DESIGN AND DEVELOPMENT OF A NOVEL FRACTAL ANTENNA FOR WIRELESS APPLICATIONS

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Abstract

An innovative concept is utilized to develop the fractal antenna by coalesce the Koch prefractal and meander line. This fractal antenna is proposed for multistandard wireless applications. The shape and dimensions of the proposed antenna are chosen to obtain the multiband behaviour as well as miniaturized structure. Initially two different fractal concepts have been chosen through previous research and merged them to obtain more than two resonant frequencies. The proposed design characterizes four bands at resonant frequencies 2.5 GHz, 6.4 GHz, 7.2 GHz and 8.15 GHz with a return loss of -12.05 dB, -16.68 dB, -14.87 dB and -26.51 dB respectively. This design also represents VSWR between the required range of 1 to 2 for the presented resonant frequencies with an appropriate value of gain in dB. The antenna is analysed with Ansoft HFSS-13.0 electromagnetic field solver.

Keywords: *Microstrip antennas, fractal antennas, miniaturized, multistandard, wireless applications*

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1. INTRODUCTION

It has been observed from the recent literature that fractal shape geometry concept can be utilized for the designing of antennas. New antennas with miniaturized structure and multistandard behaviour can be proposed as an outcome of exclusive properties of fractals. Further enhancements in the characteristics of antenna can be achieved by combining two different types of fractals. Initially Mandelbrot has launched the idea about "fractals" who expressed things that were too asymmetrical to fit in conventional geometrical shapes. Iterative function systems (IFS) are generally used to develop the different fractal objects. The complexity of fractal geometry depends upon the number of iterations and due to this, fractals exhibit distinctive features such as space filling characteristics and self-similarity. Here self-similarity signifies that all the objects in antenna look approximately the same at any scale. The space filling property generally demonstrates the increase in electrical length of the antenna elements. The longer paths for the surface currents consequence in diminish the resonant frequencies without overall extending the size of the resonator. Therefore, at a desired frequency, the size of the antenna can be reduced as compared to simple patch antennas. The fractal properties have already been utilized to develop the new antennas and in present research work we have attempted to unite two different fractals such as Koch prefractal and meander line. The innovation in the field of fractal antennas is progressing day to day as Behdad et al. [1] presented a new method of further reducing the size of an antenna and increasing the bandwidth. They examined parasitic coupling and inductive loading techniques to achieve higher bandwidths and further size reduction. Moreira et al. [2] proposed microstrip fractal antennas for multistandard terminals. They utilized Koch prefractal edge and a U-shaped slot to design a multistandard antenna for GSM 1800, UMTS, and HiperLAN2 standards. Song et al. [3] demonstrated a shorted fractal Sierpinski monopole antenna. This antenna uses half structure of a traditional Sierpinski antenna and is folded over to be parallel to the ground plane, to form an element similar to that of the inverted L antenna. Quasi log periodic resonance behaviour is obtained with a shorting pin placed at the far end of the antenna. Sung et al. [4] improved the design of microstrip patch antenna by using photonic band gap structures in the substrate material to suppress the surface waves. Singh et al. [5] proposed a miniaturized wideband antenna where they utilized aperture coupling feeding and inverted u-slot in patch to enhance the bandwidth of antenna. huang et al. [6] demonstrated a novel multiband and broadband fractal patch antenna which is compact, simple to design and fabricate. The impedance bandwidth of the proposed antenna could reach 18%, which has rarely been reported for single layer and single patch antennas. Singh et al. [7, 8] presented a design analysis of a circular polarized slot loaded microstrip patch antenna for multiband applications. Krishna et al. [9] proposed a dual wide-band CPW-fed modified Koch fractal printed slot antenna, suitable for WLAN and WiMAX operations. Studies on the impedance and radiation characteristics of the proposed antenna indicate that a modified Koch fractal slot antenna has an impedance bandwidth from 2.38 to 3.95 GHz and 4.95–6.05 GHz covering 2.4/5.2/5.8 GHz WLAN bands and the 2.5/3.5/5.5 GHz WiMAX bands. Singh et al. [10] discussed the multiband behaviour of plasmonic nano-antennas for infrared and laser communication. Mondal et al. [11] introduced a miniaturized and dual band hybrid koch fractal dipole antenna design for different wireless applications. In present work we have proposed a new fractal antenna which exhibits a good value of return loss at four resonant frequencies. The details of the development of the proposed antenna are available in the next sections.

