Improvement of seismic radon station SRS - 05

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Abstract. Designed on the base of seismic radon station SRS-05 hardware and software complex receives and forms the data of the measurements from station, perform the archiving of the data and sends it to the end users. Besides, the complex realises remote control by station. Additional devices of this complex do not influence the process of measuring of the station and just provide access to the internet and data transfer to specified ftp-server directly via the network or the mobile in places with lack of cable infrastructures. New functional properties increase the adaptive capabilities of the complex, provide its autonomous work and contribute to its transformation into a smart sensor module for monitoring of an environment. Small dimensions and low power consumption of its components provide greater mobility of the complex and increase the time of its autonomous operation.

1. Introduction
One type of natural radioactivity is represented by heavy inert radon gas soluble in water, which does not have color and odor [1]. Arising in radioactive transformations of uranium and radium, its isotopes Rn$^{219}$-actinone, Rn$^{220}$-thoron, Rn$^{222}$-radon give chains of new decays with the formation of radioactive daughter products. Sources of radon are considered to contain uranium-containing rock massifs and tectonic zones. Radon survey is used when searching for uranium ores, oil and gas deposits, identifying rock crushing zones and bursting tectonics. Radon content in air, water is associated with geodynamic processes. Radon is considered an indicator of the stressed state of rocks, a harbinger of earthquakes, mountain strikes, landslides. Some building materials highlight radon.

Radon enters the earth's surface, atmosphere and hydrosphere together with other endogenous gases by shale and rock cracks [2]. In the atmosphere, this gas causes hydration of water vapor molecules on the ions, increase in air temperature, its adiabatic expansion, rise, formation of characteristic cloud structures and jet currents, change in surface layer conductivity, growth of atmospheric electric field and other phenomena [3].

The basis of the biological action of radon and its products is the ability to ionize, excite molecules, activate mutations and form tumors. Structural plant anomalies are associated with the influence of radon [4]. When irradiated with it in the cells of the radon biological indicator, the number of microkernels grows [5].

The dangerous factors of territories and dwellings are studied by geoecology, which subject is the impact of radon on the people in particular. According to geocological data about 75% of annual individual effective dose of radiation of the population are accounted on radon and its daughter products.

Due to the high density, almost 9 times the density of air, radon accumulates in basements, mine workings, caves, tunnels, pits. However, it is mobile, soluble in water, gases, organic solvents, soil and...
surface waters. The atmospheric flows could carry it over distances of up to several kilometers. Getting into the human body with food, water and air, radionuclides become a source of internal radiation, provoke oncological diseases. According to the UN, the risk of exposure of the population to radon is 43% [6].

High concentrations of radon are characteristic of the territories of the USA, Ireland, the Czech Republic, Scandinavian countries, Austria, Germany, Russia, Iran. In Brazil, India, Canada, Russia there are areas with “hurricane” radon contents. The volumetric activity of radon in the underground air of some oil fields in the Lower Volga region reaches 106 Bq/m3. Such high volumetric activity of radon is explained by its transferring from great depths by high-speed gas jets.

The risks associated with radon make relevant its monitoring.

2. Seismic radon station SRS-05

To monitor the content of radon and toron in the premises and undersoil air, company NTM Protection developed the seismic radon station SRS-05 (figure 1, a) [7]. From known Russian products radon detectors-indicators Sirad М106 N [8], radiometers RGA-500, RGG-02T [9] SRS-05 differs in accuracy class, wide functionality, and from foreign analogues [10] low cost.

Figure 1. Seismic radon station SRS-05 (a) and the interface window for data counting (b).

The station stores measurement data in internal memory and, upon request, transmits it to the connected to it computer. Small size, light weight, reliability, ease of operation facilitate allow use of the station in hard-to-reach places.

The disadvantage of the seismic radon station SRS-05 is the impossibility of remote data transmission and remote control. An attempt to overcome it, by simulating when transmitting data to the computer, pressing the keys of the station software interface (figure 1, b) [11], was associated with the use of the computer display, which led to an increase in the size and weight of the equipment, accelerated the discharge of the battery.

