ANNOTATION

dissertation for the degree of Doctor of Philosophy (PhD) in the specialty "6D071900 - Radio Engineering, Electronics and Telecommunications"

Vitulyova Yelizaveta

Theme of the dissertation research:

"Post-industrial paradigm of development of info-communication segment of defense-industrial complex of RK".

Purpose of the dissertation research:

Creation of theoretical foundations for the formation of a new paradigm of development of the info-communication segment of the RK defense-industrial complex, based on a new approach to the formation and management of groups of unmanned vehicles, including those built on the use of multi-valued logic and elimination of disproportion between the development of ground and flying drones.

Research Objectives:

- To show that due to the increasing use of robotic weapons of various types directly near the battle line, it is required to create new approaches to information protection designed for use in the direct radio line of sight and allowing to abandon the use of cryptography methods, and to develop a theoretical basis for such methods.

- To show that due to the sharp increase in the number of unmanned vehicles used in combat operations, it is required to develop new approaches to the control of groups of unmanned vehicles, as well as to create a theoretical basis for such approaches using multi-valued logic.

- To develop new methods to ensure the use of multi-valued logic for applied purposes, in particular, to improve the algorithms of functioning of onboard computing systems of unmanned vehicles operating in a group, including those based on the establishment of correspondence between operations of multi-valued logic and operations in Galois fields.

- To show that in order to increase the efficiency of robotic armament use it is necessary to eliminate the disproportions in the development of aircraft and ground unmanned vehicles, as well as to develop the design of a ground unmanned vehicle for a specific purpose (minesweeper).

Research Methods:

Methods of abstract algebra, in particular Galois field theory, theories of wave propagation obeying the Helmholtz equation, methods of designing moving apparatus, methods of constructing and verifying the performance of electronic circuits based on logic elements were used

The main points put forward for defense:

The use of a discrete analog of the Huygens-Fresnel principle allows us to formulate and prove a generalization of the Nyquist-Shannon-Kotelnikov theorem, which creates a theoretical basis for the development of a new approach to the protection of information in the direct radio visibility zone, focused on the

identification of the location of the signal source, and allows us to abandon the use of cryptographic methods.

Bringing operations of multivalued logic to calculations in Galois fields, carried out with the help of algebraic delta-function, creates a theoretical basis for controlling groups of unmanned aerial vehicles through the use of on-board computing systems based on multivalued logic.

Taking into account the specificity of a particular Galois field allows to significantly simplify the algorithms of functioning of onboard computing systems of unmanned aerial vehicles, including those intended for use as part of a group, and built on the basis of multivalued logic, especially those using the calculation of digital convolutions.

The elimination of disproportions between the development of flying and ground unmanned vehicles is achieved, among other things, through the introduction of single-axis drones controlled by radio channel and capable of continuing movement when falling to any position.

Main results of the research:

A new approach to information protection in the area of direct radio visibility based on fixing the position of the point where the signal source is located is developed and its justification is given on the basis of the discrete analog of the Huygens-Fresnel principle and generalization of the Nyquist-Shannon-Kotelnikov theorem.

A new method of conversions of multivalued logic operations to computations in Galois fields is developed, its constructiveness is demonstrated on concrete examples, and it is shown that it forms the theoretical basis of a new approach to controlling groups of unmanned vehicles.

Algorithms of basic blocks of on-board computing systems of unmanned vehicles realizing computations in Galois fields are developed, including the use of digital logarithm operation, digital convolution, as well as the use of a triggering adder scheme, which is applicable for any Galois fields GF(p).

The design of a single-axis unmanned vehicle (a minesweeper designed to neutralize mines of the "Petal" type), having the shape of an ellipsoid, controlled by radio channel, and capable of continuing the task when falling to any position, has been developed; tests have been carried out proving the achievement of the following characteristics: speed - not less than 40 km/h, speed of rotation around the vertical axis at 3600 - not more than 1.5 sec, speed of restoration of position to continue movement when falling - not more than 25 sec.

