NATIONAL ACADEMY of SCIENCES - NATIONAL SPACE AGENCY of UKRAINE

LVIV CENTRE of INSTITUTE for SPACE RESEARCH

LONG-PERIOD MAGNETOTELLURIC INSTRUMENT LEMI-417M

User Manual

LVIV

Disclaimer notice

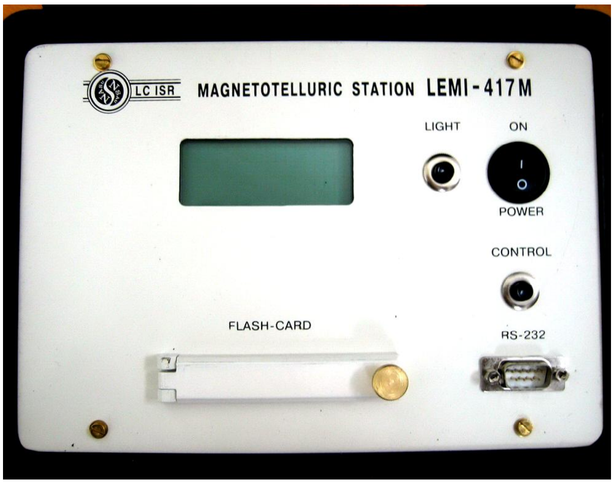
All information in the manual is believed to be accurate. However Lviv Centre of Institute for Space Research can not be held liable for any damage caused by possible inaccuracies in the Manual.

Lviv Centre of Institute for Space Research reserves the right to make corrections, modifications, enhancements, improvements, and other changes to its products at any time and to discontinue any product or service without notice. The Customer is advised to obtain the latest relevant information before placing orders and verify that such information is current and complete.

CONTENTS

1. DESTINATION

The Long-Period Magnetotelluric Instrument (LMTI) LEMI-417M is developed for the super-deep magnetotelluric sounding – the signals with periods of 20…100.000 seconds and more can be picked up with reasonable error. In order to realize such design major attention was paid to such principal parameters as thermal and temporal stability and noise level for magnetic channel and high input impedance and low drift for electric channels. For this the magnetic sensor of flux-gate type, which mainly determines these parameters, was manufactured using well-proved technology on the base of glass ceramics housing implementing recent findings in the excitation circuit construction. The waterproof sensor for field use has the support with bubble level to provide its proper levelling at the selected place (see below, left picture). The observatory and tilt-compensated sensor housing versions are available on demand. For electric channels, a filter-free technology of input stages was accepted in order to let super-long period signals to pass. Also, taking into account recent trends to measure additionally vertical component of telluric field or the component along some local geological structure, four electric channels are procured.



General view of delivery set of LMTI LEMI-417M (field version)

2. MAIN TECHNICAL PARAMETERS

Measured range of total magnetic field	± 68000 nT
Resolution along each component both at the display and registered into the internal FLASH-memory	0.01 nT
Temperature drift	<0.2 nT/°C
Frequency band for magnetometer (first-order LF filter)	DC-0.3 Hz
Frequency band for electrometer (fourth-order LF filter)	DC-0.15 Hz
Magnetometer output noise in frequency band (0.03…0.3) Hz	< 15 pT rms
Magnetic sensor components orthogonality error	<30 min of arc
Automated offset compensation band along each magnetic component	±68000 nT
Measured range of electric signal (every of 4 components)	±600 mV
Resolution of electric meter along each component	0.075 μV
Noise of electric meter in the frequency band (0.03…0.3) Hz	<1 μV rms
Sample rate	1 per s
Volume of the internal FLASH-memory	2 GB
Digital output *	RS-232 (RS-422)
GPS timing, coordinates and altitude determination (antenna cable length 3m **)	
Operating temperature range	Minus 20 to +60°C
Temperature sensors (both in magnetic sensor and electronic units) resolution	0.05 °C
Power supply	$+12^{+6}_{-3}$ V
Power consumption	<1.2 W
Weight:	
Sensor with 10 m cable	1.8 kg
Electronic unit	2.0 kg
Lightning protection unit	1.1 kg

* May be selected by user
** Other length on demand

3. DELIVERY SET

The delivery set of LEMI-417M LMTI includes:

- Flux-gate Magnetic Sensor with Cable and Installation Platform
- Electronic Unit
- Terminal Box with Lightning Protection
- GPS Antenna with Cable and Holder
- PC Connection Cable (double-side connector)
- Power Supply Cable (with one-side connector)
- Card-reader (optional)
- Technical Description and Operation Manual
- Control Software
- Non-polarised Electrodes (optional)

LEMI-417M set in a shipping container

4. SERVICE AND SHELF LIFE AND GUARANTEE

Mean lifetime of the LEMI-417M LMTI – about 10 years.

The term of guarantee is 18 months after delivery if all requirements of the present instruction as to applied voltage, weather conditions, vibrations and shocks are observed. During this term the manufacturer is liable to repair the defects occurred through no fault of the consumer or force majeure, or if not possible to repair, to change the device by other equivalent specimen.

The manufacturer maintains its obligations to make free service and repair the LMTI if necessary for still 2 years. By this the user has to cover the necessary spare parts price and transportation/visit fees only.

LEMI-417M No: _________

DELIVERY DATE: ______________

QUALITY CONTROL:

Name: ***Andrii Prystai***

5. STRUCTURE AND OPERATION

5.1. Construction Description

The LEMI-417M model has FLASH – memory card for data storage, GPS receiver for data sampling synchronization and coordinates determination and RS-232 (or RS-422) digital output for data/commands exchange with external PC. User-friendly operation software is procured which allows controlling of the LMTI, data registration and viewing.

Front panel of LMTI electronic unit (Fig. 1) has minimum number of control and commutation facilities: Power “ON/OFF” switch, buttons “CONTROL” for LMTI control and “LIGHT” - for display illumination, RS-232 connector for data exchange between LMTI and external PC. The connectors for coupling with external battery (“+12V”), GPS antenna (“GPS”), fluxgate sensor (“FG SENSOR”) and electric lines terminal box (“EL.LINES”) are installed on the left side panel (Fig. 2).

