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NPTEL

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Courses » Estimation for Wireless Communications – MIMO/OFDM Cellular and Sensor Networks

Announcements **Course** Ask a Question Progress

Unit 6 - Week 5 - Inter Symbol Interference, Channel Equalization, Zero-forcing equalizer, Approximation error of equalizer

Course outline

How to Access the Portal ?

Week 1 - Basics of Estimation, Maximum Likelihood (ML)

Week 2 - Vector Estimation

Week 3 - Cramer-Rao Bound (CRB), Vector Parameter Estimation, Multi-Antenna Downlink Mobile Channel Estimation

Week 4 - Least Squares (LS) Principle, Pseudo-Inverse, Properties of LS Estimate, Examples – Mulli-Antenna Downlink and MIMO Channel Estimation

Week 5 - Inter Symbol Interference, Channel Equalization, Zero-forcing equalizer, Approximation error of equalizer

Lecture 21 - Channel Equalization and Inter Symbol

Assignment - 5

The due date for submitting this assignment has passed. Due on 2017-08-31, 23:59 IST.
As per our records you have not submitted this assignment.

1) Consider the maximum likelihood (ML) multi-antenna channel estimation problem with N transmitted pilot vectors $\mathbf{x}(k)$, pilot matrix $\mathbf{X}$ and receive vector $\mathbf{y}$. Let the channel vector be $\mathbf{h} = [h_1, h_2, \ldots, h_M]^T$. Let the noise samples $v(k)$ be independent Gaussian with zero-mean and variance σ_k^2. Let $\mathbf{R}$ denote the covariance matrix of the noise vector $\mathbf{v} = [v(1), v(2), \ldots, v(N)]^T$. The ML estimate of the channel vector $\mathbf{h}$ is, *1 point*

- $(\mathbf{X}\mathbf{R}^{-1}\mathbf{X}^T)^{-1}\mathbf{X}^T\mathbf{R}^{-1}\mathbf{y}$
- $\left(\sum_{k=1}^{N} \frac{1}{\sigma_k^2}\mathbf{x}(k)\mathbf{x}^T(k)\right)^{-1}\left(\sum_{k=1}^{N} \frac{1}{\sigma_k^2}\mathbf{x}(k)y(k)\right)$
- $\left(\sum_{k=1}^{N} \sigma_k^2\mathbf{x}(k)\mathbf{x}^T(k)\right)^{-1}\left(\sum_{k=1}^{N} \sigma_k^2\mathbf{x}(k)y(k)\right)$
- $(\mathbf{X}\mathbf{R}\mathbf{X}^T)^{-1}\mathbf{X}^T\mathbf{R}\mathbf{y}$

No, the answer is incorrect.
Score: 0

Accepted Answers:
$\left(\sum_{k=1}^{N} \frac{1}{\sigma_k^2}\mathbf{x}(k)\mathbf{x}^T(k)\right)^{-1}\left(\sum_{k=1}^{N} \frac{1}{\sigma_k^2}\mathbf{x}(k)y(k)\right)$

2) Consider the MIMO channel estimation problem with pilot vectors $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are $\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1, 1]^T$. The size of the MIMO system is, *1 point*

- 3×2
- 2×2
- 2×3

Interference ISI Model

Lecture 22 - Least Squares based Zero Forcing Channel Equalizer

Lecture 23 - Example of ISI Channel and Least Squares based Zero Forcing

Lecture 24 - Equalization and Approximation Error for Zero Forcing Channel Equalizer

Lecture 25 - Example Equalization and Approximation Error for Zero Forcing Channel Equalizer

Quiz : Assignment - 5

Assignment-5 Solution

Week 6 - Introduction to Orthogonal Frequency Division Multiplexing (OFDM) and Pilot Based OFDM Channel Estimation, Example

Week 7 - OFDM – Comb Type Pilot (CTP) Transmission, Channel Estimation in Time/ Frequency Domain, CTP Example, Frequency Domain Equalization (FDE), Example-FDE

