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A Partial-Annular Directional Antenna with Simple Structure for Limited Space

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Abstract

A partial-annular directional antenna with wide bandwidth and high gain is proposed in this paper. The radiator is a simple partial-annular metal microstrip loaded with hexagonal patch, which is exited with coaxial cable. The ground is reduced to a rectangular patch with small area, which is required by the deployment. As the reflector, the circular Aluminum plate is $\lambda/10$ below the radiator to enhance the antenna gain and front-to-back ratio (FBR). The air gap between the semi-annular antenna and the reflector is also helpful for the improvement of impedance math. The simulation results show that the relative bandwidth of the proposed antenna is 46.6% (3.85 – 6.19 GHz), and the gain varies from 7.91 to 9.93 dBi. Due to the semi-annular strip structure and defected ground, the proposed antenna could be used for the limited deployment space, such as radio wave detection, terminal of mobile communication, and so on.

1 Introduction

For some special industrial scenarios, due to the small size of the radio detection equipment, the space left by the system for the RF antenna is limited [1]. Meanwhile, the radio detection system has high requirements on the antenna performance, which requires wide impedance bandwidth, high gain and compact size. Additionally, excellent front-to-back ratio (FBR) is also needed to avoid the influence of the radiation on the back-end circuit.

Since the microstrip patch antenna is generally low profile, plenty of innovations have been proposed for compact size based on the patch antenna. A kind of absorptive filtering patch antenna was presented, which consists of a filtering patch antenna and a bandstop filter [2]. By skillfully using the slots and stubs, the radiation nulls are generated. The multimode analysis theory was applied for the width expansion of patch antenna [3]. The higher order modes were effectively decreased and combined with the dominant mode. A simple truncated rectangular patch with U-slot and a partial ground plane was provided for the ultra-wideband application, and the omnidirectional stable radiation patterns were obtained with the shaped radiation patch[4].

Although the bandwidth could be improved with parasitic element and air gap, the gain of patch antenna might be reduced, and the complexity of antenna structure significantly increases.

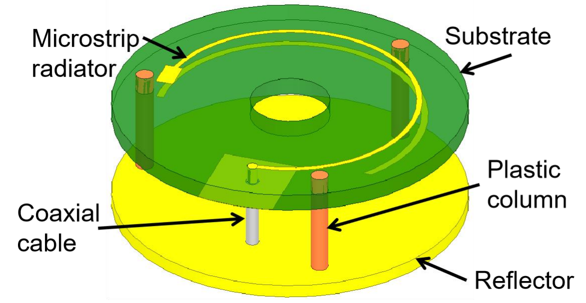
This paper proposes a partial-annular directional antenna (PADA) for limited deployment space. The gain and bandwidth is improved with the metal reflector and air gap. With the simple structure and defected ground, the PADA could be applied for various radio wave detection equipment.

2 Antenna Design

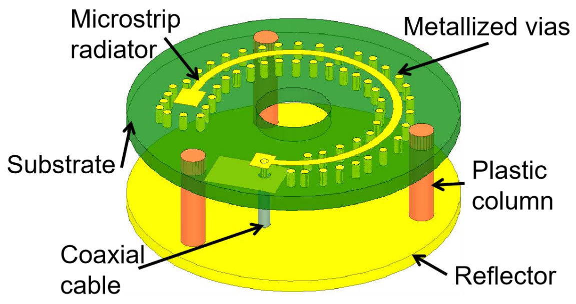
Three types of partial-annular directional antennas fed with coaxial cable are designed for limited deployment space in radio detection, as shown Figure 1. All the antennas are composed of a circular printed circuit board (PCB) with 20 mm radius and 2 mm thickness and a metal reflector, and the plastic columns of 6 mm height are used to support the structure. The cylindrical hollow structure in the center of the PCB helps the antenna to be installed on the RF equipment.The substrate of PCB is FRA with relative permittivity 4.4, of which the micostrip and the ground are copper. The radiators are partial-annular microstrips, which could also be regarded as part of a one-turn helix on a plane. Thus, the ground on the other side of substrate is relatively small compared with the radiator, which could avoid the interference with the cylindrical hole of the PCB. Moreover, the three partial-annular antennas are linearly polarized.

The microstrip of design A is of 70.6 mm length and 0.6 mm width in Figure 1 (a). The small rectangular patch is loaded at the end to provide additional capacitance to the input impedance Z_{in}, and the parasitic partial-circular strip on the bottom of the substrate is used to expand the bandwidth. Furthermore, the parasitic partial-circular strip is replaced with a couple of metallized vias in design B, as shown in Figure 1 (b), with which the electric field below the PCB is bounded to improve the distribution of electric currents on the radiator.

