RESULTS OF EXPERIMENTAL RESEARCHES OF METROLOGICAL CHARACTERISTICS NANOELECTRODES FOR MEASUREMENT OF ELECTRIC FIELDS OF THE GROUND AND BIOPOTENTIALS OF THE PERSON

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Measuring of constant electric fields of the Earth spend with the purpose of detection of anomalies of an electric field of the Earth at geophysical measurements. In medicine measuring of superficial biopotentials it is widely applied to functional diagnostics of various bodies and fabrics of the person, however diagnostics on values of constants and lowfrequency potentials in an organism of the person is absent in practical public health services.

The frequency range of investigated biopotentials reaches from 0,01Hz and above (up to 20000Hz at research of hearing of the person).

Not less important problem is also ecological monitoring of a condition of the Earth and socially-hygienic monitoring in public health services.

The problem consists in improvement of quality of measurement of electric constant fields of the Earth and biopotentials of the person.

Quality of measurements depends on stability of electrode potential on a direct current, contact and polarizing properties of electrodes.

Now lead electrodes are applied to measurement of constant fields of the Earth and liquid copper-zakisny. Lead electrodes are ecologically unsafe. In medicine electrodes are applied metal, silver, chlorine-silver.

Developed nanoelectrodes are based on manufacturing techniques chlorine-silver of electrodes on the basis of porous ceramics (manufacture of Tomsk Polytechnic University, Scientific Research and Development Institute of Introscopy) and modern nanotehnologies and nanomaterials.

The basic metrological parameters of the nanoelectrodes are: the drift of the difference of electrode potentials at constant current, polarization voltage of the electrodes, the impedance of the electrodes.

The two electrode cells EC_1 and EC_2 - "electrode-electrolyte-electrode" were investigated during several days.

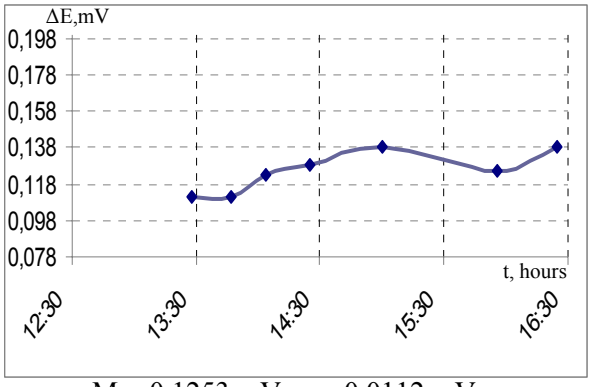
The measuring the drift electrode potential at the constant current were carried out using device for the automated testing of medical electrodes DTE-2 (Certificate number 33700, registered in the State register of measuring instruments under № 39325-08).

The dependences of electrode potential drift, obtained at the cell EC1 are presented on the fig. 2a,b,c shows. The dependences of electrode potential drift, obtained at the cell EC_2 are presented on the fig. 2a,b,c.

The graphics also shows the average values M, the average square deviations σ, the maximum deviations from the average values towards higher values (+ ΔXmax) and the maximum deviations from the average value toward lower values (-ΔXmax).

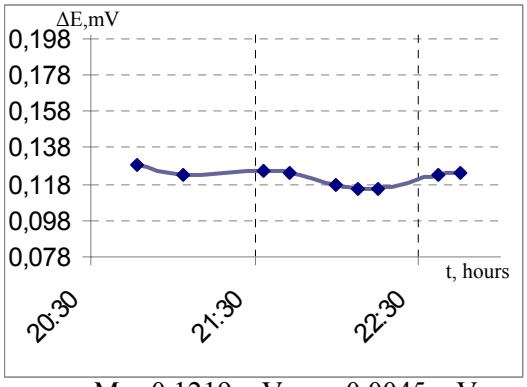
The maximum deviation in the direction of positive values is 0,0136 mV, the maximum deviation in the direction of negative values is (-0,0140) mV, the maximum average square deviation is 0,0112 mV.

Drift with the current of ≤ 1nA is equal (1-3) nV/sec.



M = 0,1253 mV; σ = 0,0112 mV;

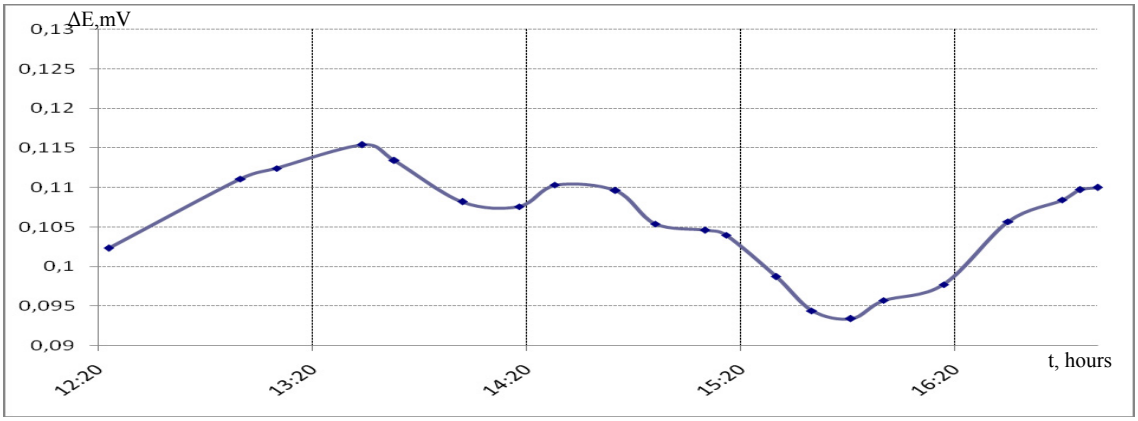
$+\Delta X_{max}$ = +0,0136 mV; $-\Delta X_{max}$ = -0,0140 mV



