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Dual Band Octagonal Microstrip Patch Antenna Loaded with Array of Split Ring Resonators

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ABSTRACT

This article presents a proposal about an octagonal microstrip patch antenna (MPA) loaded with Split Ring Resonators (SRR) the antenna's ground part. The antenna size reduction using multiband radiators will suits for miniaturization of day-to-day handheld devices. The dual band behaviour of the antenna will integrate more communication standard in one system which saves the installation space in the device. In this context, an octagonal antenna structure is conceived for a dual operational frequency of 5.63 GHz and 5.97 GHz. Hereby, a Co-planar Waveguide (CPW) structure is adapted to the octagonal patch and the structure has been observed by simulation analysis under HFSS platform. The overall geometry of the antenna is 30 x 26 x 1.6 mm^3. The antenna feed using a microstrip for earning a better impedance matching between the antenna and transmission line. The antenna design provides a wider bandwidth of 580MHz and average gain of 3.25 dBm. The attainment of dual band operational frequencies is due to the CPW and SRR structure in the antenna design.

Keywords: Octagonal Patch, CPW feed, FR-4 Substrate, Split Ring Resonator and C-band applications.

I. INTRODUCTION

Wireless communication has attained wide growth in the present era; it involves many types of conventional and smart antennas. Staring from handheld tags to the satellite, people started using antennas. It generally functions with the EM signals that can transfer information to its parallel enabled devices in air. Antenna transforms electric current to EM waves and vice versa. Among all different types of antenna, microstip patch antenna has a simplest configuration and merits such as low fabrication cost, fits in the compact space, easy implementation, etc. Also, have major constraints like narrow band, less efficient and low gain, etc [1-3]. For improving the constraints the antenna should be made well efficient to overcome such limitations. By including the extra advancements to the patch antenna, it can withstand the limitations such as narrow bandwidth, low gain. Multi-bands can be achieved in the MPA by including slots or by reforming the shapes of the patch of the antenna [4-7]. Here, an octagonal shape has been used in the patch section for achieving multiple bands in the MPA [8-11]. The surface current on the patch will get limited to the slots made on the rectangular patch and leads to attain multiple frequencies in the single antenna. Wider bandwidth can be achieved by the CPW structure, which conserves the current flowing through the patch. It introduces a wider bandwidth to the antenna design [12-15].

FR-4 substrate is used as the dielectric medium for this antenna design which is an important functioning element in the antenna. The thickness and the dielectric constant of the dielectric medium will regulated the outcome of the antenna. Better efficiency and bandwidth can be obtained by using substrate with thick and least dielectric constant and vice versa. FR-4 is an easy available and less priced material [16-19]. The surface current flows better when the size of the antenna patch is reduced and also provides an even flow of current all around the patch and conserves the power. There are two different feeding categories such as non-contact method and contact method. In the non contacting methodology like CPW feed, it allows a wider bandwidth compared to the other type. In contact methodology like inset feed, the radio frequency power is directly fed to the radiating patch. A split-ring resonator (SRR) is the structure used to induce metamaterials. The SRR structure has two circular / square rings with a gap in the either sides. The SRR induces the LC circuit into the antenna structure. This distributed capacitor – inductor circuit will act as lumped resonator with improved quality factor [20-22]. Patch antennas are used in many handheld devices because of its spatial arrangements and hardiness to environment. High Frequency Simulation Software (HFSS) is the platform used to design the antenna structure [23]. The proposed antenna design is used for C-band applications which are the frequency band that is allotted for day-to-day telecommunication via satellite [24, 25]. It is also used for terrestrial microwave radio relay chain. Here, the operating frequencies of the proposed antenna are 5.63 GHz and 5.97 GHz.

The organization of this document is as follows. In Section 2 (**Methods and Material**), elaborates the materials and dimensions of the antenna design. In Section 3 (**Result and Discussion**), presents the simulation parameters and results of the proposed antenna. Discussed in Section 4(**Conclusion**) concludes the features of the simulation results.

