Analysis And Design Of Hexagonal Patch Antenna With Fractals For Wide Band Applications

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Abstract*: The increasing demand for wireless applications lead to spectral congestion of frequency bands that are allocated conventionally. Hence, to satisfy this demand it is necessary for all the satellite systems to employ higher frequency bands like Kurz (Ku) band (12-18 GHz), Kurz above (Ka) band (26.5-40 GHz) etc. This paper presents a microstrip patch antenna that operates effectively over the frequency range starting from 3.5 GHz to 33.5 GHz. The proposed antenna is analysed using HFSS (High Frequency Structure Simulator). It consists of a circular patch which is cut on its circumference to obtain the hexagonal shape and has a defected ground plane that has a slit at its centre. The impedance bandwidth achieved by this compact antenna covers the region from 3.5 GHz to 33.5 GHz, hence it can be extensively used in many satellite, defence and aerospace applications.

Index Terms*: HFSS, Microstrip patch antenna, Satellite applications.

I. INTRODUCTION

The development of latest technologies in the field of communication has improved the functionality of electronic applications with reduced size [10]. Keeping in mind that the sizes of electronic devices are reducing, it is necessary to use low profile antennas like microstrip antennas [1]. The microstrip antennas are of greater importance in the field of wireless communication because of their low cost, small size and their flexibility for fabrication. The microstrip patch antennas have a range of extensive applications in fields like spacecrafts, satellite services etc [12]. Because of latest technologies in the era of wireless communication the cost of manufacturing a microstrip antenna has reduced significantly. A microstrip antenna in general consists of a substrate material with permittivity ranging from 2.2 to 12 [3], a radiating patch, a defected or normal ground structure and a feed line. The metallic patch is supported by the substrate under which the ground plane is placed. The radiating element of a microstrip antenna can take any configuration like rectangle, square, circle etc. The dimensions of the patch should be properly selected such that the antenna is radiated at required frequencies. The impedance matching can be obtained by adjusting the position of the microstrip feed line such that maximum power gets radiated. In order to obtain the operating region of the antenna at desired frequencies slots can be made in the radiating patch such that its characteristics are varied. The height of the substrate can also be varied such that the radiation characteristics of the antenna can be altered [7]. Generally, for a patch antenna the ground plane and the radiating patch are the conducting materials while the substrate is a dielectric material. There are many ways to feed the microstrip patch; in this design a defected ground plane with a symmetrical slit at its centre is used [17]. The main purpose of this design is to facilitate effective transmission and reception at higher frequencies.

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II. GEOMETRY OF PROPOSED ANTENNA

The designed patch is supported by an epoxy Fr-4 substrate using a thickness of 0.8 mm. The loss tangent of the substrate material is 0.02. The patch element of the proposed designed is of hexagonal shape, whose equation for resonant frequency is obtained using the resonant frequency equation of a circular radiating element by comparing their areas. The resonant frequency is given by [15]:

$$f_{res} = \frac{Ymn\ C}{5.714\ Re\sqrt{\varepsilon reff}} \tag{1}$$

here Ymn = Y_{11} (TM_{11} mode) = 1.841; Ymn = Y_{21} (TM_{21} mode) = 3.054; Ɛ reff is the effective dielectric constant; C is the velocity of light and Re is the effective radius of circular patch. The Comparison of circular and hexagonal patches is pictured in fig.1. The circular patch has the radius given below:

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$$Re = Rc.\sqrt{(1 + \frac{2.t}{Rc.\pi.\varepsilon r}\ln\left(\frac{\pi.Rc}{2.t}\right) + 1.7726])} \qquad (2)$$

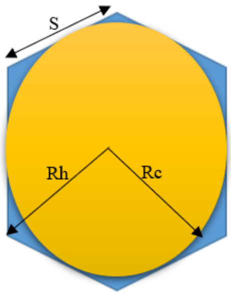

Fig.1. Representation of circle and hexagon with equal area.

