

## DRONE AIRFRAME ACTING AS A MAGNETIC LOOP ANTENNA

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### Abstract

This paper elaborates on the use of magnetic loop antenna employed in long range over the horizon radio communications on board of small to medium sized drones. The radio band of interest is the shortwave band (SW) also known as high frequency band (HF). Due to the well-known fact that standing wave antennas have sizes comparable to the wavelength of the radio signal, the installation of such antennas on board of small or medium sized drones is not feasible. To overcome this obstacle and enable a small drone to be used for radio communications in the HF band, we resort to electrically short antennas. A suitable option is the magnetic loop antenna. Although geometrically small, it is sized in meters when applied to shortwaves and becomes well suited to the dimensions of small to medium sized multicopters.

The current report offers a solution that accommodates a magnetic loop antenna within the fuselage of small to medium sized multicopters. The project is being developed by a team at the Space Research and Technology Institute, Bulgarian Academy of Sciences. We have already obtained two patent registrations in the field.

**Key words:** magnetic loop antenna, communications drone, radio relay drone

**Introduction.** This article discusses the implementation of a magnetic loop antenna for radio transmission and reception of radio signals with the purpose of long range over the horizon communication with drones. The radio band under

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consideration is the high frequency band (HF) also known as short wave band. As it is well known, all standing wave antennas have geometrical sizes of at least wavelength divided by 4. Installing such an antenna for shortwaves on a small drone is impossible. In order to enable a small drone to communicate using radio waves on HF band the only solution is implementing electrically short antennas. One such antenna is the magnetic loop antenna. Although small, it has sizes in the vicinity of meters and such sizes become comparable to the dimensions of small to medium sized multicopters.

The current article presents a solution that incorporates a magnetic loop antenna within the airframe of a small to medium sized multicopter having maximum size of one to two meters. A team at the Space Research and Technology Institute, Bulgarian Academy of Sciences, has recently developed two inventions in this area [1, 2]. The inventions elaborate on a magnetic loop antenna which is effectively the airframe of the unmanned aerial vehicle (Fig. 1). The airframe is circular in shape, made of duraluminium tubing and clad with copper on its outer surface to increase the antenna efficiency. Due to the skin effect of high frequency currents flowing in the antenna conductor, the current does not penetrate deep into the conductor and with proper copper cladding practically all of the current flows inside the thin copper surface layer that coats the duraluminium tubing of the airframe. The airframe may be additionally covered with non-conductive paint or varnish to protect the copper from oxidizing.

This article researches such an antenna and observes the results of a numerical simulation thereof for the shortwave band and specifically for the 40 meters HF band or 7 MHz.

**The multicopter design.** The inventions describe multicopters having in-built magnetic loop radio antenna inside the airframe. The application is in radio communication between a base station and airborne drones with the purpose of flight control, telemetry, and data gathering. The radio frequency band under consideration in both inventions is high frequency band (shortwave band). Under constraints of efficiency other bands with lower frequency may be utilized such as medium wave band (MW) or even long wave band (LW). To achieve antenna implementation in small to medium sized drones for these radio bands a shortened antenna is needed. The magnetic loop antenna has circular shape that is well suitable with the airframe shape of a multicopter drone. Another application of the inventions is of radio relay communications drone used to connect over-the-horizon radio links to long distances [3].

According to the inventions, the multicopter with inbuilt magnetic loop radio antenna consists of an airframe (or fuselage) and a multitude of rotors (more than 3). All rotors are made of brushless electric motors and propellers mounted on them. The rotors are positioned under the fuselage plane. The multicopter additionally encompasses an autopilot and radio transceiver. The fuselage of the aircraft is made of a duraluminium (or other suitable material) circularly