Justification of the novelty and importance of the results obtained, compliance with the directions of scientific development or government programs:

Qualitative transformations of the nature of fighting, caused by the mass use of robotic weapons, are expressed, first of all, in the increasing role of electronic warfare, as well as systems that provide group control of unmanned vehicles. Hence the need to develop new approaches to both information protection during transmission in the direct radio visibility zone (information exchange between vehicles composing a group, etc.) and to the control of groups (swarms), providing

for their maximum autonomy. These factors are supplemented by economic considerations, which are expressed in the expediency of maximum reduction of the cost of physical components of drone groups with the center of gravity shifted to the intellectual component, which provides, among other things, for the elimination of disproportions between the development of ground and flying drones.

The systemic solution of this set of problems de facto results in the creation of a new paradigm for the development of the info-communications segment of the RK military-industrial complex, since a significant modernization of drone control algorithms, as well as the transformation of the basic concept of REB cannot but lead to qualitative changes in the principles of operation of onboard computing systems, and further - in their design, etc.

This paper is the first to develop a new approach to information protection in the area of direct radio visibility, based on the identification of the coordinates of the point where the signal source is located [1,2]. The novelty of this approach is guaranteed by the fact that for the first time a generalization of the Nyquist-Shannon-Kotelnikov theorem [3] has been formulated and proved, which allows, among other things, to bring the description of an arbitrary wave transducer to the tensor form [4].

Also new is the developed approach to controlling groups of unmanned vehicles [5,6] based on multi-valued logic, including those intended to be used for training purposes [7,8], to provide diagnostics of extended objects [9-11]. Its connection with the proposed approach to ensuring information protection in the direct radio visibility area is reflected in [12-14]. The method allowing to bring operations of multivalued logic to computations in Galois fields [15], based, among other things, on the results of [16], is proposed for the first time. Among other things, proofs of the importance of taking into account the specificity of a particular Galois field when using this method are given for the first time [17-19].

The method of realization of calculations in Galois fields by means of radioelectronic circuits is new [20]. For the first time it was proposed to realize computations by means of trigger adders [21]. It is first shown that this kind of computational procedures significantly simplify the computation of digital convolutions [22]. It is also shown for the first time that there exists an algorithm for digital logarithmization in relatively large Galois fields, which takes into account their specificity and allows, among other things, to significantly improve the efficiency of the computation of digital convolutions [23], there is a possibility of further improvement of this approach by means of computations using finite algebraic rings [24,25].

For the first time the design of a single-axis unmanned vehicle (minesweeper designed to neutralize mines of the "Lepestok" type) was developed; the novelty is confirmed by the patent [26], this design allows for further modernization, in particular, it can be used as a basis for the implementation of an unmanned vehicle designed to counteract mass riots [27].

Generalization of the results of the conducted research is presented by the author in the monograph [28], and philosophical aspects of the developed approach are presented in [29-31].

The research was carried out in accordance with the approved research plan of MNVO RK and within the framework of scientific projects AP14870281 "Development of new approaches to digital image processing using convolutional neural networks" (2022-2024), AP14870416 "Development of new approaches to solving philosophical problems of multi-valued logic as a means of establishing patterns of thinking" (2022-2024), "Zhas ғalym" AP15473224 "Development of new approaches to building a theory of scientific revolutions" (2022-2024).

The doctoral student's contribution to each publication and patent:

1. Ermukhambetova B.B., Mun G.A., Kabdushev S.B., Kadyrzhan A.B., Kaisarali K.K., **Vitulyova Y.S.,** Suleimenov I.E. New approaches to the development of information security systems for unmanned vehicles. Indonesian Journal of Electrical Engineering and Computer Science. – 2023. – 31(2). – P. 810-819. http://doi.org/10.11591/ijeecs.v31.i2.pp810-819. (The author's contribution is the development of an algorithm for the operation of the basic electronic circuitry).

