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MICROWAVE IMAGING USING FDTD BASED TECHNOLOGY FOR BURIED TARGET

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***Abstract:* The finite-differences time domain (FDTD) method is used most widely in computational methods of electromagnetic. In this paper FDTD method is applied on to determine the location and presence of the buried target in a dielectric medium.**

***Keywords:* Finite difference time domain (FDTD) method, Nondestructive Evaluation (NDE), and microwave imaging.**

I. INTRODUCTION

Many concrete structures fail to achieve their expected life due to their structural deficiency. So it is necessary required to determine their actual life time by analyzing different aspects that are visible to as well as non-visible to us. The structural deficiency that is visible to us by naked eyes is right but to determine the non-visible deficiency then we use many applications like X-ray, microwave imaging etc. X-ray mammography presents a few concerns such as high positive and negative rates [1] leading to increased healthcare cost of undergoing unnecessary medical procedures. Microwave imaging systems exists under different types of technologies and these technologies are found in the medical imaging systems. There are already several papers discussing the use of microwave imaging via the analysis of dielectric properties of tissues using different techniques [2][3]. Among all microwave imaging is one of the best techniques that is used because of its no adverse effects as well as it provides best results in varying dielectric medium under time domain. Microwave used to face the issue of expensive hardware and insufficient computing power, but now the technologies have advanced, indicating a brighter future for microwave systems, especially with the knowledge of the interaction of electromagnetic waves between human body tissues and their dielectric properties [4][5].

II. METHODOLOGY

The finite difference time domain (FDTD) method is arguably the simplest, both conceptually and in terms of implementation, of the full-wave techniques used to solve problems in electromagnetic [6]. The FDTD technique is used in solving electromagnetic scattering problem, because it can model an inhomogeneous object of arbitrary shape [7]. This is a technique which is used for solving Maxwell's equations. In this FDTD rectangular grid is formed and each cubic unit is known as Yee unit cell. The electric field is defined at edge centers and magnetic field at face center of a cube. Each cell edge contains different materials property. If we assume same material property throughout the mesh then our computation time will be very fast and vice-versa.

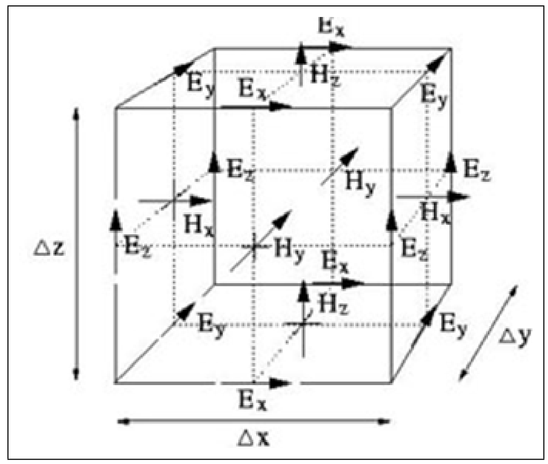

Figure 1: Yee Cell

FDTD algorithm solves Maxwell's curl equations with the help of central finite differences in both space and time. FDTD method is a time step process. In this calculation of magnetic and electric field at each time step is done and alike fields are propagated in the whole mesh.

Maxwell's differential form equations are given as :

$$(\nabla \times E) + \frac{\partial B}{\partial t} = 0 \quad (1)$$

$$(\nabla \times H) - \left(\frac{\partial D}{\partial t} + J\right) = 0 \quad (2)$$

By using central finite difference in Maxwell's curl equations assume that at coordinates (x, y, z, t) is an Hx node,

$$\frac{H_x^{n+\frac{1}{2}}(i, j+1/2, k+1/2) - H_x^{n+\frac{1}{2}}(i, j+1/2, k+1/2)}{\Delta t}$$

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$$= \frac{1}{\mu_0\mu_r(i,j+1/2,k+1/2)}\left[\frac{E_y^n(i,j+1/2,k+1)}{\Delta z}\right]$$

$$- \frac{1}{\mu_0\mu_r(i,j+1/2,k+1/2)}\left[\frac{E_y^n(i,j+1/2,k+1)}{\Delta z}\right]$$

$$- \frac{1}{\mu_0\mu_r(i,j+1/2,k+1/2)}\left[\frac{E_z^n(i,j+1,k+1)}{\Delta y}\right]$$

$$- \frac{1}{\mu_0\mu_r(i,j+1/2,k+1/2)}\left[\frac{E_z^n(i,j,k+1/2)}{\Delta z}\right] \tag{3}$$

Similar way is used to find out the equations for Hy and Hz field. In the same way Ex field is find out.

$$\frac{E_x^n(i+1/2,j,k) - E_x^n(i+1/2,j,k)}{\Delta t}$$

$$= \frac{1}{\varepsilon_0\varepsilon_r(i+1/2,j,k)}\left[\frac{H_z^{n+\frac{1}{2}}(i+1/2,j+1/2,k)}{\Delta y}\right]$$

$$- \frac{1}{\varepsilon_0\varepsilon_r(i+1/2,j,k)}\left[\frac{H_z^{n+\frac{1}{2}}(i,j-1/2,k)}{\Delta y}\right]$$

$$- \frac{1}{\varepsilon_0\varepsilon_r(i+1/2,j,k)}\left[\frac{H_y^{n+\frac{1}{2}}(i+1/2,j,k+1/2)}{\Delta z}\right]$$

$$- \frac{1}{\varepsilon_0\varepsilon_r(i+1/2,j,k)}\left[\frac{H_y^{n+\frac{1}{2}}(i+1/2,j,k-1/2)}{\Delta z}\right]$$

$$-\sigma(1/2,j,k)\frac{E_x^{n+1}(i+1/2,j,k) + E_x^n(i+1/2,j,k)}{2} \tag{4}$$

These calculated values of both E and H fields most probable contains non integer values so for computer implementation these values are approximated to the nearest values. The field update equations are given as by equation 5 and 6 :