Here, Rc is radius of circular patch, t is substrate height. A hexagonal patch can be designed by comparing the areas of circle and hexagon as shown below:

$$\Pi.\ (Rc)^2 = \frac{3}{2}\sqrt{3}.\ S^2 \qquad (3)$$

Here, S is length of side of the hexagon. The effective value of dielectric constant is given by:

$$\varepsilon\ reff = (\frac{1+\varepsilon r}{2}) \qquad (4)$$

The proposed antenna has the dimensions of 25 mm × 30 mm × 0.8 mm. The wide band operating region is obtained by using the symmetrical defected ground plane with a slit at its center. The fractal nature is created with the antenna by incorporating triangular and circular elements in hexagonal rings. The hexagonal patch is iterated 3 times so that the operating region of the antenna is limited to desired frequency bands. The geometry of ground plane and top view are shown in figures (2) and (3) respectively, the dimensions of patch and ground plane are mentioned in table (1).

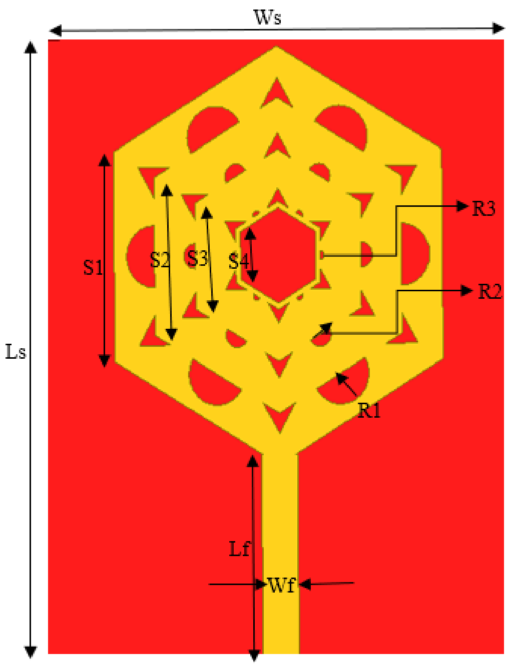

Fig.2. Top View of Proposed Antenna

Table.1. Dimensions of Proposed Model

Parameter	Notation	Value in mm
Substrate Length	Ls	30
Substrate Width	Ws	25
Substrate Thickness	t	0.8
Feed Line Length	Lf	10
Feed Line Width	Wf	1.9
Side Lengths of Hexagons	S1	10
	S2	7.5
	S3	5
	S4	2.5
Radius of Circular slots	R1	1.5
	R2	0.6
	R3	0.2
Ground Plane Length	Lg	9.5
Ground Plane Width	Wg	24
Top Width of Ground	Wg2	12
Hypotenuse of Triangle	Hg	7.65
Length of Rectangular slot	Lr	2
Width of Rectangular slot	Wr	2.4
Height of Triangular slot	Lg1	4.75
Base of Triangular slot	Wg1	6
Length of ground plane	Lg2	4.75

III. ANALYSIS OF DIFFERENT PARAMETERS

The wide band characteristics of the designed antenna are analyzed for different parametric values by modifying that particular parameter in steps.

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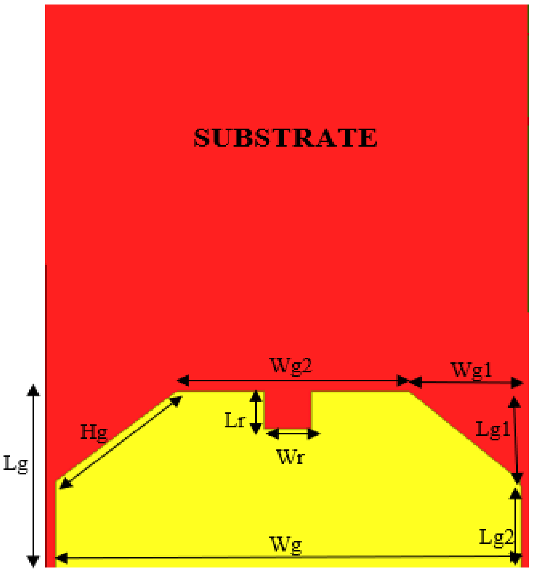

Fig.3. Ground Plane of Proposed Antenna

A. Effect of Defected Ground Plane

The main purpose of inscribing triangular slots in the top corner of defective plane is to improve the operating region. In order to provide coupling between the radiating element and the ground structure, a rectangular slit is etched at the center of the defective ground plane. The significance of using defected ground plane is that proper impedance matching can be obtained between the patch and the ground plane such that less amount of power gets reflected.

