☒ **Public**

☐ **Confidential**

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Title:	Final Dissemination and Use Plan
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Date:	31-July-2010

1. Executive summary

This document outlines the ICESTARS Dissemination and Use Plan, detailing the dissemination efforts and envisaged exploitation of the project results in both academic and commercial context.

The diverse background of the ICESTARS partners (5 academic and 4 commercial partners) guarantees the balance between the dissemination of the project results, i.e., making them available outside the limited group of project partners, and the commercial usage of gained knowledge in day-to-day design activities to improve the competitiveness of the European semiconductor companies and EDA tool providers.

In alignment with their professional objectives and standard activities the academic partners focus more on the dissemination of the results, while industrial partners will concentrate more on the fast inclusion of the results in their design tools and products. Thus University of Cologne (KLN) coordinates the dissemination efforts, while Infineon Technologies (IFX) coordinates the exploitation of the results.

The ICESTARS Dissemination and Use plan summarizes the economic, scientific and social impact and the benefits of the project for different target groups. It consists of the following sections:

Section 1	*Executive summary*	Gives brief overview of the document purpose and structure
Section 2	*Knowledge Management*	Provides the most important aspects of the ICESTARS knowledge management plan
Section 3	*ICESTARS impact*	Summarizes impact of the ICESTARS results on European Industry
Section 4	*Dissemination*	Details Consortium dissemination activities
Section 5	*Exploitation*	Details Consortium exploitation plans
Section 6	*Intellectual Property*	Specifies IP protection setup of the Consortium

2. Knowledge Management

The Dissemination and Use Plan is the basis of Knowledge Management within the ICESTARS project. It contains plans to disseminate project results, both within the ICESTARS Consortium and externally, as well as the envisaged use of the project results beyond the project duration. In this document we describe both general strategies of the Consortium as well as the individual dissemination and usage approaches of academic and commercial partners. Since dissemination is an important and rather natural task for academic institutions, whereas exploitation is ranked more important in an industrial environment, it has been decided to entrust KLN with coordination of dissemination and IFX with coordination of exploitation of results coming out of ICESTARS.

The Dissemination and Use Plan includes the management of knowledge going into the project, created within the project (together with feedback by reviewers and other experts), and going out of the project, including Intellectual Property Rights (IPR) protection. The following Table 2.1 gives an overview of the Knowledge Management Plan.

Knowledge	What	Expertise / Responsible	Plan
Into ICESTARS	Investigation of State-of-the-Art	Advisory board, Project Officers, Review auditors	Timely knowledge of the State-of-the-Art, keeping informed on progress in the field
within ICESTARS	Exchange of knowledge	Coordinator, WP 4	Web based communication structure (wiki)
	Creation and protection of knowledge	Coordinator, WP 4 – Task Intellectual Property	See Section 6
out of ICESTARS	Dissemination	All, WP 4 – Task Dissemination	public web site, See Section 4
	Exploitation	All, WP 4 – Task Exploitation	See Section 5

Table 2.1 – *Knowledge Management Plan*

ICESTARS aims to not just supporting the immediate propagation and use of project results but also at promoting a close cooperation of the ICESTARS partners and exchange of knowledge beyond the lifetime of this project.

2.1 Dissemination activities

All partners are actively involved in the dissemination of knowledge created during the project. The Consortium encourages and supports various forms of actions whose goal is to distribute the ICESTARS findings and results among the members of public as well as internally. In particular, dissemination activities of ICESTARS comprise strategies for:

- distribution of information about the scientific advances and achieved results to the research community and broader public
    - Publications in leading journal papers
    - Participation in related scientific conferences
    - Organisation of the workshops and symposia
- direct exchange of knowledge between industrial partners, CAD tool vendors and academic partners participating in the project

These activities are important both to demonstrate the scientific advances of ICESTARS partners to the global scientific community and benchmark them against current state-of-the-art scientific knowledge. The authors of technical/scientific publications are responsible for the contents of their contributions. They are obliged to notify the Project Coordinator of all dissemination activities and the coordinator will make sure that IPR and other issues are taken into account. In particular, all project related publications need approval of all partners. The Project Coordinator is responsible for dissemination of the results of the project as a whole. The outcome of the dissemination activities is reported in the mid-term meetings as well as the annual Project Review meetings and will be summarized in the Final Project Review meeting.

2.2 Use plan

The Use plan outlines partners' intentions with respect of the exploitation of the project results to add commercial and scientific value to their respective companies and institutions. Here industrial partners and CAD tool vendor have particular interest to drive the algorithms and methods developed within the ICESTARS into productive use as soon as possible. The Use plan of the ICESTARS covers the following aspects:

- Training of target users about the novel wavelet-based techniques for circuit simulation and driving the new technique into productive use
- Exploitation of developed envelope/multirate algorithms to speed up simulation of RF circuits
- Improvement of the existing RF simulation tools based on Harmonic Balance engine to maintain the leading position of the European semiconductor companies
- Training of target users about the promising Volterra on Harmonic Balance approach to enable accurate design of highly non-linear power amplifiers and driving the generated code into a productive/commercial use
- Exploitation of developed coupled Electromagnetic-Circuit analysis approaches to further the mixed-signal designs by characterizing and optimizing the functional devices taking into account the electromagnetic interaction between neighbouring devices.
- Enhancing the state-of-the-art in science and education by
    - Incorporating the gained knowledge in university courses
    - Exploiting the new results as a basis for further research and support of young researchers pursuing their MSc. and PhD. theses

All partners are actively involved in the dissemination of knowledge and the publications in the appropriate scientific journals; contributions to conferences, etc. are stimulated and supported within the Consortium. These activities are important both to demonstrate and benchmark the scientific advances of ICESTARS partners to the global scientific community. The authors of technical/scientific publications are responsible for the contents of their contributions. They are obliged to notify the project coordinator of all dissemination activities and the coordinator will make sure that IPR and other issues are taken into account. In particular, all project related publications need approval of all partners. The project manager is responsible for dissemination of the results of the project as a whole. The outcome of the dissemination activities is reported in the mid-term meetings as well as the annual Project Review meetings.

Finally, wherever the opportunities for standardisation or patent applications arise, the individual partners will certainly do this. Property rights occurring from work done in ICESTARS will be dealt as prescribed in the Consortium Agreement and the general conditions of the EC.

3. ICESTARS Impact

3.1 Semiconductor market and EDA tools

The ICESTARS project is a combined effort of the leading European semiconductor companies and design tool providers together with European universities to harness the power and promise of nano-technologies towards a networked society. As such, the project has a strong strategic impact according to the visionary goals of the IST programme. Quoting from a Gartner Research Note (SPA-18-8621, Dec. 2002):

- By 2008, more than 30 percent of Internet access in the home will be through non-PC wireless devices (0.6 probability).
- By 2012, radio frequency identification (RFID) and similar wireless chips will evolve from a supply-chain technology into an enabler of value-added consumer applications, such as item location and status reporting (0.6 probability).

These predictions are already being materialized as confirmed by the 2009 Frost & Sullivan market research titled "Wireless Devices Market in the Process Industries - An End-user Perspective" who state the wireless devices market generated revenues of 69.4 million US-$ in 2007 growing at 14.7 per cent over 2006. The study estimated the market to reach 109.2 million US-$ in 2010 growing at a compound annual growth rate of 16.3 per cent between 2007 and 2010. Furthermore, the Gartner report "Forecast Analysis: Mobile Devices, Worldwide, 2003-2013, 4Q09 Update" state that smartphone volumes will represent 14 per cent of total mobile devices sales in 2009, growing by 23.6 per cent from 2008 and to 38 per cent by 2013.

The above predictions and estimates will most likely, together with the general vision of embedded connectivity and ambient intelligence (where computers and networks will be integrated into everyday life) become a reality due to the promise of nano-technologies and the general advance in process and fabrication technologies. In the high-tech sector, Telecommunications and Microelectronics are key enablers of jobs and economic growth in the European Union. The development of microelectronics is at the very heart of future economic developments in products and services of the ICT sector. There is no area of modern life untouched by the progress of microelectronics. Thanks to advances in microelectronics new market opportunities are emerging in Europe characterized by the needs of products and services offering both mobility and connectivity. Europe has a solid industrial base, especially in Telecommunications, Home Electronics and Car Electronics (automotive) and is well profiled for this future growth.

However, the large investment in nanoelectronics process technology and the development of advanced transistor and interconnect technologies is obsolete without accompanying design tools commonly referred to as Electronic Design Automation (EDA) tools. The industry acceleration towards smaller technology nodes (currently at 65nm, shrinking down to 4x/3x nm and further to 18nm nodes) and the ever-increasing complexity (i.e., transistor count in terms of tens of millions per chip) of integrated circuits makes EDA tools obligatory in the manufacturing process. Furthermore, the importance of shortening the time to market and stronger industry focus on reliability and yield necessitates the robust, fast and accurate design tools based on top-class numerical algorithms.

Although most design tools have been for quite a while provided by US-based companies, new opportunities arise at every technology generation. Start-up companies (SMEs) address design concerns that are difficult to address by established software providers because the overall tool sets are too rigid to deal with the fast change of design demands. This explains why the traditional software vendors acquire the modern tools by purchase more than by in-house development. Their role shifts from software development to software integration. As such, those companies forego part of their role as technology leaders and lose partial control over the pace of tool development and innovation. However, the product and services-oriented European companies still critically depend on those environments for next-generation product design and development that can keep them updated with the rate of innovation in their own fields. As such they require that development in tools and methodologies keeps pace with the technological progress and be readily available for immediate productive use.

3.2 ICESTARS partners in European contents

The ICESTARS project is a key project to impact the position of Europe's semiconductor industry in critical and strategic semiconductor market sector. ICESTARS intends to provide more effective IC design to the European semiconductor industry that will have severe impact on Europe's current strength in this important high-tech area. Without the state-of-the-art IC design tools many companies all over Europe could not keep up with global competition.

European programmes such as JESSI, ESPRIT, MEDEA, MEDEA+ and IST have already confirmed how successful cooperation between European semiconductor industry and leading research institutes and academia can be. These programs have helped the European semiconductor companies to catch up in technology, which has led to the crucial industrial and economical performance improvement of the Semiconductor industry in the European and global context. The ICESTARS consortium is the latest effort in this respect, having immersed from another strong co-operative European initiative: FENICS, the First European Network for Industrial Circuit Simulation. This network was founded in 2004 by Europe's major semiconductor industries (NXP, Qimonda/Infineon, Nokia and ST) in order to coordinate research efforts, and has been very active since with quarterly meetings.

A European approach to achieving the project's objective has a number of advantages. While acknowledging that a great deal of expertise is available at the national level amongst scientists and engineers, this expertise is unevenly dispersed between countries. Both in the Netherlands and in Germany, the respective semiconductor companies of the ICESTARS consortium have built up a large network of academic partners, but they have concentrated on different issues. Infineon/Qimonda has mainly fostered work in national projects on advanced methods for transient simulations, while NXP created a local environment concentrating on the development of computational electromagnetic simulations and dynamic partitioning. A similar observation holds for the SMEs: AWR-APLAC has built-up expertise on frequency domain simulations due to a strong Finnish network of academic institutions working in this area and their strong connections to Nokia, whereas MAGWEL benefits greatly from the knowledge available in the Leuven area on semiconductor device design and simulation.

