An Ultra Wideband Printed Helical Antenna with Low Profile

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Abstract— This paper presents a compact ultra-wideband strip helical antenna with circular polarization. In order to achieve circular polarization and impedance matching with helix of 1.1 turns, the helix is made of uniform metallic strip instead of traditional metallic wire. Considering the convenience in manufacture, the uniform metallic strip is firstly printed on a substrate with $\varepsilon_r = 2.2$, $h = 0.5\,\mathrm{mm}$, then the substrate is rolled into the shape of cylinder such that a helix is formed. A $50\,\Omega$ coaxial cable is directly connected to the helix without an impedance matching section. The ground plane, which is printed on another substrate with $\varepsilon_r = 2.2$, $h = 3\,\mathrm{mm}$, is placed under the helix. To demonstrate this method, a 1.1-turns helical antenna is fabricated, measured and analyzed. Measured results show that the proposed antenna has an impedance bandwidth ($S_{11} \leq -10\,\mathrm{dB}$) of more than 70%, and an axial ratio (AR) bandwidth ($\mathrm{AR} \leq 3\,\mathrm{dB}$) of 55%. These wideband circular polarized (CP) characteristics indicate that the proposed antenna has a potential application in wide-band/multi-band wireless communications.

1. INTRODUCTION

The conventional cylindrical axial-mode helical antenna [1] is a good candidate for circle polarization applications due to its advantages such as high gain and wideband AR bandwidth. However, its large profile limits its applications in wireless communication terminals. A series of small and low profile cylindrical helical antennas are presented by H. Nakano [2, 3]. But these types of antennas have a narrow AR bandwidth and are difficult to impedance match with $50\,\Omega$ coaxial feed. In the last twenty years, H. T. Hui and his group introduce a type of hemispherical helical antenna [4–6]. Comparing with the conventional cylindrical helical antenna, the hemispherical helical antennas have much wider beamwidth for circular polarization. Nevertheless, their AR bandwidths are less than 15% and disable to satisfy the high data rate information transmission. Recently, a wideband hemispherical helical antenna has been reported [7]. Using a tapered metallic strip instead of wire, the hemispherical helical antenna in [7] has an AR bandwidth of 24%. However, it needs a section of impedance matching thus the antenna structure is complicated and difficult to be fabricated.

In this paper, a new type of cylindrical strip helical antenna with low profile and broadband operation for circular polarization is presented. Instead of traditional metallic wire, the proposed strip helical antenna is made of uniform metallic strip. As a result, a wideband AR bandwidth of 55% is obtained when the strip helix is only 1.1 turns. Moreover, an impedance bandwidth of 77%, which can completely cover the AR bandwidth, is achieved without an impedance matching section. To verify these good CP features, a prototype of the proposed strip helical antenna is fabricated and analyzed both numerically and experimentally. Simulated results are obtained using commercial software 'HFSS'.

2. ANTENNA STRUCTURE

The structure of the strip helical antenna is illustrated as in Fig. 1. It consists of a cylindrical helix and a circular ground plane. The cylindrical helix is made of metallic strip with uniform width (w). For convenience to fabrication, it is printed on Substrate A with ($\varepsilon_{r1} = 2.2$, $h_1 = 0.5\,\mathrm{mm}$). Then Substrate A is rolled into a hollow cylinder thus a strip helix is formed. The detail dimensions of the helix are as follows: D is the diameter of the helix, S is the spacing between turns (center-to-center), α is the pitch angle ($\alpha = \arctan(S/\pi D)$), L is the length of one turn, and n is the number of turns. The circular ground plane, which is printed on the bottom layer of substrate B ($\varepsilon_{r2} = 2.2$, $h_2 = 3\,\mathrm{mm}$), is placed below the helix for axial-mode operation. A $50\,\Omega$ SMA (diameter of $1\,\mathrm{mm}$) is attached to the bottom of the strip helix.

