

FOUR INNOVATIVE DRONE INTERCEPTORS

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Abstract

Recent innovations in unmanned aerial vehicles facilitate the availability of these sophisticated devices to almost all individuals, entities and companies anywhere in the world. The various benefits drones offer might be employed in both legal and illegal scenarios. Misuse of drones is only limited to one's imagination. Common plots encompass terrorist acts, smuggling of materials over borders, spying, etc.

The advance of drone technologies asks for adequate and proportional anti-drone developments.

This paper focuses on a few recent anti-drone inventions established during 2023 in Space Research and Technology Institute at the Bulgarian Academy of Sciences. Four inventions of anti-drone interceptors are presented here. These devices are drones themselves. The inventions elaborate on the method of interception and neutralisation rather than on the detection and tracking process. All four innovations are small in size, lightweight and can be carried in multiple numbers and launched by a single person. The interceptors might be reused for several launches.

Key words: drone interceptor, anti-drone systems

Introduction. Recent innovations in unmanned aerial vehicles facilitate the availability of these sophisticated devices to almost all individuals, entities and companies anywhere in the world. Various benefits offered by drones might be employed in both legal and illegal scenarios. Misuse of drones is only limited by imagination but common plots encompass:

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- Terrorist acts through carrying munition, dangerous chemicals or biological pollutants;
- Smuggling of materials over borders;
- Spying.

Hence, the advance of drone technologies calls for adequate and proportional anti-drone inventions and innovations. The current article elaborates on a few of the latest anti-drone inventions established during 2023 in Space Research and Technology Institute at the Bulgarian Academy of Sciences. Four inventions of anti-drone interceptors being drones themselves are presented. The inventions elaborate on the method of interception and neutralisation rather than on the detection and tracking phase. All four innovative drone interceptors have small dimensions, minimal weight and are compact allowing several items to be carried by a single person and launched upon need by the same. The interceptors, in most cases, are not damaged during mission and can be reused for several launches and interception cycles.

Drone detection. The current inventions are not part of the drone detection and tracking phase but to make this initial step clear for the reader here we show some aspects of drone detection and tracking in accord with modern technologies:

1. Acoustic detection and tracking. This method utilizes a multitude of microphones positioned in two dimensional grid or array. The grid may follow a regular or pseudo-random pattern. The received sound is analysed by matching with pre-recorded footprints of known drone sound emissions. The sound produced by drones mainly comes from the propeller(s). Acoustic detection is hindered in rural environment where the background noise is rather overwhelming.
2. Video detection by cameras. Under good visibility conditions this method is more capable than the previous one. Once a moving object has been spotted, its identification through visual analysis is performed so that objects such as birds are discarded.
3. Thermal detection. This method involves thermal footprint identification and is rather inaccurate with electrically powered drones.
4. Radar detection and tracking. This technology is widely used although it has significant drawbacks related to the required high levels of radio frequency power used by the transmitters and is inapplicable in urban areas with lots of high buildings and trees.
5. Detection through radio emissions from the drone. Most drones emit a lot of radio signals. One notorious emitter, easy to spot, is the on-board video

transmitter most modern drones possess. Sadly, the culprit drones would take measures not to emit any radio signals and in this case detection of radio emissions from the drone, notably at long distance, is impossible.

Drone neutralisation. Once an intruder drone has been detected and tracked, neutralization systems are engaged. There have been many techniques implemented recently, some of which are listed below:

- Missile launch. Most destructive method in terms of debris, detonation, exhaust gasses, noise, etc. Applicable only to large drones and open areas.
- Radio jamming equipment aimed at blocking radio communications between the drone and the base station that controls it. If the drone is in autonomous mode, then such an approach is rendered useless.
- Net throwers. A simple thrower may be effective against slow moving small drones but it is hard to aim correctly at the drone and works at short distances only.
- Machine guns. Dangerous to use and inapt in populated areas. Hard to aim at small sized drones at a long distance or those moving in unpredictable paths.
- Lasers. Effective against small and medium sized drones at short to medium range. Very dangerous for humans and irrelevant in populated terrain.
- Drone interceptors. Very effective in urban areas if suitable payload for neutralization is implemented. Most solutions are reusable hence lowering the operational expenses.

Due to the benefits and drawback of different anti-drone technologies, the most appropriate one for urban environment as viewed by the authors, is the drone interceptor technology. Hence, we have worked on such solutions and managed to patent four inventions of interceptor drones in 2023. These inventions are disclosed in the current material. All four inventions are based on high voltage incapacitation methods. The generators involved are described in the next section.

High voltage generators. For neutralization of drones, high voltage pulses may be delivered to the airframe and the avionics of the drone. There are many high voltage generators available but two have shown superior capabilities, small dimensions and weight, thus they are suitable to be carried on-board the interceptor drones as payload. These two devices are the Cockcroft–Walton generator and Marx generator.