M = 0,1219 mV; σ = 0,0045 mV;

$+\Delta X_{max}$ = +0,0032 mV; $-\Delta X_{max}$ = -0,0098 mV

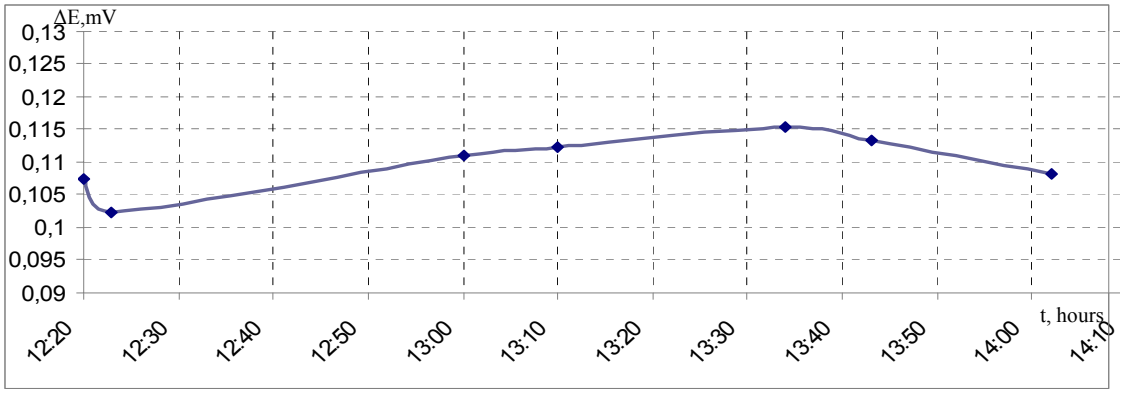
a) 1 day



M = 0,1056 mV; σ = 0,0064 mV;

$+\Delta X_{max}$ = +0,0098 mV; $-\Delta X_{max}$ = -0,0122 mV

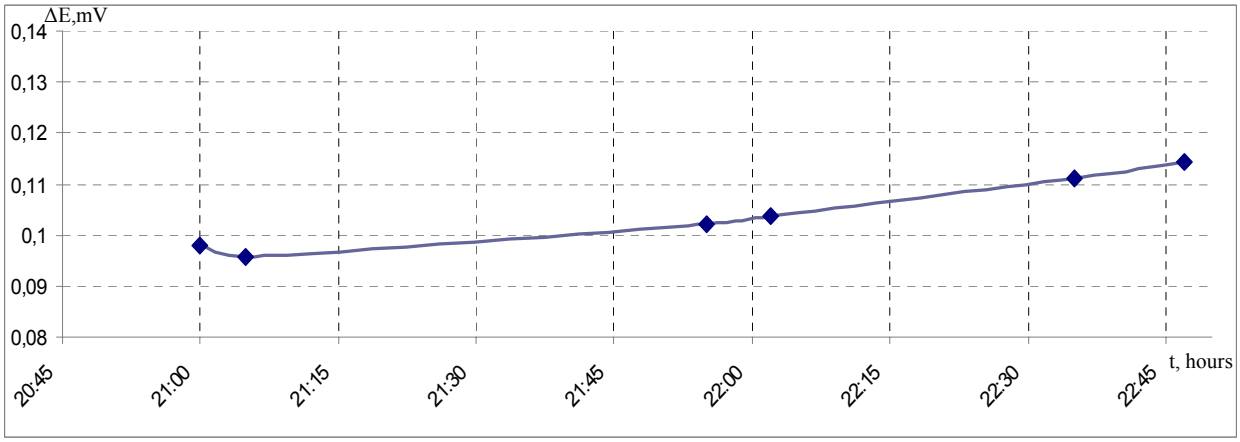
b) 2 day



M = 0,1100 mV; σ = 0,0044 mV;
$+\Delta X_{max}$ = +0,0054 mV; $-\Delta X_{max}$ = -0,0077 mV

