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The Influence of Ultrashort Electromagnetic Pulses on Unmanned Aerial Vehicle Control Systems

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Abstract*: The development of technologies for the development and use of unmanned aerial vehicles (UAV) for military purposes is especially notable. Modern UAV are used as one of the most important means increasing combat capabilities of the Armed Forces. Their combat use is desirable when performing tasks characterized by a long flight duration, increased danger and complexity. The use of UAV to ensure the safety of civilian objects and critical infrastructure facilities is also highlighted, forcing more attention to be paid to new methods of monitoring and monitoring the earth's surface. The analysis showed that there are potential threats of the emergence news power electromagnetic means of influence on unmanned aerial vehicles using ultrashort electromagnetic pulses. The article analyzes the characteristics of existing means generating ultrashort electromagnetic pulses and the trivial characteristics of aviation data exchange protocols. The necessity of testing telecommunication control systems for unmanned aerial vehicles based on the influence of ultrashort electromagnetic pulses is shown, and the experimental method is the most promising method for assessing their impact.

Keywords*: Unmanned Aerial Vehicle, Ultrashort Electromagnetic Pulse.

I. INTRODUCTION

In recent years, interest has significantly increased in the creation and use of unmanned aerial vehicles (UAV) for use in various purposes and in various industries. The development of technologies for the development and use of UAV for military purposes is especially notable. Modern UAV are used as one of the most important means increasing combat capabilities of the Armed Forces. Their combat use is desirable when performing tasks characterized by a long flight duration (patrol time in a given area), increased danger and complexity (in areas of intense fire resistance by air defense and enemy aviation).

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The use of UAV to ensure the safety of civilian objects and critical infrastructure facilities is also highlighted, forcing more attention to be paid to new methods of monitoring and monitoring the earth's surface. First of all, this applies to such organizations with extensive facilities, the control of which is quite difficult to organize.

Due to the variety of tasks performed by UAV in various conditions and places of basing, during combat duty, etc. UAV themselves can be subjected to direct electromagnetic effects [1].

The issue of the stability on-boards electronic equipment of aircraft to the effects of powerful electromagnetic pulse, electrostatic discharge, and lightning was considered in [2–10], where requirements, calculation and calculation-experimental methods for determining the consequences of these effects were developed. However, due to the high pace of development generators of very short-pulse electromagnetic radiation (VSP EMR), insufficient awareness of the mechanisms of deliberate exposure to telecommunication devices, the issues of UAV resistance to the effects of short-pulse electromagnetic radiation are insufficiently studied, which makes this task relevant today. Particularly important is the study of the stability of unmanned aerial vehicles under the influence of an VSP EMR at the stage of flight tests to determine the vulnerable nodes and operating modes of the control system with the subsequent development of recommendations for protection against the impact in question.

The article analyzes the existing types of electromagnetic effects on unmanned aerial vehicles, analyzes the characteristics of ultrashort electromagnetic pulses and their generation means, and analyzes the telecommunication control systems of modern UAV.

II. METHODOLOGY

A. S Analysis of existing types of electromagnetic effects on unmanned aerial vehicles

It is possible to classify electromagnetic radiation (EMR) according to the generality the processes of their influence on aircraft (AC). From this point of view, it is advisable to extend the concept of electromagnetic stability of UAV to electromagnetic factors and powerful electromagnetic radiation, which are described on the basis of ideas about the atomic-electronic structure of matter, namely:

- charges and potentials, static, quasi-static and pulsed currents, electric and magnetic fields;

- electromagnetic fields of the radio frequency range.

Thus, the composition of EMR includes the following groups and types:

- EMR of natural origin:

▪ electrostatic;

▪ lightning discharges:

• electrostatic fields in pre-thunderstorm and thunderstorm periods;

• direct lightning strike;

• electromagnetic field of close lightning strike.

- EMR of artificial origin:

▪ combat EMR (influence means of destruction), which is realized only in a combat situation;

▪ electromagnetic pulses of ground and high-altitude nuclear explosions (EMP NE):

• fast EMR;

• intermediate or long-term EMR (LEMR)

• magnetohydrodynamic EMR (MHD-EMR).

