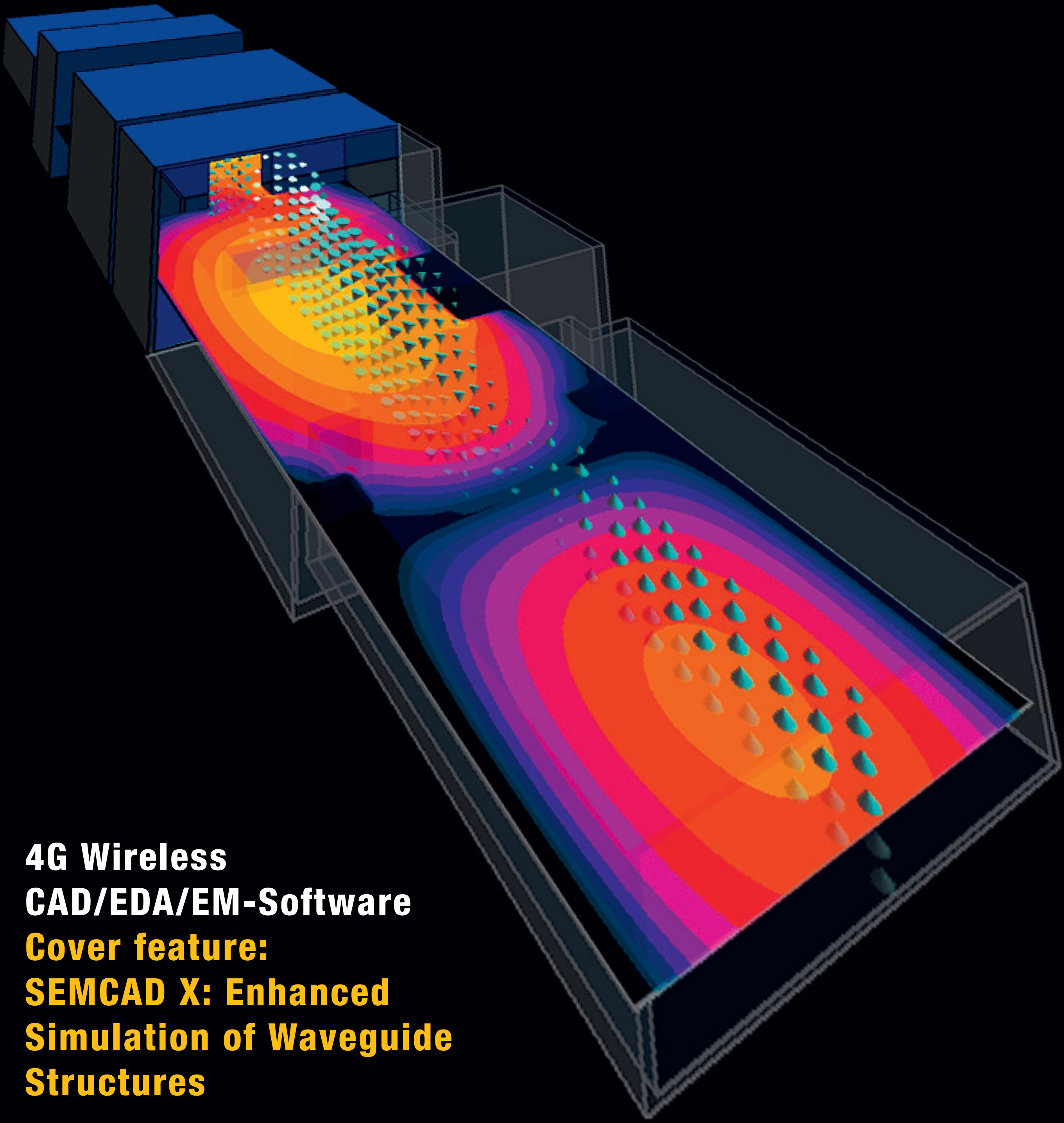
September 2011

european
business press

MICROWAVE engineering europe



4G Wireless

CAD/EDA/EM-Software

Cover feature:
SEMCAD X: Enhanced Simulation of Waveguide Structures

www.microwave-eetimes.com

The European journal for
the microwave and wireless design engineer

SEMCAD X Microwave: enhanced simulation of waveguide structures

By Erdem Ofli, Pedro Crespo-Valero, Schmid & Partner Engineering AG (SPEAG), Zurich, Switzerland
Jorge A. Ruiz-Cruz, Escuela Politécnica Superior, Universidad Autónoma de Madrid, Spain
Carlos A. Leal-Sevillano, José R. Montejo-Garai and Jesús M. Rebollar, Universidad Politécnica de Madrid, Spain