II. METHODS AND MATERIAL

The antenna structure has three layers such as Patch, Substrate and ground plane. The length and width of the patch decides the radiating frequency of the antenna. The radiating frequency, dielectric constant and thickness of the substrate are the basic values needed. Layer 1 and layer 3 is the patch and ground plane respectively made of Copper. Layer 2 is the dielectric medium with dielectric constant (ε_r=4.4). Thus, combination of all makes an efficient antenna design as shown in Fig. 1. The geometry and the design of the antenna are explained below

A. Octagonal patch

From the rectangular structure of dimension 15 x 12 x 0.04 mm^3, an octagonal shaped has been retrieved by etching the corners of the rectangle. The Fig. 1 shows the extracted octagonal shape of the patch and dimensions of those ate represented in Table. I. The octagonal patch radiates two different operating frequencies at the same time likely 5.63 GHz and 5.97 GHz which are used in C- band applications. The simulation of the antenna is made on HFSS platform. The patch geometry is obtained using the design formulae as given below [26]:

Patch Width (*W*):

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r}} \quad (1)$$

Where, *c* – Light velocity

Effective Dielectric Constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2} \quad (2)$$

Extension of Patch Length (*ΔL):*

$$\Delta L = 0.412h\left(\frac{\varepsilon_{reff}+0.3}{\varepsilon_{reff}-0.258}\right)\left(\frac{\frac{W}{h}+0.264}{\frac{W}{h}+0.8}\right) \quad (3)$$

Effective Patch Length (L_{eff}):

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad (4)$$

Patch Length (L):

$$L = L_{eff} - 2\Delta L \quad (5)$$

Substrate Width(L_s), Ground plane width(W_g):

$$W_s = W_g = 6h + W \quad (6)$$

Ground Plane length (W_g), Substrate length (L_s):

$$L_s = L_g = 6h + L \quad (7)$$

TABLE I. DIMENSIONS OF MICROSTRIP PATCH ANTENNA

Antenna Part	Parameters (symbols)	Values in mm
Substrate	Length (Ls)	26 mm
	Width ,(W-s.)	30 mm
	Height (h)	1.6 mm
Octagonal Patch	Length (L_p)	12 mm
	Width (W_p)	15 mm
Feed line	Length (W_f)	6 mm
	Width (W_f)	1 mm
CPW	Length (L_g)	5 mm
	Width (W_g)	13.5 mm
	Gap	2 mm

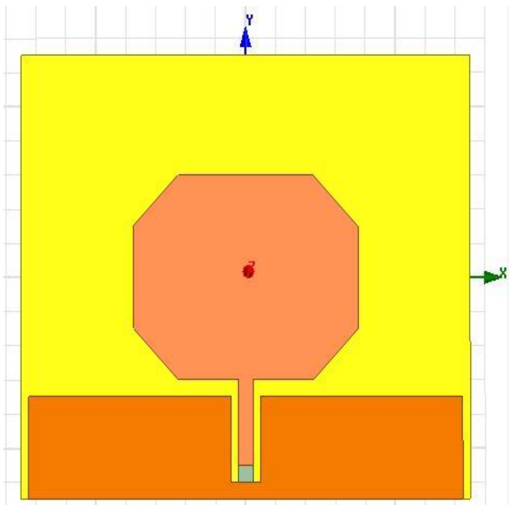

Fig.1 Octogonal Microstrip Patch

B. FR-4 Substrate

FR-4 is a dielectric medium with dielectric constant (ε_r= 4.4). Thickness of the substrate is considered as 1.6 mm. The dimension of the substrate is 30 x 26 x 1.6 mm³. The outline of the antenna and the octagonal patch on FR-4 substrate is shown in Fig. 2 & 3 respectively.

