Grid-Based SCT Approach for the Global Electromagnetic Simulation and Design of Finite-Size and Thick Dichroïc Plate

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Abstract **─** In the work presented in this paper, a grid-enabled environment for the scale changing technique (SCT) simulations is proposed. This approach allows the fast design of a finite size and thick dichroïc metallic mirror based on global electromagnetic simulation. The computed transmission and reflection coefficients, as well as radiation pattern, satisfying to some predefined technical requirements in X and Ka frequency bands are presented. Simulation results are shown in order to demonstrate the validity of the approach.

Index Terms **─** Dichroïc mirror, distributed computing, electromagnetic analysis, frequency selective surfaces, grid computing, SCT.

I. INTRODUCTION

The trend in radio frequency (RF) and microwave design is towards the accurate prediction of system-level performance and behavior. Engineers simulate larger and more sophisticated design problems in support of that goal. When it involves both large structures (in terms of wavelength) and fine details, the system or structure is said to be complex. The higher the number of scale levels in the system the higher is the complexity. Well-known examples of complex structures are provided by multi-band frequency-selective surfaces, finite-size arrays of non-identical cells and fractal planar objects. Electromagnetic modeling of such structures has been recently discussed [1-2]. In order to simulate such complex multi-scale structures, an efficient electromagnetic approach, named thus scale changing technique (SCT) [3], is used here. The SCT method allows the global simulation of a finite-size thick dichroïc mirror as shown in [4], and detailed here in this article. The scope is to define the most appropriate design of a uniform mirror satisfying to predefined technical requirements of transmission and reflection coefficients in X and Ka frequency bands. Consequently, parametric simulations must be performed.

The parametric distributed study application is now a good candidate to execute in a grid computing (GC) environment [5]. GC has emerged as an important new field, distinguished from conventional distributed computing by its focus on large-scale resource sharing, innovative applications, and, in some cases, high-performance orientation [5-6]. GC provides a safe and pervasive access to dynamically distributed computing resources, providing greater availability, reliability, and cost efficiencies that may exist with dedicated servers. In addition to the central processing unit (CPU) and storage resources, it can provide access to increased quantities of other (shared) resources and to special equipment, software, licenses, and other services.

The SCT has proven itself as a powerful tool for electromagnetic simulation of frequency selective surfaces. Various dimensions of the dichroïc mirror have been simultaneously simulated on GC nodes in order to minimize the simulation time. Overall computation time for deriving transmission, reflection coefficients, and the radiation pattern of arrays was significantly reduced compared to sequential computation while keeping the solver accuracy by deploying these simulations in distributed environments as GC.

This article is composed of two main parts. First, the frequency selective surfaces and modeling issues are discussed in section II, followed by the scale changing technique (SCT) modeling description in section III.

In the second part, the SCT algorithm is discussed and distributed computing in grid environments is presented in two different approaches. Simulation results, compared to other simulation tools, are shown here.

Finally, in section V, an overview of the key advantages of this approach coupled with SCT in the global electromagnetic analysis and design of the frequency selective surfaces is reported.

II. THE FREQUENCY SELECTIVE SURFACES

The frequency selective surfaces (FSSs) are a key component in the design of multi-frequency systems. They are used as frequency filters, and find applications, e.g. radomes and Cassegrain antenna reflectors. By nature, the FSS play the role of filters, allowing the transmission of certain frequencies and the reflection of others. They generally consist of a periodic array of conducting elements printed on a dielectric substrate, or of an array of apertures in a metallic plate. The nature and the geometry of the element (patch or aperture) are very important in the determination of the frequency response of the structure, like its bandwidth and transfer function. FSS performances depend strongly on the angle of incidence and polarization of the incident electromagnetic waves [7-8]. In our case study, we consider only a perforated metallic plate or roasts metal illuminated by a plane wave (with arbitrary angles of incidence).

Traditionally, FSS performances are assessed by making the assumption of infinite size and periodical FSS by using Floquet modes. Consequently, the computing time is being reduced almost to that of the basic cell.

To take into account the finite size of the array, several methods have been developed [9-10]. Note also that most of the methods treat only FSS with small thickness. However, the simulation of the FSS by the traditional numerical methods based on spatial meshing (finite element method, finite difference method, and method of the moments) or spectral discretization (modal methods) often leads to badly ill-matrix, numerical convergence problems and/or excessive computation times. To avoid all these problems, we adapt to the identified problem an original technique, called the scale changing technique, based on various scales modeling of complicated structures and whose principle consist in the idea that it is desirable to dissociate (separate) the complex problem into several simpler problems (Cf. Section III).

