Design and Fabrication of Wide Band Printed Multi-ring Fractal Antenna for Commercial Applications

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Abstract— This paper presents a wideband printed multi-ring fractal antenna. The ground plane is only under part of the feed line. Good performance of S-parameters is obtained. This optimized fractal antenna has the potential of operating in several of the currently broad band commercial existing systems such as, Bluetooth and GSM.

1. INTRODUCTION

Microstrip patch fractal antennas have been rapidly developed for multi-band and broad band in high data rate systems known as wideband communication systems. The use of microstrip fractal geometry antennas in electromagnetic radiations has been a recent topic of interest in the world. It has been shown that fractal shaped antennas exhibit features that are directly associated with the geometric properties of fractals. One property associated with fractal geometry that is used in the design of super special antennas is self-similarity, which means that some of their parts have the same shape as the whole object but at a different scale [1–3]. The construction of many ideal fractal shapes is usually carried out by applying an infinite number of times an iterative algorithm such as the multiple reduction copy machine (MRCM) algorithm [1]. In such iterative procedure, an initial structure called generator is replicated many times at different scales, positions and directions, to grow the final fractal structure. A fractal antenna can be designed to receive and transmit over a wide range of frequencies using the self-similarity properties associated with fractal geometry structures. The applications of fractal shapes are on scattering problems, array techniques, reduced size and multi-band and wide-band antennas. In antenna application, the Minkowski loop [4, 5], the Koch curve monopole [4, 5], the Koch island patch [6], the Sierpinski carpet [7, 8] and the Sierpinski gasket have been reported [9, 10]. Therefore, traditional fractals such as Koch curves, Sierpinski triangles, and Minkowski fractals, etc, have been used to design compact antennas for multiband or broadband operation. D. L. Jaggard et al. [11] showed that the same kind of geometrical similarity relations at several growth stages were found in the electromagnetic behavior of the fractal body. The diffraction of fractally serrated apertures [12], [13] the reflection and transmission coefficients of fractal multilayers [14] and the sidelobe properties of some fractal arrays [15], [16] are other examples of studies currently available in the literature that relate fractals and electromagnetic.

In our work, a simple structure of printed multiple elliptic ring fractal antennas has investigated and also demonstrated. A significant matched bandwidth compared to the conventional multiple ring monopole antenna has obtained. Many possibilities of improved design have been investigated by varying the width of the rings. On the other hand, this type of structure can achieve larger matched bandwidth in comparison to conventional multiple ring monopole antennas. Simulation and experimental results confirm that this type of antenna can achieve better performance than the conventional multiple ring monopole antennas, and obtain very wide bandwidth of more than 14 GHz under -10 dB. By tuning of elliptic ring partial ground size the optimum operation is obtained. The gap between antenna and ground plane is the key point for impedance matching performance of radiation pattern and S-parameters. On the other hand, a novel wide-band fractal patch antenna is designed, measured and analyzed. Based on these concepts, a compact printed fractal antenna has constructed with the aid of an electromagnetic (EM) simulator using Ansoft HFSS (a full wave simulator). The impedance antenna structure bandwidth of the proposed antenna could reach 64%, which has rarely been reported for patch antennas. All results and performance are validated and confirmed experimentally.

2. DESCRIPTION OF THE ANTENNA STRUCTURE

Figure 1 shows the geometry of the fabricated antenna. The exact dimensions for the proposed antenna are also given in Figure 1. The antenna is fed by microstrip line of width of 3.864 mm to match the 50 Ω SMA connector is then attached to end of the microstrip line, under which is