2. DESIGN METHODOLOGY

To design and analyse the proposed antenna, High Frequency structure Simulator (HFSS) electromagnetic software tool is utilized. HFSS is a high performance full-wave electromagnetic (EM) field solver for arbitrary 3D volumetric passive device modelling. It integrates visualization, simulation, solid modelling and automation in an easy-to-learn environment where solutions to 3D EM problems are quickly and accurately obtained [6]. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give unparalleled performance and insight to all 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. HFSS is an interactive simulation system whose basic mesh element is a tetrahedron thus allowing us to solve any arbitrary 3D geometry.

3. ANTENNA DESIGN

Waclaw Sierpinski proposed one of the fractal geometry in the year of 1916, which is now called as Sierpinski gasket [21]. Similarly other different shapes have been developed by the numerous researchers time to time. The concept of combining two different geometries of fractal was initially adopted during the year of 2002 to enhance the characteristics of antenna. There are so many important factors which decide the performance of the antenna and in present research work these factors are different lengths and widths as shown in the geometry of figure 1. Two individual fractal geometries are basically adopted here as Koch prefractal and meander line upto the second iteration. The combination of these two fractals is responsible for multiband behaviour as well as an acceptable value of gain. The values of different lengths and widths have been decided after proper parametric analysis to achieve the appropriate target.

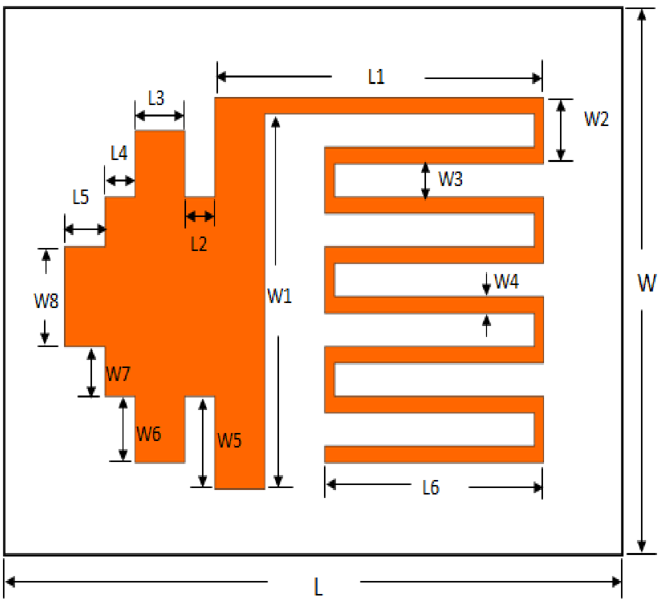

Fig 1: Geometry of the proposed fractal antenna

All the important design parameters of the proposed fractal antenna are represented in form of table 1 which clearly indicate the actual physical interpretation of the proposed design

Table 1: Design parameters of the proposed antenna

Antenna Parameters	Dimensions
W	27.00 mm
εr	4.4
h	1.58 mm
L1	16.50 mm
L2	1.50 mm
L3	2.50 mm
L4	1.50 mm
L5	2.50 mm
L6	11.00 mm
W1	11.50 mm
W2	2.00 mm
W3	1.00 mm
W4	0.50 mm
W5	2.80 mm
W6	2.00 mm
W7	1.50 mm
W8	3.00 mm

4. RESULTS AND DISCUSSIONS

The proposed fractal antenna geometry has been demonstrated through figure 1 and all the significant parameters are described through table no. 1 with their values in 'mm'. The important technique to analyse the performance of the antenna is its parametric analysis. Parametric analysis has been done by taking into consideration two valuable parameters i.e. substrate thickness 'h' and side length of the meander like structure.

