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DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute Affiliated to VTU, Belagavi)

Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

UG Semester End Examination, August 2020

Course: MIMO Communications
Course Code: TE814
Semester: VIII

Maximum marks: **100**
Duration: **03 hours**

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)	Space diversity means using different physical paths for the signal, at a _______ frequency. i) Multiple ii) Single iii) Co Channel iv) Orthogonal	01
	b)	-------order means how many degrees of freedom u can have in your design. i) Rank ii) Selection iii) Diversity iv) Uplink/Downlink	01
	c)	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
	d)	The signal radiated by a transmitter may also travel along many and different paths to a receiver simultaneously is _______ i) Fading ii) Single Path iii) Multipath iv) Scattering	01
	e)	Shannon's Capacity gives the theoretical maximum data rate or capacity of a --_________ i) Signaling Channel ii) Imperfect Channel iii) Perfect Channel iv) Noisy Channel	01
	f)	Information is an _________ in uncertainty or entropy. i) increase ii) decrease iii) same iv) no effect	01
	g)	More certain or deterministic the event is, the less ________ it will contain. i) BW ii) information iii) Energy iv)invalid data	01
	h)	Information entropy tells how much ________ there is in an event i) BW ii) information iii) Energy iv) invalid data	01
	i)	Receive diversity is that each element in the receive array receives an independent copy of the ___________ i) Interference ii) Different Signal iii) Same Signal iv) Dispersion	01
	j)	In Receive Diversity probability that all signals are in deep fade simultaneously is then significantly ___________ i) Remains same ii) Fluctuates iii) Increased iv) Reduced	01
	k)	Base station antenna comprises multiple elements while the mobile device has only one or two, due to the reason __________ i) Space considerations ii) Bandwidth iii) Interference iv) No Reason	01
	l)	Multiple transmit/receive antennas should allow us to transmit _________ i) Data Slower ii) Data faster iii) Same data rate iv) Less data rate	01

m) 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

n) Codes with output symbols that do not include the input data are called ________ Code. 01
i) Compression ii) Systematic iii) non-systematic iv) Puncture

o) Turbo codes are ________ 01
i) Convolution Code ii) FEC codes iii) Channel Code iv) all of mentioned

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) ________ is a wireless set up that used a multi element antenna array a both the transmitter and receiver, as well as diagonally layered coding sequence. 01
i) BLAST ii) V-Blast iii) K-Blast iv) D-BLAST

2 a. Describe the time variations of wireless channels can be described using several channel models 06
b. Discus in detail about the MRC, Suboptimal Combining Algorithms, selection combining (SC), equal-gain combining(EGC), switch-and-stay combining (SSC), etc. 06
c Discuss about the beamforming with smart antenna. 04

3 a. Examine Capacity and Information of AWGN channel. 08
b. Demonstrate the Outage Capacity and Outage Information Rates for Fading Channel. 08

4 a. With necessary diagram describe the Alamouti scheme that shows the time diversity with two antennas. 06
b. Compare the space times block codes with the space time trellis codes. 04
c. The information is [2 1 2 3 0 0 1 3 2}, G is generator matrix describing the space time trellis code. 06

$$G = \begin{bmatrix} 2 & 0 \\ 1 & 0 \\ 0 & 2 \\ 0 & 1 \end{bmatrix}$$

Determine the coded symbol transmitted form first and second antenna using the generator matrix representation method. Assume the number of transmitters are two. R=2 & s=2

5	a.	Illustrate Concatenated STB Coding.	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.	Analyze the Turbo Space Time Trellis coding scheme.	08
7	a.	With the input–output relationship of the MIMO FS channel, analyze the virtual antenna interpretation of transmission over MIMO FS channels.	08
	b.	Describe a Simple Full Diversity Code for MIMO FS Channels using the idea of delay diversity for the flat fading scenario.	08
		OR	
8	a.	With necessary diagram discuss the MIMO OFDM system.	06
	b.	Demonstrate Concatenated Coding for MIMO FS Channels.	06
	c.	List out the features for Channel estimation for MIMO FS Channel.	04

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Semester End Examination: UG AUGUST 2020
Semester VIII Total no of pages 7
Course MIMO COMMUNICATION
Course Code TE814
Program TCE
Scheme & Solution Prepared by: Dr. Vinod. B. Durdi

Signature

Q no.	Description	Marks
1 a	(ii) Single	
b	(iii) Diversity	
c	(ii) Power density	
d	(iii) Multipath	
e	(iv) Noisy channel	
f.	(i) Increase.	
g	(ii). Information	
h	(ii) Information	
(i)	(iii) Same signal	
j	(iv) Reduced	
k	(i) Space considerations	
l	(ii) Data faster	
m	(ii) Encoded	
n	(iii) non-systematic	
o	(iv) all of mentioned	
p	(i) Interleaving	
q	(i) spacial Equalization	

