https://doi.org/10.15407/scine16.03.036

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# SYSTEM OF AUTOMATED RAPID OPERATIVE CONTROL OF RADIATION SITUATION USING AN AIRBORNE VEHICLE

***Introduction.*** *The disaster at the Chornobyl nuclear power plant (ChNPP) resulted in releasing a huge amount of radioactive material into the atmosphere, the total amount of which is difficult to estimate reliably.*

***Problem Statement.*** *Radioecological works are radiation reconnaissance with detailed mapping of contamination levels and systematic monitoring of radiation situation. One of the most effective methods for surveying the areas contaminated with radiation, as well as for searching radioactive sources is remote measurements of ground-level gamma radiation by aerial gamma-ray spectrometry. Therefore, it is important to design and to test a modern system of operational radiation, infrared, and visual control using airborne vehicles to solve these problems.*

***Purpose.*** *Development of modern domestic equipment for automated operational control of the radiation environment using airborne vehicles.*

***Materials and Methods.*** *The methods of mathematical and computer simulation, full scale layout, machine design have been used. In order to study the technical characteristics of the system, its features, field tests of its individual channels have been conducted in the Chornobyl exclusion zone.*

***Results.*** *An automated system for rapid radiation, infrared, and visual radiation operational control and monitoring of the natural environment has been created based on the R-Navigator airborne vehicle for solving problems of remote control of NPPs and adjacent territories in the case of emergency or accidents with nuclear and radioactive materials.*

***Conclusions.*** *The proposed development provides high-sensitivity detection of gamma radiation, video recording and remote data transmission to ground control centers for prompt response to emergencies, as well as contributes to reducing the cost of aero-gamma spectrometric works.*

*Keywords: nuclear radiation accident, gamma radiation, aircraft, spectrometer, radiation monitoring, and radiation safety.*

Citation: Zabulonov, Yu.L., Burtnyak, V.M., and Odukalets, L.A. System of Automated Rapid Operative Control of Radiation Situation Using an Airborne Vehicle. *Sci. innov.* 2020. V. 16, no. 3. P. 36—42. https://doi.org/10.15407/scine16.03.036

As a result of the manmade accident at the Chornobyl NPP, a large amount of radioactive material was released into the atmosphere, the total amount of which is hard to estimate reliably. The pollution spread to 18 of the 25 regions of Ukraine with a total area of 42 thousand km$^2$. Five million hectares of land were withdrawn from agricultural practice. The radionuclides released into the atmosphere spread in the form of aerosols that gradually deposited on the soil. Some of these radionuclides are characterized by a long half-life. Pollution was very uneven, as particle propagation depended on the wind direction in the first days after the disaster. Much of plutonium and strontium fell within a 100 km radius from the plant, while iodine and cesium extended over a large area. The areas where rains were precipitating that time suffered the most [1].

Radionuclides have the ability to migrate, transform, move vertically and horizontally. Therefore, the radioactive contamination of the Exclusion Zone will always be heterogeneous and will change over time, i.e. its redistribution will occur, leading to the migration of the contamination zone. Therefore, monitoring of the Chornobyl Exclusion Zone and assessment of radionuclide contamination of the earth's surface is an urgent task.

As a rule, radio-ecological works include detailed mapping of pollution levels and systematic monitoring of radiation conditions. One of the most effective methods for the radiation reconnaissance of areas that have been contaminated with radiation, as well as for the search for radioactive sources, is the remote measurement of ground-level gamma radiation by aerial gamma spectrometry [2]. The method is based on measurements of radiation fields with a relatively small spatial pitch using a full-absorption gamma spectrometer placed on ABV. In particular, assuming that the sources of gamma radiation are on the earth surface, proceeding from the results of measurements, provided there are appropriate calibrations, one can determine the radionuclide composition and activity of these sources in the studied area. A typical survey speed is about 0.5 km$^2$ per minute of flight.

Researchers of the Institute of Environmental Geochemistry of the NAS of Ukraine have developed and created an innovative system of radiation, infrared and visual high-sensitivity operative control based on ABV for inventory of temporal localization points of radioactive waste for assessing the necessity and feasibility of their reburial. The created *R-Navigator* system for automated rapid operative control of radiation situation the basis of the aircraft based on ABV can also be used for remote control of nuclear power plants and adjacent territories in case of emergencies or incidents with nuclear and radiation materials.

