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Analysis of Multi Band Square Microstrip Patch Antenna Loaded with a pair of Horizontal and Vertical Slits

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ABSTRACT: This paper discusses an analysis of multi band square microstrip patch antenna loaded with a pair of horizontal and vertical slits. Here, impedance bandwidth of the conventional microstrip patch antenna is increased to 42.05% by introducing vertical and horizontal slits in the patch. The proposed designed antenna resonates at three frequencies namely 3.02GHz, 4.81GHz & 6.8GHz. The antenna proposed is designed and simulated using IE3D virtual platform and results like VSWR, radiation pattern, return loss, gain & impedance matching are presented. Proposed design may be utilized for multi band application appropriate for numerous wireless communication systems like WiMAX, WLAN etc.

KEYWORDS: Microstrip, Impedance Bandwidth, Return Loss.

I.INTRODUCTION

The demand of microstrip antennas still persists due to its light weight, low profile, low cost and ease of integration with microwave circuit and no other antenna still could replace its features and hence it is being used in the wireless and other applications [1-2]. The traditional microstrip patch antenna in general has a narrow band structure. However bandwidth enhancements usually demanded for practical applications. Application's in present day mobile communication systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile unit. Thus size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas. There are numerous methods to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low dielectric substrate, the use of multiple resonators; edge coupled parasitic patches, fractal patch and the use of slot antenna geometry [3-4]. However, the bandwidth and the size of an antenna are generally conflicting each other, that is, improvement of one of the characteristics normally results in degradation of the other [5-6].

Patch antennas are receiving interest in various Mobile communication systems since they can provide advantages over traditional antennas in terms of high efficiency, low EM coupling to the human head and increased mechanical reliability. In many applications the requirements on both bandwidth and physical size are quite stringent. In some applications it is desired to have a dual band or multiband characteristics [7]. These characteristics can be obtained by coupling multiple radiating elements or by using tuning devices. However these methods make antenna more complicated. A simple method to achieve the dual band characteristics in a microstrip antenna is inserting slot in the patch as the structure proposed here in which the radiating patch includes a pair of step slots. Inserting a slot on the patch can reduce the resonating frequency while reducing the dimensions of the antenna. Antenna dimensions can be reduced by creating appropriate slots making antenna useful for wideband and multiband frequency application [8-10].
Recent development on the multiband microstrip antenna progressed rapidly especially the IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMAX) application. In practical application, narrow bandwidth is a major disadvantage of microstrip patch antenna. Based on the IEEE 802.16 standard, the WiMAX operations are in 2.5 GHz band (2.5 GHz - 2.69 GHz), 3.5 GHz band (3.3 GHz - 3.8GHz) and 5.5GHz band (5.25 GHz - 5.85 GHz)[11-12]. In this paper wider bandwidth which is a major concern for practical implementation of WiMAX application is discussed.

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The proposed antenna is simulated using virtual platform IE3D [13]. This paper consists of IV sections. Brief introduction is discussed in section I. Section II describes proposed antenna design. Result analysis and performance comparison with conventional patch antenna and the modify patch antenna loaded with one, two and three pair of vertical and horizontal slits is discussed in section III. Section IV concludes the paper.

II. ANTENNA DESIGN

Antenna Geometry

The configuration of the proposed antenna is shown in figure 1 with L= W=15mm. Transmission line is placed at appropriate place to match its input impedance 50 ohm. The feed point of the antenna is X=5mm, Y= 7.25. Feed point remains same for all geometries.

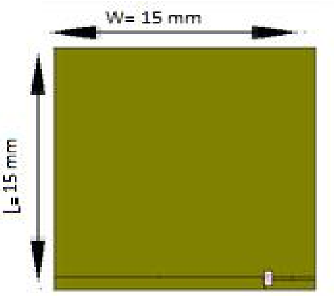

Figure 1: Geometry of proposed microstrip patch antenna

Return loss is measured below -10dB. It shows 10% of the power is reflected as shown in figure 2.