I. Introduction

SEMCAD X is a software framework with a high-end graphical user interface for electromagnetics and thermal simulations based on FDTD techniques that exploit both software and hardware acceleration strategies [1]. SEMCAD X incorporates a rich design and analysis environment by seamlessly combining modeling, simulation, optimization and postprocessing setups. To date, the FDTD techniques implemented in SEMCAD X have been successfully applied to a wide variety of both academic and industrial electromagnetic problems in a wide range of areas including antenna design, radiating/guiding microwave devices, electromagnetic compatibility, optics and bioelectromagnetics [2],[3]. Despite the versatility achieved with this pool of FDTD solvers, there is a growing demand for a platform that tackles each part of the problem with the most suitable method and processes the specific outputs into the overall result. A large number of the structures encountered in microwave applications, given its resonant nature, constitute a challenging test field for this approach. Thus, SPEAG has developed a new state-of-the-art solver based on the Mode-Matching Technique for the simulation of passive waveguide structures. This solver has been integrated into the existing SEMCAD X framework to provide the user with a common simulation environment that will abstract the method in which the solver has been implemented.

This paper presents an overview of the enhancements achieved in the simulation of mm-wave/microwave devices through a set of benchmarks, including dual-mode filters with rectangular and elliptical cavities and components for polarization discrimination.

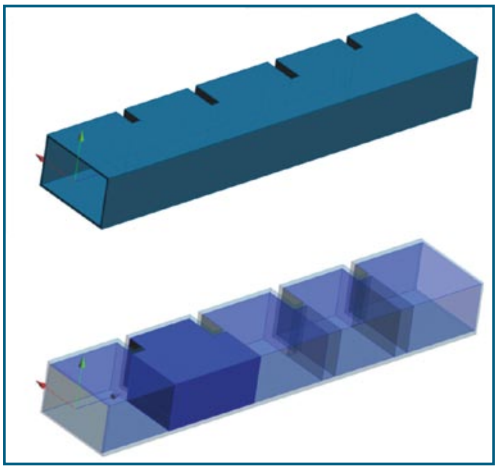
II. Mode-Matching solver

Mode-Matching (MM) techniques [4],[5] have proven to be one of the most efficient and accurate simulation methods with which to tackle waveguide structures. They have become a standard approach in the resolution of real industrial problems such as waveguide transformers, high performance filters, multiplexers, polarizers or ortho-mode transducers.

The key idea behind this method consists of the segmentation of the structure under analysis into individual waveguide regions. It is well known that the electromagnetic field at each of these regions can be expressed as a weighted superposition of the waveguide modes. The specific amplitude of each mode accounts for the boundary conditions between adjacent regions, as well as the excitation and load of the whole structure. In this sense, unlike other numerical methods, MM reduces the EM problem to a linear system on the amplitude of each waveguide mode (scalar complex numbers) rather than the vector fields at each point of a 3D mesh/grid discretization. This creates a considerable reduction in the number of unknowns as well as a more faithful representation of the EM fields, which leads to both a fast and precise resolution of the EM problem.

Taking as an example the structure of Figure 1, the aforementioned approach is implemented as follows. First, the structure under analysis is segmented into building blocks. These are typically discontinuities between waveguides and more complex junctions involving several waveguide ports. These building-blocks are then further divided into waveguide regions, where the EM field is theoretically expanded in the formulation of the algorithm as an infinite

Figure 1: Example of a microwave structure built with several inline rectangular waveguides. Views of the metallic shell (top) and the air volume inside of the structure (bottom).