The proposed helix is made of uniform metallic strip, which is different from the conventional wire helix. This change offers advantages to both input impedance and radiation characteristics

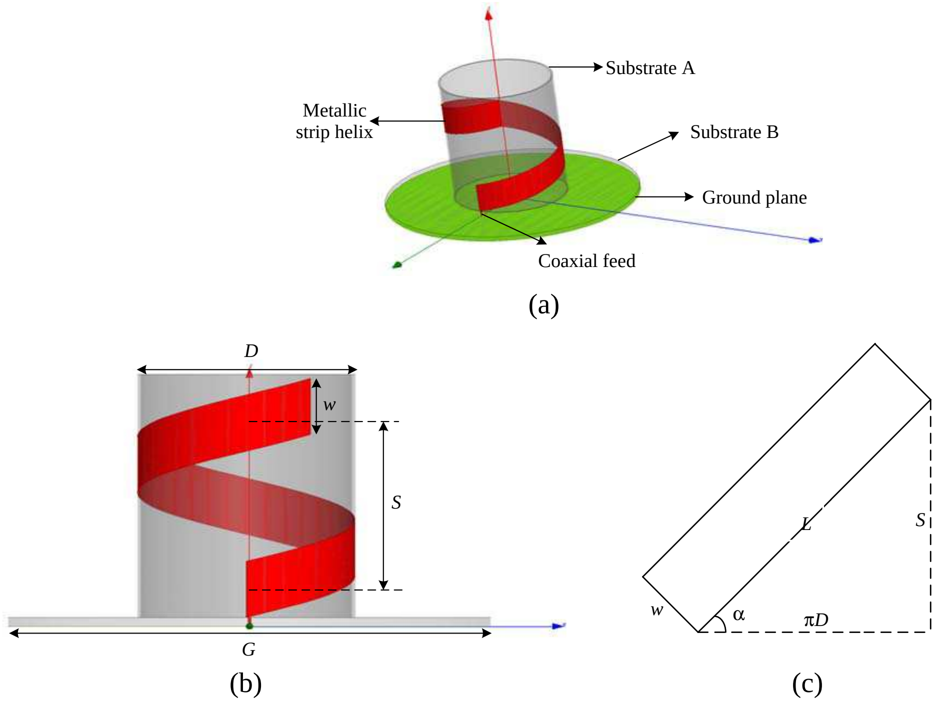

Figure 1: Geometry of the proposed antenna. (a) 3D view. (b) Side view. (c) Unrolled strip helix of one turn.

of the antenna. As is well known, a strip monopole has much more operation bandwidth than a wire monopole. Similarly, a strip helical antenna has much better impedance matching than a wire helical antenna. Particularly, the input impedance of the strip helical antenna almost keeps stable over an ultra wide frequency range. Thus, by tuning the width of the metallic strip, the strip helical antenna can reach a broadband impedance width. On the other hand, it is found that the strip helical antenna just needs around 1.1 turns to achieve axial radiation mode with circular polarization, while the conventional wire helical antenna needs at least 3 turns. Consequently, The strip helix can reduce the axial height of the antenna significantly.

3. SIMULATED AND MEASURED RESULTS

In order to demonstrate the good performance of the proposed strip helical antenna, a prototype is fabricated. The detail dimensions of the strip helix are as follows: $D = 72\,\text{mm}$, $w = 22\,\text{mm}$, $S = 65\,\text{mm}$, $\alpha = 16°$, $L = 235\,\text{mm}$, $n = 1.1$. The diameter of the circular ground plane (G) is 160 mm. Measurement is with the aid of the E5071C Network Analyzer and the Near Field Antenna Measurement System, Satimo. Measured results for reflect coefficient (S_{11}), axial ratio, gain, and radiation patterns are presented and compared with the corresponding simulated results.

The reflect coefficient (S_{11}) of the proposed strip helical antenna are depicted in Figure 2. Since the input impedance of the proposed strip helical antenna is stable and matching with 50 Ω across a large frequency range, ultra wideband impedance bandwidths are obtained. The simulated impedance bandwidths ($S_{11} \leq -10\,\text{dB}$) is more than 85% from 1.18 GHz to 3 GHz and beyond (we tested only between 1–3 GHz), while the measured impedance bandwidths is about 77% from 1.22 GHz to 2.76 GHz).

Figure 3 exhibits both the simulated and measured results for AR and gain in the axial direction of the helix. There is a good agreement between the simulated and measured results. From the AR curves, it is observed that the proposed strip helical antenna has simulated and measured AR bandwidths (AR $\leq$ 3 dB) are 56% (1.23–2.19 GHz) and 55% (1.25–2.2 GHz), respectively. The measured center operation frequency is 1.725 GHz. During the AR bandwidth, the simulated and measured peak gain is 8.5 dBic and 8 dBic, respectively. From 1.8 GHz to 2.2 GHz, both the simulated and measured gain decrease. It is because that the direction of maximum radiation is offset the axial direction with tilt angle τ in higher frequency band.

