EEE 5544 --- Noise in Linear Systems

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-requisites**: 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:

   a. Recite the axioms of probability; use the axioms and their corrolaries to give reasonable answers
   b. Determine probabilities based on counting (lottery tickets, etc.)
   c. Calculate probabilities of events from the density or distribution functions for random variables
   d. Classify random variables based on their density or distribution functions
   e. Know the density and distribution functions for common random variables
   f. Determine random variables from definitions based on the underlying probability space
   g. Use conditional probability, total probability, and Bayes' law
   h. Find maximum likelihood and maximum a posteriori decision rules
   i. Determine the density and distribution functions for functions of random variables using several different techniques presented in class
   j. Calculate expected values for random variables
   k. Find MMSE estimators for random variables
   l. Determine whether events, random variables, or random processes are statistically independent
   m. Use inequalities to find bounds for probabilities that might otherwise be difficult to evaluate
   n. Use transform methods to simplify solving some problems that would otherwise be difficult
   o. Evaluate probabilities involving multiple random variables or functions of multiple random variables
   p. Use the Karhunen-Loeve transform to decorrelate random variables and use PCA for dimensionality reduction
   q. Classify random processes based on their time support and value support

r. Simulate random variables and random processes
s. Classify random processes based on stationarity
t. Evaluate the mean, autocovariance, and autocorrelation functions for random processes at the output of a linear filter
u. Evaluate the power spectral density for wide-sense stationary random processes
v. Give the matched filter solution for a simple signal transmitted in additive white Gaussian noise
w. Determine the steady state probabilities for a Markov chain

4. **Contribution of course to meeting the professional component:** N/A.

5. **Relationship of course to program outcomes**: N/A.

6. **Instructor: Professor Jian Li**
   a. Office location: 465 EB
   b. Telephone: 392-2642
   c. E-mail address: li@dsp.ufl.edu
   d. Web site: www.sal.ufl.edu
   e. Office hours: 6th period, MWF.

7. **Teaching Assistant:** TBD.
   a. Office location
   b. Telephone
   c. E-mail address
   d. Office hours

8. **Meeting Times:** 11:45 AM – 12:35 PM, Monday/Wednesday/Friday.

9. **Class/laboratory schedule**: 3 sessions each week and 50 minutes each session.

10. **Meeting Location:** NEB 102

11. **Material and Supply Fees:** Students pay a fee for taking a course that is offered on EDGE. On-campus students are required to have an account with the selected classroom response system provider.

12. **Textbooks and Software Required:**
    a. Title: *Probability, Statistics, and Random Processes for Electrical Engineering*
    b. Authors: Alberto Leon-Garcia
    c. Publication date and edition: 2008, 3rd Edition
    d. ISBN number: 0131471228

13. **Recommended Reading:**

- Sheldon Ross, *A First Course in Probability*, Prentice Hall, 7th ed., 2006 (ISBN 0-13-185662-6)
- Henry Stark and John W. Woods, *Probability, Statistics, and Random Processes for Engineers*, Prentice Hall, 4th ed., 2011 (ISBN 0132311232).

14. **Course Outline**:
    - 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

- 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
- 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

15. **Attendance and Expectations**: Attendance will not be taken. However, attendance is expected. Cell phones not allowed.

16. **Grading:** – Grading will be based on three exams (30% each), and selected homework problems (10%). Homework sets will be graded on a spot-check basis: we may only grade a few of the problems. Late homework will not be accepted. No formal project is required, but students will be required to use MATLAB in solving some homework problems.

17. **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. For more information on grades and grading policies, please visit:

https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

    In order to graduate, graduate students must have an overall GPA and an upper-division 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:

http://gradschool.ufl.edu/catalog/current-catalog/catalog-general-regulations.html#grades

18. **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.

19. **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 UF student and to be honest in all work submitted and exams taken in this course and all others.

20. **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.

21. **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.

22. **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.