A MODIFIED GROUND PLANE DUAL BAND COMPACT PLANAR ANTENNA FOR WIMAX APPLICATIONS

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ABSTRACT

This paper presents the design of a small planar antenna with triangular patch for WiMax application. A conventional ground plane has been modified to reduce the size and increasing the bandwidth as well as to cover the WiMax band. The triangular-shaped patch is placed on top of the substrate and parasitic patch is placed at other side. By inserting a triangular patch in the coplanar ground plane, antenna is able to radiate at two resonance frequencies simultaneously. This antenna structure has been designed for covering (3.2–3.7GHz) and (5.2 to 5.8 GHz) WiMax bands. A low dielectric constant substrate with dielectric constant of 3.38 is selected to attain a compact radiating structure that also meets the challenging bandwidth requirement. The proposed antenna is fed by a 50 ohm coplanar wave guide feed. The antenna geometry has small size of 22mm x 21mm x .578mm and able to resonate on the 3.57 GHz and 5.23 GHz frequency with wide impedance bandwidth. This antenna provides the good return loss characteristics and the far field radiation pattern.These results indicates that this antenna have significant potential for WiMax applications. The simulation of designed antenna has been carried out by electromagnetic simulation software EMPIRE XCcel which is based on the powerful Finite Difference Time Domain method (FDTD).

KEYWORDS: *Triangular Patch, compact antenna, dual band antenna, FDTD, Coplanar feed, WiMax application, empire xccel*

I. INTRODUCTION

Communication plays an important role in the world wide society nowadays and the communication systems are rapidly switching frsom wired to wireless. Wireless is a term used to describe telecommunications in which electromagnetic waves carry the signal over part or the entire communication path. These electromagnetic waves are transmitted and received through antenna, so antenna plays very wide role in the communication system [1]. With the rapid expansion of wireless communications there is a growing demand for mobile phones that are small, attractive, lightweight, and compact. This has resulted in the proliferation of handsets with small antennas that are internal or hidden within the device.

In recent years, the fast decrease in size of personal communication devices has lead to the need for more compact antennas. The future technologies also need a very small antenna for miniaturization of compact and light weighted wireless handheld devices. Microstrip antenna is the most admired antenna for the miniaturization. The basic microstrip patch antenna consists of planar dielectric substrate material and a radiating patch on one surface and ground plane on the other surface. The patch is generally made of conducting material such as copper or gold. The radiating patch and the feed lines are usually photo etched on the dielectric substrate [1,3]. The radiating patch can be shaped in any number of geometries depending on the desired electrical and radiation characteristics of the microstrip patch antenna. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable**.** For a compact microstrip patch antenna design, a higher dielectric constant must be used, but it is less efficient and results in narrower bandwidth [2]. The major drawbacks of many low-profile antenna designs are low power handling capacity, Surface wave excitation and their narrow impedance bandwidth [1]. WiMAX has three allocated frequency bands called low band, middle band and high band. The low band has frequency from 2.5 to 2.8 GHz, the middle band has frequency from 3.2 to 3.8 GHz and the high band has 5.2 to 5.8 GHz. Many researchers have studied different structure and different techniques to increase the bandwidth and to have compact size of antenna.

A new reduced size single probe fed microstrip patch antenna with irregular slits has been presented to be used as a receiving antenna for Global Positioning Systems (GPS) integrated with cellular handheld mobile wireless systems. The proposed design is based on the nearly square microstrip patch antenna with two pairs of orthogonal slits cut from the edge. By embedding suitable slots in the radiating patch, compact operation of microstrip antennas can be obtained [4]. Multi layer electromagnetically coupled patch antennas have been studied for wideband applications. In this work the impact of size of parasitic patch on multilayer antennas are also examined [7]. In this work irregular slots and parasitic patches are used for reducing the size and improving the bandwidth of the conventional microstrip antenna. A CPW-fed slot antenna for wideband application was designed and Simulated [5]. In order to examine the performances of this antenna, a prototype was designed at frequency 2.4 GHz and simulated. This work also gives the information regarding variation of width of slot and effect of this on different parameter of antenna. The basic slot antenna fed by CPW, when varying the length of slot, it will affect on bandwidth and return loss. When increases width of slot, the bandwidth is also increasing. Another coplanar waveguide fed compact modified bow-tie slot antenna is proposed for use in the ultra-wideband systems is presented [6]. The modification is made by attaching a pair of meandered slot lines to the upper ends of the small bow-tie slot. With a proper slot line length, the impedance bandwidth of the proposed antenna can be adjusted to cover the entire ultra-wideband and the antenna size remains compact. In general planar slot antennas two parameters affect the impedance bandwidth of the antenna, the slot width and another is feed structure. The wider slot gives more bandwidth and the feed structure gives the good impedance matching.A coplanar waveguide fed wide bandwidth slot antenna [12] is investigated which gives the good impedance matching as well as wide bandwidth. This antennais small in size, low cross polarization, and good far-fieldradiation characteristics in the full operating bandwidth.