## MAIN FUNCTIONS AND COMPONENTS OF THE SYSTEM

The system consists of the three functionally independent measuring channels:

1. Radiation channel (RC) for remote operational detection of sources of ionizing radiation in the field. It provides remote scanning of the radiation field; detection of ultra-low radionuclide activity in the field (detection of small-scale objects with high gamma radiation on the earth's surface); construction of high-precision maps of radioactive contamination.
2. Thermal imaging channel (TIC), a system for recording and analyzing infrared radiation from the earth's surface, which provides contactless record of an object in the infrared spectrum; construction of maps of thermal fields and survey objects; fire detection and contouring.
3. Television channel (TVC), a system that provides a survey of the terrestrial surface and specifically selected objects in the visible range with a high resolution and a high sensitivity.

The systems operate in parallel and independently and are controlled by a microprocessor system and original software.

The core of the radiation channel is a spectrometric module that is a thermally insulated container, inside of which a scintillation spectrome-

*Fig. 1.* Spectrometric module

ter based on a scintillator NaI (TI) (200 × 100 mm) is placed on a vibrating platform:

- The module's sensitive volume is 3.1 l;
- The number of channels in the analyzer of each spectrometer is 1024;
- Amplitude-to-digital converter (ADC) with a fixed conversion time of 1 μs;
- The module is connected with the controller via standard USB or WiFi channels;
- The module dimensions are 520 × 330 × 330 mm;
- The weight is 12 kg;
- The energy consumption is 100 W (Fig. 1).

Depending on the task, one or more spectrometric modules are used.

To determine the coordinates of the measuring complex, the *R-Navigator* uses a positioning system based on GPS satellite sensor. Additional visual information about the studied area is provided by a camcorder that is a part of the equipment and installed on ABV. Data from the radiation channel, GPS receiver, video and thermal imaging cameras are recorded on MicroSD and transmitted via radio to a ground base station.

The TV channel contains a television camera, video blaster, mixer, line selection device, and video recorder (VCR). The service information generated on the onboard computer and released using the line selection device is laid on television image coming from the TV camera. Service information includes latitude, longitude, current time, date, adjusted altitude. This video is recorded on the VCR. In addition, in the stop-frame mode (by operator command), video with service information is recorded on the MicroSD system via the video blaster (Fig. 2).

**The specifications of the television channel**

| | |
|---|---|
| Operating wavelength range of the camcorder optical system, nm | 0.38—0.90 |
| The minimum permissible level of illumination of the video subject, lx | 3 |
| Angle of view of the camcorder, degrees | 60 |

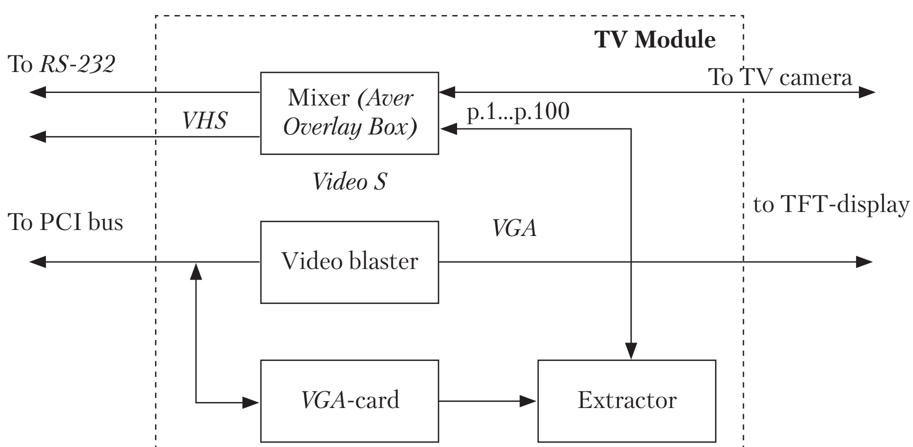


*Fig. 2.* Structure of television channel

The thermal imaging channel is designed to record the temperature of the earth's surface in the range from shortwave red rays to the far infrared region of the spectrum. The subsystem provides:

- control and detailed assessment of the fire danger of forest areas selected upon results of infrared survey;
- detection of fires in the conditions of cloudiness and general smoke contamination of the territory;
- reconnaissance and mapping of major fires and implementation of operational control over fire extinguishing.

