CST DESIGN STUDIO™: A Tool for the Design of Complex Systems

by CST of America

For complex structures three dimensional electromagnetic field simulations are challenging in terms of both memory and simulation time requirements. CST DESIGN STUDIO™ (CST DS) is a new electromagnetic simulation tool that facilitates the efficient design of complex and/or highly resonant structures. CST DS allows the combination of electromagnetic components by means of their scattering parameters. By splitting up the complex system into smaller sub-components, each described by its S-matrix the complete system's behavior can be quickly analyzed, reducing the memory requirements for the system. What makes CST DS of particular interest, is its ability to consider higher order mode coupling between the sub-components, so that the structure can be divided in smaller parts without any loss of accuracy. As an additional advantage, the single sub-components can be subject to modification without recalculating the whole system.

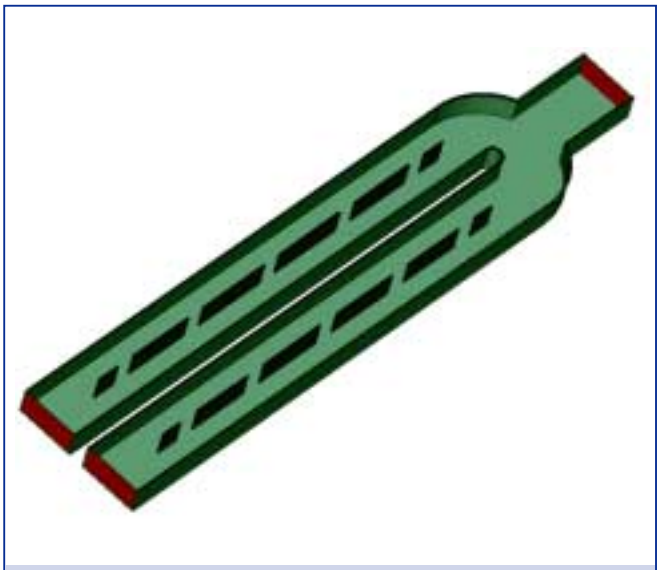

Figure 1: Geometry of the high frequency bandpass structure. In CST MICROWAVE STUDIO™ both the metal foils and the waveguide cover can be analyzed as a finite conductor under the influence of skin effect losses.

Functionality

CST DS is developed as a universal platform to manage the numerical simulation and the design of complex structures. It allows the interconnection of various devices, the so-called blocks, by their scattering matrices. Solutions for electromagnetic devices based on analytic models, libraries, measurements or numerical simulations may be contributed, e.g., using the TOUCHSTONE format.

The analytic solution for the electromagnetic fields and the S-parameters on several kinds of transmission lines is well known, and there is no need to include them into any kind of numerical simulation. For quite a number of electromagnetic devices such as perfect absorbers and phase-shifters, the analytical models are already implemented in CST DS. They can be included, changed and optimized with literally no computational cost. Other useful models include perfect absorbers, phase-shifters and well defined reflections.

Besides the inclusion of measurement data, the consideration of numerically derived results of three dimensional field data is of particular interest. The tightest integration with 3D tools naturally takes place with CST MICROWAVE STUDIO™ (CST MWS), the CST's electromagnetic field simulator. The (generalized) scattering parameters for an arbitrary number of modes and ports are the primary results of such a simulation. CST DS supports the building of a library of microwave components described by CST MWS results. It manages already calculated data and requests new simulation runs if necessary. An interface to the high frequency planar software suite SONNET EM™ is already implemented. Further interfaces will follow.

CST DS calculates the system response by evaluating the single block S-matrices, taking into account higher order mode coupling as well. The obvious advantage is, that the modification of one block leaves the other blocks untouched and the time for recalculating the system response from the S-matrices is negligible. Thus the effort to optimize a structure can be dramatically reduced.

The results can be finally visualized as impedances or S-parameters by several view options as amplitude/phase, real/imaginary part, polar or smith chart plot. For documentation purposes text boxes and images may be included inside the drawing.

Being developed in the Windows environment CST DS takes advantage of elaborated libraries. It offers a powerful Visual Basic for Applications (VBA) compatible interface, including editor and macro debugger and is seamlessly integrated into the OLE automation. Thus CST DS may steer or be steered by other programs using this mechanism. The full parameterization and the VBA macro language make complex optimization tasks feasible.

