A Compact Hexagonal Structured Dual Band MIMO Antenna for Fixed WiMAX Application

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Abstract

A new compact multiple-input multiple-output (MIMO) antenna with good isolation and compact size is proposed. In this paper, the single port wimax antenna and hexagonal structured MIMO antenna is studied experimentally regarding return loss and VSWR. The value of VSWR for both single port and MIMO antenna is ≤ 2 in the frequency ranges from 1.8 GHz to 2.9 GHz and from 4.5 GHz to 6.6 GHz. The single port wimax antenna can produce two resonant frequencies having return loss of -32 dB at 2.5 GHz and -42 dB at 5.6 GHz. The proposed MIMO antenna resonates only at 2.5GHZ, but the return loss is so minimum when compared to single port antenna. It is about -84dB twice the time greater than the single port antenna. The simulation results demonstrate the -10dB impedance bandwidth at (1.8-2.9) GHz and (4.5-6.6 GHz). The Hexagonal Structured Dual Band MIMO Antenna is simulated using Ansoft HFSS and the same structure is fabricated. This fabricated antenna is verified by good agreement between simulated and measured results.

Keywords—*Worldwide Interoperability for Microwave* ***Access*** *(WiMAX), return loss, voltage standing wave ratio (VSWR), radiation pattern, ultra wideband (UWB),MIMO.*

1. Introduction

In today's fast paced world, multiple-input multiple-output (MIMO) technology made a great breakthrough by satisfying the demand of higher quality mobile communication services without using any additional radio resources. The huge potential of MIMO technique is evidenced by a rapid adoption into the wireless standards, such as WLAN, LTE (Long Term Evolution), and WiMAX. The multiple-input multiple-output (MIMO) wireless communication system has been extensively researched due to its higher data transmission rate than the single-input single-output (SISO) system in a rich multipath environment.In 2002, the Federal Communications Commission (FCC) allocated the ultra wideband (UWB) frequency range from 3.1-10.6 GHz for unlicensed UWB applications [1]. There are some wireless communication applications which have already occupied frequencies in the UWB band such as the wireless local area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN which operate at (5.15-5.35) GHz and (5.725-5.825) GHz, respectively. In addition, the use of the 2.5 to 2.7 GHz, 3.3 to 3.8 GHz and 5.25 to 5.85 GHz frequency band has been limited by IEEE 802.16a/d/e.

WiMAX is a broadband wireless data communications technology based around the IEEE 802.16 standard providing high speed data over a wide area [2]. WiMAX is a technology for point to multipoint wireless networking. WiMAX technology is expected to meet the needs of a large variety of users from those in developed nations wanting to install a new high speed data network very cheaply without the cost and time required to install a wired network, to those in rural areas needing fast access where wired solutions may not be viable because of the distances and costs involved. Additionally it is being used for mobile applications, proving high speed data to users on the move.

Initially 802.16a was developed and launched, but now it has been further refined. 802.16d or 802.16-2004 was released as a refined version of the 802.16a standard aimed at fixed applications. The revision of the IEEE 802.16 standard falls into two categories such as Fixed WiMAX and Mobile WiMAX. Fixed WiMAX also called IEEE 802.16-2004, provides for a fixed-line connection. Fixed WiMAX operates in licensed bands (2.5 GHz and 3.5 GHz), and license free band of 5.8GHz [3, 4]. Mobile WiMAX (IEEE 802.16e), allows mobile client machines to be connected to the Internet. Mobile WiMAX opens the doors to mobile phone use over IP, and even high-speed mobile services.

