DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute Affiliated to VTU, Belagavi)

Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

Make Up Examination, December 2020/January 2021

Course:	**MIMO Communications**	Maximum marks: **100**
Course Code:	**TE814**	Duration: **03 hours**
Semester:	**VIII**	

Note: **i). Question ONE (a to t) has to be answered in first two pages only, also candidate must write the answer along with the option.**
ii). Question 1 to 4 is compulsory.
iii). Any missing data should be suitably assumed.

Q. No.			Marks
1	a)	Path loss is the reduction in _____ (attenuation) of an electromagnetic wave as it propagates through space. i.Frequency density ii. Power density iii. Data density iv. Amplitude	01
	b)	Position the Router antenna upward for a better ____ each. i.Vertical ii. Horizontal iii. Diagonal iv. None	01
	c)	______ which processes the redundantly received signals. i.Combiner ii. equalizer iii. PCM iv. Sampler	01
	d)	Diversity is used to combat i Fading ii. Co Channel Interference iii. Error bust iv. All of mentioned	01
	e)	More certain or deterministic the event is, the less _____ it will contain. i.Bandwidth ii. Information iii. Energy iv. Invalid data	01
	f)	Information is an _______ in uncertainty or entropy. i.Increase ii. Decrease iii. Same iv. No effect	01
	g)	The symbol for entropy is an ______ i.Erlang ii. K iii. S iv. N	01
	h)	_____ reflects the capacity to do non-mechanical work and the capacity to release heat. i.Erlang ii. Entropy iii. Enthalpy iv. Bandwidth	01
	i)	The use of multiple transmit antennas to achieve reliability is ______ i.Receive Diversity ii. Flexible Diversity iii. Transmit Diversity iv.Spatial Multiplexing	01
	j)	Receive diversity is that each element in the receive array receives an independent copy of the _____ i.Interference ii. Dispersion iii. Different Signal iv. Same Signal	01
	k)	In Receive Diversity probability that all signals are in deep fade simultaneously is then significantly ______ i.Remains same ii. Increase iii. Reduced iv. Fluctuates	01
	l)	Base station antenna comprises multiple elements while the mobile device has only one or two, why? i.Space considerations ii. Interference iii. Bandwidth iv. No Reason	01
	m)	Concatenated codes are ______ i.Compression Code ii. Source Code iii. Error-correcting codes iv. None	01
	n)	The ______ decoding principles have found widespread applications not only in error control, but in detection, interference suppression and equalization. i.Reed Solomon Code ii. Turbo Code iii. BCH Code iv. Hamming Code	01

o) The recursive systematic convolutional (RSC) encoder is obtained from the non-recursive nonsystematic (conventional) convolutional encoder by feeding back one of its ---- outputs to its input. 01

i.Decoded ii. Encoded iii. Compressed iv. Expanded

p) ______, a technique for making forward error correction more robust with respect to burst errors. 01

i.Interleaving ii. Puncturing iii. Equalization iv. Source coding

q) ______ is process of adjusting the spatial attribute of a sound in order to perceive desired 3D sound sensation 01

i.Spatial Equalization ii. Temporal Equalization iii. ISI iv. ISI-Tap

r) ______ is transceiver architecture for offering spatial multiplexing over multiple-antenna wireless communication systems. 01

i.D Blast ii. BLAST iii. V Blast iv. K-Blast

s) ______ is a detection algorithm to the receipt of multi-antenna MIMO systems. 01

i.V-Blast ii. D-Blast iii. K-Blast iv. Blast

t) The DFE is fed with detected symbols and produces an output which typically is subtracted from the output of the ______ equalizer. 01

i.FIR ii. Matched iii. Linear iv. Decision feedback equalizer (DFE)

