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A New Design of a Low Cost Multiband Fractal CPW-Fed Antenna

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***Abstract-* This paper presents a new design of the fractal multiband antenna structure. The proposed antenna is optimized by using CST-MW studio, this structure is a CPW-Fed antenna which makes it easier to integrate with RF devices. The final validated circuit is designed to operate in the Industrial Scientific and Medical (ISM 2.4 – 2.5GHz), worldwide interoperability for microwave access (WiMAX 3.30 – 3.80 GHz), IMT advanced system (3.40 – 4.20 GHz). The properties of antennas, for example, yield loss, radiation patterns and gain are determined by numerical simulation and measurement.**

***Index Terms-* Antenna Fractal, Multi-Band, Co-Planar.**

I. INTRODUCTION

Recently, the technologies of wireless communication systems have been rapidly ever growing demands for greater capacities broadband service and transmission speeds to support multimedia, image, speech, and data communication [1-3]. In order to response the rapidly growing demands, an antenna should operate in many frequency bands [4-5]. Accordingly, the multiband antenna is desired in many systems. In the literature reviews, there are several multiband antennas that have been developed over the years, which can be used to achieve multi-band operation objectives, for example, PIFA for using in the mobile phone application [6-8], the slot spiral antenna for dual band or multiband operation [9], Monopole Triangle-shaped antenna [10], and others [11-12]. 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] 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).

In this paper, 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), Worldwide Interoperability for access Microwave (WiMAX 3.30 to 3.80 GHz), IMT advanced system (3.40 to 4.20 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. The organization of this paper is as follows. In Section 2, we will have a definition of fractal geometry. In section 3 the parameters of the antenna, Subsequently the simulation and the measured properties of the proposed antenna will be discussed in Section 4. Finally, in Section 5 measurement results will be discussed and compared with simulation.

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II. FRACTAL ANTENNAS

Fractal' term was first coined by Benoit Mandelbrot in 1983 to classify the structure whose dimensions were not whole numbers. One of the properties of fractals geometry is that it can have an infinite length while fitting in a finite volume. The radiation characteristic of any electromagnetic radiator depends on electrical length of the structure. Using the property of fractal geometry, we may increase the electrical length of an antenna, keeping the volume of antenna the same.

One of the important benefits of fractal antenna is that we get more than one resonant band. Also, the fractal concept can be used to reduce antenna size, such as the Koch dipole, Koch monopole, Koch loop, and Mi'nkowski loop. Or, it can be used to achieve multiple bandwidth and to increase the bandwidth of each single band due to the self-similarity in the geometry, such as the Sierpinski dipole, and fractal tree dipole.

III. DESIGN OF THE PROPOSED ANTENNA

The designed antenna is achieved on a low cost FR4 substrate with a dielectric relative permittivity Ɛr= 4.4, a thickness H=1.58mm, and a loss tangent of 0.025, the entire area of the antenna is 70 x 60 mm^2. The 50Ω SMA Connector is used to feed the antenna at the CPW-Fed line.

A. Calculating Antenna Dimensions

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

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

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

$$W = \frac{\lambda_e}{2} = \frac{c}{2 f_r \sqrt{\varepsilon_e}} \quad (2)$$

- Calculation of the length L of the printed pattern as a function of the effective permittivity

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

B. Calculate the width of the gap

The formulas use "a" for the track width and "b" for the sum of the track width plus the gaps either side.

$$Zo = \frac{60.\pi}{\sqrt{\varepsilon_{eff}}} \frac{1}{\frac{K(k)}{K(k')} + \frac{K(k1)}{K(k1')}} \quad (4)$$

Where

$$k = \frac{a}{b}$$

$$k' = \sqrt{1 - k^2}$$

$$k1' = \sqrt{1 - k1^2}$$

$$k1 = \frac{\tanh\left(\frac{\pi a}{4h}\right)}{\tanh\left(\frac{\pi a}{4h}\right)}$$

$$\varepsilon_{eff} = \frac{1 + \varepsilon r \frac{K(k')}{K(k)} \frac{K(k1)}{K(k1')}}{1 + \frac{K(k')}{K(k)} \frac{K(k1)}{K(k1')}}$$

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Before validating the final antenna structure, we have started our work by studying the structure presented in figure 1, the design starts with a simple rectangular patch of 56 x 46mm^2. For this first structure, the iteration order is zero.