B. Effect of Iterating the Patch

The patch of the designed model is iterated 3 times such that the bandwidth of the operating region is enhanced. For each iteration the comparision of return loss plots is pictured in figure (8) while the patch configurations for each iteration are shown in figures (4), (5), (6) and (7) respectively.

Effect of Varying the Width of the Feedline

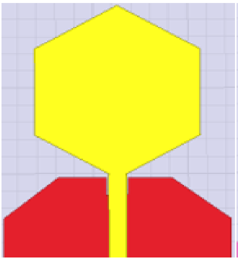

Fig.4. Iteration 0

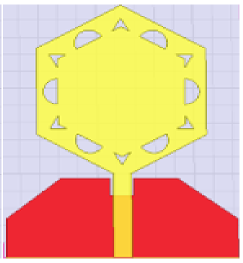

Fig.5. Iteration1

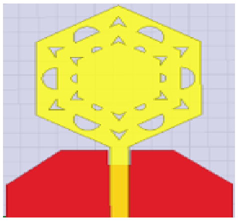

Fig.6. Iteration 2

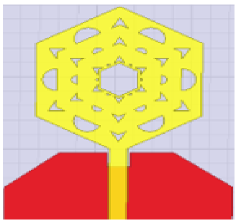

Fig.7. Iteration 3

The width is also important for improving the operating region of the microstrip patch antenna. If the width is maintained properly then the ground plane and the patch will properly such that no power would reflect back. The variation in return loss for different widths of feedline is shown in figure (9). From the comparison it is clear that good values for return loss is obtained when Wf = 1.9mm.

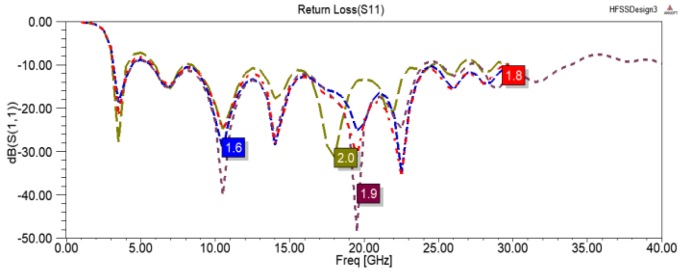

Fig.9. Comparison of Return Loss Plot for Different Feed Widths

IV. RESULTS

A. Return Loss Plot

The analysis of the proposed model is done using the Ansoft High Frequency Structure Simulator (HFSS). The return loss plot with respect to frequency is pictured in figure 10. The impedance band width is achieved as 30 GHz starting from 3.5 GHz to 33.5 GHz with a minimum return loss of -48.45 dB at 19.5GHz. Hence, from this observation we can conclude that the reflection coefficient would be relatively good as the value of return loss obtained is minimum. Therefore, only a little amount of power would reflect back.

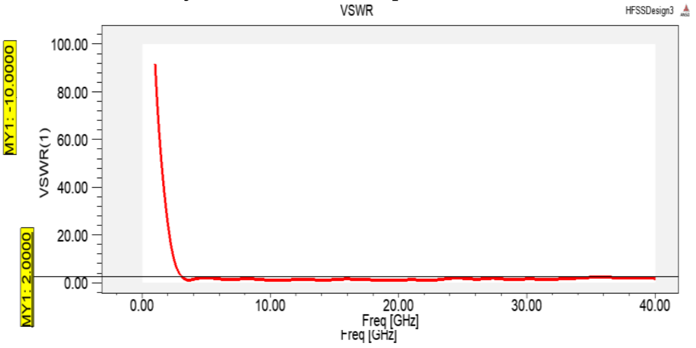

Fig.10. Return Loss Plot

B. VSWR

Voltage Standing Wave Ratio (VSWR) indicates the impedance matching within the system. A system is said to be matched perfectly if the value of VSWR is obtained as 1 but for practical considerations its value can lie between 1 and 2. For the designed model the VSWR for the entire operating region is between 1 and 2 which clearly says that the microstrip feed and line and the patch are matched properly. The VSWR plot for the proposed model is shown in figure 11.