The article is devoted to a software and hardware complex developed on the basis of SRS-05, which performs these functions without using a computer display due to the station's docking with a mini-computer and Internet access devices. Without affecting the measurement process, the complex can quickly process and forward data, receive external commands, conduct diagnostics, and change station operation modes.
3. Results and discussion

3.1. Structure and functioning of the complex

The structure of the complex is shown in figure 2a. As a measuring module, the station SRS-05 measures the volumetric activity of radon and toron, pressure, temperature, air humidity, battery voltage at predetermined intervals and stores this data in memory. A mini-computer connected to the station controls the complex. The computer is inactive most of the time. At regular intervals, the computer establishes a connection with the station and sends a request for data transmission in intervals between measurements. If the request is received at the time of measurement, the computer goes into standby mode and repeats the call to the station after a predetermined period of time. According to the measurements collected per day, the computer program generates a file, archives it and sends it to the ftp server of collective access or to individual users.

![Figure 2. Structure of complex (a), plate of mini-computer «Raspberry Pl» Model B+ (b) and USB-RS232 challenger for connection the SRS-05 station with computer (c).](image)

The method of connecting a computer to the Internet depends on the location of the station, is carried out using a cable system, a Wi-Fi network, or over GSM networks through mobile communication modems. Due to the lack of cable infrastructure, the latter possibility is more often implemented outside settlements.

3.2. Design and program features of the complex implementation

The radon station SRS-05 is a portable small-sized device operating under its own control, having internal memory and connectors for connecting a computer and power supply. The operation cycle of the station consists of time-separated measurement and standby modes.

The radon and toron content measurement includes air pumping through the chamber, electrostatic deposition of the radon and toron daughter products Po$_{218}$ and Po$_{216}$ to the semiconductor detector, calculation of the number accompanying the decay of alpha particles, determination of their energies. Data is read in standby mode, station operation modes are selected and parameters are set. The station is powered by a battery. Battery operating voltage range - 10.6-12.6 V. Due to low consumption: current in the measurement mode is 500 mA, in the standby mode - 100 mA without recharging battery - the station can work for about two weeks. It is recommended to use the station at a relative humidity of not more than 80% and a temperature of not less than +6°C. To manage the complex, the Raspberry Pi Model B + mini-computer of the Raspberry Pi Foundation was chosen (figure 2b). This computer has established itself as a modern, flexible, reliable means of process automation. The computer has 4 USB 2.0 connectors, an Ethernet connector, 512Mb RAM, 40 GPIO pins, uses a voltage rated 5В from a USB port or battery through a voltage divider. The maximum allowable computer consumption current is...
2.5A. The computer is connected to the station via the BM 8050 USB-RS232 converter (figure 2, c). Mounting on the computer station housing, comparable in size to a bank card, practically does not change the size and weight of the station. The software is focused on the usual forms of interaction between the computer and the station: receiving data without spectrum, receiving data with spectrum, setting parameters [12]. The data reader repeats the SRS-05 interface procedure without using virtual buttons, generates a daily data file and sends it to the ftp server at a given time. The program for obtaining data with a spectrum additionally reads the energies of the registered $\alpha$-particles and builds their spectrum, which is necessary when detecting disturbances in the operation of the station. In the remote control mode, after receiving a task over the Internet, the computer sends a command to the station to set parameter values and confirms their values after installation.

The mini-computer runs under the Linux operating system. Its software modules are written in Python version 2.7. Communication between the station and the mini-computer is carried out through the RS-232 interface according to the request-response scheme. Periodically asking the station the minicomputer sends a special byte. Having received it, the station, if it is not in measurement mode, reports readiness for the communication session. The forms of the computer request for data transfer and dial tone response are presented as

\[
\begin{align*}
&\text{com_prv} <command length} <command code} <parameter 1} \ldots <parameter n} \\
&\text{com_anz} <response length} <command code} <parameter 1} \ldots <parameter n}
\end{align*}
\]

Here "\text{com_prv}" and "\text{com_anz}" bytes are signs of the start of computer request and dial response commands. "command length" and "response length" mean the number of bytes of the command starting with the command code. The last parameter is the checksum calculated when generating and sending control commands. Measurement data is transmitted with acknowledgement of reception of each unit. In the non-spectral data acquisition mode, the length of the data block is 32 bytes, in the spectral data acquisition mode, 256 bytes. The data is written to the file with the extension * .csv with the date of receipt. At the end of transmission, the station outputs the transmission end byte and the computer terminates the communication session.

