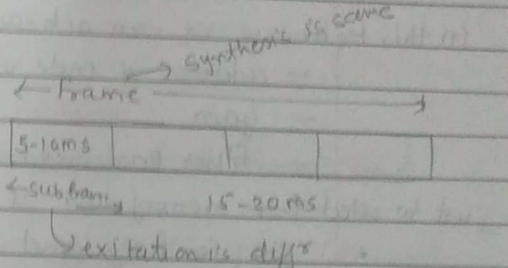
(IPN - 61)

Linear predictive coding:

→ synthesis filter (Predict the actual signal) previous samples
→ excitation generator
→ error minimization

(A) Multi pulse excited Technique:





(filter and excitation parameters are transferred, not the speech)

- speech signal is transferred / transmitted in form of synthesis signal.
  This is done through (linear predictive coding)
- 3 components through which prediction is done:
  (i) synthesis (ii) Excitation (iii) Error minimization

Synthesis filter → generates synthetic speech by linear prediction coding.

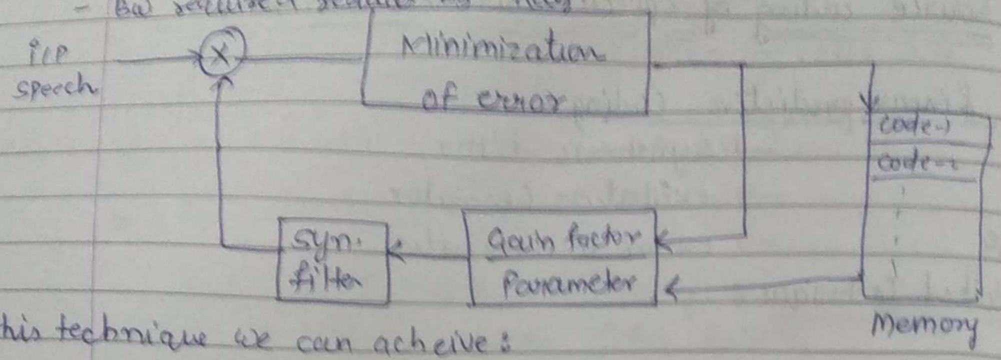
- Excitation parameters change from subframe to subframe
- synthesize filter parameters change from frame to frame.
- synthesize filter has 13-16 previous samples of speech through which it predicts the previous current signal.

Current voice signal and synthesis filter signal (Prediction) is compared and sent to error minimization block then to excitation generator → here excitation parameters changes which is sent to SF and cycle goes on.

Rx signal → Excitation gen^r → Synthesis filter → synthetic o/p speech

★ (B) code excited LPC (linear predicted coding):

- code of excitation parameter is stored in memory.
- BW required reduces by half.



in this technique we can acheive:

- address of code vector
- gain
- filter parameter. Here, Gain factor & filter parameter block just to select from memory and it does not has to generate it.

• BW is half and hardware size is ↑ed.

- in this system hardware size ↑ses.

Rx → Address → Gain/excitn. Parameters → syn. filter

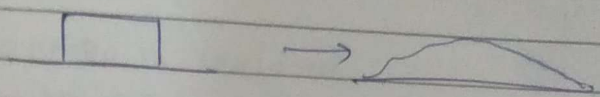
problem of wireless comm^n:

① fading (Delay spread)
② Scattering
③ Dopler shift

(A) - Excitation gen^r provides the info of when and of what magnitude pulse should be generated by SF.

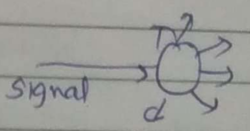
- In wired channel, signal can be sent by sampling at 64 KbPs → in wireless, for this sampling rate spectrum min to 2KbPs, 4 KbPs, 8KbPs.
  ⇒ signal Rx would be exact ⇒ LPC is used

(1) fading : fluctuation in Received signal strength induction
Signal strength is fluctuation bcuz of ISI, reflection at Rx
- All ISI, reflection noise etc., add up → cause fading.
- indoor and outdoor fading varies as no. of reflection and delay varies.
- Delay spread



(2) Scattering :

- found in satellite commⁿ, micro-wave commⁿ and not is GSM.
- Higherᵗ then object → then signal can pass / Penetrate through it.
- when signal collides with a small then energy of signal scatters.



(3) Dopler shift / Dopler effect :

- if Tx or Rx is moving then recived by Rx would be different from the Tx freq.
- Depends on direction of motion & velocity of motion.
- velocity ↑ses → Dopler effect ↑ses.

(8 2)

Date 1 - Sep

<u>Multiple Acess technique</u>: there are following techniques:

1. TDMA (Simulatenouly acess is not possible)
2. FDMA
3. CDMA
4. SDMA

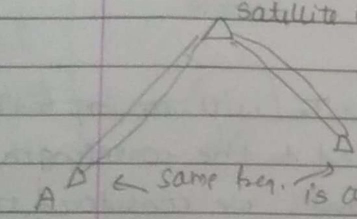
- 10 user
  100KHZ

for TDMA ⟶ 100×10 KHz BW is required

for FDMA ⟶ 100×10 KHz BW " " (Carriers are different at diff freq.

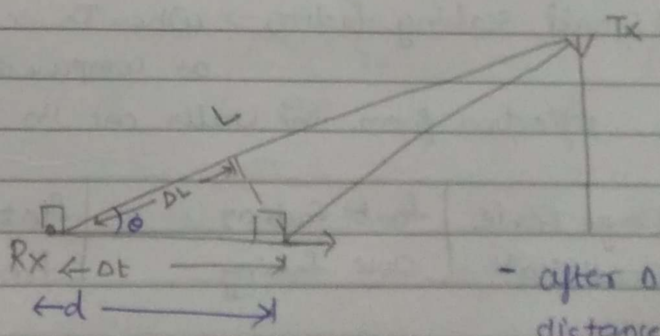
for CDMA ⟶ 10 Chips are required for 1 bit transmit
10 orthogonal diff^r codes are required
So BW is also ↑ses.

<u>space division multiplexing</u> SDMA:



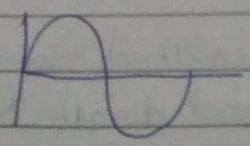
users are separated by the space
multiple users can use same satellite s/s for communication

<u>Dopler shift</u>: Dopler shift is possible when any one of Tx or Rx is moving.



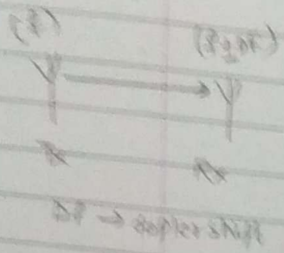
- after Δt time, distance between Tx and Rx is less by the ΔL.

$\Delta L = d\cos\theta$ —— (1)



$\lambda \longrightarrow 2\pi$ (length in complete one cycle)

$\Delta L \longrightarrow \boxed{\Delta\phi = \frac{2\pi}{\lambda} \times \Delta L}$ (2) (change is phase) change in frequency : $\omega = d\phi/dt$



$\Delta f \to$ dopler shift

$$\Delta f = \frac{1}{2\pi}\frac{\Delta\phi}{\Delta t}$$

$$= \frac{1}{2\pi} \times \frac{2\pi}{\lambda} \Delta l \cdot \frac{1}{\Delta t}$$

$$= \frac{d\cos\theta}{\lambda \Delta t}$$

$$\boxed{\Delta f = \frac{v}{\lambda}\cos\theta}$$

Ex:- $f \to 900\,MHz$; $v = 200\,km/H$; what will be the dopler shift ?

