

Lyubimov V. V.

Pushkov institute of terrestrial magnetism, ionosphere and radio wave propagation (IZMIRAN)

Russian Academy of Sciences

TEST RESULTS OF DIFFERENT ELECTROMETRIC VARIOMETER SENSORS

I. INTRODUCTION

The existence of the electric field (**EF**) in the Earth's atmosphere is mainly due to the processes of air ionization and spatial separation of the ionization occurs when positive and negative electric charges. EF, in spite of the complexity of the systems and conditions of their registration, are considered in geophysics as one of the main physical factors of the processes occurring in the surface layer.

From [1-3, 9] show that variation of the EF surface layer caused by geophysical processes may experience changes up to orders of magnitude above the background. Many atmospheric processes such as solar activity, convection and formation of clouds, precipitation, lightning discharges cause partial separation of opposite charges and the emergence of atmospheric EF, with respect to the atmosphere surface of the earth is charged negatively. Existence EF the atmosphere causes currents, discharge electric "condenser" atmosphere - surface of the Earth.

In recent years more and more attention of researchers attracts the problem of the impact on the environment geophysical factors [9], has created quite a lot of different methods and unique instrumentation for the measurement of EF, some of which are presented in [1-12]. It was important to research the electrical characteristics of the atmospheric boundary layer, where flows a large part of human activity. Changes EF here come under the influence of various anthropogenic and natural processes. Therefore, the main objective of the research is the monitoring of the EF surface layer of the atmosphere with the impact of anthropogenic processes on the natural EF.

Improvement of techniques for the study of EF surface layer of the atmosphere is currently pressing problem for researchers and practitioners, including the creation of new methods and devices for monitoring atmospheric EF. An important task is the creation, for example - ROSGIDROMET (methods RD52.04.567-96 and RD52.04.168-2001) [8], a measurement network spaced stations equipped with modern instruments capable of operating in all weather conditions.

Described in this article work is proactive and is based on the results of long-term stationary measurements of EF in the atmospheric surface layer carried out on the territory of IZMIRAN at spaced measuring points (**MP**) for small measuring range. At the same time, the ideology of the whole work was aimed at the creation of new sensors and modern digital devices that can operate under various weather conditions and to ensure the monitoring of atmospheric EF

in all of MP. Using these sensors and instruments the researchers will be able to implement ground-based diagnostics of different nature EF and analysis of their interactions with the geophysical and meteorological processes, as well as the possibility of creating a digital database of the measured data.

II. THE SENSORS

The analysis of the works of some Russian and foreign authors and the currently available devices [1, 3, 6, 10, 11] designs of the EF sensors [3-6, 12] showed that the main drawback of their work is the limited possibility of their application to work in all weather conditions, rain and snow. Designs used EF sensors made in the form of "turntables" [4, 6, 7, 10, 11], with mechanical drives of various modifications and embodiments. This scheme sensors used for converting slowly varying values of EF in the AC signal (field-voltage), which was easier to work and carry out amplification, filtering and subsequent data registration. These sensors are used for absolute measurements of EF, quite unreliable and unstable in time, as all "mechanics" as a result of intensive exploitation have limited resource. The replacement of the mechanical moving parts the sensors of EF leads to real change of their metrological characteristics. There are problems with prolonged operation and use of devices that are associated with the need for periodic calibration of sensors due to the instability of the "zero" (leaving "zero"). Because unsecured design, the EF sensors typically operate intermittently and are unable to work effectively during periods of precipitation or in conditions of high humidity. In addition to the installation of such sensors must, in accordance with the recommendations of methodic [8], to choose and equip a certain place and MP, free from manmade noise and interference, where distortion EF of the atmosphere are minimal or constant.

The purpose of our work and research was the establishment of the construction of all-weather sensor that can work in any MP.

The first prototype sensor design with digital signature, according to the above requirements, was created in 2010. The idea of the sensor construction (field-voltage converter) consisted in the rejection of mechanical components using in the external sensor (**ES**). It was proposed to build not an absolute instrument for measuring potential EF relative to the surface of the Earth, and to measure the value of EF and its variations between the two isolated from each other and spaced at a certain distance of the electrodes and measuring plates or disks. Neither of these two electrodes discs should not be grounded. The distance between disks and their size could vary and raise (move to MP) relative to the level of the Earth's surface, including measurements below this level, for example, in natural and artificial cavities. That is, a device to record the change in the potential difference between two insulated electrodes and, in fact, was – electrometric variometer (**EV**). It was assumed and implemented the replacement of the mechanical node of the

inverter slowly changing EF signal to the electronic part, based on the DC amps with MDM (modulator-demodulator) signal processing, which have high stability and low drift of the zero time. A simplified functional diagram of such a field-voltage converter EV is shown in **Fig.1a** and includes sensor and measuring amplifier A1. As the EF sensor used two ungrounded measuring plates round shape of the foil fiberglass (in the form of a capacitor), which were placed in a grounded housing at some (defined) distance from each other. General view of the ES sensors shown in **Fig.1 (b, c, d)** and **Fig.2e**.

