REPUBLIC OF AZERBAIJAN

On the rights of the manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

INTEGRATED GUARDING SYSTEM IN ENSURING AVIATION SECURITY

Speciality: 3324.04 - Operation of surface complexes, output equipments, flying machines and their systems

Field of science: Technical sciences

Applicant: **Ruslan Rustam Rustamov**

Baku - 2024

The work was performed at "Aviation security" department of the National Aviation Academy.

Scientific supervisor: "Honored Engineer" of the Republic of Azerbaijan, doctor of technical sciences, professor **Rasim Nasib Nabiyev**

Official opponents: Corresponding member of ANAS, Doctor of technical sciences, **Ramiz Mahammad Aliguliyev**

Doctor of technical sciences, professor **Tokay Murad Gasimzade**

Doctor of technical sciences, professor **Hikmet Hamid Asadov**

Dissertation council ED 2.01 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at National Aviation Academy

Chairman of the Dissertation council: Full member of ANAS, doctor of physics and mathematics sciences, academician **Arif Mir Jalal Pashayev**

Scientific secretary of the Dissertation council: Doctor of geography sciences, vice-prof. **Surkhay Hasan Safarov**

Chairman of the scientific seminar: Doctor of technical sciences, professor **Mustafa Rahim Mustafayev**

GENERAL CHARACTERISTIC OF THE DISSERTATION

Relevance of the topic and the degree of development. It is known that air transport is the basis of economic development and progress in many countries and plays an important role in the global economy. Safe air transport creates ample opportunities for the development of trade, tourism, and political and cultural relations between states. About 3,3 billion passengers and 50 million tons of cargo are transported by airships around the world every year. It is predicted that by 2030, the number of passengers will increase to 6 billion and the volume of cargo transportation will increase to 125 million tons [1].

According to the statistics of the International Civil Aviation Organization (ICAO), 184 acts of unlawful interference in civil aviation were recorded during 2011-2020: 60 attacks on civil aviation facilities, 26 unlawful occupations, 9 diversions and 89 other acts. As a result, the number of injured (603 people) and killed (1089 people) totalled 1692 people.

Acts of unlawful interference, resulting in injury and loss of life, undermine confidence in air transport, weaken tourism and trade relations. To solve these issues, member states of the ICAO are always trying to increase public confidence in the safety of aviation. By ensuring the safety of aviation, states create a foundation for strengthening international trade relations and the development of tourism [2].

Terrorists always try to use the weakest points of the aviation security system to achieve their goals. Minimizing damage at airports depends on the level of ensuring aviation security. One of the security issues is the reliable, sustainable and effective protection of civil aviation facilities to protect them from acts of terrorism and unlawful interference. For this, a guarding-warning system is installed along the perimeter of the object.

---

[1]Global aviation security plan // The 39th Session of the International Civil Aviation Organization Assembly. - Montreal: ICAO, - 2017. - 32 p.

[2]Руководство по авиационной безопасности // Doc. 8973. - Монреаль: ИКАО, - 2019. - Издание одиннадцатое, - 950 с.

The guarding-warning system has the function of initially "getting information" and "transmitting information" to guards about the entry of a person (an intruder) into the territory.

The implementation of the perimeter guarding-warning system, which is a part of the aviation security system, aims to reduce the risk of terrorist and unlawful interference as much as possible. When installing a guarding-warning system in a specific area, an integrated form of several control systems is used [3, 4].

In integrated guarding-warning systems, various radio technical systems (for example, radio waves, infrared or capacitive sensors, etc.) are used in a combined form as a control systems [3, 4]. However, it is not possible to apply equally effective guarding-warning systems in areas with different characteristics. When installing guarding-warning systems, the type of security fence, the relief of the area where the objects are located, the effect of the placement of sensitive elements of the sensors on the general appearance of the object, environmental effects, as well as the intention of the intruder, weapons and other characteristics should be taken into account. Capacitive sensors, which allow early detection of intruders, are used in integrated guarding-warning system because they are both economically efficient and reliable from the point of view of ensuring security. However, in scientific publications, the fields of application of capacitive sensor guarding-warning system and the distinguishing features of the proposed schemes have not been analyzed in detail [5, 6]. Therefore, the selection of the optimal scheme of the capacitive sensor according to the characteristics of the object and the relief of the area remains a very relevant problem [5].

---

[3] Nəbiyev, R.N. Avtomatlaşdırılmış distansion mühafizə kompleksinin layihələndirilməsi xüsusiyyətləri / R.N.Nəbiyev, N.T. Nağıyev, R.R. Rüstəmov [və b.] // MAA-nın Elmi Əsərləri, -Bakı: -2016. №2, -s.76-95 və -2017. №1, -s. 20-33.

[4] Пашаев, А.М. Особенности проектирования автоматизированного дистанционного охранного комплекса / А.М.Пашаев, Р.Н.Набиев, Р.Р. Рустамов [и др.] // Вопросы безопасности, - Москва: - 2018. №1, - с. 32-51.

[5] Paşayev, A.M. Diferensial tutum duyğacı, Patent (İxtira) İ 2022 0033, Azərbaycan Respublikası / Nəbiyev R.N., Qarayev Q.İ., Rüstəmov R.R.

State of the problem. Continued enforcement by States of the standards and recommended practices in Annex 17 of the Chicago Convention is critical to the safety, regularity and efficiency of air transport. In this case, there are necessary opportunities to improve aviation security worldwide [7].

Despite improvements in aviation security, terrorists continue to view civil aviation as an attractive target and exploit real or perceived vulnerabilities in the international civil aviation system to cause significant loss of life, economic damage and disruption of trade between states. The current threat and risk environment shows that aviation security is one of the highest priorities for states and the international community. It is necessary to continuously review the threat level and evaluate the risks in order to determine the appropriate preventive security measures. Security measures and procedures should be in accordance with the assessed risk level [1, 2, 7]. All this necessitates a serious increase in attention to the issue of civil aviation security.

The most complex and important issue to ensure the security of any object is to have a stone fence or barbed wire that reliably protects it around the perimeter, as well as a protective fence.

Through the integrated guarding-warning system of the perimeter, it is possible to detect the intruder in time and take preventive or adequate measures to prevent unlawful interference [8].

Regardless of the scale and complexity of the applied system, it is possible to monitor the entire area of the object through the integrated guarding-warning system, as well as to control it remotely, taking into account the functional capabilities and working principles of each of the subsystems used in the system [9].

---

[6]Соломеин, В.П. Емкостные датчики приближения // - Москва: Радиомир, - 2012, №6. с. 28-29; № 7. с. 20-22.

[7]Авиационная безопасность. Защита международной гражданской авиации от актов незаконного вмешательства // Приложение 17 к Конвенции о международной гражданской авиации. - Монреаль: ИКАО, - 2022. №12, -74 с.

[8]Селищев, В.А., Чечуга, О.В. Выбор системы охраны периметра // - Тула: Известия ТулГУ. Технические науки, - 2010. №2 (2), - с. 227-234.

The object and subject of the research. The object of the dissertation work is the perimeter integrated guarding-warning system in ensuring aviation security.

The subject of the study is the factors affecting the effectiveness and reliability of the perimeter integrated guarding-warning system, as well as the parameters of the applied capacitive sensor.

Purpose and tasks of the research - increasing the effectiveness and reliability of the perimeter integrated guarding-warning system in ensuring aviation security. To achieve the defined purpose, the following tasks were set and solved in the dissertation work:

- evaluation of the technical conditions and its design for the development of a remotely controlled automated guarding complex, distinguished by its universality, high efficiency, reliability and ergonomics;
- construction of the algorithm for the improved guarding-warning system's work activity;
- assessment of the effectiveness of the improved guarding-warning system and determination of its economic efficiency;
- building a mathematical model of the activity of the improved guarding-warning system, analyzing optimal ways of solving the problem to minimize all losses, and evaluating the completeness of the system;
- mathematical assessment of the degree of guarding and security risk of the protected object;
- assessment of the reliability of the guarding-warning system by studying the possibilities of the sub-systems working separately without giving up;
- analysis of the most used variants of the capacitive sensor, determination of technical conditions and the most convenient electrical scheme;

---

[9] Ворона, В.А. Комплексные (интегрированные) системы обеспечения безопасности. Книга 7 / В.А.Ворона, В.А. Тихонов. - Москва: Горячая линия - Телеком, - 2013. - 160 с.

