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



Course Announcements

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 -Mullti-Antenna Downlink and **MIMO Channel Estimation**

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

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

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

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

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

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

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 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

 $\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1, 1]^T.$ The size of the MIMO system is,



Interference ISI Model

- O Lecture 22 -Least Squares based Zero Forcing Channel Equalizer
- O Lecture 23 -Example of ISI Channel and Least Squares based Zero Forcing
- O Lecture 24 -Equalization and Approximation Error for Zero Forcing Channel Equalizer
- O Lecture 25 -Example Equalization and Approximation Error for Zero Forcing Channel Equalizer
- O 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

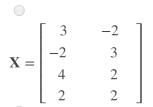
Accepted Answers:

 3×2

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



 $\mathbf{y}(1) = [-2, 1, -3]^T, \mathbf{y}(2) = [-1, 3, 3]^T, \mathbf{y}(3) = [-1, -2, 2]^T, \mathbf{y}(4) = [-3, -1]^T$ As described in the lectures, the pilot matrix \mathbf{X} for the MIMO channel estimation problem above is,





$$X = [3 -2 -2 3 4 2 2 2]$$

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

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

No, the answer is incorrect.

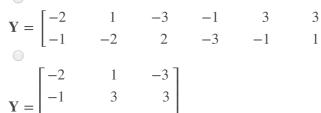
Score: 0

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,



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

$$\mathbf{Y} = \begin{bmatrix} -2 & 1 & -3 \\ -1 & 3 & 3 \\ -1 & -2 & 2 \\ -3 & -1 & 1 \end{bmatrix}^{7}$$

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

Channel **Estimation, SLS** Example

No, the answer is incorrect.

Score: 0

Accepted Answers

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





 $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. 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, $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received





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



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



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

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

No, the answer is incorrect.

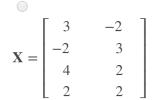
Score: 0

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,



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

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

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

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

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

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

 $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. The received output vectors y are

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, $\frac{1}{33} \begin{bmatrix} 21 & -17 & 8 \\ 13 & 20 & 17 \end{bmatrix}$ $\begin{bmatrix} \frac{2}{17} & \frac{12}{29} \\ \frac{1}{13} & \frac{12}{29} \end{bmatrix}$



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



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



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



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

No, the answer is incorrect.

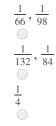
Score: 0

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

8) Consider the MIMO channel estimation problem with pilot vectors

 $\mathbf{x}(1) = [3, -2]^T, \mathbf{x}(2) = [-2, 3]^T, \mathbf{x}(3) = [4, 2]^T, \mathbf{x}(4) = [2, 2]^T$. 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?



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

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

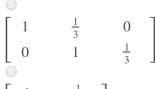


10 Consider an Inter Symbol Interference channel

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









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

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

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

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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