Sol:
$$\Delta f = \frac{v}{c/f}\cos\theta \qquad \theta = 0°$$

$$= \frac{200 \times 10^3/H}{900 \times 10^6/6\infty}$$

fading : ⓐ large scaling fading $\to$ when Rx or Tx will moving fast as compared to the wavelength then what will affect is occur, that's we considered in large scaling fading, scattering is ocur in Large sc. fading.

ⓑ Small scaling fading $\to$ When Tx or Rx will moving slow as compared to wavelength. reflection from the walls are in Small scaling fading.

Large Scale	fast fading	flat flading
Small scale	Slow fading	freq. Selective fading

coherence Bandwidth : measure of ~~trans mission~~ BW across ~~for~~ ~~which~~ for which signal distortion ~~occurs~~ ~~across~~ across channel becomes noticable.

Coherence time : measure of transmitted ~~time across~~ ~~for which signal~~ signal duration for which disortion across channel is noticable is called ch.

ⓒ flat chan...

ⓓ freq. sele...

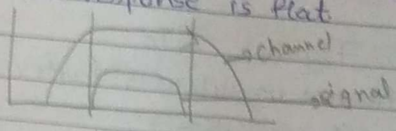
– coher...

flat fading

freq. selective fading

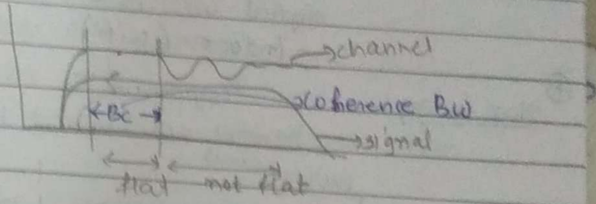
– By s... bette...

(c) flat channel : whose response is flat



$B_c > B_{signal}$
(fading)

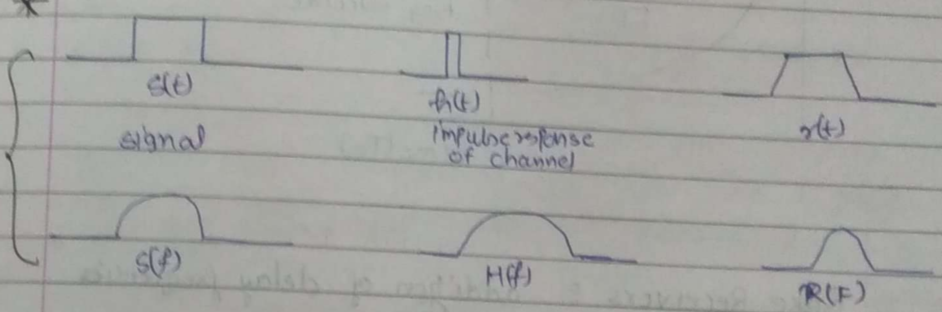
(d) freq. selective channel:



- coherence BW (B_c) < signal BW (B_s) [for freq. selective

*

flat fading



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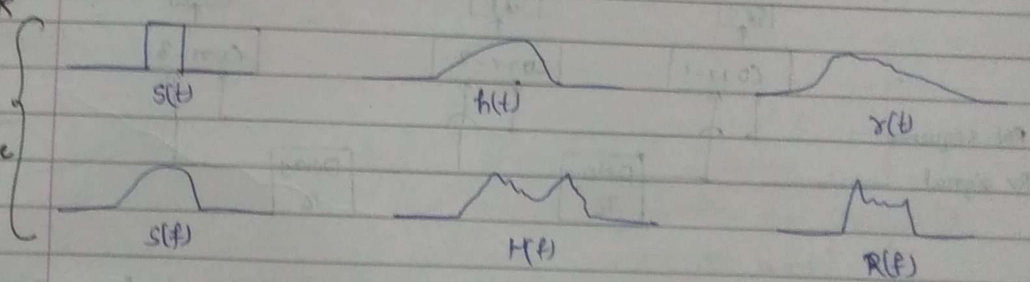
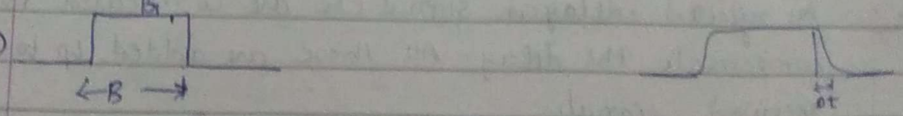
freq. selective fading



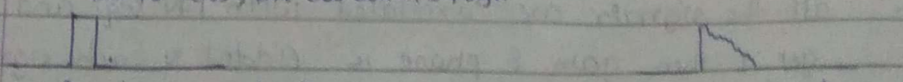
- By seen this we can say that flat fading is better

i)



BW is less, bit duration is high

ii)



BW is max, bit duration is less

spreaded more bcuz ISI interference is more

Date 7-Sep

(e) fast fading :

$T_{symbol} \not> T_c$

channel variation is faster than the ~~ch~~ baseband signal variation.

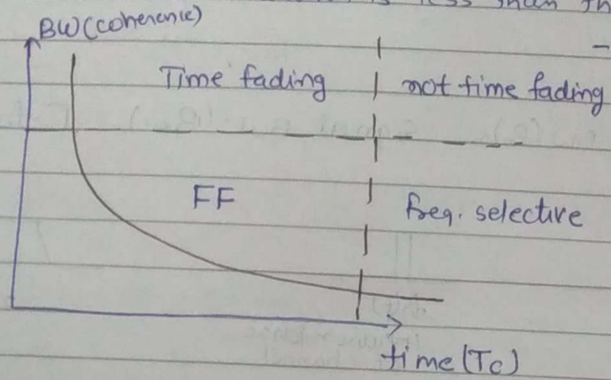
- indoor (wifi)

(f) Slow fading :

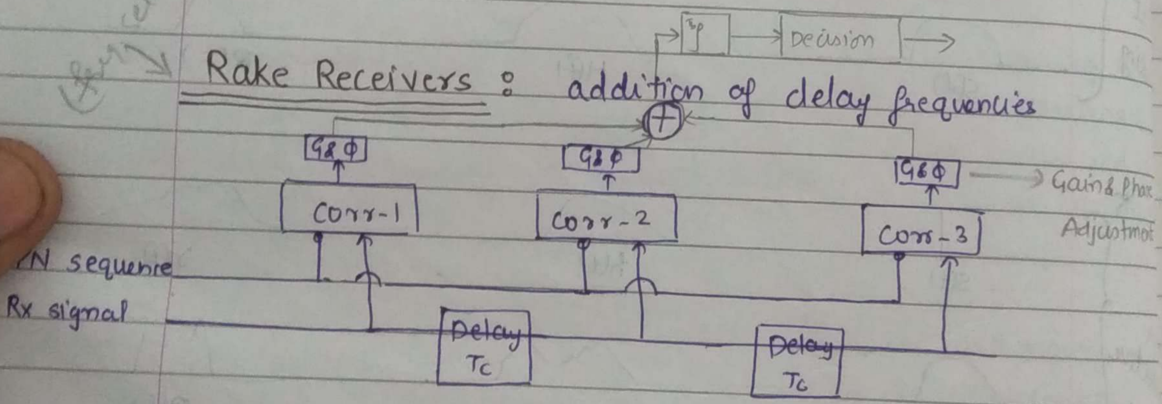
$T_{symbol} \not< T_c$

channel variation is less than the signal variation

- outdoor



Rake Receivers : addition of delay frequencies



adjust of Gain & phase of correlator before summing them.

