

Proceeding Paper

# Hilbert Fractal PIFA Antenna for DCS, PCS, UMTS and WiMAX Wireless Applications <sup>†</sup>

Youssef Zemam <sup>\*</sup>, Noureddine Boukli Hacene and Yamina Belhadef

Telecommunications Laboratory, Faculty of Technology, University of Tlemcen, BP 230, Pôle Chetouane, Tlemcen 13000, Algeria; bouklin@yahoo.com (N.B.H.); belhadef\_y@yahoo.fr (Y.B.)

<sup>\*</sup> Correspondence: youcef.optim@gmail.com

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**Abstract:** In this article, a novel quad-band fractal PIFA antenna design for DCS, PCS, UMTS, and WiMAX wireless communications systems is presented. The proposed antenna is a PIFA antenna where a slot having a Hilbert fractal shape at the third iteration has been inserted at the center of the radiating patch. The fractal shape of the implanted slot on the PIFA antenna was used in order to make the antenna operational at four frequency bands, according the required applications. The proposed antenna with the fractal shape of the slot offers quad-band operation with a miniaturized size compared to the initial PIFA antenna, such that the dimensions of the radiating patch become equal to 28 mm × 28 mm. This structure is operational in the following frequency bands: (1.73–2.08) GHz, (2.46–2.59) GHz, (3.39–3.47) GHz, and the band (4.56–5.02) GHz covering DCS, PCS, UMTS, and WiMAX mobile communications systems, respectively, with a gain ranging from 2 dB to 6 dB at the desired frequency bands. The fractal PIFA antenna design was carried out under CST MWs software with validation of the results made using HFSS software. There is good agreement between the obtained results by the two simulation software.

**Keywords:** Hilbert curve; fractal PIFA antenna; fractal shape; planar inverted F antenna; quad band antenna; CST MWs software; HFSS software



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## 1. Introduction

Currently, most wireless communications devices operate in several frequency bands and provide different services. Additionally, because of the limited available space in these devices [1], in recent years, researchers have focused their work on the realization of miniature and multiband antennas. Usually, the planar inverted-F antenna (PIFA) is the most desirable design in many applications because of its low cost, simplicity of design, and low profile [2].

However, it is difficult to realize multiband applications from conventional PIFAs antenna. To meet these constraints, several techniques are reported in the literature, notably the use of different feeding techniques by coupling [3], the use of different slots forms [4–7], and also by the adding of parasitic elements at the antenna radiating patch [8]. Several antenna designs have been based on the use of different fractal shapes to achieve multiband antennas, due to their self-similarity and space-filling properties. The space-filling property of the Peano and Minkowski fractals [9,10] has been exploited to miniaturize the antennas, while the self-similarity property of the Hilbert, Koch, and Sierpinski curves can be used to have multiband behavior [11,12].

In this work, a novel Fractal PIFA antenna design was proposed. Parametric studies were made in order to well understand the effect of the implanted fractal shape at the radiating patch on the radio characteristics of the proposed antenna. The PIFA antenna with the fractal shape at the third iteration demonstrates many advantages where the clutter

of the structure is very weak and the multiband operating serves to integrate it into the various mobile and wireless devices.

## 2. Design of the Proposed Antenna

### 2.1. Initial PIFA antenna Design

The initial antenna is a PIFA antenna with a radiating patch of dimensions  $W_p \times L_p = 34 \text{ mm} \times 28 \text{ mm}$ . The antenna is designed on an FR-4 type substrate with a permittivity  $\epsilon_r = 4.4$  and a thickness  $h_s = 1.6 \text{ mm}$ . The radiating element is located above the substrate with a height of  $H = 5.3 \text{ mm}$ , and shorted to the ground plane with a tab of a width  $s = 4 \text{ mm}$ . The initial antenna having overall dimensions of  $38 \text{ mm} \times 60 \text{ mm}$  and is fed by a  $50 \Omega$  microstrip line, as shown in Figure 1.

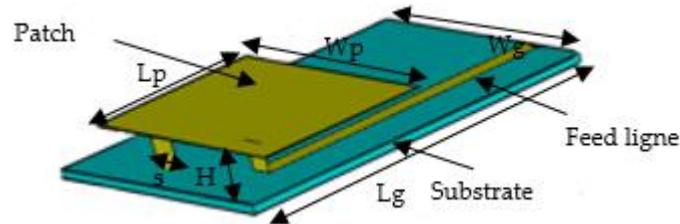


Figure 1. Structure of the initial PIFA antenna.

