A Spiral Antenna with Integrated Planar Feeding Structure

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Abstract— In practical applications, the low-profile spiral antennas suffer from the lack of proper planar feeding ways. The vertical balun always has a significantly long length, inconsistent with the requirements of the low profile spiral antenna geometry. A spiral antenna with integrated planar feeding structure is proposed in this paper. The antenna used has obviously improved axial ratio compared to the equiangular spiral antenna at low frequencies. And the traditional balun in the third dimension is moved to the planar plane. The resulting structure maintains the typical radiation behavior and the broadband operation of the spiral antennas, but the vertical balun is integrated at the same plane with the antenna. The overall size of the spiral antenna is largely reduced.

1. INTRODUCTION

Planar spiral antennas have the advantages of great performance on circular polarization, easy impedance matching, and the superior radiation efficiency. However, the conventional feeding structure for planar spiral antennas is situated in the center of the spiral and extends into the third dimension [1].

Many efforts have been made to feed spiral antennas in the planar plane, but the radiation behavior always becomes worse at the same time. Feeding the spiral from the terminations on the perimeter is proposed. This method achieves a completely planar spiral antenna at the cost of limited band width [2]. The coplanar waveguide (CPW)-fed slot antenna has received considerable attention [3]. Despite the advantages of completely planar structure, the CP (circularly polarization) bandwidth is also limited.

Feeding the spiral with a transmission line that follows the metal layer beneath the spiral arm to the center point is proposed [4]. This method is used to feed equiangular spiral antenna and achieves axial ratio below 5 dB over the frequency range of 3–10 GHz, but it is impossible to feed the Archimedean spiral antenna in the same way because of its long and thin arms. However, the Archimedean spiral antenna has a noticeable advantage at axial ratio bandwidth over its equiangular counterparts. On this condition, this paper uses the similar feeding way to feed a newly designed spiral antenna. The antenna designed has largely improved axial ratio compared to the equiangular spiral antenna at comparable size, and the arms are wider and largely shorter than the Archimedean spiral antenna to make it possible to feed the antenna in similar way with [4]. The spiral antenna and a Dyson-style balun have been integrated into a multi-layer structure. The resulting structure maintains the typical radiation behavior and broadband operation of spiral antennas, and achieves good axial ratio performance without the vertical balun. The overall size of the spiral antenna is largely reduced.

2. ANTENNA DESIGN

Figure 1 shows the conventional equiangular spiral antenna, Archimedean spiral antenna and the newly designed antenna. The new spiral antenna edge is described by (1).

$$r(\varphi) = r_0 * A * \left[\frac{\arctan(\varphi - B)}{C} + D\right] \tag{1}$$

where r is the radial distance, φ is the winding angle, and r_0 is the inner radius. A, B, C and D are constants related to the defining geometrical parameters of the antennas.

As shown in Figure 1, the Archimedean spiral has thin and long arms and is impossible to be fed in the new way mentioned in [4]. However, Archimedean spiral has an obvious advantage of axial ratio bandwidth at comparable size. On this condition, the new kind of spiral antenna is designed to achieve improved axial ratio and shorted arm length. The design process of the new antenna is well explained in our former work [5].

Figure 2 shows the newly designed antenna with integrated planar feeding structure. The balun and the antenna are integrated together at the border. The spiral antenna uses one arm of the

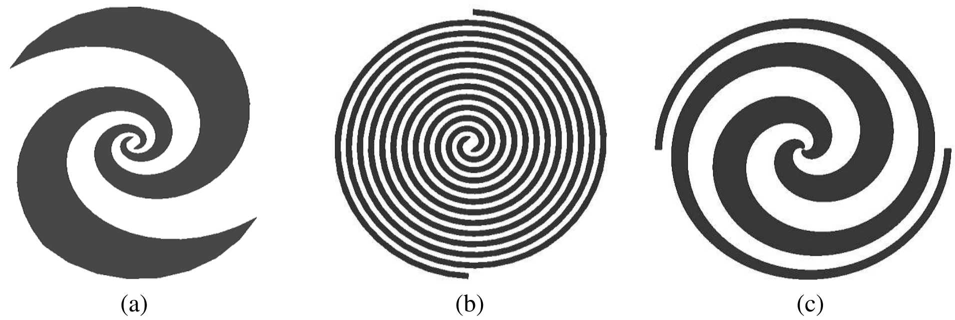


Figure 1: The antennas discussed in this paper. (a) Equiangular spiral, (b) archimedean spiral, (c) new spiral.

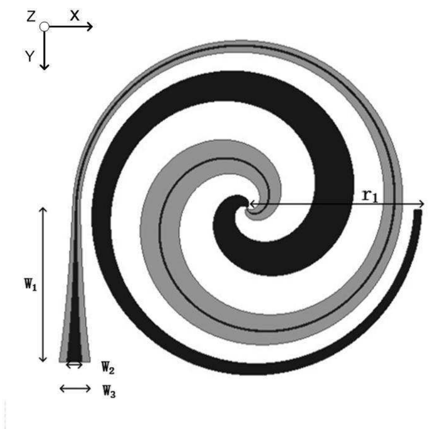


Figure 2: The geometry of the proposed antenna. Metal on the front side (black) and metal on the back side (gray).