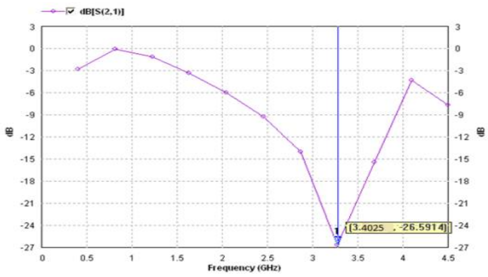

Figure 2: Variations in Return Loss with frequency for proposed antenna

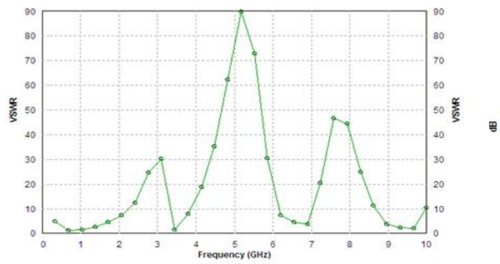

Figure 3: Variations in VSWR with frequency for proposed antenna

Simulation results obtained for proposed square patch antenna have return loss=-26.59dB, VSWR= 1.12 , Gain= 1.9dBi and input impedance =48.13-j0.12at resonating frequency 3.40GHz as shown in figure 2, 3, 4& 5 respectively.

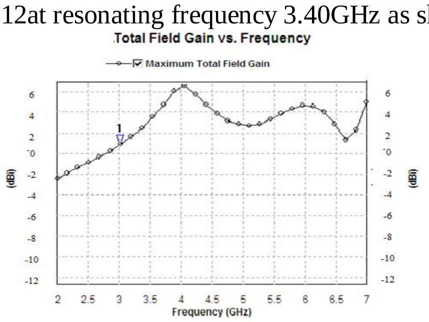

Figure 4: Variations in Gain with frequency for proposed antenna

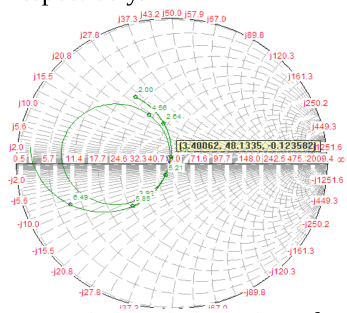

Figure 5: Variations in input impedance with frequency for proposed antenna

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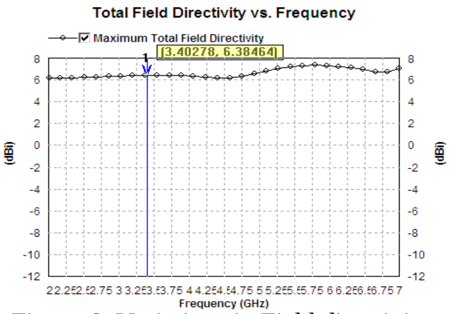

Figure 6: Variations in Field directivity with frequency for proposed antenna

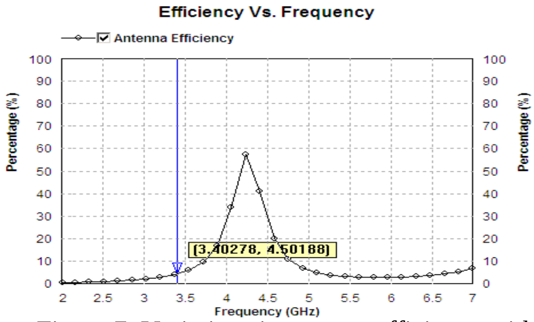

Figure 7: Variations in antenna efficiency with frequency for proposed antenna

The proposed antenna has a field directivity of 6.38dBi, antenna efficiency of 4.50%, radiating efficiency of 57.42% as shown in figure 6, 7 & 8 respectively.

