A New Spiral Antenna with Improved Axial Ratio and Shorted Arm Length

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Abstract— A new spiral antenna is proposed in this paper. The developed antenna has improved axial ratio (AR) and shorted arm length. The developed spiral antenna combines the low frequency characteristic of power spiral antenna and high frequency characteristic of Archimedean spiral antenna. The results reveal that the developed spiral antenna has noticeable improved axial ratio at low frequencies compared with Archimedean spiral antenna, and the problem of axial ratio degradation of power spiral antenna is also solved. The arm length is shorted by 46.4% than conventional Archimedean spiral antenna, and 63.5% than power spiral antenna.

1. INTRODUCTION

Among all frequency-independent antennas, Archimedean spiral antenna can be a good choice in ultra-wideband systems because of its great performance on circular polarization and maintaining consistent gain and input impedance. The radiation mechanism based on the current band theory is shown in [1]. Many efforts have been made to improve radiation characteristics without enlarging the size of the antenna.

Absorbing material that exhibit dielectric or magnetic loss tangents is placed under the antenna [2]. Electromagnetic band gap (EGB) reflector is used [3]. Spiral surrounded with a metallic ring is analyzed in [4].

Power spiral antenna [5] achieves noticeable improvement in axial ratio at low frequencies, but axial ratio degrades at high frequencies. Archimedean spiral antenna and power spiral antenna are combined to achieve good AR at both low and high frequencies [5]. But the antenna is not a self-complementary structure, and the arm length inevitably becomes longer.

In many occasions, short arm length is necessary. In recent studies, spiral antennas with planar feeding structure achieved more attraction. Feeding the equiangular spiral with a transmission line that follows the metal layer beneath the spiral to the center point is proposed [6], and the vertical balun is replaced by parallel-plane feeding structure and the overall size of the antenna is largely reduced. But it is impossible to feed Archimedean spiral antenna the same way because of the long and thin arm. However, Archimedean spiral antenna has a noticeable advantage at axial ratio bandwidth over its equiangular counterpart. On this condition, improving radiation characteristics as well as reducing the arm length is necessary.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the spiral antennas which will be discussed in this paper. These three antennas are defined by the formulas below:

$$r(\varphi) = r_0 + A_1 * \varphi \tag{1}$$

$$r(\varphi) = r_0 * [A_2 * \varphi + 1]^{B_2} \tag{2}$$

$$r(\varphi) = r_0 * A_3 * \left[\frac{\arctan(\varphi - B_3)}{C_3} + D_3\right] \tag{3}$$

where r is radial distance, φ is the winding angle. The inner and outer radius is defined by r_0 and r_1. The start and end of the winding angle is defined by φ_0 and φ_1. A_1, A_2, A_3, B_2, B_3, C_3, D_3 are constants related to the defining geometrical parameters of the antennas.

In typical Archimedean spiral antenna, coils are equally distributed. As shown in Figure 2, the growth rate of r is a constant. The defining formula is (1), and the antenna is shown in Figure 1(a). As presented in [5], Figure 1(b) shows power spiral antenna, in which coils are not equally distributed. The defining formula is (2).

The new spiral antenna has similar structure at outer coils with power spiral antenna but wrapped tighter in the inner coils. The new antenna is shown in Figure 1(c). The defining formula is (3).

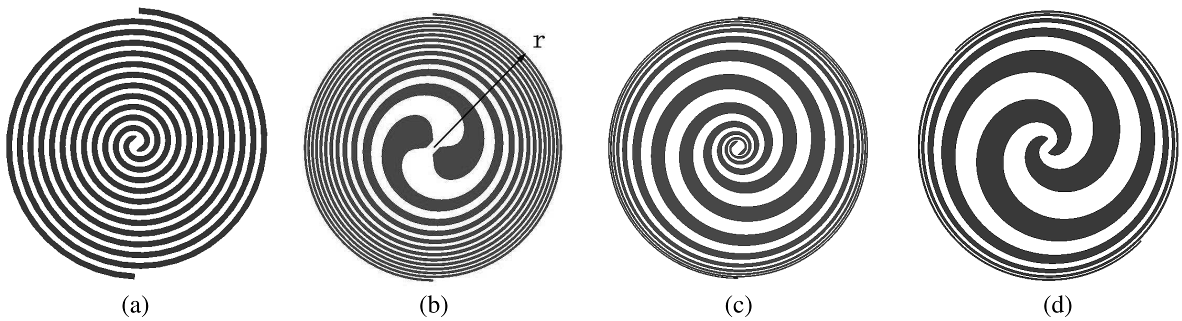


Figure 1: The antennas discussed in this paper. (a) Archimedean spiral, (b) power spiral, (c) new spiral, (d) shorted new spiral.

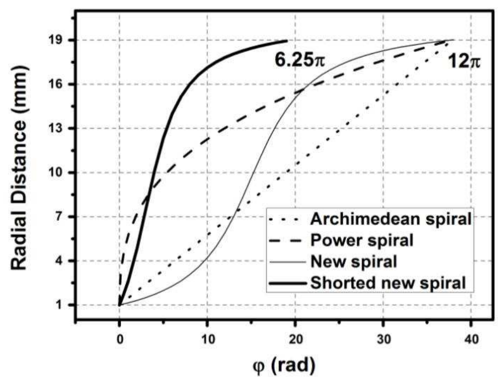


Figure 2: The relationship between r and φ.

Table 1: Parameters of the antennas.

