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# DAYANANDA SAGAR COLLEGE OF ENGINEERING

*(An Autonomous Institute Affiliated to VTU, Belagavi)*

ShavigeMalleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

## Department of Telecommunication Engineering

## Online Continuous Internal Assessment Test - II

Course: **MIMO Technologies**
Course Code: **17TE7DCMTN**
Semester: **VII - 'A' &'B'**

Date: **10/11/2020**
Maximum marks: **50**
Duration: **90 Min**

| | Note: Answer 5 full questions. | Marks |
|---|---|---|
| 1 | a) The use of multiple transmit antennas to achieve reliability is -------------<br>i) Receive Diversity ii) Transmit Diversity iii) Flexible Diversity iv) Spatial Multiplexing<br><br>b) Receive diversity is that each element in the receive array receives an independent copy of the--------<br>i) Interference ii) Different Signal iii) Same Signal iv) Dispersion<br><br>c) In Receive Diversity probability that all signals are in deep fade simultaneously is then significantly --------------.<br>i) Remains same ii) Fluctuates iii) Increased iv) Reduced<br><br>d) Base station antenna comprises multiple elements while the mobile device has only one or two, why?<br>i) Space considerations ii) Bandwidth iii) Interference iv) No Reason<br><br>e) Multiple transmit/receive antennas should allow us to transmit ---------<br>i) Data Slower ii) Data faster iii) Same data rate iv) Less data rate<br><br>f) The capacity of the channel is defined as the maximum possible mutual information between the input (x) and --------.<br>i) CSI ii) input(x) iii) output (y) iv) CQI<br><br>g) Max Capacity is calculated by maximization of the probability distribution of the ---------<br>i) Input $f_x(x)$ ii) output $f_y(x)$ iii) both Input(x) &output (y) iv) f(y)/f(x)<br><br>h)Concatenated codes are ---- ---<br>Compression Code ii) error-correcting codes iii) Source Code iv) none<br><br>i)Concatenated codes are constructed from----------Codes<br>i) 2 or more ii) single code iii) hundreds of iv) none<br><br>j) Concatenated codes are having -------- performance and reasonable complexity<br>Bad ii) Worst iii) Good iv) none | 1x10 |

| | | |
|---|---|---|
| 2 | Elaborate Alamouti Code with 2 transmit antenna and Nr Receiving Antenna | 10 |
| 3 | Explain and Brief about Space-Time Trellis Code. | 10 |
| 4 | Evaluate Decoding of Linear Orthogonal Designs ~~in terms of Performance~~. | 10 |
| | **(OR)** | |
| 5 | Hypothesize Performance Analysis of Space-Time Block Codes | 10 |
| 6.a<br>6.b | What are Space-Time Code Design Principles?<br>List the Comparison of Space-Time Block and Trellis Codes. | 05<br>05 |
| | **(OR)** | |
| 7 | Demonstrate VBLAST/HBLAST/SCBLAST encoder features with diagram. | 10 |

Faculty: Dr. SAYED ABDULHAYAN

No. of copies: 85

# Solution Scheme

CIE-II

Subject: MIMO Technologies   SEM: 7th SEM 'A' & 'B'

Code: 17TE7DCMTN

Date: 10/11/2020   Incharge & prepared by: DR. SAYED ABDULHAYAN.

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Q1. (a) Transmit diversity — (ii)

(b) Same Signal — (iii)

(c) Reduced — (iv)

(d) Space considerations — (i)

(e) Data faster — (ii)

(f) output (y) — (iii)

(g) Input fx(x) — (i)

(h) Error correcting code — (ii)

(i) 2 or more code — (i)

(j) Good — (iii)

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Q2. Alamouti Code with 2 Tx antenna & Nr Receiving antenna

Receive diversity in addition to existing Transmit diversity is done by using multiple Rx antennae.

$j = 1, 2 \ldots N_r$ receive antenna

$y_j(k) \rightarrow$ output received at $j^{th}$ receive antenna at $k$ time slot.

$k =$ Time slot $= 1, 2$.

