

Abstract

General characteristics of the work. This dissertation presents the results of developing new approaches to protecting information when transmitting commands to UAV groups within line-of-sight.

Relevance of the research topic. The relevance of this work is determined by current trends in the use of robotic weapons and military equipment. There is a significant increase in the concentration of UAVs near the line of contact (LOC), as well as the growing importance of electronic warfare (EW), including that conducted directly near the LOC. Secure use of UAVs under control from relatively short distances (on the order of several kilometers) is becoming increasingly important, which is achieved, in particular, by transmitting commands via fiber-optic communication lines. There is also a steady shift toward using UAVs in group mode, where the protection of information from the operator to the group is also extremely important. Thus, the development of new methods for protecting information in the zone of direct radio visibility (in order of magnitude, this corresponds to the distance of the horizon line, i.e., about 4 km) becomes relevant, which would make it possible to abandon both the use of encryption systems and the use of extended fiber-optic communication lines.

Relation of the topic to grant funding competitions for scientific and/or scientific-technical projects:

The research was conducted in accordance with the approved research plan of the Ministry of Higher Education of the Republic of Kazakhstan and as part of research project AP23490107, "Development of Information-Theoretical Methods for Describing Wave Signal Converters Using Finite Algebraic Structures."

The objects of the research are information security systems designed to transmit commands from an operator to a group of UAVs within direct radio visibility.

The subject of the research is the theoretical foundations of controlling groups of unmanned defense vehicles.

Research objective:

Development of an information security system designed to transmit commands from an operator to a group of UAVs within direct radio visibility, and its testing on physically implemented electronic circuits.

To achieve this goal, the following tasks must be solved:

- Develop a theoretical foundation for organizing a secure command transmission channel from an operator to a group of UAVs connected by fiber-optic data lines, intended for use in a line-of-sight radio zone;

- Develop a method for measuring the instantaneous values of frequency, amplitude, and phase of a quasi-harmonic oscillation, intended for use in a system for protecting information transmitted from an operator to a group of UAVs;

- Develop and implement electronic circuits proving the feasibility and practical utility of the proposed information protection method;
- Develop a new data obfuscation method based on the discrete logarithm operation in quasi-Mersenne Galois fields.

Methods for achieving the goal:

Methods of mathematical modeling, methods for developing and debugging electronic circuits, and methods for testing and proving the functionality of electronic circuits were used.

Research Results:

- A theory has been developed for creating a secure channel for transmitting commands from an operator to a group of UAVs connected by fiber-optic data lines, designed for use in a line-of-sight radio zone.
- A method for measuring the instantaneous values of frequency, amplitude, and phase of quasi-harmonic oscillations, based on the use of phase portraits, has been developed and tested. This method is intended for use in a system for protecting information transmitted from an operator to a group of UAVs.
- Electronic circuits have been developed that demonstrate the feasibility and practical utility of the proposed information protection method.
- A new data obfuscation method based on the discrete logarithm operation in quasi-Mersenne Galois fields has been developed, and its basic electronic components have been verified.

The scientific novelty of this dissertation research lies in the following:

- a theory has been developed that enables the creation of a secure channel for transmitting commands from an operator to a group of UAVs linked by fiber-optic data lines, intended for use in a line-of-sight radio zone;
- a method for measuring the instantaneous values of frequency, amplitude, and phase of a quasi-harmonic oscillation, based on the use of phase portraits, has been developed and tested, intended for use in a system for protecting information transmitted from an operator to a group of UAVs;
- electronic circuits have been developed and implemented, demonstrating the feasibility and practical utility of the proposed information protection method;
- a method for calculating discrete logarithms in quasi-Mersenne Galois fields has been developed, taking into account the specific features of such fields to the greatest extent possible, and it has been demonstrated that a new data obfuscation method can be implemented on this basis.

Key points to be defended:

1. Protection of information transmitted from the operator to the UAV group within line-of-sight is ensured by using fiber-optic communication lines between the group elements and identifying the operator's location using radio-technical methods.

2. Identification of the radio signal source's position is possible using radio-technical methods through the use of a circuit that measures the instantaneous values of frequency, amplitude, and phase of a quasi-harmonic signal using phase portraits.

3. A new method for calculating discrete logarithms, developed specifically for quasi-Mersenne Galois fields, enables the implementation of a new data obfuscation method.

The significance of this research on a national and international scale lies in the fact that the results of the completed work form the basis for the creation of a new type of information security system and a riot control system (national scale), as well as the development and validation of a new method for measuring the instantaneous frequency, amplitude, and phase of a quasi-harmonic signal using phase portraits (international scale).

Scientific and technological needs (economic and industrial interest).

In the context of increasing geopolitical turbulence, Kazakhstan requires significant modernization of the military equipment in service with the Kazakh Armed Forces and other security agencies, including systems designed to counter riots.