ICESTARS consortium operating on a European level therefore provides benefits in terms of introducing new technologies and experience from different countries, combining technologies in complementary fashion, disseminating the technologies to end-users at a European scale, and proposing a code of standards Europe-wide. Dissemination of the ICESTARS results outside the participating partners will be established by "open" workshops, publications in leading journals, conference presentations, and via the ICESTARS Website

3.3 Socio-economic and scientific impact of ICESTARS

Being essential for the design of future RFICs, e.g. for high data-rate wireless applications, the socio-economic impact of the ICESTARS project can be traced via its contribution to the creation of a communication infrastructure that allows the user to communicate anything, anytime, anywhere, to anybody, in an affordable, interactive and intuitive way. Such an infrastructure enables a large number of uses that will revolutionize society in all its facets. This will include applications like *e* - commerce, *e* - business, *e* - work, *e* - learning, *e* - health, *e* - safety, *e* - governance and many more.

The *economic impact* of the creation of such an infrastructure is large. It entails the creation of new markets (for hardware / software / content / services) and more efficient business processes (leading to higher productivity / agility). In turn, the new markets lead to the creation of new, high-quality, jobs (both direct and indirect), whereas the more efficient business processes will improve the competitive position of companies in the market.

The *scientific impact* will be large as well. First and foremost, this holds for advances over the state-of-the-art in the field of nanoelectronics. Second, results obtained are not restricted to the problem areas considered in this FP7 call, but also to other areas of application. Systems of DAEs having a similar structure arise in many other fields such as in mechanics (e.g., multibody problems,

crash tests, mechanical oscillations), in fluid dynamics and material science. It is expected that, based on the novel PDAE approach, the techniques to be developed in this project will have a significant impact on the progress of numerical simulation methods in the above mentioned research areas.

Last, but not least, the *social impact* is equally high. During the last 20 years microelectronics influenced quality of life and health and safety more drastically than any other introduction of a new industry, due to increased switching frequency of the devices, miniaturisation and better and faster designs. This will cause even more changes in our future society due to mobility and communication, changing the lives of the European citizens drastically, boosting applications of which only a few are mentioned:

- **Learning:** The vision of conducting a fully interactive class session, including showing of items, such as maps, articles or experiments.
- **Working:** The key to this new trend of working from home will be aided by ICESTARS. This will allow people working at home to feel like they are working in the office.
- **Healthcare:** Getting better, faster and more accurate diagnosis will be possible if communication between the patient's home and the medical centre is improved (remote monitoring).
- **Aids for disabled people:** For those who have only the choice between either working from home or not being able to work at all, evolved modern communication techniques are extremely important.

Most of the above mentioned applications require broadband access to the infrastructure, which when added together, leads to an enormous capacity demand on that infrastructure. This demand can only be satisfied if the infrastructure operates at (very) high data rates. In turn, this requires hardware capable of operating at very high frequencies. Coupled with the demand for low-cost, small-size and low-power consumption, this leads to a major role for microelectronics. With the development of an essential enabler in this area, the ICESTARS project takes a fair share in the (large) socio-economic impact of the intended communication infrastructure.

4. Dissemination

It is of fundamental importance to the consortium that the knowledge generated in the proposed project is shared with other research groups and companies in order to:

- Generate broader acceptance for the developed technology and its applications
- Inspire more research projects in the area
- Generate interaction and feedback from other groups and learn from their experience
- Generate other positive benefits to the consortium or the European Community

Therefore, the ICESTARS dissemination activities include:

- Public information about the project results via the public project web page http://www.icestars.eu
- Internal information exchange via the internal project web page http://wiki.icestars.eu
- Organisation of seminars and workshops.
    - ICESTARS Workshop 2009, Hagenberg, Austria
    - Two ICESTARS Symposia at ECMI 2010, Wuppertal, Germany
- Participation in important conferences and workshops,
    - such as SCEE, ECMI, DAC, EuMW, DATE, ECCTD, SPI, PIERS, etc.
- Publication in top-level scientific journals, such as IEEE MTT Trans., IEEE TCAD Trans., Journal of Circuit Theory and Applications, etc
- Information on the research activities is also published in the popular press, e.g., Science & Technology magazine
- Publication of the results in the various web sites of the European Commission, especially CORDIS PROJECTS and CORDIS RESULTS.
- Demonstration of the results to visitors from companies and research institutions all over the world, including the software demonstration to the EU officer and the Reviewers in the Final Review Meeting scheduled for January 2010
- Use of ICESTARS results in the educational process, for training of students and employees of the Consortium members

4.1 Joint dissemination methods and media

At the start of the project the project logo was created to enable easy identification of work done during the ICESTARS. In addition, set of presentation templates was setup to support uniform representation of Consortium members during joint dissemination activities, both public and within the Consortium.

The press release at the project start and the setup of the official ICESTARS web page (www.icestars.eu) announced the start of the project to the members of public.

The strong presence of the Consortium members on relevant conferences as well as set of publications in specialized scientific journals as well as in magazines addressing broader public ensure that also the results achieved during the project are made available to the general public.

Finally, internal wiki pages (http://wiki.icestars.eu) and email reflector lists are setup as a backbone of the internal communication between Consortium members.

4.1.1 Project logo and presentation templates

A project logo and standard presentation material, give a project a definitive mark, both online and offline, and support the clear identification of a project, its contributors and its results. Thus, the following steps have been taken to establish distinctive ICESTARS identity:

- An ICESTARS logo was created at the project start to provide a visual ID for the project

Fig. 4.1 - ***ICESTARS logo***

- A standard presentation template has been created for usage by all partners in all presentations involving project activities and results. This template also reflects ICESTARS' funding by the European Commission.

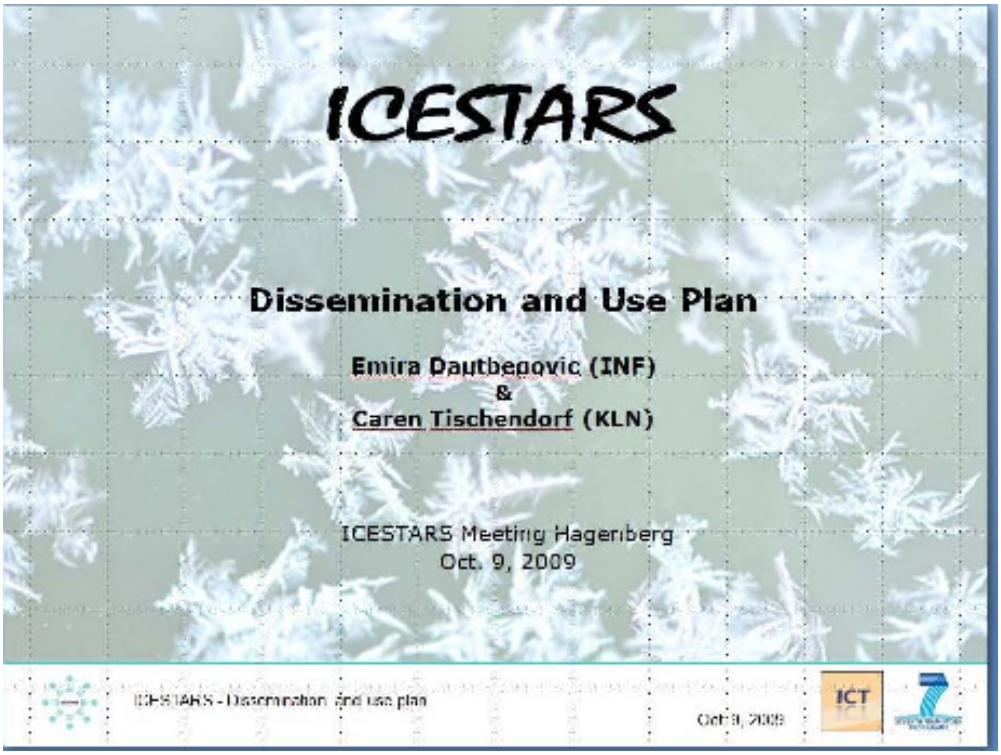

Fig. 4.2 - ***An example of the standard ICESTARS template***

4.1.2 Press releases

The press release informing the public about the start of the project as well as its goals was published by University of Cologne on 4th November 4 2008. Next to an English language version also a German language version and a Finnish language version were made available by the respective partners to address the media in their respective languages.

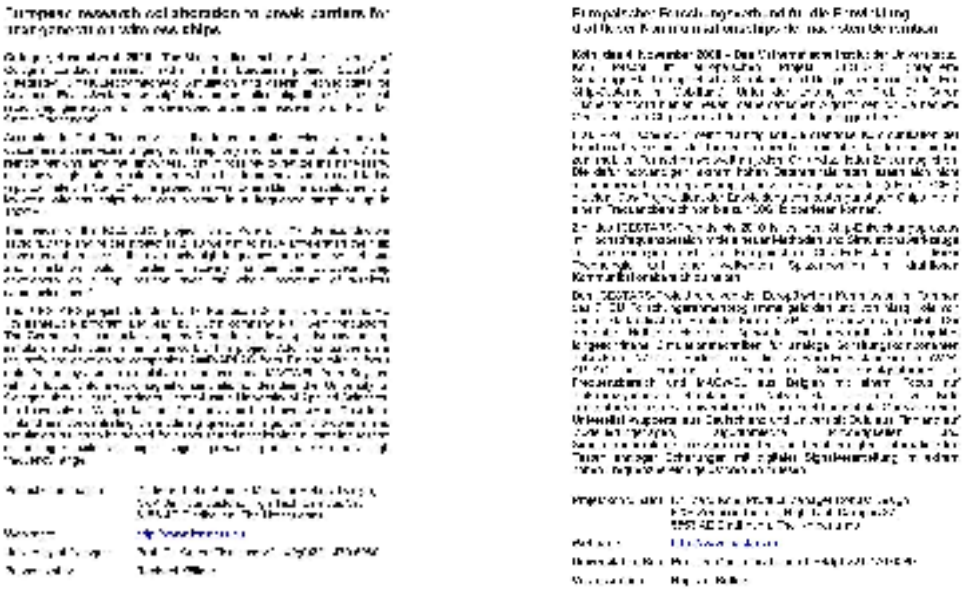

Fig. 4.3 - ***ICESTARS press releases in English and German published at project start***

The information of the press release was well accepted by media and distributed globally in various languages. The following links show a few samples of more than 100 press releases informing about the ICESTARS project:

- Schnellere drahtlose Datenübertragung on infoweek.ch website (05/11/2008).
- Breaking Barriers For Next Generation Wireless Chips on sciencedaily.com website (04/11/2008).
- New Mathematical Algorithms to Break Barriers for Next Generation Wireless Chips on azom.com website (04/11/2008).
- Das Mathematische Institut der Universität zu Köln forscht im europäischen Projekt ICESTARS on the ExtremNews website (04/11/2008).
- ICESTARS: Drahtlose Kommunikationschips der nächsten Generation on the website of Kölner Wissenschaftsportal (04/11/2008).
- Innovativer Chip on rundschau.co.at website (04/11/2008).
- Drahtlose Datenübertragung wird beschleunigt on Innovations Report website (05/11/2008).
- AWR joins European wireless design effort on eetimes.com website (04/11/2008).
- AWR Collaborate on Advanced Radio Systems-on-Chip on EDA Geek website (04/11/2008).
- European Research Collaboration to Break Barriers for Next-generation Wireless Chips on the microwave journal (04/11/2008).
- AWR To Conduct Research For Advanced Radio Systems-On-Chip Project on rfglobalnet.com (05/11/2008).
- ICESTARS: Mathematiker an europäischem Forschungsprojekt beteiligt on the website of Wuppertaler Stadtnetz (18/11/2008).

