Design and Miniaturization of a Novel Fractal Micro-strip Antenna for UWB Applications

Zeynab Zohrabi, Yashar Zehforoosh
Department of Electrical Engineering, Urmia branch, Islamic Azad University, Urmia, Iran
Emails: zeynab_zohrabi@yahoo.com; Y.zehforoosh@srbiau.ac.ir.

Abstract

A novel printed octagonal fractal micro-strip antenna with semi-elliptical ground plane is presented for ultra wide band applications. The proposed antenna has a compact size of 20×20×1 mm³. The measured result of the antenna exhibits the ultra-wide band characteristics from 2/9 to 14/2 GHz. In this paper, reducing antenna's size by 35%, the same results were achieved, while small dimension fractal micro-strip antenna is presented. The antenna's size is 15×12×1 mm³ which has a small and appropriate size for nowadays' telecommunication systems and utilization. The design and simulation results of micro-strip patch fractal antennas using Ansoft HFSS is presented and discussed below.

Keywords: Fractal, Micro-strip Antenna, Ultra-Wideband (UWB).

1. Introduction

The rapid growth of the wireless telecommunication systems in one hand and the huge publicity of this industry these days mandate extensive research in the fields of UWB, double band, and multiple band antennas. A large number of such antennas have been proposed, often with sizes that may be too large to be used practically [1].In addition, there is a burgeoning demand for antennas able to meet the needs of compressed smaller sizes, multi band, ultra wide band, etc. In recent years, there have been noticeable achievements partly satisfying such demands and expectations. In today's telecommunication systems, fractal antennas have proved to be efficient ones. Several UWB printed monopole antennas with various shapes have been used in different forms [2].The key problems in the antenna theory and technology are a decrease in dimensions, wide range variation in the electromagnetic parameters, and extension of the working frequency band [3]. Micro-strip antenna is a simple antenna that consists of a radiated patch component, dielectric substrate and ground plane. The major motive of micro-strip patch antenna to make people interested in it is its innate features such as light weight, low profile, little cost, easy to manufacture, small dimension, cheap and easy to integrate with other circuits. The reduction size of micro-strip patch antenna is a contemporary issue of interest. There are various ways to diminish the size of micro-strip patch antennas such as introducing U-slots, using fractal, using high permittivity materials. It is possible to show how two different structures for fractal antennas may be used for UWB applications [4].

This paper aims at presenting a new design of fractal antenna, which is a new octagonal fractal micro-strip antenna proposed for the UWB system applications. Impacts of the fractal repetitions and a semi-elliptical ground plane will be demonstrated. The designed antenna can back up most of the communication standards such as IEEE802 in the US, HIPERLAN12 in Europe and UWB [5].The proposed antenna design, simulation, and measured results are shown and discussed.

2. Antenna Design

The ultimate fractal shape and the structure of the proposed antenna which consists of the fractal patch with a semi-elliptical shaped ground plane is portrayed in Fig.1. [6].Fractal micro-strip patch antenna is designed based upon an iterative method. As it can be seen, the radiation element of the antenna is formed by adding and combining the octagonal and square shapes. In the first iteration, a 10×10 mm^2 square is cut out of the base octagonal patch. This is the first of the five consecutive iterations. The antenna’s semi-elliptical ground and its distance from the patch have a significant impact on the antenna’s return loss.

Measurement of each iteration is distinctive. A number of iterations can be achieved, but considering fractal antenna's compactness, only five iterations are achieved. Besides, in upper iterations there is no critical alteration in the properties of the antenna.

The designed UWB antenna is validated by simulation using High Frequency Structure Simulator (HFSS). This UWB antenna is realized on FR4 substrate with relative permittivity of 4.4, loss tangent of 0.02, and thickness of1-mm-wide. The antenna has compact dimensions of 20×20×1 mm^3 (Wsub×Lsub×h) with a ground plane whose detailed dimensions are shown in Table.1..

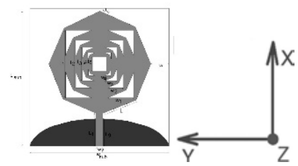

Fig.1. Geometry of a fifth iteration of fractal micro-strip antenna for UWB uses.