**The technical characteristics of the TIC subsystem**

| | |
|---|---|
| Registration of flame radiation generated by test fires TP-1, TP-3 (open combustion of wood, afterglow of cotton), | |
| Spectral range, μm | 1.5—4.7 |
| The subsystem remains operational and does not give an alarm at the maximum background illumination: | |
| from electroluminescent sources, lx | 2500 |
| from incandescent lamps, lx | 250 |
| Distance to the object, m | 25 |
| Continuous operation time, hours | at least 10 |
| Operating temperature, °C | from –50 to +50 |
| Vibration resistance, Hz | from 10 to 150 |
| Impact resistance, J | up to 1.9 |
| Power supply, V | 24 |
| Weight, g | 1000 |

## SPECIFIC FEATURES OF RADIATION CONTROL FROM ABV

The works are done in the two modes: detection and mapping.

The detection. The ABV flies along the specified route at the highest possible altitude. In this case, the infrared scanning system and the system for collecting navigational data are operating continuously. When a high-temperature radiation source is detected, the subsystem determines the probability of false alarm and reports the event to the onboard computer. From there, the signal is transmitted to the ground center.

Mapping is performed at the ground center when an alarm is received. According to the computer algorithms, the fire contours are calculated and displayed on the graphic device, with outlines of fire development forecasted.

According to the algorithm of operation, all channels of the *R-Navigator* system perform the following functions:

- cyclical measurements (period 1 s) of the gamma-radiation spectra of radionuclides in the soil or on the surface of the surveyed areas, as well as images of television and thermal imaging cameras;
- time matching of the obtained spectra and images with the determined topographic coordinates of the place of measurements;
- time matching of the obtained spectra with the determined height of measurements to take into account the influence of gamma-ray attenuation in the air strata while processing the measurement data using software of the ground station;
- formation and record of files containing measurement data on a MicroSD of the onboard computer;
- use of track files for data processing using software of the ground station.

Thus, having conducted remote measurements from ABV (Fig. 3), a base of primary measurement data on the activity of radionuclides contained in the soil or on the surface of the surveyed area, taking into account the altitude (attenuation of radioactivity in the air strata) and topographic survey is formed, as well as the television and thermal images of the earth's surface are recorded on the MicroSD.

