RESEARCH ARTICLE OPEN ACCESS

Gain and Bandwidth Enhancement of Electromagnetic Gap-Coupled Assembly of Various Patches Forming Rhombus Shaped Microstrip Patch Antenna for C-Band Applications

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ABSTRACT
The aim of this research work is to enhance the gain and bandwidth of rhombus shaped microstrip patch antenna. For this purpose, we used electromagnetic gap-coupled technique. We design an assembly of one central rectangular patch with four triangular patches forming rhombus shaped microstrip patch antenna. We used IE3D simulation software for this work. The dielectric substrate material of the antenna is glass epoxy FR4 having ε_r=4. 4 and loss tangent 0.025. The performance of the final modified antenna is compared with that of a conventional rectangular microstrip antenna and a conventional rhombus shaped microstrip antenna. The designed antenna has two resonant frequencies 5.80 GHz and 6.29 GHz. So this antenna is applicable for the C band communication system. This electromagnetic gap-coupled antenna offers much improved impedance bandwidth 25.71%. This is approximately four times higher than that in a conventional rectangular patch antenna (Bandwidth= 6.70%) having the same dimensions.
***Keywords* –** Broadband, Electromagnetic Gap coupled technique, FR4 substrate, Gain, Resonant frequency

I. INTRODUCTION

The microstrip patch antenna has found extensive applications in wireless communication systems owing to their advantages such as low profile, conformability, low fabrication cost and ease of integration with feed network. Microstrip patch antennas come with a drawback of narrow bandwidth, but wireless communication applications require broad bandwidth and relatively high gain [1-2]. The serious problem with patch antenna is their narrow bandwidth due to surface wave losses and large size of the patch. As a result, various techniques to enhance the bandwidth are proposed [3]. Microstrip antennas are very popular nowadays due to their unbeaten advantage and qualities. The shape of antenna varies according to their use, the work is continuously getting occurred to achieve faithful factors, by small size antenna for broadband communication [4]. Several techniques have been used to enhance the bandwidth by interpolating surface modification in patch configuration [5].

To increase the gain and bandwidth of the proposed microstrip patch antenna it is divided into five triangular patches and one centralized rectangular patch. Now the modified antenna is radiated by electromagnetic gap coupling technique. A comparative analysis is also made by varying the gap between each divided patch and observing its effect on antenna performance.

II. ANTENNA DESIGN

We considered a single layer conventional microstrip patch antenna. Dimension for this conventional patch were taken as Length L=40mm and Width W= 64mm. FR4 substrate is used to design this conventional patch by us. The dielectric constant of FR4 is 4.4, loss tangent is 0.025 and The thickness of FR4 substrate is 1.6mm. The coaxial probe feed technique was used to excite the patch. Design and simulation process were carried out using IE3D simulation software 2007 version 12.30.

The geometry of the conventional rectangular microstrip patch antenna is depicted in figure 1.

