PROBE FEEDING SIMULATION USING OVERLAPPING-GRID TECHNIQUE FOR FDTD

Kyeong-Sik Min and Manh-Dat Vu

Department of Radio Sciences and Engineering,

College of Sciences and Engineering, Korea Maritime University,

#1 Dongsam-Dong Yeongdo-Ku Busan, 606-791, Korea

E-mail: ksmin@mail.hhu.ac.kr , Tel: +82-51-410-4425

Abstract

This paper presents an application of overlapping-grid technique for probe feeding simulation. The overlapping grid technique is used to solve contour path problem. In this technique, field interpolation is very important to make communication between two coordinates. By applying overlapping-grid technique, error of contour path in probe feeding simulation is reduced.

1. Introduction

The FDTD algorithm is a direct solution of Maxwell's equation with differential form for the electric and magnetic field intensities, as first proposed by Yee in 1966[1]. The algorithm is based on the discretization of Maxwell's curl equations(Ampere's and Faraday's Laws) using central difference approximations of spatial and time derivatives. The original Yee FDTD is second-order accuracy in both space and time. Numerical dispersion and grid anisotropy errors are kept small by having a sufficient number of grid spaces per wavelength. Taflove was the first to present the correct stability criterion for original orthogonal-grid Yee algorithm[2]. Nowadays, FDTD has been an exact tool simulation to support studiers in design of antennas and RF structures for several applications ranging from simple microstrip antennas to complex phased-array antennas. In FDTD, probe feeding model is studied further more. The study consists of input impedance, return loss, probe current and sub-cell technique, etc. In FDTD, contour path problem is also considered very much. Many methods were presented to solve this problem and cylindrical coordinate is one in them. However, application of cylindrical coordinate is limited in the cylindrical shape of simulation structures. Because of the cylindrical shape of probe feeding structure, the error occurs when we use rectangular coordinates to define probe feeding structure. This paper presents an application of overlapping-grid technique for probe feeding simulation using FDTD. In here, the overlapping-grid technique uses cylindrical and rectangular coordinates to define probe feeding structure as shown in Fig. 1.

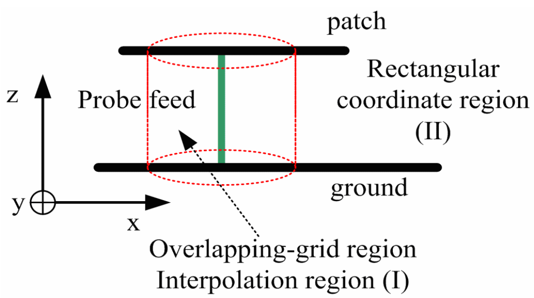

Fig. 1 Probe feeding model.

The rectangular coordinate is applied for all simulation space. However, the cylindrical coordinate is only applied in probe feeding position, between ground and patch of antenna. The overlapping-grid is just applied at probe feeding position so it does not much affect to time simulation. The center of cylindrical coordinate is located at center of the probe. First of all, the structure is fed by setting electric field E_z at probe position, in cylindrical coordinate. After that, the electric field E_z is interpolated to rectangular coordinate. The next, the electric field is used to update magnetic field in rectangular coordinates. After that, the magnetic field H_x, H_y is interpolated to H_r, H_ϕ in cylindrical coordinates as shown in Fig. 2.

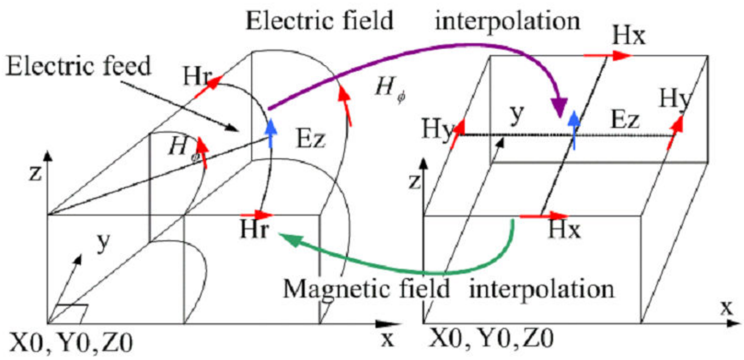

Fig. 2 Interpolation model.

