Non-Polarized Electrodes LEMI-701

User Manual

LVIV

NON-POLARIZED ELECTRODES. DESCRIPTION AND USER MANUAL

The lead-free non-polarized electrodes LEMI-701 are destined for the measurement of the electric field variations in the soil.

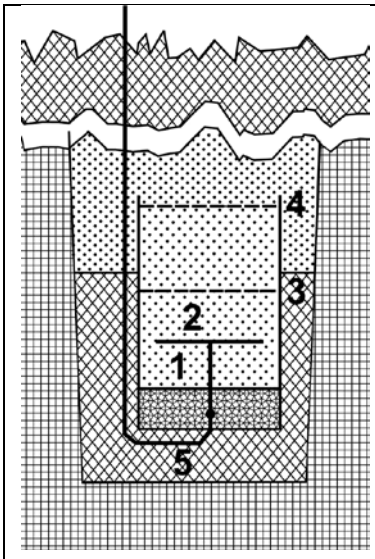
The quality of the electrodes used for the measurement of electric field horizontal components at magnetotelluric (MT) sounding of Earth's crust is the main limiting factor to raise the resolution of MT survey and, correspondingly, the credibility of the constructed Earth crust electric models. Different types of electrode constructions are used, as well as different materials are applied to provide as low as possible electrode noise, especially long-term drift. The most widespread between the materials to manufacture a non-polarized electrode are combinations Ag-AgCl and Pb-PbCl (Petiau and Dupis, 1980), by this the last one is reported to be the best one (Petiau, 2000).

Recently, the new law is adopted in Europe demanding elimination of lead and lead composites from use in every application. This forced to renew the study of other possible electrodes construction and materials. As a starting point, a Schlumberger electrode based on copper and copper sulphide ($Cu\text{-}CuSO_4$) was accepted. Its drawbacks were studied (Korepanov and Svenson, 2007), and new improved non-polarized electrode construction based on $Cu\text{-}CuSO_4$ combination was developed.

Our long-term study revealed that the new LEMI-701 geophysical electrodes, besides their ecological safety, also have considerable metrological advantages in comparison with Pb-PbCl ones. To compare, the measured noise of randomly selected pair – recently produced LEMI-701 non-polarized electrodes (Fig.1) was ~20 nV at 1 Hz versus 0.4 μV for Pb-PbCl (Petiau and Dupis, 1980). For a matched pairs selected by using training stand and developed selection procedure, the drift for about 4 months was about 50 microvolt versus 1 mV/month for Pb-PbCl (Petiau and Dupis, 1980). The electrode in transportation container is shown on Fig. 2, the electrode internal structure and recommended installation layout for long-term measurements is given on Fig.3 and the porous ceramic contact surface view – on Fig.4.

Fig. 1. Non-polarized electrode.

Fig. 2. Non-polarized electrode in protective container



1 - electrode
2 - clay + $CuSO_4$ suspension
3, 4 - porous membrane
5 - cable

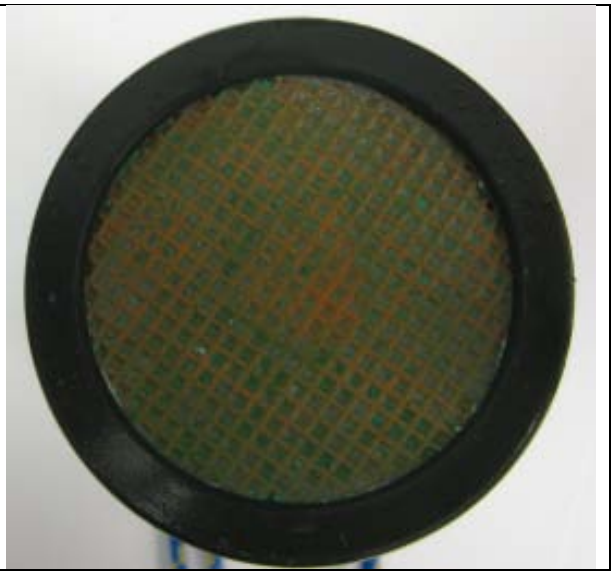


Fig. 3. Non-polarized electrode structure and its installation for long-term survey.