- chip duration is small
- Rake receivers are used in CDMA.
- All reflected, delayed signal etc are correlated to remove/compensate the delay. All these are added up to get received signal.
- all the signals are correlated with PN seq. and if we get 1 then gain & phase is added to each signal from each correlator and then they are added up i.e., constructive correlation is done at end.

In GSM: ...
... link < U/P link freq.

GSM :

- GMSK modulation is used.
- Downlink freq. > than uplink freq. as
  for uplink, mobiles are the source
  downlink, base stations are the source.
- 900 MHz and 1800 MHz ~~used for Uplink~~ are two Bands
  - 890 to 915 MHz → Uplink
  - 935 to 960 MHz → downlink

- 25 MHz band is divided into 125 diff^r channels using FDMA.
  1 channel is of 200KHz → and then through TDMA each channel is divided into 8 parts, i.e., 8 diff^r signals can be transmitted.

- 25 MHz

$\downarrow$ FDMA

125 channels of 200KHz each

$\downarrow$ TDMA

each channel divided into 8 parts / users
(of 25KHz BW available for each user)

Voice → 13.4 KHz

* GSM s/s Architecture
- 26 bits training is used by equalizer.
- signal Processing in GSM - channel coding: error correcting cap

IS95 : (CDMA)

- 20 channels are present
- each channel BW is 1250 KHz
- used in CDMA
- 20 - 35 parts / User per channel with 62.5 KHz BW available for each user
- QPSK modulation used.
- By using rake receiver, multipath

CDMA + TDM ⟶ UMTS (3G → mobile phone)

LTE	3G	2G
- MIMO	- IS 95	- GSM
- Carrier Aggregation	- W-CDMA	- CDMA

નિષ્ફળતા ગુપ્ત શક્તિઓને સતેજ કરે છે.

get 1 then gain & phase is added to each signal from each correlator and then they are added up i.e., correlation is done at end.

In GSM : UP link freq. < down link freq.
Satellite : down link < UP link freq.

- In GSM : (mobile wireless commⁿ)

  890 to 915 MHz & 935 to 960 MHz & Tx/Rx freq.
  UP Link — Downlink — (935 - 890)

  20MHz — Spacing = 45 MHz

  Tx/Rx time slot spacing = 3 time slots

  200 KHz — 125 channels

  TDMA
  125 channels

  alloted channel BW for: 8 TDMA slots (200/8 = 25 freq. range)

  Users : 125 × 8 = 1000 users

- if 25 Users

  $25 \times \underset{\downarrow \text{ min.}}{60} \times \underset{\uparrow \text{ hours}}{24} = 1500 \times 24$ /Rs-
  = 36000Rs/- and fully busy n/w
  ↓
  50% (12 hours)
  ↓
  18,000 Rs/-

	GSM	IS95 (CDMA)
channel :	125	20
BW :	200KHz	1250 KHz
slots :	8	20 to 35
BW / Users :	$\frac{200}{8} = 25$	$\frac{1250}{20} = 62.5$
	GMSK	QPSK

→
- all the components of Rx signal are treated individually.
- chip duration should be small because when symbol duration is small, ISI would be present reflected / signal / components reach Rx with less delay compared to los (line of sight) signal.

* GSM s/s Architecture
- 26 bits training is used by equalizer.
- signal Processing in GSM - channel coding : error correcting cap

Date 8-sep.

for Ting the capacity of GSM, data rate will decrease
one frame is fix user in GSM

#PPT

Signal Processing in GSM :

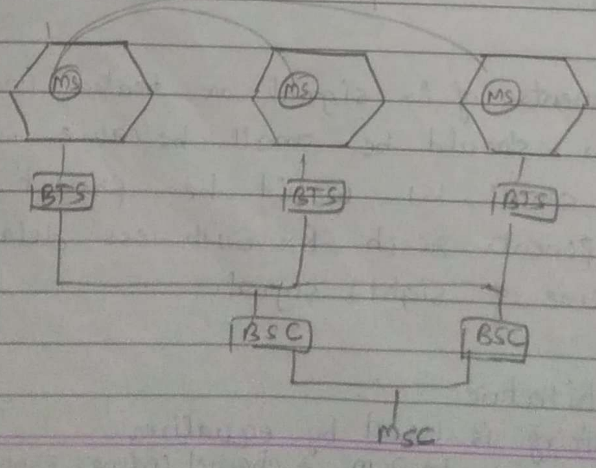
speech
↓
Digitizing and Source coding
↓
channel coding
↓
interleaving (data is set in such a way that only known by Rx)
↓
Burst formating
↓
ciphering
↓
modulation ⟶ Radio Channel ⟶ Demodulation
↑
De-ciphering
↑
Burst formating
↑
De-interleaving
↑
channel decoding
↑
Source Decoding
↑
speech

(data

we hack this for 3 sec. it is not secure type of commn.

*

BTS ⟶ MS ⟶
BSC ⟶ district
MSC ⟶ State



Date 8-Sep.

...ate will decrease

Speech
↑
Source Decoding
↑
...nel decoding
↑
interleaving
↑
formating
↑
ciphering
↑
...odulation

...e type of commn.

Date 19-Sep

in CDMA [Modulation (Orthogonal BPSK)
         → Spreaded (QPSK)

CDMA features:

- Power control (nearer to cell Power is more, So equalize power from all users)
- reduced interference
- Universal frequency reuse
- Reduce interference
- N/W capacity - higher capacity than GSM, i.e, more no. of calls may be made by reducing the quality.

UMTS : Universal Mobile telecommunication S/S

- ~~FDM + CDMA technique is used~~
- UMTS uses wideband - code division multiple access (W - CDMA)
- freq. division duplex (FDD) } By using this, we can manage the uplink & downlink freq. & time
- time (TDD) } By TDD we can reduce the uplink & downlink time.
- modulation is done with QPSK

in CDMA uplink & downlink freq. are fixed, which we can't to change.

WCDMA FDD :

- channel BW = 5 MHz
  frame length = 10 ms

⇒ 3G, H, H+

HSDPA (High speed downlink packet Access)
  - Use 16 QAM to reach 10 Mbps

HSPA+ (High speed Packet Access)
  - 64 QAM 21 Mbps

DSP

Jumbo Book

Date ________
Page ________

Resource Allocation:

180 KHZ , 12 subcarrier

1User	2User	1user

0.5ms

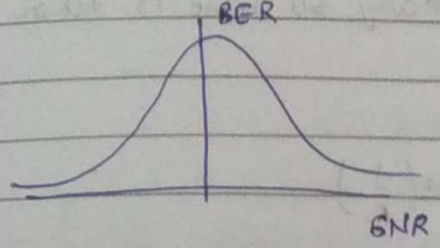
7 symbols OFDM

12 subcarrier

Date 22 - Sep
Page

Information Theory

error free commn is not possible because as seen in gaussian curve. BER cannot be 0 even if E_b is increased to high value.



