Hindawi Publishing Corporation
International Journal of Antennas and Propagation
Volume 2014, Article ID 352126, 7 pages
http://dx.doi.org/10.1155/2014/352126

Research Article

Design of Monopole Antenna Based on Fractal Geometry

Zhao Yuanqing,[1] Qiu Jinghui,[1] and Wang Wei[2]

[1] *Department of Microwave Engineering, Harbin Institute of Technology, P.O. Box 3054, No. 2, Yikuang Street, Nangang District, Harbin, Heilongjiang 150001, China*
[2] *Communication Research Center, Harbin Institute of Technology, P.O. Box 3043, No. 2, Yikuang Street, Nangang District, Harbin, Heilongjiang 150001, China*

Correspondence should be addressed to Zhao Yuanqing; tracymy_29@126.com

Received 15 August 2013; Revised 18 November 2013; Accepted 11 December 2013; Published 12 January 2014

Academic Editor: Ahmed A. Kishk

This paper presents a circular disc monopole antenna based on fractal geometry. The antenna is designed to be applied in UWB systems. So it is essential to ensure that the bandwidth of the antenna ranges from 3.1 GHz to 10.6 GHz, that is, IEEE 802.15.3a. However, the proposed antenna has achieved working in the required bandwidth. Compared to the antennas illustrated in most similar literatures, the proposed antenna has a much smaller size, which makes the antenna possible to be integrated with portable devices. Firstly, the antenna was designed through CST Microwave Studio. Then, the antenna was fabricated according to the simulated results. At last, the comparison between the simulated results and measured results was carried out which demonstrated good consistency.

1. Introduction

With the development of society, UWB systems are becoming increasingly important in our life. Given the fact that antennas play a vital role in the whole systems, design of appropriate antennas attracts lots of interest from researchers and engineers.

There are several different methods utilized to devise the required antennas. The circular disc monopole antenna is of great popularity for its wide bandwidth characteristic. The antenna presented in [1] utilizing multicircular blades has an ultrawide bandwidth. Likewise, the antenna reported in [2–7] also has potential to be used in UWB systems. Nevertheless, the dimensions of these antennas are sometimes too large to be used in practice. So, in order to make an improvement to this drawback, we make the combination of conventional circular disc monopole antenna with fractal theory. As well known, fractal theory including various different shapes like Sierpinski gasket, Sierpinski carpet, and Descartes circle may have different impacts on the performance of an antenna. In this paper, the Descartes circle theorem [8] is used in the design of circular disc monopole antenna for the sake of realizing outstanding properties. The concept of multicircular blades is also taken into consideration. Based on the theorems mentioned above, it is predictable that the proposed antenna has a wide bandwidth from approximately 2.9 GHz to 13.5 GHz, which satisfies the requirement of UWB systems. Meanwhile, the radiation patterns of the antenna almost remain stable in the operating bandwidth and are similar to those of the conventional cylindrical monopole antenna. More importantly, a compact configuration is obtained through this method, which makes the antenna capable of being used in practice more conveniently.

2. Antenna Design

In this paper, a monopole antenna based on fractal geometry has been proposed. The antenna has a wide bandwidth from approximately 2.9 GHz to 13.5 GHz, which includes the required bandwidth of UWB systems. The fractal antenna was constructed based on the Descartes circle theorem [8]. Firstly,

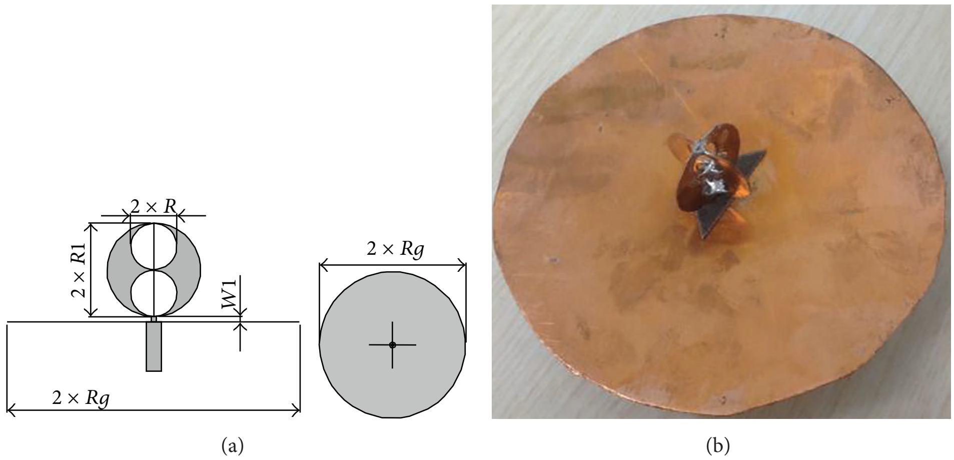


Figure 1: (a) Model of the proposed monopole (left: front view; right: top view). (b) Photograph of the fabricated prototype.