2	a.	Bring out the differences between wired and wireless channels.	04
	b.	With neat diagrams explain the Diversity Techniques in Wireless Communication.	07
	c.	Beamforming used for improving the signal to noise ratio and reducing the interference discuss this with the neat diagram.	05
3	a.	Focus on Capacity of Noisy Channel.	08
	b.	Analyze the information Rate of Noisy Channel.	08
4	a.	With example discuss the Orthogonal Space-Time Block Codes	06
	b.	Compare the space times block codes with the space time trellis codes	04
	c.	Describe the representation of space time trellis codes for PSK constellations	06
5	a.	Write a Note on Development of Concatenated Notes.	08
	b.	Elaborate on Turbo Coded Modulation for MIMO Channels.	08
		OR	
6	a.	List out the features briefly for Concatenated Space Time Turbo Coding.	08
	b.	Write about SOVA Decoder.	08
7	a.	With mathematical equations describe the capacity and information rates of MIMO frequency selective fading channels.	08
	b.	With neat diagram describe the space time trellis coding over a MIMO frequency selective fading channels.	08
		OR	
8	a.	With the example describe the full diversity code for MIMO frequency selective channels.	08
	b.	With necessary diagram discuss the MIMO OFDM system.	08

~~Semester End~~ Makeup Examination: Makeup Exam December 2020 - Jan 2021

Semester: VIII Total no of pages:

Course: MIMO Communications

Course Code: TE814

Program: Telecommunication Engineering

Scheme & Solution Prepared by: DR. SAYED ABDULHAYAN

Signature: Quadri

Q no.	Description	Marks
Q1	(a) Power density — (ii) (b) Horizontal — (ii) (c) Combiner — (i) (d) All of mentioned — (iv) (e) information — (ii) (f) increase — (i) (g) S — (iii) (h) Enthalpy — (iii) (i) Transmit diversity — (iii) (j) Same Signal — (iv) (k) Reduced — (iii)	

(l) Space considerations – (i)

(m) Error correcting Codes – (iii)

(n) Turbo Code – (ii)

(o) Encoded – (ii)

(p) Interleaving – (i)

(q) Spatial Equalization – (i)

(r) BLAST – (ii)

(s) V-BLAST – (i)

(t) Linear – (iii)

2

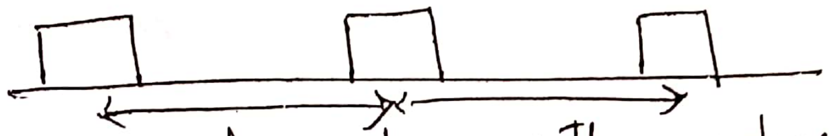
(a) Differences between wired and wireless channels

Wired Channels	Wireless Channels	
(1) Uses cables to connect devices	(1) Uses wave medium to connect through antennas	(2)
(2) Device is tethered to router	(2) Device is not tethered to router	(2)

1) Diversity Techniques in Wireless communication

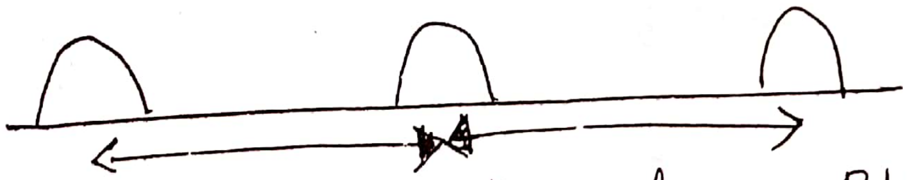
Diversity techniques collectively refers to methods of improving performance by effectively transmitting the same information multiple times where each replica sees a different ideally independent channel. 2

