Noise in Linear Systems
EEE 5544   Section 11999
Class Periods: M W F 4 (10:40 -- 11:30 AM)
Location: NEB
Academic Term: Fall 2020

Instructor:
Sean Meyn
meyn@ece.ufl.edu
352 392 8934
Office Hours: Monday 11:30-12:30 and Thursday 10-11 (or by appointment)

Teaching Assistant/Peer Mentor/Supervised Teaching Student:
Please contact through the Canvas website
- TBD

Course Description
Fundamental analytical techniques for modeling, analyzing, and processing electrical signals and computer data in the presence of noise and randomness. Covers from probability to filtering of random processes, with applications to communications, signal and image processing, data compression, and simulation. Prereq: Students may not take this course if they have already taken EEL4516.

Students enrolled in the hybrid section will need to take at least two of the three hour exams in person.   The location will be determined soon.

Course Pre-Requisites / Co-Requisites
EEL 3135 (Introduction to Signals and Systems) or equivalent, MAS 3114 (Computational Linear Algebra) or equivalent. Computer programming in Python or Matlab is required.

Pre-requisite knowledge for success in this course: Very strong mathematical skills, including multivariable calculus. Solid understanding of systems theory, including convolution, Fourier transforms, and impulse functions. Knowledge of basic linear algebra, including matrix properties and eigen-decomposition.

Materials and Supply Fees
List if applicable

Course Objectives
Clearly state the learning objectives of the course, and how those objectives will be accomplished (give a list of specific actions or course elements).

Upon completion of this course, the student should be able to
- Apply the axioms and corollaries of probabilities to solve problems and ensure that answers are reasonable
- Understand apply combinatorics for experiments with equally likely outcomes
- Use random variables to model numerically valued random phenomena and use the probability-mass, density, distribution functions to calculate probabilities
- Know and apply common random variables to model random phenomena
- Understand and use conditional probability to model dependent phenomena to break problems down into simpler parts, and to make optimal decisions, using tools such as total probability, Bayes' law, MAP and ML detection, and MMSE estimation
- Understand how a function of a random variable transforms the probability to create a new random variable, and be able to determine the density, distribution, and expected value of functions of one or more random variables

- Determine the expected values, moments, variances, and covariances of random variables
- Use inequalities and bounds for probabilities that cannot be solved in closed form
- Use transform methods to simplify solving some problems that would otherwise be difficult
- Use the Karhunen-Loeve transform to decorrelate random variables and use PCA for dimensionality reduction
- Build Monte Carlo simulations of random phenomena and understand how to choose the number of samples to ensure the estimates are reasonable
- Understand stationarity and evaluate whether random processes are wide-sense stationary, covariance-sense stationary, strict-sense stationary, or none of these
- Characterize wide-sense stationary random processes using the mean, autocovariance, and autocorrelation functions
- Evaluate the power spectral density for wide-sense stationary random processes
- Analyze wide-sense stationary random processes in linear systems
- Give the matched filter solution for a simple signal transmitted in additive white Gaussian noise

Summary: Understand fundamental mathematical tools of probability and use them to solve many types of problems involving random phenomena.

Required Textbooks and Software
- *Probability, Statistics, and Random Processes for Electrical Engineering*
- Alberto Leon-Garcia
- Pearson Prentice Hall, 3rd ed., 2008
- ISBN number: 0131471228

Recommended Materials

Other good texts:
- *Random Processes in Linear Systems*
- Michael B. Pursley
- Prentice Hall, 2002
- ISBN number: 0-13-067391-9

- *Random Processes for Engineers* (a bit more advanced)
- Bruce Hajek
- Cambridge University Press, 2015
- ISBN number: 1107100127

Basic undergraduate probability:
- *A First Course in Probability*
- Sheldon Ross
- Prentice Hall, 8th ed., 2009
- ISBN number: 978-0136033134

Course Schedule

Week 1:

– Introduction to probability models & philosophies

– Random experiments

– Samples spaces and set operations

– Combinatorial (counting) analysis

Week 2:

– Probability spaces and axioms of probability

– Statistical independence

– Mutually exclusive events

– Conditional probability

– Chain rule

– *Assignments:* Homework 1 Preparation Assessment, Homework 1

Week 3:

– Total probability

– Bayes' rule

– Maximum likelihood and maximum *a posteriori* decision rules

– Sequential experiments

– The Poisson law

– Single random variables and types of random variables

– *Assignments:* Homework 2. Preparation Assessments, Homework 2

Week 4:

– Distribution and density functions

– Important random variables

– Computing probabilities for Gaussian random variables

– Point conditioning, total probability, Bayes' rule for continuous random variables

– *Assignments:* Homework 3. Preparation Assessment, Homework 3

Week 5:

– Multiple random variables

– Joint and marginal distribution and density functions

– *Assignment:* Homework 4. Preparation Assessment, Homework 4

Week 6:

– Computing probabilities using joint distributions and densities

– Conditioning with multiple random variables

– *Assignment:* Homework 5

Week 7:

– Functions of one random variable

– One function of multiple random variables

– Order statistics

– *Exam 1 (in person)*

Week 8:

– Functions of several random variables

– Generating random variables

– Expected value of a random variable

– Expected value of a function of a random variable

– Moments of a single random variable: mean, variance, standard deviation, Nth moment, Nth central moment

– *Assignment:* Homework 6

Week 9:

– Poisson points

– Expected value of function of multiple RVs: sum or RVs, product of RVs

– Joint moments

– Covariance and correlation coefficient

– Bivariate jointly Gaussian random variables

– Cauchy-Schwartz Inequality

– Conditional expected value

– Minimum mean-square error estimation

– *Assignment:* Homework 7

Week 10:

– Complex random variables

– Transform methods: Characteristic and moment-generating functions, Laplace

transform and probability generating functions

- – Applications of transform methods: determining moments, characterizing functions of random variables, sums of independent random variables

- – Markov and Chebyshev inequalities, Chernoff bound

- – *Assignment:* Homework 8

Week 11:

- – Laws of Large Numbers

- – The Central Limit Theorem

- – Random Vectors

- – Jointly Gaussian random vectors

- – Covariance matrices and properties

- – Decorrelating/whitening random variables and application to principal components analysis

Week 12:

- – Random processes

- – Moving average and autoregressive processes

- – Mean, autocorrelation, and autocovariance functions

- – Power at the output of a filtered random process

- – *Exam 2 (in person)*

Week 13:

- – Properties of autocorrelation and autocovariance functions

- – Stationarity

- – Gaussian random processes

- – Multiple random processes

- – *Assignment:* Homework 9

Week 14:

- – Time-invariant filtering of random processes

- – Important classes of random processes

- – Power spectral density

– *Assignment:* Homework 10

Week 15:

    – Matched filters

    – Sampling random processes

    – Markov chains

    – *Exam 3 (in person)*

Online Course Recording
Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

F2F Course Policy in Response to COVID-19
We will have face-to-face instructional sessions to accomplish the student learning objectives of this course. In response to COVID-19, the following policies and requirements are in place to maintain your learning environment and to enhance the safety of our in-classroom interactions.

• You are required to wear approved face coverings at all times during class and within buildings. Following and enforcing these policies and requirements are all of our responsibility. Failure to do so will lead to a report to the Office of Student Conduct and Conflict Resolution.

• This course has been assigned a physical classroom with enough capacity to maintain physical distancing (6 feet between individuals) requirements. Please utilize designated seats and maintain appropriate spacing between students. Please do not move desks or stations.

• Sanitizing supplies are available in the classroom if you wish to wipe down your desks prior to sitting down and at the end of the class.

• Follow your instructor's guidance on how to enter and exit the classroom. Practice physical distancing to the extent possible when entering and exiting the classroom.

• If you are experiencing COVID-19 symptoms (Click here for guidance from the CDC on symptoms of coronavirus), please use the UF Health screening system and follow the instructions on whether you are able to attend class. Click here for UF Health guidance on what to do if you have been exposed to or are experiencing Covid-19 symptoms.

• Course materials will be provided to you with an excused absence, and you will be given a reasonable amount of time to make up work. Find more information in the university attendance policies.

Attendance Policy, Class Expectations, and Make-Up Policy

This class will be presented online using Zoom and requires access to a working webcam and stable internet connection. I prefer that students keep their camera on during the class so that I can see you as I would during normal face-to-face classes. Studies show that if we can see each other's faces then we will have more engagement,

more student success, and more faculty success. However, this is not a requirement. I understand if on certain days you can't have your camera on due to internet bandwidth limitations, other family members, health issues, or any other reasons.

Excused absences must be in compliance with university policies in the Graduate Catalog (http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance) and require appropriate documentation.

Evaluation of Grades
Assessment Guidance from the ECE Graduate Committee: Course evaluation components should include:

1. At least one component that individually evaluates each student's understanding of course material and ability to apply concepts.
2. At least one evaluation activity that takes place in class.
3. When a project is involved, evaluation rubrics should be explicitly stated.
4. When team work is expected, individual student contribution verification method should be explicitly stated.

If an in-class exam is administered then 1 and 2 are fulfilled. In the case of a project, a project report that is graded per the stated evaluation rubrics and states which work was done by each student in the project team will address both 3 and 4.

Assignment	Total Points	Percentage of Final Grade
Homework Sets (10)	100 each	10%
Quizzes (4)	100 each	15%
Midterm Exam (3)	100	75%

Grading Policy
The following is given as an example only.

Percent	Grade	Grade Points
90.0 - 100.0	A	4.00
87.0 - 89.9	A-	3.67
84.0 - 86.9	B+	3.33
81.0 – 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 79.9	C+	2.33
72.0 – 74.9	C	2.00
69.0 - 71.9	C-	1.67
66.0 - 68.9	D+	1.33
63.0 - 65.9	D	1.00
60.0 - 62.9	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:
http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:
• Your academic advisor or Graduate Program Coordinator
• Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
• Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
• Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:

U Matter, We Care:
Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus: https://care.dso.ufl.edu.

On-Line Students Complaints: http://www.distance.ufl.edu/student-complaint-process.