Design of Wideband Fractal Antenna with Combination of Fractal Geometries

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Abstract—**A new small size fractal antenna is proposed for the application in wide-band frequency range. It is designed with the combinations of two fractal geometries. The wideband mechanism is explored by investigating the behaviour of the current on the patch. The length and width of Koch and cantor fractal geometries are optimized to achieve a wide bandwidth. The feed circuit is a microstrip line with a matching section over a rectangular ground plane. The measured -10dB reflection bandwidth for frequency range (1.64 GHz to 3.5 GHz) is 72.37%.The EM characteristics of the antenna are presented by surface current distributions. The radiation characteristics and gain of the proposed antenna are also presented and discussed.**

Keywords-Koch Fractal; Cantor set; Wideband; Microstrip line.

I. INTRODUCTION

Owing to the progress in wireless communication systems and increase in their application, small size and wideband antennas are in great demands. These have recently received a great deal of attention from researcher creating new antenna structure. One such structure is the fractal shape antenna.

Due to the concept of self-similarity, infinite complexities and detail in their geometrical properties, fractal antennas allow smaller, multiband and broadband antenna design [1]. Most fractal objects have self-similar shape, with different scales [2]. The fractal shape can be carried out by applying the infinite number of iteration using multiple reduction copy machine (MRCM) algorithm [3]. On the other hand, Koch wire monopole [4]–[6] and Combination of Giuspe Peano and Sierpinski Carpet fractals [7] have fractal boundaries incorporated along the patch edge to reduce the size of the patch.

B. Mandelbort [8] proposed the fractal geometries in 1951, which were extensively used in various science and engineering fields. They were also applied for the design and realization of frequency independent and multiband antennas.

In this paper, we proposed a new design antenna structure for wideband application, which is realized with the combination of Koch and Cantor fractals shapes. Basic antenna structure is rectangular shape, feed by microstrip line [9]. These Koch structure is applied to the down edge of basic antenna shape. Cantor shape fractal is implemented by cutting slot on the upper side of the patch. The design of antenna was performed and optimized using CST Microwave studio and return loss measured by Network Analyser Model No. E5071C. The proposed antenna has an omnidirectional radiation pattern and good gain.

Figure 1. The initiator and Generator of Cantor Set Fractal Structure

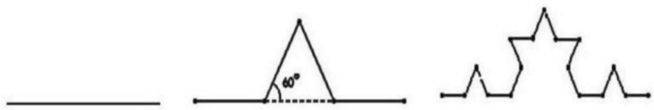

Figure 2. Generator of Koch Fractal Structure

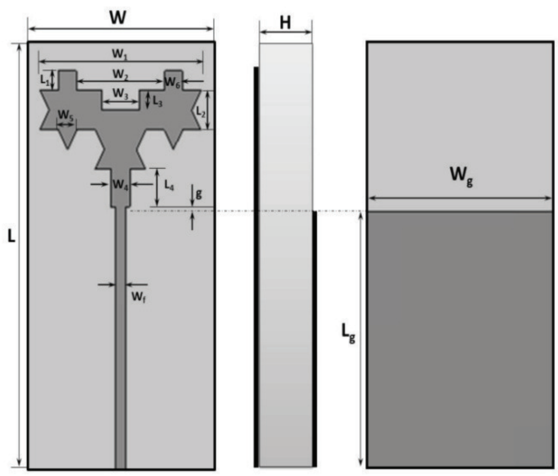

Figure 3. The Structure of Proposed Fractal Antenna

II. DESIGN OF FRACTAL PATCH ANTENNA

The procedure of the Cantor and Koch fractal structure is shown in figure 1 and figure 2. This is applied on the top and bottom edges of the basic antenna patch. The proposed antenna is shown in figure 3, where the parameter values of final structure are shown. The antenna is fed through a microstrip line with a matching 50 Ω and it is calculated using (1) and (2)

TABLE I
DIMENSIONS OF PROPOSED FRACTAL ANTENNA

Parameters	Dimensions (mm)
H	1.61
W	25
L	66
W_1	25.4
W_2	14
W_3	6
W_4	3
W_5	2.9
W_6	2.8
L_1	2.9
L_2	2.9
L_3	5.8
L_4	5.5
L_g	5.5
W_g	5.5
W_f	5.5
g	5.5

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\left[\frac{1}{\sqrt{1 + 12\frac{h}{w}}}\right] \quad (1)$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{w}{h} + 1.393 + 0.667\ \ln\left(\frac{w}{h} + 1.444\right)\right]} \quad (2)$$

Table 1 shows the dimensions of the proposed antenna. The selected substrate is FR4 with dielectric constant ε_r=4.4 substrate thickness H=1.6 mm and loss tangent tanδ=0.02. The overall dimension of the patch is $L \times W$. The ground plane is a rectangular sheet covers feed line with gap (g=0.5 mm) from the patch. Proposed patch dimensions are optimized by CST microwave studio simulation software. This is also used for analysis of antenna.