a circular disc monopole antenna was devised according to the traditional theory. The lower frequency can be determined according to the equation proposed in [9]:

$$f = \frac{c}{\lambda} = \frac{(30 \times 0.24)}{(l + r)} \text{ GHz}, \quad (1)$$

where l is circular disc height (cm) and r is equivalent radius (cm), which can be obtained from

$$2\pi l r = \pi r^2. \quad (2)$$

Then, the first iteration of the Descartes circle was utilized in the design of the circular disc monopole antenna. At last, as mentioned in [1], the multicircular blades antenna design was introduced in order to get an ultrawide bandwidth and stable radiation patterns. Through simulation by CST Microwave Studio, optimal dimensions of the proposed antenna have already been obtained. Radius of the circular disc is $R1 = 9.6$ mm, while the radius of circular ground is $Rg = 50$ mm and the feed gap $W1$ is determined to be 1 mm. At the same time, it has also been found that the first iteration contributes to the best performances of the antenna, as it does not have a negative impact on the distribution of the surface current on the circular disc. According to the Descartes circle theorem [8], the radiuses of two inner circles all ought to be $R = R1/2 =$ 4.8 mm. Thus, $R = 4.75$ mm is adopted for a wider bandwidth based on simulated result.

Nevertheless, the radiation pattern in either the vertical plane or the horizontal plane is not always stable with the variation of the operating frequency. For the purpose of working in the required bandwidth with stable radiation patterns, the concept of multicircular blades [1] is introduced as well. The antenna constructed by two orthogonal circular blades is presented, of which the model and the fabricated prototype are shown in Figure 1.

From the simulated results, it is evident to see that the bandwidth of this antenna is broadened compared with the single blade structure, complying with the standard of UWB system required by FCC. Meanwhile, also evident is the fact that radiation patterns can keep stable in the entire bandwidth. According to the simulated results, the proposed antenna was fabricated, followed by the measurement. The comparison between the simulation and measurement is carried out, which demonstrates good consistency. Furthermore, in contrast with the antenna reported in [1], it realizes a compact configuration with a reduction of 36% in the dimension.

The simulated VSWR of three different monopole antennas with the same size are displayed in Figure 2. It indicates that the proposed monopole antenna is capable of occupying a wider bandwidth from about 2.9 GHz up to 18 GHz.

In Figure 6, the radiation patterns of the proposed antenna in either vertical or azimuth plane at 4 GHz, 6 GHz, 9 GHz, and 12 GHz are demonstrated, which are similar to those of the conventional monopole antenna.

3. Parametric Study

Based on this design, some sensitive parameters have been analyzed for the sake of investigating the operating principles of this antenna. The analysis is implemented by CST Microwave Studio. In the analysis, when one parameter varies, the others are required to keep constant.

3.1. Effect of the Order of Iteration. There are infinite iteration orders in the concept of fractal geometry. In this paper, only first, second, and third order iterations were discussed for their convenience to be constructed in the simulation as well as in practice. The models of these iterations mentioned above are shown in Figures 3(a), 3(b), and 3(c), respectively. Their VSWR performances are compared in Figure 3(d), implying that the first order iteration can achieve a relatively lower VSWR in a wider bandwidth from 2.9 to 18 GHz. Thus, the structure of the first order iteration is adopted as the final plan to enhance the bandwidth compared to a conventional monopole antenna.

3.2. Effect of Different Values of Feed Gap W1. The value of feed gap has a vital impact on the input impedance characteristic, which is associated with the bandwidth characteristic. Through the simulation, different VSWR performances