Fig. 4. Electrode ceramic contact surface

The mean plot of LEMI-701 electrode noise density is demonstrated on Fig.5.

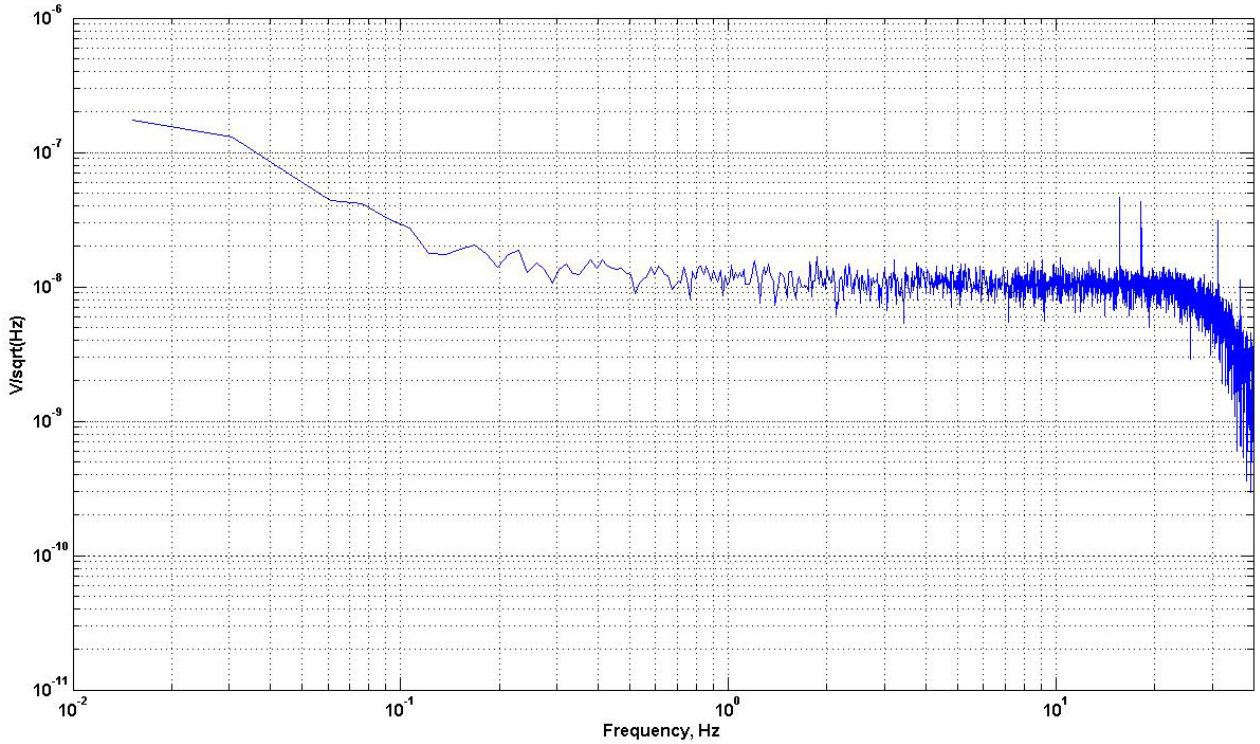


Fig. 5. Electrode spectral noise density.

Next advantage of these electrodes is that, if all requirements given below in the Operation Manual are fulfilled, they do not need any maintenance during all service life.

On Fig.6 the results of short-period (5 days) tests for selected matched pairs are given which show the worst-case rms error about 13 μV!

