The Design of Shaped-Beam Bifilar Helix Antenna with Conical Pattern

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Abstract. A shaped-beam antenna is proposed using bifilar helix antenna. The antenna is fed by a notched balancer. The radiation pattern and the axial ratio changing with the helix pitch distance are simulated in the paper. The measured gain and |S11| are also given. The antenna has a wide bandwidth of more than 40% with conical radiation pattern and circular polarization. It can be used in outer space communications due to its low profile and high reliability.

Keywords: helix antenna, bifilar helix antenna, shaped-beam, impedance match.

1 Introduction

The circular polarization antenna has been widely used for its inherent performance with the development of wireless communication, measurements and electronic reconnaissance. A number of novel circular polarization antennas have been invented in these years [1-6]. Among these antennas, helix antennas with double or quad filar are of the most popular ones used in satellite measurement and control system [1-4].

There are mainly two types of radiation pattern of helix antennas, axial mode and normal mode. The axial mode helix antenna has a heart-shaped pattern and is the most widely used one. The normal mode helix antenna has a radiation pattern vertical to its axis as dipole antenna.

In this paper, a bifilar helix antenna with circular polarization is proposed. The beam of the proposed antenna can be shaped with conical pattern. The radiation energy of the antenna is concentrated into a cone. Therefore, the radiation pattern can be shaped for particular use in the out space. The proposed antenna is of fast-wave mode type.

The shaped-beam antenna is becoming more and more favorite in the application of the satellite-to-satellite and satellite-to-earth communications. By use of this kind of antenna, the amplitude of the signal can be kept relatively stable for the needed radiation range, and the coverage range of the antenna can be enlarged efficiently.

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2 Antenna Design

2.1 Design of the Bifilar Helix Antenna

The main parameters of the helix are defined as following :

D: diameter of the helix,
p: pitch distance of the helix,
n: number of the turns,
$l=n\times p$: length along the axis.
θ_m: the maximum radiation direction of the pattern.

The antenna presented in this paper is a fast-wave mode helix antenna. The radiation beam of the antenna is opposite to the direction of the feeding current. The radiation pattern of the bifilar helix antenna is mainly determined by the ratios of D/λ and p/λ. By tuning the parameters of helix pitch distance and diameter, the maximum radiation angle can change from the axial direction to the normal direction. Therefore the radiation pattern can be shaped as conical shape. The conical pattern of bifilar helix antenna is introduced by the complex propagation constant which can be written as [7]:

$$\beta = \beta_r + \beta_i \tag{1}$$

where β_r is the real part of the propagation constant. And the propagation factor is:

$$e^{-j\beta z} = e^{-j\beta_i z} e^{-j\beta_r z} \tag{2}$$

When this kind of wave is excited, the angle of the maximum radiation direction is approximated as

$$\theta_m = \cos^{-1}(\beta_r / k) \tag{3}$$

The eigen value equation can be obtained from the boundary conditions. And the propagation constant and radiation field can be solved from the equation. It is not so easy to get the antenna's pattern from the equation. After all, some simulation software can help us to optimize the antenna to satisfy the required radiation performance.

2.2 Feeding of the Bifilar Helix Antenna

Compared with the quadrifilar helix antenna, the bifilar helix antenna is more compact in size, and easier to feed [4]. The feeding point is at the top, the two arm of the antenna is feed out of phase.

A balancer is adopted when using coaxial cable to feed the antenna. As shown in Fig. 1, a slot is cut along the outer conductor of the coaxial transmission line. One arm of the helix is connected with the inner conductor, and the other is connected with the outer conductor. Compared with the typical balancer, the outer conductor is turned about 45 degree around the axial to get better impedance match and wider bandwidth.

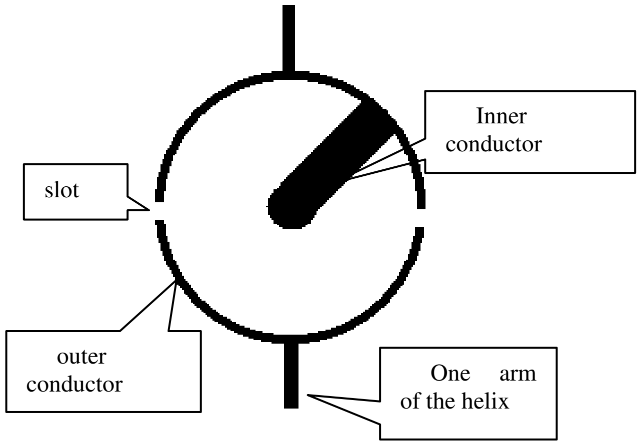

Fig. 1. Notched balancer

3 Simulation and Measurement

Considering the special environment in the outer space, the selection of the material of the bifilar helix antenna is quite important during the design. The radiation part of the antenna is supported by a kind of insulated material with permittivity of 3 or so. The thickness of the support can be as thin as possible if it is strong enough. The feeding point is located at the top of the antenna. The terminals of the two helixes can be released as free or connected together with the ground due to less current flowing along the terminal of the radiation part.