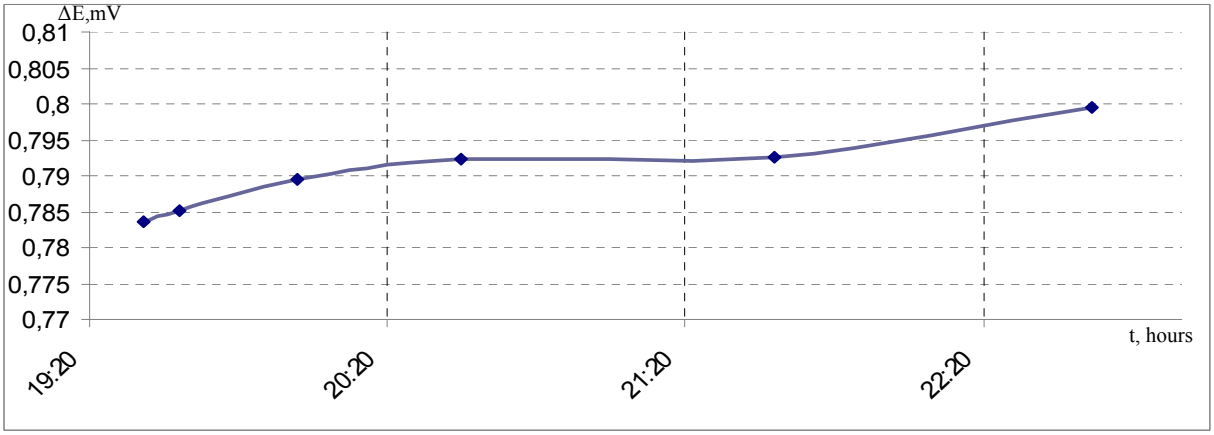
c) 3 day

Fig. 1a,b,c. Electrode potential from time of the electrode cell EC_1



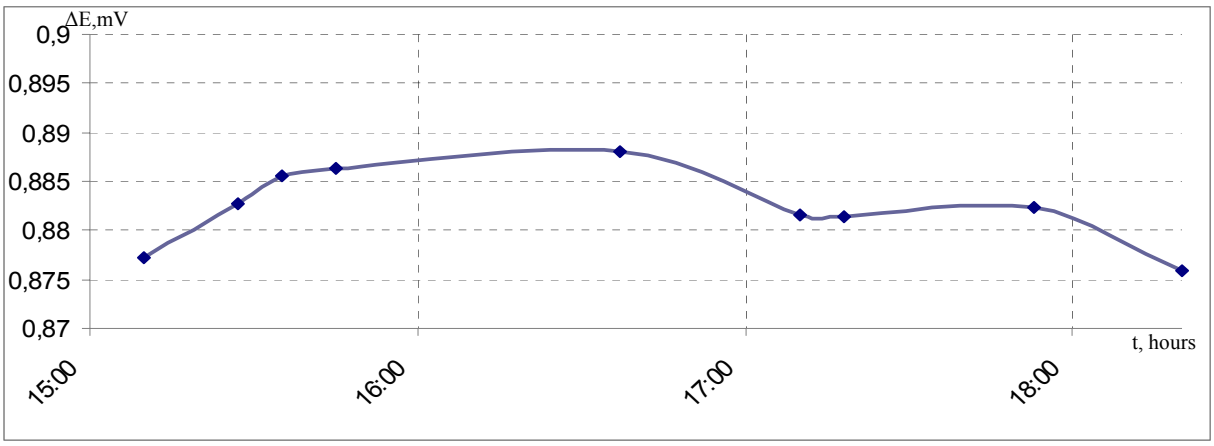
M = 0,1042 mV; σ = 0,0073 mV;
$+\Delta X_{max}$ = +0,0102 mV; $-\Delta X_{max}$ = -0,0086 mV

a) 1 day



M = 0,7904 mV; σ = 0,0057 mV;
$+\Delta X_{max}$ = +0,0090 mV; $-\Delta X_{max}$ = -0,0069 mV

b) 2 day



M = 0,8823 mV; σ = 0,0040 mV;
$+\Delta X_{max}$ = +0,0057 mV; $-\Delta X_{max}$ = -0,0064 mV

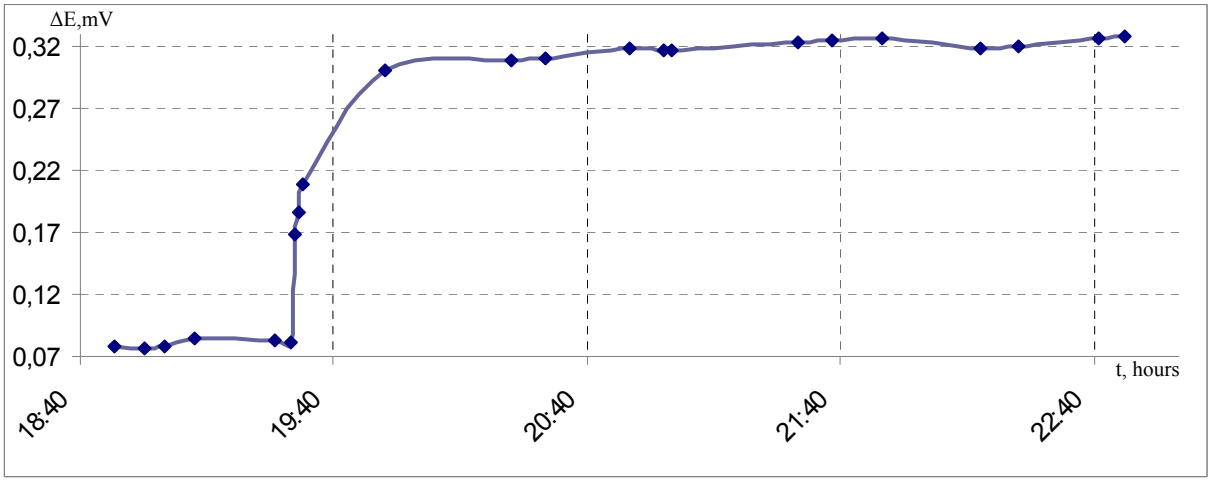
c) 3 day

Fig. 2a,b,c. Electrode potential from time of the electrode cell EC_2

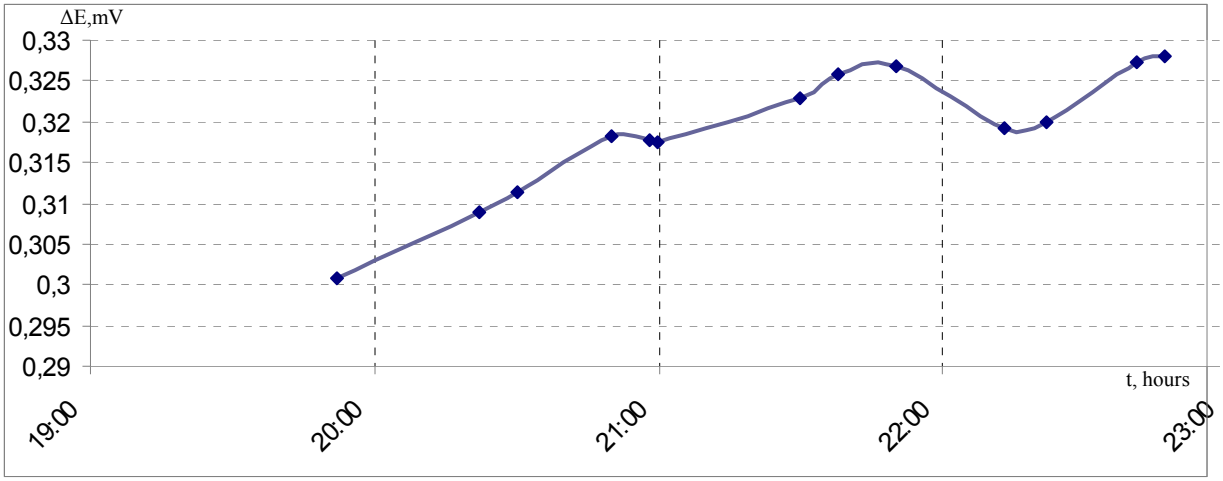
The permissible value of the DC between two electrodes set on the human body is equal 0,1 μA[1-3].

