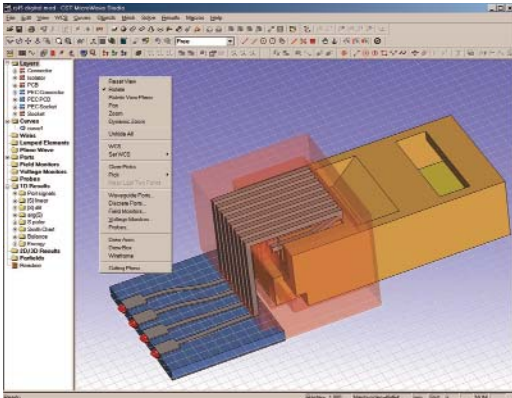


COVER FEATURE



A REVOLUTION IN THE TIME DOMAIN

CST MICROWAVE STUDIO® Version 4 (CST MWS) is a major new release of the company's flagship 3D EM microwave modeling and design package. Over 1400 changes, enhancements and new features have been added to make this already powerful tool truly comprehensive and an invaluable resource. The microwave design engineer seeking rapid evaluations and optimizations of his virtual prototypes can now find a complete solution in a software tool that, despite its new power, has remained as user friendly and fun to use as ever.

CST MICROWAVE STUDIO incorporates not only the highly versatile Time Domain Solver, but also an Eigenmode and a Frequency Domain Solver which serve to further augment its wide applicability. CST MWS is fully integrated into the open CST design environment (CST DESIGN STUDIO™) and can be tightly integrated with any other compliant software through the COM interface. At MTT-S 2002, Agilent and CST premiered the new direct link between ADS and CST MWS.

This article reveals the key new features of CST MWS Version 4 and specific application areas addressed by the new features will be

shown. Regular users will come across many other improvements as they start using the software. The photo above shows a screen shot of the single window interface of Version 4.

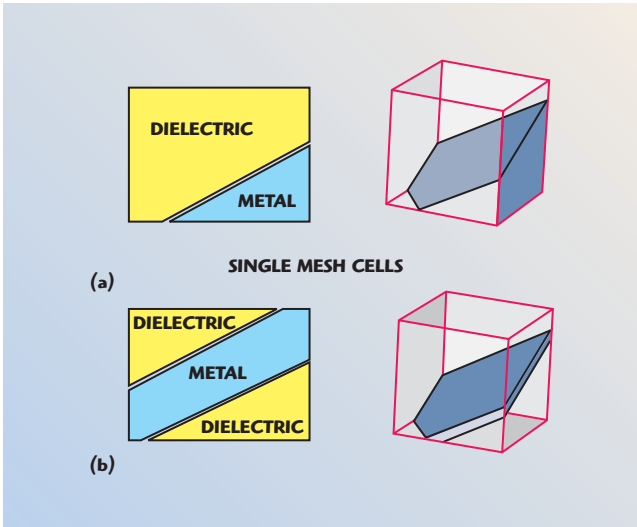
MESHING

CST MICROWAVE STUDIO is based on a rectangular meshing scheme, which has been shown in many studies to be the most efficient time domain method available. In the scheme field values are distributed around the edges and face centers of mesh cells, but the software has always had the ability to arbitrarily slice a cell into two regions — one dielectric field region and one metal region through the PBA® method. This has allowed for very good geometrical representation of curved and inclined objects without a fine mesh or 'staircasing.'

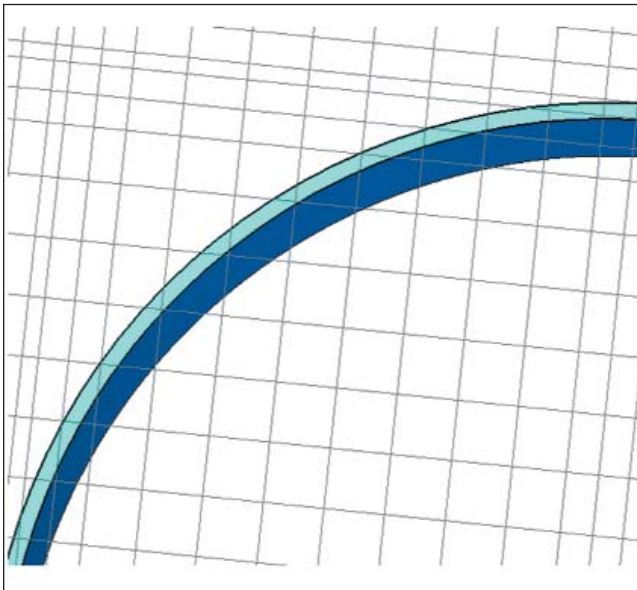
A first for time domain software, version 4 now has the ability to arbitrarily slice a single mesh cell into three regions: two decoupled dielectric field regions and a thin metal region

