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Broadband Electromagnetic Gap-Coupled Assembly of Patches Forming Trapezoidal Microstrip Antenna for S-Band Application

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ABSTRACT
In this paper our aim is to design an Electromagnetic Gap Coupled Trapezoidal Shaped Microstrip Patch Antenna [GCTSMPA] which is suitable for Microwave S-band applications. This antenna offers much improved impedance bandwidth 20%. The proposed antenna has achieved a suitable gain of 3.90 dBi and 0.99 dBi at resonating frequencies 3.59GHz and 4.10 GHz respectively. Other antenna parameters such as antenna input impedance, the Voltage Standing wave ratio (VSWR), Return Loss, Gain and Bandwidth are simulated for the proposed antenna. Antenna geometry and other simulated results are also presented in a tabular form. The antenna designed on glass epoxy FR-4 dielectric substrate, that has a dielectric constant 4.4, a Loss tangent 0.025 and thickness of the dielectric substrate h=1.6mm.

Keywords **–**Electromagnetic gap-coupled, S-Band, GCTSMPA, Loss tangent, FR4 Substrate

I. INTRODUCTION

The design and development in microstrip antennas have undergone with a tremendous growth because of its light weight, conformability, low cost and ease of fabrication [1-3]. In this paper the design and analysis of trapezoidal shaped microstrip patch antenna have been considered. The designed trapezoidal shaped antenna has broadband operation and provides better bandwidth and gain as compared to the rectangular shaped patch antenna of the same dimensions [4]. Microstrip patch antennas are widely used in S and C band because they posses embedded structure within compact geometries, better angular coverage and desirable gain depending upon the shape [5]. However, some serious problems are also associated which includes its narrow bandwidth due to surface wave losses and large size dependency of patch for getting some good results. Nowadays, many researchers are proposing their results to enhance the bandwidth with the smallest size patch. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane [6].

II. RECTANGULAR MICOSTRIP PATCH ANTENNA

We have used glass epoxy FR-4 as a dielectric substrate having 4.4 as a dielectric constant and loss tangent 0.025 To simulate the antennas. Thickness of dielectric (h) is 1.6 mm.

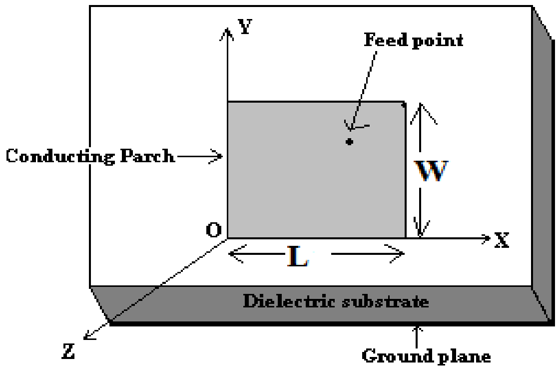

Fig.1: 3D view of Rectangular Microstrip Patch Antenna

We have chosen a rectangular microstrip patch antenna, with dimensions L=44 mm and W=36 mm. The 3D & 2D geometry of the conventional rectangular microstrip patch antenna (CRMPA) is presented in figures 1 and 2 respectively.

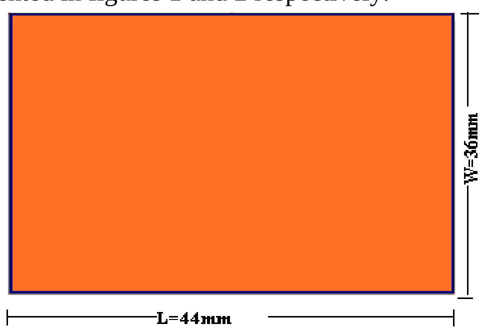

Fig.2: Geometry of Rectangular Patch Antenna

This conventional antenna is resonating at frequencies 3.19 GHz, 4.79 GHz and 5.70 GHz as shown in figure 3.