Program TCE

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Signature

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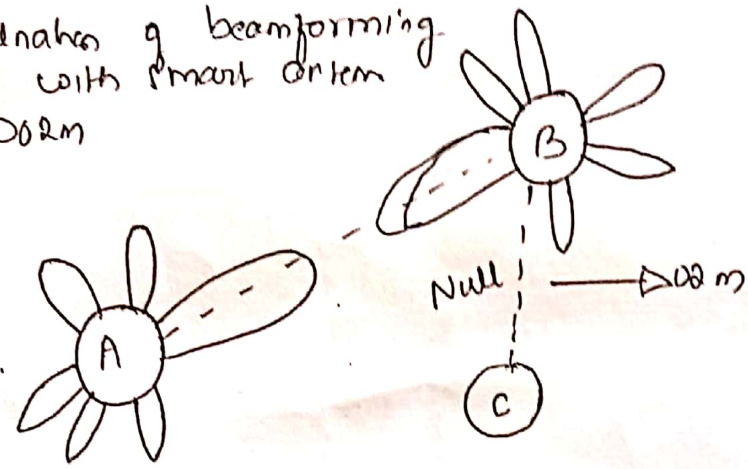
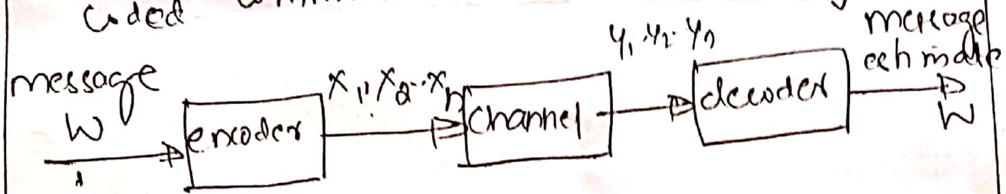
q	(i) spacial Equalization	

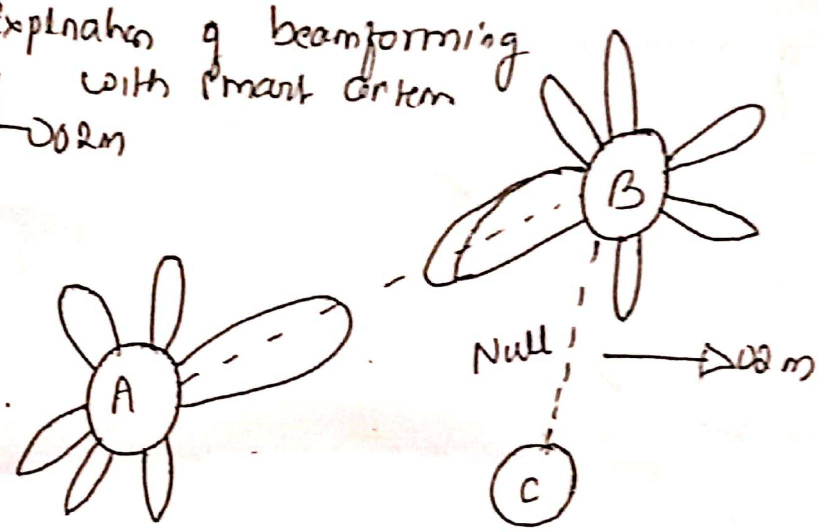
r (ii) BLAST

s (i) V-BLAST

t (iv) D-BLAST

Q no.	Description	Marks
c	Explanation of beamforming with smart antenna ↳ 02m 	04
3 a	$y = \sqrt{\rho}x + n$ Channel capacity is $C = \log(1+\rho)$ Generic block diagram of a channel coded communication system. → 04 M  Channel capacity (C) $C = \lim_{n\to\infty} \frac{1}{n} \max_{p(x_1, x_2 .. x_n)} I(x_1, x_2 .. x_n; y_1, y_2 .. y_n)$ Memoryless channels $P(y_1, y_2 .. y_n \mid x_1, x_2 .. x_n) = \prod_{i=1}^{n} P(y_i \mid x_i)$ $C = \max_{p(x)} I(X; Y)$ → 04 m $I(X, Y) = E\left(\log \frac{P(X,Y)}{P(X)P(Y)}\right)$	08

