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LVIV CENTRE of INSTITUTE for SPACE RESEARCH

INTERMAGNET 1-SECOND STANDARD FLUX-GATE MAGNETOMETER LEMI-025

User Manual

LVIV

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CONTENT

1. DESTINATION

Fluxgate magnetometer (FGM) LEMI-025 was specially developed for the super sensitive measurements of 3 components of Earth magnetic field induction and their variations in accordance with new 1-second INTERMAGNET standard. The signals with periods from 1 to 100.000 seconds and more may be collected with reasonable error. In order to realize this design the major attention was paid to such principal FGM characteristics and parameters as frequency response and sampling synchronization accuracy as well as thermal and temporal stability and noise level. To fulfil such mutually contradictory requirements as speed of response and deep suppression of industrial noise, the specific combination of analogue and digital filters was realized in this instrument. The magnetic sensor of flux-gate type, which mainly determines magnetometer stability and noise level, was manufactured with high-tech glass-ceramics having close to zero thermal expansion factor using well-proved technology, which implements recent findings in the excitation circuit construction and operation mode. The rotating sensor support has two bubble levels and levelling facilities to provide proper orientation of its components at the installation place. Using best available voltage references and passive components provides excellent stability of the FGM electronics.

This FGM is intended for operation in the geomagnetic observatory conditions and in normal operation mode requires external PC for storing the acquired data. For this purpose FGM includes RS-232 digital interface. It is also possible to accumulate data into an embedded removable Compact FLASH memory card up to 2 GB volume. This mode of operation is recommended as a temporary one only. The instrument has GPS receiver for data sampling synchronization and FGM location co-ordinates determination.

2. MAIN TECHNICAL PARAMETERS

Measured range of magnetic field variations	± 4000 nT
Automated offset compensation band along each magnetic component	± 70000 nT
Resolution along each component: at the display in the 1-second and 1-minute data files in the 0.1-second file and Flash card data	 0.1 nT 0.01 nT 0.001 nT
Temperature drift	<0.2 nT/°C
Frequency band	DC-3.5 Hz
Output noise in frequency band (0.01 – 1) Hz	< 0.01 nT rms
Magnetic sensor components orthogonality	<30 min of arc
Sampling rate at the magnetometer digital output and FLASH card after PC software digital filtration	 10 per second 1 per second 1 per minute
Error of synchronization with UTC time	< 10 ms
Volume of the removable Compact FLASH memory card	2 GB
Digital output	RS 232
GPS timing and co-ordinates determination	
Operating temperature range	Minus 5 to +40°C
Power supply	12^{+3}_{-2} V
Power consumption	<4 W
Weight: sensor with 10 m cable electronic unit with cables GPS antenna with 15 m cable	 3.3 kg 3.8 kg 0.7 kg

3. DELIVERY SET

The delivery set of LEMI-025 FGM includes:

- Flux-gate magnetic sensor in transportation box
- Electronic Unit.
- GPS Antenna.
- Compact Flash card 2Gb (installed in the Electronic Unit).
- Card reader.
- Flux-gate magnetic sensor cable (10 m).
- GPS antenna connection cable (15 m).
- PC Connection Cable (with double-side connectors).
- Power Supply cable (with one-side connector).
- Technical Description and Operation Manual.
- Control software.

4. SERVICE SHELF LIFE AND GUARANTEE

Mean lifetime of the LEMI-025 FGM – about 10 years.

The term of guarantee is 12 months after delivery if all requirements of the present manual as to applied voltage, usage and 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 FGM if necessary for still 2 years. By this the user has to cover the necessary spare parts price and transportation/visit fees only.

Delivery date: LEMI-025, Nos 004
APRIL, 15, 2010

Quality control:
signed_____ /A. Marusenkov /

5. STRUCTURE AND OPERATION

5.1. Construction Description

Front panel of FGM electronic unit (Fig. 1) has following control and commutation facilities: “POWER” switch, button “CONTROL” for FGM control, slot for Compact FLASH CARD, and button “LIGHT” for LCD lighting.

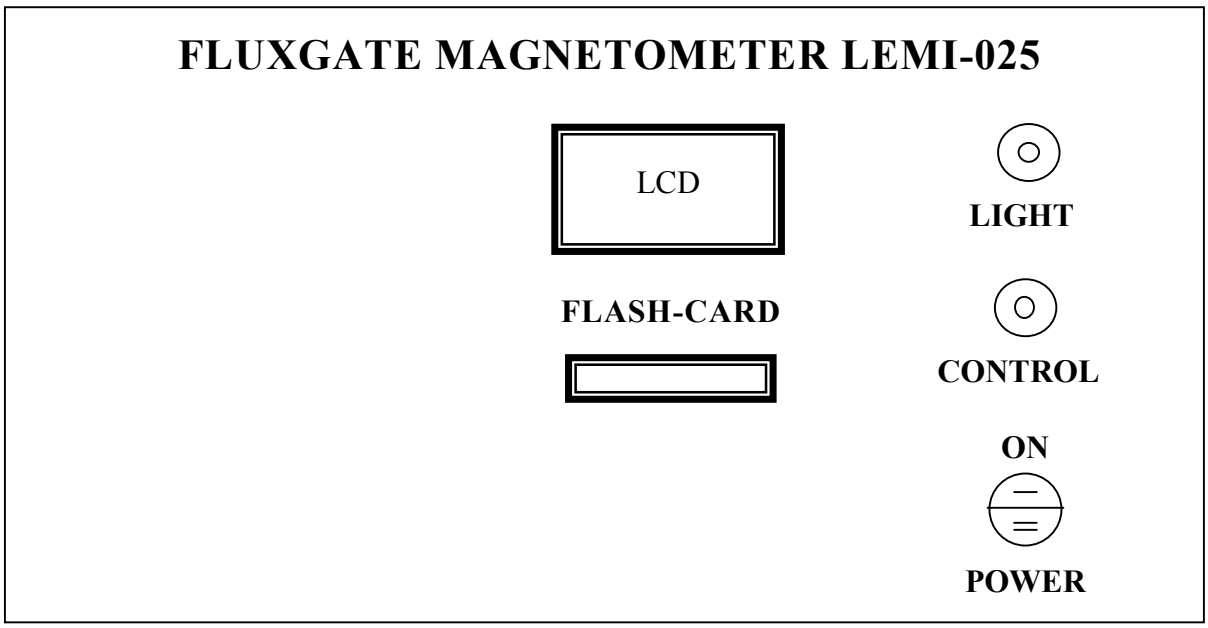


Fig.1. Front panel of FGM

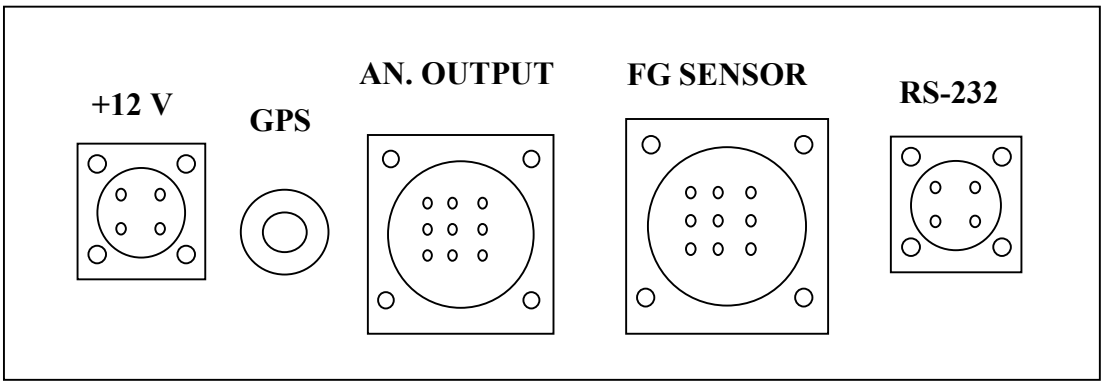


Fig.2. Side panel of FGM.

On the right side of the FGM electronic unit housing there is a side panel (Fig.2) with following connectors:

- Connector for power supply unit +12V;
- GPS antenna connector (SMA type);
- Connector for the magnetometer analogue outputs “AN.OUTPUT” (**not used in current version**);
- Fluxgate sensor connector “FG SENSOR”;
- “RS-232” connector for data transmission from FGM to external PC.

The delivered version of the sensor cable has operation temperature range -5...+80 C when it is flexible and allows twisting, below -5 till -30 C it is allowed only fixed installation of the cable.

The GPS antenna connection cable has normal operating temperature range -20 +70 C, its length is equal to 15 meters.

PC Connection Cable (with double-side connectors) length is equal to 2 meters, operating temperature range -5...+80 C flexible, below -5 till -30 C - fixed installation.

Power Supply cable (with one-side connector) length is equal to 2 meters, operating temperature range -15...+80 C flexible, below -5 till -40 C - fixed installation.

The instrument has to be powered from stabilized power supply. The using of the back-up battery is highly recommended for uninterrupted magnetometer operation during AC power mains breaks.

Non-magnetic housing and minimal magnetism of components enable the instrument to be used conveniently close to FG sensor, if necessary (≥ 3 m).

During the transportation FG sensor has to be placed inside the transportation box.

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

Each sensor consists of flux-gate probe with core in the shape of racetrack 50 mm long. The core is made from 5 wraps of low-noise μ-metal tape 20 μm thick. 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 high-tech glass-ceramics having close to zero thermal expansion factor. The compensating windings are fixed on the frames made from the same material.