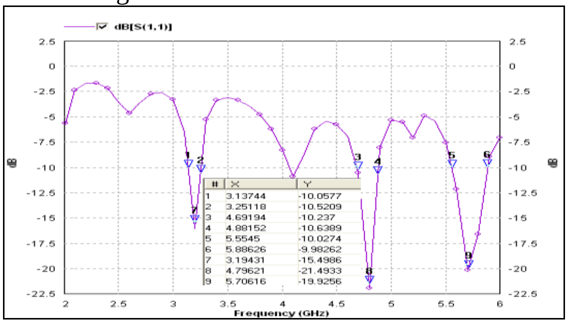

Fig.3: Variation of reflections coefficient versus resonating frequencies of CRMPA

After impedance matching (50 Ω) we also analyzed to gain & its percentage bandwidth and observed that the Conventional Rectangular Microstrip Patch Antenna (CRMPA) posses low bandwidth of 3.7%, 4.17% and 5.41% at 3.19 GHz, 4.79GHz and 5.70GHz respectively.

III. TRAPEZOIDAL MICOSTRIP PATCH ANTENNA

For the purpose of enhancement in the bandwidth of rectangular patch we have to apply the broadband technique i.e. modification of patch geometry. We modified rectangular patch by cutting two opposite right triangles to convert a rectangular patch in to trapezoidal patch. This geometry is shown in figure4. The patch mounted on a FR-4 substrate and above from the ground plane at a height of 1.6 mm. As we energized at feed location X = 2mm and Y=3.5mm the antenna starts resonating at frequency 2.8GHz having bandwidth 5.51% as shown in figure 5, Which is still unsatisfactory in terms of broadband antenna, therefore antenna required further modifications.

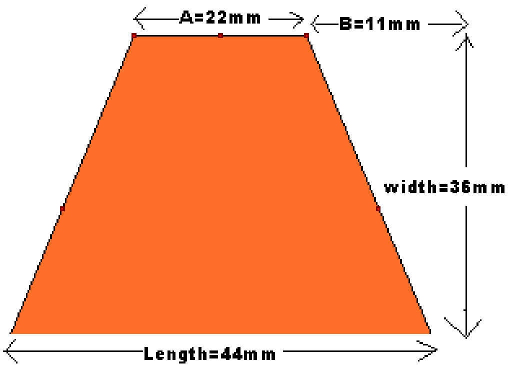

Fig.4: Geometry of a Trapezoidal Microstrip Patch Antenna

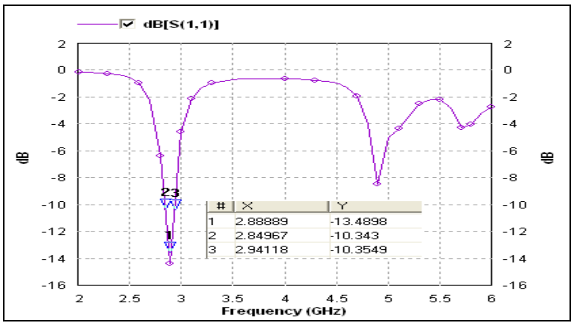

Fig.5: Variation of reflection coefficients versus resonating frequencies of Trapezoidal microstrip patch antenna

IV. GAP-COUPLED TRAPEZOIDAL SHAPED MICOSTRIP PATCH ANTENNA

The bandwidth of the microstrip antennas can be further improved by using the gap-coupled structure. In this structure, a parasitic patch is placed close to the feed patch and gets excited through the coupling between the patches. The feed patch is excited by a feeding method and the parasitic patch is excited by gap-coupling. If the resonant frequencies of these two patches are close to each other, then the broad bandwidth is obtained as shown in Figure 7. The overall input return loss will be the superposition of the responses of the resonators resulting in a wide bandwidth [11]. By adjusting the feed location and various dimension parameters of the gap-coupled microstrip antennas, the bandwidth can be enhanced. If the dimensions of the feed patch and parasitic patch are same, due to coupling the coupled structure creates two different resonant frequencies. Therefore, we have to enhance the bandwidth of the trapezoidal patch. Now to further enhance the bandwidth by above technique, we divided our same trapezoidal patch geometry in six segments.

