International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:9, No:1, 2015

Design of a Novel Fractal Multiband Planar Antenna with a CPW-Feed

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***Abstract*—**This work presents a new planar multiband antenna based on fractal geometry. This structure is optimized and validated into simulation by using CST-MW Studio. To feed this antenna we have used a CPW line which makes it easy to be incorporated with integrated circuits. The simulation results presents a good matching input impedance and radiation pattern in the GSM band at 900 MHz and ISM band at 2.4 GHz. The final structure is a dual band fractal antenna with 70 x 70 mm² as a total area by using an FR4 substrate.

***Keywords*—**Antenna, CPW, Fractal, GSM, Multiband.

I. Introduction

MOBILE telephony has been evolved rapidly over the past two decades in terms of frequency bands. This has prompted researchers to find new antennas that request some stringent requirements. Fractal antennas are one of these new types known by their small size and multiband behavior [1].

The word "fractal" comes from the Latin "fractus" which means "broken". In effect, a fractal is a geometric object "infinitely fragmented" whose details are observed to any chosen level. Although a number of fractal forms already known, the discovery of fractals is assigned to a French polytechnic, Benoit Mandelbrot (1924, 2010). His early research dating back to 1964 when he uses the term self-similar in a study conducted at IBM. But in 1975 he exhibited his work and gives the name "fractal" in his book "Les objects fractals" [2]. The easiest way to get a fractal is to be found in nature, snowflakes and ocean waves have fractal forms [3], [4].

After the book of Benoit Mandelbrot, the fractals start to be used in many applications like the image compression [5], computer and video game design [6], generation of new music [7] and antenna design. The first scientific publication on fractal antennas was in 1995 by Nathan Cohen [8]. He demonstrated that the concept of fractal could reduce the antenna size without degenerating the performance. Since then, this research axis has continued to evolve and many studies were done [9]-[18].

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Antennas like Koch dipole [19] and Sierpinski triangle dipole [20] become references to demonstrate the advantages of the fractal concept.

The Koch curve dipole is used to reduce the antenna size compared to a regular dipole. One of many examples is a study that compares a regular dipole to Koch curve dipole, with the same length, the first resonant frequency of a Koch curve dipole is at 961 MHz versus 1851 MHz for the regular dipole [21]. The Sierpinski triangle is more known for his multiband behavior, the resonant frequencies grow after every iteration [22].

In this paper, we will present a new antenna structure based on fractal configuration. The following sections will present the different steps followed to optimize and to validate this CPW fractal multiband antenna.

II. Antenna Design

A. Basic Antenna

The aim of this work is to design an antenna matched and centered at 900 MHz and 2.45 GHz, for this we started with a basic planar structure that has an equilateral form. Fig. 1 illustrates the designed antenna and the substrate specifications.

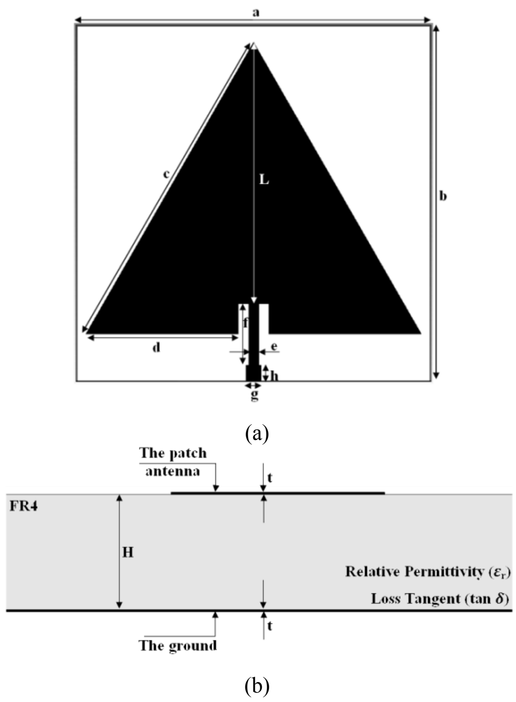


Fig. 1 The designed antenna (a) and the substrate specifications (b)

The dimensions of the triangle antenna and the substrate are presented in the Table I:

TABLE I
DIMENSIONS OF DESIGNED ANTENNA AND SUBSTRATE

Parameter	Length (mm)
a	70
b	70
c	66.5
d	30.25
e	2
f	12.2
g	3
h	3
L	51.59
t	0.035
H	1.6

The substrate used to design the antenna is FR4 with the different characteristics: relative dielectric constant $\varepsilon_r = 4.4$ and loss tangent $\tan\delta = 0.025$.

Fig. 2 shows the return loss of the simulated antenna by using CST Microwave Studio software [23].

