Efficient Parametric Analysis of Cavity-Backed Slot Coupled DRA with Finite Element Method

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Abstract – **In this paper an application of mesh deformation technique for the parametric finite-element analysis of a dielectric resonator antenna is considered. It is shown that the mesh deformation significantly reduces the computational cost of parametric analysis, since it allows for the adaptively generated mesh to be reused while the geometry is modified. The efficiency and accuracy of the proposed approach is verified and compared with commonly used techniques for parametric analysis that involve remeshing.**

Index Terms — **Antenna design, CAD, finite element method, mesh deformation**

1. Introduction

Design of passive devices for modern high frequency communication systems usually involves extensive electromagnetic simulations. The increasing complexity of modern components and stringent design requirements enforce designers to use accurate and versatile numerical techniques, such as 3D finite element method (FEM). The computational cost of simulations involving such an advanced numerical technique is usually high, both on meshing and solution stages. In particular, if one uses the FEM for the analysis of devices with complex geometry, time consuming adaptive mesh refinement is usually applied to ensure the reliability and accuracy of the simulation results.

The process of adaptive mesh refinement starts from a coarse mesh, then based on the solution of the problem the mesh is locally refined using the information provided by local error indicators [1]-[2]. The procedure is repeated iteratively, and in each iteration the problem with increasing size has to be solved (usually at a single frequency point). In practice, the number of adaptive mesh refinement iterations can reach beyond 10. This makes the adaptive mesh refinement strategy very time consuming. Unfortunately, if the geometry is changed (as in the case of parametric analysis or design tuning) the mesh is usually regenerated from scratch – it implies that the entire adaptive mesh refinement procedure is also restarted, and the information about previously generated adaptive mesh is not used.

2. Mesh deformation

An alternative approach that allows one to pass the information about adaptive mesh for modified geometry is based on mesh deformation techniques. With such techniques one can transform the refined mesh corresponding to initial geometry by moving the surface and internal mesh nodes to fit to updated geometry, thereby eliminating the iterative mesh refinement when modifying the geometry. Although the concept is quite natural mesh deformation was seldom used in the computational electromagnetics. There are a few techniques that can be used to perform such mesh deformation [3]-[6]. In this paper we show the results that can be obtained by applying a technique based on elastostatic problem of solid mechanics that is implemented in InventSim framework [7]-[8].

3. Example DRA

The technique is validated on an example involving a dielectric resonator antenna that is fed from a rectangular cavity through a slot, as shown in Fig. 1. A detailed description of the DRA can be found in [10]. In this structure the width of the slot, denoted as *h,* and the offset of the slot in respect to cavity wall *d* were selected as two design variables. The initial dimensions are *h*=16mm and *d*=4mm. The antenna is simulated in the frequency range 2GHz – 3GHz using InventSIM 3D FEM simulation framework [7]-[8]. During the simulation 8 iterations of adaptive mesh refinement were applied to improve the initial coarse mesh. In Fig. 2. the return loss response $s_{11}(f)$ is shown for both initial and adaptively refined mesh. It is clearly visible that the application of the mesh refinement substantially changes the result of simulations, and therefore is recommended to be used each time the FEM simulation is performed. However the total time of the iterative refinement is high, since it takes

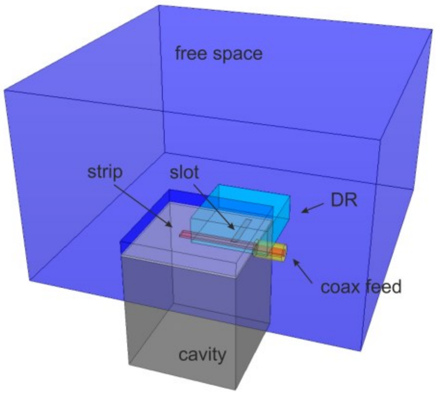


Fig. 1. Geometry of cavity-backed slot coupled DRA.