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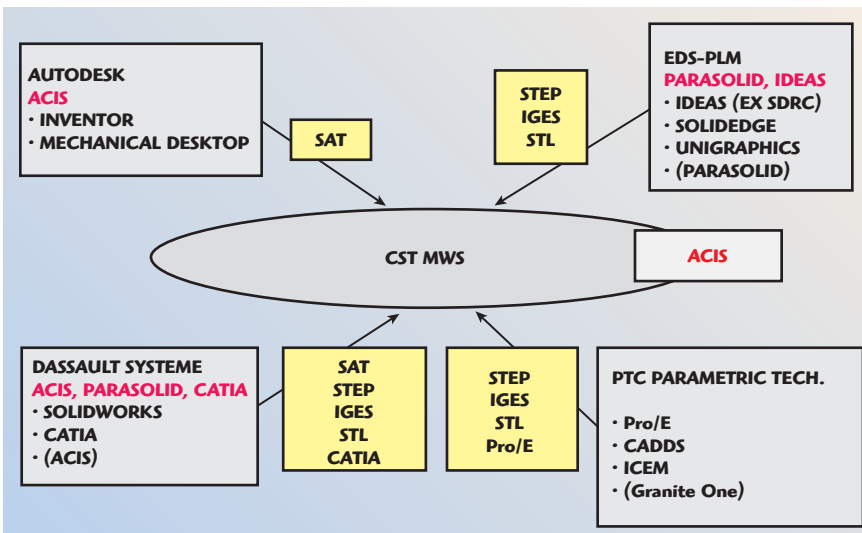
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▲ Fig. 1 Extension to the PBA method; (a) Version 3 original PBA and (b) Version 4 extended PBA.



▲ Fig. 2 PBA split cells mesh thin curved regions exactly.



▲ Fig. 3 CAD import routes.

cutting through the cell. **Figure 1** shows the extension to the PBA method introduced in Version 4.

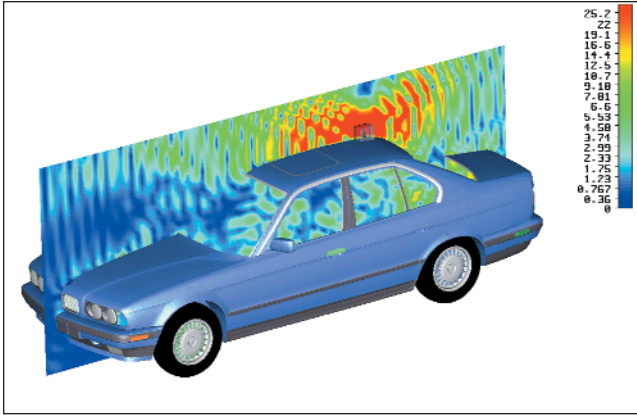
The result of this extension is that thin curved or inclined metal does not have to be meshed finely in order to give accurate results. Because the time step in time domain solutions is related to the smallest mesh cell size, this also keeps the time step high and reduces run time considerably. Application areas that will benefit from this extension are conformal antennas and signal integrity with thin inclined IC parts. **Figure 2** shows a thin metal cylindrical shape modeled with no critical cells. Clearly the geometry is matched exactly. Version 3 would work, but would fill up sliced cell areas with “critical cells” or whole cells of metal. Version 4 meshes exactly with no critical cells.

Other meshing improvements include changes to memory management so that an already efficient scheme uses even less memory. It is now possible to run up to five million mesh cell problems on an off-the-shelf business PC. CST MICROWAVE STUDIO’s expert meshing system, where the software analyses a structure and its known electromagnetic properties to give a good mesh from the outset, has been improved further with the use of built-in project templates. For every new project, the user is offered a selection of project types. These include IC packages, antennas with a ground plane and coaxial connectors. For each template the software applies appropriate units, boundary conditions, mesh properties and other settings. All of this means that the user can confidently start building a geometry straight off without having to consider the preliminary set-up and with little or no need for adaptive meshing. Helping even further in this regard is the Version 4 extension to metal edge refinement. Due to field singularities at perfect metal edges it is necessary to refine the mesh in those areas to correctly represent the fields. The expert mesher has always done this for straight edges orthogonal to the mesh, but Version 4 extends this to include all mesh edges again increasing the accuracy of the initial solution.

