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MICROPROCESSOR DEVICE FOR RECORDING INFORMATION ABOUT TELLURIC CURRENTS

The research is relevant because it is important to record information about telluric currents flowing in the Earth and study them. When analyzing the results of the study of telluric currents, it is determined that abrupt changes occur in the telluric field before earthquakes, volcanic eruptions, or tsunamis. This suggests that the observation of telluric currents is a fairly weighty basis for their further study in terms of predicting upcoming natural phenomena. The volume of the research is significant because it has the potential to revolutionize the way we predict natural disasters. By studying telluric currents, we can gain a better understanding of how the Earth's crust behaves before and during these events. This information could be used to develop early warning systems that could save lives. The paper provides an overview of scientific and technical information about telluric currents flowing in the Earth, the nature of their manifestations, registration methods, and interpretation methods. An overview of scientific and historical materials on the study of telluric currents is given. The technology for performing the work is given from modern textbooks and scientific articles. A microprocessor device for recording information about telluric currents has been developed. A scientific experiment was conducted to confirm the operability of this device. The direction of telluric current flow was determined in an open area. Based on the results obtained, graphs of the dependences of signals from grounding conductors on time were constructed. An analysis of the numerical component of the graphs was conducted.By developing a device that can record telluric currents, scientists can gain a better understanding of how the Earth's crust behaves before and during these events. This information could be used to develop early warning systems that could save lives.

Key words: microprocessor device, telluric currents, grounding, earthquake.

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Теллуриялық токтар туралы ақпаратты жазуға арналған микропроцессорлық құрылғы

Зерттеу өзекті, өйткені жерде ағып жатқан теллуриялық токтар туралы ақпаратты жазып, оларды зерттеу маңызды. Теллуриялық ағымдарды зерттеу нәтижелерін талдау кезінде жер сілкінісі, жанартау атқылауы немесе цунами алдында теллуриялық өрісте күрт өзгерістер болатыны анықталды. Бұл теллуриялық ағымдарды бақылау оларды алдағы табиғи құбылыстарды болжау тұрғысынан одан әрі зерттеу үшін өте маңызды негіз болып табылады деп болжайды. Зерттеудің ауқымы айтарлықтай, өйткені ол табиғи апаттарды болжау жолында төңкеріс жасай алады. Теллуриялық ағымдарды зерттей отырып, біз жер қыртысының осы оқиғаларға дейін және сол кезде қалай әрекет ететінін жақсы түсінеміз. Бұл ақпарат өмірді сақтап қалуы мүмкін ерте ескерту жүйелерін жасау үшін пайдаланылуы мүмкін. Мақалада жердегі теллуриялық токтар, олардың көріністерінің табиғаты, тіркеу және түсіндіру әдістері туралы ғылыми-техникалық ақпаратқа шолу жасалады. Теллуриялық токтарды зерттеу бойынша ғылыми және тарихи материалдарға шолу жасалды. Жұмысты орындау технологиясы заманауи оқулықтар мен ғылыми мақалалардан алынған. Теллуриялық токтар туралы ақпаратты жазу үшін микропроцессорлық құрылғы жасалды. Бұл құрылғының жұмысын растау үшін ғылыми эксперимент жүргізілді. Теллуриялық ток ағынының бағыты ашық жерде анықталды. Алынған нәтижелер негізінде сигналдардың жерге тұйықтау өткізгіштеріне уақытқа тәуелділігінің графиктері салынды. Графиктердің сандық компонентіне талдау жасалды.Теллурлық токтарды тіркеуге қабілетті құрылғыны жасау арқылы ғалымдар жер қыртысының осы оқиғаларға дейін және сол кезде қалай әрекет ететінін жақсы түсіне алады. Бұл ақпарат өмірді сақтап қалуы мүмкін ерте ескерту жүйелерін жасау үшін пайдаланылуы мүмкін.

Түйін сөздер: микропроцессорлық құрылғы, теллурлық токтар, жерге қосу, жер сілкінісі.

