Triple Band Microstrip Patch Antenna with Dual U Slot for WLAN/WIMAX Applications

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ABSTRACT— *In this paper a dual U-slotmicrostrippatch antenna with U shape slot cut in the groundfor wireless communication application such as WiMAX and WLAN is presented. The microstrip U shape patch antennas are gaining attenuation in various WiMAX (worldwide interoperability for microwave access) applications since last two decades. The proposed antenna is designed using FR4 substrate having dielectric constant 4.4 with microstrip feeding method. The designed antenna generates the triple frequency band of 2.40GHz,3.25GHz and 5.35GHz which can be used in industrial,scientific and medical radio band under WLAN interoperability, WIMAX and wireless networks respectively. The achieved percentage bandwidths from the designed antenna are 3.14%, 4.96%, and 2.56% respectively. It canbe seen that every U slot generates a separate resonance frequency. A bridging element is also used to shift the three frequencies to lower band. The proposed antenna is analysed using Ansoft HFSS 13 and simulated result are presented in terms of return loss,VSWR,percentage bandwidth and radiation pattern. The performance of this antenna has been analysed by modification of bridge width and slots in ground. The return loss characteristic for triple bands are -31.8dB at 2.40GHz,-25.12dB at 3.25GHz and -31.34dB at 5.35GHz respectively which suggest good antenna performance.*

Keyword—*Dual U slot,patchantennas,wimax,Ansoft HFSS, return loss.*

1. INTRODUCTION

Recently microstrip patch antenna becomes the contender for antenna designer because of its advantage such as low cost, simple configuration,ease of access,mechanically rugged and compatibility with integrated circuits[1].A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material. The radiating patch and feed lines are usually photo etched on the dielectric substrate[1]. Microstrip patch antennas are well suited for high frequency applications because the size of antenna depends on the wavelength and resonant frequency. It has been noted that a wireless communication device provides the ability to integrate multiband[3]. Nevertheless a multiband antenna maynot sufficiently cover the required operating band. Thereforean antenna which is able to operate with multiple independent frequency band is required.

The Ushape antenna designed not only for wideband application but also for dual and triple band applications Withsmall and wide frequency ratio[5].The U shape microstrip patch antenna was introduced in 1995 by Huynh and Lee [4]. The U shape patch antennausesfrequencyreconfigurable[6]. Forobtainingmultibandandwidebandcharacteristics different techniques have been used like cuttingslot in the patch,fractral geometry and DGS (defected ground structure). DGS can be realized by cutting shape from ground plane.Shapecan be simple or complex.When DGS has been applied to antenna equivalent inductive part get increased and this cause high effect dielectric constant hence bandwidth reduced[7]. The IEEE 802.16 WIMAX standard allows data transmission using multiple broadband frequency range. 802.16d allowed lower frequencies in the range 2 to 11 GHz. There are three band of operation for WIMAX technology which is2.4GHz (2.4 to 2.8 GHz) called lower band, 3.2GHz (3.2 to 3.8GHz) called middle band and 5.3GHz (5.2 to 5.8GHz) called the high frequency band respectively [8]. Since WiMAX offer multiband operation microstrippatchantennas (MPAs) are preferable[9]-[10].The various applications of slotted microstrip patch antennas were discussed in [12-17].

Theses paper focus on the dualU-slotted patch antenna using ground slot to achieve triple band operation for WIMAX and WLAN application. The antenna design proposed in this paper is unique because there are two different size U slots are used which are connected via a bridging element andU slot cut in theground to obtain third WIMAX frequency band and WLAN interoperability.Important feature of this antenna is that it can be used for 2.4 GHz WLAN operation. The proposed antenna is designed using FR4 substrate having ε_r of 4.4. The height (h) of substrate is 1.2 mm and is fed by a 50 Ωmicrostrip transmission line. The simulation of the proposed dual U slot antenna is performed using Ansoft HFSS.

Triple band characteristic is obtained by using two U slots in the patch and a bridge which connects two U slots.Ihave taken this design from[11] as reference antenna and modifying the structure to get proposed antenna, an improvement is found in return loss and in percentagebandwidth. Various attempts are made to adjust the width of bridge and different shapes of slot in ground plane. From simulation we got return loss of -31.80 dB,-25.12 dB and -31.34dBand fractional bandwidth of 3.14%, 4.96% and 2.56% at 2.40GHz,3.25GHz and 5.35GHzrespectively.

The rest of the paper is organized as follows: section II represents the antenna design methodology with the fundamental process in the design and various parameters of antennas. Simulation results of antenna are shown in section III. Section IV gives the conclusion.