Q no.	Description	Marks
c	Explnation of beamforming with Smart antenna — 02m	04



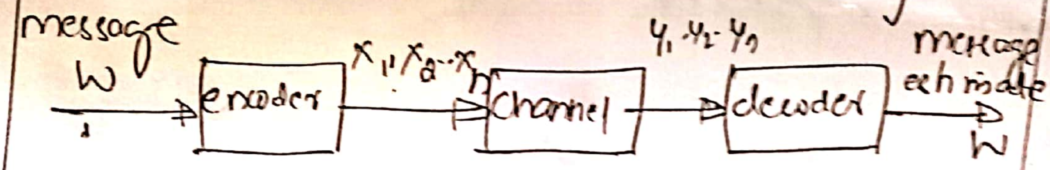
Q no.	Description	Marks
3 a		08.

$y = \sqrt{\rho}\,x + n$

Channel capacity is

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

Generic block diagram for a channel coded communication system. → 04 M



channel capacity (C)

$$C = \lim_{n \to \infty} \frac{1}{n} \max_{p(x_1, x_2 \cdots x_n)} I(x_1, x_2 \cdots x_n ; y_1, y_2 \cdots y_n)$$

Memory less channels

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

$$C = \max_{P(x)} I(X; Y)$$

→ 04 m

$$I(x, y) = E\left(\log \frac{P(X,Y)}{P(X)\,P(Y)}\right)$$

Q.no.	Description	Marks

b

Fading channel I/p - o/p relationship is given by

$$y = \sqrt{P}\, h x + n$$

h — complex gain
x — input
noise is complex gaussian with zero mean & variance 1/2 per dimension.

assume that the channel is ergodic

$$C_{fading} = \int_0^\infty \log(1 + z^2 P)\, f(z)\, dz$$

$$C_{fading} = \int_0^\infty \log(1 + P')\, p(P')\, dP'$$

where $P' = |h|^2 P$.

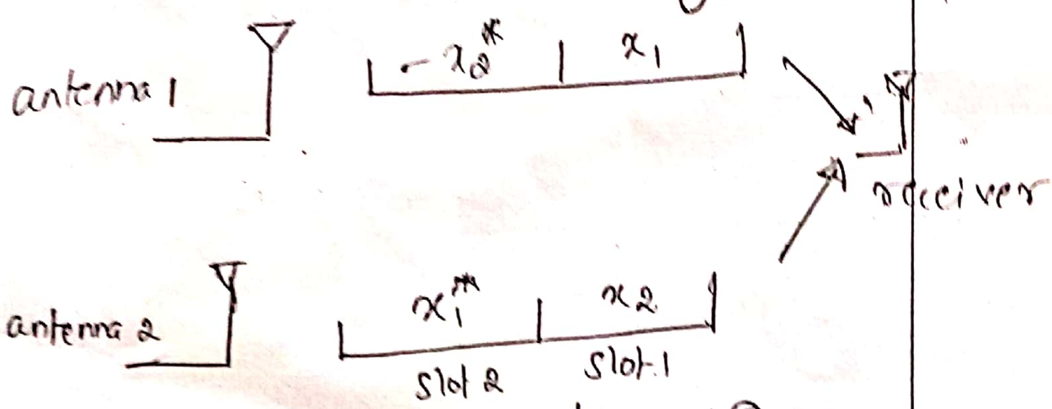
Rayleigh fading channel.

For non ergodic:

$$P_{out} = P(C(P') < R)$$

$$P_{out} = P(I(P') < R)$$

4a Explanation of Alamonti scheme → 02M



→ 02M

Q no.	Description	Marks

optimal receivers for Alamouti scheme — 06

$$y_1(1) = \sqrt{\rho}\,(h_{1,1}x_1 + h_{2,1}x_2) + n_1(1)$$

$$y_1(2) = \sqrt{\rho}\,(-h_{1,1}x_2^* + h_{2,1}x_1^*) + n_1(2)$$

$$H = \begin{bmatrix} h_{1,1} & h_{2,1} \\ h_{2,1}^* & -h_{1,1}^* \end{bmatrix}$$

$$\begin{bmatrix} n_1'(1) \\ n_1'(2) \end{bmatrix} = \begin{bmatrix} h_{1,1}^* & h_{2,1} \\ h_{2,1}^* & -h_{1,1} \end{bmatrix} \begin{bmatrix} n_1(1) \\ n_1^*(2) \end{bmatrix}$$