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Микропроцессорное устройство для записи информации о теллурических токах

Исследование актуально, поскольку важно зафиксировать информацию о теллурических токах, протекающих в Земле, и изучить их. При анализе результатов изучения теллурических течений установлено, что резкие изменения происходят в теллурическом поле перед землетрясениями, извержениями вулканов или цунами. Это говорит о том, что наблюдение теллурических течений является довольно весомой основой для их дальнейшего изучения с точки зрения прогнозирования предстоящих природных явлений. Объем исследования значителен, поскольку он потенциально может революционизировать то, как мы предсказываем стихийные бедствия. Изучая теллурические течения, мы можем лучше понять, как ведет себя земная кора до и во время этих событий. Эта информация могла бы быть использована для разработки систем раннего предупреждения, которые могли бы спасти жизни. В статье представлен обзор научно-технической информации о теллурических токах, протекающих в Земле, природе их проявлений, методах регистрации и интерпретации. Дан обзор научных и исторических материалов по изучению теллурических токов. Технология выполнения работы приведена из современных учебников и научных статей. Разработано микропроцессорное устройство для записи информации о теллурических токах. Для подтверждения работоспособности этого устройства был проведен научный эксперимент. Направление течения теллурического тока определялось на открытой местности. На основании полученных результатов были построены графики зависимостей сигналов от заземляющих проводников от времени. Был проведен анализ числовой составляющей графиков.Разработав устройство, способное регистрировать теллурические токи, ученые смогут лучше понять, как ведет себя земная кора до и во время этих событий. Эта информация могла бы быть использована для разработки систем раннего предупреждения, которые могли бы спасти жизни.

Ключевые слова: микропроцессорное устройство, теллурические токи, заземление, землетрясение.

Introduction

Telluric currents, also known as Earth currents, are weak, variable electric currents that flow through the Earth's surface. The magnitude, time, and direction of telluric currents vary depending on a number of factors, including the composition of the Earth, the geographical location, and the disturbance of the geomagnetic field. The amplitude of telluric currents is typically in the microampere range, but can be much higher during geomagnetic storms.

The volume of telluric currents is significant because they can be used to study the Earth's interior. By measuring the strength and direction of telluric currents at different locations, scientists can learn more about the Earth's composition, structure, and magnetic field. Telluric currents can also be used to monitor natural disasters, such as earthquakes and volcanic eruptions. There is no single theory that explains the origin of telluric currents. However, it is known that they are associated with a variety of phenomena occurring in the Earth's crust, on its surface, and in the atmosphere.

Scientists believe that telluric currents are caused by a variety of phenomena, including [1, 2]:

- The electrical polarization of rocks: When rocks are subjected to stress, such as during an earthquake, they can become polarized. This polarization creates an electric field, which can give rise to telluric currents.
- Electromagnetic effects during rock cracking: When rocks crack, they can generate electromagnetic fields. These fields can induce telluric currents in the surrounding rock.
- Processes occurring in the ionosphere: The ionosphere is a layer of charged particles that surrounds the Earth. The ionosphere is constantly bombarded by charged particles from the sun. These charged particles can interact with the Earth's magnetic field to generate electric fields, which can give rise to telluric currents.
- Geomagnetic activity: The Earth's magnetic field is constantly changing. These changes can be

caused by a variety of factors, including the sun's activity, solar flares, and coronal mass ejections. Geomagnetic activity can induce telluric currents in the Earth's crust.

Currently, in some countries with high seismic activity, tectonic faults, or volcanic structures, scientists are collecting data to study telluric currents. Telluric currents are weak, variable electric currents that flow through the Earth's surface. They are caused by a variety of factors, including the Earth's rotation, the sun's activity, and lightning strikes. Scientists are interested in studying telluric currents because they can be used to monitor natural disasters, such as earthquakes and volcanic eruptions. By measuring the strength and direction of telluric currents, scientists can get early warning of these events. The volume of data being collected is significant because it will allow scientists to better understand telluric currents and how they can be used to monitor natural disasters. This information could be used to develop early warning systems that could save lives. Analysis of the results of observations of telluric currents in regions with high seismic activity or volcanic activity has shown that abnormal changes in currents occur before earthquakes or volcanic eruptions. These changes can be detected by monitoring the strength and direction of telluric currents [3, 4]. The behavior of telluric currents before earthquakes and volcanic eruptions is a sufficiently weighty basis for organizing observations of them in terms of predicting upcoming natural phenomena. The research on telluric currents is still in its early stages, but it has the potential to revolutionize the way we study and predict natural disasters. By developing early warning systems for earthquakes and volcanic eruptions, we can save lives and protect property. The research task involves registering telluric currents in order to study their properties and how they are affected by physico-chemical processes in the Earth's crust and atmosphere. This research could lead to a better understanding of the Earth's interior and atmosphere, and it could also be used to develop early warning systems for natural disasters such as earthquakes and volcanic eruptions. To perform the research task of registering telluric currents, it is required to develop a universal analog information recorder that is capable of operating in the field from an autonomous power source. This is because telluric currents can be measured in remote and difficult-to-access locations, where it may not be possible to connect to a power grid. The development of this recorder is a significant challenge, but it is essential for the advancement of research into telluric currents. By developing a recorder that is capable of operating in the field, scientists will be able to collect data on telluric currents in a wider range of locations, which will lead to a better understanding of these phenomena. The recorder will also be useful for other applications, such as monitoring natural disasters and studying the Earth's atmosphere. By developing this recorder, we can make significant advances in our understanding of the Earth and its environment.