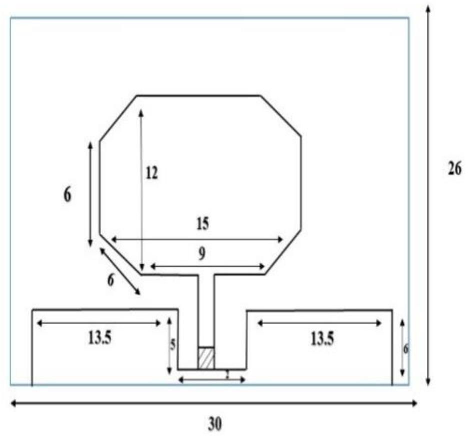

Fig.2 Outline of the proposed antenna

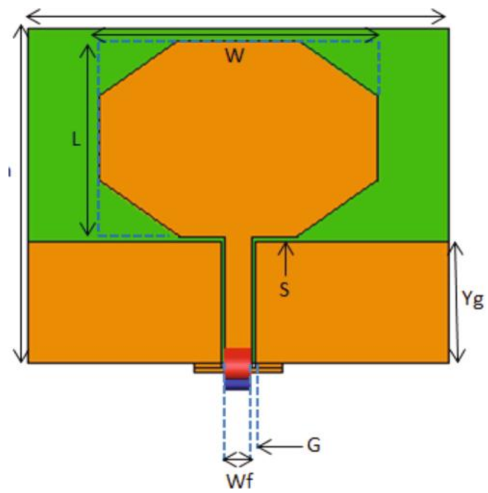

Fig.3 Octogonal patch on FR-4 Substrate

C. Ground plane and Feed

CPW is an electrical planar transmission line fed to the antenna on the PCB technology and is used to convey microwave frequency signal. It has a conducting track printed in the dielectric medium with two return conductors on both the sides. The three conductors are on the same side of the substrate with small gaps between each, and hence are coplanar as shown in Fig. 4a . The array of Split ring resonators are shown in Fig. 4b and the dimensions are represented in Table. II

TABLE II. DIMENSIONS OF SPLIT RING RESONATORS

Parameters	Values (mm)
Width (*w*)	30
Length (*l*)	26
Gap 1 (*g1*)	6
Gap 2 (*g2*)	4
Gap 3 (*g3*)	1
Gap 4 (*g4*)	1
Inter space (*a*)	0.5
Inter space (*b*)	0.5
Outer ring Width (*x*)	7
Outer ring Length (*y*)	7
Inner ring Width (*x1*)	5
Inner ring Length (*y1*)	5

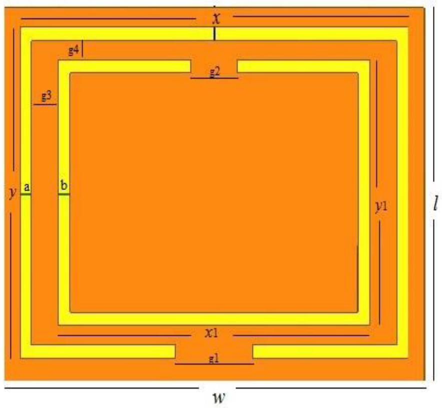

Fig.4a Unit Cell

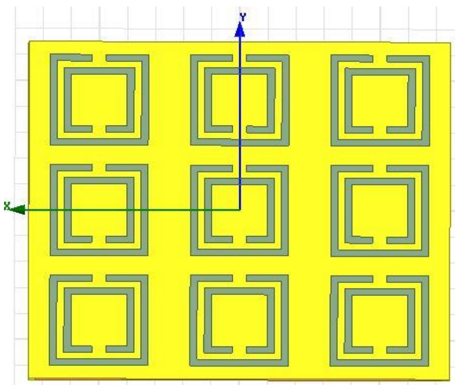

Fig.4b Array of Split Ring Resonators

III. RESULTS AND DISCUSSION

Using HFSS software the antenna has been designed and the simulation parameters are explained below:

A. RETURN LOSS

The reflected signal radiated from the antenna will make discontinuity in the transmission line due to loss of power. As shown in Fig. 5, -35.39 dB and -41.64 dB are the return loss value obtained for 5.63 GHz and 5.97 GHz respectively from the antenna design with array of SRR.

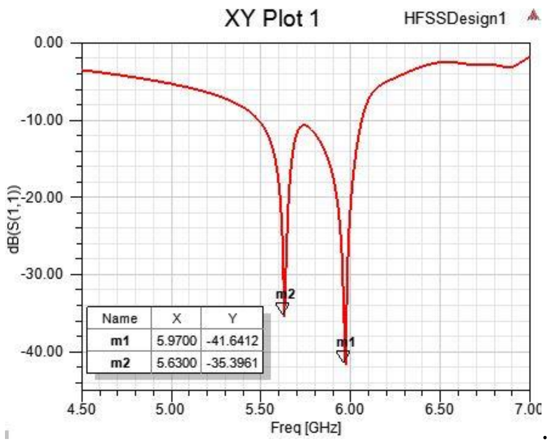

Fig. 5 Return loss

B. BANDWIDTH

The frequency range over which the designed antenna radiates properly. As shown in Fig. 6, 580 MHz is the overall bandwidth range for both the operating frequency.

