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A compact wideband fractal cantor antenna for wireless applications☆

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ABSTRACT

A low cost, compact antenna is a new exemplar in communication. Fractal geometry, a concept in mathematics is adopted to design a miniaturized low profile fractal antenna. The size of the antenna is 38.734 mm × 28.757 mm × 1.6 mm. The antenna is designed in such a way to operate at ISM band, Bluetooth, IEEE 802.11 and IEEE802.15, PCS(1900), GSM lowerband, DCS, UMTS(2100) and WLAN wireless applications. The prototype of developed antenna exhibits wideband characteristics and provides a good agreement of returnloss (S11) −30 dB. Experimental returnloss has been compared with the one which is obtained using method of moments. The main objective of implementing self-similar fractal concept in antenna design makes it flexible in controlling the resonance and bandwidth. This paper is aimed at examining the self-similar concept of fractal geometry with modified approach for wideband characteristics. The prototype of the proposed model with a good agreement of return loss is reported.

1. Introduction

The congested wireless band and the need for low cost, less weight, low profile and compact miniaturized antenna have initiated the development of a prototype fractal antenna for various wireless applications. Wireless markets give much importance to wireless local area (WLAN) with the aid of IEEE 802.11 to establish connectivity for wireless devices within short range for which a low profile antenna is needed. IEEE 802.11 series, Bluetooth, and HIPERLAN standards tend to fit the developed prototype frequencies. The frequency designation for few wireless application is listed in Table 1. The other frequency bands are designated for RFID wireless applications such as 125 KHz, 13.56 MHz, 869 MHz, 902–925 MHZ, 2.45 and 5.8 GHz. The frequency 2.4 GHz is designated for IEEE 802.11 and Bluetooth applications. Dual band or wideband is a solution for such communication systems [1–5].

The demand in wireless boards for low cost, low profile, miniaturized antennas is increasing day by day. Microstrip antenna is a solution which meets all the requirements. Microstrip antenna using fractal geometry method has a tendency to occupy less space on wireless boards. Self-similar property in fractal geometry and many new designs have been reported in the literature [6]. Fractal geometry consists of space filling cantors [7–13] which can be divided into a number of sections so that the size gets reduced. The nature of this geometry is it is similar in all the possible view of the observer. On the other hand, if the geometry is bisected into two equal halves on the vertical plane, the left-plane is the folded image of the right-plane and viceversa and this is called as self-similar property.

Depending on the mode of fractal iteration, the original size of the patch gets reduced to 45% in the total area and maintains a radiation pattern equal to that of a normal patch [14]. A self similar cantor [7] structure which is scaled down by itself to a maximum possible number of iterations (n) and due to which the volume of the geometry shrinks along its x and y coordinates by retaining its individuality.

A self-affine [7] concept has been an adopted structure in designing a low profile antenna which provides flexibility in obtaining a miniaturized antenna. By choosing proper scaling factors and optimizing the feed position, the antenna is resonated for wideband. Sinha and Jain [15] examined self-affine property of fractals and evaluated for multiband characteristics and implemented using a microstrip feed line on the other side with RT-Duroid substrate. The finite ground plane of dimension 85 mm × 85 mm with coupling aperture has been used to cover frequency bands at 2.5 GHz, 5 GHz, and 10 GHz. The cost of FR4 substrate is very low compared to RT duroid. [16] has designed a dual band antenna for WLAN

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Table 1
Wireless applications.

S.No.	Frequency designation (GHz)	Application
1	5.15–5.25 GHz (I band)	IEEE 802.11a
2	5.75–5.35 GHz (II band)	IEEE 802.11a
3	1.9 GHz	PCS
4	2.1 GHz	UMTS
5	2.4 GHz	IEEE802.11
6.	925 MHz	GSM lower band

applications of 109.03 mm × 77.88 mm × 102.8 mm by varying the length and gap using reflector. [17] designed a triple frequency meander monopole antenna on one side and the width parasitic strips on the other side as 35 mm × 31 mm. [18] The size is 18 mm × 7.2 mm × 0.254 mm and is compact in size, but the tuning is achieved for wireless applications by adjusting the "s" strip the antenna is tuned to resonance. The compact dual band antenna [4] developed measures a size of 30 mm × 30 mm operating for DCS application at 2.4 GHz with both the layers of the substrate with CPW feed is reported in the literature. Hence, a self-similar structure with fractal geometry has been adopted to avoid such complications in designing and to fulfill a variety of wireless applications. FR4 substrate of 38.734 × 28.757 size is chosen including the slots as listed in Table 2.

