Design of H-fractal antenna for multiband applications

Hemant H Patil,
Department of Electronics & Telecommunication Engineering
Dr.Babasaheb Ambedkar Technological University
Lonere,Raigad,402103,INDIA
hhpatil@dbatu.ac.in

Sanjay V Khobragade
Department of Electronics & Telecommunication Engineering
Dr.Babasaheb Ambedkar Technological University
Lonere,Raigad,402103,INDIA
svkhobragade@dbatu.ac.in

***Abstract* – This paper presents the design of an H-fractal antenna for multi band applications. Introducing fractal concept, the H-shaped microstrip antenna is designed. Using space-filling property of fractal geometry, the size of antenna is reduced. Seven iterations of H- fractal multi-band antenna are arranged and examined.The H- fractal planar antenna is fabricated on an FR4 substrate with a 1.6 mm thickness. The H- fractal planar antenna is fabricated on an FR4 substrate with a 1.6 mm thickness. The design is analyzed using HFSS v15 which is based on Finite Element Method (FEM).The antenna operates at resonant frequencies of 2.45/5.5GHz WLAN applications. Reflection coefficients |S11| and radiation properties of the proposed H–fractal antenna make it suitable for a variety of wireless applications.**

Index Terms - Fractals, multiband, planar antennas, WLAN

I. INTRODUCTION

The microstrip fractal antenna with small size and multiband characteristics are used for many applications such as cognitive radio, radar systems, satellite communication. The fractal geometry on microstrip patch has always been a keen interest for the antenna designers. Fractal antennas are known for its compact size and multiband /wideband nature [4], [7]. Fractal has many shapes like Hilbert curve, Sierpinski gasket, Koch snowflake, used for antenna designing. Fractal geometries have been recently introduced an antenna design.

The fractal antennas are having two properties named self-similarity and space filling property [12]. Design of a fractal antenna to receive and transmit over a wide range of frequencies using self-similar properties associated with a fractal geometry structure, because different antenna's part are similar to each other at different scale. The space filling property is the efficiency of some fractal shapes, which reduces the antenna size, comparatively to that of normal antennas. In this antenna design various fractal shapes that possess self-similarity have been applied to multiband and miniaturised antenna design [12].

Proposed H–fractal antenna has a more simple structure. The design process of the proposed H–fractal is quite straight forward and easy for implementation. Reflection coefficients |S11| exhibits the multiband nature of the proposed H–fractal antenna [1].

II. ANTENNA STRUCTURE AND DESIGN PROCESS

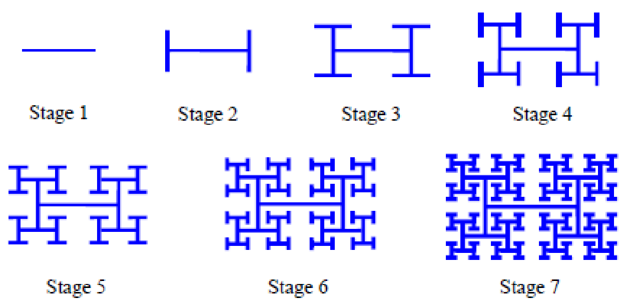

Fig. 1. Illustration of different stages of the H–shaped fractal. The geometry of Stage 7 is used to the proposed antenna.