Attention! Any shocks with acceleration more than 5 g 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

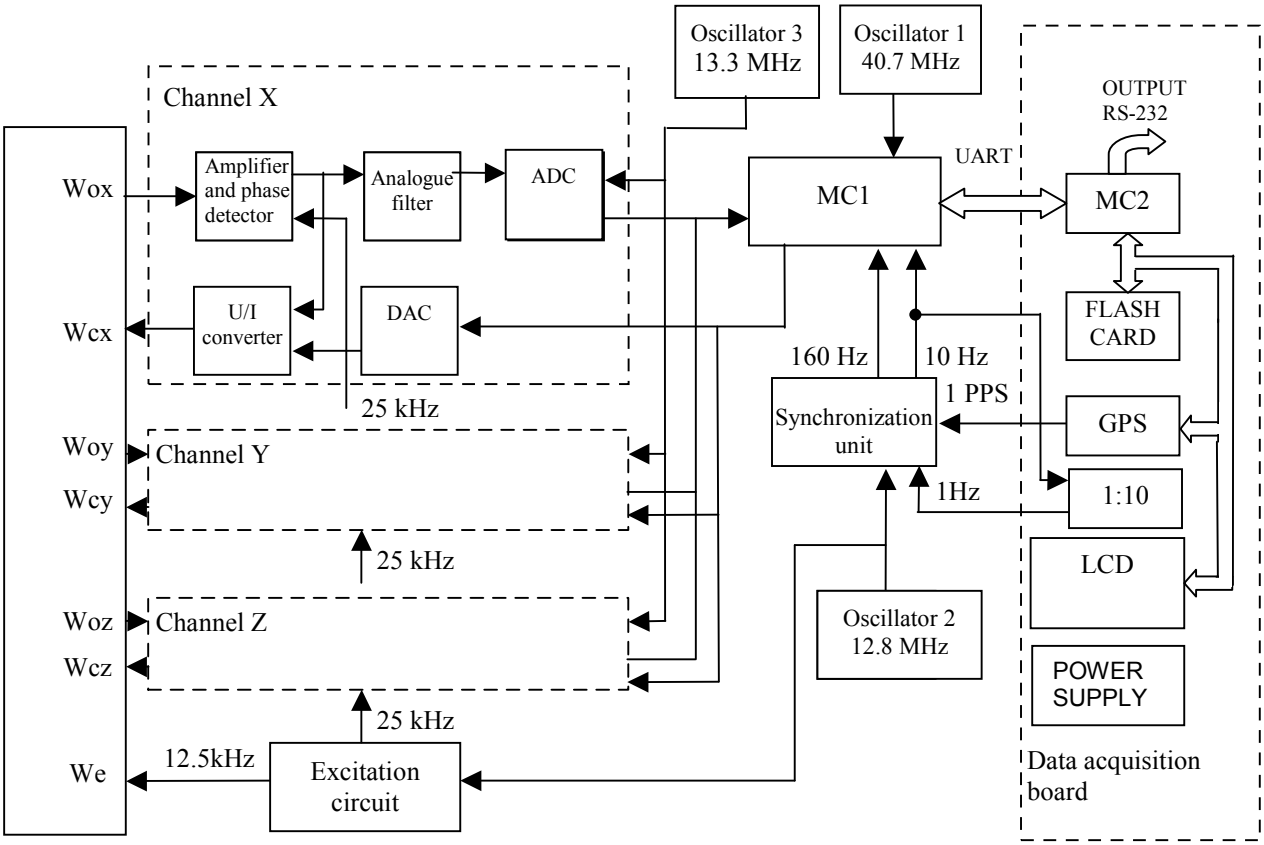


Fig.3. Functional diagram of FGM

FGM functional diagram is given on Fig.3. The FG sensor, driven at f_0=12.5 kHz by special Excitation circuit, is connected to the 3-channel measuring unit. This electronic unit consists of two printed boards. Main board contains FG magnetometer electronics. Second board contains data acquisition system.

The operation of this unit is described at the example of X-channel, other channels operate in the same way. The signal from sensor measuring winding Wox comes to the selective amplifier with central frequency f_1=25 kHz, which is equal to the second harmonic of excitation frequency f_0=12.5 kHz. Its output signal is amplified and rectified by the phase-sensitive detector. The output voltage of this detector, passing through the voltage-to-current converter, generates in the compensating winding Wcx a feed-back magnetic field. The parameters of the feed-back loop are selected in such a way, that measuring range of magnetic field variations is not less than ± 4000 nT and the cut-off frequency is

about 20 Hz. The output signal of the phase-sensitive detector also comes to the analog filter, which provides a deep suppression at the frequency of 60 Hz and -40 dB/decade slope at the frequencies higher than 100 Hz. The summary phase delay of the analogue section of the magnetometer (at ADC input) is about 12 ms in the frequency range DC – 10 Hz. Three $\Delta\Sigma$-type ADC – one in every channel - operate simultaneously and synchronously using the common external Oscillator 3 with frequency 13.3 MHz. At this, the analog-to-digital conversion time is equal to t_{conv}=6.157 ms. The output code of each ADC is read one after another by the microprocessor MC1 every t_{sample}=6.25 ms, which is defined by MC1 interruption signal with frequency f_{int1}=160 Hz coming from Synchronization unit. The data processing time (or transfer time) of each ADC is approximately equal to 0.02 ms. The new conversion cycle starts immediately after the completion of the transfer of ADC output data to MC1. So, the maximal possible time shift between the ADC readings of every magnetometer channel does not exceed t_{sample}-t_{conv}=0.093 ms.

Quantized data from ADC come to microprocessor MC1 which filters further these data using finite impulse response digital filter with coefficients presented in Table 1. The cut-off frequency of the digital filter is equal to 3.72 Hz. The filtered data are centered to the 0.1 UTC second by means of interruption signal with frequency f_{int2}= 10 Hz coming from Synchronization unit, which is based on the very stable temperature compensated internal crystal 12.8 MHz oscillator. The falling edges of both interruption signals coincide with 1PPS signal from GPS receiver within $\pm$ 0.5 μs.

Table 1

t_1, t_{80}	t_2, t_{79}	t_3, t_{78}	t_4, t_{77}	t_5, t_{76}	t_6, t_{75}	t_7, t_{74}	t_8, t_{73}	t_9, t_{72}	t_{10}, t_{71}
-21	-30	-51	-84	-133	-200	-291	-407	-550	-721
t_{11}, t_{70}	t_{12}, t_{69}	t_{13}, t_{68}	t_{14}, t_{67}	t_{15}, t_{66}	t_{16}, t_{65}	t_{17}, t_{64}	t_{18}, t_{63}	t_{19}, t_{62}	t_{20}, t_{61}
-917	-1134	-1364	-1594	-1809	-1988	-2109	-2143	-2063	-1840
t_{21}, t_{60}	t_{22},t_{59}	t_{23}, t_{58}	t_{24}, t_{57}	t_{25}, t_{56}	t_{26}, t_{55}	t_{27}, t_{54}	t_{28}, t_{53}	t_{29}, t_{52}	t_{30}, t_{51}
-1443	-846	-26	1034	2344	3904	5704	7724	9933	12287
t_{31}, t_{50}	t_{32}, t_{49}	t_{33}, t_{48}	t_{34}, t_{47}	t_{35}, t_{46}	t_{36}, t_{45}	t_{37}, t_{44}	t_{38}, t_{43}	t_{39}, t_{42}	t_{40}, t_{41}
14736	17218	19668	22015	24189	26123	27753	29027	29901	30346

The correction of the total phase delay of both analog and digital filters is executed by a special procedure of the time scale shifting. The time diagrams, which explain this procedure, are presented on Fig. 4. The upper line of time diagram presents a plot of possible geomagnetic variation (Fig. 4, a). Let's consider measurement process of the

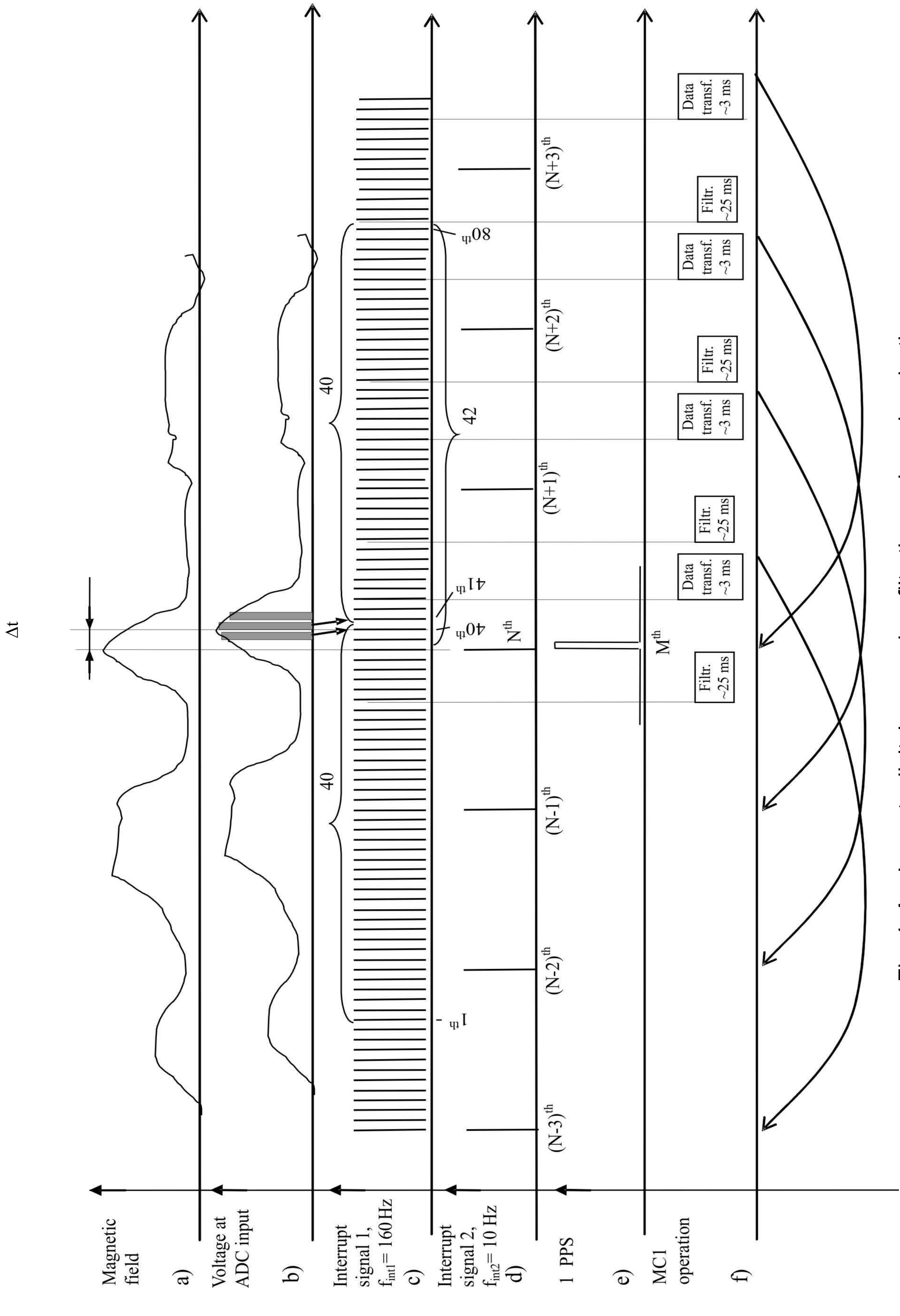


Fig. 4. Analogue-to digital conversion, filtration and synchronization.

magnetic field at the moment of time corresponding to M^{th} UTC second (and N^{th} 0.1 UTC second). Due to the time delay of the magnetometer analogue section its output voltage corresponding to the magnetic field appears at the ADC input with delay Δt=12 ms (Fig. 4, b). The values of this voltage averaged during time interval t_{conv} periodically (with Fs=160 Hz) are converted into digital codes (Fig. 4, b, c). At each step the filtration procedure uses 80 ADC samples. Due to the symmetry of the digital filter impulse response the result of the filtration is referred to the moment of time between 40^{th} and 41^{th} samples and taking into account ADC conversion time t_{conv} this moment practically coincides with 40^{th} 160 Hz interruption pulse (Fig. 4, c). In order to center filtered data to the 0.1 UTC second the filtration procedure starts as soon as 43 ADC samples after N^{th} pulse (or 11 samples after $(N+2)^{th}$ pulse) of the 10 Hz interruption signal have been received (Fig. 4, c, d). The MC1 calculates filtered values for all three channels (it takes about 25 ms) and transfers these data (Fig. 4, f) through UART interface to the microprocessor MC2 of the data acquisition board (Fig. 3). As it clearly seen from Fig. 4, e, f the packet of digital data corresponding to the magnetic field at M^{th} UTC second (and N^{th} 0.1 UTC second) appears with time shift about 0.33 s. The described digital filtration procedure is repeated every 0.1 second, then the fourth (after the N^{th} 0.1 UTC second) packet of data from MC1 corresponds to the selected moment of time.