The dependences of the electrode potential drift, obtained at the cell EC_1 at the current 0,1 μA, are presented on the Fig. 3a,b, the dependencies for EC_2 are presented in Fig. 4a,b.

The drift of the electrode potential of EC_1 is 0,005 mV / s; potential change – 0,25 mV, the average value is 0,3188 mV, standard deviation – 0,0080 mV, the maximum deviation in the direction of positive values is 0,0092 mV, the maximum deviation in the direction toward negative values (- 0,0018) mV.



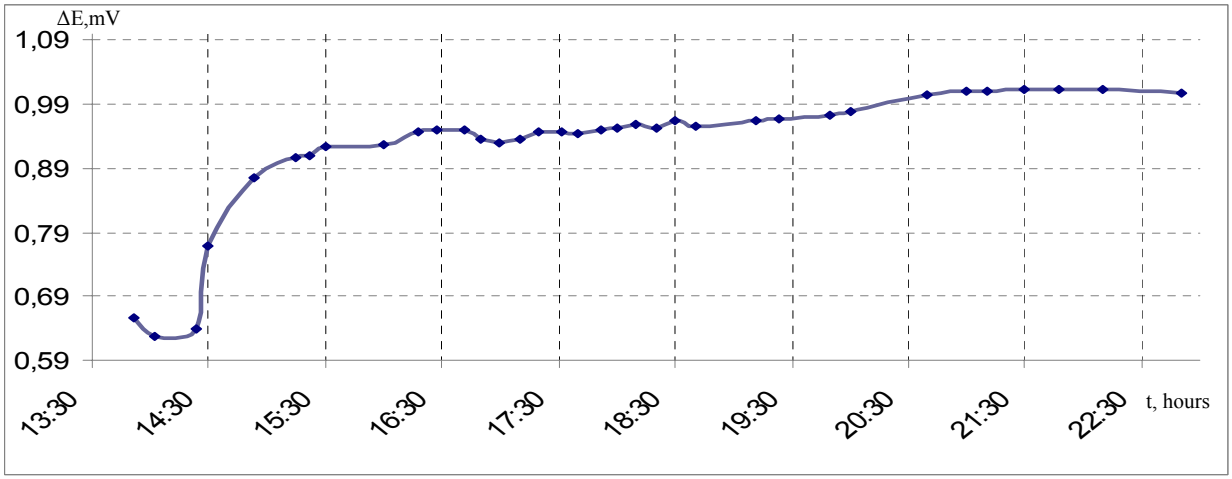
a)



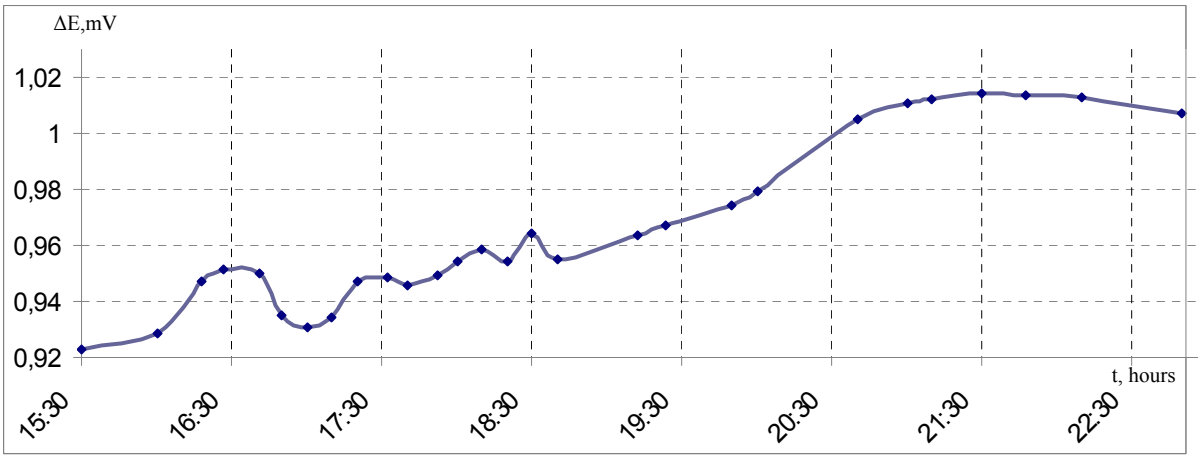
M = 0,3188 mV; σ = 0,0080 mV;
$+\Delta X_{max}$ = +0,0093 mV; $-\Delta X_{max}$ = -0,0180 mV

b)

Fig. 3a,b. The drift of the electrode potential difference EC_1 from the time at the current 0,1 μA



a)



b)

Fig. 4a,b. The drift of the electrode potential difference EC_2 in the time at the current of 0,1 μA

The drift of the electrode potential EC_2 is equal 0,01 μV/s; the potential changing - 0,3 mV, the average value is 0,9655 mV, the average square deviation – 0,0295 mV, the maximum deviation in the direction of positive values is 0,0484 mV, the maximum deviation in the direction of negative values is (- 0,0425) mV.

