A Novel Dual-frequency Quadrifilar Helix Antenna in GPS/BD Applications

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Abstract-The resonant quadrifilar helix antennas have been widely applied to space communication links due to its relatively small volume and wide beam elevation pattern coverage over the upper hemisphere. According to the requirements of GPS and BD receiving antenna, a dual-frequency enclosed antenna is designed in this paper with two 3/4 wavelength quadrifilar helix antennas and a novel feed structure combined feed network with infinite microstrip balun. The feed structure provides excellent phase performance and better impedance match, which make the antenna achieve wider angle circular polarization. The actual antenna is simulated by Ansoft HFSS software based on the finite element method. The simulation results have well agreement to the measured data.

Ⅰ. Introduction

As the antenna of satellite or ground base station, wide beam, circular polarization antennas have been widely applied to spaces communication such as conical spiral antenna, bifilar helices antenna, microstrip antenna, quadrafilar helix antenna. The quadrifilar helix antenna (QHA) was invented by C.C. Kilgus in 1968. It can provide different radiation patterns by the proper choice of helical parameters adjusting to the requirement of space communication and possible small size [1-3]. So a QHA has gained considerable attention. But, it is a resonant antenna. Its band is inherently too narrow to accommodate both GPS frequency f1 and BD frequency f2. Dual-band operation of a QHA is achieved through incorporation of two antennas into one structure by coaxially mounting them in either a “piggyback” or enclosed fashion [4]. In this paper, an enclose 3/4 wavelength QHA operated at both f1 and f2 is designed. With a novel feed structure combined feed network with infinite microstrip balun, the antenna gains excellent dual-frequency operation for satellite communication. At the operating frequencies: VSWR＜1.5, 5° elevation above Gain＞－1.5dBi, HPBWE＞155°，10° elevation above AR ＜5dBi.. The actual antenna is simulated by Ansoft HFSS software based on the finite element method. Reasonably good agreements between the simulation and measured results are obtained.

Ⅱ.Antenna Design

A. QHA Structure

The quadrifilar helix antenna[2], consisting of four tape helices equally spaced circumferentially on a cylinder and fed with equal amplitude with phases of 0º, 90º, 180ºand 270º is shown in Fig.1 in which Lax is the length along the axis of the helix and r is the radius in wavelengths. Each tape helix size is $M\lambda/4$ where M is any integer number, and the non-feed end of tape helices are open when M is any odd number or short when M is any even number. Quadrifilar helix can be considered as the combination with two bifilar helices concentric with orthogonal radials and fed in phase.

However, the quadrifilar helix is a resonant element. It is too narrow band to accommodate both f1 and f2 .We can achieve dual band operation through the incorporation of two antennas into one structure by coaxially mounting them in either a “piggyback” (G atop B) or enclosed fashion (G inside B), as shown in Fig 2 .

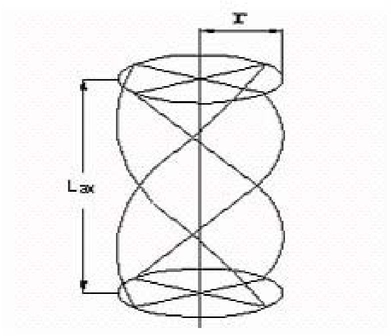

Fig. 1. Geometry of the qudrifilar helix antenna

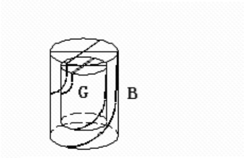

Fig. 2. (a) enclosed fashion (G inside B)

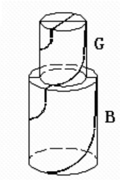

Fig. 2. (b) "piggyback" fashion (G atop B)

For the enclosed volute design neither G nor B performance is as good as with the single volute. Their gains reduce about 3.5 and 1.5 dB, respectively, and their backlobe levels at f1 and f2 have a slight increase. For the coaxial "piggyback" arrangement, performance of G and B also become poorer, their backlobe and phase center fluctuations are increased. In particular, the amplitude and phase response of G deteriorates significantly at low elevation angles [4]. So it becomes difficult for the compound antenna to satisfy dual frequency operation.

