

## **CIRCULAR FRACTAL MONOPOLE ANTENNA FOR LOW VSWR UWB APPLICATIONS**

**S. N. Khan, J. Hu, J. Xiong, and S. He** <sup>†</sup>

Centre for Optical and Electromagnetic Research  
Zhejiang University  
Zijingang Campus, Hangzhou 310058, China

**Abstract**—A new circular ultra-wideband fractal monopole antenna based on descartes circle theorem (DCT) with elliptical iterations is presented. The proposed fractal design is optimized for return loss below  $-15$  dB. The basic structure is slightly modified to ensure an overall smooth current distribution limited by the junction point nature of the fractal geometries. The measured return loss of the proposed design is below  $-15$  dB within its impedance bandwidth along with omni-directional radiation pattern. Moreover due to the fractal shape, the proposed design has less weight and wind loading effect.

### **1. INTRODUCTION**

A circular disk monopole (CDM) is known for its low VSWR over ultra wide bandwidth (UWB) and widely been used in UWB communication [1–3]. The height of the monopole depends on the lower frequency of the impedance bandwidth. For a low frequency design, the weight of the disk is high and mechanically unstable due to the wind loading effect especially for outdoor applications [4]. Circular disk with a hole (i.e., annular monopole) is usually used at the cost of impedance bandwidth and radiation pattern. Although fractal design are well known for their multi/wideband behavior [5, 6] but also been optimized for UWB [7, 8] along with some other characteristics [9]. The usual requirement for return loss is below  $-10$  dB is acceptable for academic research but a standard of  $-15$  dB is usually used for industrial and base station antenna to make antenna highly efficient [10, 11].

In this paper, a circular fractal monopole design based on modified Descartes circle theorem (DCT) is presented for low VSWR and

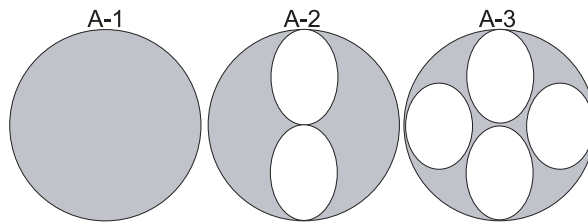
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<sup>†</sup> The fourth author also with Division of Electromagnetic Theory, Alfvén Laboratory, Royal Institute of Technology, Teknikringen 31, S-100 44 Stockholm, Sweden

omni-directional UWB requirements. In addition to low VSWR, the proposed design is less in weight and wind loading effect due to its fractal shape. The design is slightly modified to study the junction point nature of the fractal geometries [12] and consequently provides smooth current distribution over the whole radiator. Due to modification in the design, the terms like fractal ratios etc. are not discussed and varies differently with the size of CDM. The return loss and azimuth radiation pattern is also measured and discussed.

## 2. DESIGN AND SIMULATION

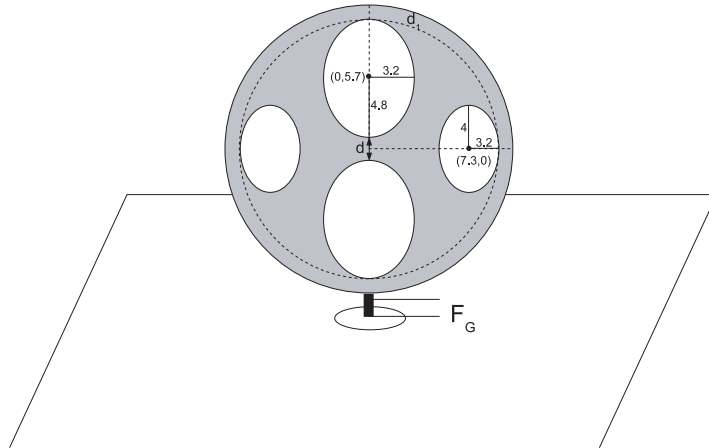
Different fractal designs based on DCT are discussed and optimized for multi-band behavior [13,14]. According to DCT, several fractal geometries are possible to design with mutually tangent circles having disjoint interiors [14]. The same methodology is applied to circular geometry with elliptical iterations and out of several possible designs one of them is shown in Fig. 1. The figure shows the iterative design procedure from simple circle to fractal circular design with elliptical iterations. The resulting geometry is called apollonian (the term is opted from [13]). However the proposed design is further modified with the help of  $d_1$  (distance between the radiator and iterative ellipses) and  $d$  (distance among 1st iterative ellipses) as shown in Fig. 2 and will be discussed later.



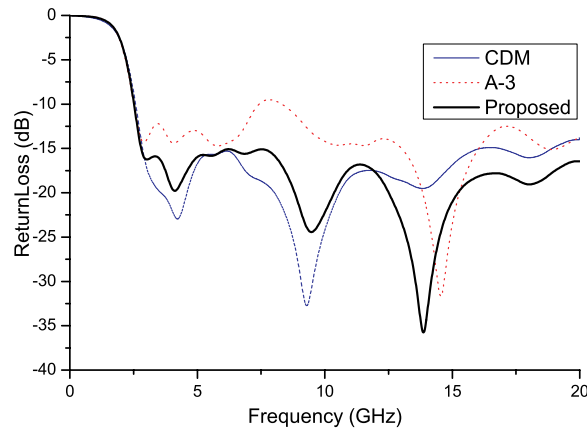
**Figure 1.** Iterative fractal design procedure based on Descartes circle theorem.