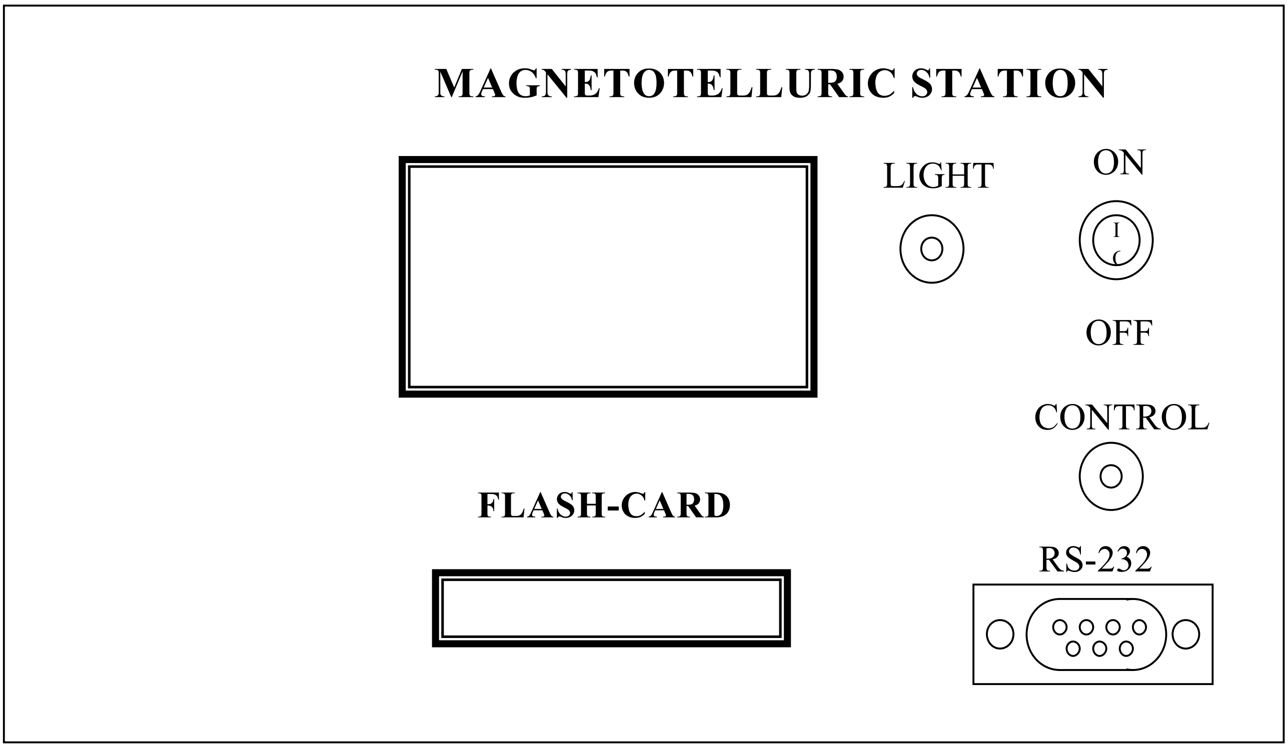


Fig.1. Front panel of LMTI LEMI-417M

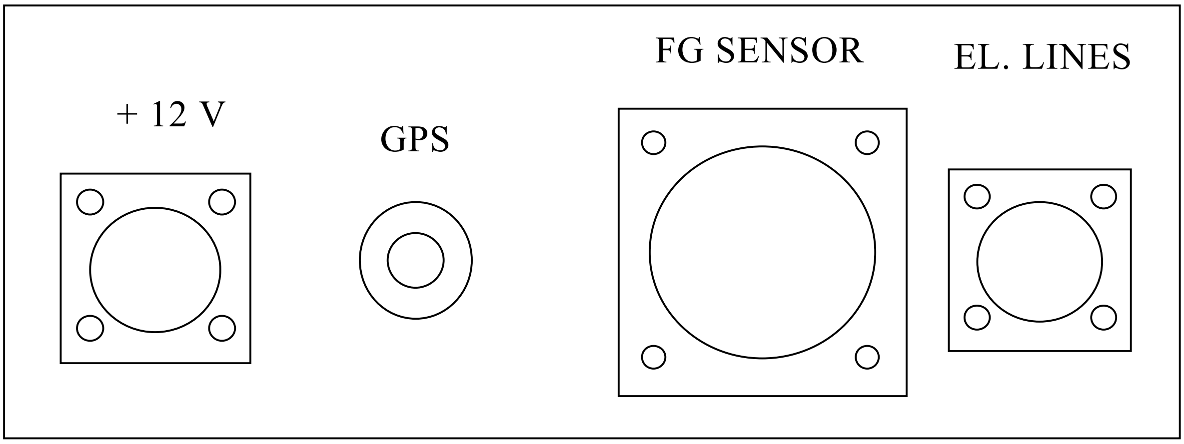


Fig.2. Side panel of LMTI LEMI-417M

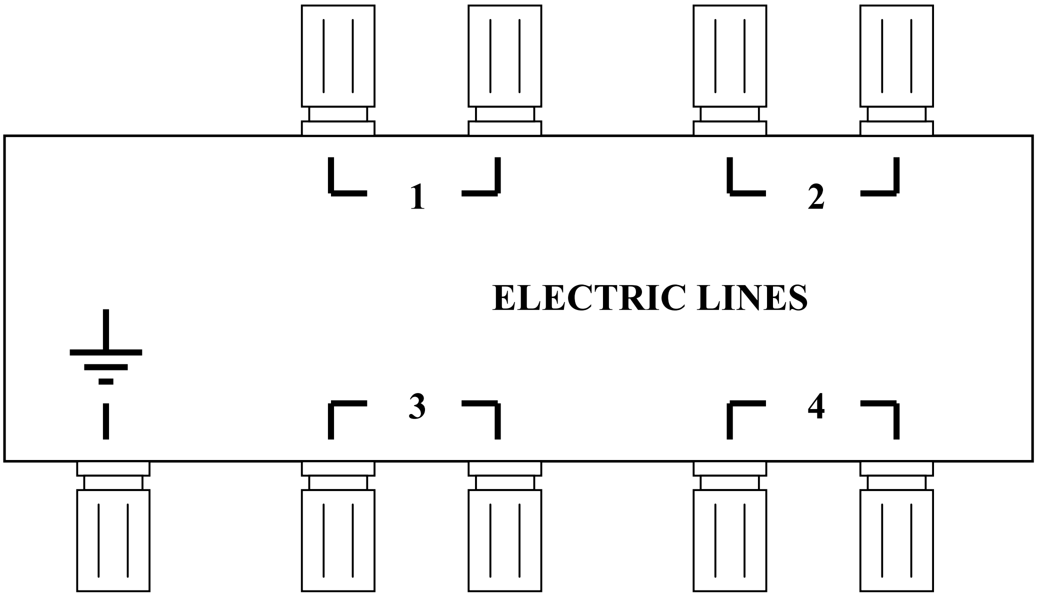


Fig.3. Terminal box with lightning protection for electric lines connection

On the side panels of the electric lines terminal box (Fig.3) the binding posts for four pairs of electric lines and earthing are placed. Red posts correspond to positive direction of electric lines.

The electronic box housing PELI™ 1150 case (IP67 protection group) is waterproof, protected against dust, moisture and rain but mast not be immersed in water! The FG sensor housing is completely sealed and can withstand temporary immersion in water.

The FG sensor unit has three orthogonal sensors fixed in one body.

Each sensor consists of flux-gate probe in the shape of racetrack (40 mm long), the core of which is made from low-noise μ-metal tape. Special means are applied to make the initial non-orthogonality of magnetic axes not worse than 30 minutes of arc. After calibration the non-orthogonality can be known with error less than 2 minutes of arc and this error does not change during all inter-calibration period.

The body of the sensor is made of glass ceramic with extremely low thermal expansion factor and is sealed hermetically with silicon compound inside the housing made of PVC. The compensating windings are wound on the frame made from the same glass ceramic material. The sensor has a thermometer inside the housing to monitor the temperature. The thermometer data, after LMTI calibration, can be used to reduce LMTI magnetometer thermal drift to negligible value.

The flux-gate sensor and the electronic unit are calibrated in pair as one complete set. Using the same units from different LMTI sets may decrease the accuracy of measurements!

The special non-magnetic connectors are used in the FG sensor for the cable coupling.

It is strongly recommended to remain them coupled all the time!

These connectors may be uncoupled only in case only in case of replacement of the damaged cable, using following procedure: one should remove (cut off) the protective heat shrink tube from the connectors at the top of the sensor, unpack a new cable and change the damaged one. The coupled connectors must be secured back by a new piece of heat shrink tube using a hot air gun.

Any shocks with acceleration more than 5 g both for sensor and electronic unit are not admissible. Especially it is necessary to avoid the fall of the sensor by the lateral side!

5.2. Functional Diagram Description and Operation

LMTI functional diagram is given on Fig. 4. The 3 components FG magnetometer is connected to the microcontroller MC1 through digital port UART1. 4 channels telluric field meter is connected to MC1 through digital isolators of port UART2. LMTI has Compact FLASH memory card, LCD display, GPS synchronization and control means connected online with MC1. The data exchange with external PC is realized through serial interface (RS-232 port). The overall stability of the LMTI electronics, both of magnetic and electric channels, is provided by using best available voltage reference and other components.

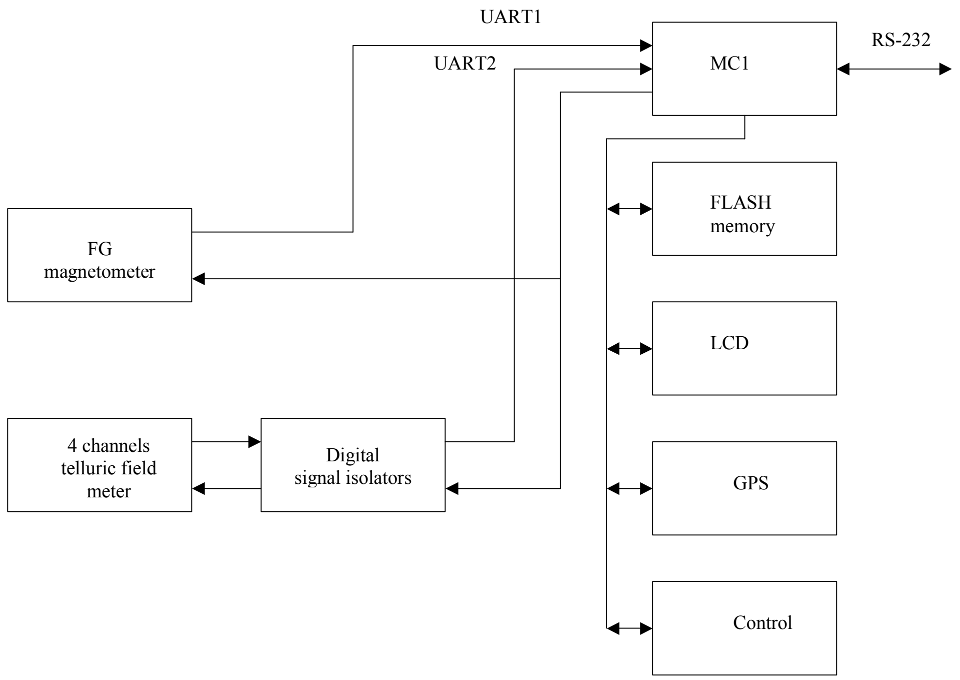


Fig.4. LMTI functional diagram

The electronic unit consists of three printed boards. Main board contains data acquisition system, the second one is FG magnetometer and the third board contains four channels telluric field meter.

6. OPERATION INSTRUCTION

6.1. Preparation for Operation

6.1.1. Open the transportation housing and take out the parts of the LMTI.

6.1.2. Make a hole at the place where the FG sensor has to be installed and put the sensor on delivered rigid non-metallic, non-magnetic support. Preliminarily press firmly this support against the ground in order to harden the soil under it and level it using bubble level. Put the sensor between clamps and turn its housing in such a way that the arrow on the top of the cover points the North approximately. Positive directions of the magnetic components are: X – to the North, Y – to the East, Z – down. Accurate orientation can be done later using magnetometer readings: usually the orientation is accomplished by sensor rotation to achieve zero value of Y component, then X component will point Geomagnetic North exactly (see item 6.2.2).

6.1.3. Tighten clamps fixation screws only after exact orientation. Check the leveling of FG sensor by bubble level after its final rotation.

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

6.1.4.1. 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 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.

6.1.4.2. Then the hole for electrodes installation has to be dug 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 hole with diameter ~7-8 cm and depth ~15-18 cm (a half-liter bottle could be a suitable forming tool). Further instructions how to install electrodes, especially efficient if LEMI-701 non-polarized electrodes are used, are given in the Electrodes Manual section (page 26). They are useful for other electrode types too.

6.1.5. Make following connections:

a) Couple the end of the FG sensor cable with the connector “FG SENSOR” on the left side panel;
b) Couple GPS antenna cable with the connector “GPS”;
c) Install GPS antenna using the holder to provide free view of sky (the holder construction allows installing of the antenna on soft and rocky ground)
d) Connect power cable to the connector “+12V”.

e) Couple electric lines to the binding posts on the electrodes terminal. If a long period installation is planned, clean thoroughly the contact surfaces of cables and posts, then fix the cables, trying to provide as big contact surface as possible, and then cover the connections with any weatherproof grease. Normal directions of telluric lines pairs have to be: 1^{st} line – positive (RED terminal) to the North, negative (BLACK terminal) to the South; 2nd line – positive to the East, negative to the West. The directions of 3rd and 4th lines, if used, have to be chosen by operator.

f) The earthing binding post ⏚ must be connected to any metallic earthing electrode that has to be inserted into the ground directly near the LMTI.

Without this connection, the telluric channels will be unstable and even may be in saturation.

If any of the telluric channels is not in use, short-circuit corresponding pair of terminals and couple it to the earthing connector.

NOTE. As all 4 telluric channels are fully isolated and have differential inputs any other connection of telluric lines can be realized by operator decision.

6.1.6. Special precautions have to be taken when POWER connector is coupled to the 12 V battery. The wire with RED mark of the power cable has to be coupled to the POSITIVE terminal of the battery, the wire with BLUE mark – to the NEGATIVE one.

