

Multiband F-PIFA Fractal Antennas for the Mobile Communication Systems

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Abstract

The fractals antennas are composed of repeated geometrical forms. Each form has single attributes. The Fractal Planar inverted F (F-PIFA) antenna, based on Koch Island form geometries, is proposed to facilitate multibands applications. The design is carried out by two software: CST Microwave Studio and HFSS. The obtained results for the various iterations allow a multiband operation finding its application in the various standards of mobile telecommunications.

Keywords: Koch Island form, fractal antenna, F-PIFA, Multibands, HFSS and CST Microwave Studio.

1. Introduction

The fractal geometry is an extension of the euclidean geometry. Its introduction constituted an opportunity for the antennists to discover new antennas configurations. Historically front even the discovery of the fractals by Mandelbrot, fractals antennas were already used. Indeed, during the 50 last years, antennas "with logarithmic periods", were used without one realizing that one handled the fractals.

The expression "fractals antennas" was published for the first time in 1994 by D.H. Werner [1]. Later, marge articles were published by Cohen [2, 3] where it presented an introduction on the application of these fractals geometries for antennas while being based on the fractals of dipole and curve type. The term "fractal antenna" is a language abuse. The studied antennas have just a pre-fractals forms: those are more or less high iterations whereas the fractal form is the result of iteration at the infinite. A part from their use in order to obtain multibands antennas, the fractals can also be used for the antenna miniaturization [4, 5].

According to B Mandelbrot [6], the fractal object (1975) is said of a geometrical figure or a natural object. The fractal term comes starting from the Latin adjective 'fractus', which means irregular or

broken. A fractal object must combine the following characteristics:

- Its parts have the same form or structure that the whole, even if it is a different scale or slightly deformed..
- Its form is, either extremely irregular, or extremely interrupted or split up, whatever the examination scale.

2. First Koch Island form multibands fractal antenna F-PIFA

The proposed antenna has a very simple structure fed with a 50 Ohms microstrip line. The total dimension of the ground plane is 70 X 70 mm². The substrate permittivity chosen for this structure is of 2.1. The radiating patch is supported by a strip and a short-circuit plan. The figure 1 and the table 1 show the structure and detailed dimensions of the initial antenna according to the reference [7] and dimensions' of the modified antenna. The design of this antenna is carried out by CST Microwave Studio software to give the various electromagnetic properties of the F-PIFA antenna.

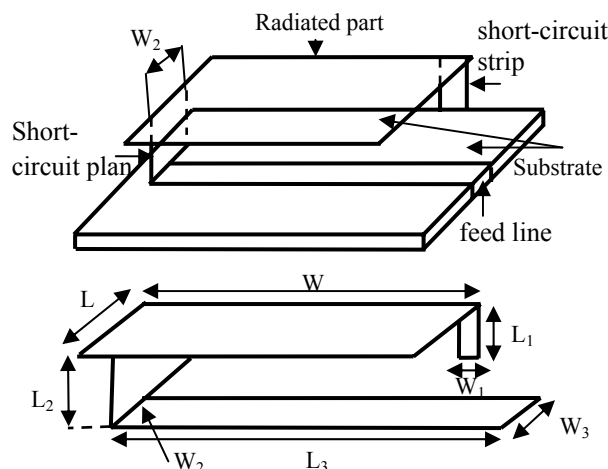


Fig. 1 : F-PIFA geometry proposed.

Parameters Table 1: Dimensions of the initial and modified antennas	L	W	L ₁	W ₁	L ₂	W ₂	L ₃	W ₃
Initial values [Ref.7] (mm)	55	53	10	10	8.5	25	64	4.64
Modified values (mm)	45	45	9.5	17	9	25	63.99	4.64

