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Simulation Of Reflected Terahertz Radiation With Perfect Matching Layer Using 2d-Fdtd Method

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Abstract
The finite-difference time-domain (FDTD) method is one of the computational methods in electromagnetic which is most widely used. This work will study the simulation of terahertz radiation using one and two Finite Difference Time Domain method. The time evolution behavior of electromagnetic radiation with high frequency will solve using Maxwell's equation in time domain and perfect matching layer boundary condition also used.The basic idea is this that the amount of reflected waves are dictated by the intrinsic impedance of the two medium. Numerical technique software program will be used.
Keywords *-Finite difference time domain (FDTD) method, perfectly matched layer (PML), simulation terahertz frequency*

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I. Introduction

Electromagnetic waves with frequencies between 0.1 to 10 THz is called Terahertz radiation [1],locate itself between the traditional research regimes of electronics and photonics in the electromagnetic spectrum, microwave and infrared to be more specifically. Another primary advantage of terahertz wave is that many common materials and living tissues are transparent or semi-transparent to light in this range [2]. Terahertz radiation can penetrate through some non-conducting materials, like cloth, paper, wood, plastic and ceramics, which may otherwise be opaque for radiation at other frequencies. Moreover, many subjects feature characteristic absorption lines, therefore making it possible to do identification by observing the Terahertz fingerprint. Numerical modeling of highly sensitive resonant detection of THz radiation using a multichannel dispersiveplasmonic has been studied[3,4]. Daneshmandian et al evaluated the effect of dispersion on the phase and attenuation constants, also the proposed dispersive full-wave model is applied to a lossy metallic grating, which can be used in a THz detector have been studied.[5]. some paper work the develop of perfect maching layer method for Neumann Laplacians on manifolds with axial analytic quasicylindrical ends and prove stability andexponential convergence of the method[6]. A Numerical modeling of highly sensitive resonant detection of THz radiation using a multichannel dispersive plasmonic has been studied by F. Daneshmandian et al, many research using tetaherts radiation frequency in Terahertz detector with integrated broadband bow-tie antenna becuase Many emerging applications in the terahertz (THz) frequency range demand highly sensitive, broadband detectors for room-temperature operation. Field-effect transistors with integrated antennas for THz detection [7-9]. The resonant detection of terahertz radiation has been evaluated by Daneshmandian et al , the authers using a dispersive multichannel high-electron-mobility transistor and then he is analyzed and modeled to find many figures indicate the high electron mobility.

II. Theory and Model

The amount of reflection waves when it stick another medium is depend on the impedance of two medium. The efficient of absorption boundary condition the perfect matched layer has been studied in this work. The impedance is given by the equation

$\eta = \sqrt{\frac{\mu}{\varepsilon}}$, where it is a relation between permeability and permittivity. And $D = \varepsilon_r(\omega)E(\omega)$ is the electric flux density We consider that the permeability is constant. Also, if μ is change with ε , then η remained constant. However, The normalized Maxell's equation are

$$\varepsilon\sqrt{\varepsilon_o\mu_o}\,\frac{\partial E}{\partial t} = \nabla x H \qquad (1)$$

$$-\sqrt{\varepsilon_o\mu_o}\,\frac{\partial H}{\partial t} = \nabla x \tilde{E} \qquad (2)$$

Where E and H represent electric and magnetic field respectively, we can reduce

Equation (1) and (2) to

$$\frac{\partial \tilde{D}_z}{\partial t} = c\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \qquad (3),$$

where c is the velocity of light in vacuum and equal $\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$

$$\frac{\partial H_x}{\partial t} = -c\,\frac{\partial E_z}{\partial y} \qquad (4)$$

$$\frac{\partial H_y}{\partial t} = -c\,\frac{\partial E_z}{\partial x} \qquad (5)$$