III. Simulatrion and Measurement Results

The prototype model of the proposed antenna is fabricated and it shown in figure 4. The simulated S_{11} plot of gap (g) between radiating patch and ground plane is shown in figure 5. It is observed that with increasing the gap, bandwidth of the antenna decreases. The comparisons of first and second iterations of proposed antenna are shown in figure 6. It is observed that, resonant frequency of second iteration is quite negligible relative to that of the first iteration. Furthermore, the bandwidth at the resonant frequency of the second iteration is more than the first iteration. Figure 7 has shown the simulated result and measured data for return loss. It is observed that the bandwidth of proposed antenna (for definition of -10dB) is from 1.6 GHz to 3.5 GHz. Which is useful for many wireless applications and it is wideband frequency range.

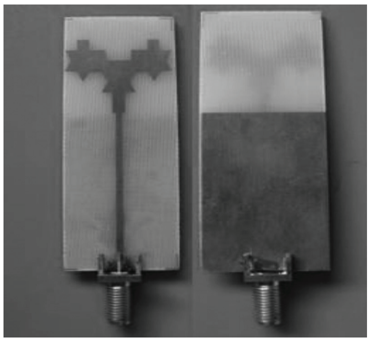

Figure 4. A prototype model of proposed antenna

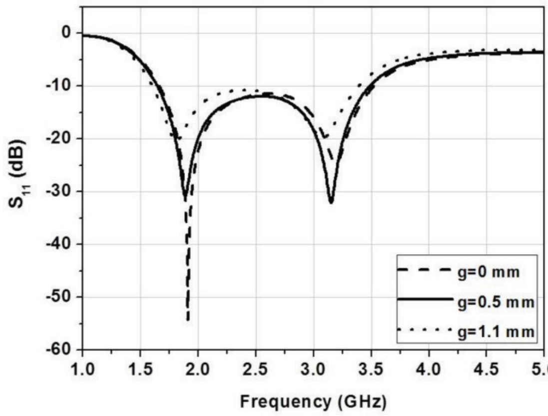

Figure 5. Comparisons return loss of gap between radiating patch and ground plane

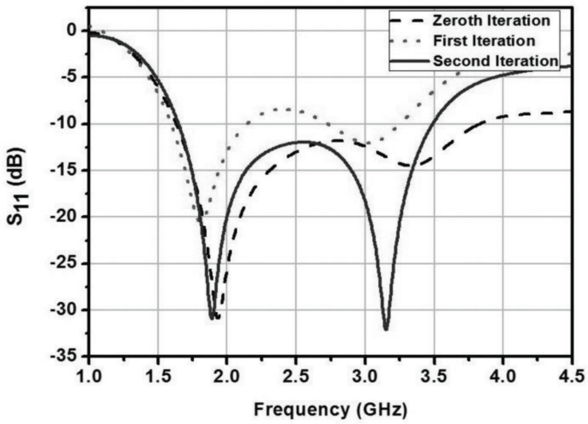

Figure 6. Comparisons return loss of the fractal antenna for different iterations.

The simulated results of normalized two cut patterns are shown in figure 8 at a frequency of 1.9 GHz and 3.15 GHz. Similarly, the directional patterns are observed in the E-Plane cut and the non-directional patterns are presented in H-plane cut. The total surface current distributions are shown in figure

9. It is observed that in this design the current at feed line is strong and at higher mode it spreads over the whole patch. The gain of proposed antenna is 2.5dBi-6dBi at wideband frequency range.

