 https://doi.org/10.1051/e3sconf/202235101077

Multiband PIFA antenna with Koch Fractal slot for GPS, LTE and WiMAX wireless communication systems

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Abstract. In this article, a five frequency band PIFA antenna for GPS (1.57 GHz), LTE (2.6 GHz) and WiMAX (3.17GHz, 4.1GHz, 4.83GHz) applications is presented. The proposed antenna consists of a PIFA antenna with a Koch fractal slot at the first iteration that was applied to all sides of a square located in the center of the radiating element. The radiating patch modification of the proposed antenna with the fractal slot made the antenna multiband and also contributed to miniaturize the proposed antenna compared to the initial form. The results presented in this work are carried out under the CST MWs software and compared to those obtained by the HFSS software where a good agreement was recorded. The proposed antenna has a gain ranging from 1.13dB to 6.01dB corresponding to the five frequency bands achieved.

1 Introduction

The domain of intelligent wireless communications systems witnessed significant and rapid development over the past decades. The addition of these new systems to consumer products is based on the performance of their antennas.

Thus, to improve their performance, they must be adapted to the most recent applications. The antenna must also meet the multiplication of frequency bands constraints. Most of wireless communication systems devices are based on the use of PIFA antennas because they present very advantageous characteristics in terms of weight, volume, cost, ease of manufacture and above all the possibility of implanting them on any type of electronic device [1-2]. However, a simple PIFA antenna can not sufficiently cover the required operating bands. For this, researchers have introduced several techniques on the PIFA antenna to meet the constraints of multifunctionality and miniaturization. Many designs are based on using different shapes slots to achieve multifunctionality [3-6]. Also, another PIFA antenna which operates at four frequency band thanks to the addition of two parasitic elements presented in [7]. Other techniques to achieve multiband operating is to use multistacked or multi-shorted pins as mentioned in [8], or the use of parasitic elements as shown in [9]. Another method to improve the antennas characteristics is to use differ ent fractal shapes for the two properties of self-similarity and space filling that they present [10-12]. The self similarity technique leads to multiband antennas while the space filling technique contributes to miniaturization. In this work a simple technique is applied on a simple PIFA antenna to obtain a miniaturized antenna structure with multi-band operating and suitable for new applications.

The proposed antenna design in this work is based on the implantation of a Koch fractal slot on the radiating patch. Parametric studies are carried out on the fractal slot and also on the height H between the radiating patch and the substrate. The simulation results are obtained using the CST software and compared to those of the HFSS software and have shown that the antenna is useful for the three applications GPS (1.57 GHz), LTE (2.6GHz), and WiMAX (3.17GHz), 4.1GHz, 4.83GHz).

2 CONFIGURATION OF THE PRPOSED ANTENNA

2.1 Configuration of the initial antenna

The initial antenna is a PIFA antenna with a rectangular shape and an overall size of 43mm × 54mm. The antenna is designed on an FR-4 type substrate with permittivity $\varepsilon_r = 4.4$ and a thickness h = 1.6mm.

The initial antenna radiating element with dimensions 38mm × 30mm is located above the substrate with a height of 7.5mm. This last is connected to the ground plane with a tab of width s = 0.5mm. A microstrip line of 50 Ω is used to feed the initial antenna as shown in figure 1.

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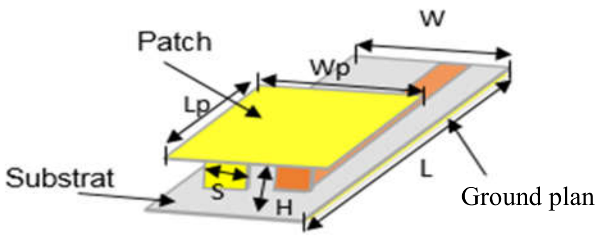


Fig. 1. Geometry of the initial antenna.

The equation (1) was used to determine the dimensions of the radiating element of the antenna from the resonant frequency *f*.

$$f = \frac{c}{4(Wp+Lp)\sqrt{\varepsilon r}} \quad (1)$$

With: c is the speed of light in the void, Lp and Wp are the length and width of the radiating patch, and f is the resonant frequency of the initial antenna.