In the control mode, the computer sends a 1 to n byte command to the station, where n is the serial number of the parameter to be transmitted. According to the received command, the station changes internal parameters, generates a response, sending a byte of command reception or a byte of failure. The scripts in the "bash" language of the Linux command shell run the start the communication program with the station, archive the data and transfer them to the ftp server. To set the time and frequency of communication sessions with the station, the standard utility "crontab" of the dynamic task scheduler "cron" built into the Linux system of the Raspberry Pi minicomputer is used.

The connection of the mini-computer and the ftp-server is organized over the Internet using mobile communications. When receiving weak signals, miniature modems with an integrated antenna in the USB modem format or a GSM terminal of industrial design Siemens Tc65 with an external antenna help. When, due to poor communication quality, the connection to the server cannot be established, the computer transmits data in the next communication cycle. Sending data to the server in small portions once a day minimizes the requirements for mobile communication, allows you to use networks of the third (3G) and second (GSM/GPRS/EDGE) generations. Separate storage of data in a station, computer, server ensures backup and preservation of data. Connection logs in the mini computer, on the server make it easier to diagnose complex problems.

3.3. Testing of the complex

The complex was tested in field experiments in 2016 in the basements of houses in the cities of Petrozavodsk, Pitkärante, the villages of Sheltozero and Tsarevichi. Measurement data from the station SRS-05 were transmitted times a day to the server of the Institute of Geology of the Karelian Scientific Center of the Russian Academy of Sciences in Petrozavodsk. The data of radon volumetric activity measurements recorded during the week in the basement of the house in the village of Tsarevichi and their spectrum (b) obtained with these data processing by the Burg's method of maximum entropy [13] with window 40 are shown in figure 3.
The complexity of radon exhalation dynamics is evidenced by a series of spectral peaks with periods of 42.7, 19.7, 12.8, 9.5, 6.9, 5.7, 4.8, 4.3, 3.6, 3.3, 2.9, 2.7, 2.6, 2.4, 2.3, 2.2 hours. The most intense peak corresponds to 4 hours 48 minutes. The nature of the cyclicity of the volumetric activity of radon is unclear. It can be associated both with the local geodynamic regime (the village is located on a narrow isthmus separating the two lakes) and with the action of such factors as variations in atmospheric pressure, temperature, unevenness of Earth's rotation, the action of lunar-solar tides [14].

The example indicates insufficient local measurements of the volumetric activity of radon. To determine the nature of cycling, it is necessary to analyse its local and global components by

![Figure 3](image-url). Time series of radon volumetric activity in basement of the house in Tsarevichi village (a) and its spectrum, obtained by Burg's maximum entropy method realized in MATLAB (b).
comparing the results of synchronous measurements made by the same type of devices, spaced over significant distances. Complexes like the one described above are quickly obtained, processed with data on radioactivity and environmental state, are flexible, reconfigurable. Since the volumetric activity of radon is a predictor of earthquakes, their use in sensory networks can increase the speed of production and decision-making.

4. Conclusion
The hardware and software complex developed on the basis of the seismic radon station SRS-05 monitors the volumetric activity of the radon, toron, pressure, temperature, humidity, transmits the received data to the ftp server or to specific users. The devices included in the complex provide communication with the remote operator and users, do not affect the metrological characteristics of the seismic radon station SRS-05. Using remote control the station is diagnosed, its operation modes are changed. Maintenance and operation of the complex facilitate its small dimensions, weight, low power consumption. The battery life of the complex, about two weeks, is determined by the discharge rate of the battery. By remotely controlling the battery charge, controlling the power supply of the station, switching it to backup sources if necessary, it is possible to significantly increase the battery life of the complex. Rarely transmitted small chunks of data minimize mobile costs.

The communicative properties of the seismic radon station SRS-05 implemented in the complex are useful in complex situations requiring prompt decision-making. Implementation in the hardware and software complex of new functional properties of the seismic radon station SRS-05 increases the degree of its adaptation to external conditions, facilitates its transformation into an intelligent sensor module for monitoring geological and geophysical media.

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