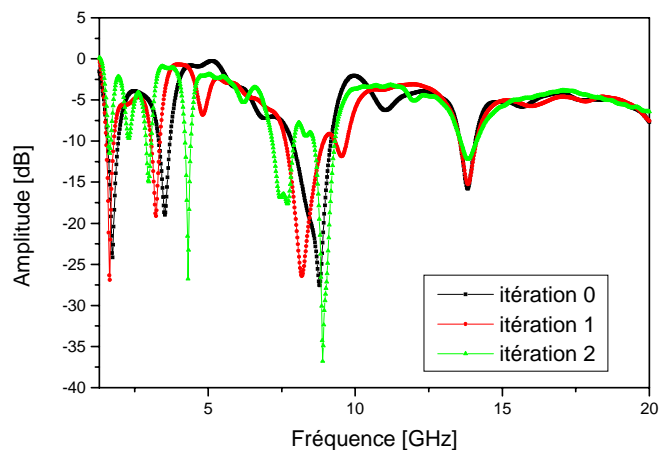
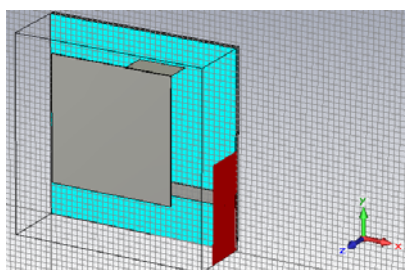
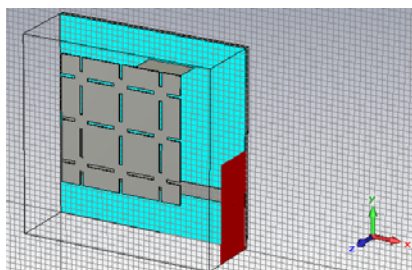


Fig. 3: Return loss for the various iterations.
 Iteration 0, (2) iteration 1, (3) iteration 2

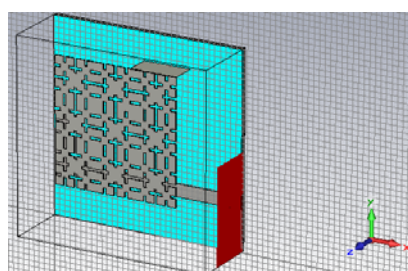
On figure 2.a one presents the modified antenna at the iteration 0 in which we applied a Koch Island form fractal method on the radiating patch. Figures 2.b and 2.c gives structures at the iterations 1 and 2 respectively, which are presented on the CST Microwave Studio editor.



(a)



(b)



(c)

Fig. 2 : F-PIFA geometry for the three iterations on the CST Microwave Studio editor.

(a) Iteration 0, (b) iteration 1, (c) iteration 2.

On figure 3, one presents the return loss for the three iterations.

Iteration number	Resonance frequency (GHz)	Return loss (dB)	Bandwidth (%)
Iteration 0	1.748	-24.137	21.38
	3.525	-18.973	11.13
	8.798	-27.55	15.93
	13.829	-15.788	4.04
iteration 1	1.655	-26.877	15.81
	3.226	-19.121	9.27
	8.181	-26.413	17.14
	9.546	-11.853	5.28
	13.829	-15.244	4.46
Iteration 2	1.655	-11.522	5.64
	2.983	-14.957	5.64
	4.310	-26.771	4.33
	7.695	-17.654	10.20
	8.892	-36.804	8.62
13.829	-12.206	4.59	

Table 2 : Electric characteristics of the antenna for each iteration .

(a) Iteration 0, (b) iteration 1, (c) iteration 2.

The reflected power of the studied antenna at iteration 0, after the modifications carried out on dimensions of the F-PIFA structure, gives a well adapted antenna to four resonances frequencies

according to standards' and/or bands DCS, UWB, Wi-MAX and Ku. At iteration 1, we noted a light adaptation improvement and a reduction in the bandwidth with the creation of a new resonator of level -11.853 dB and bandwidth of 5.28%. On the other hand at iteration 2, we noted a reduction in the resonance frequency where the resonators total number is 6 with return loss levels of -11.52, -14.95, -26.77, -17.65, -36.8 and -12.2 dB respectively, which indicates a good antenna adaptation.

The polar radiation pattern in plane H ($\varphi=90^\circ$) and plane E ($\varphi=0^\circ$) take different forms according to figure 4.