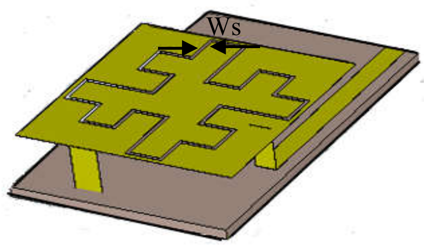
2.2 The multiband PIFA antenna

Fractal shapes are techniques commonly used to obtain miniature and multi-band antenna thanks to their property of self-similarity and space filling. The self similarity allows to get multiband antennas while space filling increases the electrical length of the antenna radiating element. In order to achieve a miniaturized antenna with multiband operating, Koch island type of a fractal slot at the first iteration cut out at the center of the radiating patch is sized and optimized as shown in figure 2.

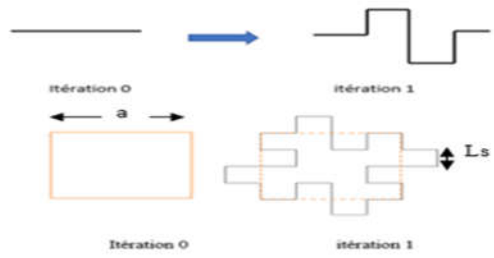
The Koch fractal slot is made from a square with side a (iteration 0), and by applying the fractal shape of Koch at the first iteration on each side a of the square, as shown in the figure. 2. The length Ls of the fractal section was determined from equation (2)

$$Ls(n) = \left(\frac{1}{4}\right)^{n} \times a \quad (2)$$

With: n is the iteration number



(a)



(b)

Fig. 2. (a) Structure of the proposed antenna, (b) Fractal shape implemented on the radiating patch.

Thanks to the space occupancy property of the fractal, the proposed antenna with its given perimeter occupies less area compared to the initial antenna. The fractal slot implanted at the radiating patch also contributed to reduce the size of the patch from 38mm × 30mm to 32mm × 27mm.

3 Parametric studies

This section includes a study of the geometric parameters effects of the fractal slot on the electrical and electromagnetic characteristics of the proposed antenna. The figures 3 and 4 show the variation of the return loss S11 according to the frequency for different length Ls and width Ws.

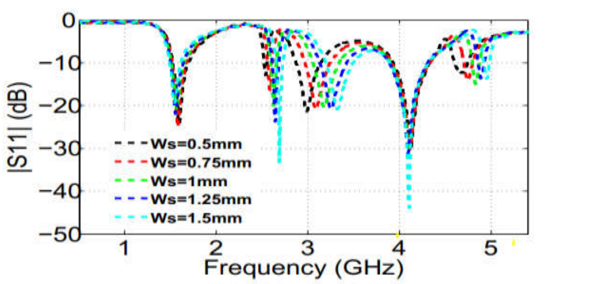


Fig. 3. Variation of return loss |S11| according to the frequency for the different widths of the fractal slot Ws.

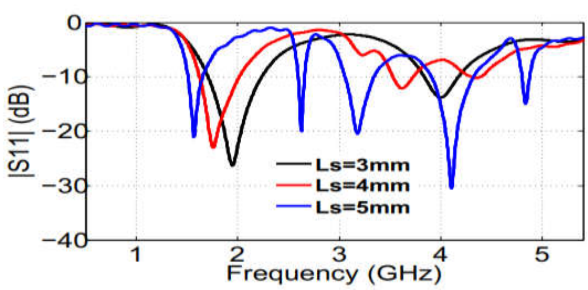


Fig. 4. Variation of return loss |S11| according to the frequency for the different lengths of the fractal slot Ls.

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From the curves of the figures 3 and 4, it is evident that the variation in the width and length of the fractal slot has an influence on the adaptation and also on the adjustment of some frequency bands. The figure 5 shows the variation of the return loss S11 according to the frequency for different height H.

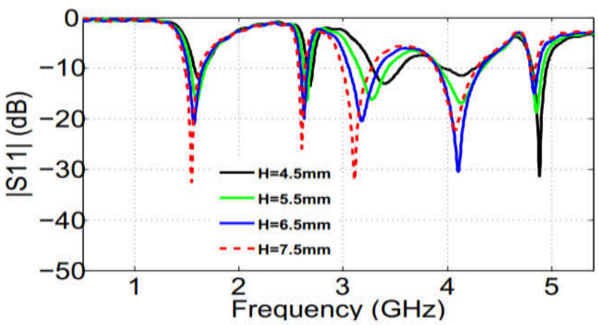


Fig. 5. Return loss |S11| dB according to the frequency for different height H.

