Design of a Novel Ultrawide-band Omnidirectional Antenna

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Abstract — Circular disk monopole antennas have received a wide popularity in recent years due to their advantages: ultrawide working bandwidth, high radiation efficiency and ease of fabrication. In this paper, an omnidirectional semicircular disk antenna based on the conventional monopole antenna is designed and fabricated, which operates from 1.9GHz to 24GHz with VSWR less than 2.5, and receives vertically polarized signals with out-of-roundness less than 4dB in the H plane when the frequency is lower than 18GHz. The antenna is proposed to be applied in ultrawide-band (UWB) wireless communication with good prospects.

I. INTRODUCTION

The antenna is an indispensable part of the communication system. With the development of UWB communication technology, research and design of UWB antennas receive a wide popularity. UWB antennas have already been used in areas such as satellite communication, remote sensing, UWB radar and so on, showing great value [1], [2].

UWB circular disk monopole antennas have simple structures and good wideband characteristics, which are widely used in wireless communication [3], [4]. Based on the conventional monopole antenna, a novel semicircular disk antenna is designed with the help of CST Microwave Studio®. The simulation results show that the novel antenna has realized better omnidirectional radiation and ultrawide working bandwidth. Then the antenna is fabricated. The measurement demonstrates that VSWR is less than 2.5 in the 1.9GHz~24GHz frequency range, and the out-of-roundness in the H plane is less than 4dB when the frequency is lower than 18GHz.

II. BASIC PRINCIPLE AND DESIGN METHOD

A. Analysis of UWB Semicircular Disk Antenna

The conventional UWB circular disk monopole antenna is composed of a ground plane and a metal circular disk which is perpendicular to the ground plane. For easier feeding and miniaturization, we change the ground plane for a hollow cone, and change the circular disk for a semicircular disk [5]. The following antenna structure parameters are chosen to analyze the performance of the antenna: the radius *r* equals to 19mm, the height of the feeding gap *h* equals to 0.5mm, and the thickness of the metal disk and the cone is 0.3mm.

The antenna is modeled and simulated by the computer, and VSWR and radiation patterns are acquired. VSWR is less than 2.5 between 1.7GHz and 31GHz, showing good UWB performance. With the increase of the frequency, the H-plane omnidirection gets worse. The out-of-roundness is above 7dB when the frequency is higher than 10GHz.

B. Improvement of Omnidirectional Radiation and Impedance Analysis

Fitting functions of the H-plane radiation patterns at different frequencies can be acquired with 10 GHz as an example (1).

$$f(\theta) = 2.346 + 3.771\times\cos(0.03491\times\theta) - 0.580\times\cos(2\times 0.03491\times\theta) - 1.115\times\cos(3\times 0.03491\times\theta) + 0.954\times\cos(4\times 0.03491\times\theta) - 0.465\times\cos(5\times 0.03491\times\theta) + 0.096\times\cos(6\times 0.03491\times\theta) + 0.074\times\cos(7\times 0.03491\times\theta) - 0.100\times\cos(8\times 0.03491\times\theta) \quad (1)$$

To improve the omnidirection in the H plane, a method is proposed where several crossed semicircular disks take the place of the single disk [6]. With the assumption that current distribution on each disk is stable and the mutual coupling is ignored, the relative normalized radiation pattern functions can be calculated as follow:

TABLE I
NORMALIZED RADIATION PATTERN FUNCTIONS OF ANTENNAS WITH DIFFERENT NUMBERS OF DISKS

Disk Number	Normalized Radiation Pattern Functions
2	$(f(\theta)+f(\theta+\pi/2))/F\max$
4	$(f(\theta)+f(\theta+\pi/4)+f(\theta+\pi/2)+f(\theta+3\pi/4))/F\max$
6	$(f(\theta)+f(\theta+\pi/6)+f(\theta+\pi/3)+f(\theta+\pi/2)$ $f(\theta+2\pi/3)+f(\theta+5\pi/6))/F\max$
8	$(f(\theta)+f(\theta+\pi/8)+f(\theta+\pi/4)+f(\theta+3\pi/8)+f(\theta+\pi/2)$ $+f(\theta+5\pi/8)+f(\theta+3\pi/4)+f(\theta+7\pi/8))/F\max$

After comparing the theoretical radiation patterns calculated according to the functions above and the simulated ones, excellent consistence can be found. It shows that when the number of the disks is no less than 4, the out-of-roundness is less than 1dB which meets the omnidirectional radiation requirements well. But with the increase of the disk number, the real part of the input impedance decreases and VSWR gets bad.

Through simulation it is found that when the semicircular disk is combined with a smaller circular disk, the real part of the input impedance increases in the low frequency range. We make the radius of the small circular disk equals to 3mm. With the increase of the distance between the centers of the circular disk and the semicircular disk, the real part of the input impedance increases. It’s a useful method to eliminate the effect of the impedance decrease in the improved antenna.

III. SIMULATION AND FABRICATION OF THE NOVEL UWB OMNIDIRECTIONAL ANTENNA

To improve the H-plane radiational omnidirection of the conventional UWB circular disk antenna, a novel crossed semicircular disk antenna is presented here (Fig. 1), with 4 crossed mental semicircular disks each with part of a circular disk on the bottom. Through simulation it’s found that when the radius of the small circular disk equals to 3mm, and the distance between the centers of the two disks is 17.2mm, the antenna is of the best performance. Then It’s fabricated and measured.

