FALL 2020

ECE 7440 T18 – Wavefield Imaging and Inversion in Electromagnetics and Acoustics

COURSE DESCRIPTION:

Microwave and acoustic imaging has various applications in engineering, geoscience, medicine, security and various others fields. At the core of these applications is solution of the inverse scattering problem. This course provides introduction to the mathematical and numerical approaches to the solution of such inverse problems. Laboratories are used to reinforce the course material using computer programming exercises in MATLAB or C++ and provide students with ready-to-use solvers for practical problems in research.

COURSE OBJECTIVE:

The goal of this course is to teach students the theory and practice of making images from waves. By the end of the course, students will be able to create such images from both a theoretical and practical perspective – that is, they will be able to derive a number of imaging algorithms and apply these algorithms to real data to make images of inside of a various set of targets (e.g. biomedical targets).

PRE-REQUISITES:

No formal prerequisite.
Note: course material has significant mathematical and programming content (MATLAB or C++).

CONTACT HOURS:

2 lectures per week (~3 hours total), 5 labs/Assignments.

COURSE CONTENT:

1. Review of basic electromagnetic theory.
    a. Maxwell Equations.
    b. TM– and TE– scattering.
    c. Green's functions.
2. Inverse problems.
    a. Classification of inverse problems.
        i. Inverse source problem.
        ii. Inverse scattering problem.
        iii. Relation between inverse source and inverse scattering problems.
    b. Formulation of forward and inverse scattering problems
        i. Integral equation formulation.
        ii. Differential equation formulation.
    c. Inverse problem solution.
        i. Existence and uniqueness of the solution.
        ii. Minimum norm solution.
        iii. Least-squares solution.
        iv. Regularized least-squares solution.

3. Inversion methods.
    a. Classification of inverse methods.
    b. Direct approximate methods.
        i. Born approximation.
        ii. Extended Born approximation.
        iii. 2-D diffraction tomography based on Born approximation.
    c. Direct iterative methods. Distorted Born iterative method (DBIM).
    d. Optimization methods. Contrast source inversion method (CSI).

HOMEWORK (LAB/ASSIGNMENT CONTENT):

1. Implementation of forward solver for 2-D transverse magnetic (TM_z) scattering problem based on paper [2].
2. Solution of inverse TM_z scattering problem using minimum-norm, least-squares and regularized least-squares.
3. 2-D diffraction tomography based on Born approximation.
4. Solution of inverse scattering problem using distorted Born iterative method (DBIM).
5. Solution of inverse scattering problem using contrast source inversion method (CSI).

TEXTBOOK:

[1] **M. Oristaglio and H. Blok, "Wavefield imaging and inversion in electromagnetics and acoustics", Delft University, Lecture Notes, 1995 (available in pdf form from instructor upon request).**

[2] J. Richmond. "Scattering by a Dielectric Cylinder of Arbitrary Cross Section Shape," IEEE Trans. on Antennas and Propagation, 1965.

[3] W. C. Chew and Y. M. Wang. "Reconstruction of Two-Dimensional Permittivity Distribution Using the Distorted Born Iterative Method," IEEE Trans. on Medical Imaging, Vol. 9, No. 2, June 1990.

[4] C. Gilmore. "Towards and Improved Microwave Tomography System," Ph.D. dissertation, Dept. Elect. Comput. Eng., Univ. of Manitoba, 2009.

[5] A. Abubakar, W. Hu, P. van den Berg, and T. Habashy, "A finite-difference contrast source inversion method," Inverse Problems, vol. 24, p. 065004 (17pp), 2008.

GRADE ANNOUNCEMENTS:

TBA – Due to COVID-19, this date to be announced by the Registrar's Office

EVALUATION:

Your final course grade is determined by your performance in the components list below in the Evaluation Table (assignments/labs, quizzes, and a final examination. Students must receive a minimum of 50% on the final examination and must complete and pass all components in the course in order to be eligible to receive a passing grade.

Each component is weighted as follows:

COMPONENT	NO	VALUE %	TOTAL VALUE	DETAILS / ADDITIONAL INFO
Labs/Assignments	5	30%	30	
Quizzes	5	20%	20	
Final Examination	1	50%	50	
TOTAL			100	

GRADE SCALE:

LETTER	MARK	LETTER	MARK	LETTER	MARK	LETTER	MARK
A+	95-100	B+	80-84	C+	65-69	D	45-54
A	85-94	B	70-79	C	55-64	F	<45

INSTRUCTOR INFO:

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Office Hours: .... By appointment

VOLUNTARY WITHDRAW:

November 23, 2020

REQUIREMENTS/REGULATIONS

Student Responsibilities: It is the responsibility of each student to contact the instructor if he/she is uncertain about his/her standing in the course and his/her potential for receiving a failing grade. Students should also familiarize themselves with Sections 4 and 6 of the Regulations dealing with, among others, incomplete term work, deferred examinations, attendance and withdrawal, etc.

Lectures: Attendance at lectures is essential for successful completion of this course. Students must satisfy each evaluation component in the course.

ACADEMIC INTEGRITY

Students are expected to conduct themselves in accordance with the highest ethical standards of the Profession of Engineering and evince academic integrity in all their pursuits and activities at the university. As such, in accordance with the General Academic Regulations and Requirements of the University of Manitoba, Section 7.1, students are reminded that plagiarism* or any other form of cheating is subject to serious academic penalty (e.g. suspension or expulsion from the faculty or university) regardless of media

- examinations
- assignments
- laboratory reports
- term exams

A student found guilty of contributing to cheating in examinations or term assignments is also subject to serious academic penalty

Please refer any questions regarding Academic Integrity to your course instructor.

***Plagiarism**: to steal and pass off (the ideas or words of another) as one's own; use (another's production) without crediting the source