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A NOVEL QUADRIFILAR HELIX ANTENNA FOR USE IN LEO SATELLITE COMMUNICATIONS

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Abstract

Spherical Quadrifiler Helix Antenna (SQHA) is introduced for producing a saddle point shaped radiation pattern. Radiation characteristics of the antenna has been simulated and its results have been compared with the characteristics of Cylindrical Quadrifiler Helix Antenna (CQHA) which was previously used for this purpose. The results show an improvement in radiation pattern of the proposed antenna in comparison with the previous antenna.

Keywords: Spherical Quadrifilar Helix Antenna (SQHA), Cylindrical Quadrifiler Helix Antenna (CQHA), saddle point shaped radiation pattern, LEO satellite ground terminal.

1. INTRODUCTION

One of the important problems in LEO satellites is their relative velocity respect to Earth. If a narrow beam antenna is used in ground terminals, It will be required sophisticated tracking system for communication with satellite and the cost of user terminals become too high. By using an antenna with saddle point shaped radiation pattern it is not needed to such sophisticated tracking systems. On the other hand the variations of free space loss between the satellite and user terminal in the period of visible time can be compensated by using this radiation pattern.

C. C. Kilgus in his paper introduced the Multi-turn Quadrifilar Helix Antenna which produced a saddle point shaped radiation pattern [1]. The obtained radiation pattern for this Antenna generally was similar to saddle point, but in broadside direction had a small deviation from the desired form.

In this paper, a spherical Quadrifilar Helix Antenna (SQHA) is introduced as a novel antenna for generation of a saddle point shaped radiation pattern with a desired circular polarization characterestics. The concept of this antenna has been created by combining of the spherical Helix Antenna, which is introduced by Safaai-Jazi, et al [2], and the CQHA. As a novel antenna with saddle point shaped radiation pattern and desired circular polarization, it can be used in ground terminals of LEO satellites.

In this paper, at first the geometrical structure of the proposed antenna is explained. Then the results of simulation with method of moments will be presented as the diagram of radiation pattern, axial ratio curve and input impedance diagram. Furthermore, the radiation patterns of the two antennas are compared with each other.

2. GEOMETRICAL STRUCTURE OF SQHA

In this section, at first, the structure of a monofilar spherical Helix Antenna is explained. The spherical helix curve is similar to cylindrical helix which has a uniform spacing between its turns, but instead of a cylinder the curve laid on a sphere with radius a. The parameters which determine the geometry of spherical antenna are: radius of sphere, a, the number of turns n. Pitch distance between two successive turns is $s = 2a/n$. In spherical helix curve the relation between Z and φ is: [2]

$$Z = a(\varphi / N\pi - 1), \quad 0 \le \varphi \le 2N\pi \qquad (1)$$

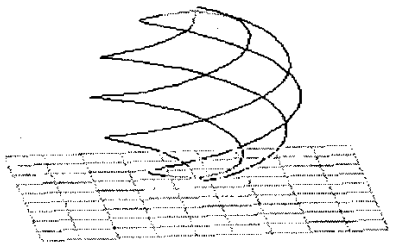

Fig. 1. The structure of SQHA

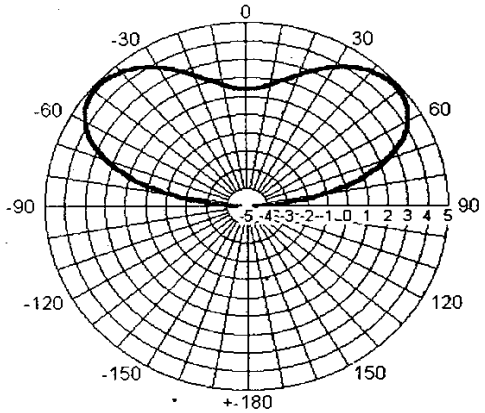

Fig. 2. Radiation pattern of SQHA

Now, by using (1), the spherical helix curve can be expressed as:

$$r = a \tag{2}$$

$$\theta = \cos^{-1}(\varphi / N\pi - 1) \quad 0 \le \varphi \le 2N\pi \tag{3}$$

Structure of (SQHA) is an extension of the Spherical Helix Antenna. This antenna consists of two bifilars which are rotated 90° with respect to their common axis. Each bifilar, also consists of two single turn helix curve which rotated 180° with respect to their common axis. Four arms of this antenna are fed with equal amplitude and 90° phase difference to each other. The structure of the antenna is shown in Fig. 1.

