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IMPROVED DISTRIBUTED IMPLEMENTATION OF THE FINITE DIFFERENCE TIME-DOMAIN(FDTD) METHOD

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INTRODUCTION

The finite difference time-domain(FDTD)method was first established by Yee[1]. The FDTD method is well known numerical technique in electromagnetic wave problem. However the method requires large computer memory space and long computation time for three dimensional and large scale two dimensional problems, restricting its use on sequential computers to small problems. This has led to the use of expensive supercomputers in the past to solve larger problems. These are the main disadvantages of the method.

Rodohan established the Distributed FDTD method[2] to overcome the main disadvantages of the FDTD method. The Distributed FDTD method is the FDTD method for computing in parallel based on distributed-memory computer architectures. The highspeed of the calculation used distributed FD-TD method is influenced to communication speed, number of communication, communication cost between computers largely. Rodohan developed a low-cost parallel implementation of the FDTD method that ran on a network of workstations and succeeded in the highspeed of calculation, in which the Mur first-order absorbing boundary conditions[3] is used. However it is desirable that an absorbing boundary condition of high accuracy must be used in fact.

In this paper we first describe our Distributed FDTD method algorithm with improved third-order absorbing boundary conditions[4]. And the communication number of the method proposed by authors is smaller than that of Rodohan method. A comparison between the simulation time by using a single and double computers is finally made in the figure.

OUR DISTRIBUTED METHOD

Each magnetic field at a given point depends on the electric field from the previous half timestep on the surrounding points in FDTD algorithm. This means that the communication and the computation cannot be overlapped directly. For computation in parallel, we improved the mesh of the FDTD method. The two-dimensional mesh is shown Fig.1. As shown in Fig.1 the computation should proceed as follows:

(1) Initialization

At each time step:

(2) Calculate the magnetic field (Hx, Hy) values:

Calculate the all magnetic field (Hy) values in Region 1 and this except over lapping points in Region 2.

Calculate the all magnetic field (Hx) values in Region 1 and in Region 2.

(3) Send the magnetic field (Hy) values of over lapping points from region 1 to over lapping points in region 2.

(4) Calculate the electric field (Ez) values except the absorbing boundary :

Calculate the electric field (Ez) values except over lapping points in Region 1 and the all electric field (Ez) values in Region 2.

(5) Send the electric field (Ez) values of over lapping points from region 1 to over lapping points in region 1.

(6) Calculate the electric field (Ez) values of the absorbing boundary :

(A) Absorbing boundary of J=0,ny:

Calculate the electric field (Ez) values except I_1=nx+1 in Region 1 and this except I_2=0 in Region 2.

(B) Absorbing boundary of $I_1=0$, $I_2=nx$:

Calculate the all electric field (Ez) values.

(7) Send the electric field (Ez) values of (I_1 , J_1)=(1,0),(1,1),(1,ny) and (1,ny-1) in Region 2 from Region 2 to over lapping points in region 1. Send the electric field (Ez) values of (I_2 , J_2)=(nx,0),(nx,1),(nx,ny) and (nx,ny-1) in Region 1 from Region 1 to over lapping points in region 2.

Each region in Fig.1 is calculated by a single computer. Therefore the calculation used in this algorithm is performed in parallel. In this algorithm we use improved third-order absorbing boundary conditions[4] in calculating absorbing boundary. Fig.2 shows comparison between our method and Rodohan method for the communication and computation of the mesh except absorbing boundary. The communication number of our method is smaller than that of Rodohan method.

EXAMPLE PROBLEM

We examine that the speed-up of computation has done by using this algorithm.An example of a plane-wave by a square conducting cylinder. The cylinder has the electrical size $k_0 a_s=5.0$, where a_s is the half-width of the side of cylinder. The plane-wave excitation is TM-polarized, with field components E_z^i and H_x^i, and propagates in the +*x* direction, so that it is at normal incidence to one side of the cylinder. The plane-wave with field components E_z^i and H_x^i is expressed by

$$E_z^i = E_0 \cos(\omega \Delta t - k_0 \, x\Delta x) \text{、} \quad H_y^i = -E_0 / Z_0 \cos(\omega \Delta t - k_0 \, x\Delta x) \tag{1}$$

where $\omega = 2\pi / 40\Delta t$, $k_0 = 2\pi / \lambda$, $Z_0 = \sqrt{\mu_0/\varepsilon_0}$, $\Delta t = 0.5\Delta h / C_0$, $\Delta h = \Delta x = \Delta y = \lambda / 20$,
k_0 is the propagation constant in the free space, Z_0 is the intrinsic impedance, λ is the wavelength, C_0 is the velocity of the light in the free space.

In this computation, compatible IBM-PC (CPU : i486DX4-100MHz) and in this communication the communication implementation (64Kbyte/sec)with parallel port are used.

Fig.4 shows the time simulated until 500 timestep, in which PR=1,2 denote the time simulated by using one computer and two computers respectively and *L* is the mesh size of the one side of total computational domain as shown in Fig.3. In the mesh size *L* that is larger than 100 mesh size, the time of PR=2 is shorter than the time of PR=1. Fig.5 shows the graph of estimated speed-up available when using two computers(PR=2) against the mesh size *L*. It is concluded that twice of simulated speed has been finally achieved by using two computers.

