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A Compact Broadband Circularly Polarized Spiral Antenna for Conformal Applications

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***Abstract*—This paper proposes a novel compact conformal broadband spiral antenna on a truncated cone. The radiating body of the antenna is composed of two-arm spiral metal strips, and the two arms with 180° differential excitation to generate unidirectional radiation and left-hand circular polarization in the axial direction of the spiral. Exclusive power divider and phase shifter are designed to form the feeding network. The presented antenna has the impedance bandwidth of 49.2 % (2.3-3.8 GHz) of $|S_{11}|$ <-10 dB and the 3-dB axial ratio (AR) bandwidth of 57.1% (2.0-3.6 GHz). The miniaturized, compact and broadband characteristics of this designed antenna make it advantageous for drones and portable equipments.**

***Index Terms*—Conformal spiral antenna, circularly polarized, compact antenna, broadband antenna.**

I. Introduction

In the modern complex electromagnetic environment, antennas are increasingly installed on missiles, drones and portable equipments. Due to the limited space on the surface of the carrier, the antenna for such applications has high requirements for compact size, conformality and robustness [1].

Wideband antennas can be widely used in multiband communication systems because the frequency band ranges of many communication standards are allocated very closely [2]. In addition, compared with linear polarization wave, the signal quality of circular polarization (CP) wave is less affected by the antenna direction, and the multipath effect of circular polarization (CP) wave can be greatly reduced [3]. The spiral antenna is a typical circular polarization (CP) antenna with inherently stable input impedance and radiation pattern in a wide frequency range [4]. The equiangular spiral antenna is the most common form of conical spiral antennas [5], while Archimedean spiral antennas are often used as a basic planar spiral antenna. In recent research, some methods for manufacturing conformal antennas based on Archimedean spiral antennas have been reported. The theory and practice of using mathematical functions to design conformal ultra-wideband Archimedean spiral antennas on hemispherical dielectrics are proposed in [6]. In [7], the planar Archimedean spiral is printed on the top of the cylinder, and the two arms of the spiral extend around the curved surface. However, the balun connecting the bottom and the top of the cylinder results in complex antenna geometry so that the antenna is difficult to be fabricated. [8] presents a novel load-bearing Archimedean

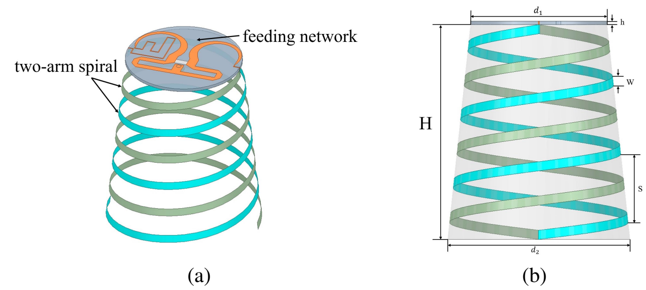


Fig. 1. (a) Perspective view and (b) side view of the proposed antenna.

spiral antenna, which is fabricated on conductive textile thread. However, the ground plane is placed at a distance of 25 mm from the spiral surface, which makes the antenna to lose the advantage of conformality.

This paper aims to design a compact broadband circularly polarized conical Archimedean spiral antenna fed by the dedicated designed feeding network.

II. Antenna Design

The proposed broadband CP antenna is shown in Fig. 1(a). The demonstrated antenna is composed of two parts, a pair of spiral metallic strips and a dedicated designed feeding network. The diameters of the spiral at top and bottom are 30 mm and 40 mm, respectively. Each arm of the spiral has 3 turns, where the width of the arm is 2 mm, and the pitch of screws is 15 mm, as illustrated in Fig. 1(b). These two spirals are fabricated on a flexible polyimide dielectric substrate with relative permittivity of 3.5, loss tangent of 0.008, and a thickness of 0.012 mm.

The feeding network is printed on a RO5880 substrate with relative dielectric constant of 2.2, loss tangent of 0.0009, and a thickness of 0.787 mm. It is composed of a Wilkinson power splitter, a gradual matching line and a phase shifting part. Two holes are dug out of the ground at the connection to avoid contact between the spirals and the ground.