Fixed WiMAX works under three different bands. The low band frequency ranges from 2.5 GHz to

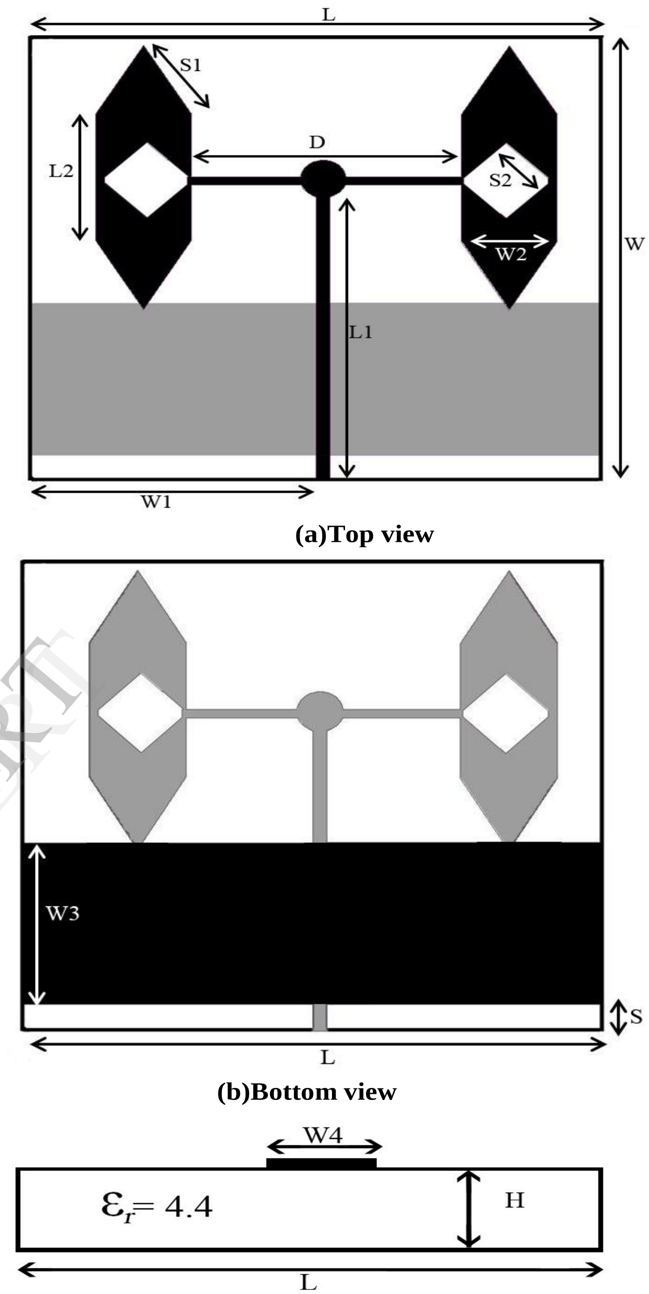
2.8 GHz, the middle band frequency ranges from 3.2 GHz to 3.8 GHz and the high band frequency ranges from 5.2 GHz to 5.8 GHz. Those antennas should be smaller in size, less weight. The material is also an important factor for designing an antenna, the characteristics of the material should have minimum loss, low cost and easily available [5, 6]. The printed microstrip patch antenna has got the above characteristic. This microstrip patch antenna consists of a dielectric substrate [7], with a ground plane on the other side. Conventional microstrip antennas in general have a conducting patch printed on a grounded microwave substrate [8].

A novel dual band[9] Hexagonal Structured Antenna for IEEE 802.16d Fixed WiMAX system is proposed which is printed on the FR4 substrate with a dielectric constant of 4.4 and thickness of 1.6mm[10]. This antenna is designed and its parameters are simulated using the electromagnetic (EM) simulator called Ansoft High frequency Structured Simulator (HFSS) package.

The paper is organized as follows: In Section 2, the single port wimax antenna is designed with optimal geometric values. In section 3, the simulation results and analysis are discussed. In section 4, the hexagonal structured wimax MIMO antenna is presented. In section 5, the simulation and analysis of MIMO antenna is discussed. Section 6, concludes the paper.

