Coaxial Probe Fed Fractal Patch Antenna for Wireless Application

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Abstract

A planar microstrip patch antenna has been designed by amalgamating two different fractal geometries in the form of notches and cuts capable of exhibiting heptaband behavior inherited by basic fractal shapes. The suggested layout reverberate at heptad frequencies and exhibits bandwidth of 300 MHz, 110 MHz, 200 MHz, 160 MHz, 300 MHz, 300 MHz and 120 MHz respectively. Entire reverberant frequencies have admissible numbers of S11 and VSWR less than 2. The proposed structure has been designed on rectangular FR4 substrate with a square patch dimensions of 45 mm × 45 mm. Proposed antenna structure is compact and can become part of portable device. Design, analysis and simulation have been done on an electromagnetic simulator.

Keywords

Hybrid fractal, Minkowski, Koch, FR4.

1. Introduction

Microstrip antennas are widely used in handheld applications. They are popular due to their easy availability, low cost and ease of fabrication on substrates. The radiating structure is a metal patch of different shapes which is placed over a ground plane [1]. The microstrip patch can be of any shape but square, rectangular, circular, elliptical and ring shapes are most common ones. It has a conducting layers on both sides or one side of a substrate.

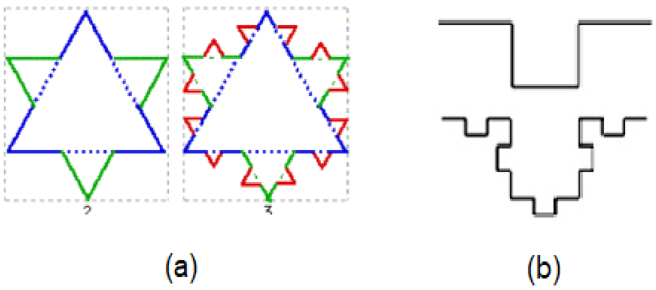

Figure 1. (a) Koch fractal and its iterations (b) Minkowski fractal and its iterations

The key attributes of a microstrip antennas are lightweight, smaller size and volume, low cost, and bulk production capability [2][3]. Traditionally, a single antenna was designed to operate at a one or two frequencies, so more than one antennas were required for various applications [4]. Such limitations has were overcome by use of fractal shapes. Fractal shapes were initially explained by Mandelbrot in 1983. Such layouts has distinctive spatial appearances [5]. In modern wireless

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communication systems fractal antennas have fulfilled requirements of obtaining multiple resonances by a single antenna. So multiband but low profile antennas are very popular for various wireless applications [6][7].

The congruous architecture of Koch curve is straightforward. A Minkowski fractal is also a well known fractal geometry, due to its space filling properties it can be used to impoverish the form factor of the layout by increasing the efficiency with which extended electrical length [8]. Both the fractal curves are shown in Figure 1.

2. Antenna Design

The proposed structure starts with a square microstrip patch of 45 mm × 45 mm designed on FR4 substrate measuring 56 mm × 54 mm in HFSS electromagnetic field solver.

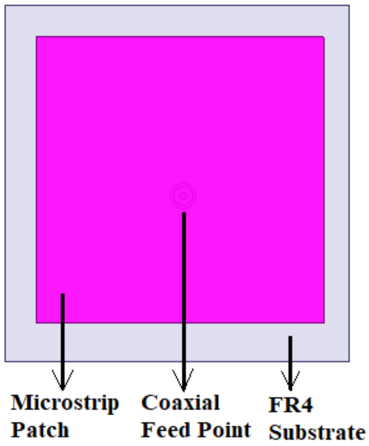


Figure 2. Square shaped microstrip patch used as an initiator

The following mathematical expressions [9] are used for calculation of various antenna geometrical parameters:

$$W = \frac{C}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_{r-1}}{2}\left(1 + 12\frac{h}{w}\right)^{-\frac{1}{2}} \tag{2}$$

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

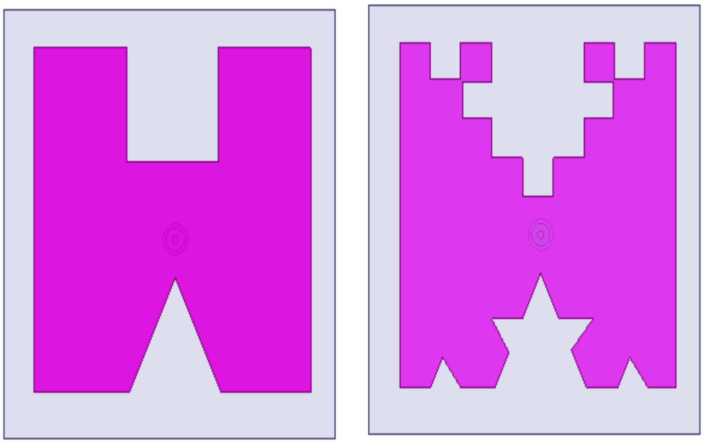
The designed microstrip patch antenna is shown in figure 2 has been simulated in its basic form and results were extracted. The coaxial feeding method and a simulated SMA connector was utilized for this antenna geometry. Full ground has been used at the back of the substrate.