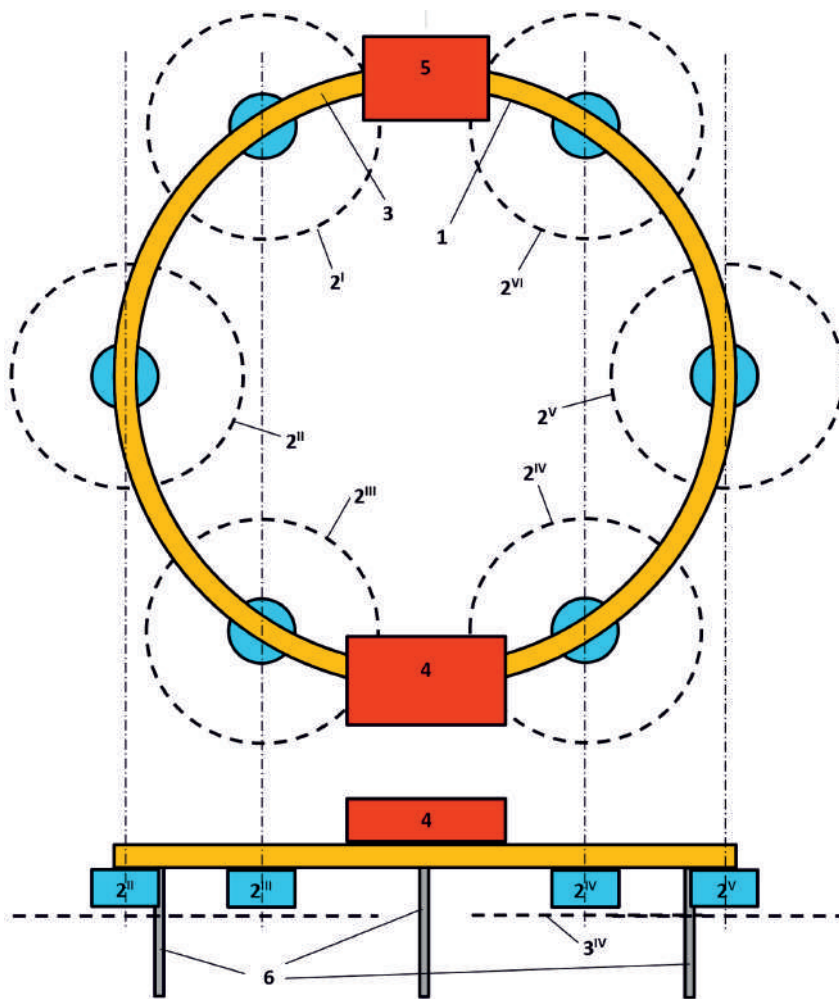


Fig. 1. Multicopter with inbuilt magnetic loop antenna

shaped tubing. The tubing is used also as the conductive element of a magnetic loop antenna. The antenna is connected to the radio transceiver. The latter is connected to the autopilot. The radio antenna is employed in simplex mode of operation, i.e. it either transmits or receives radio waves but not both at the same time. The airframe tubing has a point of disconnection in order to form an open loop. This feature is required for tuning of the magnetic loop antenna through a capacitor.

The inventions present a number of advantages. The multicopter with inbuilt magnetic loop antenna is capable of performing radio communication on short waves or medium waves without the need to carry additional antenna structure [4, 5]. Especially if the antenna would have been a standard standing wave antenna with size comparable with the wavelength of the radio signal divided by 4,

the multicopter would require enormous resources to lift such a payload. Another benefit is that instead of employing electrically short monopole antenna, the drone resorts to magnetic loop. The former is susceptible to receiving near field electrostatic noise, while the magnetic loop is not. Near field electrostatic interference on-board the drone is of large intensity due to all the electronics and electrical motors control circuits. In this manner, the invention improves the signal to noise ratio of the received radio signal. Yet, another advantage of the inventions is that magnetic loop antennas positioned horizontally ensure omnidirectional emission and reception towards the horizon in horizontal polarization. The nulls of the antenna are upwards and downwards – this is a preferred scenario as the drone is intended to communicate over large distances and any emission of radio signals below the drones are of no use. And yet another benefit of the inventions is that the electrically short radio antenna has much smaller radar footprint than a standard wavelength divided by 4 dimensions antenna.

**Antenna properties.** The antenna has narrow bandwidth and is applicable for control and telemetry signals, radio-relay applications, data gathering, etc.

The antenna shows numerous advantages when compared with standing wave variants:

- Small size
- Stiffness, rigidity, and structural strength
- Minimal wind resistance and low visual and radar profile
- Low cost to build and maintain
- Lightweight
- Offers second purpose as fuselage of the drone due to its inherent structural strength and rigidity

The antenna is calculated for the short wave frequency band and more specifically for 7 MHz. Using the tuning capacitor many other frequencies are readily available. The diameter of the outer circle is 2 m (Fig. 2). Any higher frequencies that the antenna may be parasitically resonant to are cut using a bandpass filter. The most prominent frequencies that may interfere with the antenna reception mode of operation are found inside the frequency modulation (FM) broadcast frequency band starting at 87.5 MHz and ending at 108 MHz [6]. This band is characterized by large electromagnetic power emitted by local FM broadcasting transmitter in almost all countries around the world. Due to drone high altitude of flight it is susceptible to direct radio waves coming from local transmitters most of which worldwide have transmitting powers around 10 kW.