2. Geometry of Single port Wimax Antenna

The single port Wimax antenna geometry structure is shown in Fig.1. The antenna has a compact size of 62mm (L) x 58mm (W) x 1.6mm (H). The substrate is made up of FR4 material which has an relative permittivity (ε_r)=4.4. The radiating element of the proposed antenna is composed of two hexagonal structured elements which are separated by a distance (D) as shown in Fig.1 (a) top view. The radiating element is excited by a long microstrip line of length L1 which is connected to the two hexagonal structures. Fig.1 (b) and Fig.1 (c) shows the bottom and side view of the single port wimax antenna. The Single port antenna geometric values are given in the Table I. L and W represent the length and width of the proposed antenna. L1 represents the distance between the feed line and the radiating element. W1 represents the position of feed line from the left axis. D denotes the distance between the two radiating hexagonal elements which is connected the horizontal strip of width 1mm. The width of the feed line is about 1.5mm and its impedance is about 50Ω to match it with the SMA connector. The response of the proposed antenna varies when the distance between the radiating hexagonal is varied. In [11] the radius of the circle which is used to unite the vertical feed line and the horizontal microstrip is of 2.5mm.



(c) Side view

Fig.1. Geometry of Proposed Antenna

In the proposed antenna the Hexagonal structure shape which is present at its either side gives a wider bandwidth [12] and the two rhombic slots [13] in the hexagonal structure with the sides of length S2 decides the operating frequency**.** The dimensions of the rhombic slots are tuned such that the operating frequency of the proposed antenna falls at 2.5 GHz and 5.6 GHz (Fixed WiMAX). The circular strip which is present at the canter couples the horizontal and the vertical feed line which increases the flow of energy through the vertical strip[14] to the hexagonal through the coupled horizontal strip.

TABLE I
Optimal geometric values of the Antenna

S.No	Notations	Description	Dimensions in mm
1.	D	Length of the strip line connecting hexagonal	30
2.	S	Distance between Ground and feed	3.2
3.	H	Substrate Thickness	1.6
4.	L1	Feed line length	37.1
5.	W1	Distance of feed line from X-axis	30.3
6.	L2	Length of hexagonal	16.8
7.	W2	Width of hexagonal	10.4
8.	S1	Side of the triangle	10.4
9.	S2	Side of the Diamond	7
10.	L	Substrate Length	62
11.	L3	Length of Ground plane	62
12.	W4	Width of Feed line	1.5
13.	W	Substrate Width	58

3. Results and Discussion

3.1 Return Loss

The simulated result of return loss (S_{11}) of the proposed antenna is shown in Fig.2. It can be observed that the proposed antenna exhibits dual band characteristic in WiMAX frequency range i.e. this antenna resonates at two frequency bands such as 2.5GHz and 5.6 GHz. The return loss of the proposed antenna is about -42 dB at 5.6 GHz and -32 dB at 2.5GHz. The impedance Bandwidth of the proposed antenna with respect to return loss is measured at -10dB. The 2.5 GHz band operates at bandwidth of 1100 MHz i.e. 1.8 to 2.9 GHz and the other 5.6 GHz band operates at the bandwidth of 2100 MHz i.e. 4.5 to 6.6GHz. When the distance D between the two hexagonal structures is varied [15] as 30mm and 35 mm the return loss varies as shown in the Fig.2. The return loss is about -42dB at D=30mm whereas the return loss is -30dB at D=35mm, which shows that the proposed antenna with the distance D=30mm has better return loss and all the further parameter analysis are based on D=30mm.

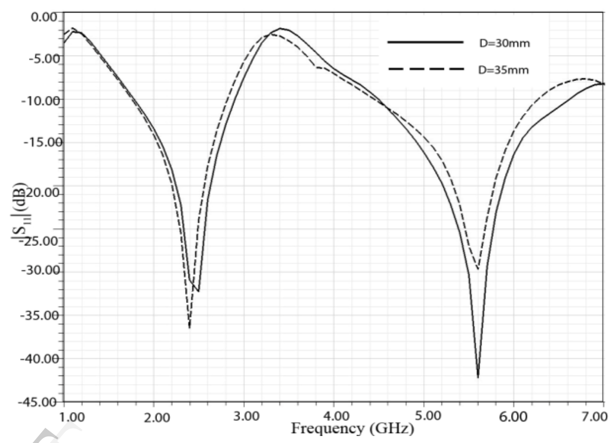


Fig.2. Simulated return loss for various ground plane length.