Figure 4 shows the simulated and measured radiation patterns at 1.725 GHz (radiation patterns at 1.25 GHz and 2.2 GHz are not shown for brevity). The proposed strip helical antenna is of right-

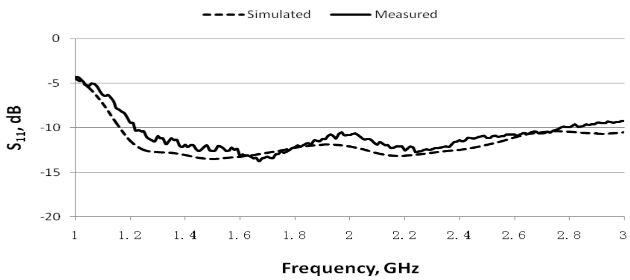

Figure 2: Reflection coefficient (S_{11}) against frequency of the proposed antenna.

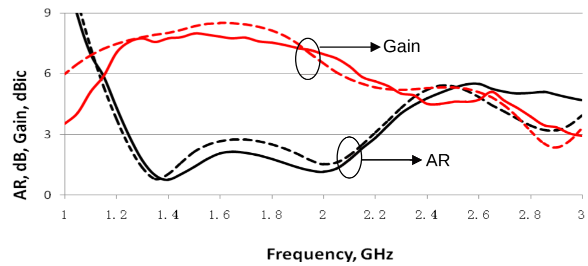

Figure 3: Axial ratio and gain against frequency of the proposed antenna. Solid line: measured data, dash line: simulated data.

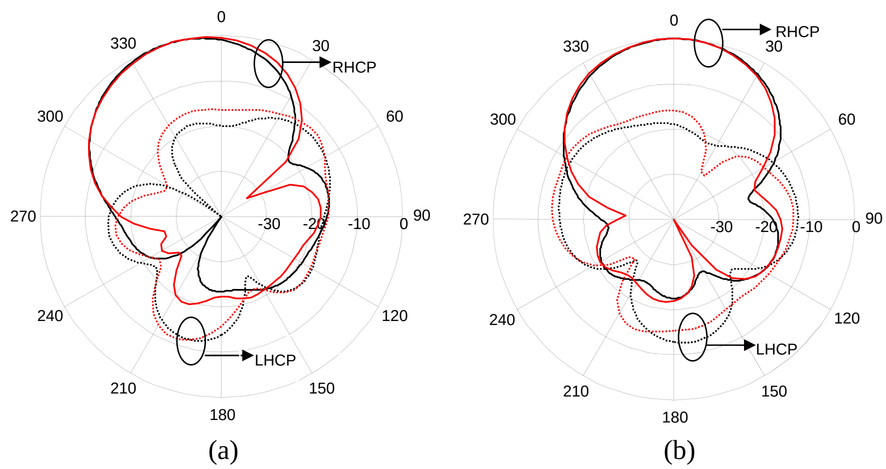

Figure 4: Radiation patterns of the proposed antenna at 1.725 GHz. (a) $\phi = 0°$ plane, (b) $\phi = 90°$ plane. Red line: measured data, black line: simulated data..

hand circular polarization (RHCP). The radiation patterns are symmetric about the axial direction at $\phi = 90°$ plane. While the maximum radiation is offset the axial direction with tilt angle $\tau = -16°$ at $\phi = 0°$ plane. In fact, in both the simulation and measurement, the radiation patterns are very symmetric in lower cutoff frequency, 1.25 GHz. As the operation frequency increases, the radiation patterns become more and more asymmetric. Since the pitch angle α is equal to $16°$ and not small, the asymmetry of the proposed antenna structure can not be neglected, especially in higher frequency band.

4. CONCLUSION

A new type of helical antenna with the use of uniform metallic strip is proposed for wideband circular polarization. Comparing with the conventional cylindrical helical antenna, the proposed strip helical antenna needs less turns helix to achieve broadband CP bandwidth of 55%. Furthermore, Its AR bandwidth is covered by a large impedance bandwidth, which reaches 77%. Due to these advantages, the proposed antenna has a potential application in high data rate wireless communication systems.

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