The method is using in the medical and the geophysical equipmens based on the constant current flowing through the system «electrode - object – electrode», the value of which reaches a value 10 μA.

The studies of polarization voltage from the value of direct current were carrying out in a range from 0,1 mA to 10 mA.

Polarization voltage ΔUp is:

$$\Delta U_p = U_2 - U_1,$$

where U1 - the difference in the electrode potentials under the influence of the constant current ≤ 1nA;

U2 - the difference in the electrode potentials under the influence of the constant current > 1nA.

Dependence of the polarization voltage ΔUp electrode cell EC1 from the value of DC is shown in Fig. 5.

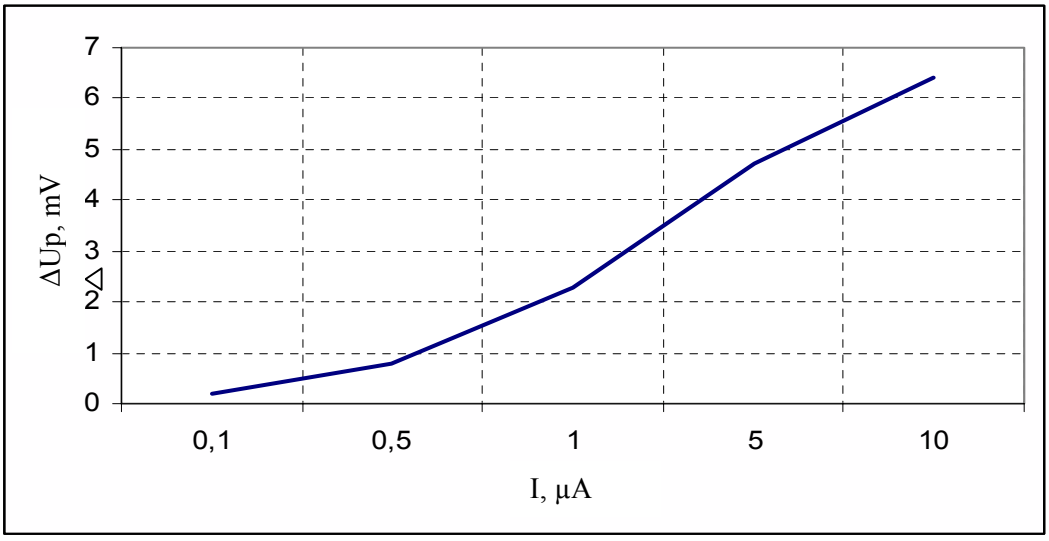
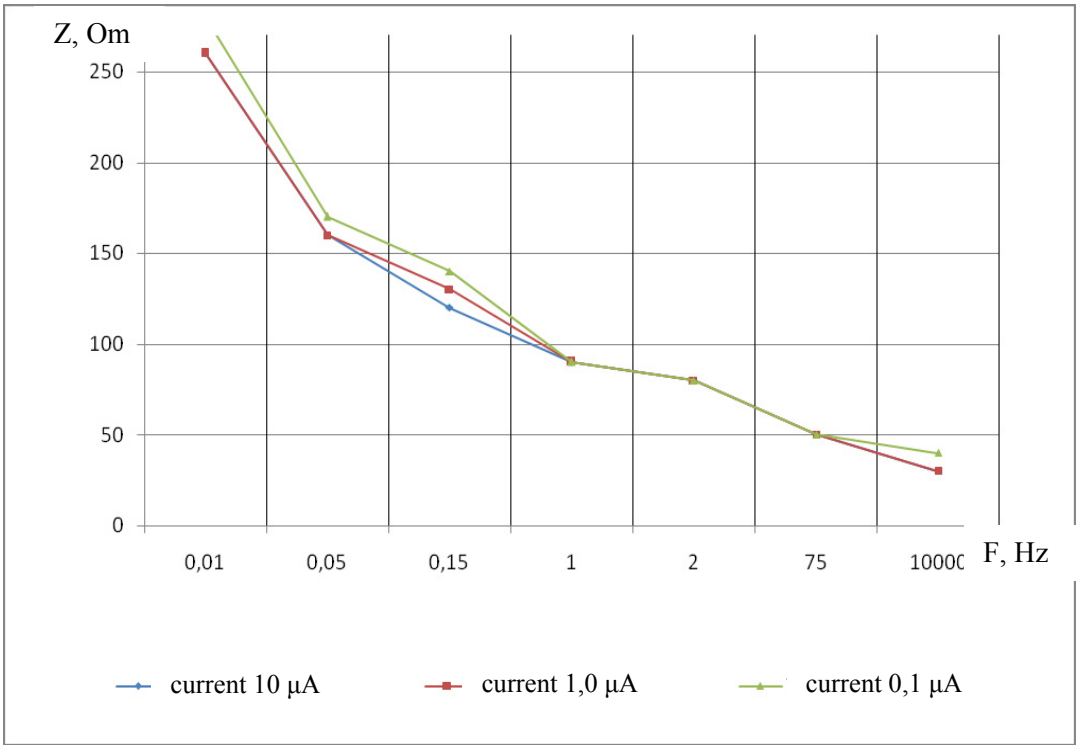