An enclosed 3/4 wavelength QHA is proposed in this paper, as shown in Fig.3, each of the four arms of antennas G and B has 3/4 turns, the top end is open and the feed point is at the other end. The twist of the helix is in left-hand. By changing the length and width of ΔL, circular polarization of G can be improved; For B, the lengths of the arms are the same. At the feed point, the arms of G and B are across within the axis angle of 45º, which weakens their coupling, therefore, decreases interaction between G and B. We can obtain required shaped radiation patterns and good circular polarization property at low elevation angles by changing the Lax-to-r ratio.

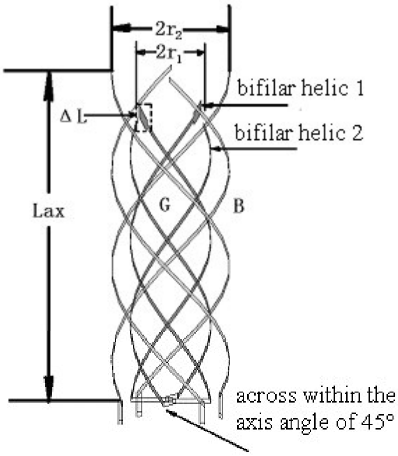

Fig.3. Geometry of the enclosed 3/4 wavelength QHA

B. QHA Feed Structure

To achieve the 90 phase relationship between bifilar helices, the feed structure can be a feed network such as a hybrid coupler or self-phase structure [2]. With self-phase structure the antenna has a compact configuration and better phase quadrature properties. In this paper, we use a feed structure combined feed network with infinite microstrip balun to provide excellent phase performance.

The feed structure of QHA G is self-phase structure, we use 1/4 wavelength infinite microstrip balun [5] to feed the antenna as shown in fig.4. This type of feed balun is a good choice to achieve the transition of microstrip line into parallel wire with imbalanced feeding transformed to balance.

The feed structure of QHA B is the feed network as shown in Fig.4, three Wilkinson power dividers are used. The two output feed lines of each power divider have a length difference of one-quarter wavelength, which makes the power divider produce two equal output powers with a 90 phase shift. In this case, the feed points 1, 2, 3 and 4 have equal output powers and phase shifts of 0 , 90, 180 and 270 degrees, respectively.

With 1/4 wavelength infinite microstrip balun through the center of the feed network, the antenna has an impact structure and less interaction.

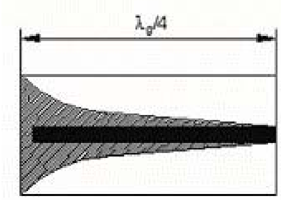

Fig.4(a) 1/4 wavelength infinite microstrip balun

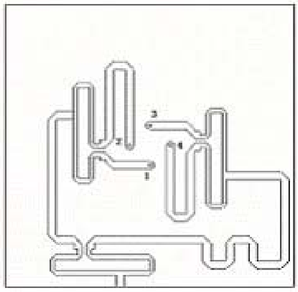

Fig.4(b) feed network

Ⅲ. Simulation and Measurement

The proposed antenna is simulated by Ansoft HFSS software based on the finite element method, and then by optimizing we obtain the proper antenna size which is given by

G: N=3/4, L= $3\lambda_1/4$, Lax=0.55 λ_1, r=0.062 λ_1 ΔL=0.06 λ_1

B: N=3/4, L= $3\lambda_2/4$, Lax=0.54 λ_2, r=0.072 λ_2

where N is number of turns and L is length of turn.

The antenna is measured by 128 Multi-probes Spherical Near Field Measure System. The measured data with comparison to the requirements of dual-frequency antenna is shown in table 1, we can see that the antenna is suitable for dual –frequency operation of space communication and has good gain and circular polarization performance in low elevation angles. Fig.5 (a) and Fig.5 (b) show the simulation and measurement radiation patterns for the antenna at the f1 and f2, respectively. Measurement results have a good agreement with simulation results. Fig.6 shows the measurement axial ratio for the antenna at f1 and f2 frequencies.

