Radiation Patterns of the Antenna Mounted on Complex Structure Using FDTD Algorithm

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Abstract: This paper presents the radiation patterns of the monopole antenna mounted on the complex structure by using finite-difference time-domain(FDTD) method. Comparison of FDTD calculated results with the exact solution of Carter[1] for cylindrical structure illustrates the accuracy of the algorithm. From the proven code, radiation patterns of complex structure is calculated and measured.

1. Introduction

The FDTD method, originally proposed by Yee , has gained acceptance as a practical algorithm for computing electromagnetic field numerically[2][3]. In the radiation of antenna mounting on the complex structure, the problem of determining the effect of a nearby flat area on feeding point and the size of one grid cell is raised an question for calculating the far-field radiation pattern. In order to investigate the possible sensitivity of the radiation pattern, the configuration of interest here is one structure; a dipole mounted on the infinite cylinder that has available exact solutions. The proven FDTD code was used to analyze the radiation patterns of antenna mounted on the complex structure.

2. Validation of the FDTD method

A number of numerical calculations have been made to test the accuracy of the FDTD code. The results obtained were compared with the exact solution. Firstly, we will investigate about the exact solution of a dipole mounted on the surface of infinite cylinder. The finite cylinder of length L and radius a excited by a radically infinitesimal dipole or stub of length dl is shown in Figure 1. An interesting cases are indicated in Fig. 1 where, after generating mesh for a finite cylinder of radius 25cm ($=\lambda/4$) and length 200cm ($=\lambda/2$), each flat regions near the short monopole antenna have the three different values; three cells (=Case I), two cells (=Case II), and one cell (=Case III), respectively. The resulting cross sections of the FDTD mesh are illustrated in Fig. 2. These modeling are used to check how does the size of flat ground plane near the monopole have an effect on the pattern of monopole.

Using Carter's approach [1], the radiation field of a radically pointing electric dipole on a perfectly conducting infinite cylinder of radius a is obtained. In the principle plane (ϕ=90), the radiation field of E_θ is given by

$$E_\theta = \frac{Idl}{\pi^2 akr} e^{-jkr} \sum_{n=1}^{\infty} \frac{nj^n \sin(n\theta)}{H_n^{(2)}(ka)} \tag{1}$$

where $H_n^{(2)}(ka)$ is the Hankel function of the second kind of order *n*.

Since the top-layer cell numbers can vary the characteristics of the antenna, acceptable cell numbers are needed for good result and cell size is an important parameter for reducing running time. Fig. 3 shows the radiation pattern of the monopole antenna according to the top-layer cell numbers shown in Fig. 2. These results are obtained with Δt=350 time steps, number of PML layer=4, reflection factor=1.0x10^{-6}, f_0=300*MHz*, *L*=200*cm*. Although there is a slightly discrepancy in the $\theta = 60^\circ$ by simulating the cylinder with the finite length in our FDTD method, Case Ⅰ, Ⅱ, Ⅲ and Carter's exact solution are about the same result. And it is confirmed that two cells are necessary to model the feeding area of the minimum ground.

3. Analysis of the complex structure by using FDTD method

Fig. 4 shows the meshed modeling of a corn type complex structure. This paper tries to analyze the radiation pattern of Fig. 4 structure by using the extended FDTD method. The parameters for calculation are listed in Table 1, and the excitation pulse used in this investigation has been chosen to be Gaussian in shape as follows [4];

$$V_1(t) = 1.0e^{-\alpha(t-\beta\Delta t)^2} \tag{2}$$

where $\alpha = (\frac{4}{\beta\Delta t})^2$ and $\beta = 32$, and the pulse truncated for $t < 0$ and $t > 2\beta\Delta t$.

To observe the radiated pattern of dipole antenna mounted on the complex structure, antenna gain relative to a lossless isotropic antenna in the θ, ϕ-direction is used.

$$Gain(\theta,\phi) = \frac{|E_F(\omega,\theta,\phi)|^2 / \eta_0}{P_{in} / 4\pi} \tag{3}$$

where $E_F(\omega,\theta,\phi)$ is the Fourier transform of the transient far-field time domain electric field radiated in the θ, ϕ-direction.

The normalized radiation patterns of far-field E_θ and E_ϕ are shown in Fig. 5, where radiated power toward aperture is observed with back radiation. There seem to be a good agreement between the simulated and measured results.

4. Conclusion

The extended finite-difference time-domain method was applied to find the radiation patterns simulations in the complex structure. These results have been verified by comparison with the exact Carter's solution and measurement. Finally, a dipole mounted on the surface of the corn type complex structure is investigated. It is recognized, also, that the radiation patterns of a dipole mounted on the curvature corn are not sensitive to the variations in the flat ground area near the feed region.