ⓐ Time Diversity



Separation larger than coherence time

ⓑ Frequency diversity



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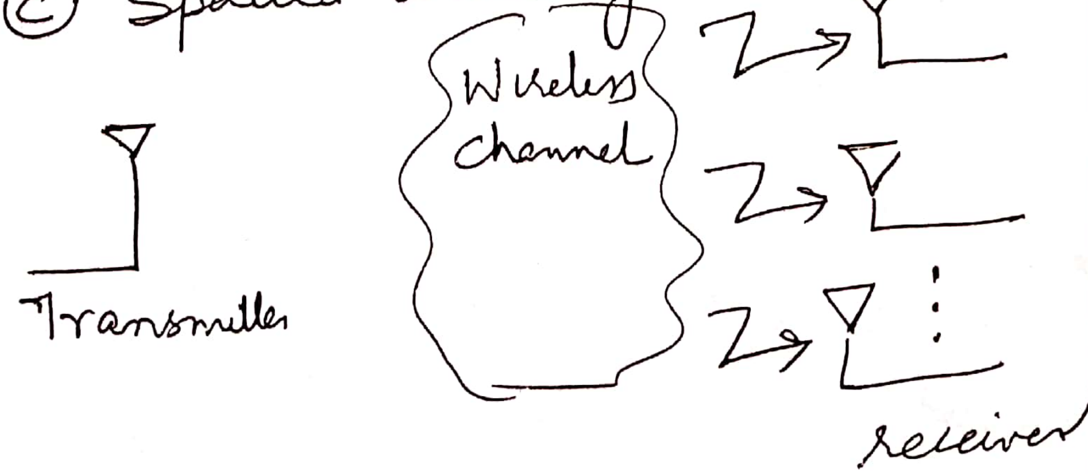
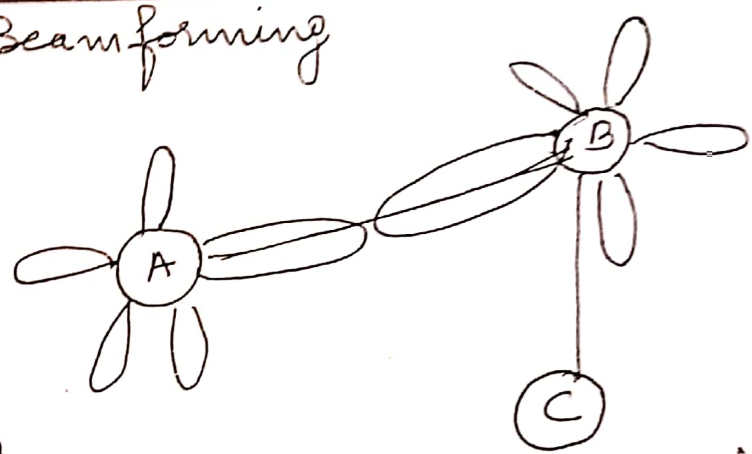
Separation larger than coherence BW.

ⓒ Spatial diversity



Q2 (C) Beamforming



B
Multiple antenna elements can be employed at transmitter in order to provide directionality for electromagnetic waves, hence improving effective SNR of channel.

A fundamental approach is the transmission of same signal from each antenna element with a certain gain and phase shift.

Different techniques can be used to find suitable coefficients of antenna beam. and also coefficients got from feedback can be computed to make effective antenna pattern beam in required direction with interference suppression

1

4

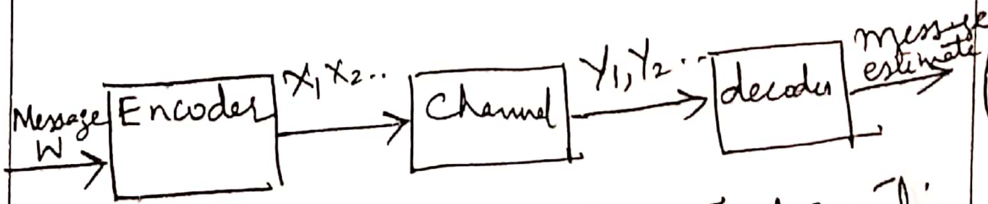
W = message

n = no of channels

$X_1, X_2, \ldots$ = Input to channels (3)

$Y_1\, Y_2 \ldots$ = Output from channels

C = channel capacity



(3)

$I(X;Y) \rightarrow$ Mutual Information

$$C = \lim_{n\to\infty} \frac{1}{n} \max_{p(x_1 \ldots x_n)} I(X_1 \ldots X_N ; Y_1 \ldots Y_N)$$

(3)

$$C = \max_{p(x)} I(X, Y)$$

$$C = \log(1+P)$$

Explanation ——— (2)