Ⅳ. Summary

The enclosed quadrifilar helix antenna has been investigated for suitability in GPS and BD applications. Compared with other wide-beam, circular polarization and dual-frequency antennas, the proposed antenna is prefer to suite for the requirements of space communication due to it's excellent circular polarization performance at low elevation angles. The feed structure of the antenna has better phase performance and impedance match, which make the antenna achieve wider angle circular polarization and have a compact and high integration structure. The actual antenna is simulated by Ansoft HFSS software and measured. The simulation results have a good agreement with the measured data.

References

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Table 1

Project	**Criterion date**	**Measured date**
Frequency	GPS～f1/BD～f2	Satisfied
Polarization	Right-hand	Satisfied
Gain	≥0dBi（elevation20°～90°）	≥0dBi（elevation 20°～90°） at f1 ≥0.5dBi（elevation 20°～90°） at f2
	≥－3dBi（elevation 5°～20°）	≥－1.5dBi（elevation 5°～20°） at f1 ≥－1dBi（elevation 5°～20°） at f2

Axial ratio	≤6dBi（elevation 10°above）	≤3dBi（elevation 5°～20°） at f1 ≤5dBi（elevation 20°～90°） ≤3dBi（elevation 10°above） at f2
VSWR	≤1.5	Satisfied

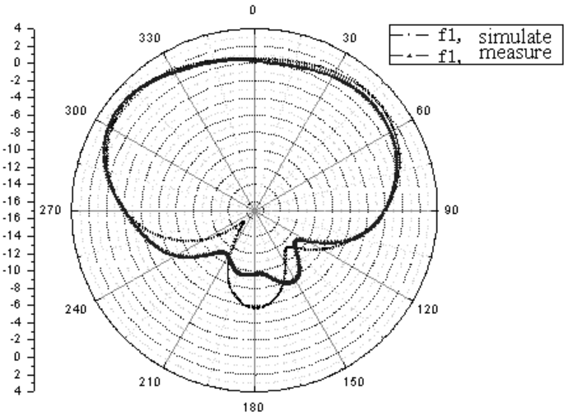

Fig.5(a) Simulated and measurement radiation patterns for the antenna at the f1 frequency

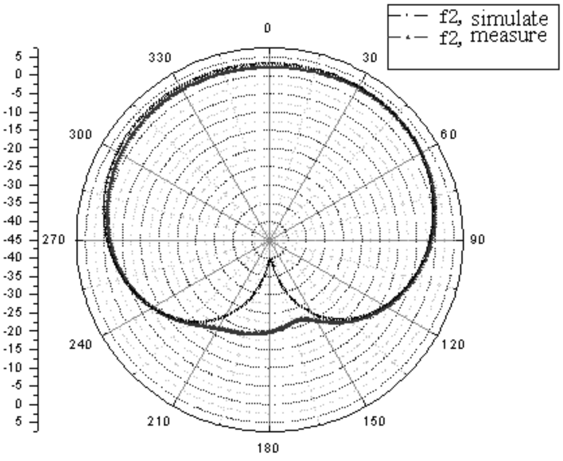

Fig.5(b) Simulated and measurment radiation patterns for the antenna at the f2 frequency

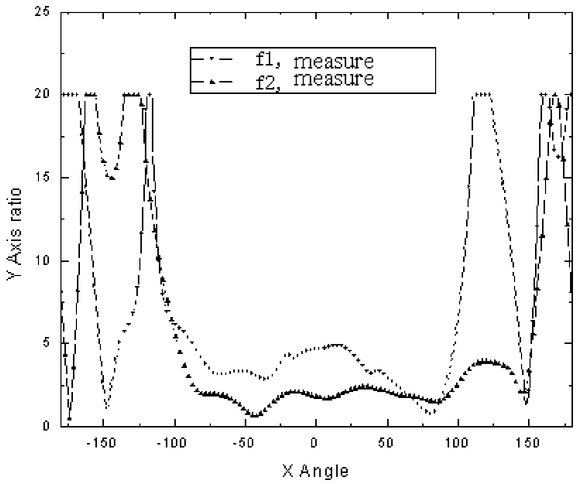

Fig.6 Measurement axial ratio for the antenna at f1 and f2 frequencies