INSTRUCTION DIVISION

FIRST SEMESTER 2019-2020

Course Handout Part II

Date: 18-08-2020

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

Course No. **: G641**

Course Title **: Applied Estimation Theory**

Instructor **: SAINATH BITRAGUNTA**

Pre-requisites: Basic linear algebra and matrix theory, Probability theory and random processes, Communication systems

1. Course description:

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

i). Probability, random variables (real and complex), random vectors, random processes.

ii). Linear algebra and matrix theory.

It then focusses on the fundamentals of phase and timing estimation in digital communication systems, estimation in additive white Gaussian noise (AWGN). Then, channel estimation error in basic and adaptive modulation schemes will be discussed in detail. Further, the course also covers a study of maximum likelihood sequence estimation (MLSE) for equalization. Finally, estimation techniques for OFDM channels, MIMO-OFDM channels, wireless LANs will be taught in detail.

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. Objectives & Outcomes:

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.

3. Text Books

[T1] Wireless communications by Andrea Goldsmith, Cambridge university press, 2009.

[T2] Fundamentals of wireless communication, David Tse & Pramod Viswanath, Cambridge university press, 2006.

4. Reference Books

[R1] Probability, random variables, and stochastic processes, A. Papoulis, McGraw-Hill, 3rd Edition, 1991.

[R2] Fundamentals of statistical signal processing, Volume-I: estimation by S.M. Kay, Prentice-Hall.

[R3] Decision and Estimation Theory, James L. Melsa, David L. Cohn, MGH.

[R4] MIMO-OFDM wireless communications with MATLAB, Yang S. Cho et al., Wiley-IEEE, 2010.

[R5] Broadband receiver design for wireless MIMO-OFDM communications, Tzi-Dar Chiueh et al., John Wiley, 2012

[R6] Fundamentals of massive MIMO, Thomas L. Marzetta et al., Cambridge university press, 2016.

[R7] Communication systems, Simon Haykin, Fourth edition, 2001.

5. Course Plan

Lect. No.	Topics to be covered	Learning Objectives	Source
1-2	Introduction to applied estimation. (self-study) Review of linear algebra and probability theory: Introduction to norms, matrix decompositions, Gaussian, random variables, random vectors, processes, summary	To apply linear algebra and probability concepts to handle estimation theory problems in communication systems	[R1]/[R2]/[R3], Lecture slides
3-5	Parameter estimation, estimation criteria: MAP, ML, MMSE	ML estimation, examples, MMSE, summary, examples	[T1]/[R1]
6-8	Estimation in Additive White Gaussian noise, estimation in fading channels	Scalar estimation, estimation in real and complex vector space, summary, examples	[T2]
9-10	Least squares estimate (LS), ML estimate, unbiased estimate, CRLB	Study of performance degradation due to estimation errors, mean square error, summary, examples	[T1]
11-13	ML sequence estimation (MLSE), Blind ML estimation	Frequency diversity and equalization, Study of MLSE for equalization, summary, examples	[T1]/[T2]
14-19	Estimation of various wireless channels	Estimation of SIMO, MISO, Multi Input-Multi Output (MIMO) channels, study of different estimators such as MMSE, linear MMSE, examples	[T1]/[T2], IEEE papers
20-25	Orthogonal frequency division multiplexing (OFDM) channels	OFDM basics review, OFDM channel estimation (LS, MMSE), channel quality	[R4]/IEEE papers

		estimation, Impact of channel estimation errors on performance	
26-30	Estimation for synchronization in OFDM	Symbol time offset, carrier frequency offset estimation, different approaches	[R4]
31-33	OFDM receiver design challenges	STO, CFO compensation, I-Q imbalance, solutions to these problems	[R5]
34-35	MIMO-OFDM wireless LAN	Synchronization and channel estimation issues and solutions	IEEE paper(s)
36-39	Massive MIMO (mMIMO) channel estimation, millimeter wave (mmWave) mMIMO	Estimation techniques for Massive MIMO, introduction to mmWave mMIMO examples	[R6]/IEEE papers
40-42	Deep learning based channel estimation	Brief introduction to deep learning (DL), use of DL for channel estimation, examples	IEEE & other journal reputed papers

6. **Assignments:** Take-home assignments mainly involve problems and coding-based exercises using MATLAB/Python. Additional details will be announced during lectures or posted on Nalanda.

7. **Evaluation Scheme***

Component	Duration	Weightage	Date & Time	Mode	Remarks
Test-1	30 minutes	15%	To be announced (TBA)	Online	Closed book (CB)
Test-2	30 minutes	15%	TBA	Online	CB
Test-3	30 minutes	15%	TBA	Online	CB
Group project	--	25%	TBA	Online	Seminar (10%) plus Report (15%)
Comprehensive Examination	2 hrs.	30%	TBA	Online	Open book

** As per AUGSD guidelines*

8. Chamber Consultation Hour: To be announced in the class.

9. **Advanced level course:** The next advanced level course is ``**adaptive array signal processing and machine learning''**. This course can be offered in the following semester. It deals with topics such as constrained and optimal estimation, adaptive filters (e.g. Wiener filters, Particle filters), filter banks for multicarrier systems and their performance, application of the adaptive signal processing and filters in cooperative and cognitive radio communication.

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