→ 02m

$$y = \begin{bmatrix} y_1(1) \\ y_1^*(2) \end{bmatrix}$$

$$y = \sqrt{\rho} \begin{bmatrix} h_{1,1} & h_{2,1} \\ h_{2,1}^* & -h_{1,1}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1(1) \\ n_1^*(2) \end{bmatrix}$$

b Both are designed to achieve full diversity. Space time block codes are easy to encode & decode. where as space time trellis codes require more complicated trellis based decoders. → 02m — 04m

Space time block codes can be employed for more than two transmit antennas. Space time trellis codes employed for two transmit antennas → 02m

c

C

$$G = \begin{bmatrix} 2 & 0 \\ 1 & 0 \\ 0 & 2 \\ 0 & 1 \end{bmatrix} \qquad R = 2, S = 2$$

Sequence = $\{2, 1, 2, 3, 0, 0, 1, 3, 2\}$

In bits

$U = \{100110110000011110\}$

$t = 0$

$x_k = U_k G$

$x_0 = U_0 G$

$U_0 = [0\ 0\ 1\ 0]$

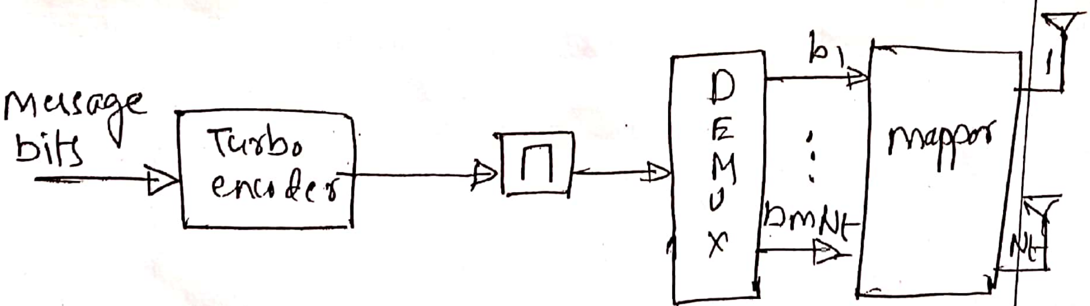
$$x_0 = [0\ 0\ 1\ 0] \begin{bmatrix} 2 & 0 \\ 1 & 0 \\ 0 & 2 \\ 0 & 1 \end{bmatrix}$$

$x_0 = [0\ 2]$, $x_1 = [2\ 1]$ $x_2 = [1\ 2]$

$x_3 = [2\ 3]$, $x_4 = [3\ 0]$ $x_5 = [0\ 0]$

$x_6 = [0\ 1]$ $x_7 = [1\ 3]$ $x_8 = [3\ 2]$

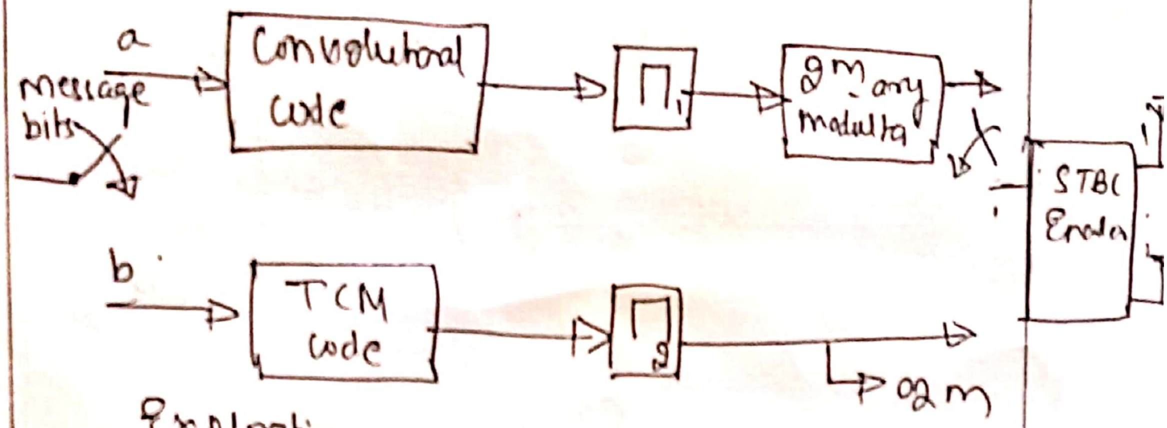
5 a



Encoder structure for the turbo coded modulation scheme.