NOTE! Due to the limited precision of microprocessor calculations the digital filtration procedure is valid only if the magnetic field fluctuation does not exceed 150 nT during 0.5 second.

Based on the filtered data the MC1 calculates the code value of compensation magnetic field using special algorithm and sends it to the DAC and U/I-converter. The output current of the latter compensates the magnetic field in the volume of the corresponding component of FG sensor.

The automatic compensation procedure at DAC output runs only once just after switching on the magnetometer power supply. At this, firstly the last used at precedent operation period DAC codes are applied and compensation procedure stops, if the residual uncompensated values occurs in the range ±2000 nT. If not, the compensation procedure goes over DAC codes until the uncompensated values falls in the range ±4 nT and these new codes are stored.

The compensation field may be also changed manually using magnetometer control software. For the detailed description of manual compensation mode please see subsection ***7.6.2.3.2*** of this Manual.

MC1 transfers the DAC and ADC codes to MC2 each 100 ms. Each second MC2 also receives a time stamp from GPS receiver.

NOTE! In order to simplify MC2 operation algorithm the data from MC1 are assigned to the nearest time mark received from GPS and the necessary time scale correcting shift (-0.3 second) is carried out by the PC software.

MC2 makes floating point calculations for scaling DAC and filtered ADC codes (see also section **7.3** of this Manual), forms the data for LCD and Compact FLASH memory card and transfers them to PC through RS-232 port. Real time data exchange between PC and magnetometer is realized through interface RS-232 at the rate 57600 Baud (start bit, 8 data bits, and stop bit). The description of the appropriate COM-port selection of the PC is given in the section **7.6.1**.

NOTE! As this instrument was developed for observatories, it operates as variometer and output data along each component are split to constant bias values (proportional to DAC codes) and variations (proportional to ADC codes). The PC files with data do not contain constant bias values, but only variations. However, bias values could be observed at the instrument LCD (see Chapter 6.2 and Fig. 5), and also could be changed manually using control software (see Chapter 7.6.2.3.2). All changes of DAC codes are fixed in the protocol file lemi025.log (see Chapter 7.6.2.2.)

6. OPERATION INSTRUCTION

6.1. Preparation for Operation

6.1.1. Open the transportation housing and take off the FG sensor.

6.1.2. Put the FG sensor on the pillar. Turn the sensor housing in such a way that the arrow at the top of the sensor cover points the North approximately. Positive directions of the magnetic components are: X – to the North, Y – to the East, Z – down.

6.1.3. Level FG sensor by bubble levels with screws on the sensor legs.

6.1.4. Make following connections:

- Couple the FG sensor with the electronic unit (connector “FG sensor”) by the FG sensor cable;
- Couple GPS antenna with the electronic unit (connector “GPS”) by the GPS antenna cable;
- Connect the external power supply and the electronic unit (connector “+12V”) by the Power supply cable.

Special precautions have to be taken when POWER connector is coupled to the 12 V battery. The wire with **RED** mark on 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 FGM. There is special protection inside against wrong polarity, but not against overvoltage! Power supply voltage must be in (9-18) V range.

It is highly recommended to use backup battery for uninterruptable operation of the instrument.

The FGM is ready for operation.

6. 2. Operation

In this section the autonomous control procedure of the magnetometer is described. Almost the same operations could be performed using PC software (see Section 7).

6.2.1. Switch the POWER switch to the position ON.

6.2.2. After POWER is switched on the information presented in Fig. 5, a will appear at the magnetometer display.

It contains manufacturer name, the magnetometer model, program software version and its serial number. After 5 seconds the microcontroller MC2 software checks the Compact FLASH card presence in the slot at the front panel and its file structure, volume and free space (Fig. 5, b).

After still 10 seconds magnetometer turns itself into main menu mode. (Fig. 5, c). From this mode it is possible to choose four submenus items:

- Time set;
- FLASH Info;
- Data Acquisition Modes (PC, FLASH, FLASH+PC);
- Start Record.

Shift along menu items is fulfilled by short pressing of CONTROL button (<1 s) and transition to the selected submenu – by long pressing of CONTROL button (> 2 s).

Marker (*) shows the requested menu item.

If the first submenu is chosen by long pressing, the program interrogates GPS receiver and displays at LCD current UTC time and magnetometer geographical co-ordinates (Latitude, Longitude). With next long pressing of CONTROL button the program comes back to the main menu mode.

The timing of the internal clock from GPS is carried out every second, if at least three satellites are received by GPS antenna. The GPS status is indicated at the right end of the second row of LCD (**A** - GPS is active and is setting the accurate time, see Fig.5, d).

6.2.3. Long pressing of CONTROL button in third menu item sets data acquisition mode to **FLASH, PC or FLASH+PC.**

Attention! The data acquisition modes FLASH and FLASH+PC are recommended as test modes only.

6.2.4. Long pressing of CONTROL button at 4-th menu item is necessary for starting measurement process and beginning data transfer. The data come to PC through RS-232 interface or/and to FLASH card memory depending on chosen data acquisition mode.

NOTE! The data transfer to PC starts exactly at the beginning of the next minute, so corresponding delay between CONTROL button pressing and beginning data acquisition is possible.

There are two own submenus in measurement mode, to which the magnetometer enters after start record. Transfer to the next submenu is fulfilled by short pressing of

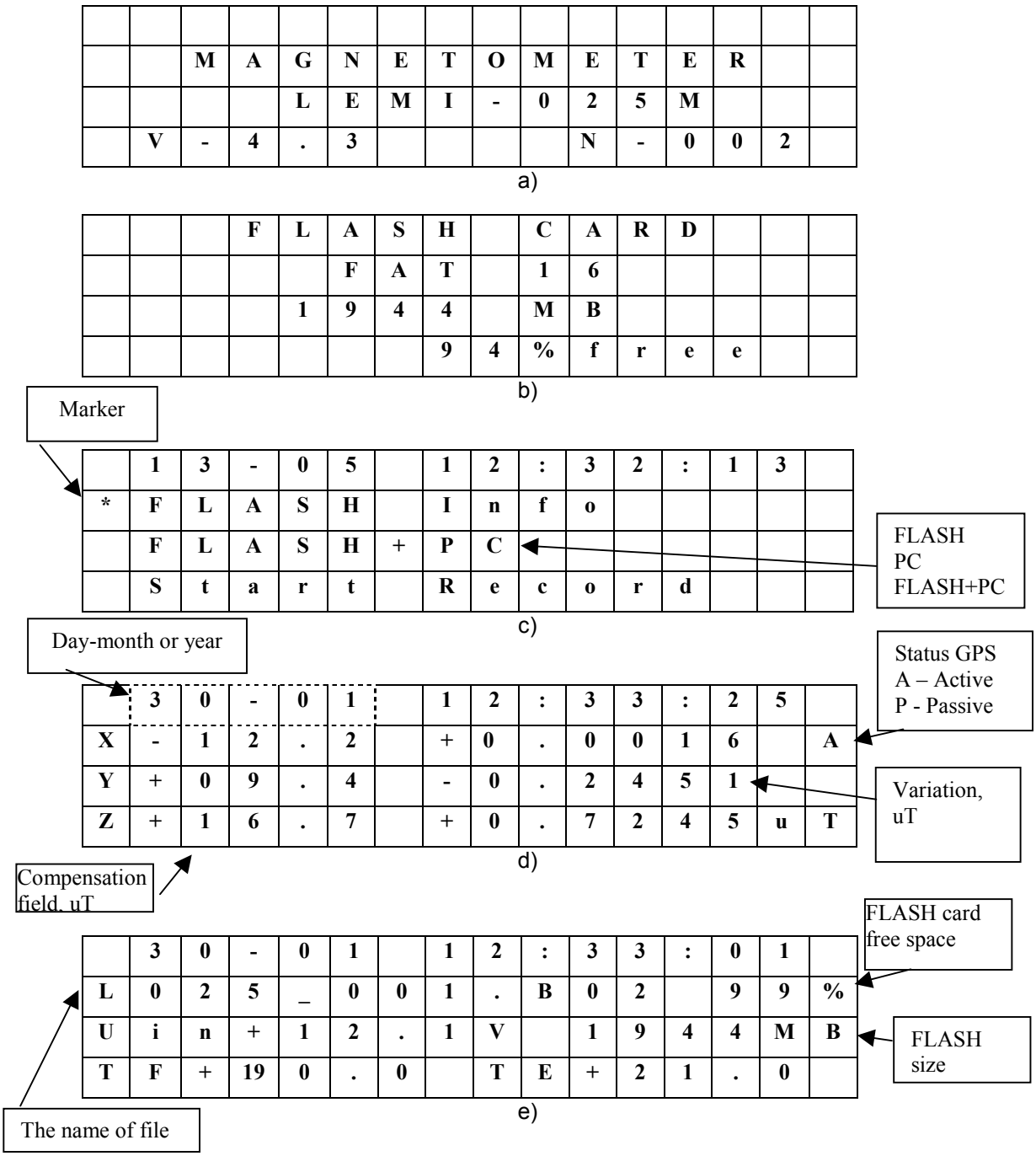


Fig. 5. Information on magnetometer LCD display

CONTROL button after the data acquisition is on and long pressing of this button leads to return to the main menu.

In first submenu (Fig. 5, d) the following data is shown on display: current data and time, the values of magnetic field components. Left part of each data of magnetic field component gives compensation field, right part – value of magnetic field variations. The day and month are displayed almost continuously in the left part of the first line. The year is displayed instead day and month during 1 sec at the beginning of the each minute.

In second submenu (Fig. 5, e) the name of the current file, FLASH card free space in percents, power supply voltage and FLASH size are indicated. FLASH card free space in percents and FLASH size are indicated in FLASH or FLASH+PC data acquisition modes only.

6.2.5. To interrupt measurements use long press of CONTROL button in measurements mode. Before stop of the measurements the program warns user: “STOP WORK?”

With short press of CONTROL button the program continue to work in measurements mode. With long press the program stops measurements and goes to main menu.

Attenttion!