The antenna has a conical pattern. Its gain and beam shape is decided by the turn numbers of the helixes. It is easier to get shaped beam with more helix turns, whereas the reliability of the structure need be considered with more turns. The turn number of each helix is chosen as 4 in this case.

The antenna is omni-directional in the azimuth plane and is shaped with conical pattern in the elevation plane. Fig. 2 shows the radiation patterns in the elevation plane with the variation of pitch distance of p when D=0.16λ. It is shown that the maximum direction of θ_m changes from 0° to 90° with the increase of p, and the beam width becomes narrower with the increase of the p. For the case of p=0.224λ, the antenna has a typical heart shape radiation pattern with θ_m=0°, and its 3dB beam-width covers -30°~+30°. For the case of p=0.425λ, θ_m =64°, its 3dB beam-width covers 45°~81°. For the case of p=0.62λ, θ_m=84°, its 3dB beam-width covers 74°~94°. The radiation pattern is close to the circularity radiation pattern.

Fig. 3 shows the simulated axial ratio of the antenna. It is shown that the axial ratio is better than 5dB within the 3dB beam width. The antenna has perfect circular polarization performance.

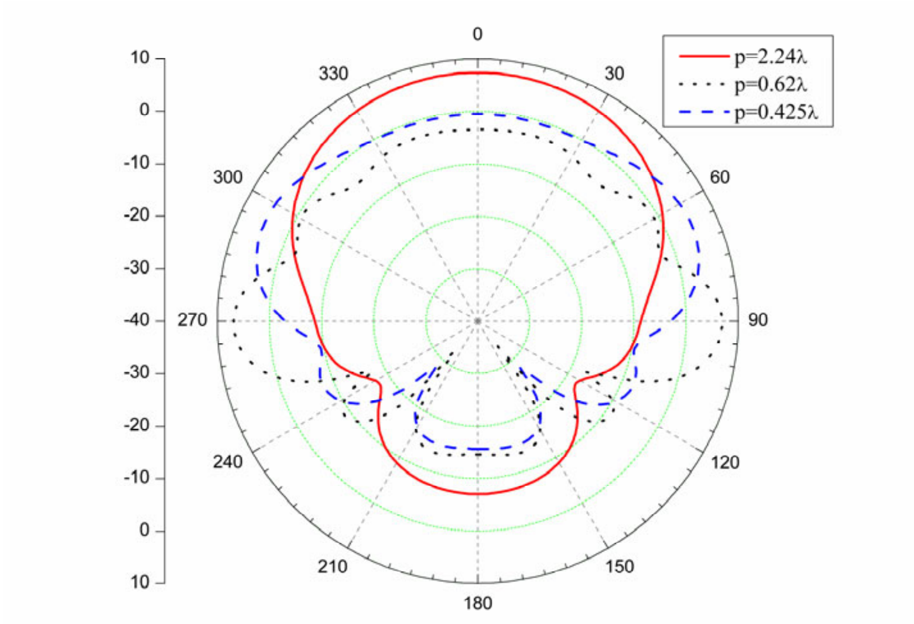

Fig. 2. Simulated radiation pattern of the bifilar helix antenna

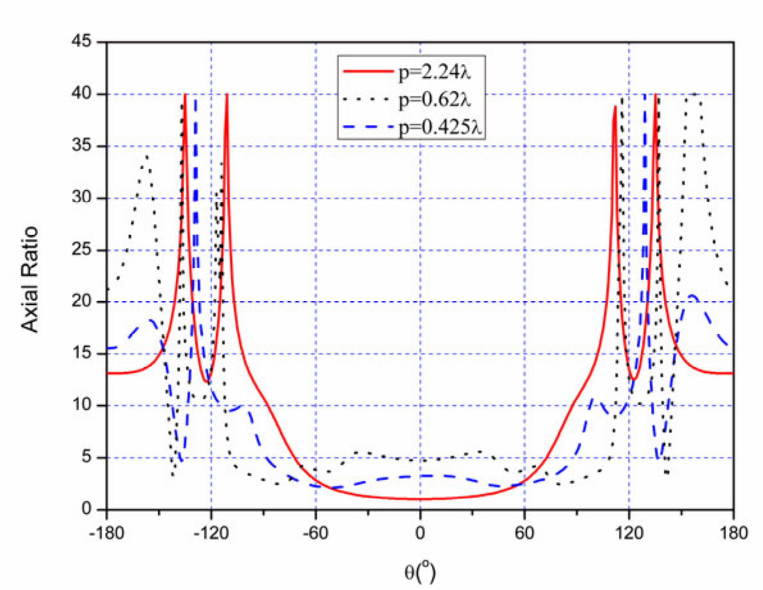

Fig. 3. Simulated axial ratio

With the notched balancer, the bandwidth is increased to more than 10 percent. This kind of back-fire antenna is less influenced by the mounting carrier, which act as the ground of the antenna, especially the main lobe. The back lobe will be decreased if the mounting carrier is made of metal material.

