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DEVELOPMENT AND MODELING OF SMALL-SIZED AIR TARGET SIMULATION MEANS BASED ON MULTICOPTERS WITH COMBINED RADAR-THERMAL EMISSION

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Abstract
This article addresses the development and modeling of small-sized air target simulation means intended for training air defense units. The main focus is on the use of multicopter platforms equipped with combined radar-thermal emitters. A comprehensive approach to modeling is proposed, encompassing aspects of aerodynamics, radar and thermal signatures, and control systems. The advantages of using such simulation means for enhancing the effectiveness of combat training and verifying the combat readiness of air defense systems in realistic conditions are discussed.

Keywords: Air target simulation, multicopters, air defense units, radar simulation, thermal simulation, combined radiation, modeling, combat training, reconnaissance assets, electronic warfare assets, aerodynamics, radar signature, thermal signature, flight control, exercises, training ground, combat readiness verification, air defense systems, drone targets, artificial targets.

Аннотация. В настоящей статье рассматриваются вопросы разработки и моделирования малогабаритных средств имитации воздушных целей, предназначенных для тренировки зенитных подразделений. Основное внимание уделяется использованию мультикоптерных платформ, оснащенных комбинированными радиолокационно-тепловыми излучателями. Предлагается комплексный подход к моделированию,

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включающий аспекты аэродинамики, радиолокационного и теплового сигнатур, а также системы управления. Обсуждаются преимущества применения таких средств имитации для повышения эффективности боевой подготовки и проверки боеготовности зенитных комплексов в условиях, приближенных к реальным.

Ключевые слова: имитация воздушных целей, мультикоптеры, зенитные подразделения, радиолокационная имитация, тепловая имитация, комбинированное излучение, моделирование, боевая подготовка, средства разведки, средства РЭБ, аэродинамика, радиолокационная сигнатура, тепловая сигнатура, управление полетом, учения, полигон, проверка боеготовности, системы ПВО, дроны-мишени, искусственные цели.

Modern armed conflicts of recent decades demonstrate a steady trend toward the increasing role of air attack assets of various classes. Along with manned aviation, unmanned aerial vehicles, loitering munitions, and small reconnaissance platforms have become widespread. Under these conditions, the importance of high-quality training of tactical-level air defense units capable of timely detecting, tracking, and classifying various types of air targets is increasing[1].

The effectiveness of combat crew training largely depends on the realism of the training environment. The use of traditional target systems provides only a limited range of scenarios and does not always allow reproduction of the characteristics of modern air threats. As a result, there is a need to develop new air target simulation means capable of reproducing not only the flight trajectory but also the physical characteristics of real objects perceived by radar and electro-optical detection systems[2].

Analysis of existing methods and technologies of air target simulation.

The effectiveness of training air defense units directly depends on the quality and realism of the simulation means employed. Historically, both simulators based on standard weapons and specialized systems have been used for training purposes.

The most common traditional simulation means are target missiles. This is a classical method based on launching specially designed missiles that imitate the flight profile and certain radar characteristics of combat aircraft or cruise missiles.

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The advantages of this target include high speed and the ability to simulate complex ballistic trajectories. Its disadvantages include high cost, danger to surrounding objects, limited reusability, and low variability of simulated targets.

Another type includes stationary and towed simulators. These simulators are used on training ranges to indicate the presence of a target. Their main advantage is ease of operation. Their disadvantages are the complete inability to simulate movement and maneuvering, as well as low realism. Acoustic and visual simulators are also available. These simulators are used for general training tasks but do not provide adequate information for radar systems.

With the development of UAV technologies, new opportunities have emerged for creating compact, flexible, and cost-effective air target simulation means. Multicopters possess several unique advantages.

Manoeuvrability and controllability: the ability to perform complex maneuvers, imitate various flight profiles (horizontal flight, dive, climb, hover), and change direction of movement.

Mission flexibility: the ability to operate under various conditions, including restricted areas and low altitudes.

