FDTD Analysis Of A Rectangular Monopole Antenna For Wireless Application

Debajit Patir, Dipak Kr. Neog

Abstract: A symmetrical slotted rectangular plus shaped patch antenna using a defected ground structure is studied with the 3D-FDTD method. The operating frequency bands of the printed monopole antenna cover the GPS, WiMAX and WLAN applications. The designed antenna is simulated with HFSS-13 and fabricated on FR4 substrate with ε_r =4.4. The dimension of the patch antenna is 38×25×1.6 mm^3. The experimental measurements of the fabricated antenna are taken by using Agilent VNA E8362C at Department of Physics, Tezpur University. It is found that FDTD simulation result along with measured and HFSS simulations are agreed satisfactory.

Index Terms: Finite Difference Time Domain (FDTD), High Frequency System Simulator (HFSS), MATLAB, Microstrip Patch Antenna, GPS, WIMAX, WLAN

1 Introduction

Today wireless communication is growing with tremendous speed which has been increasing influence on our daily life. The developments in wireless networks field, new and innovative applications based on different technology are being developed in the research as well as commercial sectors. The evolution of wireless communication has a deep impact on the field of antenna. Microstrip patch antenna fulfils all requirements of wireless devices with the power to expand systems capability adjusting operating frequency, radiation pattern and polarization [1-2]. Some prominent methods used to analyze microstrip antennas are Transmission Line Model (TLM), Cavity model and full wave models. FDTD, MOM, Finite Element Method (FEM) are prominent full wave models. Among these models primary advantage of FDTD is that it is a time domain method which allows wideband analysis of the antenna design by Gaussian pulse excitation. The antenna characteristics over a wide frequency range are obtained by taking Fourier transform of the FDTD simulation results with the Gaussian pulse [3-5]. Since its first introduction in 1966, the FDTD algorithm is widely used flexible popular tool for solving complex electromagnetic problems. Which basically works with approximating all of the derivatives as a finite difference and the system is incremented by little time steps and the solution efficiency plays itself out in time. FDTD method is used in plethora of electromagnetic problems starting from antennas, microwave complex circuits, electromagnetic compatibility (EMC), electromagnetic scattering to novel materials and nano photonics. The FDTD method solves the Maxwells time dependent curl equations in time domain by convert them into finite difference equations with alternately calculating the electric and magnetic field in an interlaced spatial grid. Many previous investigations are reported for solving antenna problems with this FDTD formulation [4-7].

- *Debajit Patir, PhD Scholar, mail id- debajit.patir@gmail.com*
- *Dr. Dipak Kr. Neog, principal, Dhemaji College, Dibrugarh University*

In this proposed work FDTD method is applied to study and analyze a symmetrical slotted rectangular patch antenna. UPML absorbing boundary conditions (ABC's) were used to terminate the simulation space of the antenna model. The results of this modelling using MATLAB code will be compared to those obtained by HFSS simulation and measured. The proposed antenna consists of rectangular monopole excited by 50Ω microstrip line printed on FR4 substrate with ε_r=4.4 loss tangent 0.025 with height 1.6 mm and area 25×38 mm^2.

2 FDTD Formulation

In FDTD method, Maxwells curl equations are converted to their corresponding scaler partial differential equations (PDE) with central difference approximation followed by discritization of space and time domain. This method was introduced by Yee in 1966. Spatial discretization is achieved by subdividing the computation space in cells called YEE cells. Each cell is marked by indices (i,j,k) and whose space steps Δx, Δy and Δz are depend on the smaller wavelength in the analysis frequency band of the structure under test. In FDTD code the object is first grid up and the size of the grid must be small enough so that the fields are sampled sufficiently to ensure the accuracy. Then the time step is determined such that numerical instabilities are avoided according to the Courant-Stability condition. In Yee cell each magnetic and electric node is surrounded by four alternate electric and magnetic nodes. Therefore centered derivative is used for all spatial derivatives present in the Maxwells equations. The computational space is of two parts one for antenna design and other for PML, where the electric field must be zero which allows the updating of the fields in the calculation algorithm. The width of the Gaussian pulse and the time delay are chosen to suit the frequency bands of interest. The stability condition of FDTD algorithm is

$$\Delta \le \lambda_{\min}/10 \quad \text{and} \quad \Delta t \le \Delta / C_o \sqrt{n}$$

Where λ_{min} is the minimum wavelength corresponding to maximum frequency supported by the structure.

