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A Novel Low Cost Fractal Antenna Structure for ISM and WiMAX Applications

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Abstract

Different fractal structures have been widely used in many antennas designs for various applications. A fractal antenna is used for miniaturization and multiband operation. This paper presents a design of a dual-band fractal antenna fed by coplanar waveguide (CPW) transmission line. The proposed antenna is designed and fabricated on an FR4 substrate with a volume of 70x60x1.6mm3, resonates at 2.42-2.62GHz and 3.40-3.65GHz with a return loss less than -10dB. The design and simulation process is carried out by using CST-MW studio electromagnetic solver. Simulation results show that the resulting antenna exhibits an interesting dual frequency resonant behavior making it suitable for dual band communication systems including the ISM and WiMAX applications. Concerning the fabrication and measurement of the final prototype of this antenna, a good agreement is found between simulation and measurement results for both frequency bands.

Keywords: *antenna fractal, dual-band, co-planar.*

1. Introduction

In the last decade, a radiofrequecy and microwave passive and active circuits are known a rapidly growing demand for greater capacities broadband service and transmission speeds to support different functions of the wireless communication systems such as image, speech, multimedia and data communication. However, recent developments in wireless communication systems have imposed additional challenges on the wireless antenna designers to produce new models that are miniaturized and multiband [1-4]. To meet the rapid growth of requirements, an antenna must operate in many frequency bands. Recently, multi-band antennas developments have been improved thanks to the concept of fractal art [5-10]. The term fractal geometry was first originated by Mandelbrot to describe a family of complex shapes that are self-similarity or self-affinity in their geometric structure [11-15].

Actually, the developing of multiband antennas have been improved through the use of the fractal concept [13-15]. Fractal geometry [16] plays an important role in these requirements. The term fractal geometry was first created by Mandelbrot [17-19] to describe a family of complex forms that have self-similarity or self-affinity in their geometrical structure. Characterization of an antenna requires two types of information: the input impedance characteristic (frequency response) and the radiation characteristic (radiation pattern).

This work is organized as follows: Firstly, the optimized and proposed fractal slot antenna fed by CPW is presented, which operates in the industrial scientific and medical (ISM 2.4-2.5GHz) and Worldwide Interoperability for access Microwave (WiMAX 3.30 to 3.80 GHz). The final antenna consists of a matching CPW-fed line, which is connected between 50 CPW line and a fractal radiating slot antenna. It has been observed that increasing the number of iterations increases the bandwidth of the antenna but on the second and third iterations the antenna starts showing the multiband behavior. Secondly, we will have a definition of fractal geometry. The parameters of the antenna, Subsequently the simulation and the measured properties of the proposed antenna will be discussed in third part. Finally, measurement results will be discussed and compared with simulation.

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2. Design of the proposed antenna

In this work, the antenna is designed and simulated on a low-cost substrate FR4 with a thickness of 1.6 mm (H), the relative permittivity of 4.4 (Ɛr) and loss tangent of 0.025. The whole size of this antenna is 70×60mm^2. The 50 SMA connector is used to feed the antenna at the CPW line.

2.1 Antenna Dimensions

The approach adopted to determine the geometric parameters of the printed antenna is based on the following two steps:

a. Calculation of the effective permittivity εe as a function of the width of the pattern W.

$$\varepsilon_e = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\frac{1}{\sqrt{1 + 10\frac{h}{W}}} \tag{1}$$

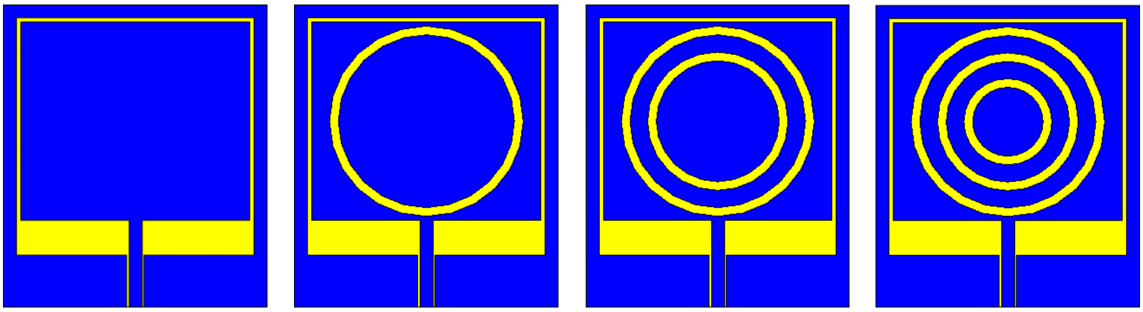
$$W = \frac{\lambda_e}{2} = \frac{c}{2 f_r \sqrt{\varepsilon_e}} \tag{2}$$

b. Calculation of the length L of the printed antenna as a function of the effective permittivity

$$L = W - 2\Delta L = \frac{c}{2 f_{r\sqrt{\varepsilon_e}}} - 2\Delta L \tag{3}$$

3. Simulation results

Our work starts by designing a simple rectangular patch which is the zero iteration of the fractal antenna structure. the first iteration of the proposed antenna having a size of 52*46 mm^2. The idea is to convert the rectangular patch into a circlar shape patch. For this reason, we have used three iterations to obtain the final proposed antenna. Figure 1 illustrates the different antenna iterations.