1. Magnetometer LEMI-025 operates with COMPACT FLASH cards with FAT16 files system only. If FLASH card is formatted under other file system (FAT12, FAT32) it is necessary to reformat it on PC with standard Compact FLASH card reader.

2. Data recording is fulfilled to the FLASH card root directory. That is why the maximum number of files can not exceed 512 files.

3. Every new day at midnight the program opens new file.

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

7. CONTROL SOFTWARE OF MAGNETOMETER LEMI-025 (Version 1.9. 02.08.2010)

7.1. Description of the software package

The software contains following files:

lemi025.exe	Magnetometer control, data visualization, data acquisition, conversion of binary FLASH cards files to text files
lemi025.log	Protocol file
.b	Binary data files
***.inf**	Text information file created at the decoding binary data files
***.txt**	Text data files (data sample – 0.1sec.)
***.sec**	INTERMAGNET standard IAGA 2002 (filtered to 1sec.) files
***.min**	INTERMAGNET standard IAGA 2002 (filtered to 1min.) files
***.def**	Text file with calibration coefficients
lemi025.ini	Text file with program operation parameters. It also contains the header of ***.sec** and ***.min** files and magnetometers compensation values.

The program is intended for:

- Magnetometer control;
- Real time data visualization (3 components of magnetic field and also electronics and FG sensor temperatures);
- Writing magnetometer data to text files on PC hard disk;
- Conversion FLASH-card binary files to text files;
- Visualization the stored data (all three types of the text data files);
- Editing of the file header in accordance with IAGA-2002 format.

7.2. Data files

Program operates with text and binary files.

Magnetometer data is written to FLASH card in binary format. It is possible to copy them to PC by standard Compact FLASH card reader and then convert to text files by program **lemi025.exe** (see section **7.6.2.1**).

In text files every line corresponds to one value of magnetic field in a certain time moment. The whole file is built with columns.

7.2.1. Structure of *.txt file

The initial magnetometer data is stored in the ***.txt** file, which structure is described in Table 2.

Table 2.

Column No	Example	Description	
1	2010	Year	UTC (Greenwich) current time
2	02	Month	
3	25	Day	
4	19	Hour	
5	29	Minute	
6	37.0	Second	
7	2270.954	BX	Magnetic field variations along orthogonal directions
8	280.505	BY	
9	439.140	BZ	
10	00.00	TE	Temperatures of electronics and sensor
11	00.00	TF	
12	12.2	Uin	Power supply voltage
13	65	Status of GPS	65 – GPS active, 80 - GPS passive

Text file example:

2010 02 25 19 29 37.0 2270.954 280.505 439.140 19.00 21.00 12.2 65

2010 02 25 19 29 37.1 2270.505 280.941 439.161 19.00 21.00 12.2 65

2010 02 25 19 29 37.2 2268.609 281.337 440.093 19.00 21.00 12.2 65

At least one space exists between columns. Line is ended with ENTER symbol - 0x0D 0x0A (hex). Time step between lines is equal to 0.1 s.

7.2.2. IAGA2002 formatted data files (*.sec and *.min)

On the base of 10 Hz data the program calculates 1-second data using digital Gaussian filter with 17 coefficients presented in Fig. 17. The filtered values are centred to the top of the second. A second Gaussian filter (with coefficients from INTERMAGNET Technical Reference Manual (version 4.4, 2008), Appendix F-1) produces 1-minute values, centred at the top of the minute, from 1-second values.

1-second and 1- minute data are stored in the separate files in accordance with IAGA2002 INTERMAGNET exchange format (for reference see Technical Reference Manual (version 4.4, 2008), Appendix E-5). The example of the 1-sec file beginning is presented below:

```
 Format                 IAGA-2002                                          |
 Source of Data         Royal Meteorological Institute of Belgium          |
 Station Name           Dourbes                                            |
 IAGA Code              DOU                                                |
 Geodetic Latitude      50.100                                             |
 Geodetic Longitude     4.600                                              |
 Elevation              225                                                |
 Reported               HDZF                                               |
 Sensor Orientation     HDZF                                               |
 Digital Sampling       0.00625 seconds                                    |
 Data Interval Type     Filtered 1-second (00:00.2-00:01.8)                |
 Data Type              variation                                          |
 #www.isr.lviv.ua                                                          |
DATE       TIME         DOY     DOUX      DOUY      DOUZ      DOUF     |
2010-02-11 15:06:02.000 042        -5.26      9.39     -5.55  88888.00
2010-02-11 15:06:03.000 042        -5.27      9.38     -5.54  88888.00
2010-02-11 15:06:04.000 042        -5.27      9.38     -5.55  88888.00
```

7.2.3. The format of data files name

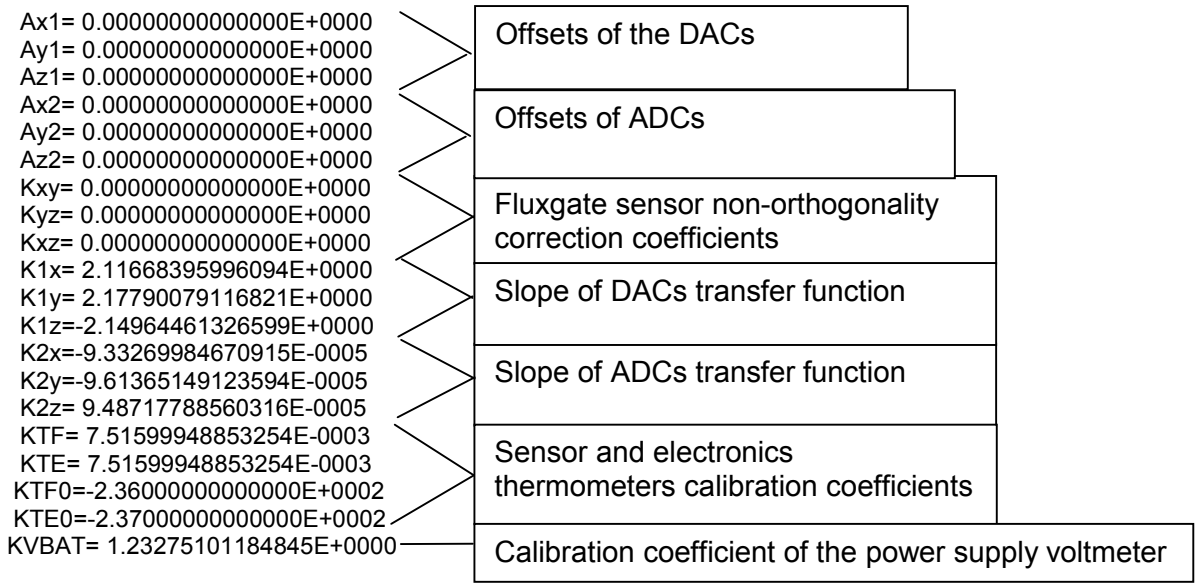
Data file name is created automatically using a current GPS time at the start of the file recording. For example: “dou20050927192937v.txt”. The format of the file name: iagyyyymmddhhmmnnv.ext, where: iag – IAGA 3-letter station code, yyyy-year, mm-month, dd-day, v-variation, ext -“txt” or “min” or “sec” files extension. If the recording was stopped and then started again a new file will be created.

If the file contains data starting at UT 00:00:00 its name looks as iagyyyymmddv.ext, for example “dou20050928v.min”.

*NOTE! The file name includes IAGA 3-letter code, which the program takes from the header edited by Customer (see for more details in the section **7.6.2.3.3**).*

7.3. The calibration file (*.def).

Calibration coefficients in the magnetometer LEMI-025 are kept in non-volatile memory and used by the instrument software for transformation of the DAC and ADC codes to output values of the magnetic and temperature channels. The program **lemi025.exe** allows edit these coefficients and save it in the file ***.def** to PC hard disk (see section **7.6.2.3.1**). The example of a calibration file is given below:



Attention! Calibration coefficients are settled by the Manufacturer and can be changed by expert users only. It is desirable to keep reserve copy of the calibration file, the configuration file lemi025.ini and the control program on independent information carrier.

7.4. The protocol file (lemi025.log)

This file is created automatically and continuously replenished with protocol information. It contains magnetometer start and stop time, given commands, magnetometer replies, errors information etc. It is very important for the designers to have it in the case of errors searching.

7.5. The configuration file (lemi025.ini)

The configuration file **lemi025.ini** is the text file with program operation parameters: name of the output folder, the serial port number, screen settings etc. It also contains default header for ***.sec** and ***.min** data files and DAC codes and compensation field values of the magnetometer. The example of the **lemi025.ini** file is given below:

```
[Config]
DACX=7480
DACY=0
DACZ=-17498
OutputDirectory=D:\LEMI-025
ComPort=COM2
[Title]
CommentOn=1
NumComment=3
Comment1= # LEMI-025#2 in 325 also measures termochamber temperature        |
Comment2= #                                                                 |
Comment3= #                                                                 |
CommentDacCompensationOn=1
Source of Data=LC ISR
Station Name=lab. 325
IAGA Code=LEM
Geodetic Latitude=
Geodetic Longitude=
Elevation=
Reported=HEZ
Sensor Orientation=HEZ
Comment4= # acquisition system                                              |
Comment5= #                                                                 |
[TMainForm]
FormVersion=0
Flags=0
ShowCmd=1
PixelsPerInch=96
MinMaxPos(1280x1024)=-1,-1,-1,-1
MinMaxPos=-1,-1,-1,-1
NormPos(1280x1024)=116,132,1243,878
NormPos=116,132,1243,878
Visible=0
OpenDialogDATA_InitialDir=
Panel0_Height=207
Panel1_Height=207
Panel2_Height=209
Panel3_Height=124
Panel4_Height=156
CrossMouseCB_Checked=False
CheckBox0_Checked=True
CheckBox1_Checked=True
CheckBox2_Checked=True
CheckBox3_Checked=False
CheckBox4_Checked=False
```

WARNING! It is absolutely forbidden to change the configuration file lemi025.ini outside of the program lemi025.exe!

7.6. Program operation

In the main window header (Fig. 6) the name of the program and file name (if it is open) is displayed.

The user can choose how many and what channels have to be displayed (Fig. 7). From 1 to 5 channels can be viewed simultaneously (Bx, By, Bz, Te, Tf).

