Course Syllabus
ECE 697L – Phased Arrays
University of Massachusetts Amherst
Srping 2020

Objectives:

This course will provide a working knowledge of the key parameters of modern phased array antenna systems. Phased arrays are a key components in radars, wireless and satellite communications, remote sensing and imaging systems, and in scientific instruments such as radio telescopes. Students will learn to critically evaluate the performance of phased array antenna systems with emphasis on factors that are important for high-performance radar and communication systems such as scanning, sidelobe levels, gain, bandwidth, sensitivity, linearity, etc. Concepts will be emphasized and theory will be developed to support key concepts. Students will learn to perform quantitative analyses of array parameters. The effects of scanning on antenna input impedance will be analyzed and array blindness will be demonstrated. The course will utilize the text, but much material will be drawn from other sources.

Background:

A good understanding of basic antenna theory and performance, and of graduate level electromagnetics for waveguides, plane-wave spectrum, radiation, etc. These topics are contained in textbooks such as*Antenna Theory* by C. A Balanis, *Antenna Theory and Designs*, by W. L. Stutzman and G. A. Thiele, *Time-Harmonics Electromagnetic Field* by R. F. Harrington and *Advanced Engineering Electromagnetics* by C. A. Balanis.

Lectures:

Meeting:	Tu & Th 11:30AM-12:45PM
Location:	Hasbrouck 130
Web-page:	UMass Amherst Moodle (lectures will be recorded via Echo 360, and posted in Moodle)

Instructor:

Name:	Marinos N. Vouvakis
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Phone:	413.577.2148
Office:	Marcus Hall 215J
Office hours:	TBD (and by appointment)

Textbook:

R. J. Mailloux, *Phased Array Antenna Handbook*, 3^{rd} ed., Artech House, 2017, ISBN 1-63081-029-0. (2^{nd} edition would also be acceptable)

References:

- *Phased Array Antennas*, by R. C. Hansen, Wiley, 1998.
- *Microwave Scanning Antennas,* R. C. Hansen (ed.) , Peninsula Publishing, 1985.
- *Finite Antenna Arrays and FSS,* by B. A. Munk, Wiley, 2003.

- *Advanced Array Systems, Applications and RF Technologies,* by N. Fourikis, Academic Press, 2000.
- *Conformal Array Antenna Theory and Design,* by L. Josefsson and P. Persson, IEEE Press, 2006.
- *Modern Antenna Handbook,* by C. A. Balanis (ed.), John Wiley, 2008.
- *Antenna Engineering Handbook,* 4^{th} ed., by J. L. Volakis (ed.), McGraw-Hill, 2007.

Course Outline:

1. **Introductory material**: Course overview, importance/motivation, history, background, basic definitions.

2. **Phased array architectures**: Beamforming architectures, amplification architectures and amplitude taper control architecture, System aspects, SWAP-C, Receive Array system performance metrics: array G/T, NF, IIP3, sensitivity, linearity, dynamic range, array intermodulation products, Transmit Array system performance metrics: EIRP, EVM, spectral regrowth, array intermodulation products.

3. **Finite arrays**: Array factor theory, phased vs timed arrays, amplitude tapers, 2D arrays grading lobes, array factor directivity, gain and quality factor, pattern synthesis, mutual impedance effects, active (scan) impedance/reflection coefficient, active & embedded element pattern, array truncation effects, array scattering, array polarization.

4. **Infinite arrays:** Comparison to finite arrays, Floquet modes, periodic green's function, formulation and analysis for scan reflection coefficient, planar array analysis (dipole, patches, waveguides, current sheet models), dielectric surface waves and scan blindness, grading lobes revisited, superstates and wide angle impedance matching (WAIM).

5. **Transmit Receive Modules**: Architectures, front end modules (duplexers, limiters, high power and low noise amplifiers), phase control (phase shifter technology, true-time delays technology, placement) alternative phase control architectures.

6. **Feed Networks and multi-beam arrays**: Constraint vs unconstraint feeds, series vs. parallel feeds, isolated vs non-isolated feeds, feed symmetry, tapered feeds, adjustable taper feeds. Matrix beamforming networks (Butler, Blass, Nolan), Lens beamforming networks (Rotman, R2R, RkR), Stein's Limit.

7. **Array Errors and Calibration**: Periodic phase & amplitude errors, quantization lobes, beam pointing error and granularity, 2D array quantization lobes, random phase & amplitude errors, gain degradation, RMS SLL, low side lobe arrays.

