

MULTICOPTERS FOR GEOPHYSICAL RESEARCH

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Abstract

The current paper presents three multicopters developed at the Space Research and Technology Institute – Bulgarian Academy of Sciences. These unmanned aircraft designs are aimed at geophysical research and are particularly usable for detection of objects on ground surface and underground. The detection is realized by taking advantage of certain objects' properties. Metals and other conductors are identified by their electrical conductivity. Ferromagnetic objects are discovered by observing their magnetic permeability. Voids and other objects are localized utilizing the difference of the dielectric permittivity that is encountered on the boundary of the object and surrounding ground or rock.

Some of the potential targets discoverable with the described geophysical drones are military land mines (including anti-personnel and anti-tank mines), ammunition depots, reservoirs, pipelines, underground galleries, voids, bunkers, tunnels, etc.

All three developments are subject to patent protection.

Key words: multicopters, unmanned aerial vehicles, geophysical research, geophysical sounding devices

Introduction. Multicopters are being implemented even wider and in an increasingly larger scale in recent years in areas such as science research and for various practical tasks. One such application is in geophysics research – sounding of physical parameters of the Earth's surface layer and searching of objects buried

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underground [1]. The existing multicopters carrying geophysical instruments as their payload exhibit certain drawbacks that can be removed and thus considerable improvement of the operational and technical properties of these drones may be achieved.

The current article presents three innovative multicopters developed at the Space Research and Technology Institute – Bulgarian Academy of Sciences. These drones are specialised for geophysical research tasks and more specifically for searching and finding of objects on the ground surface and underground. Some of the drones implement instruments that rely on the electrical conductive and ferromagnetic properties of the objects. Other models utilize the difference of the dielectric permittivity of the surrounding ground and of the object itself. Examples of targets that could be discovered include among others, military land mines (anti-personnel and anti-tank mines), ammunition depots, reservoirs, pipelines, galleries, voids, tunnels, etc.

Multicopter for land mine discovery embodying a beat frequency geophysical instrument. Figure 1 shows the principle schematic diagram and

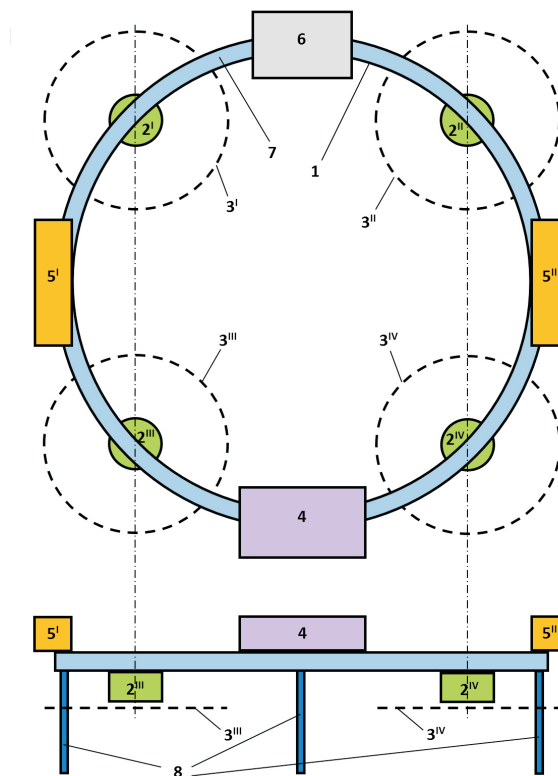


Fig. 1. Multicopter for land mine discovery embodying a beat frequency geophysical instrument

configuration of the multicopter. The latter consists of a fuselage with circular shape (1), four or more electric motors ($2^I \dots 2^n$) mounted under the fuselage that are equally distributed along the airframe main circular construction. Each electric motor turns a horizontal propeller ($3^I \dots 3^n$). The multicopter relies on control and communication electronics, again mounted to the fuselage (4). Energy is supplied by two electric rechargeable batteries (5^I and 5^{II}). The drone can carry additional payload (6) (see Fig. 1). The circular fuselage is built using a hollow curved tube made of metal or other material with electrical conducting properties. Inside the tubular fuselage a coil is positioned (7). The multicopter lands on legs (8).

The multicopter functions as follows: flight is electrically powered and attitude control and movement in space is realized by applying different and appropriate power to each of the rotors. Propellers have fixed pitch design. Most of the avionics, namely the control avionics, the autopilot, and the communication electronics are organised in one module – the control and communications module. It also governs the electric motors by supplying them with electric current over three phase control circuit. All rotors are mounted under the fuselage for a good reason. This approach decreases the aerodynamic drag with downwards direction that is otherwise created by the high speed airflow of the rotors mounted over the fuselage. Thus high speed airflow drag against the fuselage is avoided and decreased power is required for propelling the aircraft in the air – flight efficiency is increased.