Please, check the power supply voltage before to connect with LMTI. There is not special protection against overvoltage! Power supply voltage must be in (9-18) V range.

The LMTI is ready for operation.

6. 2. Operation

6.2.1. Switch the POWER switch in the position ON.

6.2.2. After POWER is switched on following information appeared at the LMTI display (First Fig.7 a, then in 5 sec Fig.7 b):

	M	A	G	N	E	T	O	T	E	L	L	U	R	I	C
					S	T	A	T	I	O	N				
				L	E	M	I	-	4	1	7	M			
	V	-	4	.	4					N	-	B	0	2	

a)

			F	L	A	S	H		C	A	R	D			
					F	A	T		1	6					
				1	9	4	4		M	B					
							9	4	%	f	r	e	e		

b)

*	1	3	-	0	5		1	2	:	3	2	:	1	3	
	F	L	A	S	H		I	n	f	o					
	F	L	A	S	H										
	S	t	a	r	t		R	e	c	o	r	d			

c)

FLASH
PC
FLASH+PC

	2	0	0	7			1	2	:	3	2	:	1	3	
B	X	+	7	5	3	3	8	.	1	2			9	8	%
B	Y	-	1	4	3	6	7	.	0	1					
B	Z	+	0	0	3	4	5	.	7	5	<	n	T	>	A

d)

GPS Active

E	1	-	0	0	0	0	0	3		3	2	:	1	3	
E	2	+	0	0	0	1	5	6							
E	3	-	1	0	0	2	3	6							
E	4	-	9	0	0	2	7	4	<	u	V	/	m	>	A

e)

GPS Passive

	1	4	-	0	7		1	2	:	3	2	:	1	3	
B	E	1	-	0	0	1	m	B	E	4	-	2	5	0	m
B	E	2	-	1	0	0	m								
B	E	3	-	0	5	0	m								P

f)

	1	4	-	0	7		1	2	:	3	2	:	1	3	
L	4	1	7	-	0	2	3	.	b	3	4				
U	i	n	+	1	2	.	1	V		1	9	4	4	M	B
T	F	+	1	2	.	3		T	E	+	1	4	.	8	

g)

	1	4	-	0	7		1	2	:	3	2	:	1	3	
L	a	t		4	9	4	7	.	9	1	6	3	,	N	
L	o	n		0	2	4	0	0	.	5	2	2	9	,	E
A	l	t		0	0	3	6	8	,	M					A

h)

Fig.7. Messages at LMTI display.

After approximately 10 seconds the main menu is displayed (Fig.7 c). Menu consists of four lines (submenus) with names:

- Date and time;
- FLASH Info
- Data acquisition mode (PC, FLASH, FLASH+PC);
- Start Record.

Menu items selection is realized by short pressing of CONTROL button (<1 s). In this case, marker (*) is moving along the menu items. Entering to the selected item or changing the mode is fulfilled by long pressing of CONTROL button (>2 s).

Internal clock synchronizing from GPS is carried out every hour.

The letter **"A"** at the end of 4-th line (Fig.7d) is the sign that GPS gives exact time. If GPS is not active the letter **"P"** will appear instead of **"A".**

With long pressing of CONTROL button in the 1-st line (see marker position on Fig.7c) the GPS geographical coordinates (Latitude, Longitude, Altitude) will appear on the display (an example on Fig.7h: 4947.9163, N 2400.5229, at Lviv, Ukraine mean: North Latitude 49° 47.9163', East Longitude 24° 0.5229'). After next long pressing of the CONTROL button the main menu will appear on the display again.

With long pressing of the CONTROL button in the 2-nd line (FLASH Info) we can see information of the FLASH CARD.

With long pressing of the CONTROL button in the 3-d line the choice of data acquisition mode can be realized:

PC **- in PC only;**

FLASH **- in FLASH only;**

FLASH+PC **- in both FLASH and PC**

With long pressing of the CONTROL button in the 4-th line (START RECORD) the data acquisition begins accordingly to the chosen acquisition mode (LMTI goes to the measurement mode).

The recording starts at the 00 second of the next minute after button release!

Measurement mode has its 4 own submenus. The choice of every submenu is carried out by short pressing of CONTROL button and stop of recording by long press of CONTROL button in any submenu.

The information on display in the 1-st submenu of measurement mode is shown on Fig.7d and in the 2-nd submenu on Fig.7e. The current values of magnetic Bx, By, Bz (in nanotesla) and electric E1, E2, E3, E4 (in microvolt per meter) fields readings may be seen for all channels. Free space of the FLASH card (percentage) can be seen in the 1-st submenu.

The value of By component is used for accurate orientation of fluxgate sensor in this operation mode during installation. Usually, an operator rotates the sensor until the By become zero with accuracy about ± 50 nT. In this case the X axis points to the Geomagnetic North.

In the 3-d submenu the lengths of all electric lines that were chosen by operator before start of recording are displayed (Fig.7f). The operator has to write the lengths of the lines the to the LMTI from PC during preparatory operations (see item 6.3).

In the 4-th submenu the name of current file, the voltage of the battery, volume of FLASH card and temperatures of the FG sensor and the electronic unit are displayed (Fig.7g).

Press (more than 2 sec) the CONTROL button in the recording mode to stop the acquisition. The LMTI will ask: “ARE YOU SURE Y/N”. With next long pressing the system will stop acquisition and goes to main menu. With shot pressing of CONTROL button the system will continue data recording.

LMTI creates in FLASH card files with following names: L417_xxx.b#, where - xxx number of current file (001 - 512), # - LMTI factory ID. For example – L417_023.b34

6.2.3. In the FLASH+PC or PC modes the data from LMTI are transmitted to an external PC through the RS-232 port. In this case one can use lemi417v.exe program (see item 6.3) for recording and visualization. Connect the PC serial port connector to the RS-232 connector on the front panel of the LMTI with the interface cable to use the PC with the station. The FLASH+PC or PC modes can be used for LMTI noise level check, magnetic and telluric field activity estimation etc.

6.2.4. Close the LMTI housing cover clamps tightly for continuous recording.

Notes

Due to the peculiarity of GPS receiver operation a time error can occur at the beginning of data recording. During conversion of binary file to ASCII format this error is listed in the “xxxxxxxxxx.INF” file, see example:

File[s] output:
071106145347.t78
Error Time: From: 2007 11 06 15 09 47 To: 2007 11 06 15 09 33

This example shows that the time error 47-33=14 sec occurred.

The described error may appear if the station is used after long non-operation period (storing or transportation).

The typical value of time error which may occur is 13…14 sec even when the GPS activity sign (letter “A” at the bottom right corner of the display) is indicating that time mark is already synchronized.

Following way to avoid the described error is recommended:

a) Switch the station on with GPS antenna connected and properly installed (pay attention to provide the necessary field of view!).

b) Wait until the letter “A” at the end of the 4-th line appears instead of “P” (fig.7).

c) Wait still about 15…20 minutes before start data recording. Usually, this time is enough to establish the synchronization. To be sure, one can check the time indicated at the display using any external precise clock.

ATTENTION!

1. LMTI LEMI-417M operates with COMPACT FLASH cards with FAT16 files system only. If the FLASH card is formatted under other file system (FAT12, FAT32) it has to be reformatted on a PC with any standard Compact FLASH card reader.

2. LMTI writes data files to the root directory of the FLASH card. That is why the maximum number of files is limited – 512 files. The maximal size of one file is about 2.5 MB.

3. Every new day at midnight the LMTI microcontroller creates a new file, so 512 days is maximal operation period without the FLASH card changing. This is highly advised, in order to make possible recording of total number of 512 files, to clean the card before long-term record.

4. The user can clear FLASH card on PC with a standard Compact FLASH card reader only.

5. Before using the station in field conditions tightly close the electronic case lid with side double-step latches to make it waterproof!

6.3. Program Manual

(LEMI-417v)

General Information

The program allows fulfilling the following operations:

- LMTI control
- Real time data acquisition and visualization (magnetic fields Bx, By, Bz, telluric fields E1, E2, E3, E4, temperatures of FG sensor and electronic unit);
- Writing LMTI data text file to the PC hard disk
- Conversion FLASH-card binary files to text files

The program set consists of following files:

lemi417v.exe	LMTI control, real time data visualization, data acquisition, binary FLASH cards files to text format conversion
***.def**	Configuration file
lemi417v.log	Log-file
***.t##**	Text data files
***.inf**	Information files
***.b##**	Binary data files

Data files

Program operates with text and binary files. In PC or FLASH+PC modes the data files in the text format are stored in PC memory.

Data exchange between PC and magnetometer is realized through the RS-232 interface at the rate 115200 bit/sec (start bit, 8 data bits, stop bit, no parity).

Every line of the text files corresponds to one sample of all measured components for the given time moment (see example below).

Data Text File Example

```
2009 10 19 07 16 00 -15794.84  -2049.67  49407.31  19.09  13.23  97.26  92.90  85.68  92.49
2009 10 19 07 16 01 -15793.62  -2050.69  49408.19  19.06  13.31  96.78  92.45  85.86  93.03
2009 10 19 07 16 02 -15794.74  -2049.45  49406.64  19.09  13.27  97.26  93.02  85.50  93.12
2009 10 19 07 16 03 -15795.25  -2047.29  49403.94  19.03  13.31  96.72  92.42  85.50  92.67
2009 10 19 07 16 04 -15792.41  -2046.87  49406.71  19.03  13.27  97.35  92.84  85.89  92.70
2009 10 19 07 16 05 -15793.54  -2047.54  49405.54  19.09  13.27  97.29  92.63  85.71  93.09
2009 10 19 07 16 06 -15791.77  -2051.29  49402.54  19.06  13.27  97.08  92.75  85.74  92.52
```

Data text file structure is following, according to columns**:**

Column	Example	Meaning	
1	2009	Year	UTC time
2	10	Month	
3	19	Day	
4	07	Hour	
5	16	Minute	
6	15	Second	
7	17742.89	Bx, nT	Magnetic field components values
8	-1.80	By, nT	
9	45229.57	Bz, nT	
10	26.28	TE, ^{o}C	Electronic unit and FG sensor temperatures
11	15.62	TF, ^{o}C	
12	-6.01	E1, μV/m	Telluric field values
13	-1.42	E2, μV/m	
14	-4.60	E3, μV/m	
15	3.25	E4, μV/m	

Columns are separated by spaces. Each line is ended with characters 0x0D 0x0A (hex). Time step (1 sec … 1 min) depends on chosen average coefficient.