In cylindrical coordinate, the gap feed model is applied which consists of a feeding structure realized as a voltage generator placed at a small gap patch and ground plane. In the source, an internal resistor is used to absorb reflecting energy return the source.

2. Probe feeding model

In this paper, overlapping-grid technique is specifically applied for probe feeding simulation. The center of cylindrical coordinate is also the center of probe in rectangular coordinate. In two coordinates, the cell sizes are independent on each other. The Courant's stability criterion (1) and (2) are applied to satisfy stability condition in two coordinates

$$\Delta t \le \frac{1}{v_{\max} * \sqrt{(\frac{1}{\Delta r})^2 + (\frac{2}{r_{\max} * \Delta\phi})^2 + (\frac{1}{\Delta z})^2}} \quad (1)$$

$$\Delta t \le \frac{1}{v_{\max} * \sqrt{(\frac{1}{\Delta x})^2 + (\frac{1}{\Delta y})^2 + (\frac{1}{\Delta z})^2}} \quad (2)$$

In here, (1) is the Courant's stability criterion in cylindrical coordinate where $\Delta t, v_{\max}, \mathrm{r}_{\max}\ \Delta r, \Delta\phi, \Delta z$ are corresponding time step, maximum speed of electromagnetic wave, maximum radius, cell sizes in r, ϕ, z directions. The cell size in the ϕ dimension increases with increasing r. The largest cells must be much smaller than a wavelength [3]. (2) is the Courant's stability criterion in rectangular coordinate where $\Delta t, v_{\max}, \Delta x, \Delta y, \Delta z$ are corresponding time step, maximum speed of electromagnetic wave, cell sizes in x, y, z directions. The structure is fed in the center of cylindrical coordinates by setting electric field at the first cell from ground of antenna structure. At others cells, electric field Ez are set to zero as shown in Fig. 3.

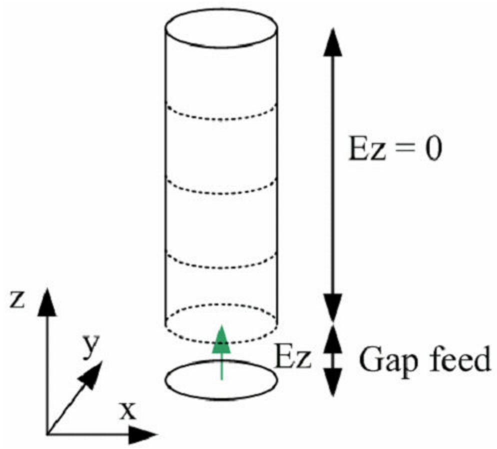

Fig. 3 Gap feed model.

After that, electric field E_z from cylindrical coordinates is interpolated to E_z in rectangular coordinate[4]. The interpolation result of E_z is shown in Fig. 4.

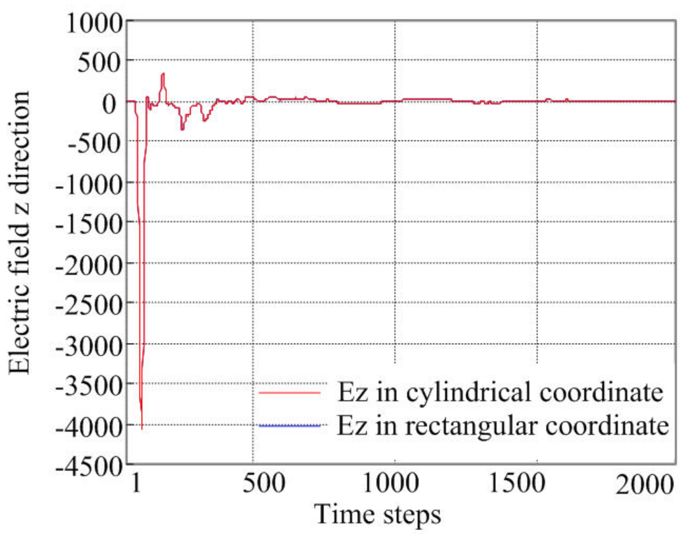

Fig. 4 Electric field interpolation.