Fig. 4 shows the measured $|S_{11}|$. By tuning the feeding part of the helix antenna we can get a perfect match with the bandwidth of more than 40% of the center frequency.

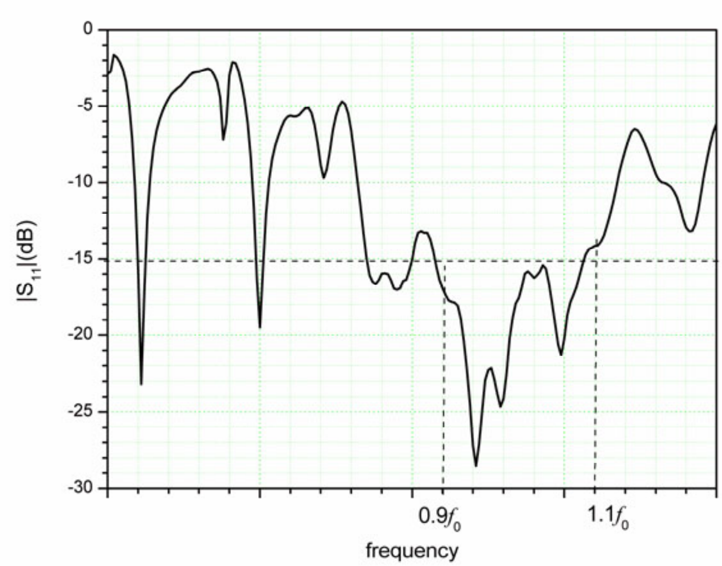

Fig. 4. Measured $|S_{11}|$ of the proposed antenna

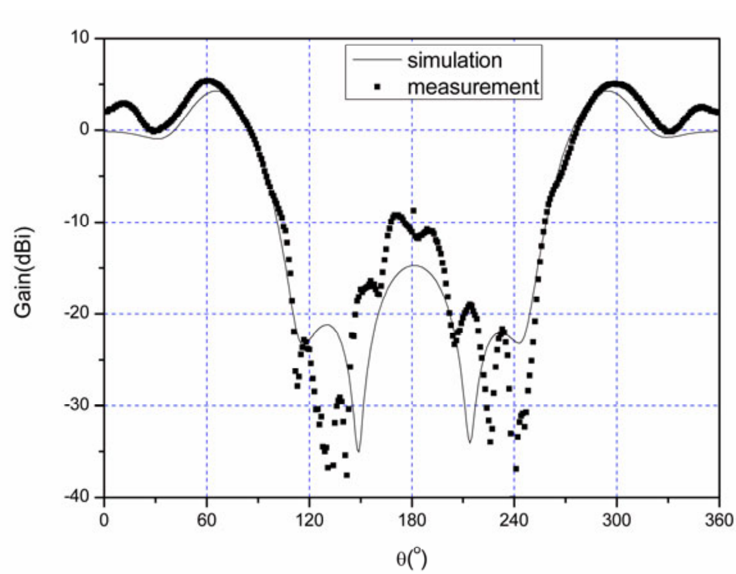

Fig. 5. Measured and simulated gain patterns in the φ=0° plane

Fig. 5 shows the measured and simulated gain patterns in the φ=0° plane. The 3dB beam width of the antenna covers 45°~78°. It is shown that the measurement agrees well with the simulation, especially in the main beam area. The maximum radiation direction is 58° from simulation result and 60° from the measurement result. This small disagreement may come from the error of permittivity of the supported material adopted in production compared with the simulation one. This kind of error can not be avoided in the first design and is easy to be corrected during the re-design procedure. The small ripples in side lobe and back lobes may come from the measurement error or the system error.

4 Conclusion

The bifilar helix antenna with conical pattern has many excellent performances, such as compact structure, easy beam shaping and high reliability. By optimizing the parameters of the helix, different radiation pattern can be obtained meeting special requirement. This kind of antenna has already found its application in the measurement and control communication between satellite and earth.

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