

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

T. Benyetho, L. El Abdellaoui, J. Terhzaz, H. Bennis, N. Ababssi, A. Tajmouati, A. Tribak, M. Latrach

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 $70 \times 70 \text{ mm}^2$ 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 objets 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].

T. Benyetho, L. El Abdellaoui, and H. Bennis are with LITEN Laboratory, FSTS, Hassan 1st University, Settat, Morocco (e-mail: t.benyetho@gmail.com, elabdellaoui20@hotmail.com, hamid.bennis@gmail.com).

J. Terhzaz is with CRMES/LITEN Laboratory, FSTS, Hassan 1st University, Settat, Morocco.

N. Ababssi and A. Tajmouati are with LITEN Laboratory, FSTS, Hassan 1st University, Settat, Morocco.

A. Tribak is with Microwave Team INPT, Rabat, Morocco.

M. Latrach is with Microwave Group ESEO, Angers, France.

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.

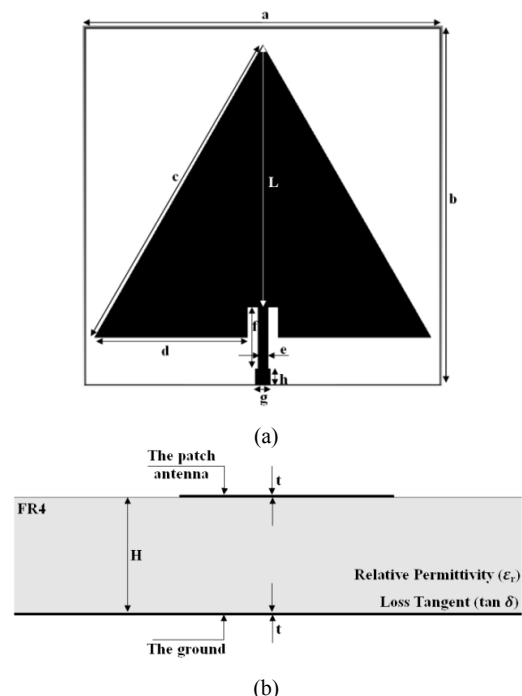


Fig. 1 The designed antenna (a) and the substrate specifications (b)

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 $\epsilon_r = 4.4$ and loss tangent $\tan \delta = 0.025$.

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

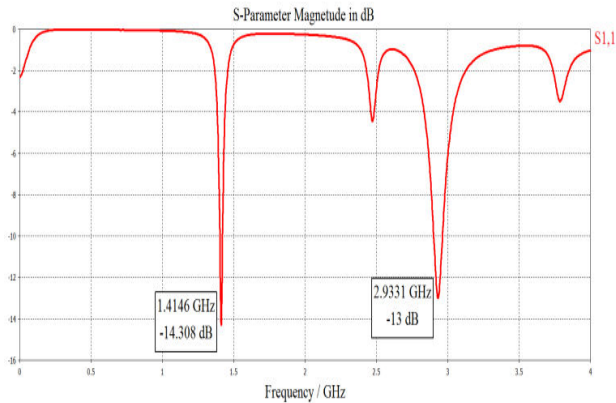


Fig. 2 Return loss of the basic antenna versus frequency

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:

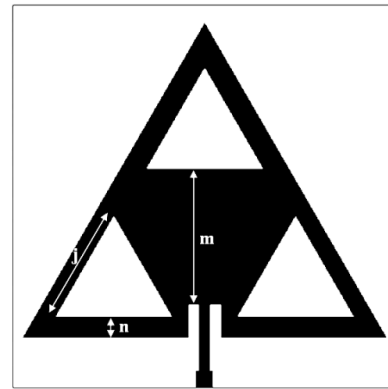
$$f_o \approx \frac{c}{2L\sqrt{\epsilon_r}} \quad (1)$$

where f_o (on Hertz) is the resonant frequency, c is the velocity of light (approximately $3 \cdot 10^8$ meter/second), L the length of the antenna and ϵ_r the relative dielectric constant.

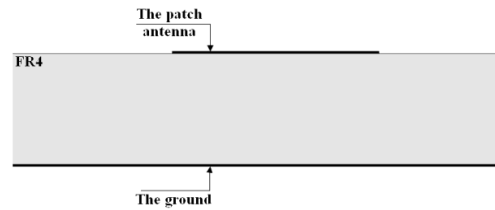
B. Fractal Concept Applied to the Triangle Antenna

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.

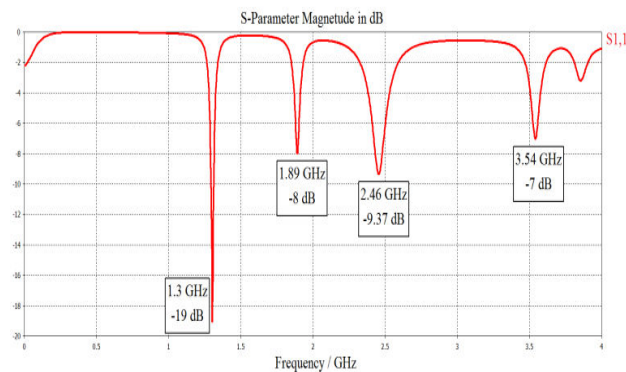


Fig. 4 Return loss of the fractal antenna

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.