In this regard, it seems most appropriate to develop a specialized device that can record analog signals and convert them into digital code. The device would be based on a microcontroller, which would be responsible for pre-processing the input signals and transferring the processed data to a computer. The computer would then be responsible for performing more complex data processing tasks, such as analysis and visualization.

Materials and Methods

Development of a microprocessor device and the methodology of the experiment

The peculiarity of the registration of telluric currents is that the recorder must operate continuously for long periods of time in the field. This factor imposes additional requirements on the recorder circuit, which must be compact, micro-powerful, and have a large amount of memory. The recorder must also be powered by an autonomous power source.

The structural and functional diagram of the recorder is shown in Figure 1. The recorder consists of the following main components:

- Analog-to-digital converter (ADC): The ADC converts the analog input signal into a digital signal.
- Microcontroller: The microcontroller controls the operation of the recorder and performs data processing tasks.
- Memory: The memory stores the data that is recorded by the recorder.
- Power supply: The power supply provides power to the recorder.

The recorder is a complex device that must meet a number of requirements in order to be able to record telluric currents. The recorder must be compact, micro-powerful, have a large amount of memory, and be powered by an autonomous power source. The recorder must also be able to operate continuously for long periods of time in the field.

The structural and functional diagram of the recorder shows how these components are interconnected. The ADC converts the analog input signal into a digital signal, which is then processed by the microcontroller. The microcontroller stores the processed data in the memory, and the power supply provides power to the recorder. The recorder is a valuable tool for scientists who study telluric currents. The recorder can be used to collect data on telluric currents in a variety of locations, which can be used to improve our understanding of these phenomena.

The task of determining the values and directions of the currents under study can be reduced to measuring and continuously recording the potential difference between two pairs of electrodes mounted on two mutually perpendicular directions. The potential difference between the electrodes is proportional to the strength of the current flowing through the electrodes. The direction of the current can be determined by the polarity of the potential difference. The electrodes can be mounted on two mutually perpendicular directions to measure the components of the current in two different directions. This allows us to determine the magnitude and direction of the current. The potential difference between the electrodes can be measured using a variety of devices, such as a voltmeter or an oscilloscope. The data can be recorded continuously using a data logger. The data from the data logger can be analyzed to determine the values and directions of the currents under study. This information can be used to study the Earth's interior and atmosphere, and to develop early warning systems for natural disasters such as earthquakes and volcanic eruptions.

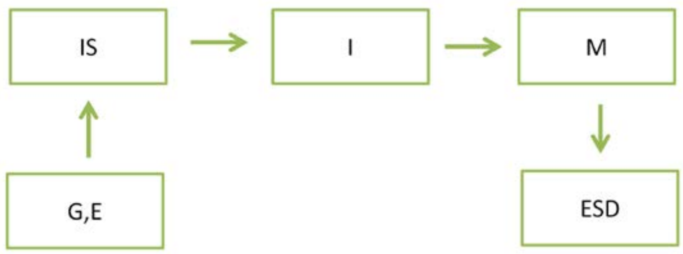

Figure 1 – Structural and functional diagram of the telluric current recorder:
G, E – grounding electrodes of the ground loop (East-West); IS – input stage;
I – integrator; M – microcontroller; ESD – external storage device

The input stage of the IR is a circuit that adds two signals together and then converts the signal to a lower frequency. The input stage also suppresses high-frequency interference up to frequencies of several Hertz. The pulse integrator and pulse counter are two important components of the electricity quantity dispenser. The pulse integrator is responsible for measuring the total amount of electricity that has been consumed, and the pulse counter is responsible for counting the number of pulses that have been generated by the electricity meter. The pulse integrator works by adding up the individual pulses that are generated by the electricity meter. The pulse counter works by counting the number of pulses that are generated by the electricity meter.

