A rectangular microstrip fed printed triple band monopole antenna for wireless application is presented. The proposed antenna is analysed with the implementation of Uniaxial Perfectly Matched Layer (UPML) boundary condition using 3D-finite difference time domain (FDTD) method. The overall size of the antenna structure is 25x25x1.6 mm$^3$. The study of the proposed structure started with taking a finite open ended 50Ω transmission line of 25 mm in length and 3.5 mm in width designed on a FR4 substrate of dielectric thickness of 4.38. As the radiation efficiency of the transmission line structure is negligibly small, so it is transformed to a radiating element by modifying the structure. In this case a ground plane of 10mm X 25mm is taken below the strip line to resonate the antenna at 3.5 GHz. Asymmetrical slots are placed to enhance the performance and determine the resonant frequency of the antenna for required communication bands. The proposed antenna is resonated at 3.4 GHz, 4.12 GHz and 5.7 GHz covering WLAN, WiMAX and C-band system. The final return loss plot of the proposed antenna found from the FDTD simulation has been plotted with Ansoft HFSS (High Frequency Structure Simulator) result for comparison. The antenna is fabricated and measurements are taken in Department of Physics, Tezpur University, Assam, India. It is found that the measured results are in good agreement with the FDTD and HFSS simulated result.

Keywords: Printed monopole antenna, FDTD, UPML, HFSS.

I. INTRODUCTION

Recent advances in communication engineering have led to the improvement in the performance of compact small antennas, which are essential to meet the requirement
for practical applications. Microstrip antennas have light weight, low profile, conformability to a shaped surface and are compatible with other integrated circuit. Miniaturization and multiband antennas are current topic of interest for many research projects. The present day research also moving towards the development of efficient electromagnetic (EM) simulation technique to design multi band antennas which are significant in wireless local area network (WLAN), wireless interoperability microwave access (WiMAX) and radio frequency identification systems [1]. There is a trade off between number of operating bands and antenna size. The finite-difference time-domain (FDTD) method has become very popular technique for analyzing the performance of broadband, multiband antennas and microstrip devices for the applications of two and three dimensional scattering problems [2-3]. To truncate the unbounded problem space for decaying the unwanted evanescent waves, the selection of effective EM boundary problem is very challenging.

The work proposed in this paper is an application of the FDTD method to the study of an asymmetrically slotted rectangular patch antenna. A boundary condition Uniaxial Perfectly Matched Layer (UPML) is implemented for truncating the analysis of printed monopole antenna. The antenna is able to resonate over three operating frequency bands covering WiMAX band (3.3-3.6 GHz), C band system (3.7-4.2 GHz) and WLAN (5.15-5.825 GHz).

II. FINITE DIFFERENCE TIME DOMAIN FORMULATION

The FDTD is a computational electromagnetic technique that directly solves the Maxwell’s differential curl equations in the time domain using discretized space time grid. The finite difference time domain method was introduced by Yee [4] in 1966 for solving Maxwell’s equations directly in the time domain on a space grid.

Figure 1: Structure and design parameters of the proposed antenna
Kane Yee introduced a set of finite difference equations for Maxwell’s curl equations in the time domain on space grid. Each cell is marked by indices (i, j, k) and whose space steps $\Delta x$, $\Delta y$, $\Delta z$ are depending on the smaller wavelength in the analysis frequency band of the structure under rest. The space steps chosen must be small enough so that the fields are sampled sufficiently to ensure accuracy. In a cell, electric and magnetic field components are in three-dimensional space so that each electric component is surrounded by four circulating magnetic component and each magnetic component is surrounded by four circulating electric component. It is interested to resolving 12 equations concerning field component variation that are evaluated in the following order $Dx, Dy, Dz, Ex, Ey, Ez, Bx, By, Bz, Hx, Hy, Hz$ as in [5-6].