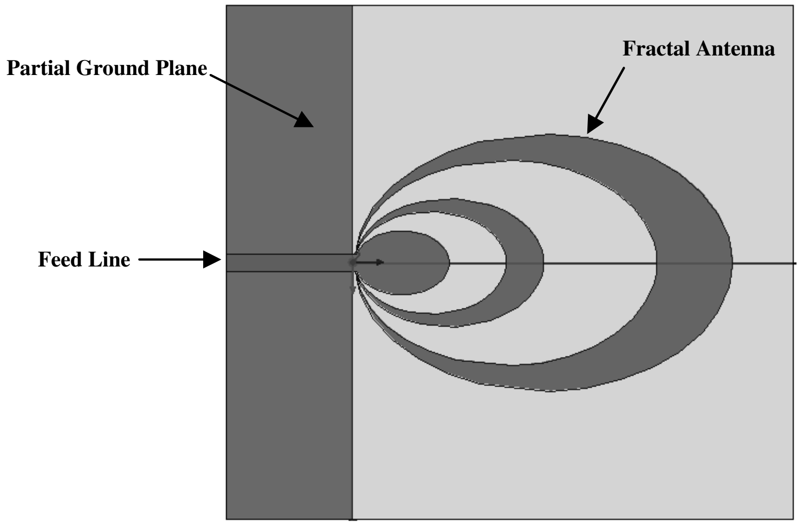
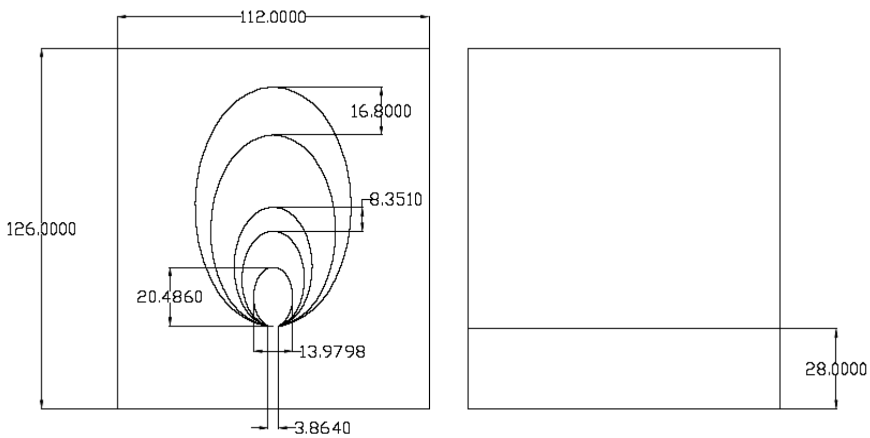


Figure 1: Fractal antenna structure using Ansoft HFSS software.



(a)

(b) (c)

Figure 2: (a) Exact dimensions of proposed planar microstrip multi-ring fractal antenna in mm, (b) Fabricated antenna structure, (c) Feed and partial ground plane.

the ground plane. There is no plane under antenna and the antenna's ground plane is only under the feed. The gap between ground plane and antenna is 0.663 mm to achieve better performance. The optimized length and width of the ground plane is 28 and 112 mm respectively. The patch is printed on a microwave substrate with low relative permittivity and thickness $H = 0.62$ mil.