The control and communications module has still another function – it controls the geophysical instrument by applying sinusoidal alternating electric current to the coil inside the fuselage. To realize this sinusoidal excitation the control and communications module employs a feedback generator. The module further observes the frequency of the electric current that is dependent on the disturbance of the generated magnetic field around the coil. By analysing the frequency deviation the control and communications module is capable of identifying and localising certain types of targets underground. These targets or objects need to have either electrical conductivity, ferromagnetic properties, or both in order to be detected by the drone. The conductivity of the fuselage tubing is interrupted at an arbitrary point along the circumference of the circular tubing and thus ensures shielding of the coil from static electric noise without short circuiting and magnetic field.

The used batteries are preferably Li-Ion rechargeable batteries because this chemistry delivers the highest energy density available at reasonable price and thus the duration of flight is considerably improved. Two batteries are carried on-board for two reasons – first, if one battery malfunctions the drone will still have power to return to the base point. Second, the two batteries balance the weight on the fuselage and by distributing it along a larger distance an increase of the moment of inertia of the whole drone is achieved making it more stable in turbulent winds.

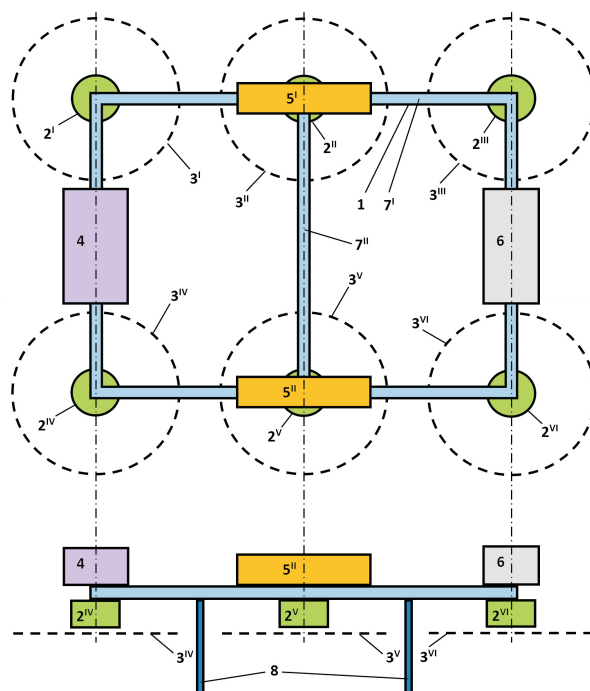


Fig. 2. Multicopter embodying a pulse electromagnetic geophysical instrument

By introducing the geophysical instrument inside the airframe, the drone is capable of carrying additional payload such as camera with gimbal.

Multicopter embodying a pulse electromagnetic geophysical instrument. Figure 2 presents a diagram of the multicopter configuration. It consists of a fuselage with rectangular shape having a transverse bar connecting the middle points of the longer parallel sides of the rectangle (1). The drone is propelled by four or a larger number of rotors each consisting of an electric motor ($2^I \dots 2^n$) and a fixed pitch propeller ($3^I \dots 3^n$). All rotors are mounted under the fuselage and along the outer beams. Control and communications module (4) encompasses the functions of the autopilot, the radio communications subsystems, the powering of the electric motors, and the operation of the geophysical instrument. Two electric batteries (5^I and 5^{II}) provide power for all the avionics, electric motors, the geophysical instrument and the payload (6). Inside the hollow fuselage two coils are placed. The transmitting coil (7^I) and the receiving coil (7^{II}) are positioned in induction balance. The multicopter lands on legs (8).

The multicopter embodying a pulse electromagnetic geophysical instrument functions as follows. The flight is realized by aerodynamic thrust force created by the rotors. By controlling the power delivery to each rotor the control and communications module and more specifically the autopilot inside it is capable of

propelling and orienting the aircraft in the air. Similarly to the previous model, the electric motors and propellers are positioned under the fuselage. This design, again, lowers the aerodynamic downforce otherwise created by the rotor high speed airflow drag against the fuselage. Hence, lower power is required to fly the vehicle and flight efficiency increases.

The control and communications module sends periodic voltage pulses to the transmitting coil. The receiving coil is in induction balance with the transmitting coil thus these pulses are not inducing observable electric current in the receiving coil. Both coils are inside the electrically conducting tubing of the fuselage and are thus electrostatically shielded from external noise sources (tubing conductivity has appropriate interruptions). When a target with electrical and ferromagnetic properties enters the magnetic field of the transmitting coil, disturbance of this field occurs and the balance between the transmitting and receiving coil is no longer maintained. A signal is observed in the receiving coil. By analysing this signal identification of the detected object may be carried out. The apparatus is also capable of detecting underground voids because they, in contrast to surrounding ground, have absent electrical and ferromagnetic characteristics.

The drone model relies again on two electric rechargeable batteries. All said about the previous multicopter is true for the current invention, namely the preferred battery types (Li-Ion rechargeable batteries) delivering longer flight times, the battery placement in the airframe and the consequential increase of the moment of inertia. There is improved reliability by implementing two separate batteries in situations when one of the batteries malfunctions.

Due to the installation of the geophysical instrument inside the fuselage, the drone is able to lift additional payload such as camera with gimbal.