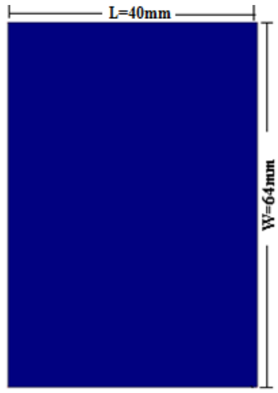

Figure 1: Geometry of Conventional Rectangular Patch Microstrip Antenna

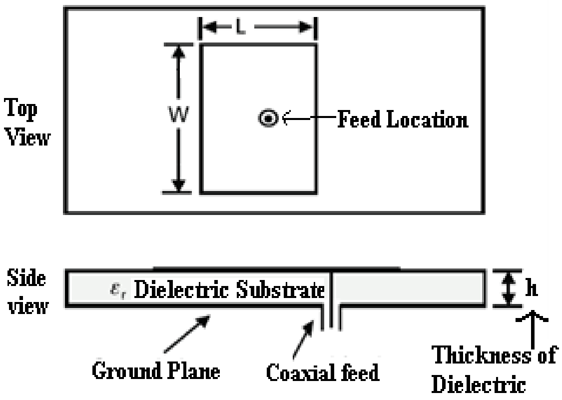

Figure 2: Structure of Conventional Rectangular Patch Microstrip Antenna

III. RESULTS

The conventional rectangular patch antenna is simulated first using IE3D software. This simulated reflection coefficient curve shows that the our conventional rectangular patch antenna is resonating at frequency 3.79 GHz as shown in figure 3. The value of impedance bandwidth of conventional rectangular microstrip patch antenna is 6.70%. The simulated input impedance of the antenna at resonance frequency 3.79 GHz is (48.16 - j 3.98) ohm which is close to 50 ohm impedance. Since the rectangular patch antenna has low bandwidth, so to improve the performance of this antenna further modifications are required.

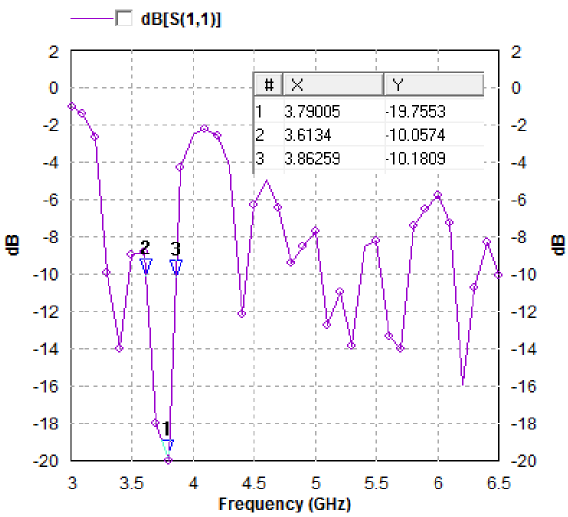

Figure 3: Variation of Reflection Coefficient v/s Resonant Frequencies

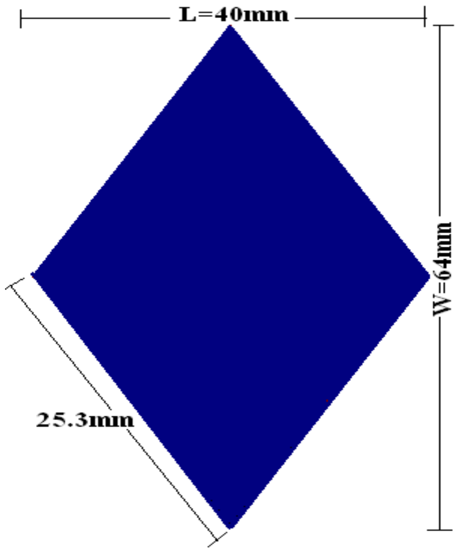

Figure 4: Structure of Rhombus Shaped Microstrip Patch Antenna (RSMPA)

So we designed the rhombus shaped antenna by cutting four triangles from the corner sides. The structure of Rhombus Shaped Microstrip Patch Antenna (RSMPA) is shown in figure 4. The figure 5 shows the variation of reflection coefficient with frequency. It shows that the modified antenna is resonating at 4.098 GHz frequency. After modification of rectangular patch we get the value of impedance bandwidth of RSMPA is 9.5%.

The simulated result shows that the input impedance at resonant frequency 4.098 GHz is (49.80-j2.4) ohm which is very close to 50ohm.

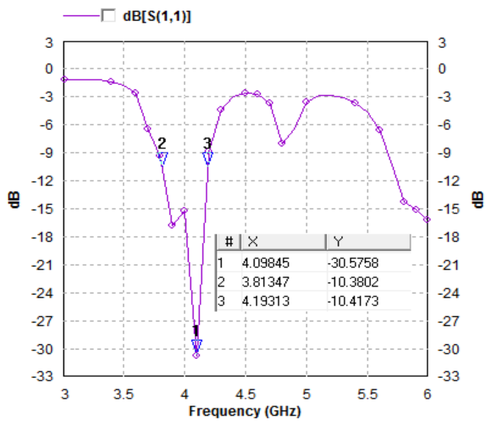

Figure 5: Variation of Reflection Coefficient v/s Resonance Frequency of RSMPA.

