Research Networking Programmes

Science Meeting – Scientific Report

***Proposal Title**: 8th LEMA-EPFL Workshop on Integral Techniques for Electromagnetics (INTELECT' 2014)*

***Application Reference N°**: 5672*

1) Summary

The Workshop INTELECT 2014 was organized with the goal of exchanging ideas and experiences in the integral equation based analysis of high-frequency (millimeter waves and above) electromagnetic structures, as well as in the development of accurate and efficient software for designing electromagnetic devices.

After the success of Lausanne, Switzerland (2007), Chiclana, Spain (2008), Istanbul, Turkey (2009), Diablerets, Switzerland (2010), Florence, Italy (2011), Sevilla, Spain (2012) and Dubrovnik, Croatia (2013), LEMA-EPFL Switzerland has organized the 8th Workshop on "Integral Techniques for Electromagnetics" (INTELECT'2014). This one-day workshop took place on 26 September 2014 in Ovronnaz, Valais, Switzerland.

The topics of interest are related to development of fast and accurate programs, based on solving integral equations in electromagnetics, for analyzing different types of challenging electromagnetic structures: antennas (in particular complex and large antennas in terms of wavelength such as lens antennas), guiding and focusing structures and periodic structures. Examples of related problems are: volumetric integral equation techniques, mixed-potential integral equation techniques, higher order basis functions, modelling of rotationally symmetric structures, Galerkin's analysis of periodic arrays, single- and multilevel Fast Multipole Method (FMM): evaluation of singular integrals in electromagnetics, domain-decomposition methods, non-linear acceleration of series, inverse and forward scattering problems, etc.

As in previous editions, we experienced an informal gathering of 22 academia researchers and commercial code software developers, in provenance from many countries ranging from USA to Russia. Furthermore, the high quality of the Workshop presentations resulted in 14 papers a convened full session accepted in the next EuCAP'2015 conference (Lisbon, Portugal, 12-17 April 2015, www.eucap2015.org).

Technical information:
Dates: 26/09/2014
Venue: Thermalp hotel in Ovronnaz, Valais, Switzerland.
Organizing institutions: Ecole Polytechnique Fédérale de Lausanne (EPFL)
Organizers: Juan Mosig (EPFL)
Participants: 22 with 21 staying overnight at the workshop venue
Material: All speakers got an official backpack with all the materials in it: program, abstracts and brochure with most interesting information's about Ovronnaz. A CD-rom with the presentations slides and related materials is going to be distributed to all participants.

Sponsorhip:
This project has been sponsored and financially supported by the ESF activity NEWFOCUS 'New Frontiers in Millimetre / Sub-Millimetre Waves Integrated Dielectric Focusing Systems' with a contribution of 3000 EUR (application reference number 5672)
The main incurred expenses where the accommodation of the external participants, combined with the rental of the meeting room and its facilities. The hotel policy is to use an all-inclusive "forfait seminaire". The total amount of this forfait seminaire for the 21 persons was of 4'220 CHF (Swiss francs, equivalent to 3'517 euros according to the Swiss official exchange rate for universities) This amount was invoiced by Thermalp to our laboratory LEMA-EPFL (invoice and payment receipt available on demand). Furthermore, additional expenses, like transportation from and to the airport, wi-fi access and the workshop dinner were covered internally.
INTELECT will use the NewFocus contribution of 3'000 euros to partially support the above described workshop expenses.

2) Description of the scientific content of and discussions at the event

The aim of the workshop was to exchange experiences in developing analysis methods of high-frequency electromagnetic problems based on the integral equation approach. Special attention was given to new methods of analysis as well as to the efficient numerical implementation into electromagnetic solvers. The titles and authors of the different contributions and topics treated are the following:

- **"Accelerating MR Electromagnetic Analysis using Sampled Projection Methods",** A. Hochman, A. Polimeridis, J. Villena, L. Daniel and J. White (MIT, USA)
- **"Low rank approximations of matrices and tensors: efficient tools for the solution of large-scale problems"**, Ivan Oseledets (Skoltech, Russia)
- "**Fully Numerical Evaluation of 4-D Reaction Integrals in the Method of Moments",** D. R. Wilton, F. Vipiana and W. A. Johnson (Politecnico di Torino, Italy & University of Houston, USA)
- **"Boundary Element Formulations Based on Quasi-Helmholtz Projectors"**, Francesco P. Andriulli (Institut Mines-Télécom / Télécom Bretagne, France)
- **"SIE-MoM with multiregion basis functions in plasmonics"** D. M. Solís, J.M. Taboada, F. Obelleiro, L. Landesa, M.G. Araújo, J. Rivero, J.O. Rubiños-López and J.L. Rodríguez (Universities of Vigo & Extremadura, Spain)
- **"The IE-MoM Analysis of Dielectric Resonators Embedded in a Shielded Stratified Medium"** Bartosz Bieda, Robert Borowiec, Andrzej Kucharski, and Piotr Slobodzian (Wroclaw University of Technology, Poland)