LMTI data are stored to the FLASH card in binary format. It is possible to rewrite them to a PC by a standard Compact FLASH card reader and convert to text files by the program **lemi417v.exe.**

Data File Name

Text data file names are created automatically from UTC time. For example:

“20051215135000.txt”. The structure of file name is: yyyymmddhhnnss.t##, where yyyy-YEAR, mm-MONTH, dd-day, hh-HOUR, nn-MINUTE, ss-SECOND.

LMTI control program lemi417v.exe

Before start control program lemi417v.exe couple together connectors RS-232 of the PC and LMTI with interface cable.

After lemi417v.exe program starting the main window appears on the PC display (Fig.8 – with data visualization). In the main window header the name of the currently displayed data file can be seen. A user can select the LMTI channels that will be drawn on the screen by using corresponding menu items (see example on Fig.8). From 1 to 5 channels can be shown on display simultaneously. The full control of the LMTI can be done from this window by corresponding menu items.

Main program menus commands:

- **File → Open file –** Open file for visualization from hard disk

  - List of files… – show list of recently opened files

  - Exit – exit program

- **ComPort –** serial port number change
- **About –** information about program version

Program buttons:

start / stop recording

«Status» - choice of initial LMTI settings

- binary file decoding and conversion to text file

- read log file

Buttons «Range» and «Zoom» are used for graphics control. Button «Range» evens all selected plots on display, button «Zoom» changes the plot dimensions to show it on display in full. Button “Mouse” allows values measuring directly from the plots on display by positioning the mouse cursor on a necessary plot point.

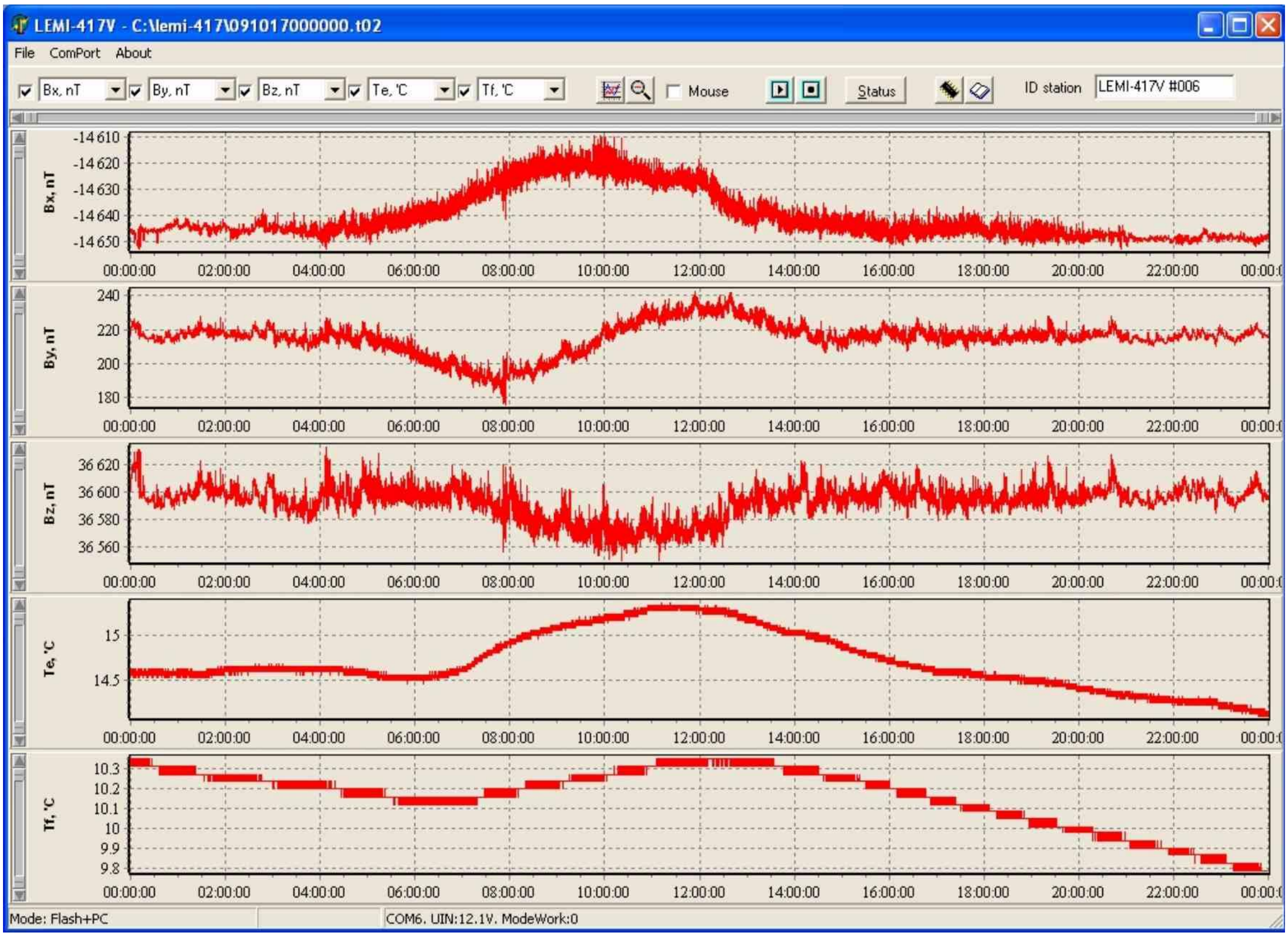


Fig. 8. Main program window

Command window «Status»

For LMTI control and initial setting press button «Status» (Fig. 8). From window "Status" (Fig.9) it is possible:

1. Get LMTI ID.
2. Get LMTI date/time.
3. Set LMTI date/time from PC (when GPS is active the time is set automatically from GPS).
4. Choose data acquisition mode (Flash / PC / Flash+PC).
5. Open window "Coefficients". (Fig.10). In this window calibration coefficients can be read from LMTI, edited and written back during calibration procedure.
6. Set parameter of data averaging for text files (1, 2, 5, 10, 15, 20, 30, 60 s.).
7. Get battery voltage (UIN)
8. Get FLASH card free space (Flash, Mb)
9. Get LMTI coordinates from GPS (GPS data)
10. Activate/deactivate output status of GPS to the text file (Add GPS Status). A – GPS active; P – GPS passive.

Example:

2010 11 29 09 56 00 23893.85 5640.32 36169.29 16.53 19.78 242.64 194.84 200.72 192.46 **A**

2010 11 29 09 56 01 23894.20 5637.93 36161.40 16.50 19.78 242.34 194.47 200.20 192.54 **P**

The items 4 duplicates the commands that can be sent from LMTI front panel LCD (see Fig.7)

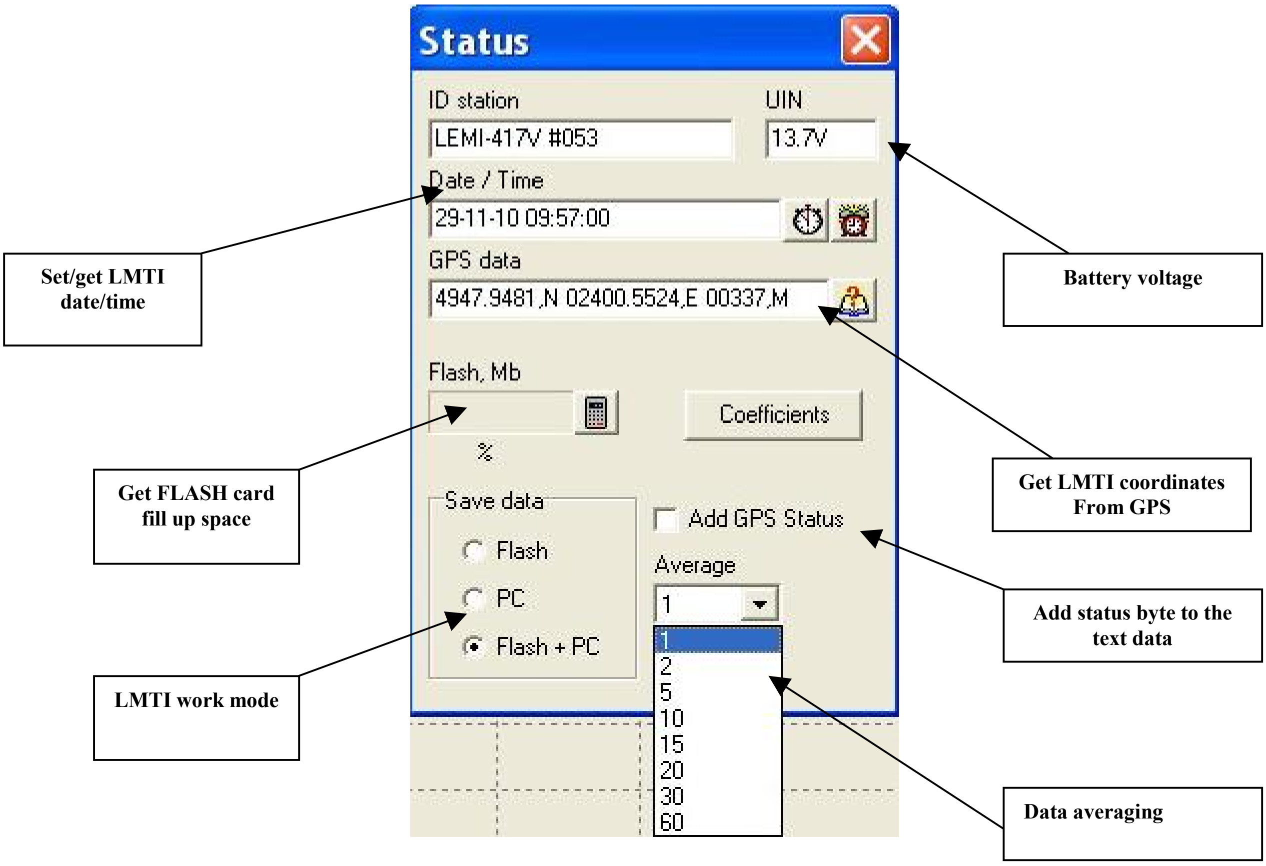


Fig. 9. Command window “Status”