The structure of SQHA can be expressed from (1–3) as follow:

$$r = a \tag{4}$$

$$\theta = \cos^{-1}(\varphi_m / N\pi - 1)$$

$$m\pi/2 \le \varphi_m \le (m+1)\pi/2 \quad m = 0,1,2,3 \tag{5}$$

3. Simulation and Results

The proposed SQHA is simulated and optimized by NEC[1] software which operates based on the method of moments. Optimum dimensions of the antenna are given in Table 1 for operation at center frequency 1300 MHz.

[1]- Numerical Electromagnetic Code

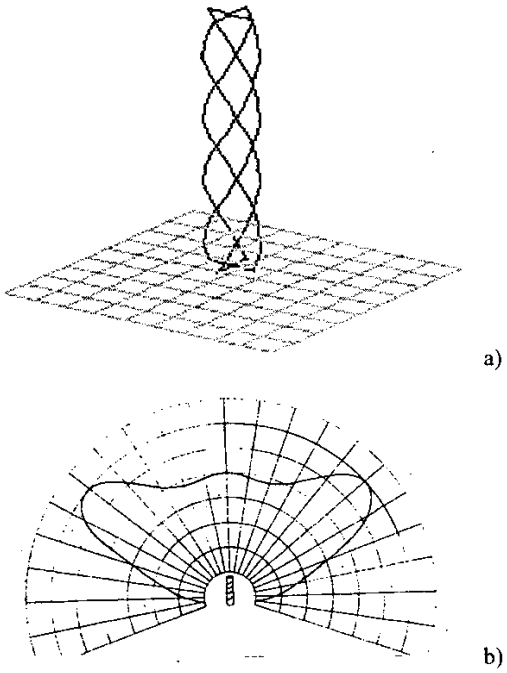

Fig. 3. a) The structure of MQHA
b) Radiation pattern of MQHA

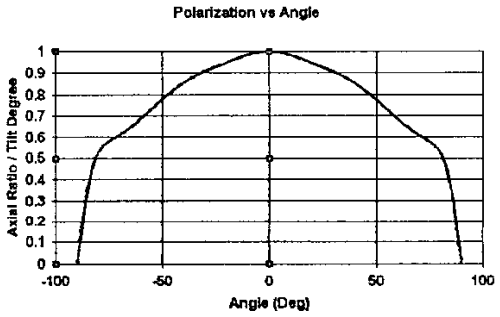

Fig. 4. Axial ratio variations for SQHA

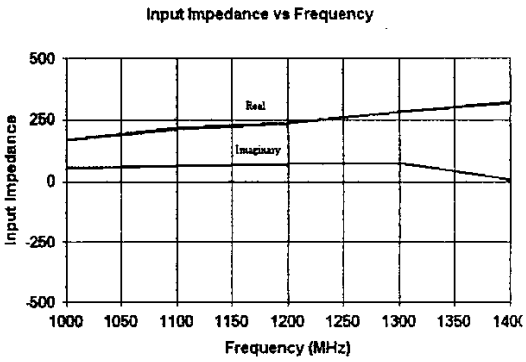

Fig. 5. Real and Imaginary part of input impedance

Radiation pattern of SQHA is illustrated in Fig. 2. As shown in this figure the radiation pattern has the shape of saddle point in which maximum gain

(4.5 dB) obtained at 40° elevation angle and in broadside direction the gain decreases to 2 dB. In Fig. 3 the structure and radiation pattern of Multi-turn Quadrifilar Helix Antenna (MQHA) are shown. By comparison of the radiation pattern of these two antennas, it is clear that the radiation pattern of SQHA is better coincided with desired saddle point shape.

The curve of axial ratio variations versus the off angle respect to broadside direction is illustrated in Fig. 4. Over beamwidth of approximately 120°, the axial ratio is greater than 0.7 which shows a good circular polarization characteristic for this antenna. As shown in Fig. 5, which illustrates real and imaginary parts of input impedance versus frequency, the real part at center frequency is 275 Ω and the imaginary part is about 50 Ω.

4. CONCLUSION

In this paper, SQHA is introduced as a novel antenna for generation of the desired saddle point shaped radiation pattern and circular polarization for application in LEO satellite ground terminals. This antenna analyzed by method of moments and cleared that its radiation characteristic, in comparison with existing antennas is more attractive for mentioned application.

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