IMPROVEMENTS IN GDFIDL

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Abstract

The finite difference code GdfidL computes 3D electromagnetic fields. It has been rewritten to implement better material dicretization with generalized diagonal fillings, modern absorbing boundary conditions in time domain and periodic boundary conditions in x- y- and z-direction when computing eigenvalues. The generalized diagonal material fillings reduce the frequency error caused by the boundary approximation by a factor of 10. The modern absorbing boundary conditions work for arbitrarily large port dimensions without the need to consider any portmodes.

1 GENERALIZED DIAGONAL FILLINGS

Material-fillings are parameters of the differential equations or, when perfect electric or magnetic materials are present, they are boundary conditions for the differential equations. The approximation of the material fillings often deteriorates the quality of the solution more than the approximation of the differential equation itself. The simplest material approximation is the assumption of a homogeneous filling inside every single cell. This is the "staircase" approximation. The approximation with triangular prismatic cells allows that there are two different materials in each cell. This approximation is in wide use and gives good results for geometries that are essentially cylindric. For boundaries with general curvature, the approximation with prismatic cells gives results only slightly better than a staircase approximation.

Fortunately, the filling with prismatic cells can be generalized. Since the finite difference coefficients for a field component depend only on the material in the immediate vicinity of the edge where the component is defined on, one can work easily with a mesh-filling that is constructed by a boolean combination of prismatic fillings. Figure 1 shows some of the possible discretized material distributions. A similiar mesh filling is mentioned in [1]. Figure 2 shows an example of the quality of the material approximation.

In order to show the effect of the generalized filling, figure 3 shows the computed resonance frequency of the fundamental mode in a sphere as a function of the mesh-spacing. For comparison, the results for prismatic filling and the optimal quadratic behaviour is plotted also. The error with the improved filling is about as low as the optimal quadratic behaviour. If the boundary conditions, ie. the materials would have been discretized perfectly, the result would not be much better.

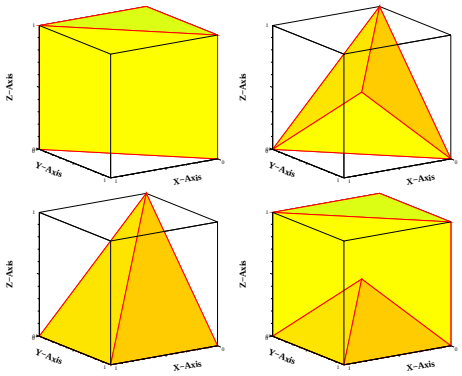

Figure 1: Some examples of the possible inhomogeneous fillings of a cell. Upper left: a prism. Lower left: Intersection of two prisms. Upper right: Intersection of three prisms. Lower right: Union of "upper left" and "lower left". The prism in the upper left can be oriented in 2 x 3 different kinds in a cell, the other three material fillings are possible in 4 x 3 x 2 different orientations.

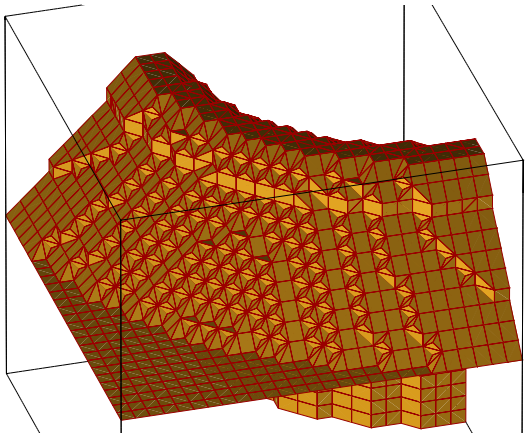

Figure 2: Detail of the "nose" of a reentrant cavity, discretized with the generalized diagonal fillings.

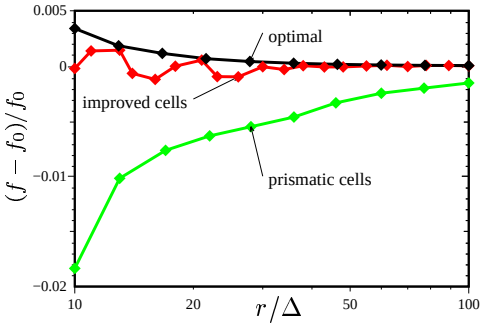

Figure 3: Error in the computed frequency of the lowest mode in a sphere as a function of gridplanes / radius.

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2 PERIODIC BOUNDARY CONDITIONS

GdfidL's resonant solver allows periodic boundary conditions in all three cartesian directions simultaneously.

To demonstrate the capability, the periodic boundary conditions are applied to compute the dispersion relation in a crystal made of an rectangular array of conducting spheres connected by round rods. Figure 4 shows an elemental cell of this array. Figure 5 shows the computed frequencies as a function of the wave-vector $\vec{k}$.