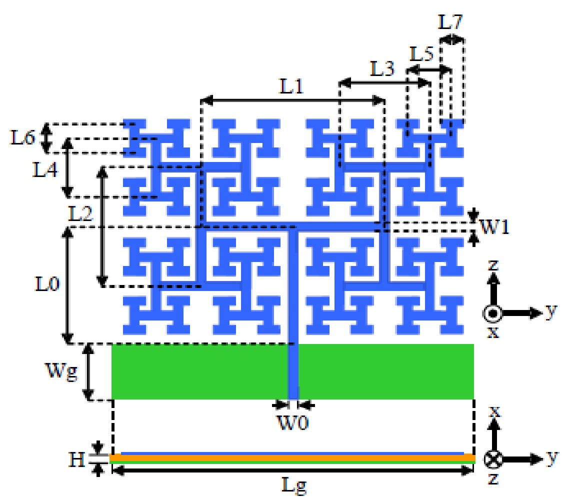

Fig. 2. The proposed H–fractal antenna geometry

Figure1 shows the design of H-shaped fractal antenna. Beginning with Stage 1, the antenna consists of a horizontal metal strip with length L1 and width W1. In Stage 2, the length of the two vertical strips (L2) is δ times L1, where δ *is* the scale factor with the value between 0 and 1. Hence, the L2 is smaller than L1. Meanwhile, the two vertical strips are added to the two ends of the horizontal strip. Two vertical strips are of 3.0 mm width, which is the same as that of the horizontal strip. The same procedure is applied to Stage 3 to Stage 7 as well. Finally, the proposed H–fractal antenna is achieved at Stage 7 as shown in Fig. 2.

The length of strips in each stage can be determined by

$$L(i+1) = \delta\, L(i). \quad (i = 1,2,\ldots,6) \qquad \text{- (1)}$$

The width of all metal strips is identical as 3.0 mm. The geometry of the H–fractal is symmetric to the 50 ohms microstrip fed line with the corresponding width of W0. The size of the ground plane is Lg by Wg. It is having monopole ground structure [4].The geometry of the H–fractal should be carefully determined to avoid overlapping between strips when designing the proposed antenna. The scale factor δ can control the size of the antenna. It is one of the key parameters affecting the resonances and impedances of the proposed antenna.

To achieve a compact antenna size, the fractal antenna usually operates at its dominant resonant frequency. To design the proposed H–fractal antenna procedure is implemented as below.

(a) Determine the total electric length L about quarter wave-length in free space at the lowest band (the dominant resonant frequency).
(b) Determine the stage number N and L1 that the H–shaped fractal will be used. The strip lengths can be determined based on L and (1).
(c) Obtain the range of the scale factor δ between 0 and 1.
(d) Determine δ and obtain the H-shaped fractal configuration.
(e) Modify the dimensions of the proposed antenna based on the L1 and δ to achieve the desired resonant frequencies. This will repeat the operations in the step (b) to step (e).
(f) Achieve good impedance match at operating bands.

The parameters that are considered for this design are the length, dielectric constant, resonant frequency fr, Return loss, thickness, input impedance, bandwidth, directivity, Gain, VSWR and Radiation efficiency. The dimensions of the optimized antenna are listed in Table I.

Dimensions of antenna are calculated as per following [11],

Calculation of Width;

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

Where C = free space velocity of light

ϵ_r = Dielectric constant of substrate

In this design, FR4 substrate of relative permittivity of 4.4 and height h=1.6mm is used.

The effective dielectric constant of the microstrip patch antenna calculated as,

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{W}}}\right)$$

Due to the fringing fields at the two edges, the effective length of the patch radiating electromagnetic radiation is given by,

$$L = L_{eff} - 2\Delta L \quad \text{where}$$

$$L_{eff} = \frac{C}{2f_r\sqrt{\epsilon_{eff}}}$$

Calculation of Length Extension given as,

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

Where h is the thickness and ϵ_{reff} is effective dielectric constant.

The width of the microstrip feed line (Wo) for Zo=50Ω characteristic impedance, can be calculated as

$$\frac{W_o}{h} = \begin{cases} \dfrac{8e^{A}}{e^{2A}-2}; & \dfrac{W_o}{h} < 2 \\ \dfrac{2}{\pi}\left[\begin{array}{c} B-1-\ln(2B-1)+ \\ +\dfrac{\epsilon_r-1}{2\epsilon_r}\left\{\ln(B-1)+0.39-\dfrac{0.61}{\epsilon_r}\right\}\end{array}\right]; & \dfrac{W_o}{h} > 2 \end{cases}$$

$$A = \frac{Z_o}{60}\sqrt{\frac{\epsilon_r+1}{2}} + \frac{\epsilon_r-1}{\epsilon_r+1}\left(0.23+\frac{0.11}{\epsilon_r}\right);$$

$$B = \frac{377\pi}{2Z_{o\sqrt{\epsilon_r}}}$$

TABLE I
THE DIMENSIONS OF THE OPTIMIZED H–FRACTAL ANTENNA.