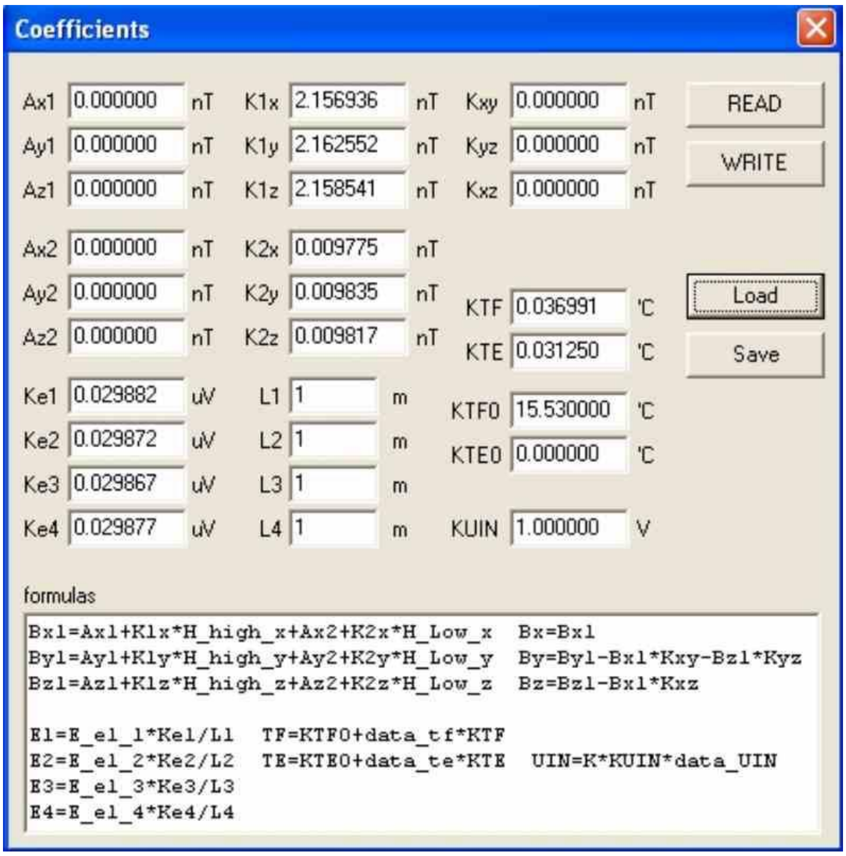


Fig.10. Dialog window “Coefficients”

With pressing button “READ” the current values of calibration coefficients can be read from LMTI nonvolative memory. The values can be edited in this window and written back with button “WRITE”. With pressing button “SAVE” this values will be written to LF417.def file on PC hard disk. If necessary the values from this file can be loaded to the window “Coefficient” by button LOAD. Also the current lengths of electric lines must be entered to the L1 – L4 positions in window “Coefficients” and written to LMTI nonvolative memory with button “WRITE” before start of recording. The meaning of every coefficient in the configuration file is given below.

Configuration File lemi417v.def

The calibration and configuration information of LMTI is saved in configuration file **lemi417v.def.**

ATTENTION! These parameters can be changed by expert user only! Always create spare copy of the *.def file on independent information carrier. In most cases this file is never changed during instrument lifetime, except the length of electric lines L1…L4. The *.def file information also is stored in internal LMTI nonvolative memory.

Configuration def file example:

Ax1=0.000001 Ay1=0.000001 Az1=0.000001	Offsets of high-order DACs
Ax2=0.000001 Ay2=0.000001 Az2=0.000001	Offsets of low-order DACs
Kxy=0.000000 Kyz=0.000000 Kxz=0.000000	Fluxgate sensor non-orthogonality correction coefficients
Ke1=0.048000 Ke2=0.048000 Ke3=0.048000 Ke4=0.048000	Electric channels calibration coefficients
K1x=1.920010 K1y=1.920010 K1z=1.920010	Calibration coefficients of high-order DACs
K2x=0.007801 K2y=0.007801 K2z=0.007801	Calibration coefficients of low-order DACs
KTF=0.031928 KTE=0.031928 KTF0=16.100000 KTE0=16.100000	Fluxgate sensor and electronics thermometers calibration coefficients
KUin=1.232751	Calibration coefficient of built-in voltmeter
L1=100 L2=200 L3=91 L4=11	Lengths of electric lines for channels 1-4

Program current version

To look information about current program version press button <About> in main menu (Fig. 11).

Fig.11. Window «About»

Protocol File lemi417v.log

This file is created automatically and is appended continuously with protocol information. For example, start and stop time of the program are stored in this file, time of commands sending, errors information etc. **Please, never delete this file, as it will help designers to search the errors and modify the program if necessary.**

Binary to text data file conversion

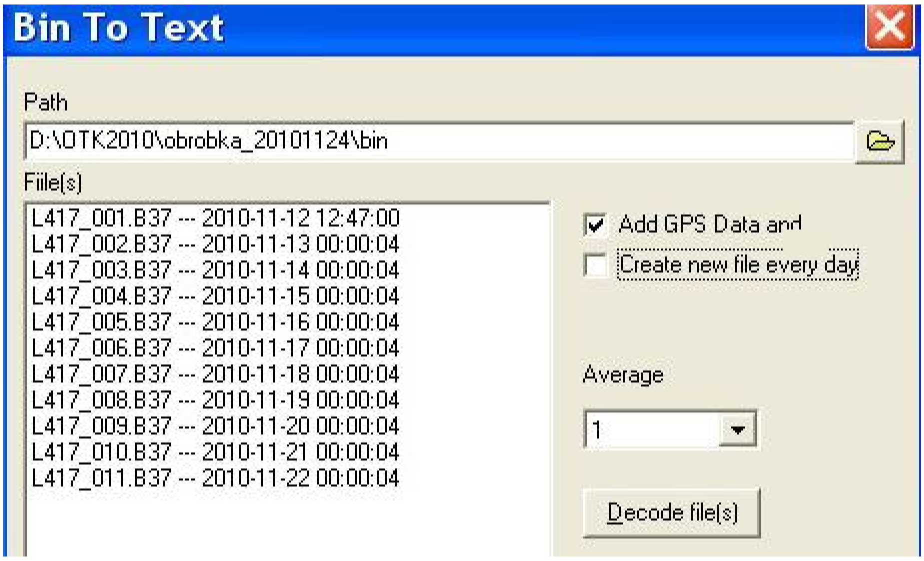


Fig.12. Window for decoding binary data into the text format files

This window is intended for decoding binary data into the text format files and allows:

1) Set a list of binary files for decoding. To select several files use standard Windows commands in the window “Open”: buttons Shift (Ctrl) + left mouse button click on selected files;
2) Set data averaging (Average) (1,2,5,10,15,20,30,60 сек.);
3) Activate/deactivate of creating of separate daily files (Create new file every day);

4) Activate/deactivate of adding GPS data and battery voltage to the information file (Add GPS data).

Notes. In order to get continuous, round-the-clock text files (from 00:00:00 to 23:59:59) one has to make "binary" -> "text" conversion of the several, consecutively recorded binary files (whole group for the period of record). Otherwise (at “one by one” decoding), one will get "pieces" in the beginning of days that are produced due to structure of the Compact Flash Memory Card recording - each data block of the card consists of 16 readings. Therefore, some readings of a binary file may belong to next day and results in a separate file generated if the number of seconds remaining to the midnight is not divisible with 16.

If GPS signal disappeared/appeared at operation, during decoding some "gaps" or "overlaps" can appear because of this. The PC software (lemi417v.exe) creates a new file for every such an error and the information about time of errors are written in *.INF file during decoding.

Information File lemi417v.inf

This file is created from binary data file during binary to text format conversion and contains the following information:

1) Binary data file name;
2) Manufacturer ID number of the LMTI;
3) Start recording date and time;
4) GPS coordinates and altitude (with option **«Add GPS data and Uin»**);
5) Averaging coefficient;
6) Battery voltage (with option **«Add GPS data and Uin»**);
7) Length of electric lines (L1 – L4);
8) Names of output data text files.

Also it may contain the errors information during binary to text file conversion.

Information file example:

```
Input file: L417_000.B98
Data from: 417V N 098
Date: 28-12-2010
Time: 11:04:00
Latitude: 4947.9418,N
Longitude: 02400.5780,E
Altitude: 00323,M
UIN: 13.9V
L1: 1
L2: 1
L3: 1
L4: 1
Average: 1
```

File[s] output:
20101228110400.t98
2010 12 28 11 04 00: 4947.9418,N 02400.5780,E 00323,M A 13.9V
2010 12 28 11 04 16: 4947.9485,N 02400.5808,E 00340,M A 13.9V
2010 12 28 11 04 32: 4947.9488,N 02400.5809,E 00340,M A 13.9V
…

FILE NAME FORMAT for files created from binary data file:

Text data file names are created automatically from UTC time.

An example of file name: “060719171600.t54”.

The structure of the name is: yymmddhhnnss.t##,

where yy-YEAR, mm-MONTH, dd-day, hh-HOUR, nn-MINUTE, ss-SECOND, “,## - instrument ID

7. STORAGE AND TRANSPORTATION

7.1. LMTI storage conditions:

- Temperature - from +5 to +40 °C;
- Relative humidity - not more than 85%.

7.2. LMTI can be transported by any transport vehicles without limitation

7.3. During storage and transportation the shocks more than 5 g are inadmissible.

7.4. As LMTI housing is hermetically sealed it is very desirable to keep under the LMTI cover the Peli™ desiccant cartridge with dry silica gel (Peli ref. number 1500D) to prevent water condensation from trapped air when case is opened in high humidity condition or an ambient temperature is decreased.

7.5. A user has to check periodically the color of the silica gel through the inspection window at the cartridge. When it becomes pink, the cartridge has to be reactivated by oven drying at 150 °C during 3 hours.

7.6. In order to keep the silica gel desiccant as long as possible, try to keep the case lid closed all the time during operation and storage of the LMTI.

7.7. To remove the cartridge for silica gel drying two fixing screws (at the lower surface of the case cover) have to be loosened. After drying, install the cartridge back and carefully fix it by screws.

