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Performance Analysis of Antenna Using Fdtd

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Abstract: *Microstrip patch antennas are widely used because of thin profile, light weight, low cost; conformability to shaped surface and compatibility with integrated circuits. In order to increase the strengths of antenna using time domain method, a micro strip patch antenna is directly treated in the time domain, using modified Finite Difference Time Domain (FDTD) method. The Finite Difference Time Domain (FDTD) method, first introduced by Yee, is a powerful, robust, and popular modelling algorithm based on the direct numerical solution of Maxwell'sequationsin the differential, time domain form. The most important feature of the FDTD method is that broad-band frequency information can be provided in a single pass simulation. It has been extensively used in the parameter extraction of wave guides, micro strip circuits and multiple coupled lines. Broad band characteristics of network parameters such as input impedance, scattering parameters are calculated from time domain simulated data. The Microstrip patch antenna is again simulated using Ansoft High Frequency Structure Simulator (HFSS) software. To reduce the cost, fR4 substrate with permittivity 4.4 is used. The obtained return loss also indicates the antenna has good matching at the output port. The result of the modelling is compared with HFSS simulated results to show effectiveness of this approach.*

I. Introduction

To solve electromagnetic problems, many numerical methods, such as the finite-element method, the method of moments, and the finite-difference time-domain (FDTD), have been developed in both time and frequency domains. To observe transient responses of electromagnetic fields or to obtain a wideband response in a single simulation, time domain numerical methods are preferred to frequency-domain methods. Among them is the FDTD method,[1],[2], which has been popular in computational electromagnetic due to its easy implementation and strong capability of handling complex materials including ones.

In wireless communication the transmission and reception of the signal is through the isotropic antennas. Since this antenna radiates in all direction, this system has a limitation of high power and reduced transmission length [3]. So the transmission in desired direction is required which inspires scientists to develop Directional Antenna (DA). Directional antenna has a characteristic of radiating in one particular direction. Real time application requires transmission of the signals in desired direction without mechanical movement of antenna. Microstrip antennas have several advantages compared to other bulky type of antennas. Some of the main advantages of the microstrip antennas are that it has low fabrication cost, its lightweight, low volume, and low profile configurations that it can be made conformal, it can be easily be mounted on rockets, missiles and satellites without major modifications and arrays of these antennas can simply be produced. In FDTD method to perform time domain simulation of pulse propagation in several microstrip circuits [4]. In addition to this, the frequency dependent scattering parameters and the input impedance of rectangular microstrip patch antenna are also calculated and measured. FDTD method is widely used in the field of electromagnetic due to the direct time domain calculation method, saving storage space and calculation time, simple and easy to understand and can be used to analyze the complex structure.

To perform the electromagnetic simulations in space regions the absorbing boundary condition (ABC) is a key problem with the FDTD technique. One of the most efficient and flexible absorbing boundary conditions is perfectly matched layer (PML) first proposed by Berenger [5]**.** A PML is an artificial absorbing medium that is used to truncate the compute designed to have the property that the interfaces between the PML and the adjacent media are reflection less in the exact wave equation. Now a days the mostly used PML formulations Convolutional PML (CPML). CPML constructs the PML from an anisotropic, dispersive material. CPML does not require the field to be split and can be implemented in a relatively straightforward manner.

Ii. Finite Difference Time Domain (Fdtd) Method

The Finite Difference Time Domain (FDTD) method is a computational electromagnetic method that can be used to simulate any electromagnetic problem. In the FDTD method corresponding scalar Partial Differential Equations (PDE). This is followed by the discretization of space and time domain. Central difference approximations are applied to the scalar Partial Differential Equations (PDE) with respect to the discretized time and space domain. This will result in discrete equations for each field component, which can be used to evaluate these field components. These equations are called update equations or time – stepping equations. The update equation for a particular field component can be defined as the discrete equation that expresses the future value of the same field component using previous value of the same field component and the spatial derivatives of other field components at the present time.

