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NOVEL DESIGN OF ULTRA-WIDEBAND PRINTED DOUBLE-SLEEVE MONOPOLE ANTENNA

T. Dong

Satellite Application System Department
China Academy of Space Technology
Beijing 100086, China

Y.-P. Chen

Department of Electronics Engineering
Beijing Institute of Technology
Beijing 100081, China

Abstract—A novel design of printed sleeve monopole antenna is presented in this paper. Because of using double-sleeve and CPW-fed technique, this antenna has advantages of ultra-wideband (UWB) impedance characteristic, simple structure, easy fabrication and low cost. The details of simulated and experimental results for the proposed design are presented and discussed. This antenna can be designed for UWB wireless communication applications.

1. INTRODUCTION

The ultra wideband (UWB) technology promotes the communication system particularly wireless multimedia system with high data rate. Several antenna configurations have been studied for UWB applications [1–3].

Monopole antennas have been widely used in communication system for many years. The electrical properties of such antennas are dependent upon the geometry of both the monopole element and the ground plane. The length of the monopole is approximately a quarter-wavelength. The sleeve monopole antenna is a modification of the conventional monopole antenna with the outer conductor of the coaxial feed line projected over the ground. Sleeve monopole antenna

Corresponding author: T. Dong (dongtaoandy@163.com).

has broad-band characteristic. However, the impedance bandwidth of sleeve monopole is generally less than 2 : 1 [4–6].

In this paper, a printed monopole antenna is proposed. This antenna is fed by coplanar waveguide (CPW). Double sleeves with different size have been added to the ground planes. By this novel design, the CPW-fed double-sleeve printed monopole antenna has ultra-wideband impedance characteristic. The measured results show that the impedance bandwidth ratio of 2.57 : 1 (2.7 GHz ∼ 6.95 GHz) has been achieved. The radiation patterns in the *H* plane are close to omnidirectional radiation in the UWB frequency range.

This monopole is planar structure. It has single layer metallic trace and no via hole. Therefore, it is easily fabricated by printed circuit technique and it has the advantages of simple structure, easy fabrication and low cost. It is compact, low profile, lightweight and easy to integrate with monolithic microwave integrated circuits (MMICs).

2. ANTENNA DESIGN

The model of the proposed UWB printed double-sleeve monopole antenna as shown in Fig. 1 was simulated with the aid of high frequency structure simulator (HFSS). This antenna is printed on the FR4

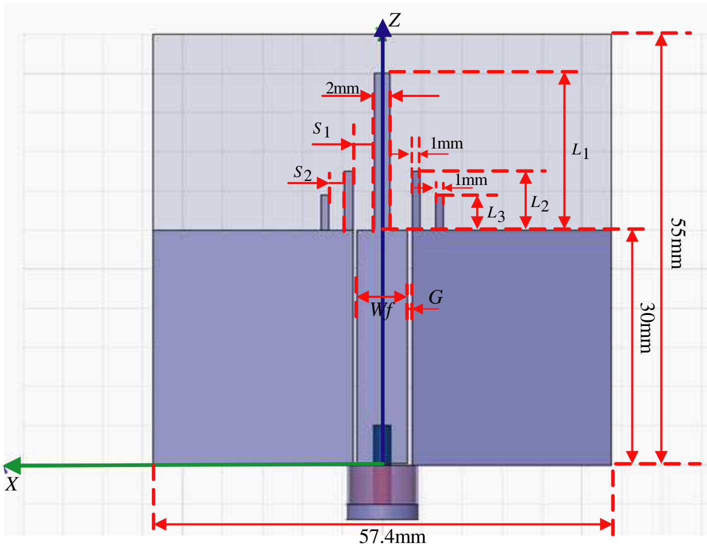

Figure 1. Antenna configuration.

substrate with a thickness of 1 mm and a relative dielectric constant of 4.4. The length of each side of the substrate is 55.0 mm and 57.4 mm respectively. The proposed antenna is composed of four parts. The first part is the printed radiating monopole. The length of L_1 is 20.0 mm and the width is 2.0 mm. The second part is two pair of sleeves. The length of sleeve is the key parameter, which is designed as quarter wavelength in substrate like the monopole design. Another parameter is the distance between the sleeve and monopole, which is designed using parametric sweep by HFSS. The first pair of sleeves are close to the radiating monopole and the length of L_2 is 7.5 mm and width is 1.0 mm. The distance of S_1 between the sleeve and the radiating monopole is 2.7 mm. The second pair of sleeves are far from the radiating monopole and the length of L_3 is 4.4 mm and width is 1.0 mm. The distance of S_2 between the two pair of sleeves is 2.0 mm. The third part of this antenna is feeding structure which is composed of two components. One component is CPW feed structure and the other component is the transit from CPW to SMA. CPW feeding structure is a kind of UWB transmission line. In order to match with the impedance of printed monopole antenna, the parameters of the CPW have been optimized as $W_f = 6.4$ mm and $G = 0.5$ mm. The fourth part is two symmetrical ground planes. G_w is the width of the symmetrical ground and G_h is the height. They are optimized as $G_w = 25$ mm and $G_h = 30$ mm.

