METHODS AND MEANS OF FOREIGN ARMIES IN THE FIGHT AGAINST UNMANNED AERIAL VEHICLES

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Abstract. *In order to develop air defense, to protect troops, special facilities, territories and cities from air attack, one must first of all know the principles of operation of this system and the history of its development. It is necessary to approach this from a scientific point of view and study the air defense of foreign countries in order to create a unique air defense system of the Republic of Uzbekistan. The air defense of foreign countries is studied on the basis of various theories, concepts, approaches, positions, directions.*

Keywords: *air attack, reconnaissance, concept, development, defense, direction, application.*

The ever-growing number of unmanned aerial vehicles, the variety of possible scenarios of their use in military conflicts to solve various tasks and the difficulty of destroying them with traditional air defense systems, mainly due to the small size and altitude of the UAV flight, determined the need to develop special methods and means to combat them.

An additional complexity for the development of methods and means of combating UAVs is introduced by a wide range of existing unmanned vehicles — with a mass of less than 0.025 kg and up to strategic UAVs with masses, heights and flight durations characteristic of manned vehicles. In addition, there are other types of unmanned aerial targets — barrage munitions and planning aerial bombs that have flight speeds comparable to UAVs, effective scattering area (ESR) and a set of onboard radio and optoelectronic (OE) equipment.

In general, the avionics of modern UAVs can include radio communications, radio navigation and radar, optoelectronic, radio and radio intelligence, electronic warfare and electronic protection.

The analysis of the methods and results of the use of UAVs in military conflicts and terrorist attacks in the last decade in the Middle East, Ukraine and Nagorno-Karabakh shows that a modern system of combating UAVs that effectively responds to emerging threats should promptly and automatically provide timely detection and identification of single and group unmanned targets; determination of their possible load, nature the emerging threat and ways to neutralize it by appropriate methods.

Currently, the main methods of combating UAVs are: electronic suppression of radio communication channels and radio navigation; information impact on the control system; disabling of UAVs by using laser or microwave radiation; destruction of UAVs by traditional air defense weapons.

These methods are implemented by various technical means of land, sea and air-based, while the means themselves can be portable, mobile, placed directly on transport platforms or in appropriate containers, and stationary.

In the course of these works , the following basic principles of the functioning of modern systems for combating military UAVs were formed:

• complex application of various methods of detection and neutralization of UAVs, taking into account all possible ways of their application, flight and technical characteristics (optical, electronic, etc.), as well as vulnerabilities of devices and means of information exchange with them;

• openness and scalability of the hardware and software structure of complexes and means of struggle, facilitating their modernization, including through the introduction of technical and software modules from other manufacturers;

• multifunctionality, which provides the possibility of using means of combating small-sized objects of various classes (missiles, shells, mines, barrage ammunition, planning bombs, UAVs) in various conditions of the operational and tactical situation;

• solving the main part of functional tasks based on unified software in order to reduce the time and cost of adapting combat systems to new operating conditions (the emergence of new types of UAVs, the equipment they carry, methods of their application, etc.);

• widespread use of artificial intelligence (AI) technology both in the means of detecting and identifying aerial objects, and and in the control system of the means of combating UAVs, taking into account the constantly changing situation;

• the ability to work in a single information and communication space (UICP) in order to exchange data with all involved means of reconnaissance and destruction (suppression) of UAVs;

• application of a standardized control system for the entire set of distributed forces and means of missile and air defense.

Three main approaches are used to implement these principles.

The first one provides for the modernization of existing complexes and individual air defense systems to combat aircraft.

The second is the need to take into account the tactical and technical characteristics of the UAV when creating new complexes and air defense systems.

The third is the development of specialized technical and software tools focused only on combating UAVs and taking into account the specific features of various devices and (or) equipment installed on them when exposed.

In the air defense system of developed countries, as a rule, the whole set of means is used, including both traditional air defense systems and special means. Some complexes and means of combating foreign-made UAVs will be presented below, the description of which is given in more detail in open sources.

A typical example of the first approach is the modernization of radar stations (radars) in service in order to enable the detection and tracking of small-sized UAV-type targets. It should be noted that the use of radar stations (radars) provides detection of UAVs at long ranges compared to OE and acoustic detection means.

