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Protection Against the Effects of FPV Drones

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Abstract. *In the modern era, the high efficiency of using various types of drones in conducting aerial reconnaissance of territories, correcting artillery fire, destroying armored vehicles and personnel, as well as executing numerous combat missions, must be taken into account. The direct destruction of drones through fire and their complete neutralization without causing any damage to them using electronic warfare (EW) means are of particular importance. As we know, since it is not possible to fully protect unmanned aerial vehicles (UAVs) from the effects of EW (Electronic Warfare) means, in wartime conditions, anti-drone weapons such as guns, mobile laser devices, and other weapons are practically used to disable FPV drones. The simplest method to avoid these effects is changing the control frequency of the drone, which makes it impossible for EW systems to affect the drone. It should be noted that since this method provides only temporary protection, work should be carried out to develop EW devices capable of monitoring and effectively jamming non-typical frequencies.*

Keywords: *Drone, control channels, electronic warfare tools, frequency range, satellite navigation signals, video signal, navigation system*

Introduction

Until recently, drones were mainly used for aerial photography at low altitudes during prestigious sports events and other mass gatherings. Currently, they are extensively utilized in the military sphere, particularly in the Ukraine-Russia conflict, for reconnaissance of the area, correction of artillery fire, destruction of armored vehicles and personnel, and the execution of numerous other combat missions.

Considering the high effectiveness of various types of drones in combat operations and their direct impact on combat tactics, different methods have been developed to combat them. Among these methods, the direct destruction of drones with fire and the use of EW (Electronic Warfare) tools that disable drones without causing any damage are particularly significant. It is precisely these EW tools that are considered more effective means of countering drones in warfare.

EW (Electronic Warfare) tools can interfere with the control channels of drones, capturing them, disrupting their radio signals, or creating artificial radio jamming signals to impair their control systems.

Main Section: FPV (First Person View) drone is a type of unmanned flight vehicle where the operator uses special glasses or video cameras mounted on the drone to see the area in real-time on a screen. This allows the operator to perform various tasks in real-time, such as area surveillance, reconnaissance, striking different targets, and executing precise maneuvers with the drone. These drones, especially in recent times, are being widely used for tasks such as reconnaissance, surveillance, and striking targets.

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FPV drones, compared to manned flight vehicles such as fighter jets and helicopters, have some significant advantages: they are cost-effective, very inexpensive, durable, highly resilient, and pose almost no risk to the operator. Their small size allows them to perform agile maneuvers in confined spaces and quickly evade enemy countermeasures. Since analog video transmission systems are used in such UAVs, they are more resistant to jamming by electronic warfare tools. However, it should be noted that this factor (analog communication) also enables the enemy to determine the drone's launch location (Makarenko, 2020; FPV-drony: sfery primeneniya, tipy i printsip raboty, 2024).

Research

The structure and components of FPV drones are shown in Figure 1.

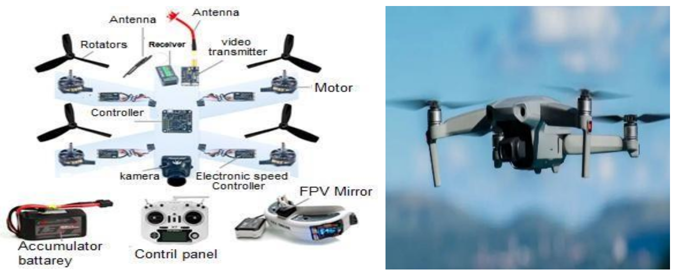

Figure 1
Model of the FPV drone

The main threat to drones from REM is the loss of control by the operator. In many cases, control is taken over by others, control signals are completely blocked, or GPS coordinates are altered.