***Fig. 3.*** Technology for remote control of atomic power plants using the *R-Navigator* system

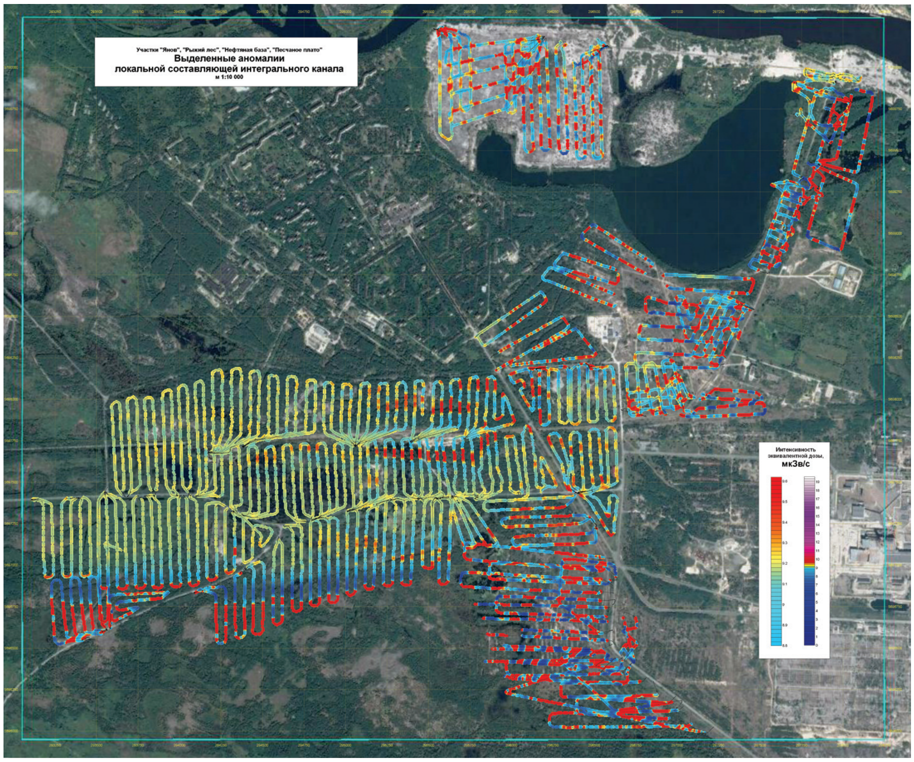


***Fig. 4.*** Detection of radioactive contamination using the *R-Navigator* system

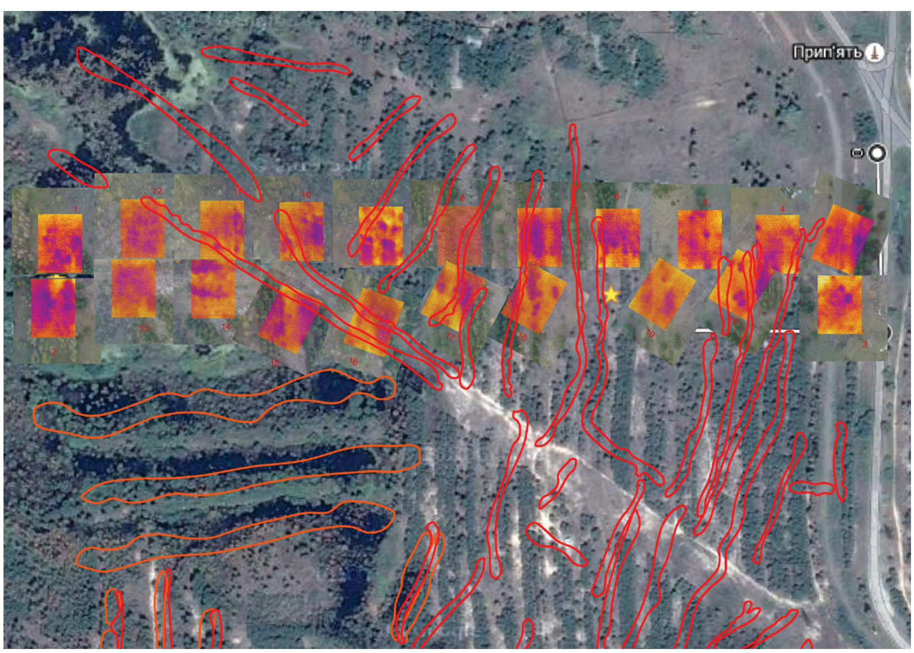


***Fig. 5.*** Results of operation of thermal imaging channel

Having processed the base of primary measurement data, the ground station equipment of the system makes it possible [3]:

- to form a 2D picture of the gamma-ray field of the earth's surface;
- to identify any point and distant unscreened gamma radiation sources with a relatively low activity;
- to identify the radionuclide composition of each source;
- to measure the surface density of radionuclide activity (post-accident radioactive trail);
- to determine the coordinates of the source with an accuracy of up to 5—10 m (depending on the speed and altitude of the flight).

Thus, the multifunctionality of the measuring complex enables solving a wide range of radiation control problems.

The developed complex has a number of significant advantages, including:

- high automation of the radiation survey of large territories and specifically selected object, speed and efficiency of obtaining the survey results, high informativeness and sensitivity of the system;
- automatic synchronization of all measurement channels to the specific object selected;
- detection of sites with a high radiation background with automatic identification of sources of radiation pollution;
- detection of fire places;
- storage of measurement data in independent memory, visualization of integral and average values obtained;
- creation of maps of radiation contamination with reference to specific coordinates.

Below, there are the results of processing the aero-gamma-spectrometric data obtained by the researchers of the Department for Nuclear Physical Technologies, Institute of Environmental Geochemistry of the NAS of Ukraine (Figs. 4–6). Fig. 4 shows 2D fields of radioactive contamination of the exclusion zone of the Chornobyl NPP. To processes the aero-gamma survey data, *ArcGIS* software from *ESRI* (USA) was used [4]. The surface contaminated with Cs-137 isotope has been obtained. Fig. 5 shows the images made by thermal imaging camera along the ABV route; Fig. 6. features the results of processing of primary measurement data at the ground station.