$\sqrt{E_b/N_0}$

$S_i \rightarrow$ signal Power
$E_b \rightarrow$ energy
$R_b \rightarrow$ data rate

$$S_i = E_b R_b$$

$$E_b = \frac{S_i}{R_b}$$

S_i can be ↑sed to an extent and R_b cannot be zero as this mean no data commn $\rightarrow$ to make $E_b = \infty$

→ **Information (I)**

prob of error (P)

$P = 0 \Rightarrow I = \infty$
$P = 1 \Rightarrow I = 1$

$$I \simeq \log(1/P)$$

→ **entropy** : average information per message

$$H(m) = \Sigma P_i \log(1/P_i) = \Sigma P_i I_i$$

	m_1	m_2	m_3	m_4
P =	0.25	0.25	0.3	0.2

$$H(m) = P_1 I_1 + P_2 I_2 + P_3 I_3 + P_4 I_4$$
$$= P_1 \log\left(\frac{1}{P_1}\right) + P_2 \log\left(\frac{1}{P_2}\right) + \ldots$$

$H(m) = \Sigma P_i \log\left(\frac{1}{P_i}\right)$

$H(m) = 0.597$ for given 4 messages.

$\Rightarrow$ m_1 m_2 $\longrightarrow$ message in binary so base is taken as 2

0.1   0.9

$$H(m) = P_1 \log_2\left(\frac{1}{P_1}\right) + P_2 \log_2\left(\frac{1}{P_2}\right)$$

$$= 0.468$$

- message with higher probability occurs more frequently and vice-versa.

- when message is equi-probable (equal prob) then the average msg per signal is max. i.e, entropy is max.

Example : There are 6 msg

m_1	m_2	m_3	m_4	m_5	m_6
0.3	0.25	0.15	0.12	0.10	0.08

encode this msg with Hauffman coding technique using 2 array code.

m_1	0.30 00	0.30 00	0.30 00	0.43 1	0.57 0
m_2	0.25 10	0.25 10	0.27 01	0.30 00	0.43 1
m_3	0.15 010	0.18 11	0.25 10	0.27 01	
m_4	0.12 011	0.15 010	0.18 11		
m_5	0.10 110	0.12 011			
m_6	0.08 111				

$\therefore$ message with high prob. has less no of bits and vice-versa.

(first set the msg signal in decending order and then add bottom 2 prob and set the sum b/w the other places. Then assume 0 & 1 to last two Prob which we get) base is taken

more frequently

average
is max.

technique using

→ 0.57 0
0.43 1

of bits

order and
ens b/w
last two Bo

$H(m) = \sum P_i \log_2\left(\frac{1}{P_i}\right) = 2.42$

avg no of bits/msg $= \sum P_i L_i$

$L = 0.3(2) + 0.25(2) + 0.15(3) + 0.12(3) + 0.10(3) + 0.08(3)$

$= 2.45$

$$\boxed{\begin{array}{l} \text{code efficiency} = \frac{H(m)}{L} = \eta \\ \text{Redundancy} = 1-\eta \end{array}}$$

(repetition)

Ex.– using 4 array code

m_1		0.30	0	0.30	0
m_2		0.25	2	0.30	1
m_3		0.15	3	0.25	2
m_4	10	0.12		0.15	3
m_5	11	0.10			
m_6	12	0.08			
m_7	13	0			

assumed when we use 4 array code.

– for 4 array code, take $\log_4$ while calculating $H(m)$.

$H(m) = \cancel{2.42}\sum P_i \log_4(1/P_i)$

$L = 0.30\times1 + 0.25\times1 + 0.15\times1 + 0.12\times2 + 0.10\times2 + 0.08\times2 + 0$

$= 0.30 + 0.25 + 0.15 + 0.24 + 0.20 + 0.16$

$= 1.34$

DSP

Jumbo Book

6-10

Channel capacity:

$L > H(m)$

$\eta < 1$

$r > 0$

- Redundancy ↑ses, data loss ↓ses
  - ↳ extra bits are added to find out error
  - ex:- parity bits

$H(m) = 1.2 \rightarrow$ entropy

$L = 2 \longrightarrow$ length of code

$\therefore$ Redundancy $= 0.8$

according to shanon:

if data rate < channel capacity → error free communication is possible.

- channel capacity $(C_s) = 1 - \cancel{H(\ldots)} \left[P_e \log \frac{1}{P_e} + (1-P_e) \log \frac{1}{(1-P_e)} \right]$

- word length $= \frac{H(m)}{C_s} = 2.5\, H(m)$ [if $C_s = 0.4$)

So, here if $H(m) = 3$ then word length will be $2.5 \times 3 = 7.5 \approx 8 \Rightarrow$ a single msg can be expressed in 8 bits i.e. redundancy of $(8-3) = 5$ bits are added.

- Hamming distance: The no of change in bits Tx and Rx message.

Base depends on → Code taken
like if binary → take base 2 for log
4 → take " 4 for log

Date: 23 Sep

Second Order Huffman's Coding:

(1st order):

$m_1 = 0.2 \rightarrow 0$

$m_2 = 0.8 \rightarrow 1$

$0.2 \times 1 + 0.8 \times 1 = \cancel{H(m)} = 1 = L$

$H(m) = 0.72$ ~~$\eta = H(m)/L = 1/2 = 0.5$~~

2nd Order

$m_1 m_2 = 0.16$

$m_1 m_1 = 0.04$

$m_2 m_2 = 0.64$

$m_2 m_1 = 0.16$

3rd order

$m_1 m_1 m_1 = 0.08$

(2nd order):

descending order:

0	$m_2 m_2$	0.64
11	$m_1 m_2$	0.16
100	$m_2 m_1$	0.16
101	$m_1 m_1$	0.04

$0.16 + 0.04 = 0.20$

$m_2 m_2 - 0.64 \rightarrow 0$

$m_1^3 m_2 - 0.20$

$m_1 m_2 - 0.16$

$0.36 \rightarrow 10$

11

$m_2 m_2 - 0.64 \rightarrow 0$

$0.36 \rightarrow 1$

$$L = \sum P_i L_i$$

$$= 0.64 \times 1 + 2 \times 0.16 + 3 \times 0.16 + 3 \times 0.04$$

$$= 0.64 + 0.32 + 0.48 + 0.12$$

$$= 1.56$$

$$H(m) = \sum P_i \log\left(\frac{1}{P_i}\right) = 1.44$$

~~$= 0.44$~~

$$\eta = \frac{H(m)}{L} \times 100 =$$

(3rd order):

$m_1 m_1 m_1$	0.008
$m_1 m_1 m_2$	0.032
$m_1 m_2 m_1$	0.032
$m_1 m_2 m_2$	0.128
$m_2 m_2 m_2$	0.512
$m_2 m_1 m_2$	0.128
$m_2 m_1 m_1$	0.032
$m_2 m_2 m_1$	0.128

