ECE 802 – Section 604

SENSORS TECHNOLOGIES FOR NONDESTRUCTIVE EVALUATION (NDE)

Fall 2019

COURSE: On-Line Lectures at: https://d2l.msu.edu/

INSTRUCTOR: Dr. Yiming Deng, Associate Professor;
Room 2535B EB; 517-884-0926;
Email: dengyimi@msu.edu

Dr. Lalita Udpa; University Distinguished Professor;
Room 2325A EB; 517-355-9261
Email: udpal@msu.edu

WEB SITE: Optional: www.egr.msu.edu/ndel

LECTURE HRS: M W; 10:20 AM - 11:40 PM, A130 Wells Hall

OFFICE HRS: F: 10:20 AM – 11:40 AM, (Dr. Deng and Dr. Udpa's offices at 2325 EB or NDE Laboratory at 2580 EB)

GRADER: N/A

HELP ROOM HRS: 3:00 PM – 5:00 PM on Fridays
Location: NDE Laboratory 2580 EB

TEXTS: **Required:** None. Lecture notes will be posted online at D2L website.

References:

1. Nondestructive Testing Handbook, Vol. 5, Electromagnetic Testing, Satish S. Udpa, Patrick O. Moore, 3rd Edition.
2. Non-destructive Evaluation Methods, Thomas Luthi, 2014.
3. Handbook of Nondestructive Evaluation, Charles Hellier, McGraw-Hill, 2003.
4. Nondestructive Testing Methods and New Applications, Mohammed Omar
5. Technical presentations and supplemental materials (copyright belongs to NDEL, Michigan State University)

OBJECTIVES: This is an introductory course in nondestructive evaluation, sensors technologies and data analytics. Emphasis is placed on understanding the fundamental physics of NDE sensors and applications on real-world NDE challenges.
The educational objectives of this ECE802-604 are listed, as follows:

- facilitate in-depth study of particular electromagnetic and acoustic aspects of sensors and sensing applications for NDE;

- gain hands-on experiences at NDEL through real-world research problems with an organizational support;
- extend the knowledge, expertise and skills through collaboration with NDE industries, in the form of guest lectures, collaborative projects, and discussion of the issues in industrial practice;
- encourage more students to participate in local and nationwide NDE organizations, e.g. ASNT local chapters, and continue their career in the field of NDE;
- train professionals through in-class and/or distance learning to upgrade their qualifications and prepare them for leadership roles in this field.

The student learning outcomes for ECE802-604 reflect the ABET curriculum philosophy and also tailored to fit ASNT educational goals:

- knowledge of mathematics, science, and engineering for NDE
- awareness of contemporary NDE and Sensor Technologies issues
- ability to use the techniques, skills, and modern engineering tools necessary for engineering practice specific to nondestructive testing
- understanding of basic material science concepts, and the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve NDE problems
- ability to design and conduct electromagnetic and acoustic NDE experiments, as well as to analyze and interpret NDE data
- ability to take measurements and interpret data from NDE systems and address the problems associated with field-flaw interactions
- skills to function on multidisciplinary teams
- ability to communicate effectively

GRADING:

Midterm project 1	25%
Literature review and project proposal submission	10%
Final Project (presentation and report)	35%
Homework (50% Theoretical, 50% Computer assignments) (100 points each)	25%
Attendance and Quizzes	5%

Grading criteria:
4.0 (85% and above); 3.5 (80% to 85%); 3.0 (75% to 80%); 2.5 (70% to 75%); 2.0 (65% to 70%); 1.5 (60% to 65%); 1.0 (55% to 60%), 0.0 (below 55%)

IMPORTANT DATES: Midterm project 1 due: **10/14**, Monday
Project proposal due: **10/23**, Wednesday
Final presentation materials due: **11/27**, Wednesday
Final Report due: **12/11**, Finals week
No Class Dates: Holidays: **9/2** (Monday)