2. **Vitulyova Y.,** Kadyrzhan K., Kadyrzhan A., Suleimenov I. 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. – 2024. – vol. 70, № 3. – P. 699-705. http://doi.org/10.24425/ijet.2024.149599. (The author's contribution is the development of an algorithm for the operation of the basic electronic circuitry).

3. **Vitulyova Y.S.,** Suleimenov I.E., Matrassulova D.K., Bakirov A.S. Discrete form of the Huygens-Fresnel principle: to the multi-dimensional analog of the Nyquist–Shannon sampling theorem. International Journal of Information Technology (Singapore). – 2023. – № 15(7). – P. 3751-3759. https://doi.org/10.1007/s41870-023-01423-3. (The author's contribution is to perform analytical calculations for the basic two-dimensional case).

4. **Vitulyova Y.,** Kadyrzhan K., Kadyrzhan A., Shaltykova D., Suleimenov I. Reducing the description of arbitrary wave field converters to tensor form. International Journal of Information Technology. – 2024. https://doi.org/10.1007/s41870-024-01863-5. (Author's contribution - proof of use of the technique in radiology).

5. Suleimenov I.E., Gabrielyan O.A., Malenko S.A., **Vitulyova E.S.,** Nekita A.G. Algorithmic basis of battle neural networks and crisis phenomena in modern society // European Proceedings of Social and Behavioural Sciences. – 2021. – Vol 120. – P. 247-255. https://doi.org/10.15405/epsbs.2021.12.03.33. (The author's contribution is the analysis of complex systems based on the analogy with neural networks)

6. Мун Г.А., **Витулёва Е.С.,** Байпакбаева С.Т., Кабдушев Ш.Б., Сулейменов И.Э. Проблематика постиндустриальной войны и деловые образовательные экосистемы // Вестник НИА РК. – 2020. – № 4 (78). – С. 87-93. https://doi.org/10.47533/2020.1606-146X.36. (The author's contribution is a forecast of the nature of the development of robotic armaments)

7. Ermukhambetova B.B., Suleimenov I.E., **Vitulyova Y.S.,** Konshin S.V., Kadyrzhan K.N., Kabdushev Sh.B., Mun G.A. Algorithm for group control of game prototype combat neural network // Вестник НИА РК. – 2022. – № 4 (86). – С. 52-

61. https://doi.org/10.47533/2020.1606-146X.194. (The author's contribution is the basic idea of the possibility of using the developing approach for game and training purposes.)

8. Bakirov A.S., Kadyrzhan K.N., Kabdushev Sh.B., **Vitulyova Ye.S.,** Konshin S.V. A simplified algorithm for group control of a game prototype of a combat neural network // Известия НТО «КАХАК». – 2022. – № 2 (77). – С. 61-69. (Author's contribution is a simplification of an algorithm for controlling groups of unmanned systems)

9. **Витулёва Е.С.,** Кадыржан К.Н., Кадыржан А.Б., Шалтыкова Д.Б., Сулейменов И.Э. Радиодиапазондағы беткі қабат астындағы объектілерді диагностикалау үшін дрон топтарын қолдану // Вестник НИА РК. – 2024. – № 3 (93). – С. 300-312. https://doi.org/10.47533/2024.1606-146X.69. (The author's contribution is to analyze the nature of the interaction of electromagnetic waves with objects of complex configuration.)

10. **Vitulyova E.S.,** Kadyrzhan K.N., Kadyrzhan A.B., Shaltykova D.B., Suleimenov I.E. Diagnostics of subsurface objects using unmanned aerial vehicles: using generalized Fourier optics methods // Вестник НИА РК. – 2024. – № 2 (92). – С. 88-93. https://doi.org/10.47533/2024.1606-146X.36. (The author's contribution is to justify the possibility of using generalized Fourier optics methods.)

11. **Витулёва Е.С.** Цифрлік сигналды өңдеу үшін кешенді бағалы логикаларды пайдалану үшін фон // Известия НТО «КАХАК». – 2022. – № 1 (76). – С. 27-34. (Written by myself)

12. **Vitulyova Ye.S.,** Mun G.A., Suleimenov I.E. Justification of the need for substantial modernization of the info-communication segment of the defense-industrial complex of the Republic of Kazakhstan. Известия НТО «КАХАК». – 2024. – № 1 (81). – P. 60-73. (The author's contribution is a critical analysis of available open sources of information).

