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A Folded Printed Quadrifilar Helical Antenna Employing a Compact Feeding Network

Ping Xu*, Zehong Yan, Xiaoqiang Yang, and Tianling Zhang

Abstract—A folded printed quadrifilar helical antenna (FPQHA) with an integrated and compact feeding network is proposed. The axial length of the proposed antenna is miniaturized of about 54.7% than the conventional PQHA by folding the helix arms into several elements. A T-junction power divider combining with two Wilkinson power dividers is utilized to feed the antenna. A fabricated prototype of the FPQHA using the compact feeding network is presented. The measured positive gain bandwidth covers 380–430 MHz with the reflection coefficient below −20 dB, axial ratio below 1.5 dB and a half-power beamwidth of about 120°. Details of the proposed antenna design and experimental results are presented and discussed.

1. INTRODUCTION

Circularly polarized antenna has been generally used in satellite communication systems due to their insensitivity to ionospheric polarization rotation [1–7]. In many applications such as mobile satellite communication and position-location, the systems require antennas exhibiting a good radiation performance with a wide beamwidth over the operating band.

The advantages of the hemispherical radiation pattern of the printed quadrifilar helical antennas (PQHA) are very attractive for satellite communications. However, in order to resonate at the require frequency with hemispherical radiation pattern, the axial length of conventional PQHA is too long to be integrated into the systems. Moreover, for feeding the four helix arms with equal power and 90° of phase shifting between adjacent ports, the conventional network is relatively large in size at low frequency [2]. And external or commercial feeding system providing almost ideal magnitude and phase shifting is not practical for antenna system [1, 4–7]. Therefore, PQHAs with a compact size employing a simple and compact feeding network are then required.

In this letter, a folded printed quadrifilar helical antenna (FPQHA) with integrated compact feeding network is presented. By proper folding the helix arms into several same elements, the axial length of FPQHA can be reduced by 54.7%. A dual-layer structure feeding network consisting of a T-junction power divider and two Wilkinson power dividers is designed to realize the equal division and 90° phase shifting.

2. ANTENNA CONFIGURATION AND DESIGN

Figure 1 shows the configuration of the proposed FPQHA, which is printed on a thin FR4 substrate with thickness of 0.2 mm, a relative permittivity of 4.5 and a loss tangent of 0.02. The four helix arms are wrapped around a cylindrical support and mounted on a small ground plane. Each helix arm is composed of several same helix elements. The helix element consists of four segments with a width of W, a pitch of P and turn numbers of $Turn_1$ and $Turn_2$, as shown in Fig. 1(a). By proper folding the

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* Corresponding author: Ping Xu (pingxu@mail.xidian.edu.cn).
The authors are with the National Key Laboratory of Science and Technology on Antennas and Microwaves, Xidian University, Xi'an, Shaanxi 710071, China.

helix arms, the antenna can resonate at a much lower frequency than the conventional PQHA with equal axial length. The axial length of the proposed PQHA has been reduced by 54.7% from a conventional PQHA.

Simulated results of the proposed FPQHA are shown in Fig. 2. It can be seen that the −10 dB reflection coefficient bandwidth covers 370–393 MHz (about 6%). The gain varies between 3.3 dBic and 4.2 dBic over the same impedance band with the maximum gain of 4.2 dBic at 385 MHz. Simulated normalized radiation patterns at 385 MHz are presented in Fig. 2(b). As can be found, a wide half-power beamwidth of about 120° can be obtained.