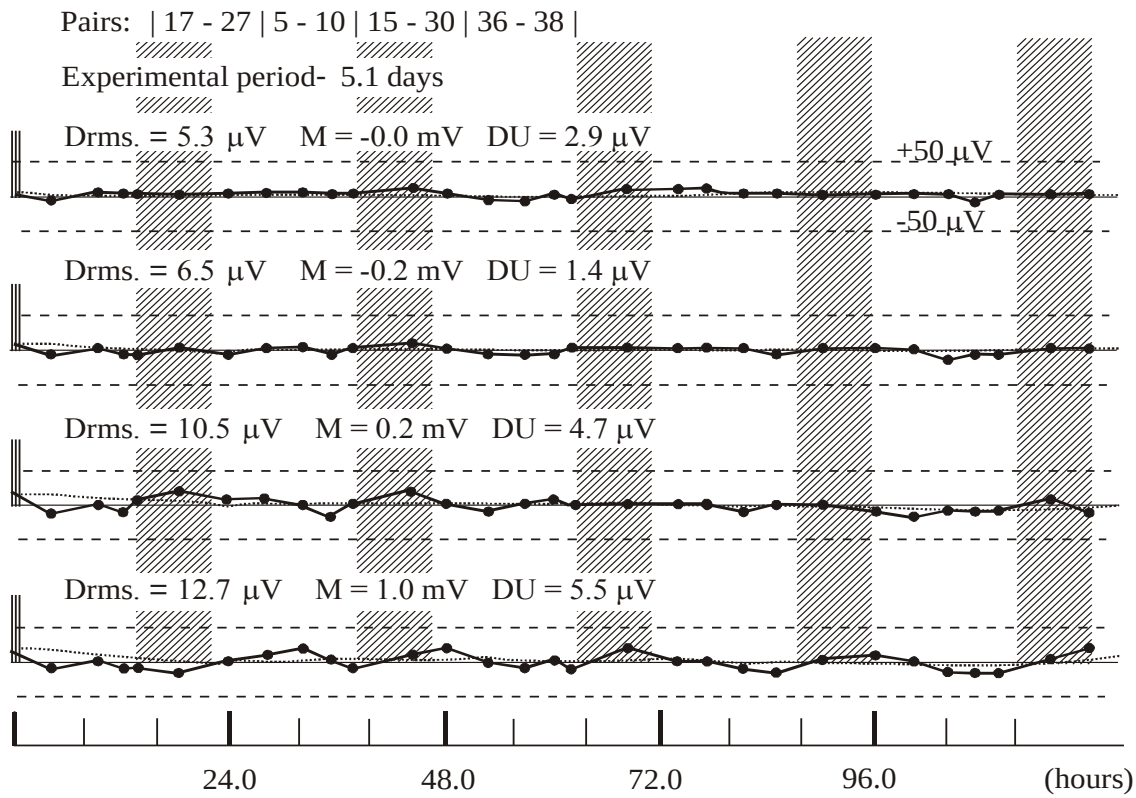


Fig. 6. Drift of selected electrode pairs (short term): Drms – root mean square error; M – baseline shift; DU – averaged dispersion.

On Fig.7 the same tests results, but for longer period - ~ 144 days – are given. Here again, for the worst case Drms ~ 56 microvolt only.

