Dual Band High Gain Union Shaped Micro-strip Patch Antenna

G. Bhide[1], A. Nandgaonkar[1] and S. Nalbalwar[1]

Department of Electronics and Telecommunication Engineering, Dr. Babasaheb Ambedkar Technological, University, Lonere[1]

{ggb_rtn@yahoo.co.in, abnandgaonkar@yahoo.com, nalbalwar_sanjayn@yahoo.com}

Abstract. A union shape has been proposed for getting the dual band operation of the micro-strip patch antenna operating at the 2.19 GHz and 3.98 GHz. In this work the patch shape is modified by uniting semicircular shapes at the two radiating edges of the square patch. A simulation study of the proposed antenna structure with probe feed has been done with finite element based commercial software HFSS. It is showing the dual band operation with return loss less than -25 dB at both the bands. The antenna offers a gain of 3-7 dB and nearly 2% bandwidth.

Keywords: ***Union shaped, dual band, micro-strip patch antenna.***

1 Introduction

Micro-strip patch antennas are very famous due to their attractive advantages, such as light weight, low profile, conformal, and compatibility with the monolithic microwave integrated circuits. However these antennas suffer from few disadvantages such as, narrow bandwidth, small efficiency etc. The modern communication systems, such as satellite links (GPS, vehicular etc.) and upcoming applications, such as wireless local networks (WLAN), 4G are in need of low cost antennas with compact size. In such WLAN applications a broadband operation is desirable. In some applications there is a need for operating at two separate sub-bands, which is an alternative to the enhancement of total bandwidth. These applications have given a boost for research on new techniques that overcome the bandwidth limitations of the patch antennas [1, 2, 3, 4, 5, 6, 7, 8, 9]. Dual-frequency antennas have a single radiating structure and have two distinct resonant frequencies [9]. At these frequencies, the transmission and/or reception of the signal are done. Complexity in the feeding network has reduced the attention towards such antennas. It is expected that dual-frequency patch antennas should have similar performance in terms of radiation and impedance matching at two separate frequencies.

There are different techniques reported in the literature in order to obtain dual-frequency operation of patch antennas. Notable amongst them are 1) *orthogonal mode dual-frequency patch antennas*, 2) *multi-patch dual frequency antennas*, and 3) *reactively loaded dual-frequency patch antennas*.

The orthogonal mode dual-frequency performance is obtained using a rectangular patch [10, 11]. Multi-patch dual-frequency antennas are designed using stacked configurations and co-planar configurations [12, 13]. The reactively loaded dual-frequency antennas are realized using stubs, notches, pins, slots [14, 15, 16, 17].

In this work multi-patch design is achieved by uniting two different types of shapes 1) Rectangular or square and 2) Semicircular. The semicircular shaped patches are attached on the radiating edges of the rectangular or square shaped patch. It is the intuitive heuristic approach that is used while designing the antenna as discussed in the next section.

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For the modification purpose the usual rectangular micro-strip patch antenna with size 4cm x 3cm designed with RT duroid 5880 substrate having relative permittivity of 2.2 and thickness of 0.32cm was studied.
It is found to be resonating at 2.3625 GHz and the radiation pattern is almost hemisphere with a total gain ranging from 1dB to 7dB over the main lobe.

2 Design Methodology

It was decided to keep the total area of the new patch as 12 sq. cm same as the one studied earlier, so that we can compare it on the basis of area. It is decided to unite a square patch and two semicircular patches. The union of square and semicircular patches may be done with any ratio. In this work the proportion of a square patch and two semicircular patches was decided as 3:1.

2.1 Antenna Design

Now the square patch size becomes 9 sq. cm and the two semicircular patches will be of 3 sq. cm put together. The semicircular patch radius is calculated as shown in equation 1.

$$= \sqrt{\frac{12 -}{\ }} \qquad (1)$$

For a square patch with 3 cm x 3 cm size, we have s = 9 sq. cm and hence the radius of circular sections comes out to be 0.977 cm. The layout of such a union patch is shown in fig. 1.