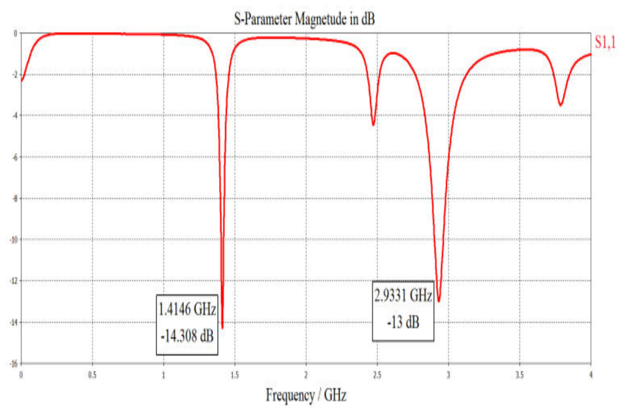


Fig. 2 Return loss of the basic antenna versus frequency

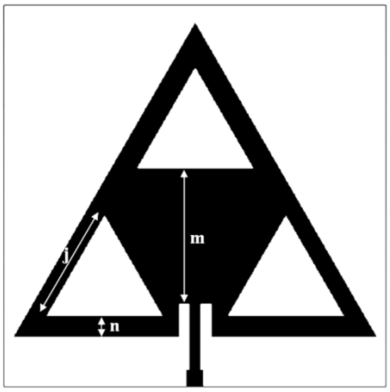
This basic triangular antenna is matched in the band 1.41 GHz. The second resonant frequency 2.93 GHz is just an harmonic frequency of the first resonant frequency which is the fundamental frequency [24]. By using (1) it was possible to determine the dimensions of the antenna to get the desired resonant frequency:

$$f_o \approx \frac{c}{2L\sqrt{\varepsilon_r}} \quad (1)$$

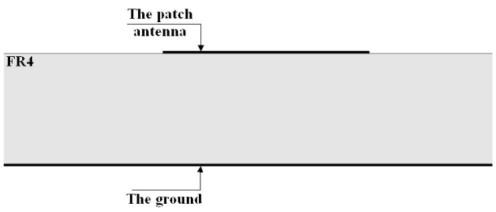
where f_o (on Hertz) is the resonant frequency, c is the velocity of light (approximately 3.10^8 meter/second), L the length of the antenna and ε_r the relative dielectric constant.

B. Fractal Concept Applied to the Triangle Antenna

The purpose of applying the fractal concept to the basic antenna is to have the multiband behavior. The triangle structure is inspired from Sierpinski triangle form known for its multiband performance, but the fractal concept is different. We created three equilateral triangles form. As shown in Fig. 3, the triangles emplacement is designed to have a self similar structure at the end.



(a)



(b)

Fig. 3 The top side (a) The bottom side (b) of the fractal designed antenna

The dimensions of the fractal antenna are listed in Table II:

TABLE II
DIMENSIONS OF THE FRACTAL ANTENNA

Parameter	Length (mm)
j	21.5
m	25.85
n	3.7

The return loss of the fractal antenna is shown in Fig. 4.

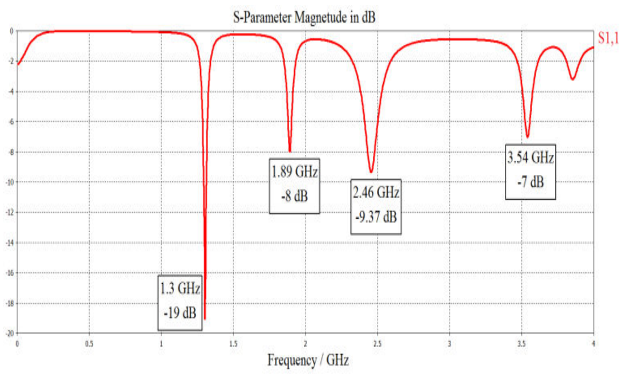
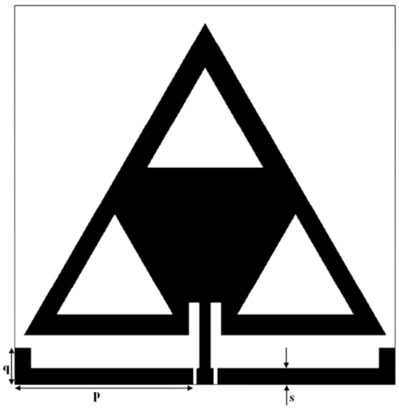


Fig. 4 Return loss of the fractal antenna

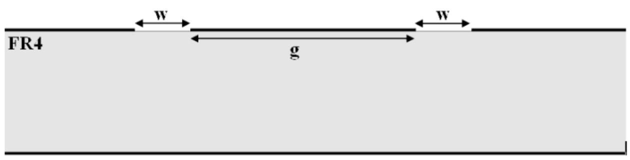
The fractal antenna has good performances at 1.3 GHz frequency. The fundamental resonant frequency has changed compared to the basic antenna. With the same antenna length we have a lowest resonant frequency and with good matching input impedance. Also, the multiband behavior starts to take birth. Two problems persists, the first is the narrowband of the structure and the second is the bad matching at the frequencies 1.89 GHz, 2.46 GHz and 3.54 GHz.