The Cockcroft–Walton generator is an electronic device producing high direct current voltage. It is powered by low voltage sources such as batteries. The generator bears its name from two physicists – John Douglas Cockcroft and Ernest

Thomas Sinton Walton. They implemented the generator in their particle accelerator in 1932. As a result the two scientists managed to achieve the first artificial nuclear disintegration in history. In 1951 they won the Nobel Prize in Physics for “Transmutation of atomic nuclei by artificially accelerated atomic particles” [1,2].

The generator was invented in 1919 by the Swiss physicist Heinrich Greinacher. Today these generators are widely employed in electronic devices requiring high voltages, such as photocopiers, X-ray machines, etc.

On the other hand, the Marx generator is an electronic device invented by Erwin Otto Marx in 1924 [3]. It generates high-voltage pulses using low-voltage power supply such as a battery. Similar to Cockcroft–Walton generator, Marx generator was primarily employed in high-energy physics experiments. Later it was extensively used for lightning simulation and testing of aviation equipment.

Four innovative drone interceptors. The first of the four inventions [4] is a drone interceptor. The invention has a number of benefits over existing devices [5]. It is a drone itself propelled by a propeller mounted on the tail of a fixed wing airframe. Upon encounter with a malicious drone the interceptor neutralizes the drone through electrical discharge generated by an on-board Cockcroft–Walton generator (see Fig. 1). The interceptor uses a delta wing and aerodynamic fuselage (component 1 in Fig. 1). By mounting the propeller and motor on its tail (component 2 in Fig. 1), the front of the fuselage becomes available for mounting the payload, namely the Cockcroft–Walton generator (component 3 in Fig. 1) and a laser (component 4 in Fig. 1).

The interceptor is applied in countering and subduing malevolent drones by means of electrical discharge advancing along the path of a laser beam. The laser

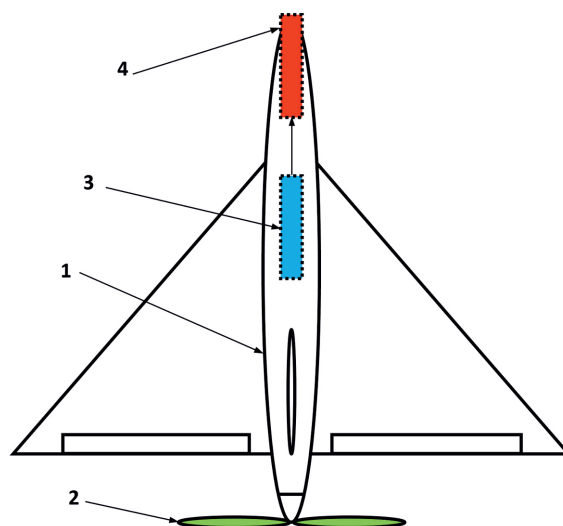


Fig. 1. Drone interceptor with propeller propulsion and Cockcroft–Walton generator

ionizes the air along its path making it electrically conductive for the electrical discharge generated by the Cockcroft–Walton generator to propagate. The electrical impulse and the laser are engaged when the interceptor is at close enough distance to the offender drone. After neutralisation, the interceptor returns to launch location or to another place where it is meant to land. The described method allows the interceptor to be reused multiple times. Furthermore, during one flight, the interceptor is capable of initiating several electrical discharges attacking more than one drone or charging the same intruder multiple times if initial shots have failed.

Application is with blocking of infringing drones performing unlawful operations.

The second invention is devised on a drone interceptor having a propeller propulsion and Marx generator [6]. The interceptor is a drone, similar in construction to the previous invention with the important distinction in the payload. This time, instead of a Cockcroft–Walton generator and a laser, a Marx generator and an electrode are exploited. The interceptor is presented in Fig. 2. The fuselage carries a fixed wing of the delta topology (component 1 in Fig. 2.). The propeller and motor are mounted on the tail of the airframe (component 2 in Fig. 2). The Marx generator (component 3 in Fig. 2) is positioned at the front of the fuselage along with an electrode (component 4 in Fig. 2) protruding outwards from the airframe's nose. The interceptor neutralises the drone with the help of electrical discharges developing through air in front of the interceptor. At the moment

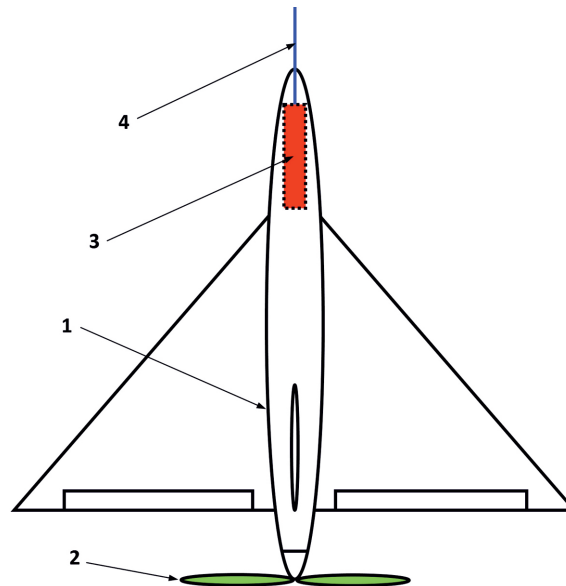


Fig. 2. Drone interceptor with propeller propulsion and Marx generator

when the interceptor has acquired the correct position in respect to the intruder drone, the former engages the Marx generator and emits an electrical discharge from the electrode. Due to the very high voltage inherent in Marx generator, the discharge spark may overcome significant distance in the air and reach the target drone without the need for a laser beam ionizing air in a channel. After discharge the interceptor flies back to the location of the launch or to a predetermined place for landing. Multiple discharges are possible during a single flight thus attacking several drones or reengaging the same drone for a number of times until successful intervention.