The data from the pulse integrator and pulse counter is used to calculate the total amount of electricity that has been consumed [5]. The control unit is responsible for synchronizing the operation of the complex. Before starting work, all registers and counters are reset to zero. After starting, the timer generates a periodic sequence of pulses with a specified period, ΔT. During this period of time, the pulse counter accumulates information proportional to the amount of electricity measured in the ground loop circuit. The information accumulated by the pulse counter is then used to calculate the total amount of electricity that has been consumed.

When the next pulse arrives, the control unit generates a signal to transfer the data from the pulse counter to the external memory. The contents of the pulse counter are then reset to zero and the accumulation of new information begins. The address counter register is incremented by one after each procedure of writing data to an external storage device. While working in the field, the VSU unit is used to collect data. When the external memory of the VSU unit is filled, it is replaced with another VSU unit. The data from the filled VSU unit is then read into a PC in the laboratory. The PC is used to process the data, perform necessary calculations, and plot the data.

Earth currents can only be measured by observing signals from grounding electrodes that are placed in the ground and spaced far apart. When the potential difference between the grounding electrodes is measured, an electrical circuit is formed. This circuit is a closed loop that includes the Earth as a conductive medium. The circuit is completed by connecting the grounding electrodes to the IR input stage via a communication line. The electrodes of the grounding circuit are typically located in the cardinal directions (north, south, east, and west) to make it easier to find the direction of the resulting vector. For example, consider a contour in which the grounding electrodes are located along an east-west line.

The electrodes of the grounding circuit are typically located in the cardinal directions (north, south, east, and west) to make it easier to find the direction of the resulting vector. For example, consider a contour in which the grounding electrodes are located along an east-west line. According to the calculation of the contour parameters carried out using the dependencies [6], the active resistance between two cylindrical earthing devices in the ground at a distance of 100 m between them is about 30 ohms, the inductive component at a frequency fC = 50 Hz is 0.02 ohms, and the active resistance of the communication line is approximately 2 ohms. The total resistance of the circuit is the sum of the active resistances of the grounding electrodes, the inductive component, and the active resistance of the communication line. In this case, the total resistance is about 32.02 ohms.

The input stage of the recorder has a very high input resistance. This means that it draws very little current from the circuit. The resistance of the communication line is much less than the resistance of the ground between the electrodes. This means that the current flowing through the communication line is much greater than the current flowing through the ground. As a result, the voltage at the input of the recorder will be equal to the voltage at the grounding electrodes. This is because the voltage drop across the communication line is negligible.

$$u_1 = u_{ВЗ} + \left(\Delta u_В - \Delta u_З\right) + u_П = u_{ВЗ} + \Delta u_Э + u_П \quad (1)$$

where $u_{ВЗ}$ – instantaneous value of informative signal from grounding conductors;

$u_П$ – instantaneous value of interference voltage of various nature;

$\Delta u_Э = \Delta u_В - \Delta u_З$ – quantity characterized by the difference of potential jumps $\Delta u_В$ и $\Delta u_З$ at the electrode-electrolyte interface of both ground electrodes and heterogeneity of electrolytes filling wells with electrodes [7, 8, 9].

The integrator can only operate in unipolar mode, meaning that the input signal must be positive. If the input signal is negative, it must be offset by a positive voltage before it is applied to the integrator. This offset voltage is typically chosen to be slightly larger than the maximum negative value of the input signal. In this case, the offset voltage is ≈ +0.4 V.

Thus, the integrator input receives a total signal, which can be represented as follows:

$$u_{1\Sigma} = u_1 + u_0 = u_{ВЗ} + \Delta u_Э + u_П + u_0 \quad (2)$$

The integrator in this scheme is used to average the values of input signals at regular intervals. The averaging is done over a time interval of ΔT. The averaged values are then converted to binary codes and written to external memory.