2.ANTENNA GEOMETRY AND DESIGN PROCEDURE

The proposed antenna is depicted in fig.1configuration of proposed triplebandmicrostrippatchantenna consists offourpart,arectangular patch having width of W=40mm and and length of L=47mm in which two U slots of different dimension in the patch and abridging element which connects

Two U slots, microstrip feed line, substrate and a slot of U shape inthe ground as shown in the figure. Triple band is achieved by insertion of two U slots in the main patch. The rectangular patch generates the lower frequency band of 2.4GHz whereas the two U slots generate the upper and middle band of frequency. To obtain 50Ω characteristic impedance,the optimized dimension of transmission line is 20mm× 2mm.The proposed antenna is designed on FR4 substrate having dielectric constant of4.4. The height of dielectric constant is selected as 1.6mm. The radiating patch is fed by a 50Ω microstrip feed line. First the dual U slot patch antenna is designed and only simulated results are presented. To enhance the antenna performance width of bridge is changed and a U shape slot is cut in the ground and its dimension is verified to get the best result.

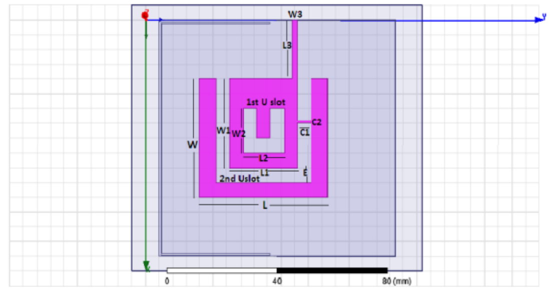

Fig.1 Structure and dimension of proposed dual U slot
Antenna

In the proposed antenna designed parameters are selected based on the transmission line model [1]. The resonant frequency is given by

$$f_o = \frac{C}{2W\sqrt{\varepsilon r+1}}$$

Where

f_o= resonance frequency
c = speed of light
w = width of patch
ε_r= relative dielectric constant

And length is given by

$$L_{eff} = \frac{C}{2f_o(\sqrt{\varepsilon reff})}$$

Effective dielectric constant is given by

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+12\frac{h}{w}]^{-1/2}$$

h= height of substrate
w= width of patch

The antenna dimensionsare summarized in the table below.

TABLE I DIMENSIONS OF DUAL U SLOT PATCHANTENNA

Parameter	Value(mm)	parameter	Value(mm)
W	40	L2	15
L	47	W3	2
W1	30	L3	20
L1	25	C1	5
W2	15	C2	1

Two U slots are combined together in a single antenna element to study overall antenna behavior, they are connected together using a bridging and after carefully tuning its length(C1) and width (C2) ,the desired frequencies are achieved .The overall behavior of dual U slot patch antenna using a bridging element and one U shape slot in ground isanalysed. The main function of bridge is to shift the higher frequency band to a lower value.

3. PARAMETRIC STUDY

This section presents a parametric study that how the operating frequency and return loss(S11) changes with the change in bridge dimensions and change in ground slots. An iterative simulation study is performed using the initially observed data to optimize each antenna parameter and achieved the best desired result.

3.1 Variation in bridge width

Initially, the width of bridge of U slot antenna is tuned to understand the effect of variation on antenna return loss(S11).The results are summarized in tableII below. The iterative simulation study shows that the change in dimension of bridge width only affects the return loss. Initially the width is 3mm, When the width is 1mm wegot the best result that is improved return loss m1=-30.34dB, m2=-18.5dB and m3=
-18.85dB.

TABLE II EFFECT OF BRIDGE WIDTH (C2) ON ANTENNA RETURN LOSS

Bridge width(C2)	m1(dB)	m2(dB)	m3(dB)
4mm	-16.26	-16.27	-14.99
3mm	-18.20	-14.43	-15.12
2mm	-25.97	-16.33	-17.31
1mm	-30.34	-18.5	-18.85
0.5mm	-20.91	-19.6	-20.57

Fig. 2 shown below shows the result of comparison in return loss at three resonant frequency due to change in the bridge width between both U slots.

