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POSSIBILITIES OF INCREASING THE ENERGY OF RADIO LINES FOR CONTROLLING DRONES

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Background. The creation of an antenna system consisting of two spiral structures for the 2,4 GHz and 5,8 GHz frequency bands is caused by practical needs determined by the results of using drones to monitor the environment. The proposed technical solution was based on a study of known antennas for the 2,4 GHz (right circular polarisation) and 5,8 GHz (left circular polarisation) frequency bands. Due to the mismatch of the polarisation of the electromagnetic wave and the antenna, losses of up to 20 dBp can occur. To reduce losses, a design of spiral antennas with the ability to change the polarisation direction was proposed. The article discusses the physical nature of the work and the relationship between the design and electrical parameters of spiral antennas. These provisions provide directions for improving these characteristics and technical solutions for their realisation. When creating the proposed design, the core issue was to solve the problem of matching the direction of polarisation of the electromagnetic wave generated by the antenna of the ground control station with the direction of the drone antenna rotation. The problem is proposed to be solved by ensuring the possibility of promptly changing the polarisation of the ground control station antenna. The prototype for the development of such an antenna is a well-known antenna without the possibility of changing the polarisation, which has two coaxial spirals for the frequency bands 2,4 GHz and 5,8 GHz with different types of polarisation.

Objective. The article aims to develop a dual-band antenna system for a ground control station with the ability to change the direction of rotational polarisation.

Methods. A certain number of sources concerning rotationally polarised antennas, various types of ultra-high frequency antennas, and their application for communication between a ground control station and a drone have been reviewed and analysed. According to the problem statement, spiral antennas were selected for the antenna array elements, which provide the possibility of communication with a drone when changing the direction of rotational polarisation. Various antenna designs can solve the creation of a rotationally polarised wave. One solution is to use horn antennas and vibrator-type antennas, however from the perspective of the ratio of antenna gain and its dimensions, it makes sense to choose a spiral antenna.

Results. The results of modelling the structural, technical, and electrical characteristics of the antenna system indicate the possibility of creating a dual-band spiral antenna design for use on ground control stations for radio contacts with UAVs in the frequency bands 2,35 ... 2,45 GHz and 5,75 ... 5,85 GHz.

Conclusions. The implementation of the antenna system of spiral antennas for ground control stations in the frequency bands 2,35 ... 2,45 GHz and 5,75 ... 5,85 GHz for drone control makes it possible to change the direction of rotational polarisation, which is related to the drone antenna's rotational polarisation direction.

Keywords: *drones; unmanned aerial vehicles; polarisation; spiral antennas; radiation pattern; directional coefficient; ground control station.*

Introduction

Different types of antennas are used depending on the functionality and principles of drone application. The main parameters of antennas for drones and ground control stations (GCS) are the following [1]:

– frequency range ($\Delta f = f_U \dots f_L$): 2,35 ... 2,45 GHz and 5,75 ... 5,85 GHz;

– is the antenna gain in a given frequency range Δf, relative to an isotropic radiator: 8...10 dBp;

– width of the antenna pattern: 40°...60°;

– standing wave coefficient (SWC) in the frequency range Δf, usually within 1,1 ... 1,5;

– the type of radio wave polarisation created by the antenna (horizontal, vertical, circular, or circular);

– type of interface for connecting to the receiver/transmitter (depending on the task of communication with the drone);

– availability of an antenna system that ensures in real time the requirement that the main lobe of the GCS antenna pattern is constantly located in the sector of the main lobe of the drone antenna pattern;

– weight and dimensions of drones;

– resistance of drones to wind loads and vibrations;

– type of attachment to drone frames and ground control stations.

Each type of antenna on board the drone and the GCS, which together make up the unmanned aerial vehicle (UAV), is used depending on the following main factors [2]:

– functional purpose of the drones that make up the UAV;

– the principle of creating the drone's lift;

– the number of applications;

– the class of drone in the UAV;

– the nature of the use of electronic warfare;

– the specifics of the flight mission.

From the analysis and research of sources devoted to this topic, it is possible to gain an understanding of modern antennas of drones and ground control stations [3].

The video signal from the drone's camera to the GCS is mainly transmitted at 1,2, 2,4 and 5,8 GHz using antennas with right circular polarisation because it has historically been so. The rule that right polarisation is used for analogue video transmission and left polarisation for digital video transmission is only a rule of thumb. Signal loss when the direction of polarisation of the wave and the antenna does not match is 15...20 dBp. If the polarisation of the antennas does not match, there will be almost no image. It should be noted that the signal loss between circular and linear polarisation antennas is approximately 3 dBp [4].