The gain of the RSMPA is 0.08 dBi, which is very low and needed to be improved. Still, we have not received a precise bandwidth. In our next step of designing process, we modified our RSMPA to get wider bandwidth and higher gain. We named this modified patch electromagnetic gap-coupled Rhombus Shaped Microstrip Patch Antenna having a central square patch (EGCRSMPACSP) with gap coupling 0.8mm. We divided the single patch into five patches (Assembly of one center square and four triangular) as shown in figure 5. The gap between each patch is 0.8mm.

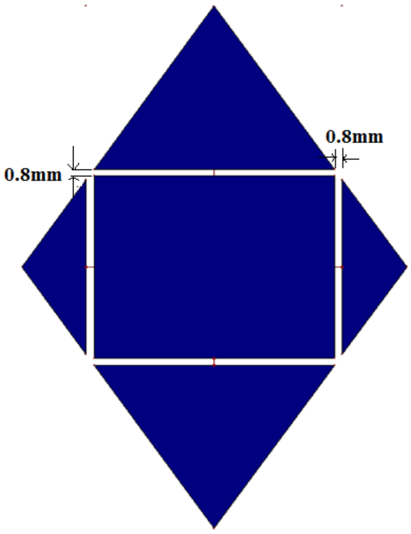

Figure 6: Structure of EGCRSMPACSP with gap coupling 0.8mm

The figure 6 shows the variation of reflection coefficient with resonant frequencies. It shows that the after second modification the antenna is resonating at three resonant frequencies 5.40 GHz, 5.90 GHz and 6.20 GHz. In this case we achieved the bandwidth of 5.37% at 5.400 GHz and the bandwidth of 10.26%, corresponding to the central frequency 6.05 GHz.

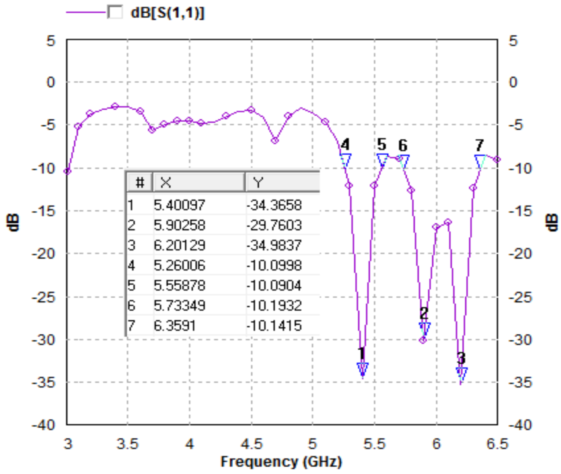

Figure 7: Variation of Reflection Coefficient v/s Resonance Frequencies of EGCRSMPACSP

The simulated gain at three resonant frequencies 5.40GHz, 5.90GHz and 6.20 GHz are 1.28 dBi, 1.15 dBi and 1.56 dBi respectively. The smith chart for this antenna is shown in the figure 8. At the resonant frequencies 5.400GHz, 5.902 GHz and 6.201 GHz the measured input impedances are (48.55-j1.30) ohm, (48.28+j1.97) ohm and (50.53-j1.89) ohm.

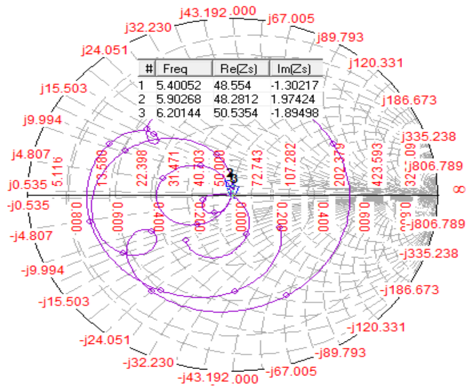

Figure 8: Smith chart of EGCRSMPACSP with gap coupling 0.8mm

After introducing the electromagnetic gap coupling we achieved a comparative higher gain and bandwidth than RSMPA but still enhancement of bandwidth is not satisfactory. To accomplish our object we did some more modification in the previous geometry. Now we have chosen electromagnetic gap-coupled Rhombus Shaped Microstrip Patch Antenna having a central rectangular patch (EGCRSMPACRP) with 0.2mm gap coupling. The geometry of the modified RSMPA antenna is depicted in figure 9.