Qualitative changes in the nature of combat operations require the development of fundamentally new approaches to ensuring the protection of information transmitted from the operator to robotic weapons of various purposes.

The author's personal contribution includes independent planning and execution of the experimental portion of the study, as well as interpretation and processing of the obtained data, and development of algorithms and mathematical models. The author also collaborated with scientific advisors on defining the objectives and discussing the study results.

Performance testing.

The main results and conclusions obtained during the study, as well as proposals and recommendations based on these findings, were presented and discussed at national and international conferences and published in scientific journals. All of these publications fully reflect the results of this study, which relates to the topic of the dissertation.

Publications.

The research results are reflected in the following scientific papers, including:

Seven papers have been published on the topic of the dissertation. One of these was published in a journal ranked in the first quartile of the Scopus database (Scopus), three in journals ranked in the 2nd quartile of the Scopus database, one in a journal ranked in the 3rd quartile of the Scopus database, one in a journal ranked in the 4th quartile of the Scopus database, and one in journals recommended by Committee for Quality Assurance in Science and Higher Education. The doctoral student made a significant contribution to each published article; they reflect the positions defended and the results obtained by the doctoral student during the course of their research:

1. Shaltykova, D., Kadyrzhan, A., Vitulyova, Y., & Suleimenov, I. (2026). The Provision of Physical Protection of Information During the Transmission of Commands to a Group of UAVs Using Fiber Optic Communication Within the Group. *Drones*, 10(1), 24. <https://doi.org/10.3390/drones10010024>

- implementation of a specific information security scheme in accordance with the proposed method.

2. Suleimenov, I., Kadyrzhan, A., Vitulyova, Y. et al. The use of fiber optics for securing information during command transmission to UAV groups. *Int. j. inf. tecnol.* (2025). <https://doi.org/10.1007/s41870-025-02719-2>. - 1

- implementation of a specific information security scheme in accordance with the proposed method.

3. Ermukhambetova, Bayana & Mun, Grigoriy & Kabdushev, Sherniyaz & Kadyrzhan, Aruzhan* & Kadyrzhan, Kaisarali & Vitulyova, Yelizaveta & Suleimenov, I. (2023). New approaches to the development of information security systems for unmanned vehicles. *Indonesian Journal of Electrical Engineering and Computer Science*. 31. 810. [10.11591/ijeecs.v31.i2.pp810-819](https://doi.org/10.11591/ijeecs.v31.i2.pp810-819). – 1

- implementation of a specific information security scheme in accordance with the proposed method.

4. Vitulyova, Yelizaveta & Kadyrzhan, Kaisarali & Kadyrzhan, Aruzhan* & Shaltykova, Dina & Suleimenov, I. (2024). Reducing the description of arbitrary wave field converters to tensor form. *International Journal of Information Technology*. [10.1007/s41870-024-01863-5](https://doi.org/10.1007/s41870-024-01863-5). – 2

- justification of the connection of the proposed method with information security issues

5. Vitulyova, Yelizaveta & Kadyrzhan, Kaisarali & Kadyrzhan, Aruzhan* & Suleimenov, I. (2024). Application of focusing systems to the protection of information during data transmission in the zone of direct radio visibility. *International Journal of Electronics and Telecommunications*. 699-705. [10.24425/ijet.2024.149599](https://doi.org/10.24425/ijet.2024.149599). – 1

- implementation of a specific information security scheme in accordance with the proposed method.

6. Kadyrzhan, A.; Matrassulova, D.; Vitulyova, Y.; Suleimenov, I. Discrete Cartesian Coordinate Transformations: Using Algebraic Extension Methods. *Appl. Sci.* 2025, 15, 1464. <https://doi.org/10.3390/app15031464> - 3.

- implementation of specific examples of the use of the methodology proposed in the work

7. Kadyrzhan, A., Vituleva, E., Kadyrzhan, K., Suleimenov, I., & Zhauyt, A. (2025). PROSPECTS FOR THE DEVELOPMENT OF UNMANNED ROBOTIC SYSTEMS FOR MILITARY AND CIVIL PURPOSES. *Vestnik KazATK*, 137(2), 544–553. <https://doi.org/10.52167/1609-1817-2025-137-2-544-553> - 1

- writing a section of the article related to the use of metamaterials in the radio frequency range.

Title of Protection of the Republic of Kazakhstan

One patent exists for the invention "Method for Implementing an Unmanned Airborne Munition Carrier."

An application has been filed for the invention "Method for Protecting Information in a Line of Radio Visibility." The formal examination has been positive.

Scope and Structure of the Dissertation. The dissertation consists of an introduction, four chapters, a conclusion, and a list of 220 references. It contains 136 pages of main computer text, including 40 figures, 10 tables, and 186 formulas.