According to the academic theory of radio wave propagation, polarisation is determined by the vector of the electric component of the electromagnetic field.

Typically, drones use omnidirectional antennas that transmit and receive in roughly the same way in all directions. After all, the drone can turn in any horizontal direction, and it is important to maintain control of the drone regardless of its orientation relative to the pilot of the ground control station. The remotes and video receivers on the side of the GCS are equipped with directional antennas. To focus the signal in one direction, in this case towards the drone, it is necessary to use a directional antenna of the appropriate design, which depends on the frequency range. Under such conditions, it is possible to achieve signal transmission/reception over longer distances [2, 5]. Thus, without directional GCS antennas, the use of drones at a given distance is virtually impossible.

Directional antennas, which are usually located near the GCS, focus the antenna pattern in the direction of the drone, resulting in a much longer signal travel. Based on the analysis of the ratio of antenna gain to its dimensions, as well as the ability to create circular polarisation waves without additional means, spiral antennas were chosen for the study.

Spiral antennas belong to the class of antennas with a travelling current wave. They are a metal spiral fed by a coaxial line. Among the known types of antennas, there are cylindrical (Fig. 1), conical, and flat spiral antennas [4, 6, 7]. Tapered and logarithmic spirals are more bandwidth efficient and can operate with more than 2,5 times frequency overlap. For the tasks at hand, a cylindrical design is sufficient.

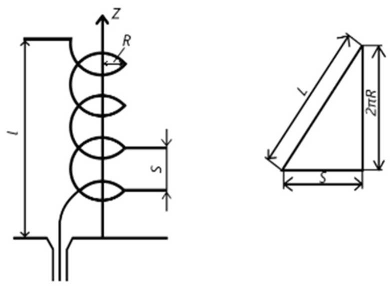
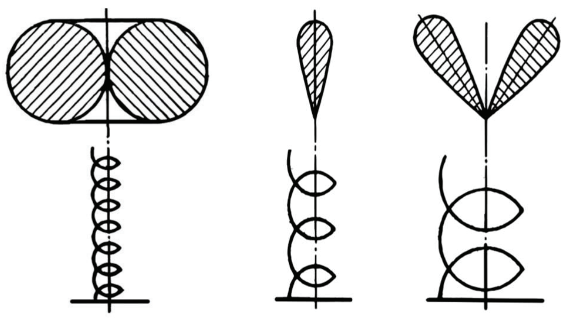


Fig. 1 – Schematic and scan of the coil of a cylindrical spiral antenna

When the length of the spiral turn is less than 0.65 λ (with a wavelength $\lambda > 5D$), the T_0 wave prevails, which is characterized by a change in the current phase within 360^0 for several turns. The T_0 wave has a constant amplitude along the length of the helix and a phase velocity $v_0 = c$. The reflection of the T_0 wave from the end of the helix leads to the creation of standing waves that form the antenna pattern. The T_0 wave has a tiny amplitude. The maximum radiation for this case occurs in a plane perpendicular to the spiral axis (Fig. 2, a) [9] and is not directed in this plane [6, 7].



a) b) c)

Fig. 2 – Three types of radiation from cylindrical spiral antennas:
a) undirected radiation: b) axial radiation; c) conical radiation

If the length of the spiral coil is in the range from 0.75 λ to 1.3 λ, the T_1 wave prevails in the spiral, the phase velocity of which is less than the speed of light $v_1 \approx 0{,}8$ s. The T_1 wave is emitted more intensively by all turns, so a travelling current wave is established in the spiral and maximum radiation is formed along the spiral axis (Fig. 2, b) [7, 8].

The width of the range of axial radiation of a cylindrical spiral is ±0.3 λ, while the electrical characteristics change insignificantly [7, 8].

With an increase in the ratio of the coil length to the wavelength, the spiral begins to form a funnel-shaped radiation pattern (Fig. 2, c).