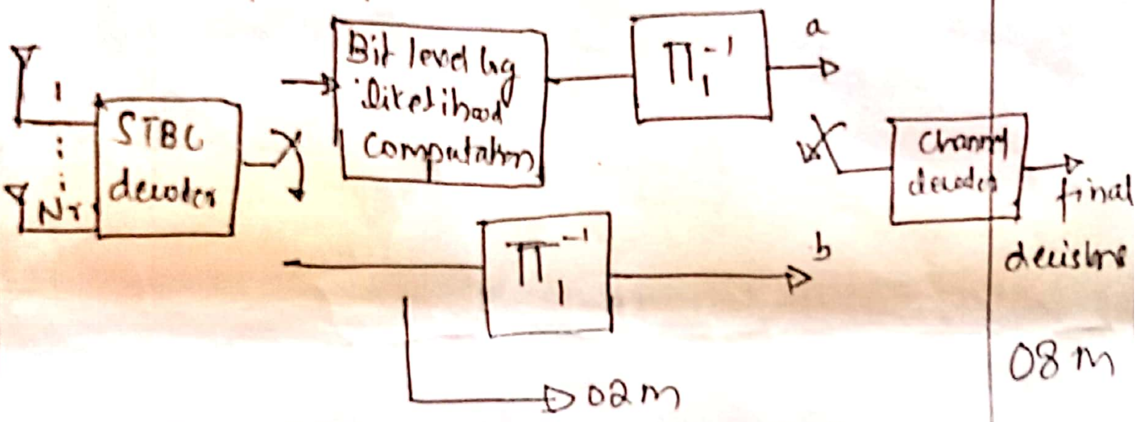
Q no.	Description	Marks

Encoder structure of STBC



Explnation ⟶ 02 m

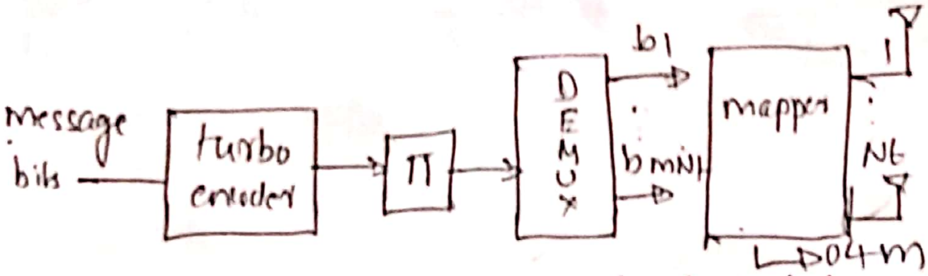
Decoder structure



08 m

Explnation ⟶ 02 m

b



08

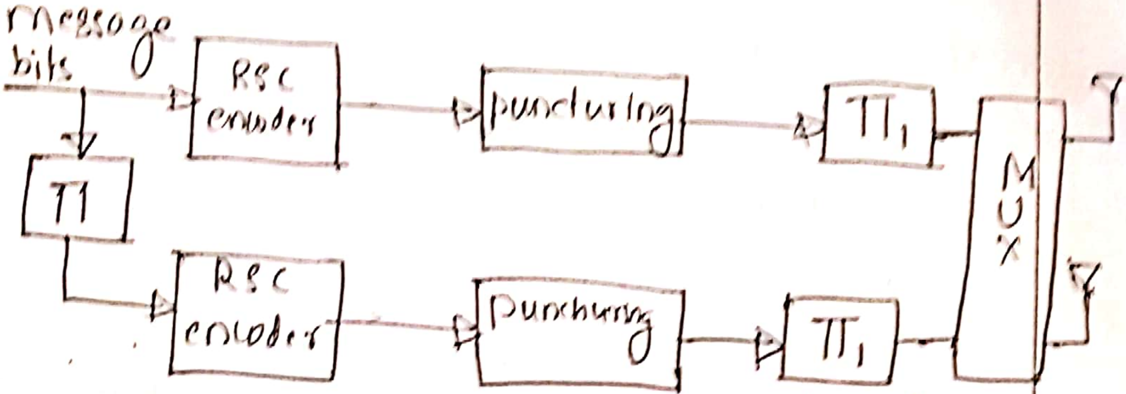
Encoder structure for turbo coded modulation scheme

⟶ primitive data is first encoded by a turbo encoder.