▪ EMR of technogenic origin.

▪ EMR using electromagnetic weapons:

• vibromagnet generators;

• instruments for ultra-wideband (short-pulse) pulses;

• microwave radiation devices [11].

Intermediate and magnetohydrodynamic EMR pose a serious danger to extended ground structures (wire lines, power lines, etc.); for aircraft, they are not dangerous compared to early EMR. Thus, UAV resistance to the effects of EMR nuclear explosions is their resistance primarily to the early EMR of high-altitude and ground explosions.

EMR of technogenic origin, in essence, is operational, since they arise during the operation of UAV and as a result of the operation their own electrical and radio equipment..

B. Analysis of ultrashort electromagnetic pulses and means of their generation

Studies have established [7] that when the duration of EMR is reduced to values of the order c, when their spectrum lies in the range from hundreds of MHz to units of GHz, the radiation has a number of properties that allow them to be used solve new problems that are inaccessible to conventional radio engineering. They are a thin layer of electromagnetic energy with a pulsed power of tens and hundreds of MW, which spreads in space at the speed of light. In the beginning, research developed in two main areas - VSP EMR radar and VSP EMR radio.

Locators were created to detect and identify objects in the air on the ground (including under the canopy of the forest), as well as under water. This was done due to the fact, successively reflected from element of the objects, VSP EMR of the locator carries information about both the coordinates and the dimensions, structure and material of the object. The design of such locators made it possible to develop a number of technical means for alarm systems, for automatic control of distances between vehicles, etc. The sensitivity of VSP EMR locators to the detection of signals reflected from pulsating organs of the human body (heart, lungs, trunk vessels) made it possible to develop inexpensive small-sized devices for continuous remote monitoring of pulse, respiration and filling of vessels.

Developments in the direction means of VSP EMR radio communications also led to new discoveries in this area. These means of communication, subject to certain rules, do not interfere with traditional radio communications. Devices such as VSP EMR radiotelephone, as well as hidden two-way telephone equipment and wireless local area network, were developed.

The main advantages of VSP EMR communication: low power consumption; insensitivity to re-reflected signals proved to be extremely important when applied in military affairs. For number reasons, the main field of application VSP EMR communications is tactical radio communications at distances of up to 10 km. Thus, the technologies of VSP EMR have a fairly wide scope in various fields. The development of computing systems is characterized by a constant increase in the number of tasks to be solved and the level of their complexity, the expansion of intellectual and adaptive capabilities. Modern computers, which are the core of telecommunication control and UAV control systems, are increasingly equipped with electronic elements that are sensitive to electromagnetic influences. An increase in the degree of integration elementals base electronics, and, as a result, decrease in the electric strength of individual components the equipments, leads to a decrease in the stability of the onboard UAV control system under the influence of electromagnetic factors various origins, including short-pulse electromagnetic radiation.Under influence of VSP EMR in the circuits of electronic and electronic computing systems signals are given that are similar to working signals, leading to disruption of the operation these systems [12]. The most typical examples the manifestations of influence VSP EMR on elements and nodes can be such phenomena as failures in communication channels, loss of information in on-board networks, failure of the entire monitoring and control system of a mobile complex, etc. It turned out that a fairly powerful VSP EMR, which is capable of disrupting the operation electronics computing facilities, can be located at a great distance from the target. Such effects can hit a large number of targets and, importantly, all of these devices are inaccessible for detection and suppression by existing radio countermeasures that use narrowband signals. In this regard, the new term "electromagnetic terrorism" has appeared. Most domestic and foreign military experts believe that electromagnetic weapons, including those based on VSP EMR emitters, will have the same meaning as nuclear weapons in the second half of the 20th century. At the same time, this weapon is highly effective, environmentally “clean”, relatively “humane,” and can act covertly, directionally, and instantly. A review of the works shows that in the next decade, the most likely appearance of powerful emitters ultrashort electromagnetic pulses, which will be used including for the functional destruction of information and telecommunication systems by the destruction (damage) of elements or nodes. So in recent years, new powerful generators have appeared that emit periodic and one-time ultrashort electromagnetic pulses with pulse durations of hundreds picoseconds, field strengths of hundreds of kV and a repetition rate of tens of megahertz.

