

## **SC 4 Transformation electromagnetics and its applications to antenna engineering**

Course Lecturers Prof. Yang Hao  
Prof. Raj Mittra

### **Course Description**

Current designs of electromagnetic cloaks are largely based on the use of metamaterials and on a technique called "transformation optics/electromagnetics." Free space cloaks require materials with extreme properties and, hence, they are difficult to implement in practice. However, the theory of "transformation optics/electromagnetics" offers a useful design tool for antenna engineers, and enables them to develop novel antennas. In this course, the concepts of transformation electromagnetics are introduced first, and later applied to the design of antennas and microwave devices such as flat reflectors, lenses and electrically small antennas. Novel FDTD techniques to deal with the design of gradient index metamaterials will be also demonstrated. In addition to the above, a novel design strategy based on field transformation technique will also be included in the presentation.

The main topic/technical areas to be covered in this course are:

- What is transformation electromagnetics (YH and RM)?
- An overview of current transformation electromagnetics research (YH);
- Fundamentals of differential geometry including coordinate transformation and metric tensors etc;
- Introduction of Maxwell's equations in curvilinear coordinate systems, including mesh generation, material and geometry relations (YH);
- Formulae and simulation results of sample devices based on the FDTD method including dispersive and conformal FDTDs (YH and RM);
- Design of gradient index materials and metamaterials including material property extraction and FDTD modeling of physical structures of transformation devices (RM);
- Applications and experimental demonstration of Transformation Electromagnetics in antenna and microwave designs (YH);
- Future Challenges and Industrial Applications (RM).

The short course is designed for antenna engineers and researchers with basic knowledge of antennas, electromagnetics and microwave engineering. It is also ideal for PhD students who are currently studying projects related to metamaterials and antennas.

### **Biography**

**Yang Hao (M'00–SM'06)**, received the Ph.D. degree from the Centre for Communications Research (CCR), University of Bristol, Bristol, U.K., in 1998. From 1998 to 2000, he was a Postdoctoral Research Fellow with the School of Electrical and Electronic Engineering, University of Birmingham, U.K. In May 2000, he joined the Antenna Engineering Group, Queen Mary College, University of London, London, U.K., first as a Lecturer and was promoted to Reader in 2005, and Professor in 2007. He is active in a number of areas including computational electromagnetics, electromagnetic bandgap structures and microwave metamaterials, antennas and

radio propagation for body centric wireless networks, active antennas for millimeter/submillimeter applications and photonic integrated antennas. He is a co-editor and coauthor of the books *Antennas and Radio Propagation for Body-Centric Wireless Communications* (Boston, MA: Artech House, 2006), and *FDTD modelling of Metamaterials: Theory and Applications* (Boston, MA: Artech House, 2008), respectively.

Professor Hao is an Associate Editor for the *IEEE Antennas and Wireless Propagation Letters* and *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*. He was also a Co-Guest Editor for the *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION*. He is a Vice-Chairman of the Executive Team of IET Antennas and Propagation Professional Network and a member of the “New Emerging Technology” Committee of the IEEE Antenna and Propagation Society. He is also a member of Board of the European School of Antenna Excellence, a member of EU ASSIST Cost Action and the Virtual Institute for Artificial Electromagnetic Materials and Metamaterials, “Metamorphose VI AISBL”. He has served as an invited (ISAP’07, LAPC’07, IWAT’08) and keynote speaker (ANTEM’05, IWAT’10), a conference General Chair (LAPC’08, Metamaterials’09), a Session Chair and short course organizer at many international conferences.

Professor Hao was elected a Fellow of the ERA Foundation in 2007 and a Fellow of IET in 2010.

**Raj Mittra** is Professor in the Electrical Engineering department of the Pennsylvania State University. He is also the Director of the Electromagnetic Communication Laboratory, which is affiliated with the Communication and Space Sciences Laboratory of the EE Department. Prior to joining Penn State he was a Professor in Electrical and Computer Engineering at the University of Illinois in Urbana Champaign. He is a Life Fellow of the IEEE, a Past-President of AP-S, and he has served as the Editor of the *Transactions of the Antennas and Propagation Society*. He won the Guggenheim Fellowship Award in 1965, the IEEE Centennial Medal in 1984, the IEEE Millennium medal in 2000, the IEEE/AP-S Distinguished Achievement Award in 2002, the AP-S Chen-To Tai Distinguished Educator Award in 2004 and the IEEE Electromagnetics Award in 2006. He has been a Visiting Professor at Oxford University, Oxford, England and at the Technical University of Denmark, Lyngby, Denmark. He has also served as the North American editor of the journal *AEÜ*.

His professional interests include the areas of Communication Antenna Design, RF circuits, computational electromagnetics, electromagnetic modeling and simulation of electronic packages, EMC analysis, radar scattering, frequency selective surfaces, microwave and millimeter wave integrated circuits, and satellite antennas.

He has published over 1000 journal and symposium papers and more than 40 books or book chapters on various topics related to electromagnetics, antennas, microwaves and electronic packaging. He also has three patents on communication antennas to his credit. He has supervised about 100 Ph.D. theses, 100 M.S. theses, and has mentored more than 50 postdocs and Visiting scholars. He has directed, as well as lectured in, numerous short courses on Computational Electromagnetics, Electronic Packaging, Wireless antennas and Metamaterials, both nationally and internationally.