3.2 VSWR

As shown in the Fig.3 the proposed antenna had achieved VSWR of value ≤ 2 at two frequency bands of frequency i.e 1.8 GHz to 2.9 GHz and from 4.5 GHz to 6.6 GHz for 2.5 GHz and 5.6 GHz respectively. The value of VSWR is exactly one at the operating frequencies 2.5GHz and 5.6 GHz, this shows that the proposed antenna suits well for the WiMAX services especially for IEEE 802.16-2004 or 802.16d.

3.3 Radiation Pattern

The proposed antenna is directional in nature as it radiates symmetrically as shown in Fig.4 (a) and Fig.4 (b). The radiation characteristic [16] of the novel dual band antenna is simulated for both H-Plane and E-Plane. The far field radiation pattern is being checked for two frequencies 2.5 GHz and 5.6 GHz. At 2.5GHz, the E-Plane and H-Plane characteristic is symmetric in nature and it radiates at two direction equally at $\varphi=0^o$ (E-Plane) and $\varphi=90^o$ (H-Plane) as shown in Fig.4. (a).The radiation characteristic at 5.6 GHz is shown in Fig.4 (b) which is symmetric in nature.

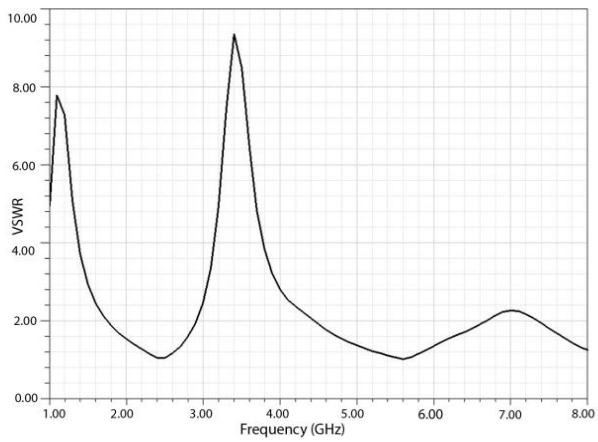


Fig.3. Simulated VSWR of proposed antenna

The E-Plane which is radiated at 5.6 GHz is symmetric which radiates in both the sides equally [17] but it has two minor lobs at φ=90° (H-Plane).

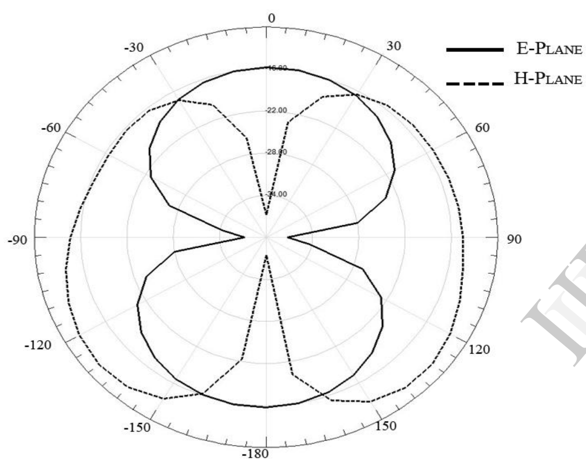


Fig.4 (a). 2.5 GHz Gain (dBi) for φ=0° (E-Plane) and φ=90° (H-Plane)

The comparison of proposed dual band hexagonal structured antenna with existing [3] wide band umbrella antenna is shown in Table II.

3.4 Fabrication of Proposed Work

The proposed hexagonal structured dual band antenna has been fabricated on the FR4 substrate which is of thickness 1.6mm. The front and bottom view of the fabricated antenna is shown in Fig.5 (a) and Fig.5 (b).