Thus, the AN/MPQ-64A4 Sentinel A4 radar currently being created in the interests of the US Army is an improved version of the AN/MPQ-64A3 three-coordinate radar with an active phased array antenna array with expanded functionality, including the ability to detect and classify small-sized UAVs.

Similarly, the Spexer 2000 3D radar (Spexer 2000 3D) of the 9.2—10 GHz band, which is widely used in the Armed Forces of Germany, has undergone a special upgrade to ensure the

ability to work on targets with low ESR. This made it possible to use it in several mobile and stationary anti-UAV complexes created since 2020 for the Armed Forces of Germany. Another direction of increasing the capabilities of existing air defense systems and means is the modernization of their control systems. For example, the Sky Capture air defense control and control system (Fig. 2) the production of Israel makes it possible to significantly increase the capabilities of outdated models of anti-aircraft artillery and short-range anti-aircraft missile systems (SAMs), including the defeat of small-sized and low-flying aircraft.

The system includes an EL/M-2106 radar and OE surveillance equipment, as well as a control subsystem. The data received from the radar and optoelectronic means are automatically processed in order to issue guidance and fire control commands for various connected air defense systems. It is known about the supply of this system to foreign aircraft.

Another Israeli short-range complex "Red Sky-2" (Red Sky 2) integrates infrared (IR) surveillance equipment and various man-portable air defense missile systems (MANPADS), including American (Stinger) and Russian (Strela and Igla). The complex is capable of detecting, controlling movements and hitting objects at a distance of about 6 km or more, i.e. at the effective range of MANPADS missiles.

In most modern UAV control systems, a modular construction principle is implemented, involving the integration of a wide variety of means of detecting, tracking and neutralizing aircraft, including radar, OE and electronic reconnaissance (RER) equipment, as well as electronic warfare (EW) and various means of destruction by type of impact.

Thus, in 2020, the British Air Force (RAF) received the first set of the ORCUS system, which includes radar, OE and RER modules, as well as electronic warfare equipment and a control subsystem.

The Israeli anti-UAV complex EL/I-4030 "Drone Guard" (Drone Guard) includes a three-coordinate radar, OE and THEIR surveillance means, as well as means of electronic warfare and electronic warfare. This complex automatically detects and controls the movements of up to 100 aerial objects in one group, including UAVs.

Separate examples of the implementation of methods of combating UAVs in modern multifunctional air defense systems are mobile complexes designed to protect troops during their movement and deployment, capable of hitting aerial targets while the vehicle is moving.

Thus, the set of means of the US Marine Corps air defense system "Madis" (MADIS — Marine Air Defense Integrated System) is placed on tactical vehicles and includes: body-mounted and portable air defense systems "Stinger"; 30-mm automatic cannon; 7.62-mm machine gun; electronic warfare; means of OE surveillance; radar RPS-42 and a management system capable of interacting with other complexes and facilities in the EICP. The RPS-42 wide-range radar is capable of detecting aerial targets at a distance of up to 30 km and altitudes of 10-10, 000 m, classifying various aerial objects, including micro and mini-UAVs at a distance of 3.5—10 km.

Such a mobile complex, placed on an armored personnel carrier or a special platform and equipped with radar, means of OE surveillance and fire destruction of small-sized air targets, is manufactured for the Armed Forces of Germany. As a basic element of the complex, the vehicle-mounted module of remotely controlled weapons and surveillance systems "Protector" is used, which allows the use of various weapons, including machine guns of different calibers, automatic guns of 20-50 mm caliber, short-range anti-aircraft guided missiles, etc. The Spencer 2000 3D radar is used to detect and track targets.

The Drone Dome complex used in the Armed Forces of Israel and other countries in a mobile version is mounted on a light buggy-type vehicle, consists of an RPS-42 radar, OE and IR surveillance equipment, electronic warfare equipment, including radio monitoring equipment and suppression of broadband radio networks. There is a version of the complex equipped with laser weapons.

In general, modern combat laser systems are capable of destroying various targets, including UAVs. For example, in the interests of the US Air Force, a light ground complex "HELWS" (HELWS — High Energy Laser Weapon System) is being created, mounted on a pickup truck or buggy.

An OE target detection and tracking system is used to guide the laser installation. The radiation power in the pulse is in the range of 10-50 kW, the battery charge should provide about 20-30 laser shots.