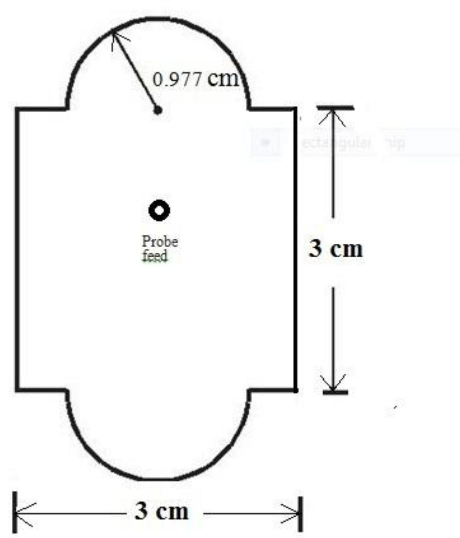

Fig.1. Design Layout of Proposed Antenna

3 Simulation

The micro-strip patch antenna with above said shape is simulated using ANSOFT's HFSS. The following fig.2 indicates the Patch antenna along with air box of height 3 cm above the plane of patch. The ground plane size is 10 cm x 9 cm. The substrate material used is RT Duroid 5880 with relative permittivity of 2.2.

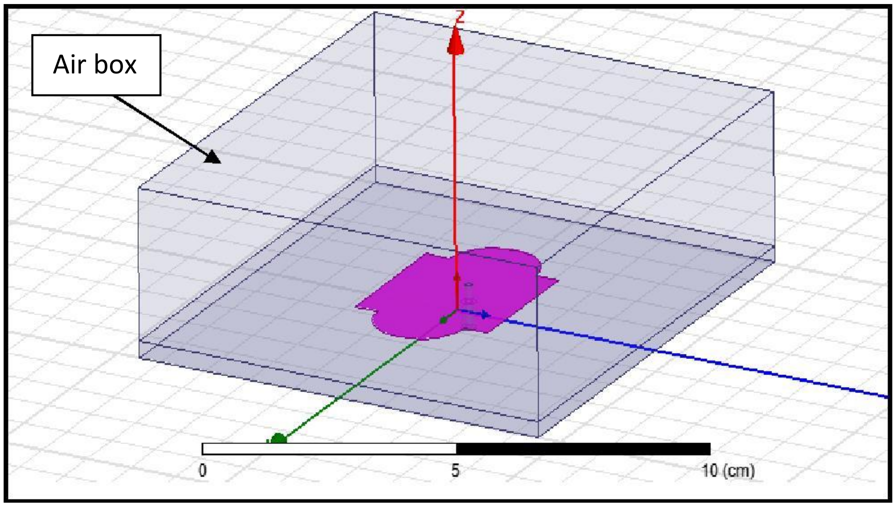

Fig.2. Structure of the Union Shape MSA in HFSS

4 Results

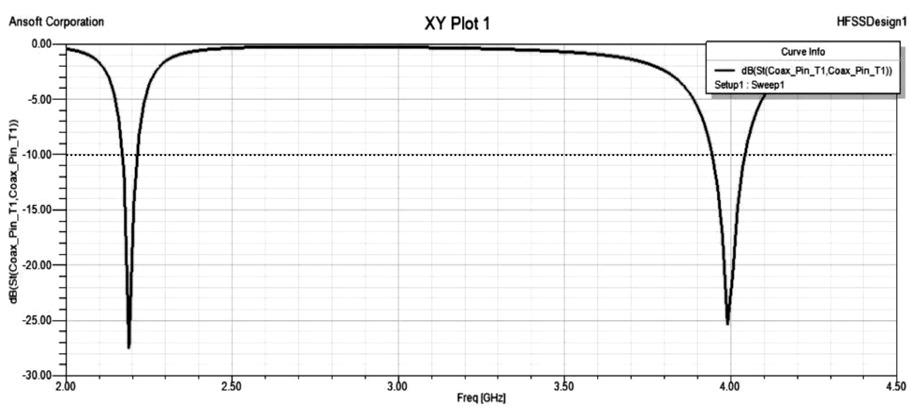

Fig.3. Return Loss S_{11} Versus Frequency Showing Dual-Band Operation

The performance of the antenna in terms of S_{11} versus frequency as shown in fig. 3 clearly indicates dual-frequency operation. The lower band has the resonance frequency of 2.19 GHz while the upper band has the resonance frequency of 3.98 GHz. At both these frequencies S_{11} value is obtained below -25 dB. The -10 dB bandwidth in the lower frequency band is ranging from 2.165 GHz to 2.215 GHz which comes out to be 50 MHz i.e. 2.28%.