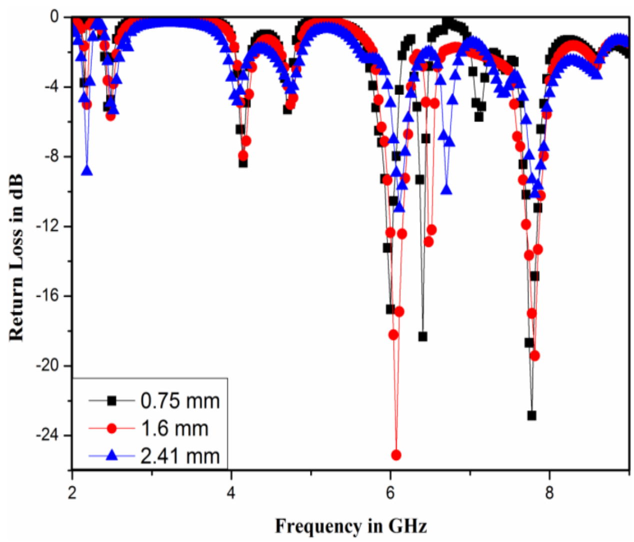

Fig 2: Return Loss versus operating frequency characteristics of proposed antenna by variation in substrate thickness 'h'

Figure 2 represents the return loss versus operating frequency characteristics of the proposed antenna by varying the substrate thickness which is ranging between 0.75 mm and 2.41 mm. It is observed from the figure 2 that if the value of 'h' is taken to be 0.75 mm, the antenna resonates at frequencies 6.1 GHz, 6.40 GHz and 7.77 GHz at a corresponding return losses of -16.76 dB, -18.02 dB and -22.84 dB. This is represented by black line of figure 2. With a certain change in 'h' value from '0.75 mm' to '1.6 mm' the resonant frequencies are modified as 6.07 GHz, 6.48 GHz and 7.81 GHz with corresponding return loss values -25.11 dB, -12.88 dB and -19.40 dB. Further if the 'h' value is increased to 2.41 mm the antenna resonates at frequencies 6.11 GHz, 6.70 GHz and 7.81 GHz with the return loss values -10.95 dB, -9.94 dB and -10.14 dB respectively. this is represented by blue line curve of figure 2. From the above said discussion about the 'h' parameter of the proposed antenna it has observed that its value should be 1.6 mm at which it resonates absolutely at specific values of return loss. For the convenience of the reader the results of figure 2 related to the 'h' parameter analysis are tabulated in table 2.
After setting the value of substrate height/thickness ('h' in mm) another important parameter has taken into consideration i.e. side length of meander like structure 'L1'. The parametric analysis of side length 'L1' is demonstrated through figure 3. At first step the parameter 'L1' has taken to be 16.05 mm and at this value the proposed antenna resonates at operating frequencies 2.81 GHz, 6.85 GHz, 6.96 GHz and 8.59 GHz with return loss values -11.24 dB, -18.11 dB, -10.22 dB and -26.82 dB respectively. This is represented by black line of figure 3. Now if we increase the side length 'L1' value from 16.05 mm to just 16.50 mm the antenna resonates at operating frequencies 2.81 GHz, 6.81 GHz, 7.33 GHz and 8.55 GHz with return loss values of -14.3 dB, -17.43 dB, -15.05 dB and -29.01 dB respectively. This is represented by red curve plot of figure 3.

Table 2: Resonant frequencies and return loss characteristics at different values of substrate height

Substrate height in mm	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB
0.75	6.1	-16.76	6.40	-18.02	7.77	-22.84
1.6	6.07	-25.11	6.48	-12.88	7.81	-19.40
2.41	6.11	-10.95	6.70	-9.94	7.81	-10.14

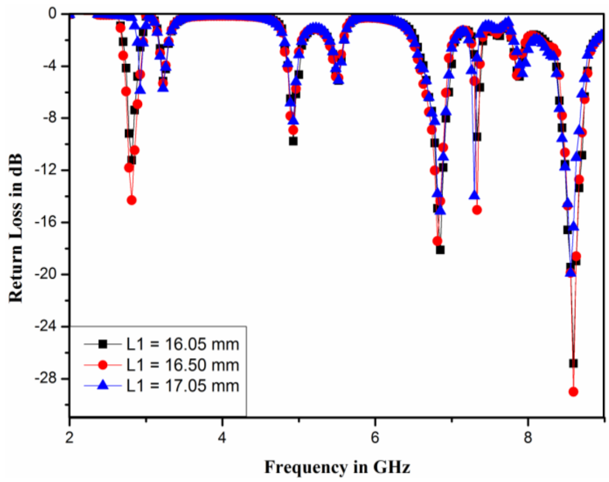

Fig 3: Return Loss versus operating frequency characteristics of proposed antenna by variation in side length 'L1'