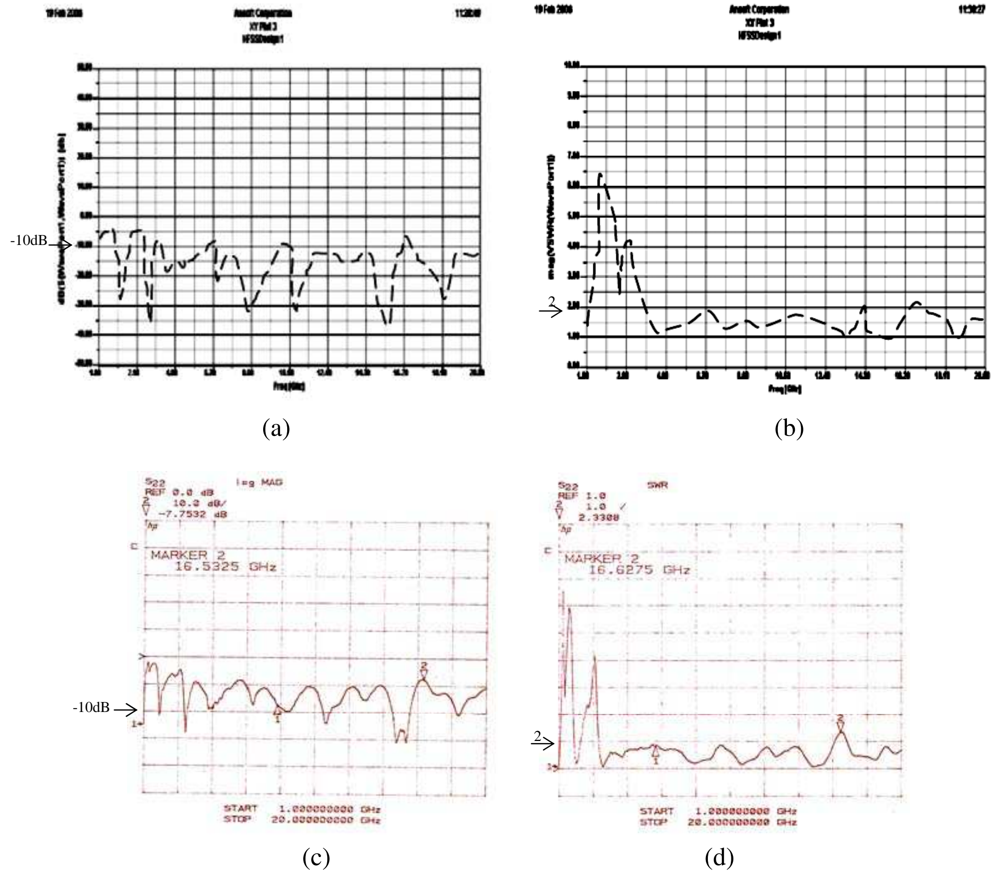


Figure 3: Simulated and measured results for fabricated antenna. (a) Simulated return loss, (b) Simulated VSWR, (c) Measured return loss, (d) Measured VSWR.

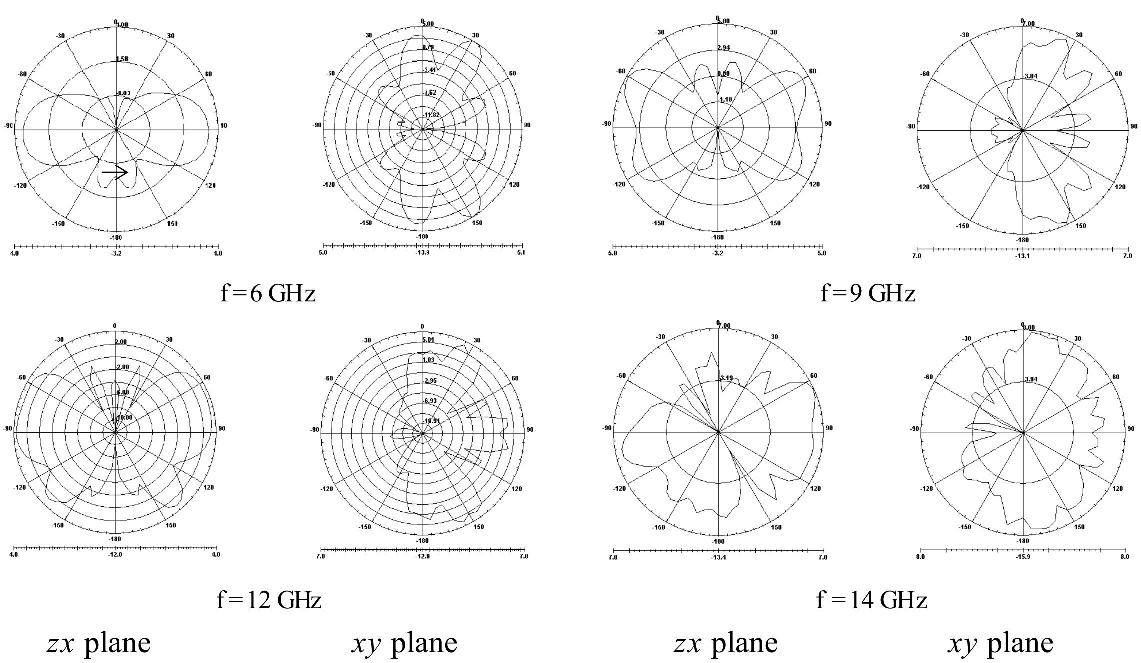


Figure 4: Radiation patterns of proposed antenna in the some operation frequencies.

3. SIMULATED AND EXPERIMENTAL RESULTS

Design procedure and simulation of the proposed antenna is carried out by commercially full wave simulator, Ansoft HFSS (Figure 1) and measured with a vector network analyzer (VNA). The exact dimensions and fabricated antenna is shown in Figure 2. Figure 3 compares the simulated and measured return loss and VSWR of the antenna. The measured impedance bandwidth of the optimized antenna is approximately 64% (2 GHz–16 GHz). In addition, the Good agreement can be seen between the simulated and measured results. From the measured results, it can be clearly concluded that the antenna has good improved performance for all 2–16 GHz band. In order to determine the antenna's radiation patterns of the antenna in zx-plane and xy-plane at four different frequencies in dB over the operation frequency band are measured in an anechoic chamber and acceptable radiation patterns were obtained and were well controlled over frequency range for this wideband antenna, as shown in Figure 4. It is observed that the results are in good agreement in all the patterns, though some deviations are noticeable due to the interference of the feeding cable during the measurement procedure. The patterns of the bands exhibit some degree of similarity, although it is not strong. It is expected that when operating at higher frequencies, ripples along the plots are inevitable due to the fixed ground plane size. Therefore, The fact that the ground plane is not self-scalable, i.e., its electrical size becomes longer as the frequency increases or on the other hand, as the wavelength becomes smaller, the microstrip feed ground plane begins to look much larger, is responsible for the characteristic ripple displayed at the higher frequencies.