- Drahtlose Datenübertragung wird beschleunigt - Simulationswerkzeuge dienen dem Chip-Design on Nena website.
- Schnellere drahtlose Datenübertragung on the InfoWeek website (05/11/2008).
- Drahtlose Datenübertragung wird beschleunigt on the Wallstreet Online website (05/11/2008).
- Mit "ICESTARS" unabhängig kommunizieren on media in NRW website (05/11/2008).
- Schnellere drahtlose Datenübertragung on PC Welt website (06/11/2008).
- European research collaboration to break barriers for next generation wireless chips on the innovations report website (04/11/2008).
- Breaking Barriers For Next Generation Wireless Chips on ScienceDaily (04/11/2008).
- European Research Collaboration To Break Barriers For Next Generation Wireless Chips on Wireless Design Online (05/11/2008).
- Европейские ученые разрабатывают беспроводные технологии нового поколения on Soft Mail Russia (06/11/2008).
- ICESTARS eyes next generation wireless chips on CORDIS News (05/12/2008).
- EU □□□□□□□□ICESTARS□□□□□□□□□□□□□□□□□□□□ on NEDO (NEDO is Japan's largest public R&D management organization for promoting the development of advanced industrial, environmental, new energy and energy conservation technologies).
- El proyecto "Icestars" desarrollará chips inalámbricos de bajo coste on laflecha.net (Spanish online journal about science and technology).
- ICESTARS y la próxima generación de chips inalámbricos on FECYT, the Spanish Science and Technology Foundation (11/12/2008).
- Le projet ICESTARS s'intéresse à la prochaine génération de puces sans fil on mediterranee-technologies.com.
- ICESTARS guarda alla prossima generazione di chip wireless on venetonanotech.it (09/12/2008).

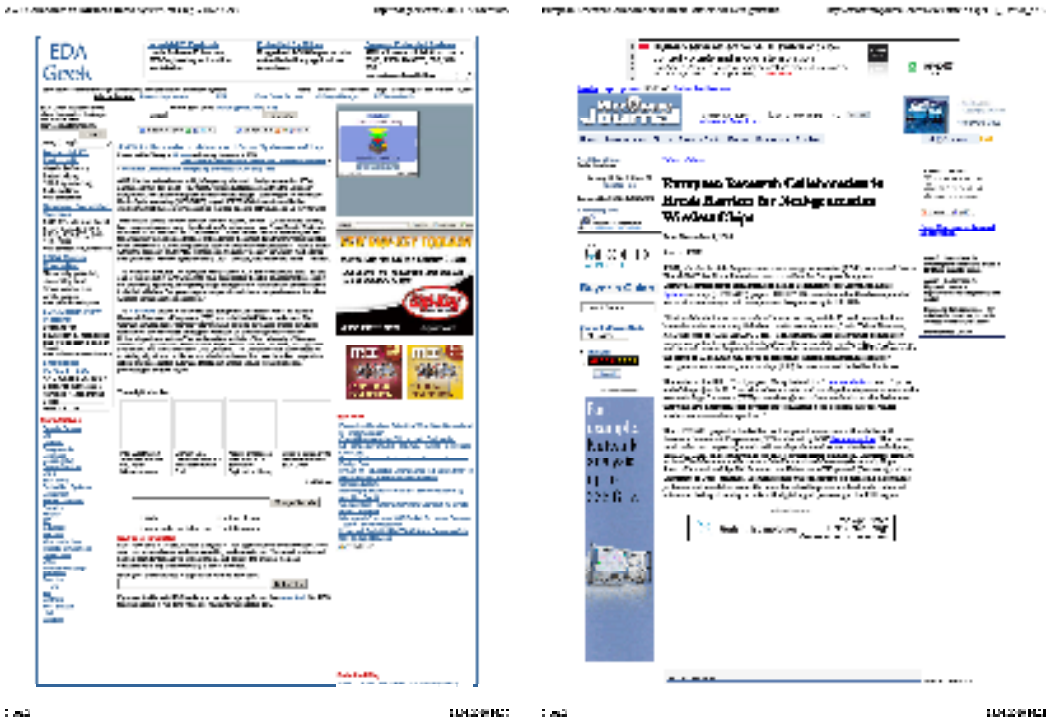

Fig. 4.4 - ***Two examples of articles on ICESTARS***

The second and final press release will be published at the end of the project.

4.1.3 Public ICESTARS project webpage

The URL www.icestars.eu (Fig. 4.5) is reserved for the Worldwide Web presentation of the ICESTARS project. The purpose of the public webpage is to inform community about the research activities and results of the ICESTARS project. Consequently, the ICESTARS web-presence contains:

- Homepage with details on ICESTARS and Consortium; Homepage also reflects ICESTARS' funding by the European Commission.
- Page on ICESTARS research objectives
- Page on general topic of RF design
- Pages detailing objectives and research results of each technical WP
- Glossary page
- Download areas containing press releases, public ICESTARS deliverables, journal and conference papers published by Consortium members in pdf format (when copyright permits), slides from ICESTARS workshop, etc.

Fig. 4.5 - ***ICESTARS homepage***

The initial set-up of the ICESTARS webpage provided:

- detailed information on the project partners and their role in the project
- Detailed information on the objectives and plans of each research activity.

At the beginning of 2010 the layout of ICESTARS website has been updated to accommodated better organisation of the material. In particular

- A subpage is setup for each WP detailing the objectives and results specific to the WP
- Additional pages on "general" topic of RF design and summary of the ICESTARS research focus are added, see Fig. 4.6
- A comprehensive glossary of acronyms and abbreviations of difficult or specialized terms with their accompanying definitions employing an alphabetized, dictionary-style format was added, see Fig. 4.7
- Download area is setup, containing public ICESTARS deliverables, publications of Consortium members, etc.

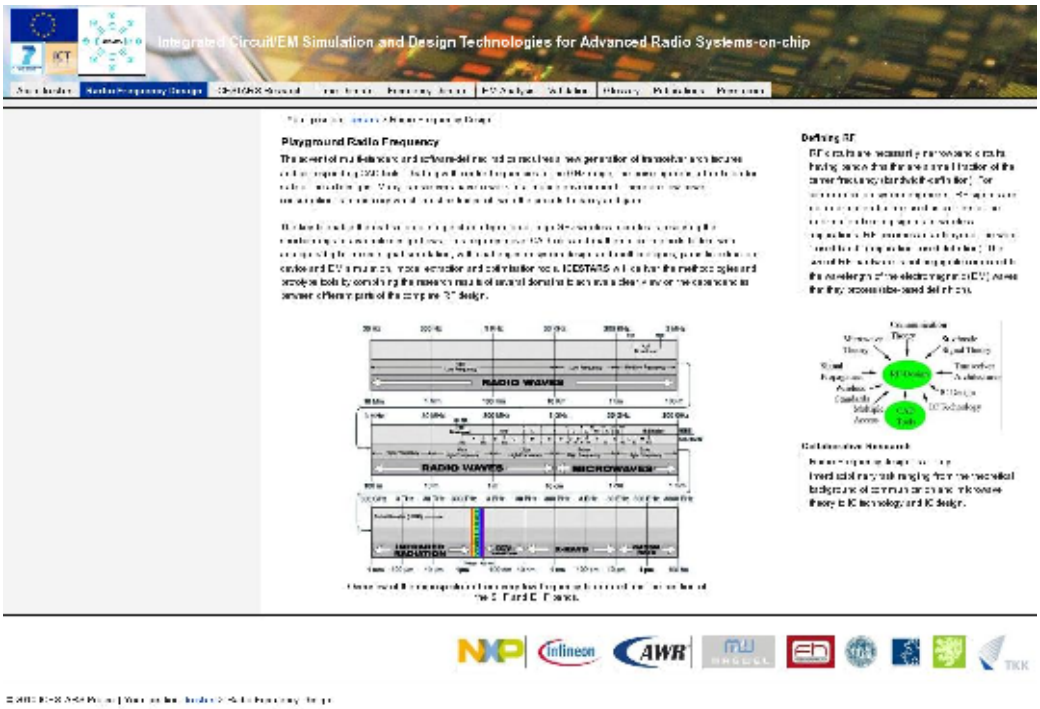

Fig. 4.6 – *Radio Frequency Design subpage*

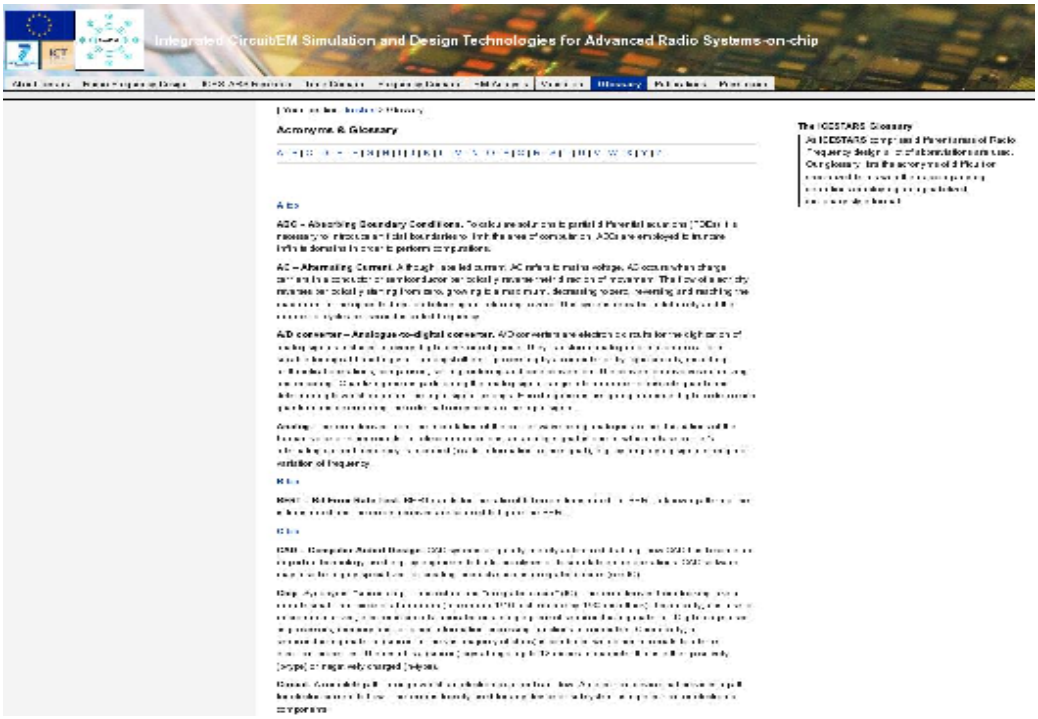

Fig. 4.7 – *Glossary*

4.1.4 Conferences, journal and scientific papers, MSc. and PhD. theses

The ICESTARS partners have been published their project results at different international conferences, such as the *7th International Conference on Scientific Computing in Electrical Engineering* (SCEE 2008) in Espoo, Finland; the *European Microwave Week* (EuMW 2009) in Rome, Italy; the *8th Mississippi State - UAB Conference on Differential Equations & Computational Simulations* (2009) at Mississippi State University, USA; the *7th International Conference of Numerical Analysis and Applied Mathematics* (ICNAAM 2009) in Rethymnon, Crete, Greece; the *12th Conference on the Numerical Solution of Differential and Differential-Algebraic Equations* (NUMDIFF 2009) in Halle, Germany; and the *Design Automation Conference* (DAC 2009), San Francisco, USA. The selected contributions from SCEE 2008 are also published in Proceedings at Springer, 2010. Table 4.1 details the contributions of the ICESTARS partners to various international conferences.

