Compact helical antenna with small ground fed by spiral-shaped microstrip line

Longsheng Liu, Yue Li, Zhijun Zhang and Zhenghe Feng

A compact helical antenna with a small ground is proposed for 5.2/5.8 GHz WLAN applications. The proposed antenna can be easily mounted in the space-limited systems. Good impedance matching is achieved by a spiral-shaped microstrip line feed structure. Relatively uniform current along the helix is observed owing to the travelling-wave current on the feed structure, which contributes to high-gain performance even with a small ground. The measured 3 dB axial ratio bandwidth and impedance bandwidth for $S_{11} \leq -10$ dB overlap over 5–6 GHz, whereas the realised gain of about 13–14 dBic is achieved over the 5.2/5.8 GHz WLAN band.

Introduction: Circularly polarised (CP) antennas are attractive for WLAN, WiMAX, and in the fields of navigation and satellites [1]. Circular polarisation is less sensitive to the respective orientations between transmitters and receivers; meanwhile, it provides a better immunity over a multipath fading channel [2].

The axial-mode helical antenna is an attractive candidate for CP applications [3]. It has good CP performance and desired radiation pattern over a wide bandwidth, which benefits from the travelling-wave propagation property of the antenna shape.

In the past decades, there has been extensive literature on improving the gain of helix antennas [4–7]. The gain of a helical antenna was increased by 1 dB using a parasitic helix as a director [4]. In [5], a helical antenna was proposed with a cylindrical ring as a director which enhanced the gain by 3.8 dB. The gains of the helical antenna were boosted by modifying the ground into a cylindrical cup [6] or a conical shape [7].

Most of the grounds in [4–7] are larger than 1λ, which is not practical for some portable applications with a finite-sized ground. However, the implementation of a helical antenna with a small ground is still very limited. The impedance characteristic and radiation property of the helical antenna deteriorate when the size of the ground plane decreases. To reduce the size of the ground used in the helical antenna, a 10-turn axial-mode helical antenna with two loops, instead of the conventional ground plane, was proposed in [8]. The authors recently presented a helical antenna with a small ground capacitively coupled by a driven patch and a parasitic patch [9].

In this Letter, a compact helical antenna with a small ground operating at the 5.2/5.8 GHz WLAN is proposed. It implements high gain with a wide axial ratio (AR) bandwidth and a good impedance matching by using a spiral-shaped microstrip line feed structure. High-frequency structure simulator software is used to optimise this antenna, and reasonable agreement between the measured and simulated results is achieved.

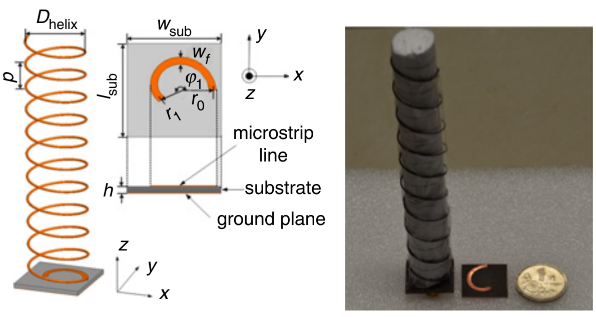


Fig. 1 *Configuration of proposed antenna*

a Geometries of proposed antenna ($w_{sub} = 23$, $l_{sub} = 23$, $h = 1.5$, $w_f = 1.6$, $r_0 = 9.5$, $r_1 = 3.8$, $D_{helix} = 20$, $p = 17$, $\varphi_1 = 216$, all values are in millimetres, except that φ_1 is in degrees)
b Photograph of proposed antenna

Antenna structure: As shown in Fig. 1*a*, the proposed helical antenna consists of a 10-turn left-hand helix and a spiral-shaped microstrip line in a clockwise direction (from the feed port to the terminal connected to the helix), which radiates a left-handed circular polarisation (LHCP) pattern. A right-handed circular polarisation (RHCP) pattern will be obtained by using a right-hand helix and a spiral-shaped microstrip line in a counterclockwise direction. The helix is made of an enamel-insulated copper wire with a diameter of 0.8 mm, whereas the spiral-shaped microstrip line is printed on a Teflon dielectric substrate with a relative permittivity of 2.65 and a loss tangent of 0.002.

Different from the traditional design with the ground plane about 1λ, the proposed antenna has a square ground of 23×23 mm^2 (only about $0.4\lambda \times 0.4\lambda$ at 5.2 GHz). The current along the helix in the traditional design decays exponentially near the input terminal, which can be explained as a transition between a helix-to-ground mode and a pure helix mode [10]. Travelling-wave current on the feed structure can be observed by using the spiral-shaped microstrip line. A relatively high gain even with a small ground is obtained owing to more uniform current distribution on the helix without exponential attenuation near the input end of the helix.

