

# **ECE 5973: Fundamentals on Phased-Array Antennas**

**Fall 2024**

## **Class information:**

- **Lecture:** M & W 3:00 PM - 4:15 PM (RIL-202)
- **Laboratory:** W 3:00 PM - 4:15 PM (Optional at the Microwave Lab. RIL first floor)
- **Location:** Radar Innovation Laboratory (RIL), RIL-202
- **Credits:** 3 hours
- **Instructor:** Dr. Jorge L. Salazar-Cerreno, **e-mail:** salazar@ou.edu **Tel:** (405) 9227848
- **Instructor office hours:** M 4:30 PM - 5:30 PM (RIL-110 or RIL 202)

## **Course description:**

This graduate course covers the fundamentals of the phased array antennas and most critical design trade-offs for radars and communication systems for civil and military applications. Emphasis on the critical components that degrades the overall performance of phased array antenna systems, especially for atmospheric applications. This course out emphasizes in high-performance radiating elements for PAR, feed-array beamformers and architectures, wide scanning range, mutual coupling, infinite and finite active arrays, T/R modules and technologies, multi-beam arrays, adaptive arrays and side-lobe cancelers and graceful degradation.

## **Prerequisites:**

The student is expected to have a good understanding of basic antenna theory, graduate-level electromagnetic for plane-wave spectrums, and antenna radiation theory. Course prerequisites include ECE4693, ECE5703, or prior consent of the instructor.

## **Textbook:**

Phased Array Antenna Handbook, 2nd Ed. by Robert J. Mailloux Other editions of the book are acceptable.

## **Suggested references:**

The following reference books are not mandatory, but provide valuable background information on phased arrays. One set of these books is available for students to share and must be requested from the professor.

- Phased Array Antenna, 2nd Ed. by Robert C. Hansen
- Antenna Theory Analysis and Design, Constantine Balanis, Fourth Edition

## Topics:

- Introduction to phased array antennas
- Basics of radiating antenna elements
- Basics of array feeding architectures
- Collimation and beam forming
- Grating lobes and lattice array analysis
- Surfaces waves
- Phased array antenna scanning bandwidth
- Mutual coupling
- Array Antenna Synthesis
- Active impedance and scan blindness
- Infinite array theory
- Transmit and receive modules and technology
- Excitation errors in phased arrays (quantization, beam granularity, random errors, side lobes, etc).
- PAR Graceful degradation
- Millimeter wave antennas
- PAR radar systems (AIR, CPPAR, HORUS and PAIR)

## Homeworks:

Homework, which might include some analysis in MatLab, will be assigned regularly. Homework assignment must be turned in at the beginning of the class of the due date. Homework received after the due date will be returned without grading and scored as zero. Each student will allow one late homework during the term without penalty, not to exceed seven calendar days beyond the scheduled due date.

## Laboratory Projects and Final Project:

Three lab. group projects and one individual final project will be assigned during the semester. Software, hardware and course theory will be used in the design and implementation process. If a student's project requires a fabrication process or equipment, training in the use of the RIL facility is mandatory. Material for each project will be provided. It is important that students scheduling the use of the RIL be aware that the priority of the lab is for research, and arrangements for lab use should be made well in advance to avoid interfering with other research projects.

## Project proposal deadline

Every student (or group of students) is required to submit a two-page proposal at **August 31st**. Latex Template will be provided.

Lab. Group projects:

- Lab. Group Project (LGP-1): Isolated radiating element, design, fabrication and test. (Micro-fab and Far-field test are required)

- Lab. Group Project (LGP-2): Mutual coupling, active reflection coefficient, embedded elem. pattern, and finite array characterization and test (Far-field test is required)
- Lab. Group Project (LGP-3): Active array characterization and test (Near-field test is required)

Example of previous projects, Note: each year the projects change

- Final Project 1: Dual-polarized slotted series feed waveguide linear array.
- Final Project 2: Dual-polarized 2D square lattice array with -20 dB SLL.
- Final Project 3: Near-Field array antenna characterization using a 6-axis robotic arm.
- Final Project 4: Near-Field array antenna calibration of an active array antenna.
- Final Project 5: Index gradient 2D scan lens antenna for millimeter wave applications.
- Final Project 6: Phased Array Antenna MatLab ToolBox.
- Final Project 7: Reflectarray antenna for narrow field of view scanning mode.
- Final Project 8: Ultrawide scanning range phased array antenna.
- Final Project 9: Overlapped subarray array antennas using surface wave antenna elements.
- Final Project 10: Deployable array antenna for space communications.

#### **New suggest topics for Fall 2024:**

- mmWave dielectric resonator antenna array
- Leaky-wave linear array antenna
- GRIN lens with beam scanning
- S-band digital sub-array beamforming
- S-band active array with digital sub-array beamforming
- mmWave metallic multibeam antenna lens
- Wearable flexible conformal antenna array
- Fully 3D printed conformal antenna array
- Multibeam antenna array
- W-band series feed antenna array

#### **Exam:**

The first half of the course will establish the theoretical framework for the rest of the semester, and this will be reflected in the Take-home exam. Makeup exams will not be given unless an official excuse is established with the professor prior to the exam. Working in groups is allowed for homework and may be required for projects, but copying or cheating will not be tolerated.