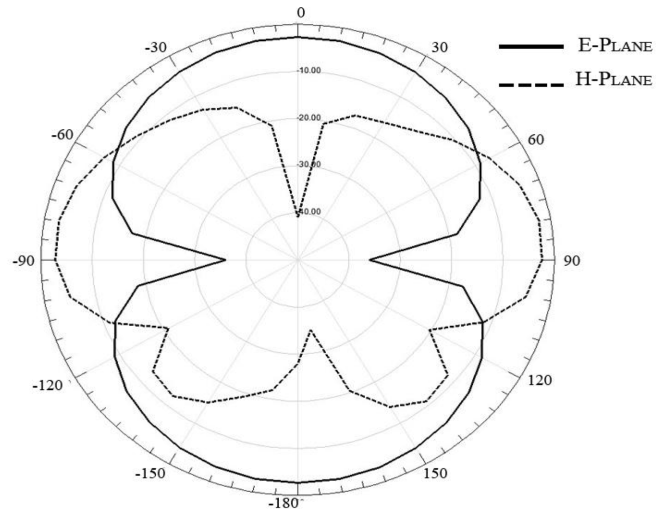


Fig.4 (b). 5.6 GHz Gain (dBi) for φ=0° (E-Plane) and

TABLE II

Comparison of Existing WiMAX antenna and proposed antenna

Parameters	**Existing Antenna**[3]	**Proposed antenna**
Size	20x30x1.6mm^3	62x58x1.6mm^3
Material	Neltec (ε_r=2.6)	FR4 Epoxy(ε_r=4.4)
Substrate Thickness	1.6mm	1.6mm
Return loss	-30dB at 5.6 GHz	-32dB at 2.5 GHz and -42dB at 5.6 GHz
VSWR	Less than 2	Approximately equal to one at operating frequencies
No. of Bands	Single Band at WiMAX	Double Band
Design Complexity	Very difficult to fabricate such a small antenna	Easy to fabricate

Finally, the designed hexagonal structured dual band antenna is measured with an Agilent N5230A vector network analyzer. The simulated and measured *S*-parameters and VSWR are in an excellent agreement as observed in Fig.5.1 (a) and Fig.5.1 (b).

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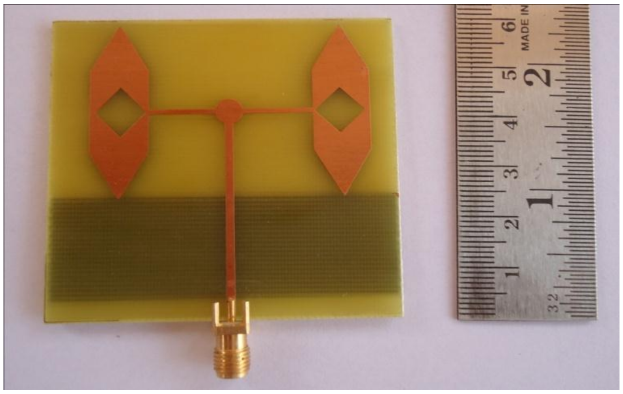