CAD IMPORT/EXPORT

The range of CAD exchange formats has been substantially increased in Version 4. The universal STEP format is added to the existing IGES and STL capabilities. The industry’s two main kernels, ACIS and Parasolid, are addressed — directly in the case of ACIS, as this is CST MICROWAVE STUDIO’s native format, and through one of the universal interchange formats in the case of Parasolid. CATIA® and Pro/E® files can now be imported directly. Furthermore, STEP and 2D DXF have been added to the list of CAD formats that can be exported. **Figure 3** shows the main commercial CAD vendors and their products and how CST MWS can deal with them. The grey boxes show the vendor in black, the kernel they use in red and their main products. The yellow boxes show the interchange formats that can be used to transfer data to CST MWS.

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▲ Fig. 4 Electric field slice for an STL imported car with sheet meshing.

CST MICROWAVE STUDIO Version 4 now has a direct link to Agilent's ADS circuit simulator. CST MWS can import an ADS model or alternatively ADS can export a model directly to CST MWS for field simulation.

To address the significant problem of differing requirements for mechanical and electromagnetic CAD, healing capabilities have also been improved in CST MWS Version 4. Automatic healing with individual part reporting is set by default on import of external geometry.

THIN SHEET MESHING

For large thin metallic bodies with many details such as a car, direct CAD import and subsequent meshing may become impractical due to the large number of unnecessary details and materials. The ideal solution to this is to use a sheet meshing scheme as implemented in Version 4. Here metal materials are represented by two-dimensional (2D) internal surface conditions, not full three-dimensional (3D) cells. This technique allows very fast runs for apparently complex objects such as an STL imported BMW car with a monopole communications antenna. **Figure 4** shows the car plus antenna in CST MICROWAVE STUDIO with results. This was solved in 1 hour and 38 minutes on a 1.9 GHz P4 and used 1.6 M mesh cells.

MATERIALS — FREQUENCY DEPENDENT LOSSES AND DISPERSION MODELS

Time domain methods are inherently broadband so that a shaped time pulse excites a geometry with all

required frequencies in the pulse. This can give rise to difficulties in setting correct material properties for every frequency. Generally the user can specify conductivity or a tangent δ at a particular frequency creating a fixed “effective conductivity” across the band. **Figure 5** shows the equations involved where the effective conductivity is $\omega\epsilon'' + \sigma$.

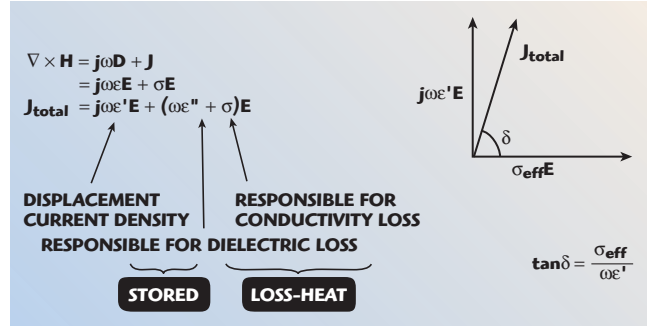
In order to maintain the fixed effective conductivity the imaginary part of the permittivity (ϵ'') must change across the band, giving rise to a non-physical dispersion effect. Moreover, the tangent delta also changes across the band.

Version 4 addresses this area with more material options. It is now possible to define a constant tangent delta across the band or a “dispersion fit” tangent delta where the user can specify a table of tangent delta values against frequency. **Figure 6** shows the fraction of a decibel accuracy now possible with a coplanar line above a lossy substrate.

Version 4 allows many other material options to be specified, including magnetic conductivity, dielectric dispersion models such as Debye, Drude and Lorentz, and magnetic dispersion models, including gyrotropic. Among other things, these new material options allow plasmas and ferrites to be included so that for example isolators and circulators can now be modeled.