- development and research of the electrical circuit of the two autogenerators differential capacitive sensor assembled in digital logic elements, adaptable to environmental changes;

- the study of the dependence of the frequency change of the autogenerator applied in the capacitive sensor on the distance of approaching the sensitive element of people of different weights and determining the maximum distance at which the sensitivity is ensured;

- development of hardware and software support of two autogenerators differential capacitive device and determination of characteristics.

Research methods. Theoretical, comparison, analysis, classification, synthesis, experiment, measurement, observation, as well as mathematical modelling, probability theory and statistical methods were used during the research.

The main provisions for defence:

1) The conceptual structural scheme of the improved guarding-warning system, which is distinguished by its universality, high efficiency, reliability and ergonomics, adapted to modern requirements;

2) Working algorithm of the improved guarding-warning system;

3) Indicators registered with a priori reports reflecting the effectiveness and economic efficiency of the implementation of the integrated guarding-warning system;

4) The proposed scheme of two autogenerators differential capacitive sensor assembled in digital logic elements and connected to sensitive elements for integrated perimeter guarding-warning systems;

5) Time-dependence of the probability of the automated guarding-warning system to work without fail every 50 hours for reliability assessment;

6) The dependence of the average values of the frequency changes of autogenerators on the length of the sensitive elements on different days to determine the frequency changes;

7) The dependence of resonance frequencies on the distance of the human approach to sensitive elements connected to autogenerators for determining the sensitivity distance of the capacitive sensor.

The scientific novelty of the research consists of the following:

- two autogenerators differential capacitive sensor with more stable parameters based on logic elements without using *RLC* elements with lumped parameters as a frequency-determining element were worked out for the first time, and the expediency of its application in guarding-warning systems has been determined [5, 10, 11];

- the automatic tuning of the differential capacitive sensor to the environment and the measurement of the differential frequency as an useful signal has been provided by using one of the two autogenerators that are mutually replaced as a support and the other as a measurement frequency generator [5,11];

- the working algorithm of the differential capacitive device with two autogenerators has been worked out [11, 12];

- taking into account the drift of resonance frequency values of autogenerators over time, it has been determined by experimental measurements where the object approaching the sensitive elements along its length was recorded from a distance of more than 3 m [13];

- with the symmetrical cross-distribution of an even number of logic elements located within one microcircuit in the circuit of both autogenerators, the same change in the characteristics of the autogenerators is ensured [12]. When using microcircuits of different brands on the same basic electrical circuit, the significant difference in the output frequencies of the differential capacitive sensor affects the operation of the capacitive device does not affect;

---

[10] Nəbiyev, R.N. İki avtogeneratorlu diferensial tutum qurğusu / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2021. №3 (21), - s. 1-7.

[11] Nəbiyev, R.N. Tutum duyğacları üçün avtogenerator sxemlərinin tədqiqi / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2019. №2 (21), - s. 26-33.

- the structure, functional capabilities, and technical parameters of the capacitive device developed for the perimeter guarding-warning systems were defined and two autogenerators differential capacitive sensor worked out into the digital logic elements included in the device were being worked out for the first time and were prepared [5, 10, 14].

Theoretical and practical significance of the research:

1) In autogenerator schemes, not using lumped parameter *RLC* elements as a frequency-determining element and a varicap for adaptation to environmental changes led to the simplification of the scheme and an increase in the reliability of the capacitive sensor;

2) The automatic adaptation of the guarding device to environmental changes is ensured by using autogenerators with alternating signal and reference frequency without using a reference generator with a quartz resonator in a differential capacitive sensor with two autogenerators;

3) The number of false starts is significantly reduced by reliably converting the frequency change of the differential capacitive sensor with two autogenerators into a warning signal during the approach of the intruder in guarding-warning systems through the been worked out unified software;

4) By means of a guarding-warning device created on the basis of two autogenerator differential capacitive sensors, it is possible to detect intruders approaching the protection line from a greater distance (more than 3 m) than its counterparts (detection distance less than 1,3 m);

---

[12]Nəbiyev, R.N., Ramazanov, K.Ş., Rüstəmov, R.R. Avtomatik distansion idarə edilən mühafizə-xəbərdarlıq sisteminin iş fəaliyyətinin alqoritmi // "Aviakosmik məsələlərin həllində Gənclərin yaradici potensiali" IV beynəlxalq elmi-praktiki gənclər konfransının. Fevral məruzələri, - Bakı: - 27-28 fevral, - 2019, - s. 177-179.

[13]Nəbiyev, R.N. Məntiq elementlərində qurulmuş həssas elementli iki avtogeneratorun rezonans tezliklərinin tədqiqi / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, -Bakı: -2019. №3 (21), -s.19-31.

[14]Набиев, Р.Н. Дифференциально-емкостное устройство с двумя автогенераторами / Р.Н.Набиев, Г.И.Гараев, Р.Р.Рустамов // Известия ЮФУ. Технические науки, - Таганрог: - 2022. №2 (226), - с. 145-153.

5) The high probability of detection of unlawful interferences in objects by means of a guarding device with two autogenerator differential capacitive sensors allows it to be effectively used in the aviation security system.

Approbation and application of the research. Related to the dissertation work 17 scientific works (2 - without co-author) were published in scientific journals and 8 conference materials (1 - without co-author) were published in foreign and national countries and 1 patent (I 2012 0088) was obtained. The main scientific-theoretical and practical results of the dissertation work were discussed at the following international and national scientific-technical conferences:

1. “Creative potential of young people in solving aerospace issues” III international scientific-practical conference. Baku, MAA, February reports, February 12-14, 2018.
2. “Creative potential of youth in solving aerospace issues” IV international scientific-practical youth conference. Baku, MAA, February reports, February 27-28, 2019.
3. “International United Academy of Sciences, Science of Russia: goals and objectives” XV annual conference. Part 1, Ekaterinburg, June 10, 2019.
4. “International United Academy of Sciences, Trends in the Development of Science and Education” conference. Samara, June, 2019.
5. “February reports 2021: creative potential of young people in solving aerospace issues” VI International scientific-practical youth conference. Baku, MAA, February reports, February 2-4, 2021.
6. Proceedings of the XXVIII International Scientific and Practical Conference International Trends in Science and Technology, - Warsaw, Poland: - 30 april, - 2021.
7. International Gobeklitepe Applied Sciences Congress-II. Harran University, - Sanliurfa, Turkey: - 6-8 may, - 2021.

Name of organization where the disseration is accomplished. The work was performed at "Aviation security" department of the National Aviation Academy.

The total volume of the dissertation with a sign indicating the volume of the structural sections of the dissertation separately. The dissertation was written in accordance with the requirements set by the Higher Attestation Commission under the President of the Republic of Azerbaijan. The dissertation consists of an introduction (13480 signs), four chapters (first chapter four paragraphs - 45080 signs, second chapter six paragraphs - 64205 signs, third chapter five paragraphs - 52085 signs, fourth chapter four paragraphs - 51600 signs), conclusion (1835 signs), a bibliography of 122 names used, 3 appendices, 58 figures and 18 tables. The total volume of the dissertation (excluding gaps in the text, pictures, tables, appendices and bibliography) consists of 228,285 signs and is presented on 185 printed sheets.

MAIN CONTENT OF THE DISSERTATION

In the "Introduction" part of the dissertation, the relevance and degree of elaboration were mentioned, the object and subject, goals and tasks, and methods of the research were determined, the main propositions defended were indicated, and the scientific novelty and theoretical and practical importance of the dissertation were justified.

In the first chapter, the measures implemented by the states against the increasing cases of large-scale acts of terrorism and unlawful interference in modern times have been analyzed. It has been known that terrorist acts committed in strategic facilities, especially in international airports, cause a high resonance among the public. Therefore, protection of civil aviation (CA) against acts of unlawful interference (AUİ) is a very important issue [15].

In order to improve aviation security (AS), it has been noted that it is necessary to introduce new requirements for the guarding of strategically important objects and on the maximum distance from the security zones of intruders, given that the CA aviation sector is more attractive [3, 4, 15].