13. **Vitulyova Y.,** Gabrielyan O., Bakirov A., Suleimenov I. Humanist ideals in an era of increasing confrontation: the need to renew basic paradigms // Journal of Ecohumanism. – 2024. – Т. 3, № 7. – P. 2064-2076. https://doi.org/10.62754/joe.v3i7.4361. (The author's contribution is to analyze the nature of the development of robotic weapons from the perspective of artificial intelligence issues.)

14. Мун Г.А., Жумабай Р.А., Молдахан И., Байпакбаева С.Т., **Витулёва Е.С.,** Копишев Э.Е. К вопросу о постиндустриальной парадигме развития инфокоммуникационного сегмента оборонно-промышленного комплекса РК // Известия НТО «КАХАК». – 2021. – № 1 (72). – С. 29-36. (The author's contribution is to analyze the nature of the development of robotic weapons.)

15. Suleimenov I.E., **Vitulyova Y.S.,** Kabdushev S.B., Bakirov A.S. Improving the efficiency of using multivalued logic tools. Scientific Reports. – 2023. – № 13(1). – P. 1108. https://doi.org/10.1038/s41598-023-28272-1. (Author's contribution - preparation of material, data collection and analysis). **The article complies with p. 5-1 of the Rules for awarding degrees.**

16. **Vitulyova E.S.,** Matrassulova D.K., Suleimenov E.I. New application of non-binary Galois fields Fourier transform: Digital analog of convolution theorem //

Indonesian Journal of Electrical Engineering and Computer Science. – 2021. – № 23(3). – P. 1718-1726. http://doi.org/10.11591/ijeecs.v23.i3.pp1718-1726. (The author's contribution is to conduct analytical calculations.)

17. Suleimenov I.E., **Vitulyova Y.S.,** Matrassulova D.K. Features of digital signal processing algorithms using Galois fields GF (2^n+1). Plos one. – 2023. – 18(10). – P. e0293294. https://doi.org/10.1371/journal.pone.0293294. (Author's contribution - formal analysis, writing - checking and editing). **The article complies with para. 5-1 of the Rules for Awarding Degrees.**

18. **Vitulyova Y.S.,** Bakirov A.S., Suleimenov I.E. Galois Fields for digital image and signal processing: evidence for the importance of field specificity. In 2022 5th International Conference on Pattern Recognition and Artificial Intelligence (PRAI). – 2022. – P. 637-642. https://doi.org/10.1109/PRAI55851.2022.9904074. (The author's contribution is the application of the methodology to a particular Galois field).

19. Suleimenov I., **Vitulyova E.,** Bakirov A. Hybrid Number Systems: Application for Calculations in Galois Fields // 3rd Asia Conference on Computers and Communications. – 2022. – P. 126-130. https://doi.org/10.1109/ACCC58361.2022.00028. (The author's contribution is the connection of hybrid systems with Galois fields).

20. Пат. 36266. Способ и устройство для умножения по модулю семь /Сулейменов И.Э., Мун Г. А., Кабдушев Ш.Б., Байпакбаева С.Т., **Витулёва Е.С.,** Бакиров А.С.; опубл. 16.06.2023. (Author's contribution - proving the patentability of the proposed approach).

21. Пат. 36236. Сумматор по модулю 2^2-1 /Мун Г.А., Байпакбаева С.Т., Қадыржан Қ.Н., Кабдушев Ш.Б., **Витулёва Е.С.,** Коньшин С.В., Сулейменов И.Э.; опубл. 26.05.2023. (Author's contribution - proving the patentability of the proposed approach, conducting analytical calculations).