AWGN

$$y_j(1) = \sqrt{P}\,(h_{1j} x_1 + h_{2j} x_2) + n_j(1)$$

$$y_j(2) = \sqrt{P}\,(-h_{1j} x_2^* + h_{2j} x_1^*) + n_j(2)$$

noise

After Linear combining and scaling by factor we get

$$y_j(1) = \sqrt{P}\sqrt{|h_{1j}|^2 + |h_{2j}|^2}\; x_1 + n_j''(1)$$

$$y_j(2) = \sqrt{P}\sqrt{|h_{1j}|^2 + |h_{2j}|^2}\; x_2 + n_j''(2)$$

noise terms

$$y(k) = \sum_{j=1}^{N_r} \sqrt{|h_{1j}|^2 + |h_{2j}|^2}\; y_j(k)$$

$k = 1, 2 \ldots$

$$\hat{x}_1 = \underset{x_1}{\operatorname{argmin}} \left| \sum_{j=1}^{N_r} h_{1j}^* y_j(1) + h_{2j} y_j^*(2) - \sqrt{P}\left(|h_{1j}|^2 + |h_{2j}|^2\right) x_1 \right|^2$$

$$\hat{x}_2 = \underset{x_2}{\operatorname{argmin}} \left| \sum_{j=1}^{N_r} h_{2j}^* y_j(1) - h_{1j} y_j^*(2) - \sqrt{P}\left(|h_{1j}|^2 + |h_{2j}|^2\right) x_2 \right|^2$$

$$\hat{x}_1 = \begin{cases} 1 & \text{if } \operatorname{Re}\left\{ \sum_{j=1}^{N_r} h_{1j}^* y_j(1) + h_{2j} y_j^*(2) \right\} > 0 \\ 0 & \text{otherwise} \end{cases}$$

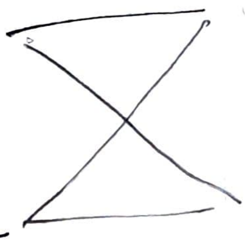
$$\hat{x}_2 = \begin{cases} 1 & \text{if } \operatorname{Re}\left\{ \sum_{j=1}^{N_r} h_{2j}^* y_j(1) - h_{1j} y_j^*(2) \right\} > 0 \\ 0 & \text{otherwise} \end{cases}$$

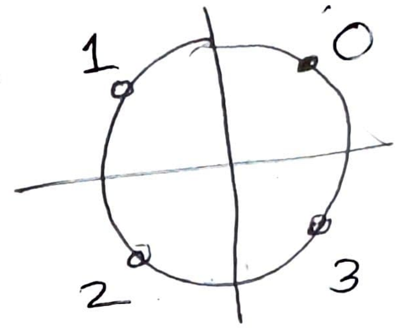
# Space Time Trellis Code

Input : 0 1   $S_0$

00 01

10 11   $S_1$






branch Labels.

$N_t = 2$. $N = 2$. - time slot.

Input stream 2 1 2 3 0 0 1 3 2

- $T_x 1$ 0 2 1 2 3 0 0 1 3 2

$T_x 2$. 2 1 2 3 0 0 1 3 2

$2^R$ branches emmanating from each slot

- R bits per channel. R = 2 bits here

$2^R$

There is basic trellis structure that determines the coded symbols to be transmitted from different antenna element.

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

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

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

$$Y = \sqrt{P}\, X H + N$$

$X \to N \times N_t$ transmitted code word.

