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ON DETECTION OF UNMANNED AERIAL VEHICLES

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Abstract

The use of unmanned aerial vehicles has recently become an integral part in the life of modern society; they are used in solving video surveillance tasks, for photo and video shooting, monitoring the water and land surface, delivering goods, and so on. The constant improvement of their technical characteristics, including the reduction of unmanned aerial vehicles size, makes it difficult to detect them. This article discusses the main characteristics of unmanned aerial vehicles, as well as various methods of their detection, based on the use of radiation recorders in the infrared range of electromagnetic waves, optical range cameras, radar stations and the use of radio monitoring technology.

Keywords: small unmanned aerial vehicles; detection; infrared imager; video camera; radar station; radio monitoring.

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ОБ ОБНАРУЖЕНИИ БЕСПИЛОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ

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Аннотация

Применение беспилотных летательных аппаратов в последнее время стало неотъемной частью в жизни современного общества, они используются при решении задач видеонаблюдения, для фото и видеосъёмок, мониторинга водной и земной поверхности, доставки товаров и так далее. Постоянное совершенствование их технических характеристик, в том числе и уменьшение размеров беспилотных летательных аппаратов, затрудняет их обнаружение. В данной статьи рассмотрены основные характеристики беспилотных летательных аппаратов, а также различные способы их обнаружения, основанные на применении регистраторов излучения в инфракрасном диапазоне электромагнитных волн, камер оптического диапазона, радиолокационных станций и на использовании технологии радио мониторинга.

Ключевые слова: малоразмерные беспилотные летательные аппараты; обнаружение; тепловизор; видео камера; радиолокационная станция; радио мониторинг.

The development and implementation of UAVs (unmanned aerial vehicles) is one of the main and important directions in the development of modern aviation, the first samples of this technology appeared in the middle of the 20th century. They represent a separate type of vehicle with significant prospects for further development. UAVs are constantly being improved in terms of technology and are becoming compact and affordable. In the modern world, this technology is used effectively in all areas of human activity (Fig.) [1-4].

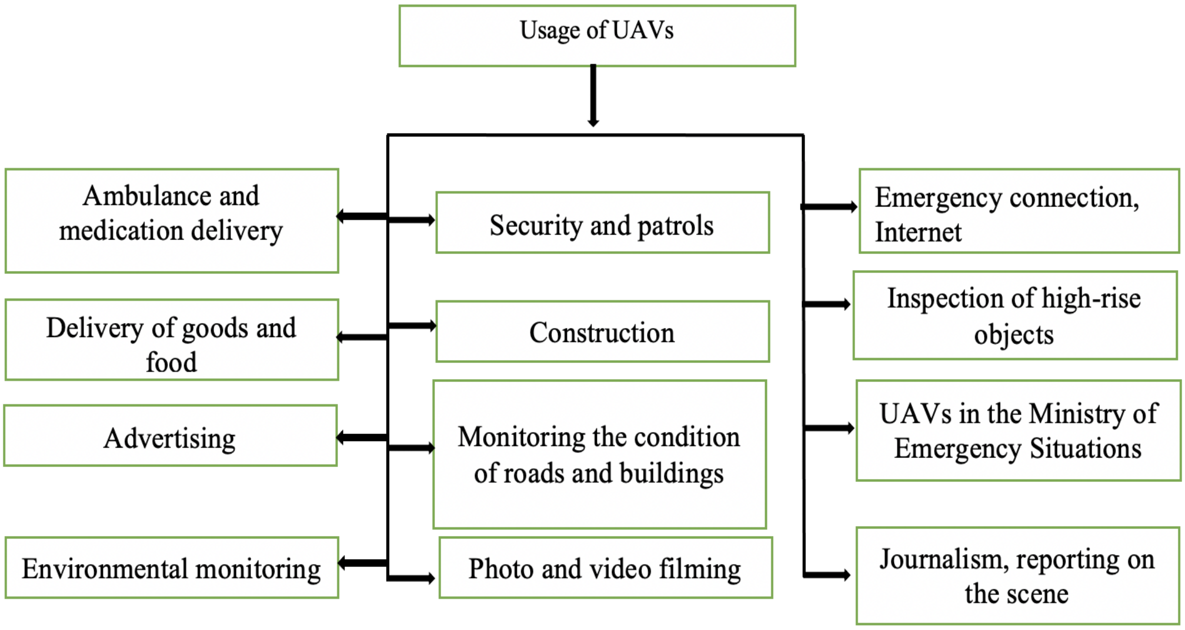

Fig. Usage of UAVs

Unmanned aerial vehicles (Drones) are divided into two groups according to their size [2]:
- small unmanned aerial vehicles (S-UAVs);
- unmanned aerial vehicles of medium and large sizes.