**Week 8 - Sequential Least Squares (SLS) Estimation – Scalar/ Vector Cases, Applications - Wireless Fading

3×3

No, the answer is incorrect.
Score: 0

Accepted Answers:
3×2

3) Consider the MIMO channel estimation problem with pilot vectors *1 point*
$\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are
$\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1,$.
As described in the lectures, the pilot matrix $\mathbf{X}$ for the MIMO channel estimation problem above is,

$$\mathbf{X} = \begin{bmatrix} 3 & -2 \\ -2 & 3 \\ 4 & 2 \\ 2 & 2 \end{bmatrix}$$

$$\mathbf{X} = [3 \quad -2 \quad -2 \quad 3 \quad 4 \quad 2 \quad 2 \quad 2]$$

$$\mathbf{X} = [3 \quad -2 \quad -2 \quad 3 \quad 4 \quad 2 \quad 2 \quad 2]^T$$

$$\mathbf{X} = \begin{bmatrix} 3 & -2 & 4 & 2 \\ -2 & 3 & 2 & 2 \end{bmatrix}$$

No, the answer is incorrect.
Score: 0

Accepted Answers:
$$\mathbf{X} = \begin{bmatrix} 3 & -2 & 4 & 2 \\ -2 & 3 & 2 & 2 \end{bmatrix}$$

4) Consider the MIMO channel estimation problem with pilot vectors *1 point*
$\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are
$\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1, 1]^T$.
As described in the lectures, the output matrix $\mathbf{Y}$ for the MIMO channel estimation problem above is,

$$\mathbf{Y} = \begin{bmatrix} -2 & 1 & -3 & -1 & 3 & 3 \\ -1 & -2 & 2 & -3 & -1 & 1 \end{bmatrix}$$

$$\mathbf{Y} = \begin{bmatrix} -2 & 1 & -3 \\ -1 & 3 & 3 \\ -1 & -2 & 2 \\ -3 & -1 & 1 \end{bmatrix}$$

$$\mathbf{Y} = \begin{bmatrix} -2 & 1 & -3 \\ -1 & 3 & 3 \\ -1 & -2 & 2 \\ -3 & -1 & 1 \end{bmatrix}^T$$

$$\mathbf{Y} = \begin{bmatrix} -2 & 1 & -3 & -1 & 3 & 3 \\ -1 & -2 & 2 & -3 & -1 & 1 \end{bmatrix}^T$$

Channel Estimation, SLS Example

No, the answer is incorrect.
Score: 0

Accepted Answers:

$$\mathbf{Y} = \begin{bmatrix} -2 & 1 & -3 \\ -1 & 3 & 3 \\ -1 & -2 & 2 \\ -3 & -1 & 1 \end{bmatrix}^T$$

5) Consider the MIMO channel estimation problem with pilot vectors $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are $\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1, 1]^T$. The LS estimate of the MIMO channel matrix is given as, *1 po*

- $\mathbf{Y}\mathbf{X}^T(\mathbf{X}^T\mathbf{X})^{-1}$
- $(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{Y}$
- $\mathbf{Y}\mathbf{X}^T(\mathbf{X}\mathbf{X}^T)^{-1}$
- $(\mathbf{X}\mathbf{X}^T)^{-1}\mathbf{X}^T\mathbf{Y}$

No, the answer is incorrect.
Score: 0

Accepted Answers:
$\mathbf{Y}\mathbf{X}^T(\mathbf{X}\mathbf{X}^T)^{-1}$

6) Consider the MIMO channel estimation problem with pilot vectors $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are $\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1, 1]^T$. The pseudo-inverse of the pilot matrix $\mathbf{X}$ is, *1 point*

