A Fractal Tetrahedron Antenna Fabricated Using Metal 3D printing

S. Jun, B.Sanz-Izquierdo, E.A Parker
School of Engineering and Digital Arts, University of Kent, Canterbury, Kent CT2 7NT, UK
b.sanz@kent.ac.uk

Juan Franco
Eichenberger AGline 2, Kirchgasse 5, CH-5734 Reinach, Switzerland
juan.franco@ebcasting.chmail

***Abstract*—A Sierpinski tetrahedron fractal antenna is fabricated using metal additive manufacturing techniques. Metal 3D printing is able to fabricate the complex internal and external features while providing acceptable mechanical strength. The main advantage of this type of fractals is that it is able to reduce the amount of material used in additive manufacturing processes. This can also lead to weight reduction, an important factor in aerospace and defense applications. Selective laser melting of metal powder has been employed for the fabrication. The input matching has been optimized for a first resonance at the 2.4GHz, making it suitable for existing wireless communications. The basic performance of the antenna is summarized through simulations and experimental results.**

Keywords—Sierpinski; fractal antenna; additive manufacturing; 3D printing

I. Introduction

Additive manufacturing (AM) or 3D printing (3DP) is a technology that has attracted significant attention in recent years. One of the main features of 3DP is its ability to fabricate complex structures. The two dominant methods for printing with metals are selective laser melting of metal powders (SLM) and electron beam forming (EBM) [1]. Researchers and industrialists have started to explore its applicability to electrical engineering [1, 2]. In [1], for example, summarises a study of the performance of horn antennas fabricated via additive manufacturing with metals.

The use of fractal shapes to the development of antennas have been reported for more than two decades [3, 4]. The Sierpinski gasket is one of the simplest and well reported fractals [3 - 4].

In this paper, the fabrication of a fractal monopole antennas via AM with metals is presented. A Sierpinski tetrahedron fractal antenna has been fabricated. The structure has several advantages compared to the standard tetrahedron such as been able to reduce the amount of material used for 3D printing, and the corresponding reduction is weight. The designed has been tuned for a first resonant frequency operating at the 2.4GHz wireless frequency band. CST Microwave Studio™ was used for the calculations in this paper.

II. Antenna Design and Fabrication

A Sierpinski tethrahedron gasket developed from 3 mathematical iterations is shown in Fig. 1. This produces a total number of 64 tetrahedrons. Each constituent tetrahedron has a side of dimension s = 3.4mm and height l = 2.7. The total height of the structure is h = 18mm. Note that each consecutive pair of tetrahedrons were overlapped slightly in order to maintain mechanical strength at their joints. The fractal shape was placed on a cylindrical copper ground plate of diameter d = 140mm. The feeding of the antenna was through a coaxial probe with the inner connected to the lowest point of the antenna and the outer to the cylindrical ground plane (Fig 2).

The computed reflection coefficient S_{11} of the antenna is shown in Fig. 3. The S_{11} characteristic of a non-fractal tetrahedron monopole antenna of the same dimensions is included. In this specific design, the first and second resonance occurred at about the same frequency as those for the non-fractal tetrahedron antenna, but higher modes differ both in resonant frequency and input match. The mode at 2.4 GHz is almost identical for the two antennas while the mode at 10GHz is better matched in the case of the fractal antenna. At these modes, the fractal structure uses 58% of the external area and 22% of the volume of an equivalent non-fractal tetrahedron. This is nearly 80% reduction in the material used in the 3D printing process.

The CST™ digital design was exported into a STL file and uploaded into a selective laser melting (SLM) machine. The model was fabricated using 316L stainless steel. The sample was treated with an electroplating process until a layer of about 50μm layer of copper was deposited on the outer surface. The radiating element was then placed on circular copper ground planes through a 50Ω SMA connector. Photographs of the resulting structure is shown in Fig. 2.