We are going to the Fourier domain in time, so $\frac{\partial}{\partial t}$ becomes (i ω) and replace $D = \varepsilon_r(\omega)E(\omega)$, the equations above becomes

$$i\,\omega\varepsilon E_z = c\ .\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \qquad (6)$$

and

$$i\,\omega H_x = -c\ \frac{\partial E_z}{\partial y} \qquad (7)$$

$$j\,\omega H_y = c\ \frac{\partial E_z}{\partial x} \qquad (8)$$

We use bogus dielectric constant and permeability's called ε^*_{Bz} , μ^*_{Bx} and μ^*_{By} [ref 5 fdtd book] .To form perfect matching layer that the impedance going from the background medium to the perfect matched layer, it must be constant as

$\eta_o = \eta_k = \sqrt{\frac{\mu^*_{Bx}}{\varepsilon^*_{Bx}}} = 1$, where $\varepsilon^*_{Bx} = 1/\varepsilon^*_{By}$ and $\mu^*_{Bx} = 1/\mu^*_{By}$

Using the relation $\varepsilon^*_{Bk} = \varepsilon_{Bk} + \frac{\sigma\varepsilon E_k}{i\,\omega\varepsilon_o}$ and $\mu^*_{Bk} = \mu_{Bk} + \frac{\sigma\varepsilon E_k}{i\,\omega\varepsilon_o}$,that is $\mu^*_{Bx} = \varepsilon^*_{Bx} = 1$,where k represent x or y

Then,

$$\eta_o = \eta_k = \sqrt{\frac{\mu^*_{Bx}}{\varepsilon^*_{Bx}}} = \sqrt{\frac{1+\sigma(x)/i\,\omega\varepsilon_o}{1+\sigma(x)/i\,\omega\varepsilon_o}} = 1$$

Starting by implementing a PML in X direction, we have

$$i\,\omega\varepsilon E_z .\varepsilon^*_{Bx}(x) = c\ .\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \qquad (9)$$

$$i\,\omega H_x .\mu^*_{Bx}(x) = -c\ \frac{\partial E_z}{\partial y} \qquad (10)$$

$$i\,\omega H_y .\mu^*_{By}(x) = c\ \frac{\partial E_z}{\partial x} \qquad (11)$$

The value of $\mu^*_{Bx} = \varepsilon^*_{Bx} = 1$ leads to the new formula as

$$i\,\omega\left(1+\frac{\sigma\varepsilon E(x)}{i\,\omega\varepsilon_o}\right)\varepsilon E_z = c\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \qquad (12)$$

$$i\,\omega\left(1+\frac{\sigma\varepsilon E(x)}{i\,\omega\varepsilon_o}\right)^{-1} H_x = -c\ \frac{\partial E_z}{\partial y} \qquad (13)$$

$$i\,\omega\left(1+\frac{\sigma\varepsilon E(x)}{i\,\omega\varepsilon_o}\right)\ H_y = -c\ \frac{\partial E_z}{\partial x} \qquad (14)$$

Now, put equations (12,13,14) into the FDTD formula to become as

$$\varepsilon E_z^{n+1/2}(i.j) = \left\{ \frac{1-\sigma_E(i).\Delta t/(2.\varepsilon_o}{1+\sigma_E(i).\Delta t/(2.\varepsilon_o} \right\} .\varepsilon E_z^{n-1/2}(i.j) + \qquad (15)$$

$$+\left\{ \frac{1}{1+\sigma_E(i).\Delta t/(2.\varepsilon_o} \right\} .0.5.\left[H_y^n(i+1/2,j) - H_y^n(i-1/2,j) - H_x^n(i,j+1/2 - H_y^n(i,j-1/2) \right]$$

where $\frac{\Delta t}{\Delta x}c = \frac{\Delta x/(2c)}{\Delta x}c = \frac{1}{2}$

and for magnetic field equation we have

$$H_y^{n+1/2}(i+1/2,j) = \left\{ \frac{1}{1+\sigma_E(i+1/2).\Delta t/(2\varepsilon_o)} \right\} H_y^n(i+1/2,j) + \qquad (16)$$

$$+\left\{ \frac{1-\sigma_E(i+1/2).\Delta t/(2\varepsilon_o)}{1+\sigma_E(i+1/2).\Delta t/(2\varepsilon_o)} \right\} .0.5[E_z^{n+1/2}(i+1,j) - E_z^{n+1/2}(i,j)]$$