The resonant frequency  $f_r$  of the initial antenna was determined from the following equation:

$$f_r = \frac{C}{4(W_p \times L_p) \sqrt{\epsilon_r}} \tag{1}$$

where:  $C$  is the speed of light in the void,  $L_p$  and  $W_p$  are the length and width of the radiating patch

### 2.2. Quad-Band PIFA Antenna

Fractals have been widely used in the design and realization of multiband antennas due to the significant improvements in their performance. To improve the electromagnetic characteristics of the initial PIFA antenna, the Hilbert shaped fractal slot at the third iteration was implanted in the initial antenna radiating patch. The proposed antenna structure and the first four iterations of Hilbert’s fractal form are shown in Figure 2.

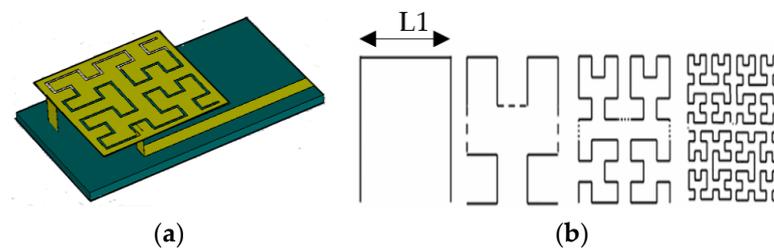


Figure 2. (a) Proposed antenna structure, (b) the first four iterations of Hilbert’s fractal form.

The Figure 3 shows the return loss  $S_{11}$  of the initial antenna and the proposed antenna.

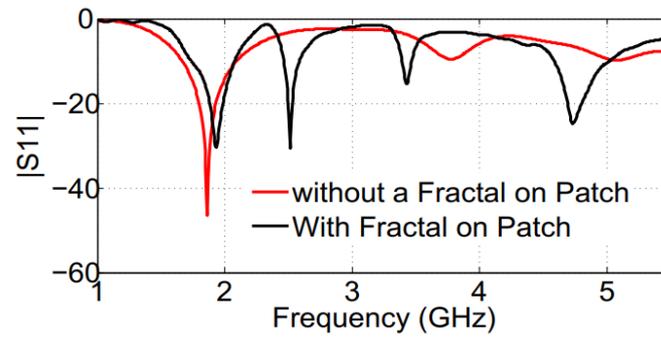


Figure 3. Return loss of the initial antenna and the proposed antenna.

### 3. Parametric Studies

In this part, parametric studies have been carried out to illustrate the effect of the fractal slot dimension on the radio electric characteristics of the proposed antenna.

Figures 4 and 5 represent the variation of the return loss  $S_{11}$  according to the frequency for different lengths ( $L_s$ ) and widths ( $W_s$ ) of the fractal slot.

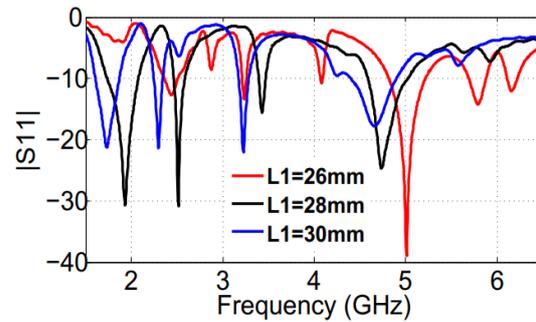


Figure 4. Return loss  $S_{11}$  of the proposed antenna for different lengths ( $L_s$ ) of the fractal slot.

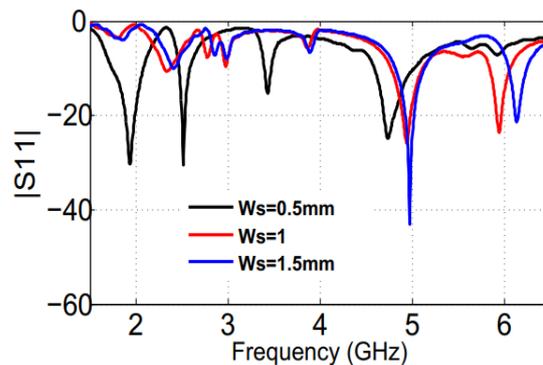
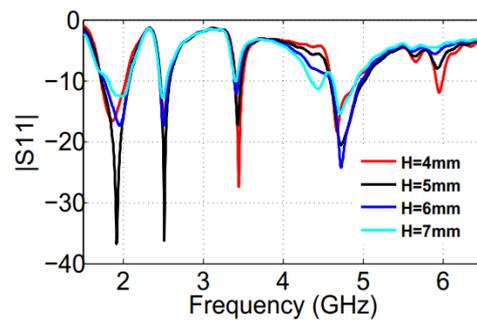


