Calculation of Electromagnetic Waves Interactions with Dielectric and Perfect Electric Conductor (PEC) Obstacles in Computational Domain by Using Finite Difference Time Domain (FDTD) Technique

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Abstract: This research focuses on electromagnetic waves propagation when the incident waves interact with different materials. The finite difference time domain (FDTD) technique is utilized for studying the propagation of the electromagnetic waves when the wave interacted with obstacles such as a dielectric and perfect electric conductor (PEC) inserted in the domain. The electromagnetic problems could be solved by discretizing the differential form of Maxwell's curl equations. The propagations of electromagnetic waves in a dielectric material in a one dimension (1D) demonstrated that the symmetry of distributions appeared when the results compared as the sources assigned to different electric field node. Moreover, we simulated the problems in two dimensions (2D) for calculating the electric and magnetic field components as pixel by pixel in the x-y plane. In this case, two different types of obstacles utilized to compare the results. The results illustrated that the waves totally reflected back into the space and the waves propagated in the opposite direction compared with the incident signal once the PEC inserted. There is no field appeared inside the PEC obstacle whereas utilizing a dielectric obstacle, the fields generated inside a dielectric and everywhere nearby the obstacle. The results compared between the calculations when the dielectric slab and PEC slab placed in the same area. The first simulation showed that part of signal transmitted into next area whereas the second simulation result illustrated that the field reflected, there is no signal appeared and produced in the next area after the slab. The results have explained that the electric and magnetic fields reflected back and updated after the obstacles in the space when dielectric slab in the same area of the PEC slab.

Keywords: Maxwell's curl equations, finite difference time domain (FDTD) technique

Introduction: The finite difference time domain (FDTD) method utilizes for many electromagnetic problems, for the examples electromagnetic scattering and propagations [1]. It is very essential to understand the wave propagation phenomena. This can be done by solving Maxwell's equations to describe the fields. Electromagnetic wave propagation will be studied once discretizing Maxwell's equations in one and two dimensions and an obstacle inserts in a space. The advantage of the simulation of a one-dimensional problem is to investigate the behaviour of the wave when the wave propagates through an obstacle such as a relative permittivity to distinguish among the wave travels in a free space. Moreover, there are many kinds of the obstacles will be utilized in a domain because the obstacles have different electromagnetic properties to do a comparison. For an example, we inserted in the calculation a dielectric to compare with a Perfect electric conductor (PEC). The electromagnetic waves propagate in a space and then the waves hitting the materials. We expected that the patterns would affect due to reflection and diffraction. Therefore, the waves generate with different distributions once including different materials. Many complicated problems in the area of electromagnetic may be very hard to solve analytically that can be treated numerically by solving Maxwell's equations [2]. The method employs to solve problems as the finite difference time domain (FDTD) technique. It is usually utilized to solve a number of issues in different applications of electromagnetic [3]. For examples, the method utilizes to describe the propagation of electromagnetic wave in free space in the area of designing phones [4], designing radio frequency coils and antenna for magnetic resonance imaging [5] as well as the method could be solved the problems in plasma physics [6]. In this work, we will utilize the FDTD technique for studying electromagnetic wave propagation and the waves interact with a dielectric material and a perfect electric conductor (PEC). The interactions of waves with the material can be a source of the reflection, scattering, refraction and diffraction and depend on the kind of materials. Therefore, these phenomes will discuss and display in graphs and images in the results. The behaviour of a wave could understand once solving Maxwell's equations. Utilizing the central finite difference approach to acquire discretizing of Maxwell's forms to write them in a program. Hence, the aim of this research is to study the behaviour of electromagnetic waves when including a dielectric material and perfect electric conductor (PEC) in the calculations to compare with the calculation when there is no any material. For example, the obstacles inserted in the space as a square shape, dielectric slab as well as PEC slab. Moreover, simulating a system as an infinite space requires very large space to simulate a region of interest and the problem can treat by storing huge arrays, which may cause a problem like increasing a simulation time, memory and store huge data. However, an absorbing boundary condition treats this issue to stop any reflections, because the reflection causes a problem on the accuracy. The absorbing boundary can utilize to reach very good an accurate calculation.

The paper is organized as the follows: the part one provides the simulations in a one-dimensional. This study will illustrate the interactions of electromagnetic wave with a dielectric material by utilizing sinusoidal wave. The part two provides the simulations of two dimensions problem by including a relative permittivity and PEC obstacles. This work will explain the difference between two types of materials to compare the wave propagations once the wave interacts with objects.