Iteration 0 | Iteration 1 | Iteration 2 | Iteration 3

Figure 1. Antenna iterations

The proposed antenna is simulated by using the electromagnetic solver CST-MW. The geometrical parameters of the final antenna are shown in Figure 2 and its dimentions are presented in the Table 1. The simulated return loss of the proposed antenna is shown in Figure 3. From this figure, we can conclude that the proposed antenna operates at 3.5 GHz and 2.45 GHz with reflexion coefficient of -22 dB and -21 dB, wich is suitable for WiMAX and ISM applications. The antenna has an impedance bandwith of 250 MHz and 200 MHz respectively. Table 2 report the obtained results for the different iteration.

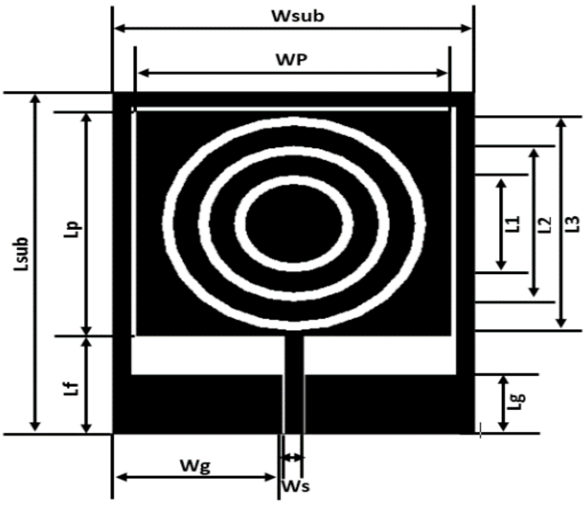


Figure 2. The proposed patch antenna.

Table 1. Dimensions of the Fractal Antenna

Parameters	Values (Unit in mm)	Parameters	Values (Unit in mm)
Lsub	70	Ws	3
Wsub	60	G	0.5
H	1.6	Lp	46
T	0.035	Wp	52
Lg	12	L1	20
Wg	28	L2	32
Lf	20	Ws	3
L3	44		

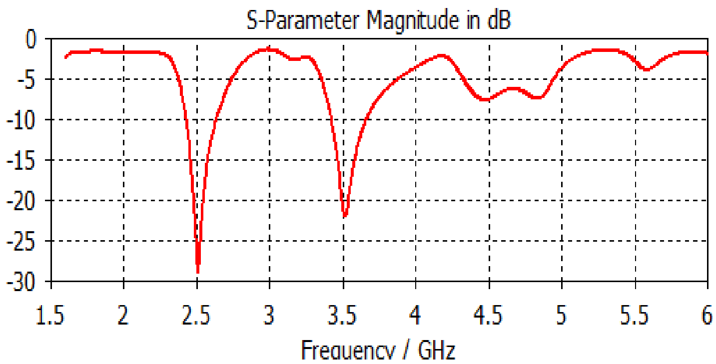


Figure 3. Simulated return loss versus frequency

Table 2. Frequency bandwidth versus return-loss value

Parameters	Iteration 1	Iteration 2	Iteration 3	
Frequency	3.47-3.67	2.45-2.58	2.42-2.62	3.40-3.65
Bandwidth	200	130	200	250
S-Parameters	-25	-26	-21	-22

Figures 4 and 5 present the radiation pattern for different center frequencies, which give a stable radiation for different frequency bands. The Gain of final iteration is shown in Figure 6. As we can observe, we have obtained a gain about 5.47dB at 2.45GHz and 5dB at 3.5GHz

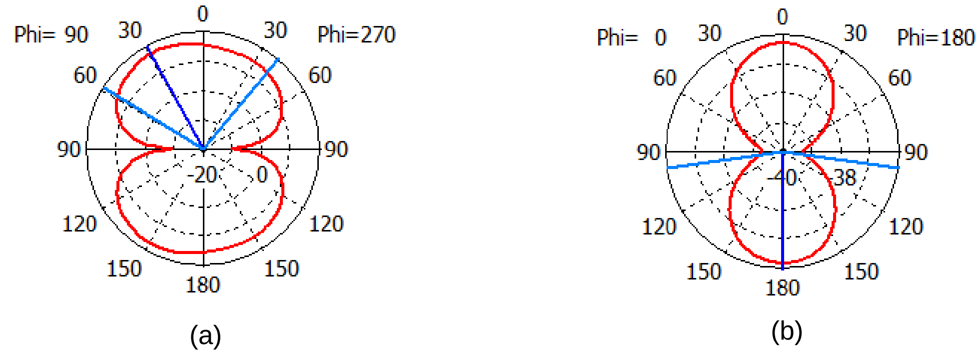


Figure 4. Radiation pattern of the proposed antennaat 2.45GHz at (a) E plane. (b) H plane