III. Results And Discussions:

Using the perfect matching layer (PML) boundaries will absorb reactive fields which may consist of important information such as in the case of input impedance, It work more accurately when placed afew farther away from the scattered. To obtain fine discretization, four cells may be in the near field. The parameter are calculated at i+1/2 because of the position of H_y in the FDTD grid. In this work, we simulated electric and magnetic radiation as Ex, Ez and Hy respectively. Also the figure below shows the electric and magnetic field simulated by 2 D FDTD method. Furthermore, the curve illustrated many figures with 100,200 and 500 time steps which shown in figures below. Figure (1) simulation of 2D electric field (Ex) FDTD with perfect matching layer at frequency 0.3 THz and 100 time steps, the effectiveness of an 8 point PML. In figure (2),the curve represent 200 time steps. Figure (4) the simulation of 2D Electric field (Ez) by FDTD method with perfect matching layer at frequency 0.3 THz and 100 time steps is presented. With the origin off set five cells from center in both X and Y direction. In. Another simulation shown in Figure (5), which simulation Electric field (Ez) by FDTD method with perfect matching layer at frequency 200 time steps in the same frequency.also by contine to plot the electric field in z direction to show how the reflected waves behave when incred the time steps to reach 500 steps as evaluated in figure (6). figure (7,8,9) represent the magnetic field in different time steps with frequency 0.3 THz. In all figures we noticed that the amount of reflected waves are dictated by the impedance of the two medium

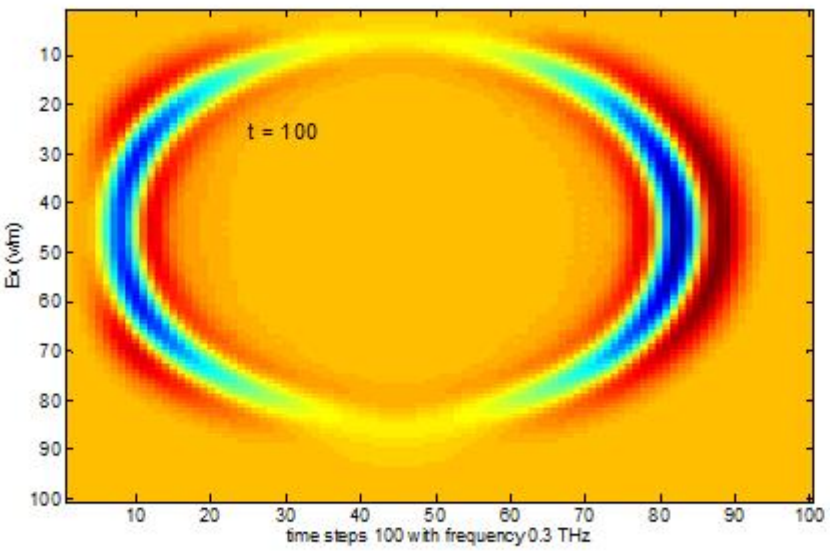

Figure (1) simulation of electric field in x- direction after 100 time steps with frequency 0.3 THz