The fight against S-UAVs implies a set of measures for their detection, recognition, aiming, capture and defeat. Since small unmanned aerial vehicles have low visibility, the task of detecting and recognizing them is difficult [3, 5].

The detection and recognition of S-UAVs is based mainly on the analysis of their various characteristics, some of which are shown in Table.

Table

Main characteristics of S-UAVs

Category	Weight	Range	Flight Altitude	Endurance
Micro	< 3 kg	< 10 km	250 m	1 h
Mini	< 30 kg	< 10 km	150-300 м	2-2,5 h
Close Range (CR)	25-150 kg	10-30 km	3000 m	2-4 h
Short Range (SR)	200 kg	30-70 km	3000 m	3-6 h
Low Altitude Lone Endurance (LALE)	< 30 kg	< 500 km	3000 m	< 24 h

Currently existing small unmanned aerial vehicles usually consist of composite materials and plastics with special colors and special combinations of layers. Their small engines (gasoline, electric) emit a little heat and are practically silent during operation. Therefore, for effective S-UAVs detection, it is necessary to simultaneously apply different detection methods.

A significant vulnerability of S-UAVs is the presence of electromagnetic radiation in various ranges of the electromagnetic spectrum.

The main methods for detecting S-UAVs in the electromagnetic spectrum include:
- use of a thermal imager of infrared range of electromagnetic waves;
- the use of cameras of the optical range of electromagnetic waves;
- the use of radar stations;
- use of radio monitoring technology, etc.

Infrared thermal imaging cameras are used to identify objects with temperatures different from the external environment, which makes it possible to monitor S-UAVs with their help even in conditions of limited visibility and at night [6].

It is known that all objects emit thermal energy and the higher the temperature of the object, the more radiation it emits. Thermal radiation of objects occurs in a certain range of wavelengths of the electromagnetic spectrum. As the temperature of the object increases, the wavelengths in the spectra of the emitted radiation decrease. Objects with a higher temperature emit shorter wavelengths, which corresponds to a higher radiation frequency [7].

Thermal imagers are used to register thermal radiation, in contrast to a video camera, which allows detecting radiation in the visible part of the electromagnetic spectrum. In this case, thermal imagers can detect minor differences in thermal radiation, such as 0.01° C. The result of detecting the thermal radiation is then displayed in different colors on the computer screen.

To achieve the most informative and stable results, it is necessary to combine thermal imagery with a visible image. The use of a thermal imager and a camera will ensure the simultaneous implementation of aerial photography in the infrared and visible ranges.

The use of various methods for detecting S-UAVs in the optical range of electromagnetic waves together with detection in other ranges of the spectrum makes it possible to increase the accuracy of detecting and tracking S-UAVs coordinates. Usually, there are two types of methods for detecting S-UAVs in the optical range [8]:

1. active detection.

With active detection in the visible range, the main analyzed parameter is the effective scattering surface (ESR) of MBLA in the visible range, which characterizes the reflectivity of the object. For detection in many cases, anaglyphic method of stereoscopic observation is used.

2. passive detection.

In passive detection, the main analyzed parameters are the contrast of the object against the background of the sky and its area, which determine the distinguishability of the object from the surrounding background. For detection in many cases, the method of visual observation is used.

The anaglyph method of stereoscopic observation consists in the use of additional illumination of an area (object) by emitters of two different colors (red and green or orange and blue). As a result of illuminating the object from opposite ends of the base, for example, with red and green colors, the resulting image is projected into the binocular device. This image is viewed through light filters (glasses), with a red filter placed in front of one lens of the device (eye), and a green one in front of the other. On the retinas of the right and left eyes, images are obtained with different complementary colors. As a result, the observer sees a stereoscopic image of the object [9].

The radar cross-section (RCS) of any object with active detection in the visible range is defined as the surface area of an ideal isotropic reflector, which, when placed at the target location, creates the same reflected radiation flux density at the optical recorder location as a real object. The RCS value has the dimension of area and is measured in square meters.

RCS assessment of Small unmanned aerial vehicles (S-UAVs) is carried out using special meters, for example SIEPKh-2, usually by the method of relative measurements. At the same time, with the help of special software, the values of the radiation power reflected in the direction of the illumination source both from the studied S-UAVs and from the RCS sample (an object with a known RCS previously determined in laboratory conditions) are compared. To improve the accuracy, measurements are carried out at different angles of the S-UAVs bearing, that is, at different orientations with respect to the illumination source [10].

Currently, when using active methods for detecting S-UAVs, various devices are widely used:

- active-pulse devices with various types of backlight emitters (for example, argon flash lamp; ruby laser; semiconductor laser, high-power LEDs, etc.);
- laser emitters, etc.

