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DESIGN OF OPEN SLOT ANTENNA FOR BANDWIDTH ENHANCEMENT WITH A RECTANGULAR STUB

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Abstract—In this paper, a novel design of open slot antenna for bandwidth enhancement is proposed and investigated. The bandwidth enhancement of the proposed antenna is achieved by simply attaching a rectangular stub to the circular radiating patch. Experimental results indicate that the bandwidth of the antenna can achieve an operating bandwidth of about 139% over a wideband frequency range from 2.57 to 14.23 GHz. This antenna has a small size of dimensions $20 \times 35\,\mathrm{mm}^2$ and is suitable for wideband applications in various wireless communication systems.

1. INTRODUCTION

Recently, wideband slot antennas [1–13] have received much attention in wireless communication systems, owing to their attractive merits, such as low profile, low cost, easy manufacture, and wide impedance bandwidth. In these antenna designs, different geometries are introduced to obtain wide impedance bandwidth, such as a square-ring slot [1], E-slot [2], a rectangular notch [3], wide rectangular slot [4], and open L-slot [5]. There is an apparent contradiction between the reduced antenna size and wide bandwidth in practice. The sizes of the antennas [1–3] having adequate bandwidth are too large for the portable systems, while the bandwidths of the antennas [4, 5] with small size are not sufficient for ultra-wideband requirement. Many configurations for bandwidth enhancement in the antenna designs are proposed, such as rectangular aperture [6], multi-via holes [7], fractal-shaped slot [8], and multiple resonant slots [9], but the dimensions of

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these antennas are too large for portable systems. In addition, there are many techniques for wideband and small size in the antenna designs are proposed [10–12]. In [10], the monopole slot at the center of the ground plane is parametrically studied for its impedance bandwidth, and the obtained bandwidth of the design is approximately 52%. Moreover, two new designs of open slot antennas with shorter vertical lengths are presented in [11] to attain wider bandwidths. The antennas in [12] have the same size of dimensions $30 \times 50\,\mathrm{mm}^2$ and their bandwidths are all over 105%. However, the configuration of this antenna is difficult to enhance bandwidth for some specified requirements. How to design a slot antenna with wider bandwidth and smaller size is still a significant and challenging subject.

In this article, a novel design to enhance impedance bandwidth by simply attaching a rectangular stub to the circular radiating patch is proposed. Experimental results indicate that the impedance bandwidth of the proposed antenna is enhanced from 68 to 139% by simply attaching a rectangular stub to the circular radiating patch. Meanwhile, this antenna has a small size of dimensions $20 \times 35\,\mathrm{mm}^2$ and is suitable for various wireless communication systems. The proposed open slot antenna is implemented, and the detail antenna designs and experimental results are presented and discussed.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure 1. The overall dimensions of the antenna is $20 \times 35\,\mathrm{mm}^2$. The open slot antenna is printed on an FR4 substrate with a thickness 0.8 mm and relative permittivity 4.4. The antenna is fed by a $50\,\Omega$ microstrip line of width 1.53 mm and length 19.5 mm. In the ground plane, there is a circular slot connected to a rectangular slot of the width 8 mm in the x-direction. It has been reported in Ref. [12] that by using a circular radiating patch in this structure, a wideband operation can be obtained. To improve the impedance bandwidth, a rectangular stub is attached to the circular radiating patch. By choosing proper dimensions of the rectangular stub, the proposed antenna can achieve a large impedance bandwidth. The optimum geometrical parameters shown in Figure 1 for the maximum impedance bandwidth are obtained by High Frequency Structure Simulator (HFSS). In all parameters, W and L are the most vital parameters that can influence the impedance bandwidth signally. The optimum design parameters of the rectangular stub were set as follows: $L = 7\,\mathrm{mm}$ and $W = 5\,\mathrm{mm}$. A prototype of the proposed antenna has been fabricated and shown in Figure 2.