- **"Full-Wave Analysis and Equivalent Circuit Modeling of SIW Components",** Maurizio Bozzi, Luca Perregrini and Ke Wu (University of Pavia, Italy & École Polytechnique de Montréal, Canada)

- **"Efficient analysis of gap-waveguide structures through a rigorous mode-matching approach",** Mladen Vukomanovic, Marko Bosiljevac and Zvonimir Sipus (University of Zagreb, Croatia)

- **"Efficient MoM analysis of multilayered periodic arrays of stacked rectangular patches. Application in the design of reflectarray antennas"** Rafael Florencio, Rafael R. Boix and José Antonio Encinar (University of Seville & UPMadrid, Spain)

- **"Efficient analysis and design of reflectarrays through the use of characteristic modes"** Erdinc Ercil, Lale Alatan, Ozlem Aydin Civi (METU, Ankara, Turkey)

- **"Volumetric testing for the nonconforming discretization of Integral Equations in scattering problems",** E. Ubeda, I. Sekulic, Juan M. Rius and A. Heldring (UPC, Barcelona, Spain)

- **"On the Computation of Power in VIE Formulations"** A. G. Polimeridis, M. T. Homer Reid, S. G. Johnson, J. K. White and A. W. Rodriguez (MIT and Princeton University, USA)

- **"MoM in CEM: differentiated matrices, stored EM energy and current optimization"** Mats Gustafsson, Lund University, Sweden

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

We believe that the workshop INTELECT 2014 was very successful. The following goals are achieved:

1. Open discussion about difficulties, which the scientists have encountered in their research, was present at the workshop. In the held presentations the scientists have shown not only the mature results, but also research attempts that were not successful till now, i.e. research that have not been completed. Thus, we believe that the participants of the workshop got inspiration on how to overcome the difficulties that have encountered.

2. There have been a lot of discussions about future cooperation between the groups. In informal atmosphere the joint projects were discussed, new joint research topics were considered, as well as the exchange of researchers between universities.

3. The researchers were interested in the extension of analysis methods to other technical areas. In particular, the lecture of Dr. Jacob White (MIT) was of particular interest. He pointed out the importance of accelerating volume integral equation methods to reduce the computational time of 3-D simulations from hours to minutes, thus being able to develop efficient codes for volumic inhomogeneous problems including applications as diverse as planar integrated mm-wave lenses and patient-specific MRI strategies.

4. The experts from commercial companies developing electromagnetic solvers were present. They showed interest to implement some of solutions in their commercial

products. Experience from past editions clearly demonstrates that some of the advancements described in the workshop end as additional options in the newest versions of their softwares and we expect this trend to be continued.

5. Everybody agreed that the workshop was really an useful complement to exsiting more formal conferences and that it should be continued and organized again next year. Indeed all the participants showed interest to attend the next-year workshop and several initial proposal for potential venues were already discussed.

4) Annexes 4a) and 4b): Programme of the meeting and full list of speakers and participants

See next pages

Annex 4.a: Final programme of the meeting

Friday, 26 September 2014, 09h00-17h15

- 09:00-09:05 Welcome to INTELECT'2014: Juan R. Mosig, EPFL Switzerland

- 09:05-09:35 INVITED TALK (30')

"Accelerating MR Electromagnetic Analysis using Sampled Projection Methods"

A. Hochman, A. Polimeridis, J. Villena, L. Daniel and J. White (MIT, USA)

- 9:35-10:50 Three talks (total time including questions 25' each)

1) **"Low rank approximations of matrices and tensors: efficient tools for the solution of large-scale problems",** *Ivan Oseledets* (Skoltech, Russia)

2) **"Fully Numerical Evaluation of 4-D Reaction Integrals in the Method of Moments",** *D. R. Wilton, F. Vipiana and W. A. Johnson* (Politecnico di Torino, Italy & University of Houston, USA)