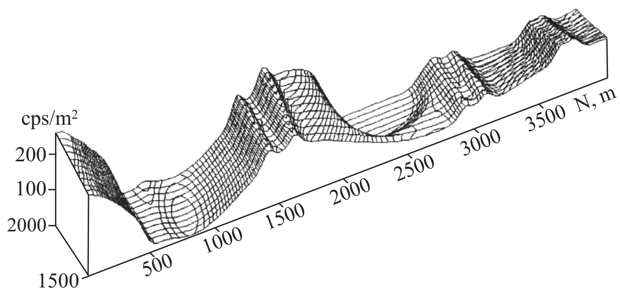


***Fig. 6.*** Density of surface radiation source on the soil, within the scan swath

Hence, the developed *R-Navigator* system for automated rapid operative control of radiation situation based on ABV provides solving the following important problems:

- remote monitoring in real time;
- pregistration of radioactive contamination of environment in the places of operation of nuclear energy facilities, nuclear waste burial sites, and transportation of containers with spent nuclear fuel;
- determination of spatial distribution density and radionuclide composition of radioactive pollutions, intensity and directions of their distribution, quantitative and qualitative composition of radioactive trail;
- obtainment of final information (in the form of map) on the nature of the surface distribution of radioactive substances with a high spatial resolution and sensitivity, visualization of their spatial distribution and identification of the isotopic composition by gamma radiation spectrum;
- determination of the presence and contouring of the radioactive cloud directly on the board of ABV (possible use of video channel);
- creation of a database of radioactive burial sites using elements of geographical information system;

- assessment of the effectiveness of radiation decontamination measures;
- inspections of nuclear waste burial sites, nuclear technologies;
- periodic monitoring of the radiation situation at the locations of authorized and unauthorized burial sites, storage of nuclear materials; and
- fire detection.

REFERENCES


1. Chernobyl accident. https://ru.wikipedia.org/wiki/ Avaria_ na_ Chernobylskoy AES.
2. IAEA-TECDOC-1092/R. Nuclear or radiation accident monitoring guide. IAEA International Atomic Energy Agency (2002), 314 [in Russian].
3. Lysychenko, G. V., Zabulonov, Yu. L., Makarets, N. V. (2005). 1. Results of model and field experiments on the detection of low-intensity sources of radioactive radiation. *Collection of scientific works of the Institute of modeling problems in power them. G.E. Puhova NAS of Ukraine "MODELING AND INFORMATION TECHNOLOGIES"*, 31, 96—100 [in Ukrainian].
4. ArcGIS for Desktop Software. URL: //http://www.esri.com/software/arcgis/about/gis-for (Last accesad: 25.12.2019).



**Received 20.02.19**
**Revised 31.10.19**
**Accepted 07.11.19**



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## СИСТЕМА АВТОМАТИЗОВАНОГО ОПЕРАТИВНОГО КОНТРОЛЮ РАДІАЦІЙНОЇ ОБСТАНОВКИ ШВИДКОГО РЕАГУВАННЯ НА БАЗІ ЛІТАЛЬНОГО АПАРАТУ


**Вступ.** В результаті техногенної аварії на Чорнобильській АЕС в атмосферу було викинуто величезну кількість радіоактивного матеріалу, загальний обсяг якого складно коректно оцінити.

**Проблематика.** Радіоекологічні роботи — це радіаційна розвідка з детальним картуванням рівнів забруднення та проведення систематичних спостережень за радіаційною обстановкою. Одним з найбільш ефективних способів радіаційної розвідки територій, які зазнали радіаційного забруднення, а також пошуку радіоактивних джерел є дистанційне вимірювання приземного гамма-випромінювання за допомогою аерогаммаспектрометрії. Отже, важливим є розроблення та апробація сучасної системи радіаційного, інфрачервоного та візуального оперативного контролю на базі літального апарату (ЛА) для вирішення зазначених завдань.

**Мета.** Розробка сучасного вітчизняного обладнання для автоматизованого оперативного контролю радіаційної обстановки швидкого реагування на базі літального апарату.

**Матеріали й методи.** Використано методи математичного й комп'ютерного моделювання, натурного макетування, машинного проєктування. Для дослідження технічних характеристик системи, її особливостей було проведено натурні випробування окремих її каналів в зоні відчуження Чорнобильської АЕС.

**Результати.** Розроблено та створено інноваційну систему радіаційного, інфрачервоного та візуального оперативного контролю високої чутливості на базі літального апарату «Р-Навігатор» для вирішення задач оперативного дистанційного контролю АЕС та прилеглих територій у випадку виникнення аварійних ситуацій або інцидентів з ядерними та радіаційними матеріалами.

**Висновки.** Запропонована розробка забезпечує високу чутливість детектування гамма-випромінювання, відеозйомку та дистанційну передачу даних на наземні центри управління для оперативного реагування на аварійні ситуації, а також сприяє зменшенню вартості аерогаммаспектрометричних робіт.



Ключові слова: ядерно-радіаційна аварія, гамма-випромінювання, літальний апарат, спектрометр, радіаційний моніторинг, радіаційна безпека.