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# Parallel Processing of Forward-backward Time-stepping Method for Time Domain Inverse Scattering

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**Abstract**— Parallel computing is applied to FBTS method, which is one of the solution methods of time domain inverse scattering problem, to shorten the calculation time. A cluster of 8 PCs is constructed and parallel processing is realized using MPI. A 3-D reconstruction of wooden hollow cylinder from the experimental data is examined by parallel FBTS algorithm. It is shown that the parallel processing reduces the calculation time and FBTS algorithm provides proper reconstructed profiles of target with respect to relative permittivity and conductivity.

## 1. INTRODUCTION

Electromagnetic wave inverse scattering problem are investigated in various fields such as medical imaging, geophysical exploration, nondestructive testing, and target identifications [1–6]. We have proposed a time-domain inverse scattering imaging technique, the forward-backward time-stepping (FBTS) method, to reconstruct the electrical parameter profiles of scattering objects. It was clarified that quite good reconstructed results were obtained using the FBTS method in several numerical simulations [7]. We also showed its usefulness in real situations by applying the FBTS method to experimental data [8]. Although the FBTS method is effective to inverse scattering problems, the computation time is quite long to get accurate results in dealing with three-dimensional (3-D) objects. Therefore reconstruction processing time in the FBTS method is required to be greatly reduced.

In this paper, we investigate the reduction of the computation time of the FBTS method by introducing parallel processing of the method. In the FBTS method, it is necessary that the same number of direct and adjoint scattering problems as that of transmitter points are calculated in order to obtain the gradient vector which is related to the update of the estimation for electrical parameters [1–4]. We construct a cluster of 8 personal computers and implement a parallel algorithm for FBTS method using Message Passing Interface (MPI) library. Since the calculation of direct and adjoint problems is conducted simultaneously by several computers, parallel FBTS algorithm is expected to reduce the computation time. The experiment to acquire the measured data of a wooden hollow cylinder by circular array antenna in cross sectional slices is carried out, and 3-D reconstruction of the target is examined by proposed parallel FBTS method. In the following sections, the FBTS algorithm, parallel method and reconstruction results are shown.

## 2. FBTS ALGORITHM

Maxwell's equations in the matrix form is given by

$$L\mathbf{v} = \mathbf{J} \tag{1}$$

where

$$\begin{aligned} \mathbf{v} &= [E_x(\mathbf{r},t)\ E_y(\mathbf{r},t)\ E_z(\mathbf{r},t)\ \eta H_x(\mathbf{r},t)\ \eta H_y(\mathbf{r},t)\ \eta H_z(\mathbf{r},t)]^T, \\ \mathbf{J} &= [\eta J_x(\mathbf{r},t)\ \eta J_y(\mathbf{r},t)\ \eta J_z(\mathbf{r},t)\ 0\ 0\ 0]^T. \end{aligned} \tag{2}$$

The differential operator $L$ is defined as

$$L = \bar{A}\frac{\partial}{\partial x} + \bar{B}\frac{\partial}{\partial y} + \bar{C}\frac{\partial}{\partial z} - \bar{F}\frac{\partial}{\partial (ct)} - \bar{G} \tag{3}$$

where $\bar{A}$, $\bar{B}$ and $\bar{C}$ are constant matrices, $\bar{F}$ and $\bar{G}$ are matrices consisting of the tensor permittivity and tensor electric conductivity (These parameters are introduced in reference [8]). $c$ and $\eta$ are the