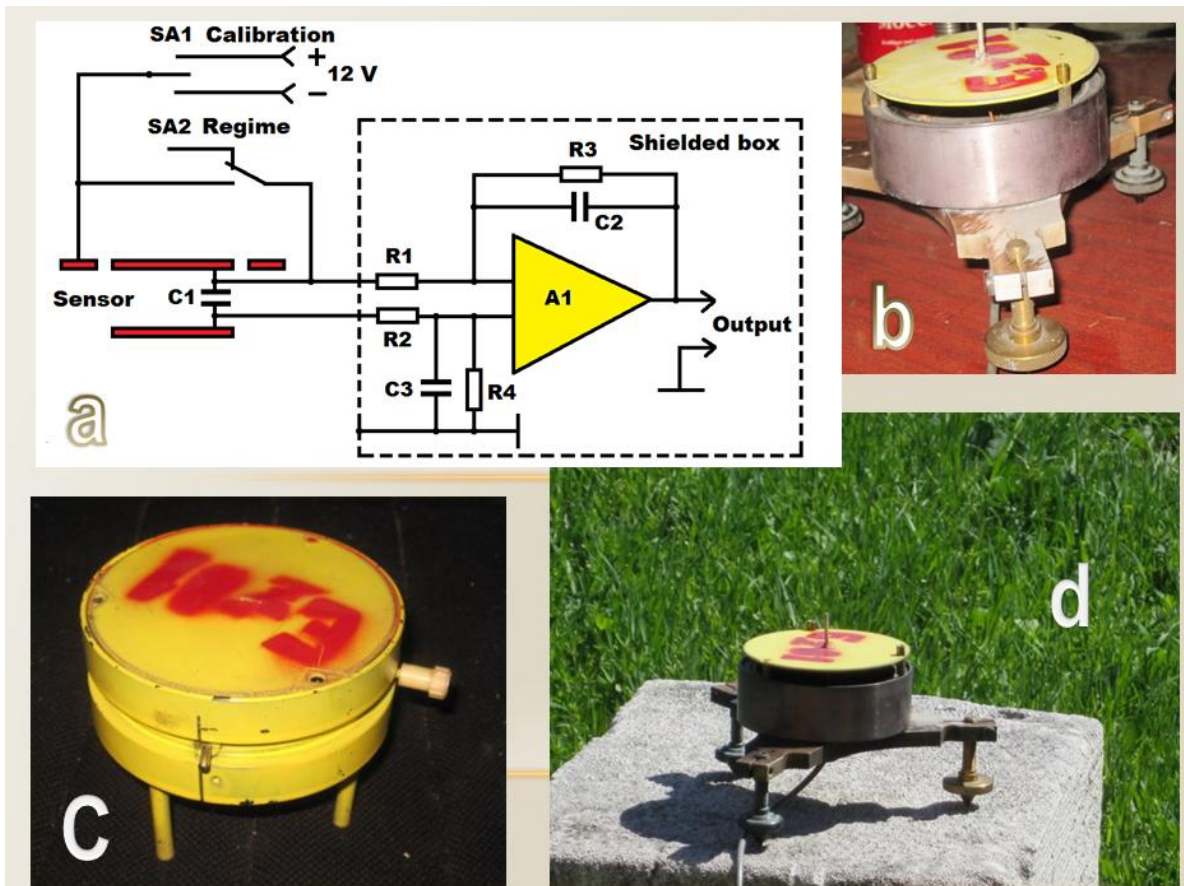


Fig.1. A simplified scheme of the field voltage converter EV is made with the use of MDM-amplifier (a) and general view of various ES designs (b), (c) and (d).

The operation of the circuit is as follows. The flow electrostatic induction measured EF induces an electric charge on the sensors measuring plates, which is made in the form of a flat capacitor. Further, with the help of the electronics box (EB), is the transformation of the electric field – current – voltage – digital code, whereby on the recorder (e.g. on the display of a personal computer - PC) is indicated by process changes (variations) of EF in time, and the digital data recorded on the hard disk (or flash drive) in a PC.