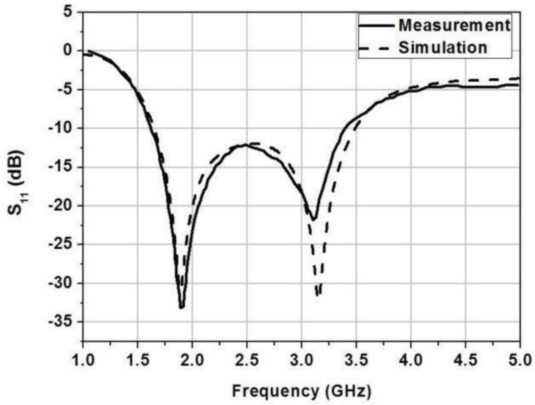

Figure 7. Simulated and measured Return Loss of proposed antenna

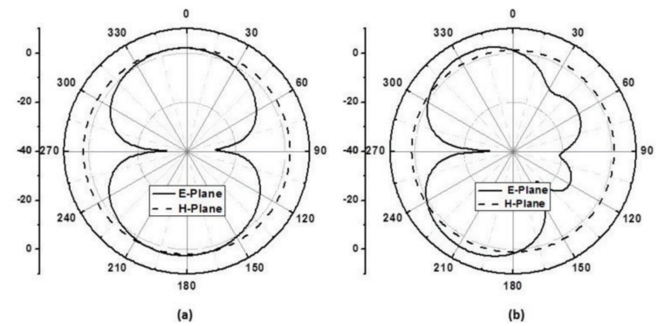

Figure 8. Radiation pattern of proposed antenna (a) 1.9 GHz, (b) 3.15 GHz

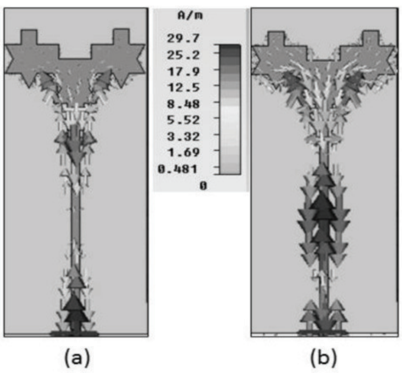

Figure 9. Radiation pattern of proposed antenna (a) 1.9 GHz, (b) 3.15 GHz

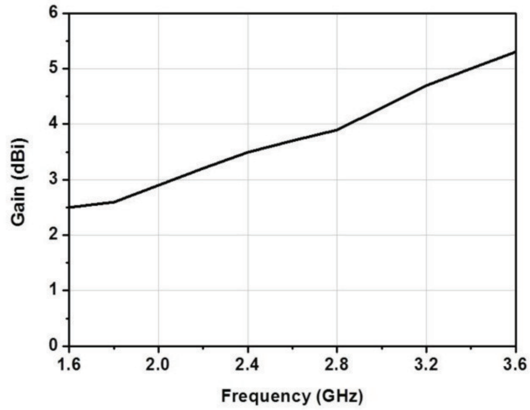

Figure 7. Gain versus frequency of proposed antenna

IV. Conclusion

The combination of fractal shape antennas is designed for wideband operation and presented. The simulation and measurement results show the antenna is suitable for various wireless applications. The proposed antenna has an omnidirectional radiation patterns and good gain at wideband frequency range (1.6-3.5 GHz). The current distribution is simulated to clarify the EM characteristics of the antenna.

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References

[1] D.H. Werner and R. Mittra, "Frontiers in Electromagnetics", New York, Wiley/IEEE Press, 1999.

[2] Kenneth Falconer, Fractal Geometry: Mathemetical foundation and Application, New York, Jhon Wiley & Sons, 1990.

[3] H. Peitgen, H. Jurgens, and D.Saupe, Chaos and Fractals: New Frontiers of science. Newyork : Springer-verlag, 1992.

[4] C.P. Baliarda, J. Romeu, and A. Cardama, "The koch monopole: a small fractal antenna," *IEEE Trans. on Antenna and Propagation,* vol. 48, pp. 1773–1781, 2000

[5] S. R. Best, "On the performance properties of koch fractal and other bent wire monopole", *IEEE Trans. on Antenna and Propagation,* Vol. 51, No. 6, pp. 1292-1300, 2003

[6] R. Azaro, G. Boato, and M. Donelli, "Design of miniaturized ism.band fractal antenna," *Technical Report, DIT-05-009, University of Trento*, 2005.

[7] S. Oraizi, H.; Hedayati, "Miniaturized UWB monopole microstrip antenna design by the combination of Giusepe peano and Sierpinski carpet fractals," *Antennas and Wireless Propagation Letters, IEEE*, vol. 10, pp. 67–70, 2011.

[8] B.B. Mandelbort, The Fractal Geometry of nature, New york: Freeman, 1983.

[9] Y. Choukiker and S.K. Behera, "Design of planar monopole antenna for 2.4 GHZ WLAN," *IEEE International Conference on Computational Intelligence and Communication Networks (CICN),*, vol. 52, pp. 16–19, 2010.