Q3 (b) Information Rate of Noisy Channel

$$C = \lim_{n\to\infty} \frac{1}{n} \max_{p(x_1, x_2 .. x_n)} I(X_1 .. X_N ; Y_1 -- Y_N)$$

(2)

Maximum mutual Information

$C = \max_{p(x)} I(X,Y)$ for memoryless channels i.e if output input relationship can be written as

$$P(y_1, y_2 \ldots y_n | x_1, x_2 \ldots x_n) = \prod_{i=1}^{n} P(y_i/x_i)$$

$$I(X;Y) = E\left[\log \frac{P(X,Y)}{P(X), P(Y)}\right]$$ 4

E → expectation is over joint density of X and Y.

Explanation ——— 2

Q4 (a). Orthogonal Space time Block Code

* Here transmit diversity can be extended beyond 2 antennas.

* If we design a set of $N_t \times N_t$ matrices with elements from a desired signal constellation whose columns are orthogonal to each other 2

* It is not full rate.

column 1 is orthogonal to all columns. Similarly all columns are orthogonal to each other 2

	slot 4	slot 3	slot 2	slot 1
ant 1	$-x_4$	$-x_3$	$-x_2$	x_1
ant 2	$-x_3$	x_4	x_1	x_2
ant 3	x_2	x_1	$-x_4$	x_3
ant 4	x_1	$-x_2$	x_3	x_4

2

Q4 (b)

STBC (Space time Block code)	STTC (Space Time Trellis code)
① Easy to encode and decode	① Complex to encode or decode
② Relatively easy to employ for more than 2 transmit antenna	② Relatively complex to employ for more that 2 transmit antenna
③ Resulting Error rate are more	③ Resulting Error rates are less

4

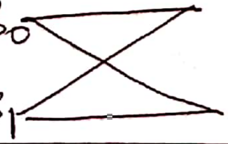
Q4 (c) Representation of STTC for PSK constellation

1

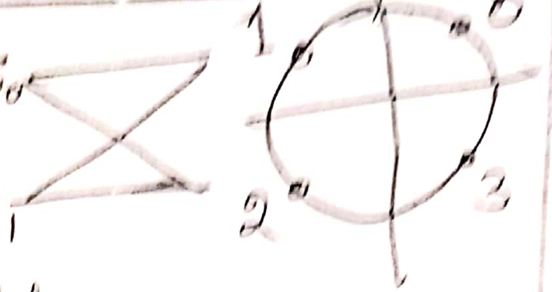
PSK Input : 0 , 1

00 01 S_0 — 0 1

10 11 S_1 — 2 3



0 1
00 01
10 11
$\underbrace{\qquad\qquad}$
branch labels



$N_t = 2$ $N = 2$ = time slots

Input stream 2 1 2 3 0 0 1 3 2

Tx 1 0 2 1 2 3 0 0 1 3 2

Tx 2 2 1 2 3 0 0 1 3 2

2^R branches emanating from each state

R bit per channel

$R = 2$ bits here 2^R

This is basic trellis structure that determines the coded symbols to to transmitted from different antenna elements

$x_i(k) \rightarrow$ transmitted signal from antenna i at time k

$$y_j(k) = \sqrt{P} \sum_{i=1}^{N_t} h_{ij}\, x_i(k) + n_j(k)$$

$i = 1, 2 \ldots N_t$ $t = 1, 2 \ldots N$

1
2
1

4(c) $Y = \sqrt{\Gamma}\, X H + N$

$X \rightarrow N \times N_t$ transmitted codewords

$H \Rightarrow N_t \times N_r$ Matrix of channel coefficients | 1

$Y \rightarrow N \times N_r$ received matrix

$N \rightarrow N \times N_r$ noise code matrix

Q5(a) Development of Concatenated code

- Ungerboeck, Deng, costello (1989) proposed TCM - inner code
  RS - outer code | 2

  SDVA ⟶ Inner decoder

  R.S decoder ⟶ outer decoder

- Hagenauer and Hoeher (1989) proposed serial concatenated of two convolution codes separated by ~~RR~~ via pseudo random interleaver. | 2

  SOVA ⟶ Inner decoder

  Viterbi decoder ⟶ outer decoder

- Berrou. proposed Turbo (1993) codes.

