New developments of the Electromagnetic Data Exchange

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Abstract— **The development of the Electromagnetic Data Exchange (EDX) standard was initiated as a joint effort in the Antenna Centre of Excellence (ACE) and the European Antenna Modelling Library (EAML) project, respectively funded under EU-FP6 and ESA-TRP budgets. Since the end of ACE the development continues in the Working Group on Software of the European Association on Antennas and Propagation (EurAAP) in close cooperation with the EAML partners.**

The key issues in the recent developments have been a vastly improved interface to MATLAB and so-called companion tools which enable easy browsing of EDX files and graphical visualization of the contents of such files. Further, new methods for automatic formal data set validation have been studied and new validation tools have been implemented. The future role of the EDX as an important component for data exchange is also discussed showing its potential for improved EM modelling.

I. INTRODUCTION

One of the major obstacles to an effective use of electromagnetic modelling tools is the lack of a common language for the description of the data involved in the calculations. Despite the understandable wishes of tool developers to provide all-in solutions and given the persistent lack of modelling accuracy estimates any engineer committed to high design quality will use multiple tools in its development and verification. Clearly having to produce and maintain multiple coherent description of a design and to compare results in different forms is a burden.

The Electromagnetic Data Exchange (EDX) language is a proposal to overcome the incommunicability problem, born with special attention to University research and space antenna modelling. Its development begun in 2004 as a major joint effort among the Antenna Centre of Excellence (ACE) and the European Antenna Modelling Library (EAML) project, respectively funded under EU-FP7 and ESA-TRP budgets [1],[2],[3],[4]. Since the end of ACE the development continues in the Working Group on Software of the European Association on Antennas and Propagation (EurAAP) in close cooperation with the EAML partners. The activity is one of the three core activities of the Working Group on Software.

The initial work focussed on establishing a robust framework for data exchange and defining the first data models (or Data Dictionaries) for electromagnetic fields and current on structures described by meshes. The most recent activities have concentrated on a vastly improved interface to MATLAB and a couple of, so-called, companion tools which enable easy browsing of EDX files and graphical visualization of the contents of such files. Further, new methods for automatic formal data set validation have been studied and a validation tool has been implemented. These tools are currently undergoing comprehensive tests.

II. A NEW MATLAB EDI INTERFACE

One of the objectives of EDX is to simplify access to data for end users. The availability of a user friendly interface to MATLAB is a major step in this direction. On one side it allows the use of EDX since the early stages of development of new modelling algorithms. On the other it enables the easy combination of home-brew utilities for data processing with proven EM modelling tools.

The MATLAB interface [5] comprises a small set of high level functions for easy use as well as low level functions for MATLAB developers. The high level functions enable an easy, but at the same time comprehensive, handling of all data in an EDX file. Two core functions enable reading and writing of an EDX file. The values and data structure in the EDX file is represented with a `struct` variable on the MATLAB side. This implies that the structure of the data is available also on the MATLAB side, as opposed to the former interface. This provides a platform for further development of MATLAB tools operating on data stored in EDX files.

The new interface automatically deals with data types and sizes, and hence provides a modern MATLAB look and feel. Developers' help functions are provided for translation of EDI data types to MATLAB types.

Validation with the far field data dictionary is built-in by hand, and validation to other dictionaries can be added with a limited effort. The core function for reading data does not depend on any data dictionary definitions, and is designed to work in general. Future plans comprise file-based automatic data validation.

The former interface is still available but it will only be needed in rare cases.