$1 \leftarrow 0.512$

$0.128 \rightarrow 000$

$0.128 \rightarrow 010$

$0.128 \rightarrow 0010$

$0.032 \rightarrow 0011010$

$0.032 \rightarrow 001100$

0.032, 0.008 → 0.040 (001110)

$1 \leftarrow 0.512$

$0.128 \rightarrow 000$

$0.128 \rightarrow 010$

$0.128 \rightarrow 0010$

$0.040 \rightarrow 00111$

0.032 (00110), 0.032 (001100) → 0.064

$1 \leftarrow 0.512$

000 0.128

010 0.128

0010 0.128

0.064 (00110), 0.040 (00111) → 0.104

$1 \leftarrow 0.512$

$000 \leftarrow 0.128$

$010 \leftarrow 0.128$

$0010 \leftarrow 0.128$

$0011 \leftarrow 0.104$

0.232

$0.512 \rightarrow 1 \quad 1 \leftarrow 0.512 \rightarrow 1 \quad 0.616 \rightarrow 0$

$0.256 \rightarrow 01 \quad 00 \leftarrow 0.360 \quad 0.616 \rightarrow 0 \quad 0.512 \rightarrow 1$

$001 \leftarrow 0.232 \quad 0.360 \quad 01 \leftarrow 0.256$

$000 \leftarrow 0.128$

$$L = (0.512 \times 1) + (0.128 \times 3) + (0.128 \times 3) + (0.128 \times 4)$$
$$(0.032 \times 4) + (0.032 \times 7) + (0.032 \times 6) + (0.008 \times 6)$$
$$= 2.48$$

- as we ↑se the order of Hoffman encoding
  ⇒ efficiency ↑ses.

- given Haffmann encodig table is :-
  m_1 — 00

- no code is subset of another code.

0

10

110X 111

for ex: $m_1 - 00$

$m_2 - 10$

$m_3 - 010$

$m_4 - 011$

$m_5 - 110$

$m_6 - 111$

decode using given table: $\underbrace{00}_{m_1}\ \underbrace{110}_{m_5}\ \underbrace{10}_{m_2}\underbrace{0}_{m_1}\ \underbrace{011}_{m_4}\ \underbrace{010}_{m_3}\ \underbrace{111}_{m_6}$ (Received) (decoded)

6-Octo

entropy : average information per message

channel capacity : $L > H(m)$

$n < 1$; $r > 0$

for find out the error in signal we added some bits (as parity bit) so we can says that by Ting the redundenteity, we can easily find the error.

- max. data rate over which reliable communication is done known as channel capacity.

for reliable communication $C_s = 1 - H(m)$

$= 1 - \left(P_e \log_2\left(\frac{1}{P_e}\right) + (1-P_e)\log_2\left(\frac{1}{1-P_e}\right)\right]$

$(C_s < 1)$

Word length $= \frac{H(m)}{C_s}$

$H(m) \longrightarrow$ entropy bits of message information per message

if $C_s = 0.4$

Word length $= 2.5\ H(m)$

$\Downarrow$

1 bit is represented by 2.5 bits

(means 1.5 bits we added to Pse the rel...

for ex: 0 $\longrightarrow$ 000 then we detect the data correct

1 $\longrightarrow$ 111 if one bit is change

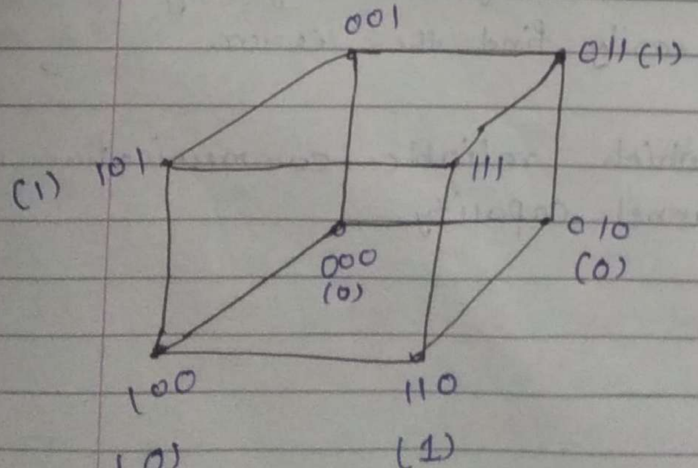
mess.bit parity bit

hamming distance:

Tx	0 0 0	0 0 0
Rx	0 0 1	1 1 0
	1 0 0	0 1 1
	0 1 0	
	HD = 1	HD = 2

hamming distance = 1 hamming distance = 2

no. of bits is changes. $\rightarrow$ hamming distance

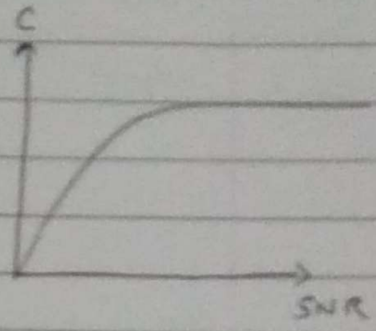


if M ↑ses in MPSK → channel capacity ↑ses till a certain limit bcoz-

$$\boxed{C = B \log(1 + SNR)}$$

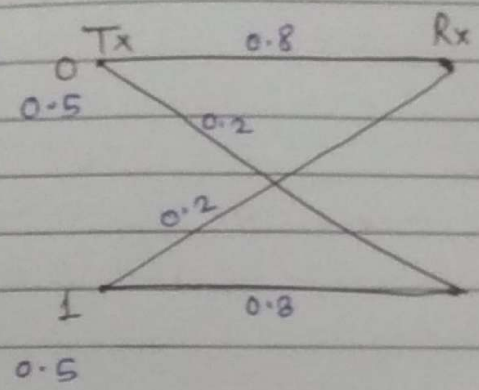
C → channel capacity

B → Bandwidth



(↑ing the SNR is not the smart soln for increasing the channel capacity)

⇒



$P_e = 0.5 \times 0.2 + 0.5 \times 0.2$
$= 0.2$

$P_e = P(0)\,P(1/0) + P(1)\,P(0/1)$
$= 0.5 \times 0.2 + 0.5 \times 0.2$
$= 0.2$

$$C_s = 1 - \left(0.2 \log(1/0.2) + 0.8 \log(1/0.8)\right)$$

$= \cancel{0.22}\ 0.78$

19-Octo

Block Codes :

$(c_1, c_2, \ldots, c_n)$

$$\underset{\substack{\downarrow \\ \text{code word} \\ 2^k}}{\overset{n}{C}} = \underset{\substack{\downarrow \\ \text{data word} \\ 2^k}}{\overset{k}{d}} \; G \to \text{Generator matrix}$$

$(d_1, d_2, \ldots, d_k)$

there are two types of Block code :
- Systematic block code
- non systematic block code

- Systematic block code

in this $c_1 = d_1$

$c_2 = d_2$

$\vdots$

$c_k = d_k$

$\left.\begin{matrix} c_{k+1} \\ c_{k+2} \end{matrix}\right\}$ parity

- for generation or detection of code block :