$H \to N_t \times N_r$ matrix of channel coeffic

$Y \to N \times N_r$ receive matrix

$N \to N \times N_r$ noise matrix

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Q4 Decoding of Linear orthogonal Design in terms of performance

$$\tilde{y}_j = \sqrt{P} \sum_{m=1}^{M} \left\{ \begin{bmatrix} A_m h_j \\ B_m^* h_j^* \end{bmatrix} x_m + \begin{bmatrix} B_m h_j \\ A_m^* h_j^* \end{bmatrix} x_m^* \right\} + \tilde{n}_j$$

optimum decision can be obtained by minimizing the squared Euclidean distance between candidate codeword $(X(\hat{x}))$ and received signal,

$$d(\hat{x}) = \sum_{j=1}^{N_r} \| y_j - \sqrt{P} X(\hat{x}) h_j \|^2$$

$$2(d\hat{x}) = \sum_{j=1}^{N_r} \left\| \tilde{y}_j - \sqrt{P} \sum_{m=1}^{M} \left\{ \begin{bmatrix} A_m h_j \\ B_m^* h_j^* \end{bmatrix} x_m + \begin{bmatrix} B_m h_j \\ A_m^* h_j^* \end{bmatrix} x_m^* \right\} \right\|^2$$

$$u_m = \sum_{j=1}^{N_r} h_j^H A_m^H y_j + y_j^H B_m h_j$$

$$V_m^2 = \sum_{j=1}^{N_r} \sum_{i=1}^{N_t} \underbrace{d_{im}}_{\text{diagonal entries}} |h_{ij}|^2$$

$$\tilde{d}(\hat{x}) = \sum_{m=1}^{M} \left( \frac{|u_m - \sqrt{P}\, V_m^2 x_m|^2}{V_m^2} \right)$$

$$\hat{x}_m = \arg\min_{x_m} \frac{\left|\sqrt{P}\, V_m^2 x_m - u_m\right|^2}{V_m^2}$$

Using decision rule with the code defined by matrices $A_m, B_m$ where $m = 1, 2 \ldots$ we can easily generate specific decision rule.

## Performance of Space time Block Codes

Q5.

$$u_m = \sqrt{P}\, x_m \sum_{j=1}^{N_r} \sum_{i=1}^{N_t} d_{im} |h_{ij}|^2 + n'_m$$

by using properties of Linear orthogonal designs.

$$\alpha = \sum_{j=1}^{N_r} \sum_{i=1}^{N_t} d_{im} |h_{ij}|^2$$

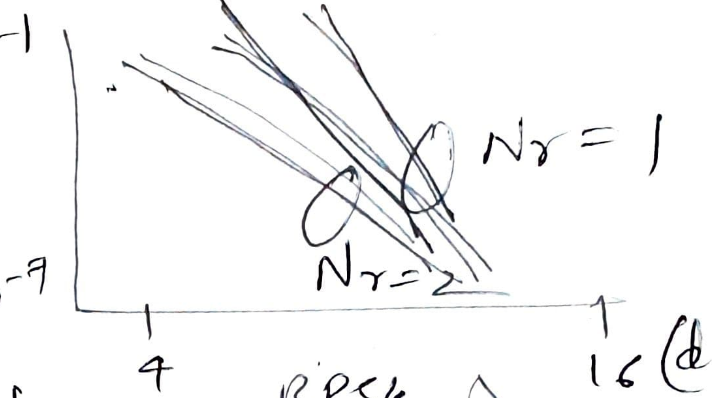
Probability of bit error conditioned on the channel gains

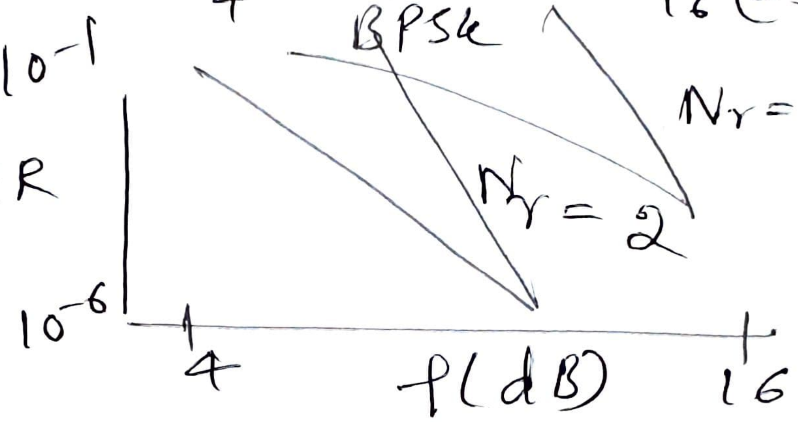
$$P_b(\alpha) = Q\left(\sqrt{\frac{2\alpha P}{N_t}}\right)$$

$$P_b \simeq \left(\frac{2N_tN_r - 1}{N_tN_r}\right)\left(\frac{N_t}{4\, d_m P}\right)^{N_tN_r} \quad \text{for Large SNR}$$

Alamonti code.

plots for $10^{-1}$




X2 with Q PSK.