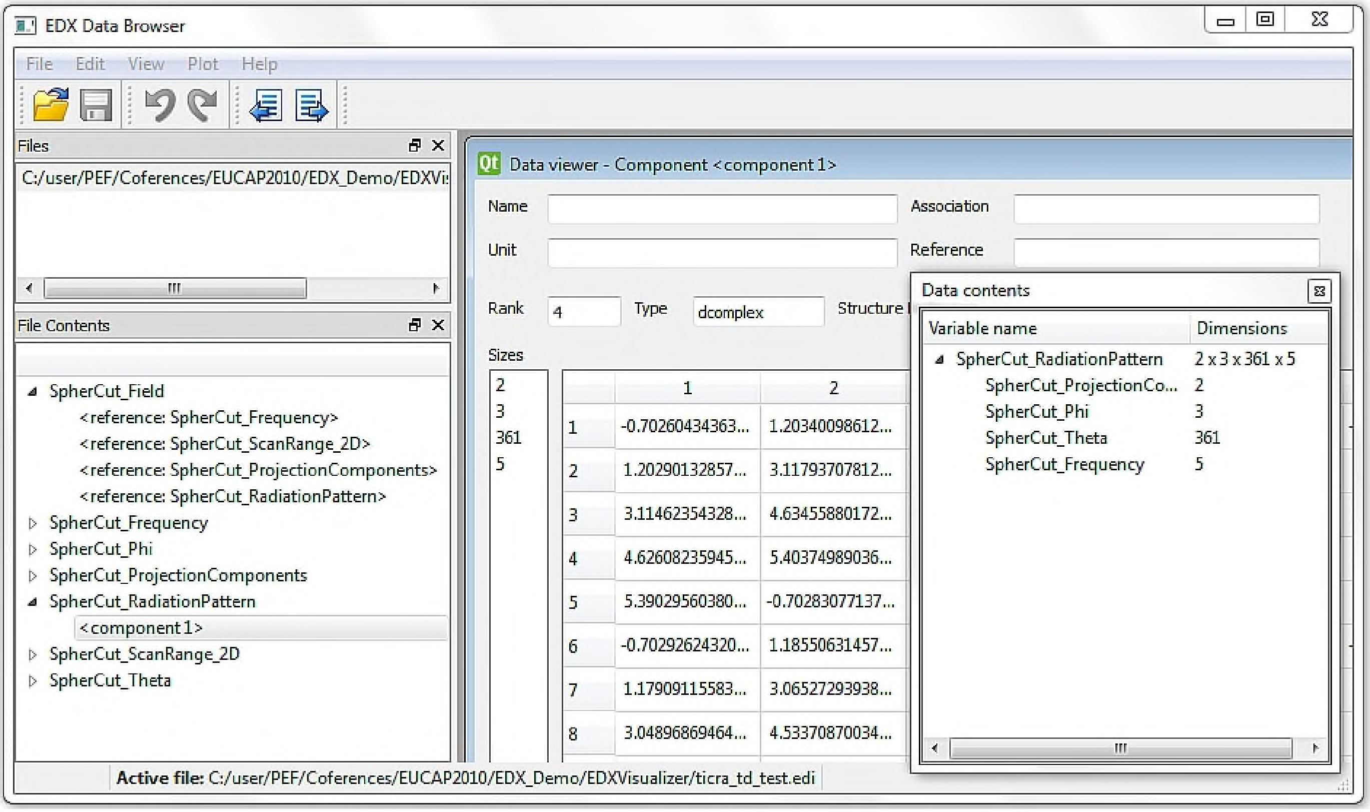

Fig. 1 EDX Browser interface

III. Browsing EDX Files

While being very flexible and powerful, MATLAB may be excessive when a user simply would like to quickly inspect the content of an EDX file. Therefore tools for browsing and visualization have also been developed and are equipped with up-to-date graphical user interfaces [6],[7].

They exploit the fact that EDX files are written using the so-called Electromagnetic Mark-up Language (EML), which has been designed to describe complex data sets in even complex data structures using a relatively simple and uniform syntax. Files are written in a clear and intelligible form where data are organised in a tree-like hierarchy.