At the input of the amplifier A1 (to improve its stability covered both internal and external negative feedback) is a precision modulator which converts the input DC voltage to the amplitude of the AC. Next, the AC signal is amplified and is demodulated by a synchronous demodulator,

which allows to maintain the linearity of the conversion and small zero drift. MDM-amplifier circuit performs the function similar to the exposure plates in the sensors-"turntables" [4, 6, 7, 11], which periodically with the frequency of rotation of the ground (exposed) potential EF, achieve the working plate charging. That is, with the period of the operating frequency, which is MDM transformation, MDM-amplifier controls the change of the potential difference on the working of measuring plates. The output of such a converting is a slowly varying voltage proportional to the change in EF between the measuring plates. This scheme of input part of the EV has a low level of noise, high sensitivity and very low "zero drift". The performance of the amplifier circuit A1 is limited in our case, the value of the carrier frequency (110-130 Hz) at which the signal conversion.

The main part of the scheme was implemented on the basis of the operational amplifier (OA) type 140 UD13 and placed inside the grounded housing of ES under measuring plates. The ES connection with the recording equipment located in the technical building, was carried out by means of connecting shielded cable of 25 m length. Power schemes EV was carried out using the AC adaptor (SA) with 12 V DC from AC.

In early 2012, created a new design ES shown in **Fig. 2a**, **Fig.2c** and **Fig.2e**, which differed from the previously described sensor of EF the fact that there was no built-in electronic unit, as well as were designed protection from bad weather conditions for use of MP in conducting continuous research. ES is designed to work in open atmosphere. Operating conditions: temperature from -50° to 50°C , humidity $\leq 100\%$, pressure 750 ± 30 mm Hg.St. The dynamic range of the measured values of variation of the EF intensity from 0 to ± 1500 V/m (regulated and had the ability to scale by means of specially written programs for the PC).

In the same year, has been designed and developed EV new design described in [15], and a general view of the ES is shown in **Fig.2b** and **Fig.2d**. Case of ES is made in the form of a flat cylinder with a diameter of 120 mm and a height of 40 mm (see diagram in **Fig.1a.**), within which are mounted: MDM-amplifier, integrator, bandpass filter and DC-DC converter and control circuit for the calibration of the device. The measuring plates of this sensor EV are flat (sectional) metal plate thickness of 1 mm and a diameter of 240 mm, mounted on the insulator polycarbonate at a distance of 10 mm from each other. On the sensor housing are EV controls, which are the inclusion and calibration of the sensor.

MDM-amplifier was made on the basis of OA type ICL7650, which had a high input impedance (10^{12} Ohm), low temperature coefficient ($0,01 \mu\text{V}/^{\circ}\text{C}$) and very low drift over time (100 nV/month). This OA was already a higher frequency compared to the previously used, the operating frequency of MDM-conversion was in the range from 120 to 375 Hz. All the ES and EB schemes were powered a constant voltage of ± 5 V from the power source, which used rechargeable battery (RB) voltage 9...24 V (in the field) or standard SA when powered EV from AC voltage of 220 V

and frequency 50 Hz, the consumption of the device was not more than 1,2 VA. The cable, which will connect ES and EB, were screened and had a length (at different points in experimental studies) from 10 to 25 m. With this cable were feeding the supply voltage for all ES circuits, as well as the transmission of analog data in EB. Further, by using located in EB of 24-bit ADC (based on the AD7734 chip), the analog data is converted into digital form and then supplied to the registrar, as using a PC.



Fig.2. General view of various ES designs installed in MP to IP.

III. THE THREE-CHANNEL ELECTROMETRIC VARIOMETER

All created by the EP sensors have different sensitivity and to compare them with each other in scale and in time, was designed multichannel data acquisition system, functional scheme of which is shown in **Fig.3**. This system includes three measuring channel and was created based on EB, which was used in the devices described in [13, 14], but without the positioning systems and systems connected with the wireless transmission distance.

EB included three-channel amplifier (**US**), a control circuit (**CC**), control microprocessor (**CMP**), ADC, and power supply unit (**PSU**). To control the temperature of the external environment used precision integrated temperature sensor (**DT**) made on the basis of LM35 chip

connected to one of the ADC channels. When powered EV from AC voltage of 220 V and frequency 50 Hz device consumption was not more than 1,5 VA.