[15]Rüstəmov, R.R. Məsafədən idarəedilən inteqrasiya olunmuş mühafizə-xəbərdarlıq sisteminin tətbiqi imkanları // - Bakı: Milli Aviasiya Akademiyasının Elmi Məcmuələri, - 2019. №4 (21), - s. 31-39.

Depending on the level of integration, the issues of timely, reliable and stable response of guarding-warning systems (GWS) to expected threats have been investigated. It has been determined that the stable and reliable operation of the GWS allows to receive information about possible threats at the initial stage, regardless of the influence of the environment [16].

The criteria of the characteristic features of the objects were indicated, and based on these criteria, the categories of the objects have been selected for more reliable guarding against acts of terrorism and unlawful interference [17]. In addition, the sensors that ensure the protection of the perimeters of CA facilities and the requirements imposed on them have been described.

In order to determine the optimal structural scheme of the GWS, the characteristics of some systems were considered, taking into account the high demands placed on the technical means of the perimeter that make up the first line and affecting its reliability, as well as the degree of stability. Natural, mechanical and technical barriers are used as technical means of security along the perimeter. In addition, the following requirements are imposed on the GWS of the perimeter [17]:

1. High detection ability;
2. Minimizing false alarms;
3. Lack of dependence on climate and weather conditions;
4. System masking;
5. Easy maintenance and reliability;
6. Economic efficiency, etc.

The characteristics of widespread types of subsystems used as a control systems (for example, capacitance, radio-beam, IYT, radio-wave, IR, vibration-sensitive, vibration-seismic, optical fiber sensors

[16] Введенский, Б.С. Интеллектуальные датчики для охраны периметров (часть первая) // - Москва: Системы безопасности. Охранная и охранно-пожарная сигнализация, периметральные системы, - 2011. №3, - с. 118-120.

[17] Rüstəmov, R.R. Mühafizə olunan obyektlərin xarakterik xüsusiyyətlərinə görə sinifləşdirilməsi // "Aviakosmik məsələlərin həllində gənclərin yaradıcı potensialı" III beynəlxalq elmi-praktiki gənlər konfransının materialları. Fevral məruzələri, - Bakı: - 12-14 fevral, - 2018, - s. 248-250.

and video surveillance means, etc.) in the perimeter of GWS, as well as some integrated GWS ("NIR", "SICURIT", "SOKOL", "STRATUM", "DTR 2000" and "IQM" etc. systems) that are currently applied, have been comparatively analyzed, and their advantages and disadvantages have been given [15, 18]. It has been noted that it is appropriate to use the organic integration and complex automated management of several subsystems based on a single software base in GWS for effective guarding of the object regardless of the type of intruder and weather conditions [16]. For this purpose, the optimal technical conditions for the implementation of remotely controlled (RC) the integrated GWS, which meets modern requirements, is less exposed to environmental influences, works effectively and reliably have been determined.

In the second chapter, the electric circuits of different types of capacitive sensors have been comparatively analyzed, taking into account their characteristics, their pros and cons have been shown. It has been noted that one of the devices used in the perimeter GWSs of CA facilities and which works reliably in all types of weather conditions is a capacitive sensor. Optimum technical conditions for the preparation of electric circuits of capacitive sensors during the projecting of new GWSs applied in the RC automated guarding complex have been given [19, 20].

Various autogenerator schemes, what frequency-determining elements are mainly *LC*-circuit or *RC*-circuit, were analyzed for forming the signal frequency in capacitive sensors. In order to determine the autogenerator scheme that provides higher sensitivity, the dependence of the resonance frequency changes of various autogenerator schemes with external *RLC* elements on the distance of

---

[18]Nəbiyev, R.N., Rüstəmov, R.R. Aeroportların perimetrinin mühafizə sistemlərinin müqayisəli təhlili // - Bakı: Azərbaycan Milli Aerokosmik Agentliyinin Xəbərləri, - 2017. №1 (20), - s. 41-46.

[19]Nəbiyev, R.N. Tutum vericilərinin elektrik sxemlərinin müqayisəli təhlili / R.N. Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2016. №3 (18), - s. 32-43.

[20]Набиев, Р.Н. Сравнительный анализ электрических схем ёмкостных датчиков / Р.Н.Набиев, Г.И.Гараев, Р.Р.Рустамов // Известия ЮФУ. Технические науки, - Таганрог: - 2017. №3 (188), - с. 51-64.

the object approaching the sensitive element (SE) was investigated in laboratory conditions. The obtained results were analyzed in a comparative way, and the advantages and disadvantages of the schemes were determined [21].

The frequency change of the autogenerator during the approach of the person to the SE was investigated by means of a digital oscilloscope. Based on the recorded value of the frequencies in cases with and without convergence, their difference was calculated and a diagram of the frequency change was constructed. According to the diagram, it was determined that the frequency change in cases of the person approach to the sensitive element is both in the direction of increase and decrease [21].

The scheme of the differential capacitive sensor with more stable parameters worked out for the GWS is described, it is shown that it is not appropriate to use lumped parameter *RLC* elements as a frequency-determining element in the scheme [11, 22, 23]. In addition, various autogenerator circuits worked out in logic elements for capacitive sensors were analyzed, and the electric circuit of the differential capacitive sensor with two autogenerators, which provides the sensitivity and stability required by the frequency change, and is adaptable to environmental changes, was developed [11, 22]. Using the mathematical expectation or variance of the frequency change, it has been shown that false starts of the device can be significantly reduced

The issues of evaluating the effectiveness of the GWS activity have been considered, and the probability of detection of the intruder by the technical means under ideal conditions for evaluating the effectiveness of the improved GWS of the perimeter of the meteorolo-

---

[21]Nəbiyev, R.N., Qarayev, Q.I., Rüstəmov, R.R. Tutum duyğacları üçün yüksək həssaslı avtogenerator sxeminin müəyyənləşdirilməsi // International Gobeklitepe Applied Sciences Congress-II. Harran University, - Sanliurfa, Turkey: - 6-8 may, - 2021, - p. 126-133.

[22]Набиев, Р.Н., Гараев, Г.И., Рустамов, Р.Р. Исследование схем автогенераторов для емкостных датчиков // Международная Объединенная Академия Наук, Наука россии: цели и задачи, Сборник научных трудов по материалам XV международной научной конференции, - Екатеринбург: - 10 июня, - 2019, Часть 1, - с. 51-53.

gical radar (MLR) object under the conditions of its technical means being in working condition was calculated by the expression (1) [24].

$$P_{ef} = P_{GG} \cdot P_{per.tec} \cdot P_{pro.det} \cdot K_{GG} \cdot K_R \cdot K_{EGD} \qquad (1)$$

where, the probability of intruder prevention by the guarding group (GG) - $P_{GG} \approx 0{,}950$; the probability that intruders cannot cross the protected technical zone through each subsystem - $P_{per.tec} \approx 0{,}999$; probability of detecting unlawful interferences that may occur in the area under ideal conditions - $P_{pro.det} \approx 0{,}999$; the coefficient of preparation of GG - $K_{GG} \approx 0{,}968$; the readiness factor of the radio modem that collects information to the central object control unit (COCU) and processes that information from the zone control unit (ZCU) and transmits it to the control centre (CC) - $K_R \approx 0{,}999$; preparedness coefficient of engineering guarding devices - $K_{EGD} \approx 0{,}995$ has been adopted. Based on these, it was determined that the value of the effectiveness indicator for the GWS of the meteorological radar object is $P_{ef} \approx 0{,}912$.

Taking into account the high effectiveness indicator obtained with a priori reports, it is considered appropriate to apply the improved GWS in CA [24, 25,].

Depending on the nature of the obstacles worked out along the perimeter (for example, a stone fence), the probability of the threat being realized by the intruder was calculated, and the methods of reducing material losses in the event of the threat being realized have been analyzed.

The methods of evaluating the value and economic efficiency of the GWS for the timely prevention of acts of unlawful interference for the MLR object have been considered. Appropriate calculations were performed for the improved GWS, and taking into account the

---

[23]Nəbiyev, R.N. LC-generatorunun tezliyinin onun həssas elementinə yaxınlaşma məsafəsindən asılılığı / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov [və b.] // Milli Aviasiya Akademiyasının Elmi Əsərləri, - Bakı: - 2018. №1, - s. 28-41.