The EDX Browser is a general tool to interactively inspect the contents of an EDX file. It can be used to dig into the data hierarchy and allows full access to the structure and content of the data sets in any EDX file. All the definitions, conventions, structure and data can be viewed and inspected with few mouse clicks. Figure 1 depicts its very nice user interface, browsing has been organised in a hierarchical manner through the four sections *File*, *File Contents*, *Data Contents* and *Data Viewer*, each showing additional details on the data elements. In this way the Browser smoothes the EDX learning curves by providing a simple and yet quite powerful interface to dig into electromagnetic data, thus providing a visual introduction to the EDX key concepts (e.g. Variables, Components, Domains).

The EDX Data Browser has been developed in C++ starting from Ticra EDX Viewer [6], and is an extension of it rather than a replacement.

IV. Data Dictionaries and Automatic Validation

A further element in the EDX utility family allows the validation of EDX implementations. A step behind the scenes is required to fully understand its background and usefulness.

All data in standardised data sets are described in a data dictionary. Currently there are two complete data dictionaries one for *Fields* and one for *Currents on structures* [8],[9]. Each data dictionary is defined in a document containing a comprehensive and very detailed description of all physical and mathematical entities forming the data set and including the meaning and the form of such data. These are traditional documents that contain a mixture of descriptive text and long lists and tables describing the various data in detail including their mutual relations. Several sections in the dictionary can also contain complex mathematical definitions such as the polarization definitions in the Fields DD and complex software engineering derivations may also appear.

The actual form of a specific dictionary is selected by the group of developers that prepare the document. The two completed dictionaries have taken quite a different form and identical entities may be presented and defined in quite different ways. Even a simple entity as the frequency is formulated quite different in the two dictionaries. In the Fields DD the frequency is defined with the statement:

> *Frequency is specified in Hz (Hertz) and can have any real positive value.*

Further, the frequency is shown in an example of a far field data file and the frequency is listed as a *class* in the table that maps class names to EDI variable names. In the Currents dictionary the frequency is defined in a table form as follows:

Use	*Element*	*Tool Capabilities*
Mandatory	Frequency or Time	Any values

Frequency Axes	**Units**	**Type**	**Range**
Frequency	Hz	Real	Strictly positive

The same physical entity is thus formulated in different ways. Several other dictionaries are expected in the future. Such dictionaries could introduce yet other ways of defining the required entities and different ways of defining a more complex entity both in meaning and form. This could lead to situations where a software tool would need to handle different versions of the same data. Also, for complex data, the text form may and, likely, will yield different interpretations by different developers.

To ensure uniformity and true interoperability of modelling tools, most of the information should, however, be handled in a common way. A standardized formal way to reformulate the definition of data has therefore been elaborated producing the Data Dictionary Language (DDL), as discussed in [10], [11], [12],[14]. As explained in [13] the language enables concise and unique definition of all mathematical, physical and computational entities need in a specific dictionary. Moreover, one dictionary may borrow definitions from other dictionaries thus avoiding deviating or even contrasting formulations. The application of the EDX DDL has been tested on a private data dictionary (see [14]) by TICRA for reflection coefficients. Although of limited size, this case exemplifies how precise and short a dictionary can be formulated when compared to the textual approach used until now.

Besides offering uniformity and robustness, standardised data dictionaries enable automatic validation. A given EDX file that claims to comply with a certain dictionary may thus be checked automatically by the newly developed EDX Validator [13], which enables the validation of I/O functions that provide access to data stored in the EDX language in EM modelling software. The validation is based on the automatic checking of files generated by the I/O functions for compliance with the relevant Data Dictionaries. The Validator performs its function by reading and parsing the Data Dictionaries expressed in the EDX DDL, then performing the checks dictated by the Data Dictionaries on the files supposed to be EDX-compliant and finally providing a detailed report of all non-compliances found in them.

Currently the Validator has the form of a standalone tool. A version for integration in Fortran90 and C++ programs is foreseen thus enabling embedded validation in the EM tools. As mentioned above, the private data dictionary for reflection coefficients was used as the major test case for the Validator. The dictionary has 28 classes. The validation of the related EDX files is performed in fractions of a second.