III. Fdtd Solution Of Maxwell's Equation

The FDTD method is concerned with the numerical solution of expressions, Yee(1966) introduced finite differences for these expressions by dividing the space in Cartesian cells. In three dimensions, the nodes have discrete coordinates ($i\Delta x$, $j\Delta y$, $k\Delta z$) and the time is measured in discrete intervals $t = n.\Delta t$, where i, j, k, n are integers. In this scheme any arbitrary vector function *F(r,t)* can be approximated by a discrete value d function *F (i, j,k) n[6]* . For each node, there is a corresponding cell where the *H* and *E* components reside (Figure 1.1). Observe that the electric field components are placed in the middle of the edges and the magnetic field components reside in the centres of the faces. It is worth noticing that the spatial offset gives readily a geometric representation of the integral form of Maxwell's equations .The computational domain is divided in Nx×Ny×Nz cells. Due to thespatial offset, the magneticfield components Hx(i,j+0.5,Nz+0.5), Hx(i,Ny+0.5,k+0.5), Hy(Nx+0.5,j,k+0.5),Hz(Nx+0.5,j+0.5,k), Hz(i+0.5,Ny+0.5,k) and the electric field components Ex(Nx+0.5,j,k),Ez(i,j,Nz+0.5) are not denied.

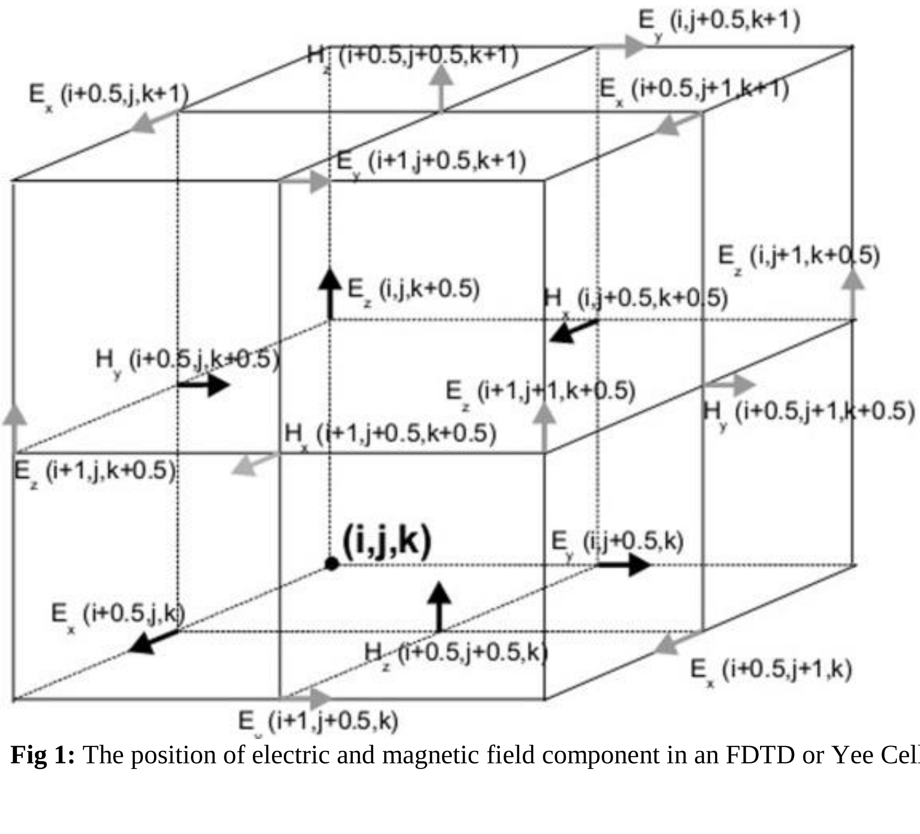

Fig 1: The position of electric and magnetic field component in an FDTD or Yee Cell

IV. Grid Truncation Techniques

Absorbing boundary conditions are applied at the boundary mesh walls of finite difference to compute an unbounded space. A large number of electromagnetic problems have associated open space regions, where the spatial domain is unbounded in one or more directions. The solution of such a problem in this form will require an unlimited amount of computer resources. To avoid this, the domain must be truncated with minimum error. For this, the domain can be divided into two regions: the interior region and the exterior region as shown in Fig 2

