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Triple Band CPW-Fed Microstrip Antenna with Hexagonal Shape Slot for WLAN/WiMAX Applications

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Abstract: In this research work, a CPW-fed diamond shaped patch embedded with hexagonal shape slot and L-shape strip attached to it which produces tri-band operation which is suitable for WLAN/WiMAX applications. The proposed antenna has a simple structure and occupies size of 28.5 × 33.125 mm^2. The parametric study is performed to understand the characteristics of the proposed antenna. The proposed antenna is capable of generating three distinct operating bands 2.12-2.82 GHz, 3.33-4.27 GHz, 5.12-7.09 GHz, covering all the 2.4/5.2/5.8 GHz WLAN bands and the 2.5/3.5/5.5 GHz WiMAX bands. The various antenna parameters like S-parameters, current distribution and radiation pattern are studied.

Keywords: Microstrip Antenna, WLAN, WiMAX, CPW feed.

1. INTRODUCTION

The growth of modern wireless communication system has caused wide interests in designing multiband antennas; especially for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) [i]. To satisfy the IEEE 802.11 WLAN standards in the 2.4/5.2/5.8 GHz operating bands or WiMAX 2.5/3.5/5.5 GHz bands, multiple bands antenna with low cost, compact size, easy fabrication, and higher performance are required. The demand for smaller and low profile antennas has brought the Microstrip Antenna (MSA) to the forefront [ii]. The various designs of multiband antenna suitable for WLAN/WiMAX applications have been studied [iii-xii] such as monopole antenna, circular ring patch antenna, monopole antennas with meander strips, rectangular microstrip antenna with 'H' and 'U' slots, fork-shaped antenna. These antennas cover both WLAN/WiMAX bands. The fast growing WLAN protocols operating bands are at 2.4 GHz (2400–2484 MHz), 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725–5825 MHz), the operating bands of WiMAX is 2.5/3.5/5.5GHz (2500–2690/3400–3600/ 5250–5850 MHz) bands. In this investigation, triple band diamond shape microstrip antenna with hexagonal slot is presented for wireless communication application. In this design, the main patch is of diamond-like shape and is fed by CPW (Coplanar Waveguide) feed. Further, modifications are done in the patch to improve the bandwidth. The details of antenna design are discussed in section 2. The parameters of antenna are studied in section 3. Simulated results and discussions are provided in section 4, and conclusions are presented in section 5.

2. ANTENNA GEOMETRY

The geometry of proposed antenna is shown in Fig.1. The antenna is designed on FR4 substrate with dielectric constant of 4.4 with thickness of 1.6 mm. The overall dimensions of proposed antenna are 28.5 × 33.125 mm^2. As shown in figure, the antenna consists of a diamond shape with rectangular strip and 'L' shape patch attached to it. A hexagonal slot is cut in the proposed antenna. The antenna is constructed with the above described patch and fed by Coplanar Waveguide Feed (CPW) feeding. The ground size of the proposed antenna is 15.8 mm x 13 mm. The ground plane is symmetrical at the base line of the feeding strip line. To obtain the optimal parameters of the proposed antenna for WLAN/WiMAX application, IE3D, 14.10 version of Zeland that can simulate a finite substrate and a finite ground structure, is used. Thus, the proposed antenna design can provide a wide bandwidth while retaining stable performance via the optimized geometrical parameters. The parameters of proposed antenna are shown in Table 1. The distance between patch and ground is 0.5 mm and between feed and ground is 0.25 mm. The rectangular strip feed line has dimensions of 16.3 mm × 4.5 mm. Initially, a diamond shape like patch is taken then modifications are done in patch like addition of rectangle and 'L' shape patch is attached to it step by step and a hexagonal slot is cut in the proposed antenna. The parametric study is done in next section like variation in distance between patch and ground and distance between feed and ground.