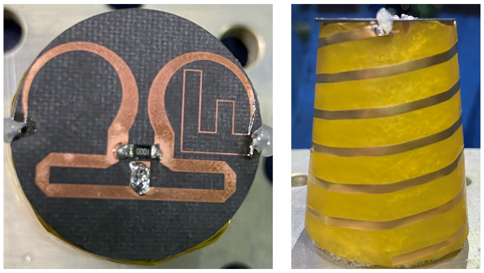
The geometric parameters are summarized in detail in Table I. And the prototype of the antenna is shown in the Fig. 2.

III. Simulated and Measured Results

Fig. 3(a) provides the simulated and measured AR for the presented antenna. The measured 3-dB AR bandwidth frequen-

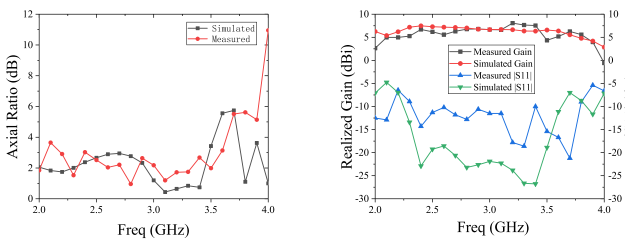
TABLE I
GEOMETRIC PARAMETERS

H	47 mm	S	15 mm	W	2 mm
h	0.787 mm	d_1	30 mm	d_2	40 mm



(a) (b)

Fig. 2. (a) Top view and (b) side view of the prototype of the antenna.



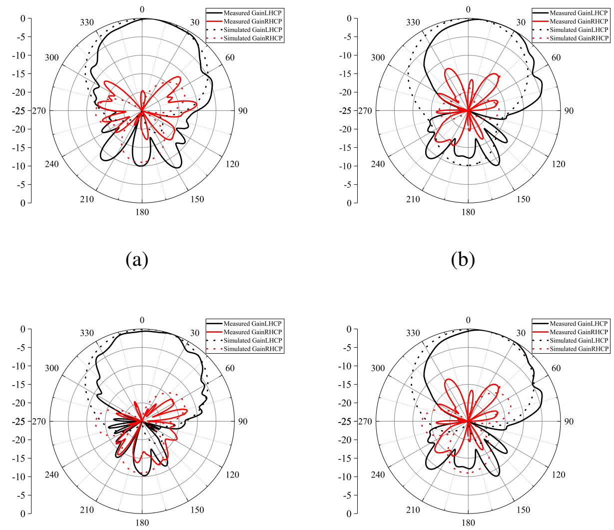
(a) (b)

Fig. 3. Measured and simulated (a) AR, (b) $|S_{11}|$ and Realized Gain.

cy range is 2.0-3.6 GHz, while the simulated bandwidth is 2.0-3.5 GHz. Obviously, the simulated AR is in good agreement with the measured AR for the proposed antenna. The simulated and measured $|S_{11}|$ are shown in Fig. 3(b). The measured -10 dB $|S_{11}|$ bandwidth ranges from 2.3 to 3.8 GHz. Fig. 3(b) shows that the frequency range and resonance point of the measurement results are roughly the same as those of the simulation results. However, the reflection coefficient of the antenna prototype is significantly greater than the simulated value. The main reason is poor impedance matching caused by processing error. The measured and simulated gains are depicted in Fig. 3(b) , where the measured gain is in good agreement with simulated gain in the antenna working frequency band. The simulated and measured radiation patterns of the proposed antenna at 2.3 and 3.3 GHz in the case of $\varphi = 0°$ and $\varphi = 90°$ are illustrated in Fig. 4, respectively. Unidirectional radiation is well maintained in the working frequency band.The processing error makes the measured beam to tilt slightly.

IV. CONCLUSION

A compact conical two-arm spiral antenna is designed in this paper. A differential feeding network is designed and dedicated optimized to match the impedance of the radiating element and produce a phase difference of 180°. The proposed antenna has a working bandwidth of 44% from 2.3 to 3.6 GHz.



(a) (b) (c) (d)

Fig. 4. Simulated and measured radiation patterns at (a) 2.3 GHz, $\varphi = 0°$, (b) 2.3 GHz, $\varphi = 90°$, (c) 3.3 GHz $\varphi = 0°$ and (d) 3.3 GHz, $\varphi = 90°$.

Radiation features of the presented antenna including radiation patterns, gain, axial ratio, and $|S_{11}|$ were confirmed to have broadband characteristics, which makes it a strong competitor for drones and portable applications.

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