UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Advanced Applications of Multipole Analysis in Electromagnetics"

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Short Abstract: Multipole Analysis counts to the classical methods in Electromagnetics, and its outstanding mathematical and physical features are of practical importance for many areas of modern electromagnetic applications and developments. Of course, multipole techniques are not only used for analytically treating simple problems. Rather, they are applied to enhance the features of numerical methods (e.g., for the MultiLevel Fast Multipole Approach - MLFMA), for a very accurate probe-corrected near field antenna measurement, for investigating the general limits and features of radiating structures, or in the context of distinguishing very low quasi-stationary magnetic fields coming from the brain to those coming from external sources (Signal-Space Separation method), to mention just a few. Finally, multipole analysis allows a unique insight into - and thus deepens the understanding of - the mathematical and physical properties of electromagnetic fields.

After a brief introduction and motivation the course summarizes the derivation of the spherical-multipole expansion of the electromagnetic field including a discussion of its physical interpretation and low-frequency interpretation in case of a quasi-stationary magnetic field. In a kaleidoscopic manner then three examples of applications will be demonstrated: The process of radiation including the interpretation of radiated and reactive (non-radiated) energies, the spherical antenna near-field measurement, and the application of a spherical-multipole expansion for the noise reduction in sensoring bio-magnetic fields.

Course Contents in brief:

- Introduction 6hrs.
  - History and classical applications
  - Derivation of the spherical-multipole expansion
  - Physical interpretation as modes
  - Specialization to quasi-stationary magnetic field

- Radiated fields 5hrs.
    - Multipole interpretations of near-fields and far-fields
    - Inseparability of radiated and non-radiating field parts
    - What would be an optimal antenna?

- Spherical antenna near-field measurement 4hrs.
    - Basis outline of a measurement system
    - Summary of the multipole approach
    - Probe-corrected measurement system

- Noise reduction for bio-magnetic measurements 4hrs.
    - Bio-magnetic measurements
    - Example: Magnetoencephalography
    - Distinguishing between internal and external magnetic fields

- Summary, Conclusion and Outlook 1hr.

Total # of hours: 20

References:

1. Klinkenbusch, L.: Brief Review of Spherical-Multipole Analysis in Radio Science. Review of Radio Science, in: URSI Radio-Science Bulletin, March 2008, 5-16.
2. Blume, S.; Klinkenbusch, L.: Spherical-Multipole Analysis in Electromagnetics. In: D.Werner, R. Mittra (ed.): Frontiers in Electromagnetics. IEEE Press 2000, 553-608.
3. Hansen, J. E., Spherical near-field antenna measurements, Peter Peregrinus Ltd., London: 1988.
4. Adam, J., Klinkenbusch, L., Mextorf, M., and Knoechel, R., “Numerical multipole analysis of ultra-wideband antennas," IEEE Trans. on Antennas and Propagation 58, 3847-55, 2010.
5. Taulu, S., Kajola, M., “Presentation of electromagnetics multichannel data: the signal space separation method,” J. Appl. Phys. **97**, 124905-10, 2005.

CV of the Teacher

Ludger Klinkenbusch received the Diploma degree and the Dr.-Ing. degree (summa cum laude) in Electrical Engineering from the Ruhr-Universität Bochum (RUB), Germany, in 1986 and 1991, respectively. From 1991 to 1996, he was a Research Associate in the Faculty of Electrical Engineering at RUB. He received the Habilitation degree and was appointed Lecturer in 1996. In 1998, he joined the Faculty of Engineering at Kiel University as Professor of Computational Electromagnetics and Director in the Department of Electrical and Information Engineering. His areas of interest comprise theoretical and computational aspects of scattering and diffraction, numerical methods for high- and low-frequency electromagnetics, theoretical aspects of electromagnetic compatibility, and the solution of forward and inverse problems in bio-magnetic applications. He also has been working as consultant for industry in the context of antenna near-

field measurements. Dr. Klinkenbusch is a Fellow of IEEE for “contributions to spherical-multipole analysis of electromagnetic fields,” an elected member of URSI Commission B, and a member of German VDE.

Room and Schedule

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

Schedule:

5 to 9 September, 2016: 9:00-13.00 each day