Method

Solving Maxwell's equations is very important to describe any electromagnetic phenomena such as the interaction of electromagnetic wave with a dielectric material and perfect electric conductor (PEC). In this research, numerous simulations examples can be done numerically as the propagations of the waves in a domain by providing the solutions of the Maxwell's equations numerically [7]:

$$\frac{\partial \mathbf{E}}{\partial t} = \frac{1}{\varepsilon_r \varepsilon_o} \nabla \times \mathbf{H} \quad (1.a)$$

$$\frac{\partial \mathbf{H}}{\partial t} = -\frac{1}{\mu_o} \nabla \times \mathbf{E} \quad (1.b)$$

Where the **E** and H are the electric field component and magnetic field component, respectively. The ε_o and μ_o are the permittivity and the permeability of free space, respectively, and the ε_r is a dielectric constant of medium. Various numerical methods have been developed by researchers for simulating the electromagnetic fields by solving Maxwell's equations such as the finite difference time domain (FDTD) technique since in 1966, Yee was the first researcher suggested and utilized the technique [8] for solving the Maxwell's equations:

$$\frac{\partial E_x}{\partial t} = \frac{1}{\varepsilon_r \varepsilon_o}\left(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z}\right) \quad (2.a)$$

$$\frac{\partial E_y}{\partial t} = \frac{1}{\varepsilon_r \varepsilon_o}\left(\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x}\right) \quad (2.b)$$

$$\frac{\partial E_z}{\partial t} = \frac{1}{\varepsilon_r \varepsilon_o}\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \quad (2.c)$$

$$\frac{\partial H_x}{\partial \mathrm{t}} = -\frac{1}{\mu_o}\left(\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z}\right) \quad (2.d)$$

$$\frac{\partial H_y}{\partial \mathrm{t}} = -\frac{1}{\mu_o}\left(\frac{\partial E_x}{\partial z} - \frac{\partial E_z}{\partial x}\right) \quad (2.e)$$

$$\frac{\partial H_z}{\partial \mathrm{t}} = -\frac{1}{\mu_o}\left(\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y}\right) \quad (2.f)$$

The above equations utilize to find the solutions of Maxwell's equations in three dimensions. However, in this research, we will study a 2D. Therefore, we must write the equations in 2D to simulate the wave propagation in a dielectric in two dimensions. In this case, we need to acquire the updating equations by substituting this condition in the equations (2) [9]:

$$\frac{\partial}{\partial z} = 0,\ E_x = E_y = H_z = 0 \quad (3)$$

Therefore, the transverse magnetic (TM_Z) wave equations provided by:

$$\frac{\partial E_z}{\partial t} = \frac{1}{\varepsilon_r \varepsilon_o}\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \quad (4.a)$$

$$\frac{\partial H_x}{\partial \mathrm{t}} = -\frac{1}{\mu_o}\frac{\partial \mathrm{E_z}}{\partial \mathrm{y}} \quad (4.b)$$

$$\frac{\partial H_y}{\partial t} = \frac{1}{\mu_o}\frac{\partial E_z}{\partial x} \quad (4.c)$$

The 2D problem needs three equations in the calculation to compute the wave propagates in the *x-y* directions.

Two dimensions (2D) FDTD: This section presents the simulation of electromagnetic in 2D. To write any program by utilizing the MATLAB or C-language, the equation (4) must discrete in the space and time to write a program. Consequently, it is necessary to utilize the central finite difference approximation to covert three equations in new forms. The approach provides approximation of Maxwell's derivatives equations in two-dimensional [8]:

$$\frac{\partial F^n(i,j)}{\partial t} = \frac{F^{n+\frac{1}{2}}(i,j) - F^{n-\frac{1}{2}}(i,j)}{\Delta t} \quad (5.a)$$

$$\frac{\partial F^n(i,j)}{\partial x} = \frac{F^n(i+\frac{1}{2},j) - F^n(i-\frac{1}{2},j)}{\delta x} \quad (5.b)$$

By substituting equation (5.a) and equation (5.b) into the equations (4) then new forms as discretizing Maxwell's equations given by [9]:

$$H_x^{n+\frac{1}{2}}(i,j+\tfrac{1}{2}) = H_x^{n-\frac{1}{2}}(i,j+\tfrac{1}{2}) - \frac{\delta t}{\mu_0\,\delta}\left(E_z^n(i,j+1) - E_z^n(i,j)\right) \quad (6.a)$$

$$H_y^{n+\frac{1}{2}}\left(i+\tfrac{1}{2},j\right) = H_y^{n-\frac{1}{2}}\left(i+\tfrac{1}{2},j\right) + \frac{\delta t}{\mu_0\,\delta}\left(E_z^n(i+1,j) - E_z^n(i,j)\right) \quad (6.b)$$

$$E_z\big|_{i,j}^{n+1} = E_z\big|_{i,j}^{n} + \frac{1}{\varepsilon_r \varepsilon_o}\left(\frac{\triangle t}{\delta}\left(H_y\big|_{i+\frac{1}{2},j}^{n+\frac{1}{2}} - H_y\big|_{i-\frac{1}{2},j}^{n+\frac{1}{2}}\right) - \frac{\triangle t}{\delta}\left(H_x\big|_{i,j++\frac{1}{2}}^{n+\frac{1}{2}} - H_x\big|_{i,j-\frac{1}{2}}^{n+\frac{1}{2}}\right)\right) \quad (6.c)$$

Where the n is the time step and $\delta = \delta x = \delta y$ is the space increment. The updating equations (6) can utilize to produce the electric and magnetic fields. The components compute from old time step as described in equation (6) and figure 1. From the above equations can see that the mesh will filled with a free space or a dielectric.