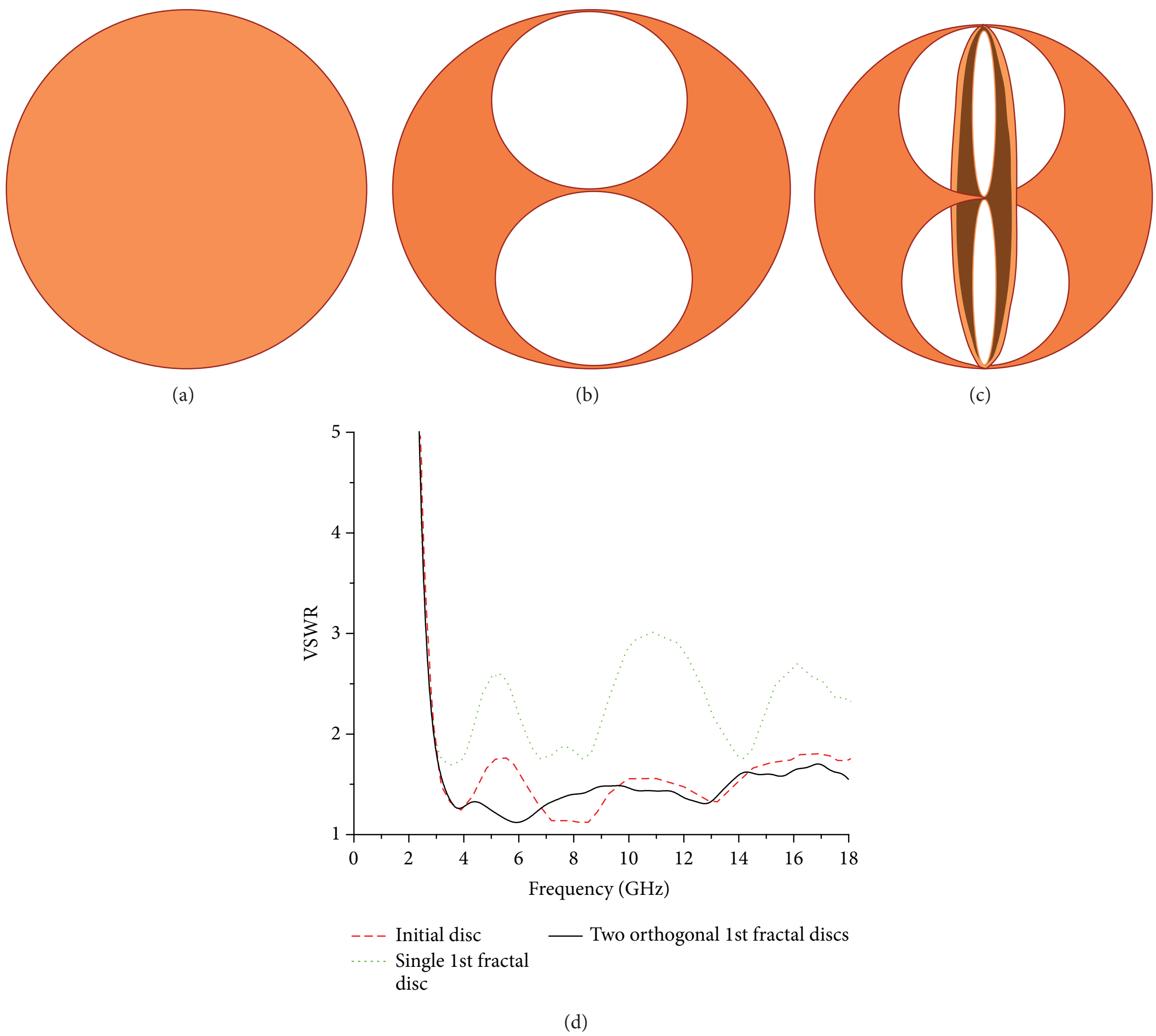


Figure 2: (a) Initial disc. (b) Single 1st fractal disc. (c) Two orthogonal 1st fractal discs. (d) Simulated VSWR of different structures.

under several conditions, that is, different feed gap values $W1$, were obtained and shown in Figure 4. Apparently, the most appropriate VSWR is gained only when the feed gap $W1$ is determined to be 1 mm.

3.3. Effect of Different Values of Rg. The distributions of the surface current on the proposed monopole antenna at several frequencies are given in Figures 5(a), 5(b), and 5(c). In the low frequency band, the surface current mainly concentrates on the inner part of the ground plane, while it becomes gradually weak along the radial line out of the center of the ground plane. With the increase of the frequency, the surface current on the outer part of the ground plane tends to firstly decrease gradually, followed by a growth which can be seen in the high frequency band on the outer part of the ground plane.

Consequently, there is no doubt that the alteration in the dimension of the ground plane affects the impedance performance of the antenna in both high and low frequency bands. The VSWR corresponding to different Rg are shown in Figure 5(d).

4. Result

According to simulated results and the analysis above, the antenna reported in this paper has been fabricated with copper. The measurement was carried out in the anechoic chamber. The radiation patterns in both E- and H-planes at selective frequencies and VSWR have been obtained as shown in Figures 6(a), 6(b), 6(c), and 7, respectively together with the corresponding simulated results. Plots show a good match between the simulated results and the measured results of the proposed antenna. Because of numerical dispersion and some practical limitations (such as bad soldering effect and fabrication tolerance), there are some discrepancies between the simulated results and measured results in mainly the upper frequency band, which is more sensitive to the dimension of the antenna.