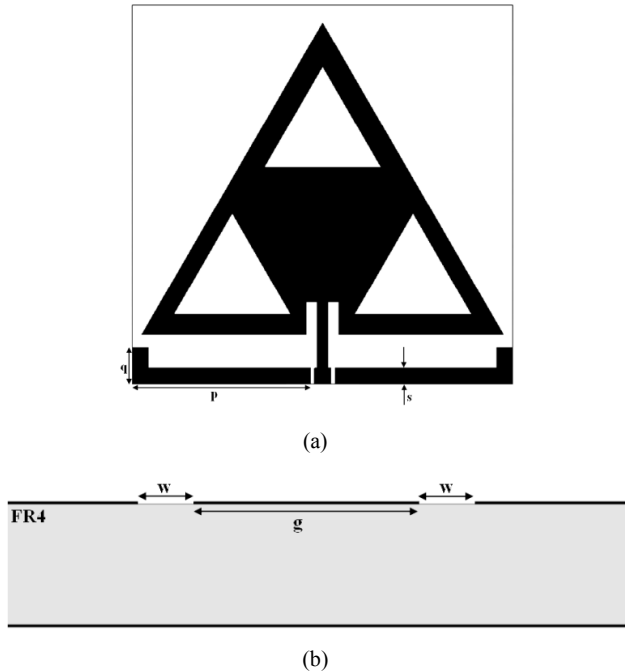


Fig. 5 The top side (a) and the bottom side (b) of the final fractal designed antenna

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.

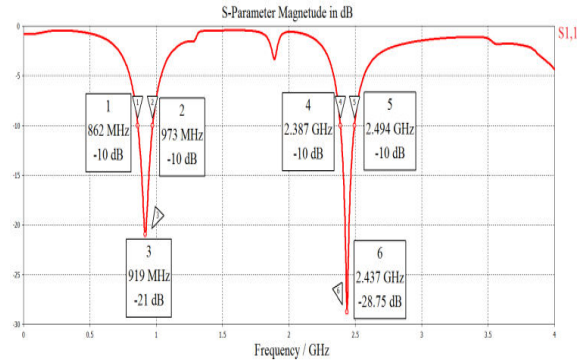


Fig. 6 Return loss of the final fractal designed antenna

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.

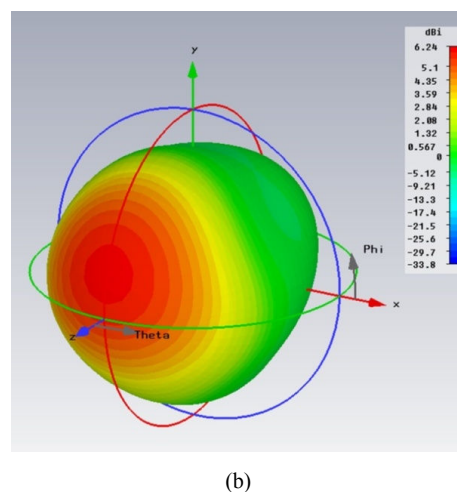
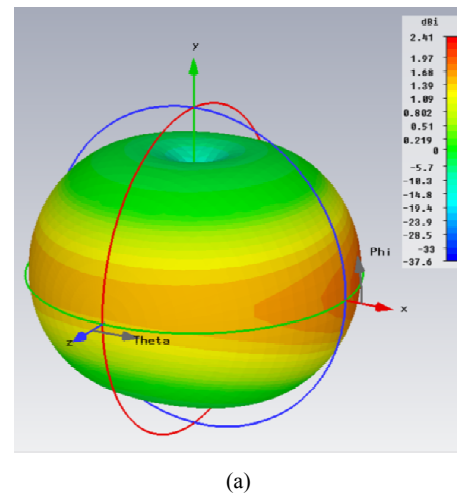


Fig. 7 The radiation patterns of the final designed antenna at 940 MHz (a) and 2.44 GHz (b)

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.

