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NUMERICAL AND EXPERIMENTAL RESEARCH OF HELICAL ANTENNAS FOR GPS APPLICATIONS

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Abstract

The results of research and development of helix and spiral antennas for producing both narrow and wide radiation patterns specified for GPS applications are presented.

Keywords: helical conical antenna, helical cylindrical antenna, GPS antenna.

1. INTRODUCTION

Recently demand in designing simple antennas with circular polarization for GPS (Global Positioning System) applications has been arouse. There are a number of antennas that radiate and receive circular polarization waves. Among them are well-known simple spiral and helix radiators that find a variety of applications as wideband antennas, reflector antenna feeds, antenna array elements. However in spite of many textbooks and papers [e.g., 1-3] dedicated to helix and spiral antennas there is not enough detailed information about the selection of geometrical parameters to obtain a specified radiation pattern, especially with very wide main lobe and rather good circular polarization.

Spherical quadrifilar helix antenna which provides wide radiation pattern (3-dB beamwidth up to 140^0) has been introduced in [4], but construction of such an antenna is quite complicated.

2. SIMULATION AND RESULTS

This paper focuses on research and development of helical antennas, suitable for GPS applications that provide the following electrical characterictics: antenna 1 − 3-dB beamwidth $\geq 135^0$, right-hand circular polarization, axial ratio is no less than 0.7, VSWR < 1.5; antenna 2 − 3-dB beamwidth $\leq 40^0$, the rest of parameters are the same as for antenna 1. Central operating frequencies for GPS applications are 1227 and 1575 MHz. We have numerically (using CSTMS software) researched the next five types of antennas (Fig. 1) to choose optimal one for parameters referred above:

- helical antenna on the sphere
- conical helical antenna
- cylindrical helical antenna
- planar spiral antenna
- quadrifilar cylindrical helical antenna

Dimensions of all antennas are chosen to meet above mentioned GPS specifications at central operating frequencies. Satisfactory front-to-back radiation ratio is achieved using a screen with diameter close to the operating wavelength (according to this front-to-back radiation ratio is near 15 dB). In antennas of type 1 only one turn length is equal to operating wavelength. It allow to obtain low SLL (side-lobe level). Bifilar helical and spiral antennas are chosen to obtain required axial ratio. As far as beamwidth has definitely relation with antenna gain the antennas referred above are compared by 3-dB bandwidth parameter. Ways to achieve other parameters are shown above.

3-dB bandwidth calculated for the five antenna types are presented in Tab. 1.

Table 1. 3-dB bandwidth of antennas

Antenna	3-dB beamwidth
helical antenna on the sphere	84
conical helical antenna	144
cylindrical helical antenna	38
planar spiral antenna	93
quadrifilar cylindrical helical antenna	79 on average (unsymmetrical)

In Fig. 2 and Fig. 3 radiation patterns of the planar spiral antenna and the helical antenna on the sphere are shown accordingly.

It has become clear after our analysis, that possibility to provide the specified parameters is connected with conical spiral antenna. So it has been chosen for the further analysis. Also it has been made a conclusion, that parameters of antenna 2 could be better achieved using a cylindrical helical antenna. For this kind of antennas required beamwidth can be achieved by proven choosing of the number of turns. Optimal winding angle is $12\text{-}15^0$ [1], that provides the minimal back-radiation level and highest axial ratio. After optimization the next geometry of cylindrical spiral antenna has been obtained: screen diameter – 100 mm, dielectric permeability of cylinder material – 2.2, winding angle – 13^0, number of turns – 7. Model of this monofilar helical cylindrical antenna is shown in Fig. 1,e. It has the following radiation characteristics:

- 3-dB beamwidth 38.4^0,
- front-to-back radiation ratio 9.8 dB,

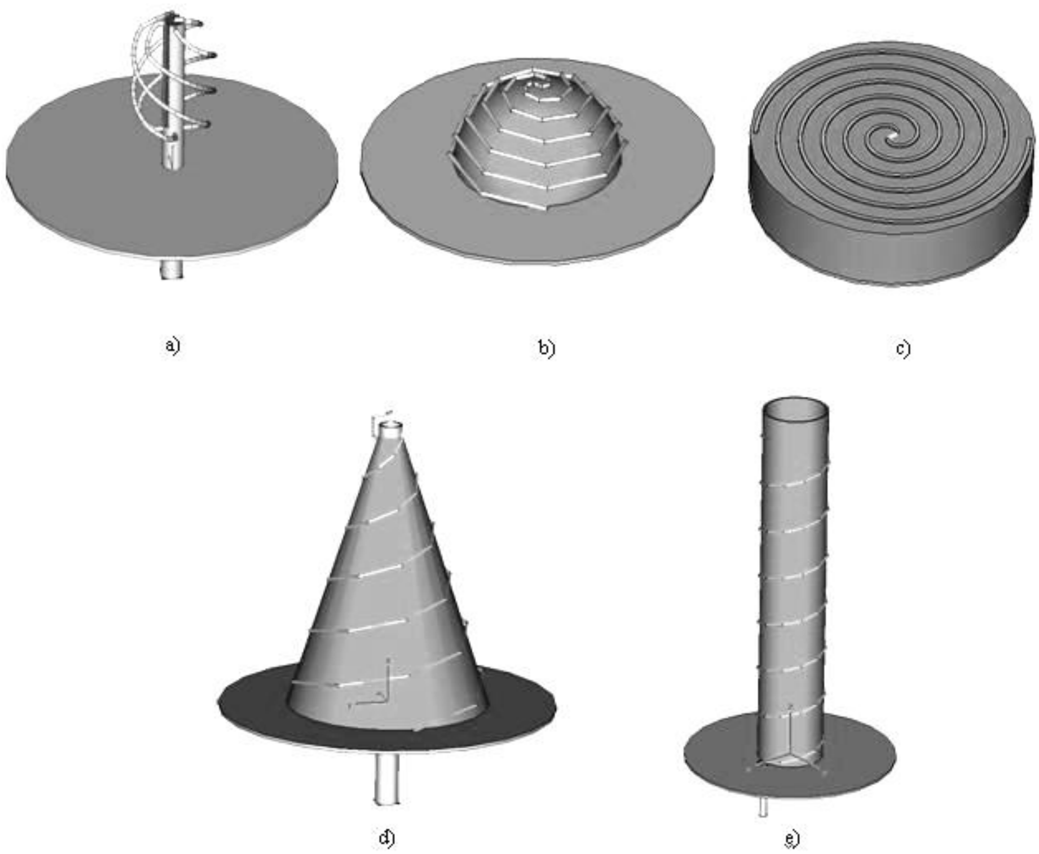

Fig. 1. The model of: a) quadrifilar cylindrical helical antenna; b) helical antenna on the sphere; c) planar spiral antenna; d) conical helical antenna; e) cylindrical helical antenna

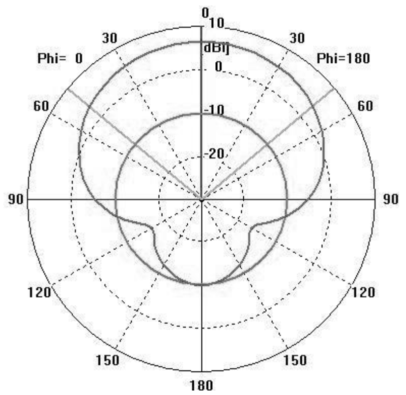

Fig. 2. Radiation pattern of the planar spiral antenna

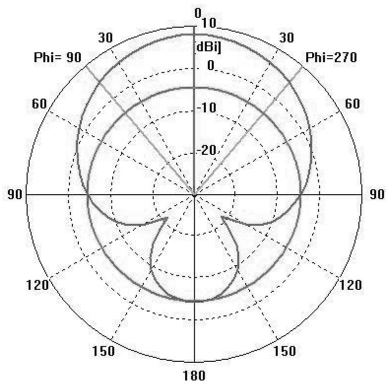

Fig. 3. Radiation pattern of the helical antenna on the sphere

- axial ratio is no less than 0.7.

