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Broadband Gap-Coupled Assembly of Patches Forming Elliptical Microstrip Patch Antenna for C- Band Applications

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Abstract: The radiation performance of a compact gap-coupled assembly of patches forming the geometry of elliptical patch antenna is simulated using glass epoxy FR4 substrate material. This assembly is achieved by cutting conventional elliptical patch antenna geometry into four independent patches through three narrow slits parallel to the minor axis of elliptical patch. So the elliptical patch is divided into four independent patches out of which two outer patches and two inner are identical in shape and size. The part of the inner patch in the first quadrant is exited through inset feed, and the three other patches are gap coupled to this patch. This arrangement of antenna elements resonate at the frequency 6.2GHz. This arrangement gives an improved bandwidth (~20%). The radiation pattern of antenna at resonant frequency is almost identical in shape and nature. Details of the antenna design and simulated results are presented and discussed systematically. The simulated result shows that the antenna is resonating at frequency 6.2GHz. This antenna successfully achieves the bandwidth of 19.9% (at VSWR: 1.15) and suitable for C- band applications.

Keywords: Microstrip antenna, gap-coupled antenna, elliptical patch antenna.

I. INTRODUCTION

Microstrip antennas are now finding applications in those communication systems where small size, light weight, low profile, and low cost antennas are required. These antennas can be easily fabricated and assembled with other circuit components. However, basic geometries of these antennas suffer narrow bandwidth, which is of the order of few percent of the operational frequency. Due to this reason, microstrip antennas in their simplest form fail to find commercial applications. In modern communication systems, higher antenna bandwidth is a major requirement and broadening of bandwidth of antennas has been one of the major subjects concerning antenna designers. To meet these demands, several alternatives have been suggested in recent past for printed antennas with improved bandwidth. Among the conventional patch geometries, microstrip antennas with rectangular, circular, or triangular shapes are extensively analyzed and applied in different applications. Other regular shapes of patch geometries are rarely touched on perhaps because of the involvement of difficult mathematical modelling and boundary conditions in their analysis. For example, elliptical patch geometry cannot become popular, perhaps because of the involvement of elliptical coordinates and application of Mathieu function in theoretical analysis. However, owing to their advantage of having smaller patch size at a given frequency, as compared with rectangular and circular patch antennas, several papers on elliptical patch antennas may be seen in recent times. Kumar and Gupta [9] reported incorporation of two additional resonators gap-coupled to the radiating edges of a rectangular patch for increasing bandwidth. Bhardwaj et al. achieved wide bandwidth with a square patch antenna by applying triangular notch in one of its edges. Rafi and Shafai applied V-shaped slot inside diamond shaped microstrip patch antenna to improve its bandwidth. The bandwidth of the microstrip array antenna can be enhanced by using a gap-coupled elements in the resonator of the array antenna as suggested by Meshram and Vishvakarma. Use of parasitic element in coplanar configuration not only increases bandwidth, but also increases the overall size of the antenna and hence limits its applications. This limitation can be

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compensated by embedding suitable slots in the radiating patch. With size reduction at a fixed operating frequency, impedance bandwidth of antenna usually decreases. Enhanced impedance bandwidth may be achieved either by increasing substrate thickness of antenna or by using meandered ground plane. In this communication, enhanced radiation performance of a compact gap-coupled assembly of patches forming the geometry of elliptical patch antenna is simulated using glass epoxy FR4 substrate material.

II. DESIGN SPECIFICATIONS

A. Design of simple elliptical microstrip antenna

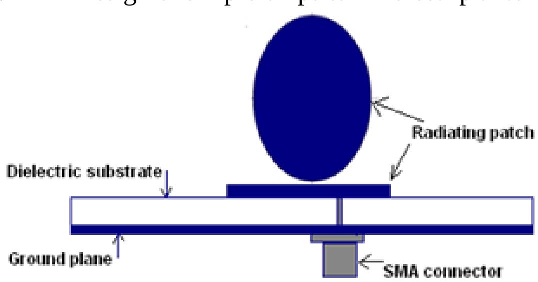

Figure 1 Side and top view with feed arrangement of designed elliptical patch antenna

A conventional elliptical patch microstrip antenna (EPMA) with considered inset feed arrangement is shown in Figure 1. The dimensions of its semi major and semi minor axis are ‘‘a’’=10 mm and ‘‘b’’=15 mm, respectively with ellipticity ratio (a/b) is 0.66. The metal thickness is 0.0035 mm, and patch geometry is printed on glass epoxy FR4 (ε_r = 4.4, tan δ = 0.024 and substrate height ‘‘h’’= 1.59 mm).