Table.1. Optimal parameter values of the antenna

Lsub	20 mm
Wsub	20 mm
Lf	4.7 mm
Wf	1 mm
Lg	4 mm
L	5.7 mm
W	3.5 mm
L1	10 mm
W1	3.7 mm
L2	7 mm
W2	2.2 mm
L3	5 mm
W3	1.3 mm
L4	3.4 mm
W4	0.3 mm
L5	2 mm
L6	0.5 mm

As it is mentioned before, the schematic of the antenna is based on the integration of the square and the octagonal structure. The space between the angles of the squares and the angles of the octagons ought to be 0.4

mm and this is repeated for all five iterations. The length of the feed space between the patch and the ground plane is also an influential parameter to handle the impedance bandwidth. Actually the separation between the feed, ground and the patch affect the Ultra Wide Band. Owing to the growing fractal iteration on the fractal patch, it is supposed that the bandwidth of the antenna be increased; however, more iteration isn't applied because of the insignificant impact on impedance bandwidth of recommended antenna.

3. Results and Discussion

The parameters of both proposed antennas are studied and analyzed by using An soft HFSS [7]. The variation of S11, the ratio of reflected power to the reference power in dB with frequency is plotted in Fig.3. From the simulation results in Fig. 3, it is perceived that the impedance bandwidth increases as the fractal iterations are increased, thus we have maximum impedance bandwidth for the fifth iterated antenna. As can be seen, the proposed antenna offers the promising S11 parameter below -10 dB in the entire UWB operating range from 3.1 GHz to 10.6 GHz with two distinct resonant frequencies at 6.3 GHz, and 10.2 GHz. The proposed fractal antenna is not only simulated, but further fabricated by using common Printed Circuit Board (PCB) methods (Fig.2). Simulated results of the radiation patterns of the proposed fractal antenna at 5, 9, and 11 GHz are depicted in Fig.4. It is observed that the fractal antenna affords Omni directional radiation patterns in the H-plane and steady patterns in the form of figure-eight in the E-plane.