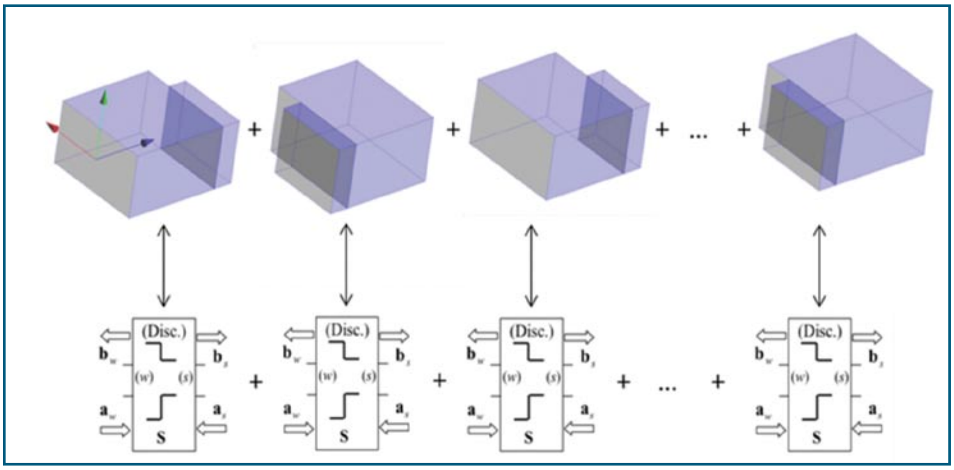


Figure 2: Building blocks of the previous structure. Each one is characterized by its GSM relating modal amplitudes at each side (denoted with a, b). At a final stage, the GSMs are cascaded, providing the system response.

series of propagating and evanescent modes. Obviously, for computational reasons, these series are truncated according to the degree of accuracy required. This is determined by the relative number of modes retained in each field expansion and the total number of modes used in the entire problem.

At the interface between adjacent regions, the modal series defined at each side have to be matched to fulfill boundary conditions. This leads to a linear system, whose solution determines the amplitude of the modes at each waveguide region. This is usually formulated using a scattering matrix formalism, although other approaches based on admittance or impedance matrices are also possible. Thus, the characterization of each building block results in the Generalized Scattering Matrix (GSM), which includes both propagating and evanescent modes.

Finally, the GSM of each building block is cascaded, providing the response of the entire structure. In this sense, the initial problem has been reduced to a multi-port circuit problem (one circuit port per mode), capturing at the same time all the EM interactions within the structure. The S-parameters of the modes at the input/output ports can be extracted from the final GSM.

Moreover, depending on the application, the analysis may require the computation of the EM fields at any point of the structure. In that case, the fields can be reconstructed summing up the modal series previously computed at each specific waveguide region. The main advantage of this approach is that it does not require of any additional interpolation procedure since the waveguide modes are known in an analytical or quasi-analytical form.

The current capabilities of the MM solver in SEMCAD X allow the simulation of structures composed of inline waveguide sections with rectangular, circular, elliptical and circular/elliptical coaxial sections. In addition, structures with N-furcations and cubic-junctions can also be tackled following a similar approach. The combination of these components provides a simulation toolset capable of efficiently and accurately solving a wide variety of waveguide problems such as those presented in the examples of the following section.

