Electrical and Computer Engineering

ECE7440 – T02

WAVEFIELD IMAGING AND INVERSION IN ELECTROMAGNETICS AND ACOUSTICS

COURSE OUTLINE - WINTER 2019

Course Objectives

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.

Contact hours

1 lecture/discussion session per week (~2.5 hours), 5 labs.
Video-lectures and notes available online.
3 credit hours.

Prerequisites

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

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).

Lab 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 and papers

[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.

Evaluation

The final course grade will be determined from a student's performance in quizzes, labs and oral lab exams. The weighting of each of these components will be as follows:

Component	Value	Details
Quizzes	20%	10 quizzes (5 in lectures, 5 in labs)
Labs	30%	5 labs + lab reports.
Final Exam	50%	Final Exam

Note:

- The voluntary withdrawal date for this course is **March 20, 2019**.
- Attendance at lectures is essential for successful completion of this course. Students must satisfy each evaluation component in the course.
- It is the responsibility of each student to contact the instructor if he or she is uncertain about his or her standing in the course and about his or her potential for receiving a failing grade. Students should also familiarize themselves with Sections 4 and 6 of the Regulations dealing with incomplete term work, deferred examinations, and attendance and withdrawal.

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 in examinations, assignments, laboratory reports or term tests is subject to serious academic penalty (e.g. suspension or expulsion from the faculty or university). A student found guilty of contributing to cheating in examinations or term assignments is also subject to serious academic penalty.

Instructor

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Teaching Assistant

TBA

Office Hours

After lectures or by appointment