The data entered into computer memory arrays are presented in the form of binary codes. Each binary code represents a certain number of pulses. The number of pulses is proportional to the value of the input signal. The input signal is sampled at regular intervals of time. The sampling period is denoted by . The value of each parameter is the average value of the input signal over the sampling period. To determine the value of the desired signal, the average value of the input signal over the period , it is necessary to subtract the offset from the total value. The offset is a constant value that is added to the input signal before it is sampled. The offset is used to compensate for the bias in the sampling process.

$$\underline{u}_1 = \underline{u}_{1\Sigma} - u_0 = \underline{u}_{ВЗ} + \Delta u_Э \quad (1.3)$$

The parameter characterizing the average minute value of the difference in potential jumps between the electrodes corresponds to the value of the number of pulses equal to the average value of the input signal over a period of one minute.

$$\Delta N_i = N_i - N_0 , \qquad (1.4)$$

where N_0 – number of pulses proportional to the offset u_0.

This information can be conveniently analyzed using graphs. The ordinate axis of the graph shows the values of the current, taking into account the sign. The abscissa axis of the graph shows the time in hours. The transition to the parameter can be carried out by the formula:

$$\underline{u}_{1i} = u_{1\Sigma i} - u_0 = \frac{S_0}{\Delta T} \cdot \left(N_i - N_0 \right) = \\ = \frac{S_0}{\Delta T} \cdot \Delta N_i = K_{np} \cdot \Delta N_i , \qquad (1.5)$$

where $K_{np} = \frac{S_0}{\Delta T} \approx 0,56$ mV/imp. — proportionality factor;

S_0 = 3,355·10-2 V·s/imp. – quantum of volt-second area;

ΔT = 60 s – averaging time.

If the averaging interval is 1 minute, then 1440 samples of data are entered into the computer's memory per day. This is because there are 24 hours in a day and 60 minutes in an hour, so there are 24 * 60 = 1440 minutes in a day.

Results and discussion

The choice of the integration time interval, ΔT, depends directly on the frequency range of the information that needs to be received. A shorter integration time interval will allow for the detection of higher frequencies, while a longer integration time interval will allow for the detection of lower frequencies. The choice of the integration time interval, ΔT, depends directly on the frequency range of the information that needs to be received. A shorter integration time interval will allow for the detection of higher frequencies, while a longer integration time interval will allow for the detection of lower frequencies.

With the help of an integrator, the analog signal u_1 is quantized over the volt-second area S_0 (Figure 2). This means that the integrator converts the analog signal into a series of discrete values, each of which represents a certain amount of charge. The values are then stored in the computer's memory.

This means that as the accumulation of a given quantum of area (S0) under the curve $u_1(t)$ during Δt_{qii}, a sequence of rectangular pulses is formed at the output of the integrator. This is because the integrator output is proportional to the area under the input signal curve, and the input signal curve is a series of rectangular pulses.

The total signal u_1 is converted in real time into a sequence of pulses in the integrator. These pulses are then summed up in digital counters, which turns them into a code having a weight proportional to the average voltage u_1 for the averaging time interval T=10 seconds.

At the output of the pulse integrator, the number of pulses at the maximum input signal level for 1 minute should not exceed 999. This means that no more than 16.66 pulses should be formed in one second.

$$N/\Delta T = 999/60 \approx 16,65 \text{ (imp/s)}$$

The frequency of fluctuations of the output voltage for a functional generator of this type is typically in the range of 100 Hz to 1 MHz. This means that the output voltage of the functional generator may vary slightly from its nominal value over a period of time. The amount of variation depends on the specific functional generator and the settings that are used.:

$$\mathrm{f} = \frac{(\mathrm{R1} + \mathrm{R2}) \cdot \mathrm{U_0}}{\mathrm{4R1RCU_{МАКС}}} , \qquad (1.9)$$

where U_0 – maximum input voltage.

$U_{макс} = U_{пит}$ – supply voltage. $U_{пит}$ = 7,4 V.

The hardware part of the device is implemented on the Arduino Nano platform, (Figure 3).