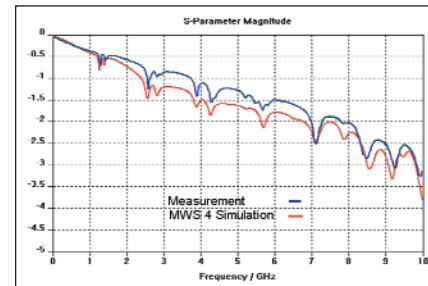
TRUE DE-EMBEDDING

Inhomogeneous ports are modelled with high accuracy in CST MWS Version 4. An inhomogeneous port is a 2D port driving a problem that has more than two materials in it — for example, a microstrip line where there is metal, air and a dielectric substrate. At such a port a quasi TEM mode is



▲ Fig. 5 Material equations.

Fig. 6 High accuracy with new material options. ▼

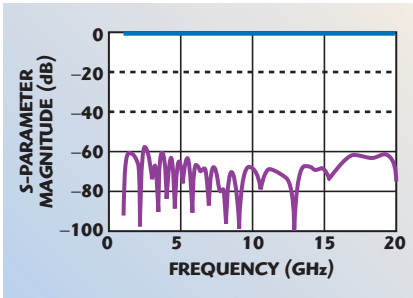


created where, as well as the transverse field components, some longitudinal field components also exist due to the differing permittivities of the dielectrics. The quasi TEM mode created at an inhomogeneous port will vary slightly at different frequencies and that difference will increase the more inhomogeneous the port is.

The upshot of all this from a time domain software point of view is that the Q-TEM mode is only 100 percent accurate at a single frequency and this is usually set at the center of the band of interest. For highly inhomogeneous ports where the difference in dielectric constants is large, the accuracy of the overall 3D solution can suffer, particularly at the extremities of the band. Traditionally, running several narrower band problems or shifting the “mode calculation frequency” can rectify this problem.

CST MWS Version 4 addresses this issue head on by using a unique de-embedding technique that decouples the port region from the 3D solution region. A single check box is checked for de-embedding and a number of samples chosen. The number of samples determines the number of port calculations and directly influences the achievable accuracy. **Figure 7** shows the CST MWS Version 4 results for a particular microstrip device. The return loss is below 60 dB across most of the band.

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▲ Fig. 7 Accuracy improvement using de-embedding.

OTHER MAJOR CHANGES

A new optimizer is included in the default configuration of CST MWS. Based on the interpolated quasi-Newton technique, it gives convergence to the desired result with many fewer runs than previously possible. It is also possible to create much more complex goal functions. Target functions (for example, S_{11}) can be allocated an operator (for example, minimum), a target value, a frequency range and a weight. With multiple target functions it is possible to build up complex goals such as a filter response. All intermediate results from optimization runs can now be stored in a cache for later analysis if required. This also applies to parametric studies.

To reduce the number of runs necessary for complete S-matrix multipoint devices, it is now possible to define port symmetries. If S-Parameter symmetries exist, then groups of

S-Parameters can be defined so that only one of the group is calculated. For simultaneous port excitation, it was previously possible to combine solutions as a post processing step to see the combined far field effect. It is now possible to simultaneously excite ports during the analysis, which may give some further insight due to coupling effects and also allows coupled near fields to be determined.

The Eigenmode Solver has received particular attention in CST MWS Version 4 and now makes use of the Frequency Domain Solver (no additional license required) to achieve a first solution. Whereas the old Eigenmode Solver may have required 100 eigenmodes to get a good solution for resonances and S-Parameter levels, the new solver can achieve equal or better accuracy with the one frequency domain solution and four eigenmodes. Periodic boundaries with arbitrary phase have been introduced into the Eigenmode Solver and also the Frequency Domain Solver.

Post processing has improved in CST MWS Version 4 to include better visualization of plane waves with field vectors automatically orthogonalized to the propagation direction. Far field plots compliant with electromagnetic compatibility (EMC) regulations have been implemented so that a reference distance can be set along with appropriate units such as dB- $\mu\text{V}/\text{m}$. EMC

current and voltage sources can be defined when the model is being built. Near field values can now be plotted based on a user-defined curve, which includes a 3D curve in Version 4. Line integral values are shown and a one-dimensional entry is created in the navigation bar to show the field variation result.

CONCLUSION

CST MICROWAVE STUDIO Version 4 is a major upgrade to the existing software with many new features based on both structured long term development and user requests. The new features are implemented with the microwave design engineer in mind. The aim throughout has been to add throughput benefits while retaining the unique user-friendliness of the software. Although there are many new features, both existing and new users will find the software very approachable. For the casual user, less input is required due to the improvements in the systems and large number of new CAD imports available. For the expert user, new features will provide faster and more accurate virtual prototyping.

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