Figure 5. Return loss  $S_{11}$  of the proposed antenna for different widths ( $W_s$ ) of the fractal slot.

Figure 6 shows variation of the return loss of the proposed antenna with different values of the height  $H$  between the radiating patch and the substrate.

From the results obtained in Figures 4–6, we can see that the width ( $W_s$ ), the length ( $L_s$ ) of the fractal shape, and the height ( $H$ ) have remarkable influences on the radio electric characteristics of the proposed antenna. As a result, the antenna present a good performance with fractal slot width and length:  $W_s = 0.5 \text{ mm}$ ;  $L_s = 28 \text{ mm}$ ; and optimal height:  $H = 5 \text{ mm}$ .

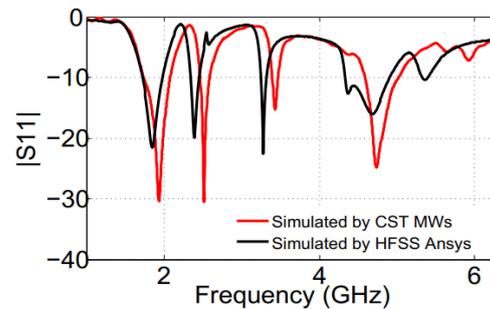


**Figure 6.** Variation of the return loss of the proposed antenna with different values of the height (H).

#### 4. Discussion of Results

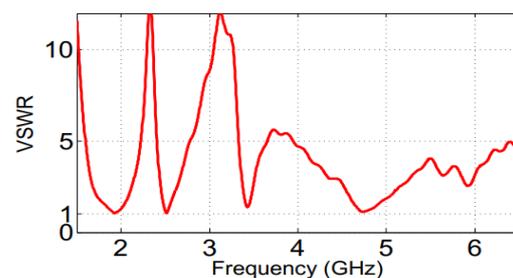
The parametric studies and the optimization of the geometric parameters of the proposed model were executed by CST Microwave Studio.

To validate the obtained result after the parametric study, we used the HFSS Ansys software, as shown in Figure 7.



**Figure 7.** Return loss  $|S_{11}|$  of the proposed antenna simulated under CST MWs and HFSS Ansys.

The Figure 8 shows the variation of the standing wave ratio (VSWR) of the proposed antenna according to the resonant frequency.

