EEL 5544 Noise in Linear Systems

Will be renamed to Stochastic Methods in Engineering I

SYLLABUS

1. **Catalog Description:** (3 credits) Passage of electrical noise and signals through linear systems. Statistical representation of random signals, electrical noise, and spectra.

   *Instructor’s clarification:* This course starts from the fundamentals of probability and covers probability, random variables, random vectors, and random processes.

   The focus is on the mathematical tools required to quantify random phenomena.

2. **Pre-requisite:** No course pre-requisite.

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

3. **Course Objectives:** Upon completion of this course, the student should be able to

   - Recite the axioms of probability; use the axioms and their corrolaries to give reasonable answers
   - Determine probabilities based on counting (lottery tickets, etc.)
   - Calculate probabilities of events from the density or distribution functions for random variables
   - Classify random variables based on their density or distribution functions
   - Know the density and distribution functions for common random variables
   - Determine random variables from definitions based on the underlying probability space
   - Use conditional probability, total probability, and Bayes’ law
   - Find maximum likelihood and maximum a posteriori decision rules
   - Determine the density and distribution functions for functions of random variables using several different techniques presented in class
   - Calculate expected values for random variables
   - Find MMSE estimators for random variables
   - Determine whether events, random variables, or random processes are statistically independent
   - Use inequalities to find bounds for probabilities that might otherwise be difficult to evaluate
• Use transform methods to simplify solving some problems that would otherwise be difficult
• Evaluate probabilities involving multiple random variables or functions of multiple random variables
• Use the Karhunen-Loève transform to decorrelate random variables and use PCA for dimensionality reduction
• Classify random processes based on their time support and value support
• Simulate random variables and random processes
• Classify random processes based on stationarity
• Evaluate the mean, autocovariance, and autocorrelation functions for random processes at the output of a linear filter
• Evaluate the power spectral density for wide-sense stationary random processes
• Give the matched filter solution for a simple signal transmitted in additive white Gaussian noise
• Determine the steady state probabilities for a Markov chain

4. **Contribution of course to meeting the professional component:** *Does not apply*

5. **Relationship of course to program outcomes:** *Does not apply*

6. **Instructor:** Dr. John M. Shea
   
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   (b) Phone: 352.575.0740 (Text messaging is okay)
   (c) Email: jshea@ece.ufl.edu
   (d) Web site (personal): http://wireless.ece.ufl.edu/jshea
   (e) Twitter (personal account): @jmshea
   (f) Office hours: Monday 9:35 AM – 10:25 AM, Wednesday 3:30 PM – 4:30 PM, or by appointment

7. **Teaching Assistant:** Jixin Feng
   
   (a) Office: NEB 403
   (b) Phone: (518)290-0421
   (c) Email: fengjixin@ufl.edu
   (d) Office hours: MWF 3pm-5pm (starting on Aug. 26th)

8. **Meeting Times:** 12:50 PM–1:40 PM, Monday/Wednesday/Friday

9. **Class/laboratory schedule:** 3 classes/week, 50 minutes each
10. **Meeting Location:** NEB 102

11. **Class Response System:** To get full course participation credit, on-campus students will need to register with Poll Everywhere and join the EEL 5544 group using the following URL: www.polleverywhere.com/register?p=1mrb3-xu5k&pg=LHiF. Students can answer Poll Everywhere polls and quizzes using their phone, tablet, or laptop computer. Registration is $14/year.

12. **Material and Supply Fees:** Students pay a fee for taking a course that is offered on EDGE. On-campus students are required to have a PollEverywhere account to get full course participation credit.


   *Instructor’s note:* The course will most closely follow the presentation in the book by Stark and Woods. However, the book by Leon-Garcia is easier to read and has more engineering-related examples.

15. **Course Notes:** Course notes developed by the instructor will be provided in PDF form and will also be available for purchase as a soft-cover book.

16. **E-Learning:** All students must use the class web site, which is on E-Learning Sakai: https://elearning2.courses.ufl.edu/portal.

   **Some problems will require MATLAB.** MATLAB is available on the ECEL cluster. As departmental computer resources are limited, students may want to purchase the student version of MATLAB or install GNU Octave, which is a free MATLAB replacement\(^1\). Not being able to get MATLAB access is not a valid excuse for late work.