Consideration of the antenna to which this article is devoted arose from the analysis of a study of a known antenna for the frequency bands 2.35 ... 2,45 GHz and 5,75 ... 5,.85 GHz. In our opinion, it is possible to eliminate some shortcomings in this antenna, namely (Fig. 3):

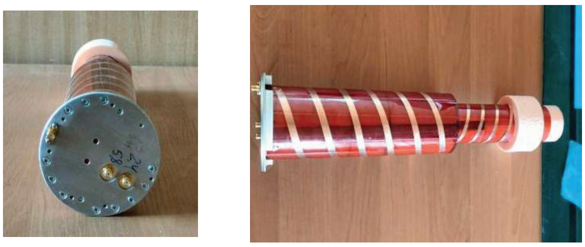


Fig. 3 – Photos of the known prototype antenna

– the antenna has only one polarisation in each band. Nowadays, drones and GCS have begun to use antennas with a different polarisation, but the linear polarisation remains;

– the antenna coil is wound on a frame made of dielectric material on a lathe. Such a product is expensive and requires a skilled craftsman.

The following solutions were proposed to address these shortcomings:

– to place two coaxial spiral antennas for the 2,4 GHz and 5,8 GHz frequency bands with different winding directions and with the ability to quickly switch from right-handed to left-handed spiral on one screen [9];

– to make a frame for winding the spirals from standard polyethylene water pipes that are widely available.

Thus, after the experimental study and final tuning of the antenna, it will be possible to manufacture antennas for GCS in small workshops without any machines. A file, screwdriver, metal scissors, and a drill are enough to make them.

It is clear that tuning the antenna is a complicated process, so you will need to experiment with the diameters of the frames, the material of the spirals, the spiral pitch, the matching element, etc.

The electrical characteristics of a spiral antenna are calculated based on its parameters. The parameters of a cylindrical helix (Fig. 1) are as follows [10, 11]:

– n is the number of turns of the helix;
– a is the angle of rise of the coil;
– R is the radius of the helix;
– L is the length of the coil;
– S is the pitch of the helix.

The following relationships exist between these parameters [7, 11]:

$$L^2 = (2\pi R)^2 + S^2,$$

$$\sin a = \frac{S}{L},$$

$$L = nS.$$

The first two relations follow from Fig. 1, which shows the unfolding of one turn of a spiral in which S is equal:

$$S = L\frac{c}{v} - \lambda,$$

where v is the phase velocity of the wave along the spiral.

The width of the half-power beam pattern, expressed in degrees:

$$2\theta_{0,\delta} = \frac{52^\circ}{\frac{L}{\lambda}\sqrt{\frac{nS}{\lambda}}}.$$

Directional coefficient:

$$D_0 = 15(\frac{L}{\lambda})^2 n \frac{S}{\lambda}.$$

Input resistance:

$$R_{BX} \cong 140\frac{L}{\lambda}, \text{Ом}.$$

Thus, the design of a dual-band spiral antenna for use on the GCS for radio contacts with a drone in the frequency bands 2,35 ... 2,45 GHz and 5,75 ... 5,85 GHz is proposed. The antenna design is based on spiral elements wound on polyethylene pipes of different diameters, with the ability to switch polarisation between right- and left-handed. A technical solution using two coaxial tubes and N-type connectors to feed each band separately is proposed. The antenna consists of two coaxially wound spirals with opposite polarisation for the 2,4 GHz and 5,8 GHz frequency bands, which are located on pipes with diameters of 50 mm and 40 mm, respectively. The smaller diameter pipe is inserted into the larger diameter pipe. The polarisation is changed using different connectors or coaxial switches.

The rapid development of technology has led to the need for high-performance antenna-feeder systems for stable communication and data transmission between drones and ground control stations. Recent publications indicate a growing demand for lightweight, compact, and multifunctional antennas with high gain and adaptive polarisation.

One of the promising solutions is the use of spiral antennas, which provide a wide frequency band and circular polarisation. In this paper, we propose a dual-band design that meets the modern requirements of radio communication and video data transmission from drones.

The main advantage is the provision of high efficiency with limited dimensions and weight of the antenna system [12]. The description of the design, technical, and electrical characteristics of the proposed antenna system is as follows:

– type of polarisation – right-handed / left-handed, switchable;

– the radius of the pipe for the 2,4 GHz band is 25 mm, and for the 5,8 GHz band – 20 mm;

– the pipes are made of polyethylene with a low dielectric constant;

– installation method – two pipes for the 5,8 GHz band inside two pipes for the 2,4 GHz band;

– each antenna has a separate power supply unit with a matching device (N-type power connector, Fig. 3, 4), to which high quality coaxial cables are connected [13, 14];

– the screen is made of a duralumin plate, the heat shrink tube has a diameter of 60 mm.