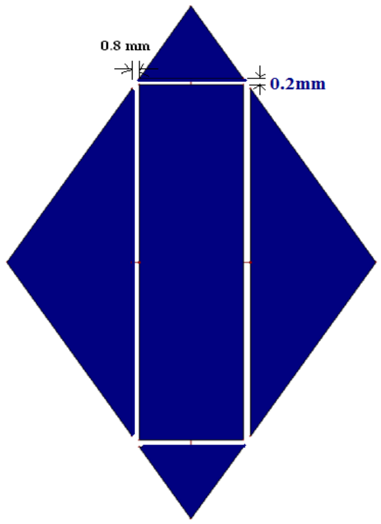

Figure 9: Structure of EGCRSMPACRP with 0.2mm gap coupling

In this modified RSMPA we firstly kept the gap of 0.2mm between each patch. The figure 10 shows the variation of reflection coefficient with frequency. It shows that the modified antenna is resonating at resonant frequency 5.20GHz. At this resonant frequency input impedance is (48.55+j6.32) ohm which is shown in figure 11.

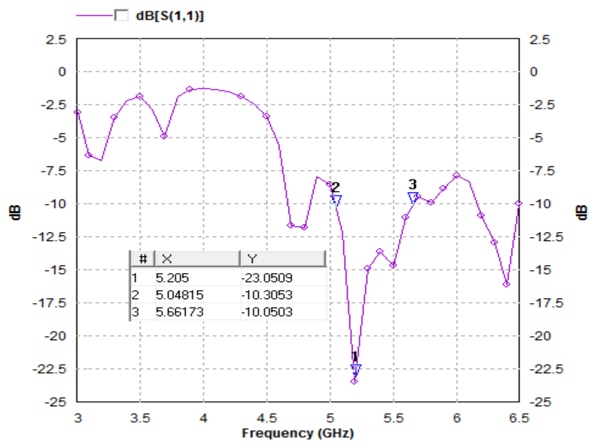

Figure 10: Variation of Reflection Coefficient v/s Resonance Frequency of EGCRSMPACRP with 0.2mm gap coupling.

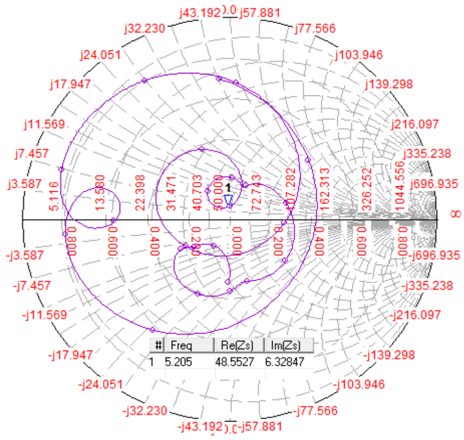

Figure 11: Smith chart of EGCRSMPACRP with 0.2 mm gap coupling.

The performance of this antenna is found better than the previous one as the bandwidth at the resonant frequency 5.205 GHz is 11.58% and the gain is 2.02 dBi. Now for the sake better performance further modification in the patch is required. So we increase the gap between each divided patch of 0.4mm, 0.6mm and 0.8mm with the difference of 0.2mm. After analyzing results of each geometries we get optimized results for gain and bandwidth at 0.8mm gap coupling.The structure of electromagnetic gap-coupled Rhombus Shaped Microstrip Patch Antenna having a central rectangular patch (EGCRSMPACRP) with 0.8mm gap coupling is shown in figure 12.