17. **Recommended Reading:**

   - If you feel like you are having a hard time with basic probability, I suggest:

   - For more depth on filtering of random processes:

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\(^1\)Some problems may require MATLAB toolbox commands that are not available in Octave, and not all code is directly compatible.
18. **Course Outline:**

- Probability spaces and axioms of probability
- Combinatorial (counting) analysis
- Conditional probability, total probability and Baye’s rule
- Statistical independence
- Sequential experiments
- Single random variables and types of random variables
- Important random variables
- Distribution and density functions
- Functions of one random variable
- Expected value of a random variable
- Mean, variance, standard deviation, Nth moment, Nth central moment
- Markov and Chebyshev inequalities
- Transform methods: Characteristic and generating functions, Laplace transform
- Generating random variables
- Multiple random variables
- Joint and marginal distribution and density functions
- Functions of several random variables
- Decorrelating/whitening random variables and application to principal components analysis
- Joint moments and joint characteristic functions
- Conditional expected value
- MMSE estimation
- Laws of large numbers and the central limit theorem
- Random processes
- Mean, autocorrelation, and autocovariance functions
- Stationarity
- Time-invariant filtering of random processes
19. **Attendance and Expectations:** Attendance is not mandatory. However, students are expected to know all material covered in class, even if it is not in the book. Furthermore, the instructor plans to give a variety of graded questions during lectures with no make-up option. The two lowest scores of these graded questions will be dropped.

20. **Grading:** Grading for on-campus students will be based on three exams (30% each) and class participation, selected homework problems, and quizzes (10%). Grading for EDGE students will be based on three exams (25% each), homework (15%), and class participation and quizzes (10%). The participation score will take into account in-class participation, e-mail or instant messaging exchanges, discussions outside of class, etc.

Homework sets for off-campus students will be graded on a spot-check basis: if I give ten problems, I may only be able to grade four or five of them. Homework will be accepted late up to two times, with an automatic 25% reduction in grade.

No formal project is required, but, as mention above, students will be required to use MATLAB in solving some homework problems.

When students request that a submission (test or homework) be regraded, I reserve the right to regrade the entire submission rather than just a single problem.

21. **Grading Scale:** Grades (and the corresponding grade points) will be assigned according to the Registrar’s official policies. Grades will be curved. However, an A grade of > 90% is guaranteed an A, > 80% is guaranteed a B, etc.

Undergraduate students, in order to graduate, must have an overall GPA and an upper-division GPA of 2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. Graduate students, in order to graduate, must have an overall GPA of 3.0 or better (B or better). Note: a B- average is equivalent to a GPA of 2.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit: [https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx](https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx)

22. **Make-up Exam Policy:** If an exam must be missed, the student must see the instructor and make arrangements in advance unless an emergency makes this impossible. Approval for make-up exams is much more likely if the student is willing to take the exam early. Any other exam absence will result in the student receiving a zero for that grade. Students who miss pop quizzes or online quizzes will receive zeros for that grade.

23. **Honesty Policy:** All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action.
This statement is a reminder to uphold your obligation as a student at the University of Florida and to be honest in all work submitted and exams taken in this class and all others.

Additional requirements and information:

Honor statements on tests must be signed in order to receive any credit for that test.

I understand that many of you will have access to at least some of the homework solutions. Time constraints prohibit me from developing completely new sets of homework problems each semester. Therefore, I can only tell you that homework problems exist for your benefit. It is dishonest to turn in work that is not your own. In creating your homework solution, you should not use the homework solution that I created in a previous year or someone else's homework solution. If I suspect that too many people are turning in work that is not their own, then I will completely remove homework from the course grade.

Collaboration on homework is permitted and encouraged unless explicitly prohibited, provided that:

(a) Collaboration is restricted to students currently in this course.
(b) Collaboration must be a shared effort.
(c) Each student must write up his/her homework independently.
(d) On problems involving MATLAB programs, each student should write their own program. Students may discuss the implementations of the program, but students should not work as a group in writing the programs.

I have a zero-tolerance policy for cheating in this class.

If you talk to anyone other than me during an exam, I will give you a zero. If you plagiarize (copy someone else's words) or otherwise copy someone else's work, I will give you a failing grade for the class. Furthermore, I will be forced to bring academic dishonesty charges against anyone who violates the Honor Code.

24. Accommodation for Students with Disabilities: Students requesting classroom accommodation must first register with the Dean of Students Office. That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation.

25. UF Counseling Services: Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- UF Counseling & Wellness Center, 3190 Radio Rd, 392-1575, psychological and psychiatric services.
- Career Resource Center, Reitz Union, 392-1601, career and job search services.

26. Software Use: All faculty, staff and student 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.