II. ANTENNA DESIGN

The geometry of the designed antenna has shown below in the Figures with various dimensions, where all the dimensions are in mm. The proposed antenna geometry is mounted on a low dielectric constant substrate having height, width and thickness 22 mm, 21 mm and 0.508 mm respectively with dielectric constant of 3.38. Figure 1.1 shows the geometry and dimensions of the coplanar ground plane with patch. The triangular slot has been loaded to coplanar ground plane and shape of the patch is triangular type with side of 8 mm. For further reduction of antenna size and increasing the bandwidth, slotting and meandering have been done in the structure of the parasitic patch. Figure 1.2 shows ground plane parasitic patch length 22mm and width 21 mm. This meandered structure provides wide impedance bandwidth as well as reduction in size of the Antenna. The parasitic patch is electromagnetically coupled to the driven patch. The notches and slots are responsible for lowering the resonance frequency .In this structure the L type slot width is 1mm and meandered slots are having the slot width of 0.5 mm. The proposed antenna is fed by a 50 ohm coplanar wave guide feed. The no. of simulation for different width of middle conductor of CPW has been carried out and the optimized width of this conductor is obtained as1mm wide. Coplanar waveguide feed location is (11, 0). The figure 1.3 shows the geometry of coplanar wave guide feed. Rest of the dimensions are shown on the geometries of figure 1.1, 1.2 and 1.3. The 3 dimensional view of designed coplanar fed triangular patch antenna is shown in Fig. 1.4.

This designed antenna calls for a source of the microstrip patch antenna for dual band operation. To achieve this, an antenna design software package, called EMPIRE XCcel, has been optto develop and to simulate this antenna. Considering the effects of size reduction and bandwidth enhancement techniques a new and better design of antenna has been formed. Simulations of this designed antenna were conducted in order to obtain the frequency response extending from 0 to 10 GHz. The response gave us the S_{11} parameter, which was used to calculate the VSWR referred to a 50 Ω transmission line.

The design parameters of the microstrip patch antenna are calculated by following design equations:

The resonance frequency for triangular patch antenna [10] is give by

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}} \tag{1}$$

In this relation the fringing effect is not considered. The resonance frequency may be determined with the better accuracy if ε_r and a is replaced by effective dielectric constant ε_{eff} and a_{eff}

$$a_{eff} = a + \frac{h}{\varepsilon_r} \tag{2}$$

$$\varepsilon_{eff} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{4}\frac{(\varepsilon_r - 1)}{\sqrt{1 + \frac{12h}{a}}} \tag{3}$$

Hence the resonance frequency is given by

$$f_r = \frac{2c}{3a_{eff}\sqrt{\varepsilon_{eff}}} \tag{4}$$

The overall dimensions of the slotted microstrip patch antenna are given in table below:

2.1.Geometry of radiating patch and ground plane parasitic patch

Table 1. Dimension of the patch

W	22 mm
L	18 mm
A	8 mm
B	2 mm
C	10 mm
D	7.75 mm
E	7 mm
F	5 mm
G	2 mm
H	5 mm
I	3 mm
J	1.5 mm
K	3 mm
Patch thickness	.035mm