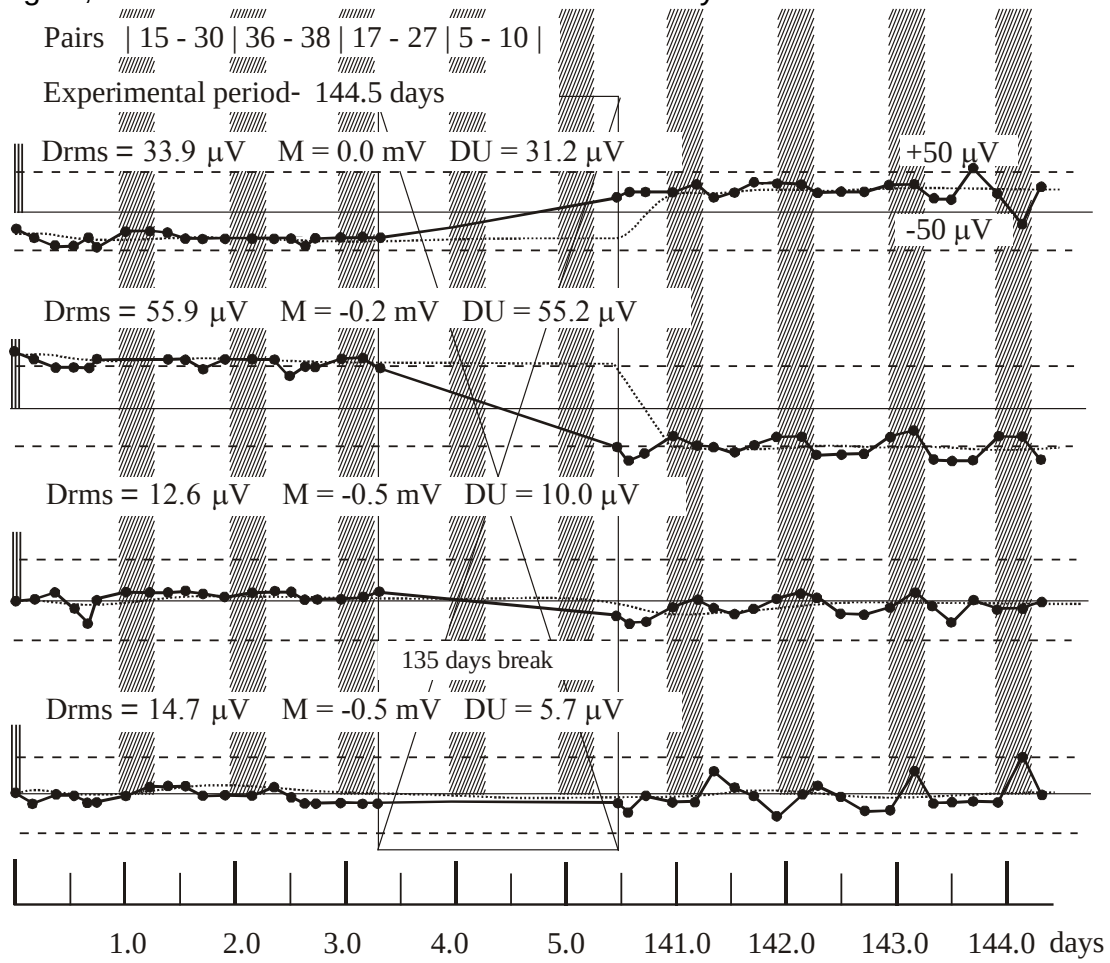


Fig.7. Drift of selected electrode pairs (long term).

Then the next comparison tests of copper, lead and silver electrodes were made during rather long period in laboratory stand with the electrodes based at the combinations of Cu-CuSO4, Ag-AgCl and Pb-PbCl. As it is easily seen, copper electrodes outstrip other types (Fig.8).