Based on the design A and design B, the antenna structure is furtherly simplified and improved in design C, as shown in Figure 1 (c). The length of microstrip is reduced to 47.9 mm, and the the loaded patch is changed into a hexagon of 5.7 mm side length. Meanwhile, the width of the microstrip is also optimized into 2.1 mm. According to the antenna performance discussed below, the design C is proposed for engineering application.



(a)



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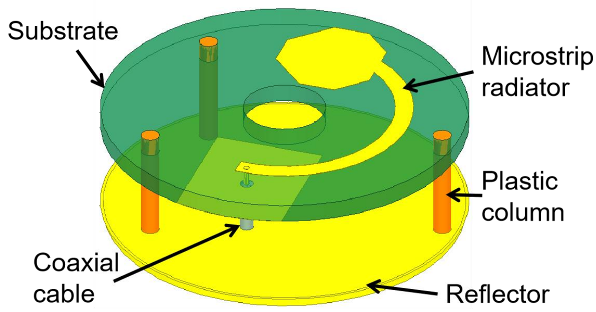
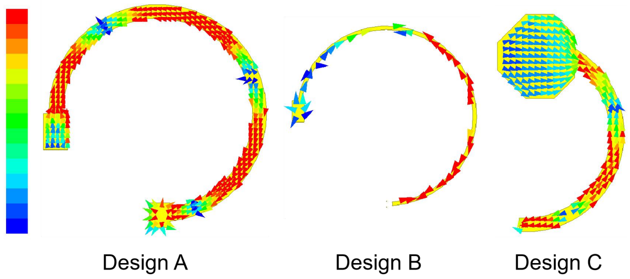


(c)

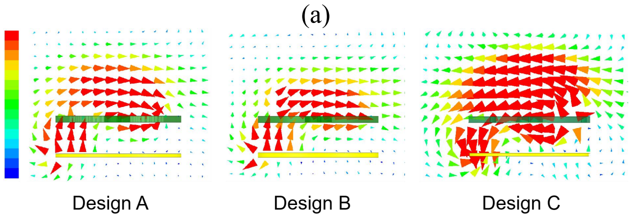
Figure 1. Geometries of partial-annular directional antennas. (a) Design A. (b) Design B. (c) Design C (proposed).

3 Simulation and Discussion

The electric currents of design A, B and C at 5.00 GHz are shown in Figure 2 (a), and the corresponding electric field distributions in near zone are respectively shown in Figure 2 (b). Although it seems that the currents of design A are the strongest, the opposite currents direction is apparently found in both of design A and B. The nonuniform directions of currents could lead to the increase of cross polarized radiation component and weaken the antenna gain. According to the microwave circuit theory, the extra length of microstrip is related to the multiple resonance frequencies, which is a negative factor for the wide bandwidth. The strongest electric field distribution is also found in the design C, which shows the linear polarization radiation. Moreover, the strong field between the PCB and reflector indicates that the optimization of reflector is necessary for the impedance match and front to back ratio FBR.

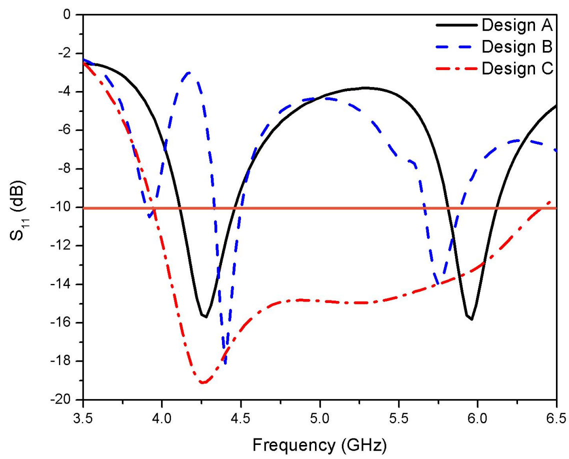


(a)

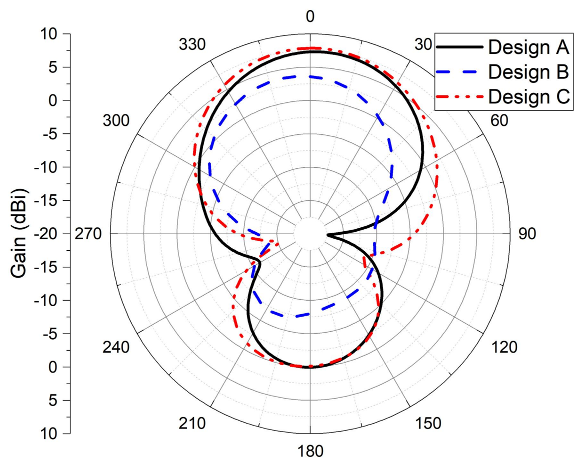


(b)

Figure 2. Comparisons of the electric current and field distributions of the Design A, Design B and Design C (proposed). (a) Electric currents distributions on semi-annular microstrip with hexagonal patch. (b) Electric field distribution in near zone.