In the upper frequency band the -10 dB bandwidth is ranging from 3.93 GHz to 4.03 GHz which comes out to be 100 MHz i.e. 2.51 %. It is equally important to find out the VSWR levels near the resonating frequency. The VSWR Bandwidth is defined as the range of frequencies over which the VSWR is between the range 1dB < VSWR (dB) < 2dB. Two such plots around 2.19 GHz and 3.98 GHz are shown in fig.4 and fig.5 respectively.

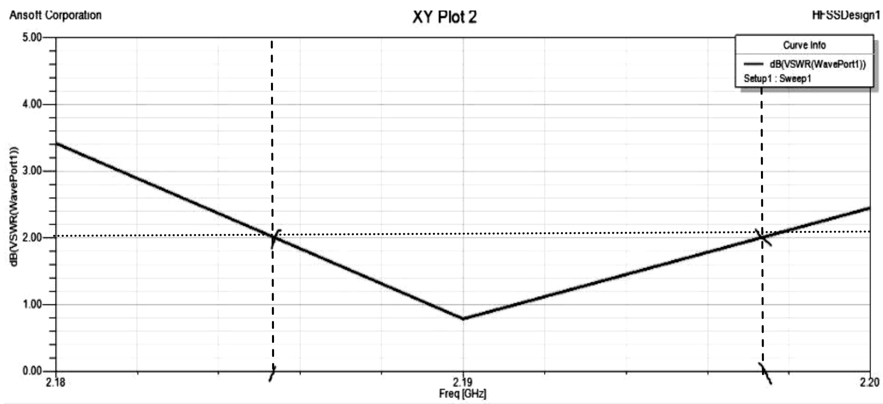

Fig.4. VSWR (dB) in the Lower Band

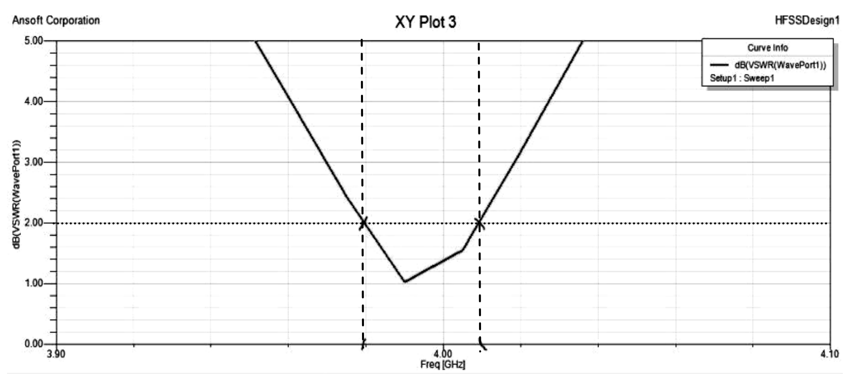

Fig.5. VSWR (dB) in the Upper Band

The VSWR bandwidth as per plot for the lower band is from 2.1852 GHz to 2.1974 GHz i.e. 12.2 MHz at a center frequency of 2.1913 GHz. The VSWR bandwidth as per plot for the upper band is from 3.978 GHz to 4.008 GHz i.e. 30 MHz at a center frequency of 3.993 GHz. The gain of the antenna at 2.19 GHz is plotted in fig. 6. In the E-plane i.e. $\Phi = 0°$ the gain is very small i.e. < -20 dB. In the plane $\Phi = 90°$, it is around 6 dB. The radiation pattern exhibits a large beam width in the hemisphere form. Thus it has low directivity.