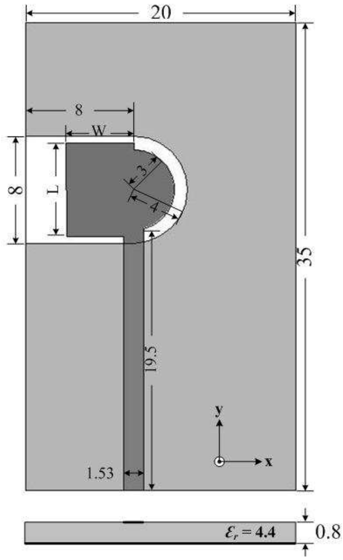

Figure 1. Geometry of the proposed antenna (Units: mm).

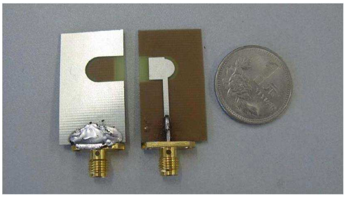

Figure 2. Prototype of the proposed antenna.

3. RESULTS AND DISCUSSIONS

With the aid of the HFSS and WILTRON37269A vector network analyzer, the simulated and measured return losses with and without the rectangular stub of the open slot antenna are shown in Figure 3. From the simulated and measured results, it is obvious that the rectangular stub can improve the bandwidth performance of the open slot antenna. The bandwidth of the open slot antenna with the rectangular stub is approximately 139% from 2.57 to 14.23 GHz, while the antenna without a rectangular stub is approximately 68% from 4 to 8.1 GHz. It can be found that the bandwidth of the proposed antenna is almost twice as much as that of the antenna without the rectangular stub.

The influences of the rectangular stub on the impedance bandwidth of the open slot antenna are illustrated in Figures 4 and 5. It is obvious that the rectangular stub has a strong effect on the impedance bandwidth of the proposed antenna.

The far-field radiation patterns of the proposed antenna in x-y plane, y-z plane and x-z plane operating at 3 GHz, 6 GHz, and 9 GHz are presented in Figure 6, respectively. Based on these results, it can be seen that the open slot antenna has asymmetric radiation

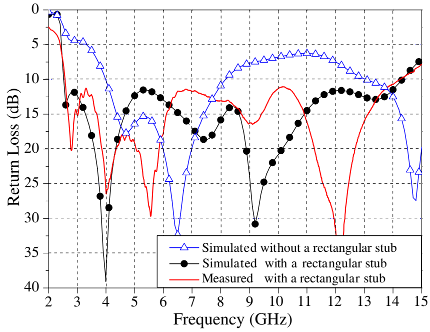

Figure 3. Measured and simulated return losses of the proposed antenna with and without the rectangular stub ($L = 7$ mm and $W = 5$ mm).

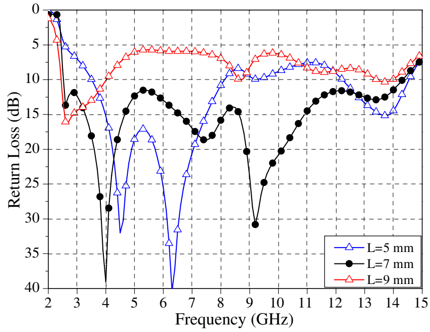

Figure 4. Simulated return losses of the proposed antenna with different vales of L ($W = 5$ mm).

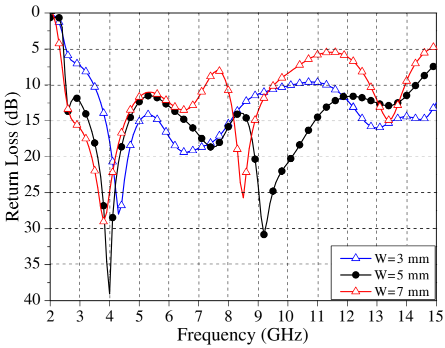

Figure 5. Simulated return losses of the proposed antenna with different vales of W ($L = 7$ mm).

characteristics at x-y plane mainly because of its inherent asymmetric structure. Moreover, the proposed antenna has an approximately omnidirectional radiation pattern in the x-z plane. Eventually, the peak gain of the proposed antenna is shown in Figure 7. It is observed that the antenna gain varies in the range 1.58–5.12 dBi over the whole band, and the variation is less than 3.54 dBi. The maximum gain is 5.12 dBi, occurring at 9 GHz. The open slot antenna exhibits good radiation pattern characteristics and gains.

