A study of backfire microstrip antenna as a primary radiator

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Abstract: This paper proposes a compact backfire circular patch antenna (BCPA). The BCPA is fed from radiation aperture (patch side) by a coaxial cable, which acts as a support structure for a primary radiator of reflector antenna. A balun is used to improve the tilted radiation pattern produced by an unbalanced current on the feeding coaxial cable. We show that antenna characteristics of the BCPA is stable by using balun in both the simulation and measurement. The proposed BCPA is compact and easy to fabricate.

Keywords: back fire antenna, patch antenna, microstrip antenna, primary radiator

Classification: Antennas and Propagation

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1 Introduction

Reflector antenna consists of a primary radiator and reflector, which is a simple structure with low loss and easy to fabricate as compared to phased array antenna. It is important to set an appropriate beamwidth of primary radiator and focal length to diameter ratio (i.e. F/D ratio) for high efficiency of reflector antenna. Generally, horn antennas are used as primary radiator because its beamwidth can be easily calculated from the aperture size [1, 2, 3]. A robust structure is required to support the heavy weight of horn antenna, and there is also a need of a complicated feeding circuit due to the feeding point on the backside. The supporting structure disturbs the radiation from the reflectors depending on its size, resulting in efficiency reduction. Backfire antennas which are self-supporting structure have been proposed to resolve this problem [4, 5, 6, 7, 8]. According to [4], backfire antennas are a modified version of ordinary endfire antennas proposed by H. W. Ehrenspeck in 1960 [5, 6]. The circular waveguide with dielectric cap [7] or corrugated hat [8] have been proposed as backfire antenna of primary radiator. However, these structures are slightly complicated for fabrication. In this letter, we propose a novel backfire microstrip antenna, which is light, simple in structure and easy to fabricate. Our proposed structure is a circular patch antenna fed by coaxial cable from radiating element side. The circular patch antenna does not easily change its beamwidth as compared to a horn antenna, but we slightly adjust beamwidth by array [9]. We discuss the antenna characteristics with the coaxial cable length, and also discuss how to stabilize the radiation pattern by the influence of feeding coaxial cable. The structural details and simulated characteristics of backfire microstrip antenna are presented in Section 2, and the comparison of simulation and measurement result is described in Section 3. We conclude the papers in Section 4.

2 Simulation result

Fig. 1 shows the design parameters of backfire circular patch antenna (BCPA) with substrate of FR-4 ($\varepsilon_r = 4.2$, $\tan \delta = 0.0004$). We design the BCPA with the radius $a_c$ for resonance frequency $f_r$ of 5 GHz by using (1) [10],

$$a_c = \frac{87.94}{f_r \sqrt{\varepsilon_r}}$$

(1)

where the radius $a_c$ includes the edge effect which is quite small and negligible due to high permittivity and the thickness of substrate. The BCPA is fed by the coaxial cable on the radiation element, and it radiates the beam to the cable side ($z$-axis in
Fig. 1). This coaxial cable becomes a supporting structure for the primary radiator. The proposed structure can be used for rectangular instead of circular patch antenna. The balun suppresses the unbalanced current which affects the radiation pattern. Fig. 2 shows the radiation pattern and current distribution which are simulated by a commercial full wave 3D simulator, CST MW studio suite 2017 [11] (We use same simulator in this paper). The main beam direction is tilted to 30° in zx-plane, and the cross polarization in yz-plane is increased by changing cable length as shown in Fig. 2(a1) and (a2). It is not desirable to obtain good aperture efficiency of reflector antenna because the uniform amplitude distribution can not be excited on the reflector. To clarify this reason, we simulate the current distribution as shown in Fig. 2(b1) and (b2). The current flow is observed on the cable, which affects the radiation pattern of the BCPA as shown in Fig. 2(b1). We use a Sperrtop balun with length of λ/4 (15 mm) and the diameter of 6.58 mm to remove this undesired current as shown in Fig. 2(b2). The comparison of the simulated reflection and radiation pattern with measured ones is presented in the next section.

![Fig. 1. Design parameters of BCPA with (a) bird eye view, (b) top view, (c) cross section, \( l_{\text{semi}} = 32 \) mm, \( r_{\text{sub}} = 10 \) mm, \( r_{\text{patch}} = 8.2 \) mm, \( d_{\text{feed}} = 3.8 \) mm, \( r_{\text{semi}} = 1.2 \) mm, \( h = 0.78 \) mm, \( t = 35 \) μm, \( l_{\text{balun}} = 15 \) mm, \( r_{\text{balun}} = 6.58 \) mm](image)

**3 Measurement result**

The BCPA was fabricated with balun and without balun. The cable length is set to 10 mm. Fig. 3(a) shows the comparison of reflection between simulation and measurement. In both cases with and without the balun, the measurement result shows a good agreement with simulated result. Fig. 3(b) and (c) show the comparison of directivity without balun. The main beam direction in zx-plane is tilted and disordered in both simulation and measurement case. This is caused by the unbalanced current on the coaxial cable as mentioned in Section 2. The cross
polarization which is not observed in the simulation is observed in the measurement. In $yz$-plane pattern, the main beam direction and beamwidth show a good agreement, but measured cross polarization is larger than that of simulation. We consider that the difference is caused by current flow in the coaxial connector in the measurement setup, which is not modeled in simulation. Fig. 3(d) and (e) show the comparison of measured and simulated directivity of BCPA with balun. We confirm a very good agreement, and the tilted main beam is improved in $zx$-plane. In addition, the cross polarization is also suppressed by the balun. In $yz$-plane, the directivity of backside does not show good agreement, but we consider this direction not important for the primary radiator. Therefore, we show the effectiveness of the backfire circular patch antenna for primary radiator.

Fig. 2. The simulated radiation pattern and current distributions of BCPA. (a1) $zx$-plane (a2) $yz$-plane with changing cable length. Solid: $l_{semi}=5\,\text{mm}$, Dash: $l_{semi}=10\,\text{mm}$. (b1) current distribution without balun, (b2) with balun.
4 Conclusion

In this letter, we proposed and demonstrated the performance of backfire circular patch antenna which is compact, small and easy to fabricate. We show the influence of the coaxial cable to antenna characteristics which improved its performance by using balun. This antenna would be useful for primary radiator of reflector antennas.