Fig.2. Photograph of the fabricated Fractal patch Antenna

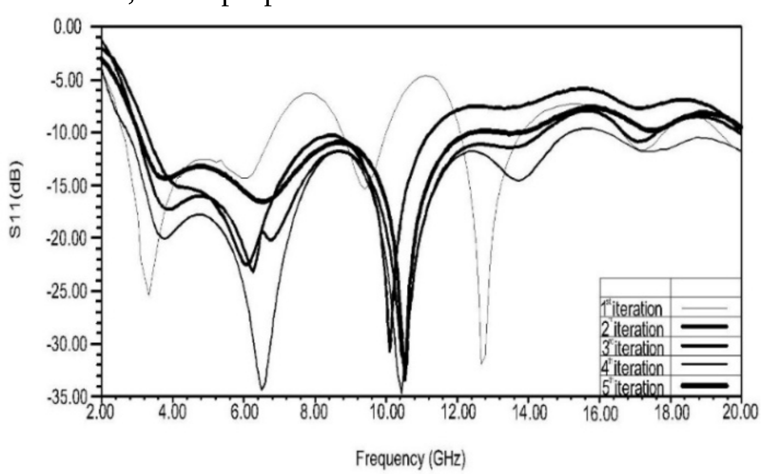

Fig.3. The simulated curves for five iterations of fractal

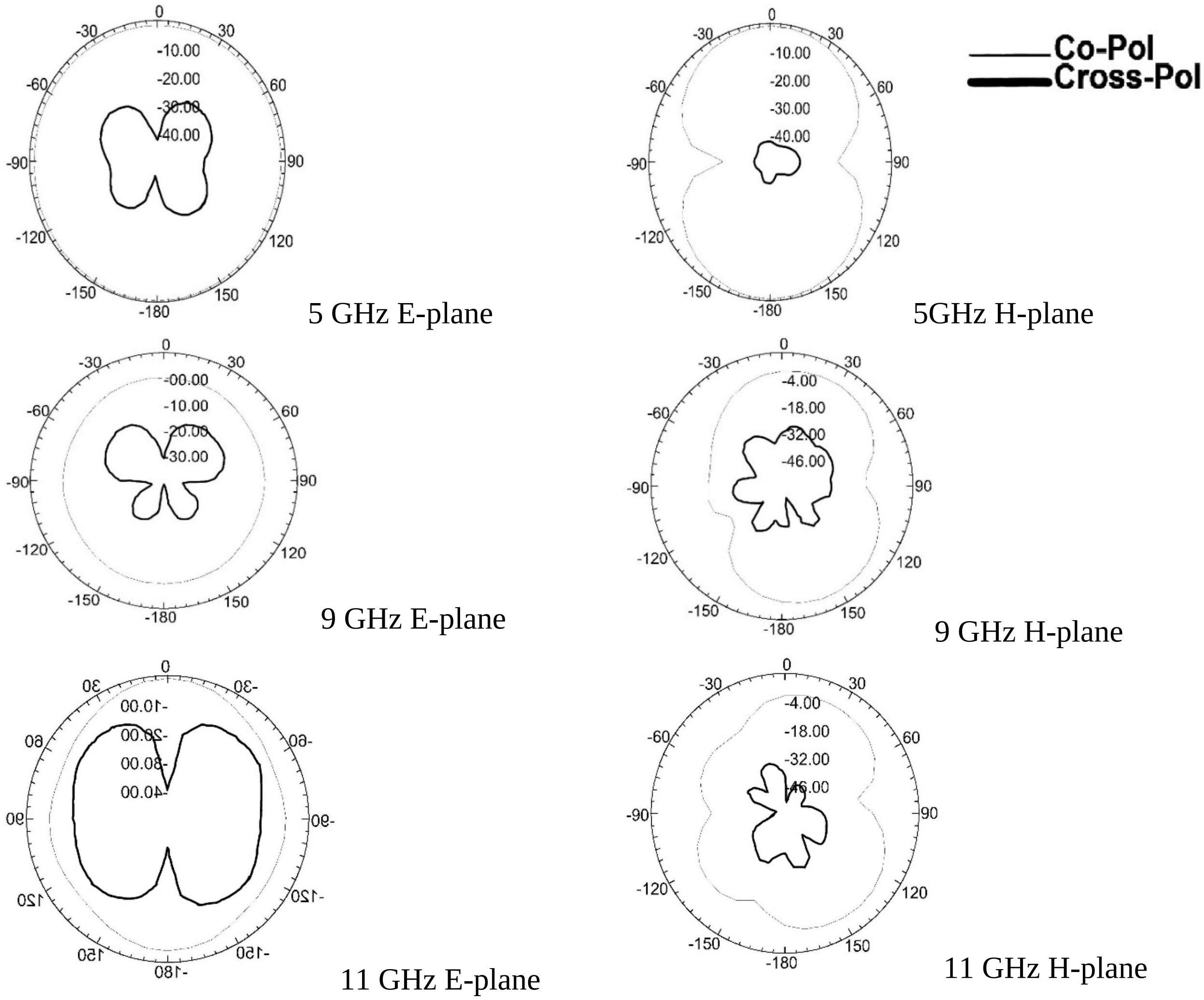

Fig.4. Measured E-plane and H-plane radiation patterns of proposed antenna at 5, 9, and 11 GHz

The comparison of the simulated and measured results shows a reasonable agreement at all frequencies that can be found it in Fig.5. This may be because of the minor parametric discrepancies existing in the FR4 substrate between the practical representation and the simulated models. It is also possible that the dielectric constant and dissipation factor has some variations with frequency.

4. Reduction Size

Nowadays the significance of the antenna's compaction has highly increased, which is accordingly considered. In this paper, reducing antenna's size by 35%, the same results were achieved, while small dimension fractal micro-strip antenna is presented. The antenna's size is 15×12×1 mm³ which has a small and appropriate size for nowadays' telecommunication systems and utilization.

Fig.6 shows the miniaturized size of the fractal antenna and table II contains its dimension. As it is clear from the shape of the miniaturized antenna, the dimension is highly diminished, yet we could achieve the same results. The reflection coefficient of the reduced one is depicted in Fig.9.

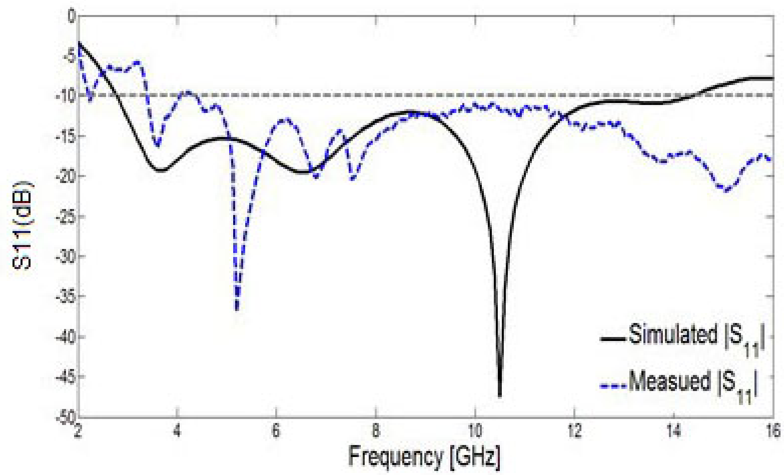

Fig.5. Simulated and measured S11 for five iteration of fractal

By comparing the measured results of S11 parameter of the designed antenna and the simulated results which is presented in Fig.9, it is apparent that the simulated and measured results of frequency responses are in good agreement. The photograph of the realized very compact fractal antenna is shown in Fig.7.