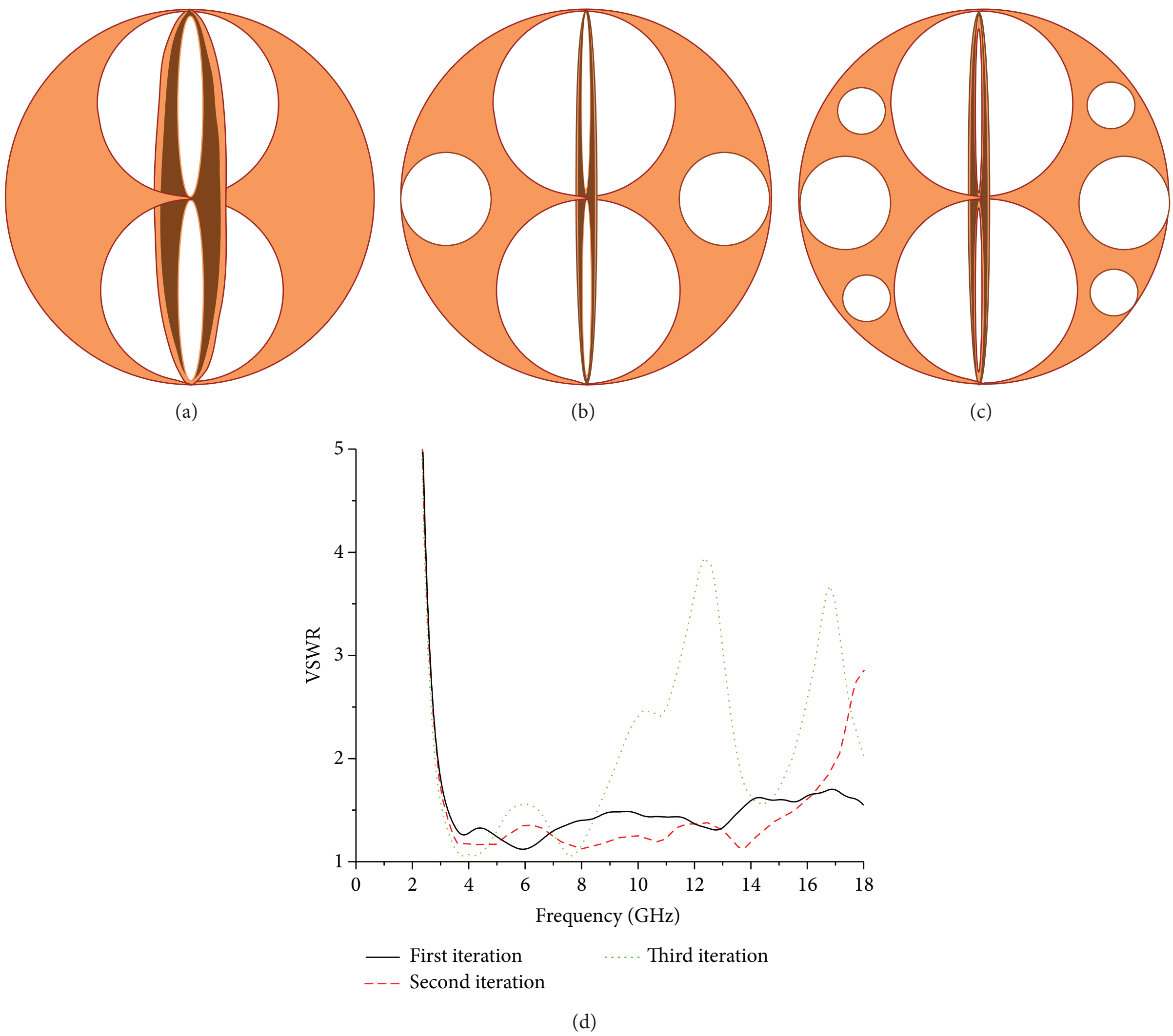


Figure 3: (a) Monopole with first iteration. (b) Monopole with second iteration. (c) Monopole with third iteration. (d) Simulated VSWR of monopole antennas with different structures.

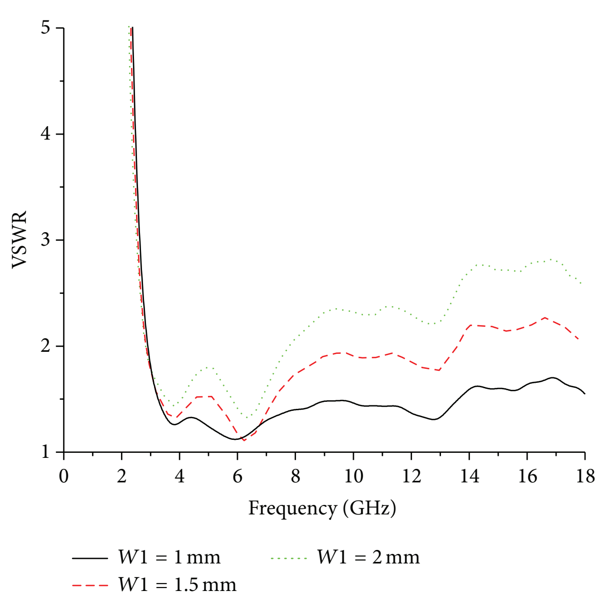


Figure 4: Simulated VSWR of different $W1$.