Table 1: Parameters of the antennas.

A	B	C	D	r_0	$\varphi_{\max}$	W_1	W_2	W_3
64.1	4.6	3	1	0.2 mm	3.75π	25 mm	2.5 mm	5 mm

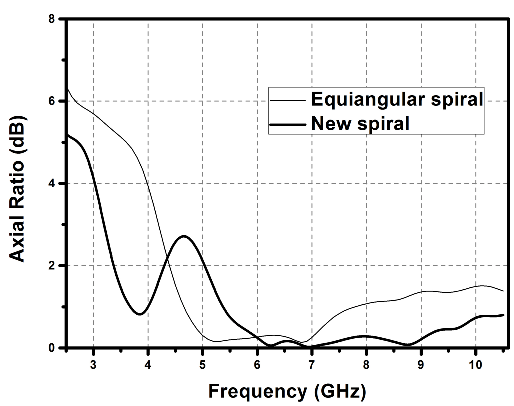


Figure 3: Simulated axial ratio for the new spiral and equiangular spiral.

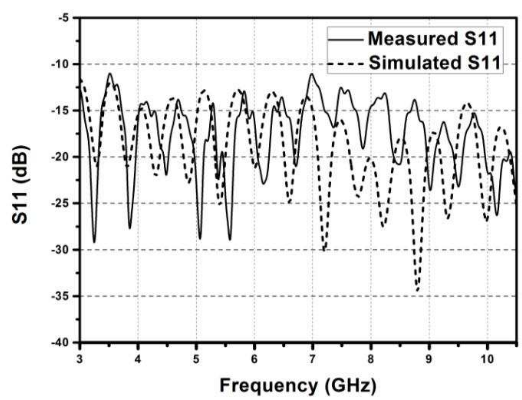
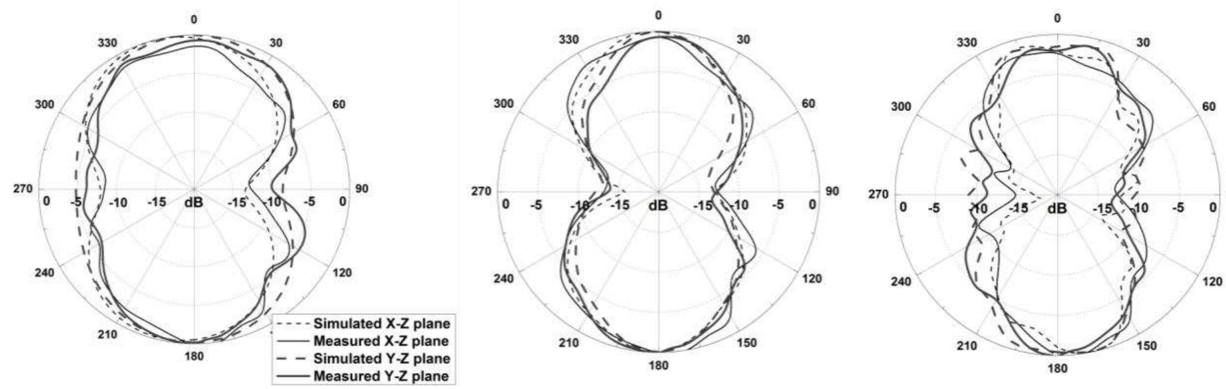


Figure 4: Measured and simulated S_{11}.

spiral antenna as ground of the stripline feed network and the center conductor of the strip line provides the other spiral arm.

The parameters A, B, C, D, r_0, $\varphi_{\max}$, W_1, W_2, and W_3 are illustrated in Table 1. The antenna is constructed on the F4B substrate with the dielectric constant of 2.2, the loss tangent of 0.0009 and the thickness of 0.8 mm, occupying an area of $70 \times 70\,\mathrm{mm}^2$.



(a) (b) (c)

Figure 5: Measured and simulated radiation directivity, (a) 3 GHz, (b) 6 GHz, (c) 9 GHz.

3. SIMULATIONS AND MEASUREMENTS

The antenna performance is investigated by HFSS simulation software. The axial ratio of the new spiral antenna and equiangular spiral antenna are compared in Figure 3. The new antenna has a noticeable advantage of axial ratio at low frequencies compared to equiangular spiral antenna at even smaller size. The radium of the equiangular spiral antenna is 32.5 mm. The radium of the new spiral antenna is only 28 mm, and the axial ratio is largely improved at low frequencies.

Figure 4 shows measured and simulated results of S_{11} for the developed spiral antenna with feeding structure.

Figure 5 shows comparison between simulated and measured results of normalized radiation patterns for the total gain at 3 GHz, 6 GHz, and 9 GHz.

4. CONCLUSION

A new spiral antenna with a planar feeding structure is proposed in this paper. The antenna used has a noticeable advantage of axial ratio over equiangular spiral antenna. And the traditional vertical balun has been replaced by integrated planar feeding structure. The resulting structure maintains the typical radiation behavior and broadband operation of spiral antennas, and achieves good axial ratio performance without the vertical balun.

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