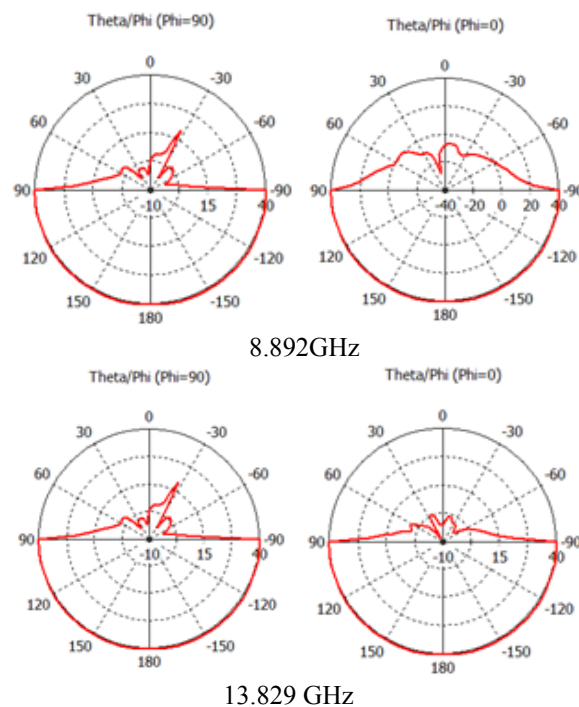
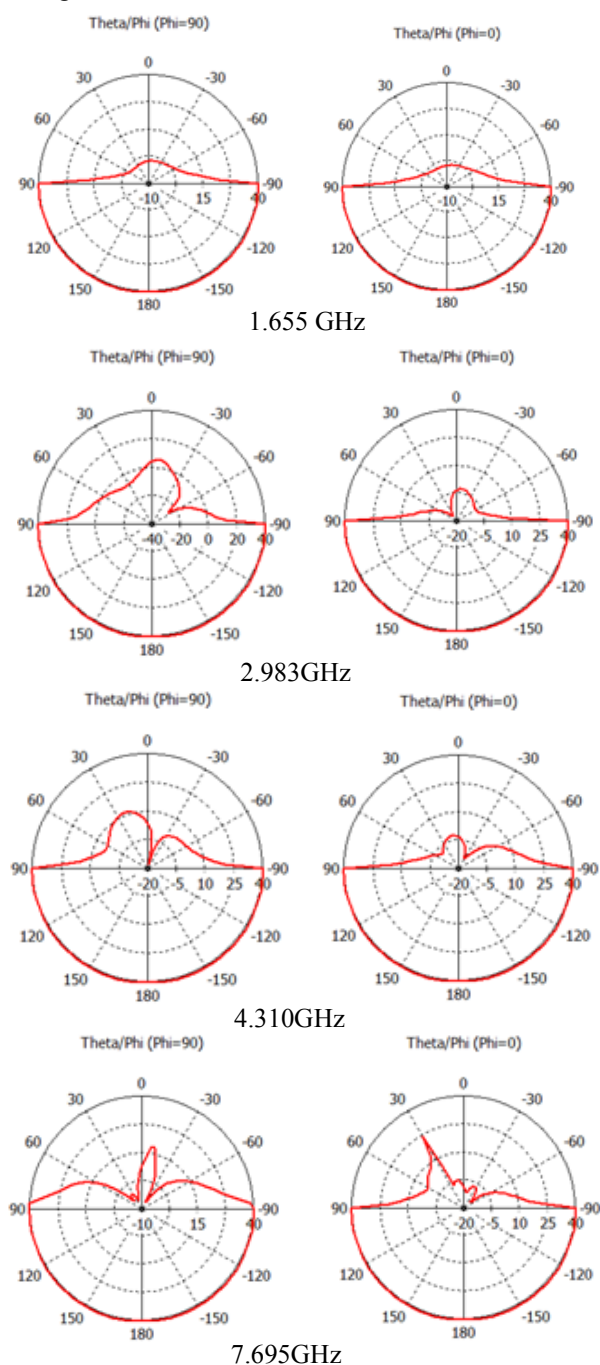


Fig. 4 : Radiation patterns in plane H and plane E for various frequencies of the iteration 2.