Ultrashort pulse emitting devices, consisting of short-duration pulse generators and radiating antennas, allow you to create directional radiation with the following parameters:

- pulse duration from 0.1 to 0.3 ns;
- pulse front duration from 85 to 250 ps;
- the amplitude of the electric field strength 56 kV / m at a distance of 100 m;
- pulse repetition frequencies vary from hundreds of hertz to several kilohertz [13].

In view of the foregoing, it follows that today, intentional ultra-wideband electromagnetic interference is a new serious threat to telecommunication control systems for UAV.

To date, experts have carried out a significant number of studies confirming that using ultrashort electromagnetic pulse generators it is possible to influence the exchange of data over the network between end users, while the network connection is not destroyed.

In this regard, it is especially important to solve the problem of ensuring the stability unmanned aerial vehicles from the actions of VSP EMR, as the most promising and functionally important objects, perform various tasks, both for civilian and military purposes. To solve this problem, it is necessary to determine the most sensitive nodes with VSP EMR.

C. Analysis of the telecommunications control system of modern UAV

The case is considered in the case of direct UAV irradiation by means of generation VSP EMR. When an UAV is irradiated by means of generating VSP EMR, obstacles reaching the aircraft's hull penetrate its internal space through the aperture of hull structure and through cables connecting the avionics. Thus, it is necessary to consider in detail the composition of board REA (BREA) and its operating modes. The process of penetration and propagation VSP EMR in UAV is shown in Fig. 1.

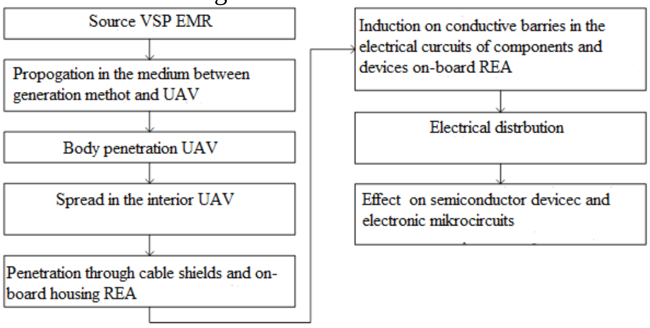

Fig. 1. The process of propagation electromagnetic interference in the interior of aircraft

As control equipment, as a rule, specialized calculators based on digital signal processors or PC/104, MicroPC format computers running real-time operating systems (QNX, VME, VxWorks, XOberon) are used. The software is usually written in high-level languages such as C/C ++, module-2, Oberon SA or Ada95. To transmit video data received from the onboard sensors to the control center, UAV includes a radio transmitter that provides radio communication with the receiving equipment. Depending on the format of image and degree of compression, throughput of digital radio links for data transmission can be several hundred Mb/s. In addition, the onboard radio UAV must include a receiver of control commands, as well as a transmitter of service (telemetric) information.

Due to the fact that VSP EMR is ultra-wideband and has the property of signal comparability with the operating signal of device, most sensitive UAV system to this radiation is a telecommunication system that provides data exchange both locally between the BREA and the ground control point.

The telecommunication system, which ensures the functioning of UAV control system, consists of devices between which information is exchanged according to special protocols on the corresponding buses.

System buses are effective means of exchanging data between various on-board devices of the UAV control system. The serial bus requires less wiring but is slower. A parallel bus consists of one wire for transmitting each bit in a data word, but transmission is much faster.

In aircraft data bus systems, parallel data transmission is used, since it minimizes the size and weight of the aircraft cable. With so many devices in the control system, modern UAV require a significant number of cables. Aircraft cables make up a significant proportion of its total weight. The use of multiplexing allows you to connect all subsystems with only one set of wires. Multiplexing simplifies the transfer of information in a data stream. This allows the transmission of multiple signal sources in one telecommunication system. Table I shows the aviation data exchange protocols and their comparative characteristics [7].