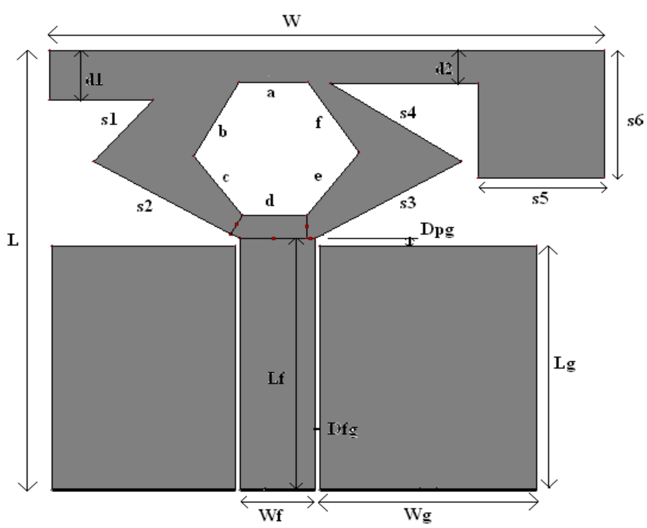

Fig 1: Geometry of proposed Antenna

Table 1: Parameters of the proposed antenna

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Parameter	Size (in mm)	Parameter	Size (in mm)	Parameter	Size (in mm)
L	28.5	D_{fg}	0.25	s_6	8.25
W	33.125	d_1	3.25	a	4.1
L_g	15.8	d_2	2.15	b	4.775
W_g	13	s_1	3.975	c	3.85
L_f	16.3	s_2, s_3	5	d	3.875
W_f	4.5	s_4	5.05	e	4.1
D_{pg}	0.5	s_5	7.5	f	4.525

3. PARAMETRIC STUDY

Fig. 2 shows the evolution of proposed antenna design and its corresponding simulated frequency response of return losses. The following analysis is based on basic antenna structure as shown in fig 2(a) named as Antenna 1, which consists of a diamond shape patch. Then modifications are done in the patch step by step as shown in fig 2(b), fig 2(c), and fig 2 (d).