(a)



(b)

Figure 3. Comparisons of the simulated results for the Design A, Design B and Design C (proposed). (a) S_{11}. (b) Radiation patterns.

The comparisons of antenna performances with three designs are shown in Figure 3. Corresponding to the currents distributions in Figure2, there are two resonance frequencies in both design A and B, and the antenna gain of design C is much better than the others.

The Figure 4 shows the antenna gain and efficiency as the function of frequency. It is found that the gain varies from 7.91 to 9.93 dBi in the impedance match bandwidth (3.85 – 6.19 GHz). Due to the simple antenna structure, the good antenna efficiency from 79.2% to 87.6% is achieved. It should be figured out that the lowest efficiency is at the middle point of the bandwidth, which is related with the weakened impedance match.

The radiation patterns of design C during the operation frequency band are shown in Figure 5. The patterns at different frequencies are almost converged, which indicates the stable radiation performance.

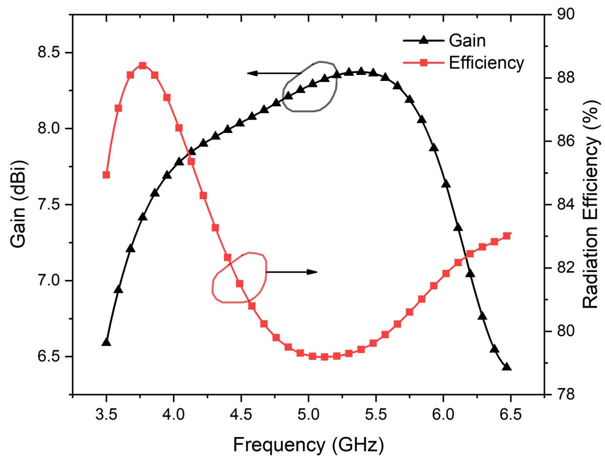
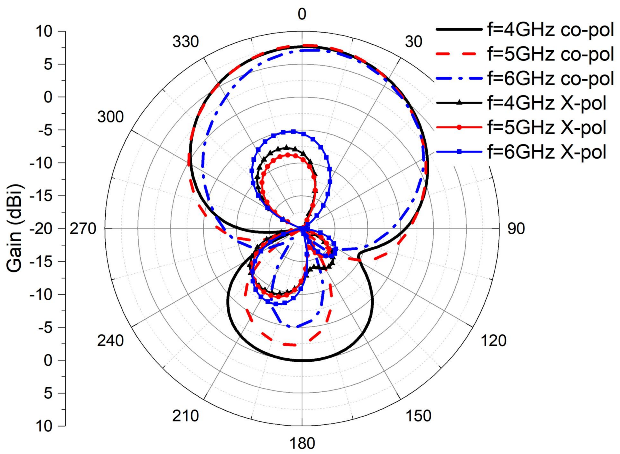
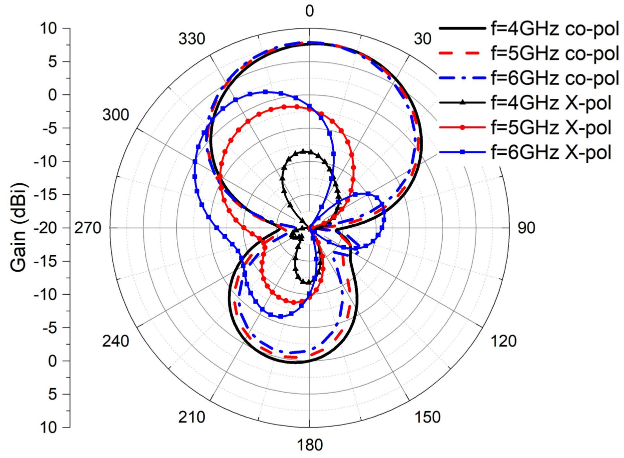


Figure 4. Simulated gain and radiation efficiency of the proposed PADA.



(a)



(b)

Figure 5. Radiation patterns of the proposed PADA in the operation frequency band. (a) E plane. (b) H Plane.

4 Conclusion

The development of radio wave detection technology requires various high performance and compact antenna. The proposed PADA in this paper takes the advantage of low profile, high gain and wide bandwidth, which also has simple structure and low cost. For the limited space application, the PADA is a promising candidate.

References

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