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Hexagonal Fractal Antenna for 5G Applications

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Abstract:
Fractals with self-similarity and space filling properties help to achieve wideband characteristics. In this paper, a wideband hexagonal fractal antenna for wireless 5G communications is developed. By introducing polygon shaped slots between hexagonal rings and partial ground plane, wide bandwidth is achieved. It was fed by an inverted L shaped strip line. The simulation and experimentation is done on FR4-EPOXY substrate of height 0.8 mm. The return loss is minimum for obtained resonant frequencies. The bandwidth is 19.4 GHz ranging from 3.6 GHz – 23GHz.

Keywords:*Fractal, hexagon, partial ground plane, slots, wideband.*

I. INTRODUCTION

Defense and radar applications require low-profile, low weight and compact antennas that are suitable for wideband applications. Wireless 5G communication system has great demands for miniature sized antennas. Thus fractal antennas has spread its wings in this communication world. Coupling the pre-fractal shapes with patch antennas reaped more benefits. Fractal shapes with their superior characteristics like iterative structures and symmetry play an important role in antennas.

Present day communication system requires radiating patch with superior characteristics, less volume and easy to design to attain its goals. Diverse methods and designs have been implemented in the previous years by antenna development researchers to enhance bandwidth. R. Azim et al. [1] have presented a circular ring antenna for wireless and UWB applications with notched band characteristics. Etching a sectional circular slot in the patch obtains frequency notching that has no interference with other bands. Patch antennas with different radiator shapes, closed shape slots and open slits in ground or in patch implemented for wideband applications. A compact planar antenna comprising of U-shaped radiator and same inverted U cut in ground has been designed for wide-band applications [2]. A compact antenna which includes V-shaped cuts at every end corner of rectangular radiator was developed for S-band microwave communications [3].

Using fractals is a better technique in reducing the antenna size. Fractals with self-similarity and space filling are primary properties in achieving wide bandwidth [4]-[5].The first property can be considered as whole shape is divided into subparts and each part is reduced copy of whole. This causes multiband and broadband behavior in antennas. The second property leads to size reduction as they have long electrical length but accumulates into small physical volume and utilizes space effectively. The discontinuities due to convoluted and ragged shape of fractal increases bandwidth and effective radiation of antenna.

K. J. Vinoy et al. [6] have related Koch curve with fractal dimension for the first time to know the multi resonant frequency characteristics. Many research articles reported different fractal antenna designs considering proper geometry selection to shorten the physical size with improved length and maintaining the properties through the whole broad band. Susamay Samanta et al. [7] presented a triple band antenna using Sierpinsiki fractal on hexagonal patch for short range vehicular communications. Naresh K. Darimireddy et al. [8] have presented a miniaturized hexagonal-triangular fractal antenna using ROGERS RT DUROID 5870 as dielectric substrate for wide-

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band applications. A defective ground structure made by a rectangular open slit at upper edge center is taken as ground structure. Patch has a combination of hexagonal rings and triangular elements which creates a fractal essence within the antenna.

A partial ground plane minimises the return loss compared to full ground plane. Seok H. Choi et al. [9] have presented an ultra-wide band antenna with partial ground plane for UWB applications. By altering patch and slot shapes and using different tuning stubs wide band characteristics are achieved. Here, a wideband fractal antenna is proposed for wideband applications. Its simulation is done using HFSS software. This proposed wideband fractal antenna provides a large bandwidth of 19.4 GHz.

II. DESIGN

The overall volume of proposed antenna is 27.5 mm x 23 mm x 0.8 mm. The substrate used here is FR4-EPOXY.

III. FORMULATION

To obtain resonant frequency for the hexagonal patch, resonant frequency equation of circular patch antenna is used by comparing their physical areas [10]. By using the following equations, side length of hexagon and its resonant frequency are obtained. The resonant frequency equation of circular patch is given by

$$f_{res} = \frac{Y_{MN}\, C}{5.714\, R_{EFF} \sqrt{\epsilon_{reff}}} \qquad (1)$$

Where Y_{MN} is nth zero derivative of the Bessel function with order m. Y_{11} (TM_{11} mode) =1.841, Y_{21} (TM_{21} mode) =3.054, ϵ_{reff} = effective dielectric constant, R_{EFF}= effective radius of circular patch, C= velocity of light in free space.

