# An Ultra-Wideband Stacked Spiral-Helix Composite Antenna

Jiachun Jiang[1], Long Zhang[1], Ning Luo[1], Yejun He[1]*, Sai-Wai Wong[1], Xiao Zhang[1], Steven Gao[2]
[1]College of Electronics and Information Engineering, Shenzhen University, 518060, China
[2]School of Engineering and Digital Arts, University of Kent, UK
Email: 1810262089@email.szu.edu.cn, long.zhang@szu.edu.cn, ningluo2915@163.com, heyejun@126.com, wongsaiwai@ieee.org, xiao.zhang@szu.edu.cn, s.gao@kent.ac.uk

***Abstract*—This paper presents an ultra-wideband stacked spiral-helix antenna. The proposed antenna consists of two stacked Archimedean spirals and a pair of helix. By connecting the two stacked spirals to the ends of two helixes, the effective electrical length is increased, and thus the low-end cutoff frequency of the proposed antenna can be greatly decreased. By reasonably designing the height and number of turns of the helix, the helical antenna can operate in the axial mode. Since the proposed antenna is mainly radiated by the spiral at high frequency and mainly radiated by the helix at low frequency, the proposed antenna can obtain bidirectional radiation at high frequency range and unidirectional radiation at low frequency range. Simulated results show that the proposed antenna can achieve a 3-dB axial ratio bandwidth from 1.5 GHz to 20 GHz.**

***Index Terms*—Archimedean spiral antenna, helical antenna, stacked spiral, unidirectional radiation, wideband antenna.**

## I. Introduction

Archimedean spiral antennas are widely used in industry and military due to their ultra-wide bandwidths [1], [2]. However, the large diameter in excess of one wavelength obstructs their applications to ultra-wideband arrays.

In order to broaden the bandwidth (BW) of the spiral antennas without increasing its radius, various techniques have been reported. In [3], high-permittivity substrate was utilized to reduce the antenna size. Nevertheless, the BW was degraded and the surface wave was inevitably excited. In [4], the bandwidth of the equiangular spiral was improved by using parasitical metallic posts. In [5], a stacked spiral antenna was presented, where the vertical connection lowered down the cutoff frequency by a factor of 4. But the axial ratio (AR) of the stacked spiral deteriorated for frequencies higher than 950 MHz. In [6], a four-arm spiral-helix antenna was proposed, where the helix was used to improve the antenna performance in low frequency range. In [7], the bandwidth of the antenna was greatly improved by connecting the arms of adjacent spiral in a ring array. In [8], two arms of an Archimedean spiral antenna were extended on the profile and connected together at the end to elongate current path, which improved the bandwidth performance.

In this paper, a circularly polarized (CP) stacked spiral-helix composite antenna is presented. In order to lower down the cutoff frequency of the traditional Archimedean spiral antenna, two orthogonally polarized Archimedean spirals are connected by a pair of helixes. By doing this, the electrical length of the proposed antenna can be increased effectively without increasing the radius of the spiral. As a consequence, the lower limit of the operating frequency range can be greatly decreased. In addition, the helix can operate in the axial mode by reasonably choosing the height and number of turns. Since the proposed antenna is mainly radiated by the spiral at high frequency and mainly radiated by the helix at low frequency, the proposed antenna can obtain bidirectional radiation at high frequency range and unidirectional radiation at low frequency range.

## II. Antenna Configuration and Operating Principles

### A. Antenna Configuration

As shown in Fig. 1, the proposed antenna is mainly composed of four parts, the lower spiral, the upper spiral, a pair of helixes and a hollow cylinder substrate (see Fig.2c). The lower spiral is printed on the bottom side of the hollow cylinder substrate, where a source is located at the center of the lower spiral to feed the proposed antenna. The upper spiral is printed on the top side of the hollow cylinder substrate, where a 175 ohms RF resistor is loaded at the center of the upper spiral to decrease the reflected current in the low-frequency range. In order to elongate the electric current path, the end of the two spiral arms is connected by the two helices. The relative permittivity of the hollow cylinder substrate is 2.89, while the loss tangent is 0.02 and the thickness is 1 mm.

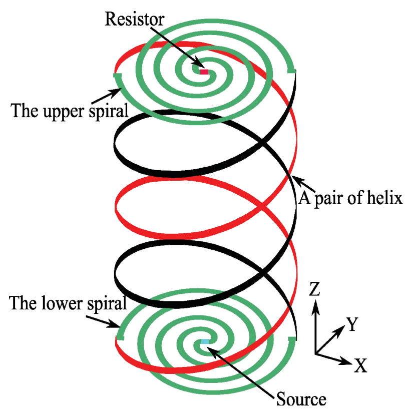


Fig. 1. Perspective view of the proposed antenna.