For numerous applications, the FSS is generally in the near field region, so that the operation of the cell strongly depends on its position in the array. The possibility offered by SCT to optimize a non-periodic grid, with each element selected according to its position in the array, should make it possible to improve the response of the FSS usually used, in particular to reduce their impact on the radiation diagram of the source in transmission (deformation of the mean lobe, high cross-polarization…).

Since the SCT allows global electromagnetic simulation of FSS, it will be used here to define the best dimensions design of dichroïc mirror satisfying to predefined reflection and transmission conditions in X and Ka frequency bands without using Floquet modes. It allows taking into account the finite size of the array as well as its thickness. The grid computing nodes will be used to run this parametric study.

III. THE SCALE CHANGING TECHNIQUE

The SCT is an efficient monolithic (unique) formulation for the electromagnetic modeling of complex (multi-scale) structures i.e., structures that exhibit multiple metallic patterns whose sizes cover a large range of scales [3].

SCT consists of interconnecting scale-changing networks (SCN), each network models the electromagnetic coupling between adjacent scale levels. The cascade of the scale changing networks allows the global electromagnetic simulation of multi-scale structures, from the smallest to the highest scale.

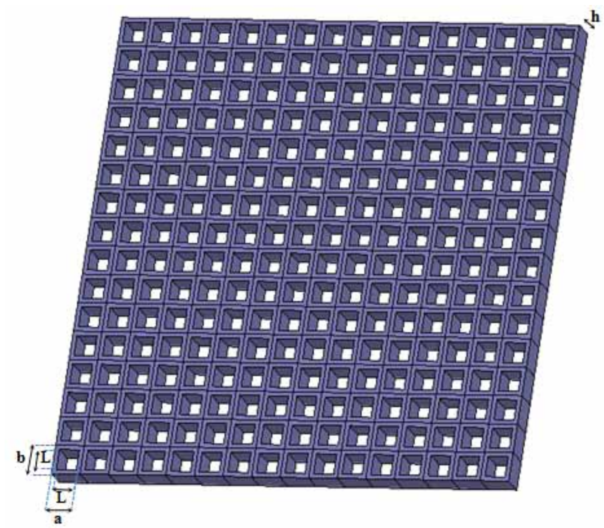

Fig. 1. Topology of a FSS consisting of uniform rectangular waveguides perforating a thick metallic plate.

The global electromagnetic simulation of multi-scale structures via the cascade of the scale changing networks has been applied with success to the design and electromagnetic simulation of specific planar structures such as reconfigurable phase-shifters [11, 12], fractal selective surfaces [13], discrete self-similar (pre-fractal) scatterers [14, 15], and patch antennas [16, 17]. This scale-changing technique is a very fast technique and this makes it a very powerful investigation, design and optimization tool for engineers who design complex circuits [18 - 20].

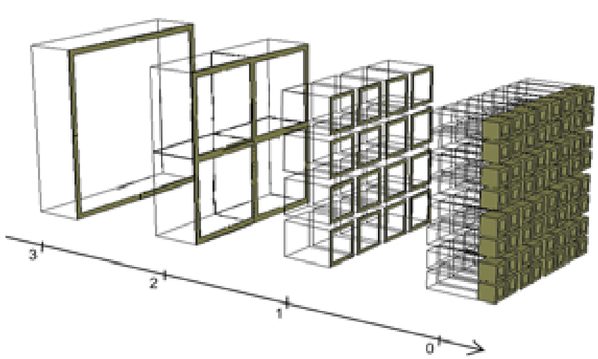

Fig. 2. An example of partitioning of finite size and thick dichroïc metallic mirror.

The proposed topology consists of a metallic grid of thickness h = 5 mm, with a = b = 10 mm (Cf. Figure 1). The dimensions of the apertures are uniform and the cells have the same thickness. To demonstrate the potential of the method, we consider the transmission and reflection coefficients of a finite size (256 cells) uniform FSS illuminated by a normal incident plane wave, as well as the radiation pattern.

A. Partitioning of the finite size and thick dichroïc metallic mirror

The starting point of the proposed approach consists of the coarse partitioning of the dichroïc mirror into large-scale (called scale level s_{max}) sub-domains of arbitrary shape; in each sub-domain a second partitioning is then performed by introducing smaller sub-domains at scale level s_{max}–1; again, in each sub-domain introduced at scale level s_{max}–1 a third partitioning is performed by introducing smaller sub-domains at scale level s_{max}–2; and so on. Such hierarchical domain-decomposition, which allows us to focus rapidly on increasing detail in the dichroïc mirror plane, is stopped when the finest partitioning (scale level s=0) is reached. An illustration of the partitioning of a metallic grid of 265 cells is sketched in Figure 2. We can easily see that a high scale ratio exists between the highest and the smallest dimensions. Four different scale levels exist when cells are grouped by four. Boundary conditions (perfect electric or perfect magnetic boundary conditions) are artificially introduced at the contour of all the sub-domains generated by the partitioning process, taking into account the physics of the problem.