Table 1: Modified trapezoidal microstrip patch antenna (GCTSMPA) design parameters

S. No.	Parameters	Design Considerations
1	Patch dimensions	L=44mm, W=36mm
2	Dielectric substrate (FR4)	tanδ= 0.025, ε_r=4.4
3	Substrate height	1.6 mm
4	Probe Radius	0.62 mm
5	Width of gaps	0.5mm for Vertical Gap and 1.0mm for Horizontal Gap

The modified Trapezoidal patch includes two triangles, two rectangles and two right trapezoids by cutting two vertical slits having same width 0.5 mm and one horizontal slit having width 1.0mm as shown in figure 6. This antenna is energized from lower rectangular part of the gap-coupled trapezoidal patch, remaining five parasitic patches are coupled electromagnetically. Thus, by single feed all six parts of modified patch are radiated.

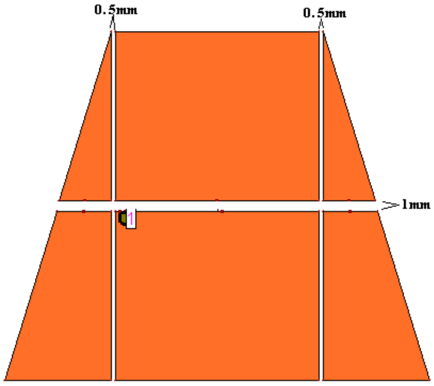

Fig.6: Geometry of a gap-coupled trapezoidal shaped (L=44mm, Width=36mm) Microstrip Patch antenna [GCTSMPA] with feed location

After applying modification for gap-coupled technique, we received better results in terms of bandwidth, gain and at the same time desired frequency bands for broadband applications. The figure 7 shows the variation of reflection coefficient with frequency. It shows that design considerations of the final modified antenna are resonating at 3.60 GHz and 4.10 GHz. The impedance bandwidth of the antenna is 20%, corresponding to the central frequency 3.8GHz.

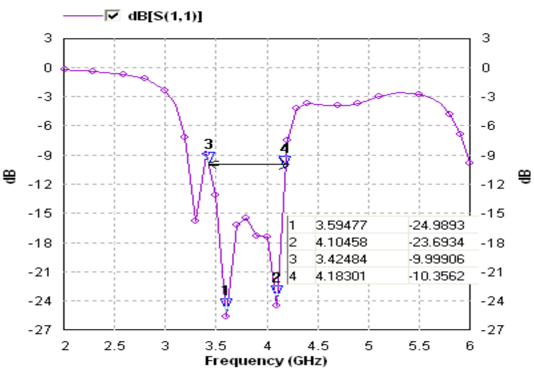

Fig.7: Variation of reflection coefficients versus resonating frequencies of GCTSMPA

The simulated results also show that the input impedance at two resonating frequencies 3.6 GHz and 4.10 GHz are close to 50 ohm impedance of the feed line considered in the present work. These results, as per figure 8 indicates that simulated antenna is nicely matched with the feed line and very little reflections are taking place at the feed location.

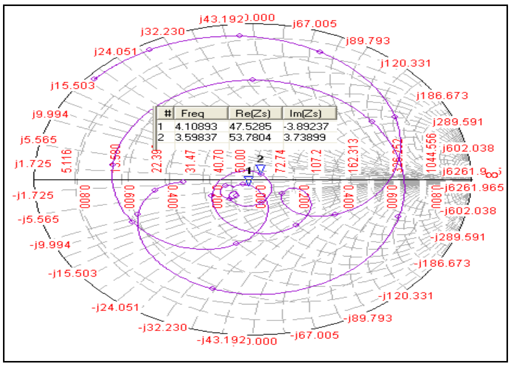

Fig.8: Variation of input impedance versus resonating frequencies of GCTSMPA

The gain of modified trapezoidal microstrip patch antenna [GCTSMPA] is 3.9dBi and 0.99dBi at frequency 3.59 GHz and 4.10 GHz respectively as shown in figure 9.