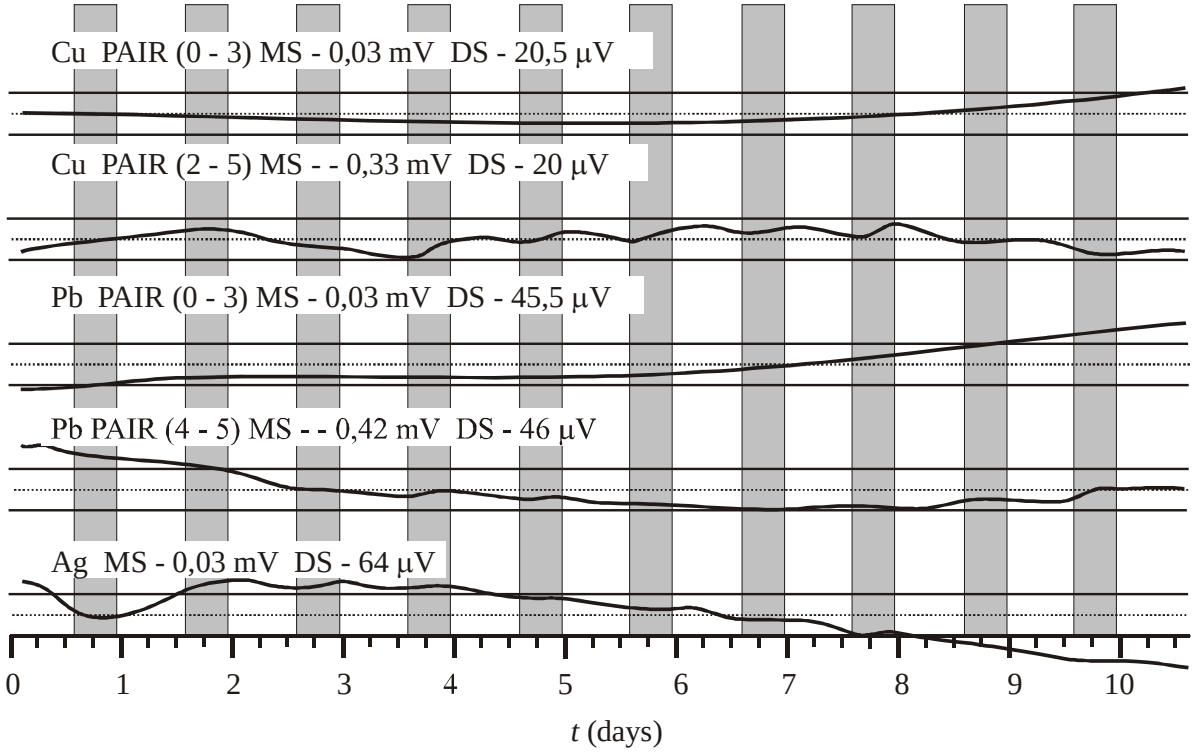


Fig. 7.The results of comparison test of copper, lead and silver electrodes. Here MS is the zero shit and DS is rms dispersion.

REFERENCES

Petiau, G., Dupis, A.., 1980. Noise, temperature coefficient and long time stability of electrodes for telluric observations. Geoph. Prospecting. 28 (5), 792-804.

Petiau, G., 2000. Second generation of lead-lead chloride electrodes for geophysical applications. Pure and Appl. Geophysics, 157 (3), 351-382.

Korepanov, V. E., and Svenson, A. N., 2007. High precision non-polarized electrodes for field geophysical prospecting. NAUKOVA DUMKA, Kiev, Ukraine, 96 p. (in Russian).

Installation Procedure

Special attention has to be paid as to the electrodes installation, especially if long-term measurements have to take place.

1 First, the proper selection of places where the electrodes have to be buried has to be made. It is important to select as much as possible similar places for the arrangement of two electrodes composing one measuring line. The principal requirements are to have the same soil composition, orographic features (i.e., hill-hill or valley-valley, under the tree – under the tree etc.) and especially moisture conditions. Clayish grounds are recommended to select, if possible, for long-term measurements.

2 Then the hole for electrodes installation has to be digged at the selected places. Experimental practice shows that for majority of soils the hole depth about 70-80 cm is enough to avoid daily thermal variations. At the hole bottom it is recommended to make a round deepening with diameter ~7-8 cm and depth ~15-18 cm (a half-liter bottle could be a suitable forming tool for this).

3 Next, the clayish suspension has to be prepared (about 3 liters for each electrode pair). For this light-colored clay has to be taken which does not contain ferrous oxides and calcareous impurities. To check this, about 200 g of a clay has to be diluted by distilled or at least boiled water in plastic can to form the consistency as yoghourt and a 10% $CuSO_4$ solution has to be added, all then thoroughly stirred and left for ~1 hour. The clay will be accepted as suitable if the liquid at the top of the obtained suspension conserves blue color after 1 hour.

4 The necessary amount of suitable clay has to be taken and diluted in a plastic can by 10% $CuSO_4$ solution in as clean as possible water – from rain the best, or from a local spring - to form a yoghourt-consistency suspension (~ 3 liters for each electrodes couple).

5 After this the electrodes taken by matched pairs (which are marked at delivery) have to be removed from their protective transportation containers/cases.

Important!

Each electrode has a tight fit with the container to avoid the leakage of $CuSO_4$ solution with which the soft insert at the container bottom is impregnated what is necessary for electrode parameters maintenance. That is why, to extract the electrode

from the container, pull it gently by hand, softly swinging it all time laterally. Do not pull strongly by cord, this may damage electrode!