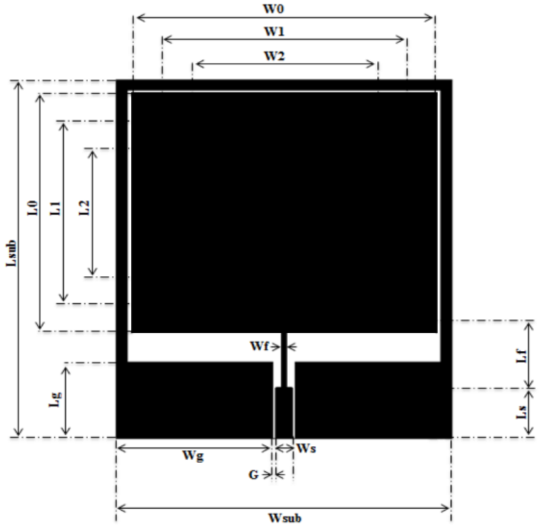

Fig. 1. CPW Rectangular Patch

The shape that was chosen for fragmentation is elliptical. The rectangular patch is converted into elliptical patch for the first iteration. Then this shape is repeated three times to obtain the final structure shown in Figure 2. Dimensions and parameters are listed in Table I.

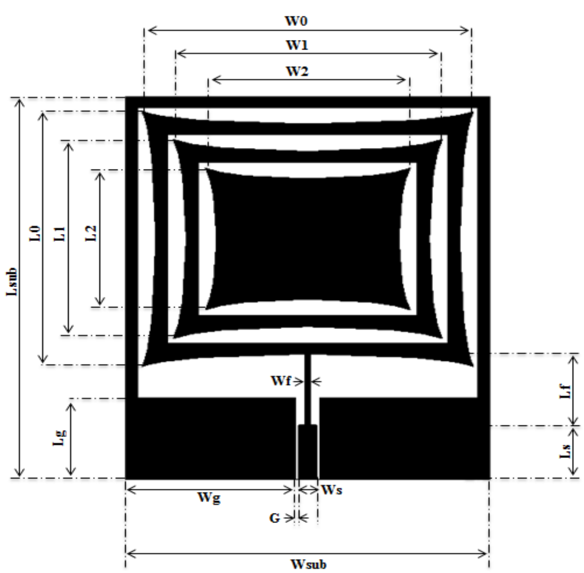

Fig. 2. Final Iteration

Table 1: Dimensions Of the final Iteration

Parameters	Values (Unit in mm)
Lsub	70
Wsub	60
H	1.58
T	0.035
L0	48
W0	56
Lg	15
Wg	28
Ls	10
Ws	3
G	0.5
Lf	10
Wf	2.2
L1	38
W1	46
L2	28
W2	36

IV. RESULTS DISCUSSION

The reflection coefficient of an antenna is an important parameter in any antenna design analysis, which measures the amount of power that will be reflected back from the antenna. It should be kept as minimum as possible. The proposed antenna is simulated by using the electromagnetic solver CST-MW. The simulation results for all three cases were swept over a frequency range between 2 and 5 GHz.

As shown in Figure 3, we have generated the first iteration of this design. Figure.4 demonstrate that we have a multiband behavior of this antenna.

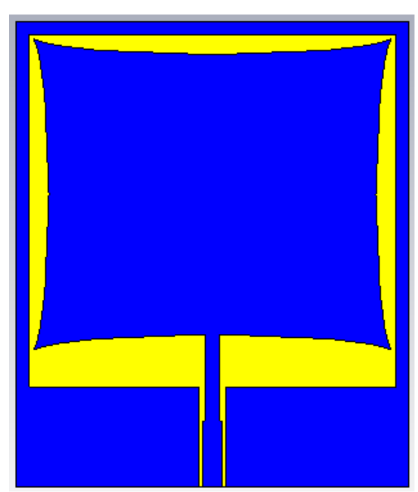

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Fig. 3. Iteration 1

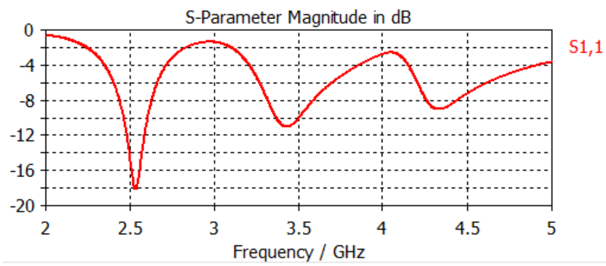

Fig. 4. Simulated Return loss of the First Order Iteration

After this step, we have conducted a study integrating the fractal technique, then we have generated the second iteration of this design as presented in Figure.5, which improves the input impedance as shown in Figure.6.