[24] Nəbiyev, R.N. Avtomatlaşdırılmış mühafizə-xəbərdarlıq sisteminin effektivliyinin qiymətləndirilməsi / R.N.Nəbiyev, K.Ş.Ramazanov, R.R. Rüstəmov // Azərbaycan Mühəndislik Akademiyasının Xəbərləri, - Bakı: - 2020. №1 (12), - s. 84-91.

probability of detection of illegal intrusions that may occur in the area during its application – $P_d \approx 0{,}999$ and the possibility of slowing down the intruder's actions - $P_{slo} = P_{GG} = 0{,}950$, the probability of successful realization of the threat inside the protected object - P_{real}^{j} was calculated:

$$P_{real}^{j} = \prod_{V=1}^{3}(1 - 0{,}999) \cdot \prod_{z=1}^{3}(1 - 0{,}95\,0) = 0{,}125 \cdot 10^{-12}$$

Assuming that the probability P_{real}^{j} is equal to the probability of an attack by an intruder who wants to commit AUİ - $P_{real}^{j} = 0{,}125 \cdot 10^{-12}$, the total value of the object's resources (radar system) - $C_{L_j} \approx 1\,823\,176$ man. and the probability that the intruder will enter the object - $P_{i\,nt}^{j} = 0{,}001$, the calculated value of the material cost of the risk of the radar system located at the object being destroyed due to the effect of an attack typical of a type *k* intruder is not taken into account is small.

Taking into account that the value of the material resources of the protected object is made up $C_{L_j} \approx 1\,823\,176$ man. and the value of the improved GWS is in general - E_g = 94002.12 man., the percentage ratio of the resources of the protected object with the value of the GWS - E_p can be calculated:

$$E_p = \frac{E_g}{C_{L_j}} \cdot 100\% = \frac{94002{,}12}{1\,823\,176} \cdot 100\,\% \approx 5{,}16\%$$

The value of the security system should be from 5% to 20% of the value of the protected property [26]. The fact that E_f = 5,16% determines that the application of improved MXS is economically viable. Based on the relevant calculations, it was determined that the implementation of the GWS is effective and economically efficient.

---

[25]Набиев, Р.Н., Рамазанов, К.Ш., Рустамов, Р.Р. Оценка эффективности применения автоматизированной охранно-оповестительной системы // Международная Объединенная Академия Наук, Тенденции развития науки и образования, - Самара: - июнь, - 2019. №51 (7), - с. 21-24.

In general, since the provision of aviation security is one of the important conditions, the researches conducted show the importance of continuing the work related to the constant improvement of security measures in this field in accordance with international standards. The costs spent on the timely prevention of aviation incidents are a capital investment and, as in other areas, are the main factor in achieving the economic efficiency of the application of protection systems. Improving aviation security around the world brings economic benefits [26].

In the third chapter, the technical conditions for the creation of an improved form of the RC integrated security system of strategically important objects have been determined, taking into account the universality, high efficiency, reliability and ergonomics. A general description of the placement of this system in the area has been given, and a conceptual structural scheme of the GWS reflecting the functional capabilities of the sub-systems that make up the system has been worked out (Figure 1) [3, 4, 12].

A scheme of an improved GWS, which can be adapted to any landscape morphology and has the possibility of expansion, has been proposed. The GWS consists of a CC located several kilometres away from the object, and several ZCUs, one of which is the central one. The CC consists of a radio modem and a computer. Each zone has an independent guarding system. Video cameras, radio modem, searchlights, capacitive sensor, alarm and warning devices (siren, flashing, etc), as well as laser beam systems have been applied in the integrated GWS as additional security measures to detect air attacks and intruder attempts.

To monitor the zones from all sides along the perimeter, a pair of infrared (IR) receiving and emitting sensors is installed on the designated posts. In addition to these, vibrating sensors have been installed at a certain depth of the soil along the perimeter of the object to detect the approach of the intruder from a longer distance.

[26]Ramazanov, K.Ş., Rüstəmov, R.R. Avtomatlaşdırılmış mühafizə-xəbərdarlıq sisteminin iqtisadi səmərəliliyinə risklərin təsiri // "Fevral məruzələri 2021: Aviakosmik məsələlərin həllində gənclərin yaradıcı potensialı" VI Beynəlxalq elmi-praktiki gənclər konfransının materialları, - Bakı: - 2-4 fevral, - 2021, - s. 186-188.

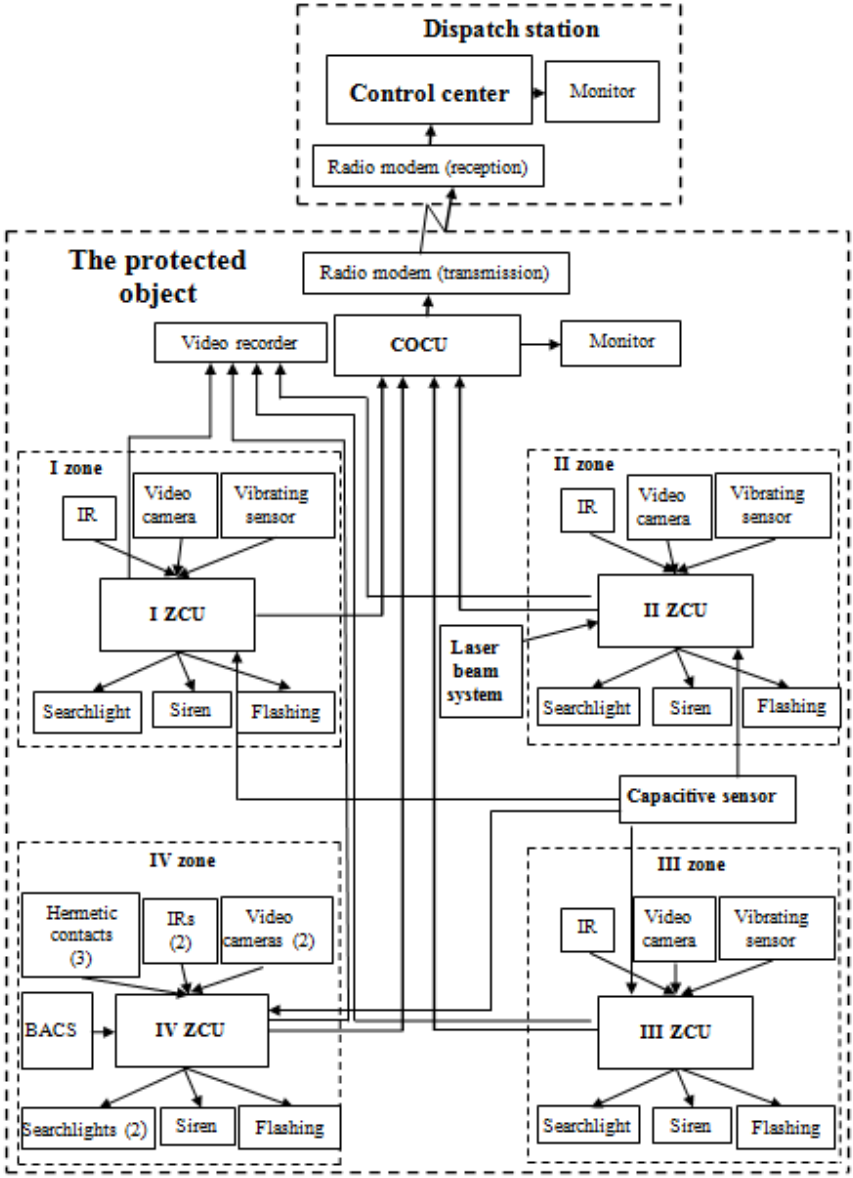

Figure 1. Conceptual structural scheme of the improved guarding-warning system

To prevent unauthorized access from the access control point and to ensure authorized access for operating personnel, control has been developed through hermetic contacts and a biometric access control system (BACS) [3, 4].

The activity of the GG has been described in relation to the work of the GWS and the protection characteristics, an algorithm has been worked out that allows to minimize of the number of the group, as well as ensures the timely detection of unlawful interferences in the area through the GWS (Figure 2) [12].