The unifying feature for borrowing definitions across dictionaries has also been implemented in the first version of the EDX Validator, but the testing has been limited since no comprehensive dictionaries have yet been translated into the EDX DDL. This is however one of the ongoing EAML activities where an EDX DDL version of the Fields Data Dictionary is under preparation and the Currents and Meshes Dictionary is expected to be reformulated subsequently.

V. The Role of the EDX in a Future EM and Antenna Software Scenario

Today the EDX language is a reality, its power and reach should be assessed by looking at the global picture of electromagnetic modelling tools.

It is clear that over the last 25 years the computational electromagnetics community has seen drastic changes. In the 80's very few commercial solvers were on the market, and the university groups were not really concerned with formats and the technicalities of interfacing to each other. They just wanted properly working software to design their antennas. Nowadays the situation is totally different. First of all, dozens of tools are on the market. Many of them have their own well-defined internal formats and standards. It can be expected that in the coming 10 years a consolidation phase is going to take place. Only a few major players are expected to grasp and maintain a substantial market share. Second, since nowadays practical antenna design is already being dominated by the commercial tools, the university groups involved in modelling tend to lose the incentive to build really coherent software. Instead, there is a tendency to concentrate on the pure scientific output: the modelling techniques themselves, without going the necessary "next mile" to transform the technique and embed it within a real tool. This is a pity, but is perfectly explainable. It is of course a consequence of the fact that a proper formatting and interfacing requires a considerable amount of time and effort.

It is one of the missions of the EurAAP Working Group on Software to change this paradigm. It is our sincere hope that the existence of the EDX framework may again stimulate researchers to contribute to real software development, without having to compromise their scientific output by spending too much time on formats and interfacing. The EDX has to be seen as a real aid, developed and funded by the community as a whole, in order to serve it. It is evident that this goal is long term. The size of the effort required building the EDX and the time to penetrate within the university research groups is such that a considerable impact is only expected within a time frame of the next 10 years.

The latest EDX development described above settle the last cornerstone required to achieve the above goal. Clearly they do not constitute the end of the work, rather the beginning.

VI. The European Antenna Modelling Library Case

Over the past years to promote the spreading of the language, the EDX development team has also been busy with its actual use in commercial and space-related antenna design tools. In parallel with the EDX development and continuing a trend toward better interoperability launched in the late 1990's by the European Space Agency, the EAML team has set up