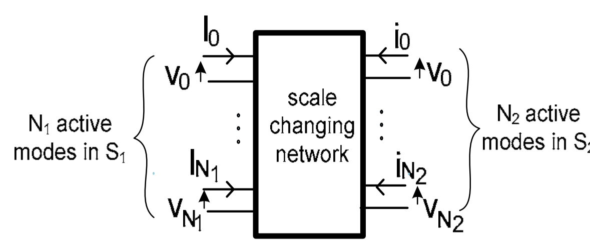

Fig. 3. A scale changing network (SCN) [1].

The next step consists of computing the electromagnetic coupling between two successive scale levels via the scale changing network (SCN) (Cf. Figure 3). The cascade of SCNs allows crossing the scale from the lowest scale (s=0) to the highest one (s=s_{max}).

The scale changing technique can be applied several times to different scale levels. The transition from one level to another level is modeled by multiport associated with active modes of the two scales.

B. Surface impedance matrix

Consider the pattern given in Figure 4(a), where the thickness is taken into account. It presents a passive sub-domain D_S containing many fine geometrical details and composed of: (1) the perfect conductor domain D_M and (2) the aperture domain D_A, with $D_S = D_M \cup D_A$ (Figure 4(b)).

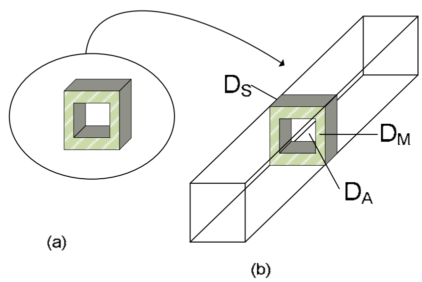

Fig. 4. (a) Initial lossless metallic pattern with a passive sub-domain DS presenting many fine geometrical details; (b) artificial rectangular waveguide of cross section DS in which the set of propagating and evanescent modes constitutes the basis for the electromagnetic field.

The electromagnetic field in D_S can be expanded on a local modal electromagnetic field in basis. Such basis can be viewed as the set of propagating and evanescent modes in the artificial rectangular waveguide of cross section. The time average electromagnetic energy stored by higher-order evanescent modes is localized in the vicinity of discontinuities or geometrical details of the planar structure. Consequently the contribution of such modes in the expansion of the electromagnetic field is expected to be insensitive to the choice of the surface, as far as the boundary conditions enclosing this surface are applied sufficiently far from discontinuities. We consider here that such modes are shunted by their (pure imaginary) impedance and are called *passive* by analogy with variational techniques in waveguide discontinuities. The electromagnetic coupling between the lower-order –or active– modes is characterized by the surface impedance matrix Z_S (or admittance matrix Y_S) and consequently, the original sub-domain is replaced by surface impedance (or admittance) boundary conditions.

C. S-parameters calculation

The thick metallic grid presents a symmetry plane cutting the thickness of the plate in two equal parts (Figure 5(a)).

The grid impedance matrix $[Z_{total}]$ can then be derived from the combination of the two impedance matrices $[Z_{even}]$ and $[Z_{odd}]$ of half-structures obtained by inserting respectively a magnetic wall and electric wall in the symmetry plane, as follows [5]:

$$[Z_{total}] = \frac{1}{2}\begin{pmatrix} [Z_{even}] + [Z_{odd}] & [Z_{even}] - [Z_{odd}] \\ [Z_{even}] - [Z_{odd}] & [Z_{even}] + [Z_{odd}] \end{pmatrix}. \quad (1)$$

The scattering matrix $[S_{total}]$ is then deduced from the following relationship:

$$[S_{total}] = ([Z_{total}] - [Z_0])([Z_{total}] + [Z_0])^{-1} \quad (2)$$

where $[Z_0]$ designates the diagonal matrix of active mode impedances. The scale changing technique is applied for the derivation of matrices $[Z_{even}]$ and $[Z_{odd}]$ associated with half-structures.