2. Design techniques

2.1. Proposed self-affine technique

The self-affine fractal structures are constructed by scaling a rectangle whose dimensions are *x* and *y* units i.e., the initiator K0 by a factor of two along *y* and three along *x* coordinates, which leads to three rectangles on the upper half and three on the lower half, resulting in rectangles with equal dimension. The upper middle region is eliminated thereby retaining the remaining five regions as shown in Fig. 1b. First, the initiator is made to resonate at design frequency 2.4 GHz by adopting coaxial feed technique. This process is a repetitive procedure and is continued up to *n*th iteration. Fig. 1c–d shows that the number of iterations undergone by the initiator K0. Fig. 3 shows the performance of fractal antenna for all the iterations with different feed positions. It is evident from the graph that the return loss is greater than −20 dB approximately with wideband characteristics. In the above self-affine fractal structure, the segments are developed at each iteration of same dimensions except K2 and K3. The antenna design on these concepts tends to reduce in size and occupies less space.

2.2. Antenna design

The self affine antenna structure is developed on a FR4 substrate (thickness 1.6 mm, $\varepsilon_r = 4.4$, $\tan\delta = 0.01$) with ground plane at the bottom of the substrate. The patch antenna is initiated with (K0) of dimensions 38 mm × 28.8 mm × 1.6 mm and the value is listed in Table 2 which resonates at 2.4 GHz. Then, the initiator is iterated into segments, for (K1) to (K3) and the structure is obtained as shown in Fig. 2(a)–(b). The iterative coefficient values are derived

Table 2
Size of fractal geometry.

S.No.	Dimensions (mm)			
1	a	b	c	d
	38.734	28.757	12.9	5
2	e	f	g	h
	4	4	35	0.569
3	i	j	k	l
	0.5	2.276	0.099	29.979 × 13.525

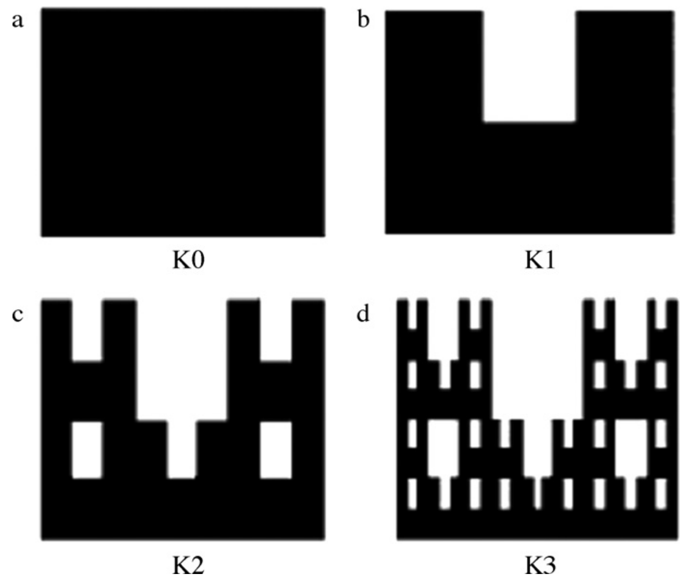

Fig. 1. Self-affine fractal structure: (a) initiator K0; (b) first iteration K1; (c) second iteration K2; (d) third iteration K3.

from Table 2 using equations below.

$$w(A) = \bigcup_{i=1}^{6} A_i \quad (1)$$

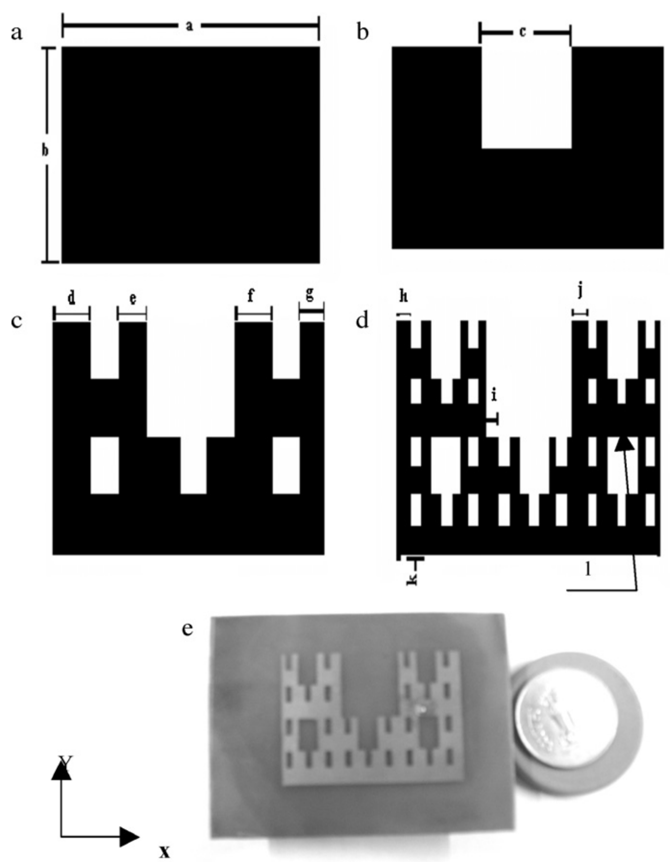

Fig. 2. (a) Geometry of the initiator K0; (b) first iteration K1; (c) second iteration K2; (d) third iteration K3 fractal antenna (dimensions are not to scale); (e) fabricated prototype model.