6 Put extracted electrodes in the plastic can with the prepared clay-$CuSO_4$ suspension and keep them there all time till the moment of installation in the ground. Several pairs can be placed in one plastic can.

It is recommended, to avoid further mess, to check the electrode pair transient resistance before installation.

For this a voltmeter with input resistance ≥10 MOhm and 10 μV resolution and reference resistor have to be used. First couple the voltmeter to the output wires of electrodes (forming matched pair in the can with suspension) and measure the voltage U1. Then connect to both electrodes outputs the reference resistor R ~ 3 - 5 kOhm for a short time and measure the voltage U2. The value of transient resistance R_I has to be calculated as:

$$R_l = \frac{R(U1 - U2)}{U2}$$

For example, with U1=40 mV, U2=10 mV, R=3 κOhm we get R_I =9 κOhm. Normally, the value of this resistance in the can is within 200-300 Ohm.

7 Then put the electrodes from the plastic can by pairs and place them in the ground as follows: for long-term installation it is recommended to install electrodes “bottom-up” (see Fig. 9a); for short time (up to 1-2 days) in a tilted position (see Fig. 9b).

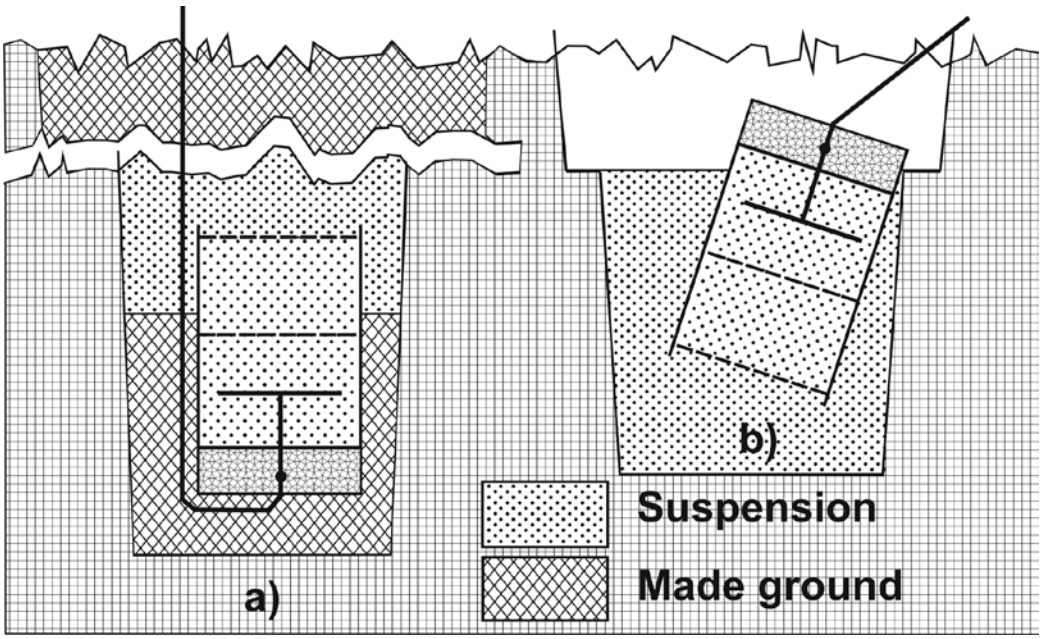


Fig. 9. Electrode installation in operation position: a – long-term; b – short-term.

For such type of electrodes, it is prohibited to install the electrodes in a vertical position with sensitive part below!

This is because Cu-$CuSO_4$ solution in the water may produce free oxygen O_2 due to its dissociation at even tiny currents possibly flowing through the electrodes (the more often observed cause of this is a wrong method of the transient resistance measurement, when the ohmmeter is directly applied to the electrode pair). Then, if the electrode is not tilted, oxygen is gathered below its ceramic partition, so increasing considerably the transient resistance.