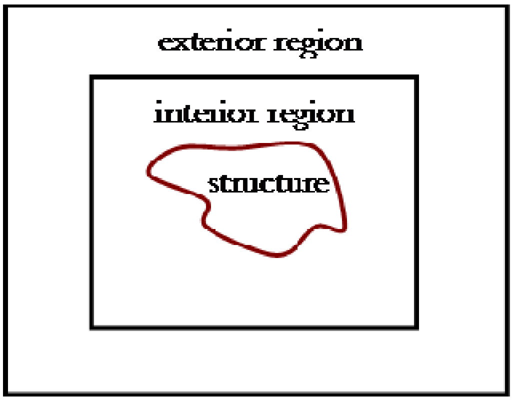

Fig 2: Truncation of the domain by the exterior region in FDTD algorithm

The interior region must be large enough to enclose the structure of interest. The exterior region simulates the infinite space. The FDTD algorithm is applied in the interior region. It simulates wave propagation in the forward and backward directions. However, only the propagation in the interior region is desired with minimum space without reflection from the truncated boundary. These reflections must be suppressed to an acceptable level so that the FDTD solution is valid for all time steps. Two options are available to simulate the open region surrounding the problem space.

1. Terminate the interior region with equivalent currents on the surface of the interior region and use the Green's function to simulate the fields in the exterior region.
2. Simulate the exterior region with absorbing boundary conditions in order to minimize reflections from the truncation of the mesh.

Simulation of the open region with the help of equivalent currents yields a solution whereby the radiation condition is satisfied exactly. But the values of fields on the surface enclosing the interior region are needed, for which CPU time and storage requirement increases rapidly with the surface size. On the other hand, the absorbing boundary concept truncates the computation domain and reduces the computational time and storage space. The absorbing boundary condition (ABC) can be simulated in a number of ways. These are classified as analytical (or differential) ABC and material ABC. The material ABC is realized from the physical absorption of the incident signal by means of a lossy medium, whereas analytical ABC is simulated by approximating the wave equation on the boundary.

V.Antenna Design

The geometry of the proposed rectangular patch antenna is shown in Fig.3. The antenna is designed on FR4 substrate with dielectric constant 4.4. To analyse the antenna correctly space steps Δx, Δy, Δz are used as integral number of nodes to represent antenna parameters exactly. The size of the space cells are Δx=.2375mm Δy=0.175mm and Δz=0.100mm.The total mesh dimensions are 80x120x30 in x, y and z directions. The rectangular patch size is $69\Delta x \times 57\Delta y$ and the length of the microstrip line is $45.7\Delta y$. The stability condition for the FDTD method is given by $\Delta \leq (\lambda min/10)$ and $\Delta t \leq \Delta / c\sqrt{(n)}$ where, $\lambda min = c/fmax$, is the minimum value wavelength supported by the structure being studied and n varies depending on dimension. Here c is the velocity of light in vaccum.

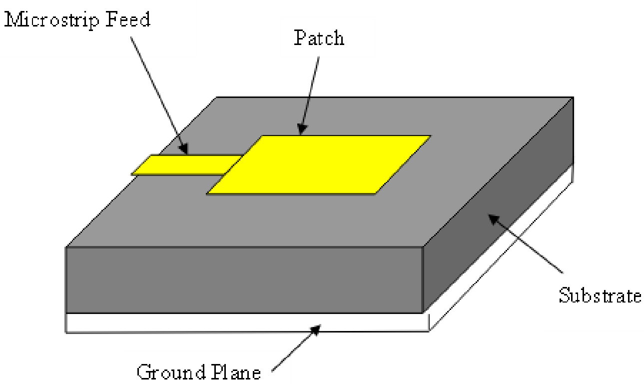

Fig. 3: Proposed geometry of the antenna

Design parameters(mm)	value
Ls	19
Ws	20
Lp Wp	10 16.5
Lf	9
Wf	2.4

Table 1: Dimensions of the microstrip patch antenna

VI. Result

This plot shows the variation of S11 (dB) with respect to frequency. Good matching obtained from 1.5 to 2.8 GHz range of frequencies. It indicates that these frequencies the antenna radiates it's maximum.