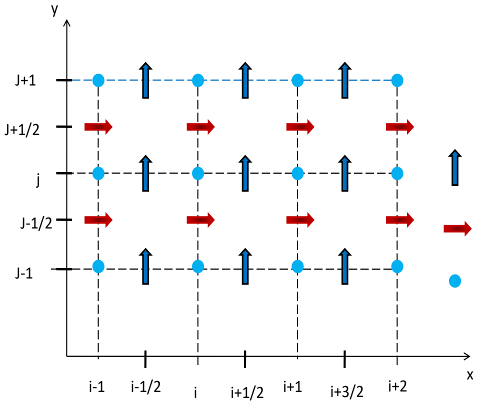

Figure 1: Two dimensions (2D) spatial grid [10].

This section explains how to simulate in two dimensions once utilizing an absorbing boundary condition (ABC) to terminate the mesh and model an open space. There are an advantages to simulate the wave utilize this condition to minimize the reflections as much as possible that come from the first and last electric field nodes on the boundaries. Mur's first-order absorbing boundary condition (ABC) can utilize on the boundaries. For demonstrating this approach, it requires to consider the ABC at x=one [11]:

$$\frac{\partial E(i,j)}{\partial x} - \frac{1}{c}\frac{\partial E(i,j)}{\partial t} = 0, \qquad (7)$$

Utilizing the finite difference approach into the equation (7), the above derivatives equation can convert into new forms by:

$$\frac{\partial E(i,j)}{\partial x} = \frac{1}{2}\left(\frac{E^{n+1}_{(2,j)} - E^{n+1}_{(1,j)}}{\Delta x}\right) + \frac{1}{2}\left(\frac{E^{n}_{(2,j)} - E^{n}_{(1,j)}}{\Delta x}\right) \qquad (8.a)$$

$$\frac{\partial E(i,j)}{\partial t} = \frac{1}{2}\left(\frac{E^{n+1}_{(1,j)} - E^{n}_{(1,j)}}{\Delta t}\right) + \frac{1}{2}\left(\frac{E^{n+1}_{(2,j)} - E^{n}_{(2,j)}}{\Delta t}\right) \qquad (8.b)$$

Substituting the equations (8.a) and (8.b) in equation (7), the ABC is obtained at x=1:

$$E^{n+1}_{(1,j)} = E^{n}_{(2,j)} + \frac{(c\,\delta t - \delta x)}{(c\,\delta t + \delta x)}\left(E^{n+1}_{(2,j)} - E^{n}_{(1,j)}\right) \qquad (9)$$

Where the δx and c are the spatial step and the velocity, respectively. The equation (9) will utilize in 2D and the same procedure can write the other equations to updating the electric nodes on the boundaries shown in figure 2.

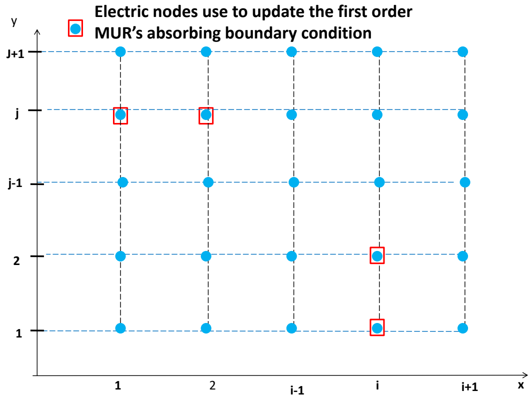

Figure 2: the electric nodes require updating the boundaries in the mesh at n and n+1-time steps.

One dimension (1D) FDTD: This section explains how to simulate a wave travelling in a one dimension (1D). By making reduction to the equations (2), once there are no variations in the y and z directions, the field components in a one dimension (1D) given by [12]:

$$\frac{\partial E_y}{\partial t} = -\frac{1}{\varepsilon_r \varepsilon_o}\left(\frac{\partial H_z}{\partial x}\right) \qquad (10.a)$$

$$\frac{\partial H_z}{\partial t} = -\frac{1}{\mu_o}\frac{\partial E_y}{\partial x} \qquad (10.b)$$

The equation (10) is a transverse electric (TE) wave [12]. From equation (10.a) can note that the temporal derivative of the electric field depend on the spatial derivative of the magnetic field as well as the equation (10.b) the temporal derivative of the magnetic field depend on the spatial derivative of the electric field.