Further operating frequencies are shifted to 2.92 GHz, 6.85 GHz, 7.29 GHz and 8.56 GHz at return loss values of -5.84 dB, -15.13 dB, -13.96 dB and -19.89 dB respectively when side length 'L1' value assumed as 17.05 mm. It is represented through blue curve plot of figure 3. It is not easy to recognize the operating frequencies and corresponding return loss values through line plots of figure 3 therefore, the consolidated results of figure 3 are also demonstrated in table 3.

Table 3: Resonant frequencies versus return loss characteristics for different L1 lengths

Length L1 in mm	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB	Fr in GHz	S11 in dB
16.05	2.81	-11.24	6.85	-18.11	6.96	-10.22	8.59	-26.82
16.5	2.81	-14.3	6.81	-17.43	7.33	-15.05	8.55	-29.01
17.05	2.92	-5.84	6.85	-15.13	7.29	-13.96	8.56	-19.89

Finally it is observed from the above discussion about the parametric analysis that the substrate thickness/height and side length 'L1' of meander like structure are chosen to be '1.6 mm' and '16.5 mm' respectively. The analysis of antenna is generally based upon two broad categories, one is input parameters and another is output parameters. Return loss characteristics as shown in figure 2 and figure 3 are representing the input characteristics and gain of the antenna comes under the output characteristics. Therefore, it is important to analyse the gain response of the proposed antenna to confirm the antenna as a good radiator. Figure 4 is representing the 3D gain plot of the proposed antenna which shows that the antenna is radiating maximally normal to the plane of conductive patch. The peak gain achieved through the proposed antenna design is approximately 6.73 dB.

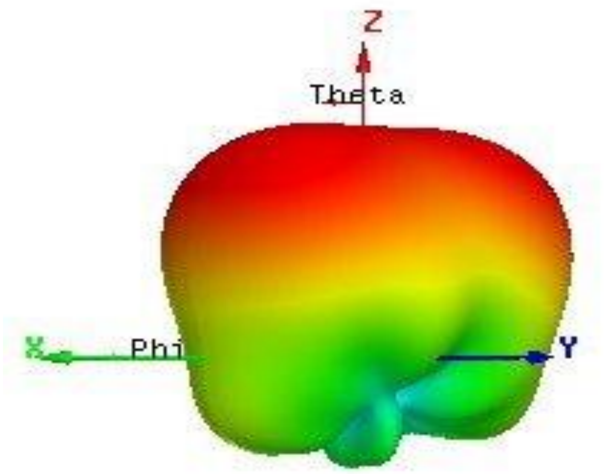

Fig 4: 3D gain plot of the proposed fractal antenna design

5. CONCLUSION

Exclusive fractal geometry is proposed for antenna. Initially some of the important parameters have taken into consideration for parametric analysis and the optimum values of these parameters are obtained. Further the fractal antenna geometry is analysed to know the characteristics of antenna. It has observed that the proposed antenna is multiband in nature and exhibiting resonant frequencies of 2.81 GHz, 6.81 GHz, 7.33 GHz and 8.55 GHz with return loss values of -14.3 dB, -17.43 dB, -15.05 dB and -29.01 dB respectively. Return loss is generally comes under the category of input characteristics and it is also important to understand the radiating behaviour of proposed antenna design. The radiating behaviour can be checked through the gain parameter of the antenna and in present work the proposed design demonstrated a gain of 6.73 dB which is a very good value for such type of minute antenna. It is concluded with reference to the discussion held on that the proposed antenna suitably address the wireless applications such as WiMAX band, Radio astronomy, Passive sensor networks and high speed applications.

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