⟶ turbo coder is interleaved. Interleaved data is demultiplexed into number of parallel substreams. ⟶ 04 m

Q no.	Description	Marks

6 a

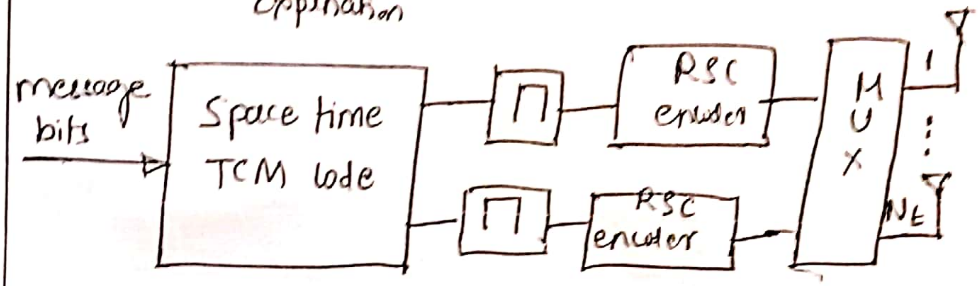


→ 02 m

Parallel concatenated space time turbo code encoder → 02 m

Explanation

08

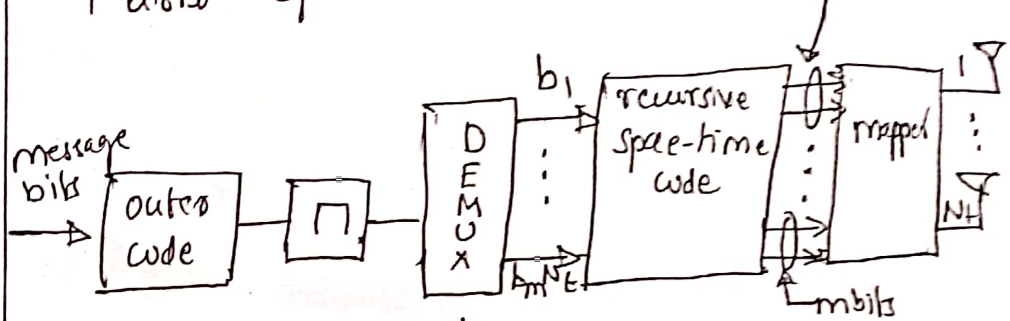


Encoder structure for the serial concatenated space time turbo codes → 02 m

Explanation → 02 m

08

b Turbo space time trellis coding scheme



→ 04 m

Explanation → 04 m

	Description	Marks
	$y = \sqrt{\rho}\, X_{eq} H_{eq} + N$	

$$X_{eq} = \begin{bmatrix} x(1) & 0 & \cdots & 0 & x_{N}(1) & 0 & 0 \\ x(2) & x(1) & & 0 & x_{N}(2) & x_{N}(1) & 0 \\ \vdots & & & & & & \\ x_2(N) & x_1 & & & 0 & x_N(N) & 0 \\ 0 & x(N) & & 0 & & & \\ 0 & 0 & & x(1) & 0 & 0 & x_{N}(1) \end{bmatrix} \rightarrow 02m$$

Equivalent channel is applied matrix

$$H_{eq} = \begin{bmatrix} h_{1,1}^{(0)} & h_{1,2}^{(0)} & \cdots & h_{1,Nt}^{(0)} \\ h_{1,1}^{(1)} & h_{1,2}^{(1)} & \cdots & h_{1,Nt}^{(1)} \\ \vdots & & & \\ h_{1,1}^{(L-1)} & h_{1,2}^{(L-1)} & \cdots & h_{1,Nt}^{(L-1)} \\ h_{2,1}^{(0)} & h_{2,2}^{(0)} & \cdots & h_{2,Nt}^{(0)} \\ \vdots & & & h_{2,Nt}^{(L-1)} \\ h_{2,1}^{(L-1)} & h_{2,2}^{(L-1)} & \cdots & \\ h_{Nr,1}^{(0)} & h_{Nr,2}^{(0)} & \cdots & h_{Nr,Nt}^{(0)} \\ h_{Nr,1}^{(1)} & h_{Nr,2}^{(1)} & \cdots & h_{Nr,Nt}^{(1)} \\ h_{Nr,1}^{(L-1)} & h_{Nr,2}^{(L-1)} & & h_{Nr,Nt}^{(L-1)} \end{bmatrix} \rightarrow 02m$$

Explanation $\longrightarrow$ 04m

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Marks

$x(1)$	$x_1(2)$	$x_1(3)$	$x_1(4)$	$\cdots$
0	$x(1)$	$x_1(2)$	$x_1(3)$	$\cdots$
0	0	$x(1)$	$x_1(2)$	$\cdots$
$x_2(1)$	$x_2(2)$	$x_2(3)$	$x_2(4)$	$\cdots$
0	$x_2(1)$	$x_2(2)$	$x_2(3)$	$\cdots$
0	0	$x_2(1)$	$x_2(2)$	$\cdots$
$k=1$	$k=2$	$k=3$	$k=4$	