Application is the same as with the first invention – stopping invader drones while guarding facilities and areas against drone attacks.

The third invention discusses an interceptor drone having fast speed and fixed wings of delta type [7]. The invention builds over existing devices [8] but delivers a number of benefits compared to these. The propulsion is by means of a rocket engine. As with the first invention, the neutralization of the invader drone is fulfilled by virtue of Cockcroft–Walton generator and laser (see Fig. 3). The interceptor consists of a fuselage (component 1 in Fig. 3), a rocket engine mounted on the tail of the fuselage (component 2 in Fig. 3), Cockcroft–Walton generator

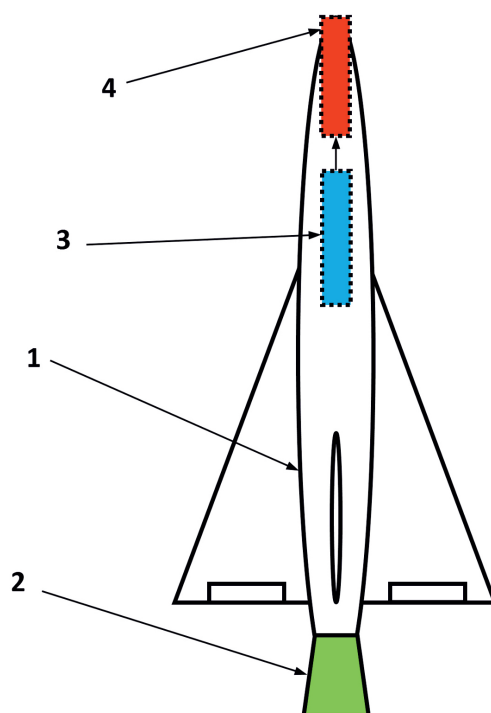


Fig. 3. Drone interceptor with rocket propulsion and Cockcroft–Walton generator

(component 3 in Fig. 3) and laser (component 4 in Fig. 3). As with the first invention, the Cockcroft–Walton generator creates high voltage pulses delivered to the offender drone along an ionized air channel established via the laser beam. In contrast to the first invention, the current device attains much higher speeds. This feature provides an advantage in intercepting much faster drones. The drawback is that the interceptor exhausts its rocket engine fuel quickly and is not capable of attacking again in one flight. Nevertheless, it is able to fly back to the launch pad or to a predefined location. After rocket engine replacement the interceptor drone is ready to fly again.

The last invention (see Fig. 4) is based on a fixed wing drone having rocket propulsion and Marx generator as payload [9]. This interceptor is capable of fast flight like the previous invention and employs Marx generator apt for delivering very high voltage discharges through air. The latter are compelling for destroying the avionics of sophisticated drones having certain level of lightning protection. Figure 4 shows the interceptor. It consists of a fuselage (component 1 in Fig. 4), rocket engine mounted on the tail of the airframe (component 2 in Fig. 4), Marx generator (component 3 in Fig. 4) and an electrode (component 4 in Fig. 4). Similarly to the previous invention, the interceptor is not good for more than one target

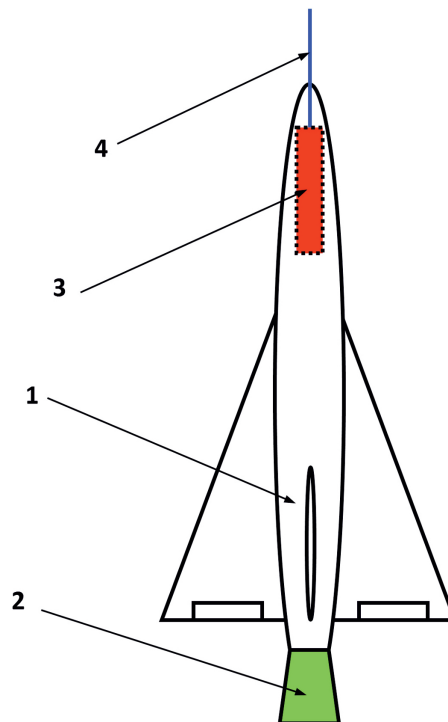


Fig. 4. Drone interceptor with rocket propulsion and Marx generator

attack during a single flight but replacing the rocket motor is straightforward and repeated flights are possible after a short period of preparation.

Conclusion. Drone interceptors are invaluable devices in certain scenarios where other means of drone countermeasures are inapplicable. Such situations are terrorist attacks in urban and highly populated areas where the presented herein interceptors yield least damage to the public and infrastructure.

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