8 In order to remove the electrodes safely back after measurements the cord fixed to the electrode top has to be twisted and then, for Fig. 9a installation type, simply fixed to the lateral electrode surface by 2-3 turns of adhesive tape. For Fig. 9b installation type, the cord has to be fixed to the electrode body forming self-tightening noose. All this will help much to pull electrodes back without the fear to damage them, what may occur when these recommendations are not followed, especially for heavy clayish and stony soils.

Just after installation of electrodes in the ground the same procedure of the transient resistance R_I verification possibly with the same R has to be repeated. The recommended value of R_I has to be below 20-50 kOhm for sandy soil and for clayish soil – below 10 kOhm. The field cables have to be connected first to the electrodes output wires. In recent versions a special contact socket with fixation screw is provided (Fig.10)

Fig.10. Electrode contact socket

9 To connect the cable, first the screw has to be released, and then the cable end has to be inserted into the socket and tightly fixed with the screw. For short time installation, it is enough to raise the contact socket above the ground with the help of any means (say, with a wooden Y-shaped stick) and cover with plastic foil bag from

rain. For long term measurements the total contact socket has to be insulated with at least two layers of insulating tape – first with the tape having the highest possible resistivity (Teflon, for example), then with insulating elastic adhesive tape on top.

10 If the contact socket is absent, better do not twist the wires but solder them or connect using special connecting tubes and pressing tool, and the connection place has to be very thoroughly insulated, better by three types of insulating tapes. The lower one has to have the highest possible resistivity (Teflon, for example), then elastic adhesive tape has to be used and finally a rubber self-amalgamated tape. This is especially important for long-term installation; for short-term one the connection places may be again slightly raised above the ground and fixed with the help of wooden Y-shaped stick and covered with plastic foil. Now electrodes are ready for installation.

11 Just before the installation take ~1.5 liters of suspension from the main can, where electrodes were placed during preparation for installation, to other plastic one and mix it with the same amount of the ground taken directly from the hole bottom.

12 Installation according to Fig. 9a (for long-term measurements).

For long-term installation it is highly recommended to protect the electric lines with plastic tubes or dig the lines into the ground at ~ 5 cm. This will help to protect them first of all from lightning, small animals and will not spoil local ecology.

a) Put the electrode in the hole the contact surface up.
b) Put the ground taken from the hole bottom till approximately half of electrode length.
c) Pour the prepared mixture of suspension with ground in the hole in order to cover sensitive part of the electrode by a layer ~3-5 cm.
d) Fill the hole with remaining ground.

After the hole is filled, it is advised to water it with spring- or rainwater taken in the area (approximately 10 liters per one hole) and then cover with a plastic foil about 1x1 meter size. This will protect the electrodes from instantaneous potential changes due to rainfalls.

13 For short-term measurements (up to few days) it is possible to install the electrode in a tilted position (Fig. 9b) in the hole, cover it with the suspension mixed with local ground as above, then again, fill up the hole with the ground taken from the hole and cover it with plastic foil.

14 A special procedure is recommended for dry sand conditions. A plastic can without top (so called “Russian bucket”) has to be filled with local sand impregnated with 10% solution of $CuSO_4$ in local spring or rain water and the electrode has to be

placed inside the can as advised above for short- or long-term installation. Then it is necessary to bury the plastic can in the sand at the depth not less than 1 meter and cover by the sand from the top.

15 For a stony and rocky ground the only solution is to look for local cracks and then try to widen and deepen them. By this the orthogonality of the electric array may be not kept, but measured, then this is easily corrected during the processing.

16 It is possible to use the LEMI electrodes not by matched pairs as recommended, but in this case the initial voltage zero shift of electrode pair may reach unities of millivolt (no more than ~ 10) and its variations may be within ~ 100 microvolt.

17 After measurements it is necessary to wipe every electrode with a wet and clean rag and then to poor a small amount of the 10% $CuSO_4$ solution into the transportation container/case in order to make wet the insert from soft material at the bottom and put there the electrodes up to the end, as shown on Fig.2.

It is recommended that the matched electrodes pairs have to be tied together for storage!