Reference

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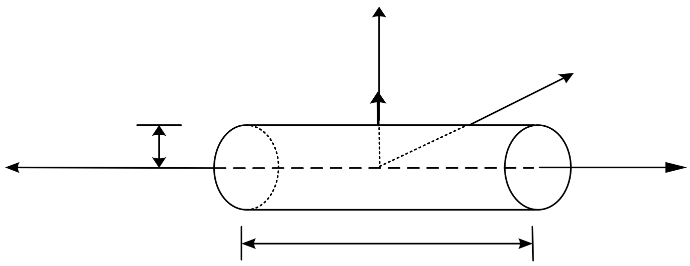
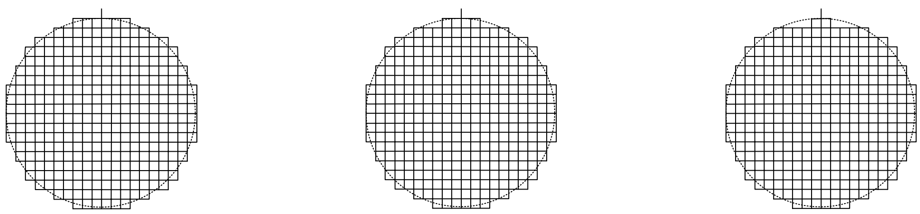


Fig. 1 Short monopole antenna on a finite cylinder with length *L*



(a) Case Ⅰ (three cells) (b) Case Ⅱ (two cells) (c) Case Ⅲ (one cell)

Fig. 2 Cross section of the meshed cylinder with different top-layer cell numbers

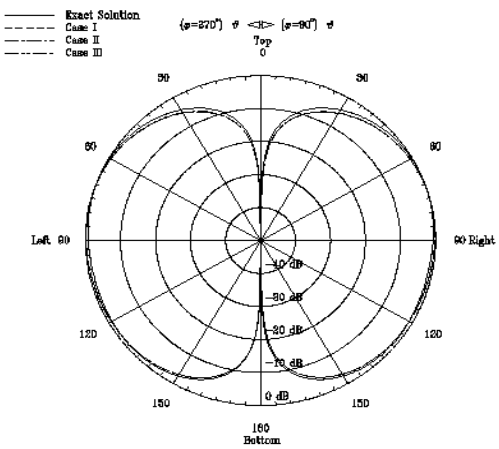


Fig. 3 Radiation patterns of the monopole antenna with various top-layer cell numbers.

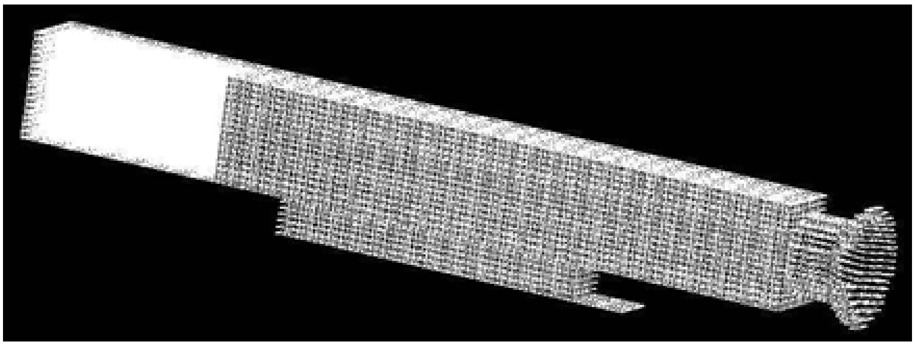
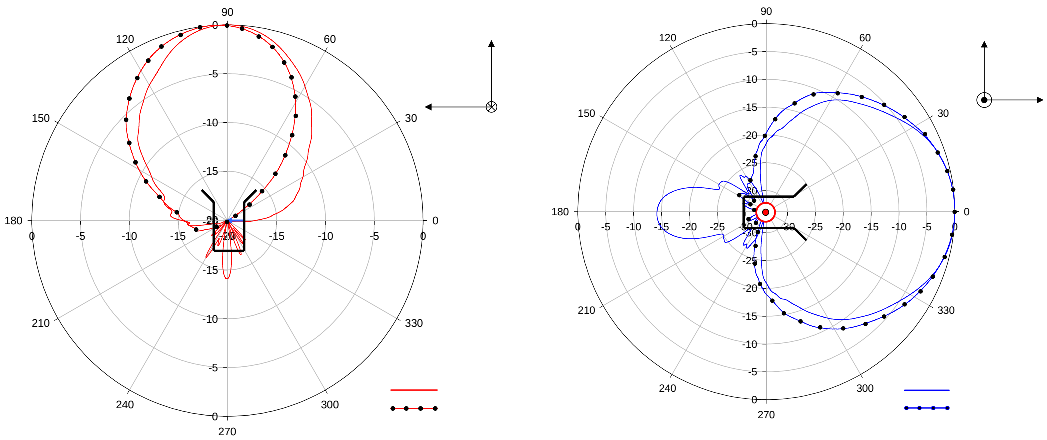


Fig. 4 Meshed model of dipole mounted on the corn type complex structure

Parameters	Value
Length of structure	Tx. : 3,302 x 332 x 254 [mm] Rx. : 987 x 127 x 160 [mm]
Δx, Δy, Δz	$\lambda / 15(f_0 = 1GHz)$
Mesh dimension	166 x 42 x 54
Δt	9,600
Position of antenna	Tx. : (143Δx, 21Δy, 24Δz) Rx. : (129Δx, 21Δy, 16Δz)
Antenna length	1 cell(20mm)

Table 1. Parameters for the calculation



(a) (b)

Fig. 5 Radiation patterns of (a) E_θ and (b) E_ϕ