IMPORTANT!

The electrodes have to be washed by spring- or rainwater after use. If a short break between the measurements is expected (up to one week), it is allowed to put the electrodes in the common can with clay-$CuSO_4$ suspension. If longer break is expected, put the electrodes back in their containers. Before this, moisture the porous plastic at the container bottom with 10% $CuSO_4$ solution.

The FG sensor before its placing into transportation housing must be carefully cleaned and dried.

Any questions about LMTI exploitation and operation can be sent to designers:

klimovich@isr.lviv.ua – general and electrodes

pristaj@isr.lviv.ua – magnetometer and electrometer

kuzn@isr.lviv.ua – data logger

leon@isr.lviv.ua – software for LEMI-417M

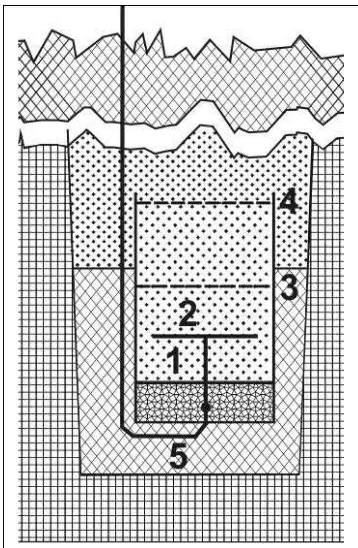
APPENDIX 1

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-CuSO4) was accepted. Its drawbacks were studied (Korepanov and Svenson, 2007), and new improved non-polarized electrode construction based on Cu-CuSO4 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 ~2nV 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 case 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. The plot of electrodes noise density is demonstrated on Fig.5.

Fig. 1. Non-polarized electrode.

Fig. 2. Non-polarized electrode in transportation protective case



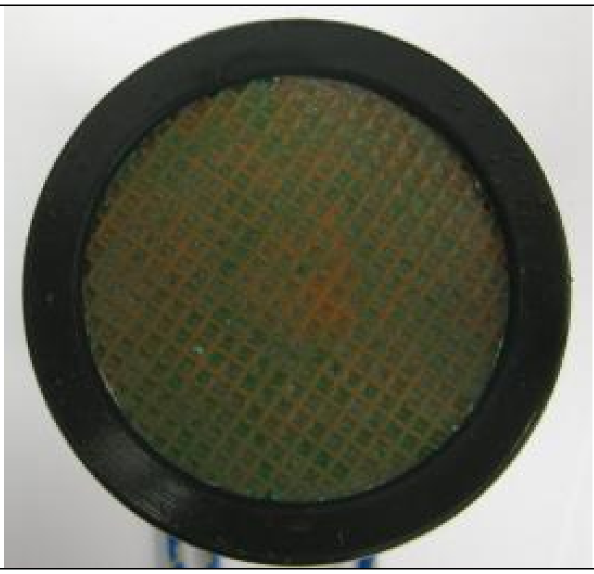


Fig. 3. Non-polarized electrode structure and installation for long-term survey.

Fig. 4. Electrode ceramic contact surface

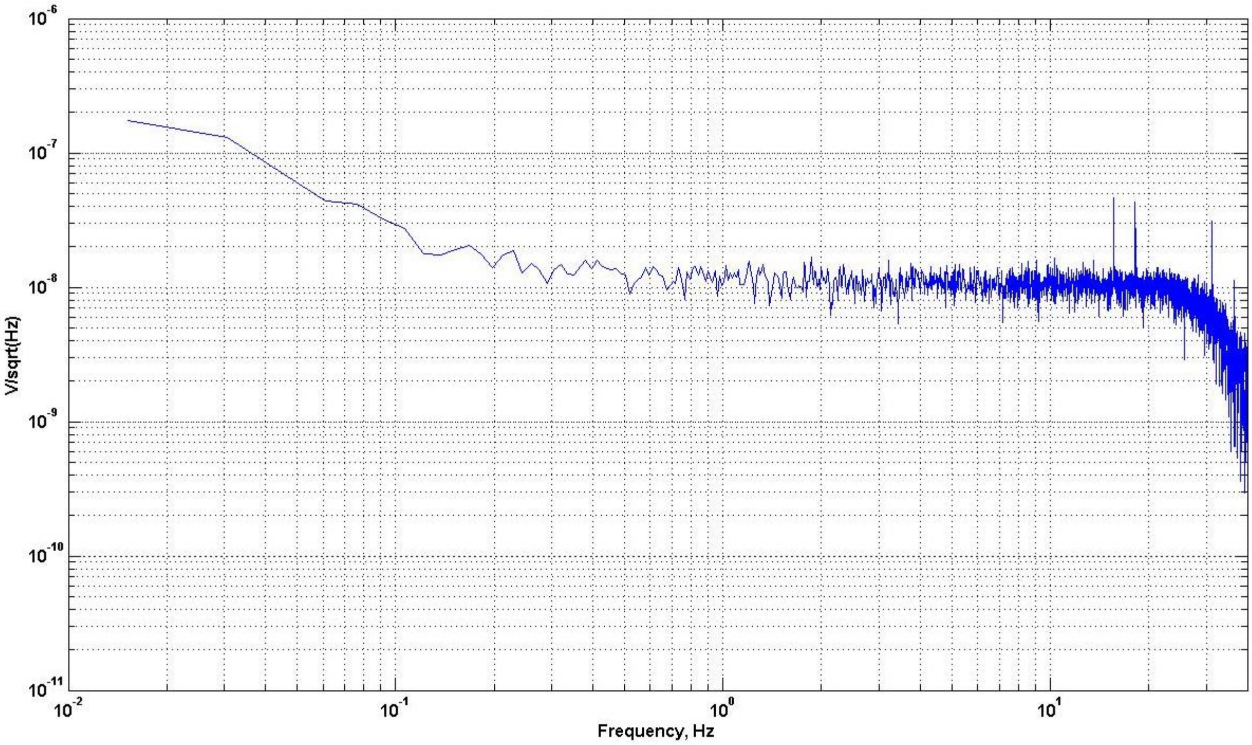


Fig. 5. Electrode spectral noise density

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!

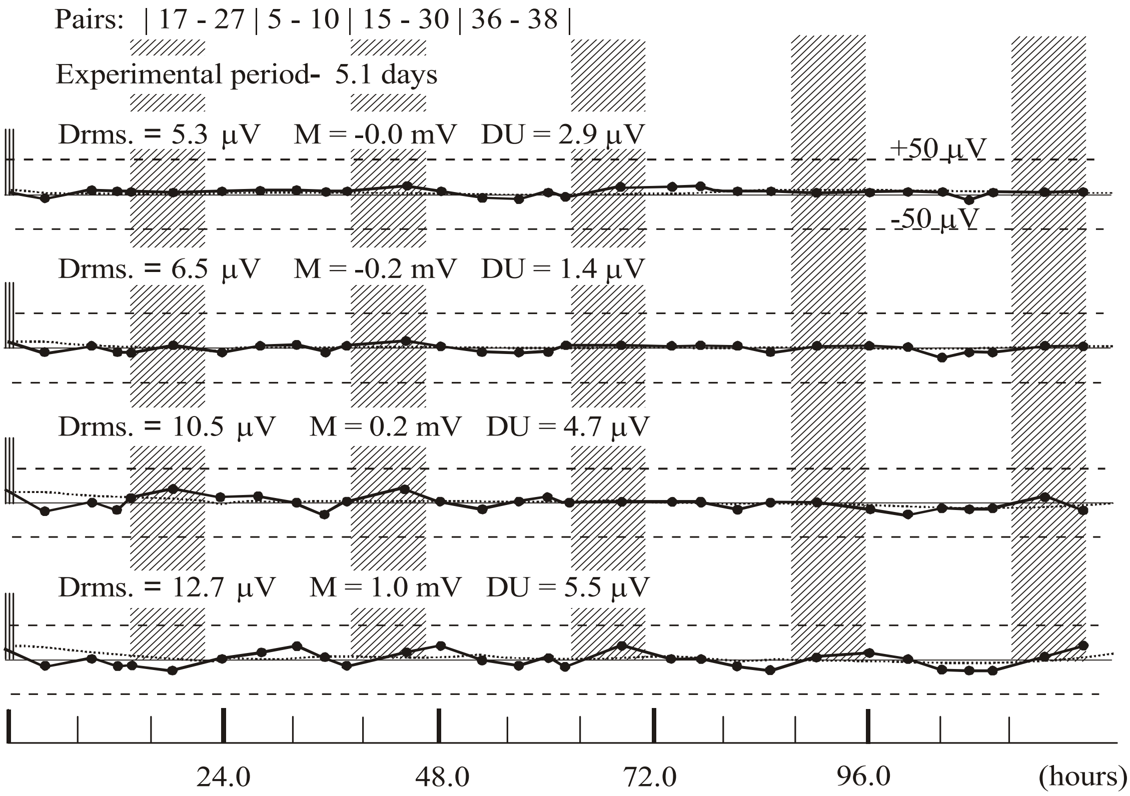


Fig. 6. Drift of selected electrode pairs (short term)
Drms – root mean square error; M – baseline shift; DU – averaged dispersion

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.

