***A Short Course Proposal*** to ***NEMO 2019***, IEEE MTT-S International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization, May 29-31, 2019, Cambridge, MA

**Tentative topic**: Broadband Green's functions for electromagnetic and acoustic wave scattering

**Abstract**: Green's functions are associated with point source responses and are key to integral equation formulations of wave scattering problems. Earlier efforts on Green's function are on analytical formulations of free space, of circular cylinders and spheres, of rectangular or circular waveguides and cavities, etc. These known point source responses are limited to few special structures. Green's functions with periodic sources have also been studied but are limited to sources placed in empty lattice. The Green's function of waveguides, cavities, and periodic structures are typically represented in slowly converging series that requires special techniques to handle. In this tutorial, we first review the concept and fundamentals of Green's function and the basic procedures to formulate integral equations. We then shift to the focus of the course which involves Green's function of periodic structures. We discuss a recently developed method to effectively compute both the empty lattice Green's function and the Green's functions including arbitrarily shaped periodic scatterers. The Green's functions are represented in fast converging band modal fields. The representation is suitable for broadband evaluations as the band field solutions are independent of wavenumbers. The broadband Green's function approach also yields accurate band field solutions and band eigenvalues that account for strong multiple scattering within the infinite periodic scatterer array. The derived Green's functions are then applied to finite array scattering and impurities/ defects scattering problems as encountered in the design and engineering of metamaterials and photonic crystals. We also discuss the application of the broadband Green's function in analyzing exotic wave phenomena associated with topological acoustics.

**Course objective**:

The short course aims to familiarize the audience with the concept and technique of the broadband Green's function and with various applications of the technique in both electromagnetic and acoustic wave scattering analysis. Audience will get exposed to rigorous formulation of integral equations with various Green's functions for various problems and understand the advantages of the broadband Green's function technique. Audience will see the connection between integral equations and eigenvalue problems and learn a hybrid method to accurately compute band modal field solutions and a modal method to effectively compute the Green's function including periodic scatterers. Audience of interest will be able to apply the technique to problems of their own interest that is related to both homogeneous and inhomogeneous wave equations, and where broadband analysis is desired.

**Course outlines**:

- A brief review of the concept and fundamentals of Green's function and the basic procedures to formulate integral equations
- Scattering of periodic structure, the empty lattice Green's function, and the concept of the broadband Green's function
- The broadband Green's function applied to formulate liner eigenvalue problems for broadband characterization of band structures and band modal fields, including efficient band field normalizations;
- Generalization and the high order broadband Green's function;
- The modal method to derive broadband Green's function including periodic scatterers;
- The broadband Green's function including periodic scatterers applied to analyze scattering from bounded periodic arrays and periodic arrays with impurities or defects;
- Broadband Green's function applied to formulate nonlinear eigenvalue problems for characterization of topological acoustics;
- Other possible applications of the broadband Green's function technique;

**Estimated length of the tutorial/short course**: (2.5~3hrs)

**Short-sketch of the instructors**: Shurun Tan and Leung Tsang

**Shurun Tan**

Dr. Shurun Tan is presently a postdoctoral research fellow at the University of Michigan. He will join the Zhejiang University / University of Illinois at Urbana-Champaign Institute as an assistant professor in January 2019. His research interests are on electromagnetic theory, computational and applied electromagnetics. These includes wave propagation and scattering in random media and periodic structures, radar and radiometric geophysical remote sensing of terrestrial snow, polar ice sheet, sea ice, ocean, and vegetated land surfaces, photonic crystals and metamaterials, topological photonics, Casimir forces, electromagnetic compatibility and signal integrity, multi-scale and multi-physics analysis, etc.

Shurun Tan was born in Gaomi, Shandong, China. He received the B.Eng. from the School of Information Science and Engineering and the Chien-Shiung Wu College of the Southeast University, Nanjing, China, in June 2009. He received the M.Sc. from the same School of Information Science and Engineering and the State Key Lab of Millimeter Waves at the Southeast University in March 2012. He received the Ph.D. degree in Electrical Engineering from the Department of Electrical Engineering and Computer Science and the Radiation Laboratory at the University of Michigan, Ann Arbor, MI, USA, in December 2016. From Dec. 2010 to Nov. 2011, he was a Visiting Student with the Department of Electrical and Computer Engineering, the University of Houston, Houston, TX, USA. From Sep. 2012 to Dec. 2014, he was a PhD candidate with the Department of Electrical Engineering, the University of Washington, Seattle, WA, USA. From Jan. 2015, he has been affiliated with the Radiation

Laboratory, and the Department of Electrical Engineering and Computer Science, the University of Michigan, Ann Arbor, first as a PhD candidate, and recently as a postdoctoral research fellow since Jan. 2017.

Shurun Tan was the recipient of the Young Scientist Award in the 2018 Progress In Electromagnetics Research Symposium (PIERS) in Toyama, Japan. He received the travel grant from the U.S. National Committee for International Union of Radio Science (USNC-URSI) in the 2017 URSI General Assembly & Scientific Symposium (GASS) in Montreal, Canada. He won the honorable mention in the student paper competition in the 2016 IEEE International Symposium on Antennas and Propagation (APS) in Puerto Rico. He serves in the PIERS conference publication committee. He constantly reviews for more than 10 renowned academic journals and international conferences. He is the session organizer for the special issue in Water Resource Research on Advances in Remote Sensing, Measurement, and Simulation of Seasonal Snow. He is a member of the American Engineering Honor Society Tau Beta Pi.

**Leung Tsang**

Leung Tsang is presently a Professor of Electrical Engineering and Computer Science at the University of Michigan, Ann Arbor. Leung Tsang was born in Hong Kong. He completed High School at Wah Yan College, Kowloon, Hong Kong. He received the SB, SM, EE, and Ph.D. degrees all from the Department of Electrical Engineering and Computer Science of the Massachusetts Institute of Technology. He was an Assistant/Associate Professor of Electrical Engineering at Texas A&M University, College Station, Texas in 1980-1983. He was a Professor of Electrical Engineering at the University of Washington, Seattle, in 1983-2014, and was the Department Chair of UWEE in 2006-2011. Between 2001-2004, he was on leave from University of Washington and was a Professor Chair at the Department of Electronic Engineering of the City University of Hong Kong. He was the Editor-in-Chief of the IEEE Transactions on Geoscience and Remote Sensing in 1996-2000. He was the President of IEEE Geoscience and Remote Sensing Society 2006-2007. Since April 2008, he has been the President of the Electromagnetics Academy, Cambridge, Massachusetts.

Dr. Tsang is a Fellow of the Optical Society of America. He was the recipient of the IEEE Third Millennium Medal in 2000 and the Outstanding Service Award from the IEEE Geoscience and Remote Sensing Society in 2000, the Distinguished Achievement Award from the IEEE Geoscience and Remote Sensing Society in 2008 and the Fiorino Oro Award from the CeTeM, Italy in 2010, the William Pecora Award co-sponsored by the US Department of Interior and NASA in 2012, the 2013 IEEE Electromagnetics Award, and the 2018 Hendrik van de Hulst light-scattering Award.

Dr. Tsang is the co-author of "Theory of Microwave Remote Sensing" and "Scattering of Electromagnetic Waves" Volumes 1, 2 and 3. His current research interests include waves in random media and rough surfaces, remote sensing, computational electromagnetics, signal integrity and optics.