PARAMETER	H	W_G	W_0	W_1-W_7	L_G	L_O	
SIZE(MM)	1.6	20	1.69	3.0	120.0	43.71	
PARAMETER	L_1	L_2	L_3	L_4	L_5	L_6	L_7
SIZE(MM)	53.02	36.96	25.77	17.96	12.52	8.72	6.08

III. SIMULATED RESULTS

The proposed H–shaped fractal antenna fabricated on an FR4 substrate having dielectric constant of 4.4 and loss tangent of 0.02 .It is having the thickness (H) of 1.6 mm. Resonant frequencies decrease as the stage number increases. Fig.3 illustrates the simulated reflection coefficients |S11| .The multiband feature of the proposed H–shaped fractal antenna is achieved.

A. *RETURN LOSS |S11|-*

The return loss is simulated using HFSS. As shown in Fig.3 the antenna operates at in the resonant frequency of 2.425GHz having a return loss of -26.95dB and frequency of 5.5GHz having a return loss of -14.25dB for WLAN application.

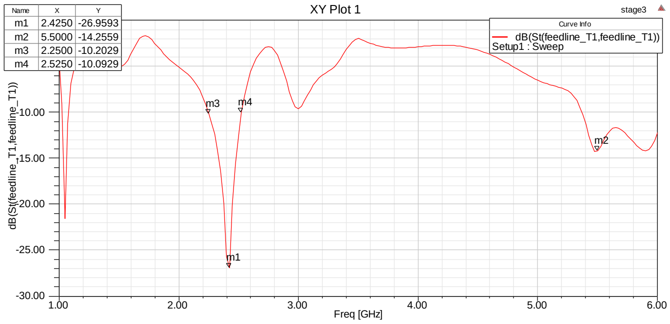

Fig. 3. The reflection coefficients |S11| of the proposed H–fractal antenna

B. VSWR-

For the resonant frequencies of 2.425GHz and 5.5GHz VSWR are less than -1.5dB.

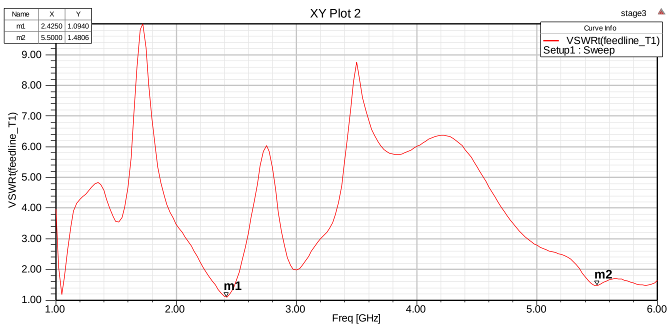

Fig. 4. VSWR vs frequency of the proposed H–fractal antenna

C. INPUT IMPEDENCE-

The proposed H–fractal antenna's input impedence is shown in fig.5. At the dominant resonant frequency of 2.425 GHz the impedence Zr is 48.91ohms and 50 ohms at 5.5GHz of frequency.

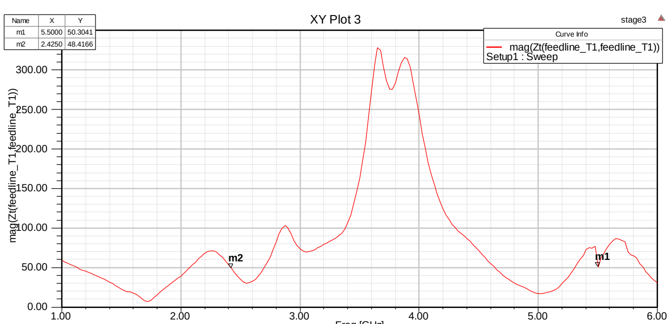

Fig. 5 The input impedance of the proposed H–fractal antenna.