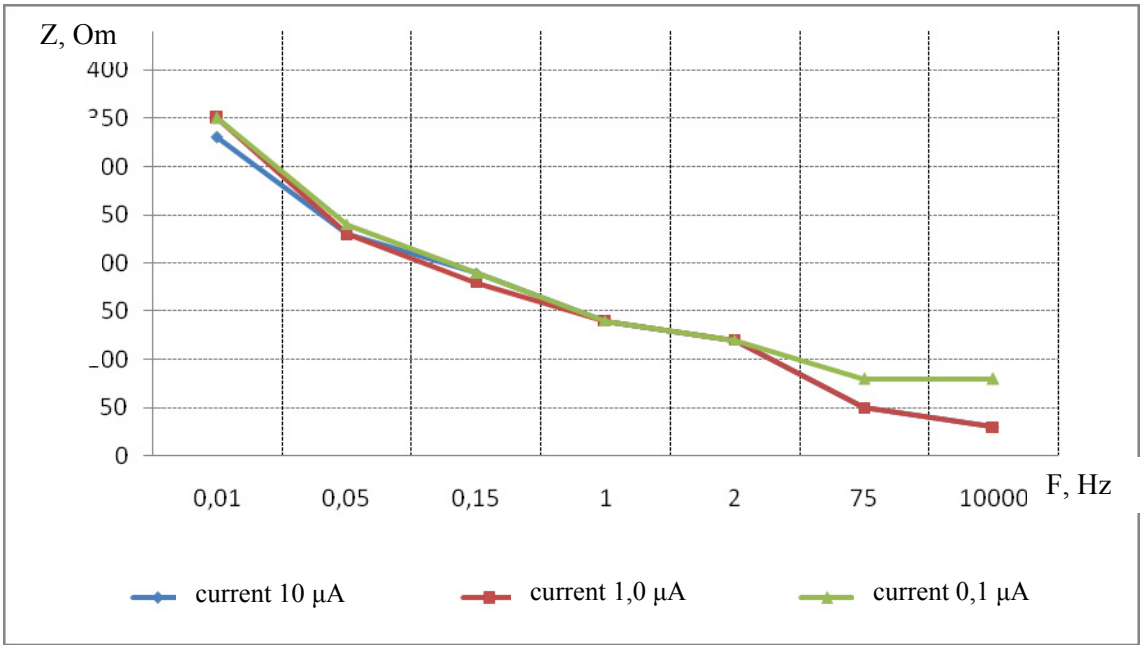
Fig. 5

The measuring of the impedance of the electrode cells EC_1 and EC_2 were carrying out using the device for the automated testing of medical electrodes DTE-2, the measuring currents - 0,1μA; 1 μA and 10μA; frequencies, Hz – 0,01; 0,05; 0,15; 1; 2; 75; 10000.

The results are shown in Fig. 6a,b.



a) EC_1



b) EC_2

Fig. 6a,b. The dependences of the electrode impedance from the frequency at the different measuring currents

The nanoelectrodes for the various purposes are presented on fig.7a-p for geophysical and medical instrumentation.