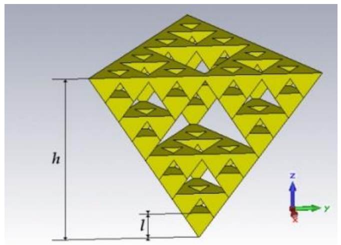


Fig. 1 *Dimensions of the Sierpinski Fractal Gasket*

(a) (b)

Fig. 2 Photograph *of the antenna (a) top view (b) perspective view of the fractal radiator*

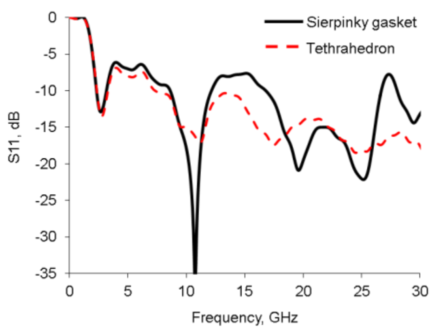


Fig. 3 *Simulated reflection coefficients (S_{11})*

The input match (S_{11}) of the two antennas were measured using a Rohde & Shwarz vector network analyser with a frequency sweep of 0 to 13.6GHz. Measured results matched very well with those from the simulation (Fig.4). There is a slight frequency shift in the in the measurements. This may be due to the additional metal layer, and fabrication tolerances. The simulated radiation patterns of the antennas at 2.4 and 10GHz in the xy plane are shown in Fig. 5. Patterns are mostly omni-directional. The calculated gain is 5.3 dB and 6.9 dB at 2.4GHz and 10GHz, respectively.

III. Conclusion and Discussion

The use of additive manufacturing techniques for the fabrication of fractal antennas has been described with reference to a relatively simple structure – the Sierpinski Gasket.

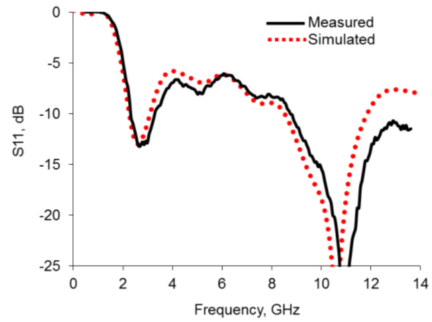
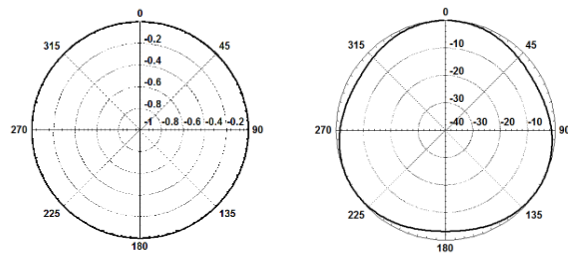


Fig. 4 *Simulated and Measured reflection coefficient (S_{11})*



(a) (b)

Fig.5 Computed radiation patterns at (a) 2.4 GHz (b) 10 GHz

3D printing enabled the manufacture of structures that can have a variety shapes and contain complex internal features. Currently, 3D printing with metals is a relatively expensive when compared with traditional fabrication methods, which can limit its use to the development of "exotic" antennas for high end products. The Sierpinski fractal has the advantage of being able to reduce the amount of metal employed, thereby reducing weight and manufacturing costs. It can also facilitate the fabrication in locations where the metallic materials can be scarce. The authors are aware that some very recent advances in AM include the direct fabrication using copper, a process that is yet to be commercialized.

References

[1] C. Garcia, H. Tsang, J. Barton and R. Rumpf, "Effects of extreme surface roughness on 3D printed horn antenna", *Electron. Lett.*, vol. 49, no. 12, pp. 734-736, 2013.

[2] Alonso, Matthew P., Evan Malon e, Francios C. Moon, and Hod Lipson, "Reprinting the Telegraph: Replicating the Vail Register Using Multi-materials 3D Printing." Cornell.edu. Web. 30 May 2012. [online]: Available: http://creativemachines.cornell.edu/sites/default/files/SFF09_Alonso.pdf (Accessed Jan 2015).

[3] C. Puente-Baliarda, J. Romeu, R. Pous and A. Cardama, "On the behavior of the Sierpinski multiband fractal antenna", *IEEE Trans. Antennas Propag.*, vol. 46, no. 4, pp. 517-524, 1998.

[4] V. Petr, R. Zbyněk, 'Sierpinski-Based Conical Monopole Antenna', *Radioengineering*, vol. 19, no. 4, pp. 633 – 638, 2010.

[5] Eichenberger Futuretech A.g., Selektives Laserschmelzen (SLM), Switzerland, http://www.eb-futuretech.ch/dynasite.cfm?dsmid=106198 (Acc. 20/01/2015)