THE ADVANCED 3D-EM SIMULATION SOFTWARE AND APPLICATIONS

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Abstract

Most of the electromagnetic problems can be analyzed and understood by 3D-EM (Electromagnetic) simulation which is performed by solving Maxwell's equations numerically. Recent advances in computer hardware technology and EM simulation algorithm enable us to visualize 3D EM wave propagation, even with personal computers. This paper reviews the most recent status of advanced EM simulation technologies and their future.

INTRODUCTION

The traditional process for solving EM (Electromagnetic) problems was to build a prototype, accumulate performance test data by subjecting the prototype to various experiments, correct deficiencies, and retesting, which normally require several cycles.

While 3D-EM (Three Dimensional Electro-Magnetic) simulation techniques existed, these methods were generally not economically feasible since they required the use of supercomputers as well as a substantial knowledge of EM theory and advanced numerical techniques. During the last decade, the three dimensional electromagnetic simulation capabilities have significantly advanced due to the tremendous progress in computer hardware technology combined with an improvement in numerical techniques.

3D-EM SIMULATION SOFTWARE

Various numerical methods have been used to solve EM problems. These methods include the finite element method (FEM), the finite-difference method (FDM), and the moment method (MM). This discussion focuses on a variation of the finite-difference-time-domain (FDTD) method, which is versatile and is applicable to nearly all EM problems. At the same time, the FDTD method's simple algorithm facilitates computational analysis.

FDTD is applied to the Maxwell equations by discretizing the differential equations with respect to the original Cartesian coordinates in time and space. These equations are then transformed into difference equations, which are solved step-by-step in time and apace.[1]

This discussion focuses on a extension of the FDTD method, that is the finite integration method (FIM) which uses a set of Maxwell's Grid Equations (MGE) transformed from the integral form of Maxwell's equations.[2] The very important feature of MGE is that the

set of matrix equations is a consistent and discrete representation of the original Maxwell's equations. Therefore it retains all analytical properties of the original Maxwell's equations as well as the physical and mathematical characteristics of EM fields. These features are extremely important since numerical analysis may lead to incorrect solutions that do not exist physically.

The disadvantage of FDTD, and TLM compared with FEM, is the usage of Cartesian meshes, being quite inflexible when discretizing non-orthogonal structures as shown in Fig 1.
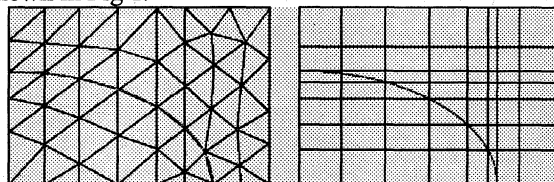

Fig. 1. Mesh representation of a curved material boundary by FEM (left) and FDTD (right).

A new approach called the Perfect Boundary Approximation (PBA) technique was developed and implemented in a new PC based 3D-EM simulation software called MICROWAVE STUDIO (MWS).[3] This method allows an accurate consideration of rounded material boundaries without requiring the orthogonal mesh to be conformal. Instead, the sub-cellular information is taken into account, leading to an algorithm with second order accuracy for arbitrary shaped boundaries (Fig 2).
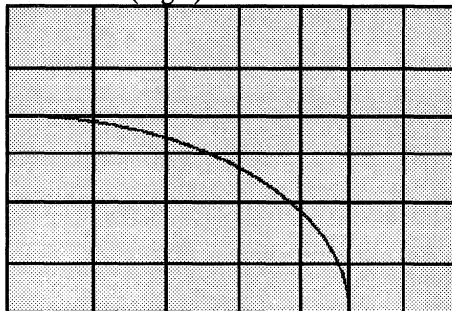

Fig. 2. Mesh representation of a curved material boundary by PBA.

SELECTION OF 3D-EM SIMULATION SOFTWARE AND BENCHMARK

The process of selecting 3D-EM simulation software is rather complicated since the optimum choice depends on a number of considerations that include the simulation

goal, budget, schedule, number of users and available computers. The following are very important criteria to be considered when selecting a 3D- EM software tool:

1) Consistently reliable results,
2) Relatively short computational time, compatible with the development schedule,
3) Simplicity of operation, particularly the ease of CAD input and mesh generation,
4) Compatibility with your requirements,
5) Compatibility with other CAD tools,
6) Versatility and expandability,
7) Customer support and service.

When making the software selection, it is very important for the user to generate benchmark results to check these criteria and to compare the various candidates.

It is highly desirable to use a benchmark problem for which the accurate experimental data has been obtained in order to evaluate the computational results.