Scope of Applications

Conventional circuit simulators using analytic library elements as well as specialized internal EM simulators are fast, but, if details such as consideration of skin effect losses or complex curvatures of materials are of importance, the accuracy of their results will quickly be compromised. 3D simulators like CST MWS overcome these limitations by their ability to solve Maxwell's equations for arbitrary geometries, including sophisticated material models. Of course, compared to standard circuit simulations, the wide application range and accuracy of such simulators have to be paid for with longer analysis times. However, in combination with CST DESIGN STUDIO™ this disadvantage is counteracted. There are two principal fields of applications for CST DS:

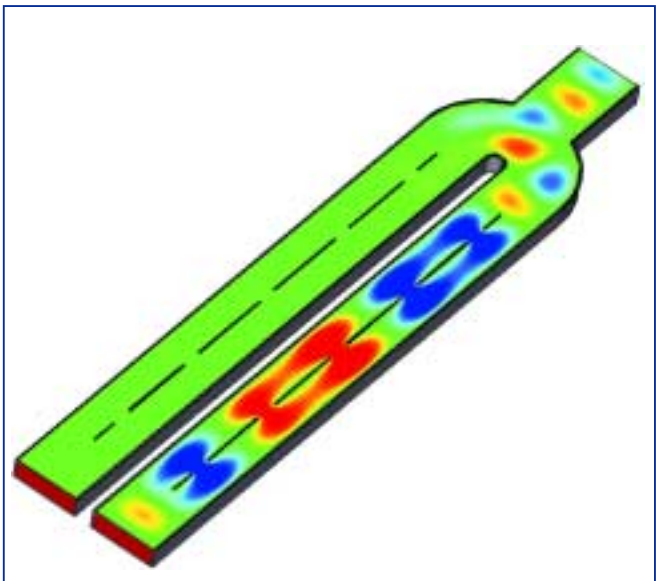

Figure 2: Strength of the electric field value at a C.W. frequency, perfectly passing through one arm and stopped in the other arm. The simulation is performed with CST MICROWAVE STUDIO™.

Large Structures

While a complete 3D simulation of a complex system sometimes requires a long analysis time, this new technique provides the same accuracy in a fraction of this time. Particularly parts of the system that can be described analytically do not have to be included in numerical field computation. The computational volume and thus the memory requirements may be reduced. Modifications or optimization can be realized quickly while maintaining the accuracy and generality of a 3D field simulation. CST DS will show its capabilities managing such projects.

Highly Resonant Structures

The accurate analysis and design of passive high frequency filter circuits is a demanding task since both geometry and material properties become more and more complex. The advantage of 3D simulators working in the time domain, i.e., calculating the broadband system's response in one simulation run, might be reduced in the presence of strong structure resonances with high quality factors. Although there are signal processing methods that allow a fast solution of such problems, CST DS offers another approach, that will be discussed in the following example.

Application Example

The diplexer structure discussed in this article consists of two bandpass filters Figure 1. In order to predict the

Continued on pg 58

Continued from pg 55

complete electromagnetic behavior including skin effect losses and curvatures, the highly developed features of a 3D simulation tool are required. Furthermore, a very fine discretization around the metal foils is indispensable, especially to accurately predict the passband's edge frequencies. Therefore, more than a hundred thousand single mesh elements, considerably varying in size (high aspect ratio) are required in order to model the device accurately. Although the geometry looks quite simple, the electromagnetic complexity of this highly resonant system and the described mesh requirements qualify it as an ideal benchmark candidate for the comparison of simulation engines.

Various simulation methods behave significantly differently with respect to the numerical effort, especially when attacking larger numbers of mesh elements. Implicit algorithms (e.g. all frequency domain methods) behave in a strongly non linear way (in terms of computer resources) with increasing problem sizes, whereas explicit algorithms such as the FDTD and FIT method can handle large problems within a reasonable memory size and time.

The simulation of the complete diplexer using CST MWS, a simulator based on the Finite Integration (FI) method is shown Figure 2. The advantage of CST MWS compared to conventional time domain codes is the precise geometrical representation even of curved shapes, achieved by the Perfect Boundary Approximation™ (PBA). This method avoids staircase approximation of curved structures, without giving up any advantages of the explicit time integration algorithm. Despite the outstanding speed and memory efficiency of CST MWS, compared to other 3D EM Simulators on the market, the complete 3D simulation of the 2-arm diplexer takes a few hours on a standard desktop PC, so that advanced design strategies, including parameter sweeping and optimization runs, are not practical.

