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A Compact Circularly Polarized Patch Antenna with Ring Reflector

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Abstract — A miniaturized antenna with circular polarization and directional pattern is presented in this paper. The conventional ground plane is replaced by a rectangular ring reflector to form the directional pattern. Since the side length of the ring reflector is around quarter-wavelength, the total size of the proposed antenna is reduced dramatically, which is about $\lambda_g/2 \times \lambda_g/2$ in the horizontal plane. In addition, the performance of the proposed antenna is still comparable with the conventional microstrip antenna. The simulated gain is 6.1 dB at the 1.575 GHz, while the back radiation is only -11.6 dB. To verify the proposed design, a prototype is fabricated and measured. Good agreement is observed between the measured and simulated results.

Index Terms — Directional pattern, circular polarization, rectangular ring reflector.

I. INTRODUCTION

Because microstrip antenna has the characteristics of light weight, easy fabrication, low profile and mass production [1], it has raised many research interests in the antenna design community. When the microstrip antenna operated at its fundamental mode, the side length of the patch is about half-wavelength. However, to maintain the antenna performance such as gain and front to back ratio, the ground plane needs to be designed large enough to avoid the diffracted field on the edge of it. Generally, the distance between the edge of the patch and the edge of the ground plane should be larger than 0.2$\lambda_g$ [2].

Many methods has been proposed to reduce the antenna size, such as the high permittivity substrate, the capacitive loading [3], the novel antenna structure [4] and the reactive impedance surface [5]. However, the size of the ground plane was not considered in all of these methods. It is well know that the performance of the antenna will be deteriorated significantly if the ground plane is very small. To address the above issue, a stacked microstrip configuration is proposed in [6], the reflector has the same structure with the excited element, while the size of the reflector should be larger than the patch antenna to be inductive and form directional pattern. In addition, the performance of the antenna was also very sensitive to the dimensions of the patch reflector.

By replacing the conventional ground plane with a rectangular ring reflector, a new design with compact size and circular polarization is proposed in this paper. In this proposal, the size of the reflector can be designed smaller than the patch antenna. Hence the total size of the antenna is determined by the patch antenna rather than the ground plane, which was with a primary limitation in the conventional microstrip patch antenna.

Fig.1 Configuration the proposed antenna. (a) Microstrip antenna on the top layer. (b) Rectangular ring reflector on the second layer. (c) Cross view.
II. THE PROPOSED ANTENNA DESIGN

The configuration of the proposed antenna is shown in Fig.1. It consists of a conventional patch on the top layer and a rectangular ring reflector on the second layer. However, if the ground plane size is the same with the patch radiator, a bidirectional pattern will be formed. Hence, a rectangular ring reflector is further installed under the microstrip patch.

![Fig.1 Proposed Antenna Configuration](image)

TABLE I

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value (mm)</th>
<th>Dimension</th>
<th>Value (mm)</th>
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<tr>
<td>L</td>
<td>55.6</td>
<td>h₁</td>
<td>2</td>
</tr>
<tr>
<td>s</td>
<td>6.8</td>
<td>h₂</td>
<td>9</td>
</tr>
<tr>
<td>a</td>
<td>53.8</td>
<td>fₑ</td>
<td>13.1</td>
</tr>
<tr>
<td>b</td>
<td>42.8</td>
<td></td>
<td></td>
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![Fig.2 Current Distribution](image)

Fig.2 Current distribution on the different antennas. (a) Dipole. (b) Microstrip antenna. (c) Rectangular ring antenna

![Fig.3 Simulated and Measured S₁₁](image)

Fig.3 Simulated and measured $|S_{11}|$ of the proposed antenna.

![Fig.4 Simulated and Measured Radiation Pattern](image)

Fig.4 Simulated and measured radiation pattern at 1.575 GHz for the proposed antenna. (a) Phi = 0°. (b) Phi = 90°.

![Fig.5 Performances Comparison](image)

Fig.5 Performances comparison of the proposed antenna with the antenna that has the complete ground (a) Gain (b) Front to back ratio
antenna to form a directional pattern, which works like a Yagi-Uda antenna. As shown in Fig.2, the current distributions on the top patch and bottom rectangular ring antenna are the same with the dipole antenna. Here the ring can be considered as an inductive reflector, and the patch can be considered as a driven element. Then, a directional pattern can be easily obtained with this novel configuration. To radiate the circularly polarized wave, a single feed microstrip dual-mode patch antenna with corner cutting is designed as the driven element.

The proposed antenna is simulated with a commercial full wave solver HFSS. The optimized dimensions for the proposed antenna are shown in Table I. The simulated $|S_{11}|$ is shown in Fig.3. It shows that -10 dB impedance bandwidth is from 1.554 GHz to 1.593 GHz. As shown in Fig. 4, directional radiation pattern is obtained with front-to-back ratio 17.7 dB. Performances of proposed antenna are compared with the antenna that has the complete ground either, as shown in Fig.5. Apparently, the proposed antenna has higher gain and larger front to back ratio, which means the proposed antenna has better performances with compact size. The maximum gain is 6.2 dBi, while the gain is larger than 5.3 dBi in the entire operating band, as depicted in Fig. 6. Fig. 7 shows the simulated axial ratio, which is from 1.57 GHz to 1.585 GHz.

III. MEASURED RESULTS

To verify the proposed design, a prototype is fabricated and measured. Fig. 8 shows the photograph of the fabricated antenna. The measured $|S_{11}|$ is shown in Fig. 3. As shown in Fig.4, there is a discrepancy between the measured and simulated radiation pattern in the back-lobe, the measured front to back ratio is 12.7 dB, while the simulated one is 17.7 dB. It is mainly caused by the measurement errors, because Satimo Starlab system is employed in this paper to measure the radiation pattern and there is no probe under the antenna, the back radiation is calculated with the approximate method in the system. The measured gain and axial ratio is shown in Fig. 6 and Fig. 7, respectively, it is found that both of them agree well with the simulated results.

IV. CONCLUSIONS

By introducing the concept of Yagi-Uda antenna, a rectangular ring reflector has been installed under a microstrip patch antenna, where the sizes of the ground plane and the ring reflector have been designed as the same as the top patch, to construct a Yagi-Uda like antenna Performance of the proposed antenna is almost the same with the conventional microstrip antenna, while the compact size is still remained.

ACKNOWLEDGEMENT

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REFERENCES