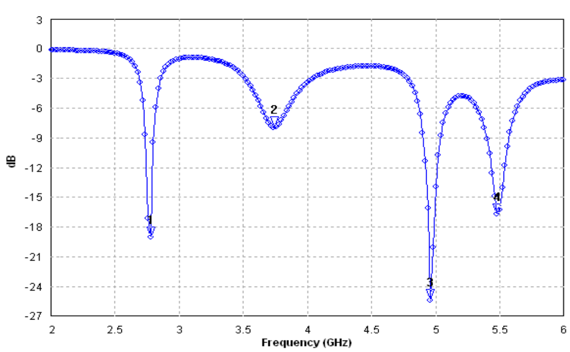

Figure 2 Simulated reflection coefficient of EPMA

The antenna is feed through 50 Ω coaxial cable through inset feed arrangement with MSA connector having probe diameter 1.24 mm. Before designing this antenna geometry, extensive simulation is carried out by using IE3D electromagnetic simulator. The dimensions of antenna are selected in such a way that resonance frequency of considered conventional EPMA may lie in C band. Simulated results reveal that on exciting the patch with (50 Ω) coaxial probe at feed location (x=4.75mm,y=4.5 mm), antenna resonates at three resonant frequencies 3.83, 4.97, and 5.6 GHz. The bandwidths of EPMA in both these bands are very narrow (about 2–3%). Modern communication systems need dual frequency or dual band antennas in association with higher bandwidth; therefore to achieve higher bandwidth, results need improvement.

B. Gap coupled elliptical shaped microstrip patch antenna

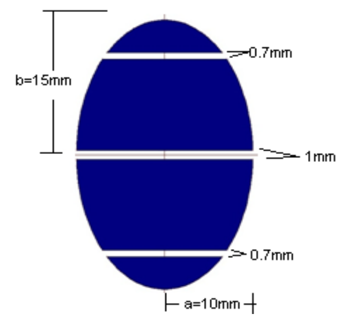

Figure 3 Designed Gap-Coupled Assembly of Patches forming Elliptical Microstrip Patch Antenna

In this section, the improved performance of EPMA structure is reported without increasing its overall size. For this purpose, we cut the previously reported elliptical patch antenna by three horizontal slits parallel to the minor axis into four parts as shown in Figure 3.

In this way, the elliptical patch is divided into four independent patches out of which two outer patches and two inner are identical in shape and size. The part of the inner patch in the first quadrant is exited through inset feed, and the three other patches are gap coupled to this patch. The slit location and slit widths on EPMA geometry are optimized to achieve best performance from this modified EPMA geometry. The modification in patch geometry is done in two steps. It is realized that on placing three slots parallel to the minor axis of the elliptical patch at identical location a' = 11 mm from the center (as shown in Fig. 3), the performance of antenna improves. In the second step, width of applied slits ‘‘w’’ is varied from 0.6 to 1.5 mm in the steps of 0.1 mm, and each time performance of the antenna is analyzed.

It is realized that on making ‘‘w’’ equal to 0.7 mm, impedance bandwidth attains a maximum value ~20% with respect to the resonant frequency 6.2GHz. The simulated bandwidth range of antenna is 1.3 GHz.

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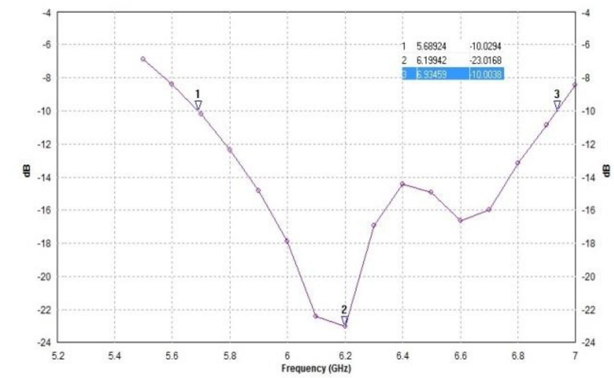


Figure 4 Simulated reflection coefficient of modified assembly of patches

Marker Positions	Resonant Frequency (GHz)	Return loss (dB)
1	6.5	-10
2	6.2	-23
3	6.93	-10

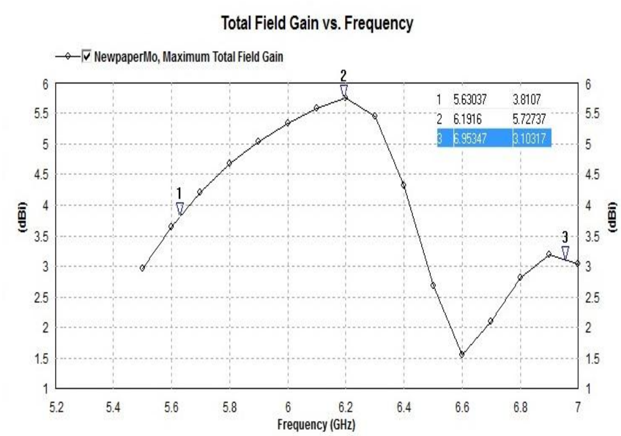


Figure 5 Simulated result of total Field Gain V/s Frequency

A figure 5 shows the variation of gain with frequency. It is clear from the result that the gain in the whole bandwidth is positive and considerable high 5.72dBi with respect to the conventional Elliptical patch antenna having gain 0.5dBi.