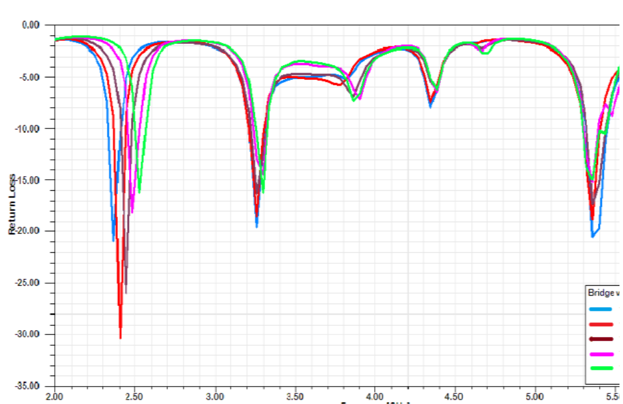

Fig.2 Comparing return loss of antenna due to change in bridge width

3.2 Effect of different shapes of slots in ground

There is variation in return loss due to Different shapes of slot in the ground. Shapes are of 4 types,1st is U shaped slot in left side ofground,2nd is U shaped slot in right side of ground,3rd is U shaped slot inboth left and right side, and 4th is boundary slot in ground. Best results are obtained when there is U shaped slot in ground in the left sided as shown in fig.5below,results improved return loss, that is -29.86dB,-19.66dB,-30.09dB at 2.4GHz,3.25GHz and -5.35GHzrespectively.Graph shown below shows the result due to different slots in the ground.

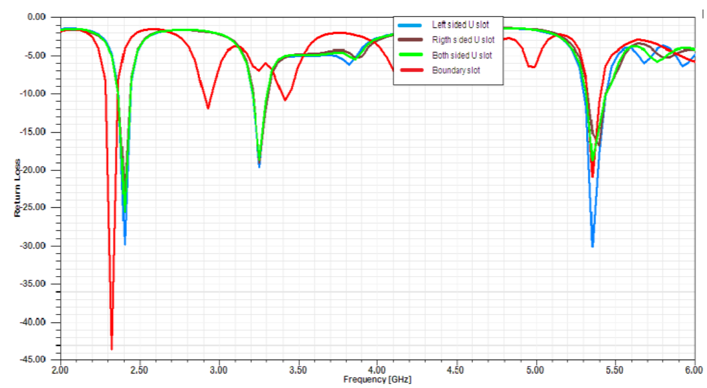

Fig. 3.Comparing return loss(S11)of antenna using different slots in ground

3.3Variation in width of left sided slot in ground

Best results are obtained when the slot is in left side of ground plane. There is variation in return loss if the dimension (A, B, C) of slot is changed.

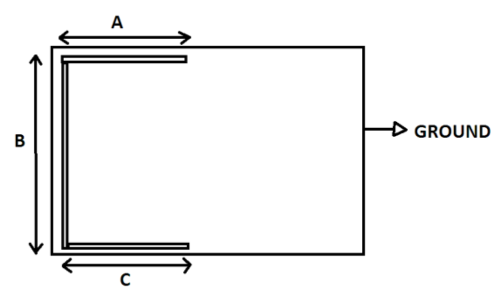

Fig.4.Left side U shape slot cut in the ground

The second frequency band is not much affected by variation in slot width,but first and third frequency band is quite affected by change in slot widths A,B and C shown in the table III below. When the width A, B and C is set to 0.6,0.2 and 0.6 we got the best Result means improved return loss that is -31.80dB,-25.12dB and -31.34dB at 2.4GHz,3.25GHz and 5.35GHzrespectively.

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TABLE III EFFECT OF SLOT WIDTH A,B,C ON ANTENNA RETURN LOSS

S.N.	Slot width(mm)			Return loss(dB)		
	A	B	C	m1	m2	m3
1.	0.2	0.2	0.2	-29.55	-18.84	-26.6
2.	0.35	0.2	0.35	-29.86	-19.66	-30.0
3.	0.35	0.35	0.35	-24.07	-19.43	-21.8
4.	0.4	0.2	0.4	-30.04	-18.48	-25.8
5.	0.45	0.2	0.45	-25.43	-19.14	-22.4
6.	0.55	0.2	0.55	-27.66	-19.80	-26.48
7.	0.6	0.2	0.6	-31.80	-25.12	-31.34
8.	0.6	0.6	0.6	-30.56	-18.98	-24.45
9.	0.8	0.2	0.8	-27.08	-19.03	-20.85

4. ANTENNA SIMULATION RESULT

This section provides the simulation result of the triple band dual U-slot patch antenna, designed in HFSS 13 software. HFSS is based on finite element method. Simulation results of return loss, VSWR, fractional bandwidth, gain, radiation pattern are measured and presented.