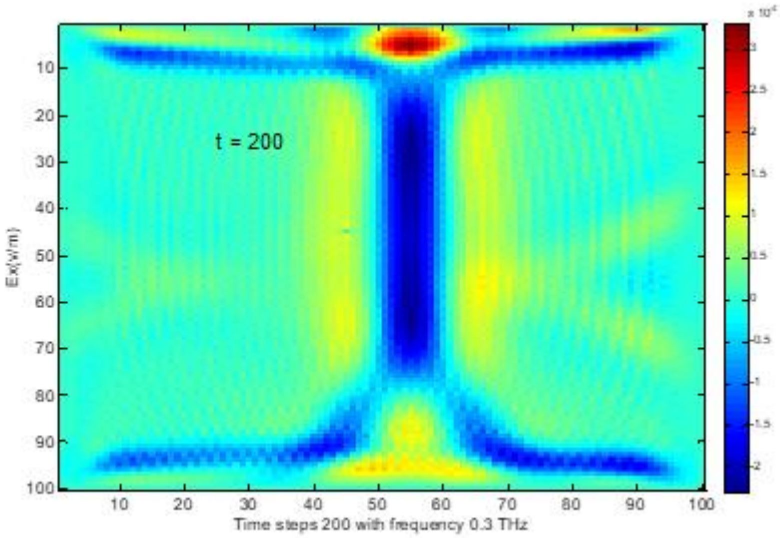

Figure (2) simulation of electric field in x- direction after 200 time steps with frequency 0.3 THz

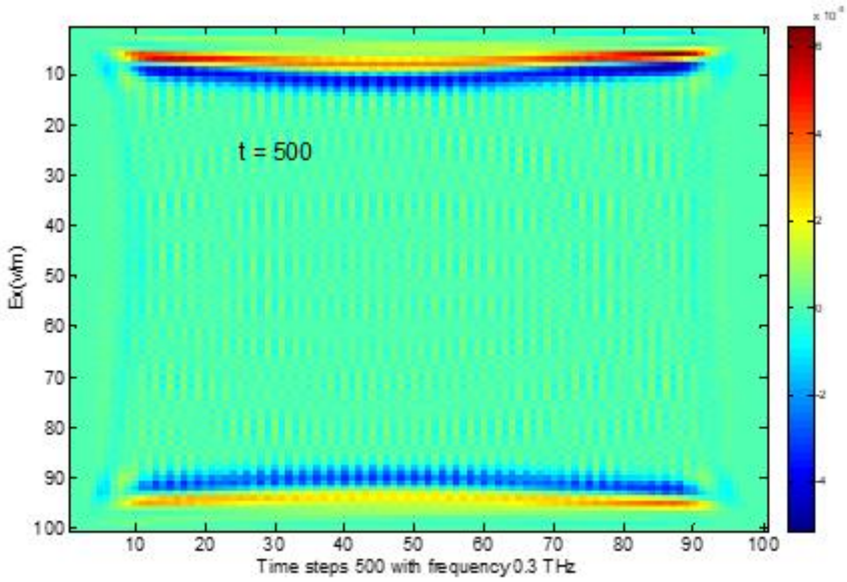

Figure (3) simulation of electric field in x- direction after 500 time steps with frequency 0.3 THz

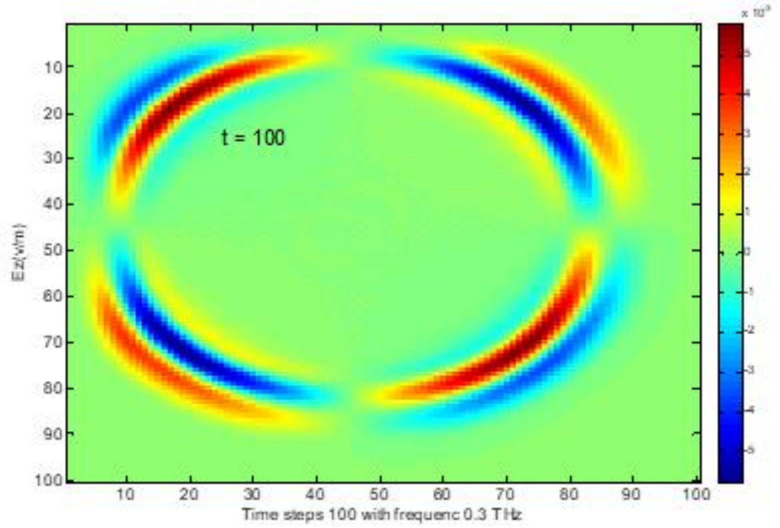

Figure (4) simulation of electric field in z- direction after 100 time steps with frequency 0.3 THz

