A Set of Radiating Structures for a European Antenna Software Benchmarking

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Abstract — **This paper will present some preliminary results from the software activity of ACE (Antenna Centre of Excellence), the FP6 Network of Excellence dedicated to the restructuring of European antenna R&D. The paper focuses on the benchmarking task that has been initiated to facilitate the assessment of antenna software.**

I. INTRODUCTION

ACE (Antenna Center of Excellence) is a Network of Excellence that has been created on the 1st of January 2004 within the European Community 6th framework program in Information Society Technologies.

It will structure the fragmented European antenna R&D, reduce duplications and boost excellence and competitiveness in key areas. The project has a duration of two years. It involves 45 participants from 13 European countries.

Antenna design is closely linked to the application; antennas must be specifically optimised for each case. On the other hand, antenna theoretical design and principles, software and test techniques can be common. In order to adapt to these two important facts, the work is divided in horizontal activities and vertical activities. The horizontal activities ensure the reuse of antenna technology and tools between the applications, while the vertical activities ensure the suitability of the technology for the different applications.

At the heart of ACE, a *Virtual centre of excellence (VCE)* will serve as a knowledge base and communications centre [1].

A more detailed presentation of ACE can be found in [2].

The software activity is one of the most important horizontal activities of the NoE. Its objective is to establish a list of existing software and make comparisons between them by using test examples. Selected groups of software will also be combined and made available with documentation and support.

To do so, three different work-packages corresponding to three distinct tasks have been planned:

- The inventory action will first give a general overview of the European antenna software domain.
- The benchmarking action will propose a set of structures to assess antenna software.
- The integration action will study possible combinations of software tools.

This communication will focus on the presentation of the benchmarking task whose main objective is to define a set of test structures to assess antenna software.

The communication begins with an expression of the needs for benchmarking (section II). Then, it gives a general presentation of the scheduled benchmarking task (section III). Some preliminary examples are discussed in section IV.

II. THE NEEDS FOR BENCHMARKING

One of the trends observed in most engineering fields for the last 20 years is the increasing importance of software (more specifically CAD tools) to model, design, and synthesize the devices under consideration. The global antenna design community is no exception. Antenna designers rely more and more on the versatility, accuracy, and speed of their software tools. The ultimate goal is to have one-pass design tools, where only a single well-functioning prototype has to be fabricated and tested, instead of the several cycles that are usually required now. This would significantly cut costs down.

Two conditions are required to reach such an ideal situation:

- On the one hand, accurate and powerful software tools must be accessible to the whole antenna community.
- On the other hand, the real capabilities of the software must be clearly established and disseminated so that everyone can choose the tool that best fits their needs.

Considering both conditions presented in the previous paragraph, one can easily get convinced that the first is almost achieved. To be more precise, we can state that many CAD tools (probably too many) are available or at least exist somewhere. Numerous commercial codes are proposed with various numerical methods and assumptions. At the same time, a lot of universities, research institutes, and companies have also developed and are still developing their own (in-house) antenna software.

The second condition is much more difficult to satisfy. This important task will be addressed by the benchmarking work-package. The assessment process is not an easy task due to several factors.

First, as already seen, there are many software packages, both commercial or home-made, with very different features and performances. Even if we limit the investigations to a single analysis method (FDTD for instance), many different tools can be found whose differences can sometimes appear very subtle for non specialists. Indeed, there is no real overview anywhere of the actual capabilities of all these codes. Some of them are obviously premature. Others exhibit good performances but are limited to very specific configurations. None of them can of course be regarded as the universal solution for antenna simulation. In case different codes yield different results, there is no way of determining which one has to be preferred. Moreover, it is very likely that the optimal CAD tool for a given job depends on the specific antenna topology under consideration. The recent emergence of new types of algorithms (wavelet-based compression techniques and other fast solvers) has sometimes significantly extended the performances of classical methods. This makes the global vision even more difficult as the traditional references have changed. In most cases, only the people that have developed the software know precisely what it can do.