4.1. Return Loss or Reflection Coefficient (S_{11})

The fig. 5 below shows the simulated return loss of designed antenna comparing with reference antenna. When the load is mismatched with the load,the whole power will not delivered to the load and is a return of the power, that is called loss, and the loss that is returned is called the return loss.Larger return loss indicates the higher power being radiated by theantenna which eventually increases the gain. In this fig 5 we observe that the simulated return loss(S_{11}) for WiMAX band 2.40GHz,3.25GHz,5.35GHz are -31.80dB, -25.12dB and -31.34dB respectively.

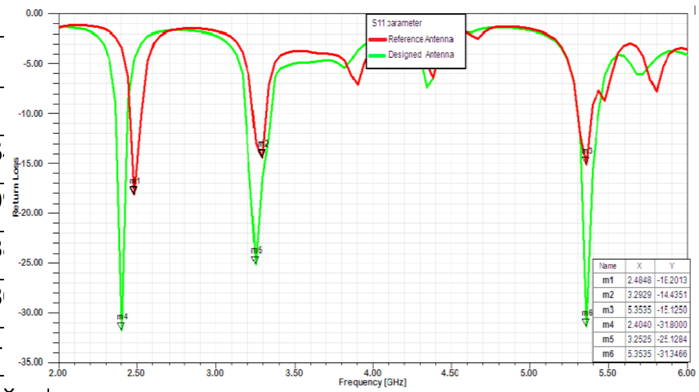


Fig.5. Comparing Return loss (S_{11}) for designed antenna
with reference antenna

4.2 Voltage Standing Wave Ratio (VSWR)

The VSWR is an important specification for all the communicating devices. It measures how well an antenna is matched to the cable impedance where theReflection|r|=0. This means that all the power is transmitted to the antenna and there is no reflection. The simulation result of voltage standing wave ratio (VSWR) is shown in fig. below. It is observed that VSWR for WiMAX operating bands 2.40GHz,3.25GHz, 5.35GHz are 0.44, 1.71, and 0.47 respectively. The antenna willonly operate at the frequencies where the value of VSWR is less than 2.

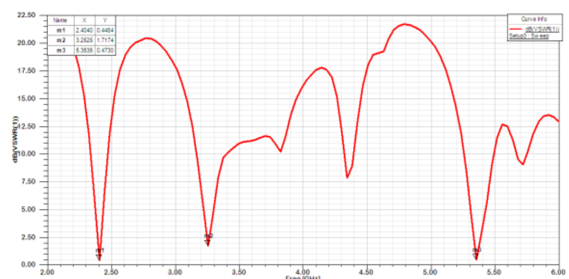


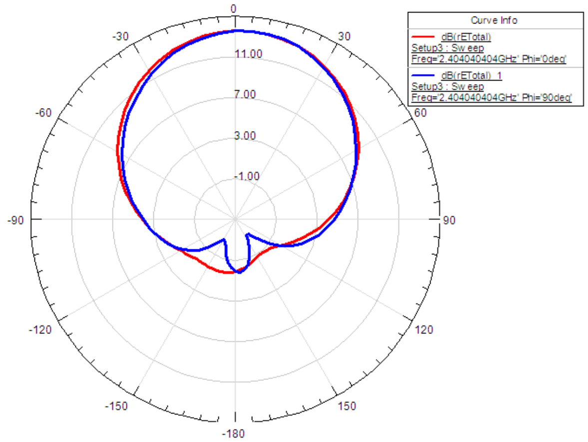
Fig.6. VSWR vs. frequency curve

4.3 Fractional Bandwidth

The fractional bandwidth of an antenna is a measure of how wideband the antenna is. It is often defined as the range over which the power gain is maintained to within 3dB of its maximum value, or the range over which the VSWR is not greater than 2.The fractional bandwidth varies between 0 and 2, and is often quoted as a percentage (between 0% and 200%),the higher the percentage, wider the bandwidth. The fractional bandwidth is 3.14% for 2.40GHz, 4.96% for 3.25GHz and 2.56% for 5.35GHz.