Primarily, the method of completely jamming the drone is used. In this method, the drone loses the signal received from the satellite, the operator cannot see the image on the screen, and manual control becomes impossible. In such cases, the drone is practically lost (Rustamov et al., 2024; Mashinnoe zrenie, 2018). The method of spoofing or changing GPS coordinates is also an effective way to quickly bring down a drone. Many drones are programmed with the coordinates of airports and other strategic sites. When the drone enters these zones, it automatically lands. When GPS coordinates are altered, the drone "thinks" according to the security protocol and performs an immediate landing, which can then be taken over by others (Slyusar, 2010).

The following methods are used to protect drones from the effects of REM devices:

- Signal encryption – this method uses complex encryption algorithms that are very difficult or impossible to crack or decipher;
- Frequency hopping – in this method, the control frequency of the drone changes hundreds or thousands of times per second, making it impossible for REM devices to jam within the frequency range;
- Autonomous mode – in this mode, the drone operates without using GPS coordinates, following a pre-planned route stored in its onboard computer. In this method, the drone is not affected by any spoofing systems (coordinate manipulation).
- Currently, additional devices are being developed to enhance the resilience of drones against various threats. For example, SIM card-based GPS trackers (navigation devices capable of tracking the drone's location remotely) enable drones to operate with accurate coordinates. Additionally, there are devices called anti-jammer (which protect navigation signals from malicious or accidental interference) that feature their own antennas synchronized with the drone's main antenna. When obstacles occur, the anti-jammer isolates these obstacles and increases the drone's resistance to external influences.

- An anti-jammer uses directional antennas during electronic interference, employing CRPA (Controlled Reception Pattern Antenna) technology to filter out interference, ensuring precise and reliable navigation.

Anti-jammers:

- Detect obstacles – identify unwanted radio signals that interfere with useful signals received from satellites;
- Counter obstacles – focus solely on satellite signals to actively jam or disrupt signals from REM devices;
- Preserve the useful signal – ensure the drone's navigation system continues to receive and process data transmitted solely from satellites, allowing for precise navigation.
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Additionally, to reduce the impact of REM devices, it is advisable to orient drones according to the following recommendations (Internet resources).

- Minimize flights or refrain from flying near strategic and military facilities equipped with 100% REM devices;
- Plan the flight route in the maximum open area possible;
- Considering the height influence boundary of REM devices, it is not recommended to plan flights above 30 meters altitude. It should be noted that simple jamming devices at 200-300 meters altitude can block the drone's signals.
- If the number of satellites "seen" by the drone is fewer than 6, the flight should be canceled.

Anti-jamming techniques:

- Detect obstacles – identify unwanted radio signals that hinder the reception of useful signals from satellites;
- Overcome obstacles – primarily focus on satellite signals and actively suppress or jam the signals of REM devices;
- Preserve the useful signal – ensure that the drone's navigation system continues to receive and process data only from satellites, allowing for precise navigation.

FPV drone components. FPV drones consist of a complex control system, including a camera, receiver, transmitter, four motors, and a frame housing the drone's control controller (Internet resources).

The camera, typically with a viewing angle of 90° to 180°, is mounted on the front part of the drone and transmits real-time images and video to the operator's screen via a transmitter.

Transmitter – An essential component of the FPV drone that sends the video signals (video data) from the camera to the operator's receiver. The transmitter operates at a 5.8 GHz frequency, ensuring high-quality image transmission and high-speed data transfer. In intensive REM environments, an additional transmitter operating at 1.3 GHz can also be installed.

Receiver – A device that receives the video signals from the drone and displays them on the screen. The display can be integrated into goggles or control controllers. The receiver operates at the same frequencies as the transmitter (5.8 GHz and 1.3 GHz).

FPV drone motors – FPV drones are controlled with the help of an ESC (Electronic Speed Controller). The ESC is connected to the operator's control unit and manages the rotational speed of each motor, allowing the operator to precisely control the drone's flight direction and speed.

When using an FPV drone, the operator wears goggles or connects a screen to the receiver to receive real-time video feed.