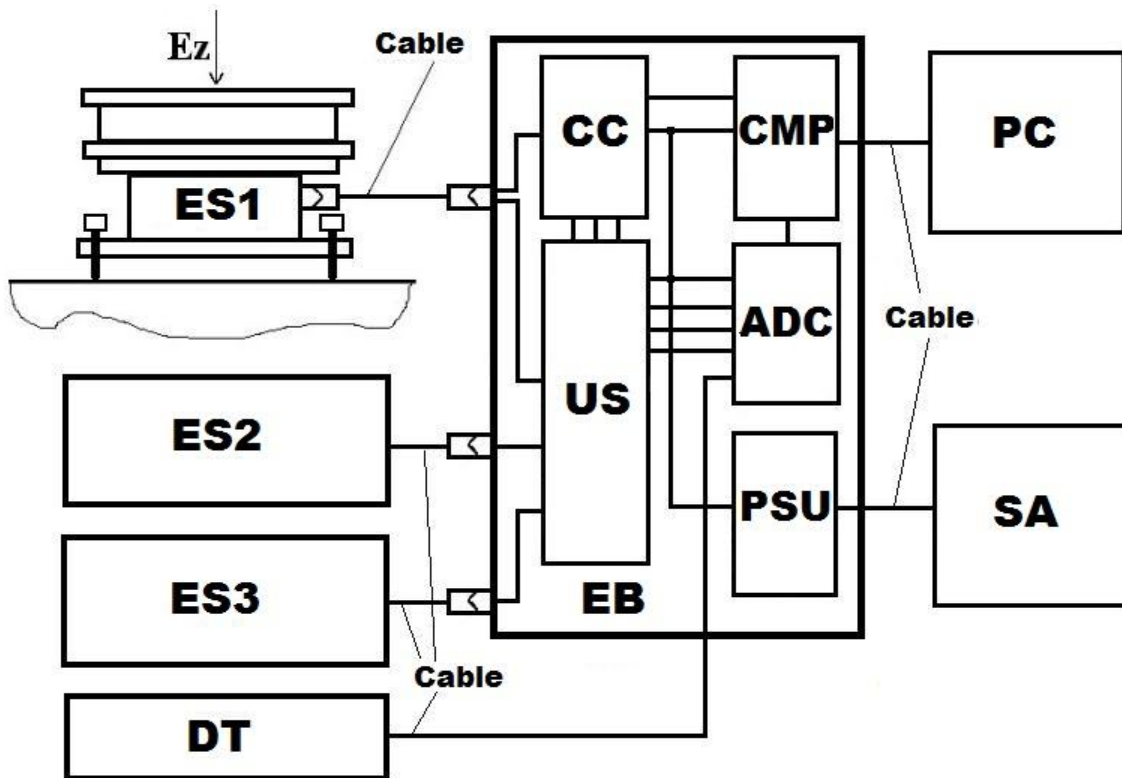


Fig.3. A functional scheme of a three-channel EV.

Structurally, EB was performed in a metal box dimensions 225x145x80 mm, on the side panels which are all the controls for EV and connectors to connect the three ES, SA (or RB) and PC. The device is designed for long continuous operation in any weather, both in the field and in the Observatory conditions with the installation of the ES on a pedestal, on a special stand outside the room (on MP) or on the measuring post (IP). Connecting ES with EB was carried out using a shielded cable type UL2464 4C and 9C (see Fig.3) different lengths depending on the distance from MP to IP.

IV. METHODOICAL WORK

For testing sensors EV was organized measuring polygon (see Fig.4), which includes technical building (pavilion) and measuring poles (IP). In the technical building recording equipment (PA) system three-channel EV, which includes EB, SA and PC. All was arranged five MP, four IP (C1...C4), which were located on both sides of the technical building, and one of MP (C5) is mast-mounted above the roof of this building at a distance of 10 m from the surface of the Earth. EV sensors were located on the IP from different sides of the pavilion in the direction East-West. Extreme of these IP separated from each other horizontally at a maximum distance of 30 m. The IP was located at a different fixed distance from each other and from the Earth's surface. On these measuring poles alternately or simultaneously varying the investigated sensors in various

combinations. General view of the technical building, measuring polygon (top view and side view) and IP (C1...C5) fitted ES shown in **Fig.4**.