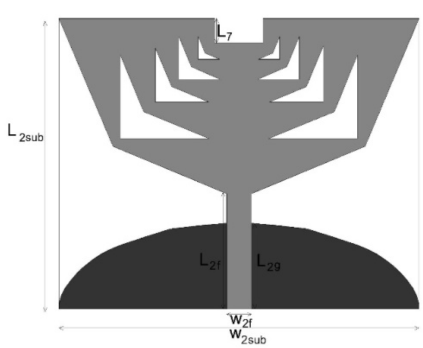

Fig.6. Geometry of the proposed miniaturized antenna

Table.2. Optimal parameter values of the miniaturized antenna

L2sub	12 mm
W2sub	15 mm
L2f	4.7 mm
W2f	1 mm
L2g	3.5 mm
L7	1 mm

Fig.8. Photograph of the fabricated miniaturized antenna

Also, the E- and H-planes radiation pattern at the same frequencies of the main fractal antenna (5, 9 and 11 GHz) for the miniaturized antenna is shown in Fig.8, respectively.

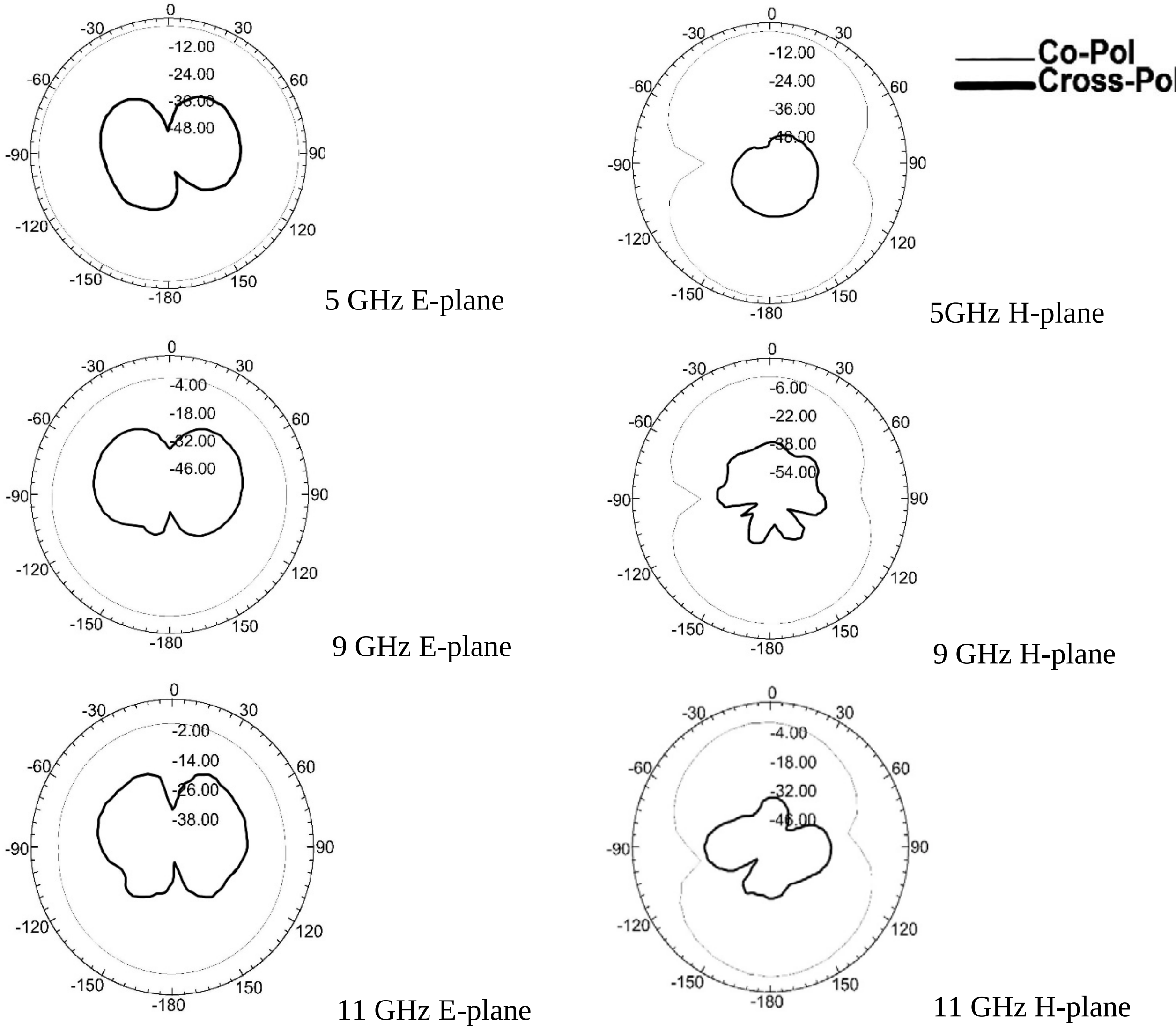

Fig.9. Measured E-plane and H-plane radiation patterns of miniaturized antenna at 5, 9, and 11 GHz