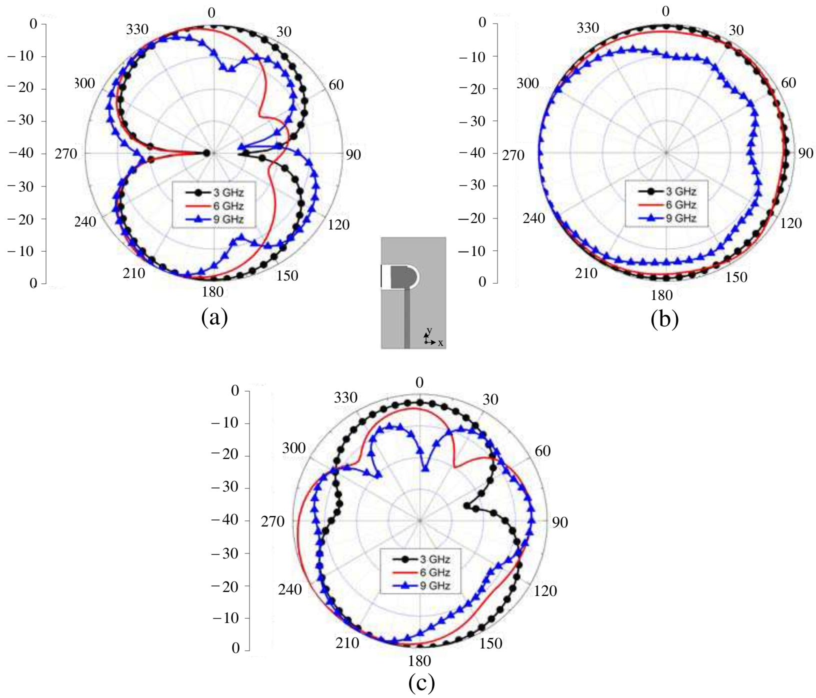

Figure 6. Far-field radiation patterns of the proposed antenna operation at 3 GHz, 6 GHz, and 9 GHz, respectively (a) y-z-plane, (b) x-z-plane, and (c) x-y-plane ($L = 7\,\text{mm}$ and $W = 5\,\text{mm}$).

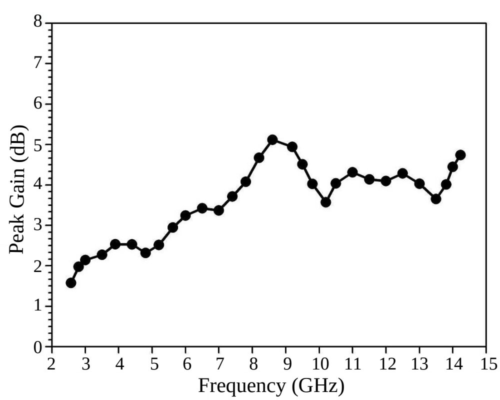

Figure 7. Peak gain of the proposed antenna ($L = 7\,\text{mm}$ and $W = 5\,\text{mm}$).

4. CONCLUSIONS

A novel open slot antenna with a rectangular stub for bandwidth enhancement has been successfully implemented, and the design details of the proposed antenna are presented. By introducing a rectangular stub with a proper size on the circular radiating patch, the bandwidth of the open slot antenna can be largely broadened. From the simulated and measured results, the obtained antenna bandwidth is almost twice as much as that of the antenna without a rectangular stub. The proposed antenna with a small size and very wide bandwidth is suitable for wideband applications in various wireless communication systems.

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