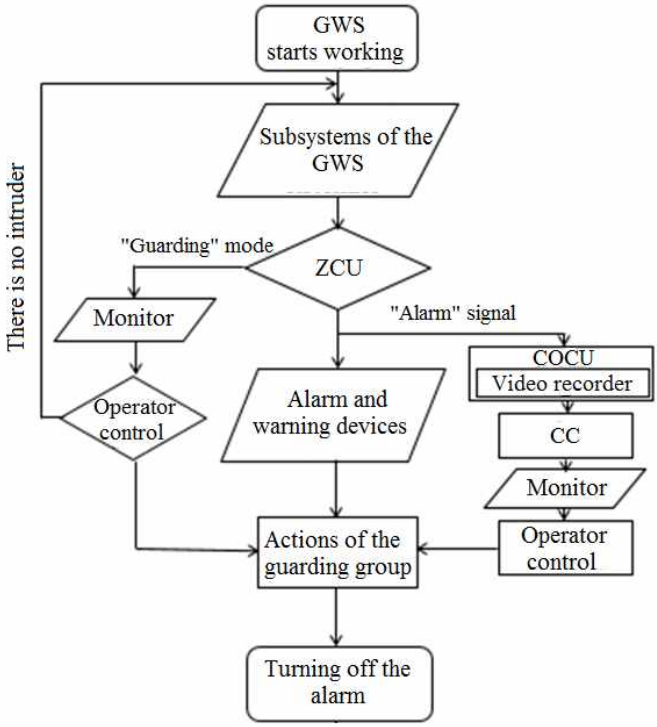

Figure 2. Algorithm of the working activity of the improved GWS

By pressing the "Start" button on the control panel, the GWS is activated, and the presence of the "Alarm" is checked based on the output signals of the sensors in the ZCU. If there is no "Alarm", the

system periodically continues to work in the "Guarding" mode. In this case, it is also possible to visually monitor the area on the monitor and manually activate the "Alarm" signal if an act of unlawful interference is detected. If the "Alarm" signal is registered in the ZCU, then the warning devices are activated. In the COCU, the light diode corresponding to that zone lights up, at the same time, the information about the act of unlawful interference is recorded and archived by a video recorder, as well as transmitted to the CC installed in a remote dispatch station via a radio modem (transmission). It is possible to observe the image of the intruder on the monitor at the dispatch station.

When the "Alarm" signal is activated, the GG immediately approaches the object and takes appropriate measures to arrest the intruder. Rebooting the system is performed using the "Start" button.

As can be seen from the algorithm, the GG does not manage the work of the GWS, but only approaches the area to investigate the cause of the "Alarm" signal.

Thus, it is possible to effectively, reliably and economically efficiently protect strategic objects and reduce the number of the GG to a minimum through the improved RC automated GWS [12].

The methods of assessing the security risk of the perimeter of the CA object and its weakest point based on mathematical analyzes have been investigated, and based on them, a priori calculations have been made to justify the effective implementation of the improved GWS in the area of the MLR object. Thus, it is possible to determine the justification for the application of the GWS through the probability assessment P_p of the object's protection level [27, 28]. In this case, the probability P_p is determined by the expression (2):

$$P_p = P_d \cdot P_{slo} \tag{2}$$

---

[27]Rüstəmov, R.R. İnteqrasiya olunmuş mühafizə-xəbərdarlıq sisteminin tətbiqi perspektivləri // - Bakı: Azərbaycan Milli Aerokosmik Agentliyinin Xəbərləri, - 2020. №3 (23), - s. 47-53.

[28]Тарасов, А.Д. Разработка и исследование математических методов обработки нечеткой информации в задаче оценки защищенности потенциально опасных объектов // Труды ИСА РАН, - Москва: - 2014. №2 (64) с. 27-41.

Where, P_d - is the probability of detecting the intruder;
P_{slo} - is the possibility of slowing down the actions of the intruder through physical barriers.

To evaluate the effectiveness of the application of the GWS, the value of the expected risk characterizing the level of protection of the object is also used and calculated by its expression (3) [24, 25, 29]:

$$W = r^k \cdot P_{oc} \tag{3}$$

Where, r^k - is the quantification of the risk of failure of a critical element located in the facility under the influence of an attack typical of a type k intruder. This quantity indicates the amount of possible material (social) losses during the impact of the attack and is considered a qualitative indicator (potential danger of the object).

P_{oc} - is the probability of occurrence of all types of AUİ as a result of an attack on the object by an intruder of type k and is calculated by the expression (4):

$$P_{oc} = P_r \cdot P_{l.v} \tag{4}$$

Where, P_r - is the probability that the intruder will reach the object by overcoming physical barriers;
$P_{l.v}$ - is the probability of the level of vulnerability of the object.

P_r *and* $P_{l.v}$ probabilities were calculated taking into account the probabilities of detection and delay of the intruder in ideal conditions in the territory of the object ($P_d \approx 0{,}999$ və $P_{slo} \approx 0{,}950$):

- the possibility of the intruder reaching the radar system in the territory of the MLR object by overcoming physical barriers has been calculated:

$$P_r = 1 - P_{slo} = 1 - 0{,}950 \approx 0{,}050;$$

- the probability of the level of vulnerability of the radar system located at the object has been determined:

$$P_{l.v} = 1 - P_d \cdot P_{slo} = 1 - 0{,}999 \cdot 0{,}950 \approx 0{,}051.$$

---

[29]Nəbiyev, R.N. Təkmilləşdirilmiş mühafizə-xəbərdarlıq sisteminin riyazi modelinin qurulması / R.N.Nəbiyev, K.Ş.Ramazanov, R.R. Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2019. №1 (21), - s. 132-140.

Based on the values of P_r and $P_{l.v}$ probabilities, the probability of occurrence of all types of terrorism and AUİ as a result of the attack of the intruder on the radar system of the MLR object:

$$P_{oc} = P_r \cdot P_{l.v} \approx 0{,}003$$

has received the value. If this value is taken into account in expression (2), the value of the expected risk for the level of protection of the radar system located in the territory of the MLR facility becomes negligible [24, 25, 29].

Thus, the probability of an intruder reaching the object by overcoming physical barriers ($P_r \approx 0{,}050$), the probability of the object's level of vulnerability ($P_{l.v} \approx 0{,}051$), the probability of all types of threats being realized as a result of the intruder's attack are low ($P_{oc} \approx 0{,}003$), and the sum of possible losses during the realization of threats to the critical elements of the MLR object is very small, indicating the effective protection of the MLR object. As a result, it was determined that the value of the expected risk to maintain the level of protection of the MLR object is negligible [27].

A mathematical models reflecting the losses related to the intruder's ability to exceed the outer perimeter of the MLR object and damage to material values has been considered. In order to prevent foreign interference to the facility and ensure security activities, the issue of minimizing losses has been formalized and the probabilities of detecting the intruder with various technical means in the surveillance zone have been calculated. A mathematical model describing the functional work of the GWS and the protection characteristics related to the activity of the GG was worked out [29].

---

[30]Nəbiyev, R.N. İki avtogeneratorlu diferensial tutum qurğusunun proqram təminatının işlənilməsi / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov [və b.] // Mathematics and computer science. Journal of Baku Engineering University, - Bakı: - 2020. №2 (4), - s. 137-142.

[31]Nəbiyev, R.N., Qarayev, Q.I., Rüstəmov, R.R., Quluzadə, H.S. İki avtogeneratorlu diferensial tutum qurğusunun proqram təminatinin işlənilməsi // International Gobeklitepe Applied Sciences Congress-II. Harran University, - Sanliurfa, Turkey: - 6-8 may, - 2021. - p. 134-140.

Based on the mathematical model of the worked out structural scheme, it was determined that the probability of the improved GWS detecting unlawful interferences that may occur in the area under ideal conditions is quite high.

The hardware characteristics of the two-autogenerator differential capacitive device used in integrated GWSs, worked out on the Arduino platform, have been defined and the software has been worked out [30, 31]. It has been used to convert the frequency values of the output signals of the autogenerators written to the laptop for processing the digital value of the frequency using Arduino Uno modules. Algorithm block schemes and startup codes of programs in Arduino Uno modules have been described.