4.1 Discussion on Advantages of Union Shape

The performance of this union shape microstrip patch antenna is compared with square patch MSA and a circular patch MSA having patch area nearly equal to the union shape area. The following table 1 indicates the performance comparison of these patches with similar ground plane, same dielectric substrate and identical probe feed arrangement. The gain at 3.98 GHz is plotted in fig. 7. The gain at $\Phi = 0°$ is around 7-8 dB while at $\Phi = 90°$, it is even less than -2dB. At this frequency there is a null at $\theta = 0°$.

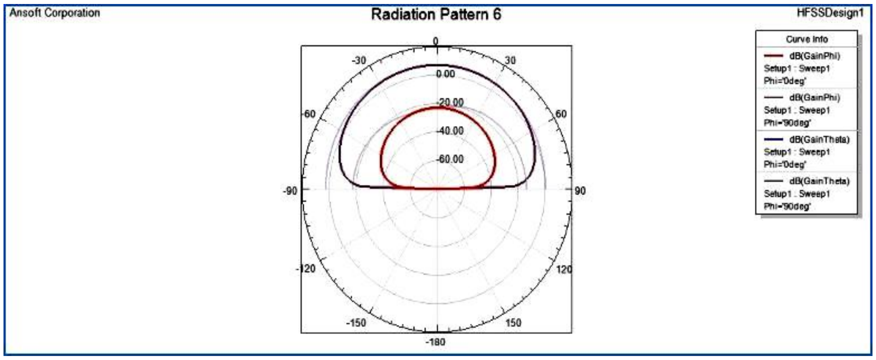

Fig.6. Gain of the Antenna at 2.19 GHz

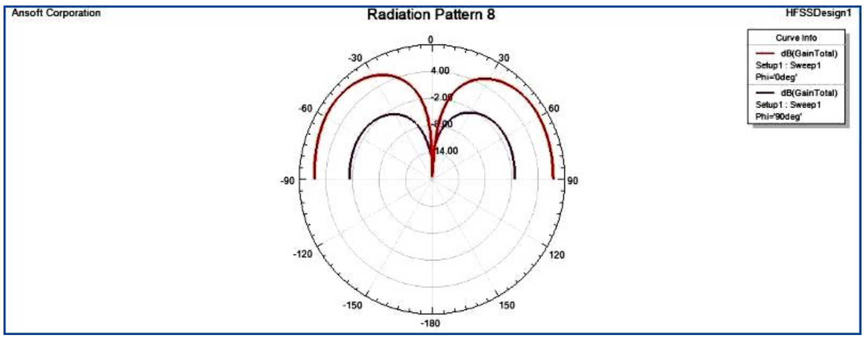

Fig.7. Gain of the Antenna at 3.98 GHz

Table 1. Performance Comparison of Square, Circular and Union Shape Patches with Probe Feed

Sr.	Type of Patch	Patch dimensions and Area	Lower frequency of resonance	Upper frequency of resonance	S_{11}	Remark
1	Square Shape	3.46 cm x 3.46 cm; Area = 11.97 cm^2	2.86 GHz	---	S_{11} below -16 dB	Single Band operation
2	Circular Shape	Radius of 1.97 cm; Area = 11.94 cm^2	2.88 GHz	---	S_{11} below -16 dB	Single Band operation
3	Union Shape (Proposed)	(3 cm x 3 cm) + (π*0.977cm*0.977 cm); Area = 11.99 cm^2	2.19 GHz	3.98 GHz	S_{11} below -25 dB at both frequencies	Dual Band operation

The entries in above table indicate that the Union Shaped Patch Antenna (Proposed) is having dual band operation, which is not there in case of square or circular patches. This justifies the importance of the Union Shape.

5 Conclusion

The novelty lies in the simplicity of patch layout design which reduces the time required for simulation. The proposed antenna structure promises high quality dual-band operation around 2.19 GHz and 3.98 GHz which can be used in certain applications. The S_{11} values at both these frequencies are < -25 dB which is a good performance indication. The gain of the antenna is around 3 dB in the lower band and around 7-8 dB in the upper band. The radiation characteristics of the antenna are good however the bandwidth obtained is less around 1-2% which needs to be improved further either by optimizing the patch design or using other standard techniques.

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