6. (a). Space time Code Design Principles

(1) Rank Criterion

$$A = (X_1 - X_2)^H (X_1 - X_2)$$

is full rank for all pairs of distinct codewords $X_1$ and $X_2$.

$$\left.\begin{matrix} r N_r \\ N_t N_r \end{matrix}\right\} \text{diversity}$$

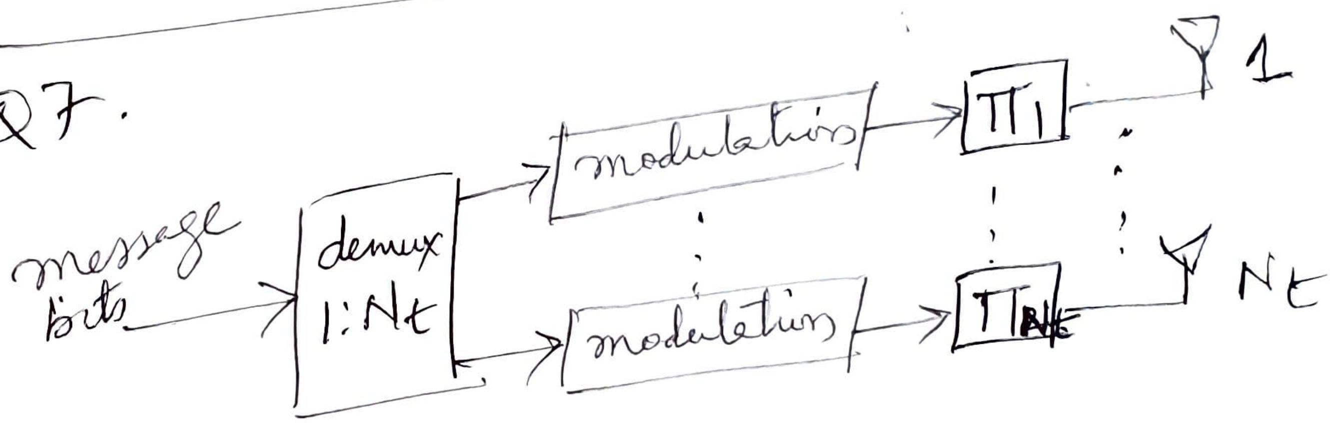
(2) Determinant Criterion

Min of product of eigenvalues of $\Lambda$ over all pairs of distinct codewords should be maximized.

