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**Electronics
Electrical Power
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ELECTRONIC ENGINEERING

Time Reversal Electromagnetic Simulation Using FDTD with MATLAB

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Abstract— The Finite Difference Time Domain method (FDTD) uses centre-difference representations of the continuous partial differential equations to create iterative numerical models of wave propagation. Initially developed for electromagnetic problems the technique has potential application in acoustic prediction. In this paper the time reversal electromagnetic simulation has been discussed. That work is based on the sensor management for a room. The reversal time for sensor from the different source of transmission could be viewed on the MATLAB command window. This research aims to develop the signal processing of the sensor management within 3 meters around signal source.

Keywords— Time Reversal Mirror, Electromagnetic, FDTD, Simulation, MATLAB

I. INTRODUCTION

The acoustic application of the technique considers wave propagation in a medium using the equations for change of acoustic particle velocity w and pressure p with respect to time.

$$\frac{\partial w}{\partial t} = -\frac{1}{\rho} \nabla p \quad (1)$$

$$\frac{\partial p}{\partial t} = -K \nabla \cdot w \quad (2)$$

Where ρ is the medium density and K is the medium bulk modulus.

Gradient operator

$$\nabla f = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \right)$$

Divergence operator

$$\nabla \cdot f = \frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} + \frac{\partial f_z}{\partial z}$$

By writing these equations as 1D centre differences we can show

$$w_{x_i+\frac{1}{2}}^{n+\frac{1}{2}} = w_{x_i+\frac{1}{2}}^{n-\frac{1}{2}} - \frac{\partial t}{\rho \partial x} \{p_{i+1}^n - p_i^n\} \quad (3)$$

$$p_i^{n+1} = p_i^n - K \partial t \left\{ \frac{w_{x_i+\frac{1}{2}}^{n+\frac{1}{2}} - w_{x_i-\frac{1}{2}}^{n+\frac{1}{2}}}{\partial x} \right\} \quad (4)$$

Where i is a spatial index n is a temporal index.

II. IMPLEMENTING PERFECTLY MATCHED LAYERS

When a wave reaches the ends of the waveguide it is reflected back into the medium. This is a problem for most simulations that can be solved with the implementation of perfectly match layers (PMLs). Originally developed by Berenger [5], the technique specifies a new region that surrounds the FDTD domain where a set of non physical equations are applied giving a high attenuation. For our 1D case the equations are

$$\frac{\partial w_x}{\partial t} + K \alpha w_x = -\frac{1}{\rho} \frac{\partial p}{\partial x} \quad (5)$$

$$\frac{\partial p}{\partial t} + K \alpha p = -K \frac{\partial w_x}{\partial x} \quad (6)$$

Where α is the attenuation coefficient.

Equations (5) and (6) give the solution

$$w_x = \psi \quad p = z \psi \quad \psi = e^{-i\left(\frac{\omega}{c} x w\right)} e^{-z \alpha a w} \quad (7)$$

Clearly by setting attenuation factor $\alpha = 0$ we get back to the original FDTD equations (1) and (2) hence it can be shown that the wave speed is the same for medium and PML region as is the impedance

$$Z_{PML} = \frac{|p|}{|w_x|} = Z_{Medium} \quad (8)$$

Berenger hence showed that the PML boundary is theoretically reflection less, though in practice one has to give the PML boundary a width of say 10 elements and gradually introduce the absorption.

To implement in 1D our update equation (5) for the PML can be given using exponential differencing