Table 2. Dimension of parasitic patch antenna

W	22 mm
L	21 mm
A	15.5 mm
B	8.5 mm
C	5.5 mm
D	13 mm
E	4.5 mm
F	4.5 mm
G	6 mm
H	6.5 mm
I	3.5 mm
J	0.5mm
K	1 mm

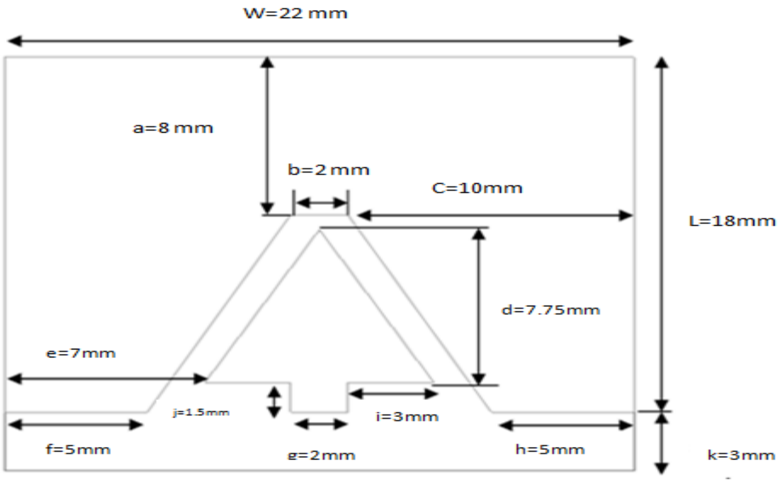

Figure 1.1. Geometry of patch for proposed microstrip antenna

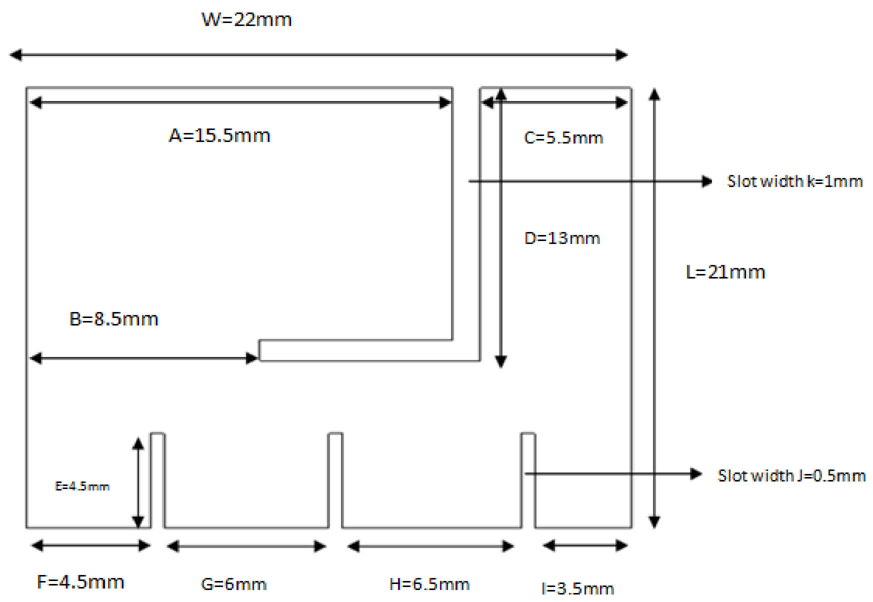

Figure1.2 Geometry of ground plane parasitic patch

2.2.Geometry of Coplanar Wave Guide Feed

Table 3. Dimension of the feed

X	9.25 mm
Y	3 mm
W_1	1 mm
W_2	1.25 mm

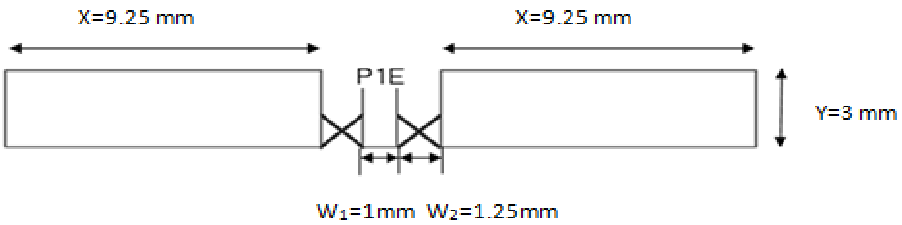

Figure 1.3 Geometry of CPW

2.3.The three dimensional view of the antenna

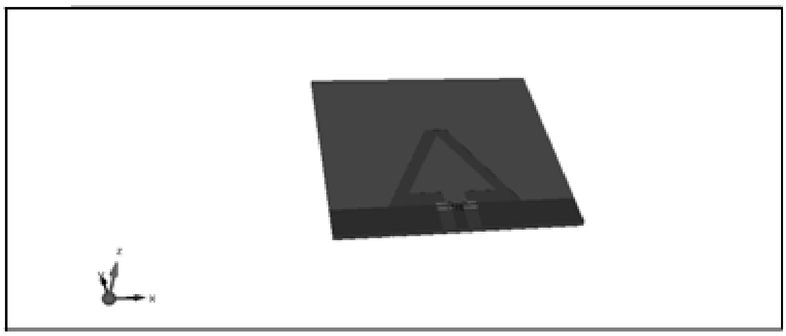

Figure 1.4 3-Dimensional view of the designed antenna geometry

III. RESULT AND DISCUSSION

Design and Simulation work of antenna configuration has been carried out by using Finite Difference Time Domain based 3D full-wave simulation software Empire XCcel. On the basis of literature review and different techniques of size reduction and bandwidth enhancement, a triangular patch coplanar antenna prototype has been designed. The results of various performance characteristics obtained from the simulation of these configurations are demonstrated.

