©2022 Published in 10th International Symposium on Innovative Technologies in Engineering and Science 21-23 October 2022 (ISITES2022 Bursa - Turkey)
https://doi.org/10.33793/acperpro.05.03.4403

5.8 GHz Helical Antenna Design and Analysis for Drone and Ground Station Communication

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Abstract

High-power wide band helical antenna is designed, analyzed and manufactured in the Electrical and Electronics Engineering Department Laboratory of the Faculty of Engineering of Karabuk University. Krauss's formulas are used in the design of the proposed antenna and Ansys HFSS program is used to simulate it. After the antenna is designed, its dimensions are optimized and analyzed. Thus, the desired antenna parameters were obtained. To maximize performance and match the input impedance to that of the antenna, the diameter of the winding wire has been increased, resulting in a lower VSWR and a much greater operational bandwidth. The proposed antenna has 4.5 turns, a wavelength of 51.72 mm, a height of 58.05 mm, spacing of 12.9 mm, and a diameter of 16.1 mm. This antenna resonates at the 5.8 GHz center frequency and has a bandwidth of 2.92 GHz. The bandwidth is 50.34% of the center frequency value. The presented antenna on Teflon substrate has achieved a gain of 12.06 dB. The proposed antenna also can be used for various wireless applications such as wideband, 5G and drone applications.

Key words: Helical antenna, drone, 5.8 GHz, wide band antenna, UAV applications.

1. Introduction

The birth of wireless communication technology dates back to the 19th century. Since then, wireless communication technology has improved rapidly to meet our social needs. Helical antennas are one of the commonly used antennas in radar, satellite, and drone applications due to their easy design, easy production, affordable cost, and simple structure. Additionally, they can provide great bandwidths compared to other antenna forms.

Helical antennas are more preferred in wireless communication systems such as RF, infrared, satellite communication, etc., since they support wide bandwidths and can be produced in circular polarization [1]. Helical antennas broadly used in high-gain RADAR communication systems, in military systems that require effective spectrum use or multifunctionality, and in environments such as hospitals that are sensitive to radio frequency [2-12]. Moreover, since they are wideband, they have fine sensitivity capabilities in real-time location systems such as the Global Positioning System (GPS) [13].

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Satellite television systems that end users receive broadcasts directly from geostationary satellites are called Direct Broadcast Satellite systems. Parabolic dish antennas are generally used in the receiver part to obtain high directivity and gain in Direct Broadcast Satellite systems [14]. These antennas can work especially in the high frequency regions of the radio spectrum and their diameters range from 43cm to 80cm. As their diameters suggest, these antennas are large, so they can only be used for large moving objects for Satellite Communications on The Move (SOTM). For tracking large moving objects, patch antennas with array configuration are used as well as parabolic dish antennas. However, it is difficult to obtain high gain with patch antennas [15-17]. The primary reason for using helical antennas in satellite communication is that they can be designed with circular polarization and provide high gain [11]. This paper presents the design and analysis of a compact, low profile, easy to manufacture helical antenna that can be mounted on any drone goggle to receive signals from the drone.

The proposed helical antenna operates at 5.8 GHz center frequency to receive the signals sent from the drone. It is designed as a single helical antenna radiating in axial mode with 4.5 turns [1],[12]. It is known that a single helical antenna radiates only a certain amount of energy in a given direction. Therefore, 2 helical antennas will be used in the proposed design of the drone goggles to reduce the beamwidth and increase the amount of transmitted energy.