CONCLUSIONS

We developed new Distributed FDTD method that decreased communication number compared with Rodohan method and used improved third-order absorbing boundary conditions. It was confirmed that a speed-up has performed by using our method.

REFERENCES

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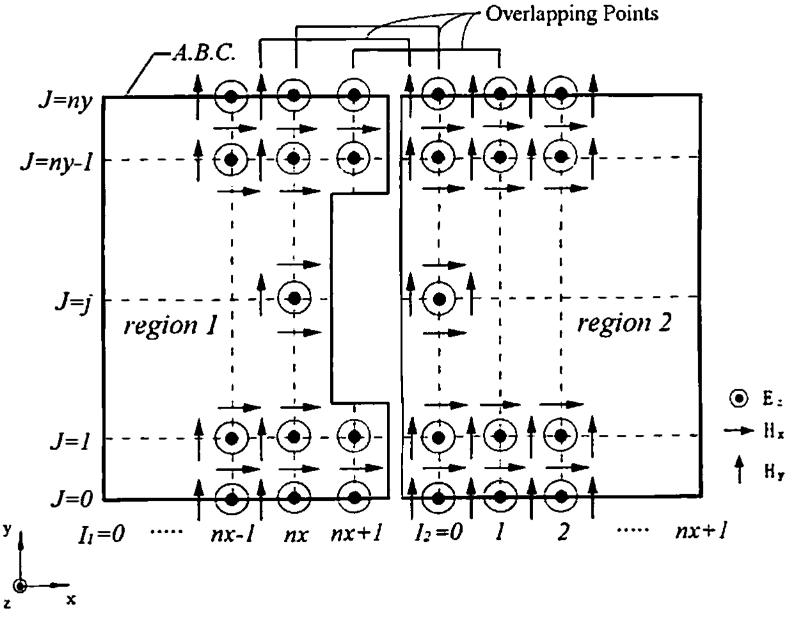

Fig.1 The two-dimensional mesh of this distributed FDTD method

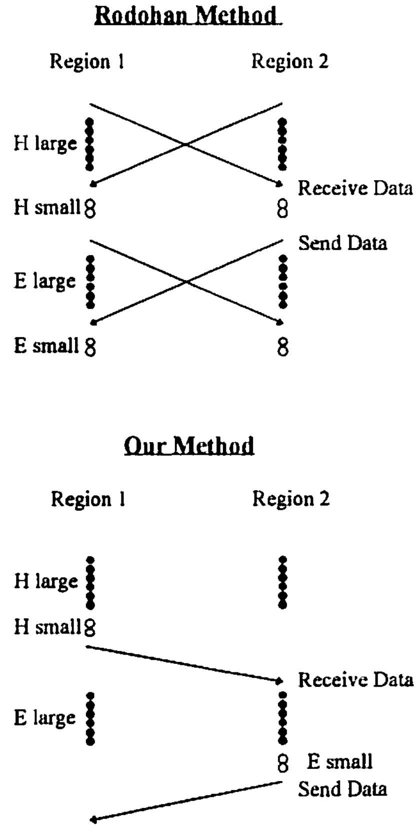

Fig.2 Communication and computation

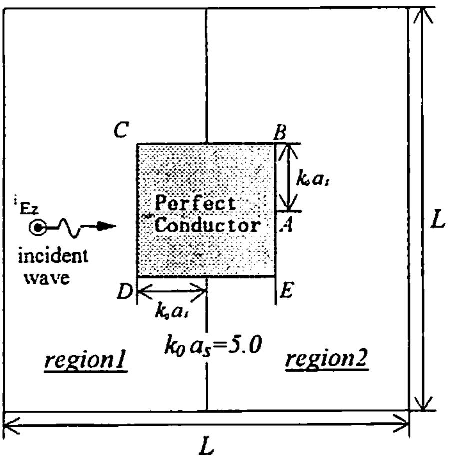

Fig.3 Computational domain of example problem

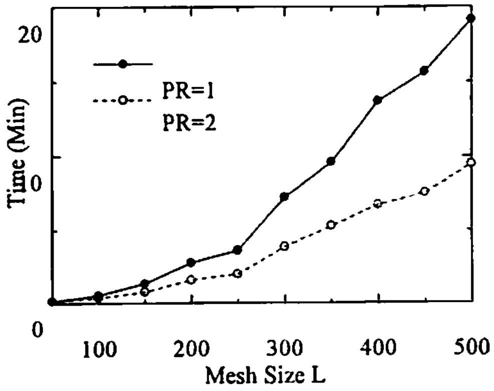

Fig.4 The graph of simulation time against mesh size *L*

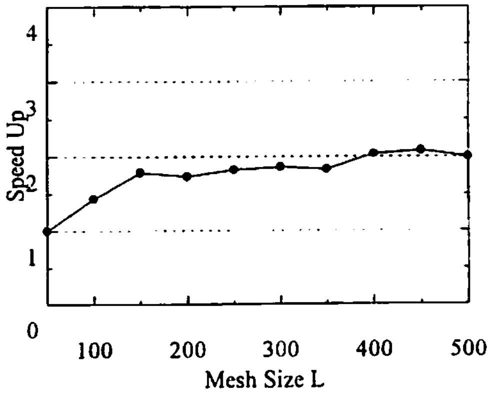

Fig.5 The graph of estimated speed-up against the mesh size *L*.