XOR :

$0 \oplus 0 = 1 \oplus 1 = 0$

$0 \oplus 1 = 1 \oplus 0 = 1$

-

$$\underset{[2^k \times n]}{C} = \underset{\substack{\downarrow \\ [2^k \times k]}}{d} \; G \to [k \times n]$$

$$[d_1 \; d_2 \ldots d_k \; c_{k+1} \ldots c_n] = [d_1 \; d_2 \ldots d_k][I_k \; P_{k \times (n-k)}]$$

$$G = \left[\begin{array}{cccccc|ccc} 1 & 0 & 0 & 0 & \ldots & & P_{11} & P_{12} & \ldots P \\ 0 & 1 & \ldots & & & & P_{21} & \ldots & \\ 0 & 0 & 1 & \ldots & & & & & \\ & & \ldots & & & 1 & P_{k1} & \ldots & \end{array}\right]$$

$\qquad\qquad I_k \qquad\qquad\qquad P$

$$c = d\,G$$
$$= d\,[I_k \; P]$$
$$= [d \;\; dP]$$
$$= [d \;\; C_P]$$

Ex: $G = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$

block code (6, 3)

Code ← 2^6 ✓ ↳ 2^3 → data

→ single bit error possibility is 6

Sol: $C = d \cdot G$

$$= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ \vdots \\ 1 & 1 & 1 \end{bmatrix}_{8\times 3} \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}_{3\times 6}$$

$0 \oplus 0 \oplus 1 = 1$
$0 \oplus 1 \oplus 0 = 1$

$$= \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ \vdots \\ 1 & 1 & 1 & 0 & 0 & 0 \end{bmatrix}$$

$$C_P = d \cdot P$$
$$C_P \oplus dP = 0$$
$$d.P \oplus C_P = 0$$
$$[d \;\; C_P] \begin{bmatrix} P \\ I_m \end{bmatrix} = 0$$
$$C \cdot H^T = 0$$
$$H^T = \begin{bmatrix} P \\ I_m \end{bmatrix} \; ; \; H = [P^T \;\; I_m]$$

if ans is non zero, then error will there.

Date 19-Octo

$C \longrightarrow CH^T = 0$

$C \oplus e \Rightarrow r \cdot H^T \neq 0$

$\downarrow$

error matrix

$$e = \begin{array}{l} \\ \\ 3^{rd} \longrightarrow \\ \\ \longrightarrow \\ \\ \end{array} \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\underbrace{r}_{\text{received}} = \underbrace{c}_{\text{code}} \oplus \underbrace{e}_{\text{error}}$$

$r \cdot H^T = S \neq 0$ (becuz if there is error)

$(C \oplus e) \cdot H^T = S$.

$CH^T + eH^T = S$

$CH^T = 0$

$eH^T = S$.

$$G = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

I_K P

$C \cdot H^T = 0$

$$H^T = \begin{bmatrix} P \\ I_m \end{bmatrix}$$

$$H^T = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

$$S(\text{error}) = e \cdot H^T$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}_{6\times 6} \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}_{6\times 3}$$

$$= \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$r = 1\ 0\ 1\ 1\ 0\ 1 \longrightarrow$ (given)

$$r \cdot H^T = \begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}_{1\times 6} \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}_{6\times 3} \longleftarrow 3\text{rd}$$

$$= \begin{bmatrix} 0 & 1 & 0 \end{bmatrix}$$

Error on ~~fifth~~ third position

actual received without any error

$r = 1\ 0\ 0\ 1\ 0\ 1$

$\uparrow$

3rd value change

Ex: ① $r = 0\ 1\ 1\ 1\ 1\ 0$

$S = r \cdot H^T = 0\ 1\ 1$

2^{nd} position

$c = 0\ 0\ 1\ 1\ 1\ 0$

$d = 0\ 0\ 1$

② $r = 0\ 0\ 1\ 0\ 0\ 1$.

$$r \cdot H^T = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$S = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$$

its having doble error, because value of s is not present in HT.

$e \cdot H^T = S = [1\ 1\ 1]$

for this e ~~should~~ can be having three values

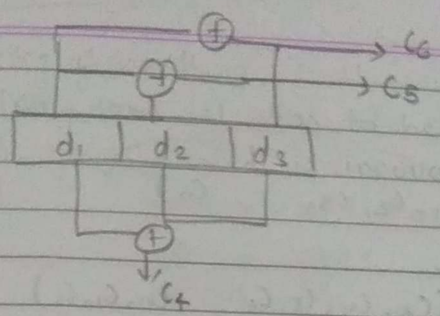
$$e = \left.\begin{matrix} 1\ 0\ 0\ 0\ 1\ 0 \\ 0\ 1\ 0\ 1\ 0\ 0 \\ 0\ 0\ 1\ 0\ 0\ 1 \end{matrix}\right\} \text{double error}$$

Example linear block code, the parity check digit are

$C_4 = d_1 + d_2 + d_3$

$C_5 = d_1 + d_2$

$C_6 = d_1 + d_3$



$$\begin{matrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{matrix}\Bigg\}$$

$c_4 = d_1 + d_2 + d_3$

$c_5 = d_1 + d_2$

$c_6 = d_1 + d_3$

$$G = [I_K \quad P]$$

$$= \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$

$$H^T = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$r = 1\ 0\ 11\ 00$ (given)

$$S = r \cdot H^T = [1 \ 0 \ 11 \ 00] \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= [1 \quad 0 \quad 1]$$

Date 20 - Octo

Cyclic Code :

$c = (c_1, c_2, c_3, \dots c_n)$

shift by 2

$c^{(2)} = (c_3, c_4, c_5, c_6 \dots c_n, c_1, c_2)$

shift by i $\quad c^{(i)} = (c_{i+1}, c_{i+2}, \dots c_n, c_1, c_2, \dots c_i)$

Polynomial form $c(x) = c_1 x^{n-1} + c_2 x^{n-2} + c_3 x^{n-3} + \dots + c_n$

$[c_4 = c_1 x^3 + c_2 x^2 + c_3 x + c_4]$

$c^{(i)}(x) = c_{i+1} x^{n-1} + c_{i+2} x^{n-2} + \dots + c_n x + c_1 x^{n-i-1} + \dots + c_i$

- $d(x) \rightarrow$ data poly. and $g(x) \rightarrow$ generator polynomial

$$P(x) = \text{Rem}\left[\frac{x^{n-k} d(x)}{g(x)}\right]$$

$$c(x) = x^{n-k} d(x) + P(x)$$

for ex: ① $g(x) = x^3 + x^2 + 1$

$(\overset{n}{7}, \overset{k}{4})$ $\quad d = 1010$

↓ ↓ $\quad c(x) = ?$

code data

$d(x) = x^3 + 0 + x = x^3 + x$

$x^{n-k} \cdot d(x) = x^3(x^3 + x)$

$= x^6 + x^4$

$x^3 + x^2 + 1 \,\big)\, x^6 + x^4 \,\big(\, x^3 + x^2 + 1$

$x^6 + x^5 + x^3$

$- \quad -$

$\pm x^5 + x^4 + x^3$

$+x^5 + x^4 + x^2$

$\cancel{2x^4 - x^3 + x^2}$ $\quad x^3 + x^2$

$x^3 + x^2 + 1$

1

* $g(x)$ is an

for ex: ②

Sol:

x^2

$x^3 + x$

Ex:

* $g(x)$ is an $(n-k)$th order factor of x^n+1

$c(x) = d(x)\,g(x)$

So, $c(x) = x^3[x^3+x] + 1 = x^6\,x^4+\cancel{x}1$

$= [1010001]$

for ex: (2)

$g(x) = x^3+x^2+1$

$d = 0101$

$C(x) = (?)$

$(7,4)$

Sol:

$d(x) = x^2+1$

$d(x)\cdot x^{n-k} = x^3(x^2+1) = x^5+x^3$

$$\frac{d(x)x^{n-k}}{g(x)} = \frac{x^5+x^3}{x^3+x^2+1}$$

$x^2+x^2+1 \,)\, \cancel{x^5} + x^3 \,(\, x^2+x+\frac{1}{x}$

$\cancel{x^5}+x^4+x^2$

$x^4+x^3+x^2$

x^4+x^3+x

x^2+x

$\cancel{x^2+x+1/x}$

$\cancel{1/x}$

$c(x) = x^3(x^2+1) + x^2+x$

$= x^5+x^3+x^2+x$

$= [101110]$

Ex: (iii) $d = 1000$

$d(x) = x^3$

$$\frac{x^{n-k}\,d(x)}{g(x)} = \frac{x^3\cdot x^3}{x^3+x^2+1}$$

$x^3+x^2+1 \,)\, x^6 \,(\, x^3+x^2+x$

$x^6+x^5+x^3$

x^5+x^3

$x^5+x^4+x^2$

$x^4+x^3+x^2$

x^4+x^3+x

x^2+x

$c(x) = x^6+x^2+x$

$= 1000110$

(iv) $d_1 = 1000$ $\quad = 1000101$

$d_2 = 0100$ $\quad c = 0100011$

$d_3 = 0010$ $\quad = 0010111$

$d_4 = 0001$ $\quad = 01101$

$\underbrace{}_{4\times 4 \rightarrow \text{identity matrix } I}$ $\quad \underbrace{}_{G}$

$dG = c$

$\Rightarrow$

$$\text{rem}\left[\frac{r(x)}{g(x)}\right] = s(x)$$

$$\text{rem}\left[\frac{c(x) + e(x)}{g(x)}\right] = s(x)$$

$$\text{rem}\left(\frac{e(x)}{g(x)}\right) = s(x) \longrightarrow \text{error at the Rx side}$$

decoding table

$$e(x) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{array}{l} s(x) \\ \longrightarrow 110 \\ \longrightarrow 011 \\ \longrightarrow 111 \\ \longrightarrow 101 \\ \longrightarrow 100 \\ \longrightarrow 010 \\ \longrightarrow 001 \end{array}$$

$e_1(x) = x^6$ $\quad s_1(x) = (1)$ $\quad g(x) = x^3 + x^2 + 1$

$$\begin{array}{r} x^3+x^2+1 \,\big)\, x^6 \,\big(\, x^3 + x^2 + x \\ \underline{x^6 + x^5 + x^3} \\ x^5 + x^3 \\ \underline{x^5 + x^4 + x^2} \\ x^4 + x^3 + x^2 \\ \underline{x^4 + x^3 + x} \\ x^2 + x \end{array}$$

$s_1(x) = x^2 + x$

$= 110$

$$
\begin{array}{l}
x^3+x^2+1 \;)\; x^5 \;(\; x^2 + x + 1 \\
\quad x^5 + x^4 + x^2 \\
\quad \overline{x^4 + x^2} \\
\quad x^4 + x^3 + x \\
\quad \overline{x^3 + x^2 + x} \\
\quad x^3 + x^2 + 1 \\
\quad \overline{x + 1}
\end{array}
$$

$$
\begin{array}{l}
x^3+x^2+1 \;)\; x^4 \;(\; x + 1 \\
\quad x^4 + x^3 + x \\
\quad \overline{x^3 + x} \\
\quad x^3 + x^2 + 1 \\
\quad \overline{x^2 + x + 1}
\end{array}
$$

(i) $r = 0101000$

$r(x) = x^5 + x^3$

$\text{rem}\left(\dfrac{r(x)}{g(x)}\right)$

$$
\begin{array}{l}
x^3+x^2+x \;)\; x^5 + x^3 \;(\; x^2 + x \\
\quad x^5 + x^4 + x^3 \\
\quad \overline{x^4 + \cancel{x}} \\
\quad x^4 + x^3 + x^2 \\
\quad \overline{x^3 + x^2}
\end{array}
$$

1100

1st Position having error

$r(x) = 1101000$ actual transmitted signal that's code.

$c(x) = r \oplus e$

$c(x) = \boxed{1101}000 \longrightarrow$ code, actual

$c(x) = g(x)\, d(x)$ $\rightarrow d(x) = x^3 + x^2 + 0 + x^0$

(1101)

$d(x) = \dfrac{c(x)}{g(x)}$

$$x^3+x^2+1 \overline{\big) x^6+x^5+x^3} \big(x^3$$
$$\underline{\cancel{x^6+x^5+x^3}}$$
$$0$$

(ii)

$r = 0\ 0\ 0\ 1\ 1\ 0\ 0$

$r(x) = x^3+x^2$

$$\frac{r(x)}{g(x)} = x^3+x^2+1 \overline{\big) x^3+x^2} \big(1$$
$$\underline{x^3+x^2+1}$$
$$1$$

$001 \longrightarrow 7^{th}$ Position

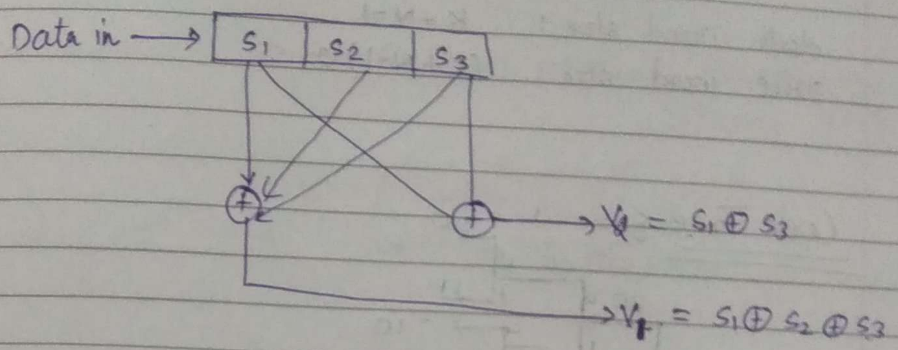
So $c(x) = \underbrace{0001}\,101$ actual transmitted signal

$d(x) = 0001$

Convolution Code:

Date: 24-Oct

In conv. code the code word is dependent on present data word and previous data word.



code O/P : V_1 & V_2

data i/p → 1 1 0 1 0 $\underbrace{0\ 0}$ (K+2 data bits)

1st ... last

initially $S_1, S_2, S_3 = 0$

	S_1	S_2	S_3	V_2	V_1
	0	0	0	0	0
1st →	1	0	0	1	1
2nd →	1	1	0	1	0
3rd →	0	1	1	1	0
4th →	1	0	1	0	0
5th →	0	1	0	0	1
	0	0	1	1	1
	0	0	0	0	0

↑ Actual size of data = K

(11010) data : 11 01 01 00 10 11 00 ← code

↓ (size) of applied data: K+2

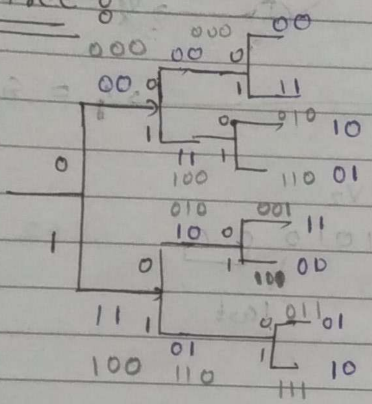
↓ size: 2×(K+2)

- In this N = 1 & v = 2 (adder)
- if N = 1, then two zeros are added.