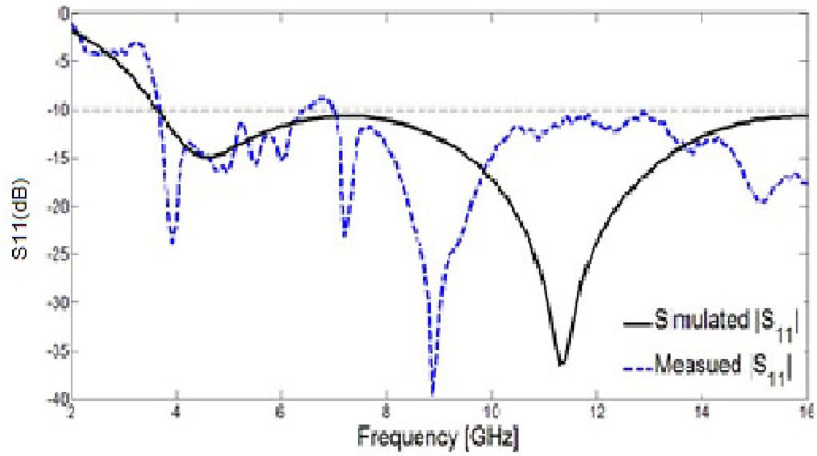

Fig.7. Simulated and measured S11 for the miniaturized antenna

Fig.10, demonstrates the proportions differences in both antennas. As it is observed from it, there is a substantial dimensional difference between the main fractal antenna and its miniaturization.

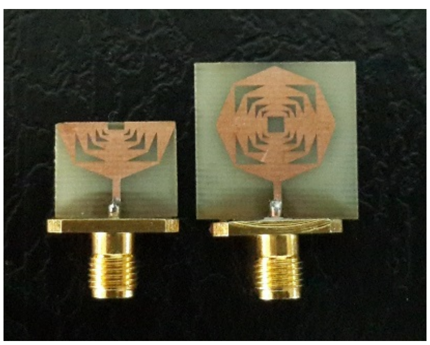

Fig.10. Photograph of the comparison between both fabricated antennas

5. Conclusion

A novel fractal micro-strip antennafor UWB applications has been designed, simulated, fabricated and tested. We demonstrated that by increasing thefractal iterations and improving antenna parameters with appropriate values, a very good impedance agreement and enhancement bandwidth can be attained.The operating bandwidth of the proposed fractal antenna supports the whole frequency band from 2.9 to 14.2 GHz. However, we could get a smaller and compact size fractal antenna out of the main structure which has the same results and is suitable for UWB applications.

This miniaturization in the UWB antenna may reduce the fabrication cost, and thus provides an appropriate choice for applications such as wireless devices, body area network, and etc.

References

[1] J. Pourahmadazar, C. Ghobadi, J. Nourinia, and H. Shirzad, "Multiband ring fractal antenna for mobile devices," IEEE Antennas WirelessPropag. Lett, vol. 9, pp. 863–866, 2010.

[2] Raha Eshtiaghi, Javad Nourinia, and Changiz Ghobadi.'Electromagnetically Coupled Band-Notched Elliptical Monopole Antenna for UWB Applications', ieee transactions on antennas and propagation, vol. 58, no. 4, April 2010.

[3] A. A. Potapov,'the base of fractal antenna theory andapplications: utilizing in electronic devices',International Conference on Antenna Theory and Techniques, 2013, Odessa, Ukraine, pp. 62-67.

[4] Wireless Propag. Lett, vol. 12, pp. 651-654, 2013.
[5] Bahman Heydari 1, Zakarya Sanaati 1, Vorya Waladi 1, and Yashar Zehforoosh ,'A Novel Fractal Monopole Antenna with Wide Bandwidth',ACES JOURNAL, Vol. 29, No. 11, NOVEMBER 2014.
[6] Pourahmadazar, J., Ghobadi, C., Nourinia, J.Felegari, N., and Shirzad,H.: 'Broadband CPW-fed circularly polarized square slot antenna with inverted-L strips for UWB applications', IEEE AntennasWirel.Propag. Lett, 2011.