Simulation of Circular Patch Antenna on a Sphere Using the Conformal Finite Difference Time Domain (CFDTD) Algorithm

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Abstract: The conformal finite difference time domain (CFDTD) algorithm is employed in this paper to simulate the radiation and impedance characteristics of circular microstrip patches mounted on a spherical surface. Numerical results not only demonstrate its versatility, but the accuracy and numerical efficiency of the CFDTD method as well.

1. Introduction

Conformal microstrip patch arrays are often preferred over planar ones for a wide variety of applications, and have been investigated recently by a number of workers. For instance, cylindrical arrays are convenient for achieving wide-angle azimuthal coverage and have been the subject of extensive studies. Much attention has also been paid to conical arrays located on missile nosecones. Spherical arrays, on the other hand, have yet to be thoroughly investigated with a view to realizing their full potential, which includes the possibility of beam scanning over a complete hemisphere.

In this paper, we have employed the Conformal Finite Difference Time Domain (CFDTD) technique [1-2] for the analysis of microstrip patch, phased array antennas on a spherical surface. The FDTD technique has the obvious advantage over the Method of Moments (MoM) [3-5] in that it provides the desired response of the array over a wide frequency band in one run; hence, it is computationally more efficient for the problem at hand. The FDTD technique is also more versatile because it can handle a partial sphere and other geometries that are not readily amenable to analysis via the MoM. However, the curved geometry of the problem makes it difficult to obtain accurate results using the conventional FDTD algorithm because of staircasing. The CFDTD technique [1], on the other hand, is well suited for handling such curved geometries.

2. The FDTD model

In the CFDTD technique [1], the H-fields are assumed to be located at the center of partial cells and are updated with a special algorithm that involves the lengths of the truncated edges of these cells. To set up the mesh for a spherical-circular patch antenna, we first obtain triangular a mesh covering the surfaces of the patch, the dielectric shell, and the conducting core. The length of truncated

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edge and the area of distorted cell are then calculated from the intersections of the FDTD grids with the triangles. Finally we apply the conditions discussed in [1] to determine the cells for which the special updating algorithm will be used.

3. Results

We begin by presenting the results for a single circular patch mounted on a spherical surface that help validate the CFDTD algorithm for the type of problems of interest in this work. The geometry of the problem is displayed in Fig. 1. The radius of the conducting sphere is 30mm, and the thickness of the dielectric shell is 1.6mm. The patch has an “arc radius” of 18.8mm and a thickness of 0.4mm. The excitation is provided by a z-directed lumped source, located at an “arc distance” of 9.4mm from the center of the patch. The size of the computational domain is $100\times100\times100\text{mm}^3$. The boundaries are truncated by using the Mur’s radiation condition. A uniform cell size of $0.4\times0.4\times0.4\text{mm}^3$ is used and the solution is found to be stable. The results of the CFDTD calculation are compared with those of the Ansoft HFSS (FEM method). Fig. 2 exhibits the total far field in the two principal planes, *viz*., $\phi=0^o$ and 90^o, while Fig. 3 shows the real part and imaginary part of the input impedance. We note that the agreement between the results obtained from the two methods is very good.

We have also simulated the mutual coupling in arrays of patches mounted on a spherical surface. An example of 5 elements is shown in Fig. 4. The patches all have an equal radius of 15mm. The radius of the conducting core is 50mm. The thickness of the substrate is 1.5mm. The axes of rotational symmetry for the patches 2 through 5 make an angle of 45^o with the axis of patch 1. The coupling coefficients $|S_{21}|$ and $|S_{51}|$ are plotted in Fig. 5. We see that the results for $|S_{21}|$ correlate very well with those computed by HFSS. The difference in the $|S_{51}|$ results, may be attributable to the fact that the level is too small to be resolved accurately. The mutual coupling levels (not shown here) are found to be smaller for the spherical case than those for its planar counterpart. The results for the radiation pattern show that the curvature primarily affects the back lobes ($|\theta|>90^o$), and that the level of this lobe oscillates as a function of the radius of the sphere.

4. Conclusion

In this study, the Conformal Finite Difference Time Domain (CFDTD) technique [1] has been used to analyze the radiation and impedance properties of circular patch arrays mounted on a spherical surface. Various numerical experiments have demonstrated that the technique is capable of accurately predicting the performance of the antenna array. The CFDTD technique is currently being used to investigate the edge effect in spherical array with a large number of elements.