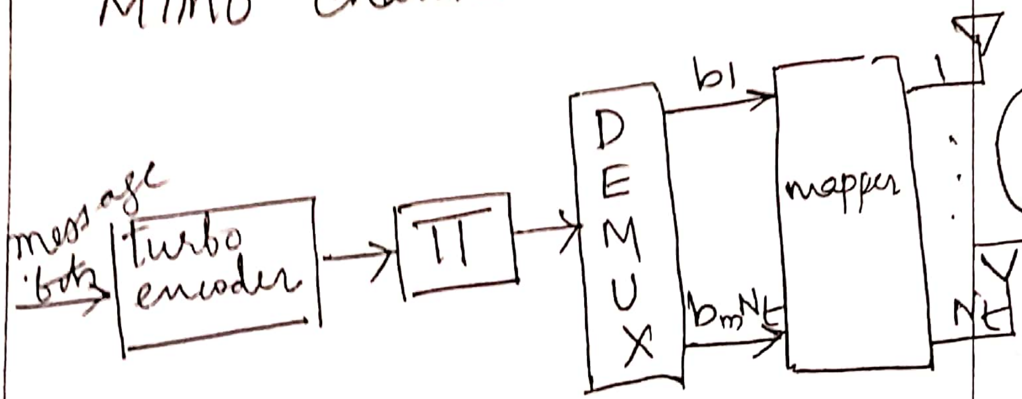
  decoding is done by APP, MAP BCJR

Benedetto proposed (1998) serial concatenation of two convolution codes seperated by interleaver
decoded using iterative decoding (2)

Divsalar and Pollara (2000) proposed hybrid concatenation
Explanation

LDPC codes was proposed by Gallager in (1962) later adopted after further research. (2)
Explanation

Q5 (b) Turbo Coded Modulation for MIMO channels



(2)

* It was introduced by Stefanov and Duman in 2001.
* It involves serial concatenation of turbo code and mapper with interleaver seperating them. (2)

primitive ... is ... by Turbo encoder. Then turbo coded sequence is interleaved so that to avoid burst errors.

Then interleaved sequence is demultiplexed into a number of parallel substreams.

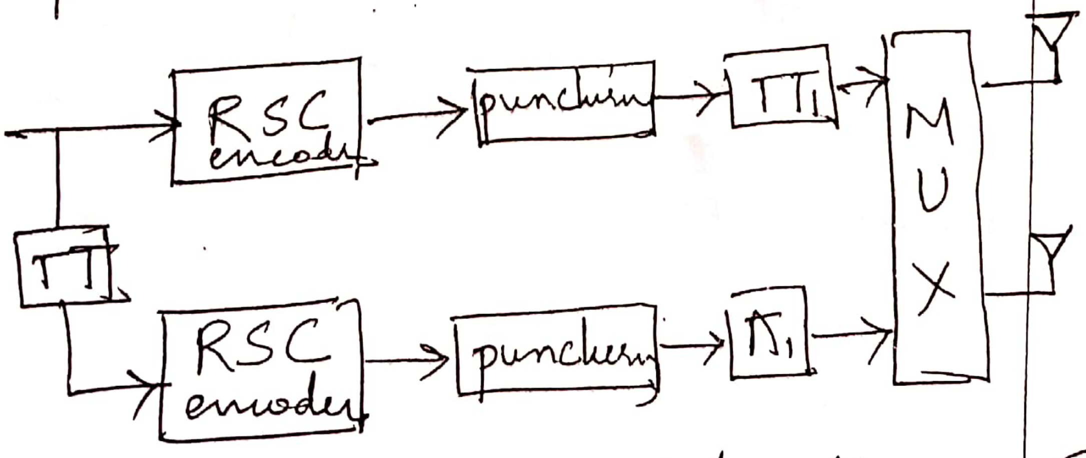
Number of substreams depends on modulation type mapping used.