- $\mathbf{X} = \begin{bmatrix} 3 & -2 \\ -2 & 3 \\ 4 & 2 \\ 2 & 2 \end{bmatrix}$
- $\mathbf{X} = \begin{bmatrix} 3 & -2 \\ -2 & 3 \\ 4 & 2 \\ 2 & 2 \end{bmatrix} \begin{bmatrix} \frac{1}{33} & 0 \\ 0 & \frac{1}{21} \end{bmatrix}$
- $\mathbf{X} = \begin{bmatrix} 3 & -2 & 4 & 2 \\ -2 & 3 & 2 & 2 \end{bmatrix}$
- $\mathbf{X} = \begin{bmatrix} \frac{1}{33} & 0 \\ 0 & \frac{1}{21} \end{bmatrix} \begin{bmatrix} 3 & -2 & 4 & 2 \\ -2 & 3 & 2 & 2 \end{bmatrix}$

No, the answer is incorrect.
Score: 0

Accepted Answers:

$$\mathbf{X} = \begin{bmatrix} 3 & -2 \\ -2 & 3 \\ 4 & 2 \\ 2 & 2 \end{bmatrix} \begin{bmatrix} \frac{1}{33} & 0 \\ 0 & \frac{1}{21} \end{bmatrix}$$

7) Consider the MIMO channel estimation problem with pilot vectors **1 point**
$\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are
$\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1,$.
The estimate of the MIMO channel matrix $\mathbf{H}$ is,

$\frac{1}{33}\begin{bmatrix} 21 & -17 & 8 \\ 13 & 20 & 17 \end{bmatrix}$

$\begin{bmatrix} \frac{2}{17} & \frac{12}{29} \\ -\frac{1}{17} & -\frac{15}{29} \\ -\frac{25}{17} & \frac{23}{29} \end{bmatrix}$

$\frac{1}{15}\begin{bmatrix} 22 & 21 & 11 \\ 15 & -17 & 27 \end{bmatrix}$

$\begin{bmatrix} -\frac{14}{33} & -\frac{7}{21} \\ -\frac{13}{33} & \frac{1}{21} \\ -\frac{5}{33} & \frac{21}{21} \end{bmatrix}$

No, the answer is incorrect.
Score: 0

Accepted Answers:
$\begin{bmatrix} -\frac{14}{33} & -\frac{7}{21} \\ -\frac{13}{33} & \frac{1}{21} \\ -\frac{5}{33} & \frac{21}{21} \end{bmatrix}$

8) Consider the MIMO channel estimation problem with pilot vectors **1 point**
$\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are
$\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1, 1]^T$.
Let the noise samples be IID Gaussian zero-mean with variance $-6dB$. What are the variances of the estimates of coefficients in any row of the MIMO channel matrix?

$\frac{1}{66}, \frac{1}{98}$

$\frac{1}{132}, \frac{1}{84}$

$\frac{1}{4}$

$\frac{5}{36}, \frac{9}{88}$

No, the answer is incorrect.
Score: 0

Accepted Answers:
$\frac{1}{132}, \frac{1}{84}$

9) Channel equalization refers to **1 point**

- Removing the effect of ISI
- Making all the channel gains equal
- Making all the transmit powers equal
- Making the channels of different users equal

No, the answer is incorrect.
Score: 0

Accepted Answers:
Removing the effect of ISI

10) Consider an Inter Symbol Interference channel $y(k) = x(k) + \frac{1}{3}x(k-1) + v(k)$. Let an $r = 2$ tap channel equalizer be designed for this scenario based on symbols $y(k), y(k+1)$ to detect $x(k)$. What is the effective channel matrix $\mathbf{H}$ for this scenario? **1 point**

- $\begin{bmatrix} 1 & \frac{1}{3} & 0 \\ 0 & 1 & \frac{1}{3} \end{bmatrix}$
- $\begin{bmatrix} 1 & \frac{1}{3} \\ \frac{1}{3} & 1 \end{bmatrix}$
- $\begin{bmatrix} \frac{1}{3} & 1 & 0 \\ 0 & \frac{1}{3} & 1 \end{bmatrix}$
- $\begin{bmatrix} 1 & \frac{1}{3} \\ 1 & \frac{1}{3} \end{bmatrix}$

No, the answer is incorrect.
Score: 0

Accepted Answers:
$\begin{bmatrix} 1 & \frac{1}{3} & 0 \\ 0 & 1 & \frac{1}{3} \end{bmatrix}$

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