REFERENCES

- [1] Werner Hödlmayr, "Fractal Antennas", *antenneX Online magazine*, Issue No. 81, January 2004.
- [2] Benoit B. Mandelbrot, "Fractals: Form, Chance and Dimension", "les objets fractals: forme hasard et dimension", *Nouvelle bibliothèque scientifiques*, French edition, January 1, 1975.
- [3] Meyer Yves and Roques Sylvie, "Progress in wavelet analysis and applications", *proceedings of the International Conference "Wavelets and Applications"*, Toulouse, France - June 1992.
- [4] Paul S. Addison, "Fractals and chaos: an illustrated course", CRC Press, pp. 44 – 46, ISBN 978-0-7503-0400-9, 1997.
- [5] Wee Meng Woon, Anthony Tung Shuen Ho, Tao Yu, Siu Chung Tam, Siong Chai Tan, Lian Teck Yap, "Achieving high data compression of self-similar satellite images using fractal", *Geoscience and Remote Sensing Symposium*, 2000. *Proceedings. IGARSS 2000, Honolulu, IEEE 2000 International*, Vol. 2, pp 609 – 611, 24 July 2000.
- [6] Parkin Simon, "Fractal: Make Blooms Not War Review", *EuroGamer*, Retrieved 5 July 2013.
- [7] Martin Supper, "A Few Remarks on Algorithmic Composition", *Computer Music Journal*, pp 48 – 53, 25 January 2001.
- [8] Nathan Cohen, "Fractal Antennas", *Communications Quarterly*: 9, 1995.
- [9] W. Ismahayati, P.J Soh, R.Hadibah and G.A.E Vandenbosch, "Design and Analysis of a Multiband Koch Fractal Monopole Antenna", *IEEE International RF and Microwave Conference*, 12th-14th December 2011, Seremban, Malisya, pp 58 – 62.
- [10] Yogesh Kumar Choukiker, Satish K Sharma, and Santanu K Behera, "Hybrid Fractal Shape Planar Monopole Antenna Covering Multiband Wireless Communications with MIMO Implementation for Handheld Mobile Devices", (Accepted for publication), *IEEE Transactions on Antennas and Propagation*, Citation information: DOI 10.1109/TAP.2013.2295213, to be published.
- [11] Pengfei Wu, Zhenqi Kuai, and Xiaowei Zhu, "Multiband Antennas Comprising Multiple Frame-Printed Dipoles", *IEEE Transactions on Antennas and Propagation*, Vol. 57, No. 10, pp 3313 – 3317, October 2009.
- [12] Jian Li, Tianyan Jiang, Changkui Cheng, "Hilbert Fractal Antenna for UHF Detection of Partial Discharges in Transformers", *IEEE Transactions on Dielectrics and Electrical Insulation* Vol. 20, No. 6, pp 2017 – 2025, December 2013.
- [13] Abolfazl Azari, Alyani Ismail, Aduwati Sali, and Fazirulhisyam Hashim, "A New Super Wideband Fractal Monopole-Dielectric Resonator Antenna", *IEEE Antennas and Wireless Propagation Letters*, Vol. 12, pp 1014 – 1016, 2013.
- [14] Werner Hödlmayr and Sonny Ganguly, "An Overview of Fractal Antenna Engineering Research", *IEEE Antenna and Propagation Magazine*, Vol. 45, No. 1, pp. 38 – 57, 2003.
- [15] Carles Puente Baliaada, Jordi Romeu and Angel Cardama, "The Koch Monopole: A Small Fractal Antenna", *IEEE Transactions on Antennas and Propagation*, vol. 48, no. 11, pp. 1773–1781, November 2000.
- [16] Homayoon Oraizi, and Shahram Hedayati, "Miniaturization of Microstrip Antennas by the Novel Application of the Giuseppe Peano Fractal Geometries", *IEEE Transactions on Antennas and Propagation*, Vol. 60, No. 8, pp 3559 – 3567, August 2012.
- [17] Homayoon Oraizi, and Shahram Hedayati, "Miniaturized UWB monopole microstrip antenna design by the combination of Giuseppe Peano and Sierpinski carpet fractals", *IEEE Antennas Wireless Propagation Letters*, Vol. 10, No. 1, pp. 67 – 70, January 28, 2011.
- [18] Mustafa Khalid, "Combined Fractal Dipole Wire Antenna", *IEEE Transactions On Antenna And Propagation*, Vol AP-30, No.6, Nov 2000.
- [19] Carmen Borja and Jordi Romeu, "On the Behavior of Koch Island Fractal Boundary Microstrip Patch Antenna", *IEEE Transactions On Antenna And Propagation*, Vol. 51, No.6, June 2003.
- [20] Carles Puente Baliaada and Jordi Romeu and Rafael Cardama, "On the Behavior Of the Sierpinski Multiband Fractal Antenna", *IEEE Transactions On Antenna And Propagation*, Vol. 46, No. 4, April 1998.
- [21] Xianhua Yang, J. Chiochetti, D. Papadopoulos and L. Susman, "Fractal Antenna Elements and Arrays", *Applied Microwave and Wireless, Technical Feature*, pp 34 – 46, 2000.
- [22] Abd Shukur Ben Ja'afar, "Sierpinski Gasket Patch and Monopole Fractal Antenna", *Thesis for the degree of master of engineering*, April 2005.
- [23] CST Microwave Studio, <https://www.cst.com/Products/CSTMWS>.
- [24] "Fundamental Frequency of Continuous Signals", *Fourier.eng.hmc.edu*, Retrieved 2012-11-27.