The central finite difference approach requires utilizing to convert the equations (10) into the discretizing forms. Therefore, the equations in a one dimension given by:

$$E_y^{n+1}(i) = E_y^{n}(i) - \frac{1}{\varepsilon_r \varepsilon_o}\frac{\delta t}{\delta}\left(H_z^{n+\frac{1}{2}}(i+1/2) - H_z^{n+\frac{1}{2}}(i-1/2)\right) \qquad (11.a)$$

$$H_z^{n+\frac{1}{2}}(i+1/2) = H_z^{n-\frac{1}{2}}(i+1/2) - \frac{\delta t}{\mu_0\,\delta}\left(E_y^{n}(i+1) - E_y^{n}(i)\right) \qquad (11.b)$$

The equation (11.a) and equation (11.b) utilize if the mesh fills by a free space and dielectric constant. The flow chart illustrates in figure 3 explained how to simulate electromagnetic and how to design a program.

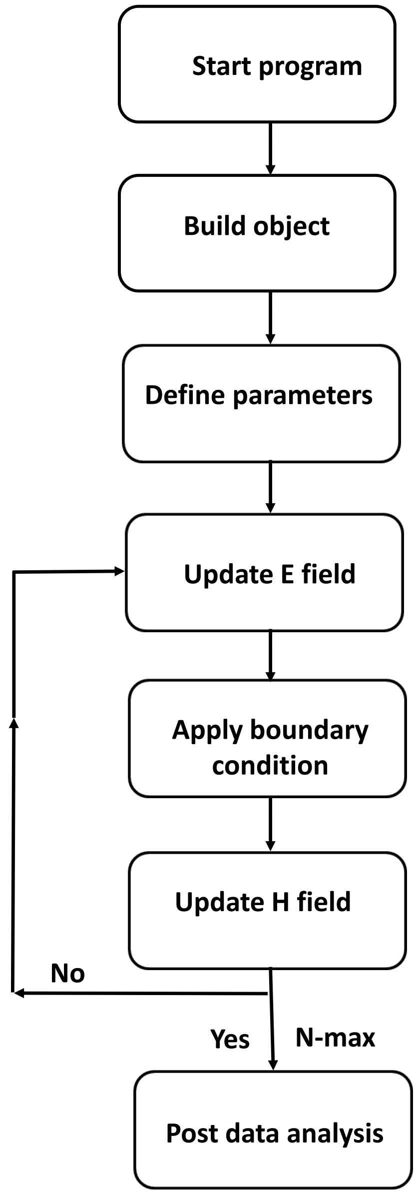

Figure 3: Flow chart illustrates the FDTD method.

Results and Discussion

The results illustrated in this research programmed by utilizing MATLAB. The equation (6) and equation (11) wrote in the programs to simulate electromagnetic in two and one dimensions, respectively as described in the method section and explained how to the FDTD scheme utilizes to simulate the propagation of electromagnetic wave in the 1D and 2D.

Numerical Solutions of one dimension system (1D): In a one-dimensional problem space, the domain contains of 300 points and a mesh filled with a free space as well as a relative permittivity. This acquired by the calculation of the field coefficient in equation (11). The kinds of sources utilize to radiate classified as a hard and soft sources [13 14]. Moreover, to radiate a space by a point source or utilizing the strips made of PECs to generate the signals and control the signals direction between the strips as published in the paper [15]. The domain radiated by a sinusoidal waveform with frequency 1 GHz. The excitation by a hard source assigned to the electric field node and there is a perfect electric conductor (PEC) on the electric node.

As a result, the electric and magnetic components demonstrated in figure 4. It means that the field components produced in the same distributions on the both sides. The purpose of the first simulation in 1-D is that considering the impact of inserting a relative permittivity and radiating by a sinusoidal waveform. To describe the propagation of electromagnetic waves in a space, we compared the results of the calculations at different electric field nodes in the mesh because the source assigned to electric field in different positions. The fields generated inside a dielectric with a relative dielectric constant of two. In this example, the grid consists of 300 points and from i=100 to i=200 filled with a dielectric and the width of a dielectric equals to 100 spatial step. Once the source inserted on the left side of a mesh, the signal travelled through a dielectric on the right side while the other part of the signal propagated on the free space on the left side as illustrated in the figure 4 at snapshot of 500 time steps. However, when exciting from the right side, the signal propagated through a free space on the right side whereas the second part of the signal propagated on the dielectric on the left side as illustrated in the figure 5 at snapshots of 500 time steps. The examples illustrated the result of changing the electric node assigned of the source. As there is an interface between the free space and dielectric on the left side while, there is an interface between a dielectric and free space on the right side of a dielectric. The wavelength has changed as appeared in figure 4 and figure 5. The difference seen as the wavelength appeared smaller inside a dielectric compared with free space. This expected as the wavelength in a dielectric material depends on a relative dielectric constant of the medium. The results have illustrated that the snapshot of the fields depend on the electric field node assigned of source. The source inserted at the first dielectric point to compare with source inserted at the end of dielectric point. The results have illustrated that two identical snapshots produced when the sources assigned on two different electric field nodes.