8. **Non-conventional Arrays (review)**: Time modulated arrays, frequency modulated arrays, wavelength scaled Arrays, thinned and sparse arrays, interferometric arrays, minimum redundancy arrays, timed arrays, array-fed reflectors , reflectarrays and transmitarrays, retrodirective arrays, spatial power combiners.

9. **Digital beamforming**: architectures, A/D conversion, I/Q, calibration), adaptive beamforming (sidelobe cancelers, jammer nulling, mainbeam jamming, adaptive imaging arrays).

Course Policies:

Grading:

HWs (total 3):	30%
Exam:	20%
Paper Reading:	20%
Final Project:	30%

Homeworks/Projects:

Total of 3 HWs/projects handouts. Individual work, but students are allowed to collaborate without exchanging computer codes, files handwritten notes. Students will be given **two-thee weeks to complete each HW/project**. HWs/Projects will be submitted via Gradoscope. Each student will have the opportunity to get seven days extension for one homework/project of her/his choice. Other that, each late homework submission will receive partial credit. No homework will be accepted after solutions have been posted.

Exam:

The only midterm exam will be held during second half of the semester at a time that will be agreed with students, and will be **take-home**. The exam will be comprehensive and based on problems and concepts converged in HWs/projects and during lectures.

Paper Reading:

Individual work. Each student will be assigned to read and present to the class one contemporary paper in the area of phased array systems. The instructor will make efforts to match student's research interests with papers. Students will be given approximately two weeks to read and prepare a **10min presentation on the paper, followed by 5-10 mins of Q & A**. It is expected that students will interact with the instructor regularly to assist them with reading and understanding those works. Presentation sessions will be help during class meetings or if necessary at additional meeting times that have been agreed by the class. Detailed information and sample presentations will be provided ahead of time.

Final Project:

Individual work. Each student will be assigned a final project around spring break. The project involve the analysis or design of a phased array system and the submission of a **written project report** (no longer than 6 double-column pages, IEEE Transactions format). Apart from theoretical foundations in the subject matter, projects may require programing skills (Matlab, Fortran, C or C++) or/and experience with advance RF design tools and electromagnetic modeling tools such as ADS, HFSS, CST, etc. A list of suggested and sample projects will be provided around the end of the first month of classes. Students are welcome to propose their own ideas. In either case, students must meet with the instructor prior to submitting a one-page proposal that outlines: project objectives and specifications, plan of attack, and deliverables. Detailed information and sample projects, report format, etc. will be provided ahead of time.

Academic Misconduct

The students of this course have to comply with the University's Academic Honesty Policies and Procedures `https://www.umass.edu/honesty/`. More specifically the Academic Honesty

Policy states:

"Since the integrity of the academic enterprise of any institution of higher education requires honesty in scholarship and research, academic honesty is required of all students at the University of Massachusetts Amherst.

Academic dishonesty is prohibited in all programs of the University, including online courses. **Academic dishonesty includes but is not limited to: cheating, fabrication, plagiarism, and facilitating dishonesty**. [See Appendix B for detailed examples of behavior that constitutes academic dishonesty.] Appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Instructors should take reasonable steps to address academic misconduct. [See Appendix C for some suggested ways to deal with issues of academic integrity.] Any person who has reason to believe that a student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor upon discovery. Instances of academic dishonesty not related to a specific course should be brought to the attention of the appropriate department head or chair. The procedures outlined below are intended to provide an efficient and orderly process by which action may be taken if it appears that academic dishonesty has occurred and by which students may appeal such actions.

Since students are expected to be familiar with this policy and the commonly accepted standards of academic integrity, ignorance of such standards is not normally sufficient evidence of lack of intent."

Accommodation Statement

The University of Massachusetts Amherst is committed to providing an equal educational opportunity for all students. If you have a documented physical, psychological, or learning disability on file with Disability Services (DS), you may be eligible for reasonable academic accommodations to help you succeed in this course. If you have a documented disability that requires an accommodation, please notify me within the first two.

Inclusivity Statement

We are all members of an academic community with a shared responsibility to cultivate a climate where all students/individuals are valued and where both they and their ideas are treated with respect. The diversity of the participants in this course is a valuable source of ideas, problem solving strategies, and engineering creativity. If you feel that your contribution is not being valued for any reason, please speak with me privately. You may also speak with Dr. Paula Rees, Assistant Dean for Diversity (rees@umass.edu, 413.545.6324, Marston 128), submit a comment to the box on the door of Marston 128, or submit an anonymous comment online `http://tinyurl.com/UMassEngineerClimate`.

Prepared by: Marinos N. Vouvakis
Date: January 21, 2020