From the result shown in Figure 5, the variation in height between the patch and the substrate has a much greater influence on the adaptation and variation of frequencies of the last three frequency bands. The results illustrated in figures 3, 4 and 5, clearly show that the proposed antenna present a good characteristics for a fractal slot with a peripheral width and a length Ws = 1mm, Ls = 5mm, and also with an optimal height H = 6.5mm between the patch and the substrate.

4 ANALYSIS OF RESULTS AND DISCUSSION

the software that was used to study and optimize the geometric parameters of the proposed antenna is the CST MWs 2016.

The Koch-type fractal slot, which has been implanted at the center of the radiating patch of the proposed antenna allow to increase the number of the antenna operating frequency bands, as shown in figure 6.

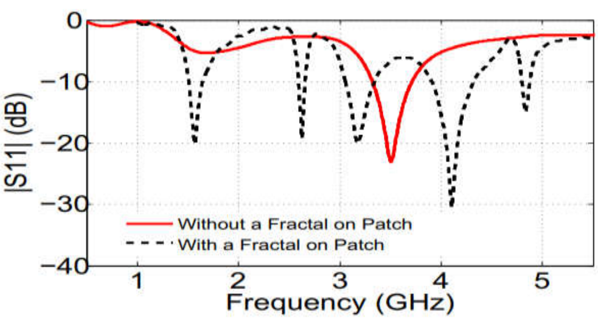


Fig. 6. Return loss |S11| dB according to the frequency for the initial antenna, and the PIFA antenna with a fractal slot.

In order to check the simulation result obtained in figure 6, another simulation is carried out on the HFSS software Ansys software 2015, as shown in figure 7

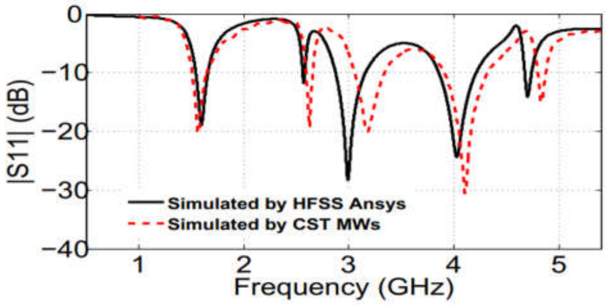


Fig. 7. Proposed antenna return loss |S11| dB simulated with CST MWs and HFSS Ansys.

The figure 8 shows stationary wave rate (VSWR) of the proposed antenna.

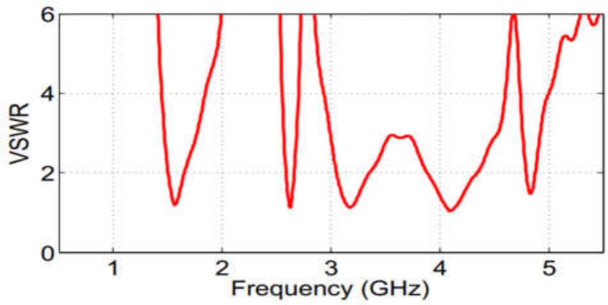
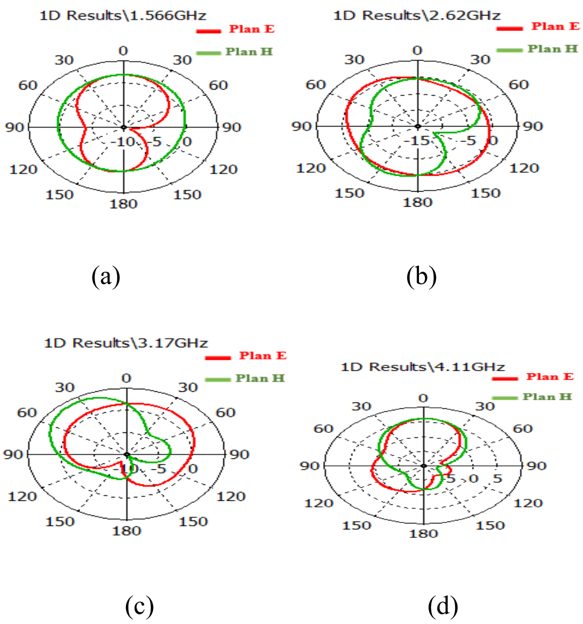
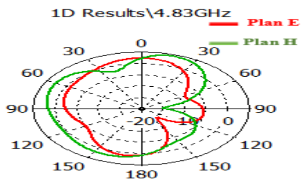


Fig. 8. Stationary wave rate of the proposed antenna.