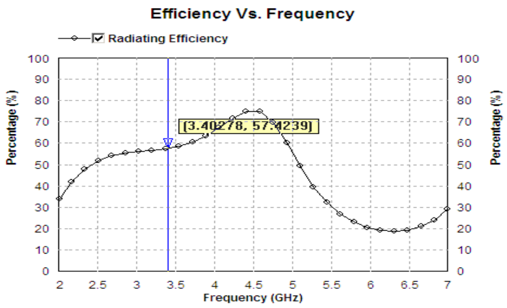

Figure 8: Variations in radiating efficiency with frequency for proposed antenna

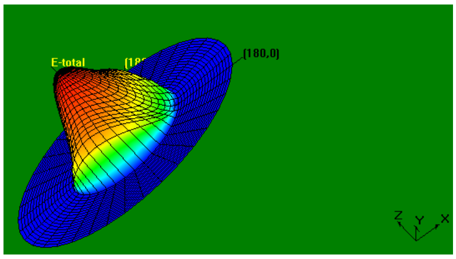

Figure 9: 3D representation for proposed antenna

Step-II Modified Microstrip patch antenna loaded with one pair of horizontal and vertical slits

Modified antenna consists of a pair of horizontal and vertical slits with dimension X1= 2mm, Y1= 6mm, S= 1mm etched on conventional microstrip patch antenna to increase the return loss and bandwidth as shown in figure 10.

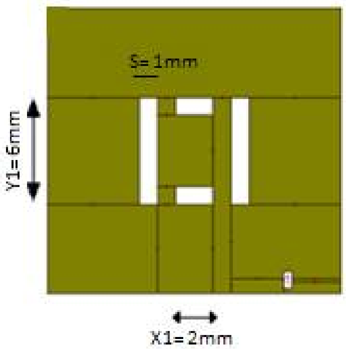

Figure 10: Geometry of modified microstrip patch Antenna loaded with one pair of slits

Figure 11 &13 shows the simulated graph of return loss and Gain of modified patch antenna. As obtained from the graph the value of return loss= (-31.49dB,-28.21dB) and Gain= (1.8dBi, 3.8dBi) at resonating frequency 3.39 GHz & 4.9 GHz respectively.

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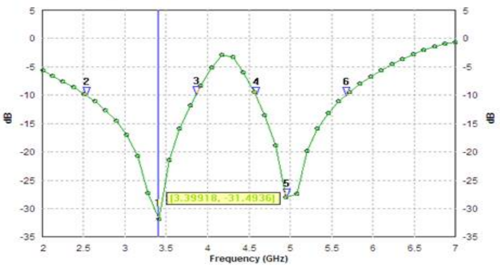

Figure 11: Variations in Return Loss with frequency for proposed antenna

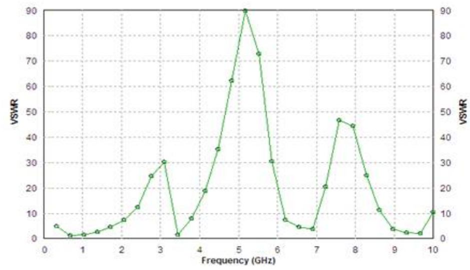

Figure 12: Variations in VSWR with frequency for modified microstrip patch Antenna loaded with one pair of slits

From figure 12 the measured value of VSWR at resonant frequency is 1.17. Figure 14 depicts the simulated variation of input impedance of antenna as a function of frequency.

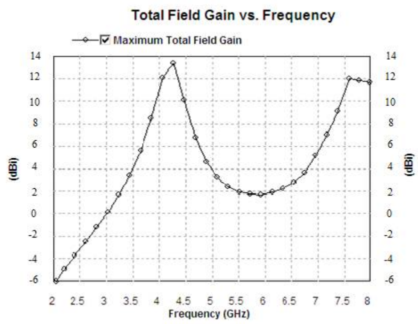

Figure 13: Variations in Gain with frequency for modified microstrip patch Antenna loaded with one pair of slits

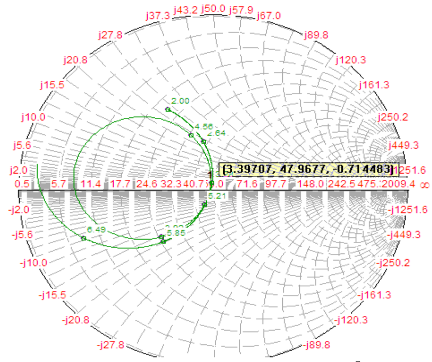

Figure 14: Variations in input impedance with frequency for modified microstrip patch Antenna loaded with one pair of slits

At resonant frequency 3.39 GHz the simulated input impedance of antenna is 47.96-j0.721ohms which is in good agreement with the 50 ohms impedance of feeding network.