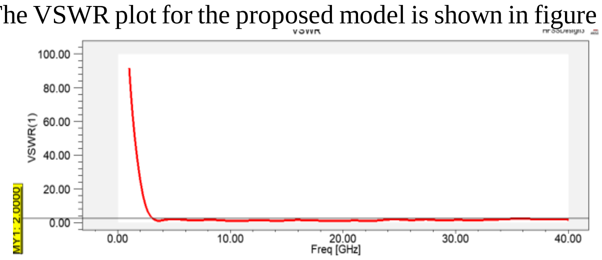

Fig.11. VSWR Plot

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C. Radiation Pattern

The radiation pattern of an antenna describes the amount of power radiated by the patch at the desired frequency. The Radiation patterns at 3.6 GHz and 10.6 GHz are pictured in figures (12) and (13) respectively.

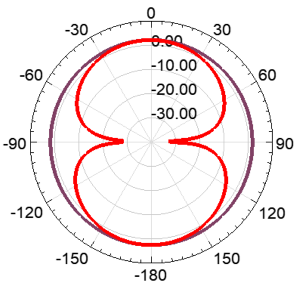

Fig.12. at 3.6 GHz

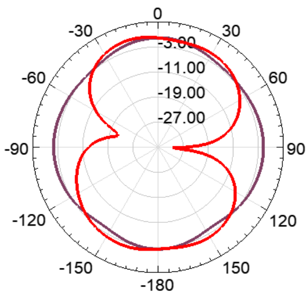

Fig.13. at 10.6 GHz

D. 3D Gain Plot

The directional characteristics of a microstrip patch antenna can be obtained with the help of its gain characteristics. The 3-D polar plots at 3.6 GHz and 10.6 GHz are pictured in figures (14) and (15) respectively.

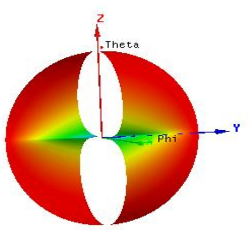

Fig.14. at 3.6 GHz

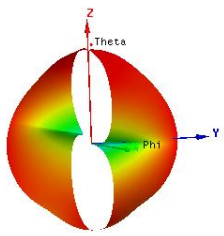

Fig.15. at 10.6 GHz

E. Current Distributions

In general, the current at the beginning and at the edges of the radiating element should be minimum because of its open circuit nature. The current should be maximum on the radiating element at its center. The Current distributions of patch and ground plane are shown in figures (16) and (17) respectively.

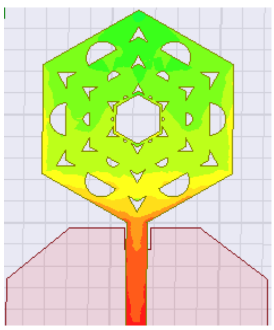

Fig.14. Patch

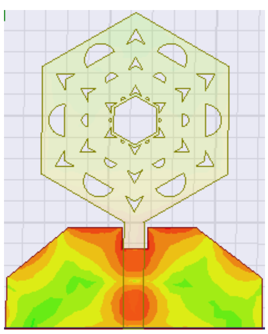

Fig.15. Ground Plane

F. Comparision with Reference Antennas

The comparison of proposed antenna in terms of operating frequencies and complexity is shown below.

Table.2. Comparison with Reference Antennas.

Reference	l×b (mm)	f_{low} (GHz)	f_{high} (GHz)	Impedance Bandwidth
[8]	28×31	3	10.6	7.6 GHz
[7]	22×33.4	3.1	26	22.9 GHz
[4]	40×40	4.34	13	8.66 GHz
[1]	25×30	3	25.2	22.2 GHz
Proposed	25×30	3.5	33.5	30 GHz

V. CONCLUSION

The designed microstrip patch antenna is of low profile and has better radiating efficiency. It can be concluded that better values for reflection coefficient, VSWR, gain and directivity are achieved by iterating the microstrip patch element. The operation bandwidth of designed antenna is 30 GHz which include most of the IEEE standard wireless frequency bands. Therefore, the proposed antenna can be used effectively for both uplink and downlink transmissions of satellite communication. The applications of this antenna extend to defence, aerospace and spacecraft technologies where compact wideband antennas are of highest preference.