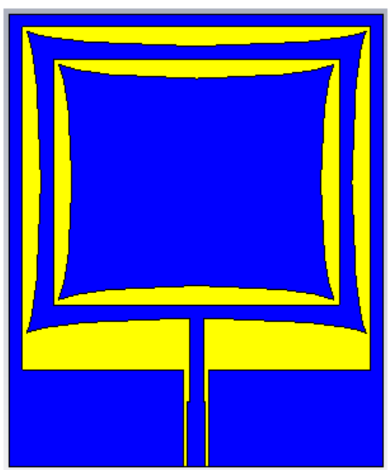

Fig. 5. Iteration 2

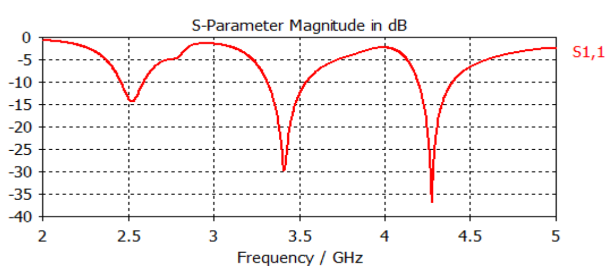

Fig. 6. Simulated Return Loss for Second Order Iteration

To adjust the problem of frequency bands, we have generated the third iteration as depicted in Figure.7. After many series of optimization in which we have studied the different parameters that can influence the bandwidth as shown in Figure.8. After this study, we have obtained the final reflection coefficient illustrated in Figure.9 permitting to validate this final antenna structure for three frequency bands as mentioned in Table.2.

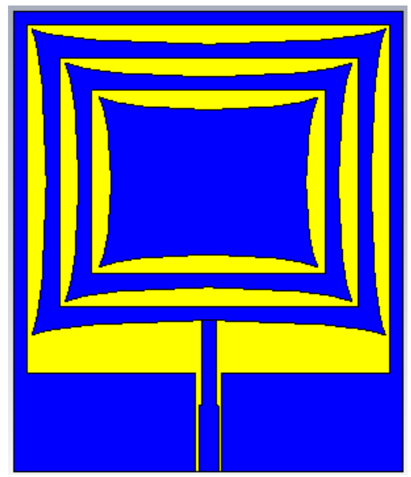

Fig. 7. Iteration 3

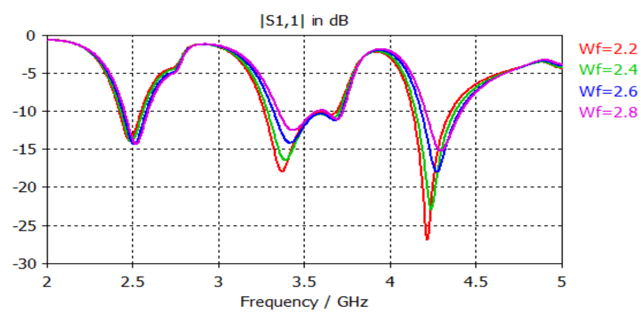

Fig. 8. Simulated Return losses For differnt values of Wf

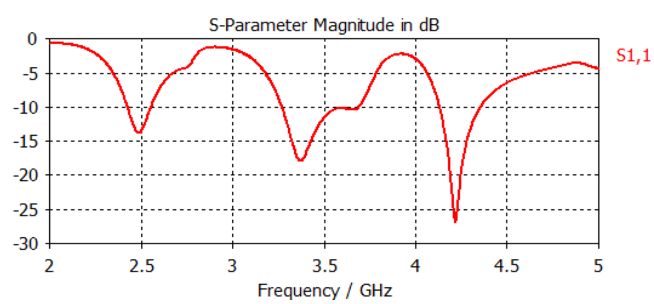

Fig.9. Simulated Return Loss for Third Order Iteration

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Table 2: Frequency bandwidth versus return-loss value

Frequency	Return Loss in dB
2.41 – 2.56 GHz	-13.83
3.26 – 3.69 GHz	-17.89
4.12 – 4.35 GHz	-26.97

Figure 10 presents the radiation pattern for different center frequencies of ISM, WiMAX and IMT in H plane and E plane. As we can see in the figure the radiation pattern is bidirectional.