Antenna matching has been provided using λ/4 transformer and special matching strip. Feeding has been performed by common way using coaxial connector placed at the screen. As a result VSWR ≤ 1.5 in the frequency range of 1.1 – 1.7 GHz has been obtained. An experimental prototype has been manufactured and it's characteristics have been measured. Theoretical (dashed line) and experimental (solid line) radiation patterns of the cylindrical helical antenna are shown on Fig. 4. Axial ratio versus angle is illustrated in Fig. 5.

Between two known variants of helical conical antenna construction – with constant winding angle and with constant step – conical helical antenna with constant step (Fig. 1,d) has been chosen, because we don't need wide band in GPS applications. Antenna has been optimized for antenna 1. Varing height we also obtain changing of winding angle, cone angle, step, if cone bottom radius is constant.

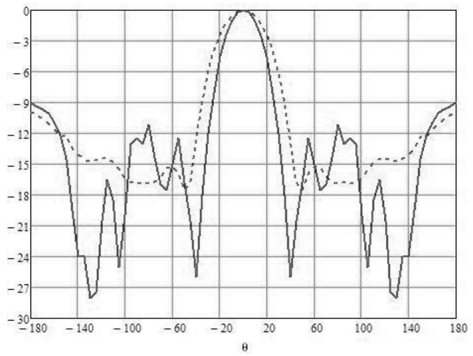

Fig. 4. Radiation pattern of the cylindrical helical antenna

After parametrical optimization the next bifilar conical helical antenna geometry has been obtained: height – 185 mm, screen diameter – 150 mm, dielectric permeability of cone material – 1.2, winding angle – 13^0. Such geometry provides the required characteristics:

- 3-dB beamwidth 148^0,
- front to back radiation ratio 16.8 dB,
- axial ratio is no less than 0.7.

Antenna matching has been provided using λ/4 transformer. Feeding is symmetrical, coaxial goes through dielectric to the top of the dielectric cone. An experimental prototype has been manufactured and it's characteristics has been measured. Theoretical (dashed line) and experimental (solid line) radiation patterns of the conical helical antenna are shown on Fig. 6. Axial ratio versus angle is illustrated in Fig. 7.

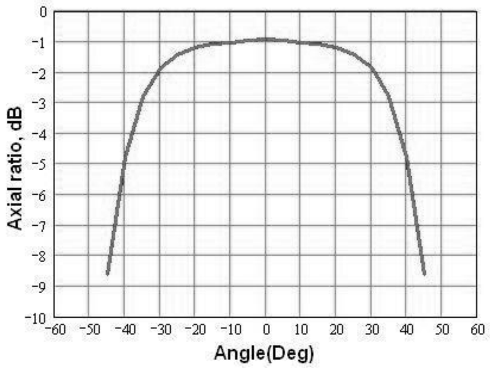

Fig. 5. Axial ratio for the cylindrical helical antenna

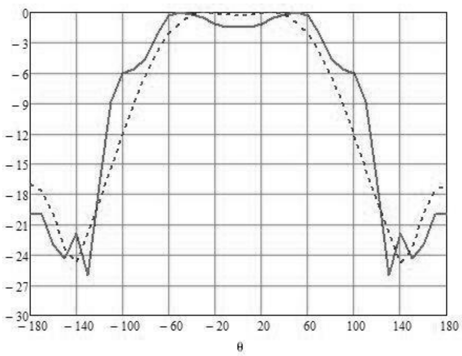

Fig. 6. Radiation pattern of the conical helical antenna

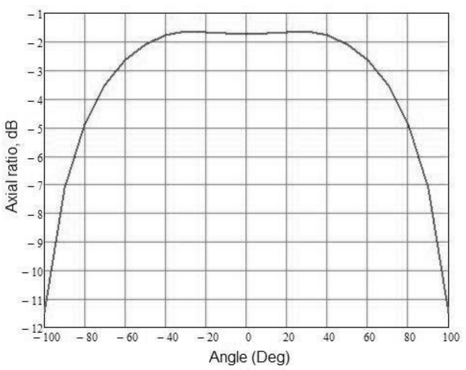

Fig. 7. Axial ratio for the conical helical antenna

3. CONCLUSION

Five helical and spiral antenna types have been optimized in order to meet the technical specifications for GPS applications. It has been found that only cylindrical and conical helical antennas fully meet the required technical specifications. Numerical results of optimization has been proved by prototype's measured data.

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