Course Structure

The course is structured to have two in-class lecture modules and one hands-on laboratory module for a total of 14 weeks in the fall2019 semester. In addition, a part of the course design in each module will

be independently developed and can be taught as a short course or tutorial on- or off-campus, onsite or online (NDEL is developing online modules for the ECE online MS program, please talk to the instructors if you would like to get involved!), so the impact and benefit to the NDE, ASNT, and industry community can be maximized. For regular semester-based teaching, the first two-week module (Module 1) of ECE802 will be given at a level to students who just need to have the basic knowledge of engineering analysis, signal processing, and sensory data acquisition after their junior year. A basic and broad understanding of the principles of NDE is provided. In order to attract students to NDE Sensor Technologies fields and eventually help address the increasing needs of NDE engineers and technicians, interaction and collaboration with local NDE industries will be emphasized and strategically integrated with in-class lectures. Guest lectures and field trips will be included in the curriculum. The inter-disciplinary nature of NDE makes the proposed NDE Sensors topic a valuable component of engineering curricula at MSU.

1) In the first two weeks, the proposed introductory NDE module (Module 1) is crucial for students to acquire a basic understanding of general NDE methods before exploring the sensors and sensing systems topics in more details.
2) As a widely used testing method, electromagnetic (EM) NDE sensing and sensor techniques will then be covered in the following module (Module 2) for 8 weeks which are composed of several sub-modules. Ultrasonic, Optical and Thermal NDE sensing and sensor techniques will also be covered in this Module 2 with slightly less emphasis. This second module not only covers the fundamentals but also the applications of major NDE sensing methods. The main objective of this module is to teach students and professionals basic NDE physical principles and sensor characteristic features in use; modeling and simulation for sensors design and optimization; sensor selection based on materials and operation conditions; design, function and applications of different NDE sensors for damage and degradation diagnosis; industrial applications and realization; and data processing and analytics.
3) Hands-on laboratory sessions (Module 3) dedicated to electromagnetic and/or ultrasonic NDE sensors system design, testing and materials/structures evaluation with data acquisition and analysis tasks will be covered for another 2 weeks. The overall course structure is shown in Figure 4.1.