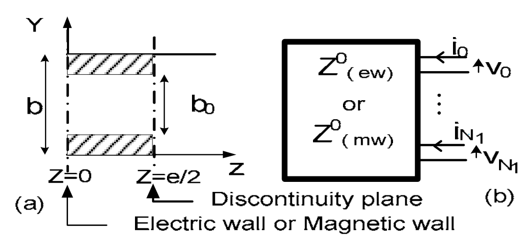

Fig. 5. (a) Side-view of half of the unit-cell for magnetic and electric wall configurations. (b) Surface impedance multiport for modeling the unit-cell. N1 denotes the number of active modes at the smallest scale.

D. Radiation pattern calculation

We consider the scattering of the wave plane incident on the FSS, formed by a thick metal grid. The electromagnetic problem consists in calculating the field scattered by a perfect thick metallic surface when illuminated by a normal plane wave incidence:

$$\vec{E}^{inc} = E^{inc}\exp(jk_0 z)\vec{y}. \quad (3)$$

We consider here the field backscattered by the half-structure obtained by inserting a magnetic wall and electric wall in the symmetry plane z =0.

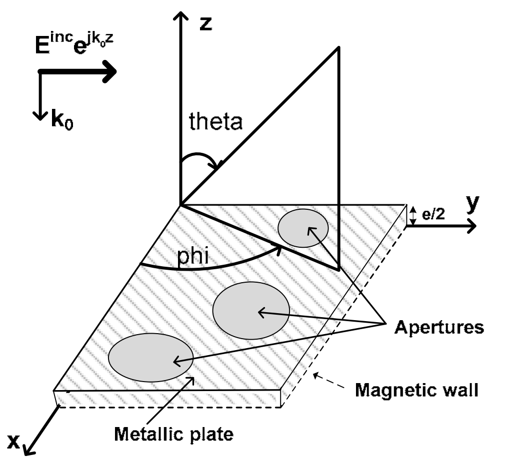

Fig. 6. Scattering problem in free space in the conventional coordinates system [14].

The induced current on the surface is defined while having the total electric field E^{total} equal zero. The integral equation in the electric field is obtained with the equivalence principle application.

With the SCT, we substitute the actual current *J* by an equivalent current *Jeq* defined by the lower-order modes (active modes) of the orthogonal modal-basis of domain S (FSS metallic grid).

The S domain is then characterized by a surface impedance matrix $[Z_s]$ (which fixes the boundary conditions of the problem) such as:

$$[E^{total}] = [Z_s][J_{eq}] \tag{4}$$

$$\vec{J}_{eq} = \sum_{i=1}^{\mathrm{NxN}} I_{eq\_i}\, \vec{g}_{eq\_i}, \tag{5}$$

where $\vec{g}_{eq\_i}$ is an entire trial function of the modal basis.

To determine the solution of the boundary value problem in free space, we are led to calculate the electric field radiated by the equivalent current. This last item being expressed on a modal basis, it is better to solve the problem in the spectral domain. Under these conditions, the equation of the boundary value problem in free space becomes:

$$\vec{E}^{inc} + \hat{G}\vec{J}_{eq} = z_s\vec{J}_{eq}, \tag{6}$$

where Ĝ is the dyadic Green's function associated with free space in the spectral domain.

The application of the method of Galerkin makes it possible to establish the following matrix equation:

$$[V^{inc}] - [Z][I_{eq}] = [z_s] \tag{7}$$

$$[I_{eq}] = ([Z] + [z_s])^{-1}[V^{inc}]. \tag{8}$$

The terms are obtained by the following scalar product:

$$[V_{inc}]_j = \langle \vec{g}_{e\_j}, E^{inc} \rangle. \tag{9}$$

The goal is to calculate the $\vec{J}_{eq}$ which will give the field diffracted by the grid. This current can be found from equation (8) if Z and Zs are known.

Z is calculated from free space Green's functions; Zs is calculated by applying the SCT and using the induction theorem and the images equivalent principle to make use of the symmetry of the problem along the z-axis [21].

The SCT is applied by introducing an artificial rectangular waveguide enclosed with periodic boundary conditions. Zs represents the surface impedance matrix of the entire structure after the connection of all bifurcation multiports. The computation is performed for even configuration. Since the structure is symmetric along z-axis, we wish to take this symmetry to consider only half space in the description of the problem.

IV. THE GRID-PARAMETRIC SCT SIMULATIONS

A. Structure of the SCT simulation

As mentioned before, the SCT is a hierarchical domain-decomposition. Consider the metallic grid sketched in Figure 2, with 256 cells. Four different scale levels exist when cells are grouped by four.