A_1	A_2	B_2	A_3	B_3	C_3	D_3
0.475	485.5	0.3	8.27	3	3	0.906

Table 2: Arm length of the antennas (unit: mm).

Archimedean spiral	Power spiral	Shorted new spiral antenna
375	551	201

To reduce the arm length, we reduce the winding angle of the antenna, and it is found that the good axial ratio caused by the tight wrapping at the outer circles is not missing as long as we choose the suitable parameters. The end of the winding angle is reduced from 12π to 6.25π.

The defining geometrical parameters of the antennas are illustrated in Table 1. The arm length can be approximately seen as the length of the first edge.

The calculated results of the three antennas are shown in Table 2. The arm length of the new spiral antenna is 201 mm, 46.4% shorter than the conventional Archimedean spiral antenna, and 63.5% shorter than power spiral antenna.

3. SIMULATION AND MEASUREMENTS

These antennas are simulated by the HFSS software. All the antennas are fabricated on the 0.8 mm thick F4B ($\varepsilon_r = 2.2$) substrate. And all antennas are surrounded with a metallic ring as described in [5].

In the initial simulations, no balun is used, and we have assumed matched conditions at the input port and excitation source impedance is set to 160 Ω in accordance with the simulated input resistance.

Figure 3 demonstrates the simulated axial ratio performance for the three antennas. At low frequencies, the axial ratio of new spiral and power spiral has an improvement caused by the relatively tighter wrapping than conventional Archimedean spiral. The tighter wrapping causes

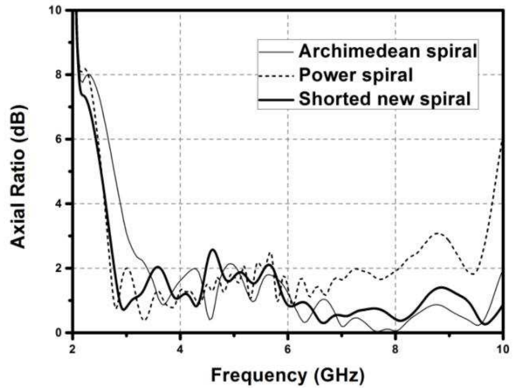


Figure 3: Simulated axial ratio for the three antennas at front side.

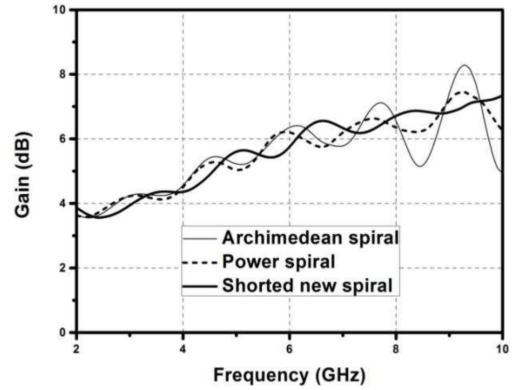
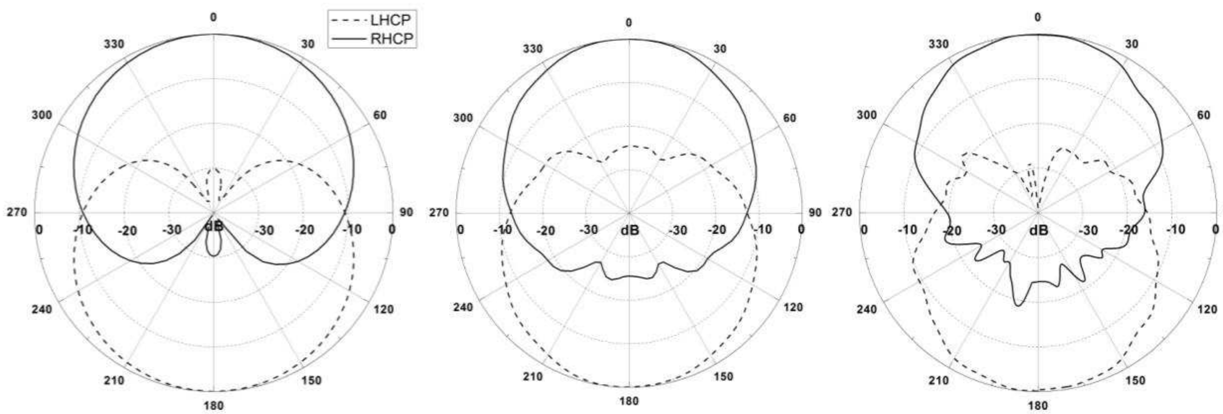


Figure 4: Simulated gain for the three antennas.



(a) (b) (c)

Figure 5: Simulated radiation pattern. (a) 3 GHz, (b) 6 GHz, (c) 9 GHz.

increased coupling between the spiral arms in active region [5]. The increased coupling reduces the residual currents and reflected derivatives. At high frequencies, the axial ratio of power spiral degrades. But the good axial performance of Archimedean spiral is maintained by the new spiral because of the relatively tighter wrapping at the inner coils. Figure 4 shows the comparison of the three kinds of spiral antennas.

And Figure 5 shows normalized RHCP and LHCP radiation patterns of the new spiral antenna at 3 GHz, 6 GHz, and 9 GHz.

4. CONCLUSION

A new spiral antenna structure is proposed in this paper. The antenna has similar part at outer circles with power antenna but wraps tighter in the inner circles. The new spiral antenna has noticeable improvement in axial ratio at low frequencies and better performance in high frequencies than power spiral, and arm length is also largely shorted.

ACKNOWLEDGMENT

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