APPLICATIONS OF 3D-EM SIMULATION SOFTWARE

A) Coupled Cavity Waveguide Filter

Fig.3 shows a coupled cavity waveguide filter (7 cavities, iris loaded). Due to high Q of the cavity filter, it is rather difficult to accurately calculate S-parameters within a reasonable time using FEM or MM.

Fig 4 shows a comparison of measurement and simulation for S11 and S21 using MWS. The computation requires 47,488 mesh nodes, 20 min. CPU time and 13 MB on a windows PC with a 1.4 GHz XEON CPU
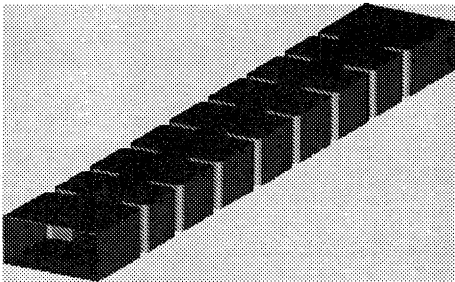

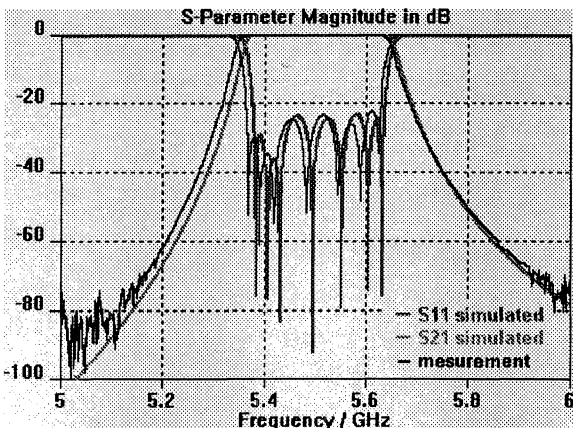Fig.3. Iris loaded waveguide filter with 7 cavities.

Fig.4. Measured and computed S-parameters of an iris loaded waveguide filter with 7 cavities.

B) Bluetooth Antenna

Another typical application for EM-Simulators is the analysis and optimization of antennas. Fig.5 shows an inverted F-antenna typically used for Bluetooth projects.
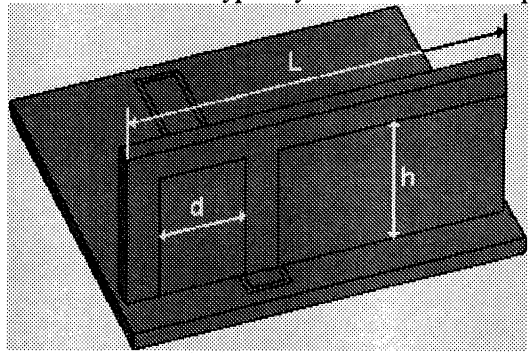

Fig.5. Inverted F-antenna and measures used for automatic optimization.

The antenna performance and resonance frequency can be optimized by varying the measures d, h and L with the built in automatic optimizer of MWS. Fig.6 shaws the S11 parameter of the initial design and optimized antenna.
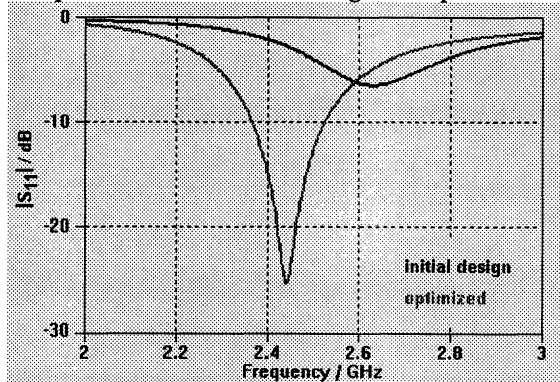

Fig.6. S11 parameter of the initial and optimized inverted F-antenna.

C) Design of RF Window

RF Windows are one of the major concerns in designing high power microwave tubes and ac-celerators. Most of conventional RF Windows uses a pillbox like cavity operating on the TE11 mode. Fig.7 shows the result of S11-parameter for a SLAC Type RF Window for frequencies between 2.5 to 6GHz.
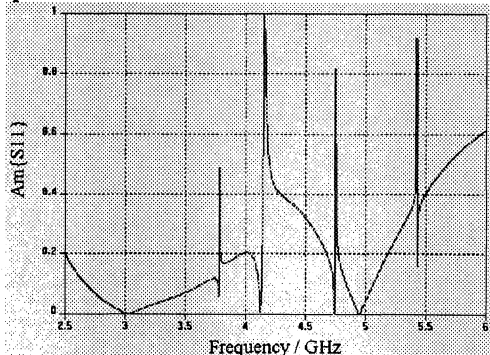

Frequency / GHz

Fig.7: Amplitude of S11-parameters of the SLAC Type RF Window.