First, the dimensions of the studied structure, frequency band, as well as the number of modes (calculated in convergence study) are defined. After an initialization phase, the different SCNs are computed independently.

The algorithm calculates the different correspondent modules, *M,1 M,2 ... M256*, as well as the four modules representing the scale changing, *M257, M258, M259,* and *M260*. Once these modules are computed, the global electromagnetic simulation of multi-scale

structures is done via the cascade represented by *C,1 C2, ... C64, C65, ... C80, C81, ... C84*, and *C85*. *C1, C2, ... C64* are executed at the first cascade level, *C65 ... C80* at the second level, *C81 ... C84* at the third level and *C85* at the final one. Note that the number of cascades and SCNs depends on the partitioning of the problem and chosen sub-domains defined by the user.
The *SCT* program serial execution:

```
Initialization
     M1
     M2
     .
     .
     M256
     M257
     .
     M260
     C1
     C2
     .
     .
     C64
     C65
     .
     .
     C80
     C81
     .
     .
     C84
     C85
```

B. Grid execution

Two scenarios of grid computing can be applied here with SCT simulations. The first one consists of executing in parallel the independent modules, at every level. This is the parallel application. The second one is based on exploring several different structures simultaneously, by executing the same algorithm but with different parameters. That is the parametric application.

1) Parallel application

The idea here consists of creating for every computing stage of SCT a service. In fact, the whole simulation requires only three types of services, since M1, M2, ... M256 are based on the same computing function. M257, M258, M259, and M260 are based on another computing function. The cascade is the same at all levels. To run a SCT simulation, the services are called with the corresponding parameters. Each service produces its results which can be used by other services. To ensure the good execution of the SCT simulation, an adapted scheduler, knowing the level scales, organize the relation between the services.

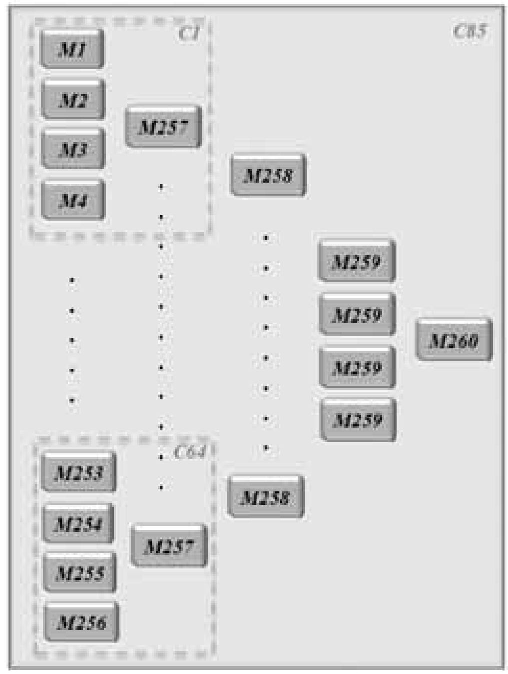

Fig. 7. SCT flowchart.

Fig. 8. Distributed parametric computing.

The services are created with the DIET tool [22], an application service provider (ASP) able to ensure the scalability of the solution on several thousand grid computing nodes if necessary. The deployment of the application on the grid is realized by TUNe [23], an efficient tool able to repair some parts of the deployment and execution (which is a critical point of the Grid).

2) Parametric application

The parametric execution (also known as embarrassingly parallel), involves execution of the same code with different input parameters, which do not request data transfer during executions. Some typical examples include frequency sweeps for antenna characterization, or design of optimal antenna geometries.

In this case, a multiple frequency band analysis (the pass band and the stop band) is required. Normally, this case is not very suitable for frequency domain software since the pass band and the stop band are 2 to 3 octaves apart.

In distributed parametric SCT simulations, a wide range of design parameters are evaluated in a single analysis run with the goal of exploring the entire design space and selecting the optimized design without need for the normal iterative process (Figure 8). In our case, the idea is to modify the aperture length, and verify the corresponding transmission coefficient.

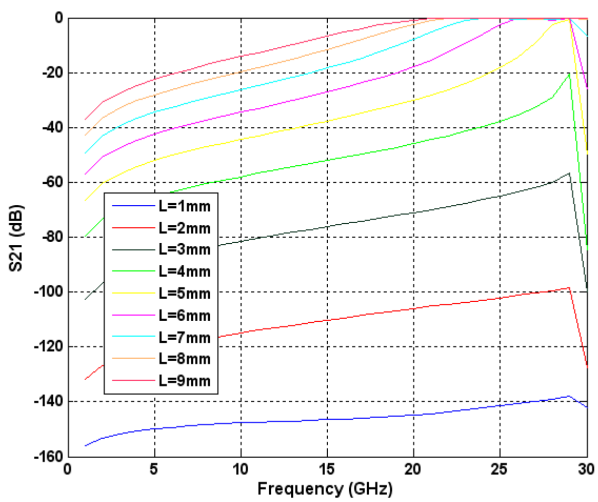

Fig. 9. Design dimension sweep of the aperture length L of 16 x 16-element uniform thick dichroïc plate.