Multicopter embodying a ground-penetrating radar. Figure 3 presents a multicopter embodying a ground-penetrating radar. The drone consists of a fuselage (1) consisting of two pairs of parallel beams. Each pair is perpendicular to the other pair and both pairs lie in one plane. The drone utilizes four or eight electric motors ($2^I \dots 2^n$), each turning a fixed pitch propeller ($3^I \dots 3^n$). All motors and propellers are mounted under the fuselage with all benefits following from this design as described with the previous two models. The control and communications module (4) controls all functions of the drone as with the previous designs. Again, two electric secondary batteries are employed (5^I and 5^{II}). Additional payload may be mounted to the fuselage (6). Inside the rectangular area of the fuselage bounded by the four airframe beams the antenna (7) of the ground-penetrating radar is positioned. The multicopter lands on legs (8).

The invention functions in the following way. Flight lift and acceleration is maintained by the electrically powered rotors. Management of the motors is carried out by the control and communications module. Electric motors and propellers are situated under the fuselage and the propeller airflow induced drag against the fuselage is thus minimised. Similarly to the previous two models, this

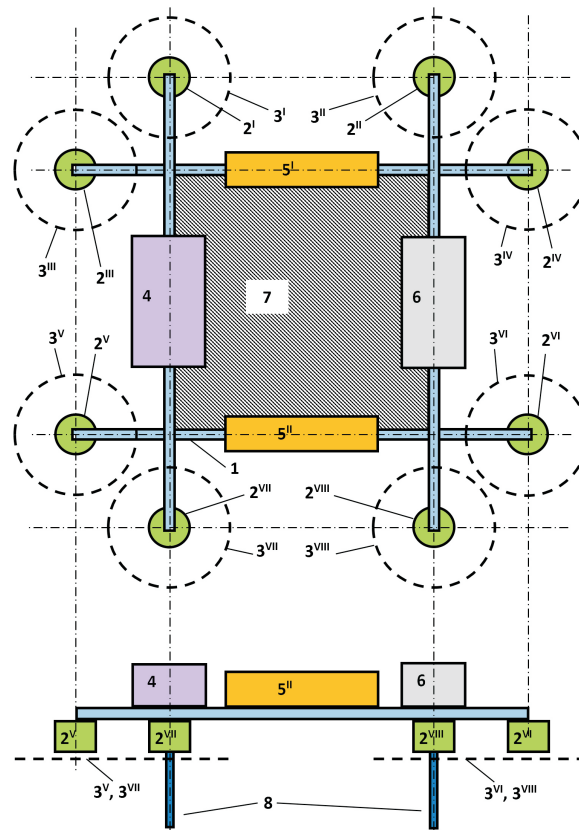


Fig. 3. Multicopter embodying a ground-penetrating radar

approach increases the flight time and drone payload maximum weight.

The ground-penetrating radar is governed by the control and communications module. Pulses of high frequency voltage are sent periodically to the antenna and radio waves are emitted downwards from the drone. The radio waves penetrate the ground and are reflected by objects and voids underground. The reflected signals are picked up by the antenna and analysed in the control and communications module. Thus objects of interest are identified underground. Object and voids reflect radio waves due to the difference of their dielectric permittivity or electric conductivity in regard to surrounding ground.

The energy source is again secondary electric batteries organized in two blocks ensuring larger moment of inertia of the whole aircraft and higher reliability in case one of the battery blocks malfunctions.

By in-building the ground-penetrating radar antenna inside the fuselage, more place and weight lift capability is achieved that may be utilized for mounting of additional payload on-board such as camera with gimbal.

Technical and utility advantages of the presented multicopters. The rotors of the multicopters are mounted under the fuselage. As a result of this approach, the accelerated airflow by the propellers does not encounter the airframe of the aircraft and no additional aerodynamic drag against the fuselage in downward direction is created. This results in extended flight time, increased payload capabilities and longer ranges of operation. Another benefit of the proposed multicopter designs is that the geophysical instruments are built inside the airframes of aircraft. Such an approach minimizes both the aerodynamic drag and the overall weight of the drone. Again, the result is prolonged flight time and extended range of the multicopter. Yet another advantage following from in-built geophysical instrument inside the fuselage is the freeing of space and weight for additional payload such as camera with gimbal.

All three innovative multicopters are patent protected at the Patent Office of the Republic of Bulgaria [2-4].

REFERENCES

- [1] GIBERT G., N. IMBERT (2018) Drone for searching and marking a target, European Patent Office, Patent number EP3476734A1, Date of publication: 01.05.2019, Bulletin 2019/18.
- [2] ZABUNOV S., G. MARDIROSSIAN, G. JELEV (2023) Multicopter embodying a geophysical instrument for land mines detection using frequency deviation, Patent application number 113661/20.02.2023, Patent Office of the Republic of Bulgaria.
- [3] ZABUNOV S., G. MARDIROSSIAN, G. JELEV (2023) Multicopter embodying a pulse electromagnetic geophysical instrument, Patent application number 113668/02.03.2023, Patent Office of the Republic of Bulgaria.
- [4] ZABUNOV S., G. MARDIROSSIAN, G. JELEV (2023) Multicopter embodying a ground-penetrating radar, Patent application number 113670/06.03.2023, Patent Office of the Republic of Bulgaria.

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