Comprehensive simulation: integration of several types of emitters (radar, thermal, and electronic) on a single platform, enabling simulation of complex radar and infrared target signatures.

Cost-effectiveness: relatively low platform and equipment costs, along with the possibility of repeated use[3].

One of the most promising directions is the use of multicopter platforms. Modern multicopters possess high maneuverability, relatively low operating costs, and extensive modernization capabilities. The availability of advanced electronic components makes it possible to integrate various devices for generating radar and thermal target signatures. This allows simulation of a wide spectrum of airborne objects with minimal training costs.

The analysis of modern air defense training programs shows that training against low-observable airborne objects is particularly challenging. Such targets are characterized by small dimensions, low radar cross-section, and limited thermal contrast. At the same time, such assets are increasingly used in modern conflicts.

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Therefore, training means must reproduce the corresponding characteristics under controlled conditions[4].

The concept of a small-sized air target simulation means involves the use of a serial medium-payload multicopter as the base platform(Figure-1). Devices for generating radar signatures and a thermal module creating infrared radiation of a specified intensity are installed onboard[5].

The combined operation of these systems enables the formation of a combined airborne target image perceived by various surveillance systems as a single object. In the development of such systems, mathematical modeling plays an important role. The use of digital models makes it possible to determine optimal design parameters before manufacturing a prototype. Modeling may include assessment of aerodynamic characteristics, the influence of additional payload on flight stability, system energy efficiency, and operational stability under different meteorological conditions.

