# HELICAL ANTENNA DESIGN FOR HIGH-SPEED WIRELESS INTERNET

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**Abstract:** This paper presents applications of Matlab software for antenna modelling. The problem that was modelled and simulated is the helical antenna at 2.4GHz for high-speed wireless Internet. Most important antenna parameters for radio communications are computed here (antenna gain, directivity, electric field, magnetic field, Poynting vector, antenna impedance).

**Keywords:** helical antenna, gain, directivity, radiation, impedance, electrical field, magnetic field, Poynting vector

## INTRODUCTION

Helical antenna is basic, simple and practical configuration of an electromagnetic radiator. It is conducting wire wound in the form of a screw thread forming helix (Fig.1). Helical antennas are usually classified in two categories, electrically small and electrically large. Electrically small are those whose overall length is usually less than about one-tenth of a wavelength. Those antennas have uniform current density and they can be analysed like infinitesimal electromagnetic dipole, so electrical and magnetic fields of these antennas can be computed analytically. Small antennas are small electromagnetic radiators. They are used in radio communications where antenna efficiency is not so important (portable radios, pagers, mobile phones). Circumferences of electrically large helical antennas are about one wavelength ($C \approx \lambda$). Current distribution of these antennas is not uniform. We cannot compute electric and magnetic fields analytically. For analysis of electrically large helical antennas we can use method of moments (MOM).

Electrically large helical antennas are used in broadband communication for point-to-point links, because of their large gain and appropriate radiation. They can be used for high-speed wireless Internet, using 802.11b standard (carrier frequency 2.4GHz).

## ANTENNA GEOMETRY

The geometrical configuration of a helix usually consists of *N* turns, diameter *D* and spacing *S* between each turn (Fig.1.). Total length of the antenna is *L=NS,* while total length of the wire is $L_n = NL_0 = N\sqrt{S^2 + C^2}$, where $L_0 = N\sqrt{S^2 + C^2}$ is the length of the wire between each turn and $C = \pi D$ represents circumference of the helix. Controlling the size of its geometrical properties compared to wavelength can vary the radiation characteristics of the antenna. Helical antenna can operate in many modes. Two basic modes are normal (broadside) and the axial (endfire) mode. The axial mode is usually the most practical, because it can achieve circular polarization over wider bandwidth and it is more efficient [2]. In this work we consider a helical antenna in axial mode at frequency 2.4GHz.

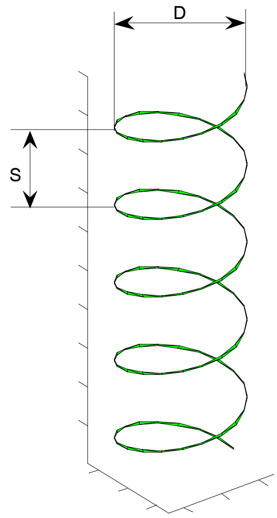


**Fig.1** – *Helical antenna geometry*

## ANTENNA DESIGN

For broadband wireless Internet we use helical antenna in axial mode. In this mode of operation, there is only one major lobe and its maximum radiation intensity is along the axis of the helix. The minor lobes are at oblique angles to this axis. Helical antenna in normal mode has small radiation and that mode is not important for us.

To excite this mode, the diameter *D* and spacing *S* must be large fractions of the wavelength. To achieve circular polarization, primarily in the major lobe, the circumference of the helix must be in the $0.7 < C/\lambda < 1.3$ range and the spacing is about $S \cong \lambda/4$. The pitch angle is usually $12° < \alpha < 14°$ [2].

In this work we compute parameters of the helical antenna at 2.4GHz using Matlab scripts [1]. The first important parameter for the helical antenna is the surface current distribution. The current distribution of the helical antenna in axial mode is not uniform. In Matlab scripts [1], the current distribution (Fig.2.) is computed using MOM. When we change antenna dimensions we get different current distribution.

