FD-FD GSM Technique for the CAD and Optimization of Combline Filters

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Abstract — **A combined frequency domain finite difference (FD-FD) generalized scattering matrix (GSM) technique is presented for the design and optimization of filters including 3D resonator structures, such as circular posts of partial waveguide height. This combination unites advantageously the flexibility of the FD method with the efficiency of the GSM technique. The formulation for the FD algorithm is based on the advanced combination of a direct subgrid technique with a locally conformal grid for modeling curved metallic boundaries. The flexibility and efficiency of the method is demonstrated at the example of the CAD of combline filters that are optimized using a genetic algorithm. The theory is verified by measurements.**

I. Introduction

Due to its flexibility, the finite difference frequency domain (FD-FD) method is well established for solving arbitrary 3D waveguide scattering problems [1] – [3]. Moreover, the FD-FD method is well appropriate to be mixed with other techniques [3]. However, as usual microwave structures often include areas of rather different field intensity, metallic boundaries of arbitrary shape, as well as large homogeneous waveguide sections, the numerical effort can be very high for the CAD and optimization of realistic components and for accurate results. Additional approaches for the FD method are therefore desirable in order to increase its efficiency.

For the FD method, several specific subgrid techniques have already been reported for both the time domain (TD) [4] – [6] and the frequency domain [2], [7]. Curved metallic surfaces have been advantageously modeled by conformal FD-TD techniques [8]. Though these techniques improve the performance of the FD method significantly, still a complete mesh for the structure under test as a whole is required.

The present paper applies a frequency domain finite difference generalized scattering matrix (FD-FD GSM) technique, which avoids this disadvantage. The FD grid is only used for those 3D building blocks that require a 3D discretization; all other portions of the structure are described via the GSM. This saves significant CPU time and storage requirements. The frequency domain FD method is preferred as the calculation of the important higher-order modes is more accurate as compared with the time domain FD. The applied FD-FD GSM method is appropriate for the realistic CAD and optimization of even rather critical microwave components, such as combline filters (Fig. 1). The accuracy of the method is verified by measurements at an optimized filter example without any tuning screws.

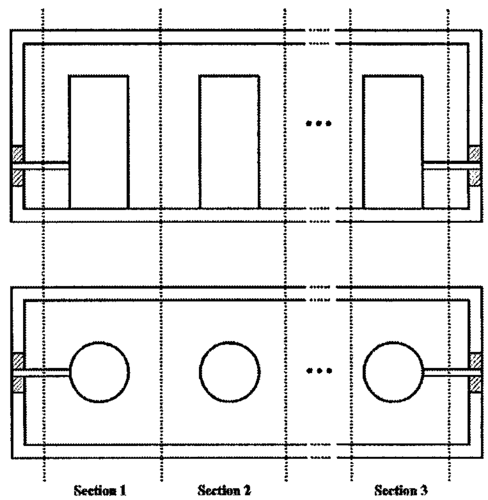

Fig. 1. Optimized combline filter structure

II. Theory

The subgrid technique for critical regions of high field intensity, like the air gap of combline resonators (Fig. 2), is based on the advanced grid distortion and orthogonalization method of [2], [7]. Unlike other techniques reported recently [4], [5], this method does not require any interpolation or correction terms. As demonstrated at the simple example of a 3D subgrid (Fig. 3), first a recursive grid generation procedure is applied based on a progressive 2 : 1 cell ratio for the subgrids. From the allocated cells, two grids are derived, the main and the dual grid [6]. The main grid is directly orthogonalized (Fig. 3) against the dual grid. This subgrid technique is efficient and precise.