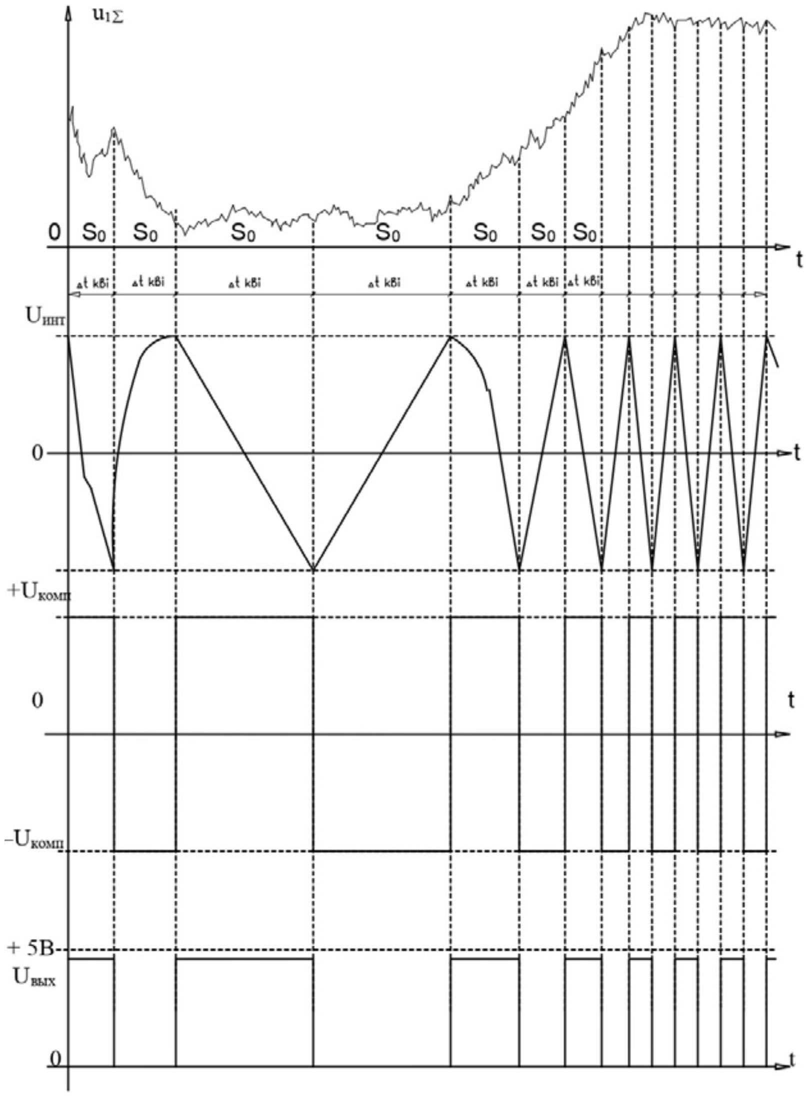

Figure 2 – The nature of the change in the input signal $u_{1\Sigma}(t)$
with a demonstration of the operation of the pulse integrator

Figure 3 – Appearance of the Arduino Nano

This platform includes the ATmega328P microcontroller from the Atmel family, as well as a TTL-USB converter on a CH340G chip. These components are necessary for connecting and programming the module via the USB port of a personal computer [10].

In addition, a clock module is installed to measure the date and time. The clock module is a board based on the DS1307 chip, which has a battery backup to protect against accidental power outages (Figure 4). This chip is a real-time clock and a calendar.

Figure 4 – Appearance of the time module

The device interacts with the time module and receives data from it in the form of: [hours; minutes; seconds; date; month; year; day of the week]. The type of transmitted data is int. The days of the week take values from 1 to 7, where 1 is Monday and 7 is Sunday. The microSD card module is used to store and output information to portable drives. It supports SDHC memory cards up to 32GB (Figure 5).

The module includes a voltage regulator to convert the 5V power supply to 3.3V, which is what the memory card requires. It also has a logic level converter to convert the 5V logic levels from the microcontroller to 3.3V logic levels, which is what the memory card expects.

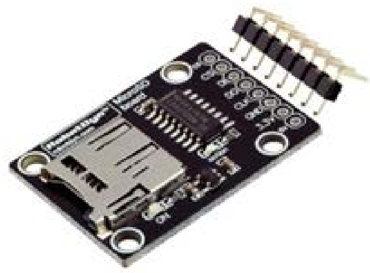

Figure 5 – Appearance of the memory module

The device is made in a small, plastic case (Figure 3). It has a switch and three LEDs on the device body. The switch is used to turn on and off the external power supply to the device. The appearance of the device assembly is shown in Figure 6.