Case1: without use of ground plane parasitic patches

Figure 2 shows the Return loss curve of designed antenna without the ground plane parasitic patch, the obtained resonant frequency (*fr*) is 5.1GHz and return loss for this frequency is -18.86 dB. The achieved value of return loss is small enough and frequency is close enough to the specified frequency band. In this case the effect of ground plane parasitic patch was not considered.

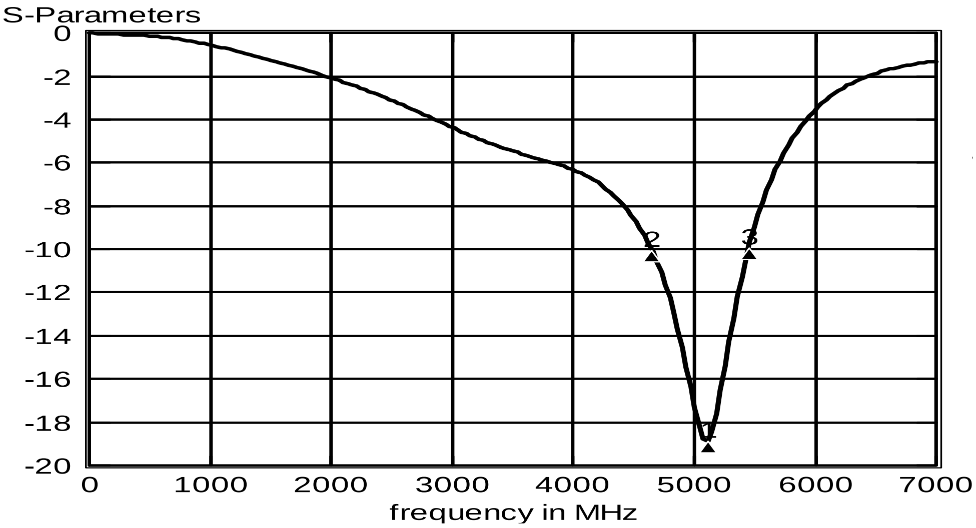

Figure 2 Return Loss (S11) characteristic

Case2: Effect of modified ground plane parasitic patches

Here the curve shown in fig 3 shows the effect of modified ground plane patch. By using the ground plane parasitic patch, antenna resonates at dual frequency with wide bandwidth.The return loss of this antenna prototype is shown in figure 3, which shows that it resonates at dual frequency with wide band width.