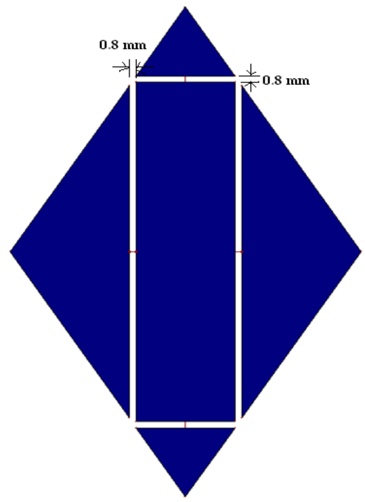

Figure 12: Structure of EGCRSMPACRP with 0.8mm gap coupling.

The reflection coefficient curve with respect to resonance frequencies is shown in figure 13.

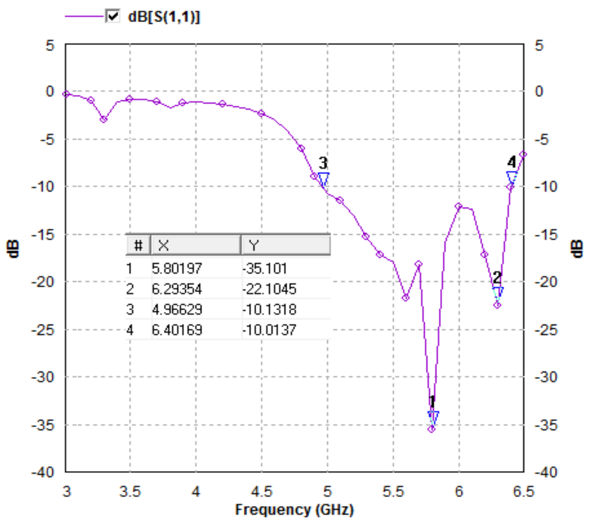

Figure 13: Variation of Reflection Coefficient v/s Resonant Frequency of EGCRSMPACRP with 0.8mm gap coupling

It is clear from the curve that this antenna mainly resonates at frequencies 5.80GHz and 6.29GHz. The smith chart of the antenna is depicted in figure 14. We can see from the figure that the impedances are (49.14-j1.38) ohm and (50.98-j5.32) ohm at two resonant frequencies 5.80GHz and 6.29GHz respectively.

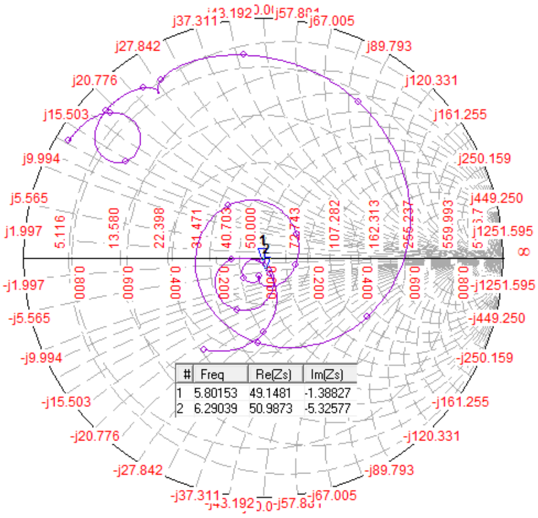

Figure 14: Smith chart of EGCRSMPACRP with 0.8mm gap coupling

The gain curve for this modified RSMPA antenna is shown in figure 15. The simulated gain at frequencies 5.80 GHz and 6.29 GHz are 4.45 dBi and 2.35 dBi respectively. So finally we got broadband antenna with good gain.