At 3D metallic surfaces of arbitrary shape, several techniques are possible. However, as the described subgrid

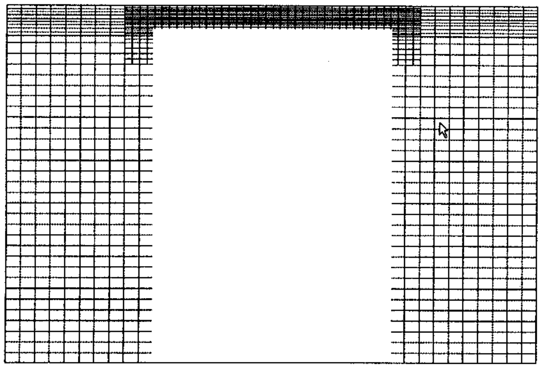

Fig. 2. Advanced subgrid technique applied for modeling the critical air gap zone of a combline filter resonator structure

algorithm (Fig. 3) is based on a distinct distortion of the grids, only methods are applicable in our case which do not require any additional distortion. Here, the principle of the 'conformal' technique described in [8] is extended to the sub cuboids of the mesh and to the related transient regions.

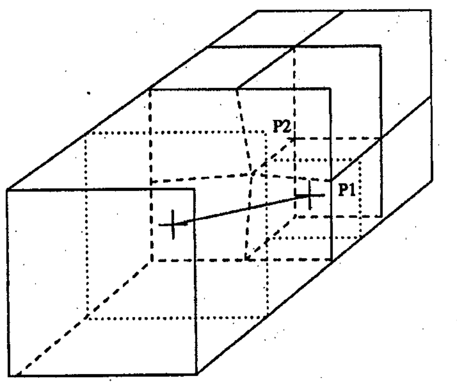

Fig. 3. Simple example for the 3D subgrid technique: Transition from a coarse grid to subgrid within a waveguide.

As the conformal technique does not change the position of the magnetic field strength, the subgrid algorithm can be improved concerning the dynamic range by an adequate displacement of the magnetic field strength [7]. In this way, the described techniques can be implemented in the FD algorithm in a unique manner. This results in an efficient computer code for calculating the GSM of arbitrary 3D FD building blocks.

The FD-FD equation system is solved usually iteratively. We apply the LU decomposition method (which is possible for smaller equation systems like in our case) because of the following advantage: As the decomposition has to be carried out only once per frequency, the CPU effort is not significantly dependent from the number of higher-order modes which have to be taken into account for the GSM combination of the building blocks.

III. RESULTS

The described method is applied for the CAD and optimization of combline filters. The filter structure is separated into suitable sections (Fig. 1) that describe the building blocks for the GSM combination. Combline filters are rather critical concerning the convergence behavior because of the high field concentration in the air gap between post and waveguide housing (Fig. 2). Sufficient accuracy for the GSM calculation requires high CPU time even for the described advanced FD method. For a realistic optimization of the filter, first the basic GSM of the FD building blocks are calculated and separately stored. As their combination via the GSM of the homogeneous waveguide sections between them is very fast, an efficient computer code is possible which is well appropriate for powerful optimizers such as the genetic algorithm [9].

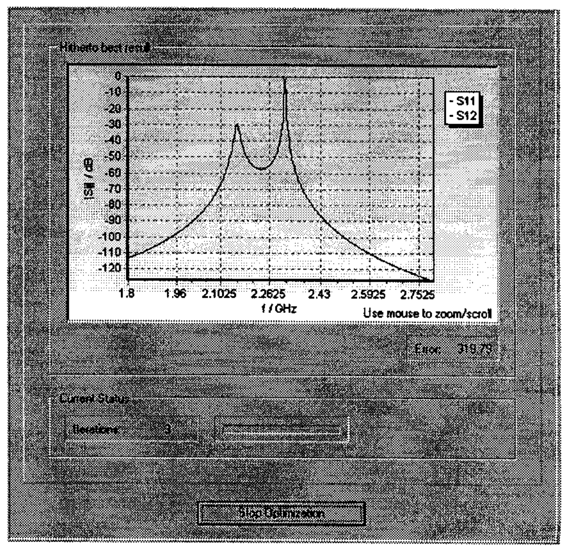

Fig. 4. Iteration 3 after rough starting values for the combline filter optimization

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Only very rough starting values for the subsequent optimization are required as is demonstrated by Fig. 4. After 100 – 500 iterations (depending from filter specifications and starting values), already good results are obtained (Fig. 5). The final results after an overnight optimization are demonstrated in Fig. 7.