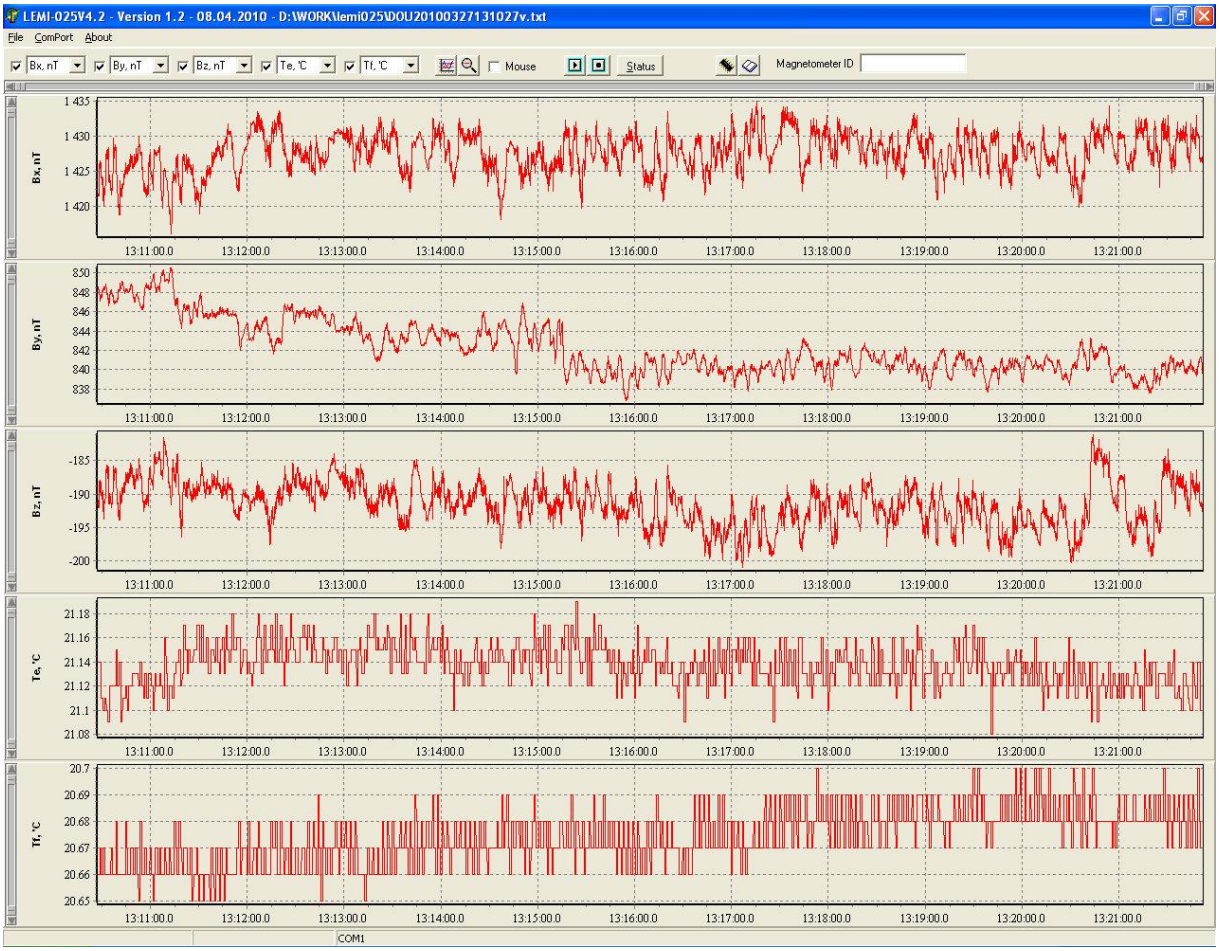


Fig. 6. The main program window.

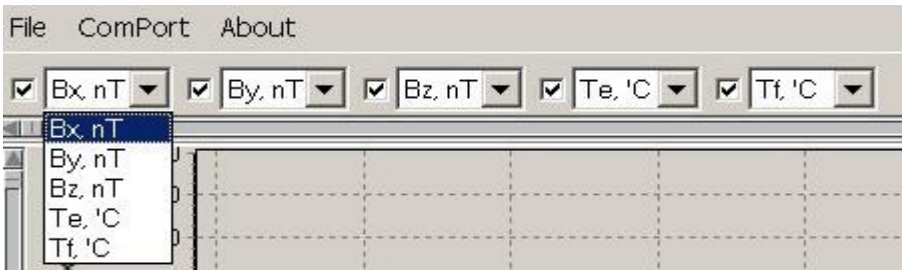


Fig. 7. Choice of displayed channels.

7.6.1. Description of the main menu

1. **File** → **Open file –** open file from the list. It is possible to choose type of the data file: ***.txt**, ***.sec** or ***.min** (Fig. 8). Basing on the selected type of file the program correctly accepts the format of the stored data.
   → **List of files… –** the list of the files that recently were opened.
   → **Output directory...** – run the window «Choose output directory» (Fig.9) for setting the name of the folder, where real time recorded data files will be stored.
   → **Exit** – exit from the program.
2. **ComPort** → Choice of the serial port number (Fig. 10). Before the manual setup of the serial port number the program checks the last used serial port (basing on the information from the configuration file **lemi025.ini**) or the last number of the serial port available in the PC. The program automatically sets up the parameters of the chosen serial port (57600 Baud, start bit, 8 data bits, stop bit).
3. **About** → program version information (Fig. 11).

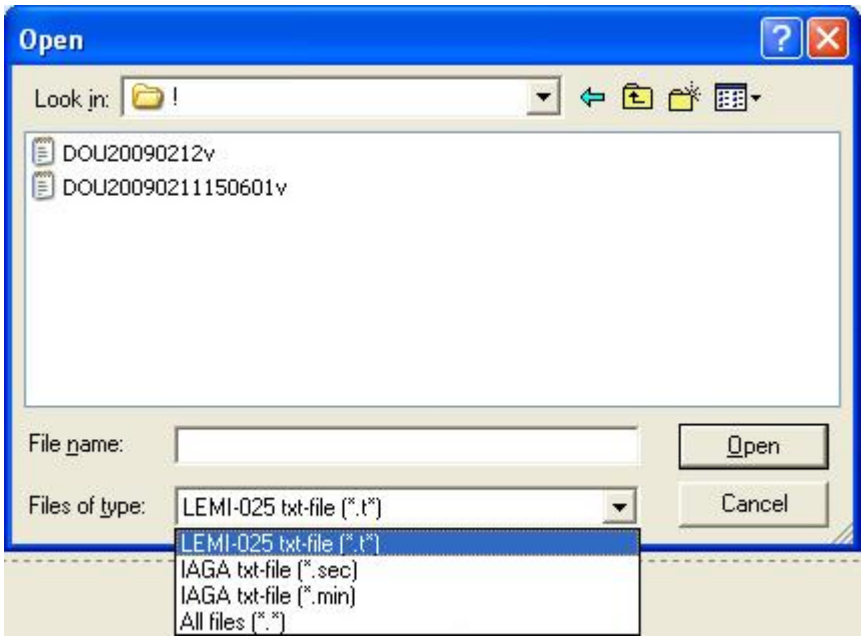


Fig. 8. The window "Open".

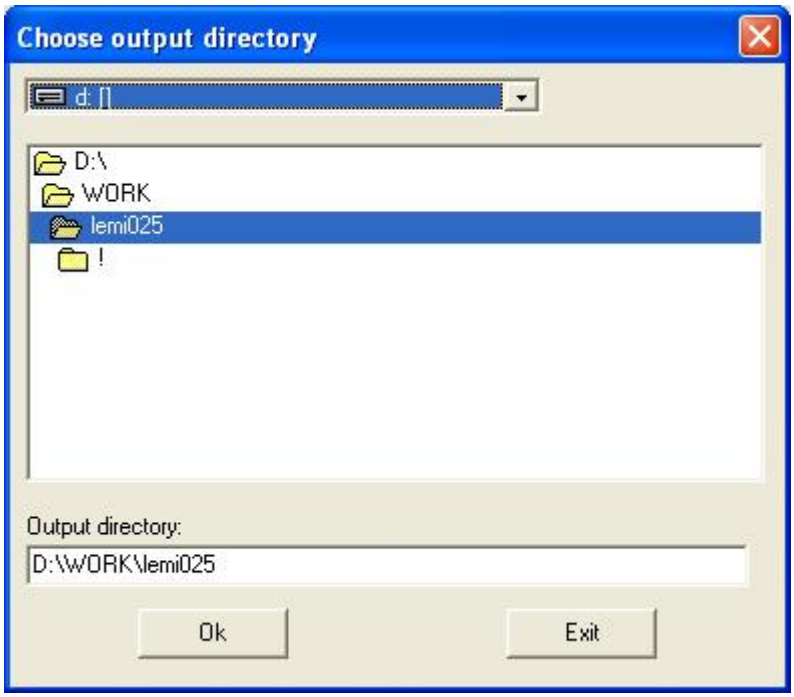


Fig. 9. The window "Choose output directory".

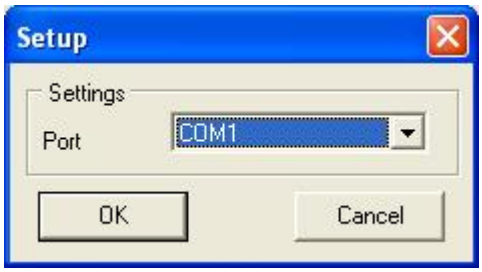


Fig. 10. Serial port choice.

Fig. 11. The window "About".

7.6.2. Description of the Buttons in the main menu

 Start and stop recording on PC disk and (or) on the magnetometer FLASH card

 Binary files choice and its conversion to text files (Fig. 12)

«Status» Open the window «Status» for magnetometer parameters setting (Fig. 16).

 Protocol file viewing (Fig. 15)

 «Range» - Arrange all plots.

«Zoom» - diminish all plots to view them in full

7.6.2.1. Decoding of the binary files.

The operation with binary files is possible only if there is no real time data record. Pressing the button  open the window «Bin To IAGA» (Fig. 12). In this window press the button «Open» (Fig. 12, step 1) and open the window «Open» (Fig. 13). Select the necessary binary file(s) (Fig. 13, step 2). For the packet file selection use keyboard buttons “Ctrl” or “Shift” and/or left button of the mouse. After pressing button “Open” (Fig. 13, step 3) return to the window «Bin To IAGA» and see the list of the selected files in the left panel of the window (Fig. 12, step 4). In the right panel of the window the time stamp of the first data record in the corresponding binary file will be indicated. (*In the current version of the program the files automatically sorted by the name, in spite of the order of its selection*). Press button «Bin To IAGA» (Fig. 12, step 5) for decoding binary files to the text files (***.txt**, ***.sec** and ***.min**). The program treats the matched binary files (it means that there is no gap between the time stamp of the last record in the file and the time stamp of the first record in the next file) as a single piece of data and correctly performs filtration procedures. The filtered data will be split to the different files in accordance with its belonging to the specific day.

The details of the decoding process will appear in the separate window (Fig. 14) and saved in the file ***.inf** (* - the same as the name of the first ***.txt** file). In the first part of the information file (Fig. 14, Zone 1) the entire data from the first decoded binary file will be displayed. The list of all created text files will be presented in the second part of the information file (Fig. 14, Zone 2). The text data files **(*.txt**, ***.sec** and ***.min**) as well as the information file (***.inf**) will be created in the same folder, where the decoded binary files are located.