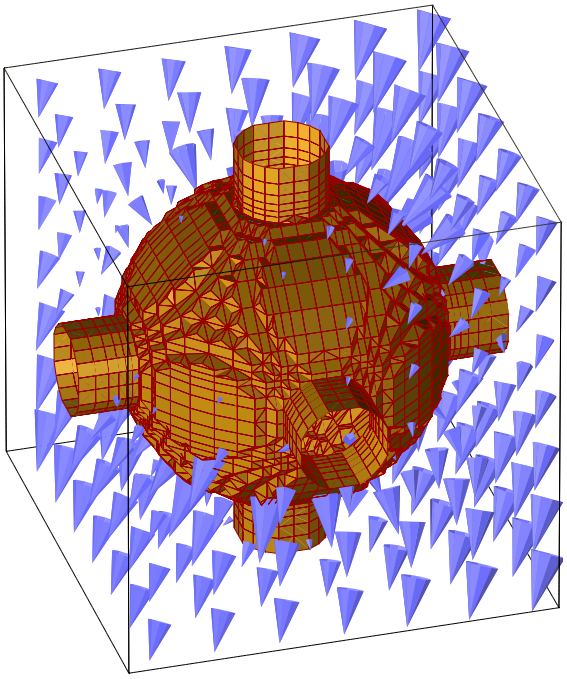

Figure 4: The elemental cell of a 3D array of perfect conducting spheres, connected by round conducting rods. The lattice constant a is the same in all three directions, the radius of the spheres is 0.375 a, the radius of the rods is $a/10$. The spheres are located at $(x, y, z) = (la, ma, na)$, $(l, m, n \in \cdots -2, -1, 0, 1, 2, 3 \cdots)$. The shown field is the real part of the fundamental mode with $\vec{k} = (1, 1, 1)\frac{\pi}{4a}$.

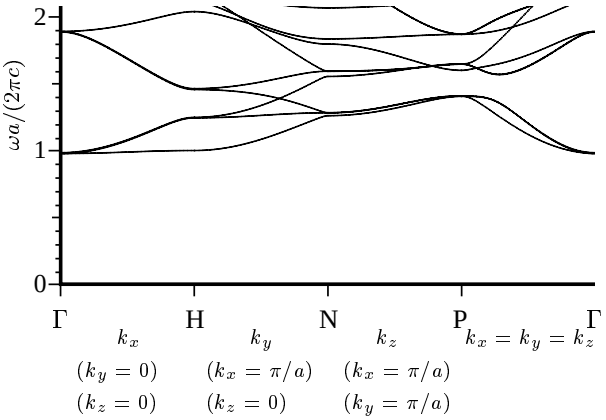

Figure 5: The band structure for the first few modes in the 3D array.

3 PML'S AS ABSORBING BOUNDARY CONDITIONS

GdfidL's time domain solver uses Berenger's "Perfectly Matched Layer" (PML) [2] to implement its aborbing boundary conditions (ABC's). The previous GdfidL [3] used an expansion in orthogonal port modes to implement its ABC's.

Compared with the expansion in orthogonal functions, PML's have two major advantages: 1.) Even for extremely large waveguides, one has negligible reflection for all fields without having to compute with a large number of port-modes. 2.) It is possible to have excellent broadband absorbing boundary conditions also for waveguides that are inhomogeneously filled with dielectrics.

Figure 6 shows such a geometry with large absorbing planes, inhomogeneously filled with dielectrics.

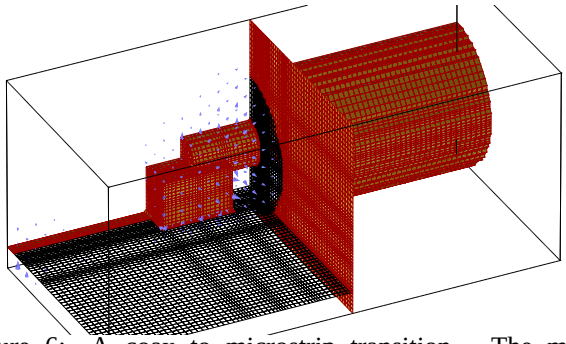

Figure 6: A coax to microstrip transition. The microstripline as a waveguide with an inhomogeneous dielectric is matched with an inhomogeneous PML.

4 CONCLUSION

An improved mesh filling has been implemented that reduces the frequency error by a factor of ten as compared to a prismatic filling.

Periodic boundary conditions are available for all three cartesian directions simultaneously.

PML's as absorbing boundary conditions allow inhomogeneously filled ports in broadband s-parameter computations.

5 REFERENCES

[1] W. Müller, J. Krueger, A. Jacobus. R. Winz, T. Weiland, H. Euler, U. Hamm, W. R. Novender, "Numerical Solution of 2- or 3-Dimensional Nonlinear Field Problems by Means of the Computer Program PROFI", *Archiv für Elektrotechnik 65* (1982) pp. 299-307

[2] J. P. Berenger, "A Perfectly Matched Layer for the Absorption of Electromagnetic Waves", *J. Comput. Physics*, vol. 114, pp. 185-200, Oct. 1994.

[3] W. Bruns, "GdfidL: A Finite Difference Program with Reduced Memory and CPU Usage", *Proceedings of the PAC-97, Vancouver*, vol. 2, pp. 2651-2653, http://www.triumf.ca/pac97/papers/pdf/9P118.PDF