III. ANTENNA DESIGN AND CONFIGURATION

The structure of the proposed microstrip line fed printed monopole antenna is shown in figure 1. The antenna is designed on FR4 substrate with thickness 1.6, relative permittivity 4.38 and loss tangent 0.025. To analyse the antenna space steps $\Delta x, \Delta y, \Delta z$ are used to represent the antenna parameters correctly. The size of space cells of computational domain are $\Delta x = 0.2375 \, \text{mm}, \Delta y = 0.175 \, \text{mm}, \Delta z = 0.100 \, \text{mm}$. The total analysis of the design composed of 106x143x30 space cells in the x, y and z direction respectively. The length of the microstrip feed line is $57.1\Delta y$. The rectangular patch and the feed line of the antenna are considered on the same top side of the substrate. The size of the optimized ground plane placed on the bottom of the substrate is $42.1\Delta x \times 143\Delta y$. The geometric parameters of the proposed antenna are as follows: $L1=14\, \text{mm}, L2=12\, \text{mm}, L3=8\, \text{mm}, W2=0.4\, \text{mm}, W3=0.75\, \text{mm}, S=0.8\, \text{mm}$.

IV. COMPUTER IMPLEMENTATION OF FDTD:

While solving Maxwell’s equations using FDTD, one must be concerned with the accuracy and stability of the algorithm. A well known criterion is the CFL (Courant-Friedrichs-Lewy) condition or Courant condition proposed the stability condition for the algorithm of the FDTD method and $\Delta t$ is chosen to satisfy the CFL stability criterion

$$\Delta t \leq \frac{1}{c \sqrt{\left(\frac{1}{\Delta x^2}\right) + \left(\frac{1}{\Delta y^2}\right) + \left(\frac{1}{\Delta z^2}\right)}}$$

where c is the highest speed of electromagnetic wave in the medium. For uniform time discretization with a sampling step $\Delta t$ and an index that corresponds to the real time $n\Delta t$. In other side component of the electric field and electric flux are calculated for multiple peers of $\Delta t/2$, whereas the components of magnetic and magnetic flux are calculated for odd multiples of $\Delta t/2$. 
A Gaussian pulse is applied to the source and it will provide frequency domain information for dc to the desired cut off frequency by adjusting the width of the pulse [5-6].

The result of this simulation is the frequency dependent parameter i.e. $S_{11}$ is estimated from the temporal data by using the relation [7]

$$S_{11}(f)_{\text{dB}} = 20 \log_{10} \frac{E_{\text{out}}(f)}{E_{\text{in}}(f)}$$

where $E_{\text{in}}(f)$ is the incident wave and $E_{\text{out}}(f)$ is the reflected wave.

The estimation of $S_{11}$ is started with a finite open ended 50Ω microstrip transmission line etched on a substrate of 4.4 and thickness 1.6 mm, which is initially considered as problem space in this study. The length of the microstrip line is 25mm and width is 3.5mm. The reflection studies show that this finite length of the transmission line is not resonating. So this can be used as only for transporting electromagnetic energy from one point to another. This finite open circuited transmission line can be efficiently transformed as a radiating element by modifying the structure and is shown in figure. In this case the full ground plane of a microstrip line is truncated to observe better reflection characteristics. Asymmetrical slot is then introduced to the rectangular patch of dimension ($15\Delta x \times 80\Delta y$) and desired $S_{11}$ value is estimated at the terminal plane.

V. RESULT AND DISCUSSION

The FDTD simulation carried out through proposed design has run for 7361 iteration steps. The two dimensional plot of $E_Z$ component in the dielectric substrate at discrete time steps is shown in figure 2. The proposed antenna has been fabricated and measured. The return loss of the antenna found from the FDTD simulation is compared with the HFSS simulated result. The $S_{11}$ of the fabricated antenna is tested using Agilent Vector Network Analyzer (VNA) E8362C. Both FDTD and HFSS simulated results are in good agreement with the measured result and are shown in figure 3. The optimum bandwidth found for three operating bands are 200MHz (3.26-3.53 GHz), 600MHz (3.78-4.38GHz) and 1630MHz (5.09-6.72GHz). The proposed antenna is resonated in three frequency bands to support the desired range of WLAN, WiMAX and C-band communication systems.

VI. CONCLUSION

In the present investigation, UPML based 3D FDTD technique is used for full wave simulation of a microstrip line fed patch antenna design for WLAN, WiMAX and C-band applications. This approach is successfully implemented to analyze the return loss of the printed monopole antenna with partial ground plane. The FDTD results matched satisfactorily with the Ansoft HFSS simulation results and both simulated results are also compared with the measured result.
**Figure 2.** The time domain result of $E_z$ component simulated over different time steps.

**Figure 3.** Comparison of return loss vs frequency plots obtained from simulated and measured results of the antenna.
REFERENCES