C. Results

Figure 9 displays the simulated transmission coefficients of a uniform metallic grid (a = b= 10 mm) (Figure 1) with a thickness h=5mm in the case of a normal plane wave incidence for different aperture length L. In this figure only a few curves are presented.

Since the transmission we are looking for is in the range of frequency going from 20 GHz to 30 GHz, an aperture of 8.2 mm will give such performance. Increasing the aperture length L of the cells, which is related to the cutoff frequencies, increased the bandwidth.

Figure 10 displays the simulated reflection and transmission coefficients of a uniform metallic grid (Figure 1) with a thickness h = 5mm and an aperture of L = 8.2 mm in the case of a normal plane wave incidence. Ansoft HFSS [24] (version 11.2) was used for FEM implementation with 0.02 stopping criterion for the adaptive convergence solution. An excellent agreement between the HFSS- and SCT-results can be observed.

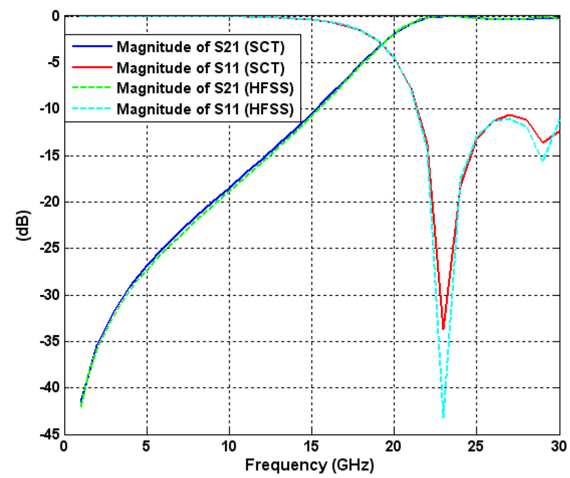

Fig. 10. S11 and S21 coefficients.

Figure 11 shows the radiation patterns in the case of a 16 x 16-element uniform thick dichroïc plate shown in Figure 1 simulated at a single point of frequency in the case of a normal plane wave incidence.

Figure 12 represents the simulation time evolution on the same computer for these two techniques calculating the transmission and reflection coefficient when the number N of cells increases.

For a given thick dichroïc plate and simulation technique, the computation time in this figure is normalized to the time required for calculating these coefficients in the case of a 4–cell array. For the scale changing technique computation, time increases very slowly as the number N of cells increases. Meanwhile, in the case of the finite element method, they increase dramatically, because of the mesh refinement needed to insure convergence.

As expected, for the parametric application, the overall execution time of the simulations depends on the number of nodes that are used, or more precisely, on the number of simulations that are executed on each node. A speed-up of ~ 2(compared to the time needed for the computation on one computer only) is reached by using two computers. Increasing the number of computing nodes to solve the problem increases the speed-up. Speedup up to 10 or more could be easily reached by distributing the simulations on less than one hundred computers.