Numerical Solutions of two dimensions system (2D): In this section, simulating the interactions of electromagnetic waves with obstacles when included in the space two types such as a dialectic material and perfect electric conductor to distinguish among the results. The simulation utilizes to describe the system when the wave travels in the x-y directions as illustrated in the equation (6) that explained in the method section. The mesh contains of 200 Yee's cells in the x-direction and 200 cells in y-direction and the cell size equals to wavelength/14 and the size should be smaller than the wavelength after that the time step (Δt) computed by utilized Courant condition to acquire very good stability then results [15]. A number of sources can utilize to radiate a space as hard and soft sources [13]. In this work, utilizing a hard source and operated at one GHz.

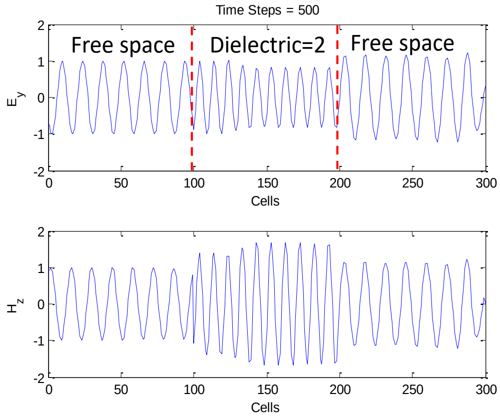

Figure 4: Normalized fields generated by the source of excitation assigned to the electric field node of 100 at the interface among free space and a dielectric. A relative dielectric constant equals of 2 from 100 to 200 points and the other point filled with a free space. The signal is propagating as the first part of it propagated through a dielectric on the right side and the second part is propagating in free space on the left side.

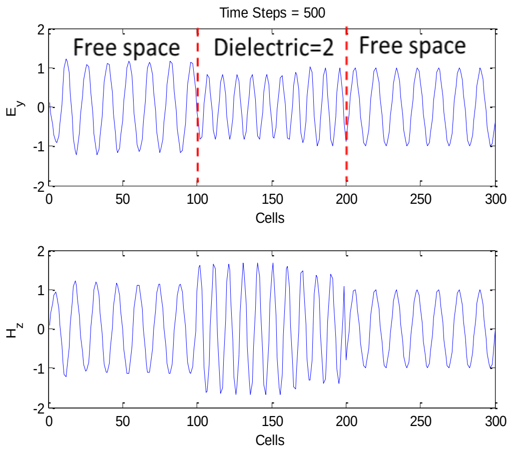

Figure 5: Normalized fields generated. A point source utilized and assigned to the electric field node of 200 at the interface among a dielectric and a free space on the right. The signal is propagating as the first part of it propagated through a dielectric material on the left side and the second part is propagating in free space on the right side.

Moreover, in this work instead of utilizing a very high conductivity for example of a copper, a PEC utilizes as this equivalent to a copper [16]. The obstacles fill by the PEC or dielectric while nearby cells fill as a free space. We studied the distributions of the field components when there is no any material. It means that the incident field updated without facing any reflection, diffraction and refraction. Secondly, simulating by adding, the regular shape as a square filled with a PEC, third simulation is the same size filled with a relative permittivity and the final simulations are included slabs such as PEC and dielectric slab. The simulations radiated by a sinusoidal waveform at one GHz. The sources have inserted away of the slabs, there is a distance between the radiated source and slabs. To acquire a slab as a PEC, the area of this material set the values of electric nodes equal zeros [17] as well as a dielectric slab area filled with a relative permittivity of two. In the case of a dielectric slab, the signal updated in space and it propagated until reached the interface then updating in a slab as pixel-by-pixel inside a dielectric as well as after the slab in space. Therefore, the signal will generated and propagated in the slab then updating everywhere in a mesh. Moreover, to acquire modelling an infinite space, the electric field notes must be truncated at the boundaries. Mur's first-order absorbing boundary condition applied by utilizing the equation (9) in the electric field nodes at the four boundaries. The result in Figure 6 illustrated the circular radiation patterns obtained and very good distributions achieved. It can be classified MUR's boundary into the first order and second order boundaries conditions. MUR's second order boundary applied in the paper [15] while MUR's first order boundary applied in our calculations in this study. The second order boundary condition utilized to terminate the mesh as published in the paper [18], the results indicated that the similar results obtained in our calculations when utilized a small shape and terminated the mesh by MUR's first order boundary. In all the cases, the circular patterns appeared in all the calculations when used the first and second orders boundaries. It can be said that the results agree very well as well as the similar patterns produced when the perfectly matched layers (PML) terminated the grid in the paper [19].