The simulated s_{11} of the antenna as a function of frequency for different L_2 is shown in Fig. 2. The simulated s_{11} of the antenna as a function of frequency for different S_1 is shown in Fig. 3. The simulated s_{11} of the antenna as a function of frequency for different G_w is shown in Fig. 4.

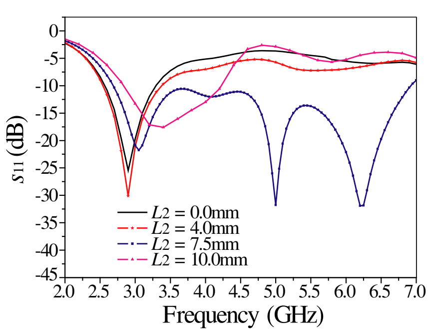

Figure 2. Simulated return loss for various L_2 versus frequency.

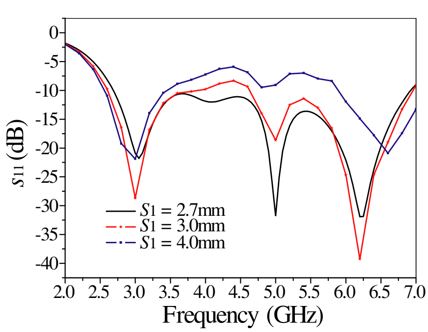

Figure 3. Simulated return loss for various S_1 versus frequency.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The prototype of the proposed antenna with optimal geometrical parameters was constructed and tested. The picture of the fabricated antenna is shown in Fig. 5.

The return loss measurement was made with Agilent 8362B network analyzer. The measured and simulated results of return loss are shown in Fig. 6. It can be seen that the -10 dB return loss bandwidth ratio of $2.57:1$ (2.7 GHz $\sim$ 6.95 GHz) has been achieved. The measured impedance is shown in Fig. 7. The solid line is resistance and the dash line is reactance.

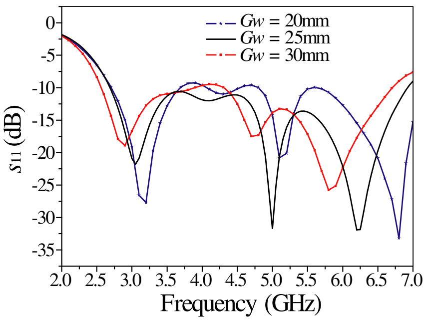

Figure 4. Simulated return loss for various G_w versus frequency.

Figure 5. Picture of the fabricated antenna.

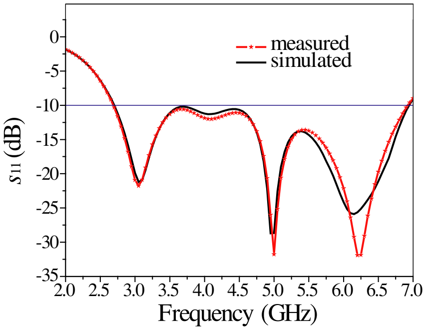

Figure 6. Measured and simulated return loss versus frequency.

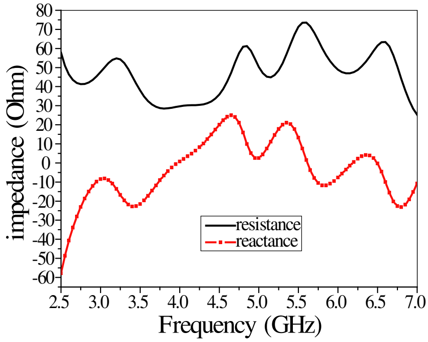

Figure 7. Measured impedance versus frequency.

The radiation patterns were measured in anechoic chamber. The measured radiation patterns at lower frequency (2.7 GHz), center frequency (4.8 GHz) and upper frequency (6.9 GHz) are shown in Figs. 8–10, respectively. It can be seen that radiation patterns in the H plane(x-y plane) are close to omnidirectional pattern in the UWB frequency range.