In rectangular coordinates, the electric field E_z is used to update the magnetic field H_x, H_y. Next step, H_r and H_ϕ are interpolated from H_x, H_y as shown in Fig. 5.

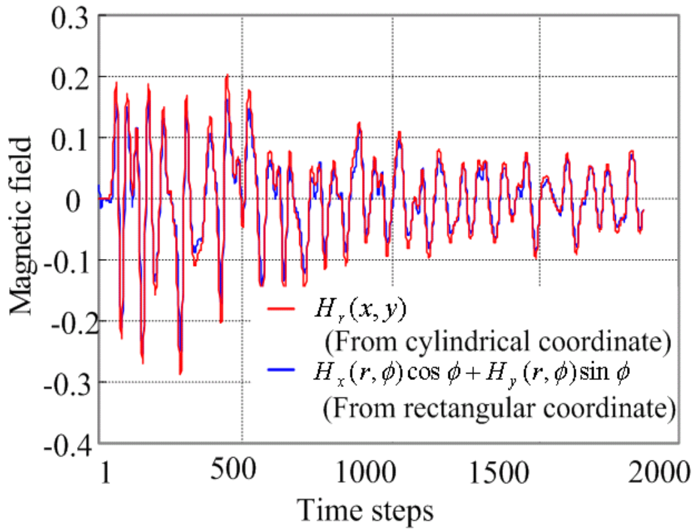

Fig. 5 Magnetic field interpolation.

In here, we have a comparison of magnetic fields from two coordinates at one position (x, y) as well as (r, ϕ) shown in Fig. 6.

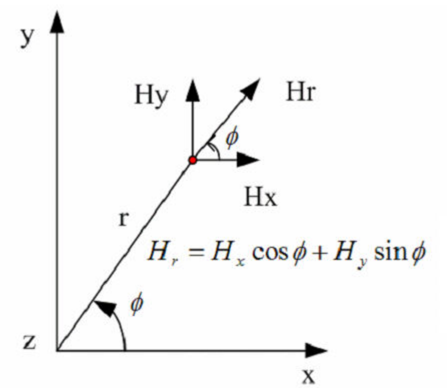

Fig. 6 Convert of magnetic fields for comparison in Fig. 5.

In process of interpolation, interpolation region must cover the entire probe feeding structure and more because boundary of the probe feeding region in cylindrical coordinates is cylindrical shape and rectangular mesh is different from cylindrical mesh. This paper applies reciprocal interpolation method to solve contour path problem in probe feeding simulation and except instability. We interpolate electric field E_z from cylindrical coordinate to rectangular coordinate to solve contour path problem in probe feeding simulation and interpolate magnetic field from rectangular coordinate to cylindrical coordinate to receive reflection energy return the source, in other word, this step of interpolation is the characteristic presentation of antenna structure into interpolation of magnetic field. The probe current is computed by take integral around probe in cylindrical coordinates using Ampere's circuital law $I = \oint_C \vec{H}_\phi \vec{d}l$ as shown in Fig. 7.

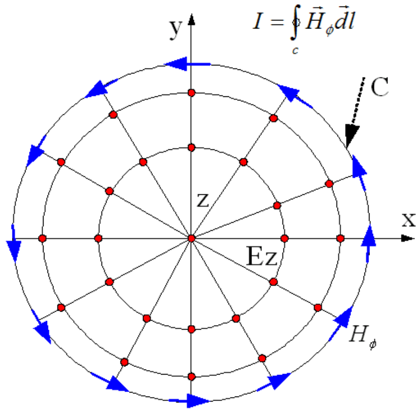

Fig. 7 Ampere's circuital law.

Finally, by applying of FFT (Fast Fourier Transform), the current and voltage source are transformed to the frequency domain. The input impedance of the antenna is obtained by $Z_{in} = \frac{V(f)}{I(f)} - R_s$, where R_s is internal resistor 50 ohm of source. Internal resistor R_s is used to absorb the reflecting wave which comes back the source. V and I are the gap source voltage and input current probe feeding structure, respectively.