All the simulations are performed using commercially available software package ( $CST^{TM}$ ) based on finite integration technique (FIT) and thickness of copper for the radiator and the ground is 0.4 mm. The dimension of the ground plane is  $100 \times 100 \text{ mm}^2$  and a SMA connector of  $50 \Omega$  is used to feed the antenna. The diameter of the probe feed is 0.5 mm while a feed gap  $F_G$  is used to connect the probe and radiator.

The simulation results for different designs are compared and shown in Fig. 3. The return loss of the CDM and the proposed circular



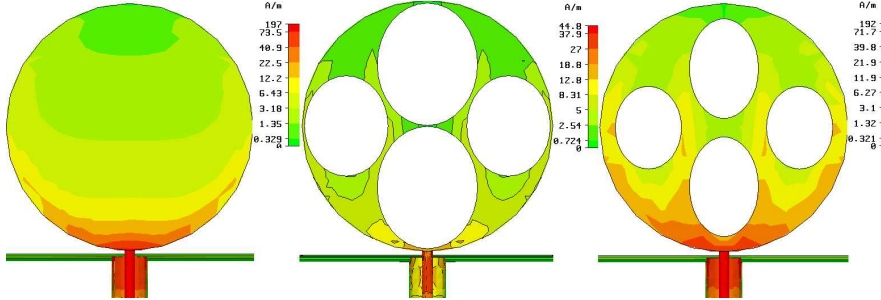
**Figure 2.** Schematic diagram of the proposed fractal antenna.



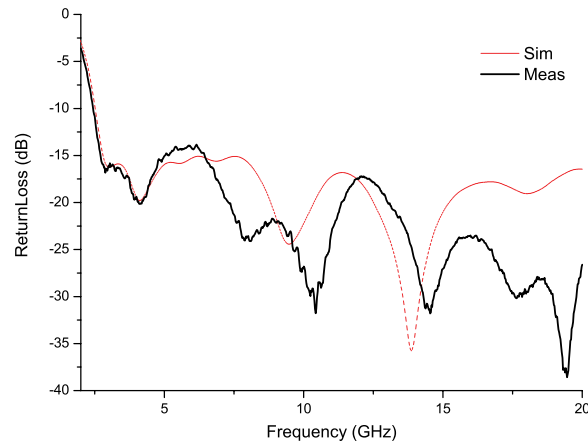
**Figure 3.** Comparison of the simulated return loss among different designs.

fractal are similar. However due to the fractal shape, the proposed design is less in weight and less wind loading effect especially suitable for outdoor applications. The impedance matching of the simple fractal design (i.e., A-3) is similar like annular monopole antenna but the modified apollonian design has better return loss and omni-directional radiation pattern which will be discuss later. The junction point nature of the fractal design is overcome with the help of  $d$  [12]. While the choice of  $d_1$  is based on the fact that current is mainly distributed

along the periphery of the structure [2, 3]. Consequently proper choice of both  $d_1$  and  $d$  provides proper impedance matching as well as smooth current distribution as shown in Fig. 4.



**Figure 4.** Simulated current distribution at 3 GHz.

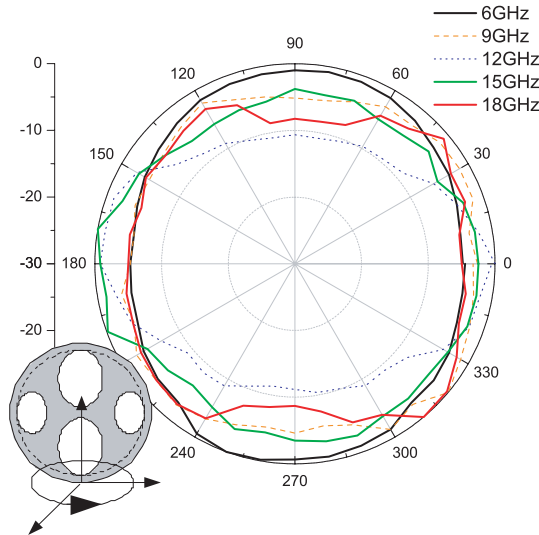


**Figure 5.** Comparison of return loss between the simulated and measured results.

### 3. RESULTS AND DISCUSSION

A prototype of the proposed design is fabricated to verify the simulated results. In addition to the design parameter discussed above as well as shown in Fig. 2, the optimized feed gap  $F_G$  obtained from the parameter sweep is 0.7 mm. The comparison between the simulated and the measured return loss is shown in Fig. 5. Measured return loss with reference to  $-15$  dB is from 2.65 GHz to over 20 GHz except

from 5.4 ~ 6.5 GHz where its around  $-14$  dB. Radiation pattern in the azimuth plane is also measured at various frequencies and presented in Fig. 6. The radiation pattern is near omni-directional with in most of its impedance bandwidth with maximum variation of  $-11$  dB at 12 GHz probably due to higher order modes.



**Figure 6.** Measured radiation pattern in the azimuth plane.

#### 4. CONCLUSION

A new fractal design based on Descartes circle theorem is optimized for low VSWR and omni-directive UWB applications. Fractal design is slightly modified to overcome the junction point nature of the fractal geometry that limits the smooth current distribution. The proposed antenna shows UWB characteristics without any compromise in terms of return loss and omni-directional radiation pattern. Furthermore, due to the fractal shape, the proposed design is less weight and wind loading effect and thus suitable for both indoor as well as outdoor UWB applications.

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