D. IMPEDENCE BANDWIDTHS-

The impedance bandwidths are shown in figure 6 at the lower and upper bands (|S11| < -10 dB) are (2.25–2.525 GHz) and (5.37–5.65 GHz), respectively, which successfully cover the 2.45 GHz (2.4–2.497 GHz) and 5.5 GHz (5.15–5.825 GHz) WLAN bands. The result demonstrates the practical utilization of the proposed H–fractal can be applied for the WLAN application.

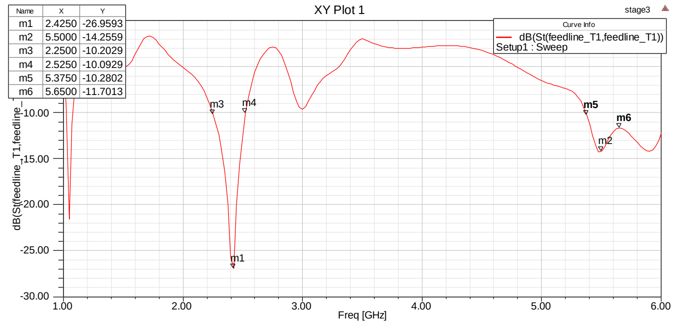

Fig. 6 Wide bandwidths of the proposed H–fractal antenna.

E. SURFACE CURRENT DENSITY-

The current density of the antenna is around the confined patch for the resonant frequencies shown in the Fig.7.

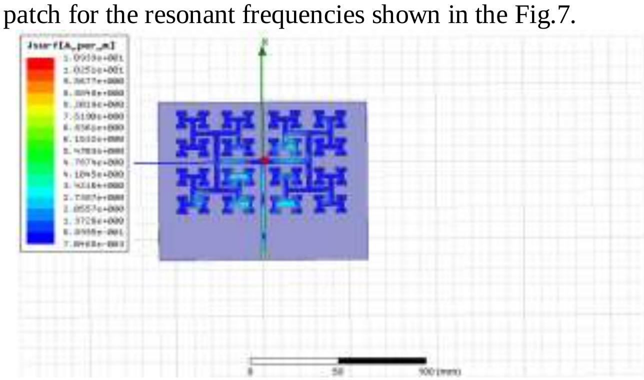

Fig. 7 Surface current density of the antenna at the resonant Frequencies at 5.5GHz.

F. 3D RADIATION PATTERN-

The antenna peak directivities are about 3.11dB and 7.2 dB at resonant frequencies of 2.425GHz and 5.5GHz respectively, the radiation efficiency is all better than 90%.

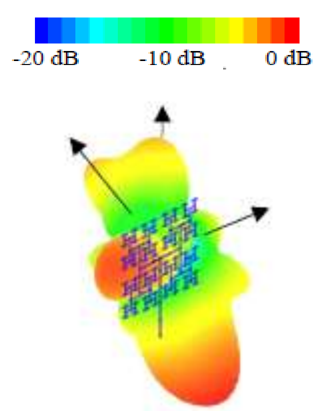

Fig. 8. Simulated 3D radiation patterns of the proposed H–fractal antenna at frequencies of 5.5GHz.

IV. CONCLUSION

In this paper, planar antenna design which is based on an H-shaped fractal structure is presented. The proposed H–

fractal has a simple structure and it is easy for implementation. The design procedure and rules avoids overlapping between strips. Results show that the proposed antenna can excite multiple resonances with reasonable antenna gain. The proposed H–fractal antenna is useful for 2.45/5.5 GHz WLAN application. Result shows that the optimized antenna successfully achieves the design goal. The proposed H–shaped fractal has a great potential for designing antennas with multiband or wideband features.

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