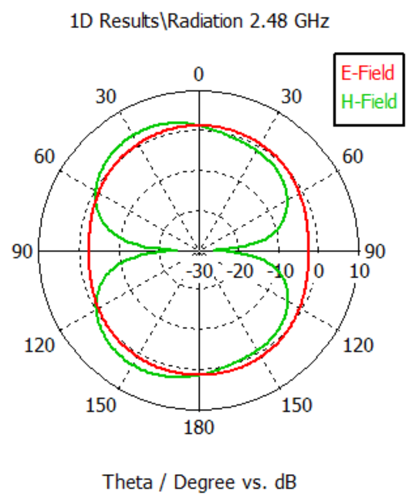

Fig. 10 (a). Radiation pattern of the proposed antenna on CST in 2.48GHz

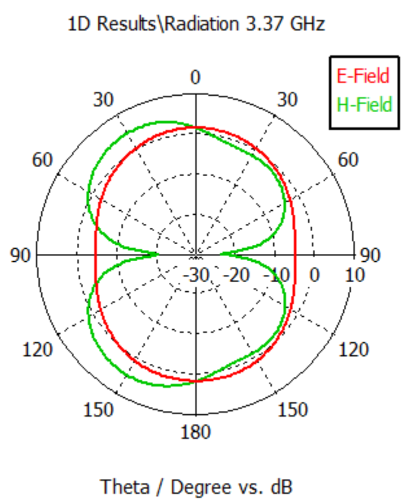

Fig. 10 (b). Radiation pattern of the proposed antenna on CST in 3.37GHz

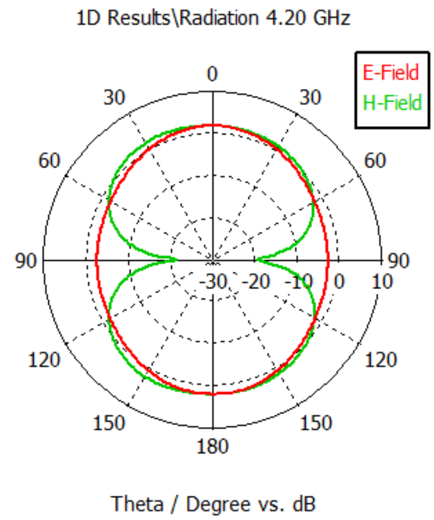

Fig. 10 (c). Radiation pattern of the proposed antenna on CST in 4.20GHz

Figure 11, illustrates the variation of the gain versus frequency. After the simulation, we have obtained the gain 3.11dB at 2.48GHz, 4.67dB at 3.37GHz and 2.13dB at 4.2GHz.

Fig. 11. Simulated gain of the proposed antenna

V. FABRICATION AND MEASUREMENTS

The fabricated antenna is shown in Fig. 12. The antenna is measured using the LPKF machine and return loss was measured by using Agilent Technologies 2-Port PNA-L Vector Network Analyzer N5230A. The fabricated antenna has a volume of 70x60x1.6 mm^3.

Figure 12. Photograph of the fabricated LPF

As illustrated in Figure 16, 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 multiband resonant behavior meeting the requirements of the ISM, WiMAX and IMT.

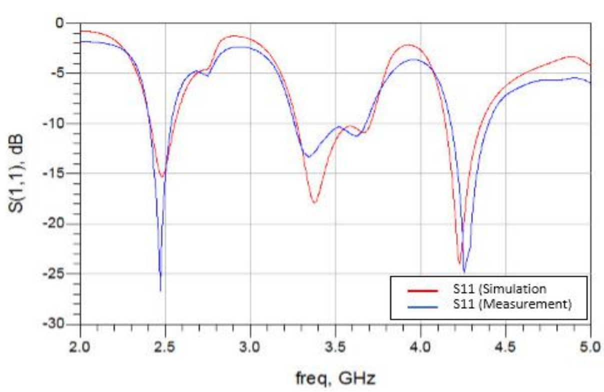

Fig. 13. Simulation and measurement results comparison for the proposed LPF

A performance comparison between the proposed antenna and other designed antenna in literatures in terms of antenna size, operating bands and antenna purpose with antennas reported in [18-20] is shown in Table 3.

TABLE 3: COMPARISON BETWEEN THE PROPOSED ANTENNA AND SOME EXISTING ANTENNA.

Ref	Antenna Size (mm2)	Total area (mm2)	Frequency bands (GHz)	Antenna purpose
[18]	75x75	5625	2.4/5.2	Dual-band
[19]	75x75	5625	2.4/5.2	Dual-band
[20]	200x260	52000	2.4/5.2	Dual-band
Proposed work	70x60	4200	2.4/3.3/4.2	Tri-Band

VI. CONCLUSION

In this work, we have validated into simulation and fabrication a fractal multiband antenna based on the use of a CPW fed line which tends to make it easy to be integrated with microwave and RF devices. The test of the antenna shows that we have a good agreement between simulation and measurement. The final circuit is validated after the generation of many iterations which permits us to design a multiband antenna in ISM, Wimax and IMT frequency bands. This antenna structure has a stable bidirectional radiation pattern and good input impedance matching with a significant bandwidth.

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