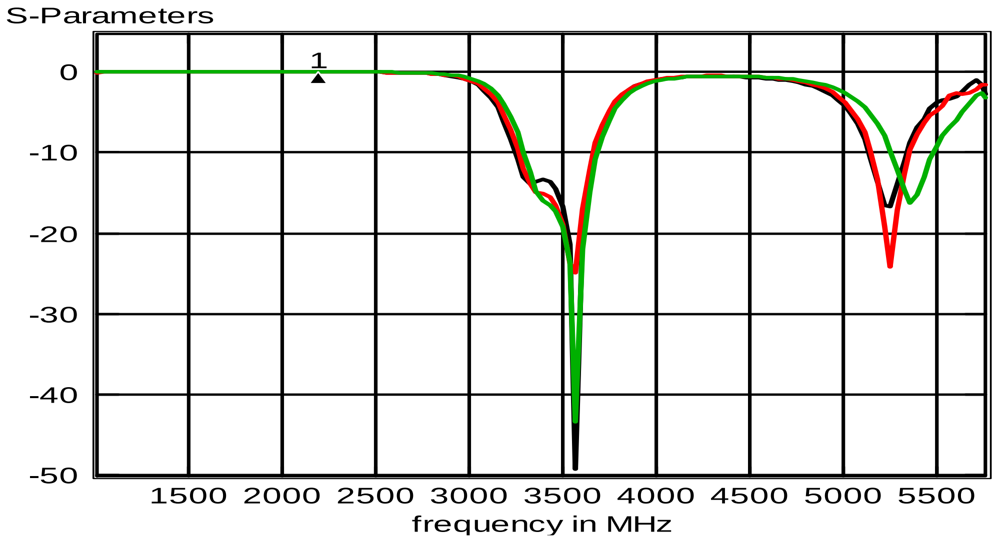

Figure 3 Return Loss (S11) characteristic

Antenna resonates on the fr_1 = 3.57 GHz and fr_2 = 5.23 GHz frequency with wide impedance bandwidth of 430 Mhz and 210 Mhz respectively. The achieved values of return losses at resonance frequency fr_1 = 3.57 GHz and fr_2 = 5.23 GHz is -49.2 dB and -16.7dB respectively, this value of return loss is much appreciable for good antenna performance. The resonance frequency is close enough to specified frequency bands. These return loss values imply that there is good impedance matching at this resonance frequency, below the -10 dB region. The effect slot length (A and B) variation on the return loss, resonance frequency and bandwidth of the antenna are also shown. The results tabulated below in the table4, are obtained after varying the slot location along the length of the ground plane patch from the left edges to its right most edge.

Table 4. Effect of variation of slot length over different parameters

Slot length(A)	Slot length(B)	Resonance Freq.(f_{r1})	Resonance Freq.(f_{r2})	$(B.W)_1$	$(B.W)_2$	$(S_{11})_1$ (dB)	$(S_{11})_2$ (dB)
15.5mm	9.0mm	3.57 GHz	5.25 GHz	400MHz	210MHz	-24.9	-24.2
15.0mm	8.5mm	3.57 GHz	5.36 GHz	390MHz	220MHz	-43.4	-16.1
15.5mm	8.5mm	3.57 GHz	5.23 GHz	430MHz	210MHz	-49.2	-16.7

This designed antenna also provides the good VSWR characteristics, Impedance characteristics and the far field radiation pattern. The Simulated curves of these characteristics are shown below in Figures.The VSWR curve shown in figure 4 shows that the value of Voltage standing wave ratio at both the resonance frequencies $fr1$= 3.57 Ghz and f_{r2} = 5.23 Ghz is 1.0 and 1.2 which is below 2.