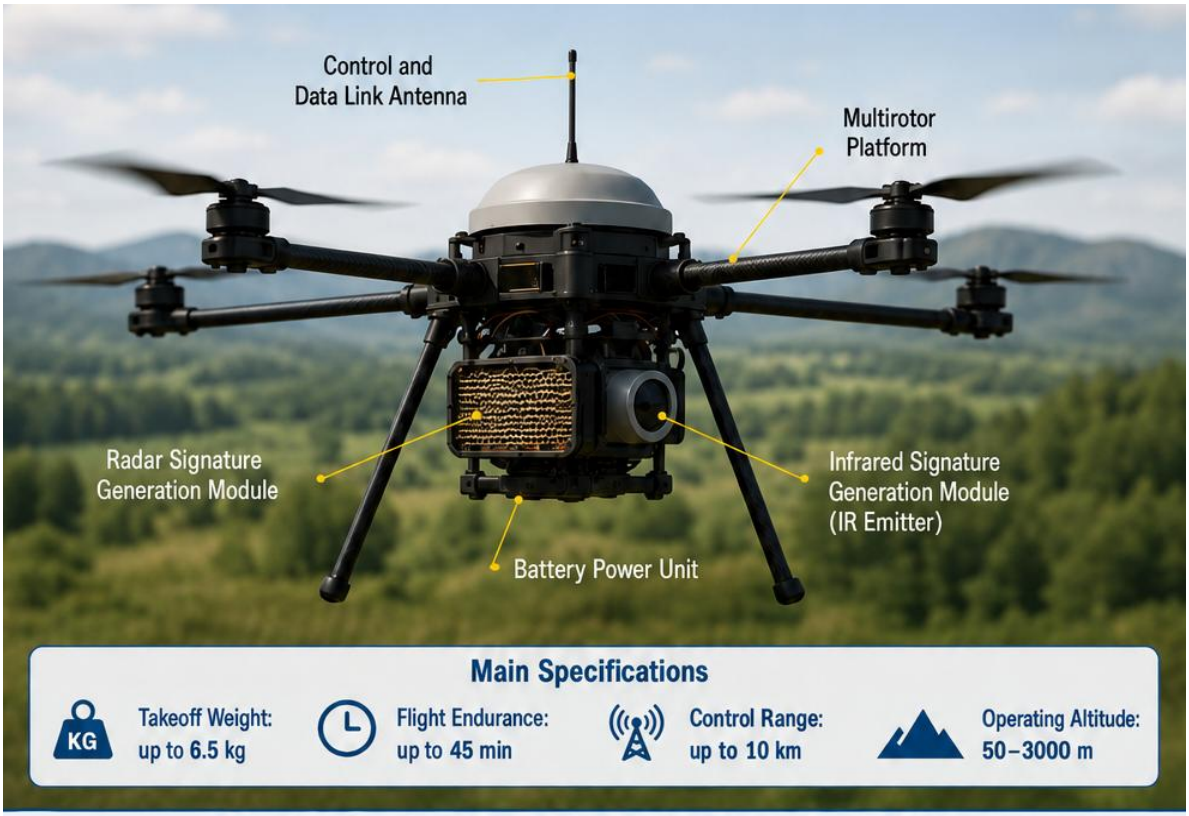

Figure-1. Placement of simulation means on a multicopter

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Modeling radar visibility is of particular importance. The radar cross-section of an object is determined by its geometric characteristics, construction materials, and the relative arrangement of its elements. To increase the visibility of a small multicopter, special reflective structures may be used. At the same time, it is important to preserve flight characteristics and avoid a significant increase in system mass[6,7].

Formation of a thermal signature is equally important. Modern detection systems widely use infrared observation channels; therefore, a training target must reproduce the characteristic thermal features of an airborne object. Compact heating elements with adjustable power may be used for this purpose. Their application makes it possible to create various simulation scenarios depending on the type of target being modeled.

The conducted analysis shows that the use of a combined radar-thermal image significantly expands training capabilities. Crews gain the opportunity to practice operations under conditions максимально close to reality. Simultaneously, the quality of training for radar operators, electro-optical surveillance operators, and command posts is improved[2,8].

An additional advantage is the ability to program different flight profiles. Modern automatic control systems allow setting movement routes that include changes in altitude, speed, and flight direction. This creates diverse air-target appearance scenarios and contributes to the formation of stable operational skills among personnel[9].

The use of multicopters as simulation means significantly reduces training costs. Compared with traditional target systems, such platforms feature lower operating costs, ease of maintenance, and repeated use. Their use also increases training safety thanks to flexible control and the possibility of immediate flight termination in emergency situations.

Requirements for a combined signature.

Air defense detection and engagement systems largely rely on radar and infrared sensors. Therefore, an effective simulation means must create signatures meeting specific requirements.

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Radar signature: it should imitate the radar cross-section of various target types (aircraft, cruise missiles, UAVs). Simulation may employ onboard transmitters generating radio signals reflected toward radar stations, as well as special corner reflectors increasing radar cross-section.

Thermal signature: it should imitate thermal radiation from critical aircraft areas such as engines and skin surfaces. This can be achieved through infrared-emitting devices, heating elements, pyrotechnic or electrothermal modules. Simulators must allow temperature adjustment and, consequently, infrared radiation intensity adjustment to model different engine operating modes and structural heating conditions[10].

Structure of multicopter-based air target simulation means. The proposed structure includes a multicopter platform, onboard control complex, radar simulation module, thermal simulation module, and power supply system.