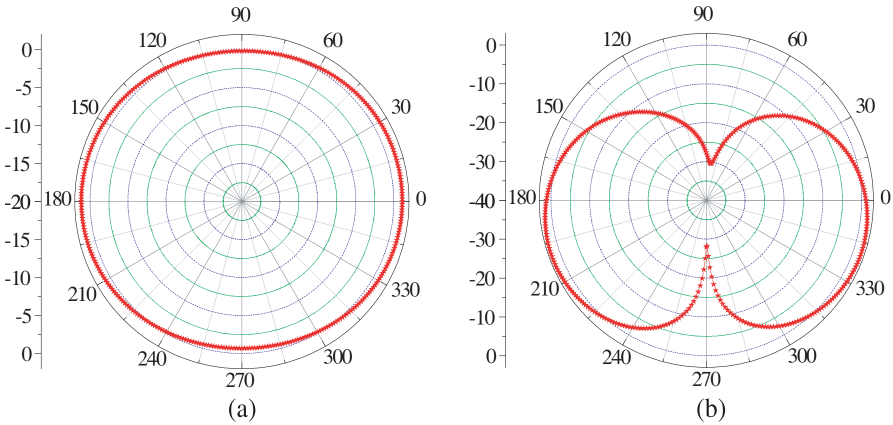

Figure 8. (a) Measured H plane (X-Y plane) radiation pattern at 2.7 GHz. (b) Measured E plane (Y-Z plane) radiation pattern at 2.7 GHz.

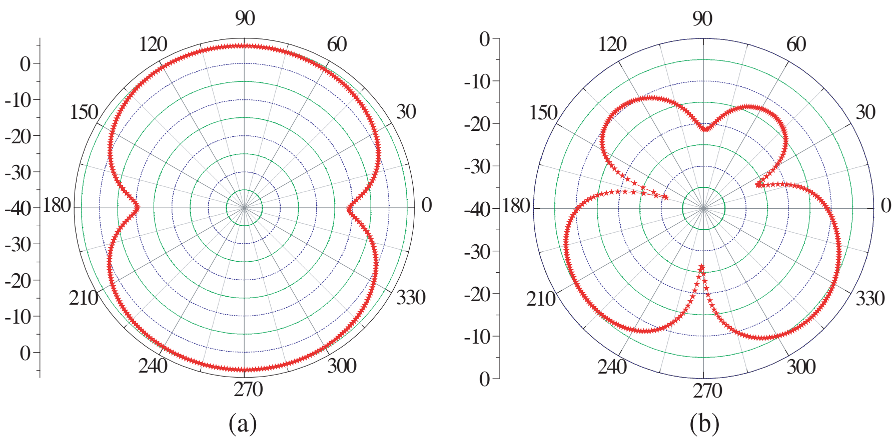

Figure 9. (a) Measured H plane (X-Y plane) radiation pattern at 4.8 GHz. (b) Measured E plane (Y-Z plane) radiation pattern at 4.8 GHz.

Theoretically, the dominant resonant frequency of the printed monopole is 1.78 GHz, the resonant frequency of the first pair of sleeves is 4.76 GHz and the resonant frequency of the second pair of sleeves is 8.12 GHz duo to their length, respectively. Because the sleeves have been added, the additional resonant modes have been generated. The current distributions on the board simulated with HFSS have been

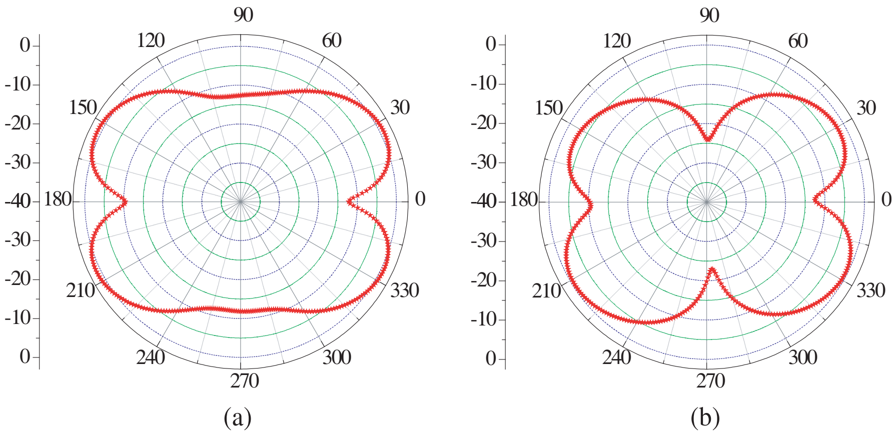

Figure 10. (a) Measured H plane (X-Y plane) radiation pattern at 6.9 GHz. (b) Measured E plane (Y-Z plane) radiation pattern at 6.9 GHz.