WP	Author(s)	Partner(s)	Title	Publication
ALL	Janssen et all.	ALL	Integrated Circuit/EM Simulation and Design Technologies for Advanced Radio Systems-on-chip (ICESTARS)	SCEE 2010 (accepted)
WP1	Awasthi	FHO	Modified Upwind Difference Scheme for Time-Dependent Singularly Perturbed Convection-Diffusion Equations on Shishkin Mesh	8th Mississippi State - UAB Conference on DE & CS
WP1	Awasthi	FHO	A Mixed Time Frequency Algorithm for Circuit Simulation	ICESTARS workshop (public)
WP1	Bittner	WUP	Wavelet-based simulation techniques in time domain	ICESTARS workshop (public)
WP1	Bittner, Dautbegovic	WUP, IFX	Wavelet algorithm for circuit simulation	ECMI 2010 (accepted)
WP1	Bittner, Dautbegovic	WUP, IFX	Adaptive wavelet-based method for simulation of electronic circuits	SCEE 2010 (accepted)
WP1	Brachtendorf	FHO	Entrainment phenomena in nonlinear oscillations	ECMI 2010 (accepted)
WP1	Brachtendorf, Bunse-Gerstner, Lang, Lampe	FHO	Quasiperiodic steady-state analysis of electronic circuits by a spline basis	SCEE 2008 / Springer 2010
WP1	Dautbegovic	QAG	Wavelets in circuit simulation (invited talk)	SCEE 2008 / Springer 2010
WP1	Pulch	WUP	Polynomial Chaos for the Computation of Failure Probabilities in Periodic Problems	SCEE 2008 / Springer 2010
WP1	Winkler	WUP	Envelope simulation by multirate methods based on wavelets	ICESTARS workshop (public)
WP2	Aikio, Mäkitalo, Rahkonen	OUL	Harmonic Load-Pull Technique Using Volterra Analysis	EuMW 2009
WP2	Hulkkonen, Honkala, Virtanen, Valtonen	TKK	Initialization of HB Oscillator Analysis from Transient Data	SCEE 2010 (accepted)
WP2	Matthes	KLN	Time-integration methods: The DAEn solver for transient applications	ICESTARS workshop (public)
WP2	Rahkonen	OUL	VoHB method and it's role in PA design	ICESTARS workshop (public)
WP2	Rahkonen	AWR	Adaptivity and scalability in HB analysis	ICESTARS workshop (public)
WP2	Rahkonen	OUL	Nonlinear distortion in differential circuits with single-ended and balanced drive	SCEE 2008 / Springer 2010
WP2	ter Maten	NXP	Initial Conditions for Harmonic Balance	ICESTARS workshop (public)

WP2	Virtanen, ter Maten, Honkala, Hulkkonen	TKK, NXP	Estimation of initial conditions for harmonic balance analysis of free-running oscillators	ECMI 2010 (accepted)
WP3	Baumanns, Selva, Tischendorf	KLN	Consistent initialization for coupled circuit-device simulation	SCEE 2008 / Springer 2010
WP3	Baumanns, Tischendorf	KLN	Consistent initialization of partial-differential-algebraic equations for circuit simulation	NUMDIFF-12
WP3	Harutyunyan, Schoenmaker, Schilders	NXP, MAG	Simulation of large interconnect structures using ILU-type preconditioners	SCEE 2008 / Springer 2010
WP3	Iwata, Takamatsu, Tischendorf	KLN	Hybrid Analysis of Nonlinear Time-Varying Circuits Providing DAEs with at Most Index 1	SCEE 2008 / Springer 2010
WP3	Kapora, Schoenmaker, Meuris	MAG	Substrate noise isolation in 90 nm CMOS Technology	DAC 2009
WP3	Matthes, Tischendorf	KLN	Convergence analysis of a coupled circuit- and device simulation	ICNAAM 2009
WP3	Matthes, Tischendorf	KLN	A Convergence Estimate of a Partial Differential Algebraic System in Circuit Simulation	SCEE 2010 (accepted)
WP3	Schoenmaker	MAG	Evaluation of the electromagnetic coupling between microelectronic device structures using computational electrodynamics (invited talk)	SCEE 2008 / Springer 2010
WP3	Schoenmaker	MAG	Construction of an electromagnetic TCAD transient solver: Interface and boundary conditions subtleties	ICESTARS workshop (public)
WP3	Schoenmaker	MAG	From Potentials to Field and Vice Versa: Using the Best of Two Worlds to Address RF Design Questions (Invited presentation)	Workshop on EM Modeling and Large Comp., Delft University of Technology
WP3	Schoenmaker	MAG	Software developments for a transient electromagnetic potential fields solver	ECMI 2010 (accepted)
WP3	Schoenmaker, de Smedt, Meuris, Verhaegen	MAG	Recent Developments for Electrical and Electro-Thermal Analysis of Power-Management Circuits	ECMI 2010 (accepted)
WP3	Schoenmaker, Matthes, De Smedt, Baumanns, Tischendorf	MAG	Transient Simulation of Electromagnetic Fields in Semi-Conducting	SCEE 2010 (accepted)

Table 4.1 – *ICESTARS scientific conference contributions*

Furthermore in the near future, during SCEE 2010, Scientific Computing in Electrical Engineering, Sept. 19-24, 2010, Toulouse, France, the following ICESTARS presentations will be given:

- WUP, IFX: Bittner, Dautbegovic, *Adaptive wavelet-based method for simulation of electronic circuits.*
- NXP, KLN, MAG, FHO, IFX, APL, OUL, WUP, TKK-Aalto: Janssen, Tischendorf, Schoenmaker, Brachtendorf, Dautbegovic, Tinttunen, Selva Soto, Rahkonen, Pulch, Virtanen, ter Maten, *Integrated Circuit/EM Simulation and Design Technologies for Advanced Radio Systems-on-chip (Icestars).*
- MAG, KLN: Schoenmaker, Matthes, De Smedt, Baumanns, Tischendorf, *Transient Simulation of Electromagnetic Fields in Semi-Conducting Materials.*
- WUP: Pulch, Winkler, *Envelope Simulation by Multirate Methods Based on Wavelets.*

In addition to the topics directly related to ICESTARS the partners also worked and published on other topics (see Table 4.2) that are important for circuit simulation and EM-simulation (Model Order Reduction, Sensitivity Analysis, etc). This work was done outside the funding by ICESTARS.

Author(s)	Partner(s)	Title	Publication
Fernández Villena, Schilders, Silveira	NXP	Block oriented model order reduction of interconnected systems.	TU Eindhoven CASA-Report 2009-01
Ilievski, Schilders, ter Maten	NXP	BRAM - Backward Reduced Adjoint Method	SCEE 2008
Rommes, Lenaers, Schilders	NXP	Model order reduction for large resistance networks	SCEE 2008

Table 4.2 – *Other publications of ICESTARS partners*

Additionally, the project results are aimed to be published in high-level scientific journals. The Table 4.3 contains the list of the ICESTARS journal publications, preprints and reports. In addition, each technical work package (WP1, WP2 and WP3) will – during the test and validation phase – prepare a journal paper to be submitted to the appropriate IEEE journal.

WP	Author(s)	Partner(s)	Title	Publication
WP1	Brachtendorf, Bunse-Gerstner, Lang, Lampe	FHO	Steady state of electronic circuits by cubic and exponential splines	Electrical Engineering, December 2009
WP1	Pulch	WUP	Initial-boundary value problems of warped MPDAEs including minimisation criteria.	Mathematics and Computers in Simulation, 2008
WP2	Aikio, Rahkonen	OUL	A Comprehensive Analysis of AM-AM and AM-PM Conversion in an LDMOS RF Power Amplifier	IEEE MTT Trans., Feb. 2009.
WP2	Harutyunyan, Rommes	NXP	Simulation of coupled oscillators using nonlinear phase macromodels and model order reduction	TU Eindhoven CASA-Report 2009-08.
WP2	Harutyunyan, Rommes, ter Maten, Schilders.	NXP	Simulation of mutually coupled oscillators using nonlinear phase macromodels	IEEE TCAD Trans 2009
WP3	Bartel, Baumanns, Schöps	KLN, WUP	Structural analysis of electrical circuits including magnetoquasistatic devices	Submitted to Applied Numerical Mathematics, 2010
WP3	Chen, Schoenmaker, Meuris Wong	MAG	An Effective Formulation of Coupled Electromagnetic-Semiconductor Simulation for Extremely High Frequency Onwards	submitted to IEEE Trans. on CAD May 2010
WP3	Riaza, Tischendorf	KLN	Semistate models of electrical circuits including memristors	To appear in Int. Journal of Circuit Theory and Applications 2010
WP3	Ricardo Riaza, Caren Tischendorf:	KLN	The hyperbolicity problem in electrical circuit theory	To appear in Mathematical Methods in Applied Sciences 2010

Table 4.3 – *List of ICESTARS high-level journal contributions*

Furthermore, the Table 4.4 details the MSc. theses completed within the ICESTARS as well as PhD. theses initiated by the ICESTARS research. Both PhD. theses are expected to be completed in 2011.

