The FDTD Analysis of the Radiation Pattern of an Antenna Mounted on a Rocket

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***Abstract* - The radiation pattern of an antenna mounted on a rocket was calculated by using FDTD method. The high-order spatial difference was utilized to reduce the influence of the grid dispersion due to the huge computation region. The subgrid algorithm was used to model the antenna elements precisely as well as to reduce computational resources.**

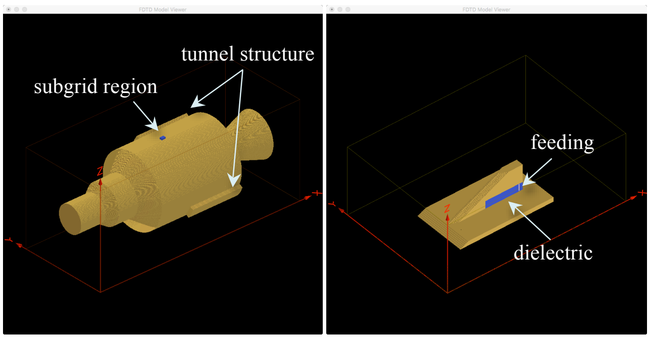
***Index Terms* — Antennas, Rocket, FDTD, Radiation pattern, High-order, Subgrid, Grid dispersion.**

1. Introduction

The radiation pattern changes while the antenna is mounted on a rocket. It is affected by the reflection of the huge rocket body and the diffraction effect of various structures of the rocket. The knowledge of the radiation pattern is very important in link design to guarantee the communication between the rocket and the ground stations for any rocket attitude. Because it is a hard task to measure the radiation pattern with such a big object, it requires some numerical approach to solve the problem. The GTD method seems very promising and effective, however, the reliability and the precision are not certain enough that they need be validated by some other methods. In this paper, FDTD method was attempted to calculate the radiation pattern by involving the whole rocket into the computation region. The subgrid algorithm[1] was utilized to model the antenna element precisely, and a high-order spatial difference[2] was applied to reduce the influence of the grid dispersion.

2. The Model and FDTD Computation

Fig.1 is the models of FDTD computation. Fig.1(a) is the simplified the second and the third stages of rocket Epsilon. It is 7.27m long, and the radius of the biggest cylindrical part is 1.3m. The body of the rocket was treated as PEC and the region was divided with 5.5mm cubic cells. The computation region was 1422 divisions in x direction (axial direction of the rocket), 600 and 630 divisions in y and z directions, respectively. The small blue rectangular on the top of the rocket is a subgrid area and was divided by 0.5mm fine cubic cells. Fig.1(b) shows the subgrid region, where it contains a blade antenna element which is operated at 2.3GHz. The blue area is dielectric material, and a coaxial feeding cable is inside. The subgrid area is 286, 198 and 110 divisions in x, y and z directions respectively with fine cells.



(a) rocket with an antenna (b) antenna in subgird region
Fig.1. Main and sub grid regions of FDTD Computation

Because the length of the second and the third stages of rocket Epsilon is 56 wavelengths, and the total length of the rocket Epsilon will be 200 wavelengths, the effect of grid dispersion will result in a considerable error in FDTD computation and as well as an error in far-zone field pattern. In our computation, a 4th-order spatial difference was utilized to reduce the influence of the grid dispersion.

3. Numerical Results

Fig.2 shows the radiation patterns of an x-oriented horizontal dipole antenna that was located in the center of a large FDTD computation region. The region is 26m tall in z-direction, and 3m width both in x and y directions. The dipole antenna was 9cm long and operated in 2.3GHz. The results denoted by ‘22’ were calculated by conventional FDTD method, and those of ‘24’ were calculated by 4th-order spatial difference. The green lines are the confirmed results calculated with a computation region of several wavelengths. It is found the results of conventional FDTD method have a considerable error in the longest dimension of the computation region. It was considered as the influence of the grid dispersion. The computation with spatial difference of high order can reduce the grid dispersion effectively and gives accurate results.

Fig.3 shows the radiation pattern of the blade antenna of Fig.1(b) mounted on an infinitive PEC ground plane. It was calculated by located the antenna on the center of a 1.2m long square PEC plane and the plane was truncated by a PML absorbing boundary. The blade antenna was modeled in the subgrid region with fine cells and was surrounded by main grid region of the same size as Fig.1(a). The antenna was also calculated by conventional FDTD method with fine cells. It is noted that the results of subgrid algorithm agree very well with those of the conventional method.

The influence of the rocket length on the radiation pattern was investigated by simplifying the rocket of Fig.1(a) with a PEC cylinder. The radius of cylinder is 1.3m, and the antenna was mounted on the middle of the top surface. Fig.4 is the results by changing the length of the cylinder from 1m to 5m. Some changes are occurred around the axis direction of the cylinder. The variation in other directions is small when the rocket is longer than 2m. The radiation patterns in the upper half-space are very similar to those of the infinitive PEC plane denoted by the yellow lines. It is also observed that the length doesn't affect the pattern on its cross-section.