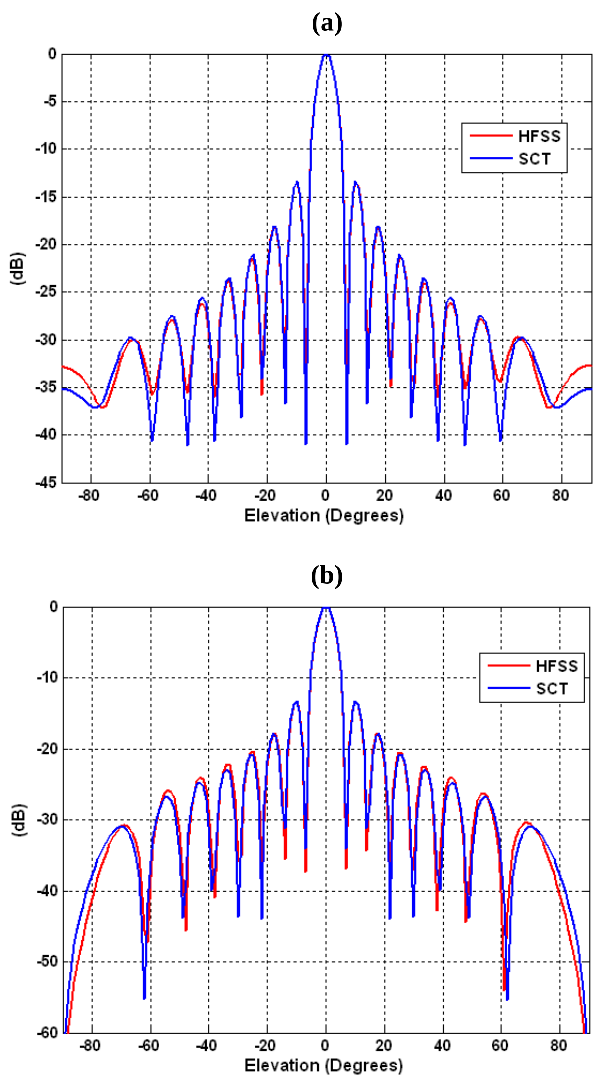

Fig. 11. Co-polarization in (a) E-plane, and (b) H-plane @ 15 GHz.

Users must choose in advance the number of grid nodes reserved in order to accommodate heavier or lighter electromagnetic simulation requests. The best performance is obtained while distributing the simulations in a way to execute one simulation per computing node. These results point out the benefit from using a large number of computational nodes for running SCT simulations.

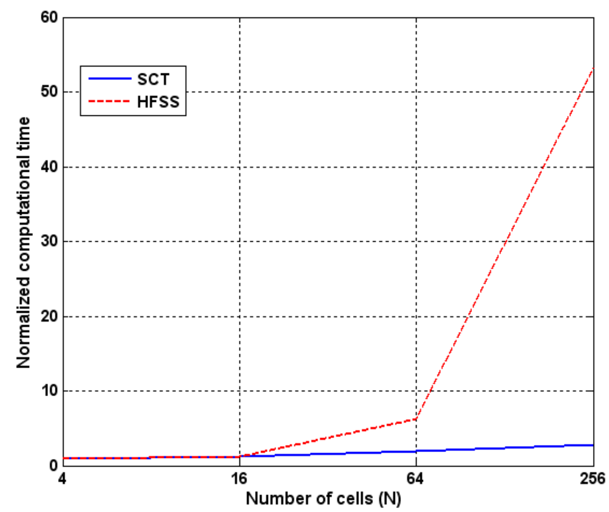

Fig. 12. Evolution of computing time compared to the standard time for the calculation of two cells of uniform arrays on the same computer.

V. CONCLUSION

Two efficient solutions contributing to the electromagnetic modeling and design of a thick dichroïc plate have been presented in this paper.

First, the scale changing technique modeling method, a well-adapted method for the problems of complex multi-scale structures and which demonstrated very good computing performance even in sequential on one computer, compared to existing commercial codes.

Second, the use of grid computing to solve electromagnetic problems was presented in an example of distributed parametric simulation of thick dichroïc plates. A wide range of design parameters are evaluated in a single analysis run with the goal of satisfying to predefined technical requirements of transmission and reflection coefficients in X and Ka frequency bands. Regardless of the number of possible parametric configurations antenna elements may have, their full-wave analysis can be carried out at the computational costs of a single one, by distributing them over a corresponding number of nodes.

Consequently, the approach consisting of combining the advantages of the scale changing technique and grid computing is so promising.

ACKNOWLEDGMENT

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REFERENCES

[1] N. Farahat and R. Mittra, "Multiscale Analysis of Panel Gaps in a Large Parabolic Reflector," Applied Computational Electromagnetics Society (ACES) Journal, vol. 21, no. 1, March 2006.

[2] R. Mittra, J.-F. Ma, E. Lucente, and A. Monorhio, "CBMOM - An iteration free MoM approach for solving large multiscale EM radiation and scattering problems," IEEE Antennas and Propagation Society International Symposium, vol. 2B, 2-5, Washington, D.C., Jul. 3-8, 2005.

[3] H. Aubert, "The Concept of Scale-Changing Network in the Global Electromagnetic Simulation of Complex Structures," *PIER B*, vol. 16, pp. 127-154, 2009.

[4] E. B. Tchikaya, A. Rashid, F. Khalil, H. Aubert, H. Legay, and N. J.G. Fonseca, "Multi-scale Approach for the Electromagnetic Modeling of Metallic FSS Grids of Finite Thickness with Non-uniform Cells," *2009 Asia-Pacific Microwave Conference* (APMC 2009), Singapore, December 7-10, 2009.