Fig.5 (a) Front view

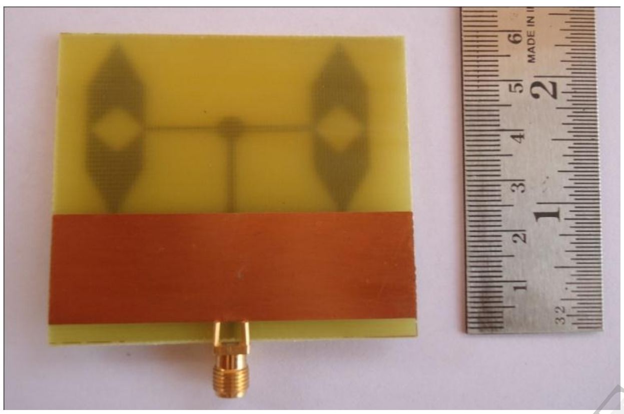


Fig. 5 (b) Bottom view

Fig.5 Prototype of the proposed antenna

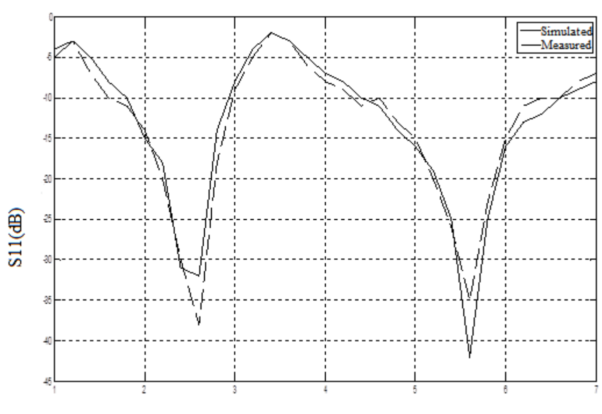


Fig.5.1 (a) Simulated and measured *S*-parameters of the proposed antenna.

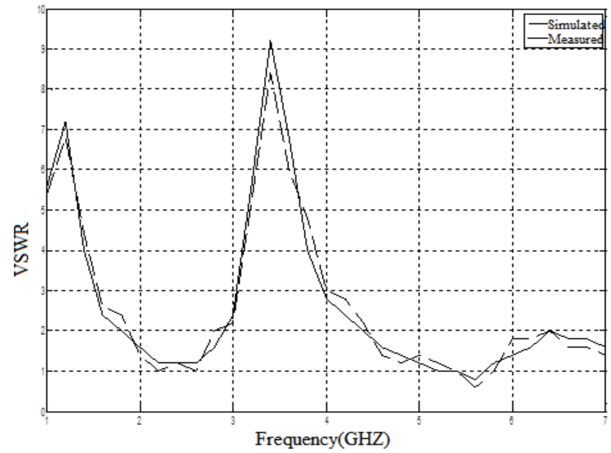
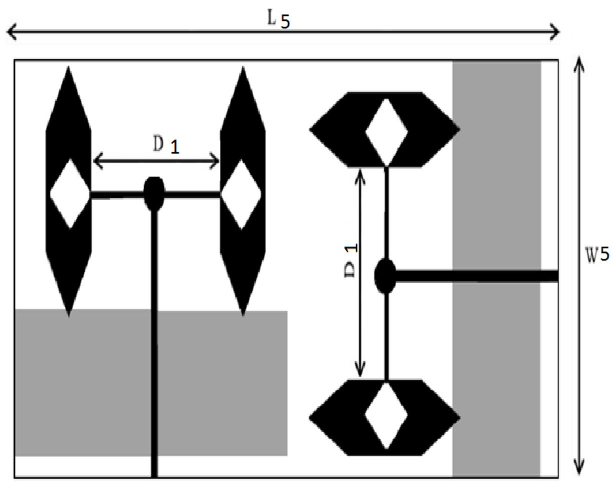


Fig.5.1 (b) Simulated and measured *VSWR* of the proposed antenna.

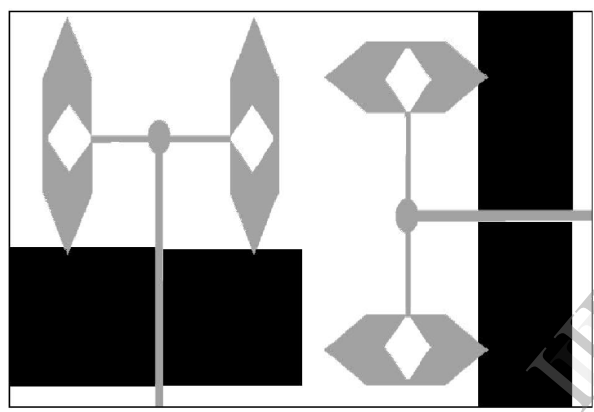
4. Geometry of Hexagonal structured Wimax MIMO Antenna