C. Final Antenna Design

The idea is to improve the matching of the bands and solve the problem of the narrowband in the fractal antenna. A solution to this problem is the coplanar technology. Fig. 5 presents the final antenna design after adding a CPW-feed.



(a)



(b)

Fig. 5 The top side (a) and the bottom side (b) of the final fractal designed antenna

The dimensions of the final fractal designed antenna are defined in Table III:

TABLE III
DIMENSIONS OF THE FINAL FRACTAL DESIGNED ANTENNA

Parameter	Length (mm)
p	32.75
q	6.7
s	3
g	3
w	0.75

Fig. 6 shows the return loss of the final fractal antenna with the bandwidth for each matched frequency band.

The final antenna presents a return loss below -10 dB in both bandwidth (862 – 973) MHz and (2.387 - 2.494) GHz with a good matching input impedance.

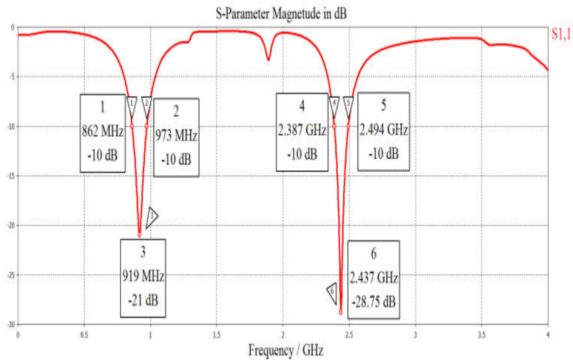
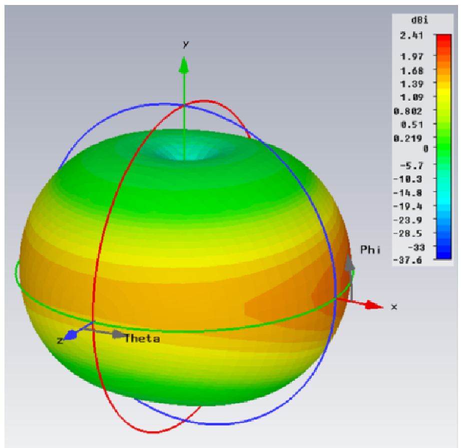


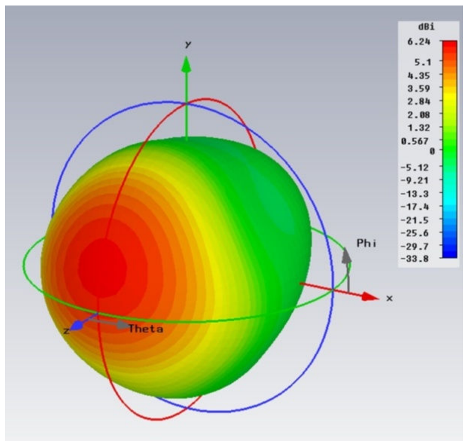
Fig. 6 Return loss of the final fractal designed antenna

By applying the CPW-feed to the fractal antenna we solved the problem of the narrowband, but also improved the matching of bands and reached a low resonant frequency.

Fig. 7 presents the radiation patterns of the final antenna at 940 MHz and 2.44 GHz which presents good performances in term of radiation.



(a)



(b)

Fig. 7 The radiation patterns of the final designed antenna at 940 MHz (a) and 2.44 GHz (b)

III. Conclusion

A new fractal multiband planar antenna has been introduced. Starting from an equilateral triangle structure, we applied a fractal geometry to get multiband behavior, then we used a coplanar waveguide feed to improve the performance of the antenna. The final structure presents excellent matching input impedance in the two bands, GSM (862 – 973) MHz and ISM (2.387 - 2.494) GHz, a compact architecture and good performances for the radiation pattern. The antenna is a low cost, simple to fabricate, easy to associate with integrated circuits and suitable for mobile applications like Extended GSM 900 band, Wi-Fi and Bluetooth.

Acknowledgment

We have to thank Mr. Mohamed Latrach Professor in ESEO, engineering institute in Angers, France, for allowing us to use all the equipments and software available in his laboratory.

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