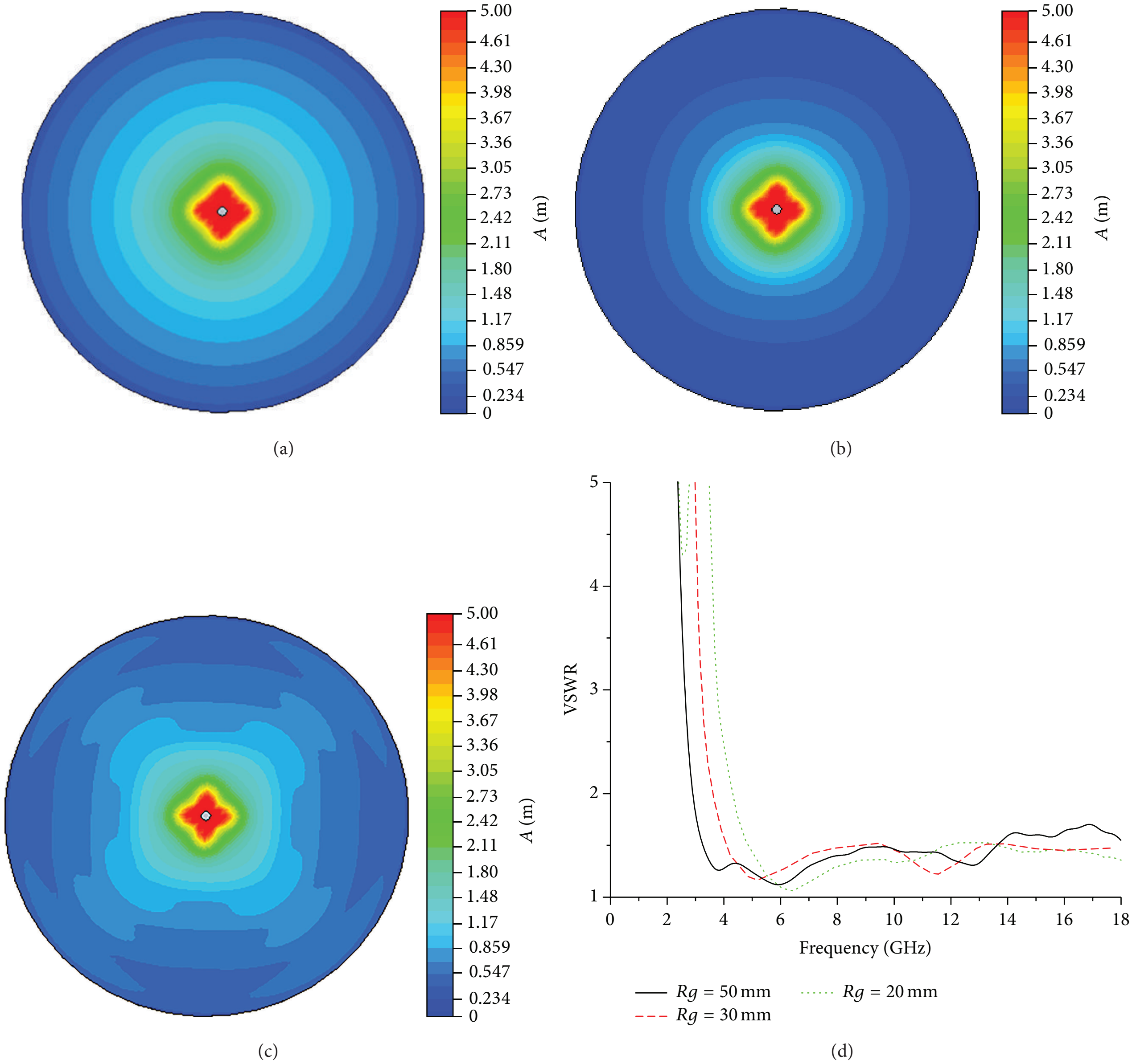


Figure 5: Surface current on the ground plane at (a) 3.5 GHz, (b) 9 GHz, and (c) 15 GHz and (d) simulated VSWR of different *Rg*.

From the measured results, it can be found that this antenna has a wide bandwidth from 2.9 GHz to 13.5 GHz with VSWR below 2. Meanwhile, relatively stable radiation patterns are also achieved through this design. Furthermore, there is about 36% drop in the dimension when compared to the antenna proposed in [1], which makes the antenna a considerable candidate in many UWB applications, especially applications in some portable devices.