Figure 6 – Device appearance

Conducting an experiment to determine the direction of flow of telluric currents. The determination of the direction of telluric current flow was carried out in an open area in the city of Omsk at the coordinates of 55.023°N. and 73.292° E. The experiment was carried out using rod steel electrodes, divided into 8 points every 45° in a circle with a diameter of 100m, Figure 7.

Figure 7 – Places for installing electrodes in open areas

To connect the electrodes to the recording device, a geophysical wire of the GSP 0.5 brand was used. The potential difference and resistance between the electrodes were measured using a universal digital multimeter with the ability to register a constant voltage in millivolts. The diagram of the electrode installation relative to the directions South-North (S-N), East-West (V-Z), South-Southeast (SZ-SE), and South-Southwest (SV-SW).

After determining the potential difference between the electrodes and the soil resistance, the current strength was calculated. The results of the study are presented in table 1.

After determining the potential difference, a microprocessor device was installed and connected. The measurements were carried out in a similar way to the measurements of the potential difference, in the directions: S-Y, V-Z, NW-SE, SW-SW. In each direction, six minutes of information was recorded, i.e. six values of the interrupt count counter. The results of the study are presented in table 2.

Based on the data, the greatest potential difference was observed between electrodes 5 and 6 in the SW-SW direction. This indicates a pronounced increase in the number of interruptions and the greatest potential difference between the electrodes, which corresponds to the direction of flow of telluric currents (Figure 8).

Table 1 – Results of the study

electrodes	Расстояние	Potential difference	Сопротивление	Current strength
№	M	mV	Om	mA
1-2	100	5,5	57	0,0965
3-4	100	112	870	0,1287
5-6	100	200	1260	0,1587
7-8	100	33	270	0,1222

Table 2 – Results of the study

№	№ directions	Time, t	Number of interrupts, Ni	ΔU, mV	R, kOm
t1	1-2	18:33	208	5,5	0,057
		18:34	205		
		18:35	204		
		18:36	206		
		18:37	208		
		18:38	208		
t2	3-4	18:57	731	112	0,87
		18:58	732		
		18:59	719		
		19:00	721		
		19:01	726		
		19:02	727		
t3	5-6	19:18	928	200	1,26
		19:19	936		
		19:20	917		
		19:21	905		
		19:22	897		
		19:23	893		
t4	7-8	19:38	280	33	0,27
		19:39	279		
		19:40	281		
		19:41	272		
		19:42	272		
		19:43	271		

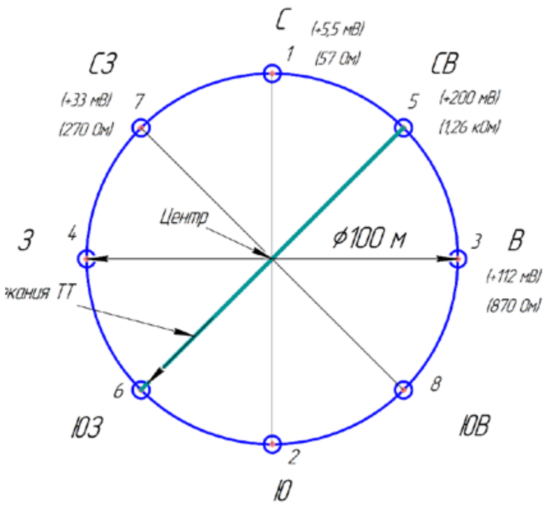

Figure 8 – Direction of flow of telluric currents

Conclusion

In this project, a recorder of digital information about telluric currents has been developed. The device is made in a compact package, relatively small size.

A scientific experiment was carried out confirming the operability of this device. The direction of telluric current flow was determined in open areas. Based on the results obtained, graphs of the dependences of signals from ground electrode systems on time were plotted.

Advantages of the designed device:

1. It is capable of automating the process of recording and processing signals when measuring stray and telluric currents.
2. Can work in the field from an autonomous 12.6V power supply (car battery).
3. Workable for long periods of time (2 weeks).
4. Equipped with a USB interface for recording information to external memory.
5. It has high reliability and noise immunity, which positively affects the accuracy of measurements.

The device is designed for short-term collection of information about stray currents in order to detect dangerous effects on underground metal structures and structures.

It can also be used to monitor the flow of telluric currents in the earth for a long time in order to collect and accumulate information about the processes occurring in the earth for further forecasting of natural disasters, such as earthquakes, tsunamis and volcanic eruptions.

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