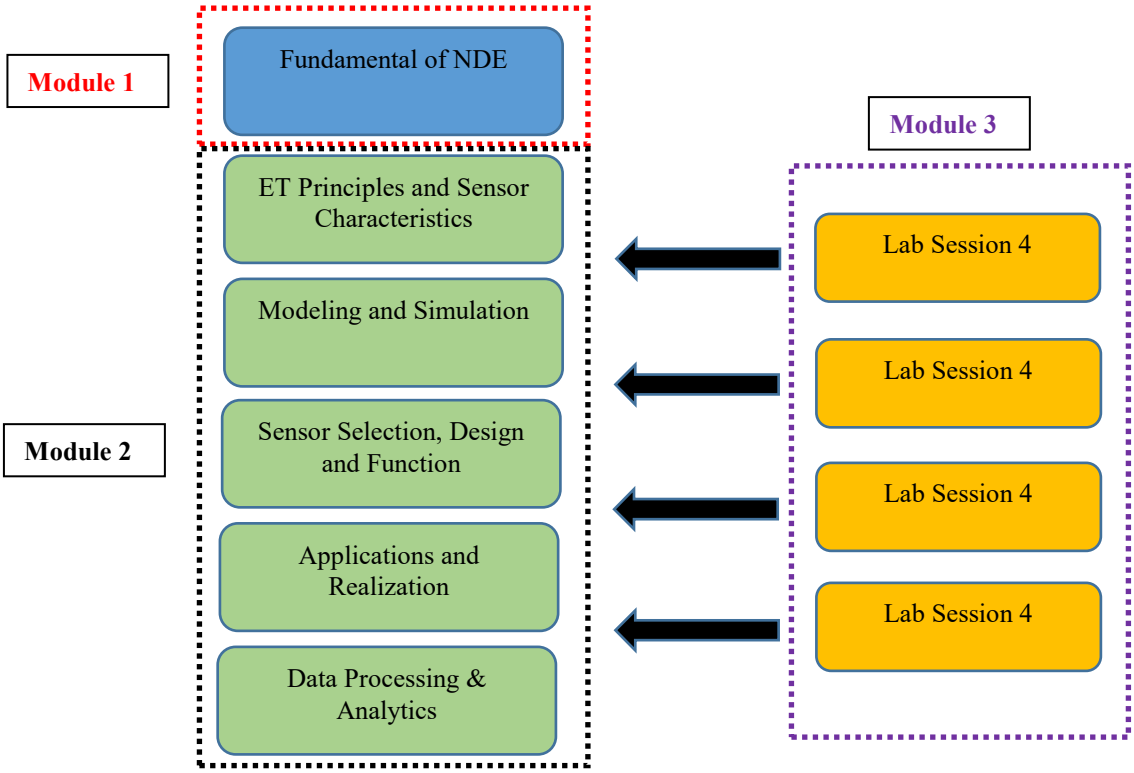

Figure 1: Overall ECE802-604 course structure

4) In the last two weeks, Physics based Signal and image processing, data analysis, pattern recognition for solving inverse problem will be discussed in Module 4.

Additional reading: All EM sensing methods in NDE involve Maxwell's equations and cover a broad range of the electromagnetic spectrum, from static or direct current (DC), such as magnetic particle method, to high frequencies, e.g., X-ray and gamma-ray methods. Advanced electromagnetic NDE sensor technologies are essential for detecting anomalies or defects in both conducting and dielectric materials by generating and acquiring two-dimensional (2D) or three-dimensional (3D) image data based on the electromagnetic principles. A generic EM NDE imaging system can be simply represented as shown in Figure 4.2 (*reprint of instructor's article published on Sensors in 2011). For forward imaging approaches, the excitation transducers couple the EM energy into the test objects, while the receiving sensors measure the response of energy/material interaction. Depending on different energy types and/or levels, various EM sensors/transducers can be used for a broad range of applications, e.g., eddy current imaging, microwave imaging, terahertz imaging, etc. After acquiring and storing the EM images, those data are passed through the inversion techniques block, which involves the defect reconstruction, pattern recognition, and machine learning, etc.

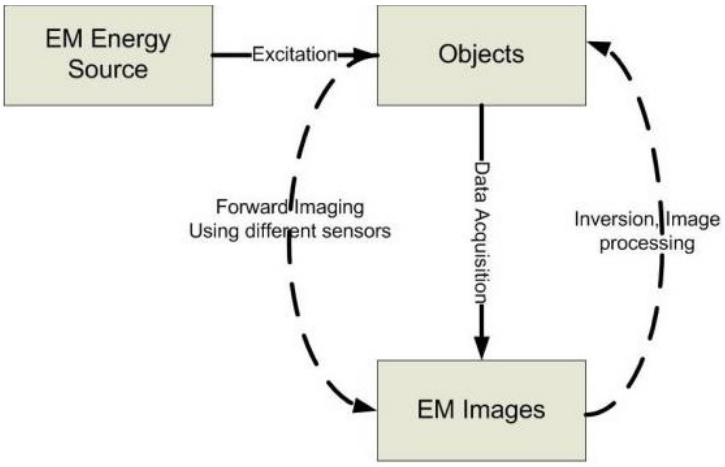

Figure 2: General schematic of electromagnetic NDE sensing and sensor system

The usable frequencies for electromagnetic NDE cover almost the entire EM spectrum, from DC to gamma radiation. The specific topics covered and discussed in the proposed course are as follows, frequencies above the IR and optical bands will not be covered in order to ensure that a balance between the depth and breadth of the curriculum materials is achieved in one semester.

- Fundamentals of NDE (2 weeks)
- Guest Lectures on Ultrasonic NDE introduction and Optical NDE/SHM introduction (1 week)
- Principle of Numerical Modeling in NDE (1 week)
- Principles of Electromagnetic NDE and Sensors (1 week)
- Magnetic Flux Sensor, DC field sensing techniques & Applications (1 weeks)
- Eddy Current Sensors, AC field sensing techniques and applications (2 weeks)
- Microwave, mm-wave and THz-wave Sensors and applications (1 weeks)
- Hands-on NDE Lab sessions (4 lab sessions for 2 weeks)
- Sensory Data Analysis for EM NDT&E (1 weeks)
- Special topics – industry guest lectures (1 week)

HOMEWORK & PROJECTS:

Homework and project (reports, computer codes, etc.) in the course must be submitted in paper form for on-campus students unless the electronic submission is required. Off-campus students, who live more than 25 miles from East Lansing, need to contact dengyimi@egr.msu.edu for the procedure for electronic submission of homework.