It means that the absorbing boundary conditions (ABCs) worked very well as absorbed the wave at boundaries. This condition treated the region of interest to prevent waves to reflect. Therefore, the ABCs stopped to produce reflection patterns during the calculations. With same manner could write the equations to other boundaries also the similar equation must be utilized in a one dimension.

In the following computations, we have inserted in the calculation obstacles such as a square shape PEC and other one has property of a dielectric material with same size to do a comparison. The square shape size is 10 cells in each side. Comparisons have made among the simulations as illustrated in figure 7 and figure 8. The figure 7 illustrated that the reflections generated front of the PEC compare with a dielectric illustrated in figure 8. The waves have diffracted nearby the boundaries of the obstacles as illustrated clearly, once a PEC placed in a domain. There are no fields updated through a PEC compare with a dielectric shape, the difference is that some of the signal penetrated and the other part will reflect into a problem space in case of a dielectric shape.

Furthermore, the obstacles will disturb the waves once include in a space, comparing the waves propagations in a space as with and without a square shape as shown in figure 6 and figure 7, respectively. The incident fields illustrated in figure 6 compared with the interactions of the wave with a square shape and calculated the total field shown in figure 8. The scattered field computed in figure 9 compared with the total field calculated in figure 8. The next examples showed the calculations when a hard point source inserted away from a dielectric slab as shown in figure 10 compared with double size of a dielectric slab as shown in figure 11 to distinguish among the calculations. More reflection occurred with a double size of the dielectric slab and less transmission of the field after the slab and circular patents affected. The double size calculation illustrated that the incident wave interfere with reflected wave as seen in the front of the slab in figure 11. Furthermore, the waves simulated to propagate between two dielectric slabs as illustrated in figure 12. The propagation of the waves in space until hitting the slab and part of the signal reflected and second part transmitted in the next side through the slabs and between slit. When the electric and magnetic fields generated by inserted the source inside a dielectric, this leads to transmit a maximum energy through a dielectric slab [20] while in our calculation the source inserted away from a dielectric, this will lead to the part of the signal penetrate in a dielectric and other part will reflect back. This proved by simulated the pulse propagated in a dielectric in a one dimension by utilizing a Gaussian pulse as published in the paper [20]. It found that the part of the pulse penetrated through a dielectric while remaining part reflected into opposite direction and transmitted to the end of a dielectric in free space. The similar results obtained in our calculation when a dielectric included in 2D case and the source inserted front of an obstacle. In this work can note that the part of the signal reflected and the other part penetrated in a dielectric until reached at the interface between a dielectric and free space. The fields updated as pixel-by-pixel in a free space on the right side. This was seen once compared the thin slab size with double size. The interference patterns taken place and more clearly observed with a double size slab. Because, the signals reflected when hitting the first side of the slab and then the wave propagated through the dielectric until reached the second face, part of the signal continues to propagate in a space and the second part reflected to the left side. The interference appeared due to the signals travelled twice distance inside a dielectric then the signal reflected at that time the incident signals added with reflected signals.

A dielectric added in the upper region and the same size of the dielectric slab added in lower region as illustrated in figure 13 and figure 14, respectively. The radiated source placed away from the slabs. The results could explain that the distributions have affected in both cases as there is gap filled by air in the middle and there is no any reflections appeared in in the regions of free space only nearby and front of the slabs.

However, the next examples explained that the effect of inserting a PEC slab instead of a dielectric in the same area. The result of the example illustrated that the incident wave totally reflected as illustrated in figure 15. The signals appeared among the left side of the boundary and the front of PEC slab and there are no signals updated in the PEC, this leads to there are no fields appeared after the PEC. This caused interfere the waves and the interference patterns illustrated in the image as the incident waves interferes with reflected waves as illustrated in figure 15. The final example, two PEC slabs added in the lower and upper regions in space as illustrated in figure 16 and figure 17, respectively. The fields changed in two cases and the distributions impact. The distributions of the fields flipped as we flipped the slabs when compared figure 16 with figure 17. More reflections generated in the lower region in the area of PEC and the wave diffracted by the slab and the signals appeared after the slab as shown in figure 16. The similar behaviour seen when the slab placed in the upper area as shown in figure 17. This is due to vary the slab location. Therefore, changing the location of a dielectric slab or PEC, the distributions changed. Comparing one dimension with two dimensions, the signals propagated and penetrated in a dialectic, in the same time in 2D there is penetrations appeared and reflections occurred in front of a dielectric.