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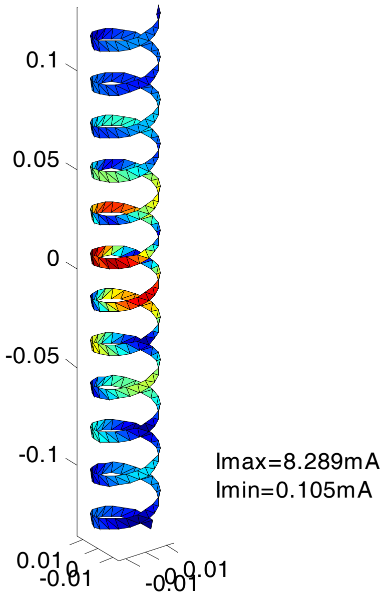


**Fig.2**- *Current distributions and maximum/minimum current of helical antenna*

We have restricted our investigation in several ways. First, we assume a constant wire diameter of 5 mm. Second, we restrict the pitch angles to 12° and 14°. These pitch angles represent the limits recommended for axial mode helical operation [2]. And third, we look at helical antennas using 12 and 14 turns. These antennas represent long antennas.

In tables 1 and 2 recorded data for different antenna dimensions are shown. In the first table the pitch angle is 12° and in the second table it is 14°. In both tables number of turns is 12. Recorded data begins with antenna gain. Second column of recorded data is antenna impedance and third is radiation resistance.

**Antenna gain**

Antenna gain is the most important parameter of helical antenna in radio communication. Helical antenna has the biggest gain for circumference 0.72λ in both cases. Figure 3 shows antenna gain for two pitch angles as we increase the circumference from 0.7λ to 1.3λ. We see on the figure 3, the lower the pitch, the higher gain we obtain for any circumference below 1.3λ. If we were to move either upward or downward from the design frequency, any circumference (and radius) of choice would change with the new frequency. Therefore, the curves on figure 3 represent a tracking of the gain at frequencies some distance from the design frequency.

If the number of turns increases, then antenna gain increases. Helical antenna with 12 turns can achieve maximum gain of 12.07 dB and antenna with 14 turns has maximum gain of 12.55 dB. The results of that increase of turns are: smaller beamwidth, side lobes begin at smaller circumference and they are more complex. With smaller number of turns we have single or double side lobes. Then, the total energy within the side lobes may be equal to single stronger lobe.

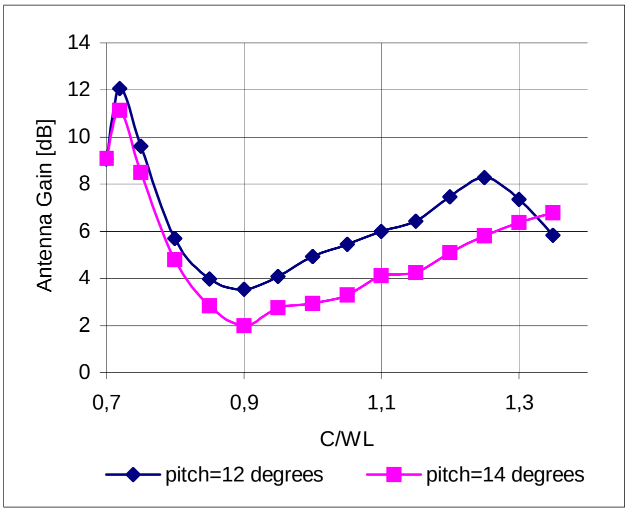


**Fig.3** - *Helical antenna gain vs. pitch angles and circumference*

**Antenna impedance**

Antenna impedance is computed using MOM in Matlab scripts [1]. In the second columns of tables 1 and 2 antenna impedances for the pitch angle 12° and 14° are shown. We see that antenna impedance has a lot of fluctuations. Small physical changes yield large changes in an antenna resistance and reactance. Smaller pitch angle results in bigger impedance fluctuation.

For the circumference of 0.72λ the helical antenna impedance is

$$Z = (46.2 + j82.4)\,\Omega$$

with inductive imaginary part. Feed line impedance is 50Ω and we see that antenna impedance is close to this value. The total feed power is 2.6mW.