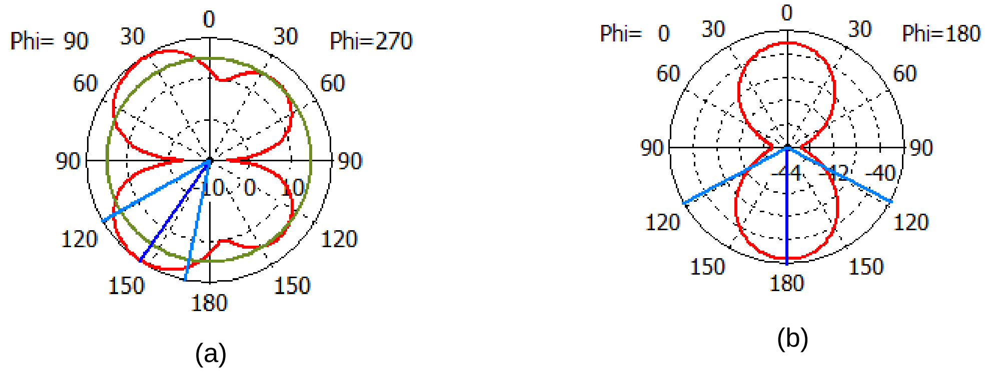


Figure 5. Radiation pattern of the proposed antennaat 3.5GHz at (a) E plane. (b) H plane

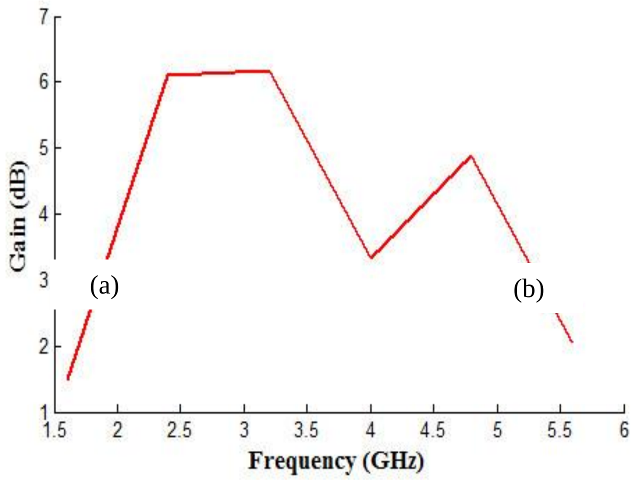


Figure 6. Simulated gain versus frequency

4. Fabrication and measuremants

After the validation of the proposed fractal antenna into simulation, the final circuit was fabricated by using LPKF machine as shown in Figure 7. The antenna is tested by using a VNA from Agilent Technologies and a 3.5 mm Calibration Kit. The fabricated antenna has a volume of 70x60x1.6 mm^3.

Figure 7. Photograph of the fabricated antenna.

As illustrated in Figure 8, the test of the antenna shows that we have a good agreement between simulation and measurement in term of return loss. The final circuit shows that the antenna has a dual band behavior meeting the requirements of the ISM and WiMAX frequency bands.

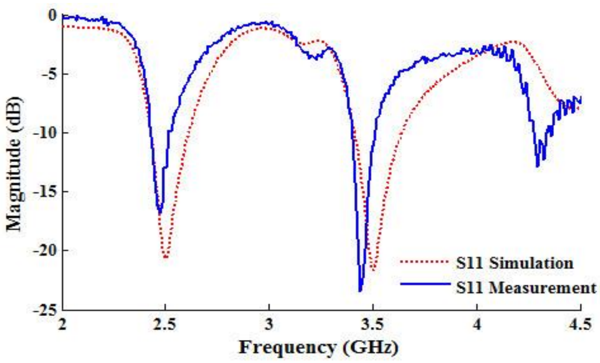


Figure 8. comparison of simulated and measured reflexion coefficient of the proposed antenna.

To compare the obtained results with literature we have done a comparison between the proposed antenna and other designed antenna structures in literature as presented in Table 3, in terms of size, return loss, and the total area occupied by the antenna. The fabricated antenna presents good performances in term of size.

Table 3. Comparison between the Proposed Antenna and Some Existing Antenna

Ref	Antenna Size (mm2)	Total area (mm2)	Frequency bands (GHz)	Antenna purpose
20	75x75	5625	2.4/5.2	Dual-band
21	75x75	5625	2.4/5.2	Dual-band
22	200x260	52000	2.4/5.2	Dual-band
Proposed work	70x60	4200	2.4/3.5	Dual-band

5. Conclusion

In this work, a novel design of a fractal dual-band antenna, this antenna is feed with CPW line which permits to associate it with printed circuits board. The measurement and simulation results agree which validate the antenna structure with a bandwidth for the two operating bands ISM and WiMAX. This antenna structure has a stable bidirectional radiation pattern and good input impedance matching with a significant bandwidth.

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