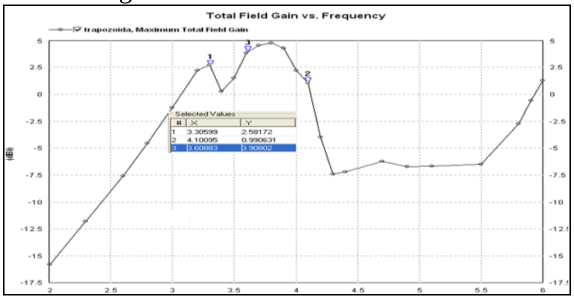

Fig.9: Variation of Gain versus resonating frequencies of GCTSMPA

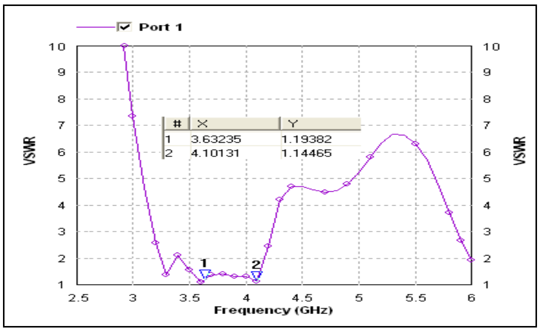

Fig.10: Variation of VSWR versus Resonance frequency of GCTSMPA.

The simulated VSWR for the two considered resonating frequency 3.6 GHz and 4.10 GHz are 1.1 and 1.31 respectively, which are close to unity.

Variation of gain with frequency is given in figure 9. Which shows that gain with respect to these two resonating frequencies is 3.90 dBi and 0.99 dBi respectively. Figure 11 shows the 3D Radiation Pattern of modified GCTSMPA at 3.6 GHz. Figure 12 shows the 2D radiation pattern in polar form. This radiation pattern is identical and uniform at the 3.6 GHz resonating frequency, whereas the pattern of figure 13 is slightly bent at an angle 30 degree at the

4.1 GHz resonating frequency. It means that the direction of maximum radiations is normal [4] to the patch geometry as shown in figure 9.

