UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Numerical methods and Simulation Techniques for RF System Design"

Prof. Etienne Perret

Univ. Grenoble Alpes, Grenoble INP – France

E-mail address: Etienne.Perret@grenoble-inp.fr

Short Abstract:

Today, the use of simulation software is essential for the design of Radio Frequency systems. Year after year, these commercial software are becoming more and more powerful in terms of calculation time, enabling ever more advanced structures to be simulated. Although they all aim to solve the same equations (Maxwell's equations), they are based on different numerical methods, each with its own advantages and disadvantages. The main objective of this course is to understand how these different methods can impact the use of these commercial software. A practical implementation through a labwork will give a precise example of how to implement one of these methods to simulate an antenna with Matlab.

Objectives

• To be able to make the connection between mathematical expressions (Maxwell's equations) and the use of commercial CAD RF software.
• To be able to use the main functions available in the common computational software (MATLAB) to address electromagnetic problems. Develop basic knowledge on MATLAB to solve partial differential equations that can be find in electromagnetic problems.
• To be able to provide theoretical elements of comparison through the implementation of various numerical methods (finite differences, method of moment, finite elements ...).
• To be able to correctly use commercial EM simulators.

Keywords:

RF simulators, numerical methods for microwave devices, Finite Differences, Method of Moments, Finite elements, Practical use of a RF simulation software.

Course Contents in brief:

0. Introduction : EM Simulators
    - 0.1 Practical implementation of theoretical aspects
    - 0.2 Numerical methods / simulators
    - 0.3 Simulators: within the reach of every user?
1. Formulations of a problem – introduction to the main numerical method used in RF
    - 1.1 Homogeneous wave equation
    - 1.2 Integral equation
    - 1.3 Variational approach
    - 1.4 Semi-analytical approaches
    - 1.5 Operators approximation
    - 1.6 Solution domain
2. Numerical methods
    - 2.1 Method of Moments (MoM)
    - 2.2 Finite Difference (FD)
    - 2.3 Basics of the Finite Element Method (FEM)

Total # of hours of lecture:

16 hours (4 hours a day for 4 days)

References:

[1] Sadiku M. N. O., "Numerical Techniques in Electromagnetics with MATLAB", Third Edition, CRC Press, 2009.
[2] Orfanidis S. J., "Electromagnetic Waves and Antennas", Initially posted online in November 2002. Latest revision date - August 1, 2016, www.ece.rutgers.edu/~orfanidi/ewa.
[3] Balanis C., "Advanced Engineering Electromagnetics", 2nd Edition, John Wiley, 2012 – Chap.12.
[4] Makarov S. N., "Antenna and EM Modeling with MATLAB", Wiley, 2002.
[5] Gibson, "The method of moments in electromagnetics", Chapman & Hall / CRC Press, 2007.
[6] Elsherbeni A., Demir V., "The Finite Difference Time Domain Method for Electromagnetics: With MATLAB Simulations", SciTech Publishing, 2009.
[7] Jin J-M, Riley D. J., "Finite element analysis of antennas and arrays", IEEE Press : Wiley, 2009.
[8] Yu W., "Electromagnetic Simulation Techniques Based On The FDTD Method", John Wiley & Sons, 2009.
[9] Harrington R.F., "Fields computation by Moment Method", New York IEEE Press, 1993.
[10] Sullivan D., "Electromagnetic Simulation Using the FDTD Method", IEEE Computer Society Press, 2000.

Requirements:

Electromagnetic / Microwave Circuit : Electromagnetics, basic knowledge in Radio Frequency

Mathematics: basic knowledge in mathematics (linear algebra in particular)
Software: basic knowledge in Matlab

CV of the Teacher

Etienne Perret (S'02–M'06–SM'13) received the Eng. Dipl. degree in electrical engineering from the Ecole Nationale Supérieure d'Electronique, d'Electrotechnique, d'Informatique, d'Hydraulique, et des Télécommunications, Toulouse, France, 2002, and the M.Sc. and Ph.D. degrees in electrical engineering from the Toulouse Institute of Technology, Toulouse, in 2002 and 2005, respectively. From 2005 to 2006, he held a post-doctoral position with the Institute of Fundamental Electronics, Orsay, France. He was appointed Associate Professor in 2006 and Full Professor in 2022 of electrical engineering at Univ. Grenoble Alpes, Grenoble INP, France, where he heads the ORSYS Research Group (20 researchers) from 2015 to 2022. From 2014 to 2019, he has been a Junior Member with the Institut Universitaire de France, Paris, France, an institution that distinguishes professors for their research excellence, as evidenced by their international recognition. From 2015 to 2020, he has been an appointed Member of the French National Council of Universities. He has authored or co-authored more than 250 technical conferences, letters and journal papers, and books and book chapters. He holds several patents. His works have generated more than 4600 citations. His current research interests include wireless communication systems based on the principle of backscatter modulation or backscattering of EM waves especially in the field of RFID and chipless RFID for identification and sensors. His research interests also include electromagnetic modeling of passive devices for millimeter and submillimeter-wave applications, and advanced computer-aided design techniques based on the development of an automated codesign synthesis computational approach. Prof. Perret has been a Technical Program Committee member of the IEEE International Conference on RFID, the IEEE RFID TA; and currently he is a member of the IMS Technical Paper Review Committee. He was a recipient of several awards like the MIT Technology Review's French Innovator's under 35 in 2013, the French Innovative Techniques for the Environment Award in 2013, the SEE/IEEE Leon Brillouin Award for his outstanding achievement in the identification of an object in an unknown environment using a chipless label or tag in 2016, the IEEE MTT-S 2019 Outstanding Young Engineer Award, the Prix Espoir IMT – Académie des sciences in 2020 and the Grand Prix de l'Electronique Général Ferrié in 2021. He was a Keynote Speaker and the Chairperson of several international symposiums. Etienne Perret was awarded an ERC Consolidator Grant in 2017 for his project ScattererID.

Final Exam: homework: solving a problem introduced during the lesson using Matlab.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

Day1 – 0. Introduction – 1. Formulations of a problem – 4 hours

Day2 – 2. 1 Methods of Moment - 4 hours

Day3 – 2.2 Finite Difference (FD) & 2.3 Basics of the Finite Element Method (FEM) – 2 hours | Labwork with Matlab – 2 hours

Day4 – Labwork with Matlab – 4 hours