[5] L. Tarricone and A. Esposito: *Grid Computing For Electromagnetics*. Artech House Publishers (2004).

[6] I. Foster, "What is the Grid? A Three Point Checklist," *GRIDtoday*, vol. 1, no. 6, July 22, 2002.

[7] B. A. Munk, *Frequency Selective Surfaces: Theory and Design*, First Edition, Wiley, New York, 2000.

[8] W. L. Ko and R. Mittra "Implementation of Floquet boundary condition in FDTE for FSS analysis," in *1993 IEEE APS*, *Int. Symp. Dig.*, vol. 1, pp. 14-1, June 28-July 2.

[9] T. Koleck, H. Diez, and J.C. Bolomey, "Technique for analyzing Finite Frequency Selective Surfaces," *IEEE international conference on Antennas and propagation*, Digest, 14-17, April 1997.

[10] R. Mittra, C.H. Chan, and T. Cwilk, 1998, "Techniques for analysing Frequency Selectives Surfaces-A review," *Proc. Of the IEEE*, vol. 76, 1593-1614, Dec. 88.

[11] E. Perret, H. Aubert, and H. Legay, "Scale-Changing technique for the electromagnetic modeling of MEMS-controlled planar phase-shifters," *IEEE Trans. Microwave Theory and Tech.*, vol. 54, no. 9, 3594-3601, Sep. 2006.

[12] E. Perret, N. Raveu, H. Aubert, and H. Legay, "Scale-Changing technique for MEMS-controlled phase-shifters," *36th European Microwave Week*, 866-869, Manchester, United Kingdom, Sep. 10-15, 2006.

[13] D. Voyer, H. Aubert, and J. David, "Scale-changing technique for the electromagnetic modeling of planar self-similar structures," *IEEE Trans. Antennas Propagat.*, vol. 54, no. 10, 2783-2789, Oct. 2006.

[14] D. Voyer, H. Aubert, and J. David, "Radar cross section of discrete self-similar objects using a recursive electromagnetic analysis," IEEE Antennas and Propagation Society International Symposium, vol. 4, 4260-4263, Monterey, California, USA, Jun. 20-26, 2004.

[15] D. Voyer, H. Aubert, and J. David, "Radar cross section of self-similar targets," Electronics Letters, vol. 41, no. 4, 215-217, Feb. 17, 2005.

[16] E. Perret, and H. Aubert, "Scale-Changing technique for the computation of the input impedance of active patch antennas," IEEE Antennas and Wireless Propagation Letters, vol. 4, 326-328, 2005.

[17] E. Perret, and H. Aubert, "A multi-scale technique for the electromagnetic modeling of active antennas," IEEE Antennas and Propagation Society International Symposium, vol. 4, 3923-3926, Monterey, California, USA, Jun. 20-25, 2004.

[18] N. Raveu, G. Prigent, H. Aubert, P. Pons, and H. Legay, "Scale-Changing technique design and optimisation tool for active reflect-arrays cell," 37th European Microwave Conference, 736-739, München, Germany, Oct. 9-12, 2007.

[19] Nathalie Raveu, E. Perret, Hervé Aubert, and H. Legay, "Design of MEMS controlled phase shifter using SCT," PIERS Online, vol. 3, no. 2, 230-232, Beijing, China, Mar. 26-30, 2007.

[20] N. Raveu, E. Perret, H. Aubert, and H. Legay, "Scale-changing technique: A design tool for reflectarrays active cells," Proceedings of the European Microwave Association, vol. 4, no. 2, 163-168, Journal of the European Microwave Association, Jun. 2008.

[21] R. F. Harrington, Time-Harmonic Electromagnetic Fields. NewYork: McGraw-Hill, 1961, pp.106-118.

[22] E. Caron and F. Desprez, "DIET: A scalable toolbox to build network enabled servers on the grid," International Journal of High Performance Computing Applications, 20(3):335–352, 2006.

[23] L. Broto, D. Hagimont, P. Stolf, N. Depalma, and S. Temate, "Autonomic management policy specification in Tune," Annual ACM Symposium on Applied Computing (SAC 2008), Fortaleza, Ceará, Brazil, ACM, pp. 1658-1663, 16-20 March 2008.

[24] Ansoft HFSS Homepage. Copyright Ansys 2010. http://www.ansoft.com/products/hf/hfss/

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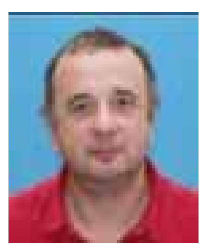

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