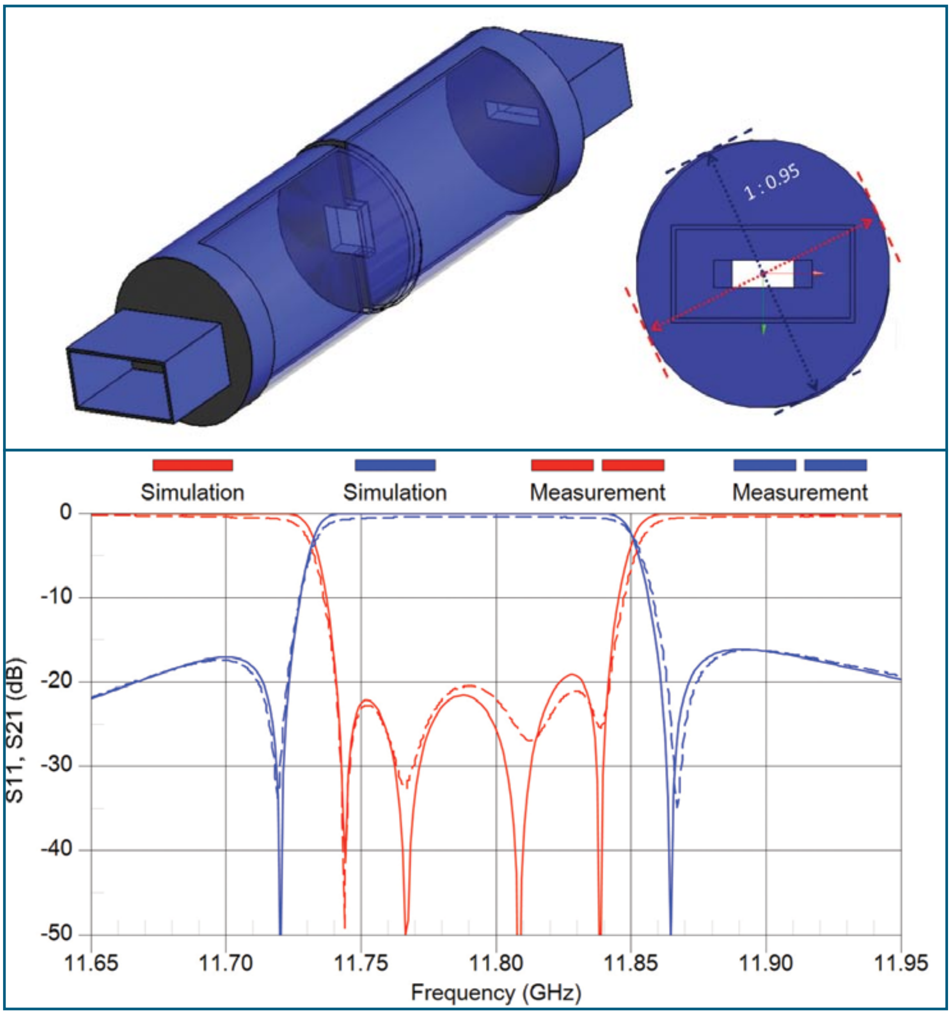
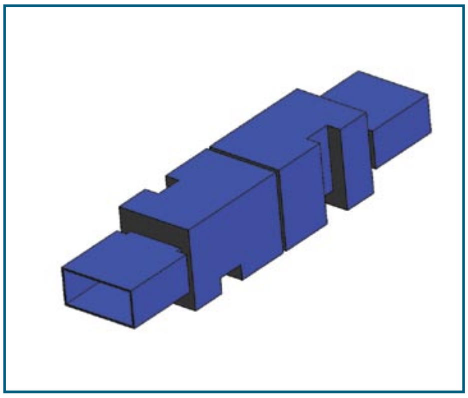


Figure 3: (a) (top) Dual-mode waveguide filter with elliptical cavities, (b) (bottom) simulated and measured response of the filter.

Figure 4: Dual-mode waveguide filter with rectangular cavities.



III. Results

Three different benchmarks were selected to outline and demonstrate the capabilities and performance of the new Mode-Matching solver for the simulation of microwave passive devices with practical interest for diverse real applications.

