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

Announcements Course Ask a Question Progress

# Unit 8 - Week 7 - OFDM – Comb Type Pilot (CTP) Transmission, Channel Estimation in Time/ Frequency Domain, CTP Example, Frequency Domain Equalization (FDE), Example-FDE



## 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 – Multi-Antenna Downlink and MIMO Channel Estimation

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

Week 6 - Introduction to

## Assignment - 7

The due date for submitting this assignment has passed. **Due on 2017-09-11, 23:59 IST.**  
As per our records you have not submitted this assignment.

1) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps 1 point denoted by  $h(0), h(1)$ . **Conventional** channel estimation is employed with the pilot symbols transmitted on all the subcarriers given as  $X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The transmitted block of samples in the time domain is,

- $1 - j, -1 + 2j, -2 - j, 1 + j$
- $-\frac{1}{4} + \frac{1}{4}j, \frac{1}{2} - \frac{1}{2}j, -\frac{1}{4} - \frac{5}{4}j, 1 + \frac{1}{2}j$
- $1 + \frac{1}{2}j, -\frac{1}{4} + \frac{1}{4}j, \frac{1}{2} - \frac{1}{2}j, -\frac{1}{4} - \frac{5}{4}j, 1 + \frac{1}{2}j$
- $1 + j, 1 - j, -1 + 2j, -2 - j, 1 + j$

**No, the answer is incorrect.**

**Score: 0**

**Accepted Answers:**

$$1 + \frac{1}{2}j, -\frac{1}{4} + \frac{1}{4}j, \frac{1}{2} - \frac{1}{2}j, -\frac{1}{4} - \frac{5}{4}j, 1 + \frac{1}{2}j$$

2) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps 1 point denoted by  $h(0), h(1)$ . **Conventional** channel estimation is employed with the pilot symbols transmitted on all the subcarriers given as  $X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The action of the channel on the transmitted block of OFDM samples can be modeled as,

- Linear convolution in Time
- Multiplication in Time

**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**

Lecture 31 - Comb Type Pilot CTP Based Orthogonal Frequency Division Multiplexing OFDM Channel Estimation

Lecture 32 - Comb Type Pilot CTP Based Orthogonal Frequency Division Multiplexing OFDM Channel Estimation

Lecture 33 - Example Comb Type Pilot CTP Based Orthogonal Frequency Division Multiplexing OFDM Channel

Lecture 34 - Frequency Domain Equalization FDE for Inter Symbol Interference ISI Removal in Wireless System

Quiz : Assignment - 7

Assignment-7 Solution

**Week 8 - Sequential Least Squares (SLS)**

- Circular Convolution in Time
- Circular Convolution in Frequency

**No, the answer is incorrect.**

**Score: 0**

**Accepted Answers:**

*Circular Convolution in Time*

3) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps denoted by  $h(0), h(1)$ . **Conventional** channel estimation is employed with the pilot symbols transmitted on all the subcarriers given as  $X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The noise samples  $V(l)$  on the  $l^{th}$  subcarrier are,

- Zero-mean, Gaussian, variance  $\sigma^2$
- Zero-mean, Non-Gaussian, variance  $\sigma^2$
- Zero-mean, Gaussian, variance  $\frac{\sigma^2}{4}$
- None of the above

**No, the answer is incorrect.**

**Score: 0**

**Accepted Answers:**

*None of the above*

4) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps denoted by  $h(0), h(1)$ . **Conventional** channel estimation is employed with the pilot symbols transmitted on all the subcarriers given as  $X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The received symbols across the subcarriers are

- $1 - j, -2 + j, 1 - j, 1 + 2j$
- $2 + j, -3 - 4j, 5j, -3 + 2j$
- $-1 + j, 2 - j, 2 + 2j, -1 - j$
- $2 + j, -3 - j, 1 + 3j, -1 - j$

**No, the answer is incorrect.**

**Score: 0**

**Accepted Answers:**

*$2 + j, -3 - 4j, 5j, -3 + 2j$*

5) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps denoted by  $h(0), h(1)$ . **Conventional** channel estimation is employed with the pilot symbols transmitted on all the subcarriers given as  $X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the



Estimation –  
Scalar/ Vector  
Cases,  
Applications -  
Wireless Fading  
Channel  
Estimation, SLS  
Example

cyclic prefix be of length one symbol. The estimate of the channel coefficient  $H(1)$  across subcarrier 1 is,

- $-1 + 2j$
- $\frac{1}{2} + \frac{3}{2}j$
- $-\frac{4}{5} - \frac{3}{5}j$
- $1 - 2j$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$-1 + 2j$

6) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps denoted by  $h(0), h(1)$ . Comb type channel estimation is employed with the transmitted symbols on the subcarriers given as

$X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the pilot subcarriers be  $l = 0, 2$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The estimate of channel coefficient  $H(1)$  across subcarrier 1 is,

- $1 - \frac{1}{2}j$
- $-2 + j$
- $-1 - 2j$
- $\frac{3}{2} - j$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$\frac{3}{2} - j$