The simulation was performed in the CST Microwave Studio software under the following conditions:

– the gain at 2,4 GHz was approximately 9 dBp, and at 5,8 GHz approximately 10 dBp;

– standing wave coefficient in the operating range was less than 1,5;

– the width of the radiation pattern was considered in orthogonal planes ≈ 60^{O}.

The proposed design of a dual-band spiral antenna (Fig. 4) is promising for SNCs due to the following main advantages: compactness and lightness of construction, availability of materials for manufacturing, high efficiency in two frequency bands, and the possibility of dynamic polarisation switching.

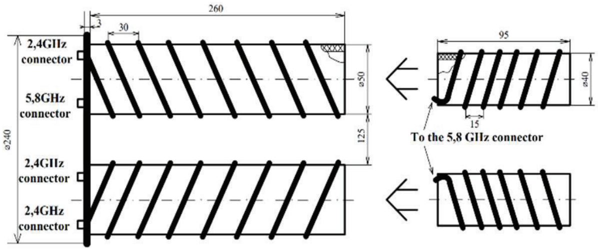


Fig. 4 – Sketch of an antenna with variable polarisations

In the future, it is planned to optimize the design using modern composite materials to reduce weight.

Conclusion

An antenna system of spiral antennas for ground control stations of drones in the frequency bands 2,35 ... 2,45 GHz and 5,75 ... 5,85 GHz with the possibility of changing the direction of rotational polarisation, which is related to the direction of rotational polarisation of the drone antenna, is proposed.

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Бердников О.М., Гічко Ю.Г., Мазор С.Ю., Храновська Т.В.
Можливості збільшення енергетики радіоліній для керування дронами
Інститут спеціального зв'язку та захисту інформації КПІ ім. Ігоря Сікорського, м. Київ, Україна

Проблематика. Практичні потреби, що визначались за результатами застосування дронів при веденні моніторингу навколишнього простору, обумовили створення антенної системи з двох спіральних конструкцій для діапазонів частот 2,4 ГГц і 5,8 ГГц. Така система з'явилася на підґрунті дослідження відомих антен для діапазонів частот 2,4 ГГц (права кругова поляризація) і 5,8 ГГц (ліва кругова поляризація). Для зменшення втрат внаслідок незбігу поляризації електромагнітної хвилі та антени для станцій наземного керування дронами була запропонована конструкція зі спіральних антен з можливістю зміни напрямку поляризації. При створенні конструкції, що пропонується, вирішувалась головна задача узгодження проблеми збігу напрямків поляризації електромагнітної хвилі, що створюється антеною станції наземного керування з напрямком обертання антени дрона. Прототипом для розробки такої антени запропоновано відому антену без можливості зміни поляризації, що має дві коаксіальні спіралі для діапазонів частот 2,4 ГГц і 5,8 ГГц з різними типами поляризації.

Мета досліджень. Розробка дводіапазонної антенної системи для станції наземного керування з можливістю зміни напрямку обертальної поляризації.

Методика реалізації. Розглянуто та проаналізовано певну кількість джерел, що стосується антен з обертальною поляризацією, різних видів антен надвисоких частот, щодо їх застосування для зв'язку станції наземного керування з дроном. Згідно з постановкою проблеми для елементів антенної решітки були вибрані спіральні антени, що забезпечують можливість зв'язку з дроном при зміні напрямку обертальної поляризації. Створення хвилі обертальної поляризації може бути вирішено різними конструкціями антен. Одним із рішенням є застосування рупорних антен і антен вібраторного типу, але з погляду співвідношення коефіцієнта посилення антени та її габаритів є сенс вибрати спіральну антену.

Результати досліджень. Моделювання конструктивних, технічних та електричних характеристик антенної системи свідчать про можливість створення дводіапазонної спіральної антенної конструкції для використання на наземних пунктах управління для радіозв'язку з безпілотними літальними апаратами в діапазонах частот 2,35...2,45 ГГц та 5,75...5,85 ГГц.

Висновки. Запропоновано антенну систему зі спіральних антен для станцій наземного керування дронами в діапазонах частот 2,35…2,45 ГГц і 5,75…5,85 ГГц з можливістю зміни напрямку обертальної поляризації, яка пов'язана з напрямком обертальної поляризації антени дронів.

Ключові слова: *дрони; безпілотні літальні апарати; поляризація; спіральні антени; діаграма направленості; коефіцієнт направленої дії; станція наземного керування.*

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