Then Incoming bits are mapped to a particular signal constellation

4

(a). Features of Concatenated STTuC

parallel concatenated STTuC



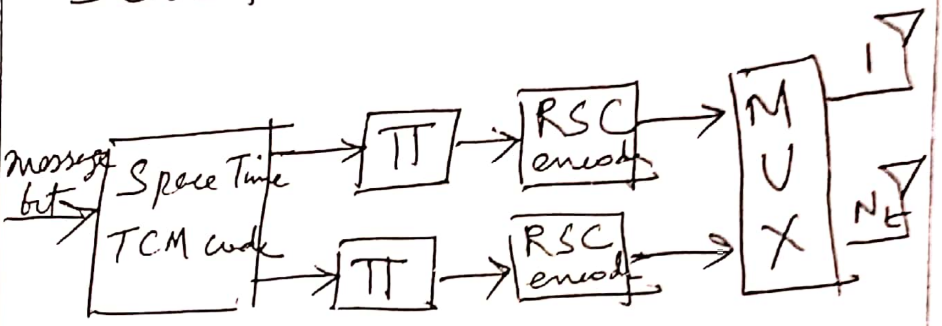
- puncturing is used to allow flexible code rate.
- Channel interleaving and multiplexing

4

are intended to take advantages of both time and Space diversity..

- Overall rate is dictated by modulation scheme used..
- decoder is iterative based on belief propagation

Serial concatenated STTuC



- convolution codes should be identical, recussive and of rate one
- Numerator of Transfer function should be 1
- Recussive convolution codes are decoded seperately

4

Q6(b) SOVA decoder

SOVA is alternative to APP complexity in SOVA is 1/2 that of APP at the expense of degradation

2

Scanned with CamScanner

$m_k(s) \rightarrow$ cumulative metric for state s at time k will be updated according to

$m_k(s)$

$$m_k(s) = \max\left\{ \begin{array}{l} \lambda(s', s) + m_{k-1}(s'), \\ \lambda(s'', s) + m_{k-1}(s'') \end{array} \right\}$$

2

$\lambda(s', s) \rightarrow$ branch metric of transition from s' to s state

In iterative decoding, branch metric when incorporating the priori information

$$\lambda(s', s) = \frac{1}{2} L^e(b_k) b_k + 2\sqrt{P}\, y_k^b b_k + 2\sqrt{P}\, y_k^p p_k$$

$L^e(b_k) \rightarrow$ extrinsic information

2

$\Delta_k \rightarrow$ difference metric for state s at time k.

$$\Delta_k = \left| \left(m_{k-1}(s') + \lambda(s', s)\right) - \left(m_{k-1}(s'') + \lambda(s'', s)\right) \right|$$

$$\Delta_k \simeq \log \frac{P(\text{correct})}{1 - P(\text{correct})}$$

$P(\text{correct}) \rightarrow$ probability of path decision of survivor at time k was correct.

$\Delta_k^* = \min\{\Delta_k, \Delta_{k+1} \ldots \Delta_{k+\delta}\}$

δ = delay → decoding depth

$L(b_k) \approx \hat{b}_k \cdot \Delta_k^*$ 2

Given $\hat{b}_k$ and Δ_k^* the soft output for bit b_k is approximated as $L(b_k)$

Q7 (a) Capacity and Information Rates of MIMO FSFC.

System with N_t (transmit ant) & N_r receiving antennas

channel has L ISI Taps

at j^{th} receive antenna at k^{th} tap is given by 2

$$y_j(k) = \sqrt{P} \sum_{l=0}^{L-1} \sum_{i=0}^{N_t} h_{i,j}^{(l)}(k)\, x_i(k-l) + n_j(k)$$

for Gaussian Inputs 2

$$I_{Gauss} = \int_0^\infty \log\left(\det\left(I_{N_r} + \frac{P}{N_t} \tilde{H}_f^T \tilde{H}_f^H\right)\right) df$$