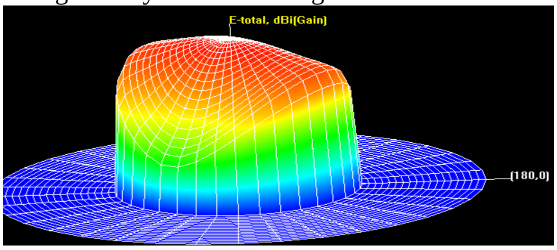

Fig.11: 3D Radiation Pattern of modified GCTSMPA at 3.6 GHz

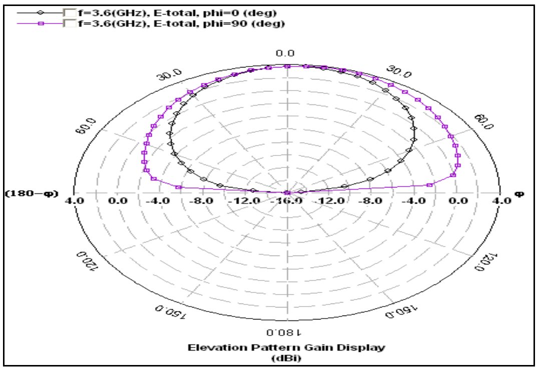

Fig.12: 2D Radiation Pattern of modified GCTSMPA at 3.6GHz

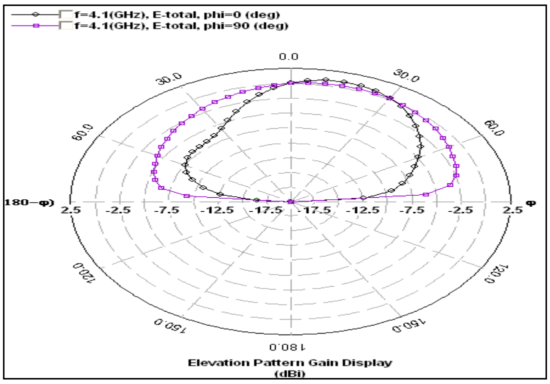

Fig.13: 2D Radiation Pattern of modified GCTSMPA at 4.10GHz

V. CONCLUSION AND DISCUSSION

The Electromagnetic Gap Coupled Trapezoidal Shaped Microstrip Patch Antenna is designed and simulated in this research work. This antenna is suitable for Microwave S-band applications. The whole analyses are carried out by considering three geometries with the same dielectric substrate glass epoxy FR-4. We conclude that due to the effect of gap-coupling the bandwidth of trapezoidal shaped microstrip patch antenna (GCTSMPA) enhanced up to 20 %, corresponding to the center frequency 3.8 GHz in comparison with a rectangular patch antenna having bandwidth 5.5%. It is also concluded that in case of gap-coupled microstrip patch geometry, if gap/ spacing between the patches will increase from 0.5mm to 1.0mm than due to coupling effect and the combination of various resonant frequencies corresponding to each parasitic patch the effective bandwidth will be increased up to 20%. We are also developing a gap-coupled trapezoid microstrip patch antenna and its actual outcome will be tested in due course.

VI. ACKNOWLEDGEMENT

We extended our sincere thanks and gratitude to Professor Deepak Bhatnagar for providing the simulation facilities at their antenna research laboratory at University of Rajasthan, Jaipur and Dr. S. M. Seth, Chairman Poornima College of Engineering, Jaipur, for providing us valuable direction for research work.

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Table 2: Comparison Variation of Antenna Parameters between antenna parameters of rectangular & modified trapezoidal patch antennas

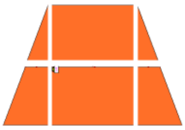
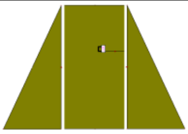
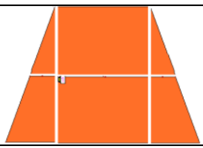
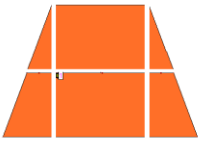
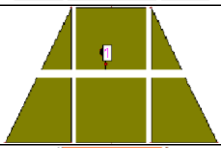
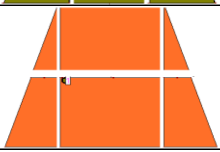
Type of antenna	**Designed Patch**	**Dimensions (mm)**	**Resonating Frequency (GHz)**	**Gain (dBi)**	**Bandwidth (%)**
Conventional Rectangular Microstrip Patch antenna [CRMPA]		L=44,W=36	3.19, 4.79, 5.70	1.05, 2.65, 4.04	3.7, 4.17, 5.41
Trapezoidal Microstrip Patch antenna [TMPA]		L=44,W=36, A=22,B=11	2.8	3.4	5.51
Electromagnetic Gap-Coupled Trapezoidal shaped Microstrip Patch antenna [GCTSMPA]		L=44, W=36, Vertical Slot width=0. 5mm and Horizontal Slot width= 1.0mm	3.6, 4.10	3.90, 0.90	20

Table 3: Variation of Antenna Parameters of Electromagnetic Gap Coupled Trapezoidal shaped Microstrip Patch antenna (L=44mm, W=36mm) with width of vertical & horizontal gap-coupling

Designed Microstrip Patch antenna	**Vertical Gap width (mm)**	**Horizontal Gap width (mm)**	**Resonating Frequency (GHz)**	**Gain (dBi)**	**Bandwidth (%)**
	0.5	Not applicable	2.99, 5.79	0.88, 2.06	2.04, 10.18
	0.5	0.5	5.80, 2.99	1.6, 0.61	5.36, 2.66
	0.8	0.8	5.68 5.43	4.74 5.01	9.69 12.17
	0.8	1.0	4.19, 3.56, 3.29	0.89 1.23 1.36	2.03 4.3 3.6
	0.5	1.0	3.60, 4.10	3.90, 0.99	20