BITS-Pilani, Hyderabad Campus
First Semester 2021-2022

Course Handout

Date:

03/08/2021

In addition to Part I (General Handout for all courses appended to the Timetable) this portion gives further specific details regarding the course.

Course Number : EEE G641 3 2 5
Course Title : Applied Estimation Theory
Course Coordinator : Dr. PRASHANT K WALI.

1. Course Description

The course starts with a brief overview of the following mathematical tools:

i) Probability, random variables (real and complex), random processes,
ii) Linear algebra and matrices

It then focusses on the fundamentals of estimation in additive white Gaussian noise (AWGN). We will cover the Maximum Likelihood Estimation concepts for both scalar and vector complex parameters, and the error associated with MLE. We derive Cramer Rao Bound to for parameter estimation. The concepts learnt will be applied to the channel estimation problems in a fading wireless channel for both SISO and MIMO cases. Then we will cover OFDM and channel estimation in OFDM, MLSE estimation and its application. Then the course covers the Bayesian Estimation framework and looks at MMSE estimation concepts and its applications to wireless fading channel. We will also briefly spend time understanding the wireless channel model in order to motivate the channel estimation problems.

The course has take-home lab assignments as well. It includes experiments on the review of probability, random variables, and, random processes, different types of estimation algorithms and their application in wireless/mobile communications.

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2. Scope and Objective of the Course:

Estimation theory is applied in various communication systems. The course mainly covers estimation techniques for different channels, namely, additive white Gaussian channels (AWGN), fading channel, and, OFDM channels. This course serves as a precious tool to learn several advanced courses on communications

such as MIMO wireless communication, advanced satellite communication, Adaptive signal processing and filter theory for advanced communication systems.
Expected outcomes of this course and manifold. Estimation is a fundamental tool to solve estimation problems arise in different modern communication systems. After the completion of the course, students gain conceptual knowledge and will be able to apply this powerful tool in their projects on communication and control. Some specific areas that involve application of estimation are MIMO wireless systems, MIMO-OFDM systems, wireless LANS, UWB communication systems, and many other fields.

iii) Text Books:

1. Fundamentals of statistical signal processing, volume-I: estimation by S.M.Kay, Prentice-Hall

iv) Reference Books:

1. Probability, random variables, and stochastic processes, A. Papoulis, Mcgraw-Hill, 3rd Edition, 1991.
2. Probability Theory and Random Processes with Applications to Signal Processing and Communications by Scott Miller and David Childers, Elsevier
3. Linear Algebra by Gilbert Strang.
4. Fundamentals of wireless communication, David Tse & Pramod Viswanath, Cambridge university press, 2006.
5. Wireless communication, by Andreas.F.Molisch, Wiley, 2nd Edition.
6. Wireless communications by Andrea Goldsmith, Cambridge university press, 2009.
7. LTE-The UMTS Long Term Evolution, From Theory to Practice, Stefan Sesia, et.al, Wiley.
8. LTE for 4G Mobile Broadband, Farooq Khan, Cambridge University Press
9. OFDM Baseband Receiver Design for Wireless Communications, Tzi-Dar Chiueh and Pei Yun Tsai, John Wiley and Sons.
10. Resources from the Internet and Research Publications.

v) Course Plan / Schedule:

Sl. #	Learning objectives	Topics to be covered	Source	No. of lectures
1.	Review of Wireless Channel Behavior	Wireless Channel Modeling, Fading, Coherence Time, Coherence Bandwidth, Delay Spread, Doppler Spread.	T4/T5	3

2.	The Problem of Channel Estimation in 4G LTE Networks	LTE Physical Layer Frame Format, Time Frequency Grid, OFDM in LTE, Reference Signals and Channel Estimation, Channel Quality Indicator (CQI), CQI based Multi User Opportunistic Scheduling	T6/ R4/ R5/R6	3
3.	Introduction to the theory of Estimation	The mathematical estimation problem, Assessing Estimator Performance	T3	1
4.	Mathematical Prerequisites for the study of Estimation Theory	Review of linear algebra: Inverse, Pseudo Inverse, Eigen Values, Eigen Vector. Review of probability theory: Probability space, axioms, events, random variables, random processes.	T1/T2/ R1	2
5.	Minimum Variance Unbiased Estimator (MVUE) and Cramer Rao Lower Bound (CRLB)	Unbiased Criterion, Minimum Variance Criterion, existence and finding, CRLB, Fisher Information	T3	3
6.	Linear Models	Linear Model Definition and Properties, Examples.	T3/T4/ T5	3
7.	General Minimum Variance Unbiased Estimation	Sufficient Statistics, Finding sufficient statistics, using sufficiency to find the MVU Estimator.	T4/T5	2
8.	Best Linear Unbiased Estimators (BLUE)	Definition of BLUE, Finding the BLUE	T3/T4/ T5	3
9	Maximum Likelihood Estimation (MLE)	Finding the MLE, Properties of the MLE, Examples	T3/T4/ T5	2
10	Least Squares	The Least Squares Approach, Linear Least Squares, Sequential Least Squares, MLSE	T3/T4/ T5	3
11	The Bayesian Philosophy	Prior Knowledge and Estimation, Choosing a prior PDF, Properties of the Gaussian PDF, Bayesian Linear Model	T3/T4/ T5	2
12	General Bayesian Estimators	Risk Functions, Minimum Mean Square Estimator (MMSE), Maximum A	T3/T4/ T5	3

		Posteriori Estimator (MAP), Examples		
13	Linear MMSE (LMMSE)	Linear MMSE Estimation, Geometrical Interpretations, The Vector LMMSE Estimator, Sequential LMMSE Estimation	T3/T4/ T5	3
14	Application of the theory: Carrier Phase Estimation, Symbol and Timing synchronization, Pilot Signal Design for Channel Estimation, Different Channel Estimation Methods in 4G LTE.	MLE, MMSE, LMMSE techniques to estimate channel using pilot subcarriers in LTE frame, interpolation to non non-pilot (data) subcarriers, some interpolation techniques.	T6/ R5/R6	8
		Total no. of classes planned		**42**

Laboratory component: Laboratory exercises will involve simulations using MATLAB.

vi) Evaluation Scheme:

Component	Duration	Weightage	Marks	Date & Time	Evaluation type
Mid sem	90 min	35%	70	TBA	Open Book
Lab		30%	60	WEEKLY	Open Book
Compre. Exam.	2 hours	35%	70	TBA	Closed Book

Total			**200**		

vii) **Make-up Policy:** Make-up will be given on extremely genuine grounds only. Prior application should be made for seeking the make-up examination. Please note that generally the make-up exam will be tougher than the regular exam.

viii) **Notices:** Notices, if any, concerning the course will be put up on CMS only

Instructor-in-Charge
EEE G641