Paper homework is to be done on 8.5" x 11" paper using only one side. It must be stapled and ragged edges must be trimmed. Whenever possible, the correct answer is to be circled or boxed. MATLAB and other computer assignment can be submitted either in hardcopy or

electronically through D2L.

Homework is due at the **beginning** of class on the due day. No late homework will be accepted unless prior arrangements have been made. There will be 4-5 homework assignments, which students usually have 1-2 weeks to work on. Please feel free to ask homework questions via e-mail.

Details on the hands-on research project will be provided during class.

POLICIES:

You may work with other students on homework. Some work you submit must be done by only you, which will be explicitly mentioned by the professor before that assignment. Assignments that are identical will all receive a grade of **zero**. You must type and run all of your own computer work. Copying of old assignments or computer files will be dealt with severely. Solutions will be posted one day after the submission deadline. Homework recital and discussion will be scheduled in class and in help room (Dr. Deng's office weekly).

OTHER:

You are not required to attend lectures. However, I will take attendance or quizzes on an unannounced day. Illnesses (with a doctor's excuse) and other excused absences will be handled on a case-by-case basis.

Accommodations for Persons with Disabilities
Students who have a registered disability may be entitled to an accommodation (note taker, separate room for tests, additional time on tests, etc.). Any student granted an accommodation must inform you and show you a VISA form from the Resource Center for Persons with Disabilities (RCPD). We are obligated to provide the described accommodation. If there are questions or concerns that the accommodation is not reasonable, please discuss with the RCPD staff, me, or Dr. Amanda Idema.

Academic Dishonesty
If you have a case of academic dishonesty, it is reportable on the Registrar's Instructor Systems menu where you get class lists and file grades. Whatever is written by you will be transmitted to the student. The student will automatically be required to complete a remedial course on academic integrity, and the information will be shared confidentially with me and the Associate Provost for Undergraduate Education for further consideration. The student will have appeal rights. For questions, see the Ombudsperson's website or contact me.

Policy on religious observances
If any exam or assignment conflicts with a religious observance, let me know **ahead of time** and we will make other arrangements.

Policy on recording lectures

You may make audio recordings of the lectures **for personal use only**. Do not post or otherwise distribute the recordings. Video recording are not allowed.

DETAILED TOPICS:

Week		Module	Topics	Comments
1	Aug 26	1	Course logistics; Introduction to NDE and Math Review	First class: Aug 28
2	Sept 2	1	Introduction to NDE and Math Review	No class: Sept 2 (Holiday)
3	Sept 9	1	Guest lectures: Ultrasonic NDE by Dr. Chakrapani Optical NDE/SHM by Dr. Han	ENDE and ISEM trip: Dr. Deng and Dr. Udpa
4	Sept 16	2	Introduction to Numerical Modeling for NDE (2 Lectures)	NDEL Senior PhD student: Anton E.
5	Sept 23	2	Principle of eNDE and Sensors	Midterm Project Assignment
6	Sept 30	2	DC field sensing: MFL, etc.	
7	Oct 7	2	AC field sensing: Eddy Current based methods	Final Project Topics
8	Oct 14	2	AC field sensing: Eddy Current based Methods	Midterm Project Submission due on 10/14
9	Oct 21	2	AC field sensing: High frequency Methods	Final Project Proposal due
10	Oct 28	2	AC field sensing: High frequency Methods	
11	Nov 4	3,4	Lab Sessions; Data Acquisition and Analysis	
12	Nov 11	3,4	Lab Sessions; Data Acquisition and Analysis	
13	Nov 18	3,4	Lab Sessions; Data Acquisition and Analysis	
14	Nov 25	3	Lab Sessions; Special Topic by industry collaborators	Presentation materials due
15	Dec 2		Presentations and Demos	ECE802 NDE Sensors Workshop
16	Dec 9		Final Project reports due	Finals Week: Reports and Codes due on D2L