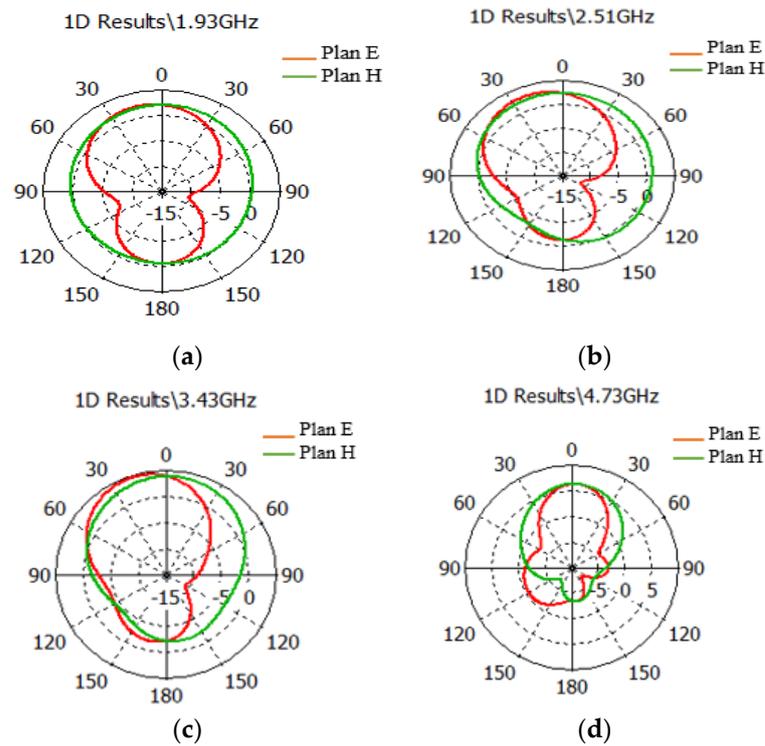


**Figure 8.** Variation of the VSWR of the proposed antenna according the resonant frequency.

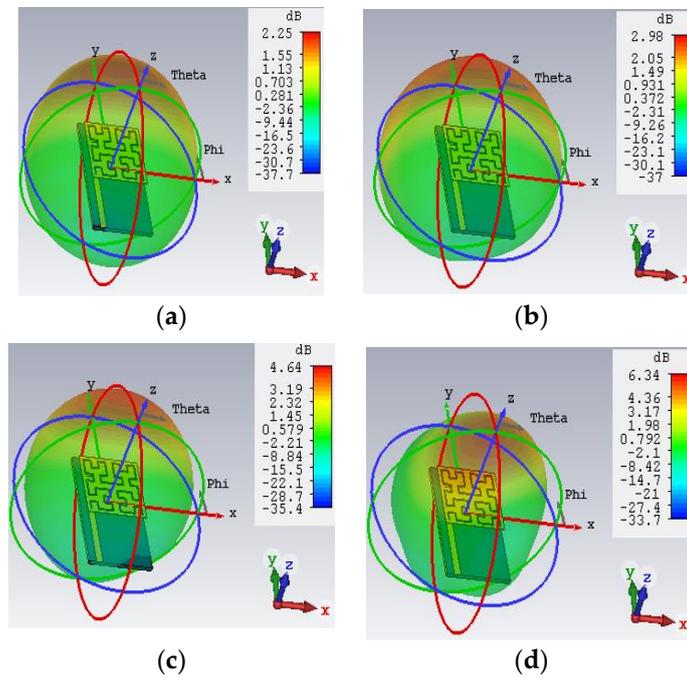
Figure 8 shows that the standing wave ratio is between 1 and 1.4 at the four resonance frequencies. This gives a very good adaptation to the desired frequencies.

The radiation patterns in 2D (polar) of the proposed antenna on the two planes E and H are plotted at the four resonant frequencies 1.93 GHz, 2.51 GHz, 3.43 GHz, and 4.73 GHz, as shown in Figure 9.

To clearly see the radiation behavior of the designed antenna, we have plotted the 3D radiation patterns at the four chosen resonant frequencies, as shown in Figure 10.



**Figure 9.** Radiation patterns in 2D of the proposed antenna on the two planes E and H plotted at the four resonant frequencies: (a) at 1.93 GHz, (b) at 2.51 GHz, (c) at 3.43 GHz and (d) at 4.73 GHz.



**Figure 10.** Three-dimensional radiation patterns of the proposed antenna at the four resonance frequencies: (a) at 1.93 GHz, (b) at 2.51 GHz, (c) at 3.43 GHz and (d) at 4.73 GHz.

From the polar radiation patterns, we notice that the proposed antenna present a gain ranging from 2 dB to 6 dB at the four resonant frequencies. The results found show well that the antenna is suitable at the four wireless communications systems: DCS, PCS, UMTS, and WiMAX, respectively.

## 5. Conclusions

In this paper, a fractal PIFA antenna for DCS, PCS, UMTS, and WiMAX wireless communications systems is studied.

The integration of the fractal slot at the center of the initial antenna radiating patch is a technique which was used to have multiband operating and also to miniaturize the proposed antenna. The Hilbert fractal slot at the third iteration, which was inserted at the center of the radiating element, allowed to allocate a multi-band operating of the proposed antenna and also contributed to reduce their size compared to the initial antenna with a miniaturization rate equal to 46.15%.

The proposed antenna simulation results with the two software CST and HFSS show a good agreement in terms of return loss S11. These obtained results was allowed to prove that the proposed antenna has good radiating characteristics and able to covering the frequency bands corresponding to the following four wireless communications systems: DCS, PCS, UMTS (1.73–2.08) GHz, WiMAX (2.46–2.59) GHz, WiMAX (3.39–3.47) GHz, and the WiMAX (4.56–5.02) GHz band, with compact dimensions occupy less space in wireless communications devices.

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