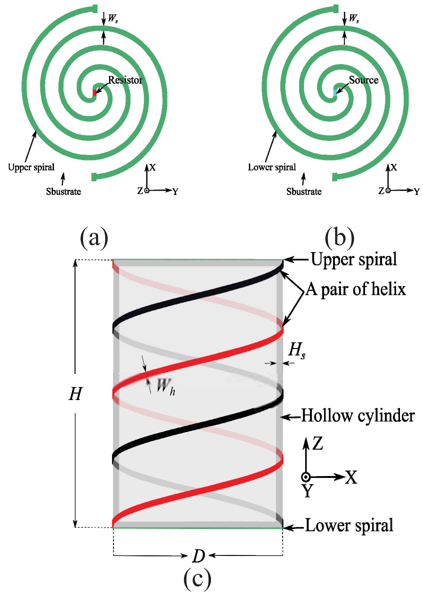


Fig. 2. (a) Top view of the proposed antenna; (b) Bottom view of the proposed antenna; (c) Side view of the proposed antenna.

TABLE I. ANTENNA DIMENSIONS (MM)

| Parameter | $H$ | $D$ | $H_s$ | $W_h$ | $W_s$ |
|---|---|---|---|---|---|
| Value (mm) | 40 | 28 | 1 | 1 | 0.8 |

Fig. 2 shows the top view, bottom view and the side view of the proposed antenna. As shown, the two spirals are wound in orthogonal directions, which makes the proposed antenna radiate right-hand circularly polarized (RHCP) wave in +Z direction and left-hand circularly polarized (LHCP) wave in -Z direction. Table I summarizes the detailed geometry dimensions of the proposed stacked spiral-helix composite antenna.

### *B. Operating principles*

For the traditional Archimedean spiral antenna, the low-end frequencies of operation are determined by the outer radius of the spiral. Therefore, the traditional Archimedean spiral antenna may not fulfill the dimension requirement in some cases, especially for the antenna array designs when several-octave bandwidth is demanded. In order to lower down the cutoff frequency of the traditional Archimedean spiral antenna without increasing its radius, the upper spiral and the lower spiral arm of the proposed antenna are connected by a pair of helixes. By doing this, the electric current can flow from the lower spiral to the helix and finally to the upper spiral, and thus the electrical length of the proposed antenna can be increased effectively. As a consequence, the low-end cutoff frequency of the proposed antenna can be greatly decreased. In addition, by reasonably designing the height and number of turns of the helix, the helix can operate in the axial mode. Since the proposed antenna is mainly radiated by the spiral at high frequency and mainly radiated by the helix at low frequency, the proposed antenna can obtain bidirectional radiation at high frequency range and unidirectional radiation at low frequency range.

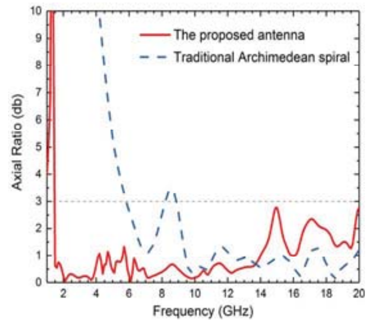


Fig. 3. Comparison of simulated AR between the traditional Archimedean spiral antenna and the proposed antenna.

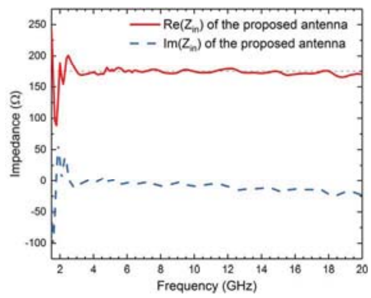


Fig. 4. The simulated input impedance of the proposed antenna

## III. SIMULATION RESULTS AND DISCUSSIONS

The simulated ARs of the proposed stacked antenna and the traditional Archimedean spiral antenna are depicted in Fig. 3. As shown, the proposed antenna can achieve a 3-dB AR bandwidth from 1.5 GHz to 20 GHz. Moreover, it is noticed that the low frequency limit of the traditional Archimedean spiral antenna is greatly decreased from 6 GHz to 1.5 GHz by connecting the two spirals with the helix. Simulated input impedance of the proposed antenna is plotted in Fig. 4, which demonstrates that the proposed antenna can achieve ultra-wide impedance bandwidth when it is fed by 175 ohms transmission line. Fig. 5 shows the simulated gain of the proposed antenna and the traditional Archimedean spiral antenna. It is noticed that the proposed antenna has a higher gain at low frequencies compared to the traditional Archimedes spiral antenna, which verifies that the proposed antenna is mainly radiated by the helix at low frequencies. The large variation of the gain with frequency is due to the excitation of the high-order mode of the helix at certain frequency points, which causes the maximum radiation direction of the proposed antenna deviating from the Z-axis direction.