The TM11 like mode which has E field components normal to the surface of ceramic disc, may aggravate the bombardment of electrons. Fig.8 shows the |E| patterns on the surface of the ceramic disc for both modes.
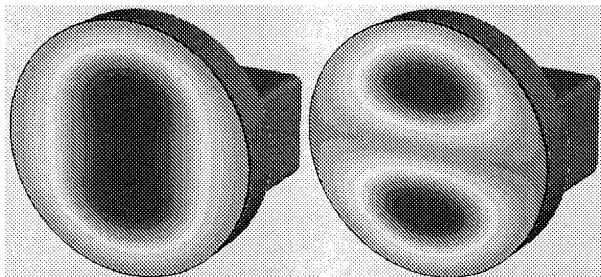
Fig.8: |E| of TE11 (left) and TM11 (right) like modes on the surface of the ceramic disc in the SLAC Type RF Window.

The total computational time was less than 30 min on a 450MHz Pentium II PC using MWS.

D) Accelerator Design
The time domain calculation is very useful for designing multiple cavity coupled structures such as linear accelerators. Fig.9 shows the mesh model of a S-band, 6-cell travelling Wave Accelerator and the magnetic field vectors at $2\pi/3$ mode resonance in a cross section. The rounded irises are considered very accurately by the PBA technique.
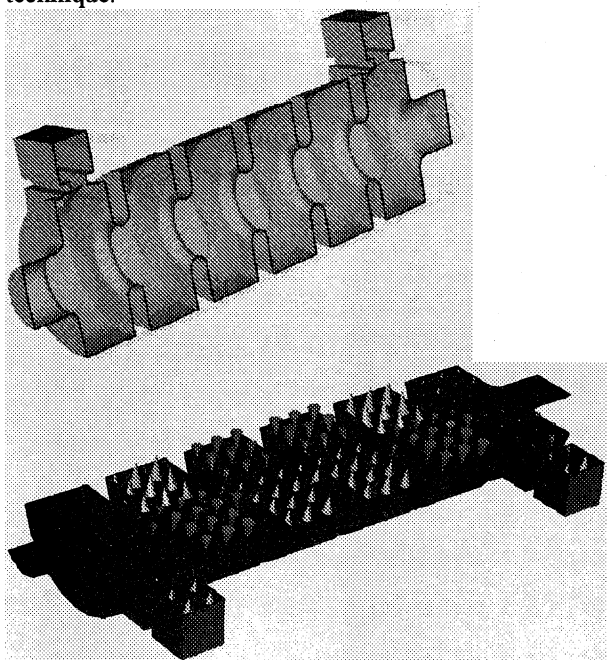
Fig.9: Mesh model of a 6-cell Travelling Wave Accelerator (above) and magnetic field of the $2\pi/3$ mode in a cross section (below).
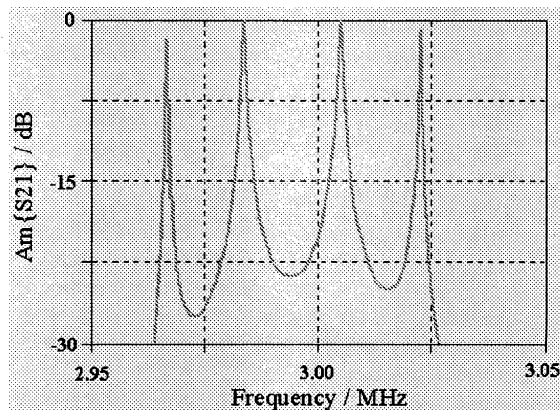
Fig.10: Amplitude of S21 of the 6-cell Traveling Wave Accelerator.

Fig.10 shows the amplitude of the S21-parameter. S-parameters can be obtained from a single time domain computation by using Discrete Fourier Transformation (DFT) or Auto Regressive Filter techniques that can speed up S-parameter calculations for high Q structures drastically.

CONCLUSIONS

The advanced EM simulation technique utilizes FIM and PBA is presented and various examples of the method are discussed. The examples are taken from practical applications in research and industries. These results indicate that even the most complicated calculation can be performed within the reasonable computational time with PCs. In future, 3D-EM simulation tools, like MWS will be commonly used in R&D, engineering and even in manufacturing.

REFERENCES

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