The effective radius equation is given by

$$R_{EFF} = R_C \sqrt{\left(1 + \frac{2.t_S}{R_C.\pi.\epsilon_r}\left[\pi \ln \frac{\pi.R_C}{2.t_S}\right] + 1.7726\right)} \quad (2)$$

Where R_C is radius of circular patch, and $t_S$is thickness of the substrate. The radius of circular patch is given by

$$R_C = \frac{Z}{\sqrt{\left(1+\frac{2.t_S}{F.\pi.\epsilon_r}\left[\pi \ln \frac{\pi.F}{2.t_S}\right]+1.7726\right)}} \qquad (3)$$

The parameter $Z = \frac{8.791 * 10^9}{f_o \sqrt{\epsilon_{eff}}}$

The side of the hexagonal patch S_H is found out by equating the areas of the circular patch and hexagonal patch.

$$\pi.(R_{EFF})^2 = \frac{3}{2}\sqrt{2}.{S_H}^2 \qquad (4)$$

$$S_H = \sqrt{\frac{2\pi.(R_{EFF})^2}{3\sqrt{2}}} \qquad (5)$$

The effective dielectric constant is given by

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-\frac{1}{2}} \quad \text{For W/h >1}$$

Where ϵ_r is actual dielectric constant of substrate, h refers to substrate height and W refers to patch width. By considering operating frequency as 4.2 GHz and by using the above equation (1) - (5), side length of hexagon is evaluated as 11.5 mm. The mean current path is equal to this hexagon side.

$$P = S_H = 11.5\, mm$$

The proposed fractal antenna has four iterations made from hexagonal rings of 1mm width whose sides are combined with polygon shaped slots inside the patch. The rings are partitioned by 2 mm length. The arrangement of hexagonal rings is displayed in Figure 1.

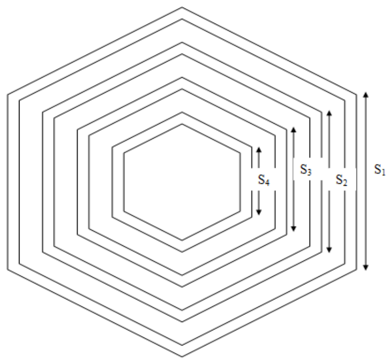

Fig 1: Hexagonal rings.

This antenna is fed by microstrip line feed technique. In this line feed technique, a strip of inverted L-shape is attached directly to the side (parallel to x-axis) of hexagonal patch. The geometry of proposed antenna is given in Figure 2 a and b. This strip line breadth is smaller than radiator width. This feed line technique is more useful because etching of feed line and patch is on same side of the substrate thus providing planar structure. The combination of four hexagonal rings along with

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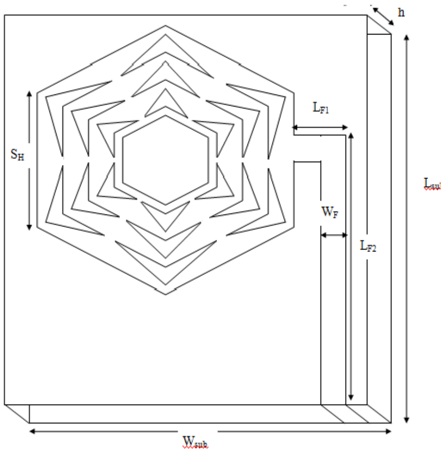
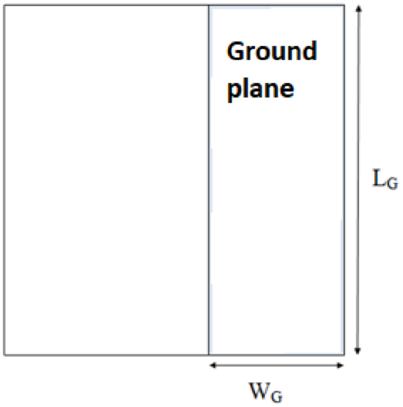
polygon shaped elements between the rings creates fractal nature of antenna. A partial ground plane structure of 9.5 mm x 25 mm is considered. The proposed antenna dimensions are given in the Table 1.



a) Front view (patch with feed)



b) Back view (ground)

Fig 2: Proposed antenna configuration.

Table 1: Dimensions of wideband fractal antenna

Parameters	Notation	Dimension (mm)
Substrate width	W_{SUB}	23
Substrate length	L_{SUB}	27.5
Feed line width	W_{FL}	2.3
Feed line length	L_{F1} L_{F2}	4 9
Side lengths of hexagonal rings	s_1 s_2 s_3 s_4	11.5 9 7.5 5
Partial ground length	L_{PG}	27.5
Partial ground width	W_{PG}	9.5

The fabricated wideband fractal antenna front and back views are shown in Figure 3.

a) b)

Fig 3: Fabricated Antenna. a) Patch (front view). b) Partial ground (rear view)

IV. RESULTS

The designed antenna is simulated for return loss and VSWR using HFSS. The simulated results are presented below. The return loss graph is shown in Figure 4.

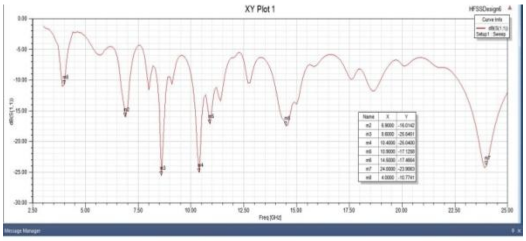


Fig 4: Return loss of the proposed antenna.