3) **"Boundary Element Formulations Based on Quasi-Helmholtz Projectors***",* *Francesco P. Andriulli*
(Institut Mines-Télécom / Télécom Bretagne, France)

- 10:50-11:15 Coffee break

- 11:15-12:30 Three talks (total time including questions 25' each)

4) **"SIE-MoM with multiregion basis functions in plasmonics"** *D. M. Solís, J.M. Taboada, F. Obelleiro, L. Landesa, M.G. Araújo, J. Rivero, J.O. Rubiños-López and J.L. Rodríguez* (Universities of Vigo & Extremadura, Spain)

5) **"The IE-MoM Analysis of Dielectric Resonators Embedded in a Shielded Stratified Medium"** *Bartosz Bieda, Robert Borowiec, Andrzej Kucharski, and Piotr Slobodzian* (Wroclaw University of Technology, Poland)

6) **"Full-Wave Analysis and Equivalent Circuit Modeling of SIW Components***",* *Maurizio Bozzi, Luca Perregrini and Ke Wu* (University of Pavia, Italy & École Polytechnique de Montréal, Canada)

- 12:30-14:00 Lunch

- 14:00-15:15 Three talks (total time including questions 25' each)

7) **"Efficient analysis of gap-waveguide structures through a rigorous mode-matching approach",** *Mladen Vukomanovic, Marko Bosiljevac and Zvonimir Sipus* (University of Zagreb, Croatia)

8) **"Efficient MoM analysis of multilayered periodic arrays of stacked rectangular patches. Application in the design of reflectarray antennas"** *Rafael Florencio, Rafael R. Boix and José Antonio Encinar* (University of Seville & UPMadrid, Spain)

9) **"Efficient analysis and design of reflectarrays through the use of characteristic modes"** *Erdinc Ercil, Lale Alatan, Ozlem Aydin Civi* (METU, Ankara, Turkey)

- 15:15-15:45 Coffee break

- 15:45-17:00 Three talks (total time including questions 25' each)

10) **"Volumetric testing for the nonconforming discretization of Integral Equations in scattering problems",** *E. Ubeda, I. Sekulic, Juan M. Rius and A. Heldring* (UPC, Barcelona, Spain)

11) **"On the Computation of Power in VIE Formulations"** *A. G. Polimeridis, M. T. Homer Reid, S. G. Johnson, J. K. White and A. W. Rodriguez* (MIT and Princeton University, USA)

12) **"MoM in CEM: differentiated matrices, stored EM energy and current optimization"** *Mats Gustafsson,* Lund University, Sweden

- 17:00 - 17:15 Workshop wrap-up *Juan R. Mosig,* EPFL Switzerland

- 20:00 Workshop Dinner in a typical Swiss mountain restaurant

Annex 4.b: Full list of speakers and participants

No.	Participant	Institution	Country
1	Juan Mosig	École polytechnique fédérale de Lausanne	
2	Jacob White	Massachusetts Institute of Technology (MIT)	USA
3	Juan M. Rius	UPC Barcelona	Spain
4	Ivan Oseledets	Skoltech	Russia
5	A. G. Polimeridis	Massachusetts Institute of Technology (MIT)	USA
6	Francesca Vipiana	Università degli Studi di Torino	Italy
7	Piotr Slobodzian	Wrocaw University of Technology	Poland
8	Rafael R. Boix	University of Seville	Spain
9	Lale Alatan	Middle East Technical University	Turkey
10	Maurizio Bozzi	University of Pavia	Italy
11	Zvonimir Sipus	University of Zagreb	Croatia
12	Francesco Andriulli	Institut Mines-Télécom	France
13	Mats Gustafsson	Lund University	Sweden
14	Diego Martínez Solís	University of Vigo	Spain
15	Bieda Bartosz	Politechnika Wrocławska	Poland
16	Michel Ney	Telecom Bretagne	France
17	Jens Eberhard	CST	Germany
18	Francisco L. Mesa	University of Seville	Spain
19	Donald Wilton	U. of Houston, Texas	USA
20	Marc Esquius	École polytechnique fédérale de Lausanne	Switzerland
21	Mina Bjelogrlic	École polytechnique fédérale de Lausanne	Switzerland
22	Pedro Robustillo	École polytechnique fédérale de Lausanne	Switzerland