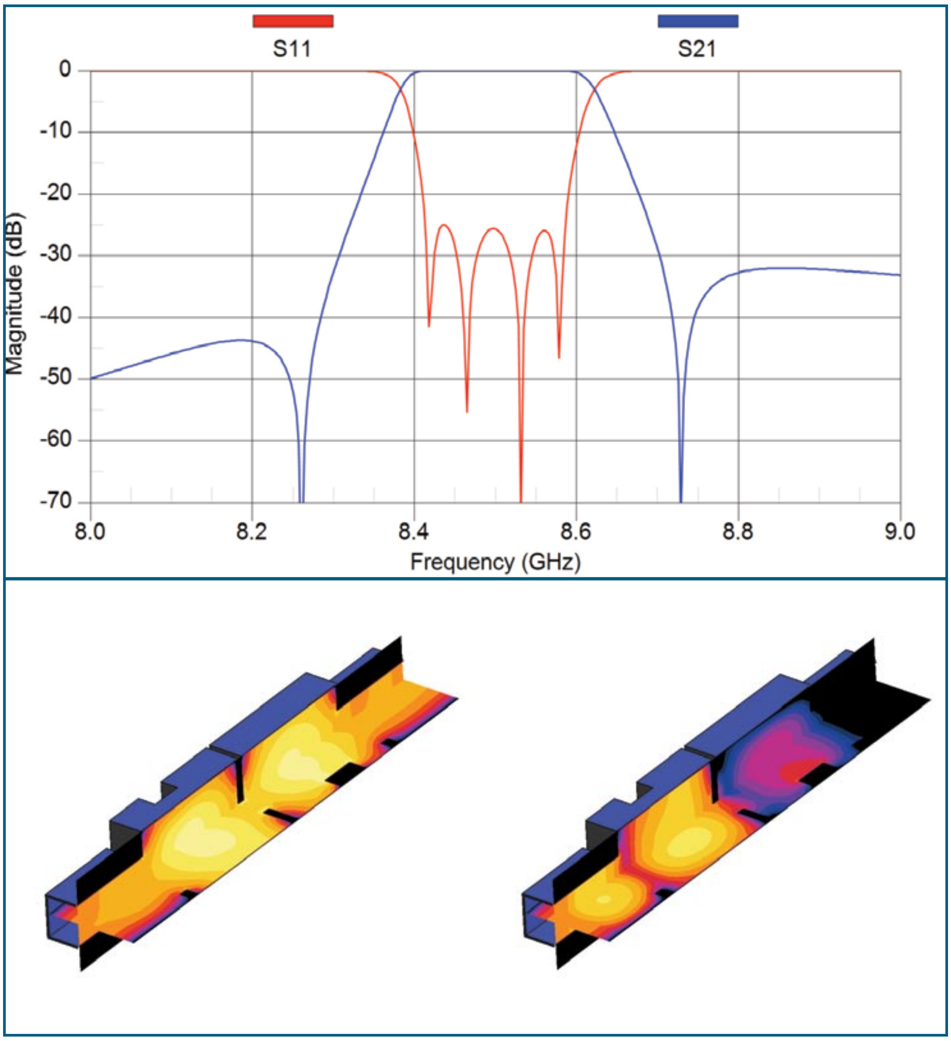
A. Dual-mode elliptical filter

The first example is a dual-mode waveguide filter realized with elliptical cavities and rectangular irises as illustrated in Figure 3(a). The structure consisting of discontinuities between an elliptical and a rectangular waveguide was simulated using the SEMCAD X Mode-Matching solver. Figure 3(b) shows the computed response of the four-order elliptical filter in X band with a center frequency of 11.8 GHz and a bandwidth of 100 MHz. The filter has been fabricated and measured by the authors following the structure in [6]. The measured response shows good agreement with the computed response (Figure 3(b)).

B. Dual-mode rectangular filter

Another dual-mode waveguide filter based on rectangular cavities [7] was simulated to demonstrate the performance of the new solver. The structure shown in Figure 4 consists of two rectangular iris coupled dual-mode cavities with square cross-section. The cross-coupling between orthogonal modes is achieved by perturbations which result in square coupling sections. The SEMCAD X Mode-Matching solver takes into account the interactions between all discontinuities of the structure via all higher order modes. The computed frequency response of the filter and the E-field distribution at the center frequency are shown in Figure 5. The filter achieves four poles and two transmission zeros with two dual-mode cavities with a center frequency of 8.5 GHz and a bandwidth of 170 MHz.

Figure 5: (a) (top) Simulated return loss and insertion loss response of the filter, (b) (bottom) vertical and horizontal slices of the magnitude of the E-field distribution at different frequencies in the passband (left) and at the transmission zero (right).



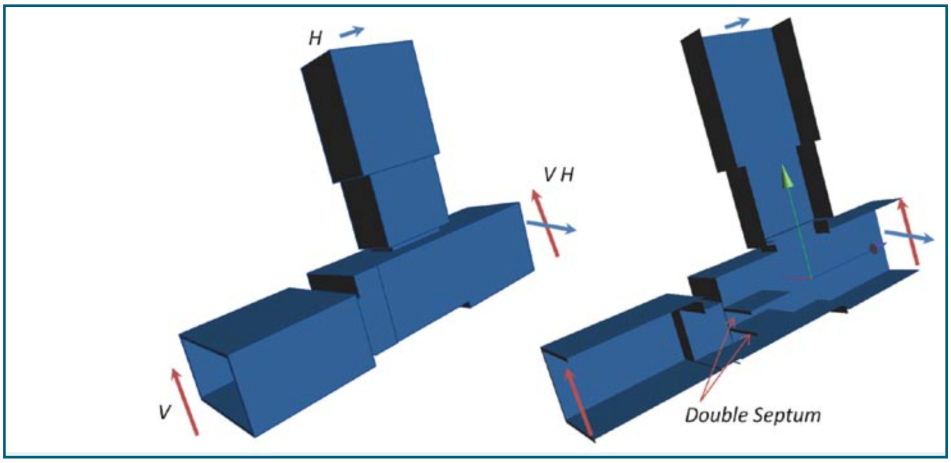


Figure 6: Orthomode Transducer (OMT) with double septum.