The characteristics discussed above are all associated with frequency performance. However, an antenna capable of being applied in UWB systems must also satisfy the requirements in time domain for transmitting or receiving signals without disturbing distortion. On that basis, the group delay is introduced in this paper to demonstrate the suitability of this antenna for applications in UWB systems. The plot in Figure 8 indicates that the variation of the group delay cannot exceed 1 ns in the required band, which means the distortion of transmitting or receiving signals would not occur in the far field [10]. Therefore, the proposed monopole antenna is considerably promising for applications in UWB areas.

5. Conclusion

In this paper, a circular disc monopole antenna based on fractal geometry for applications in UWB systems is proposed. The antenna occupies an ultrawide bandwidth from 2.9 GHz to 13.5 GHz in accordance with the regulations of IEEE 802.15.3a. Meanwhile, the radiation patterns keep stable in the entire band and exhibit omnidirectional characteristic. More importantly, the size of the antenna is evidently decreased

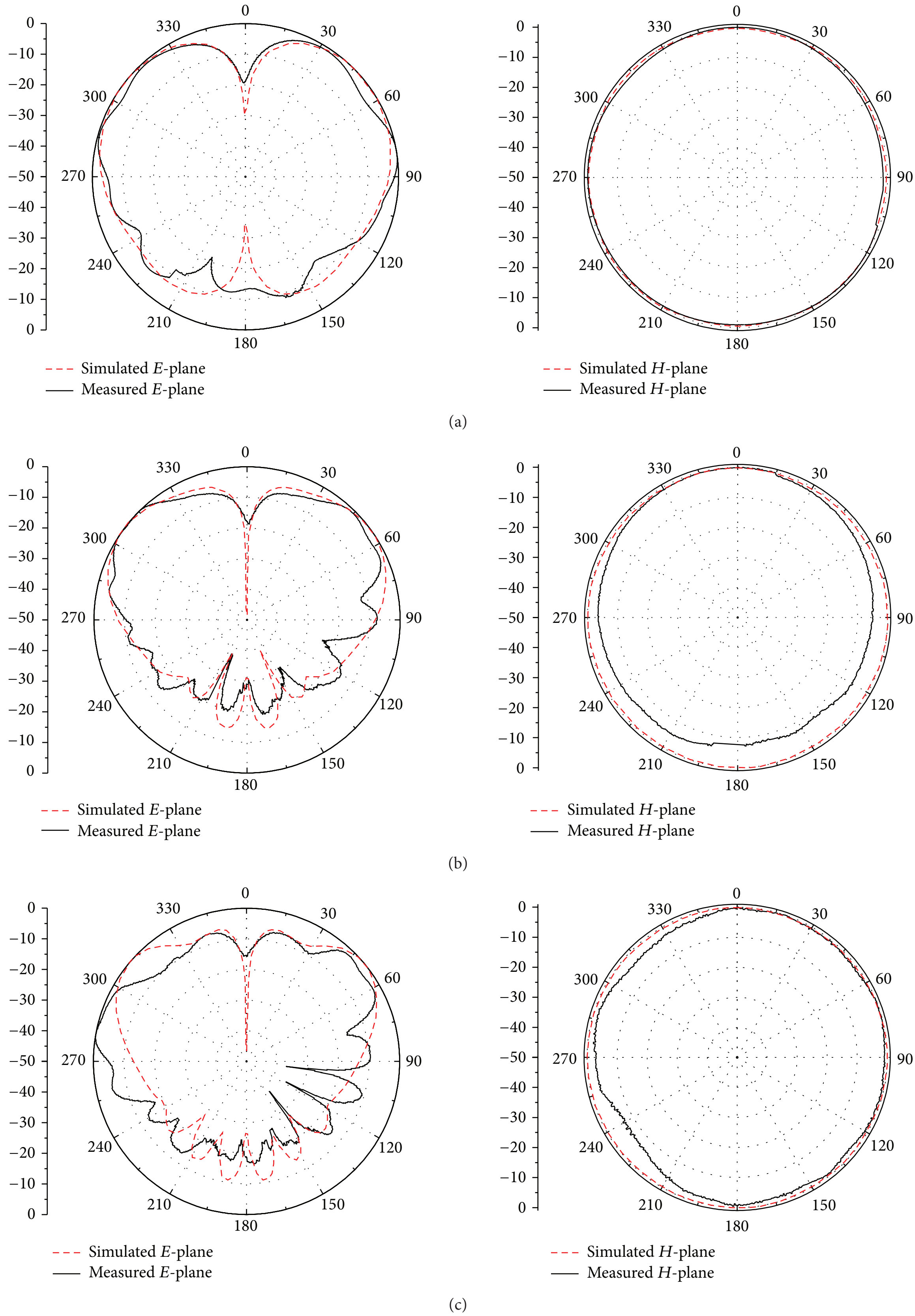


Figure 6: Simulated and measured radiation patterns (left: E-plane; right: H-plane) at (a) 3 GHz, (b) 9 GHz, and (c) 11 GHz.