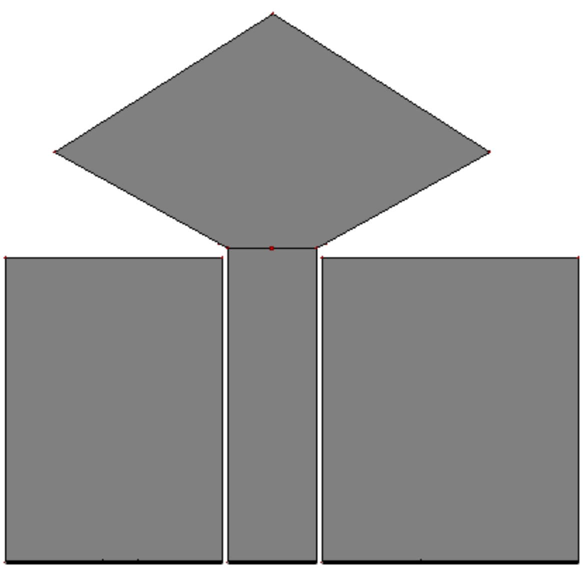

Fig 2(a): Antenna 1

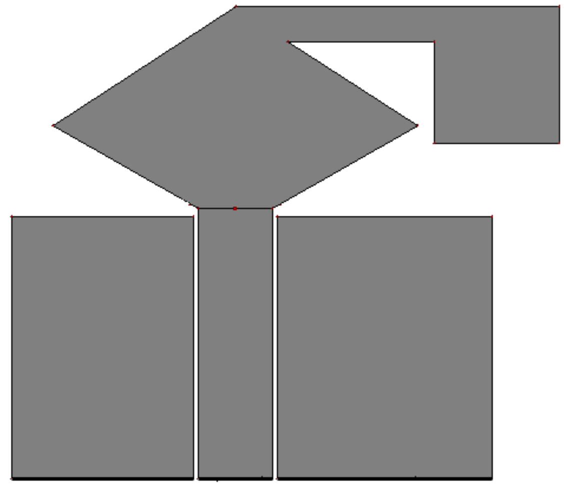

Fig 2(b): Antenna 2

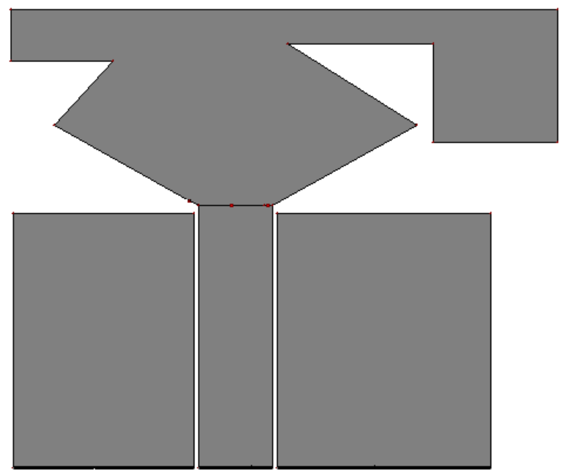

Fig 2(c): Antenna 3

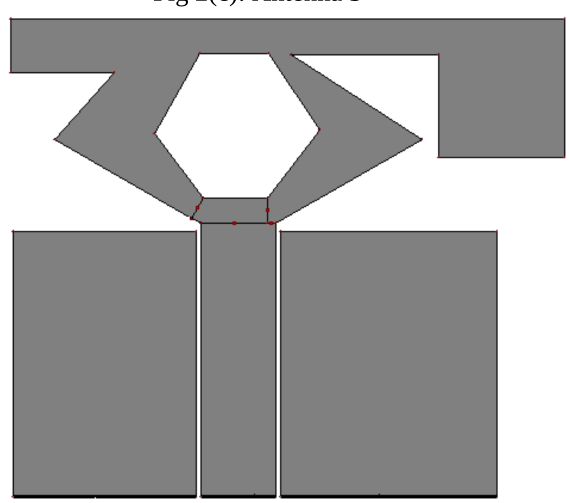

Fig 2(d): Antenna 4 (Proposed Antenna)

Fig. 3 shows the corresponding return losses of various proposed design. Only higher bands of WLAN/WiMAX are obtained by antenna 1. Then 'L' shape strip is added to the right side of the diamond shaped patch. The return losses are improved by adding L shape strip. It has been observed that the return loss is improved and a partially lower band is also obtained for Antenna. For improving the results, a rectangular strip is added to left side of patch. It has been observed form figure that all required bands of WLAN (2.4/5.2/5.8 GHz) and WiMAX (2.5/3.5/5.5 GHz) bands (Antenna 3) are obtained. Then, a hexagonal slot is cut in the diamond shape patch for obtaining higher peak of return losses. Peak of return losses is increased by doing this as shown in figure 3 (Antenna 4).

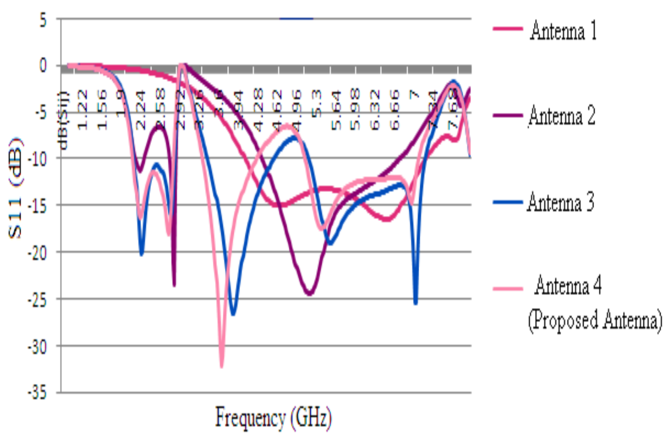

Fig 3: Comparison of Return Losses of different antenna Configuration

3.1 Effects of D_{pg} and D_{fg} on impedance bandwidth:

In this section the distance between patch and ground is varied as shown in fig. 4 and fig. 5 shows the distance variations between feed and ground. It can be observed clearly that D_{pg} and D_{fg} are affecting the results.

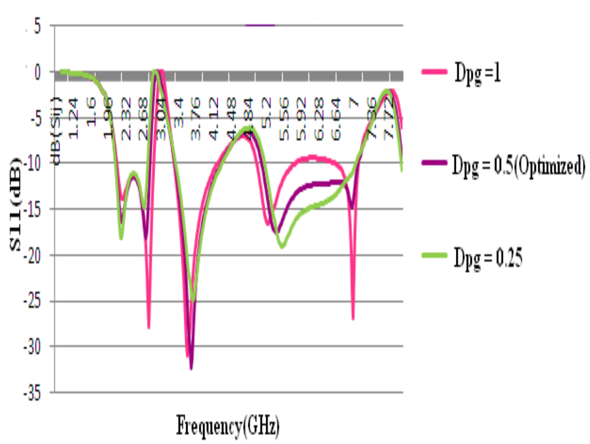

Fig 4: Return Loss Variations for different values of D_{pg}

In fig. 4, for different values of D_{pg} , parametric study is done. When D_{pg} is 1, higher bands are not properly obtained. By changing these values, there is improvement in results. On changing these values, we got all required bands of WLAN/WiMAX. Similarly in fig. 5, when the distance between feed and ground is 0.75, in that case bandwidth for lower band is less and peak of the middle band is less. By changing the values, we will get improved results like improved bandwidth and higher peak of return losses.