In the fourth chapter, the issues of evaluating the reliability of the automated GWS have been considered [32]. Unrelenting work intensity - λ_{C4}.

$$\lambda_{C4} = \sum_{i=0}^{10} \lambda_i N_i = 640{,}28 \cdot 10^{-6} \frac{1}{hour};$$

the probability of failure of the elements included in the system every 50 hours - $P_{C4}(t)$,

$$P_{C4}(t) = e^{-\lambda_{C4} \cdot t} = 0{,}96849;$$

average continuous operation time - T_{C4}

$$T_{C4} = \frac{1}{\sum_{i=0}^{n} \lambda_{c4}} \approx 1562\ hour$$

and the frequency of rejections - $\theta_{C4}(t)$ has been calculated:

$$\theta_{C4}(t) = \sum_{i=0}^{n} \lambda_{C4} \cdot e^{-t \cdot \sum_{i=0}^{n} \lambda_{C4}} = 62{,}01 \cdot 10^{-5} Hs$$

Where, N_i - is the number of elements.

---

[32] Paşayev, A.M. Avtomatlaşdırılmış mühafizə-xəbərdarlıq sisteminin etibarlılığının qiymətləndirilməsi / A.M.Paşayev, R.N.Nəbiyev, R.R.Rüstəmov [və b.] // Milli Aviasiya Akademiyasının Elmi Əsərləri, - Bakı: - 2018. №2, - s. 11-27.

Based on the reliability indicators obtained as a result of the calculations, a time dependence graph of the probability of fail-safe operation for the automated GWS has been constructed (Figure 3), and it has been determined that these reliability indicators are within the limit range set for CA equipment [33].

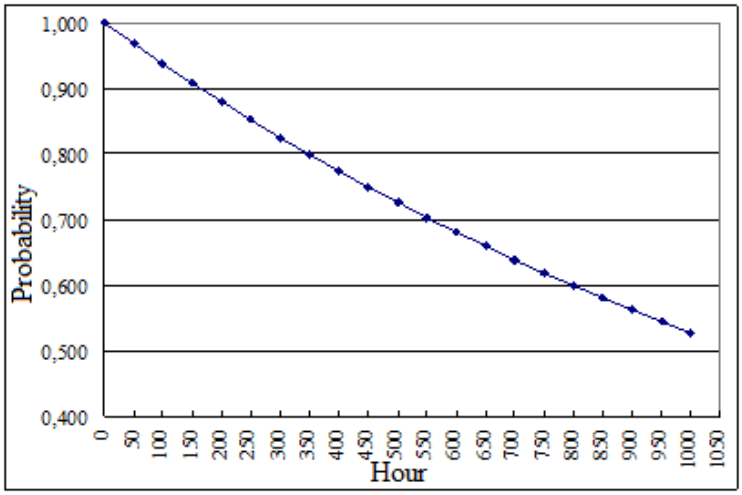

Figure 3. Time-dependent graph of fail-safe operation probabilities for an automated guarding-warning system

A graph of the dependence of the frequency change of the two autogenerators assembled on the digital logic elements that make up the differential capacitive sensor on the length of the SE has been constructed (Figure 4, curve 2). The average value of the values recorded in the measurements performed during three days of the frequency change has been used in the construction of the graph. The figure also shows the frequency value of the autogenerator without a SE for comparison (Figure 4, curve 1). As it can be seen from the figure, the frequency of the autogenerator without a SE varies around 16,5 MHs with values smaller than ±0,5 MHs.When a SE of a certain length is connected to the autogenerator, its frequency decreases than that without a SE and varies around 14,5 MHs. However, the case in which the length of the SE is 6 m is a special case. In all the experiments performed on three different days with a 6 m long SE,

the frequencies of both autogenerators have being repeated as high as compared to the case without the SE and were, respectively, $f_{1a.v}$ = =17,345066 MHs and $f_{2a.v}$ = 17,345066 MHs (Figure 4, curve 2) [34].

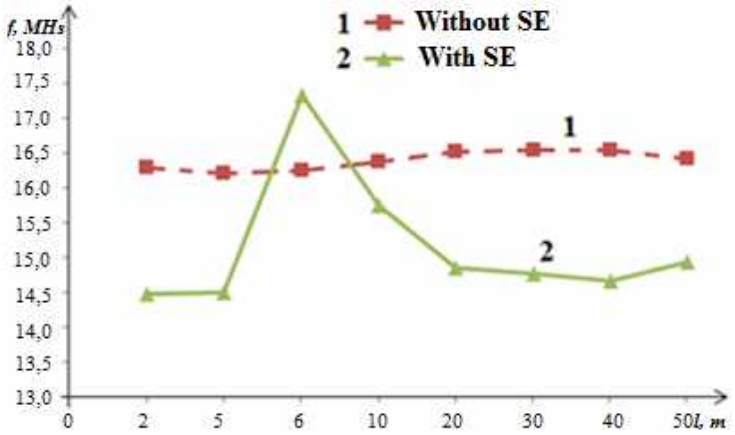

Figure 4. Dependence of the frequency of the autogenerator on the length of the sensitive element

When a person weighing 93 kg approached the SEs (P-274M telephone field cable) of different lengths (2 ÷ 50 m) from the beginning, middle and end perpendicularly from a distance of 3 m, the frequency of the autogenerators (Δf_{per}) has been changed in all cases.

These changes, the length of sensitive elements:

a) when it is 2 m,

- Δf_{per} = 0,15130 MHs for I autogenerator;
- Δf_{per} = 0,15248 MHs for II autogenerator;

---

[33]Nəbiyev, R.N. Diferensial tutum duyğacının rezonans tezliklərinin pozucunun yaxınlaşmasından asılılığının tədqiqi / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Mathematics and computer science. Journal of Baku Engineering University, - Bakı: - 2021. №1 (5). - s. 31-38.

[34]Nabiyev, R.N., Garaev, G.I., Rustamov, R.R. The study of dependence of the resonance frequencies of differential sensor on the intruder's approaching // Proceedings of the XXVIII International Scientific and Practical Conference International Trends in Science and Technology, - Warsaw, Poland: - 30 april, - 2021, - p. 3-8.

b) when it is 5 m,

- for I autogenerator in I case Δf_{per} = 0,00262 MHs, in II case Δf_{per} = 0,03448 MHs, in III case Δf_{per} = 0,03304 MHs;
- for II autogenerator in I case Δf_{per} = 0,00263 MHs, in II case Δf_{per} = 0,03431 MHs, in III case Δf_{per} = 0,03302 MHs;

c) when it is 10 m, (connected through a 5 m long coaxial cable),

- for I autogenerator in I case Δf_{per} = 0,04199 MHs, in II case Δf_{per} = 0,00345 MHs, in III case Δf_{per} = 0,02788 MHs;
- for II autogenerator, Δf_{per} = 0,04202 MHs in I case, Δf_{per} = 0,00346 MHs in II case, Δf_{per} = 0,02788 MHs in III case.

d) when it is 50 m (Figure 5),

- for I autogenerator in I case Δf_{per} = 0,00651 MHs, in II case Δf_{per} = 0,04884 MHs, in III case Δf_{per} = 0,04556 MHs;
- for II autogenerator, Δf_{per} = 0,00651 MHs in I case, Δf_{per} = =0,04885 MHs in II case, Δf_{per} = 0,04556 MHs in III case.

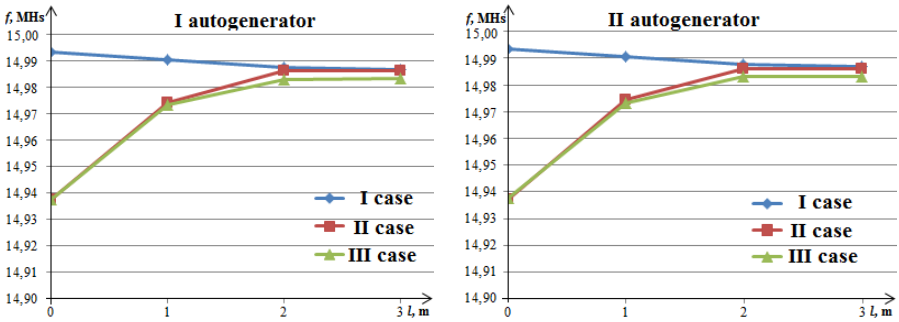

Figure 5. Dependence of the frequency of two autogenerators on the distance of person approach to the 50 m long SE connected to them

In the Figure 5 shows the graph of the dependence of the frequency change of both autogenerators on the distance of approaching the 50 m long SE of the specified weight person. As it can be seen, the frequency of autogenerators during the approach changes in the same way, increasing in I case, and decreasing in II and III cases.