In UPML formulation, the computational space is considered as anisotropic medium and Maxwells curl equations are written as

$$\nabla \times H = j\omega\varepsilon SE$$

$$\nabla \times E = -j\omega\mu SH$$

Where E and H are electric and magnetic fields, S is the diagonal tensor permittivity The reflection coefficient of the computational design is estimated by the following formulae,

$$S_{11}(dB) = 20 \log_{10}\left[E_{ref}(f)/E_{inc}(f)\right]$$

Where $E_{ref}(f)$ denote the reflected wave and $E_{inc}(f)$ is the incident wave.

3 Antenna Design and Configuration

The geometrical view of the proposed microstrip line fed patch antenna is shown in Fig. 1. The proposed antenna is designed using FR4 substrate with height 1.6mm, ε_r=4.4 and loss tangent of 0.025 and the geometrical dimensions of the proposed antenna structure are given in Table 1. Here an optimal method is applied on the patch and ground plane of the antenna structure efficiently by introducing symmetrical slots for achieve better and desired reflection characteristics.

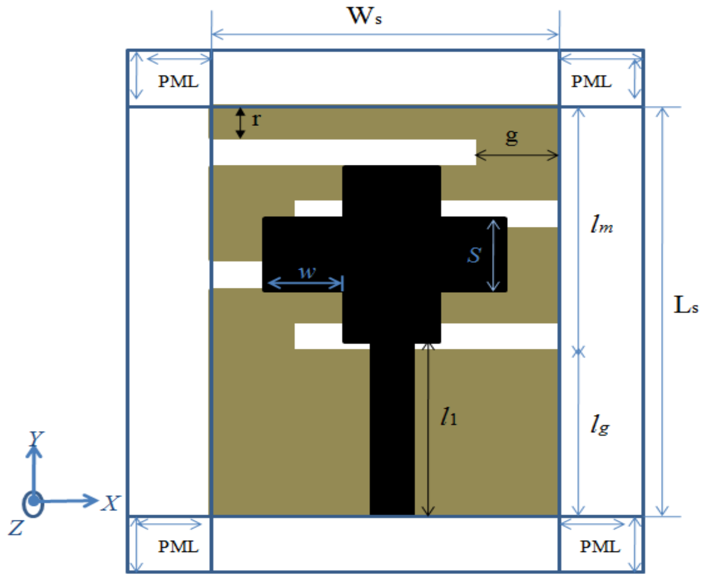

Fig. 1. *Geometrical dimensions of the proposed antenna*

TABLE 1

Geometrical dimensions of the proposed antenna structure .

Dimensions	L_s	W_s	l_1	S	w	l_g	l_m	g	r
(mm)	38	25	12	5	5	14	24	6	3

To analyze the antenna model in FDTD technique, the sizes of the step cells along all directions of the computational domain are taken correctly to represent the dimension of the antenna model. For this antenna model the spatial discretization of the computational domain are taken as Δx= 0.2372mm, Δy= 0.2265 mm and Δz= 0.1000 mm. The total mesh dimension of the space cell of computational space composed of 70×100×30 cells along X, Y and Z axis respectively. The length and breadth of the microstrip line in terms of discretization are 52.9×Δy and 10.2×Δx.

4 Results and Discussion

The simulation with the FDTD technique is run for 7361 iteration steps for this antenna model. The designed antenna was fabricated and Fig 2 shows the photographs of the fabricated antenna. The antenna parameter was measured using Agilent VNA E8362C at Department of Physics, Tezpur University. Time domain result of the E_z components simulation over different time steps in the dielectric substrate of two dimensional plot is shown in figure 3. The final return loss of the proposed antenna found from FDTD simulation along with the HFSS simulation and measured has been plotted for comparison in Fig 4. From this comparison plot it is shown that the simulation results are good agreed with measured one and which validate the design accuracy. For this antenna design resonant frequency is obtained at 1.54GHz, 3.36 GHz and 4.72 GHz. The bandwidth and peak gain are 21%, 83.33%, 83.33% and -3dB, 1.62dB, 2.91dB for this three resonant frequencies respectively. The resonant frequencies obtained for this antenna model is suitable for desired range of GPS, WIMAX and WLAN application.