REFERENCES

1. R. Ramana Reddy, A. Mallikarjuna Prasad, Naresh K. Darimireddy, "A Miniaturized Hexagonal-Triangular Fractal Antenna for Wideband Applications", IEEE Antennas and Propagation Magazine, April 2018.
2. R. M. Joany, Mekala Harinath Reddy, A. Sahaya Anselin Nisha,and G. Manikandan,"Design of Microstrip Patch Antenna with Multiple Slots for Satellite Communication", IEEE, International Conference on Communication and Signal Processing, 2017, April 6-8.
3. Shehana Pareeth, Jobins George, "Multiband Microstrip Patch Antenna using Parallel Slots for Wireless Communication", International Conference on electrical, electronic and Optimisation Techniques (ICEEOT – 2016).
4. P.P. Sarkar and K. Mandal, "A Compact Low-Profile Wideband Antenna with Slotted Rectangular Ground Plane", Int. J. Electron. Commun., vol. 70, no.3, 2016.
5. S. N. Vijay, Prerna Gupta, "Design and Parametric Study of Rectangular Microstrip Patch Antenna for C – Band Satellite Communication", IEEE, International Conference on Recent Advances and Innovations in Engineering (ICRAIE – 2016), 2016, December 23-25.
6. Sunandan Gokhroo and Souryendu Das, "Microstrip Patch Antenna at 7 GHz for Satellite Communication", International Journal of engineering technology and science, vol. 2 issue 11, 2015, November.
7. S. Pal, N. Chattoraj and B. L. Shahu, "A Compact Super Wideband Monopole Antenna Design using Fractal Geometries", Microwave Rev., vol.20, no.1, pp. 20-24, 2014.
8. S. Raghavan, A. Subbarao,"Compact coplanar waveguide fed palanr antenna

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for ultrawide band and WLAN applications", Wireless Pers. Commun., vol. 71, no. 4,pp. 2849-2863, 2013.
9. M. T. Islam, R. Azim, M. Ali Dorostkar "Design of novel super wideband circular-hexagonal fractal antenna", Prog. Electromagn. Res., vol. 139, pp. 229-245, 2013.
10. Kumar SS, Pillalamarri R and Rao GS, "Printed Planar Circular Radiating Patch Ultra-wide Band Antennas", Microsyst Technol", 2015; 21:2321-2325.
11. Achraf Jaoujal, M. H. Diallo Yaccoub, "Rectangular Ring Microstrip Patch Antennas for Ultra-wide Band Applications", International Journal of Innovation and Applied Studies, vol. 4, pp. 441-446, 2 Oct 2013.
12. M. A. Tarar, F. A. Tahir, W. Mazhar, F. A. Bhatti and S. Ullah "Compact Microstrip Patch Antenna for Ultra-wide Band Applications", PIERS Proceedings, pp. 680-684, July 2013.
13. P. K. Singhal and Tajeswita Gupta, "Ultra-wide Band Slotted Microstrip Patch Antenna for Downlink and Uplink Satellite Applications in C – Band", International Journal of Innovation and Applied Studies, vol. 3, no. 3, pp. 680-684, July 2013.
14. K. Jayanthi, V. Nagarajan and R. Jothi Chitra, "Design of Microstrip Slot Antenna for WiMAX Application", IEEE, International Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), pp 645-649, Mar 2013.
15. A. Azari, "A new Super Wideband Fractal Microstrip Antenna", IEEE Trans. Antennas Proprag., vol. 59, no. 5, pp. 1724-1727, 2011.
16. J. P. Shinde, M. D. Uplane and Raj Kumar, "Effect of Slots in Ground Plane and Patch on Microstrip Antenna Performance", International Journal of Recent Trends in Engineering ", vol. No. 6, Nov 2009.
17. Jae-Hyeuk Jang and M. Tanaka, "Wearable Microstrip Patch Antenna", Antennas and Propagation Society International Symposium, Vol. 2, pp. 704-707, June 2003.
18. M. David and Pozar, "Microstrip Antennas", Proceedings of the IEEE, vol. 80(1), pp. 79 – 91, Jan 1992.

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