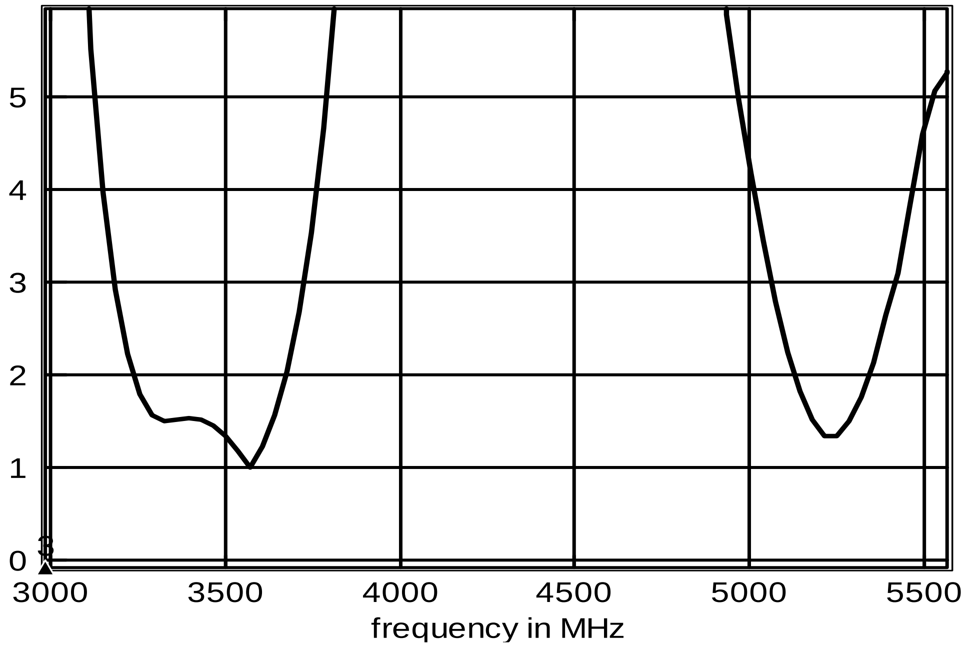

Figure 4 VSWR curve

The value of VSWR for both frequency bands is also less than the 2. This shows good antenna impedance matching at these two frequency bands and less radiation losses. The 2:1 VSWR bandwidth which corresponds to -10 dB return loss is found to be 430 Mhz for band-1 and 210 Mhz for band-2. The antenna impedance variation with frequency is shown in figure 5. In order to match the antenna impedance to 50 Ohms, its imaginary part should be zero, this means the impedance of antenna is equal to its resistance. For good antenna characteristics, the reactance curve should be nearly equal to zero.

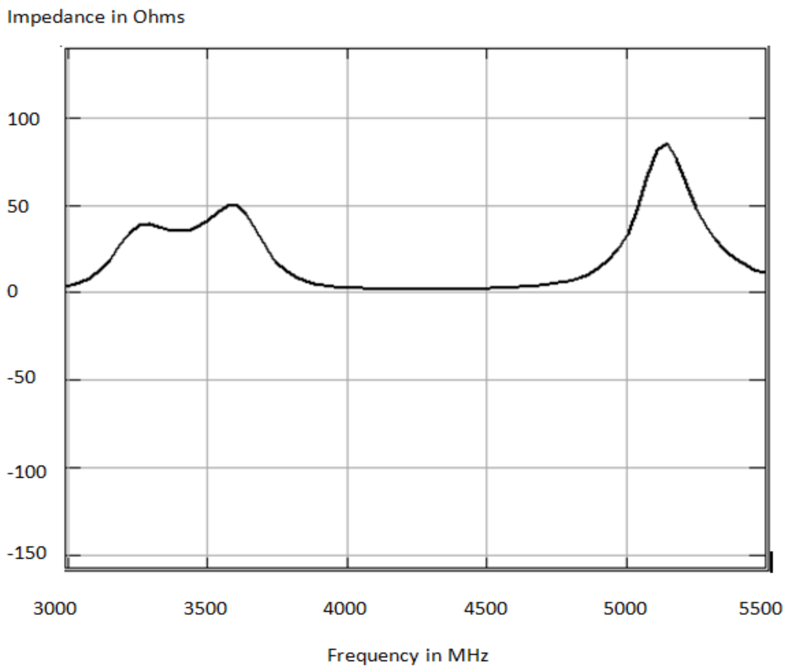

Figure 5 Impedance curves

The curve indicates the good impedance matching, which is close to 50Ω at both resonance frequencies.As the reactance value was nearly about zero over a large frequency range, a wide impedance bandwidth has been achieved which was sufficient for WiMAX application.