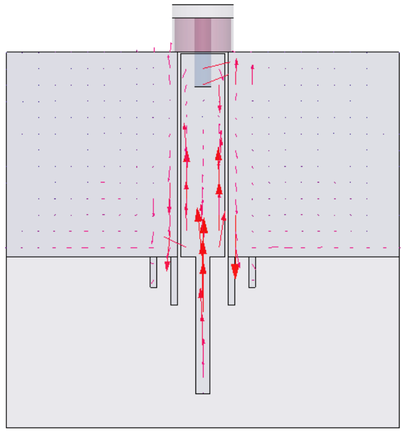

Figure 11. Current distribution at 2.7 GHz.

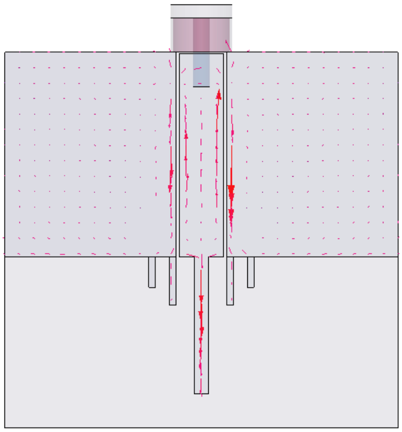

Figure 12. Current distribution at 4.8 GHz.

shown in Figs. 11–13 at lower frequency (2.7 GHz), center frequency (4.8 GHz) and upper frequency (6.9 GHz), respectively. Different sleeve with different length has different resonant frequency. It can be seen strong current distribution on the monopole and the two pair of sleeves in Fig. 11. Therefore, the radiation patterns in Fig. 8(a) are very omnidirectional. In Fig. 13, the current distribution on the monopole becomes weaker. However, the current distribution on the sleeves becomes stronger. That is to say the sleeves are resonant and have strong radiation. The simulated and measured peak gains are compared in Fig. 14.

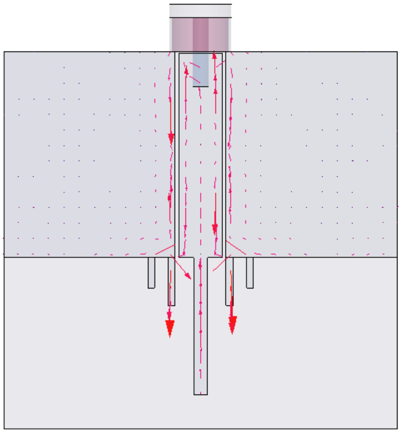

Figure 13. Current distribution at 6.9 GHz.

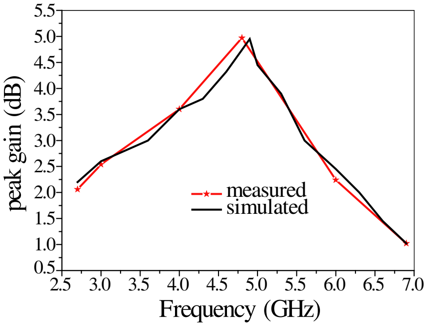

Figure 14. Measured and simulated peak gain versus frequency.

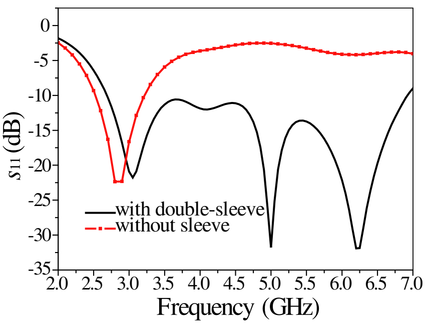

Figure 15. Measured s_{11} of the antenna with and without double-sleeve.

The measured s_{11} of the antenna with double-sleeve and without sleeve is compared in Fig. 15. The double-sleeve plays two important roles in the proposed antenna. Firstly, it expand the impedance bandwidth of the printed monopole antenna. This is similar with traditional sleeve monopole antenna. Secondly, different sleeve with different length has different resonant frequency. The sleeve has strong radiation at its resonant frequency like the printed monopole. If the distribution of these resonant frequencies is reasonable in the whole frequency band, the radiation patterns are close to omnidirectional characteristics in the whole frequency band. Of course, the bandwidth and radiation characteristics depend on the complex electromagnetic coupling effects between the monopole and sleeves.

4. CONCLUSION

A simple structure, easy fabrication and low cost printed monopole antenna is proposed in this paper. This planar antenna has UWB impedance characteristics and approximate omnidirectional patterns in the whole band from 2.7 GHz to 6.95 GHz because of two pair of additional sleeves. It can be widely applied for wireless communication and radar systems.

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