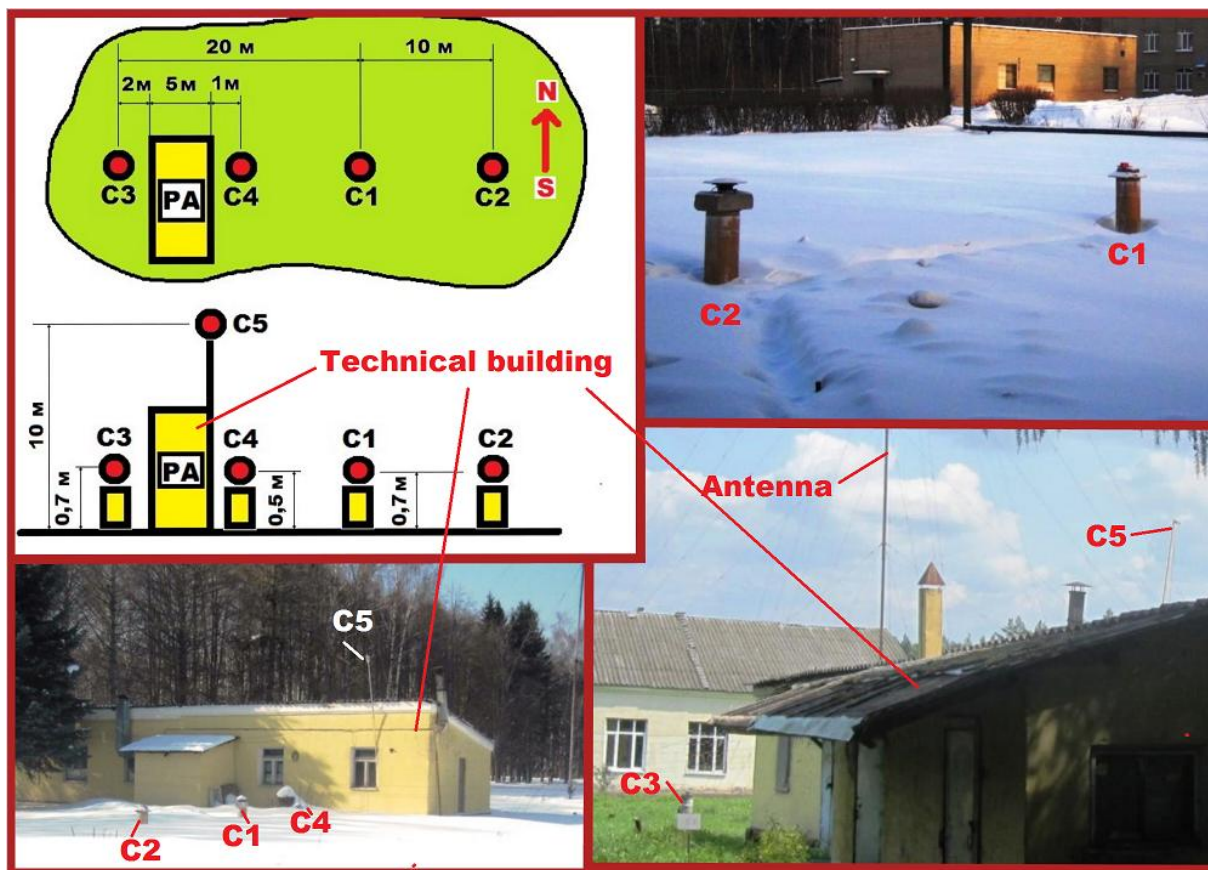


Fig.4. The scheme of technical building location and IP with ES at the measuring polygon.

About 50 meters from the measuring polygon was located in the building of ionospheric stations with a high radiating antenna, which can also be seen in **Fig.4**. Periodic radiation of this ionospheric station has had a strong influence on the measurement of EF in various MP, when carrying out methodological work on the measurement range. Radiation station in addition to the generated interference, which is shown in the records of EF in [15], were (and still used) as a "calibration part" of the whole EV measuring system and served as a positive when comparing the ES sensitivity if they are both installed on the same IP. It should be noted that all of the ES every 15 minutes felt a strong electromagnetic effect (with different frequency and amplitude of the radiated high frequency signal) and back to normal mode register EF without displacement of their "zero level".

Examples of the registration of different amplitude and different frequency of impacts of the emission spectrum of the ionospheric station on the ES measurement installed in three MP (C1, C4 and C5) on the measuring polygon shown in **Fig.5**. Recording EF made by PA in real time with a speed of 16 measurements p/s.