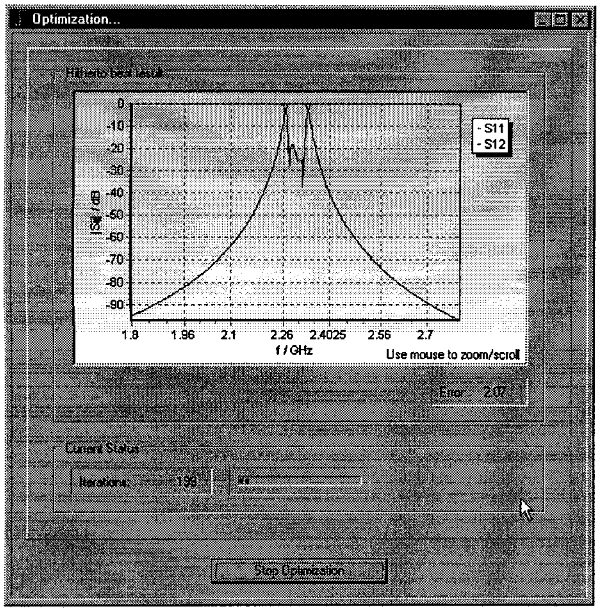

Fig. 5. Optimized result after 199 iterations

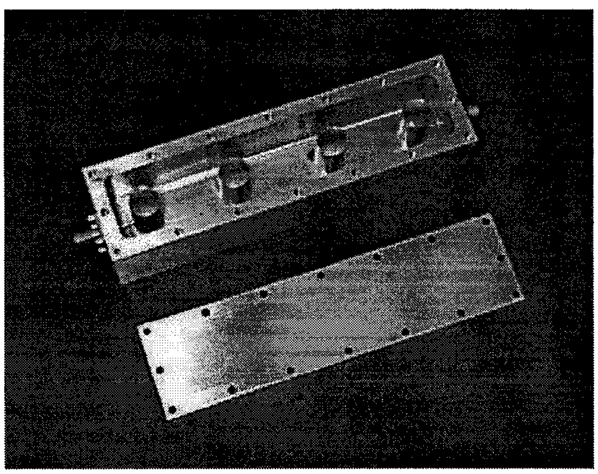

Fig. 6. Photograph of the fabricated combline filter (note that there are no tuning screws)

In order to verify the accuracy of the presented FD GSM method, an optimized combline filter structure has been fabricated (Fig. 6) and measured. For the FD calculation of the combline filter building blocks, about 40 000 cells have been used and about 20 000 sub cells. The GSM is calculated with ten combination modes ("accessible modes").

Good agreement between theory and measurements may be stated. Note that there are no tuning screws.

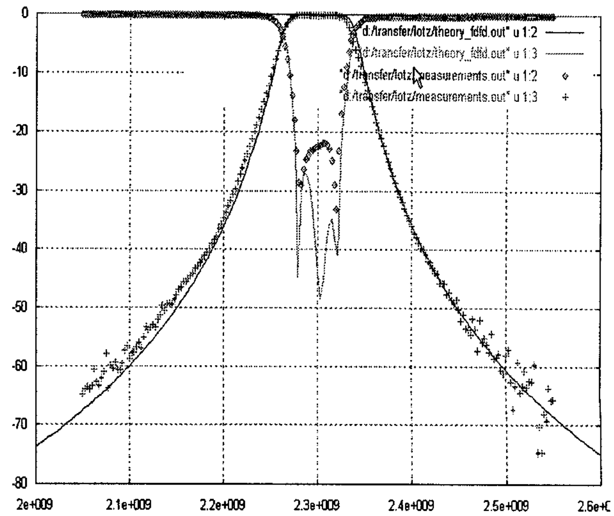

Fig. 7. Theory and measurement

IV. Conclusion

An advanced finite difference generalized scattering matrix (FD GSM) technique has been described which combines the flexibility of the FD method with the efficiency of the GSM combination of building blocks. The FD technique utilizes a mixed subgrid conformal algorithm for providing the required accuracy for rather critical filter structures, such as combline filter resonators. The method has been verified by measurements.

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