The geometry of the proposed Hexagonal Wimax MIMO Antenna is shown in Fig.6.1. The antenna has a compact size of 124mmx58mmx1.6mm. The substrate is made up of FR4 material which has a relative permittivity (εr) =4.4. As shown in Fig 6.1 (a) top view two similar structures of hexagonal is designed. One Structure is placed at 0o and other structure in placed at angle of 90^o [7]. Both the structures are placed on same substrate which is made of FR4 Epoxy. Two different ground plane in made for the two structures separately and each one is excited with a long microstrip line of width 1.5mm.There is no physical contact between two structures and thus an array of antenna element is made. Each SMA connected to the strip lines is having the same impedance of about 50Ω. L5 and W5 represent the length and width of the proposed antenna. L1 represents the distance between the feed line and the radiating element. D1 denotes the distance between the two radiating hexagonal elements which is connected the horizontal strip of width 1mm as shown in Fig.1.

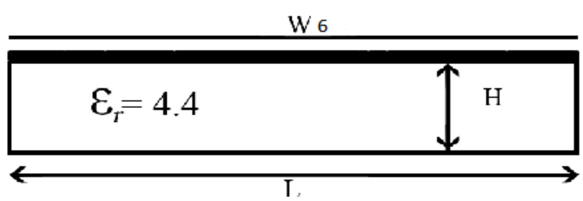
The width of the feed line is about 1.5mm and its impedance is about 50Ω to match it with the SMA connector. The response of the proposed antenna varies when the distance between the radiating hexagonal is varied. The radius of the circle which is used to unite the vertical feed line and the horizontal microstrip is of 2.5mm. The two antenna elements are kept in such a way that it gives better return loss. The elements which are placed at 90^o difference give better response.



(a)Top View



(b)Bottom View



(c) Side View

Fig.6.1 Geometry of Proposed MIMO Antenna

The antenna response changes from dual band to single band because of placing of multiple antenna elements. The antenna resonates only at 2.5GHz, but the return loss value is so minimum when compared to single element antenna. It is about -84dB twice the time greater than single element antenna.

5. Results and Discussion of MIMO Antenna

5.1 Return Loss

The simulated result of return loss (S_{12}) of the proposed antenna is shown in Fig.6.2. It can be observed that the proposed antenna exhibits 2.5GHz band characteristic in WiMAX frequency range. The return loss of the proposed antenna is about -84 dB at 2.5 GHz. The impedance Bandwidth of the proposed antenna with respect to return loss is measured at -10dB.The 2.5 GHz band operates at bandwidth of 1100 MHz i.e. 1.8 -2.9 GHz.

As we discussed earlier, the two antennas are integrated on the same dielectric substrate to construct a co-located antenna system in such a position relative to each other that there is maximum isolation between them. For MIMO systems, the mutual coupling between the antennas is one of the important parameters to evaluate the performance of the antenna system. It is clear from the Fig 6.2 the mutual coupling between (S_{12}) and (S_{21}) is always less than -15dB in the frequency range of interest therefore, it ensures that two elements on proposed co-located antenna system can operate simultaneously.

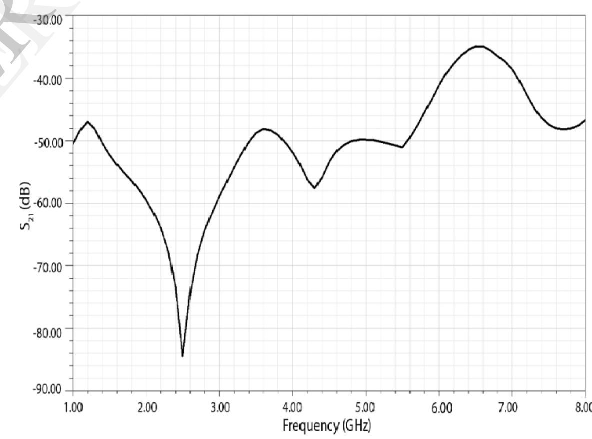


Fig.6.2 Return loss for proposed MIMO antenna

5.2 VSWR

As shown in the Fig.6.3 the proposed antenna had achieved VSWR of value ≤ 2 at two frequency bands of frequency i.e. 1.8 GHz to 2.9 GHz and from 4.5 GHz to 6.6 GHz for 2.5 GHz and 5.6 GHz respectively. The value of VSWR is exactly one at the operating frequencies 2.5GHz, this shows that the