7) Consider an  $N = 4$  subcarrier OFDM system with  $L = 2$  channel taps denoted by  $h(0), h(1)$ . Comb type channel estimation is employed with the transmitted symbols on the subcarriers given as

$X(0) = 1 - j, X(1) = -1 + 2j, X(2) = -2 - j, X(3) = 1 + j$ . Let the pilot subcarriers be  $l = 0, 2$ . Let the corresponding received samples in the time domain be  $y(0) = -1 + j, y(1) = 2 - j, y(2) = 2 + 2j, y(3) = -1 - j$ . Let the noise samples  $v(k), 0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The estimate of channel coefficient  $H(2)$  across subcarrier 2 is,

- $\frac{3}{2} + \frac{1}{2}j$
- $2 - j$
- $-1 - 2j$
- $\frac{1}{2} + \frac{3}{2}j$



No, the answer is incorrect.

Score: 0

Accepted Answers:

$$-1 - 2j$$

8) Consider an  $N = 4$  subcarrier OFDM system with **conventional** channel estimation i.e. pilot symbols transmitted on all the carriers, given as,  $X(0) = 3 - j$ ,  $X(1) = 2 + 3j$ ,  $X(2) = -1 - 2j$ ,  $X(3) = -2 + j$ . The ISI channel has  $L = 2$  taps, denoted by  $h(0)$ ,  $h(1)$ . Let the corresponding received samples in the time domain be  $y(0) = 2 + j$ ,  $y(1) = 3 + 2j$ ,  $y(2) = -1 - j$ ,  $y(3) = 2 - 3j$ . Let the noise samples  $v(k)$ ,  $0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also let the cyclic prefix be of length one symbol. The transmitted block of samples in the time domain is,

$\frac{3}{4} - \frac{3}{2}j \quad \frac{1}{4} - \frac{1}{2}j \quad \frac{5}{4} - \frac{1}{2}j \quad -\frac{7}{4} - \frac{1}{2}j \quad \frac{3}{4} - \frac{3}{2}j$

$2 - 5j \quad 2 - j \quad 6 + 3j \quad 2 + 7j \quad 2 - 5j$

$\frac{3}{2} - \frac{3}{4}j \quad \frac{1}{2} + \frac{1}{4}j \quad \frac{1}{2} + \frac{5}{4}j \quad \frac{1}{2} - \frac{7}{4}j \quad \frac{3}{2} - \frac{3}{4}j$

$2 + 5j \quad 2 + j \quad 6 - 3j \quad 2 - 7j \quad 2 + 5j$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\frac{3}{2} - \frac{3}{4}j \quad \frac{1}{2} + \frac{1}{4}j \quad \frac{1}{2} + \frac{5}{4}j \quad \frac{1}{2} - \frac{7}{4}j \quad \frac{3}{2} - \frac{3}{4}j$$

9) Consider an  $N = 4$  subcarrier OFDM system with **conventional** channel estimation i.e. pilot symbols transmitted on all the carriers, given as,  $X(0) = 3 - j$ ,  $X(1) = 2 + 3j$ ,  $X(2) = -1 - 2j$ ,  $X(3) = -2 + j$ . The ISI channel has  $L = 2$  taps, denoted by  $h(0)$ ,  $h(1)$ . Let the corresponding received samples in the time domain be  $y(0) = 2 + j$ ,  $y(1) = 3 + 2j$ ,  $y(2) = -1 - j$ ,  $y(3) = 2 - 3j$ . Let the noise samples  $v(k)$ ,  $0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The symbols received across the subcarriers in the frequency domain are,

$6 - j \quad 8 + j \quad -4 + j \quad 2 - 3j$

$6 - j \quad 8 + j \quad -4 + j \quad -2 + 3j$

$6 - j \quad 8 + j \quad 4 - j \quad -2 + 3j$

$6 - j \quad -8 - j \quad -4 + j \quad -2 + 3j$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$6 - j \quad 8 + j \quad -4 + j \quad -2 + 3j$$

10) Consider an  $N = 4$  subcarrier OFDM system with **conventional** channel estimation i.e. pilot symbols transmitted on all the carriers, given as,  $X(0) = 3 - j$ ,  $X(1) = 2 + 3j$ ,  $X(2) = -1 - 2j$ ,  $X(3) = -2 + j$ . The ISI channel has  $L = 2$  taps, denoted by  $h(0)$ ,  $h(1)$ . Let the corresponding received samples in the time domain be  $y(0) = 2 + j$ ,  $y(1) = 3 + 2j$ ,  $y(2) = -1 - j$ ,  $y(3) = 2 - 3j$ . Let the noise samples  $v(k)$ ,  $0 \leq k \leq 3$  be zero-mean IID Gaussian with variance  $\sigma^2$ . Also, let the cyclic prefix be of length one symbol. The estimate of the channel coefficient  $H(2)$  across subcarrier 2 is,

$$\frac{7}{5} - \frac{4}{5}j$$



$$\frac{19}{13} - \frac{22}{13}j$$



$$\frac{19}{10} + \frac{3}{10}j$$



$$\frac{2}{5} - \frac{9}{5}j$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\frac{2}{5} - \frac{9}{5}j$$



Previous Page

End

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