The image of the illuminated object is fixed using measuring chambers and then processed using a computer. In the resulting frame, the total power of the reflected radiation is determined (in arbitrary units) due to the two-dimensional integration of the intensity distribution on the image of the illuminated object (the total volume under the surface of the intensity distribution of the reflected radiation is determined). The use of a camera and computer processing makes it possible to isolate the object under study and exclude any influence on the value of the reflected optical signal of various glare from foreign objects.

Most modern passive S-UAV detection systems based on the use of video cameras have the following characteristics:

- use of passive high-definition video cameras;
- S-UAVs detection is available 24/7;
- automatic continuous recording of video and telemetry data, images of all detected S-UAVs;
- application of the panoramic function;
- tracking and classification of detected S-UAVs;
- availability of a large base of characteristics and profiles of S-UAVs for classification and identification;
- scalability of the design, which provides quick configuration and integration to work in various environments;
- simplicity of installation, configuration and initialization, which ensures high efficiency of equipment deployment;
- the possibility of independent use as a separate stationary installation, and in combination with a larger system.

Most modern systems for passive S-UAV detection use powerful video-analytical algorithms, which makes it possible to effectively distinguish S-UAV detected in the observed area from other objects, such as birds, etc. This feature is essential to minimize the likelihood of false detections [11].

Radar stations are a widely used means of locating UAVs. Usually, small unmanned aerial vehicles are difficult to detect due to their small size. S-UAVs devices have a small effective scattering area, which requires significant efforts to find them and is a rather difficult task. In real conditions, there is an insignificant detection range.

Radio monitoring is also used to detect S-UAVs. Radio monitoring involves obtaining information using technical means in the process of its passage through radio communication lines. Often it includes work on the study and analysis of the radio situation, search, detection and control of various communication channels, other sources of radio emissions [12].

Radio monitoring tasks are:

- panoramic spectral analysis in real time;
- finding radiation from S-UAVs, measuring their parameters, comparing with the database to identify their belonging;
- recording of radio signals with service parameters (frequency, time, signal level, spectrogram, etc.) and their subsequent reproduction;
- technical research of radio signals in real time and with delayed processing;
- direction finding of unmanned aerial vehicles.

In order to detect S-UAVs, there are approaches based on the complex application of various detection methods which are widely used in the current time.

It can be concluded that an effective solution is to combine the main detection methods: the use of radar equipment, the use of radio monitoring technology, IR and optical cameras. This solution is quite costly, however, each of the approaches allows you to identify the characteristics of detected objects that cannot be detected using other approaches, which reduces the number of false detections and increases the overall efficiency of the system [13].

In the case of the complex application of various methods, the detection process is as follows: the radar presumably finds the UAV, at the same time the video camera registers the video signals and begins the search for the signals of interest among the received video data. Then the sources of the selected signals are analyzed and a decision is made on further actions with the detected object.

The basic idea of the complex of technical means used in this case is the reservation of modules constantly transmitting service data to each other, which thereby ensures an increase in the efficiency and resistance of technical modules to external destructive influences [14].

Since the complex of technical means of detection in most cases is composed of various blocks, it is possible to create a unique configuration, taking into account the specifics of a specific task. The complex must also have resistance to extraneous electromagnetic influences and a subsystem of active resistance to risks, which implies the possibility of an independent choice of response measures or the transfer of commands to provide assistance and support in the presence of various risks. The operator controls the decisions made by the S-UAVs detection complex and sets the necessary parameters for its operation [15].

The main task of the radar module is to detect S-UAVs with a minimum level of errors at the maximum distance in conditions with a difficult radar environment. To take into account the specifics of this task, it is necessary to search for a compromise between the transmitter power and the wavelength range, the size of the antenna and its radiation pattern, the capabilities of the receiver to analyze the information received and the choice of the best radar method.

The radio receiving device must have the following equipment’s: decoders, modulators and tools for automatic and manual technical analysis of the received signals.

Thanks to various combinations of technical resources, it is possible to locate the S-UAVs over large areas, as well as the ability to distinguish drones with weak reflective properties.

The module with radio monitoring means allows solving problems of finding the transmitters available on the S-UAVs, recognizing their type, main characteristics and collecting information for intercepting control.

The main factors determining the efficiency of the system functioning include the characteristics of the radio receiver and antenna, as well as the choice of radio monitoring methods – search or interference method [16]. The search method implies the search for an informative signal in a given frequency band, which can have slow, medium and fast modes. The interference method implies a search conducted over a wide frequency range.

The radio receiving device must have such equipment as decoders, modulators and means for automatic and manual technical analysis of the received signals.

It is also possible to increase the efficiency of the radio monitoring system by using autonomous antennas that receive and send information. These antennas, receiving information data, send them to a central processing point. Further, a decision is made on further actions for detection.

Thus, thanks to the technology of complex usages of various detection methods, it is possible to create a network for the detection of small unmanned aerial vehicles over a large area.

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