There is another reason why the assessment of software is complex. The needs from the users themselves can vary from one to the other. Some of them are only interested in the accuracy of results while others also consider computer requirements (CPU time and memory storage), user-friendly GUI or any other secondary features. What is expected from a given code also depends on the particular application for which it is utilized. Moreover, the needs evolve very rapidly because of the constant improvements of antenna technologies and systems : complex environments must now be accounted when optimising antenna systems and, at the same time, many new technological details (such as MEMS) have to be considered.

Although it is not an easy task, the assessment process is essential for antenna designers. CAD tools must be seen as heavy investments that cannot be done without due consideration. They are often very expensive to purchase and to support. They also require costly training sessions and long-term experience. Only experienced engineers can extract the best performances these software tools can yield. Even when a freeware CAD tool can be downloaded instantaneously from the web, it is not acceptable to waste a couple of weeks before discovering it cannot correctly handle the antenna structure to be studied!

At this moment, for most antenna types, there is no common European criterion to judge an antenna software tool on its performances. One possibility to clarify this situation is benchmarking.

III. ORGANISATION OF THE BENCHMARKING TASK

The benchmarking task is a 18 months work-package that has been initiated in the ACE software activity. The main objective of this work-package is to define a set of benchmarking structures to assess antenna software. As a result, it should provide standards for the evaluation of existing and future antenna software. It should also improve communication between software developers and antenna designers by clarifying the actual challenges in antenna modelling (from both the expressed needs and the expected scientific capabilities). Finally, it should facilitate the convergence of the future research in antenna modelling by concentrating the effort on a set of agreed problems.

The benchmarking task started at the beginning of June, 2004, in Gothenburg. A first questionnaire has then been elaborated and agreed to submit structures for the benchmarking process. This questionnaire can be downloaded from the Antenna Virtual Centre of Excellence (VCE). First proposals are expected at the beginning of Autumn. The next step will be to categorize the proposed configurations into several areas covering the whole antenna domain as well as possible. For each considered area, a specific working group will then be created whose task is to select representative benchmarking structures. Several parameters have already been identified that should lead the choice of the set of structures :

- Representativeness with regards to real-life configurations
- Large coverage of present modelling challenges
- Large coverage of new applications and technologies
- Identification of salient parameters to be benchmarked
- Avaibility of well-accepted reference results (either experimental or analytical)
- Independence of any particular method
- ...

Indeed, two distinct kinds of benchmarking structures can certainly be considered. At a first level, canonical structures involving well-identified modelling difficulties can be used to "calibrate" software on a few basic "standards". This would permit to highlight any intrinsic limitations of the tested codes.

At a second level, real-life structures with both a practical application and measured results must be considered. This is necessary to check the actual capabilities of software with regards to realistic problems.

The collection of the benchmarking structures (including reference results for each of them) will be one of the most important result of the work-package. It will provide a European standard for antenna software evaluation. Once the set of benchmarking structures have been chosen, the

benchmarking process itself will begin. Concretely, input data files for the benchmarking structures (using a defined data format) will be made available using the VCE. Conversely, output data files will be collected for comparison. This will allow anyone to test its in-house developed simulator. It will initiate a continuous in-line benchmarking process whose preliminary results at the end of the 2-year period will be distributed.
This task will also summarize and co-ordinate (but will not be restricted to) intermediary benchmarking activities initiated in the Joint research program for the specific types of antennas considered there.
Due to its topics, this work-package will consider the main areas for which no universal simulation tool has been accepted yet. As a result, it will also identify the remaining "gaps" with regards to antenna modelling. This secondary result is essential in itself as it can be used to direct future research efforts.