Taking into account the drift of the frequency change over time, based on the frequency difference of the autogenerators, it has been determined experimentally that a person approaching the SEs 50 m long is recorded from a distance of 3 m [13, 33, 34].

The structure, installation, functional capabilities, and technical parameters of the capacitive device worked out for the perimeter GWSs, the construction of the differential capacitive sensor worked out in the digital logic elements included in the device, the schemes of two autogenerators, one of which is used as a signal and the other one as a reference frequency generator in the sensor scheme, have been described (Figure 6) [5, 10, 14].

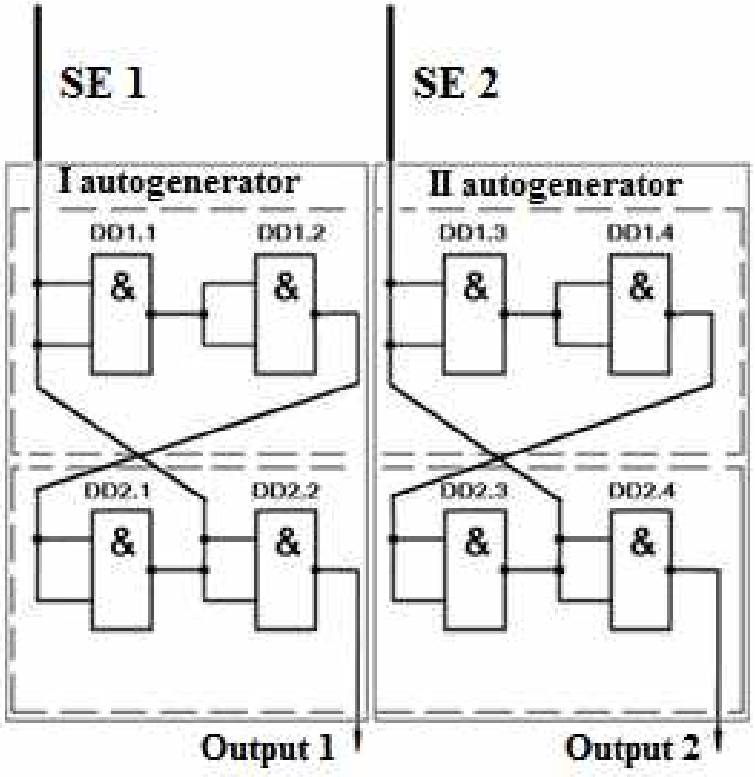

Figure 6. Scheme of two autogenerators with connected sensitive elements

The symmetrical cross-distribution of logic elements in the schemes of autogenerators is carried out in the following form:

- Logic elements *DD1.1, DD1.2* of four "NAND" logic elements located inside one digital microcircuit, first, *DD1.3, DD1.4* logic elements are connected to the scheme of the second autogenerator. From the four "NAND" logic elements located inside the second digital microcircuit, logic elements *DD2.1, DD2.2* are connected to the circuit of the first autogenerator, and logic elements *DD2.3*, *DD2.4* are connected to the circuit of the second autogenerator. To create feedback, the inputs and outputs of the autogenerators are connected directly: in I autogenerator, the output of *DD2.1* is connected to the input of *DD1.1*, in II autogenerator, the output of *DD2.3* is connected to the input of *DD1.3*.

In such a connection, *RLC* elements are not used in the feedback circuits, and the microcircuits operate at the upper limit frequency. Logic elements *DD2.2* and *DD2.4*, respectively, are connected to their outputs as a protective (buffer) cascade in order to eliminate the influence of circuits connected to their outputs on the operation of autogenerators.

Thus, it has been emphasized that the circuits of autogenerators are simplified when they are worked out on digital microcircuits without using lumped parameter elements as a frequency determiner. It has been determined that the autogenerator worked out according to the same scheme and used as a base frequency generator, which replaces each other, and automatically adapts to environmental changes without using a quartz resonator.

The obtained results have been analyzed and the possibility of application of the studied scheme in integrated guarding-warning systems to ensure aviation security has been justified [5, 10, 14].

CONCLUSION

The scientific issues set in the process of research on the subject of the dissertation were resolved and the following main results were obtained:

1. With the logical connection of the subsystems of the integrated distance guarding-warning system with defined functional capabilities, it is possible to increase the level of security in the modern era and prevent unlawful interferences in the territory almost completely. [3, 4, 19, 27].

2. Development and application of two autogenerator differential capacitance sensors built in logic elements as an important component of the integrated distance guarding-warning system allows to ensure the reliable operation of the system[10, 30, 31, 33].

3. The possibility of automatic adaptation of the capacitance device to environmental changes without using a quartz resonator in a fixed-frequency autogenerator was shown and solved by cross-distribution of logic elements in a differential capacitance sensor with more stable parameters built in logic elements [5, 10, 14].

4. The software algorithm and initialization code of the differential capacitance device have been developed [30, 31].

5. Based on the difference in the frequencies of the autogenerators, taking into account the time drift, it was experimentally determined that the intruder approaching the 50 m long sensitive elements was recorded from a distance of 3 m [13, 33, 34].

6. The high probability of detection of illegal intrusions in security zones under ideal and annual climatic conditions is justified by a priori reports [24, 25].

7. An invention-patent was obtained and a production sample was developed and applied to the developed electric circuit of two autogenerator differential capacitance sensors built in digital logic elements and sensitive elements connected to the capacitance device used in the integrated perimeter guarding-warning systems in ensuring aviation security [5, 10, 14, 19].

8. The functional capabilities, technical parameters, installation, and hardware characteristics of the developed two-autogenerator differential capacitance device have been determined [10, 14].

The main content of the dissertation is reflected in the following works of the author:

1. Nəbiyev, R.N. Tutum vericilərinin elektrik sxemlərinin müqayisəli təhlili / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2016. №3 (18), - s. 32-43.
2. Nəbiyev, R.N. Avtomatlaşdırılmış distansion mühafizə kompleksinin layihələndirilməsi xüsusiyyətləri / R.N.Nəbiyev, N.T. Nağıyev, R.R. Rüstəmov [və b.] // Milli Aviasiya Akademiyasının Elmi Əsərləri, - Bakı: - 2016. №2, - s. 76-95.
3. Nəbiyev, R.N., Rüstəmov, R.R. Aeroportların perimetrinin mühafizə sistemlərinin müqayisəli təhlili // - Bakı: Azərbaycan Milli Aerokosmik Agentliyinin Xəbərləri, - 2017. №1 (20), - s. 41-46.
4. Набиев, Р.Н. Сравнительный анализ электрических схем ёмкостных датчиков / Р.Н.Набиев, Г.И.Гараев, Р.Р.Рустамов // Известия ЮФУ. Технические науки, - Таганрог: - 2017. №3 (188), - с. 51-64.
5. Rüstəmov, R.R. Mühafizə olunan obyektlərin xarakterik xüsusiyyətlərinə görə sinifləşdirilməsi // "Aviakosmik məsələlərin həllində gənclərin yaradıcı potensialı" III beynəlxalq elmi-praktiki gənlər konfransının materialları. Fevral məruzələri, - Bakı: - 12-14 fevral, - 2018, - s. 248-250.
6. Пашаев, А.М. Особенности проектирования автоматизированного дистанционного охранного комплекса / А.М.Пашаев, Р.Н. Набиев, Р.Р.Рустамов [и др.] // Вопросы безопасности, - Москва: - 2018. №1, - с. 32-51.
7. Nəbiyev, R.N. LC-generatorunun tezliyinin onun həssas elementinə yaxınlaşma məsafəsindən asılılığı / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov [və b.] // Milli Aviasiya Akademiyasının Elmi Əsərləri, - Bakı: - 2018. №1, - s. 28-41.
8. Paşayev, A.M. Avtomatlaşdırılmış mühafizə-xəbərdarlıq sisteminin etibarlılığının qiymətləndirilməsi / A.M.Paşayev, R.N. Nəbiyev, R.R. Rüstəmov [və b.] // Milli Aviasiya Akademiyasının Elmi Əsərləri, - Bakı: - 2018. №2, - s. 11-27.
9. Nəbiyev, R.N., Ramazanov, K.Ş., Rüstəmov, R.R. Avtomatik