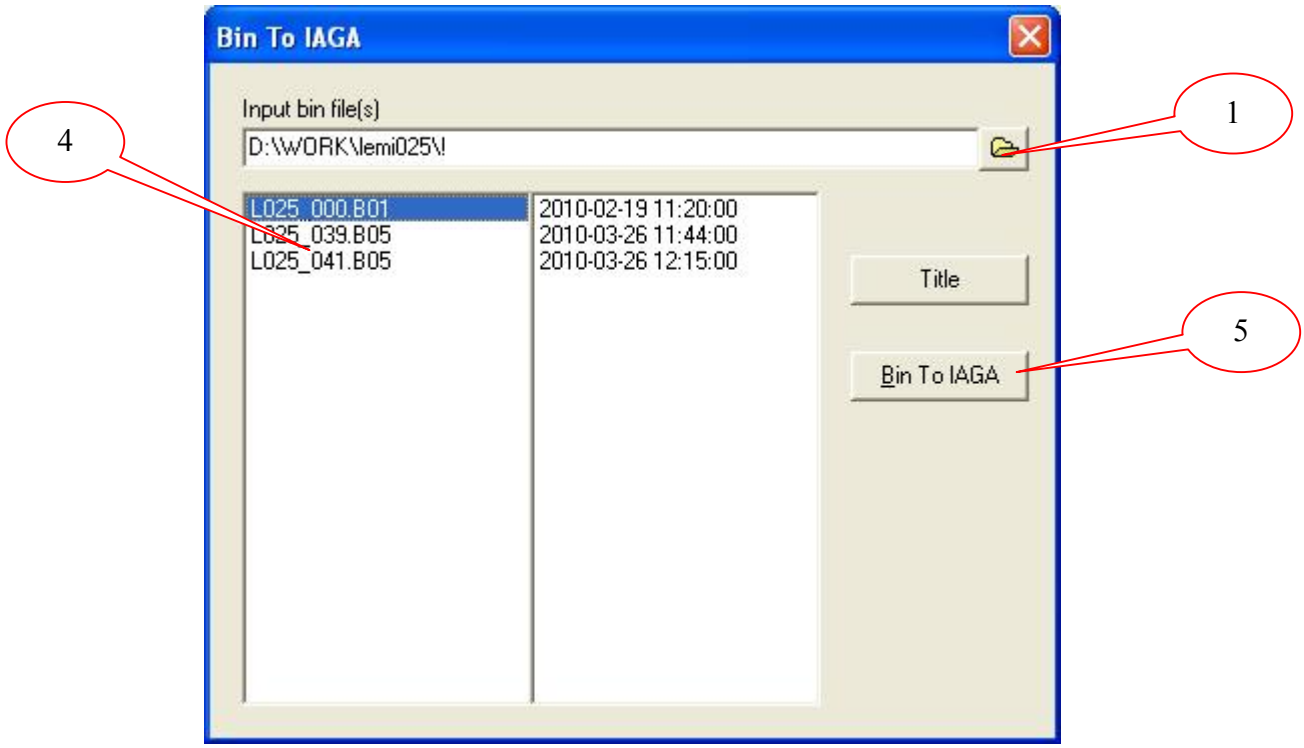


Fig. 12. The window «Bin To IAGA».

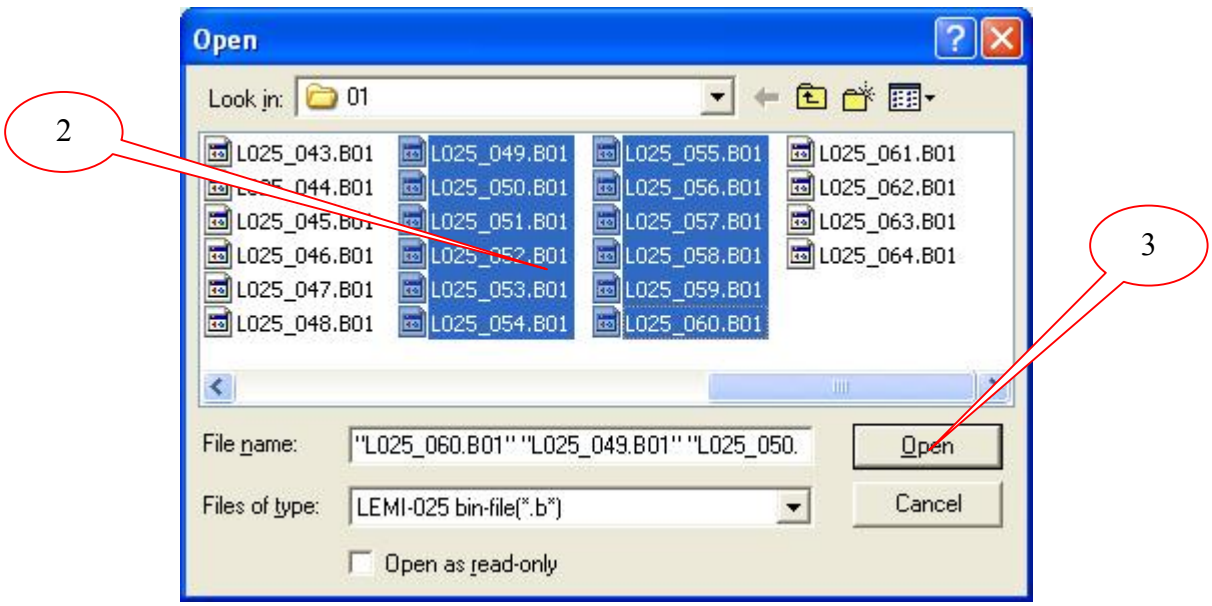


Fig. 13. Selection of the binary files for decoding.

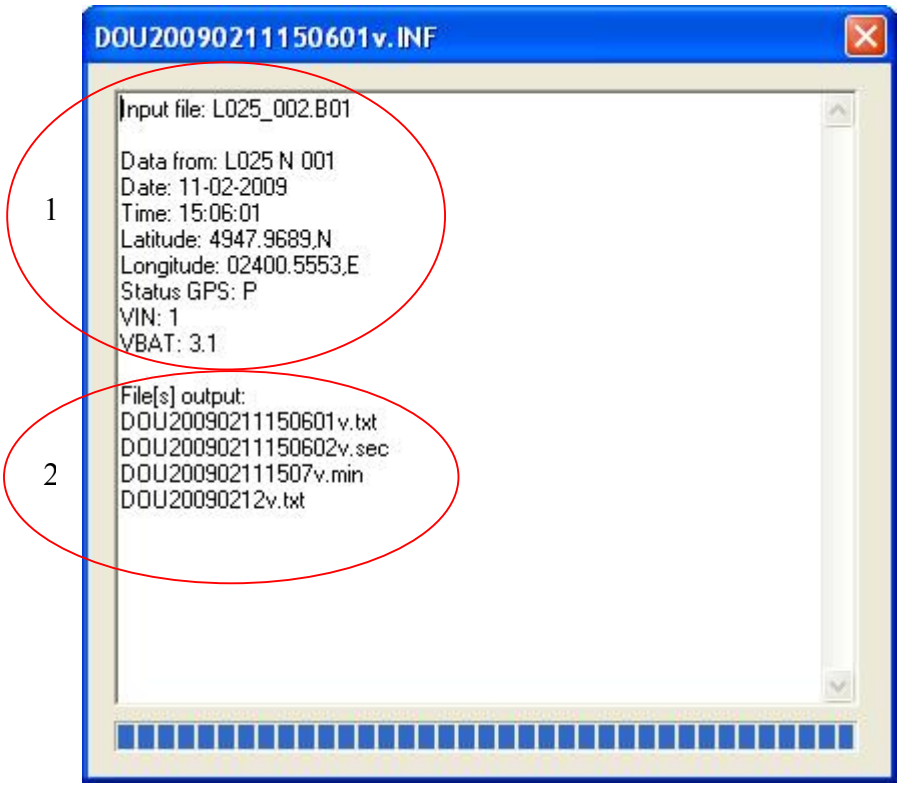


Fig. 14. The window with the information file *.inf.

NOTE! The text data files will overwrite the previous files with the same names without warning! In order to prevent undesirable loss of information, please keep binary files in the folder different from the folder with files recorded in the real time mode!

7.6.2.2. Protocol file viewing

For protocol file viewing press the button  in the main program window. At this the window «LogFile» will be open (Fig. 15). It is possible to clear all information in the protocol file by the press of the button **Clear**.

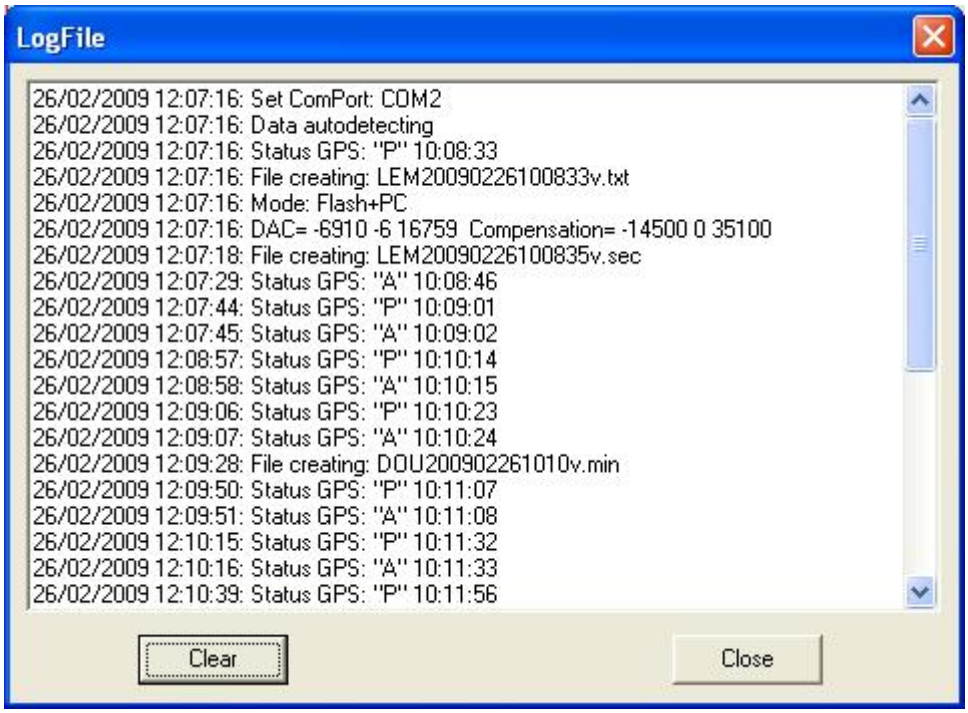


Fig. 15. The protocol file viewing.