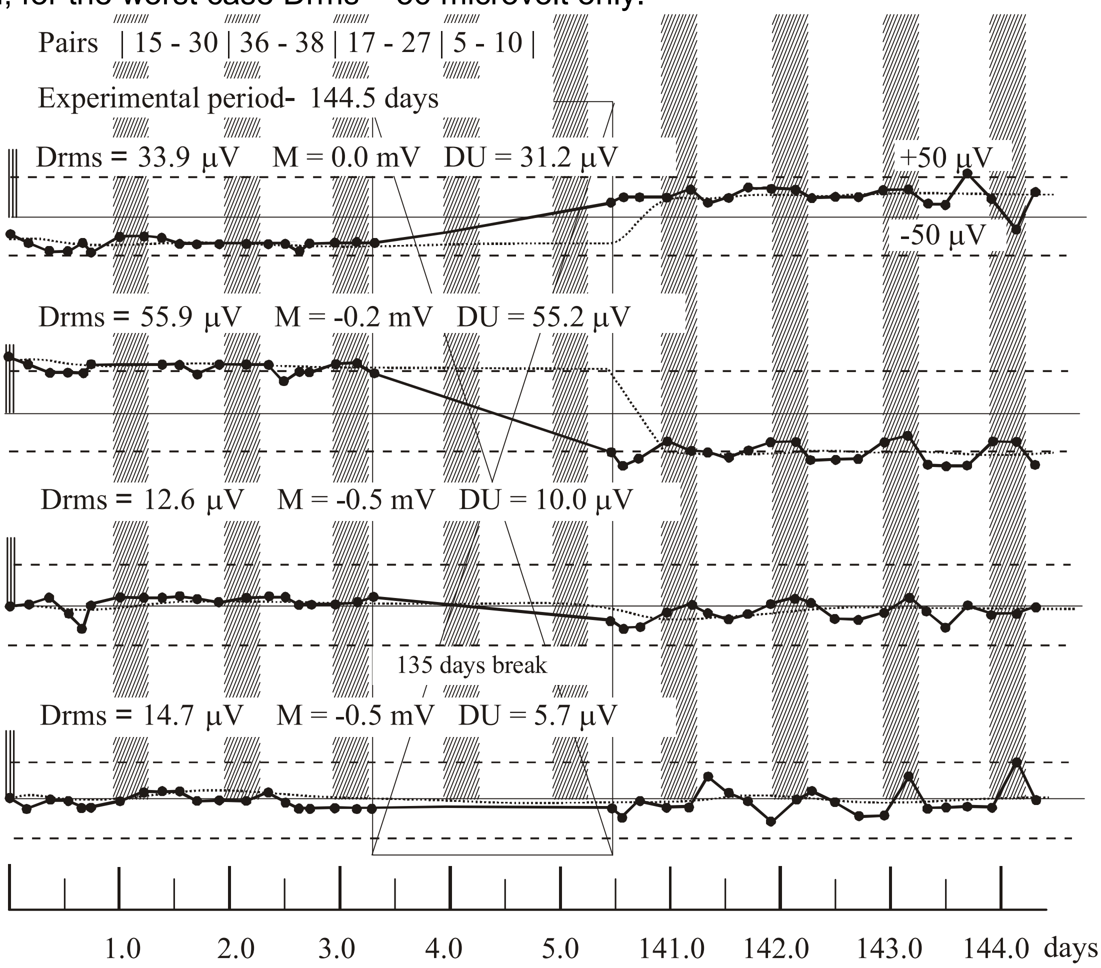


Fig.7. Drift of selected electrode pairs (long term)

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).

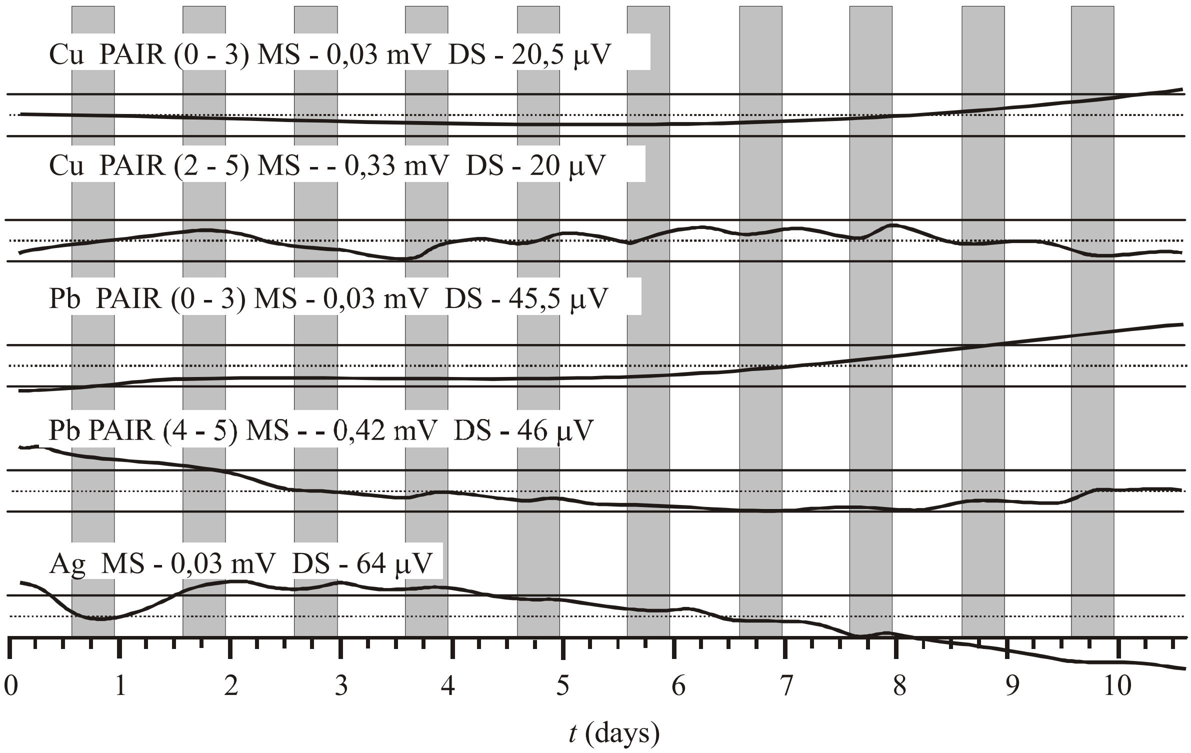


Fig. 8.The results of comparison test of copper, lead and silver electrodes
MS is the zero shit and DS is rms dispersion

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).

Electrodes 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.

3 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). Then the electrodes have to be placed: for long-term installations it is recommended to install electrodes “bottom-up” (see Fig. 9a); for short time (up to few days) in a tilted position (see Fig. 9b).

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

This is because Cu-CuSO4 solution in the water may produce free oxygen O2 due to the water 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.

4 In order to remove the electrodes 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 (Fig. 10).

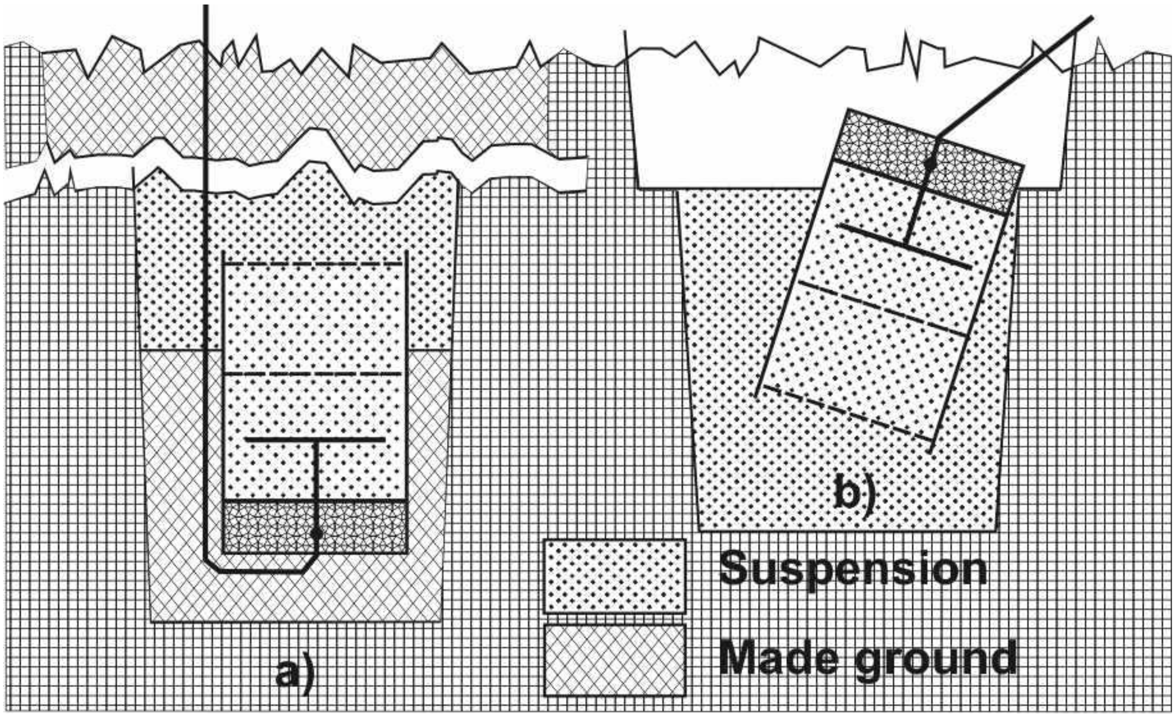


Fig. 9. Electrode installation in operation position: a – long-term; b – short-term.

Fig.10. Electrode damaged by wrong pulling from the ground.

5 Then 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.

6 Then the necessary amount of 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 electrodes couple).

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

Important! To conserve the liquid inside the transportation case what is necessary for electrode parameters stabilization, the tight fit of electrode and case is made. That is why, to remove the electrode, pull it ONLY by hand by an electrode head, softly swinging it all time laterally. Do not pull it by cord, this may damage electrode (Fig. 10)!

8 Put extracted electrodes in the plastic can with 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_l has to be calculated as:

$$R_1 = \frac{R(U1 - U2)}{U2}$$

For example, with U1=40 mV, U2=10 mV, R=3 кOhm we get R_l =9 кOhm.

9 Then the same procedure with the same R has to be repeated after electrodes installation in the ground. The recommended value of R_l has to be below 20-50 kOhm for sandy soil and for clayish soil – below 10 kOhm. The cables have to be connected first to the electrode wires. In recent versions a special contact socket with fixation screw is provided (Fig. 11). 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.

Fig.11. Electrode contact socket

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 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 and 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 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 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 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.