After getting all the equations for the E and H field the FDTD algorithm is derived. These whole equations are written in the MATLAB code and H and E field algorithms, problem space, geometry of structure, boundary conditions all are also defined in it.

$$E_x^n(i,j,k) = \frac{2\varepsilon - \sigma\Delta t}{2\varepsilon + \sigma\Delta t}E_x^{n-1}(i,j,k)$$

$$-\frac{2\Delta t}{(2\varepsilon+\sigma\Delta t)\Delta z}[\, H_y^{n+\frac{1}{2}}(i, j, k) - H_y^{n+\frac{1}{2}}(i,j,k-1)]$$

$$-\frac{2\Delta t}{(2\varepsilon+\sigma\Delta t)\Delta y}[\, H_z^{n+\frac{1}{2}}(i, j, k) - H_y^{n+\frac{1}{2}}(i,j,k-1)] \tag{5}$$

$$H_y^{n+\frac{1}{2}}(i,j,k) = H_x^{n-\frac{1}{2}}(i,j,k)$$

$$+\frac{\Delta t}{\mu\Delta z}[\, E_y^n(i, j, k+1) - E_y^n(i,j,k)]$$

$$-\frac{\Delta t}{\mu\Delta y}[\, E_z^n(i, j+1, k) - E_z^n(i,j,k)] \tag{6}$$

III. Problem Design

An electromagnetic wave source interacting with highly reflecting copper target whose relative permittivity (ε_r) is 5.7e^7 and conductivity (σ) is 1e^6 S/m which are placed inside the oil whose relative permittivity (ε_r) is 5 and conductivity (σ) is 0.010 S/m . The numbers of targets are varied and scattering of waves are measured. The grid size is of 256 points by 256 points. A plane wave is x-directed with y-polarization and of frequency 2.45 GHz is used.

IV. Results and Conclusions

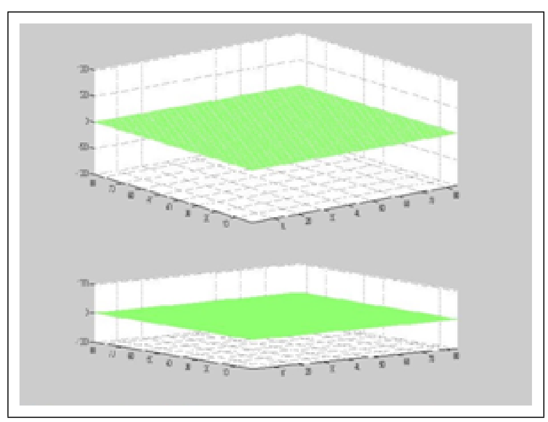

Figure 2: When wave propagates in medium without target

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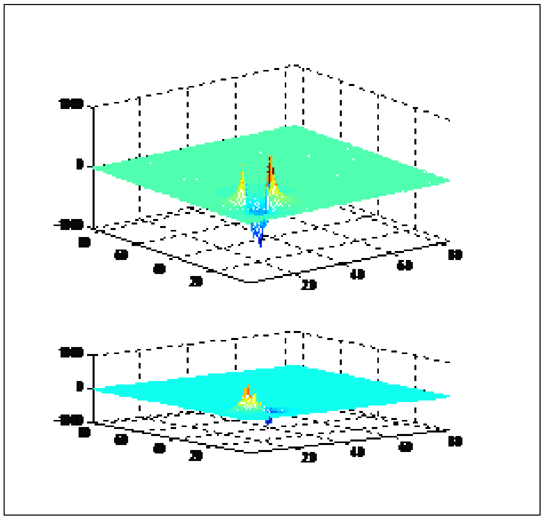

Figure 3: When wave incident on targets

The FDTD simulation is performed and wave propagation, scattering and reflection is observed. Ey field variation is used for identification of the target. When the plane wave is propagating in the free space no scattering is observed. Copper targets are embedded in it approximately at 35th to 40th cell location then the results are shown in figure 3.

The results show the reflection of the plane wave when it interacting with highly reflecting material. The presence of copper targets as well as their locations is determined in the pseudo color plots. The size of the target detected match with the assumed size. Target was considered spherical and the minimum size which is identified was 4mm. This algorithm can be extended for different types of incident waves.

References

[1] E. C. Fear, P. M. Meaney, and M. A. Stuchly. Microwaves for brest cancer detection. *IEEE Potentials*, 22(1), 2003.

[2] S. Semenove. Microwave tomography : Review of the progress towards clinical applications. *Philosophical Transactions of the Royal Society*, pages 3021–3042, 2009.

[3] Hassan, A, and El-Shenawee M. Review of Electromagnetic Techniques for Breast Cancer Detection, Biomedical Engineering. *IEEE*, (99):1.

[4] Polk C. and Postow E. Handbook of biological effects of electromagnetic fields, 2nd edition. *Newyork, NY: CRC Press*.

[5] Gabriel, S., Lau, and R.W.,Gabriel. The dielectric properties of biological tissues. *Physics in Medicine and Biology*, pages 2251–2269.

[6] John B. Schneider. Understanding the Finite-Difference Time-Domain Method.

[7] S. C. Hagness, A. T. Taflove, and J. E. Bridges. Two dimension FDTD Analysis of a Pulsed Microwave Confocal System for Breast Cancer Detection: Fixed-Focus and Antenna-Array Sensors. *IEEE Transactions on Biomedical Engineering*, 45, 1998.

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