The air defense complex of the Israeli Air Force "Aaron Beam" (Ion Beam) is designed to intercept and destroy various objects at a range of up to 7 km. It includes radar, IR surveillance equipment, two laser installations and a control system. Radar provides object detection, IR means — control of its movements, two lasers, triggered synchronously, destroy the target.

It takes 4-5 seconds to hit a single target. The pulse power of one beam ranges from 10 to 300 kW. The equipment of the Iron Bim complex is mounted in a container resembling a container for sea transportation, which provides convenience, and in some cases, secrecy of its transportation.

An example of a mobile air defense system manufactured by China is the LW-30 complex, designed to intercept various aerial targets, including small-sized ones. The complex includes a control and communication machine, a machine with a laser installation with a power of 30 kW per pulse and a machine with supporting equipment.

There are also specially designed complexes and tools that take into account various features of the use and technical equipment of the UAV. The simplest means are wearable electronic warfare devices for individual use, manufactured by various manufacturers in the form of pistols or rifles. As a rule, they provide suppression of radio equipment placed on UAVs operating in the 433 and 840-940 MHz bands, as well as radio communication equipment of the Wi-Fi standard - 2.4 and 5.8 GHz bands and navigation equipment of the Navstar space radio navigation systems, and in some cases — Glonass and Beidou at ranges from 0.5 to 2 km.

More complex products include means of OE detection, tracking and staging of UAV radio interference mounted on the same platform. In this case, the range of detection and effective suppression of the electronic equipment of the UAV increases.

An example of a high—tech specialized complex is the "THOR" (THOR - Tactical High Power Operational Response), designed to protect advanced air bases of the US Air Force from a group attack by UAVs numbering tens and hundreds of units. Powerful directional electromagnetic radiation is used to suppress their on-board electronic equipment used in control, reconnaissance, communications and navigation systems. A specialized container is used to accommodate and transport the equipment of the complex.

It is important to emphasize the possibility of simultaneous destruction of a large number of UAVs implemented in this complex.

Today, exercises involving the group use of various robotic platforms are being held in many countries of the world. For example, in the fall of 2020, China successfully tested the use of

200 interacting UAVs to solve the tasks of searching for and destroying specified ground targets. In the military conflicts of the future, the number of simultaneously operating unmanned combat vehicles will certainly increase and, accordingly, the requirements for the speed and striking ability of the means of combating them will be tightened.

The following samples of high-tech equipment manufactured in the USA, Great Britain, France, Canada, China and a number of other countries are complexes of information impact on UAV control systems. The possibility of such an impact is determined by the presence of pre-determined or revealed vulnerabilities of its hardware and software directly in the process of monitoring the UAV, allowing for specialized information attacks.

As a rule, such attacks are carried out by transmitting relevant messages via radio channels, perceived by the UAV as legitimate control commands or positioning data, but really hindering the performance of the tasks assigned to it.

Examples of modern American complexes of information impact on UAV control systems, which, according to manufacturers, allow to influence almost all known types of devices, including military ones, are "Dronefox" (DroneFox) and "Titan" (Titan). Using the I technology, these products provide automatic search and identification of radio channels used by UAVs, assessment of the nature of the transmitted data, selection of effective countermeasures, including information attacks and targeting simulation interference.

In conclusion, it is necessary to cite the following facts confirming the constant interest of the militarily leading states in improving the technologies for creating and using complexes and individual means of combating UAVs.

Currently, dozens of companies from different countries, including Russia, produce hundreds of complexes and individual means of combating UAVs of various types. In research and weapons programs related to UAVs and conducted in the interests of the US Armed Forces in 2020, more attention is paid to the development of methods and means of combating UAVs than to improving the UAVs themselves. In total, in the interests of the US Armed Forces in 2020, tests of over 40 different means and complexes of similar purpose were completed, 10 of them and one control complex were selected for further development.

Since 2019, there has been a special working group in NATO, including representatives of all member countries of the alliance, which solves the tasks of coordinating their actions to develop common policies, standards and technical solutions aimed at implementing measures to combat UAVs. In 2020, with the assistance of the group, R&D was carried out in the following directions7: development of new methods of combating UAVs, including methods of electromagnetic exposure; preparation of a database of various UAV signatures in order to improve methods and means of their detection and identification; development of technology for creating cognitive radars using AI to detect and track UAVs with various weight and size and flight characteristics.

Thus, methods and means of combating UAVs in the near and long term will remain an important object for development and will be in demand by the armed forces.

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