7.6.2.3 «STATUS» window control commands

To give the control commands to the magnetometer press button «Status» in main menu. The dialog window «Status» will appear (Fig. 16). From this window user can:

1. Get magnetometer ID – magnetometer model and serial number.
2. Get magnetometer clock time in the field **Date/Time** pressing the button  .
3. Set magnetometer clock time from computer clock pressing the button  (if GPS is active the magnetometer clock automatically synchronized with UTC time received from GPS).
4. Get GPS data pressing the button  . At this the geodetic coordinates will be indicated. During the real time file recording the button  is inactive and the status of the GPS (**A** – active, P - passive) is displayed in the field **GPS data**.
5. Get the total FLASH card volume and its occupied space in percents pressing the button  .
6. Get the magnetometer DAC codes and compensation filed values during the real time record of the files.

7. Choose data acquisition mode: «FLASH» / «PC» / «FLASH+PC» before beginning of the files record. This possibility is deactivated during the real time record.
8. Choose the type(s) of the recorded files. This possibility is deactivated during the real time record.
9. Open window «Coefficients» (Fig. 17) pressing the button **Coefficients**. From this window it is possible to handle the magnetometer calibration coefficients (for more details see section **7.6.2.3.1**). The button **Coefficients** is inactive during the real time record.
10. Open the window «DACs» (Fig. 19) pressing the button **DAC**. From this window it is possible to handle the magnetometer DACs (see also section **7.6.2.3.2**). The button **DAC** is inactive until the real time record of the files is started.
11. Open the window «IAGA Title» (Fig. 20) pressing the button **Title**. In this window the header of the files stored in accordance with IAGA-2002 format could be edited (see also section **7.6.2.3.3**).

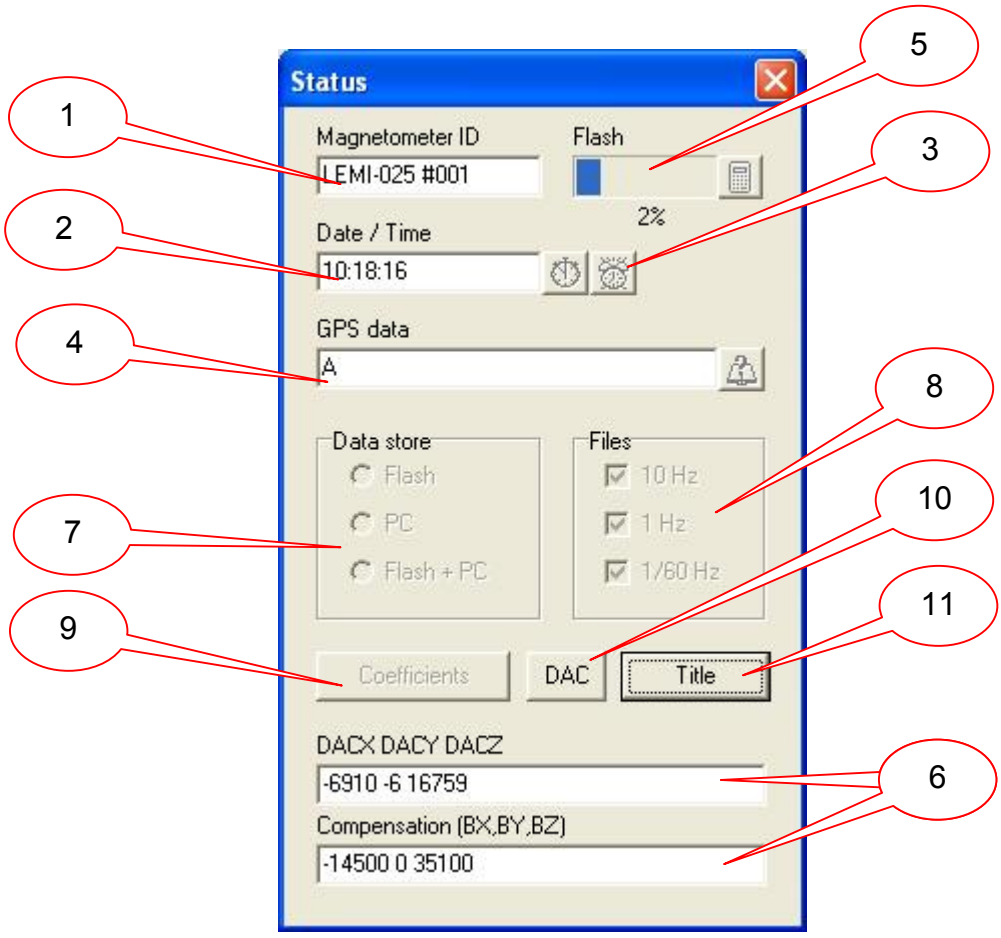


Fig. 16. The dialog window «Status».

7.6.2.3.1. Description of the window «Coefficients»

From this window (Fig. 17) user can:

1. Read the calibration coefficients from the magnetometer non-volatile memory pressing button **READ**. At this the calibration coefficients will be appeared in the corresponding fields of the window «Coefficients».
2. Edit the calibration coefficients directly in the window «Coefficients».
3. Write to the magnetometer non-volatile memory the calibration coefficients from the window «Coefficients».
4. Load the calibration coefficients to the window «Coefficients» from the calibration file (***.def**) pressing the button **Load**. At this the window «Open» will appear and it is possible to choose any file with extension **def** previously created on PC disk.
5. Write the calibration coefficients to the calibration file (***.def**) from the window «Coefficients» pressing the button **Write**. At this window «Save as» will appear and a user can specify the name of the calibration file.
6. Inspect the filter coefficients (Fig. 18), which are used for calculating 1-second and 1-minute data, pressing the button **FILTERS**.

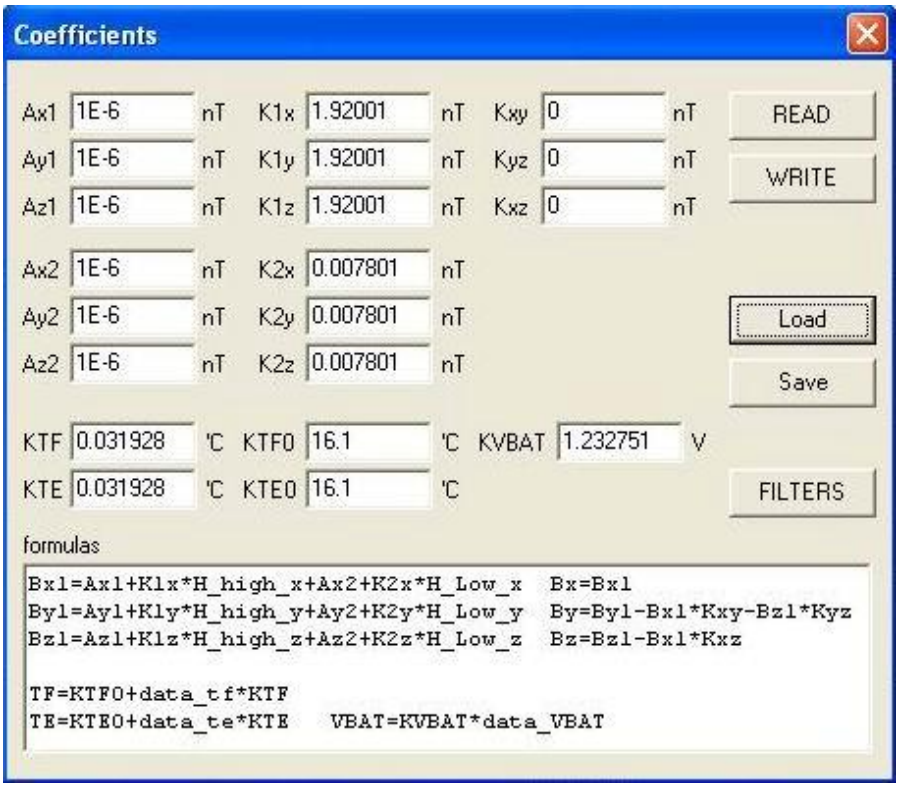


Fig. 17. The dialog window «Coefficients».

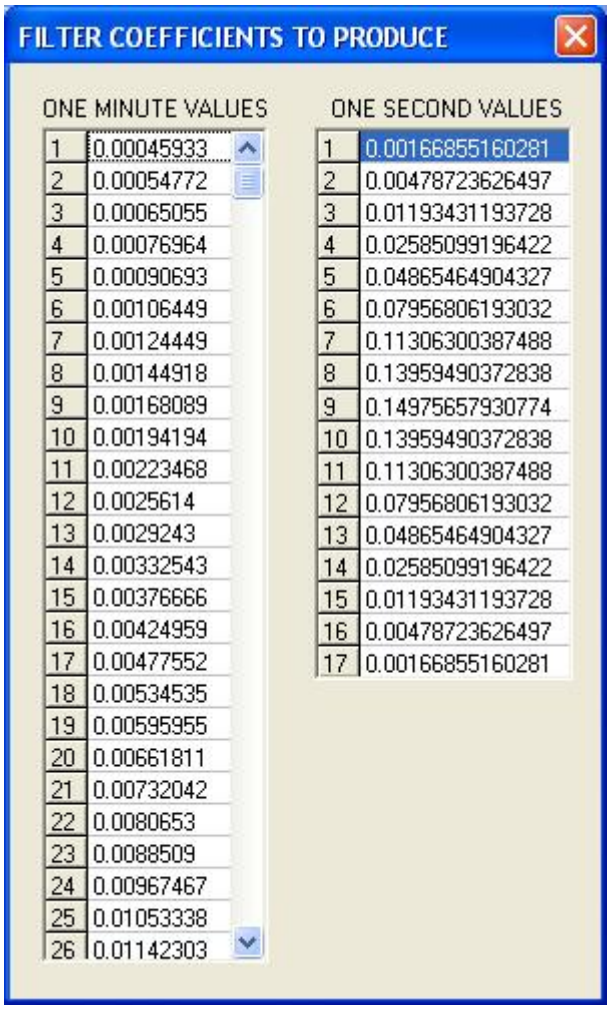


Fig. 18. The window «FILTER COEFFICIENTS».

7.6.2.3.2. Description of the window «DACs»

The window «DACs» (Fig. 19) could be open only during the real time record of the files. From this window user can:

1. Inspect the codes of the magnetometer DACs at the moment of opening the window «DACs». The magnetometer DACs codes as well as the compensation values may be also inspected in the fields **DACX, DACY, DACZ** and **Compensation (Bx, By, Bz)** in the window «Status» (Fig. 16).
2. Edit the codes in the fields **DACX**, **DACY** and **DACZ**. The codes should be integer numbers in the range -32768...32767.
3. Set the codes of the magnetometer DACs pressing the button **SET**. At this the values of the fields **DACX**, **DACY** and **DACZ** will be transferred to the magnetometer.

4. Save the edited DACs codes into the configuration file **lemi025.ini** pressing the button **Save**. *NOTE! If the edited codes have not been saved it will be lost at the restart of the program.*
5. Load the DACs codes from the configuration file **lemi025.ini** to the fields **DACX**, **DACY** and **DACZ** pressing the button **Load**.