Simulated normalized radiation patterns of the proposed antenna at 2, 2.5, 3 and 3.5 GHz are depicted in Fig. 6. As shown, unidirectional radiation patterns are achieved due to the fact that the proposed antenna is mainly radiated by the helix at these frequencies. Fig. 7 shows the simulated normalized radiation patterns of the proposed antenna at 9.5, 10.5, 11.5, 12.5, 13.5, and 14.5GHz. As shown, the proposed antenna can obtain bidirectional radiations at high frequencies, which is attributed to the radiation by the spirals at high frequencies.

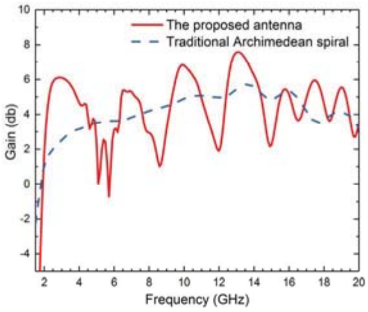


Fig. 5. Simulated gain of the traditional Archimedean spiral antenna and the proposed antenna.

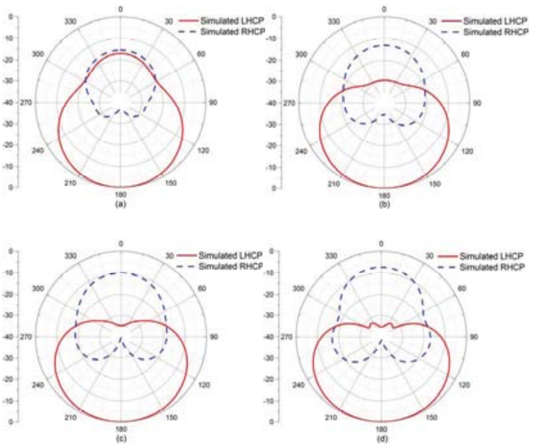


Fig. 6. Simulated normalized radiation patterns of the proposed antenna. (a) 2 GHz yoz plane; (b) 2.5GHz yoz plane; (c) 3GHz yoz plane (d) 3.5GHz yoz plane.

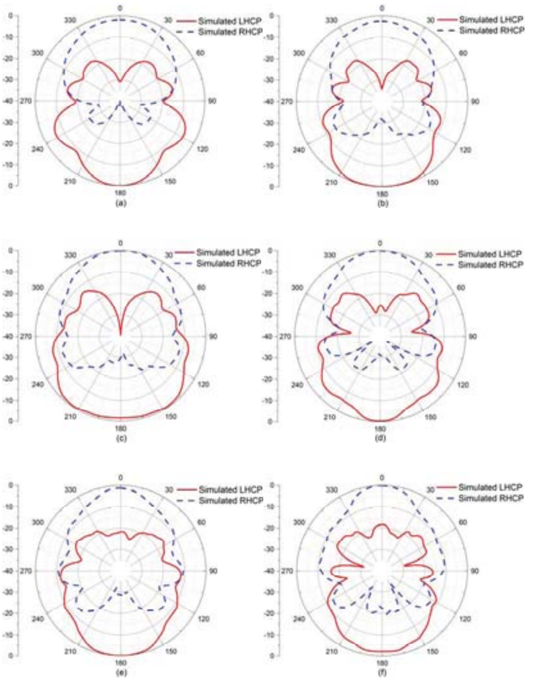


Fig. 7. Simulated normalized radiation patterns of the proposed antenna. (a) 9.5 GHz yoz plane; (b) 10.5GHz yoz plane; (c) 11.5GHz yoz plane (d) 12.5GHz yoz plane; (e) 13.5GHz yoz plane; (f) 14.5GHz yoz plane.

## IV. CONCLUSION

In this paper, a stacked spiral-helix composite antenna is presented. Compared with the traditional Archimedean spiral antennas, the effective electrical length of the proposed antenna is greatly increased, and thus the low-end cutoff frequency of the proposed antenna can be greatly decreased. Reasonably designing the height and number of turns of the helix makes the helix operate in the axial mode. By combing the radiation from the spiral and helix appropriately, bidirectional radiation at high frequencies and unidirectional radiation at low frequencies can be obtained. Simulated results show that the proposed antenna can achieve excellent AR performance from 1.5 GHz to 20 GHz. Compared to the traditional Archimedean spiral antenna, the proposed antenna can lower down the cutoff frequency by a factor of 4. With its compact size and ultra-wide bandwidth, the proposed antenna is suitable for various applications where ultra-bandwidth is required.

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