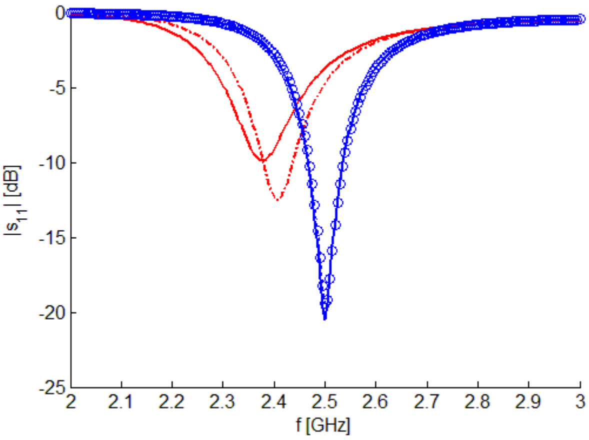


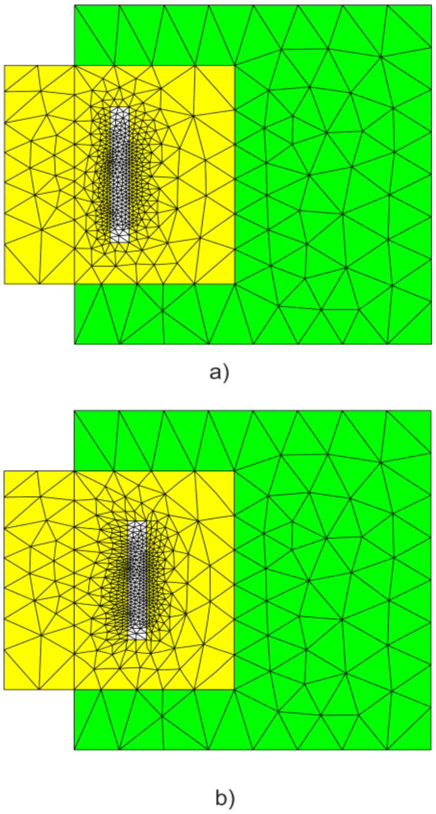
Fig.2. Scattering parameters of simulated DRA. Red plots show the response of initial geometry (dotted - coarse mesh and solid line – adaptively refined mesh). Blue plots: response of modified geometry (solid – deformed mesh, circles – regenerated, adaptively refined mesh).

about 5 minutes and 24s to complete the whole simulation stating from the initial mesh, of which the last step of adaptive mesh refinement takes 45s .

It is noted, that in a classical approach each time the structure dimensions are modified, the simulation would take a similar amount of time as the first one, since each simulation is totally independent of each other. For example, if we change the dimensions to *h*=14mm and *d*=6mm, then the simulation would take another 5 minutes.

This changes if instead of mesh regeneration one applies mesh deformation. In this case the mesh obtained from a previous (good) mesh is already close to the optimal one, since the geometry modification is limited to a small part of the structure. Moreover, the mesh deformation is fast. For the considered case it takes about 8s on the same PC to deform the mesh, and the final simulation on that mesh takes about 30s. The total is 38 seconds which is more than 8 times faster than basic mesh regeneration with adaptive refinement. Also in Fig. 2 the simulation result based on deformed mesh is compared to the response based on mesh regeneration with adaptive mesh refinement (blue curves). It is seen that the response computed on deformed mesh virtually indistinguishable from the response computed with an adaptively refined mesh.

Finally, in Fig. 3 plots of the surface mesh are shown for the cases of initial and deformed meshes (only the relevant part of mesh on the top of the cavity and bottom of the DR is shown). It is seen that both meshes share the same topology and the quality of deformed mesh is satisfactory.


a)

b)

Fig.3. Plots of surface mesh generated on top of the cavity (green) and bottom on the DR (yellow), slot area is white. Top (a) initial mesh; bottom (b) deformed mesh.

Conclusion

An efficient approach for the parametric analysis of complex passive devices involving 3D FEM simulations was shown. The technique can be useful for manual and automated tuning of passive devices, including antennas. The modification of geometry is followed by deformation of refined mesh, that limits the computational cost of parametric sweeps and design tuning.

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