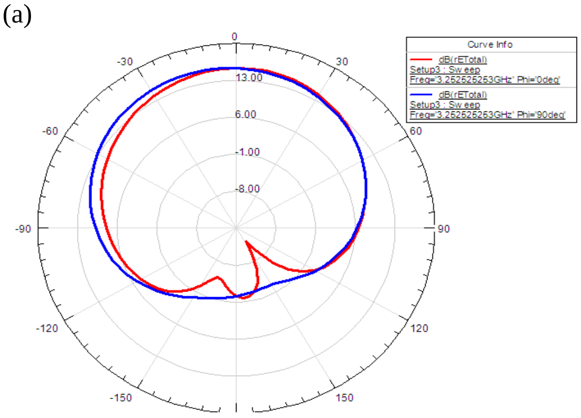
4.4 Antenna Radiation pattern

The radiation pattern of the microstrip patch antenna is the power radiated or received by the antenna. It is the function of angular position and radial distribution of the antenna. The 2D radiation pattern of the proposed microstrip patch antenna is shown in fig.8(a-c) and 3D radiation pattern is shown in fig.9(a-c). It can be seen from figure below that at the frequency bands of 2.40GHz, 3.25GHz and 5.35GHz for WiMAX applications, stable radiation pattern are observed in which suggest good antenna performance.



Ø=0° Ø=90°

(a)



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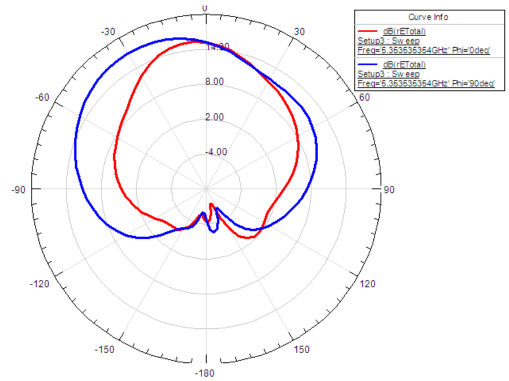
(b)



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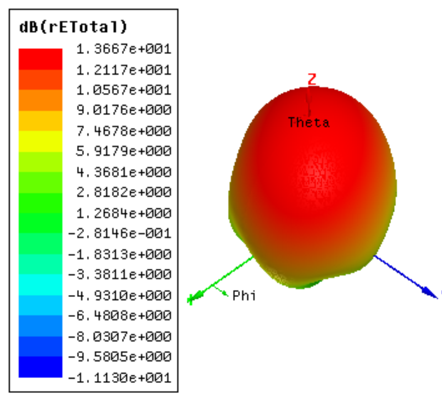
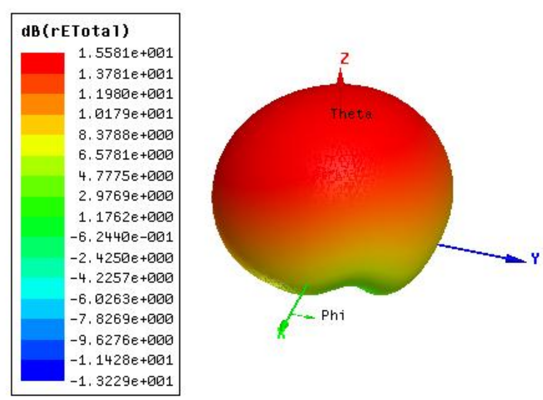
(c)

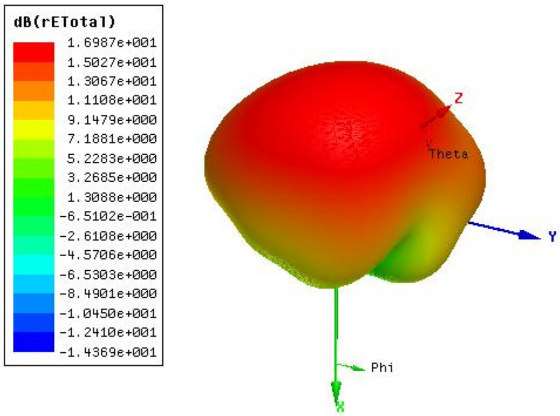
Fig.7. 2DRadiation patternat (a)2.40GHz(b)3.25GHz(c)5.35GHz



(a)



(b)



(c)

Fig.8. 3D Radiation pattern of designed antenna at (a) 2.40GHz (b) 3.25GHz (c) 5.35GHz

5. CONCLUSION

In this paper, a triple band antenna with two u slot is designed and simulated. By employing two different dimension of U slot, the antenna can obtain good return loss. In the design, the middle and high frequency band are achieved by introducing two U slots in the main rectangular patch. The proposed antenna is simulated on Ansoft HFSS 13 simulator. The designed antenna is small in size and it can be used in handheld devices. The designed antenna is suitable to operate at three frequency bands with the percentage bandwidth and return loss of 3.14%and 31.80dB at 2.40GHz,4.96% and 25.12dB at 3.25GHz and 2.56%and 31.34dB at 5.35GHz respectively. Therefore the designed antenna can work efficiently in the WiMAX and WLAN applications.

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