The VSWR plot obtained by simulation is shown in Figure 5.

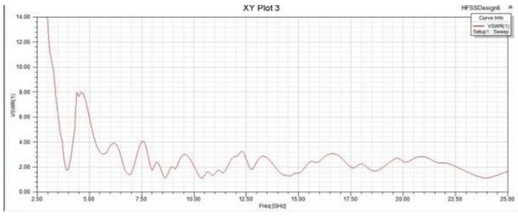


Fig 5: VSWR plot of proposed antenna.

The measured results of fabricated antenna obtained for VSWR and return loss are discussed below. The return loss graph obtained after testing fabricated antenna is shown in Figure 6.

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Fig 6: Measured Return loss plot for fabricated antenna.

The fabricated antenna is tested practically and the VSWR graph is shown in Figure 7.

Fig 7: Measured VSWR plot for fabricated antenna.

V. CONCLUSION

A wideband hexagonal fractal antenna is proposed for wideband and wireless applications. The measured results of VSWR and return loss are in good agreement with simulated results. The proposed hexagonal fractal antenna offers a large bandwidth of 19.4 GHz in the range 3.6 to 23 GHz. The return loss is less than -10 dB for all resonances. The VSWR is less than 2 for all multiple resonances. The VSWR and return loss values for simulated and measured results are compared in Table 2.It is multi-banded. The offered bandwidth of proposed antenna covers IEEE standard wireless frequency bands: UWB range (3.1-10.6 GHz), C (4-8 GHz), X band (8-12 GHz), Ku band (12-18 GHz) and K band (18-27 GHz). It can be used in 5G communications and MIMO applications.

Table 2: Comparison of simulated and measured results

Simulated			Measured		
Resonant frequencies (GHz)	Return loss (S_{11})	VSWR	Resonant frequencies (GHz)	Return loss (S_{11})	VSWR
4	-10.77	1.84	5.5	-13.75	1.51
6.9	-16.01	1.71	8.6	-21.31	1.18
8.6	-25.54	1.55	11.6	-10.12	1.90
10.4	-25.04	1.34	12.9	-11.82	1.68
14.5	-17.46	1.41	17.9	-33.20	1.04
18.6	-12.02	1.88	20.5	-15.19	1.42
24	-23.90	1.38	22.3	-31.30	1.05

The testing has been conducted at DLRL (Defence Electronics Research Laboratory), Chandrayangutta, Hyderabad, India.

VI. REFERENCES

[1] Mohammad T. Islam and R. Azim, “Compact planar UWB antenna with band notch characteristics for WLAN and DSRC”, Electromagn. Res., vol. 133, pg no. 391-406, Jan 2013.

[2] P. Pratim Sarkar and K. Mandal, “A compact low profile wideband U-shape antenna with slotted circular ground plane”, International Journal of Electronics and Communications, vol. 70, pg no. 336-340, 2017.

[3] Mohammad T. Islam, M. Samsuzzaman, Mengu Cho, and S. Kibria, “Compact Antenna for Small

Satellite Applications”, Antenna Applications corner, IEEE Antennas and Propagation Magazine, vol. 57, issue no. 2, pg no. 30-36, Apr 2015.

[4] Nathan Cohen, “Fractal antenna applications in wireless telecommunications”, Fractal Antenna Systems, Inc., IEEE, 1997.

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ISSN: 0193 - 4120 Page No. 2733 - 2737

[5] Suman Gangul and D H. Werner, “An overview of fractal antenna engineering Research” IEEE Antennas and Propagation Magazine. vol. 45, issue no. 1, pg no. 38-57, Feb 2003.

[6] J K. Abraham, K. J. Vinoy, and V K. Varadan, “On the relationship between fractal dimension and the performance of multi-resonant dipole antennas using Koch curves”, IEEE Transactions on Antennas And Propagation, vol. 51, issue no. 9, pg no. 2296-2303, Sep 2003

[7] Susamay Samanta, T. Mondal, S R. Bhadra Chaudhuri and Rowdra Ghatak, “A novel tri-Band hexagonal microstrip patch antenna using modified sierpinski fractal for vehicular communication”, Progress In Electromagnetics Research C, vol. 57, pg no. 25–34, 2015

[8] , R. Ramana Reddy, N K. Darimireddy and A. Mallikarjuna Prasad, “A Miniaturized Hexagonal-Triangular Fractal Antenna for Wide-Band Applications” IEEE Antennas & Propagation Magazine, pp. 104-110, April 2018.

[9] Jong K. Park, Seok H. Choi, Jae Y. Park and Sun K. Kim, “A new ultra-wideband antenna for UWB applications”, Microwave And Optical Technology Letters / vol. 40, issue no. 5, pg no. 399-402, Mar 2004.

[10] K. P. Ray and G. Kumar, “Broadband microstrip antennas”, Norwood, Artech house, 2003.