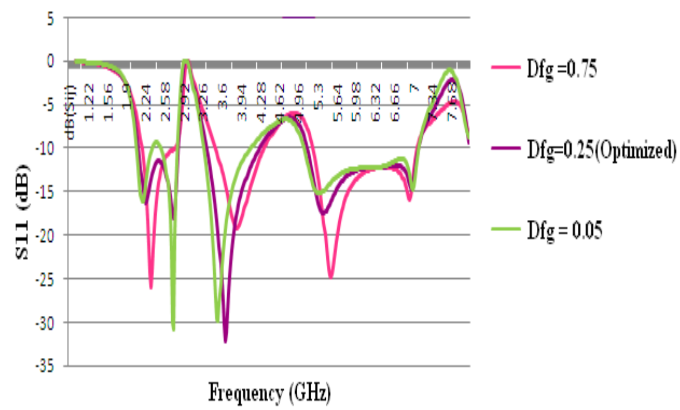

Fig 5: Return Loss Variations for different values of D_{fg}

4. SIMULATED RESULTS AND DISCUSSIONS

The simulated return losses and other parameters are obtained. The return losses are shown in fig. 6. From the results, it can be seen that -10 dB return loss bandwidths of proposed antenna are 700 MHz (2.12-2.82GHz), 940 MHz (3.33-4.27 GHz), 1970 MHz (5.12-7.09 GHz), respectively, which makes it easy for required bandwidths for WLAN bands (2.4-2.484GHz, 5.15-5.35 GHz, 5.725-5.825 GHz) and WiMAX bands (2.5-2.69 GHz, 3.4-3.7 GHz, 5.25-5.85 GHz) applications.

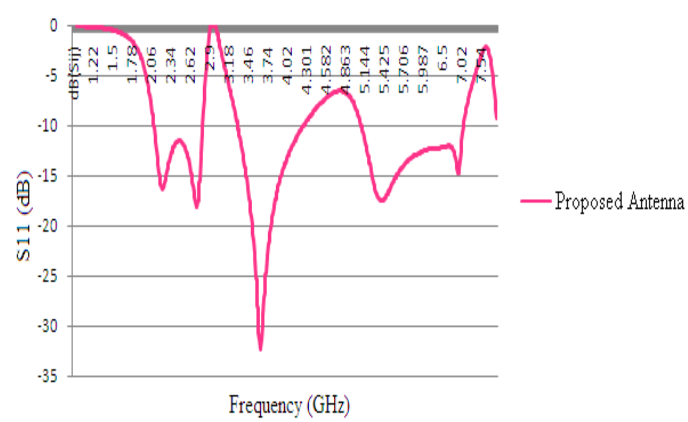

Fig 6: Return Losses of Proposed Antenna

Simulated 2D Radiation Pattern for different frequencies like 2.73, 3.65, 5.42, 6.96 GHz has been observed. In fig. 7 and 8,

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radiation pattern for 2.73, 3.65 GHz are shown. Radiation Pattern presents the graphical representation of radiation properties of antenna as a function of space coordinates. Fig. 9 shows three Dimensional radiation patterns for 2.73 GHz and 3.65 GHz.