**Radiation**

Figure 4 shows the helical antenna (12 turns, circumference 0.72λ and the pitch angle 12°) radiation intensity distribution. A big advantage of the helical antenna in the axial mode is the large increase in antenna directivity. Poynting vector (direction of radiation) has a maximum intensity along the axis of helix. Maximum radiation intensity is along the axis of helix, too. Then helical antenna in the axial mode has only one major lobe.

Using Matlab we can compute electric and magnetic field intensity in every point of near and far antenna field. The almost circular polarisation of the field in the main lobe is one very inviting property of the helical antenna in the axial mode. For example, at the point [0; 0; 100] m on the antenna axis electrical field intensity is

```
E =
  -0.0026 + 0.0105i
  -0.0105 - 0.0048i
  -0.0000 + 0.0000i
```

in V/m. The x- and y-components of the electric field appear to be very close in magnitude. The phase between these two components is approximately 90°. Magnetic field in this point is

```
H =
   1.0e-004 *
   0.2787 + 0.1275i
  -0.0696 + 0.2798i
  -0.0000 - 0.0000i
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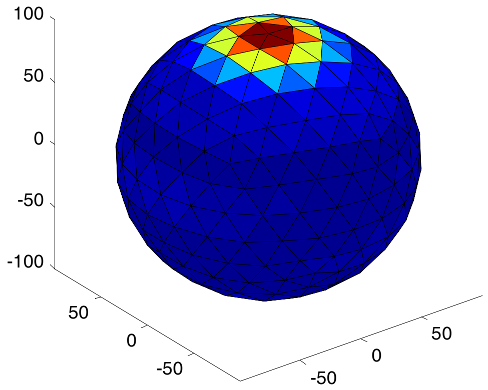


**Fig.4.** - *Radiation intensity distribution*

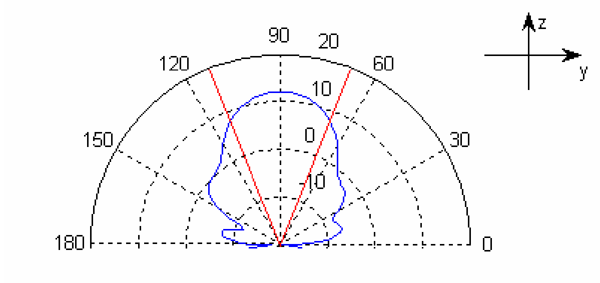


**Fig. 5.** – *Radiation pattern 12-turn helical axial mode helical antenna at 2.4GHz*

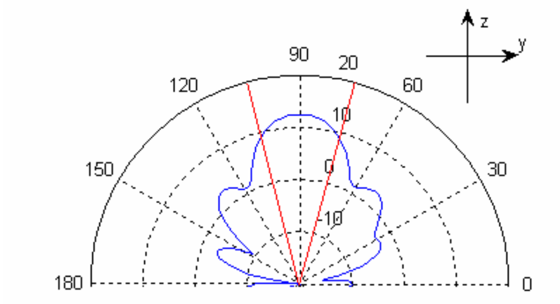


**Fig.6.** – *Radiation pattern 14-turns axial mode helical antenna*

Figure 5 shows radiation pattern of helical antenna in axial mode (12 turns, circumference 0.72λ and the pitch angle 12°). This antenna has one major lobe and few side lobes, which are reduced. Antenna with more turns (Fig.6) has more complex and stronger side lobes. The helical antenna with the bigger circumference has stronger side lobes.

Beamwidth is the measure of antenna directivity. Red lines denote antenna beamwidth on figures 5 and 6. We see from the figures that increase of number of turns results in decrease of beamwidth.

**Table I**

*Numerical parameters of the helical antenna (turns 12, the pitch angle 12°)*

| C/WL | D/2 [m] | S [m] | Gain [dB] | Impedance [ohm] | Radiation Resistance[ohm] |
|---|---|---|---|---|---|