The radiation characteristics of the antenna are used to describe the energy transmitted from or received by the antenna in the free space. Basically the radiation field has been determined from the surface electric current on the conducting patch of the antenna.With respect to wireless applications, the antenna is expected to operate efficiently while being placed at most random orientations, and is also expected to operate in cluttered environments where signal polarization is frequently randomized by reflections. Therefore, the performance of the antennas in terms of both polarizations (i.e. the E-phi and the E-theta polarization) was considered. In summary, the antenna presented in this paper possessed the most suitable far-field patterns for WiMax application. From the results (figure 6.1to figure6.4) it is found that for antenna operating at the resonant frequencies, the resulting far-field patterns were as expected from a typical microstrip antenna. In these curves different colours indicates the variation of field with theta (θ) angle, provided phi ($\emptyset$) was constant (at $0^{\circ}$and 90°) at different frequencies.

E- Plane radiation pattern is shown in figure 6.1 and 6.2 for both resonance frequencies. These curves show the variation of field with theta angle, provided phi is constant (at 0°) at the different resonance frequencies 3.57 GHz and 5.23 GHz. The values of peak gain at resonance frequencies as 1.83 dBi and 2.68 dBi has been achieved.

H-Plane radiation pattern is shown in figure 6.3 and 6.4 for both resonance frequencies. These curves shows the variation of gain field with theta angle, provided, phi is constant(at 90°) at the resonancefrequencies 3.57 GHz and 5.23 GHz. The values of peak gain at resonance frequencies as 1.52 dBi and 1.12 dBi has been achieved.

Radiation Pattern in E-Plane and H-Plane at Frequency (f_r=3.57 GHz)

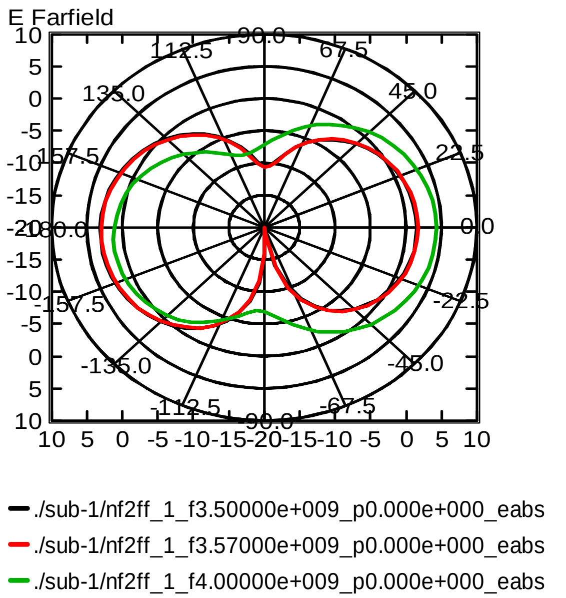

Figure 6.1 E-Plane Radiation pattern

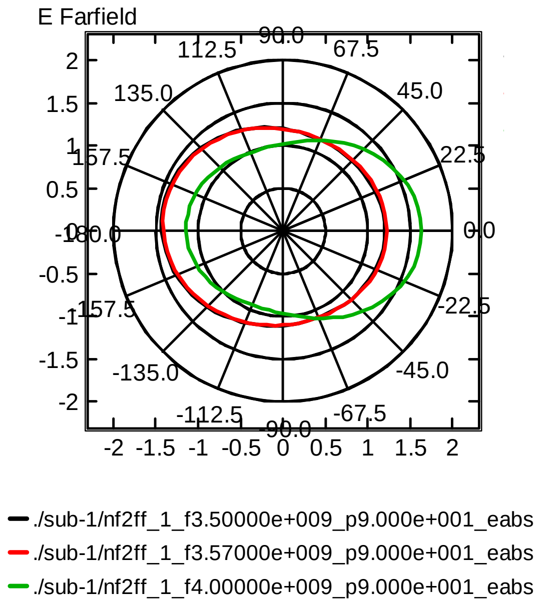

Figure 6.2 H-Plane Radiation pattern

Radiation Pattern in E-Plane and H-Plane at Frequency (f_r=5.23 GHz)