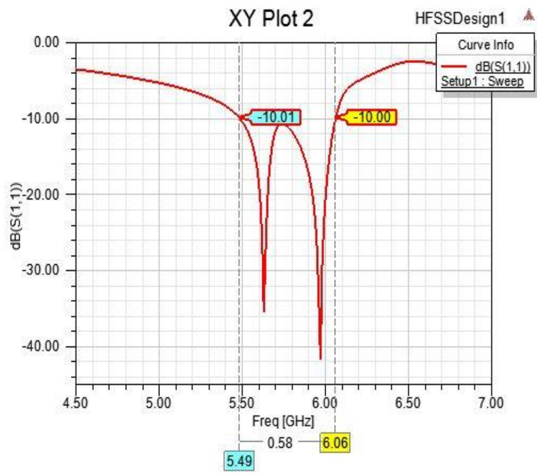

Fig. 6 Bandwidth

C. VSWR

The measure of transmission line imperfection is known as VSWR (Voltage Stationary Wave Ratio. As shown in Fig. 7, 1.034 and 1.016 are the VSWR value for the operating frequencies5.63GHz and 5.97GHz respectively.

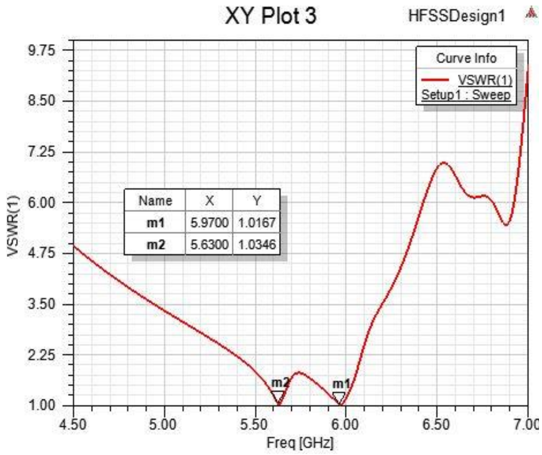

Fig.7 VSWR

D. GAIN

The ability of efficient conversion of input power to radio waves is known as Gain. As shown in Fig. 8a &b, 3.105 dBm and 3.223 dBm are the gain values of 5.63GHz and 5.97GHz respectively.

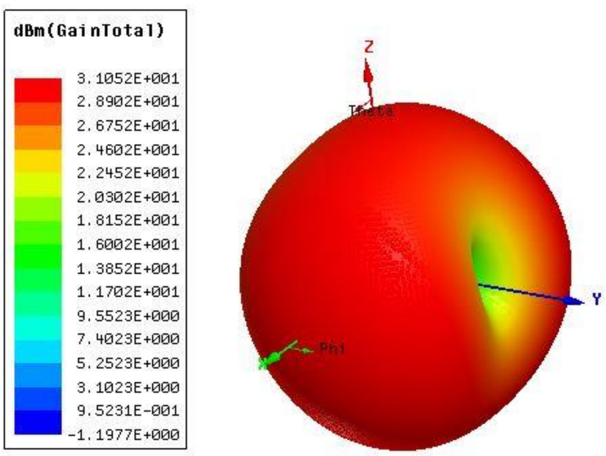

Fig.8a Gain for 5.63 GHz

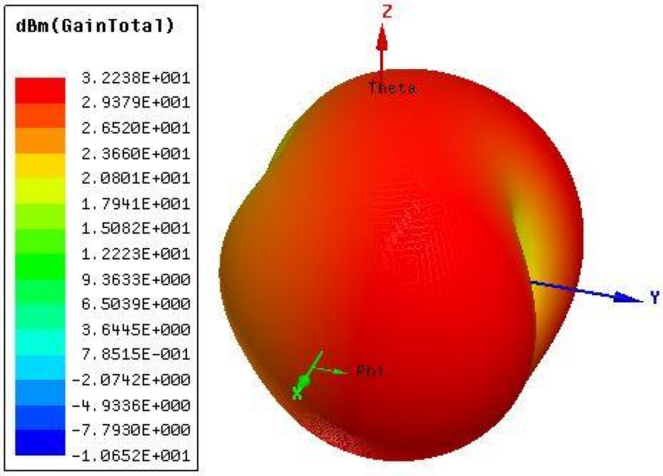

Fig.8b Gain for 5.97 GHz

E. DIRECTIVITY

Directivity is the ability of the antenna to radiate in a particular direction. As shown in Fig. 9a & b, 3.292dB and 3.429 dBm are the directivity values for the operating frequencies 5.63GHz and 5.97GHz respectively.