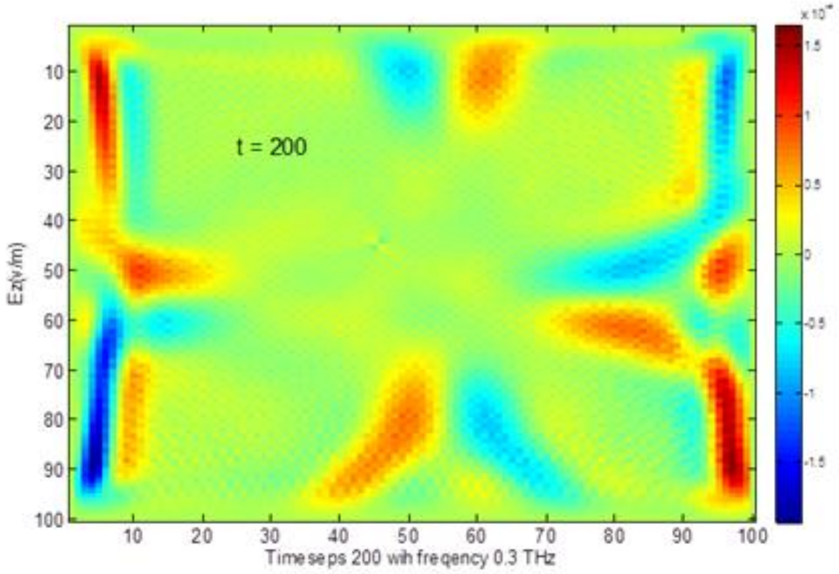

Figure (5) simulation of electric field in z- direction after 200 time steps with frequency 0.3 THz

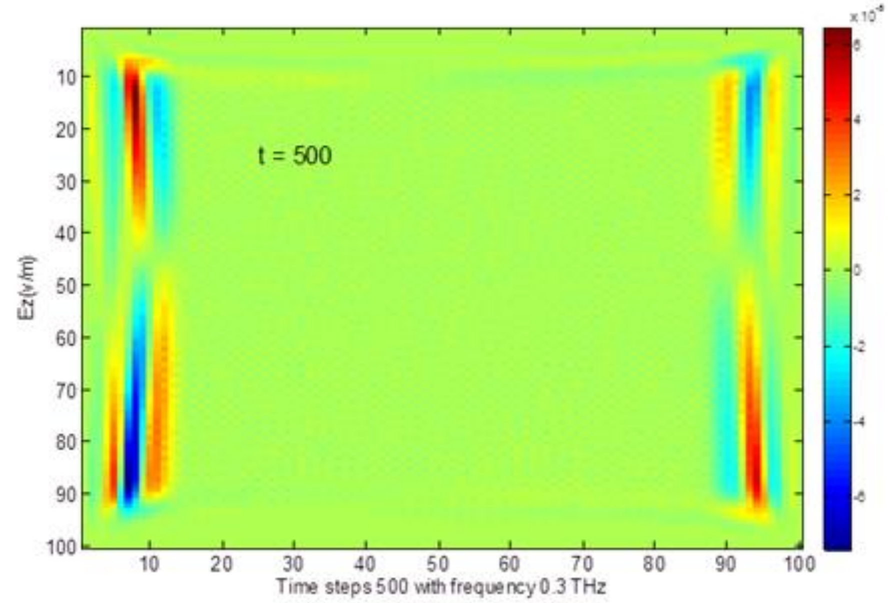

Figure (6) simulation of electric field in z- direction after 500 time steps with frequency 0.3 THz