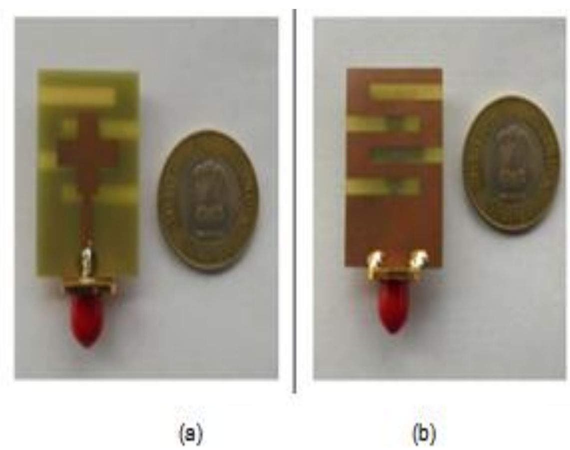

Fig. 2. *Photographs of the fabricated antenna model (a) patch (b) ground plane*

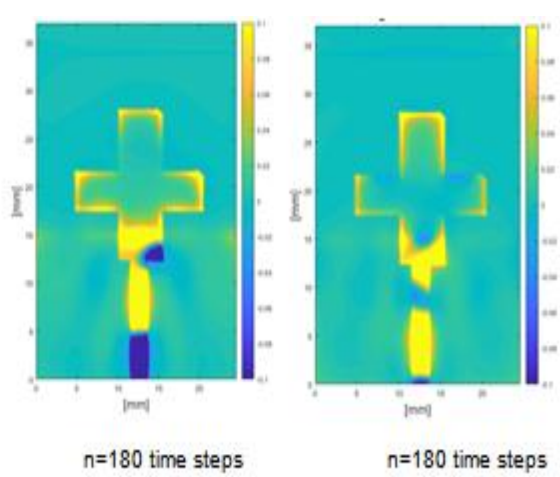

Fig. 3. *Time domain result of the E_z components simulation over*

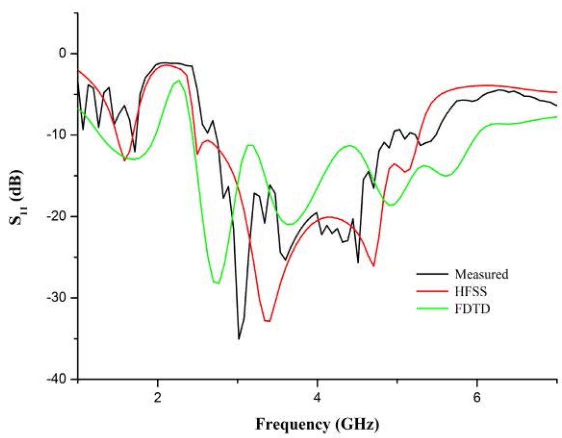

Fig. 4. *Comparison of the return loss results*

5 CONCLUSION

In this paper a compact microstrip line fed plus shaped antenna is analysed using Finite Difference Time Domain (FDTD) technique. Analysing the return loss characteristics it shows that the antenna is a good candidate for GPS, WIMAX and WLAN applications. FDTD simulation result is compared with both the HFSS simulation and measured one and the results are agreed satisfactory. Now a day's modern communication system requires microwave components with high performance with small size and this antenna fulfil all these requirements.

REFERENCES

[1] Yanhua Zheng, "An Analysis on Wireless Communications Technology in Intelligent Home", IEEE-ICEE China, pp. 1-3, May 2011.

[2] Iddi, H. U., M. R. Kamarudin, T. A. Rahman, A. Y. Abdulrahman, M. Khalily, and M. F. Jamlos, "Triple band CPW-fed planar monopole antenna for WLAN/WiMAX applications", Microwave and Optical Technology Letters, Vol. 55, 2209-2214, 2013.

[3] D. M. Sullivan, Electromagnetic Simulation Using the FDTD Method, Second Edition, New York, IEEE Press – John Wiley, 2013.

[4] G. Mur, "Absorbing Boundary Conditions for the Finite Difference Approximation of the Time–Domain Electromagnetic-Field Equations," IEEE Transactions on Electromagnetic compatibility, vol. 23, no. 4, 1981, pp. 377-382.

[5] G. Toroglu and L. Sevgi, "FDTD MATLAB Codes for the First and Second Order Electromagnetic Models", IEEE Antennas Propagation Magazine, vol. 56, no. 2. April 2014, pp. 221-239.

[6] El Hajibi Y. and El Hamichi A., "Simulation and Numerical Modeling of a Rectangular Patch Antenna Using Finite Difference Time Domain (FDTD) Method", Journal of Computer Science and Information Technology, vol. 2, no. 2, June 2014, pp. 01-08.

[7] Stephen D. Gedney, "An isotropic perfectly matched layer absorbing media for truncation of FDTD Lattices", IEEE Transactions on Antennas and Propagation, vol. 44, pp.1630-1639, December 1996.