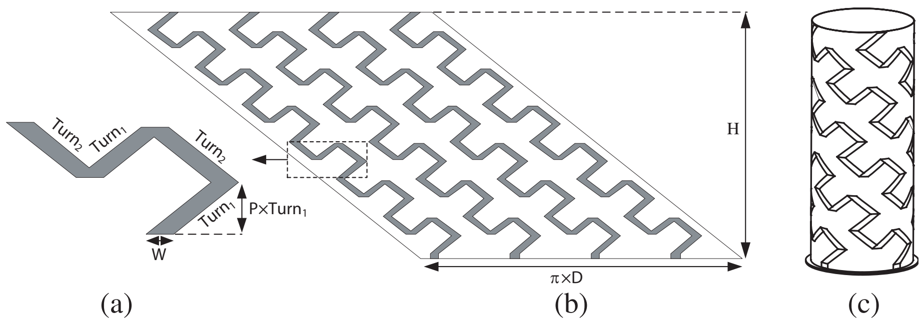

Figure 1. Configuration of the proposed FPQHA: (a) the helix element; (b) the unwrapped antenna; (c) the proposed antenna. ($H = 240.75$ mm, $D = 100$ mm, $P = 690$ mm, $W = 9$ mm, $Turn_1 = 0.067$, $Turn_2 = 0.073$).

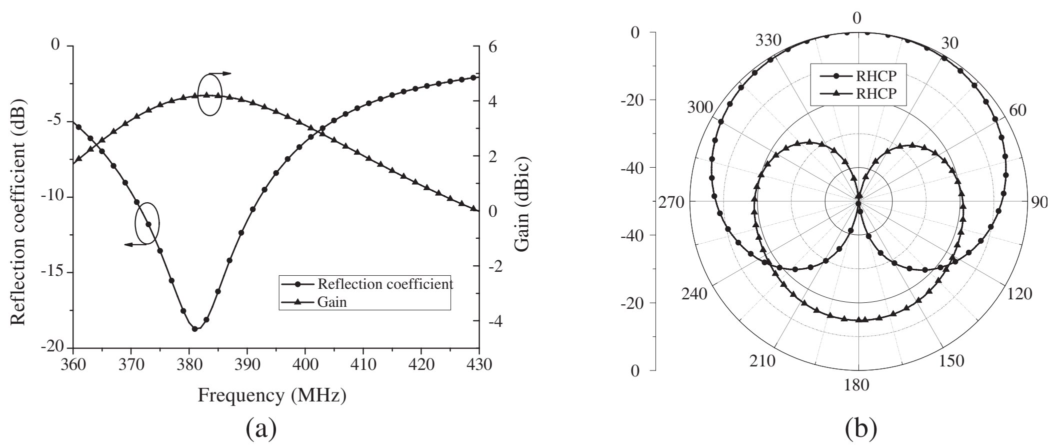

Figure 2. Simulated results of the proposed FPQHA fed with ideal amplitude and phase: (a) reflection coefficient and gain; (b) normalized radiation patterns at 385 MHz.

3. THE COMPACT FEEDING NETWORK

Figure 3 shows the geometry of the proposed compact feeding network. The dual-layer feeding network composed of a T-junction and two Wilkinson power dividers is printed on two FR4 substrates with thickness of 0.8 mm. By a T-junction power divider, the input can be divided into two identical and equal signals. A half-wavelength microstrip line is used to realize the 180° out of phase of the two signals. Then a Wilkinson power divider is connected at the top and bottom layers to achieve equal division, respectively. By adjusting the length of the end microstrip lines to about quarter-wavelength difference between adjacent ports, 90° phase shifting can be obtained.

The mid layer is the ground plane. Via pins are used to transmit the signal at the bottom layer to the top layer for feeding the helix elements. During the fabrication, rivets were used to reinforce the dual-layer structure in case binding.