The influence of a spiral-shaped microstrip line on the performance of the proposed antenna is studied in Figs. 2 and 3. As can be seen, both φ_1 and w_f have great impact on the reflection coefficient, whereas the realised gain and AR are mainly dependent on the pitch length p and the diameter of the helix D_{helix}. Therefore, good impedance matching can be obtained by appropriately tuning the parameters of the spiral-shaped microstrip line: w_f, r_1 or φ_1 ($r_1 = (360 - \varphi_1)/360 \times r_0$).

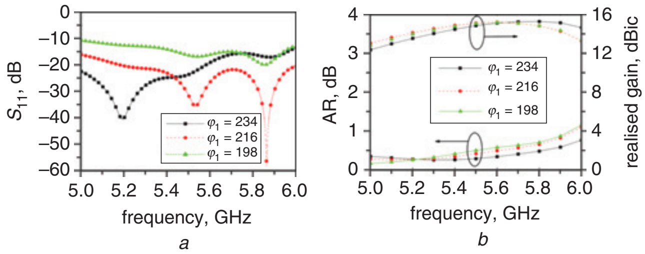


Fig. 2 *Simulated influence of φ_1*

a Reflection coefficient
b Realised gain and axial ratio

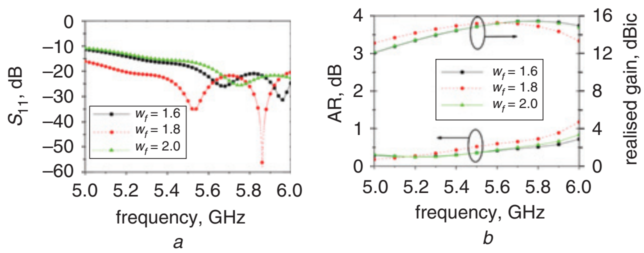


Fig. 3 *Simulated influence of w_f*

a Reflection coefficient
b Realised gain and axial ratio

Results and discussion: The proposed antenna has been fabricated (Fig. 1*b*) and tested. The reflection coefficients were measured by a vector network analyser, Agilent ENA E5071B, and the radiation patterns were performed in an ETS-Lindgren® anechoic chamber [11]. Simulated and measured results are given in Figs. 4 and 5. Reasonable agreement between them could be observed and the discrepancy may be attributed to the fabrication tolerance and measurement errors.

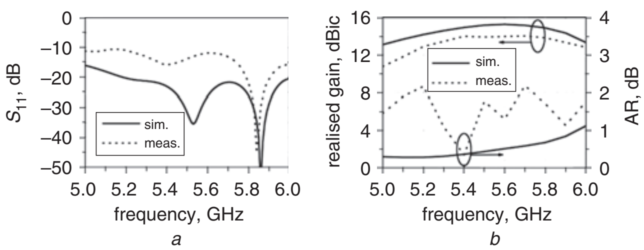
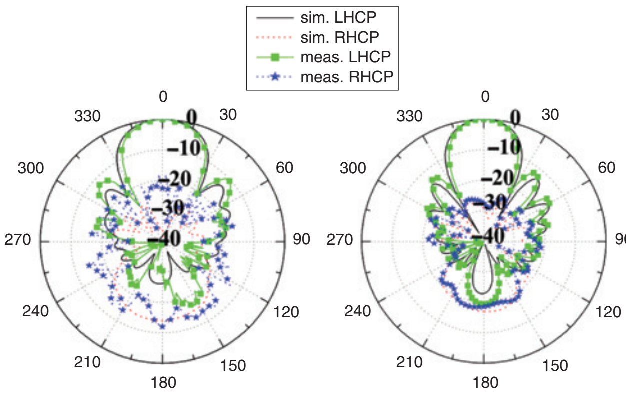


Fig. 4 *Simulated and measured results of proposed antenna*

a Reflection coefficient
b Realised gain and axial ratio



a *b*

Fig. 5 *Simulated and measured radiation patterns in xz-plane*
a 5.2 GHz
b 5.8 GHz

Fig. 4 shows the simulated and measured reflection coefficient, realised gain and AR. The 3 dB axial ratio bandwidth and impedance bandwidth for 10 dB return loss overlap over 5–6 GHz. The measured gain shown in Fig. 4*b* ranges from 13 to 14 dBic over the 5.2/5.8 GHz WLAN band.

Stable radiation patterns are observed over the whole operating frequency band. The simulated and measured co-polarisation (LHCP) and cross-polarisation (RHCP) patterns at 5.2 and 5.8 GHz in the *xz*-plane are illustrated in Fig. 5. The measured radiation patterns are unidirectional with a cross-polarised isolation of about 20 dB, and a front-to-back ratio better than 20 dB.

Conclusion: A compact helical antenna with a small ground for the 5.2/5.8 GHz WLAN is designed and tested. Good impedance matching and relatively high gain are achieved by using a spiral-shaped microstrip line feed structure. Based on the experimental results for the impedance and AR bandwidth, and the radiation characteristic, the proposed helical antenna is expected to be suitable for portable or space-limited applications.

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One or more of the Figures in this Letter are available in colour online.

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