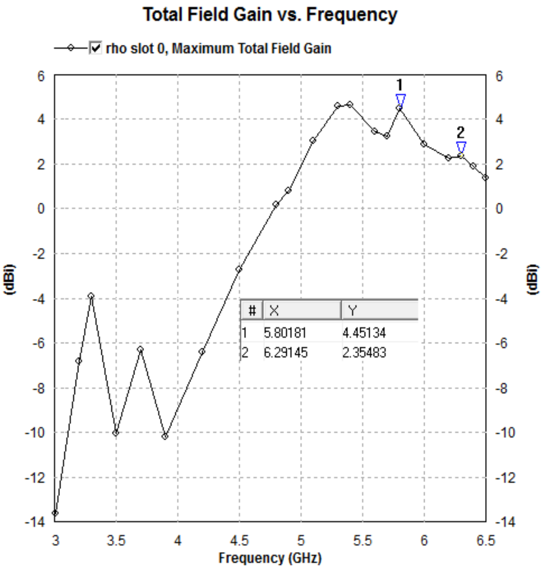

Figure 15: Variation of gain v/s resonance frequencies

The curve between directivity and resonant frequencies is shown in fig. 15. The directivity of this antenna is 9.16 dBi and 7.86 dBi for the resonant frequencies 5.80 GHz and 6.29 GHz respectively.

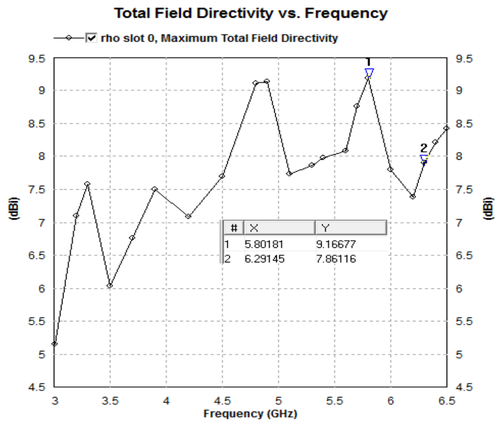

Figure 16: curve between directivity and resonant frequencies

The curve between radiation efficiency and resonant frequencies is shown in figure 17.

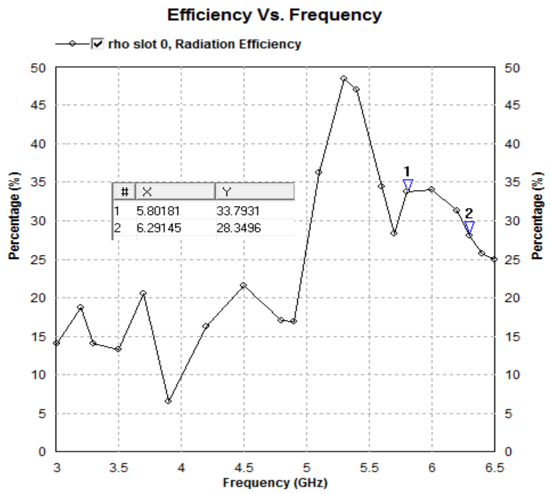

Figure 17: curve between radiation efficiency and resonant frequencies

The radiation efficiency of the antenna is 33.79 at 5.80 GHz and 28.34 at 6.29 GHz. The variation of VSWR with the resonance frequencies is shown in figure18. The values of VSWR at resonance frequencies 5.80 GHz and 6.29 GHz are 1.03 and 1.17 respectively.

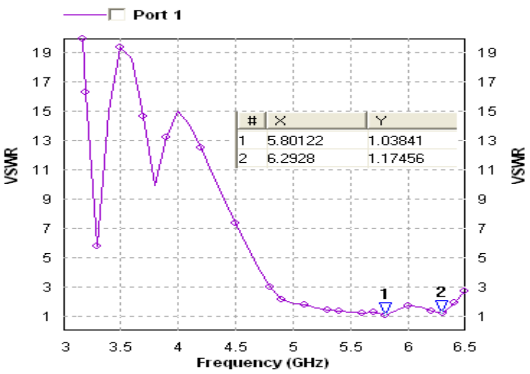

Figure 18: curve between VSWR and resonant frequencies

The radiation patterns of resonant frequencies 5.80 GHz and 6.29GHz are shown in figure 19 and figure 20 respectively. The direction of maximum radiation is shifted 30^o left from normal to the patch geometry at 5.8GHz. At 6.3GHz the direction of maximum radiation is shifted 30^o left and 30^o right side of the normal to the patch as represented in the above figures.