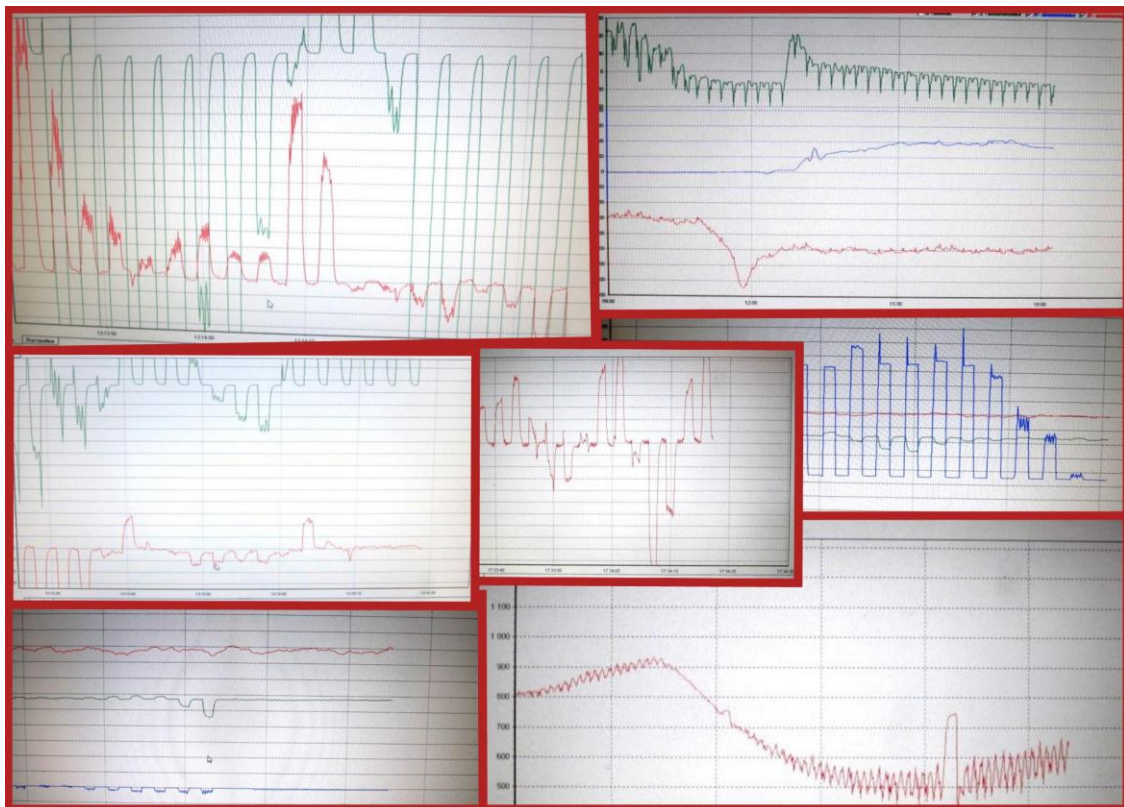


Fig.5. Examples of the ionospheric station influence on the EV measurement results located near to the measuring polygon (record in MP on the IP C1, C4 and C5).

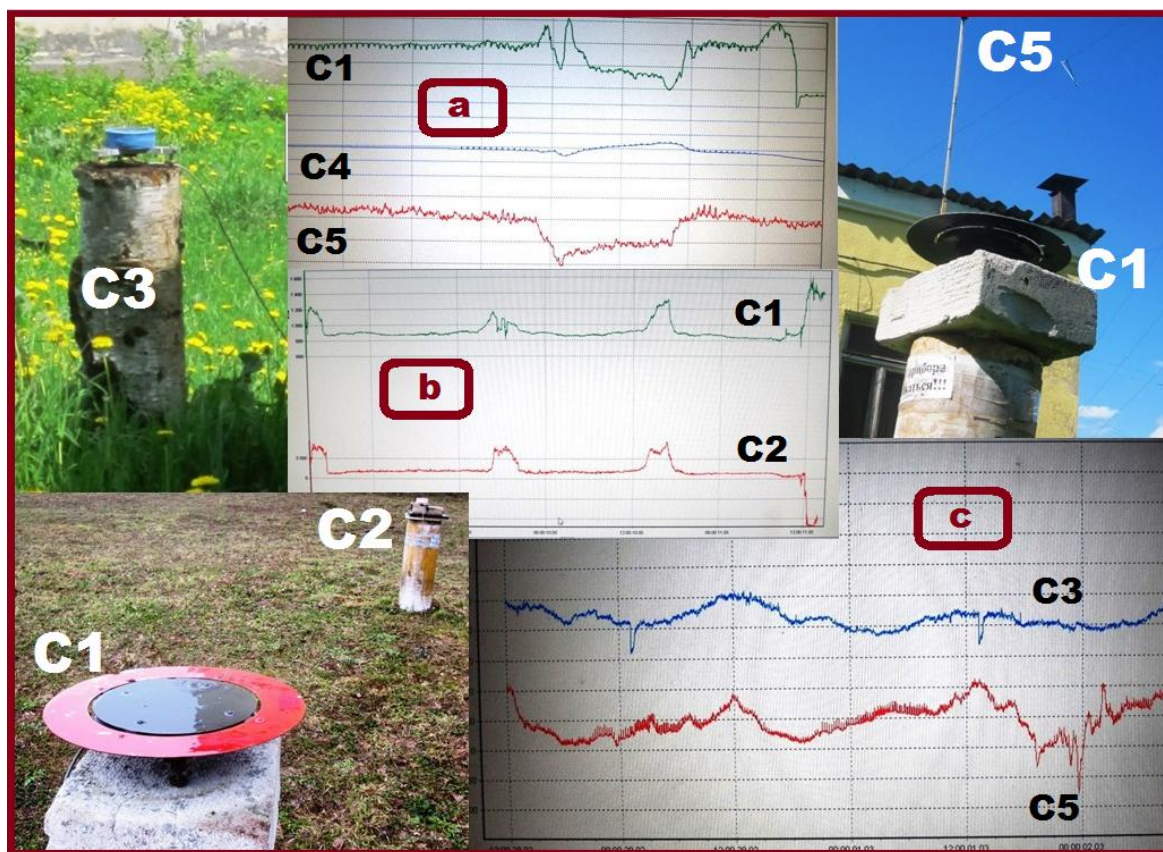


Fig.6. Fragments of the daily and three-day EF recording in MP at the IP (C1- C5).