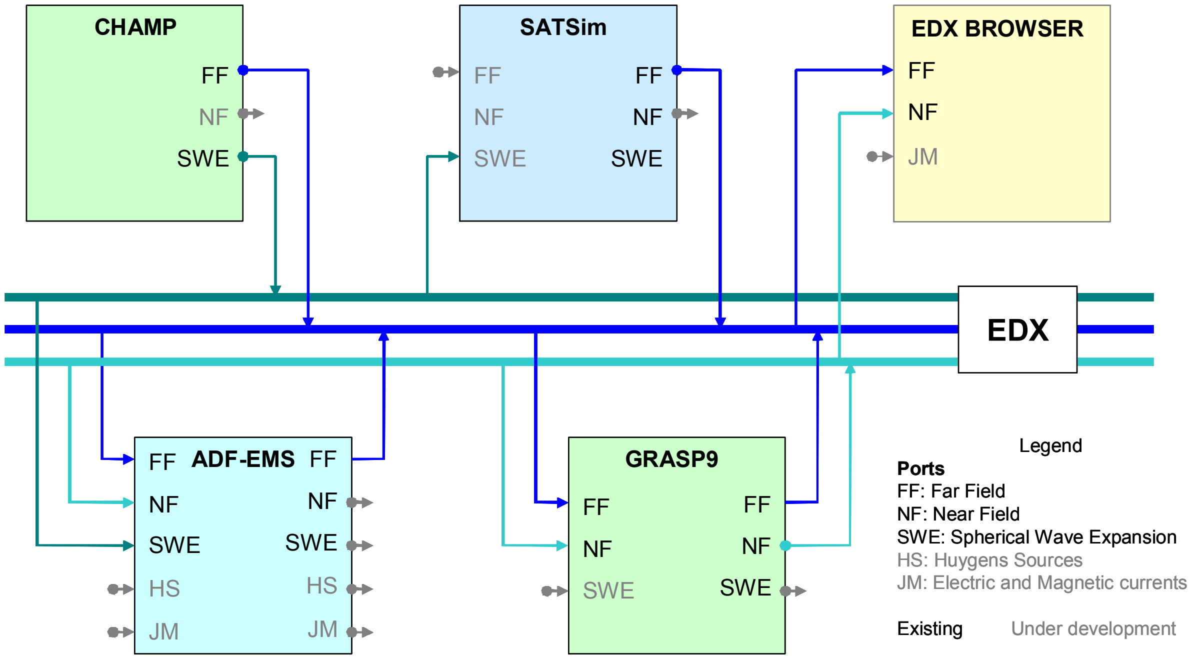

Fig. 2 EDX-EAML data circuit

using EDX a first nucleus of interoperable commercial tools, mainly aimed at space antenna design. The language is used natively by tools like GRASP and CHAMP from TICRA or as interface language like ADF-EMS from IDS and the SATIMO processing suite, SATMap, SATSim and INSIGHT. The development has also offered the possibility to extensively test the EDX library and to identify possible improvements.

The different tools within EAML are now able to exchange data with the EDX language and test cases involving different tools have been successfully modelled. The main objective has been to show how EDX allows exploiting the combined power and flexibility of multiple tools in obtaining accurate and reliable results at a fraction of the computational effort needed with any of them alone. The common language removes all the burden of data conversion and ensures that the transfer of information is free form clerical errors.

The basic idea underlying EAML is illustrated by figure 1. The different tools are connected via EDX realising a sort of data circuit. Today the circuit is operated manually by the user, but in the future its operation will be increasingly automated to further assist antenna engineer in their daily work.

The achievement goes well beyond the boundaries of the commercial tools on which it is based. Combined with the EDX utilities described above it offers a solid basis on which students, research groups and industrial users can build the next generation of electromagnetic modelling tools, aiming at applying the newest and most advanced modelling algorithms in their daily work side by side with well established commercial tools. At the same time, tool developers will have a chance to test new algorithms coming from research groups in an easier way and possibly shorten the implementation time.

VII. Conclusion

Thanks to the co-ordinated work of the EurAAP WG on Software and of the EAML project team, the EDX has been extended with a number of new and improved features and tools that makes the language much more user friendly. The new browser offers a straightforward easy and intuitive inspection of EDX data sets in EML files. The interface is in every respect up-to-date. Likewise, the new MATLAB interface represents a vast improvement in terms of user friendliness. It is much more clear and easy to access than the more subtle Fortran90 interface. It is hoped that these new features will remove or, at least, significantly reduce the barriers for new users and make the EDX much more inviting.

Next with the first applications, the importance of standardised data dictionaries, known since the beginning, has become fully evident. Clear and well defined dictionaries with unique definitions of the many entities are important to avoid confusions and varied interpretations. A formal definition of dictionaries has been the basis to make available easy-to-use validating tools, which ensure correct content of EDX files being exchanged among different tools. Much effort is currently being spent in investigations, developing and testing these validating tools and techniques.

The current and future picture in the EM and Antenna software scenario offers a clear case for the spreading of EDX. A first step in this direction has been made in the EAML project by making EDX available in software tools from a group of partners, many of which are commercially available and extensively used across the world. Recently, the team has set up modelling scenarios involving these tools where data have been exchanged intensively to demonstrate the big potentials of combining different tools.

The wider adoption of EDX, especially on the side of universities and research institutes, is the main objective of the EDX development team and a major goal for the EurAAP Working Group on Software. Work will continue in the near and foreseeable future to find ways to help new users to make the initial, more difficult, steps and to promote EDX among all EM and Antenna software developers in Europe.

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