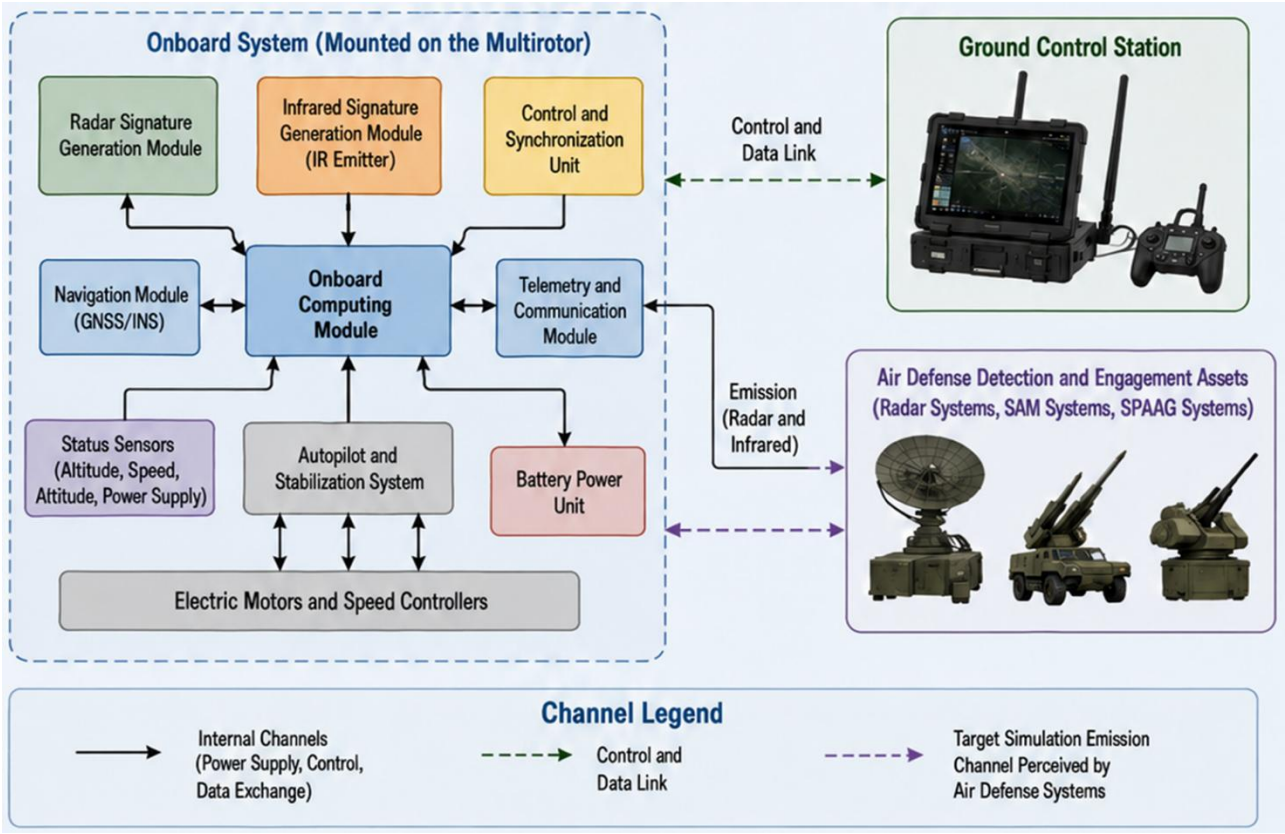

Figure-2. Structural diagram of a multicopter-based air target simulation system

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Prospects and Advantages

Implementation of the proposed multicopter-based simulation means provides increased training realism, expansion of training scenarios, cost efficiency, safety, operational flexibility, and the possibility of integration with electronic warfare systems for jamming simulation [11].

Conclusion

Based on the above considerations, multicopter platforms are highly promising as carriers of air target simulation means. The development of such systems corresponds to modern trends in training technologies and contributes to improving the effectiveness of tactical-level air defense training. The creation of a combined radar-thermal image ensures realistic simulation of the air situation and significantly expands the range of training tasks. Future research should focus on improving signature generation methods, expanding autonomous flight control capabilities, applying artificial intelligence technologies, and integrating such systems into a unified air defense training system[12].

In conclusion, the development of small-sized multicopter-based air target simulation means represents an important direction in the evolution of training systems for air defense units. The use of combined radar-thermal emission increases the realism of simulated airborne objects and provides higher-quality training of combat crews. The obtained results confirm the possibility of creating effective and affordable systems capable of significantly improving the training level of tactical air defense units. Comprehensive modeling, including aerodynamic, radar, thermal, and control aspects, enables the creation of highly effective simulation means closely resembling real airborne threats. The use of such systems improves exercise realism, expands training scenarios, and ensures economic efficiency and safety. Further research will optimize their characteristics and adapt them to the continuously evolving requirements of air defense forces.

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