WP	Author(s)	Partner(s)	Title	Thesis
WP2	Mäkitalo	OUL	Optimization of RF-amplifier's distortion using harmonic impedances,	MSc. Thesis (in Finnish), University of Oulu, 2009
WP2	Liu	NXP	Initial estimates for obtaining Periodic-Steady State solutions of free-running circuits	MSc. Thesis Eindhoven University of Technology, 2009
WP3	Baumanns	KLN	Coupled Electromagnetic Field/Circuit Simulation: Modelling and Numerical Analysis	PhD thesis, University of Cologne, to be submitted in 2011
WP3	Matthes	KLN	Existence and uniqueness of solutions of partial differential algebraic systems	PhD thesis, University of Cologne, to be submitted in 2011

Table 4.4 – *MSc. and PhD. Theses originated within the ICESTARS*

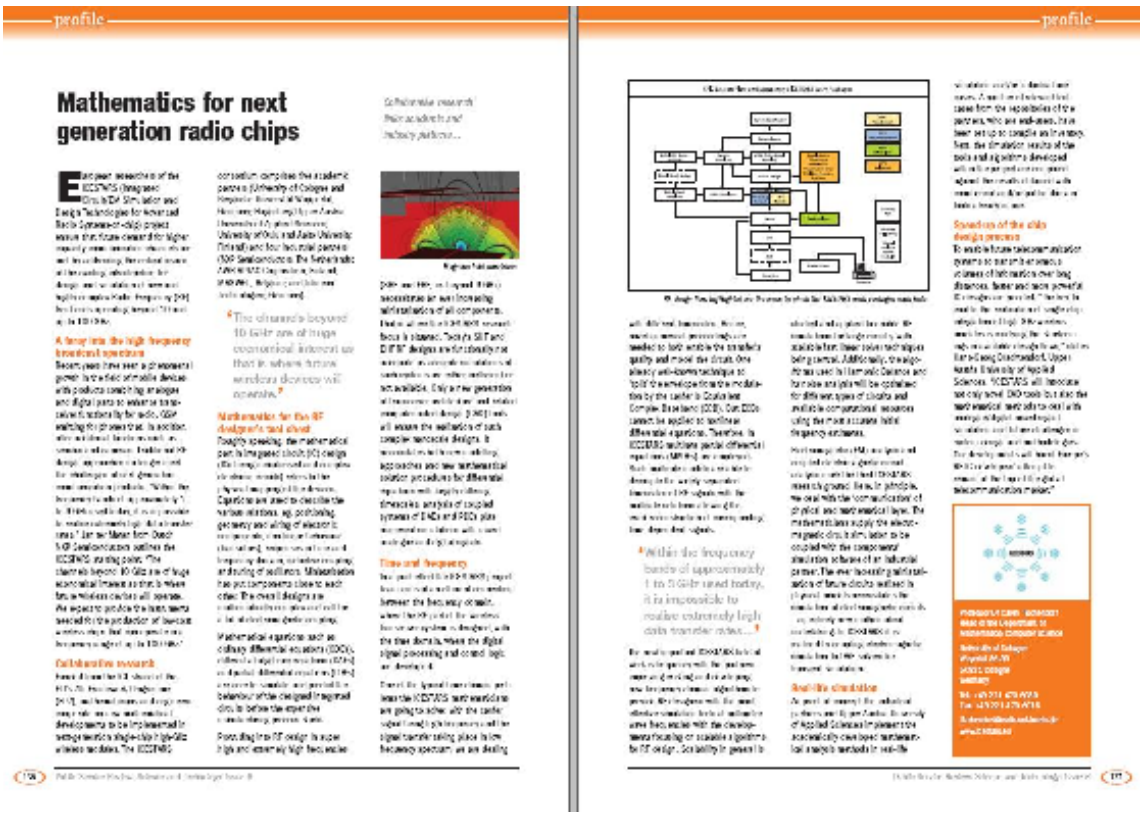

Fig. 4.8 - ICESTARS article published in the "Science & Technology" magazine

Finally, an article entitled "*Mathematics for next generation radio chips*" is published in the issue 6 of the 2010 edition of the Public Services Review "Science & Technology" magazine on pages 136-137, see Fig. 4.8.

4.1.5 Workshops and Symposia

The ICESTARS Consortium has organized a public ICESTARS Workshop in Hagenberg, Austria (October 9th, 2009) and two Mini-Symposiums at the 16-th European Conference on Mathematics for Industry (ECMI) in Wuppertal, Germany (July 26-30, 2010).

The ICESTARS Workshop (Hagenberg, Austria)

The ICESTARS project workshop was a 1-day event, which took place in Hagenberg, Austria in connection with the Hagenberg Science Day. Its aims were:

- Public overview of activities (morning session)
- Exchange of knowhow between the partners (afternoon session)

The morning session, which was open to the public, featured the invited speaker and detailed the project achievements and future plans. During this public part of the Workshop the following presentations were given:

- Invited speaker: *Uwe Knochel*, Fraunhofer EAS, Dresden, Group Manager Analog and RF Circuits: *Working areas of FraunhoferIIS/EAS focused on modelling and simulation.*

- WP1 Time Domain Techniques
  - R. Winkler (WUP) - *Envelope simulation by multirate methods based on wavelets*
  - K. Bittner (WUP/IFX) - *Wavelet-based simulation techniques in time domain.*
  - A. Awasthi (FHO) - *A Mixed Time Frequency Algorithm for Circuit Simulation.*

- WP2 Frequency Domain Techniques
  - T. Rahkonen (OUL) - *VoHB method and it's role in PA design.*
  - T. Tinttunen (AWR) - *Adaptivity and scalability in HB analysis* (presented by T. Rahkonen)
  - J. ter Maten (NXP) - *Initial Conditions for Harmonic Balance* (cancelled because of parallel meeting; presentation available).

- WP3 Electromagnetic Fields
  - W. Schoenmaker (MAG) - *Construction of an electromagnetic TCAD transient solver: Interface and boundary conditions subtleties.*
  - Michael Matthes (KLN) - *Time-integration methods: The DAEn solver for transient applications*

All presentations from the public part are available both on the ICESTARS wiki and the webpage.

During the afternoon session, which was internal ICESTARS event, the presentation focussed on the exchange of knowhow between the partners and the work packages. The following topics were presented and discussed in great details.

- WP1, Kai Bittner (WUP): Background & Usage wavelets algorithms
- WP2, Timo Rahkonen (OUL): Background & Usage Volterra algorithms
- WP3, Michael Matthes (KLN): Background & Usage Cologne software
- Exchange of SW - definition of interfaces (Kai Bittner)

After the afternoon workshop session, the mid-term Project Meeting took place. It has been concluded that the ICESTARS presentations were well accepted by members of the public attending the morning part of the Workshop. In addition, the afternoon session was deemed very helpful for further project work, in particular in terms of WP interfaces and planning of further cooperation steps. Therefore, it is general feeling among the Consortium that the milestone M4.2 was successfully reached.

The ECMI Mini-symposia (Wuppertal, Germany)

Considering that the European Conference on Mathematics for Industry (ECMI) was scheduled for end of July, 2010 the Project Management Team saw this as an excellent opportunity to disseminate the final project results to the scientific community in mathematics and electrical engineering in particular in the European context. Therefore, it was decided to organize two mini-symposia with all work packages presenting the developed algorithms and project results. The following Mini Symposia were organized

❖ MS183 (1/2): Integrated Circuit/EM Simulation and Design Technologies for Radio Systems
Session Chair: Caren Tischendorf (KLN), Emira Dautbegovic (IFX)
Presentations:

- R. Janssen, J. ter Maten, C. Tischendorf (NXP/KLN)- *The ICESTARS project, an overview and validation results*
- K. Bittner, E. Dautbegovic (WUP/IFX) - *Wavelet algorithm for circuit simulation*
- R. Winkler (WUP) - *Envelope Simulation by Multirate Methods based on Wavelets*
- H-G. Brachtendorf (FHO) - *Entrainment phenomena in nonlinear oscillations*
- J. Virtanen, J. ter Maten, M. Honkala, M. Hulkkonen (AALTO/NXP) - *Estimation of initial conditions for harmonic balance analysis of free-running oscillators*

❖ MS183 (2/2): Integrated Circuit/EM Simulation and Design Technologies for Radio Systems
Session Chair: Emira Dautbegovic (IFX), Caren Tischendorf (KLN),
Presentations:

- W. Schoenmaker (MAG) - *Software developments for a transient electromagnetic potential fields solver*
- S. Baumanns, M. Matthes (KLN) - *Modelling and numerical analysis of coupled circuit and electromagnetic simulation*
- B. Klaassen, T. Clees, C. Tischendorf (KLN) - *Mixed-level circuit and device simulation including parameter sensitivity analysis*
- C. Tischendorf, R. Riaza (KLN) - *Structural characterization of circuit configurations with undamped oscillations*

Workshop on Electromagnetic Modelling and Large Computations

Dr. Wim Schoenmaker (MAG) was an Invited speaker at the Workshop on Electromagnetic Modelling and Large Computations, Delft University of Technology, June 28, 2010 with the talk entitled

- *W. Schoenmaker* (MAG) - *From Potentials to Field and Vice Versa: Using the Best of Two Worlds to Address RF Design Questions*

Here he discussed in-depth the findings and experiences collected during the ICESTARS project on the circuit-device co-simulation work done in WP3.

4.1.6 ICESTARS internal wiki

The ICESTARS wiki (http://wiki.icestars.eu/) was set up as an internal project website a month after the project start to serve as a convenient platform for the internal information exchange of the project members.

This wiki – a website that can be read and edited by all who have access to it – has proved to be a very useful tool when it comes to communicating between the project partners, between different work packages, and within the work packages themselves. The access to the ICESTARS wiki is password-protected and not open to the public. Each project partner has access to the wiki and uses it for the administration and documentation of all management and research activities of the project. The wiki has been set up and is maintained by the University of Cologne.

A project calendar that can be filled with the relevant data for the project is readily available in wiki and used by several of the project members. The calendar also informs about upcoming events.

Fig. 4.9 - *The ICESTARS wiki*

A special area is reserved for the project management team. All PMT meetings (including phone meetings) are reported and invitation letters, agendas and minutes are included in PMT page. Also it contains administrative documents such as Description of Work and Amendments, Project Review Reports, etc. Additionally the wiki is used to share templates and administrative documents as well as to keep contact data up to date.

Each work package has its own documentation area for exchanging activity plans, working documents, data files, deliverables and publications. It allows each partner to see the status of progress of all work packages with respect to all aspects of the project at any time. All WP meetings (including phone meetings) are reported. As with PMT meetings, invitation letters, agendas and minutes are included in the WP-designated page

4.1.7 Email reflector lists

Email reflector lists have been established to support internal communication among Consortium partners. They allow easy contact to all ICESTARS members at once but also to various groups such as project management team members or members of a certain work package. The following email reflector lists are setup for ICESTARS:

- General/administrative
  all@icestars.eu, pmt@icestars.eu, office@icestars.eu

- Work packages
  wp1@icestars.eu, wp2@icestars.eu, wp3@icestars.eu, wp4@icestars.eu, wp5@icestars.eu

4.2 Dissemination activities of academic partners

By virtue of the direct educational involvement, the academic partners (KLN, WUP, FHO, OUL, AALTO) are in a prime position to translate the knowledge resulting from the ICESTARS project directly into the educational system. This direct link should not be viewed lightly as it constitutes a very relevant added value for European universities and European students. The availability of first-hand knowledge of the state-of-the-art in such brain-intensive technological areas is a key to maintaining Europe's expectations and presence and to the development of leading technical expertise in Europe. In this section we present individual dissemination activities and future plans of each of 5 academic partners.