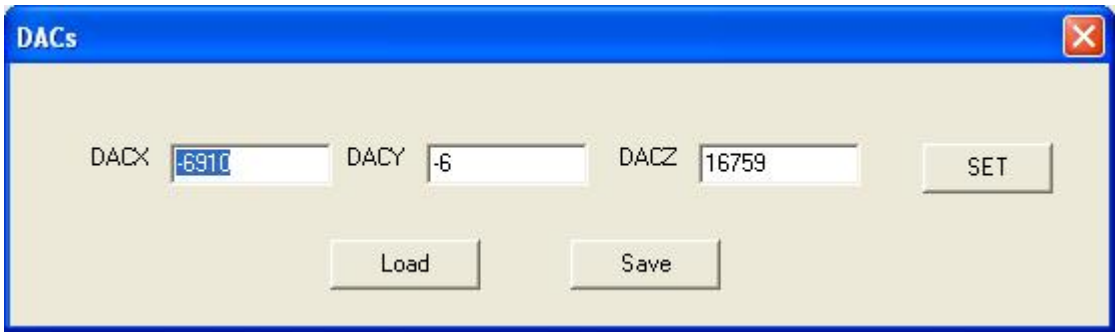


Fig. 19. The window «DACs».

NOTE! The exact values of the compensation field along each sensor component could be calculated as a product of the corresponding DACs code and the calibration coefficients (K1x, K1y or K1z). At the LCD display of the magnetometer and at the PC screen the values of the compensation fields rounded to 100 nT and 2.5 nT correspondingly are indicated.

7.6.2.3.3 Description of the window «IAGA title»

The window «**IAGA title»** (Fig. 20) could be open whether the magnetometer be on-line or off-line. At the start of the program the fields of the window are filled by the data from the configuration file **lemi025.ini**. If the program can not find the configuration file **lemi025.ini,** the default header would be used:

```
 Format                 IAGA-2002                                      |
 Source of Data                                                        |
 Station Name                                                          |
 IAGA Code                                                             |
 Geodetic Latitude                                                     |
 Geodetic Longitude                                                    |
 Elevation                                                             |
 Reported                                                              |
 Sensor Orientation                                                    |
 Digital Sampling       0.00625 seconds                                |
 Data Interval Type     Filtered 1-minute (00:15-01:45)                |
 Data Type              variation                                      |
DATE       TIME         DOY        X          Y          Z          F  |
```

Using this window user can combine the header of the ***.sec** and ***.min** data files in accordance with INTERMAGNET IAGA2002 format.

From this window user can:

1. Edit data in the fields **Source of Data**, **Station Name**, **IAGA Code (3 chars)**, **Geodetic Latitude, Geodetic Longitude, Elevation, Reported, Sensor orientation** and optional **Header comments field.** The latter could be optionally added to the header by checking the box **Add comment header records**.

   In the field **IAGA Code (3 chars)** the program automatically corrects lowercase letters to capital ones. It also possible set this field jointly with field **Station Name** choosing the appropriate name of the magnetic observatory from the list (Fig. 21).

   *NOTE! The content of the field **IAGA Code (3 chars)** is used as a part of data files' names. Be careful choosing the 3-letter code!*

   The view of the mandatory header records could be immediately inspected in the field **File title**.

   In accordance with IAGA2002 format the optional header comments should be started with "Space" and "#" symbols and ended by "|" symbol. The program automatically inserts these symbols. Editing the header comments please insert ENTER symbol (press button ENTER at the keyboard) at the end of each row (69^{th} column). The column of the symbols "|" in the field **File title** could serve as an indicator of the end of the row. **The program will be cut the comments rows longer than 69 symbols!** In order to check the view of the header comments periodically click by the left button of the mouse in any fields in the window **"IAGA title"** except the **Header comments** field.
2. Save the edited header records to the configuration file **lemi025.ini** pressing the button **Save**. *NOTE! If the edited information has not been saved it will be lost at the restart of the program.*
3. Load the header records from the configuration file **lemi025.ini** to the corresponding fields of the window pressing the button **Load**.
4. Insert into the optional header comments the information about the magnetometer DACs codes and compensation field values checking the box **Insert DAC, Compensation to comment header**. At this the actual values of the magnetometer DACs codes and compensation fields at the beginning of the real time record are used. This option is not used for the files decoded from the binary files.

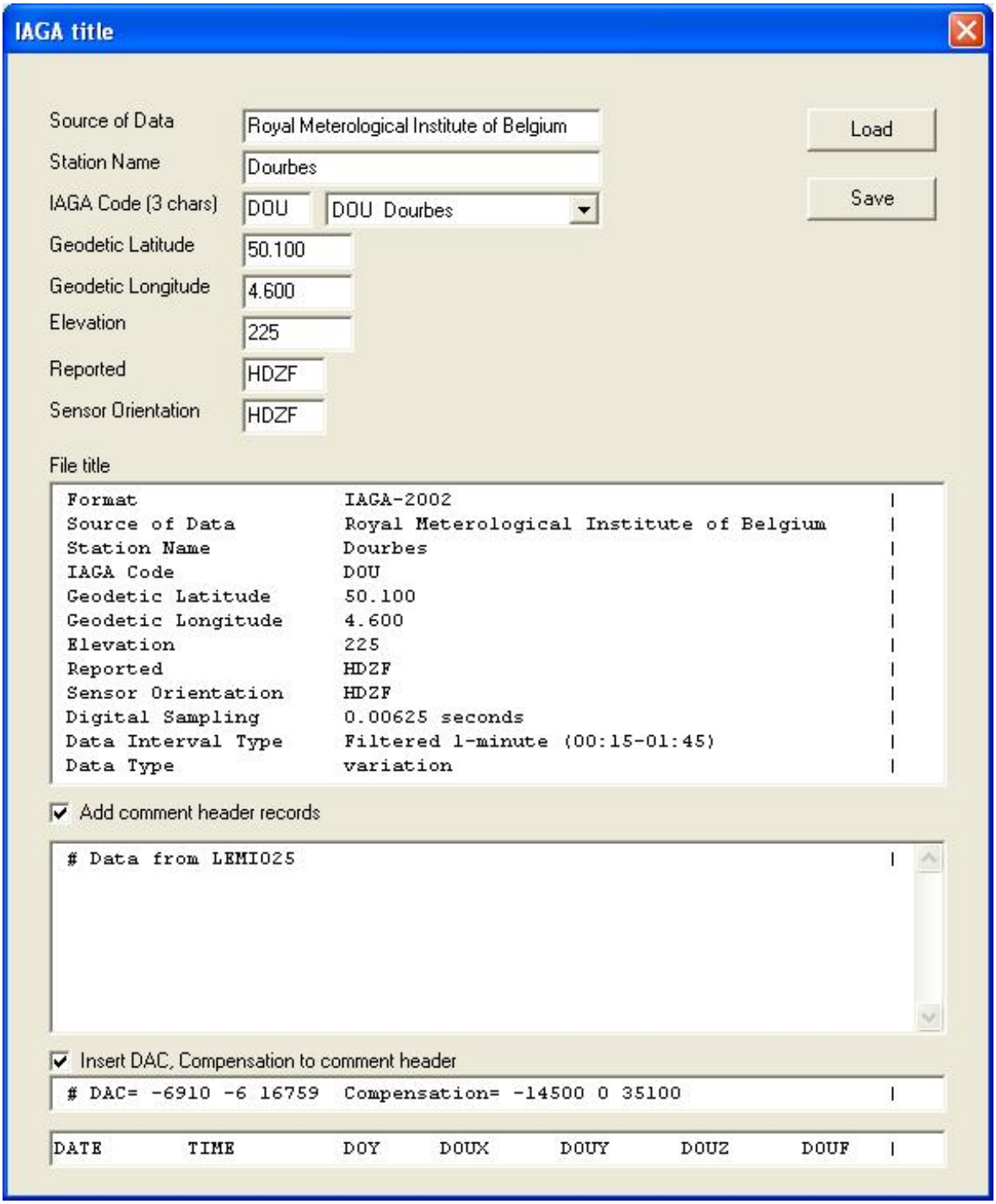


Fig. 20. The window «IAGA title».

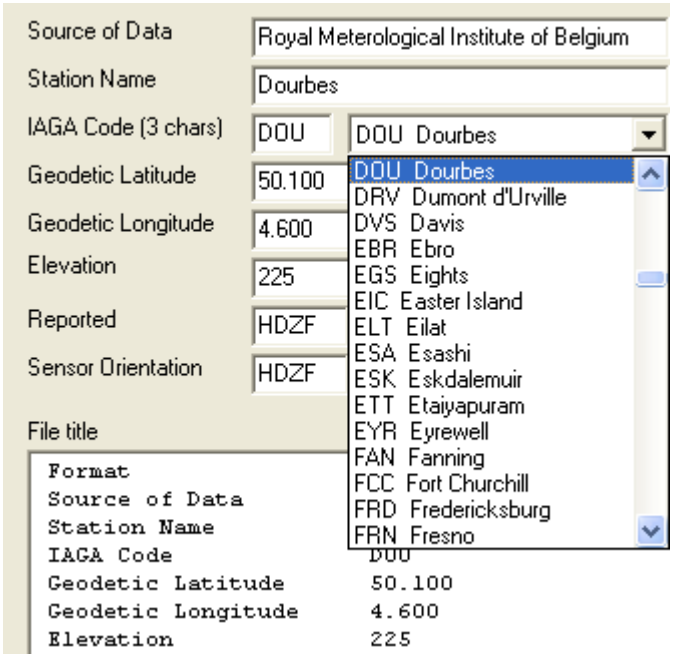


Fig. 21. Selection of the IAGA code from the list.

8. STORAGE AND TRANSPORTATION

8.1. Magnetometer storage conditions:

- temperature - from +5 to +40 ^{o}C;
- Relative humidity - not more than 85%.

8.2. Magnetometer can be transported by any transport vehicles without limitation. Recommended magnetometer position during transportation is shown on Fig.22.

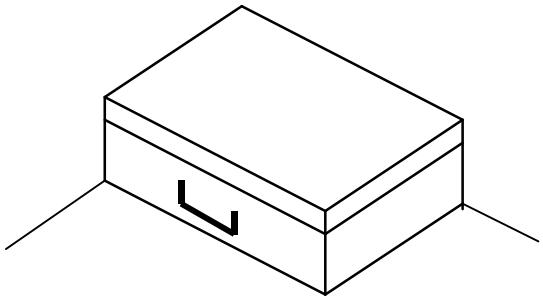


Fig. 22. Recommended magnetometer position during transportation

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

If necessary, any questions about magnetometer exploitation can be sent to the designer:

Andriy Marusenkov **marand@isr.lviv.ua** – general instrument conception

and CC to **pristaj@isr.lviv.ua** – magnetometer

and CC to **kuzn@isr.lviv.ua** – data logger

and CC to mailto:leon@isr.lviv.ua**leon@isr.lviv.ua** – software.