

## NPTEI

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



Announcements

Course

Ask a Question



## Unit 4 - Week 3 - Cramer-Rao Bound (CRB), Vector Parameter Estimation, Multi-Antenna Downlink Mobile Channel Estimation





# 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

- Cramer Rao
  Bound (CRB)
  for Parameter
  Estimation
- Cramer Rao
  Bound CRB
  Example –
  Wireless Sensor
  Network
- Lecture 13 Vector
  Parameter
  Estimation –
  System Model
  for Multi
  Antenna
  Downlink
  Channel
  Estimation
- Lecture 14 -Likelihood Function and Least Squares

## **Assignment-3**

The due date for submitting this assignment has passed. Due on 2017-08-15, 23:59 IST. As per our records you have not submitted this assignment.

1) Given the log-likelihood  $\ln p(\mathbf{y}; h)$  of the parameter h and unbiased estimator 1 point  $\hat{h}$ , the quantity  $\left(\int_{-\infty}^{\infty} \hat{h} \frac{\partial}{\partial h} \ln p(\mathbf{y}; h) p(\mathbf{y}; h) d\mathbf{y}\right)^2$  equals

- 2
- 1
- 0
- I(h)

No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

1

2) Given the log-likelihood  $\ln p(\mathbf{y};h)$  of the parameter h, the quantity  $\left(E\left\{\frac{\partial}{\partial h}\ln p(\mathbf{y};h)\right\}\right)^2$  equals,

1 point

2

1

0

I(h)

No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

0

3) The Cramer-Rao Bound for parameter h is derived as,

1 point

Cost Function for Vector Parameter Estimation

- O Lecture 15 -Least Squares Cost Function for Vector Parameter Estimation Vector Derivative Gradient
- O Quiz: Assignment-3
- O Assignment-3 Solution

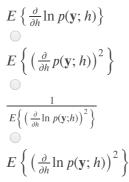
Week 4 - Least Squares (LS) Principle, Pseudo-Inverse, **Properties of LS** Estimate, Examples -Mullti-Antenna Downlink and **MIMO Channel Estimation** 

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

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



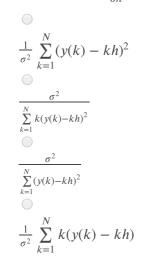


$$\frac{1}{E\left\{\left(\frac{\partial}{\partial h}\ln p(\mathbf{y};h)\right)^2\right\}}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:  $\frac{1}{E\left\{\left(\frac{\partial}{\partial h} \ln p(\mathbf{y};h)\right)^{2}\right\}}$ 4) Consider now a slightly modified version of the wireless sensor network (WSN) 1 point portion scenario described in class with each observation  $\mathbf{y}(k) = kh + y(k)$  for estimation scenario described in class with each observation y(k) = kh + v(k), for  $1 \le k \le N$ . Let the noise samples be IID Gaussian with mean zero and variance  $\sigma^2$ each. The quantity  $\frac{\partial}{\partial h} \ln p(\mathbf{y}; h)$  is



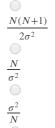
No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

$$\frac{1}{\sigma^2} \sum_{k=1}^{N} k(y(k) - kh)$$

5) Consider now a slightly modified version of the wireless sensor network (WSN) 1 point estimation scenario described in class with each observation y(k) = kh + v(k), for  $1 \le k \le N$ . Let the noise samples be IID Gaussian with mean zero and variance  $\sigma^2$ each. The Fisher information for the parameter h is,



None of the above

No, the answer is incorrect.

Score: 0

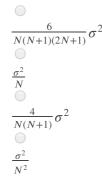
**Accepted Answers:** 

None of the above

each. The Cramer Rao Bound for the parameter h is,

Cases, Applications -Wireless Fading Channel Estimation, SLS Example

6) Consider now a slightly modified version of the wireless sensor network (WSN) 1 point estimation scenario described in class with each observation y(k) = kh + v(k), for  $1 \le k \le N$ . Let the noise samples be IID Gaussian with mean zero and variance  $\sigma^2$ 











### No, the answer is incorrect. Score: 0

## **Accepted Answers:**

$$\frac{6}{N(N+1)(2N+1)}\sigma^2$$

7) Consider now a slightly modified version of the wireless sensor network (WSN) 1 point estimation scenario described in class with each observation y(k) = kh + v(k), for  $1 \le k \le N$ . Let the noise samples be IID Gaussian with mean zero and variance  $\sigma^2$ each. The Cramer Rao Bound for the parameter h is,

- Always Lower than the variance of the ML estimate
- Always Greater than the variance of the ML estimate
- Always Equal to the variance of the ML estimate
- None of the above

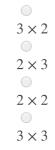
No, the answer is incorrect.

Score: 0

### **Accepted Answers:**

Always Equal to the variance of the ML estimate

8)Consider the multiple antenna downlink channel estimation problem described in 1 point class with  $x_i(k)$  denoting the pilot symbol transmitted from the  $i^{th}$  antenna at time  $k, y(k), h_i$  denoting the corresponding received symbol and fading channel coefficient for the  $i^{th}$  antenna respectively. Let number of antennas M=2 and consider the transmission of N=3 pilot vectors. The pilot matrix **X** is of size



No, the answer is incorrect.

Score: 0

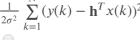
## **Accepted Answers:**

9)Consider the multiple antenna downlink channel estimation problem described in 1 point class with  $x_i(k)$  denoting the pilot symbol transmitted from the  $i^{th}$  antenna at time  $k, y(k), h_i$  denoting the corresponding received symbol and fading channel coefficient for the  $i_{th}$  antenna respectively. Let number of antennas M=2 and consider the transmission of N=3 pilot vectors. Let the vector of received output symbols be

denoted by  $\mathbf{y} = [y(1), y(2), \dots, y(N)]^T$ . The equivalent cost function to be minimized to compute the estimate of the channel vector h is,

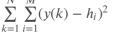
$$\sum_{k=1}^{N} \sum_{i=1}^{M} (y(k) - h_i x(k))^2$$

$$\frac{1}{2\sigma^2} \sum_{k=1}^{N} (y(k) - \mathbf{h}^T x(k))^2$$





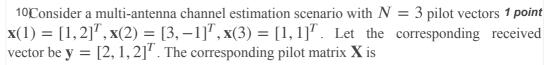
$$\sum_{k=1}^{N} \sum_{i=1}^{M} (y(k) - h_i)^2$$







$$\frac{1}{2\sigma^2} \sum_{k=1}^{N} (y(k) - \mathbf{h}^T x(k))^2$$



- It is invertible
- It has orthogonal columns
- It has identical columns
- None of the above

No, the answer is incorrect.

Score: 0

**Accepted Answers:** 

It has orthogonal columns

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**End** 

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