4. Second Koch Island form fractal antenna F-PIFA

The second antenna proposed is inspired from the reference [9]. In this reference, dimensions of the ground plane and the substrate thickness H constituting the antenna are not indicated and the patch is printed on rogers board (Rogers, RO4003C). In our case, the dimensions of the radiation rectangular element are 27×27 mm and 0.5 mm for thickness. The element is printed on the Neltec NH9338 (MT) with $\epsilon_r = 3.38$. It is located at the medium of a ground plane in copper with a thickness equals to 0.5 mm and dimensions 50×50 mm. The short-circuit plane is composed of a vertical conduction band and it is employed to also support the whole antenna. The coaxial probe of 50 Ohms feeding the rectangular patch has a radius of 0.13 mm. The operating frequency band is around 0.75 to 20 GHz.

The F-PIFA antenna is a combination of the Fractal antenna in the PIFA topology. The Koch Island Fractal design was selected to the PIFA patch which is directly placed at a short-circuit plane perpendicular to a ground plane and connected to a feed probe. The coaxial feed excites the PIFA mode TM₁₀. The operating frequency of the thickness h of the air substrate $\epsilon_r = 1$ is to 2 mm microstrip patch antenna is inversely proportional to its physical dimensions. The resonance frequency of

the antenna can be approximately given starting from the patch antenna length as follows:

$$f = \frac{c}{4(L_1 + L_2)} \quad (1)$$

Where c is the velocity of light, L_1 et L_2 are the length and the width of the PIFA superior dish, and f is the resonance frequency. The antenna is simulated by using HFSS software. The PIFA configuration proposed is shown in Figure 5.

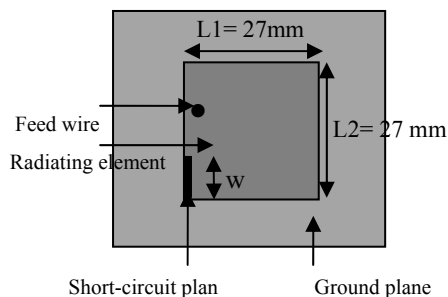


Fig.5 : Fractal PIFA antenna geometry.

We applied on the patch of the studied antenna (figure 5) a Koch Island fractal method from the reference [10]. Figure 6 shows the F-pifa antenna with slit at the third iteration. The first iteration contains four slits of size 1 X 9 mm curved in the medium on each side of the patch. The iteration process for the proposed antenna is followed until the third iteration. We added short-circuit plans of size 3 X 2.5 mm between the radiating element and the ground plane and a capacitive loading without roof which consists only in one resonator vertical descent in the other side of the patch of size 27 X 2 mm with the feed position change. The design results other than those of reference [9] are presented on figures 7 and 8.

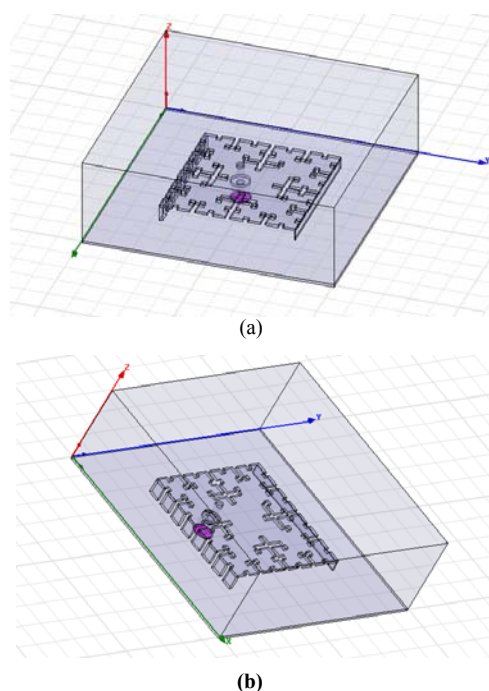


Fig. 6 : F-PIFA geometry of the modified antenna on the HFSS editor.
 (a):Left sight of the antenna, (b):Right sight of the antenna.