$$H_f = \sum_{l=0} H_l \exp(-j \ldots f l)$$

$$H_l = \begin{bmatrix} h_{11}^{(l)} & h_{12}^{(l)} & \ldots & h_{1N_r}^{(l)} \\ h_{21}^{(l)} & h_{22}^{(l)} & \ldots & h_{2N_r}^{(l)} \\ \vdots & \vdots & & \\ h_{N_t,1}^{(l)} & h_{N_t,2}^{(l)} & \ldots & h_{N_t N_r}^{(l)} \end{bmatrix}$$

where the time dependence of fading coefficients is dropped since they are constants (2)

$$I = \lim_{N \to \infty} \frac{1}{N} I(X(1), X(2) \ldots X(N); Y(1), Y(2) \ldots Y(N))$$

$X(1), X(2) \ldots X(N) \rightarrow$ sequence of channel inputs

$Y(1), Y(2) \ldots Y(N) \rightarrow$ sequence of channel outputs

$$\frac{1}{N} H(Y(1) \ldots Y(N)) = -\frac{1}{N} E\left[\log(P(Y(1) \ldots Y(N)))\right]$$

$$y(k) = [y_1(k), y_2(k) \ldots y_{N_r}(k)]^T$$

$$\boxed{P(y(1), y(2) \ldots y(N)) = \sum_{m=0}^{M_S - 1} \alpha_N(m)}$$ (2)

Non Ergodic Case and Outage Information Rates Shannons information is zero.

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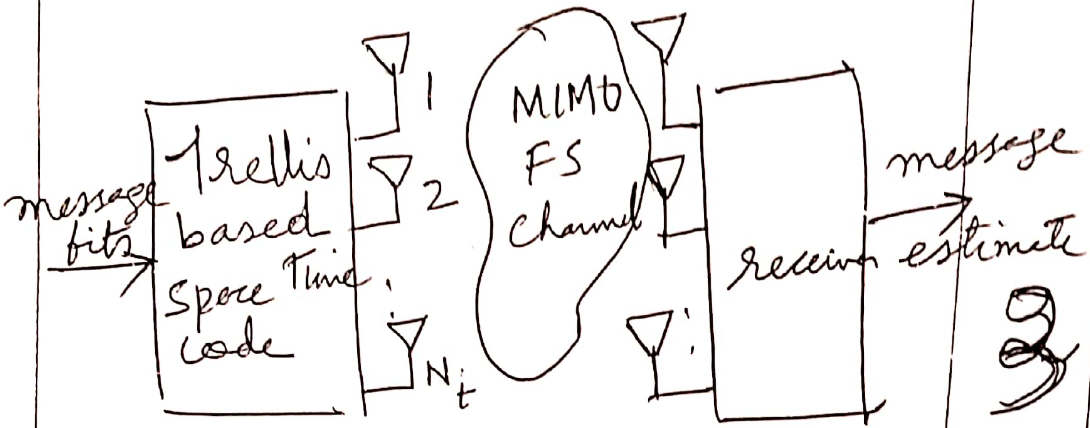
Q7(b) Space Time Trellis Coding over MIMO FSFC.



3

benefits of STBC are lost due to presence of ISI. — 1

Explanation —
Less ISI tap more error
more ISI taps less error — 4

Q8(a)

$$\begin{bmatrix} x(1) & 0 & 0 & \cdots & 0 \\ x(2) & x(1) & 0 & \cdots & 0 \\ x(3) & x(2) & x(1) & \cdots & 0 \\ \vdots & & & & \\ x(N_tL) & x(N_tL-1) & \cdots & & x(1) \\ x(N_tL+1) & x(N_tL) & \cdots & & x(2) \\ \vdots & & & & \\ x(N) & x(N-1) & \cdots & & x(N-N_tN+1) \end{bmatrix}$$