- Take-home exam: October 21th, 2024
- Final Project Presentation & Report: December 12th, 2024, 4:30 - 6:30 pm

#### **Grading:**

- Homeworks (5 to 6): 20%
- Lab. Group Projects (3): 20%

- Exam (1): 20%
- Final Project (1): 60%

### **Course Policies:**

The University of Oklahoma academic honesty policies apply to all course-related materials produced by students. Students are expected to follow all university policies, codes of conduct, and academic integrity requirements.

### **Academic Integrity:**

The Provost's web pages include information on expectations for academic integrity. Please review the material at [http://integrity.ou.edu/students\\_guide.html](http://integrity.ou.edu/students_guide.html). It is the aim of the faculty of the University of Oklahoma to foster a spirit of complete honesty and a high standard of integrity as well as academic excellence. Any attempt by students to present as their own any work that they have not honestly performed is regarded by the faculty and administration as a serious offense and renders the offenders liable to serious consequences, possibly suspension.

### **Course Evaluations:**

Course evaluation will be submitted at the website: <http://eval.ou.edu>. The College of Engineering utilizes student ratings as part of evaluating the teaching effectiveness of each of its faculty members. The results of these ratings are important in the process of awarding tenure, making promotions, and giving salary increases. In addition, faculty members use the evaluation feedback to improve their own teaching effectiveness. Please take this task seriously. Evaluate the courses as honestly and precisely as possible. Your feedback is appreciated.

### **Disability Accommodation:**

The University of Oklahoma is committed to providing reasonable accommodation for all students with disabilities. Students with disabilities who require accommodations in this course are requested to speak with the professor as early in the semester as possible. Students with disabilities must be registered with the Office of Disability Services prior to receiving accommodations in this course. The Office of Disability Services is located in Goddard Health Center, Suite 166, (405) 325-3852 (Voice), (405) 325-4173 (TDD), (405) 325-4491 (Fax), and Email: [drc@ou.edu](mailto:drc@ou.edu).

### **Copyright**

Sessions of this course may be recorded or live-streamed. These recordings are the intellectual property of the individual faculty member and may not be shared or reproduced without the explicit, written consent of the faculty member. In addition, privacy rights of others such as students, guest lecturers, and providers of copyrighted material displayed in the recording may be of concern. Students may not share any course recordings with individuals not enrolled in the class, or upload them to any other online environment.

## **Emergency Protocol**

During an emergency, there are official university [procedures](#) that will maximize your safety.

**Severe Weather:** If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather 1. *LOOK* for severe weather refuge location maps located inside most OU buildings near the entrances 2. *SEEK* refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building. 3. *GO* to the building's severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows. 4. *GET IN, GET DOWN, COVER UP*. 5. *WAIT* for official notice to resume normal activities.

**Armed Subject/Campus Intruder:** If you receive an OU Alert to shelter-in-place due to an active shooter or armed intruder situation or you hear what you perceive to be gunshots:

1. *GET OUT:* If you believe you can get out of the area WITHOUT encountering the armed individual, move quickly towards the nearest building exit, move away from the building, and call 911. 2. *HIDE OUT:* If you cannot flee, move to an area that can be locked or barricaded, turn off lights, silence devices, spread out, and formulate a plan of attack if the shooter enters the room. 3. *TAKE OUT:* As a last resort fight to defend yourself.

For more information, visit <http://www.ou.edu/emergencypreparedness.html>

**Fire Alarm/General Emergency:** If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates: 1. *LEAVE* the building. Do not use the elevators. 2. *KNOW* at least two building exits 3. *ASSIST* those that may need help 4. *PROCEED* to the emergency assembly area 5 *ONCE safely outside, NOTIFY first responders of anyone that may still be inside building due to mobility issues*. 6. *WAIT* for official notice before attempting to re-enter the building.

## **Mental Health Support Services**

If you are experiencing any mental health issues that are impacting your academic performance, counseling is available at the University Counseling Center (UCC). The Center is located on the second floor of the Goddard Health Center, at 620 Elm Rm. 201, Norman, OK 73019. To schedule an appointment call (405) 325-2911. For more information please visit <http://www.ou.edu/ucc>.

## **Religious Holidays:**

It is the policy of the University to excuse absences of students that result from religious observances and to provide, without penalty, for the rescheduling of examinations and additional required class work that may fall on religious holidays. It is the responsibility of the student to make alternate arrangements with the instructor at least one week prior to the actual date of the religious holiday.

### **Adjustments for Pregnancy/Childbirth Related Issues:**

Should you need modifications or adjustments to your course requirements because of documented pregnancy- related or childbirth-related issues, please contact the professor as soon as possible. Generally, modifications will be made where medically necessary and will be similar in scope to accommodations based on temporary disability. Please see [www.ou.edu/content/eoo/pregnancyfaqs.html](http://www.ou.edu/content/eoo/pregnancyfaqs.html) for commonly asked questions.

### **Resources:**

For any concerns regarding gender-based discrimination, sexual harassment, sexual misconduct, stalking, or intimate partner violence, the University of Oklahoma offers a variety of resources, including advocates on-call 24.7, counseling services, mutual no contact orders, scheduling adjustments and disciplinary sanctions against the per- perpetrator. Please contact the Sexual Misconduct Office 405-325-2215 (8-5) or the Sexual Assault Response Team 405-615-0013 (24.7) to learn more or to report an incident.