4. CONCLUSION

A novel 2–16 GHz fractal planar microstrip antenna with excellent very wide band performance has been successfully demonstrated. This antenna has VSWR 2 : 1 or better, inherent 50 Ω, linear polarization, SMA center fed, partial ground plane and no balun required. The impedance bandwidth of the antenna is 64%. The antenna is compact, simple to design and easy to fabricate and applicable in wide band communication systems and commercial existing systems such as, Bluetooth and GSM.

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REFERENCES

1. Peitgen, H. O., H. Jürgens, and D. Saupe, *Chaos and Fractals*, Springer-Verlag, New York, 1990.
2. Barnsley, M. F., R. L. Devaney, B. B. Mandelbrot, H. O. Peitgen, D. Saupe, R. F. Voss, Y. Fisher, and M. Mc Guire, *The Science of Fractal Images*, Springer-Verlag, New York, 1988.
3. Jones, H., D. E. Reeve, and D. Saupe, *Fractals and Chaos*, A. J. Crilly, R. A. Earnshaw, and H. Jones, Eds., Springer-Verlag, New York, 1990.
4. Cohen, N., "Fractal antenna applications in wireless telecommunications," *Professional Program Proc. of Electronics Industry Forum*, 43–49, 1997.
5. Gianvittorio, J. and Y. Rahmat-Samii, "Fractal element antennas: A compilation of configurations with novel characteristics," *IEEE AP-S International Symposium*, Salt Lake City, 2000.
6. Puente, C., J. Romeu, R. Pous, J. Ramis, and A. Hijazo, "Small but long Koch fractal monopole," *Elect. Lett.*, Vol. 34, 9–10, 1998.
7. Hara Prasad, R. V., Y. Purushottam, V. C. Misrak, and N. Ashok, "Microstrip fractal patch antenna for multiband communication," *Elect. Lett.*, Vol. 36, No. 14, 1179–1180, 2000.
8. Song, C. T. P., P. S. Hall, H. Ghafouri-Shiraz, and D. Wake, "Fractal stacked monopole antenna with very wide bandwidth," *Elect. Lett.*, Vol. 35, No. 12, 945–946, 1999.
9. Puente, C., J. Romeu, R. Pous, and A. Cardama, "On the behavior of the Sierpinski multiband fractal antenna," *IEEE Trans. Antennas and Propagation*, Vol. 46, No. 4, 517–524, 1998.
10. Puente, C., "Fractal antennas," *Ph.D. Dissertation at the Dept. of Signal Theory and Communications*, Universitat Politkcnica de Catalunya, June 1997.
11. Jaggard, D. L. and T. Spielman, "Triadic cantor target diffraction," *Microwave Opt. Technol. Lett.*, Vol. 5, 460–466, Aug. 1992.
12. Beal, M. M. and N. George, "Features in the optical transforms of serrated apertures and disks," *J. Opt. Soc. Amer.*, Vol. 6, No. 12, 1815–1826, Dec. 1989.
13. Kim, Y., H. Grebel, and D. L. Jaggard, "Diffraction by fractally serrated apertures," *J. Opt. Soc. Amer.*, Vol. 8, No. 1, 20–26, Jan. 1991.

14. Sun, X. and D. L. Jaggard, “Wave interactions with generalized cantor bar fractal multilayers,” *J. Appl. Phys.*, Vol. 70, No. 5, 2500–2507, Sept. 1991.
15. Kim, Y. and D. L. Jaggard, “The fractal random array,” *Proc. IEEE*, Vol. 74, 1278–1280, Sept. 1986.
16. Goutelard, C., “Fractal theory of large arrays of lacunar antennas,” *Electromagn. Wave Propagat. Panel Symp. (AGARD-CP-528)*, 35/1–35/15, France, June 1992.