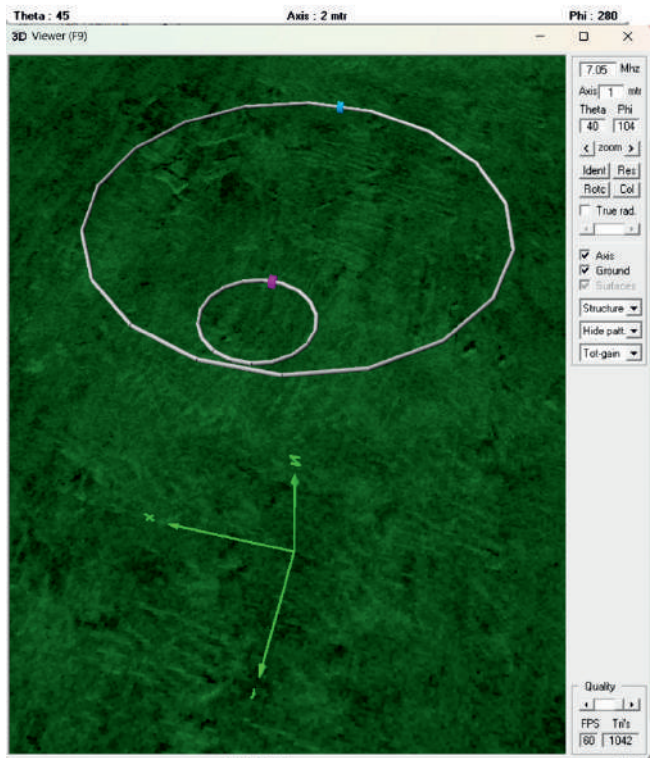
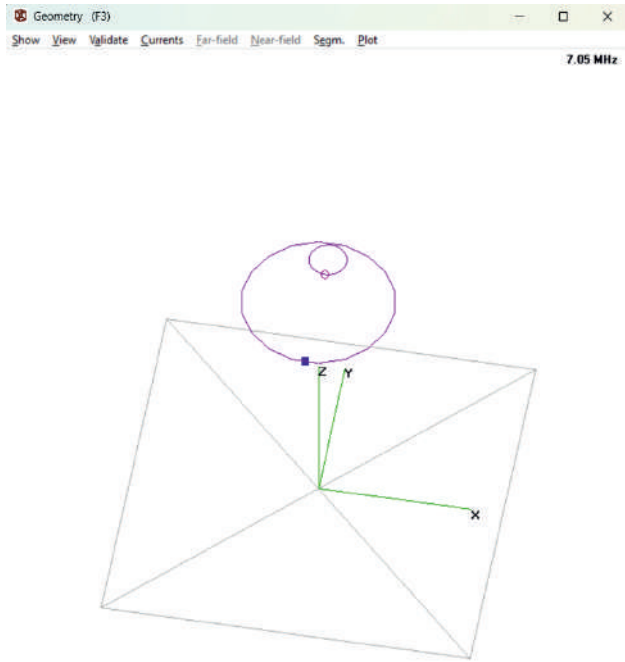