The figure 9 shows the antenna radiation patterns in polar representation in the plan E and H for the resonant frequencies 1.57GHz, 2.62GHz, 3.17GHz, 4.11GHz, 4.83GHz respectively





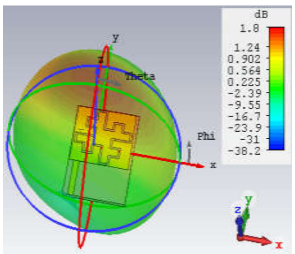
(e)

Fig. 9. Polar radiation patterns of the Fractal PIFA antenna proposed at the different resonance frequencies: (a) at 1.566 GHz, (b) at 2.62 GHz, (c) 3.17GHz, (d) 4.11 GHz and (e) 4.83GHz in the two planes E and H.

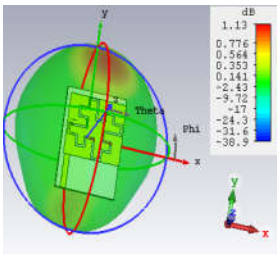
We notice that the radiation pattern is almost omnidirectional or dipolar for the five resonant frequencies 1.566GHz, 2.62GHz, 3.17GHz, 4.11GHz, 4.83GHz in the two planes E and H.

The radiation patterns in 3D of the proposed antenna with the fractal slot that was shown in Figure 2 are plotted at the five resonant frequencies: 1.566GHz, 2.62GHz, 3.17GHz, 4.11GHz, and 4.83GHz, as shown in Figure 10. The maximum gain values for these frequencies are 1.8 dB, 1.13 dB, 4.18 dB, 6.01dB and 4.33dB respectively. The proposed antenna is miniaturized compared to the initial antenna with a miniaturization rate equal to 25.32%.

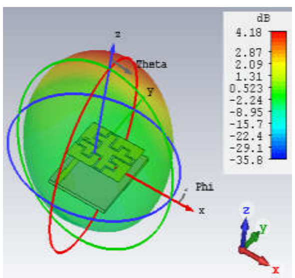
The obtained result clearly shows that the antenna has good electrical and electromagnetic characteristics at the five frequency bands that have been reached.



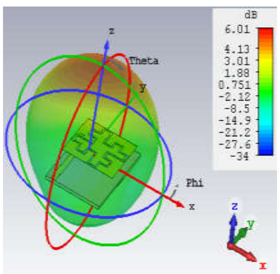
(a)



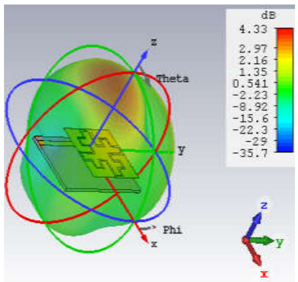
(b)



(c)



(d)



(e)

Fig. 10. Radiation patterns of the proposed antenna in 3D, (a) at 1.566GHz, (b) at 2.62GHz, (c) at 3.17GHz, (d) at 4.1GHz, (e) at 4.83GHz

5 Conclusion

In this article, a new fractal PIFA antenna design was presented for wireless communication applications. The modification of the initial antenna radiator with the fractal Koch slot that was implemented at the center of the patch made the antenna operational on five frequency bands. The proposed antenna with the fractal slot occupies less area compared to the initial antenna, like that the overall dimensions of the proposed antenna become 34mm × 51mm × 6.5mm, a miniaturization rate equal to 25.32%. Parametric studies have been carried out on the fractal slot geometry in order to show the effect of the fractal slot on the proposed antenna characteristics.

The obtained results in this article clearly show that the antenna is well suited to the three applications GPS (1.57GHz), LTE (2.62GHz), WiMAX (3.17GHz, 4.1GHz and 4.83GHz), and with a compact size which facilitates its integration into various consumer products. In the future one, other fractals forms for the slots could be studied, as well as other applications.

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