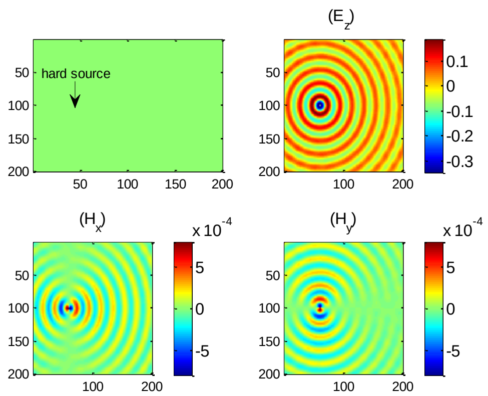

Figure 6: The incident electric (V/m) and magnetic (A/m) generated by a hard source inserted in the left side of a domain. The TM_z wave spreads out uniformly from the source in free space.

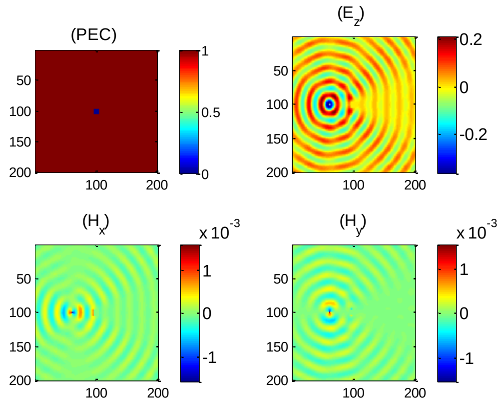

Figure 7: PEC obstacle placed in a space. The waves strike the obstacle and TM_z wave propagated around the obstacle. The electric (V/m) and magnetic (A/m) generated by a hard source inserted in the left side of a space.

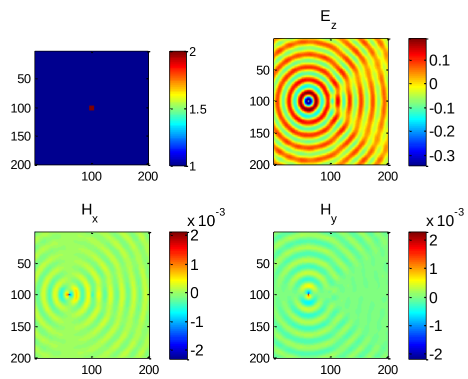

Figure 8: The total fields, the electric (V/m) and magnetic (A/m) generated by a hard source inserted in the left side of a space. A square dielectric obstacle placed in the centre of a domain.

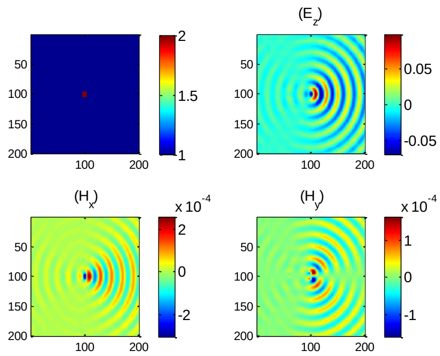

Figure 9: The scattered fields, the electric (V/m) and magnetic (A/m) generated by a hard source inserted in the left side of a space. A small square dielectric obstacle placed in the centre of a domain.

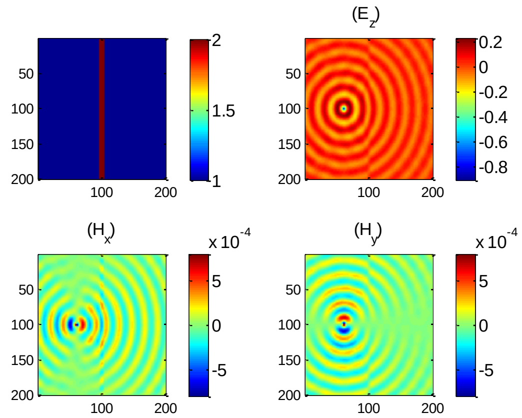

Figure 10: Electromagnetic wave generated and the part of wave transmitted and other part reflected back when hitting the dielectric slab.

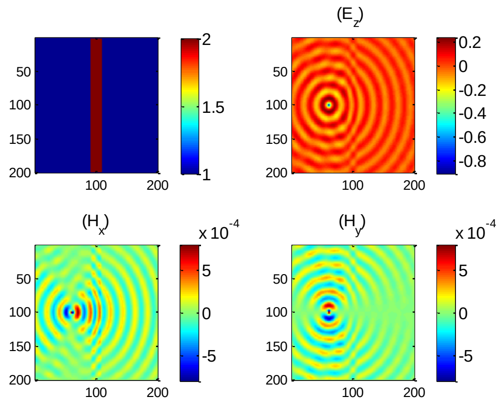

Figure 11: Electromagnetic wave generated and the part of wave transmitted and other part reflected back when hitting the double size dielectric slab.