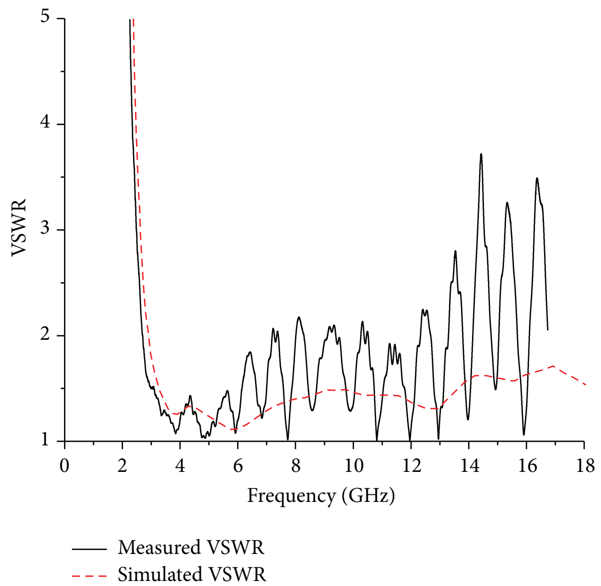


Figure 7: Simulated and measured VSWR.

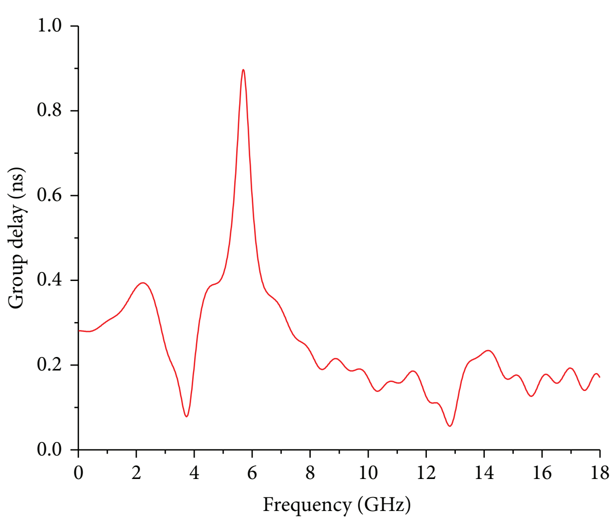


Figure 8: Group delay.

compared to some other similar antennas. The compact configuration of the antenna contributes to a much wider range of applications in practice. Also the group delay is analyzed by simulation, complying with the requirement in time domain for UWB applications.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] G. Chen, J. Sun, S. Huang, Y. D. Chen, and C. Lin, "Characteristics of UWB antenna and wave propagation," in *Proceedings of the International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS '05)*, pp. 713–716, December 2005.

[2] R. Kumar and P. Bansode, "On the design of ultra wide band antenna based on fractal geometry," in *Proceedings of the 3rd ITU-T Kaleidoscope Academic Conference: Beyond the Internet? Innovations for Future Networks and Services*, pp. 161–166, December 2010.

[3] M. M. Sharma and V. Shrivastava, "Printed fractal elliptical monopole antenna for UWB application," in *Proceedings of the International Conference of Recent Advances in Microwave Theory and Applications (MICROWAVE '08)*, pp. 374–376, November 2008.

[4] H. G. Schantz, "Bottom fed planar elliptical UWB antennas," in *Proceedings of the 2003 IEEE Conference on Ultra Wideband Systems and Technologies*, pp. 219–223, November 2003.

[5] M. Naghshvarian-Jahromi, "Novel wideband planar fractal monopole antenna," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 12, pp. 3844–3849, 2008.