The visual signals (video streams, data) that the drone "sees" are transmitted via a transmitter from the drone's camera, enabling the operator to see where the drone is flying. In other words, the operator feels as if they are inside the drone, and due to this characteristic, FPV – First Person View – refers to video footage captured from the first person's perspective, showing what the drone's camera sees (Rustamov et al., 2023).

FPV drone goggles and control transmitter

Control transmitter – The main device for operating the drone. It provides a connection between the operator and the drone and allows the drone to be controlled via a device equipped with joysticks and other buttons (Internet resources).
Goggles – Used to receive video signals from the drone's camera. To see what is happening in real-time in front of the drone, a receiver and screen are installed in the goggles. As an alternative, an external screen can also be connected to the drone. This screen is used by the operator as an assistant and is connected as soon as it is linked to the receiver and goggles. The drone control team usually consists of two people (operator and assistant).

Application of FPV drone. Before using an FPV drone, its intended purpose (such as for launching or as a kamikaze) must be determined. Additionally, attention should be paid to the size of the drone, as its dimensions affect its payload capacity. Currently, drone models are produced with the ability to carry loads of 720 grams, 1 kg, 1.5 kg, 2 kg, and 3 kg. If the drone is intended for launch purposes, it is also necessary to know which combat ammunition will be used and what platform will be installed (Optovolokno dlya upravleniya dronom, n.d.; Vasilyev, 2015).

One of the main important characteristics of an FPV drone is the transmission of video signals in active RF environments at frequencies of 5.8 GHz or 1.3 GHz. For this purpose, an additional antenna can be installed on the operator's side within a distance of up to 30 meters (BPLA: klassifikatsiya, tipy, sfery primeneniya, n.d.; *FPV dron: S chego nachat novichku*, n.d.; Rustamov et al., 2024).

In case of losing contact with the drone due to RF interference, the following precautions are recommended for operator training:

- Before deploying drones in combat, operators must practice controlling the drone in simulators provided by the drone manufacturer. Additionally, it should be noted that FPV drone operation significantly differs from the control of civilian Mavic and Autel drones, so training on FPV drone simulators only should be conducted for FPV drone control skills.
- Enemy equipment such as antennas, observation cameras, and movement parts of the enemy's attacking vehicles can be disabled using the FPV drone.
- FPV drones are the most cost-effective means to eliminate enemy personnel and combat equipment.
- If a drone is “jammed” or its control is completely lost, it can only be recovered using a GPS tracker (if equipped).
- If the drone loses GPS signals, do not activate the “return to home” program, as the drone’s location will be unknown without GPS coordinates. In such cases, since it is possible to see the surrounding area through the camera, efforts should be made to land the drone manually.

- When controlling the drone becomes impossible, attempts should be made to disconnect its engines; in this case, the drone is likely to fall and break apart.
- When GPS signals are lost, the drone switches from normal mode to ATTI mode, but it is essential to know how to fly in this mode.
- It should be kept in mind that when GPS signals are lost, the drone will be dragged, so avoiding obstacles is crucial.

Conclusion

The article analyzes the combat application of FPV drones, and certain practical recommendations have been proposed for their effective deployment in potential future combat operations.

Due to the rapid development of modern technology, it is currently impossible to fully protect unmanned aerial vehicles (UAVs) from the effects of RF interference. At present, counter-drone systems such as anti-drone rifles, mobile laser devices, and other weapons are practically used to disable FPV drones. This application has become particularly prominent in the context of ongoing combat operations in Ukraine. For example, anti-drone rifles can generate “white noise” (a stochastic process with spectral density across all frequencies) within the control signal frequency range and specific frequencies, causing the operator to lose control of the drone.

The simplest method to avoid the effects of RF interference (REM) is to change the drone's control frequency. In this case, no REM can affect the drone. However, it should be noted that this method is also temporary, as work is underway to develop REM devices that can track and effectively block these non-standard frequencies quickly.

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