Fig.5 shows the radiation patterns of the antenna mounted on the second and third stages of rocket Epsilon. Some ripples in E_θ are observed in Fig5.(b) around the angle of 330°. It was considered as the effect of tunnels that were asymmetrically located in both sides.

4. Conclusion

The radiation patterns of the antenna mounted on a huge rocket were calculated by combining the FDTD method with the subgrid algorithm and the high-order spatial difference. The affects of rocket length and rocket structures were discussed.

References

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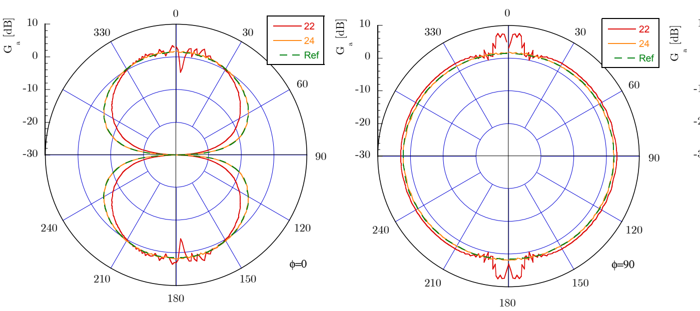
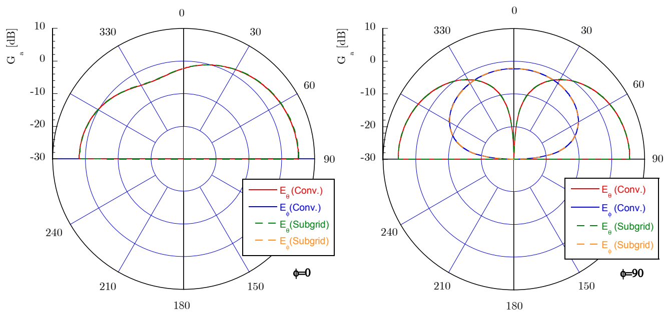


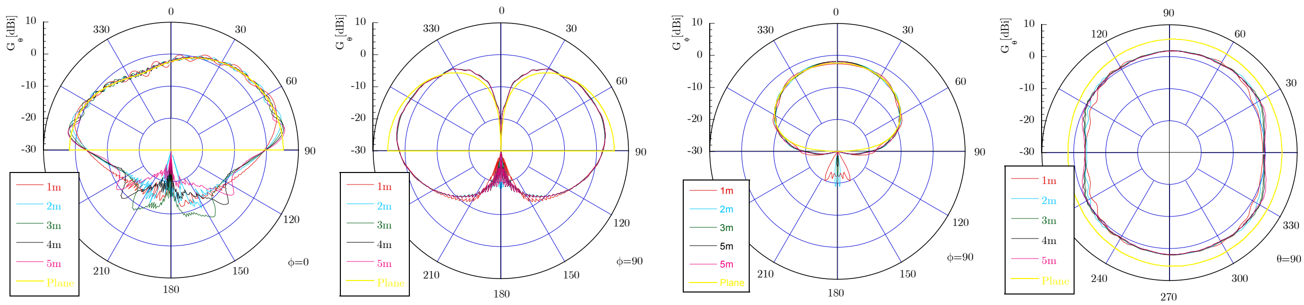
(a) E-Plane (b) H-Plane

Fig.2. Dipole pattern calculated in a large FDTD computation



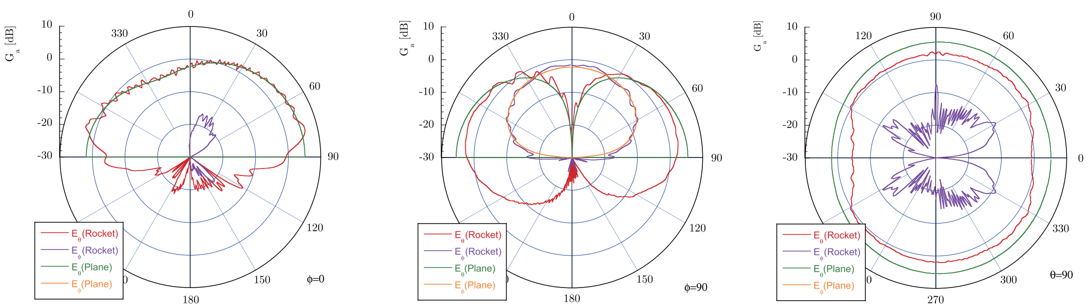
(a) xz-Plane (b) yz –Plane

Fig.3. Blade antenna pattern on an infinitive PEC plane



(a) xz-Plane E_θ (b) yz –Plane E_θ (c) yz –Plane E_ϕ (d) xy –Plane E_θ

Fig.4. Blade antenna pattern on a PEC cylinder



(a) xz-Plane (b) yz –Plane (c) xy –Plane

Fig.5. Blade antenna pattern on the second and the third-stages of rocket Epsilon