C. Orthomode Transducer

Finally, an Orthomode Transducer (OMT) was selected to illustrate the capabilities of the SEMCAD X Mode-Matching solver for multi-port and multi-mode configurations. The square waveguide constitutes the common port, where fields with perpendicular polarization coexist at the working frequency (degenerated modes). Each polarization is separated into the fundamental modes of the vertical and horizontal ports. The structure shown in Figure 6 has been designed as a Ku-band OMT for dual-polarization communication systems to fulfill different requirements for vertical and horizontal polarizations [8]. A double septum allows a shorter device as well as a better matching for the horizontal polarization. The structure has been built and measured to validate the design [8]. Figure 7 (a) presents the matching of both the vertical and horizontal ports showing good agreement between the computed and measured results. Furthermore, the E-field distribution at different cross-sections of the structure was computed at different frequencies and is presented in Figure 7 (b).

IV. Conclusions

In this article, we have introduced the main concepts of an integrated CAD tool combining advanced solvers based on the FDTD technique with a Mode-Matching solver to analyze microwave and millimeter-wave waveguide devices. The Mode-Matching technique combined with the Generalized Scattering Matrix (GSM) has been successfully applied in the analysis of many composite waveguide structures such as cavity filters, power dividers, E-plane filters, and has proved to be a power tool in the microwave industry. The performance and applicability of the SEMCAD X Mode-Matching solver was demonstrated in three specific high-end waveguide devices, highlighting another step forward in EM simulation technology.

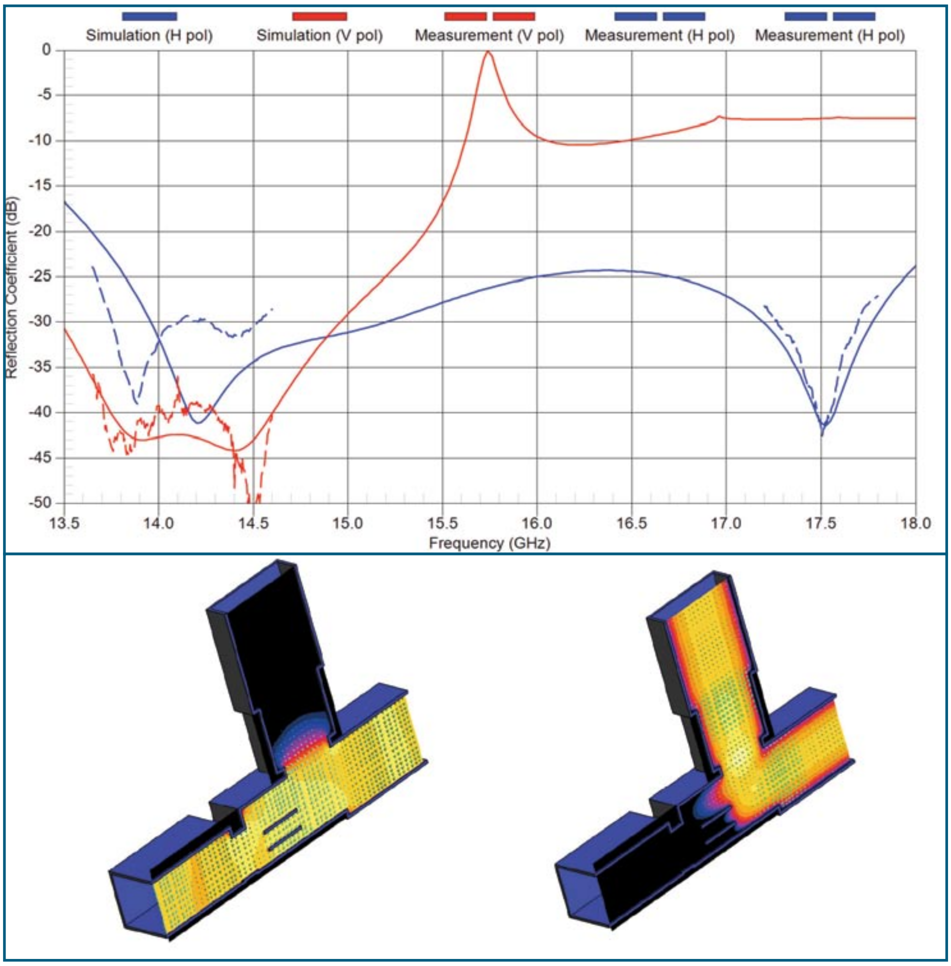
V. References

[1] "SEMCAD X: EM/T Simulation Platform. http://www.semcad.com."