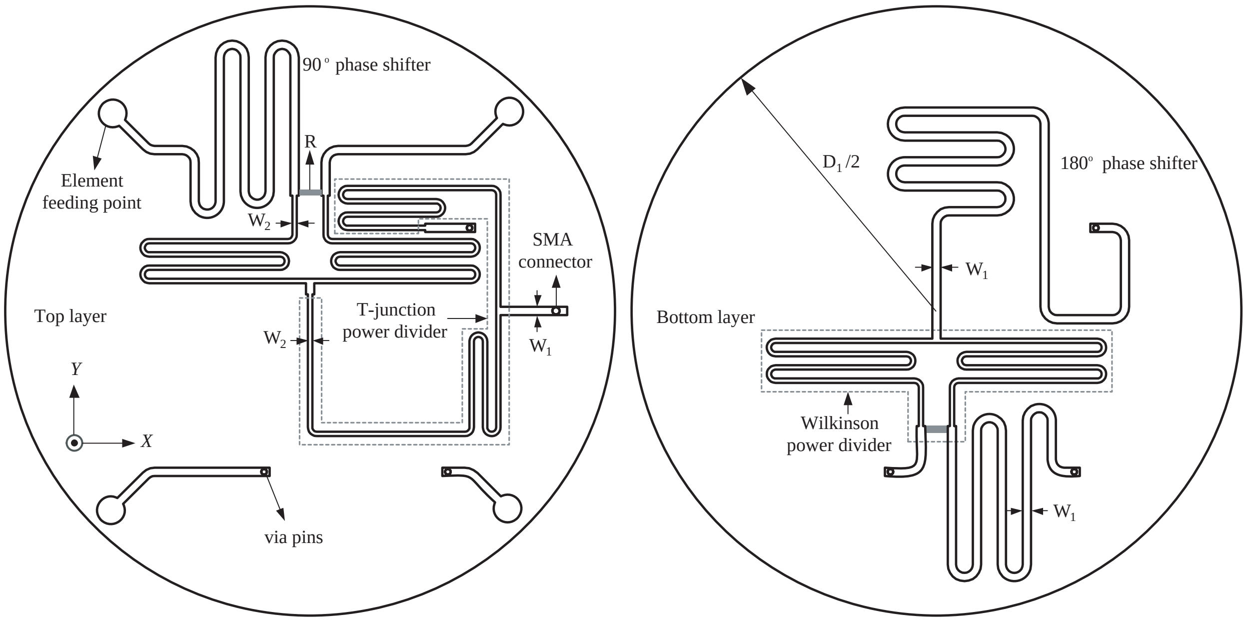

Figure 3. Geometry of the compact feeding network. ($R = 100\,\Omega$; $D_1 = 110\,\text{mm}$, $W_1 = 4.2\,\text{mm}$, $W_2 = 2.3\,\text{mm}$).

4. PERFORMANCE OF THE ANTENNA

Figure 4 presents the fabricated prototype of the FPQHA integrated with the proposed feeding network. Commercial simulation software Ansoft HFSS was utilized in the design procedure. The reflection coefficient was obtained using an Agilent E5071B vector network analyzer and the radiation performances were measured in a far-field measurement system.

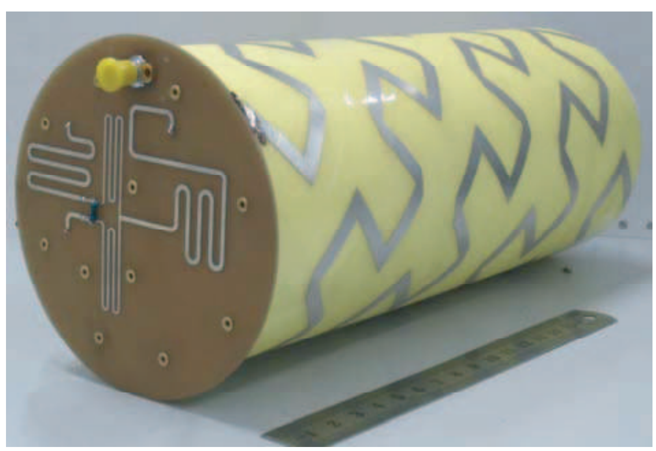

Figure 4. Fabricated antenna prototype.

Measured results of the proposed antenna fed by the compact feeding network are shown in Fig. 5. It is observed that the positive gain bandwidth covers from 380 MHz to 430 MHz with a reflection coefficient lower than -20 dB and an axial ratio below 1.5 dB. It can be seen that there is a movement of resonant point, which is mainly due to the unsteady substrate parameters of FR4 substrate. Normalized radiation patterns at 395 MHz of the proposed antenna are shown in Fig. 5(c). The discrepancy between simulated and measured radiation patterns is mainly due to the test environment. It is noted that a wide