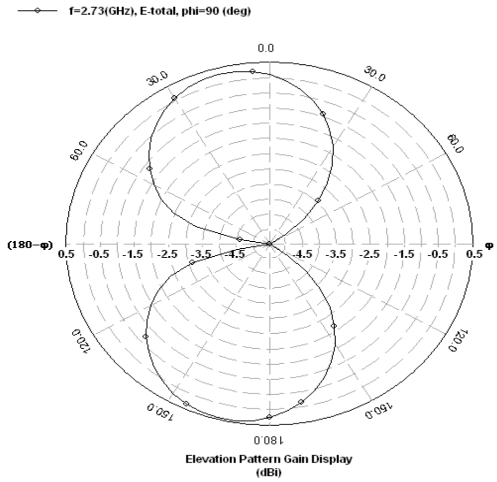

Fig 7(a): Elevation Pattern at 2.73 GHz

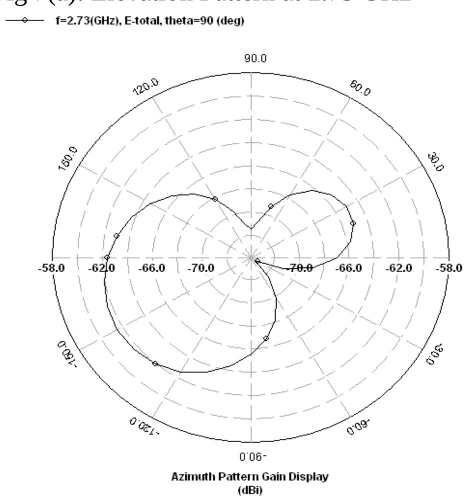

Fig 7(b): Azimuthal Pattern at 2.73 GHz

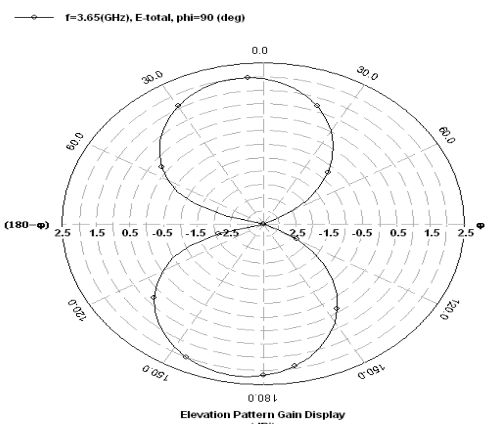

Fig 8(a): Elevation Pattern at 3.65 GHz

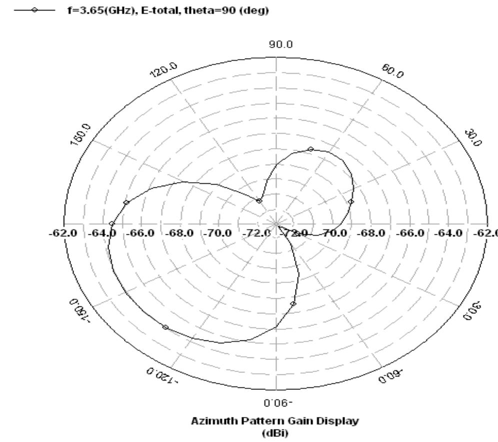

Fig 8(b): Azimuthal Pattern at 3.65 GHz

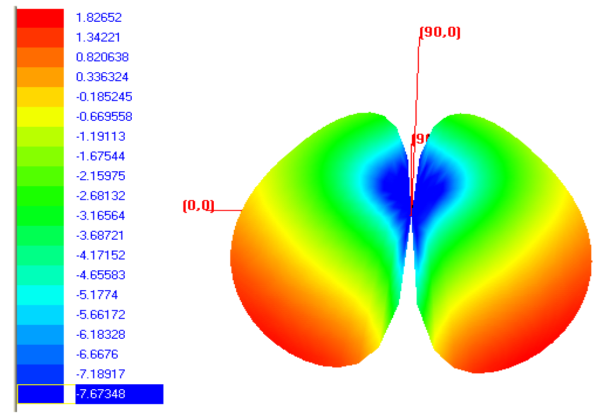

Fig 9(a): 3-D Pattern of proposed Antenna at 2.73 GHz

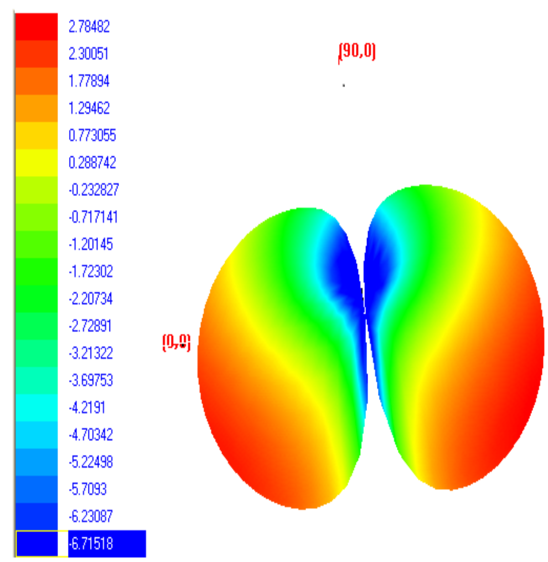

Fig 9(b): 3-D Pattern of proposed Antenna at 3.65 GHz

The formation of the lower and upper frequency resonances can be explained by observing the surface currents on the conductors of the antenna at 2.73 GHz, 3.65 GHz as shown in Fig.10. Current distribution is changed by changing the length and dimensions of patch. The maximum E-current at 2.73 GHz is 27.782 A/m and at 3.66 GHz is 13.816 A/m.