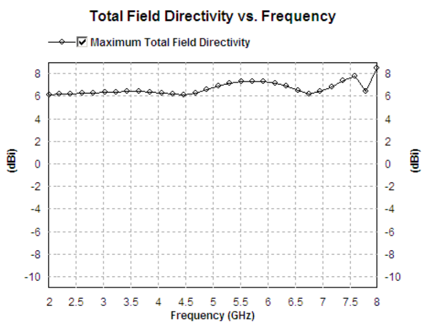

Figure 15: Variations in field directivity with frequency for modified microstrip patch Antenna loaded with one pair of slits

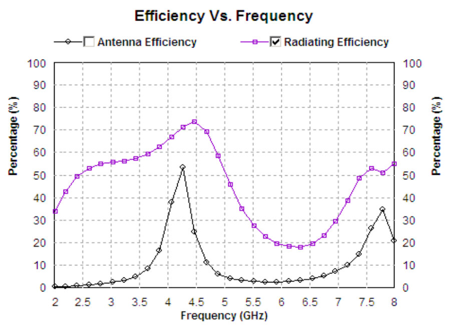

Figure 16: Variations in antenna efficiency & radiating efficiency with frequency for modified microstrip patch Antenna loaded with one pair of slits

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The other radiation characteristics of proposed antenna such as field directivity, antenna efficiency& radiating efficiency are shown in figure15 & 16 respectively. At resonant frequency the total field directivity is 6.0dBi, antenna efficiency is 4.62%& radiating efficiency is 56.92%.

Step III Modified microstrip patch antenna loaded with two pair of horizontal and vertical slits

Modified antenna consists of two pair of horizontal and vertical slits with the same slit width. The dimensions of the patch are X1=2mm, X2=6mm, Y1=6mm, Y2=10mm as shown in figure 17.

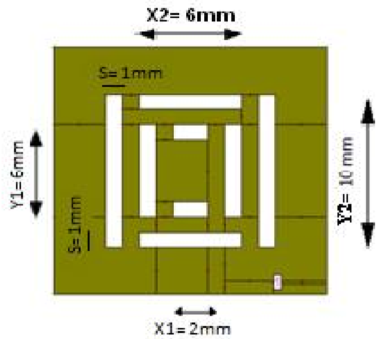

Figure 17: Geometry of Modified microstrip patch antenna loaded with two pair of horizontal and vertical slits

Simulation results of modified proposed microstrip patch antenna have return loss=-(32.43dB,-34.41dB) at resonating frequency 3.26 GHz & 4.9 GHz as shown in figure 18.

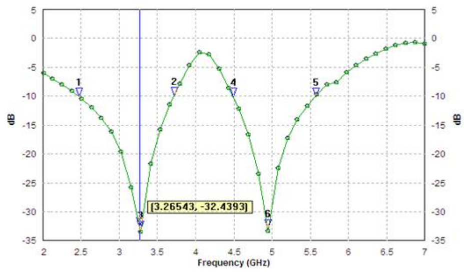

Figure 18: Variations in Return loss with frequency for modified microstrip patch Antenna loaded with two pair of slits

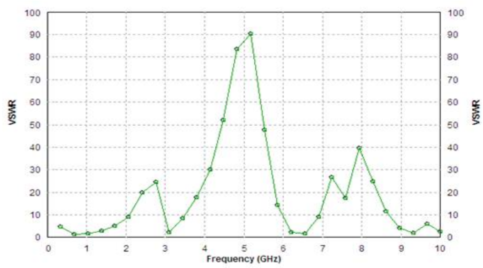

Figure 19: Variations in VSWR with frequency for modified microstrip patch Antenna loaded with two pair of slits

The simulated variation of VSWR and input impedance with frequency is shown in figure 19 & 20 respectively. From the simulated plots the value of VSWR& input impedance is 1.09 & 48.07-j0.69 ohms respectively.