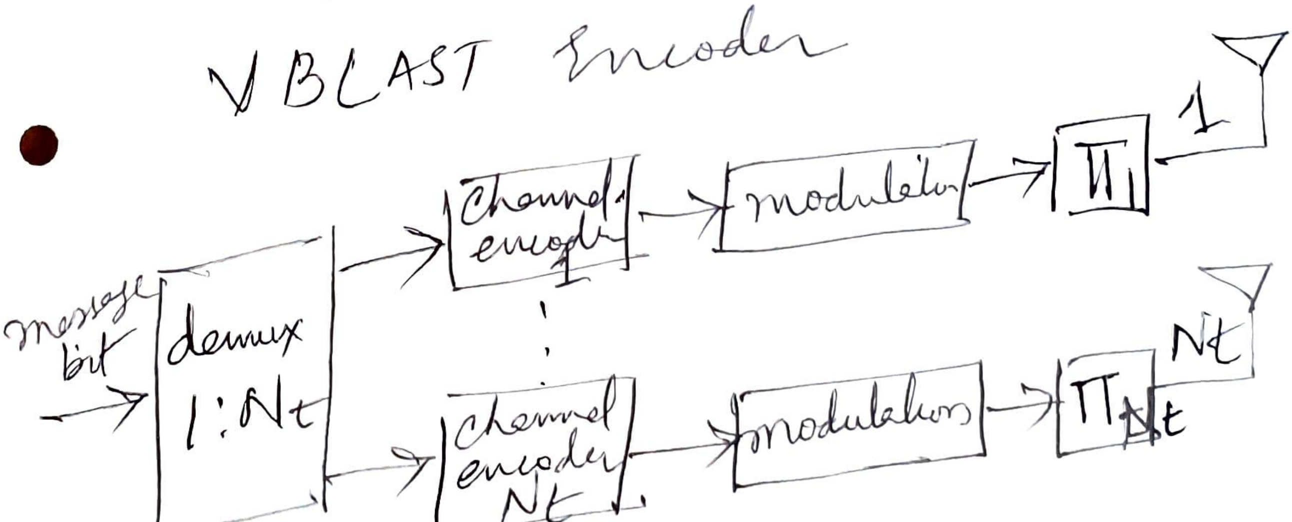
6 (b)

| STBC | STTC |
|---|---|
| (1) Easy to encode and decode | (1) Complex to Encode and decode |
| (2) Relatively easy to employ for more than 2 transmit antenna | (2) Relatively complex to employ for more than 2 Tx antenna |
| (3) Resulting Error rates are more | (3) Resulting Error rates are less |

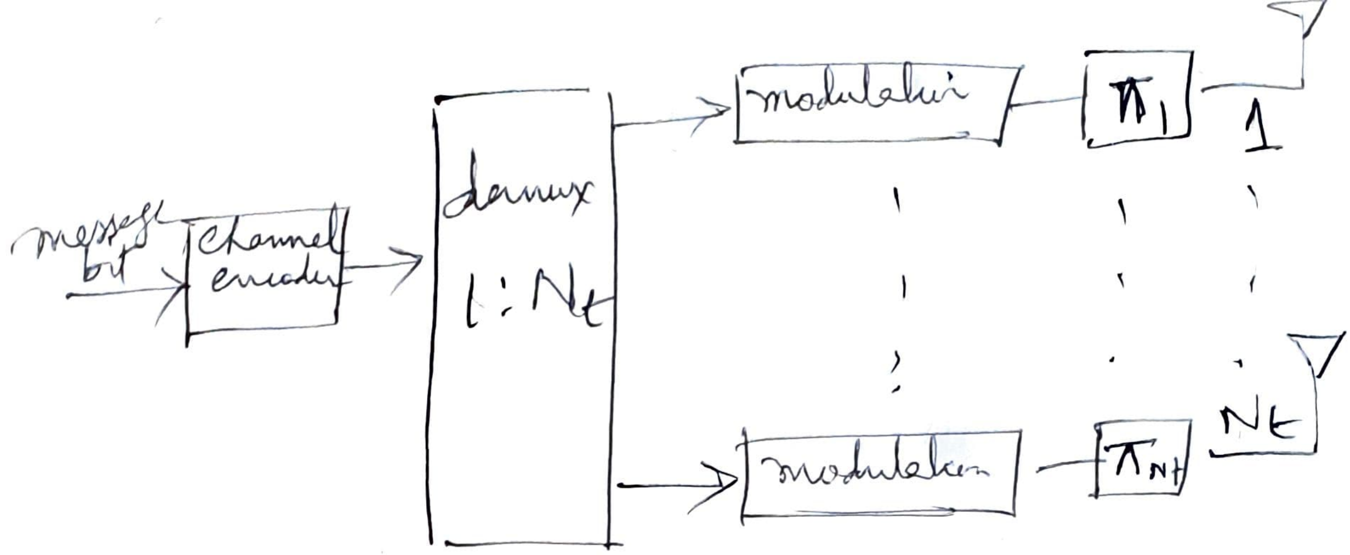
Q7.




VBLAST Encoder




HBLAST encoder




SCBLAST encoder

Explanation

END.