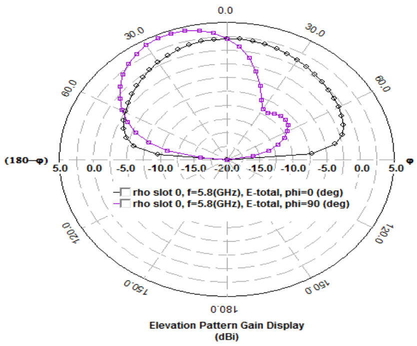

Figure 19: 2D polar Radiation pattern at 5.8 GHz

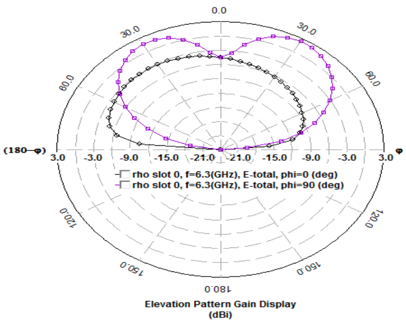

Figure 20: 2D polar Radiation pattern at 6.3 GHz

IV. CONCLUSION

The proposed electromagnetic five elements gap-coupled Rhombus Shaped Microstrip Patch Antenna having a central rectangular patch (EGCRSMPACRP) with 0.8mm gap coupling, resonates at two frequencies 5.80GHz and 6.29GHz for C band applications. After the analyzing the tabular results one can conclude that sequential increase in the gain and bandwidth up to 0.8mm gap coupling. After increasing the gap further, the bandwidth of antenna starts decreasing. The effect of gap coupling on the antenna performance is observed. The designed antenna enhances the gain up to 4.45dBi, this is quite encouraging. Finally, we got much improved bandwidth of 25.71% in comparison with a conventional rectangular patch antenna having a bandwidth of 6.70%.

V. ACKNOWLEDGEMENT

We extended our sincere thanks and gratitude to Professor Deepak Bhatnagar for providing the simulation facilities at their research laboratory and Dr. S.M. Seth, who provides us a valuable direction for research work.

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Table I: Comparison of antenna parameters of different types of micrstrip patch antenna

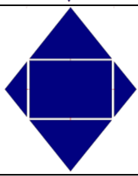
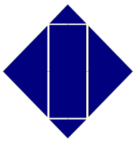
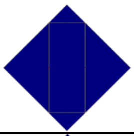
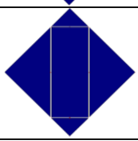
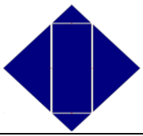
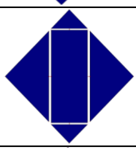
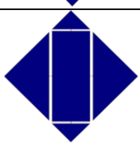
Type of Patch Antenna	Designed Patch Shape	Resonating Frequency (GHz)	Gain (dBi)	Directivity (dBi)	Bandwidth (%)
Conventional Rectangular		3.79	1.19	9.23	6.70
Rhombus shaped		4.098	0.08	6.63	9.5
RSMPA with central square patch with gap coupling 0.8mm		5.400	1.28	8.33	5.37
		5.902 6.201	1.15 1.56	8.43 9.33	10.26
RSMPA with central Rectangular patch with gap coupling 0.8mm		5.80	4.45	9.16	25.71
		6.29	2.35	7.86	

Table II: Effect of gap coupling / spacing on the performance of modified gap-coupled RSMPA

Designed Patch	Gap between each element (mm)	Resonating Frequency (GHz)	Gain (dBi)	Directivity (dBi)	Bandwidth (%)
	0.2	5.205	2.02	6.38	11.58
	0.4	5.402	3.48	7.61	19.64
	0.6	5.801	4.39	9.10	25.35
	**0.8**	**5.80** **6.29**	**4.45** **2.35**	**9.16** **7.86**	**25.71**
	1.0	5.595 5.890 6.293	3.63 4.45 2.40	7.79 9.16 7.92	20.13