2. Design and Analysis of the Helical Antenna

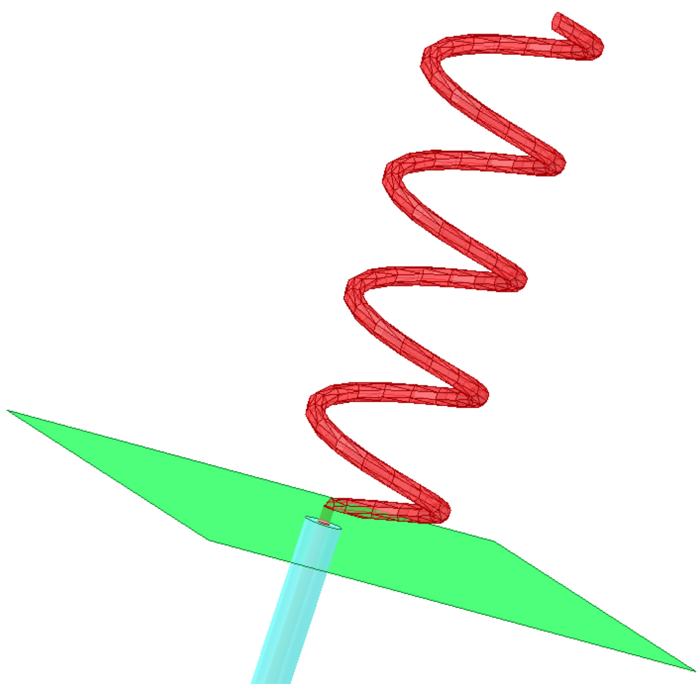


Figure 1. Proposed 4.5 turn helical antenna

The proposed helical antenna is shown in Figure 1. The antenna consists of three parts: the ground plane, a 4.5-turn helix above the ground plane, and a connector below the ground plane. The connector is powered by coaxial cable. Axial mode helical antenna is preferred so that the antenna can radiate along its axis and receive circular polarized radio signals [3],[5]. ANSYS HFSS simulation environment is used for antenna design and analysis. First, the design parameters of the antenna were calculated theoretically, then the calculated parameters were used for the design of the antenna in HFSS.

To achieve maximum efficiency and optimum size, the number of turns of the helix is set to N 4.5. The operating frequency must be 5.8 GHz for the drone to communicate with the drone goggles and the corresponding wavelength is $\lambda = c / f = 5.17\ \text{cm}$. where c denotes the speed of light. To ensure that the helical antenna has circular polarization, the following equations are calculated:

$$D_0 = \frac{15NSC^2}{\lambda_0^3} \tag{1}$$

$$HPBW = \frac{52}{C}\sqrt{\frac{\lambda^2}{NS}}\ (\deg \text{rees}) \tag{2}$$

$$FNBW = \frac{115}{C}\sqrt{\frac{\lambda^a}{NS}}\ (\deg \text{rees}) \tag{3}$$

$$A_{eff} = \frac{C\lambda^2}{4\pi}\ (\deg \text{rees}) \tag{4}$$

$$\text{Impedance at terminal} = \frac{140C}{\lambda}\Omega \tag{5}$$

$$AR = \frac{2N+1}{2N} \tag{6}$$

where D_0 is the directivity, N is the number of turns, S is the spacing between the turns, C is the helix circumference, and λ is the wavelength. *HPBW*, *FNBW*, A_{eff} and *AR* are half-power beamwidth, first null beamwidth, effective aperture and axial ratio respectively.

Also, the ratio of velocity of wave along the helix to velocity in free space is calculated as follows:

$$\rho = \frac{\frac{L_0}{\lambda_0}}{\frac{S}{\lambda_0}+1} \tag{7}$$

On the other hand, according to Hansen-woodyard, the definition of ρ can change as follows:

$$\rho = \frac{\frac{L_0}{\lambda_0}}{\frac{S}{\lambda_0} + \frac{2N+1}{2N}} \tag{8}$$

To design an axial mode helical antenna, C must be between $3/4\ \lambda$ and $4/3\ \lambda$. The parameters of the proposed 5.8 GHz helical antenna calculated using the above-mentioned equations are listed in