22. Bakirov A., Matrassulova D., **Vitulyova Ye.,** Shaltykova D., Suleimenov I. The specifics of the Galois field GF(257) and its use for digital signal processing. Scientific Reports. – 2024. – Vol. 14. – P. 15376. https://doi.org/10.1038/s41598-024-66332-2. (Author's contribution - methodology, formal analysis, resources, data curation, writing - checking and editing, supervision, project administration). **The article complies with para. 5-1 of the Rules for Awarding Degrees.**

23. Suleimenov I., Kadyrzhan A., Matrassulova D., **Vitulyova Y.** Peculiarities of Applying Partial Convolutions to the Computation of Reduced Numerical Convolutions. Applied Sciences (Switzerland). – 2024. – № 14(14). – P. 2076-3417. https://doi.org/10.3390/app14146388. (Author's contribution - conceptualization, verification, resources, data processing, writing - checking and editing, guidance, project administration, obtaining funding). **The article complies with para. 5-1 of the Rules for Awarding Degrees.**

24. **Vitulyova E.S.,** Matrassulova D.K., Suleimenov I.E. Construction of generalized rademacher functions in terms of ternary logic: solving the problem of visibility of using galois fields for digital signal processing. International Journal of Electronics and Telecommunications. – 2022. – vol. 68, № 2. – P. 237-244.

https://doi.org/10.24425/ijet.2022.139873. (The author's contribution is the application of the technique to a particular Galois field).

25. Matrassulova D.K., **Vitulyova Y.S.,** Konshin S.V., Suleimenov I.E. Algebraic fields and rings as a digital signal processing tool. Indonesian Journal of Electrical Engineering and Computer Science. – 2023. – № 29(1). – P. 206-216. http://doi.org/10.11591/ijeecs.v29.i1.pp206-216. (The author's contribution is the application of the technique to the extension of algebraic rings using reduced equations).

26. Пат. 36667. Робот для разминирования /Мун Г.А., Байпакбаева С.Т., Кабдушев Ш.Б., Қадыржан Қ.Н., **Витулёва Е.С.,** Сулейменов И.Э.; опубл. 29.03.2024. (Author's contribution - basic idea on application of single axis vehicle for mine clearance of "Petal" type mines).

27. Пат. 9303. Робот для противодействия массовым беспорядкам /Мун Г.А., Байпакбаева С.Т., Кабдушев Ш.Б., Қадыржан Қ.Н., Қадыржан А.Б., **Витулёва Е.С.,** Сулейменов И.Э.; опубл. 28.06.2024. (The author's contribution is the basic idea of using a uniaxial apparatus for crowd control).

28. **Витулёва Е.С.** Постиндустриальная парадигма развития инфокоммуникационного сегмента оборонно-промышленного комплекса РК: новые подходы к обеспечению защиты информации и теоретические основы управления группами беспилотных аппаратов с применением многозначной логики. – Алматы: ТОО «Print Express», 2024. – 172 с. – ISBN 978-601-82118-2-9. (Written by myself.)

29. Габриелян О.А., **Витулёва Е.С.,** Сулейменов И.Э. К вопросу о практическом использовании многозначных логик для моделирования сложных систем // Дистанционные образовательные технологии. Сборник трудов V Международной научно-практической конференции. – 2020. – С. 201-204. (The author's contribution is the concretization of the application of the developed apparatus).

30. Gabrielyan O.A., **Vitulyova E.S.,** Suleimenov I.E. Multi-valued logics as an advanced basis for artificial intelligence (As an example of applied philosophy) // Wisdom. – 2022. – № 1 (21). – P. 170-181. (The author's contribution is the analysis of intelligence as a system realizing multivalued logic)

31. Suleimenov I.E., Gabrielyan O.A., **Vitulyova E.S.** Dialectics of scientific revolutions from the point of view of innovations theory // Wisdom. – 2022. – № 4 (24). – P. 25-35. https://doi.org/10.24234/wisdom.v24i4.913. (The author's contribution is the consideration of the problem of multivalued logic from the point of view of the theory of scientific revolutions).

The dissertation work is presented in the form of a series of articles published by the doctoral student.