Fig. 2. Magnetic loop antenna design

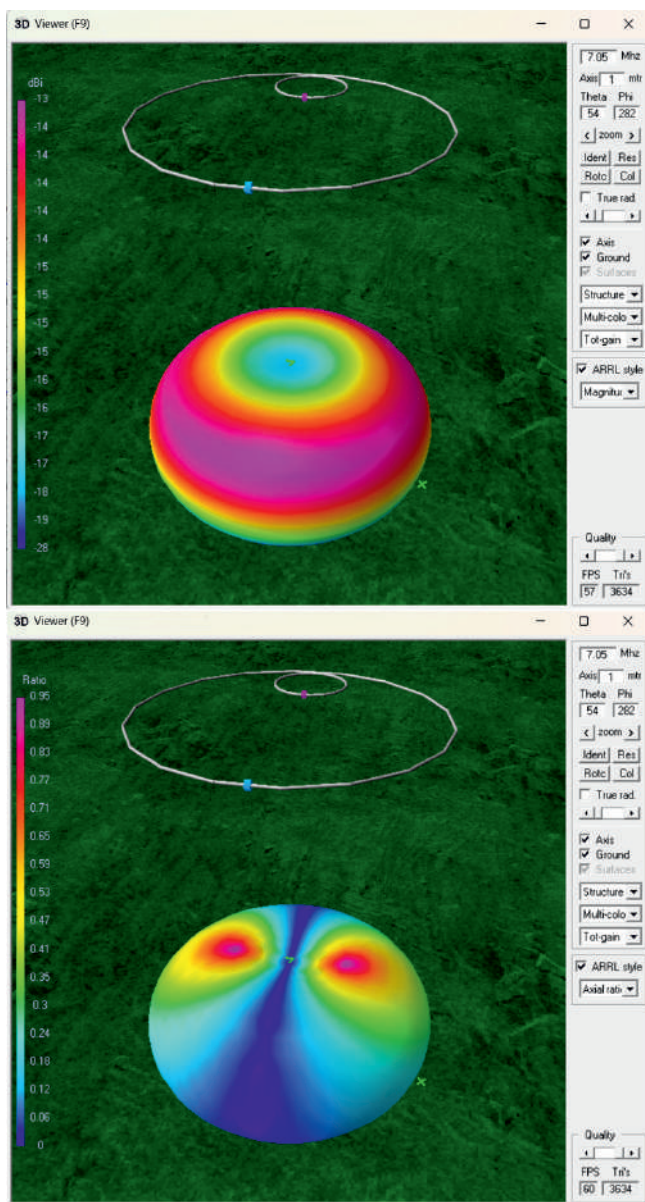


Fig. 3. Antenna total gain magnitude (top); antenna total gain axial ratio (bottom). The antenna is horizontally polarized

Nevertheless, the antenna horizontal polarization and the FM broadcasting band standard vertical polarization realize an attenuation of about 20 dB due to polarization mismatch.

Figure 3, top, demonstrates a 3D image of the antenna gain pattern at the working frequency of 7 MHz. The antenna gain pattern is omnidirectional to-

wards the horizon and has horizontal polarization. Figure 3, bottom, exhibits the antenna axial ratio, which is excellent. The worst axial ratio is found close to the vertical axis.

The narrow band characteristics of the antenna are shown in Fig. 4. The horizontal axes of the sub figures expand from 6 MHz to 8 MHz. The antenna is well matched to 50  $\Omega$  transceiver impedance. When using copper clad aluminium tubing, the antenna efficiency approaches 36.5%. The four charts show six frequency-dependent parameters (from top to bottom):

- Antenna SWR matched to 50  $\Omega$ . The SWR is approaching 1. The matching is perfect. Outside of the working band the antenna presents SWR of 400. To be implemented for various bands, the antenna requires dynamic retuning. This process is possible by the use of mechanically tuneable capacitor controlled through a servo mechanism. The returning process is feasible during flight and requires a fraction of a second to be carried out.
- Reflection coefficient. In-band characteristics of this parameter are also perfect. Out of band the antenna is highly reactive and reflects most of the incident radio frequency power.
- Impedance, both active and reactive. The active impedance of the antenna is perfect in the working band and matches the transceiver impedance of 50  $\Omega$ . The active impedance falls below 0.4  $\Omega$  outside of the working band. Reactive impedance changes widely – from 0  $\Omega$  in the working band to 160  $\Omega$  outside of it.
- Impedance as absolute value and phase angle. In-band, the absolute value is matched. Out of band it is dominated by the reactive impedance and changes in a broad range. The phase angle is zero in-band and approaches 90° out of band.

**Conclusion.** By designing an antenna for shortwave radio communications as part of the airframe of small to medium sized multicopter, the weight of the multicopter has not been increased, and at the same time a shortwave antenna has been implemented in the drone with the purpose of long range over-the-horizon communications. Such an innovative drone resolves the radio-relay over-the-horizon problem and also enables drone communication to very long distances with the purpose of unmanned aerial vehicles control, telemetry data reception, observation data collection, etc.