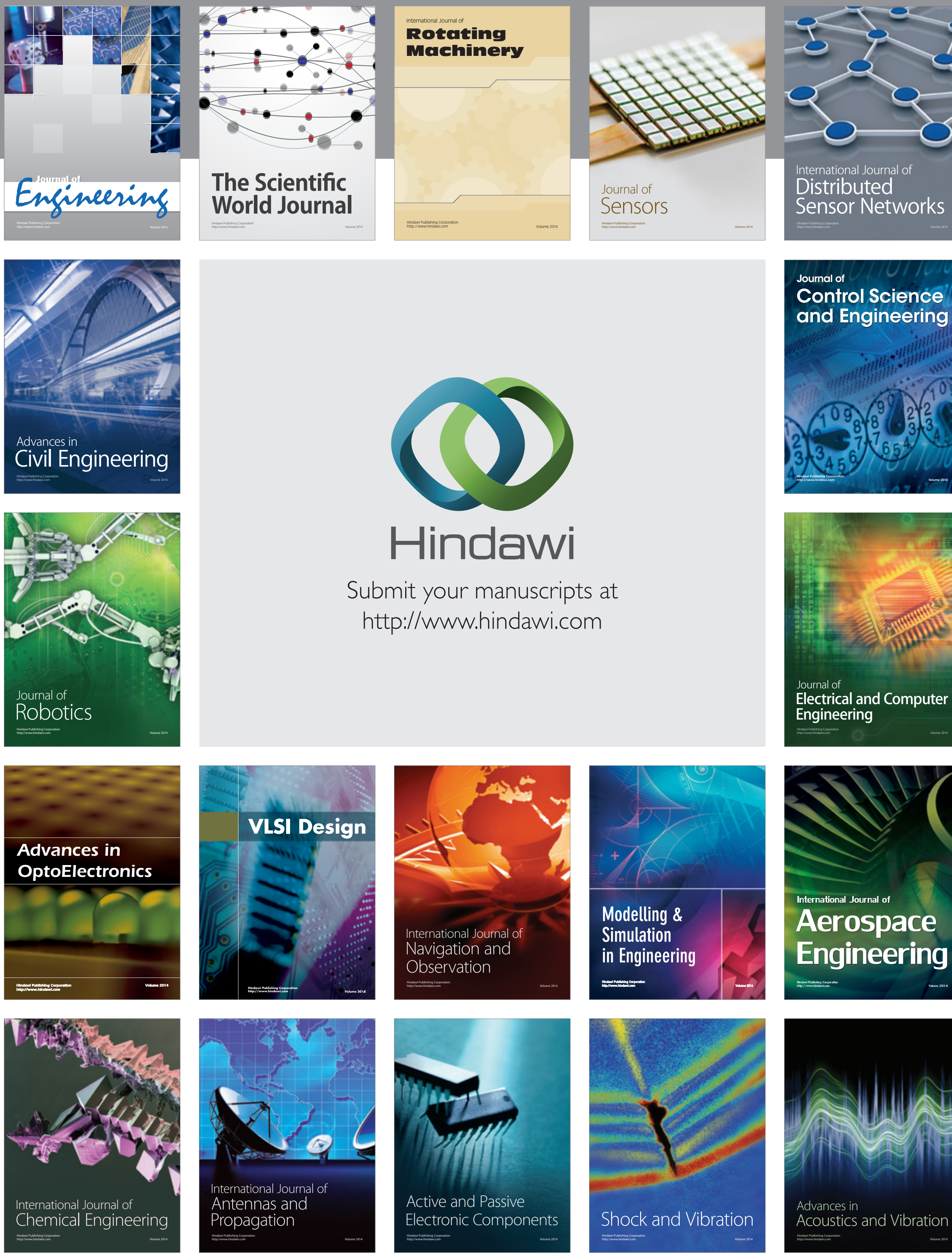
[6] S. Zhong, X. Liang, and W. Wang, "Compact elliptical monopole antenna with impedance bandwidth in excess of 21:1," *IEEE Transactions on Antennas and Propagation*, vol. 55, no. 11, pp. 3082–3085, 2007.

[7] J. Liang, C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Transactions on Antennas and Propagation*, vol. 53, no. 11, pp. 3500–3504, 2005.

[8] J. C. Lagarias, C. L. Mallows, and A. Wilks, "Beyond the descartes circle theorem," *The American Mathematical Monthly*, vol. 109, pp. 338–361, 2002.

[9] J. Powell and A. Chandrakasan, "Spiral slot patch antenna and circular disc monopole antenna for 3. 1–10. 6 Ghz, ultra wideband communication," *IEEE Transactions on Antennas and Propagation*, vol. 46, no. 2, 1998.

[10] Y. J. Cho, K. H. Kim, D. H. Choi, S. S. Lee, and S. Park, "A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics," *IEEE Transactions on Antennas and Propagation*, vol. 54, no. 5, pp. 1453–1460, 2006.


Journal of Engineering
The Scientific World Journal
International Journal of Rotating Machinery
Journal of Sensors
International Journal of Distributed Sensor Networks
Advances in Civil Engineering
Journal of Control Science and Engineering
Hindawi
Submit your manuscripts at
http://www.hindawi.com
Journal of Robotics
Journal of Electrical and Computer Engineering
Advances in OptoElectronics
VLSI Design
International Journal of Navigation and Observation
Modelling & Simulation in Engineering
International Journal of Aerospace Engineering
International Journal of Chemical Engineering
International Journal of Antennas and Propagation
Active and Passive Electronic Components
Shock and Vibration
Advances in Acoustics and Vibration