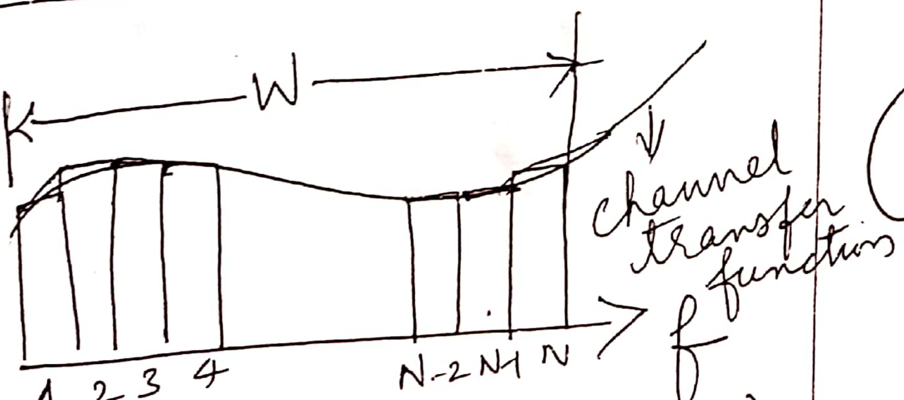
3

Space time codeword matrix

in Frequency selective fading
delaying by single symbol will not work because some columns of Space Time Codeword matrix are identical. Hence code will not be full rank.
If we delay the transmitted symbols of 1st antenna by number of ISI taps L instead of single symbol then we will achieve full diversity code of order $N_t N_r L$

5

Q8 (b) MIMO OFDM System



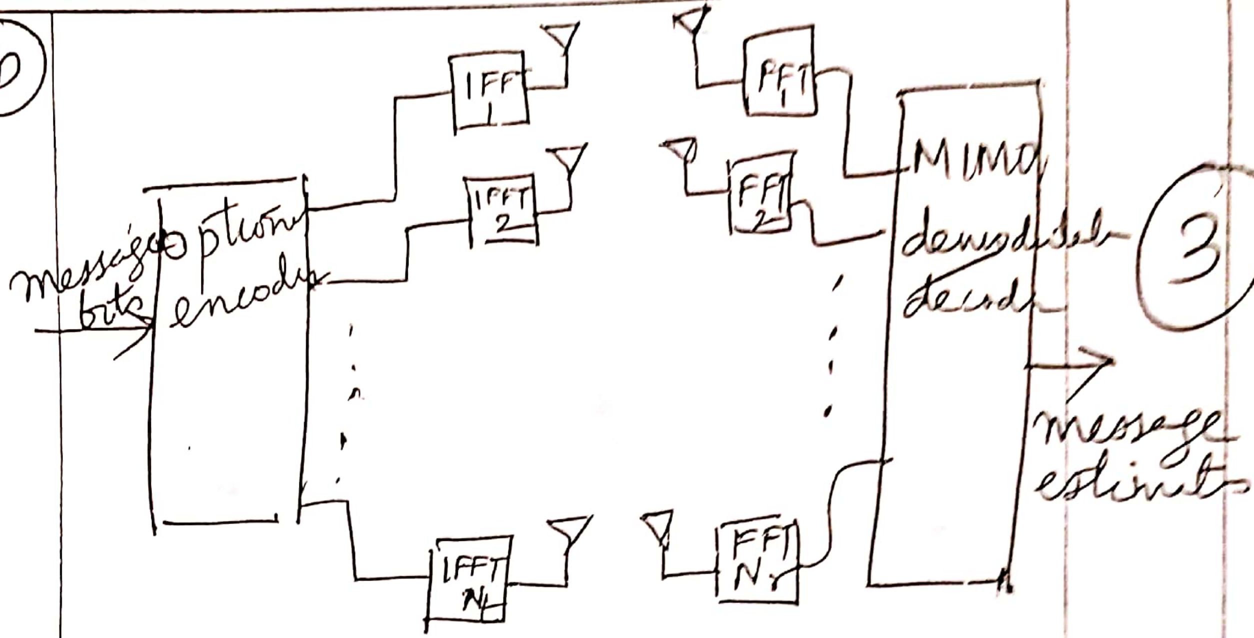
7

$X_i(0)\ X_i(1)\ X_i(2) \ldots X_i(N-1)$

Explanation ________

1

Q 8 (b)



3

Explanation ——————————— 3

END