4.2.1 KLN - University of Cologne

The ICESTARS partner University of Cologne (KLN) has disseminated research results through publications and conferences as well as presentations and discussions in PhD tutorials at the Mathematical Institute of the University of Cologne and will continue to do so.
During the second year KLN has participated in several workshops and conferences.

ICESTARS' research was presented at

- International Conference on Numerical Analysis and Applied Mathematics (ICNAM 2009) in Rethymno, Crete (Greece), 18–22 September 2009 with an article on "Convergence analysis of a coupled circuit- and device simulation" by Matthes and Tischendorf published.
- the 12th Seminar "NUMDIFF" on Numerical Solution of Differential and Differential-Algebraic Equations, taking place 14-18 September 2009 at the Martin-Luther-University Halle-Wittenberg, Germany, presenting a 20-minute research talk on "Consistent initialization of partial-differential-algebraic equations for circuit simulation" by Baumanns.
- KLN organized a *Workshop on DAE/PDAE Simulation with Python* in Daun (Germany), 27-29 May 2010 for the exchange of software developments between the working groups of Claus Führer (Lund University, Sweden), Tanja Clees (Fraunhofer Institute SCAI, Germany) and Caren Tischendorf (University of Cologne, Germany). KLN presented ICESTARS developments in three 30-minutes talks on "Introduction to the electrical circuit simulator MECS" by Sascha Baumanns, "DAE-Interfaces" by Michael Matthes and "BDF Solver for DAEs in Python" by Caren Tischendorf.

Being in charge of the Knowledge work package KLN has re-launched the ICESTARS website offering more detailed web pages on ICESTARS research and achievements. Paying tribute to the fact that RF design and the simulation techniques implemented in ICESTARS presuppose knowledge of technical terms deriving from engineering and applied mathematics a glossary has been added to the website and terms used are linked to their respective explanation in the glossary.

In June 2009 Magwel and University of Cologne published a Work Document on ICESTARS: "Transient simulation of EM-DD systems", detailing the WP 3 on EM Analysis and Coupled EM/Circuit Analysis research goals "Implementation of adaptive time stepping methods" and "Electromagnetic (EM) drift-diffusion (DD) solver in the time domain".

KLN has authored an article on "Mathematics for next generation radio chips" to be published in issue 6 of EU Science Technology introducing and explaining the mathematical part to a broad public.

KLN plans to further disseminate research results through publications and conferences such as the European Conference on Mathematics for Industry; Wuppertal, July 26-30, 2010 (ECMI 2010) and Scientific Computing in Electrical Engineering; Toulouse, September 19-24, 2010 (SCEE 2010).

Additionally, the results are presented and discussed at the bi-annual PhD seminars of the Mathematical Institute of the University of Cologne.

The simulations algorithms developed in ICESTARS are going to be implemented and integrated in the software platform of the numerical analysis group at Cologne University. This platform is both used for teaching purpose and for further research.

4.2.2 WUP - University of Wuppertal

The partner WUP disseminates research results via publications in scientific journals and presentations at international conferences like GAMM, ECMI and SCEE. Furthermore, an electronic preprint series exists at WUP. Results of recent research are included in educational activities like lectures, seminars, tutorials, etc. for training students in master courses and PhD programmes.

4.2.3 FHO - Upper Austria University of Applied Sciences

The partner FHO will disseminate the results from the ICESTARS project through publications and presentations in leading journals and conferences including, but not restricted to, IEE, IEEE TCAD, IEEE MTT, IEEE Circuits and Systems, ICCAD, ECMI, SCEE, SIAM Journals, Acta Mathematica, Numerical Linear Algebra, Computing and Numerische Mathematik and the conferences ICCAD, DAC, DATE, and GMM-ITG. FHO has organized the *FHOOE Science Day 2009*, a yearly conference dedicated to the current research activities at the University of Applied Science.

4.2.4 OUL - University of Oulu

The partner OUL's main goals are doctoral and MSc theses, and publications in good conferences and journals. The group has written e.g., to IEEE ISCAS, European Microwave week, ECCTD and (with silicon made) to ESSCIRC conferences, as well as to IEEE TCAS, JSSC, and MTT journals, and to Springer journal of analogue integrated circuits and signal processing.

4.2.5 TKK-Aalto – Aalto University

The partner TKK plans to disseminate the project results through MSc and doctoral theses as well as publications in scientific journals and presentations in international conferences. TKK (Circuit Theory Group) has also teaching and educational activities such as lectures and research seminars to report the project results. ICESTARS results will be presented on conferences ECMI 2010 and SCEE 2010.

4.3 Dissemination activities of industrial partners

The industrial partners (NXP, QAG, APL and MAG) have already actively participated in the dissemination activities towards the general public, in form of their contributions to the various scientific conferences, journal papers, the ICESTARS Workshop and ECMI Mini-symposia. In addition, they also undertook different dissemination activities within their respective organisations and customer base. The following section details each partner's individual dissemination activities and future plans.

4.3.1 NXP - NXP Semiconductors

At NXP Semiconductors in Eindhoven, an annual RF simulation meeting is held, attended by NXP employees worldwide, and organized by the PDM department that participates in the ICESTARS project.

In addition at NXP regular meetings of the NMWP (Numerical Mathematics Working Party) are held. These meetings are attended by staff of NXP (mathematicians and engineers in electronics, all involved in simulation techniques), by MSc-students, PhD-students, PostDocs, and are frequently attended by guests from TU Eindhoven, TU Delft, University of Wuppertal and Magwel (Leuven). Minutes and presentations of these meetings are available.

A selected list of meetings with topics related to ICESTARS activities is given below. After the lectures, separate meetings with more detailed discussions with the external speakers were held.

- April 1, 2008:
    - Dr. Wim Schoenmaker (Magwel): *Recent Progress of the MAGWEL's Geometrical Electrodynamics based EM-TCAD software*.
    - Prof.Dr.Ir. Herbert De Gersem (KU Leuven/Kortrijk): *Anisotropic finite-element, spectral-element discretisations for models featuring geometric symmetries*.
- June 6, 2008:
    - Prof. Ferdinand Verhulst (Utrecht University): *Periodic solutions of autonomous ODEs, stability and bifurcations.*
    - Prof. Wolf-Jürgen Beyn (Bielefeld University): *The method of freezing spatio-temporal patterns in partial differential equations.*
- January 13, 2009:
    - Dr. Rob H. Bisseling (Utrecht University): *Sparse matrix partitioning by Mondriaan 2.0: applications and recent developments.*
    - Dr. Davit Harutyunyan (TU Eindhoven): *Simulation of mutually coupled oscillators using nonlinear phase macromodels.*
- May 26, 2009:
    - Prof.Dr.Ir.Drs. Hester Bijl (TU Delft); *Uncertainty quantification for unsteady flow and fluid-structure interaction.*
    - Dr. Joost Rommes (NXP Semiconductors): *Computing sensitive eigenvalues and their use in model order reduction.*
- January 22, 2010:
    - Prof. Tom Dhaene (University of Ghent); *Automated Response Surface Model generation and adaptive sampling.*
    - Dr. Luciano De Tommasi (University of Antwerp); *Performance space exploration of RF circuit blocks via surrogate models and multiobjective optimization.*
    - Prof. Peter Benner (TU Chemnitz); Model reduction for nonlinear systems based on Carleman bilinearization: some new results.
    - Dr. Michael Striebel (TU Chemnitz); *Nonlinear Model Order Reduction via terminal interpolation.*
    - Dr. Davit Harutyunyan (TU Eindhoven*); Simulation of electromagnetic devices: Overview of past activities within O-MOORE-NICE!.*
    - Dr. Joost Rommes (NXP Semiconductors); *Mathematical challenges in the electronics industry.*
- May 6, 2010:
    - Dr. Tammo Jan Dijkema (Hypercube Business Innovation); *Adaptive tensor product wavelet methods for solving PDEs.*
    - Dr. Renate Winkler (Wuppertal University); *Envelope Simulation by Multirate Methods based on Wavelet.*

NXP plans to have additional meetings addressing topics on wavelets and periodic steady state (WP1), harmonic balance and Volterra series (WP2), coupled EM and circuit simulation (WP3).

On Aug. 17, 2009, J. Liu gave a presentation at TU Eindhoven on his MSc-Thesis Initial estimates for obtaining Periodic-Steady State solutions of free-running circuits.

NXP co-organized:

- *Workshop Model Reduction for Circuit Simulation*, University of Hamburg, Oct. 30-31, 2008.
- *Multirate time integration*, SIAM-CSE (Computational Science and Engineering), MiniSymposium MS50, March 3, 2009.
- *Advanced methods for circuit simulation*, SIAM-CSE (Computational Science and Engineering), MiniSymposium MS53, March 3, 2009.
- *COMSON Autumn School on Future Developments in Model Order Reduction*, Terschelling, The Netherlands, September 21-25, 2009.

NXP is involved in the program committees of ECMI-2010 (European Conf on Mathematics for Industry; Wuppertal, July 26-30, 2010), SCEE-2010 (Scientific Computing in Electrical Engineering; Toulouse, September 19-24, 2010), DATE-2010 (Design, Automation and Test in Europe; Dresden, March 08-12, 2010).

NXP will cooperate with the university partners in preparing presentations at conferences and publications at journals, also after completion of the ICESTARS project.

4.3.2 IFX - Infineon Technologies

As part of the close cooperation of the Infineon's TITAN development group with our designers, the TITAN group organizes several annual workshops on company level, which are usually very well visited by both designers and design support engineers. These events are perfect opportunity for timely dissemination of the ICESTARS results throughout our users' base.

Annual Circuit Simulation Community Meeting is a full-day event organised with the aim to bring together experts from different expert fields and Infineon business units to exchange experiences, design problems and their solutions with other colleagues. The event is geared towards the general analogue circuit simulation topics but the related topics such as fast-spice simulations or mixed analog-digital signal approaches are also discussed. In particular, current trends in (analog) circuit simulation and the solutions for current simulation issues and methodologies are discussed in resolution-oriented manner.

In 2010 Circuit Simulation Meeting, which was held on 16th March 2010, ICESTARS member E.Dautbegovic was invited speaker with the topic "HB-/QPSS-simulation experiences on an RF-design example from Linz with Titan/Spectre", in which the topic of the hidden floating nodes was disseminated to the broader Infineon and Lantiq design communities. The feedback from designers participating in meeting was very positive – quoting a designer directly responsible for the design of the circuit under analysis: "Finally I understand why my circuit is having so much convergence problems even in initial OP computations …"

Another annual workshop in organisation of the group directly involved in the ICESTARS is Annual New TITAN Features Workshop. It is an interactive platform for Infineon's design supporters and designers who are particularly interested in new TITAN developments. The development engineers involved in advanced designs actively participate in this workshop and as early adopters bring the new techniques into their development teams in hands-on approach. Until now they have been very valuable route of spreading the information on improvements and new techniques available in TITAN and we expect the same in the future. In close connection to the Use plan, it is aimed that the New Features Workshop of 2011 or 2012 contains a large section on a novel Wavelet analysis in TITAN.