| 0,7 | 0,0139 | 0,0186 | 9,08 | 122,7+j29,1 | 117 |
| 0,72 | 0,0143 | 0,0191 | 12,07 | 46,139+j82,36 | 46,37 |
| 0,75 | 0,0149 | 0,0199 | 9,61 | 75+j338 | 75,34 |
| 0,8 | 0,0159 | 0,0213 | 5,69 | 1076+j1191 | 1084 |
| 0,85 | 0,0169 | 0,0226 | 3,97 | 634,8-j966,6 | 639,59 |
| 0,9 | 0,0179 | 0,0239 | 3,54 | 265,2-j627 | 267,516 |
| 0,95 | 0,0189 | 0,0252 | 4,08 | 178,9-j476,1 | 180,57 |
| 1 | 0,0199 | 0,0266 | 4,927 | 143,34-j389,2 | 144,79 |
| 1,05 | 0,0209 | 0,0279 | 5,45 | 126,62-j328,8 | 127,97 |
| 1,1 | 0,0219 | 0,0292 | 6 | 118,2-j285,03 | 119,61 |
| 1,15 | 0,0229 | 0,0306 | 6,44 | 111-j248,13 | 112,3 |
| 1,2 | 0,0239 | 0,0319 | 7,46 | 105,74-j212,09 | 107,03 |
| 1,25 | 0,0249 | 0,0332 | 8,29 | 115,27-j167,33 | 116,72 |
| 1,3 | 0,0259 | 0,0345 | 7,35 | 131,5-j168,9 | 133,54 |
| 1,35 | 0,0269 | 0,0359 | 5,82 | 101,24-j136,17 | 103,14 |

**Table II**

*Numerical parameters of the helical antenna (turns 12, the pitch angle 14°)*

| C/WL | D/2 [m] | S [m] | Gain [dB] | Impedance [ohm] | Radiation Resistance [ohm] |
|---|---|---|---|---|---|
| 0,7 | 0,0139 | 0,0186 | 9,1 | 123,9+j115.3 | 124,46 |
| 0,72 | 0,0143 | 0,0191 | 11,14 | 64,21+j145,3 | 64,46 |
| 0,75 | 0,0149 | 0,0199 | 8,51 | 151,3+j533,24 | 152 |
| 0,8 | 0,0159 | 0,0213 | 4,8 | 1564,8+j1169 | 1576 |
| 0,85 | 0,0169 | 0,0226 | 2,84 | 1334,5-j953,3 | 1347,6 |
| 0,9 | 0,0179 | 0,0239 | 2 | 602,7-j777,9 | 609,94 |
| 0,95 | 0,0189 | 0,0252 | 2,76 | 395,43-j598,74 | 400,97 |
| 1 | 0,0199 | 0,0266 | 2,95 | 301,88-j481,68 | 306,82 |
| 1,05 | 0,0209 | 0,0279 | 3,29 | 249,08-j394 | 253,82 |
| 1,1 | 0,0219 | 0,0292 | 4,1 | 220,4-j322,5 | 225,24 |
| 1,15 | 0,0229 | 0,0306 | 4,26 | 208,27-j267,7 | 213,42 |
| 1,2 | 0,0239 | 0,0319 | 5,08 | 197,9-j225,3 | 203,46 |
| 1,25 | 0,0249 | 0,0332 | 5,79 | 191,31-j183,97 | 197,43 |
| 1,3 | 0,0259 | 0,0345 | 6,37 | 198,4-j137,6 | 205,59 |
| 1,35 | 0,0269 | 0,0359 | 6,79 | 188,91-j124,24 | 195,99 |

## CONCLUSION

In this paper we have shown how the helical antenna in the axial mode can be used for high-speed wireless Internet at 2.4 GHz. The helical antenna can achieve bigger gain than some other wire antennas. A big advantage of the helical antenna in the axial mode over other wire antennas is the large increase in the antenna directivity.

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