In **Fig.6 (a, b, c)** shows fragments of different EF combinations records and different designs of ES in a different time period. Here are fragments of the one - and three-day records of EF on different IP as well as recording three-channel EV (at different scales). As can be seen from the fragments of the entries of EF in various MP behave differently and have (according to MP position from the Earth's surface) is different (not exactly the same).

V. THE MORPHOLOGY OF SOME NATURAL PHENOMENA

During and in carrying out methodological and research studies on work created of EF sensors, which lasted for nearly the past 6 years, there have been many experiments and obtained interesting data in digital form on the behavior of the ES and the change of EF in various MP by simultaneous EF registration of multiple EV working sensors. Illustrate some interesting points at check EF in the process of conducting continuous works are shown in below figures. Here shows examples of the change EF registration of EV sensors under different weather conditions.

In **Fig.7a** shows fragments of the daily and three-day records EF with the change of solar activity in the summer time for the IP (C4 and C5,- see **Fig.4**) located in MP vertically one above the other and at a distance from the surface of the Earth, respectively, 0,5 and 10 m.

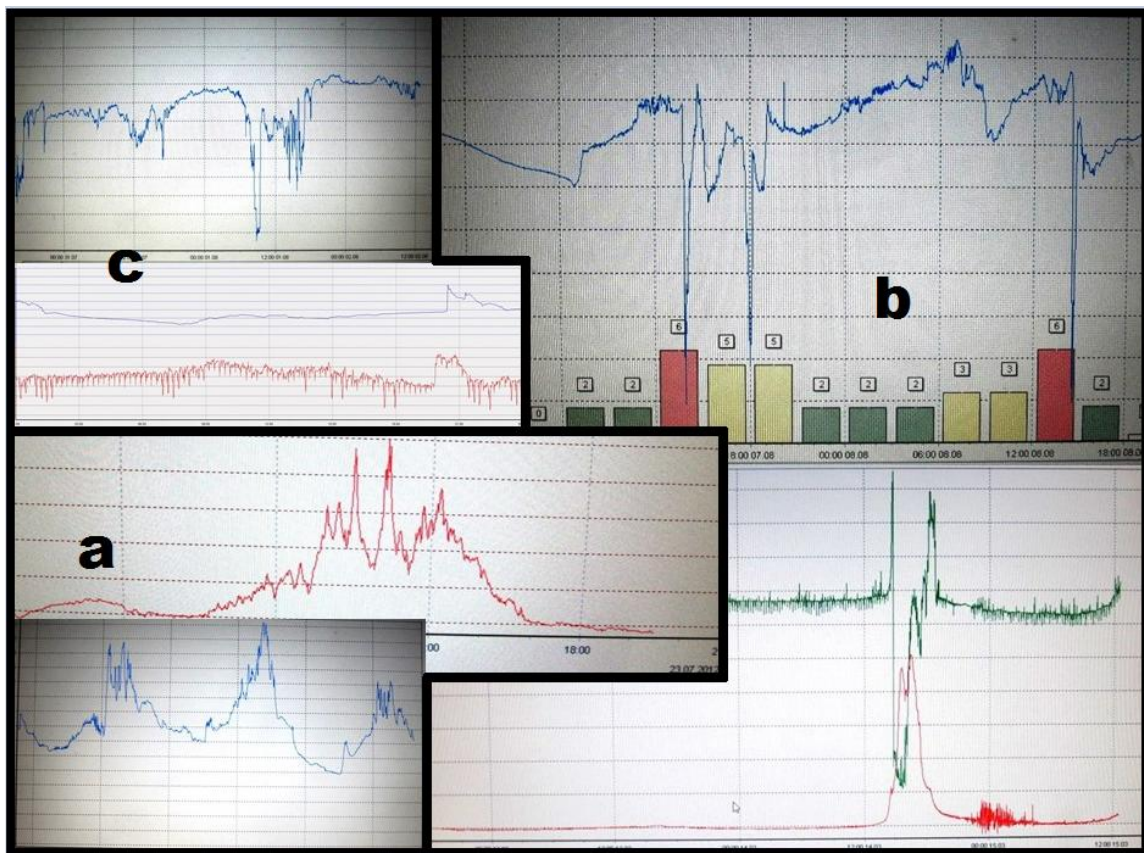


Fig.7. Fragments of the daily and three-day EF records, when the daily change of solar activity (**a**), in moments the passage of lightning discharges (**b**) and in the form of rain or heavy rain (**c**).