08

antenna 2

02M

transmitted signals

Explanation

b) For N_t transmit antenna system, a delay diversity code is obtained by simply transmitting delayed versions of the sequence on the first transmit antenna from the other antennas. That is, the i^{th} transmit antenna emits a sequence (by $i-1$ delayed version of the symbols) on the first transmit antenna

02M

$$\begin{matrix} x(1) & 0 & 0 & \cdots & 0 \\ x(2) & x(1) & 0 & \cdots & 0 \\ x(3) & x(2) & x(1) & \cdots & 0 \\ & \vdots & x(N_t-2) & & x(1) \\ x(N_t) & x(N_t-1) & x(N_t-1) & & x(2) \\ x(N_t+1) & x(N_t) & & & \\ x(N) & x(N-1) & x(N-2) & & x(N-N_t+1) \end{matrix}$$

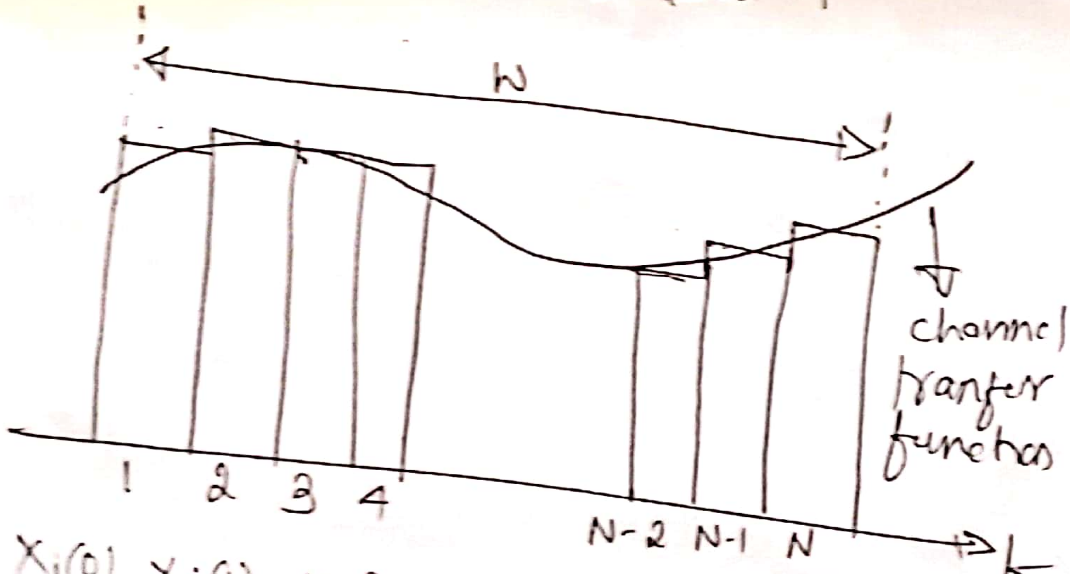
02m

Q no.	Description	Marks
	delay diversity code will achieve a full rank of $N_t N_r$ over flat fading. If we delay the transmitted signal of the first antenna by the number of ISI taps L instead of by a single symbol, we obtain the space time code word → 02m	08m