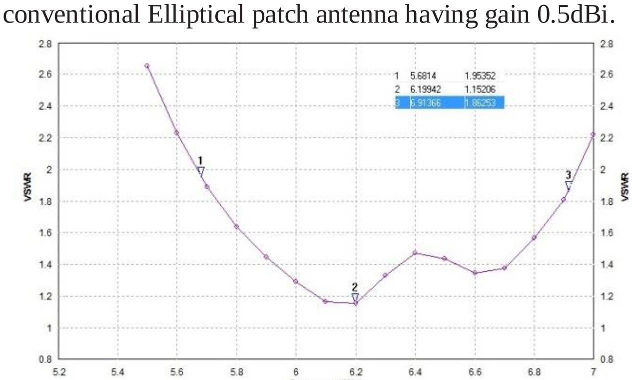
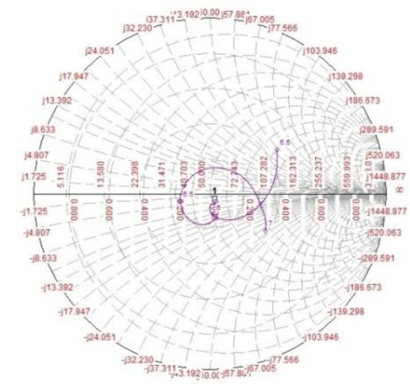


Figure 6 Simulated VSWR for modified assembly of patches with frequency

The simulated VSWR of modified EPMA geometry as a function of frequency is shown in Figure 6. The VSWR at resonance frequency 6.2GHz is 1.16. This indicates an excellent matching between design antenna geometry and the feed arrangement used for this study.



Marker Position	Input Impedance in ohm
1	52.2, -j6.4

Figure 7 simulated input impedance of modified assembly of patches with frequency

The simulated variation of input impedance with frequency for modified elliptical patch antenna is shown in Figure 7. The real part of input impedance presented by antenna at the resonance frequency is 52.2ohm.

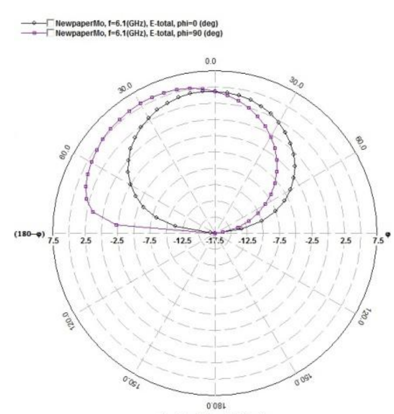


Figure 8 Simulated elevation patterns at the frequency 6.2 GHz.

The simulated normalized E and H-plane elevation patterns of modified EPMA structure at resonance frequency 6.2GHz is shown in Figure 8. It can be observed from these figures that modified elliptical patch antenna is strongly radiating normal to patch element. This kind of radiation pattern, at which the resonant frequencies have very low power in ϴ=90º and ϴ = -90º directions are suitable for C band applications.

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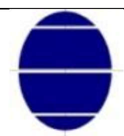
III. CONCLUSION AND FUTURE ENHANCEMENT

The performance of a compact gap-coupled assembly of patches forming the geometry of elliptical patch antenna is presented in this communication. Dimensions of the applied slots are optimized for bandwidth enhancement without spoiling other radiation characteristics, and in this way impedance bandwidth ~20% is achieved, which is much larger (more than six times) than that of a corresponding elliptical microstrip antenna without any slots. The resonance frequency of designed antenna is in C band. So this antenna can be used in various C band application like long distance radio communication, in Wi-Fi devices and in some weather radar system etc.

Proposed future work for this antenna is to enhance the gain and bandwidth by using different feeding techniques like Air gap coupling, Electromagnetic coupling and proximity coupling. The antenna gain is high, but impedance factor needs improvement. The patch antenna is simulated using EM simulator IE3D software. Comparison of antenna parameters of conventional and modified patch antennas are given in table I.

TABLE I: Variation of antenna parameters of modified patch antennas with width of rectangular slots

Patch	Geometries	Slot No	Width of Slot (mm)	Frequency (GHz)	Gain (dBi)	Band Width (%)
Conventional		Without slot	0	3.83 4.97	0.5 0.8	~2% ~3%
Modified Patch		1-2	0.7 0.7	3.6	2.4	10.2%
Final Modified patch		1-3	0.7 1 0.7	6.2	5.7	20%

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