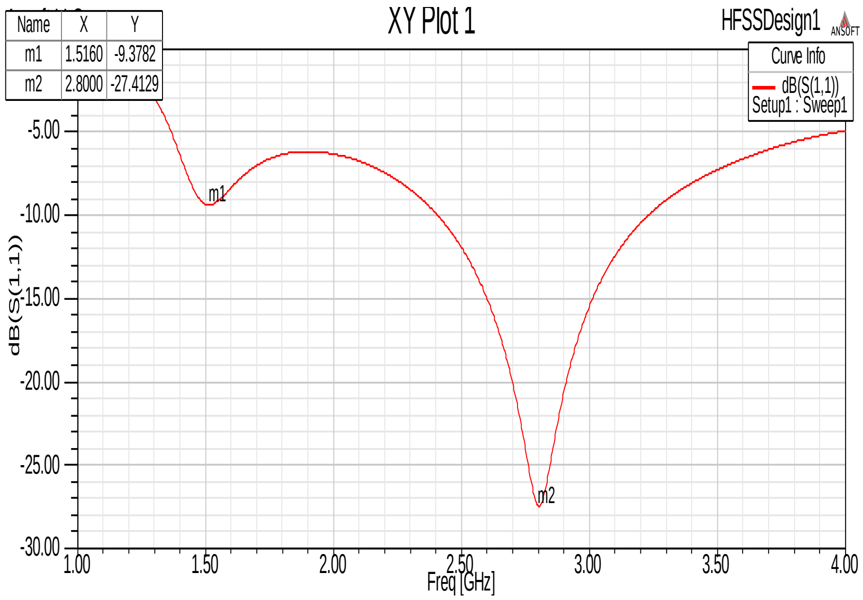

Fig 4: Return loss of the microstrip patch antenna with PML using HFSS

Fig 5 shows the variation of S11(dB) with respect to frequency. This return loss value is obtained with the help of MATLAB fast Fourier transform. From the simulation results the obtained impedance bandwidth determined from -10 dB reflection coefficient of the proposed antenna can operate from 1.5 to 2.8GHz.

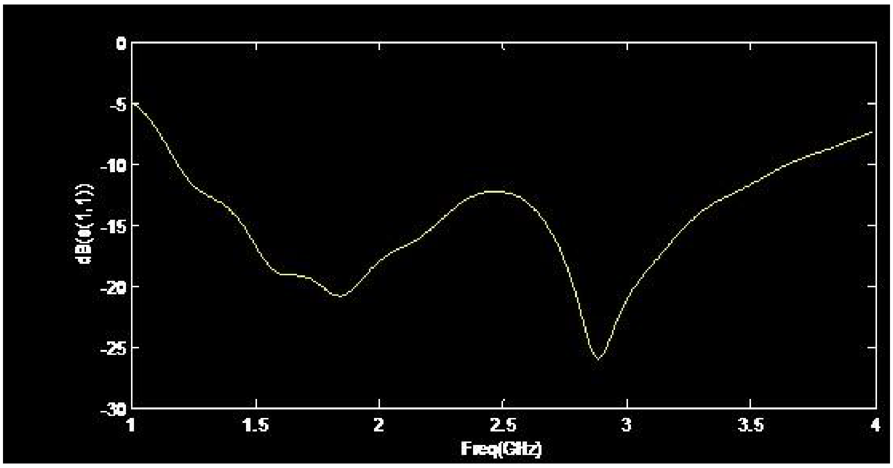

Fig 5: S11 plot of microstrip patch antenna with PML using FDTD

VII. Conclusion

FDTD method aims analysis of a compact rectangular micro strip patch antenna. FDTD is widely used for high frequency analysis. It is widely used in the field of electromagnetic due to direct time domain method, saving storage space and calculation time. The proposed antenna was again simulated on Ansoft HFSS software and a good agreement observed. From the simulation resulst, the obtained impedance bandwidth determined from -10dB reflection coefficient of the antenna can operate from 1.18to 3.5GHZ.

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