The calculated design criteria of the suggested layout are shown in Table 1.

Table 1
Dimensions of suggested layout

Parameters	Values (mm)
Patch layout	45 × 45
Ground layout	56 × 56
Feeding technique used	Coaxial feed
Substrate used	FR4

The next step in designing the proposed structure is by removing the patch material in the form of Koch fractal and Minkowski fractal from the lower and upper side of the patch at 1st iteration. After simulating this structure with coaxial probe feed, resonance has been achieved at four different frequencies 3.1GHz, 4.4GHz, 6.1GHz and 7GHz with good values of return loss. Later iteration level has been increased up to 2nd level. Multiband resonance has been achieved due to the self-similar behavior of the fractal structures which generates a lot of edges, corners, segments and perimeter [8][10][11]. The proposed hybrid fractal antenna design after 1st and 2nd iteration are shown in Figure3.



(a) (b)

Figure 3. Final proposed hybrid fractal antenna with Koch and Minkowski fractal design (a) for 1st Iteration and (b) for 2nd iteration

3. Outcome

Present portion portrays the analogizing and analysis of profuse outcome from the simulation of proposed antenna structure in the electromagnetic simulator. As mentioned in the prior section proposed antenna has been designed for iterations 1 and 2. A comparison of the reflection coefficient properties of the designed layout as demonstrated below .

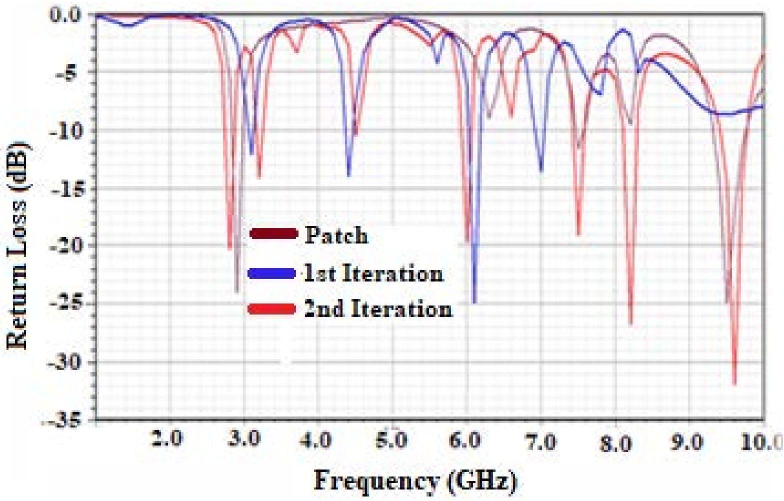


Figure 4 Comparison of return loss for the patch after 1st & 2nd iteration

For the simple square patch the structure resonates at two frequencies. The suggested layout structure reverberates at four un-identical frequencies at 1st iteration while it reverberates at 7 different frequencies for 2nd iteration. It has been noticed that suggested layout is compact and multiband radiating device. Table 2 displays the elaborated values of reverberate frequencies inclusive of VSWR and bandwidth. All obtained values are in an acceptable range.

Table 2
Various units of the suggested layout

Sr. No.	Resonating Frequency (GHz)	Return Loss (dB)	VSWR	Bandwidth (MHz)
1.	2.8	20.1	1.21	300
2.	3.2	14	1.49	110
3.	4.5	11	1.85	200
4.	6.0	20	1.23	160
5.	7.5	19	1.25	300
6.	8.2	26.5	1.09	300
7.	9.6	32	1.05	120

Emission figure is a kind of diagrammatic illustration of dissimilarity in the field strength of the radio waves in two-dimensional stretch. Two dimensional radiation designs are more often taken at particular frequency, selected polarization and at particular plane.

Figure 5. (a–g) shows the simulated 2-D far field radiation patterns for each reverberate frequency. Red color lines represents the values for phi = 0^o and blue color lines for theta = 90^o in the elevation plane.