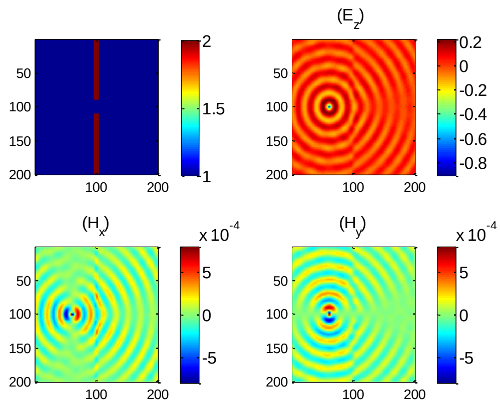

Figure 12: Two dielectric slabs and the distance between the slabs is twenty cells.

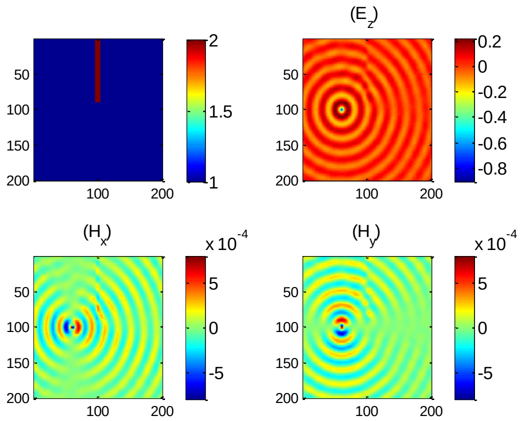

Figure 13: Dielectric slab placed in the y-direction in the upper region.

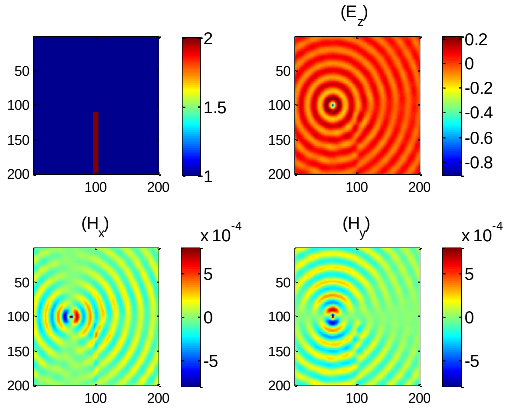

Figure 14: Dielectric slab placed in the y-direction in the lower region.

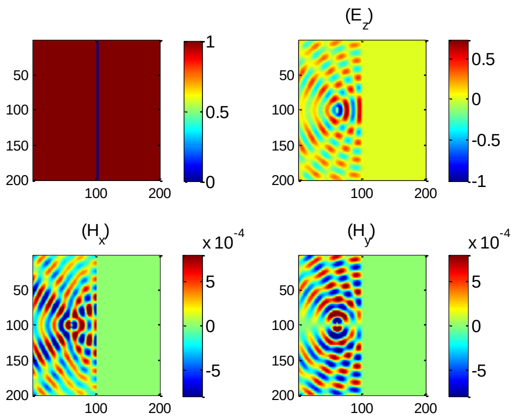

Figure 15: PEC slab and the wave totally reflected back.

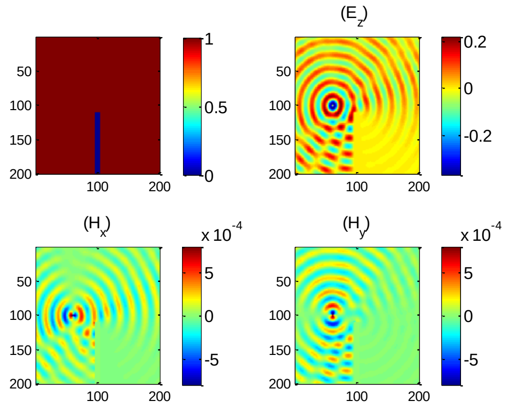

Figure 16: PEC slab in the lower region and the wave reflected back from the PEC and propagated in the upper region.

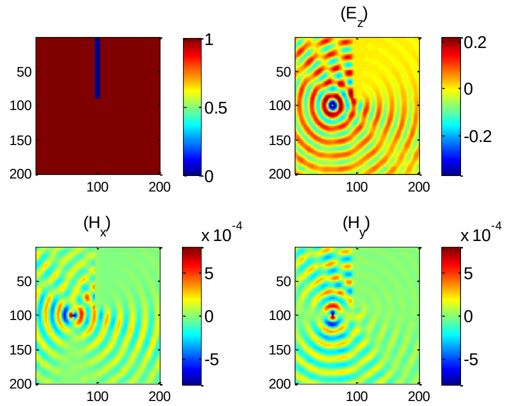

Figure 17: PEC slab in the upper region and the wave reflected back into a space from the PEC and propagated in the lower region.

Conclusion: We have calculated and described the simulations of electromagnetic waves and the numerical results achieved in this research by utilized the concepts of the FDTD technique for solving Maxwell's equations in one and two dimensions to describe the interactions of electromagnetic waves with the obstacles by varying the types of materials. This research illustrated the ABCs when utilized to simulate an infinite space. The results indicated the FDTD method is a very effective to calculate the electric and magnetic fields.

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