Reference

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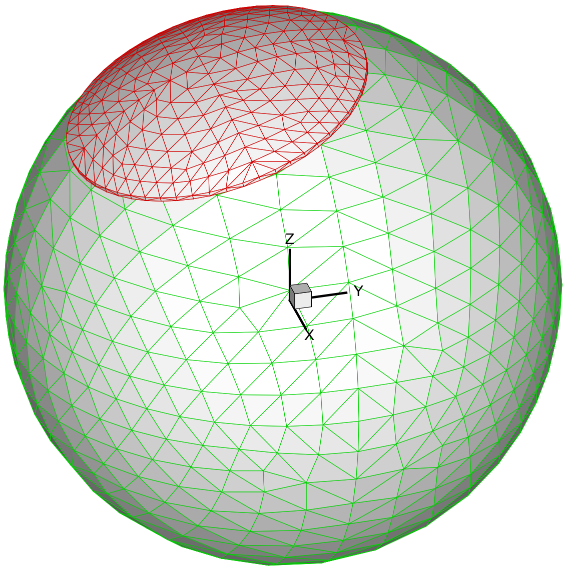

Fig. 1. Geometry of the problem: a circular patch mounted on a partial sphere.

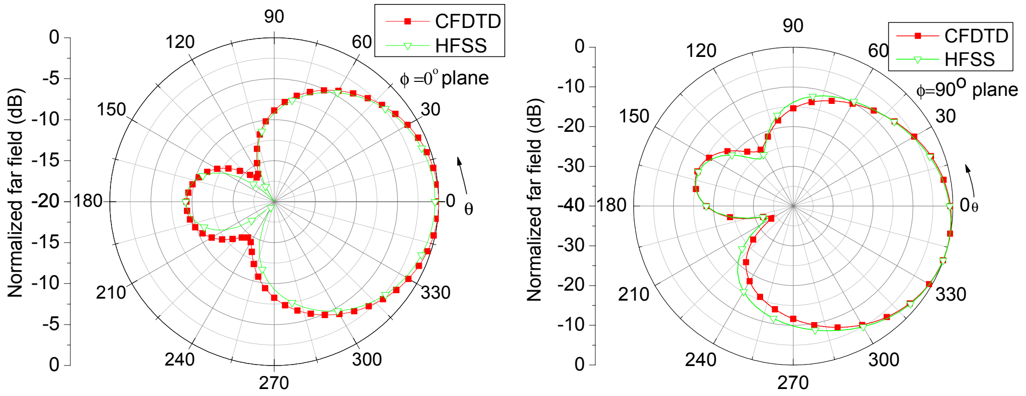

Fig. 2. Normalized total far zone electric field in the elevation plane.

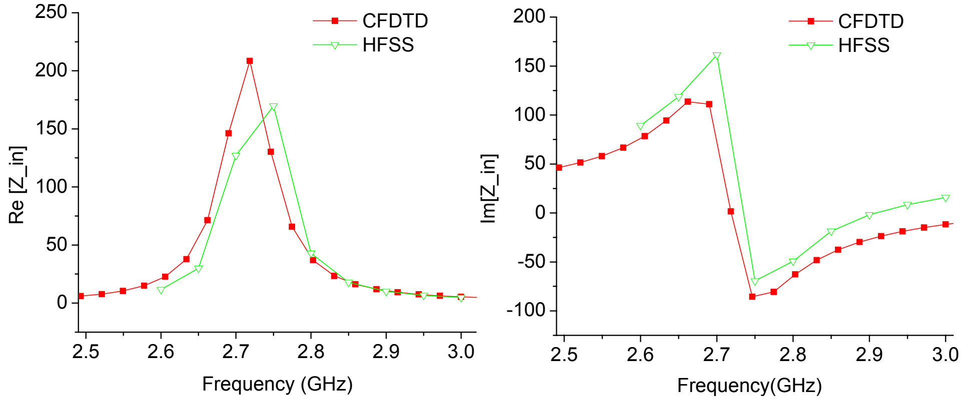

Fig. 3. Real (left) and imaginary (right) part of the input impedance.

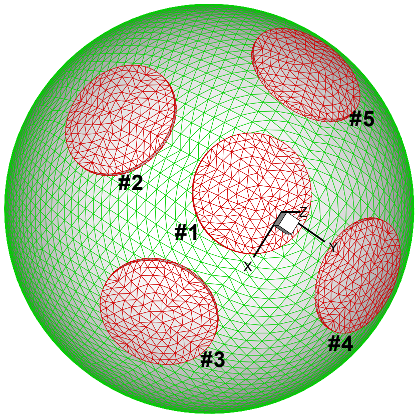

Fig. 4. Geometry of the 5-patch problem: the radius of the conducting core is 50mm

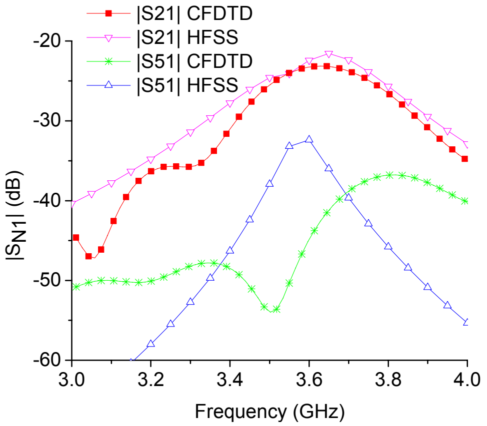

Fig. 5. Mutual coupling effects in the 5-patch configuration.