distansion idarəedilən mühafizə-xəbərdarlıq sisteminin iş fəaliyyətinin alqoritmi // Gənclərin yaradıcı potensialı aviakosmik məsələlərin həllində Beynəlxalq iştirakla III elmi-praktiki gənclər konfransının materialları. Fevral məruzələri, - Bakı: - 27-28 fevral, - 2019, - s. 177-179.
10. Nəbiyev, R.N. Təkmilləşdirilmiş mühafizə-xəbərdarlıq sisteminin riyazi modelinin qurulması / R.N.Nəbiyev, K.Ş.Ramazanov, R.R. Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2019. №1 (21), - s. 132-140.
11. Набиев, Р.Н., Гараев, Г.И., Рустамов, Р.Р. Исследование схем автогенераторов для емкостных датчиков // Международная Объединенная Академия Наук, Наука россии: цели и задачи, Сборник научных трудов по материалам XV международной научной конференции, - Екатеринбург: - 10 июня, - 2019, Часть 1, - с. 51-53.
12. Набиев, Р.Н., Рамазанов, К.Ш., Рустамов, Р.Р. Оценка эффективности применения автоматизированной охранно-оповестительной системы // Международная Объединенная Академия Наук, Тенденции развития науки и образования, - Самара: - июнь, - 2019. №51 (7), - с. 21-24.
13. Nəbiyev, R.N. Tutum duyğacları üçün avtogenerator sxemlərinin tədqiqi / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2019. №2 (21), - s. 26-33.
14. Nəbiyev, R.N. Məntiq elementlərində qurulmuş həssas elementli iki avtogeneratorun rezonans tezliklərinin tədqiqi / R.N.Nəbiyev, Q.İ. Qarayev, R.R.Rüstəmov // Milli Aviasiya Akademiyasının Elmi Məcmuələri, - Bakı: - 2019. №3 (21), - s. 19-31.
15. Rüstəmov, R.R. Məsafədən idarəedilən inteqrasiya olunmuş mühafizə-xəbərdarlıq sisteminin tətbiqi imkanları // - Bakı: Milli Aviasiya Akademiyasının Elmi Məcmuələri, - 2019. №4 (21), - s. 31-39.
16. Nəbiyev, R.N. Avtomatlaşdırılmış mühafizə-xəbərdarlıq sisteminin effektivliyinin qiymətləndirilməsi / R.N.Nəbiyev, K.Ş. Ramazanov, R.R.Rüstəmov // Azərbaycan Mühəndislik Akademiyasının Xəbərləri, - Bakı: - 2020. №1 (12), - s. 84-91.

17. Nəbiyev, R.N. İki avtogeneratorlu diferensial tutum qurğusunun proqram təminatının işlənilməsi / R.N.Nəbiyev, Q.İ.Qarayev, R.R. Rüstəmov [və b.] // Mathematics and computer science. Journal of Baku Engineering University, - Bakı: - 2020. №2 (4), - s. 137-142.
18. Rüstəmov, R.R. İnteqrasiya olunmuş mühafizə-xəbərdarlıq sisteminin tətbiqi perspektivləri // - Bakı: Azərbaycan Milli Aerokosmik Agentliyinin Xəbərləri, - 2020. №3 (23), - s. 47-53.
19. Ramazanov, K.Ş., Rüstəmov, R.R. Avtomatlaşdırılmış mühafizə-xəbərdarlıq sisteminin iqtisadi səmərəliliyinə risklərin təsiri // "Fevral məruzələri 2021: Aviakosmik məsələlərin həllində gənclərin yaradıcı potensialı" VI Beynəlxalq elmi-praktiki gənclər konfransının materialları, - Bakı: - 2-4 fevral, - 2021, - s. 186-188.
20. Nəbiyev, R.N. Diferensial tutum duyğacının rezonans tezliklərinin pozucunun yaxınlaşmasından asılılığının tədqiqi / R.N. Nəbiyev, Q.İ. Qarayev, R.R.Rüstəmov // Mathematics and computer science. Journal of Baku Engineering University, - Bakı: - 2021. №1 (5). - s. 31-38.
21. Nabiyev, R.N., Garaev, G.I., Rustamov, R.R. The study of dependence of the resonance frequencies of differential sensor on the intruder's approaching // Proceedings of the XXVIII International Scientific and Practical Conference International Trends in Science and Technology, - Warsaw, Poland: - 30 april, - 2021, - p. 3-8.
22. Nəbiyev, R.N., Qarayev, Q.I., Rüstəmov, R.R. Tutum duyğacları üçün yüksək həssaslı avtogenerator sxeminin müəyyənləşdirilməsi // International Gobeklitepe Applied Sciences Congress-II. Harran University, - Sanliurfa, Turkey: - 6-8 may, - 2021, - p. 126-133.
23. Nəbiyev, R.N., Qarayev, Q.I., Rüstəmov, R.R., Quluzadə, H.S. İki avtogeneratorlu diferensial tutum qurğusunun proqram təminatinin işlənilməsi // International Gobeklitepe Applied Sciences Congress-II. Harran University, - Sanliurfa, Turkey: - 6-8 may, - 2021. - p. 134-140.
24. Nəbiyev, R.N. İki avtogeneratorlu diferensial tutum qurğusu / R.N.Nəbiyev, Q.İ.Qarayev, R.R.Rüstəmov // Milli Aviasiya

Akademiyasının Elmi Məcmuələri, -Bakı: -2021. №3 (21), -s.1-7.
25. Paşayev, A.M. Diferensial tutum duyğacı, Patent (İxtira) İ 2022 0033, Azərbaycan Respublikası / Nəbiyev R.N., Qarayev Q.İ., Rüstəmov R.R.
26. Набиев, Р.Н. Дифференциально-емкостное устройство с двумя автогенераторами / Р.Н.Набиев, Г.И.Гараев, Р.Р. Рустамов // Известия ЮФУ. Технические науки, - Таганрог: - 2022. №2 (226), - с. 145-153.

Personal contribution of the applicant in scientific works:

[1, 2, 4, 6, 17] - Collecting data and summarizing results;

[3] - Data collection, analysis;

[7, 14] - Performing experiments, summarizing the results;

[8, 10, 16] - Collecting data, performing mathematical calculations;

[9] - Development of conceptual structural scheme and algorithm, speech at the conference;

[11] - Compilation of the scheme, implementation of experiments, summarization of results, preliminary translation;

[12] - Data collection, mathematical calculations, preliminary translation;

[13] - Assembling the scheme, performing experiments, summarizing the results;

[19] - Data collection, analysis, mathematical calculations, speech at the conference;

[20] - Performing experiments, summarizing the results;

[21] - Performing experiments, summarizing results, preliminary translation;

[22] - Performing experiments, assembling the scheme, conducting analysis, "online" speech at the conference;

[23] - Conducting the analysis, summarizing the results and "online" speech at the conference;

[24] - Assembling the scheme, performing mathematical calculations, performing experiments, summarizing the results;

[25] - Collecting data, summarizing the results, compiling the scheme;

[26] - Assembling the scheme, performing mathematical calculations, performing experiments, summarizing the results, preliminary translation and

[5, 15, 18] - the scientific works were written freely by the applicant himself.

The defense will be held on 13 December 2024 at 14:00 at the meeting of the Dissertation council ED 2.01 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at National Aviation Academy.

Address: AZ1045, Baku city, Mardakan aven. 30, meeting hall of the 3rd educational building of the National Aviation Academy.

Dissertation is accessible at the National Aviation Academy Library

Electronic versions of dissertation and its abstract are available on the official website of the NAA (naa.edu.az).

Abstract was sent to the required addresses on 06 November 2024

Signed for print: 18.10.2024

Paper format: A5

Volume: 38085

Number of hard copies: 20