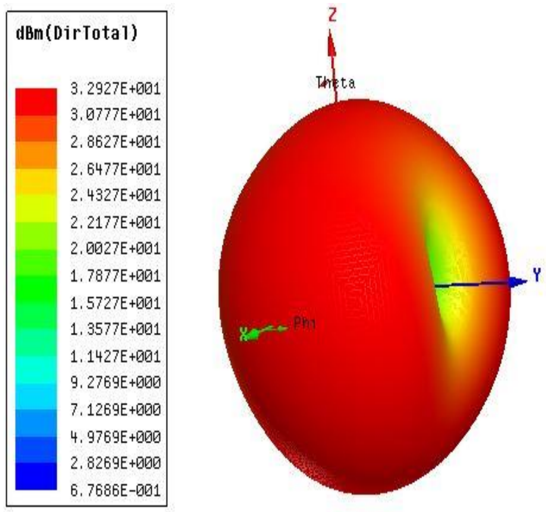

Fig.9a Directivity for 5.63 GHz

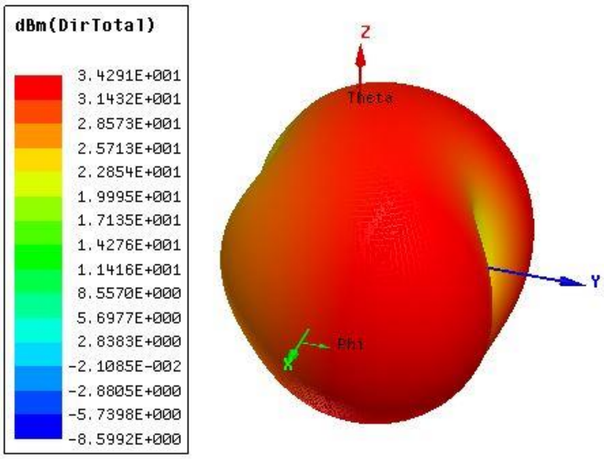

Fig.9b Directivity for 5.97 GHz

F. RADIATION PATTERN

The angular dependence of the radio wave from the antenna is known as radiation. As shown in Fig. 10 a & b, shows the radiation pattern of both the radiating frequencies 5.63 GHz and 5.97 GHz respectively.

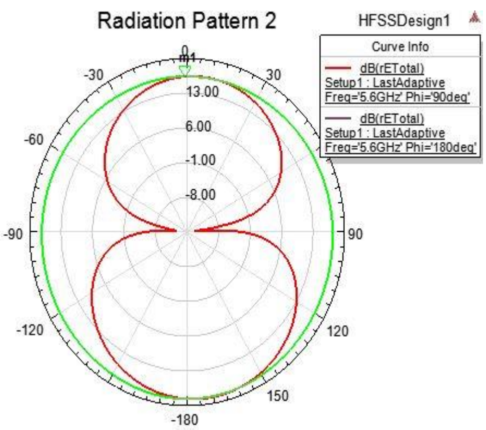

Fig.10a Radiation pattern for 5.63 GHz

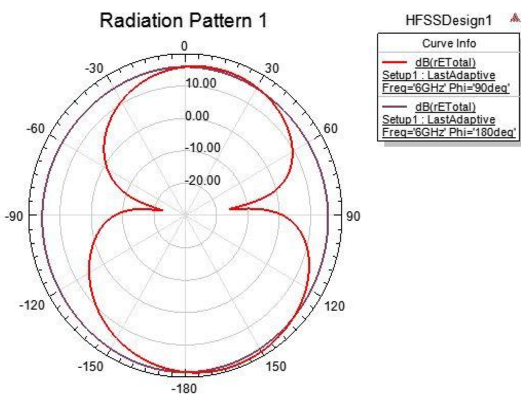

Fig.10a Radiation pattern for 5.97 GHz

TABLE III. DIMENSIONS OF ARRAY OF SPLIT RING RESONATORS

Frequency	5.63 GHz	5.97 GHz
Return loss	-35.39 dB	-41.64 dB
Bandwidth	580 MHz	580 MHz
VSWR	1.034	1.016
Gain	3.105 dBm	3.223 dBm
Directivity	3.292 dBm	3.429 dBm

IV. CONCLUSION

In the investigation of the resonator array influence on the ground plane and the octagonal patch with CPW feed, the antenna provides the behaviour of wider bandwidth of 580 MHz and average gain of 3.25dBm for C-band applications, operating on 5.63 GHz and 5.97 GHz. Through the obtained results represented in Table III, it has been analyzed that the array geometry is confined on the ground plane, concerning to the device radiation properties; over this it is possible to obtain the dual band resonance frequency. By using these multi band characteristics, the antenna can be used for different application simultaneously. Thus, the simulation results show the coherence with the referenced literature, as it obtained output from the optimized antenna structure with wider dual band operating resonant frequency.

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