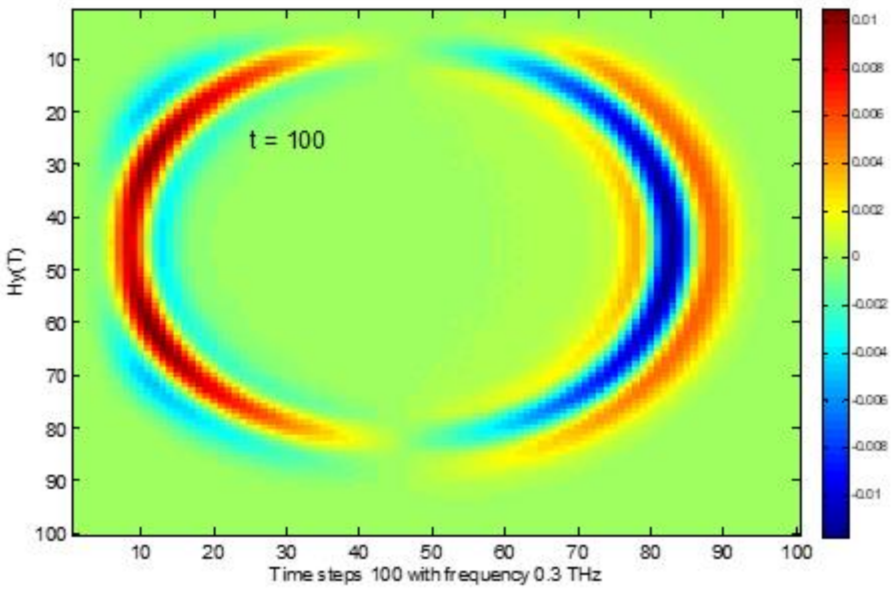

Figure (7) simulation of magnetic field in z- direction after 100 time steps with frequency 0.3 THz

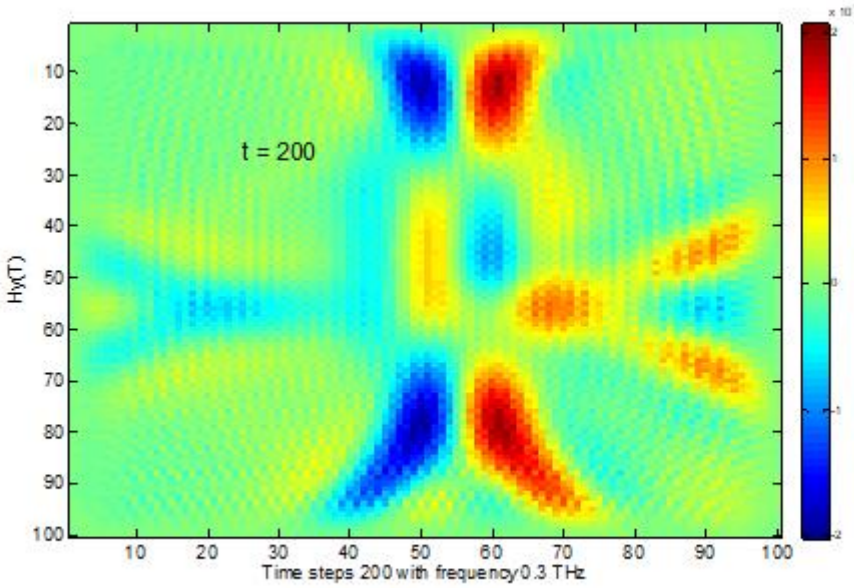

Figure (8) simulation of magnetic field in z- direction after 200 time steps with frequency 0.3 THz

IV. Conclusion

Perfect matching layer PML is exceedingly used and has become the absorbing boundary technique of choice in much of computational electromagnetism. The basic idea in is this paper that the amount of reflected waves are command by the impedance of the two medium . Matlab software programming language are used in this work to simulate the electromagnetic radiation using finite difference time domain method.

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