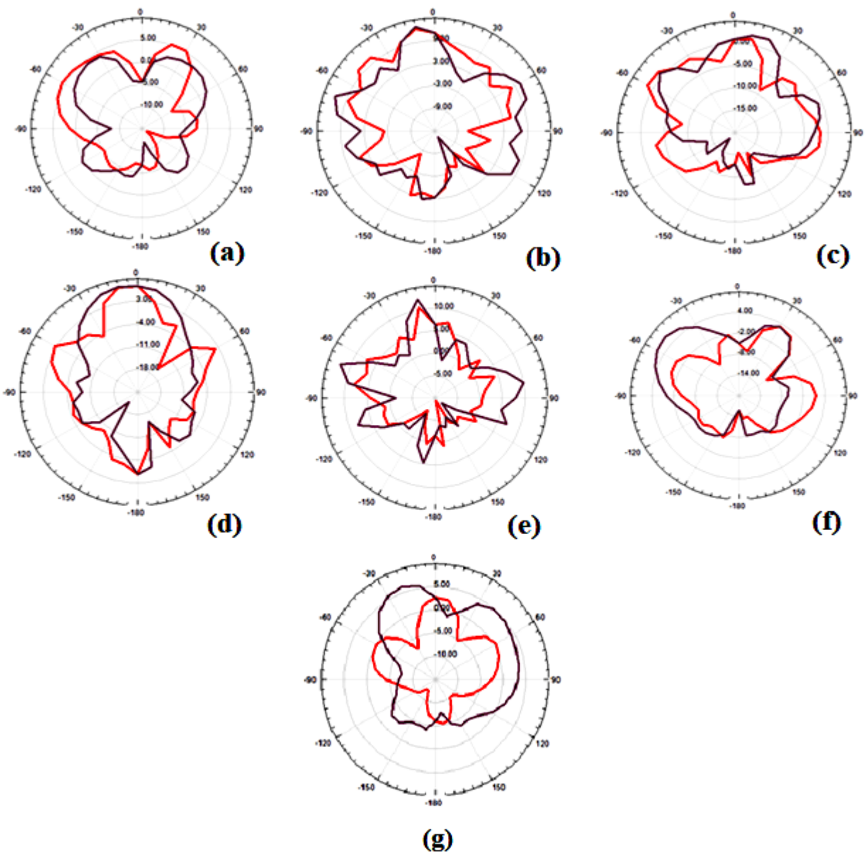


Figure 5. 2D radiation graph (a) 2.8 GHz (b) 7.5 MHz (c) 8.2 GHz (d) 9.6 GHz (e) 6 GHz (f) 3.2 GHz (g) 4.5 GHz

4. Conclusion

In this work, a hybrid fractal microstrip patch antenna has been designed by using Koch and Minkowski fractal structures. The proposed antenna has been designed on FR4 material. Probe fed coaxial feed has been used for providing signal. Simulation is done on the HFFS electromagnetic simulator and resonance has been obtained at seven different frequencies in gigahertz are 2.8, 3.2, 4.5, 6.0, 7.5, 8.2 and 9.6 with sustainable values of return loss in decibels 20.1, 14, 11, 20, 19, 26.5, 32 respectively. Suggested layout is close packed and suitable for wireless applications.

5. References

[1] A. Azari and J. Rowhani, "Ultra Wideband Fractal Microstrip Antenna Design," *Progress In Electromagnetics Research C*, vol. 2, pp. 7–12, 2008.

[2] H. Rhyu *et al.*, "Multi-band hybrid antenna for ultra-thin mobile phone applications," *Electronics Letters*, vol. 45, no. 15, p. 773, 2009.

[3] M. Barthwal, "Microstrip Slot Antenna Loaded With SRR For Multiband Operation," pp. 3–6, 1996.

[4] L. Lizzi, R. Azaro, G. Oliveri, and A. Massa, "Multiband Fractal Antenna for Wireless Communication Systems for Emergency Management," *Journal of Electromagnetic Waves and Applications*, vol. 26, no. 1, pp. 1–11, Jan. 2012.

[5] D. H. Werner and S. Ganguly, "An overview of fractal antenna engineering research," *IEEE Antennas and Propagation Magazine*, vol. 45, no. 1, pp. 38–57, 2003.

[6] Y. Kumar and S. Singh, “Performance Analysis of Coaxial Probe Fed Modified Sierpinski–Meander Hybrid Fractal Heptaband Antenna for Future Wireless Communication Networks,” *Wireless Personal Communications*, vol. 94, no. 4, pp. 3251–3263, Jun. 2017.

[7] A. Kaur, G. Singh, and M. Kaur, “Miniaturized Multiband Slotted Microstrip Antenna for Wireless Applications,” *Wireless Personal Communications*, vol. 96, no. 1, pp. 441–453, Sep. 2017.

[8] Y. K. Choukiker, S. K. Sharma, and S. K. Behera, “Hybrid fractal shape planar monopole antenna covering multiband wireless communications with MIMO implementation for handheld mobile devices,” *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 3, pp. 1483–1488, 2014.

[9] C. E. Balanis, *Antenna Theory: Analysis and Design, 3rd Edition - Constantine A. Balanis*. John Wiley & Sons, 2005.

[10] Wen-Ling Chen, Guang-Ming Wang, and Chen-Xin Zhang, “Small-Size Microstrip Patch Antennas Combining Koch and Sierpinski Fractal-Shapes,” *IEEE Antennas and Wireless Propagation Letters*, vol. 7, pp. 738–741, 2009.

[11] Y. Kumar and S. Singh, “A Compact Multiband Hybrid Fractal Antenna for Multistandard Mobile Wireless Applications,” *Wireless Personal Communications*, vol. 84, no. 1, pp. 57–67, Sep. 2015.