Table 1. Proposed 5.8 GHz helical antenna parameters

Parameters	Value
Dielectric constant (ε_r)	2.1
Substrate thickness (*h*)	0.1 mm
Wavelength (λ)	51.72 mm
Circumference (*C*)	51.72 mm
Number of turns (*N*)	4.5
Spacing between turns (*S*)	12.9 mm
Diameter of helix (*D*)	16.1 mm
Height of helical antenna (*A*)	58.05 mm

3. Results

The performance of the 5.8 GHz helical antenna is analyzed in ANSYS HFSS simulation environment. The return loss of the antenna is given in Figure 2 and the voltage standing wave ratio (VSWR) is given in Figure 3. Besides, 3D gain and directivity are seen in Figure 4, and 1D gain and directivity in polar form in Figure 5.

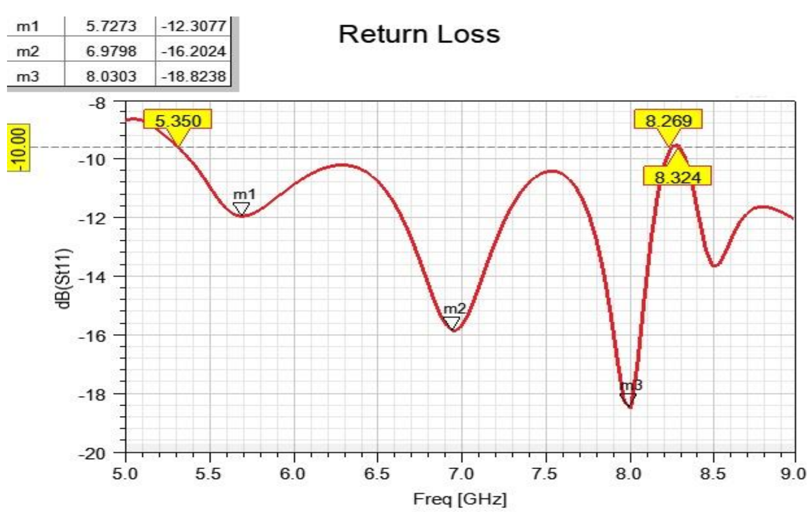


Figure 2. Return loss of 5.8 GHz helix antenna

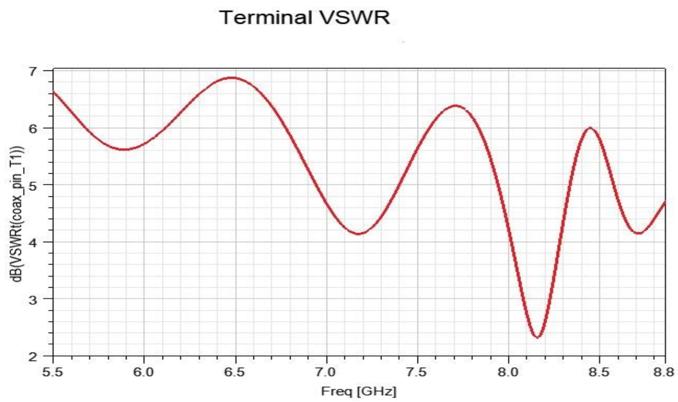
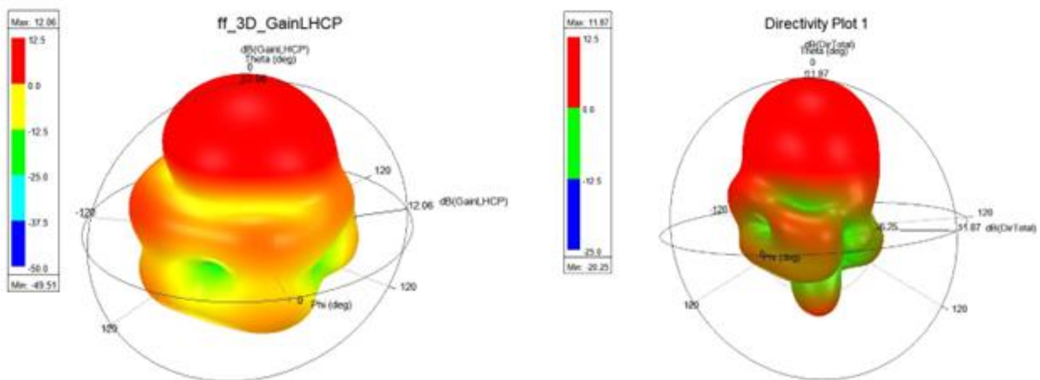
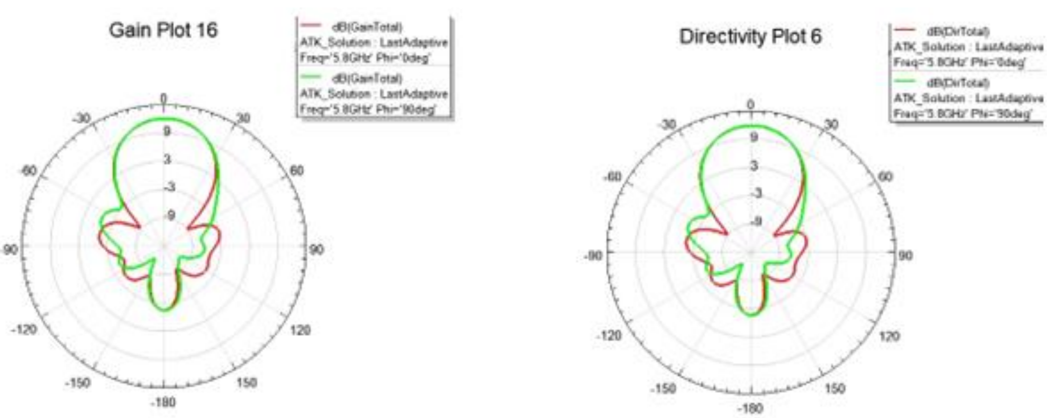


Figure 3. VSWR of 5.8 GHz helical antenna



(a) (b)

Figure 4. (a) 3D gain and **(b)** 3D directivity of 5.8 GHz helical antenna



(a) (b)

Figure 5. (a) 1D gain and **(b)** 3D directivity of 5.8 GHz helical antenna

4. Discussion

The analysis results show that a return loss (S_{11}) of -12.22 dB is obtained at the center frequency and the bandwidth of this antenna is 2.92 GHz. The maximum gain of the proposed geometry is 12.06 dB. However, its directivity is achieved at 11.87 dB. Radiation efficiency of 95.4% is obtained, which means that almost all the power supplied to the antenna is radiated. The antenna's HPBW is 36.44 degrees, pointing out a wide beam width. Additionally, the axial ratio of the antenna is 1.88.

The receiving power of the proposed antenna was calculated using the Friis equation, the path loss was included, and it was found to be -93.6 dBm [2]. When this value is compared with the antenna of a standard drone system, it is concluded that the proposed design is more successful than the antennas on the market. The designed 5.8 GHz helical antenna is promising for use in drone systems.

To effectively test the antenna in the drone system, two must be fabricate. A standard drone goggle has 4 omnidirectional antennas. Drone goggle using 4 omnidirectional antennas and drone goggle using 2 omnidirectional and 2 helical antennas should be compared. Thus, the performance of the proposed antenna can be observed clearly.

Conclusions

In this study, a compact, low profile and easy to manufacture helical antenna is presented to provide communication between the drone and the ground station. The helical antenna has -93.6 dBm receiving power with 12.06 dB gain at center frequency. Moreover, it has a very high radiation efficiency and a wide beamwidth. The performance of the proposed antenna is competitive compared to the antennas commonly used in drone systems. However, the proposed design is slightly larger than the antennas used in drone systems. Therefore, this antenna can be used in drone systems easily and safely.

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