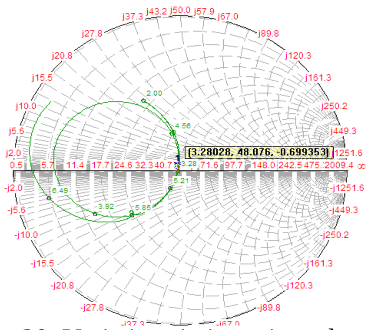

Figure 20: Variations in input impedance with frequency for modified microstrip patch Antenna loaded with two pair of slits

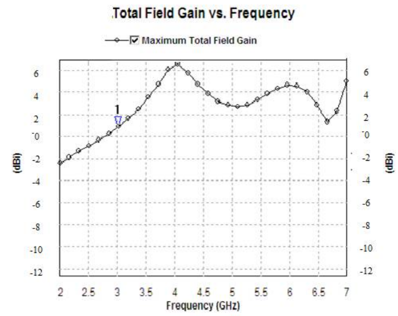

Figure 21: Variations in Gain with frequency for modified microstrip patch Antenna loaded with two pair of slits

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The proposed antenna has a field directivity of 6.38dBi, antenna efficiency of 4.16% & radiating efficiency of 52.36% as shown in figure 22 & 23 respectively.

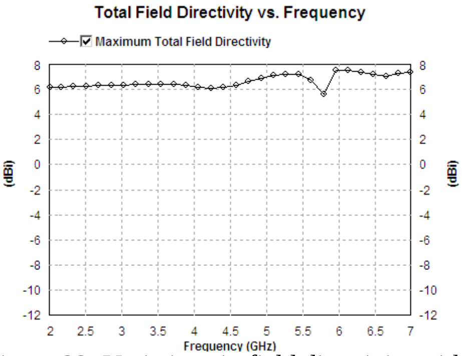

Figure 22: Variations in field directivity with frequency for modified microstrip patch Antenna loaded with two pair of slits

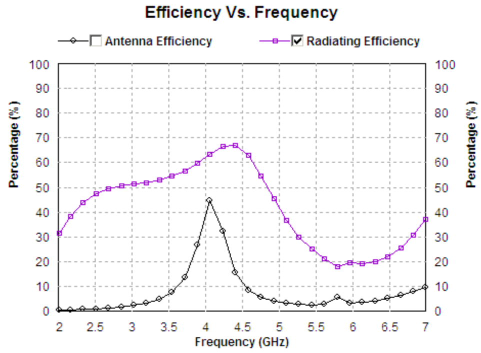

Figure 23: Variations in antenna efficiency& radiating efficiency with frequency for modified microstrip patch Antenna loaded with two pair of slits

Step IV Modified microstrip patch antenna loaded with three pair of horizontal and vertical slits

Modifed antenna consists of three pair of horizontal and vertical slits with dimension X1=2mm, X2=6mm, Y1=6mm, Y2=10mm, X3=10mm, Y3=14mm etched on conventional microstrip patch antenna as shown in figure 24.

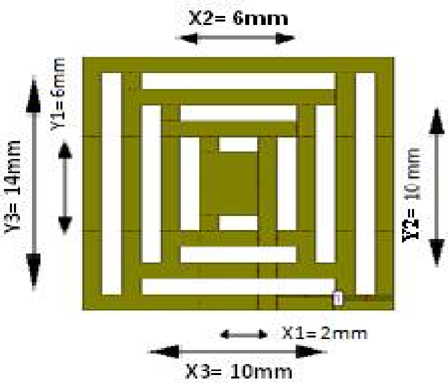

Figure 24: Geometry of Modified microstrip patch Antenna loaded with three pair of horizontal and vertical slits

Simulation results of modified proposed microstrip patch antenna have return loss=(-32.20dB, -27.12dB, -21.20dB) at resonating frequency 3.02 GHz , 4.81GHz & 6.8 GHz as shown in figure 25. The Gain values are 2.0dBi, 4.2dBi at resonating frequency 3.02 GHz, 4.81GHz respectively as shown in figure 28 respectively.