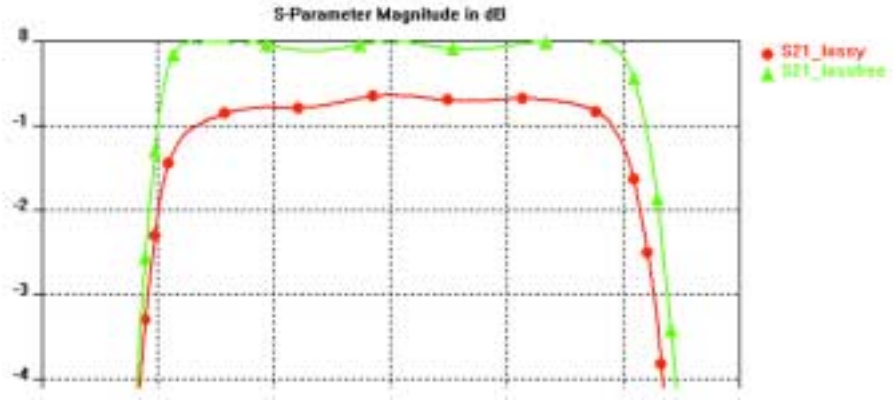

Figure 4: S21 as a function of frequency. Due to its tight integration with CST MICROWAVE STUDIO™, all advantages of this general purpose EM tool are maintained in CST DESIGN STUDIO™. As shown, the pass band transmission is reduced by more than 0.5 dB when considering skin effect losses.

Technology

At this point, the benefit of the new program CST DESIGN STUDIO™ becomes obvious: its ability to speed up the described simulation without losing accuracy. CST DESIGN STUDIO™ reaches this goal by splitting up a complex system into smaller components, described by component S-matrices. Taking into account higher order modes in the S-matrix description, the structure can be dissected even at locations where the fundamental mode alone is not sufficient to describe the electromagnetic coupling accurately.

Particularly for resonant structures the gain in simulation time can be dramatic: the structure can be split up into non-resonant parts, which are then analyzed much faster than structures with multiple narrowly spaced resonances. In addition, time domain simulators such as CST MICROWAVE STUDIO™ have the possibility of speeding up a simulation by increasing the simulation bandwidth, therefore using a shorter stimulation pulse. Finally the simulation time for the whole structure is reduced to couple of minutes.

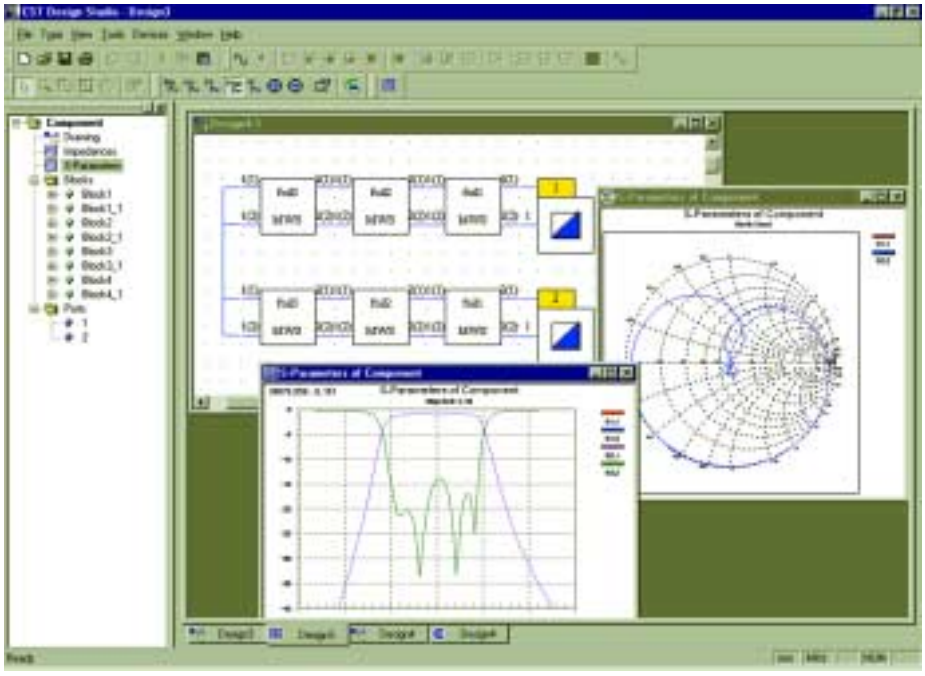

Figure 3: User Interface of CST DESIGN STUDIO™. The diplexer is split into smaller sub-components. Taking into account higher order mode coupling between the components ensures highly accurate simulation results - more than 10 times faster, compared conventional 3D simulations.

Summary

CST DESIGN STUDIO™ is a new tool for the fast design of passive high frequency devices. Even highly resonant structures can be split into non-resonant sub-components.

The new approach is capable of taking skin effect losses as well as arbitrary curved structures and boundaries into account. Since the simulation time is reduced significantly compared to conventional tools, CST DESIGN STUDIO™ now even allows fast full parameterization and optimization studies for complex systems, while maintaining all required accuracy.

CST DESIGN STUDIO™ is a package of high functionality which interfaces to different simulators or even measurement data, so that each component can be analyzed with the simulator best suited to the particular component. Furthermore, analytic models and/or libraries are available, which again speeds up the daily design work.

The intuitive and easy to use interface is based on the latest software technology Figure 3. This enables the user to build up clear schematic drawings of complex structures and circuits, keeping a clear overview by adding text and graphic elements.

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