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

→ 02m

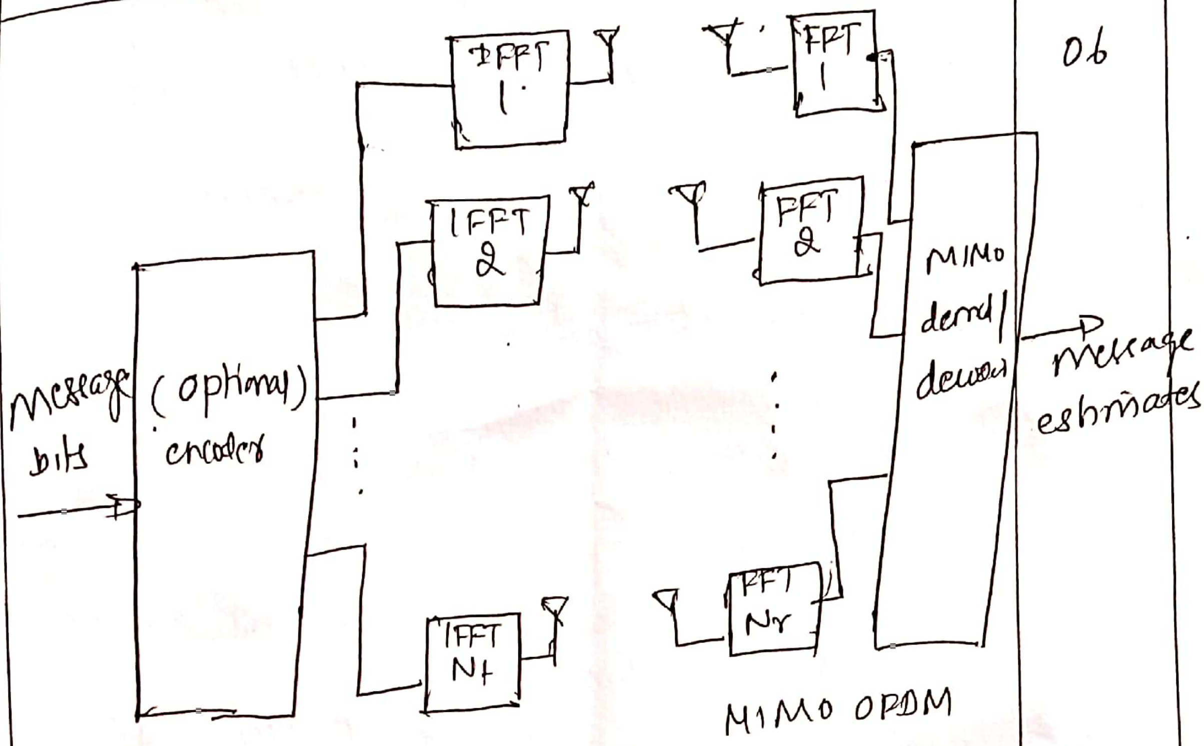
8 a



$X_1(0), X_1(1), X_1(2) \ldots X_1(N-1)$

Scanned with CamScanner

Q no.	Description	Marks
		06



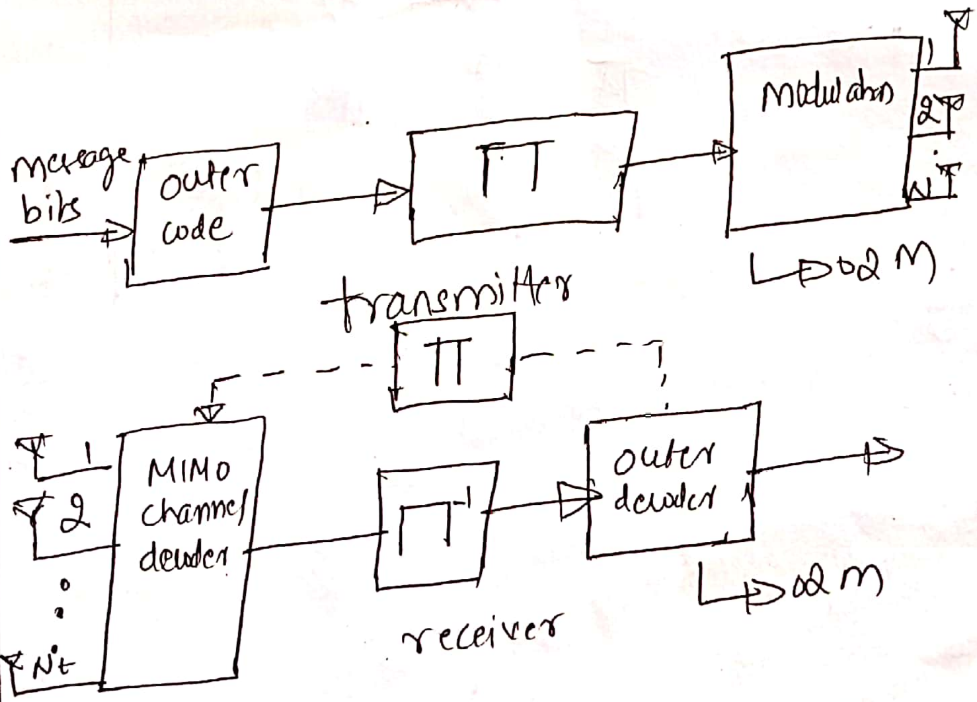
MIMO OFDM transmitter

MIMO OFDM receiver

→ 04 M

02 M → explanation

b 06



→ 02 M

→ 02 M

Explanation → 02 M

page no.

Q no.	Description
c	Soft input & Soft output type MIMO equalizers to be used in conjunction with channel coding. ⟶ 01 M Equalization needs to be done temporally & spatially ⟶ 01 M MIMO PS channels can be described by trellis with $M^{N_t(L-1)}$ states. ⟶ 01 M use the viterobi algorithms. If the minimize the symbol error probability use MAP algorithm Porblem with full complexity algorithm viterbi or MAP algorithm ⟶ 01 M