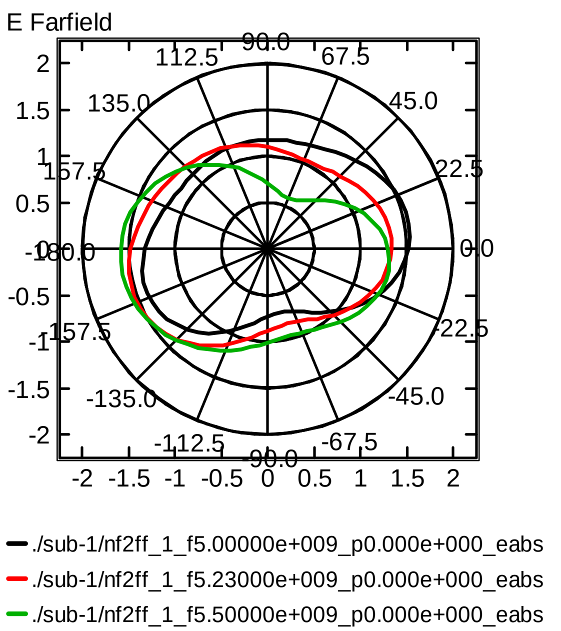

Figure 6.3 E-Plane Radiation pattern

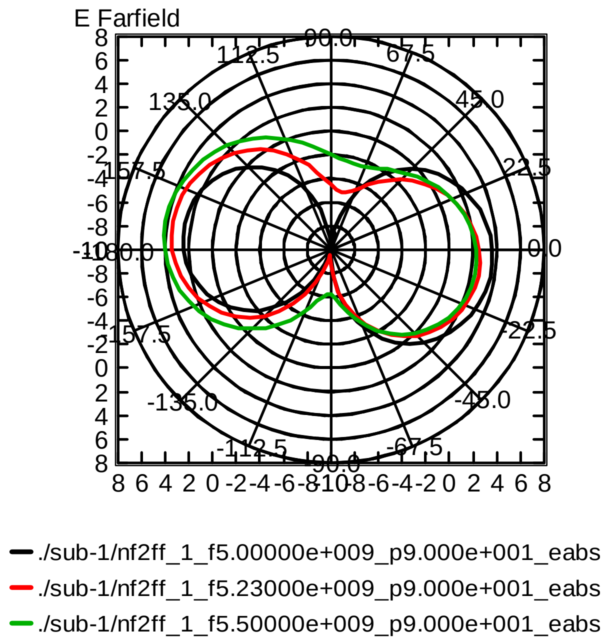

Figure 6.4 H-Plane Radiation pattern

The radiation curves at different frequencies nearer to the radiation pattern of the resonance frequency are shown in the figure which posses good field characteristics. In figure 6.1 the null is came nearly about the theta value 90°in E- plane. It was observed that dipole like radiation patterns are coming at 5.23 GHz in fig 5.4. Omani directional radiation pattern in H-plane wasshown in fig 6.2. Figure 6.3 shows a slight deviation from Omni directional but overall the pattern is acceptable.

IV. CONCLUSION

A new rectangular shaped and modified ground plane slotted antenna was designed and simulated using the electromagnetic simulation software EMPIRE XCcel. This antenna resonates on the two resonance frequencies i.e 3.57 GHz and 5.23 GHz respectively with wide impedance bandwidth. This antenna has very good impedance matching with coplanar wave guide feed. The designed antenna have produced

satisfactory performance in terms of return loss results, VSWR results and the far-field patterns and smaller size in comparison to conventional microstrip patch antenna. It indicates that these antennas have significant potential for WiMax band applications.
In future, the upcoming trends in antenna design should meet the requirements of wireless communication with better radiation characteristics, multiple function and low loss. The research in this work can be extended by investigating the possibility of further reducing the size of the planar antenna. Therefore challenges are to develop a low profile, compact and ultra wideband antenna with good radiation characteristics.

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