N → no. of shift register
v → no. of modulo adder

data word size : $K+N-1$
code word size : $(K+N-1)v$

Code Tree :



Stage

S_3	S_2	
0	0	→ a
0	1	→ b
1	0	→ c
1	1	→ d

(becuz in S_1, current bit is available)

State Diagram :

– i/p, current state, o/p

S_2 S_3

c → a   0   0 1   11
→ 0 0 (next state) a ($S_3 S_2$)

c →   1   0 1   00
→ 1 0 next state) b

d →   0   1 1   01
→ 0 1 (next state) c

d →   1   1 1   10
→ 1 1 (next state) d

(a→b)
(b→c)
(b→d)
(c→d)

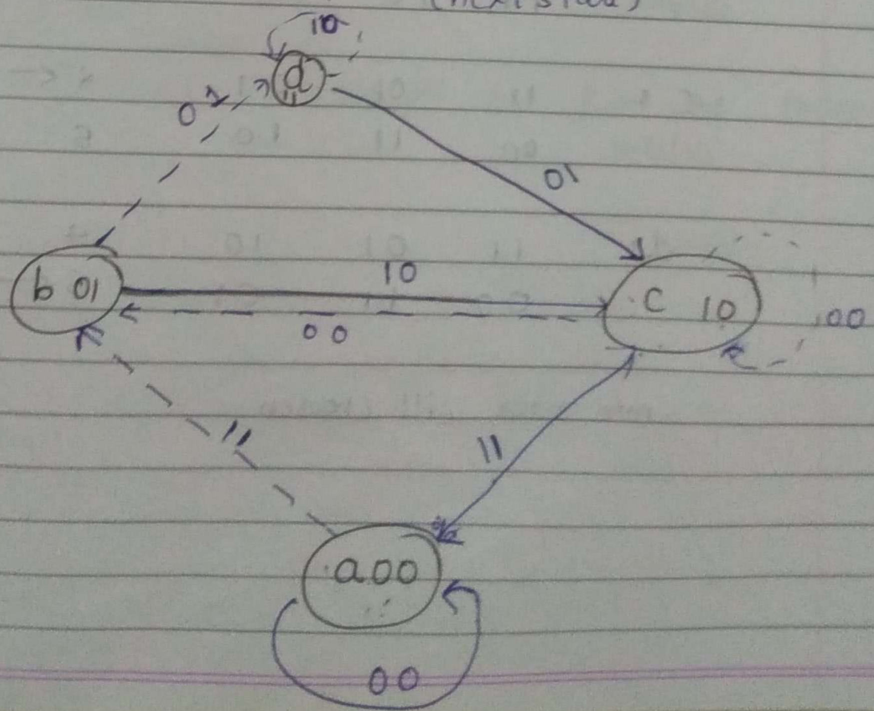
i/p

	S_1	S_2	S_3		o/p
$\vec{a}$	0	0	0	$\longrightarrow$	00
	—	0	0 (next state is not dependent on incoming i/p)		

* (——— i/p 0
- - - - - - i/p 1)

$\longrightarrow$ (a→b)	1	0	0	$\longrightarrow$	11
		1	0	(next state)	
$\longrightarrow$ (b→c)	0 →	1	0	$\longrightarrow$	10
		0	1	(next state)	
$\longrightarrow$ (b→d)	1 →	1	0	$\longrightarrow$	01
		1	1	(next state)	

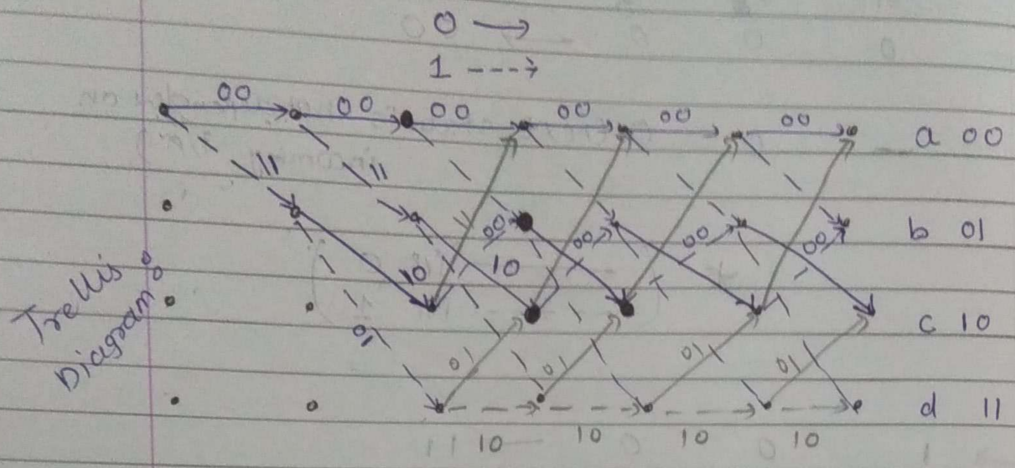
(c→d)



2
→ a
→ b
→ c
→ d
in S_1, current
available)

Date: 26-Octo

Viterbi decoder & Trellins Diagrams



if received sequence : 01 00 01 00

first three 01 00 01 diff of bits

				min error
a :	00	00	00	2 ←
deleted	11	10	11	3
b :	00	00	11	2 ←
deleted	11	10	00	3
c :	11	01	01	2 ←
deleted	00	11	10	5
deleted d :	11	01	10	4
	00	11	01	3 ←

- min error will choosen

01 00 01 00

4th from Received

00

a	2	00	00	00	00	a	2 ✓
					11	b	4
b	2	00	00	11	10	c	2+1 = 3 ✓
					01	d	2+1 = 3 ✓
c	2	11	01	01	00	b	2 ✓
					11	a	4
d	3	00	11	01	01	c	4
					10	d	4

↑ stage

✓ 00 00 00 000 → a (2)
11 01 01 000 → b (2) } min Ham. distance
00 00 11 10 → c (3)
00 00 11 01 → d (3) } X

which one is terminated at a, after adding 0

- when I/P is zero then the next state is 'a' in a code when Tx code is 0 then the next state terminated @ a.

∴ we select a
because terminate @ a from the Diagram.

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