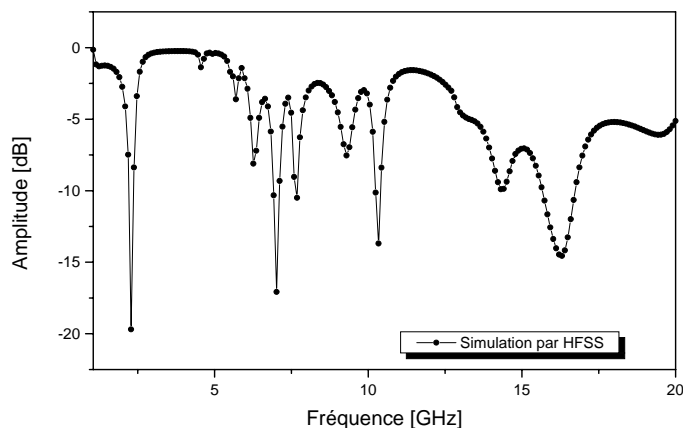


Fig.7: Return loss to the 3rd iteration.

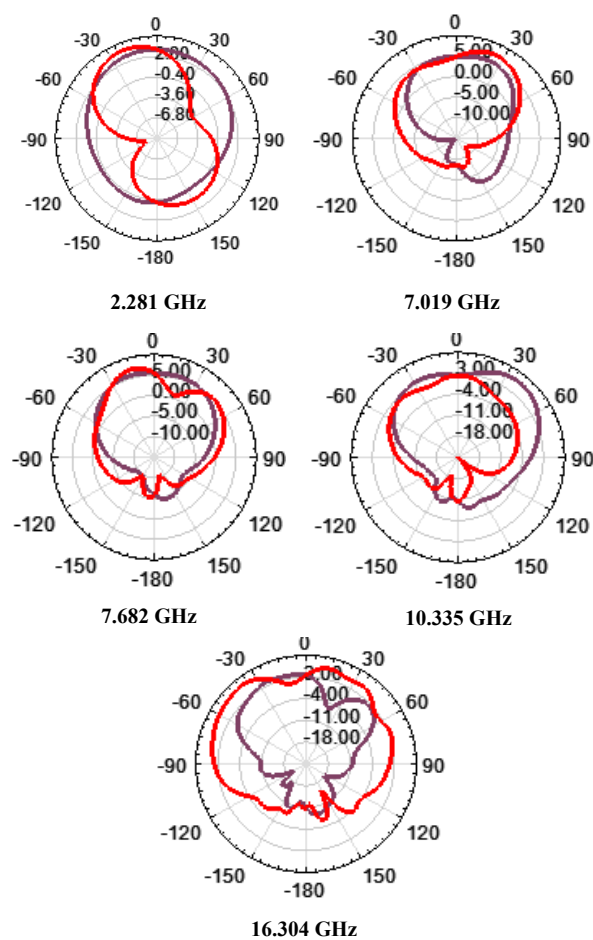


Fig. 8: Radiation pattern in 2D for the various frequencies.

— plane E ($\phi=0^\circ$)
 — plane H ($\phi=90^\circ$)

The design by HFSS of the proposed antenna gives a multiband antenna operating at five resonance frequencies equal to 2.287, 7.019, 7.682, 10.335 and 16.304 GHz with reflected power levels equal to -19.69, -17.07, -11.72, -13.69 and -14.56 dB respectively. This represents a good adaptation of the new F-PIFA antenna which can operates on the

standards and/ or bands UMTS, UWB, Wi-MAX and Ku. The operation bandwidths are 1.83%, 2.7%, 2.37%, 1.83%, 6.97% for the five frequency respectively.

The polar radiations pattern in 2D for the Koch Island form fractal antenna F-PIFA are quasi omnidirectional for the planes E and H for certain frequencies.

4. Conclusions

Today, fractal antennas become popular because they have a particular properties that make them suitable for multiband applications. The two Koch Island form fractals antennas proposed present a multiband operating. The design was carried out by CST Microwave Studio and HFSS software for the two studied fractals structures F-PIFA. The simulation results indicate that these antennas present a good adaptation for all the resonant frequencies obtained.

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