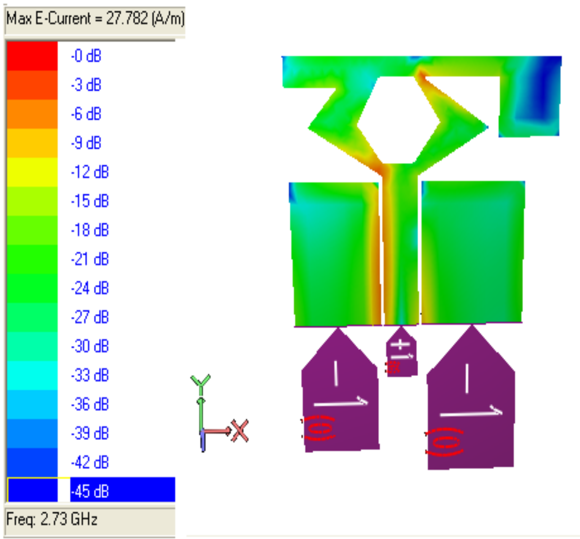

Fig 10(a): Current Distribution of Antenna at 2.73 GHz

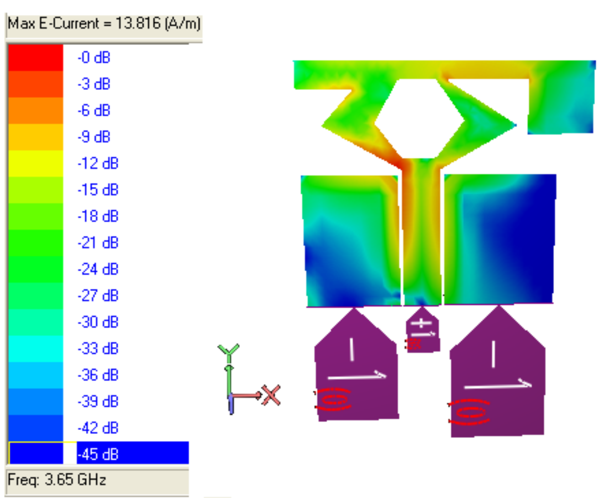

Fig 10(b): Current Distribution of Antenna at 3.65 GHz

The graph for VSWR (Voltage Standing Wave Ratio) is shown in fig. 11. The VSWR v/s Frequency graph of antenna is showing that VSWR value lies below 2.

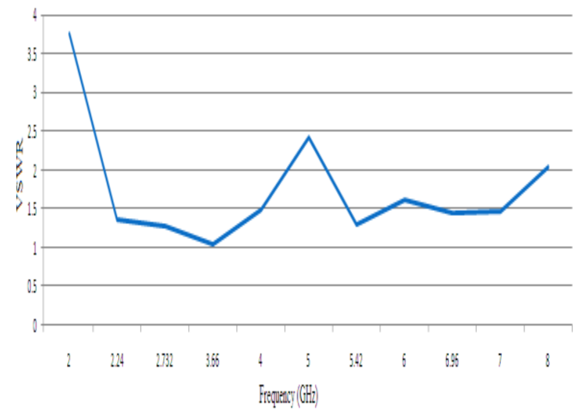

Fig 11: VSWR v/s Frequency

5. CONCLUSION

In this study, a triple band CPW-fed microstrip antenna for WLAN/WiMAX applications has been studied. With embedding 'L' shape strip with Diamond shaped like patch, two impedance bands are obtained. The middle band is obtained by introducing rectangular shape strip to the patch. A hexagonal slot is also introduced for improving the impedance bandwidth. In this way, we got three separate bands which are requirement for WLAN/WiMAX applications. The effects of varying different parameters on antenna performance have been studied. The proposed antenna has compact size of $28.5\times33.125mm^2$ generating three distinct operating bands 2.12-2.82, 3.33-4.27, 5.12-7.09 GHz, covering all the 2.4/5.2/5.8 GHz WLAN bands and the 2.5/3.5/5.5 GHz WiMAX bands. It can be concluded from the results that the designed antenna has satisfactory performance and hence can be used for wireless applications.

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