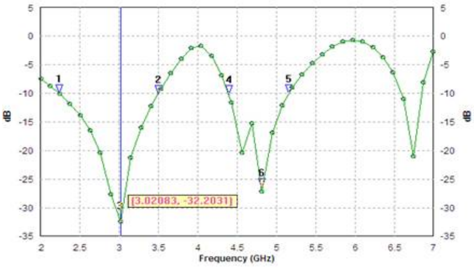

Figure 25: Variations in Return loss with frequency for modified microstrip patch Antenna loaded with three pair of slits

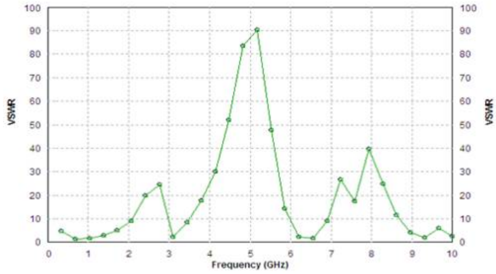

Figure 26: Variations in VSWR with frequency for modified microstrip patch Antenna loaded with three pair of slits

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The variation of VSWR with frequency as shown in figure 26 indicates that VSWR is close to 1 at resonant frequency which indicates an excellent matching between the antenna and the feed network. The input impedance variation with frequency is shown in figure 27 with a value of 48.37-j1.64 ohms.

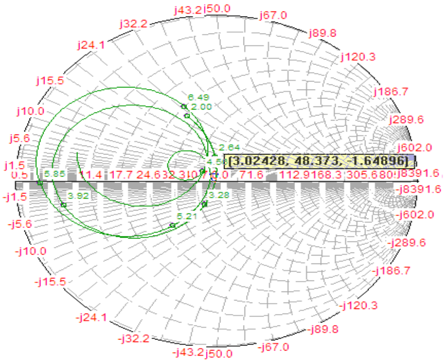

Figure 27: Variations in input impedance with frequency for modified microstrip patch Antenna loaded with three pair of slits

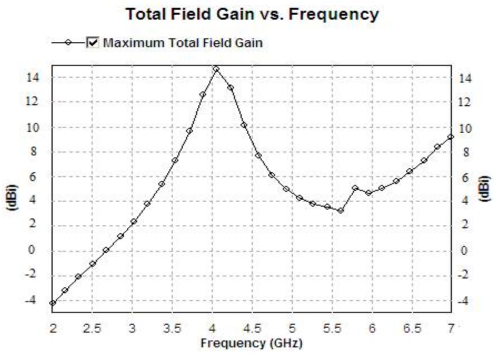

Figure 28: Variations in Gain with frequency for modified microstrip patch Antenna loaded with three pair of slits

The proposed antenna has a field directivity of 6.30dBi, antenna efficiency of 2.21%, radiating efficiency of 37.94% as shown in figure 29 & 30 respectively.

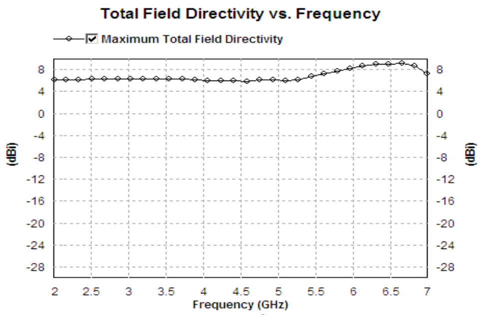

Figure 29: Variations in input field directivity with frequency for modified microstrip patch Antenna loaded with three pair of slits

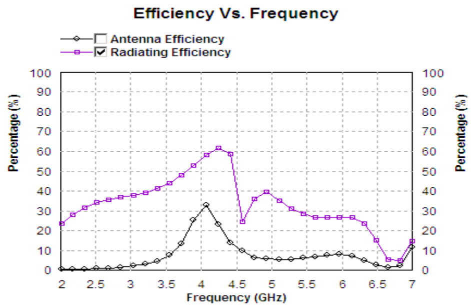

Figure 30: Variations in antenna efficiency& radiating efficiency with frequency for modified microstrip patch Antenna loaded with three pair of slits

II. RESULTS & DISCUSSION

Result obtained for all steps of modified antenna is presented in figure 31. It can be seen that resonant frequency decreases as the number of slits increases. Figure 27 depicts the input impedance loci using smith chart, as input impedance curve is passing through unit impedance circle which shows perfect matching of input.