When designing UAV control systems, much attention is paid to the reliability and timeliness of information transfer. At present, the most common data bus protocols for the telecommunication system are: ARINC 429, ARINC 629, MIL-STD 1553, MIL-STD 1773, and can also be used IEEE 1394 [14].

III. RESULT AND DISCUSSION

Based on the above, obstacles VSP EMR are given in the telecommunication system mainly on input and output signal lines and power bus. These obstacles depend on the properties of telecommunication system devices themselves, operating signals and electrical characteristics.

Thus, the analysis showed need to test the telecommunication control system of an unmanned aerial vehicle, subject to influence of VSP EMR. The solution to the problem of assessing impact of VSP EMR on the functioning of an unmanned aerial vehicle as a whole by methods of mathematical modeling today is not possible due to the lack of an appropriate methodological apparatus. Moreover, the analysis of numerical methods for solving such problems shows the impossibility of obtaining reliable calculated results [15].

Table- I: Comparative characteristics of aviation protocols ARINC 426, ARINC 629, 1553, 1773 та IEEE 1394

Protocol	ARINC 429	ARINC 629	1553	1773	IEEE 1394b
1	2	3	4	5	6
Year of manufacture	1977	1995	1973	1979	2002
Bus architecture	Simplex point-to-point	Division multiplexing time	Division multiplexing time	Division multiplexing time	Point-to-point
Ports 2	2	1st standard 2nd optional	1st standard 2nd optional	1st standard 2nd optional	4
Wires	Shielded twisted-pair cable	Unshielded twisted-pair cable	Shielded twisted-pair cable in a protective sheath	Optical fiber	Optical fiber, plastic for cable up to 50 m, glass for cable up to 100 m long.
Coding	Bipolar return to zero	Bipolar, doublets of Manchester	Manchester II	Manchester II	NRZ coding
Data transfer rate	12,5 or 100 kbit/s	2 Mbps	1 Mbps	1 Mbps	800 Mbps i 1600 Mbps
Bus frequency	12.0, 12.5, 14.5 or 100 kHz	2 MHz	1 MHz	1 MHz	24,5760 MHz
Updates of word	1 ms or 10 s	From 1 ms to 10 s	4 mks – between messages that are generated by the bus controller, 4 to 12 mks pause before sending a message	4 mks – between messages that are generated by the bus controller, 4 to 12 mks pause before sending a message	After sending 0.75 ms, confirmation is expected
Prediction of directions	Three directions: logical 0, logical 1 and zero	Four directions: periodic traffic, emergency aperiodic traffic, non-emergency aperiodic and traffic lag	Logical 1 (+ Impulse) Logical 0 (- impulse)	Logical 1 (Included); logical 0 (Off)	Asynchronous and isochronous
Data bit	11-29	4-19	4-19	4-19	0-31
Electrical parameters	6,5-13 V		18-27 V		1,5A 8-40 V

At present, the most promising method for assessing the influence of VSP EMR on the functioning of multifunctional information tools is the experimental method, which allows with certain accuracy to evaluate the critical levels of impact on such vehicles, which include unmanned aerial vehicles.

A prerequisite for assessing the UAV stability to effects of VSP EMR, especially at the stage of flight tests, is the availability of such a testing tool that would be convenient and based on the analysis of the UAV operation as a whole to bring VSP EMR beam to the object under study with optimal radiation parameters

IV. CONCLUSION

1. The analysis showed that there is a potential threat of the emergence of new power electromagnetic means of exposure to VSP EMR. In this regard, in the leading countries of the world, active work is underway to develop a new regulatory framework, means for detecting deliberate electromagnetic forces and means of protection against them.

2. The analysis of the characteristics existing means of generating ultrashort electromagnetic pulses, the features of their influence on digital devices, and the comparative characteristics of aviation data exchange protocols are given.

3. The analysis showed the need to test the telecommunication control system of an unmanned aerial vehicle with respect to the influence of ultrashort electromagnetic pulses, and the experimental method is the most promising method for assessing the effect of VSP EMR on the functioning of multifunctional information tools.

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