Finally, dissemination of results outside of the company already took place on SCEE 2008 (invited speaker on topic of wavelet-simulation) and ECMI 2010 (Chair of Mini-Symposium and co-author of one of the presented papers). For details see Sec. 4.1.4 and 4.1.5. In future, several dissemination activities will take place in close cooperation with University of Wuppertal (WUP) on the topic of wavelet-based simulation methods. In particular, the paper co-authored by Bittner/Dautbegovic is already accepted for SCEE 2010 conference (Toulouse, France) and the submission of the journal paper to the IEEE Trans. on TCAD is planned for October 2010. In addition, IFX is involved in the program committee of SCEE-2010 (Scientific Computing in Electrical Engineering; Toulouse, September 19-24, 2010).

4.3.3 APL – AWR-APLAC

AWR-APLAC will present the key results in an annual AWR technical conference attended by AWR employees worldwide. The results that are available to the AWR user base will also be presented in workshops which will be arranged in several countries in EU region.

4.3.4 MAG - MAGWEL

MAGWEL submitted a regular paper to the Design Automation Conference (DAC) for 2009. Scientific valuable results are submitted for publication in peer-reviewed journal IEEE Trans. on CAD: Quan Chen, Wim Schoenmaker, Peter Meuris and Ngai Wong An Effective Formulation of Coupled Electromagnetic-Semiconductor Simulation for Extremely High Frequency Onwards submitted to IEEE Trans. on CAD May 2010. Furthermore, MAGWEL will present their key results on the company's website and promote the outcomes of the ICESTARS project in its sales activities.

5. Exploitation

All industrial partners in the Consortium are fully capable of exploiting the enabling technologies that result from the ICESTARS project. In fact their participation in the project is a result of their internal plans for commercial exploitation of the results during and after the project end. However, due to the recent internal decision on the NXP management level, the exploitation plans of the partner NXP have been dramatically changed compared to the intermediate exploitation plan (D4.2).

The university partners intend to use the ICESTARS results to further their educative and research tasks, more specifically to support and encourage young scientists in their efforts towards MSc. and PhD. degrees. This alignment of a commercial vision of industrial partners and scientific interest of university partners is the win-win situation that guarantees the successful exploitation of the knowledge gained within ICESTARS even beyond the project end.

5.1 Use plan of industrial partners

The industrial partners are aware that the source of increased productivity is in improving the simulation accuracy and speed, as well as largely automating these improvements. Significant productivity increase does not come through experts (while they need new tools, too) but by speeding-up the work of an average engineer, who is to a large extent completely unaware of what is happening inside a design environments (s)he is using. Therefore partners APL and MAG intend to integrate the ICESTARS results into their commercial products as soon as possible and thus bring the added-value of their software to their customers. The partner IFX will use ICESTARS results in day-to-day circuit and device design activities to maintain and extend competitive advantages in the global semiconductor industry by integrating the algorithms developed within the ICESTARS into the in-house circuit simulator TITAN. An emphasis is on substantially reducing development costs and time-to-market by providing fast and accurate simulation tools to the end-users, thus enabling first-time right designs. At the end of 2009, NXP management decided to discontinue with development activities for Pstar and to migrate to commercial EDA solutions. Due to this decision there will be no further effort to integrate the algorithms developed within the ICESTARS project into the Pstar simulator.

5.1.1 NXP - NXP Semiconductor

NXP's strategy as far as simulation software is concerned centres on the development of new methodologies and tools, and to distribute these to internal customers. In addition, software from commercial vendors is constantly monitored and evaluated/benchmarked, so as to have a clear picture of the state of the art. As cost reduction is a major issue, it has recently been decided to adopt a one supplier policy, both for design and for testing. Such policies are also adopted by other major semiconductor companies.

To be at the forefront of the use of advanced RF/Mixed Signal design methods it is of the utmost importance for NXP to be competitive in the market. As far as the latter is concerned, NXP is a leader in RF/Mixed Signal. We understand the many complexities of RF/Mixed Signal design and dedicate ourselves to creating products that deliver advanced performance while simplifying design. Our portfolio covers the majority of communication and transmission systems, so it is easy to find a solution that matches the particular requirements of customers.

The output of this project is useful for enhancing the currently used virtual design environment systems by improving the efficiency of the system and adding new facilities to the system, for simulating advanced electronic structures by enabling new classes of structures to be simulated and by extending the range of the operating conditions for bringing new RF/Mixed Signal products to the market.

The main objectives of the PDM group of NXP in this area are to maintain an active knowledge on the evolution of key technologies and new concepts in this domain, to identify the most promising

evolutions, to propose, develop, and evaluate innovative functions compatible with industrial and economical viability criteria, and to organize and accompany the transfer of the retained subjects to the development phase.

The interest for NXP to be a partner of the ICESTARS project is multiple:

- Feasibility of new concepts for virtual design environments
- Development of software based upon new methodologies
- Evaluation and validation of simulation results in comparison with measurements
- Increased insight in the operation of complete IC blocks
- Faster design cycles and, therefore, shortened time to market

The NXP business lines and the research centres are eager to use the developed RF design technologies in the future commercial drive. The exploitation results of the ICESTARS project will therefore get continuous attention during the project. The developed prototype will be used as a key tool for the design of commercial data transmission products, which further extends Europe's leading position in very high speed signal processing. The development and provision of efficient design support by design tools and methods, is the basis and the key for the realisation of successful products under the aspects of performance, time to market and costs. The resulting products will be the enablers for future ambient intelligence and communication networks (high bit-rate circuits, wireless and wire-line transceiver applications), for improved healthcare, communications, mobility and transport, home electronics, and car electronics. The newly developed methods extend the underlying simulation methodology with ways to take into account modern application requirements on environment and security.

The in-house analogue circuit simulator Pstar has capabilities for RF time-domain simulation (via Periodic Steady State analysis and subsequent noise analysis), Harmonic Balance frequency-domain analysis, multi-rate time integration and pole zero analysis. It offers coupling with Matlab and with Simulink for system simulation purposes. However, at the end of 2009, NXP management decided to discontinue with development activities for Pstar and to migrate to commercial EDA solutions. Due to this decision there will be no further effort to integrate the algorithms developed within the ICESTARS project into the Pstar simulator.

Apart from that simulation software of partner MAG (Magwel) is used for electromagnetic field computations in the RF-regime.

Currently, inductive coupling effects from external fields or between various oscillators are being studied. Coupling between electromagnetic fields and circuits has become of interest (WP3). Here NXP is further interested in the combination with (nonlinear, parametric, multi-terminal) Model Order Reduction techniques. New focussing on mixed analogue digital signal analysis makes the developments on wavelet techniques and of envelope time integration techniques (WP1) of special interest. The activities in WP2 will mainly improve Pstar's capabilities for diagnosing converging problems and to make simulation more efficient.

Apart from the technical exploitation by NXP via its in-house design flows, commercial exploitation by our CAD tools partners, which vend circuit simulation tools, via superior capabilities of their software packages, will be advocated.

The right first time adagio is spreading fast within the company and the results of the ICESTARS project will be used to achieve these ambitious goals.

5.1.2 IFX - Infineon Technologies

For many years TITAN, an in-house analogue circuit simulator, is heavily used by design teams in all Infineon business units (Wireless Solutions, Automotive, Industrial & Multimarket, Chip card and security, etc.). Main users are designers involved in research and development of various analog and to a smaller extent digital building block of complex mobile platform solutions

(transceivers/receivers for GSM/GPRS, EDGE, HSxPA, LTE, WiMax, etc.), sensors, microcontrollers, contact-based and contact-less chip card security controllers, power IC modules, etc. The competitiveness of leading-edge RF production portfolios (e.g., wireless RFIC designs, mobile phone platforms, etc.) can only be maintained if key simulation tools can enable first-time-right designs and low productions costs, i.e., high yield products. Hence, the use of these improved and new RF tools is identified as the key prerequisite for maintaining competitiveness of Infineon's products in European and worldwide RF semiconductor market.

The TITAN development team, which is directly involved in this project, has a long tradition of close cooperation with our designers, not only supporting the current design processes but also identifying possible simulation roadblocks for the upcoming technology nodes. The aim is to anticipate simulation problems and offer the solution for problems and challenges at the time when designers switch to the smaller technology node, a change that usually brings into the spotlight (until then) unknown both quantitative and qualitative design and simulation issues.

Designers in various wireless/communication and automotive business units of Infineon AG, located in Infineon's worldwide design centres will be first beneficiaries of the knowledge generated within ICESTARS projects. The improved HB algorithms and tools developed within ICESTARS will be included in official TITAN version and driven into productive use as soon as their verification process is successfully completed. Both the ICESTARS benchmark set (see D5.2 - Test plan) and the most recent in-house design examples will be included in verification efforts.

The validations test performed on the examples from the Test plan (D 5.2) showed that wavelet analysis algorithm developed in WP1 can be used for initialization of Harmonic Balance computations of the WP2. Thus we estimate that one of the first productive uses of the wavelet analysis would be initialization of HB solver in case of particularly difficult circuits (e.g., low-noise amplifiers, down-converting mixers involving digital-like signals, ring oscillators with sharp transitions, etc.) and thus enable the subsequent non-linear small-signal analyses such as HBAC or HBNOISE. The actual time-line depends heavily on further advances in the code and algorithm optimization to allow inclusion of various additional models (such as transmission lines, special transistor models and black-box elements), which are usually part of the leading-edge RF circuits but at first were not considered during the prototyping of algorithm within the ICESTARS.

Furthermore TITAN users involved in the mixed-signal designs are potential beneficiaries of the novel wavelet-based simulation techniques being developed within WP1. We expect that the particular property of the wavelets of flexible time-frequency resolution will enable simulation of the mixed-signal circuits with improved efficiency compared to standard analog simulation algorithms and with better accuracy than is the case with pure digital approaches. The developed prototype code will be tested in-house on the current design examples provided by this group, as to enable the best possible testing for the envisaged productive use of the newly developed wavelet-based techniques.

5.1.3 APL – AWR-APLAC

APL is part of Applied Wave Research, Inc. (AWR). AWR is a leading supplier of high-frequency electronic design automation (EDA) products for the design of wireless telecommunications, networking systems, automotive mobility systems, and a variety of other electronics-based products. AWR-APLAC Corp. is responsible for developing next generation simulation capabilities based on APLAC Simulator technology. The exploitation plan of AWR-APLAC consists of increasing the APLAC Simulator performance to help our customers increase their productivity and shorten their design cycles. Harmonic Balance and Transient analysis engines in APLAC Simulator are the basis for future simulations in AWR Design Environment. Development in these areas, as presented in ICESTAR, is crucial for success in simulating current and future RF-circuits. ICESTARS' focus is perfectly aligned with AWR-APLAC's vision and will have a direct impact on its technology roadmap. This ensures that the exploitation results will be observed and controlled to enable technology transfer from development to products.

Some key functionality developed in ICESTARS work package 2 for Harmonic Balance analysis is already included in APLAC simulator and it is therefore available to customers already. The

validation phase has also shown that many of the adaptivity schemes are very useful and will be one of the main research branches in the future.