Figure 25 shows the variation of return loss (-32.20dB, -27.12dB, -21.20dB) at three resonating frequencies 3.02GHz, 4.81GHz & 6.8GHz respectively. The input impedance of antenna is near to 49Ω which shows perfect matching between antenna and feed network. These antennas show a good matching between antenna and feed network as the value of VSWR is close to unity.

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Table 1

Comparative Study of Simulated Results for the four Antenna geometries

Antenna	Antenna Geometry 1	Antenna Geometry 2	Antenna Geometry 3	Antenna Geometry 4
Dimension of slots (mm)	NIL	S = 1 X1=2 Y1=6	S = 1 X1=2 X2=6 Y1=6 Y2=10	S = 1 X1=2 X2=6 X3=10 Y1=6 Y2=10 Y3=14
Return Loss (dB)	-26.59	-31.49	-32.43	-32.20
Total Resonant Points	1	2	2	3
Gain (dBi)	1.9	1.8	1.9	2.0
Best Resonant Frequency(GHz)	3.40	3.39	3.26	3.02
Impedance Bandwidth (%)	39.41	39.78	37.80	42.05
VSWR	1.12	1.17	1.09	1.07
Input Impedance (Ω)	48.13-j0.12	47.96-j0.74	48.07-j0.69	48.37-j1.64
Directivity (dBi)	6.38	6.0	6.35	6.30
Antenna Efficiency (%)	4.50	4.62	4.16	2.21
Radiating Efficiency (%)	57.42	56.92	52.36	37.94

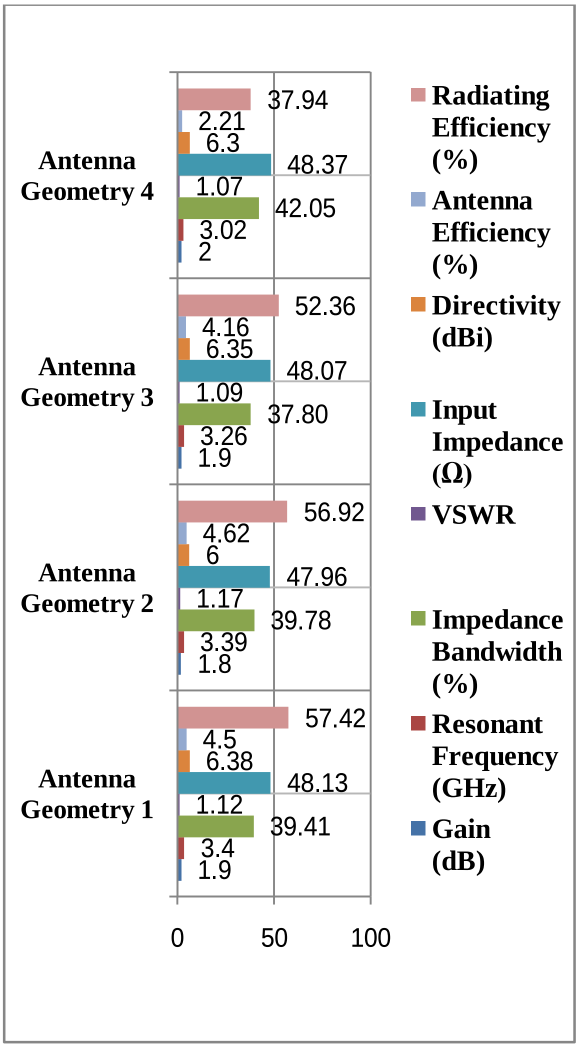

Figure 31: Comparative Analysis of Simulated Results for the four Antenna geometries

III. CONCLUSIONS

Simulation results of proposed antenna design with three pair of vertical and horizontal slits shows three resonant frequencies 3.02GHz, 4.81GHz & 6.8GHz. The impedance bandwidth of the patch antenna was initially 36% which is enhanced to 42.05% by introducing slits in the patch. The bandwidth obtained is remarkable as far as the simplicity is concerned and may be useful for multi band operation. The improvement in efficiency along with appreciable bandwidth is the major achievement. Simulation results further justify that proposed designed antenna can be utilized for WiMAX, WLAN applications.

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