3. Results and Discussions

Fig. 8 show design example of microstrip patch antenna [5]. In the reference [5], the antenna is design to operate for wireless LAN, with operating frequency 5.25 GHz and bandwidth 3 GHz, resonance at below -10 dB.

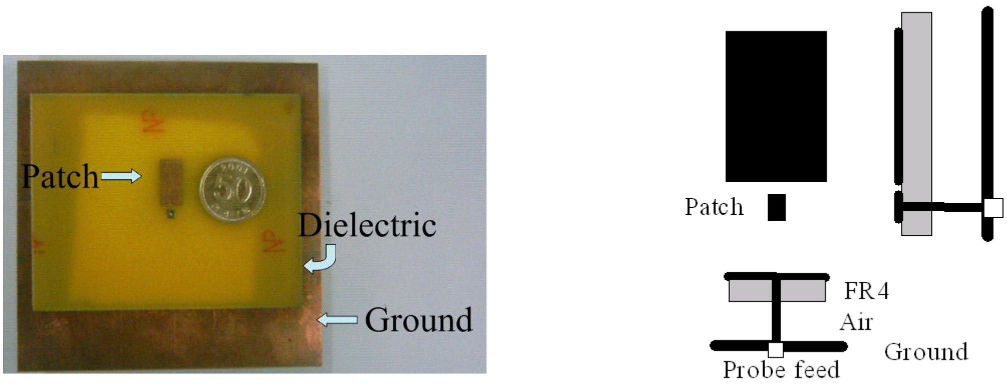

Fig. 8 The structure and picture of fabricated probe feeding broadband patch antenna.

Fig. 9 shows the return loss data of the microstrip antenna. Fig. 9 shows that FDTD simulation result has a good agreement with the measurement. The error between FDTD simulation result and measurement are caused interpolation error and fabrication error of the antennas operating at high frequency. It is necessary to know that the error of field interpolation can be occurred when position of field interpolation is far from cylindrical center, because the cylindrical cell size increase when it is far from the center. A probe feeding model of microstrip antenna which has capacitive feed has been analyzed using the FDTD method and results are compared with commercial tool simulation and measurement. FDTD results are agreed well with measurement one as well as commercial simulation one.

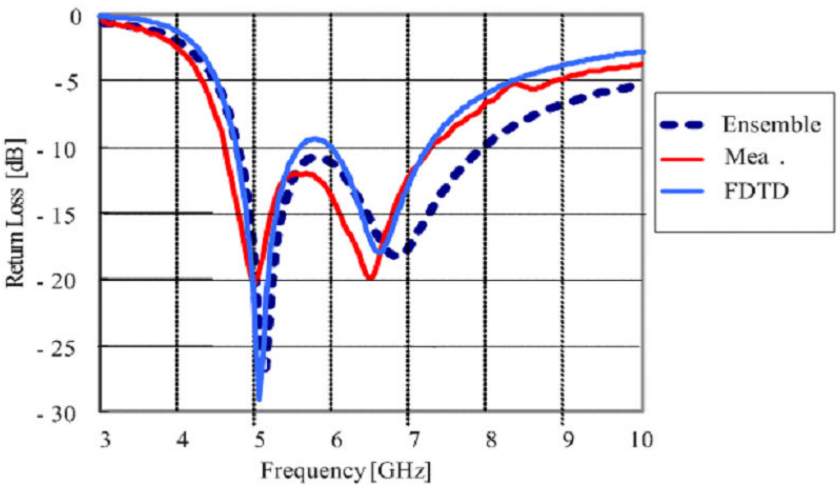

Fig. 9 The return loss of microstrip line probe feeding patch antenna.

4. Conclusion

The overlapping-grid technique can solve the contour path in probe feeding simulation. In overlapping-grid technique, field interpolation is very important because exact field interpolation can decide good simulation results and except instability. By applying overlapping-grid technique, error of contour path in probe feeding simulation is reduced. The return loss data show good agreement with prediction as shown in Fig. 9.

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