VoHB technology which was further developed in WP2 Tasks 2.4 and 2.5 has been presented to a few selected customers doing power amplifier design. This may lead to the method commercialization after beta testing phase.

5.1.4 MAG - MAGWEL

MAGWEL is an SME and provides tools for IC design in the full-range frequency regime (0-100 GHz). The tools are developed for analysis of the physical simulations of high-frequency responses. The company has a specific interest in offering design tools that are able to model accurately larger segments of the full IC design. In particular, functional blocks are the next level of complexity that MAGWEL will address in its next-generation products. The business plan of MAGWEL consists of expanding its product portfolio to cover tools that will enable customers to deal with design problems on the level of functional parts. MAGWEL has a seamless integration with industry-standard environments, such as Cadence's Open Access program. There is a strong interest from RFIC designers in a better, more accurate and faster layout extraction product than is available nowadays. As more than 60% of the design failure in this segment is due to parasitic and nowadays multiple silicon iterations are required to make working chips, current extractors are not adequate enough. A market field study, carried out by MAGWEL in 2007 shows that for several customers in US, Japan and Europe, there is an urgent need for better tools, and retooling will take place when a better tool comes available. If this product is available (partially based upon the ICESTARS project results), the size of the market can be estimated. The total number of Analogue, Mixed Signal and RF designers is approximately 10.000 worldwide, and the growth rate of this market segment is estimated to be 15%. This forecasting was actually overshadowed by the world-wide economical crisis but recently an up turn is detected for the customer base of MAGWEL. Whereas, research departments are forerunners is budget cuts, they are also signalling an uprising at the earliest stage. Given this insight we come to the following business case study.

Product description MAGWEL

MAGWEL has upgraded it star product "devEM" which performs combined on-/in- silicon simulation with a transient module. Whereas the original motivation as described in the DoW was to provide accurate 'back-up' modelling of device architectures up to the 60 GHz range by completion of transient simulation for combined device-circuit simulation, the transient solver has great potential to address issues at much lower frequencies. A major topic of interest is to accurately analyze the effects of substrate currents due to device switching and latch-up. A modelling of the substrate as a lowly-conductive layer ignores the presence of capacitively coupled junctions and this gap can be bridged by using the newly developed transient modules from the ICESTARS project. Another important development for the MAGWEL product is it extension with circuit simulation. However, contrary to the 'conventional' mixed-mode simulations, in which the field solver provides a 'client' process for the circuit simulator (master process), the MAGWEL tool allows for insertion of hundreds of ports (contacts) to which elementary circuit elements can be attached. In many interesting applications, the circuit elements are clones of an active device. The simulator is then able to perform an in-depth and accurate modelling of the current flow in power MOS devices. This product branch is now already an important pillar of the MAGWEL business and its development is clearly rooted in the WP3 activities of ICESTARS.

The experience gained in the ICESTARS project have been led to yet another application: A product line "PTM: Power Transistor Modeler" is foreseen to be extended with a transient implementation for the heat flow in space and time. This field solver approach provides a unique product for in-depth power MOS analysis which contains thousands of transistors (treated in a compact modelling fashion but with the substrate and the back-end stack analyzed in field solver mode.

Business case study

Our financial projections for the first five years after completion of the project are given in Table 5.1. We assume that the product will be launched in 2011 after the completion of the project. Before product launch we plan at least 3 beta test cycles in 2011 with motivated customers some of which will be participants in the ICESTARS project. In that year we project to sell 6 licenses of the new product primarily to our beta customers. After the first year we project a growth of the number of licenses sold of 50% per year. We project an average license price per year of 50,000 EURO in the first year and an increase of 5% per year in the following years. This starting price and the rate of increase is based on our experience with our current simulation products. Rate increase is justified because the product will gain traction and brand recognition over time.

Year	1	2	3	4	5
Price per year	50	55	60	65	170
New Licenses	6	9	12	18	23
Cumulative licenses	6	15	27	45	68
Revenue (1,000 EUR)	300	500	725	1175	1600
Cumulative Revenue	300	800	1525	2700	4325
Employees	3	4	6	7	8
Expenses	400	500	800	900	1000
Cumulative expenses	500	1000	1800	2700	3700

Table 5.1- *Financial projections for the ICESTARS solver for the first 5 years after product launch in 2011*

Number of licenses sold per year and the cumulative number of licenses sold is shown in Fig. 5.1. Product revenue in a given year is calculated as the cumulative number of licenses sold multiplied by the license price per year using a time based license (TBL) model. This leads to a cumulative product income of 9 MEUR in 5 years. We expect the product life cycle to be at least 10 years. So the cumulative product income over the total product life cycle will be at least 15 MEUR.

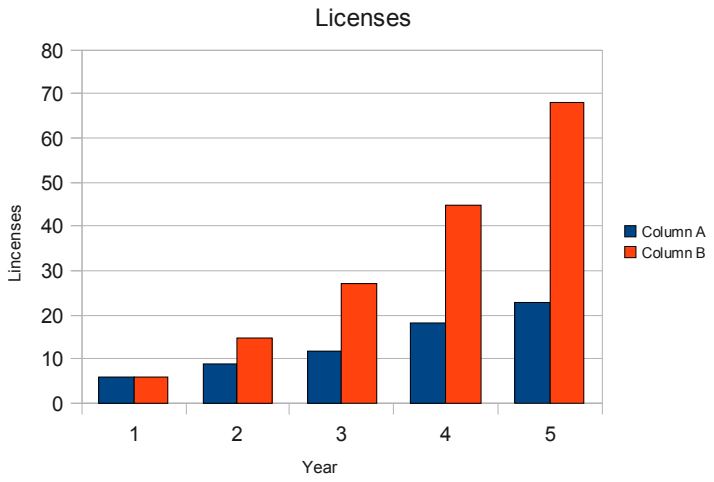

Fig. 5.1 - *Annual number (column A) and cumulative number of product licenses (column B) sold.*

5.2 Use plan of academic partners

The academic partners intend to integrate the findings of the ICESTARS project into the upcoming courses at their respective institutions, as well as to use these results as a basis for further research efforts, in particularly supporting young scientists working towards their MSc. and PhD. Degrees.

Within the ICESTARS context already two Master of Science theses have already been authored:

- University of Oulu, Department of Electrical and Information Engineering: M. Mäkitalo, *Optimization of RF-amplifier's distortion using harmonic impedances*, 2009
- Eindhoven University of Technology: J. Liu*, Initial estimates for obtaining Periodic-Steady State solutions of free-running circuits*, 2009

Also, for 2011 the submission of two PhD theses done within the ICESTARS is planned:

- University of Cologne: S. Baumanns, *Coupled Electromagnetic Field/Circuit Simulation: Modelling and Numerical Analysis*, to be submitted in 2010
- University of Cologne: M. Matthes, Existence and uniqueness of solutions of partial differential algebraic systems, to be submitted in 2010

5.2.1 KLN - University of Cologne

The Mathematical Institute of the University of Cologne provides lectures and seminars about the numerical simulation of integrated circuits and semiconductor elements to diploma, master and PhD students. It is planned to include the results of the project in terms of new methods and algorithms into the courses. Furthermore, PhD students are directly involved into the project. They profit from the close cooperation between academia and industry. It includes learning how to use and contribute to commercial simulator packages from the industrial partners. Furthermore, new mathematical methods and algorithms in the field of EM and circuit simulation will be tested directly by industrial RF circuit examples.

The Mathematical Institute of the University of Cologne gives lectures and seminars on numerical simulation of integrated circuits and semiconductor elements for diploma, master and PhD students.

It is planned to include the results of the project in terms of new methods and algorithms into lectures and seminars. The ICESTARS results have already been presented and discussed at the bi-annual PhD seminars of the Mathematical Institute of the University of Cologne and a *Workshop on DAE/PDAE Simulation with Python* in Daun (Germany), 27-29 May 2010 for the exchange of software developments between the working groups of Claus Führer (Lund University, Sweden), Tanja Clees (Fraunhofer Institute SCAI, Germany) and Caren Tischendorf (University of Cologne, Germany).

Furthermore, mathematics PhD students are directly involved in the project research. They work on Time integration for coupled circuit-EM systems. Topics of the PhD's research are coupled systems. space discretized systems, solving the DAE, numerical experiments and the use of DAEn solver. They benefit from the close cooperation of academia and industry as it includes how to how to use and contribute to commercial simulator packages from the industrial partners.

In addition, new mathematical methods and algorithms in the field of EM and circuit simulation will be tested directly by industrial RF circuit examples.

In June 2009 University of Cologne and MAGWEL co-authored a work document on "Transient simulation of EM-DD systems", detailing the WP 3 on EM Analysis and Coupled EM/Circuit Analysis research goals "Implementation of adaptive time stepping methods" and "Electromagnetic (EM) drift-diffusion (DD) solver in the time domain".

The simulations algorithms developed in ICESTARS are going to be implemented and integrated in the software platform of the numerical analysis group at Cologne University. This platform is both used for teaching purpose and for further research.

5.2.2 WUP - University of Wuppertal

WUP will use the results as an input for further research, i.e. possible PhD positions and Post-Doc activities. In addition, selected parts will enter the teaching of the group, i.e. lectures, seminars, etc. on advanced topics for master and PhD students. The results of the project allow for further intensive cooperation between academia and industry.

5.2.3 FHO - Upper Austria University of Applied Sciences

FHO will use the results for further R&D in the field of transceiver designs in the K/Ku bands. Furthermore, this project will foster the leading position in the field of multi-rate circuit simulation. The results will be disseminated via publications in leading journals in this field, in workshops and in special sessions of international conferences.

5.2.4 OUL - University of Oulu

OUL, Department of Electrical Engineering is an educational and research institution, with main interest in public research and reporting the results as journal papers and MSc and doctoral theses. The group does research on high-efficiency, high-linearity RF transmitters, and this research adds the knowledge of the design methods of these.

5.2.5 TKK-Aalto – Aalto University

TKK-AALTO (Circuit Theory Group) provides lectures ranging from fundamental circuit theory, i.e., basic courses for MSc students, to advanced courses, both theoretical and numerical, to MSc and PhD students. Having access to APLAC Circuit Simulator and working in co-operation with AWR APLAC gives us the opportunity to use the project results both in educational and teaching areas as well as in further research activities. ICESTARS results will be presented and used on the new Master Program course about numerical methods in circuit simulation starting on 2011.

6. Intellectual Property

A Consortium Agreement (CA), which is based on the EICTA model (dated 17 January 2007), is negotiated between all partners before the start of the project, settling among other things the internal organisation of the consortium, reflecting what has been described about the project management structure of ICESTARS in Section B2.1 of Annex I – "Description of Work". The agreement also provides additional rules for dissemination to ensure smooth dissemination of the results. This document is entirely in agreement with these rules. Settlements of internal disputes and of course Intellectual Property (IP) arrangements are also part of the Consortium Agreement.

The IP terms during and afterwards the cooperation of ICESTARS are based on royalty free terms and conditions if these terms may reasonably be expected. If not, fair and reasonable conditions may apply. The IP terms of ICESTARS are consolidated before the Model Grant Agreement with the Commission was signed.