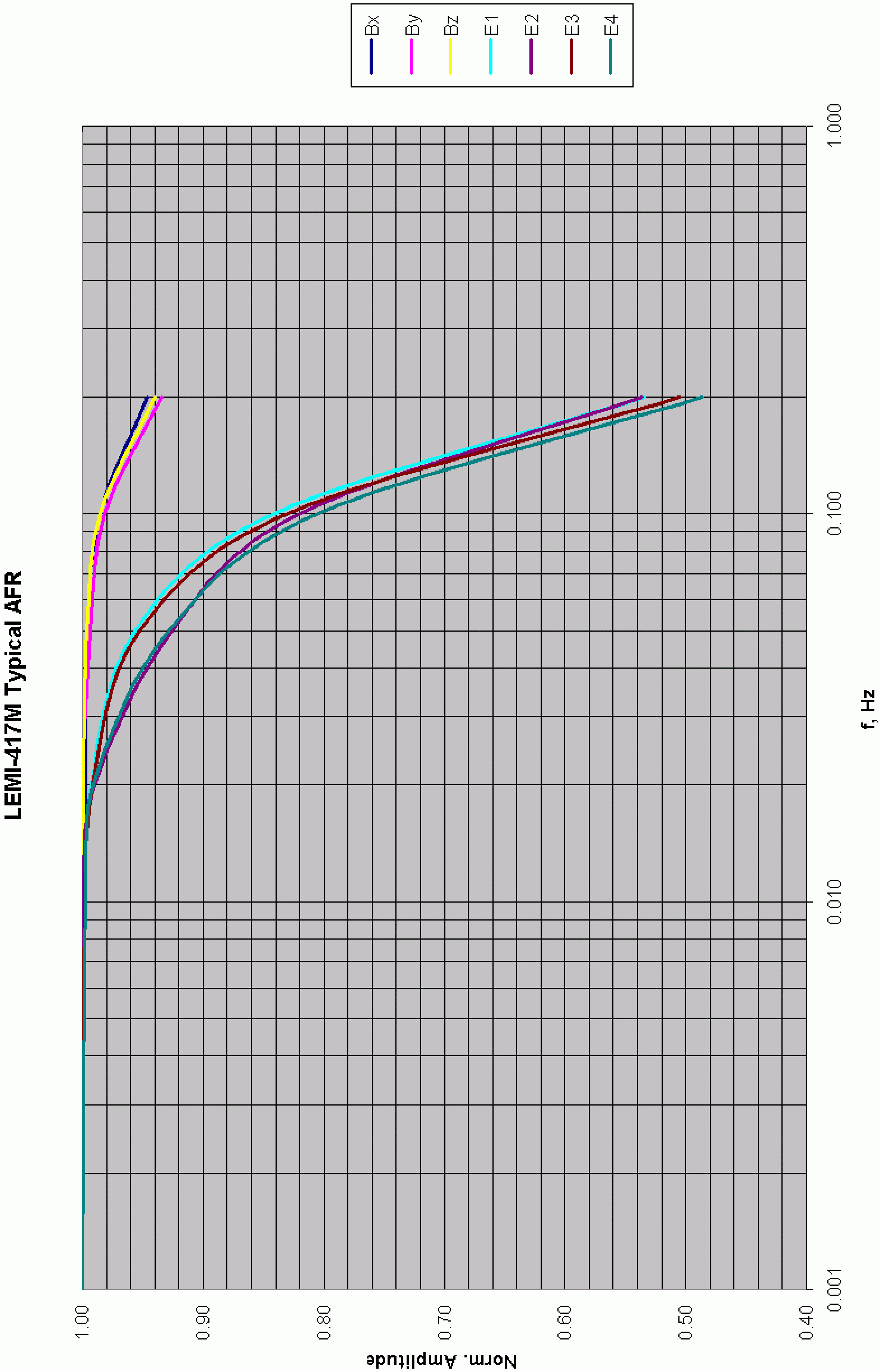
15 For a stony and rocky ground the only solution is to look for local cracks and then try to widen and deepen them. By this the orthogonality of the electric array may be not kept, but this is easily corrected during the processing.

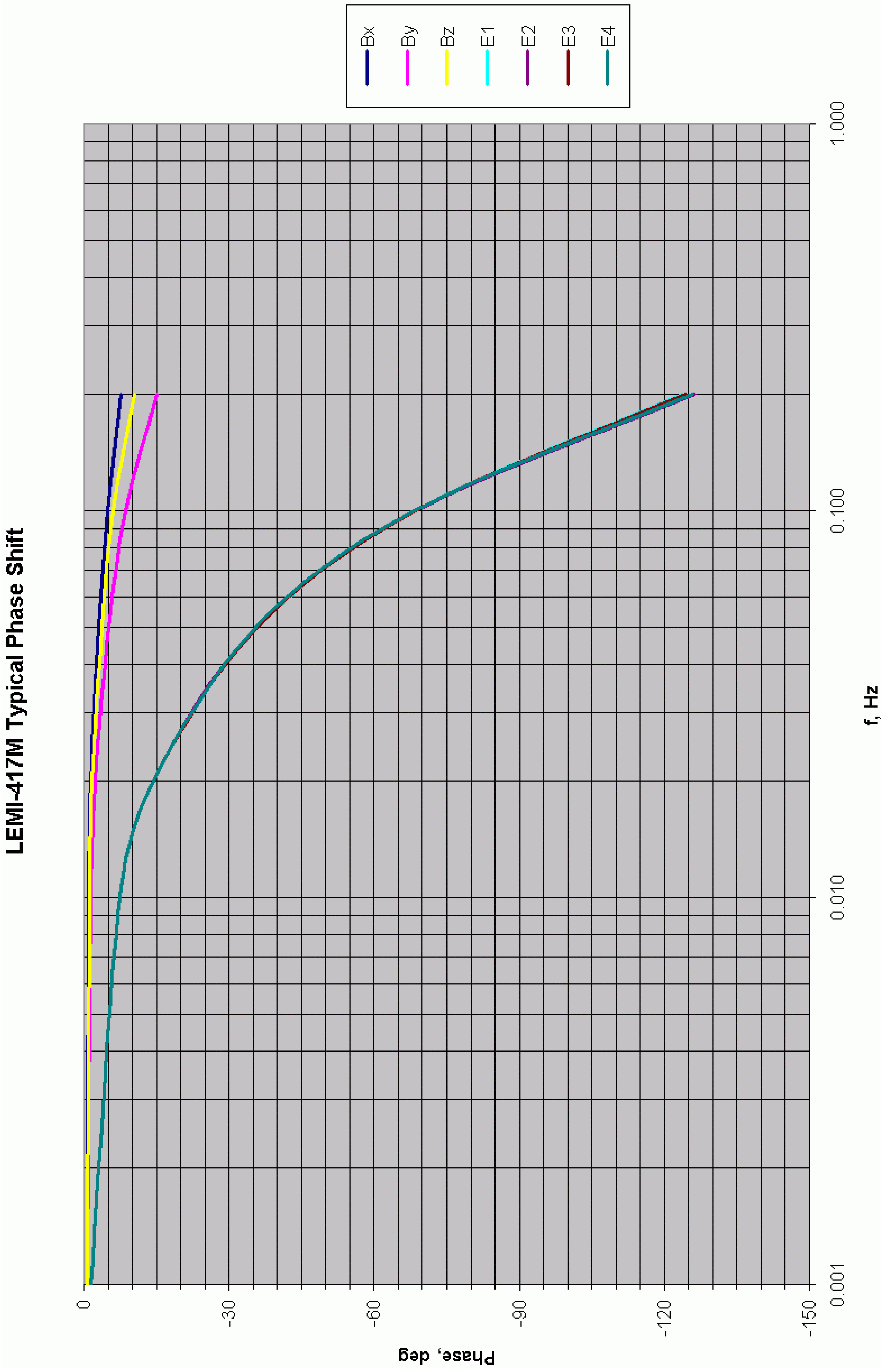
16 It is possible to use the LEMI electrodes not by matched pairs as recommended, but in this case the initial zero shift of electrode pair may reach unities of millivolt (no more than ~ 10) and its variations may be within ~ 100 microvolt.

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 cylinders/cases in order to make wet the piece of soft material at the bottom and put there the electrodes up to the end, as shown on Fig.2.

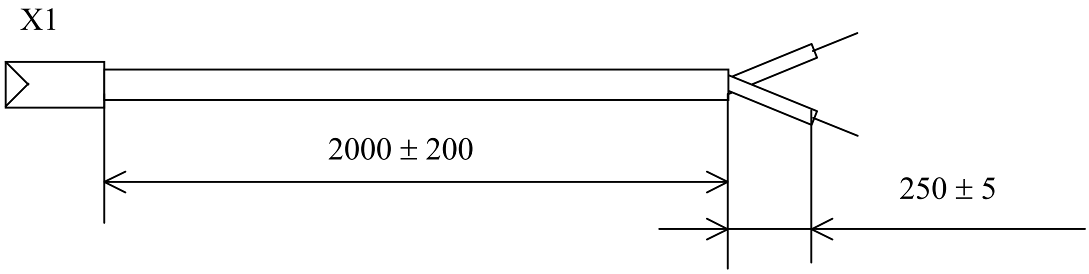
It is recommended that the matched electrodes pairs have to be tied together for storage!

Typical amplitude and phase characteristics of LMTS LEMI-417M




LEMI-417M Typical Phase Shift
Phase, deg
0
-30
-60
-90
-120
-150
f, Hz
0.001
0.010
0.100
1.000
Bx
By
Bz
E1
E2
E3
E4

POWER SUPPLY CABLE



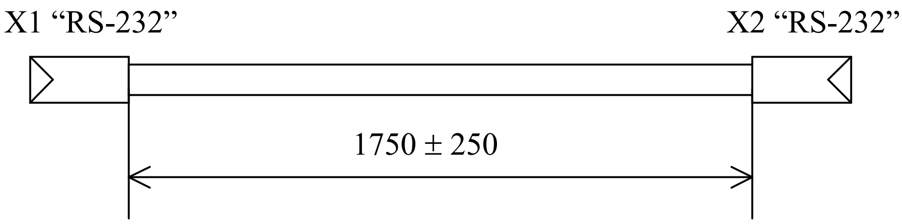
X1

circuit	contact
+VIN	1
-VIN	2
	3

Marking
"RED"
"BLUE"

Connector X1 type – socket СНЦ23-19/22Р-6-В ГЕ0.364.241ТУ.

PC CONNECTION CABLE (Interface "null-modem" cable)



X1 "RS-232"

circuit	contact
	1
TXD	2
RXD	3
	4
GND	5
	6
	7
	8
	9

X2 "RS-232"

contact	circuit
1	
2	TXD
3	RXD
4	
5	GND
6	
7	
8	
9	

X1, X2 – socket ITT Canon DE9.