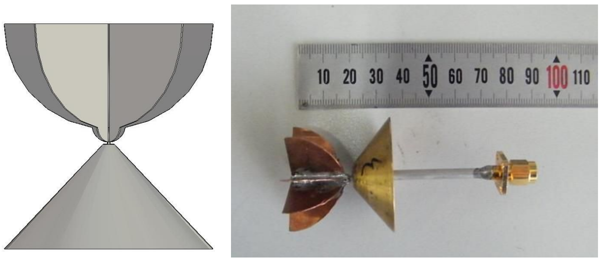


Fig. 1. The novel UWB omnidirectional antenna. Left: antenna structure, Right: actual antenna

The simulated and measured results are shown in Fig. 2 and Fig. 3. Measured VSWR is below 2.5 between 1.9GHz and 24GHz while the frequency range of the simulation result is 1.7GHz~31.5GHz. In the H plane the out-of-roundness is less than 4dB when the frequency is lower than 18GHz. It differs to a certain extent from the simulated results where the out-of-roundness is less than 1dB when the frequency is lower than 32GHz due to errors of handmade fabrication. Restricted by the experimental instruments, results of higher frequencies can’t be acquired. It's credible that better performances will be realized when mechanical fabrication takes the place of handwork.

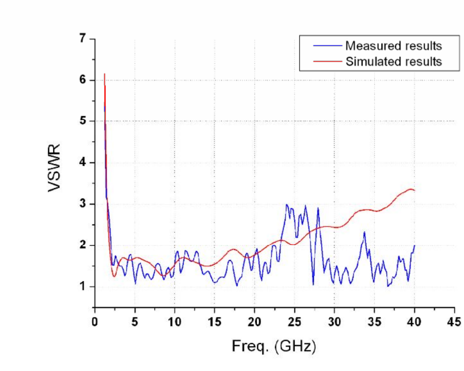
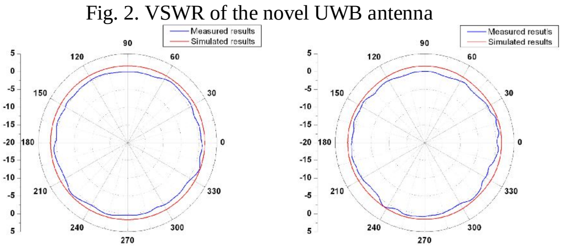
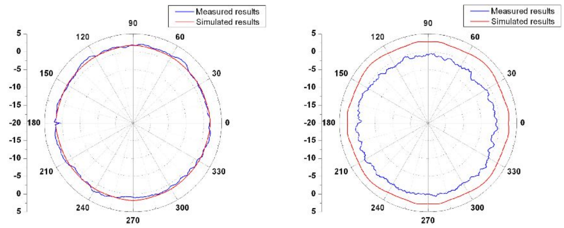


Fig. 2. VSWR of the novel UWB antenna

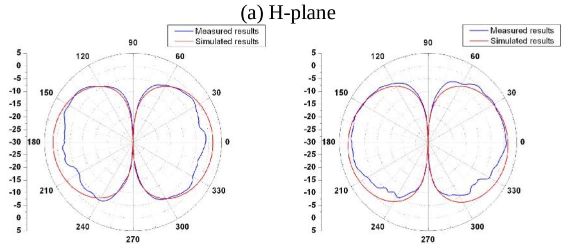


(1) 2GHz (2) 4GHz

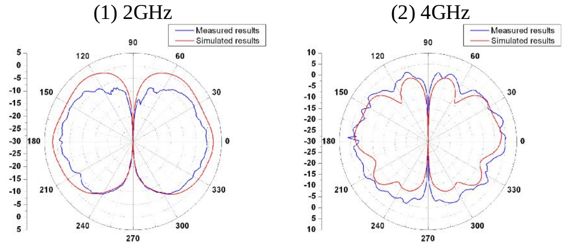


(3) 8GHz (4) 16GHz

(a) H-plane



(1) 2GHz (2) 4GHz



(3) 8GHz (4) 16GHz

(a) E-plane

Fig. 3. Radiation patterns of the novel UWB antenna

IV. REFERENCES

[1] Gaboardi P., Rosa L., Cucinotta A., and Selleri S., “Patch Array Antenna for UWB Radar Applications,” *3rd European Radar Conference*, 2006, pp. 281-284.

[2] Seok Bae, Yang-Ki Hong, Jae-Jin Lee, etc., “Miniaturized Broadband Ferrite T-DMB Antenna for Mobile-Phone Applications”, *Magnetics, IEEE Transactions on*, vol. 46, no. 6, pp. 2361-2364, 2010.

[3] J. Liang, L. Guo, “CPW-fed Circular Disk Monopole Antenna for UWB Application,” *IEEE International Workshop on Antenna Technology: Small Antennas and Novel Metamaterials*, Singapore, 2005, pp. 505-508.

[4] J. Powell, A. Chandrakasan, "Differential and Single Ended Elliptical Antennas for 3.1-10.6GHz Ultra Wideband Communication," *IEEE Antennas and Propagation Society, AP-S International Symposium*, Monterey, CA, United States, 2004, pp. 2935-2938.

[5] Zhong Ling-ling, “Ultra-Wideband Circular Disc Antenna and Its Miniaturization Research”, M. Chi. thesis, Harbin Institute of Technology, Harbin, China, 2008.

[6] P. V. Anob, K. P. Ray, Girish Kumar, “Wideband Orthogonal Square Monopole Antennas with Semi-circular Base”, *IEEE Antenna and Propagation Society International Symposium*, Boston, Massachusetts, 2001, pp. 294-297.