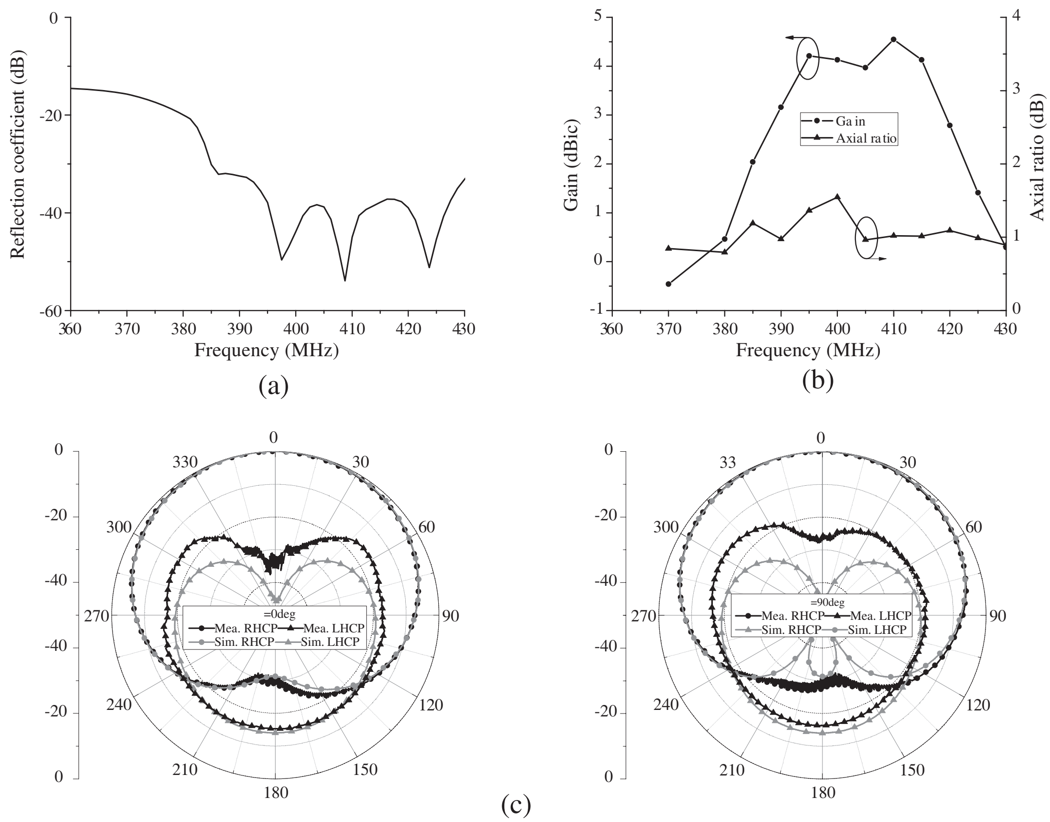

Figure 5. Measured results of the FPQHA fed by the proposed feeding network: (a) reflection coefficient; (b) gain and axial ratio; (c) normalized radiation patterns at 395 MHz.

Table 1. Comparison of the dimensions and radiation performances between the proposed FPQHA and antennas in the references.

Ref.	Axial length	Impedance bandwidth	Peak gain (dBic)	3-dB beamwidth (deg)	Feeding network
[1]	$0.574\lambda_0$	29% ($S_{11} < -12$ dB)	~ 2.7	150	Integrated
[3]	$0.47\lambda_0$	8.5% (VSWR < 1.5)	~ 3	120	Integrated
Proposed	$0.312\lambda_0$	16.4% ($S_{11} < -20$ dB)	4.5	120	Integrated

half-power beamwidth of about 120° can be obtained. Table 1 shows a comparison between the proposed FPQHA and the antennas presented in the references. It is observed that the proposed FPQHA fed by the compact feeding network has a good radiation performance with a compact size.

5. CONCLUSION

A folded printed quadrifilar helical antenna fed by a compact feeding network is presented. By proper folding helix arms, the axial length of the antenna can be reduced by 54.7%. A dual-layer feeding network composed of a T-junction phase power divider and two Wilkinson power dividers is presented. With compact size, the feeding network can be well integrated with the proposed antenna. Measured gain bandwidth with positive value covers 380–430 MHz with a reflection coefficient less than −20 dB, an axial ratio below 1.5 dB and a half-power beamwidth of about 120°.

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