Fig 7a. The geophysical nanoelectrodes

Fig 7b. Nanoelectrode ЭСК-01/н

Fig 7c. Nanoelectrode ЭСК-03/н

Fig 7d. Nanoelectrode ЭСК-02/н1

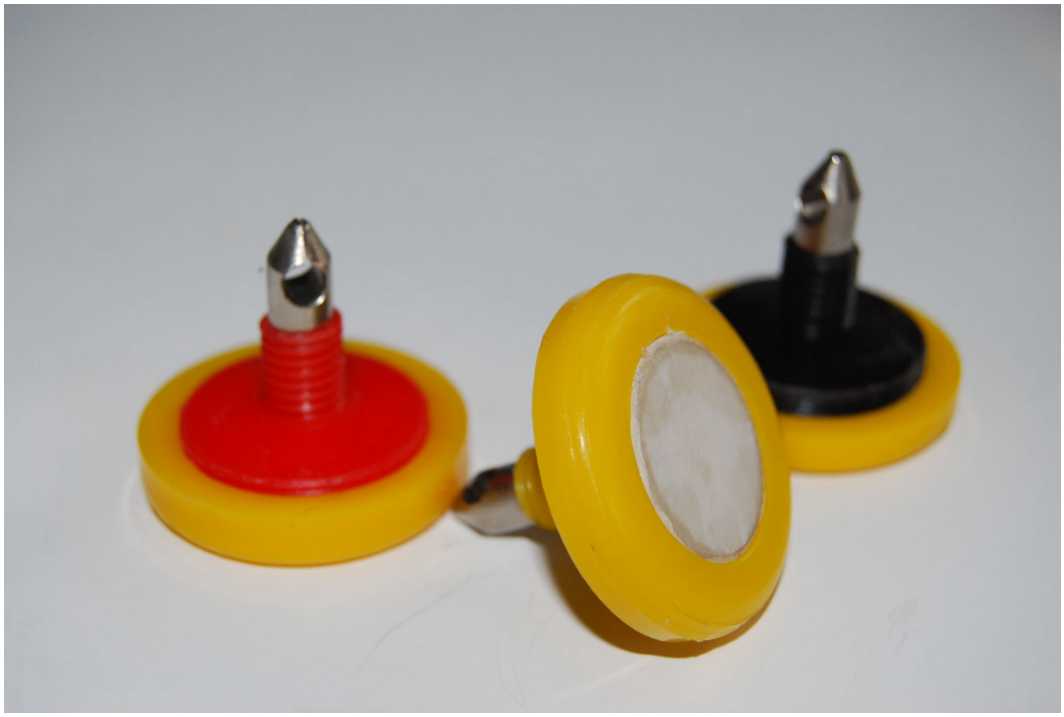


Fig 7e. Nanoelectrode ЭСК-02/н2

Fig 7f. Nanoelectrod eЭСК-02/н1 in assembly

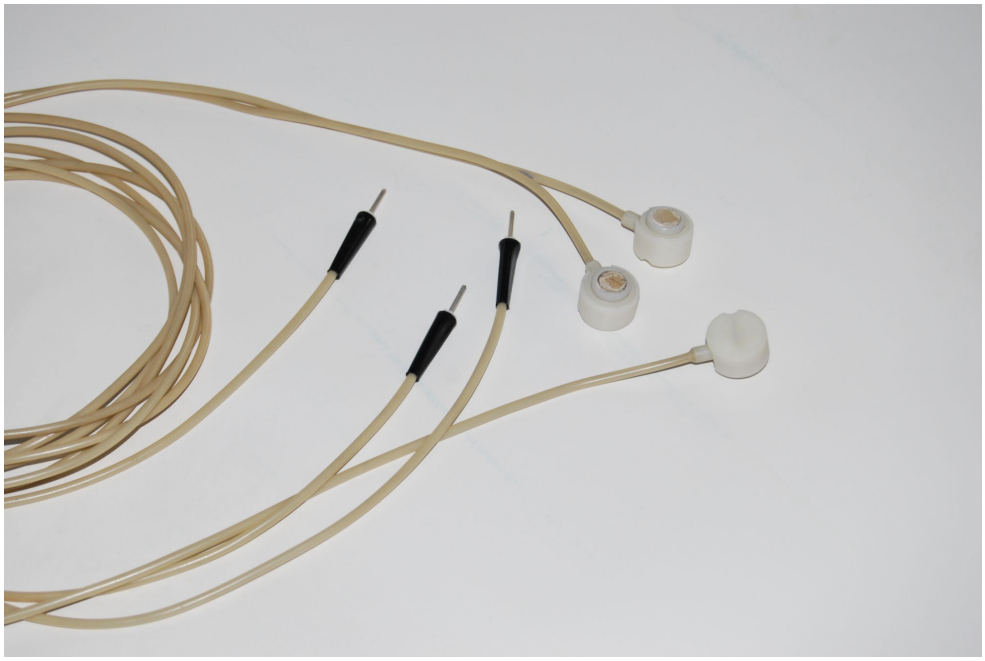


Fig 7g. Nanoelectrode ЭСЭГ-1/н2

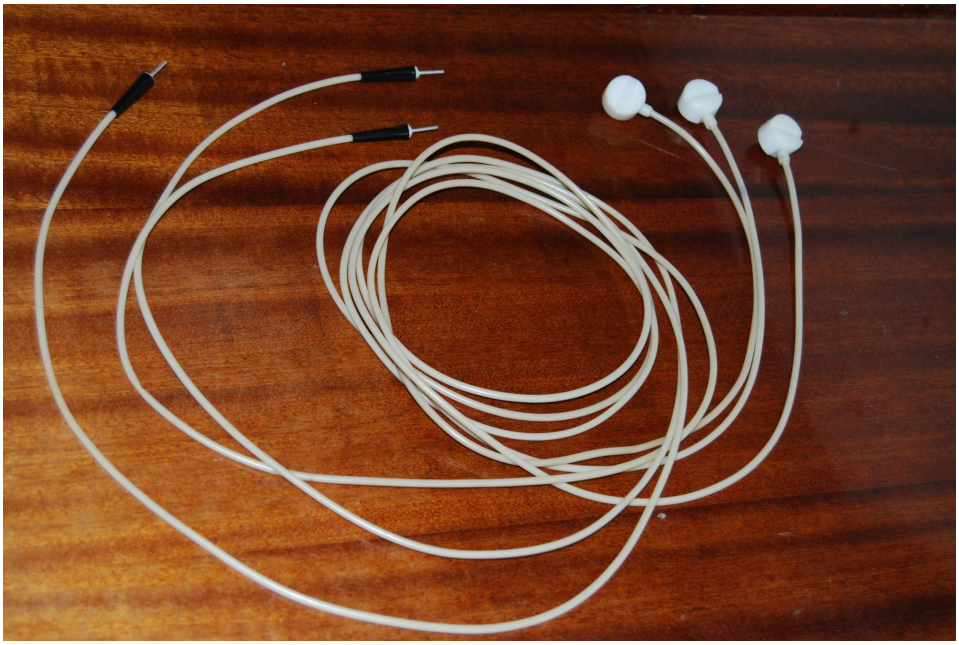


Fig 7i. Nanoelectrode ЭСЭГ-1/н2 – top view

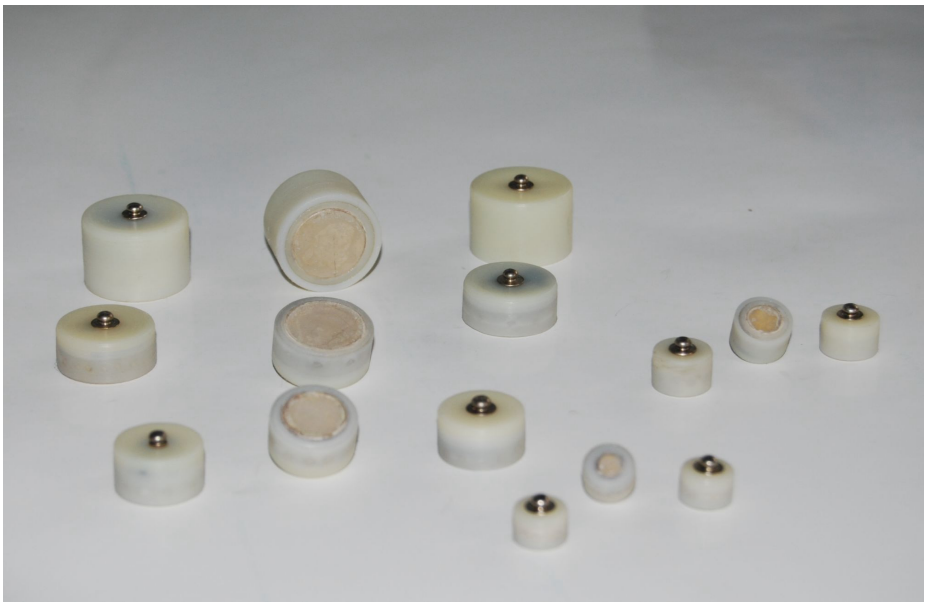


Fig 7k. Nanoelectrodes with button diverting

Fig 7l. Nanoelectrodes ЭСМГ-1/н1

Fig 7m. Nanoelectrodes ЭСМГ-1/н2

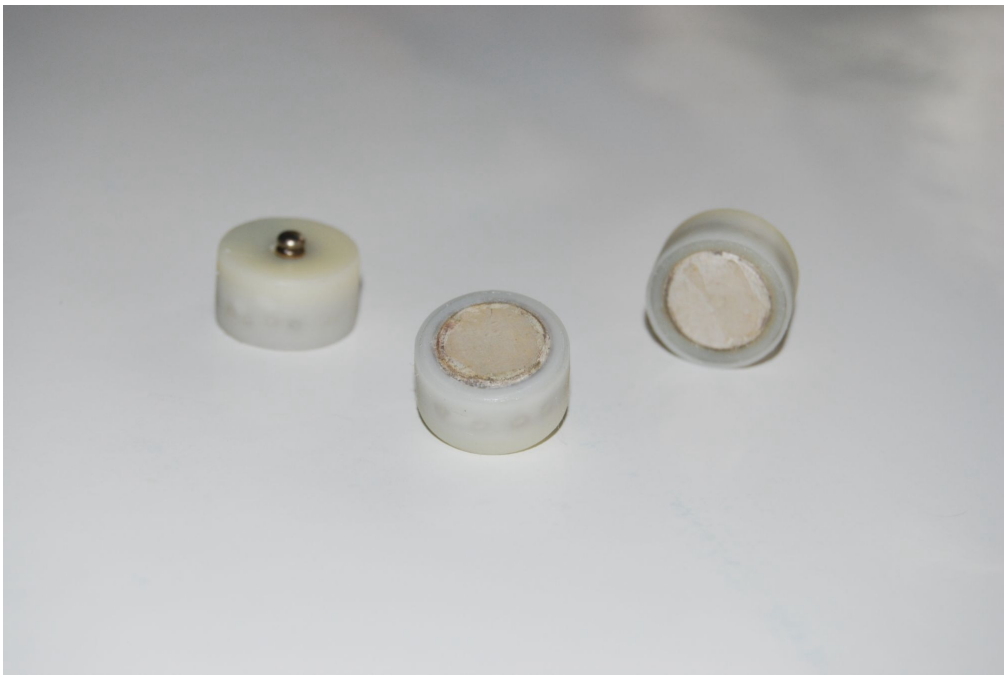


Fig 7n. Nanoelectrodes ЭСМГ-1/н3

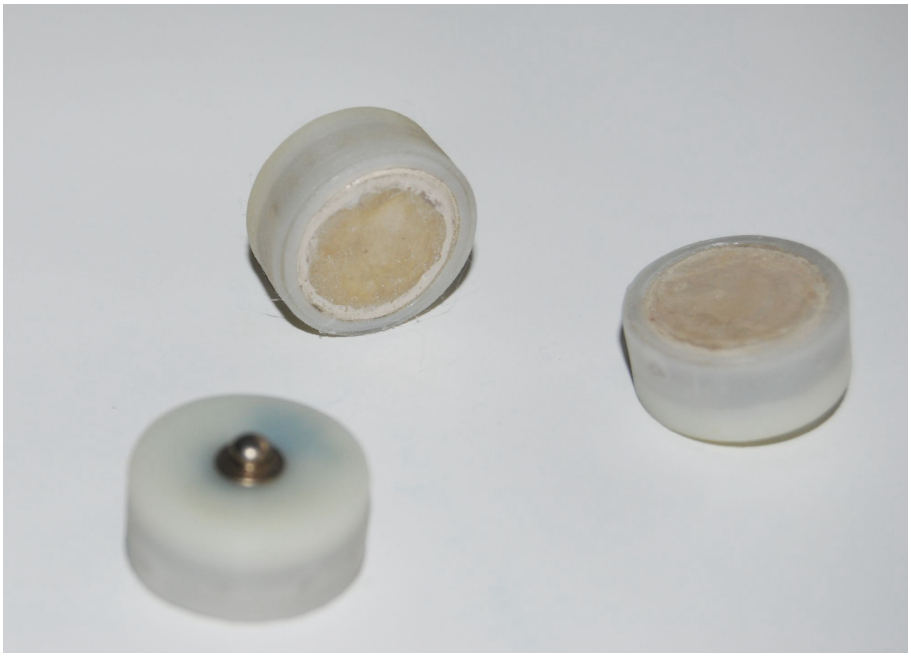


Fig 7o. Nanoelectrodes ЭСМГ-1/н4

Fig 7p. Nanoelectrodes for ECG with limb

It is possible to do the following conclusions on the basis of nanoelectrodes metrological researchings:

1. Nanoelectrodes have a high stability of the electrode potential in time at the current ≤ 1nA and at the current 0,1 μA.

The drift of the electrode potential at the current ≤ 1nA is equal (1-3) nV/sec.

The drift of the electrode potential at the current 0,1 μA is equal (5 ÷ 10) nV/sec.

2. Polarization voltage of the nanoelectrodes under the influence of a constant current 0.1 μA is equal (0,2 ÷ 0,3) mV and is not change with the prolonged force by the current.

3. Polarization voltage of the nanoelectrodes at the currents from 0,1 μA to 10 μA is varies from 0,2 mV to 6,4 mV.

4. Nanoelectrode resistance is equal the tens and the hundreds ohm depending from frequency and is not dependent from the value of the current at the frequencies < 1Hz.

Literature

1. GOST 19687-89. The devices for the measuring of the heart bioelectric potentials .

2. GOST R 50267.0-92 (IEC 601-1-88). The medical electrical devices. Part 1. The general safety requirements.

3. GOST R IEC 60601-1-1-2007. The medical electrical devices. Part 1-1. The general safety requirements. The safety requirements for the medical electrical systems.