Our team at the Space Research and Technology Institute, Bulgarian Academy of Sciences, continues further development in the field of innovative drone communication systems in various radio wave bands with the purpose of improving the range of communication and the number of radio communication tasks that

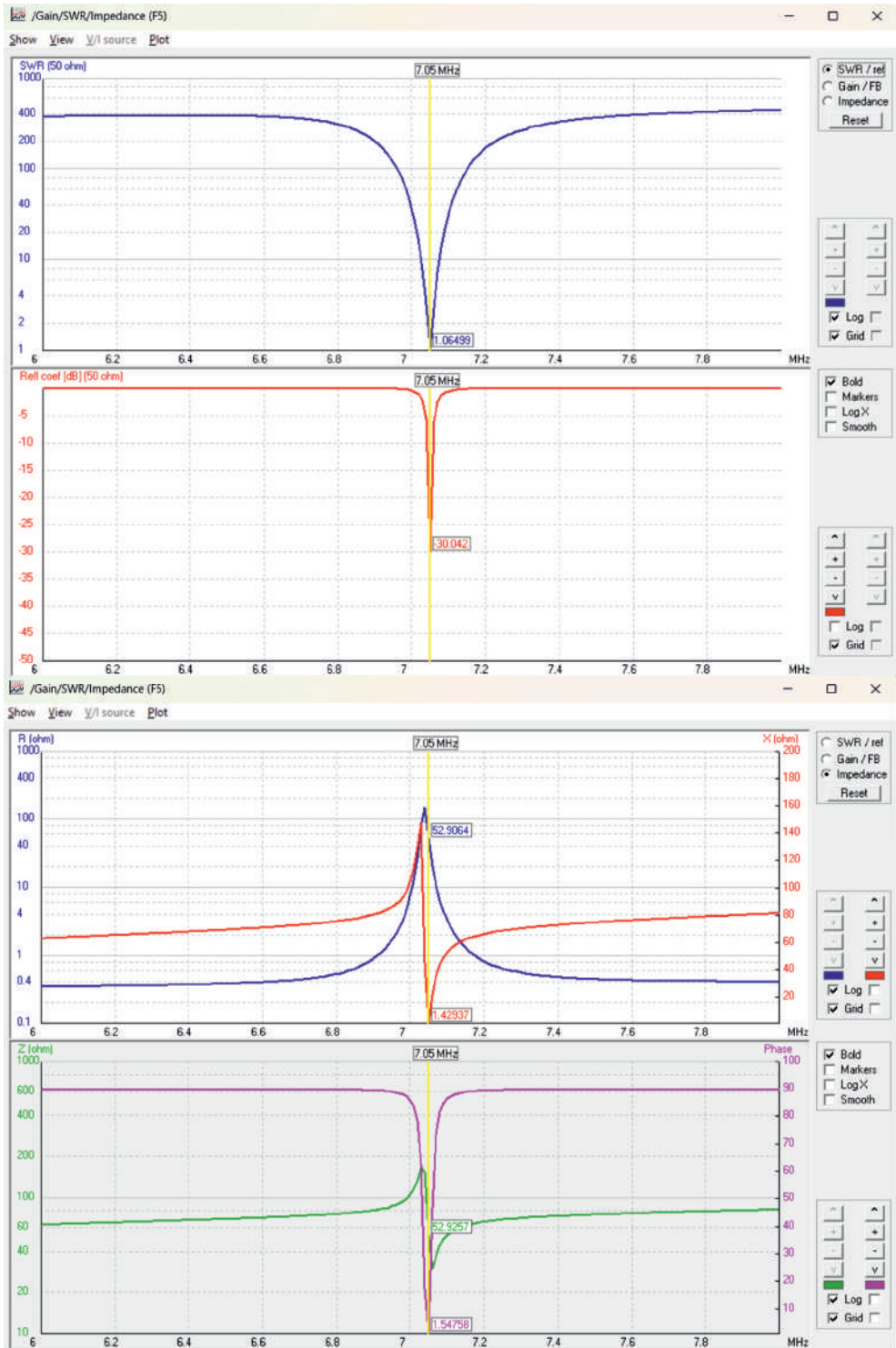


Fig. 4. Antenna parameters as functions of frequency

can be solved with the application of small to medium sized electrically powered drones in different tasks.

Future directions of investigation and research include implementing multi-band antennas in drones, resorting to long range over-the-horizon communication coupled with local line-of-sight communications and satellite powered radio links. Another field of research of our team is hybrid drone communication employing radio links along with optical communication links.

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