[2] G. Del Castillo, C. Mason, N. Chavannes, and M. Okoniewski, "High performance, high accuracy FDTD implementation on GPU architectures", Microwave Engineering Europe, July/August 2010.

[3] M. Oberle "Software platform for MRI phased array system design & optimization", Microwave Journal, vol. 53, no. 12, 2010.

Figure 7: (a) (top) Simulated and measured return loss response of the OMT, (b) (bottom) slice and vector views of the E-field distribution at 14 GHz (V-pol, left) and at 17.5 GHz (H-pol, right).



[4] A. Wexler, “Solution of waveguides discontinuities by modal analysis”, IEEE Transactions on Microwave Theory and Techniques, vol. 15, pp. 508–517, 1967.

[5] H. Patzelt and F. Arndt, “Double-plane steps in rectangular waveguides and their application for transformers, irises, and filters”, IEEE Transactions on Microwave Theory and Techniques, vol. 82, no. 5, pp. 771–776, May 1982.

[6] L. Accatino, G. Bertin, and M. Mongiardo, “Elliptical cavity resonators for dual-mode narrow-band filters”, IEEE Transactions on Microwave Theory and Techniques, vol. 45, no. 12, pp. 2393–2401, Dec 1997.

[7] J.A. Ruiz-Cruz, Y. Zhang, J.R. Montejo-Garai, J.M. Rebollar, and K.A. Zaki, “Longitudinal dual-mode filters in rectangular waveguide”, 2008 IEEE MTT-S International Microwave Symposium Digest, pp. 631-634, June 2008.

[8] J.A. Ruiz-Cruz, J. Montejo-Garai, J. Rebollar, C. Montesano, and M. Martın, “Very compact ortho-mode transducers with double septum configuration”, Microwave and Optical Technology Letters, John Wiley and Sons Ltd., 2006, 48, 765-767.

Technique discovered for drawing superconducting shapes for future microcircuits using an X-ray beam

A breakthrough in controlling defects could lead to new generation of electronic devices. Reporting in Nature Materials this week, researchers from the London Centre for Nanotechnology and the Physics Department of Sapienza University of Rome have discovered a technique to ‘draw’ superconducting shapes using an X-ray beam. This ability to create and control tiny superconducting structures has implications for a completely new generation of electronic devices.

Superconductivity is a special state where a material conducts electricity with no resistance, meaning absolutely zero energy is wasted. The research group has shown that they can manipulate regions of high temperature superconductivity, in a particular material which combines oxygen, copper and a heavier, ‘rare earth’ element called lanthanum. Illuminating with X-rays causes a small scale re-arrangement of the oxygen atoms in the material, resulting in high temperature superconductivity, of the type originally discovered for such materials 25 years ago by IBM scientists. The X-ray beam is then used like a pen to draw shapes in two dimensions.

A well as being able to write superconductors with dimensions much smaller than the width of a human hair, the group is able to erase those structures by applying heat treatments. They now have the tools to write and erase with high precision, using just a few simple steps and without the chemicals ordinarily used in device fabrication. This ability to re-arrange the underlying structure of a material has wider applications to similar compounds containing metal atoms and oxygen, ranging from fuel cells to catalysts.

Prof. Aeppli, Director of the London Centre for Nanotechnology and the UCL investigator on the project, said: “Our validation of a one-step, chemical-free technique to generate superconductors opens up exciting new possibilities for electronic devices, particularly in re-writing superconducting logic circuits. Of profound importance is the key to solving the notorious ‘travelling salesman problem’, which underlies many of the world’s great computational challenges. We want to create computers on demand to solve this problem, with applications from genetics to logistics.”

www.london-nano.com
www.phys.uniroma1.it