For this important task, 19 participants from 8 different European countries are involved:

- Ingegneria dei Sistemi Spa (IDS), Italy
- Katholieke Universiteit Leuven (KUL), Belgium
- TICRA Fond, Denmark
- France Telecom SA (FT R&D), France
- Thales Airborne Systems (TAS), France
- Laboratoire d'Electronique, Antennes et Télécommunications (CNRS-LEAT) Nice, France
- Institut d'Electronique et Télécommunications de Rennes (IETR), France
- Institute of Communication and Computer Systems of the National Technical University of Athens (ICCS-NTUA), Greece
- Politecnico di Torino (POLITO), Italy
- Universita degli Studi di Firenze (UNIFI), Italy
- Universita degli Studi di Siena (UNISI), Italy
- Universitat Politecnica de Catalunya (UPC), Spain
- Universitat Politecnica de Madrid (UPM), Spain
- Universitat Politecnica de Valencia (UPV), Spain
- Swedish Defence Agency (FOI), Sweden
- University of Chalmers (CHALMERS), Sweden
- Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland
- University of Bristol (UNIBRIS), United Kingdom
- University of Liverpool (LIVUNI), United Kingdom

IV. PRELIMINARY DISCUSSION

Although no structures have been selected yet, this section aims to discuss a few examples that could be used to illustrate the problematic.
Figure 1 presents a microstrip antenna optimised by a genetic algorithm. It is typical of a new class of antennas for which the design approach upsets traditional methodologies. In such a configuration, the metallic surface of a patch antenna is first subdivided into small rectangular cells. An optimisation procedure is then used to remove one or several cells until a given set of goals has been achieved.

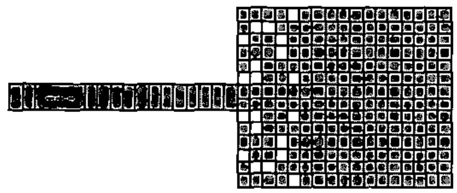

Fig. 1 : Microstrip antenna optimised by a genetic algorithm

As a result, unusual geometries are obtained. Such a problem could be regarded as a very simple one since many efficient CAD tools are now available to analyse microstrip antennas. However, the very specific topology of such genetically optimised structures makes the analysis much more difficult. Many discontinuities are involved which generate singular effects. Edge to edge couplings and corner to corner connections (two classical hot points in antenna modelling) also contribute to large and rapid variations of the fields. As a result, an unexpected dispersion of results is obtained when different simulation tools are used to analyse such a structure. This suggests it could be a good candidate for first-level benchmarking.

Figure 2 presents a completely different antenna.

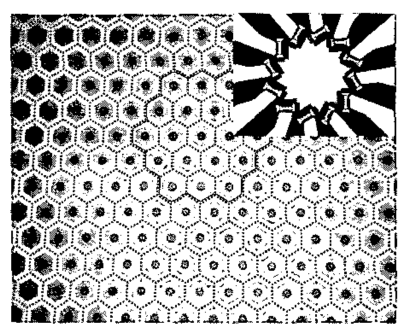

Fig. 2 : ARRESAT reflectarray antenna (Thales/Alcatel/IETR realisation with support from French RNRT)

It consists of an active reflectarray controlled by MEMS switches. Major modelling difficulties can be outlined. On the one hand, a global analysis of the elementary cell is required that must account for the presence of MEMS directly in the radiating element. Note that many technological details (via-holes, resistive lines for bias, 3D dielectric blocks, ...) must also be considered. On the other hand, the modelling of coupling effects requires the analysis of a cell with its neighbours (having different phase configurations). It can easily be understood that different scales should be considered to correctly deal with this problem. This makes it particularly interesting for second-level benchmarking.

Many other examples are expected that combine both modelling hot points and practical interest in regards to new applications, new technologies and methodologies.

V. CONCLUSION

At the time this paper is written, the benchmarking action has just started. A large effort is expected from all participants to perform this challenging task. Other past or present benchmarking actions must also be considered. The first results will be available at the middle of year 2005 and distributed thanks to the VCE. Anyone who would like to submit its own benchmarking structures is invited to contact the authors of this communication.

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