In **Fig.7b** is depicted on the PC screen fragments one-day and three-day registration of the EF change in moments the passage of lightning discharges. Illustration applies to all three measuring EV channels, registration of which was conducted in a continuous mode. Records are made ES located on the IP of C1, C4 and C5 and reflect the registration process in the vertical plane (at different levels MP embed), in the gradient mode variations in height.

In **Fig.7c** presents fragments of single-channel and dual-channel recording on the PC display EF changes during a sudden rainfall in the form of rain or heavy rain. Here are records of this phenomenon in various EV recording resolution. Digital registration in this case was conducted with the greatest possible speed (16 measurements p/s) and averages data in a time interval of 1 s. The visualization of the measurement process on the PC display was made with averaging of digital data at a minute time interval.

VI. CONCLUSION

In the result of carried out works and experiments created and passed a long test of prototypes of the sensors for measuring the EF of different types and designs that showed its full functionality in various applications. Created sensors and the EV system enables continuous long term measurements of EF under different weather conditions. Receiving data in digital form allows to accumulate these data to create a database and use them for conducting various kinds of analytical studies.

Analysis of the data showed that EF at the location of the sensors in the atmospheric boundary layer (where is a large part of human activities) is inhomogeneous and its behavior is different in different measuring points located at different heights from the ground level. Changes EF here come under the influence of various anthropogenic and natural processes. Therefore, the establishment of the measuring network EF, as is done (for "pure science") by ROSGIDROMET institutions and others in specially designated and equipped "clean places", gives a complete picture of the process of change EF in space and some of its laws.

For comprehensive research in this area is necessary to create sensors and systems (multi-sensor and multi-channel) with digital signature, is able to give continuous information in any place of their installation. In particular it needs to be done and for projects related to electromagnetic compatibility of equipment and the increasing risk associated with increasing number of emitting household equipment, its electromagnetic effect on the human environment.

VII. LITERATURE

1. Imyanitov I. M. Devices and methods for the study of atmospheric electricity. M: Gostekhizdat, 1957. - 483 p.

2. Imyanitov I. M., Chumarina E. V. Electricity of the free atmosphere. Leningrad: Gidrometeoizdat, 1965. – 240 p.
3. Afinogenov L. P., Grushin S. I., Romanov V. E. Apparatus for research in the atmospheric surface layer. - L.: Gidrometeoizdat, 1977. - 319 p.
4. Shvarts Ya. M. Rotary converter of the atmospheric electric field to AC current. Copyright certificate №558241 G01W1/16. Published 15.05.1977. Bulletin of inventions No. 18.
5. Zykov M. V., Yunda T. N. The analysis of the input circuit of the electrometer with reverse connection // Metrology, 1981, №5. P. 58-62.
6. Sensor of electric field intensity "FIELD-2". Technical description and manual. Leningrad: USSR State Committee for Hydrometeorology, 1989. – 35 p.
7. A device for measuring electric field strength. Technical description and user manual. Rostov-na-Donu: Radiation physics environmental center, research Institute of physics, Rostov state University, 1990. – 5 p.
8. RD 52.04.168-2001. The observations of atmospheric electricity. Methodical instructions. 2002. – 31 p.
9. Grunskaya, L. V., Electromagnetism surface layer and its relationship with geophysical and astrophysical processes. Vladimir: Posada, 2003. -103 p.
10. Electric field meter Vaisala EFM550. Prospect of VAISALA. – 4 p. (www.vaisala.com)
11. Anisimov S. V. Device for measuring the electrical conductivity of the atmosphere. RF patent № 2397515 G01W1/16 G01R29/12. Posted 20.08.2010.
12. Kopeikin V. V. Use of surface electric field for detecting underground inhomogeneities // Geomagnetism and Aeronomy. Moscow: Nauka, 2011. Volume 51, No. 5. P. 690-694.
13. Kiriakov V. Kh., Lyubimov V. V. Digital magnetic automatic variation station // Dynamika naukowych badan – 2012 / Materiały VIII Międzynarodowej naukowo-praktycznej konferencji 07 – 15 lipca 2012/ Fizyka. Vol.22, Przemysl. 2012. S. 31-35.
14. Lyubimov V., Kiriakov V. Digital autonomous automatic station/Exhibition centre of the Russian Academy of Sciences. M. 2012 (http://www.expo.ras.ru/base/prod_data.asp?prod_id=5300).
15. Lyubimov V. V. Electrometric variometer // Sensors and Systems / Design and manufacture of sensors, devices and systems. New appliances. M: "OOO SenSiDat", 2014. No.2. P. 47-48.