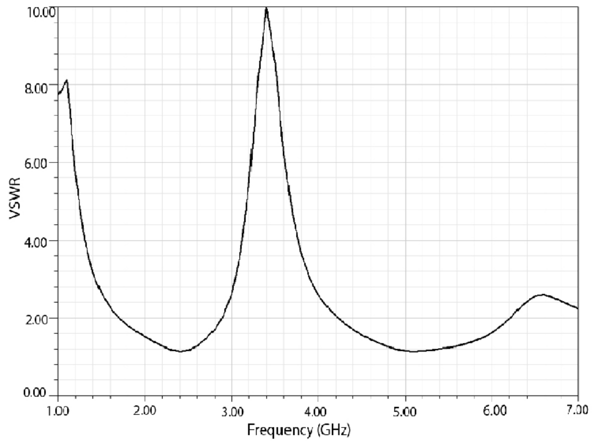


Fig.6.3. the VSWR of proposed MIMO antenna

Proposed antenna suits well for the WiMAX services especially for IEEE 802.16-2004 or 802.16d.

5.3 Radiation Pattern

The proposed antenna is directional in nature as it radiates symmetrically as shown in Fig 6.4. The radiation characteristic of the novel dual band antenna is simulated for both H-Plane and E-Plane. The far field radiation pattern is being checked for two frequencies 2.5 GHz and 5.6GHZ. At 2.5 GHz, the E-Plane and H-Plane characteristic is symmetric in nature and it radiates at two direction equally at $\varphi=0^o$ (E-Plane) and $\varphi=90^o$ (H-Plane) as shown in Fig.6.4.

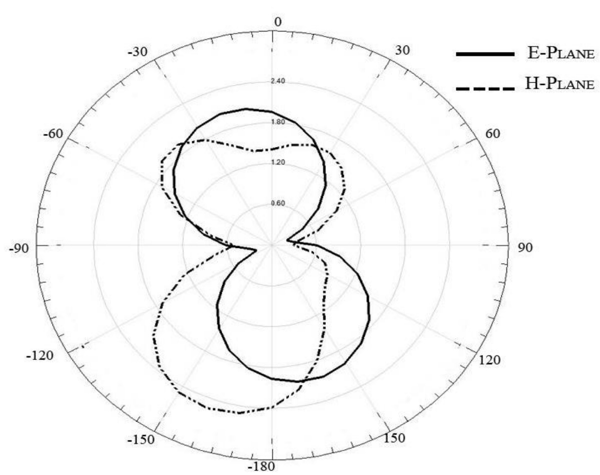


Fig.6.4 2.5 GHz Gain (dBi) for φ=0o (E-Plane) and φ=90o (H-Plane)

5. Conclusion

Wideband operations of the novel hexagonal structured dual band MIMO antenna have been demonstrated. Constructed prototype is studied at WiMAX operation at two bands in IEEE 802.16(d) Fixed band at 2.5 GHz and 5.6 GHz bands. This antenna has two bands at 2.5GHz and 5.6 GHz whereas when an antenna array (MIMO) it resonates only at 2.5GHz with better response than other types. The Proposed antenna has a low profile and is easily able to feed by microstrip line with SMA of 50Ω. The proposed antenna has the characteristics of dual band response with good return loss above 30dB and radiation pattern at E-Plane and H-Plane. The proposed antenna is a simple and effective feeding structure in design, has adequate operational bandwidth at WiMAX operating range.

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