MANUAL

MaxiMag magnetometer-gradiometer

Smart Mag magnetometer

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INTRODUCTION

This Operation Manual (hereinafter referred to as Manual) is intended to study the device, principle of operation, and correct use of **MaxiMag magnetometer-gradiometer** and **SmartMag magnetometer** (hereinafter referred to as the magnetometer / gradiometer / device / product).

This Manual contains information about configuration, design, principle of operation, technical characteristics of the magnetometer, and operational limitations; instructions for work preparation, use, transportation, and storage; safety instructions; disposal instructions and other information regarding the magnetometer necessary for its correct use, to maintain the operational reliability and safety of the instrument.

IMPORTANT: WARRANTY AND POST-WARRANTY REPAIRS OF MAGNETOMETER ARE ONLY CARRIED OUT IN MANUFACTURER'S FACILITY OR SPECIALIZED GEOPHYSICAL SERVICE FACILITY BY SPECIALISTS TRAINED AND CERTIFIED BY GEODEVICE.

The requirements of this Manual are mandatory for all persons involved in operation, storage, transportation, further disposal, and other manipulations with the magnetometer.

This manual should always be within reach from the place of operation of the device and be accessible to the users.

The operational reliability and safety of the magnetometer-gradiometer are only guaranteed if all of the following conditions are met simultaneously:

- the device is used strictly for the intended purpose;

- magnetometer is used in environment and conditions allowed by operational documentation;

- compliance with instructions for use, safety measures and all other recommendations and requirements of this manual.

IT IS **PROHIBITED** TO OPEN / DISASSEMBLE THE MAGNETOMETER, AS WELL AS TO MAKE CHANGES IN DESIGN OF THE DEVICE, TO IMPROVE IT WITHOUT AGREEMENT OF THE MANUFACTURER.

In case of violation (non-compliance) of the requirements of this Manual, the Manufacturer GEODEVICE is not responsible for arising consequences (accidents, damage to property, injuries, etc.).

GEODEVICE is constantly improving its equipment and reserves the right to make changes to design, technical characteristics, and delivery set of magnetometer. In this regard, there may be insignificant differences between the magnetometer described in this manual and the supplied one, which do not affect the conditions of its operation.

1. DESCRIPTION AND WORK PRINCIPLES

1.1 Device description

1.1.1 Use

MaxiMag magnetometer-gradiometer is designed to measure magnetic field with high sensitivity and absolute accuracy. The sensor, based on the Overhauser effect, that is used in this magnetometer does not require maintenance and operates with stability of characteristics for at least 10 years. MaxiMag can be used as a walking magnetometer, two- or multi-sensor gradiometer, stand-alone or remote base station and observatory magnetometer. MaxiMag is fully compatible with SmartMag magnetometers and recognizes them as digital sensors. Coordinate referencing and time synchronization of field magnetometer and base station are provided by built-in or external GNSS receiver.

1.1.2 Specification and dimensions

Table 1. Specification and dimensions of MaxiMag magnetometer

Specification	Value
Type	Overhauser magnetometer
Number of sensors	up to 30
Dynamic range	20 000 ÷ 110 000 nT
Absolute accuracy	<0.2 nT
Sensor sensitivity	0.021 nT/√Hz rms
Resolution	0.001 nT
Optimal angle between sensor axis and field vector	90°
Optimum tilt range relative to optimal angle	± 45°
Performance in a range of angles	360°
Orientation error	<0.15 nT (±45°)
Gradient tolerance	30 000 nT/m
Sample rates	0.2 - 999 s
Cycles of continuous sampling in synchronous polarization mode	0.2 - 3 s
Sensor's stability	10 years under normal conditions
Interfaces	USB, RS-232, CAN FD
Maximum communication cable length	up to 6 km (CAN FD), up to 100 m (RS-232)
GNSS receiver	Built-in with built-in antenna Acceptable signals: GPS L1C/A and L2C; GLONASS L1OF and L2OF; Galileo E1B/C and E5b; BeiDou B1I and B2I; QZSS L1C/A, L1S and L2C. SBAS: WAAS, EGNOS, MSAS, GAGAN, SDCM. External receiver connection via RS-232 (NMEA 0183)
Connectors	2 × CAN FD+12V / RS232+12V, USB, external GNSS antenna
Display	240 × 128, LCD heated
Membrane switch panel	32 buttons
Internal memory capacity	32 Gb microSD
Power	10 ÷ 16.8 V, Li-ion or lead battery
Li-ion battery	14.8 V, 4 A·h
Built-in light	LED 300 lumens
Operating temperature	– 40 ÷ +60 °C

Weight of a set including Li-ion battery	magnetometer – 4 kg gradiometer – 5.9 kg
Dimensions	MaxiMag console – 260×150×45 mm Sensor on a rod – 930×120×72 mm Option with sensor on cable: - Sensor on cable – Ø 72×125 mm - Electronics unit – 114×87×35 mm Option: - Small size sensor on cable – Ø 50x104 mm

Table 2. Specification and dimensions of SmartMag magnetometer

Specification	Value
Type	Overhauser magnetometer
Dynamic range	20 000 ÷ 110 000 nT
Absolute accuracy	<0.2 nT
Sensor sensitivity	0.021 nT/√Hz rms
Resolution	0.001 nT
Optimal angle between sensor axis and field vector	90°
Optimum tilt range relative to optimal angle	± 45°
Performance in a range of angles	360°
Orientation error	<0.15 nT (±45°)
Gradient tolerance	30 000 nT/m
Minimum sample rates	0.2 s
Sensor's stability	10 years under normal conditions
Interfaces	USB, RS-232, CAN FD, Ethernet (via optional CAN-Ethernet interface module)
Maximum communication cable length	up to 6 km (CAN FD), up to 100 m (RS-232)
GNSS receiver	Built-in with option of external antenna and RAW data recording. Acceptable signals: GPS L1C/A and L2C; GLONASS L1OF and L2OF; Galileo E1B/C and E5b; BeiDou B1I and B2I; QZSS L1C/A, L1S and L2C. SBAS: WAAS, EGNOS, MSAS, GAGAN, SDCM. External receiver connection via RS-232 (NMEA 0183)
Connectors	OVH sensor, 2 × CAN FD+12V / RS232+12V, USB, external GNSS antenna
Display	160 × 128, OLED
Membrane switch panel	6 buttons
Internal memory capacity	32 Gb microSD
Power	10 ÷ 16.8 V, Li-ion, or lead battery 220 V, 50 Hz, optional CAN-Ethernet interface
Li-ion battery	14.8 V, 4 Ah
Operating temperature	– 40 ÷ +60 °C
Dimensions	Sensor on cable – Ø 72×125 mm - Electronics unit – 114×87×35 mm Option: - Small size sensor on cable – Ø 50x104 mm

1.1.3 Delivery set

The delivery set depends on the ordered type of magnetometer-gradiometer and additional options.

1.1.3.1 MaxiMag magnetometer with sensor on rod

Figure 1 MaxiMag magnetometer MaxiMag with sensors on rod

Standard delivery set of magnetometer (1 sensor) includes:

- MaxiMag console
- Digital Overhauser OVHmag sensor on rod
- Backpack harness
- Li-ion battery (optional)
- Charger (optional)
- Sensor cable
- USB cable
- Lead battery power cable
- Transportation case
- Operation Manual

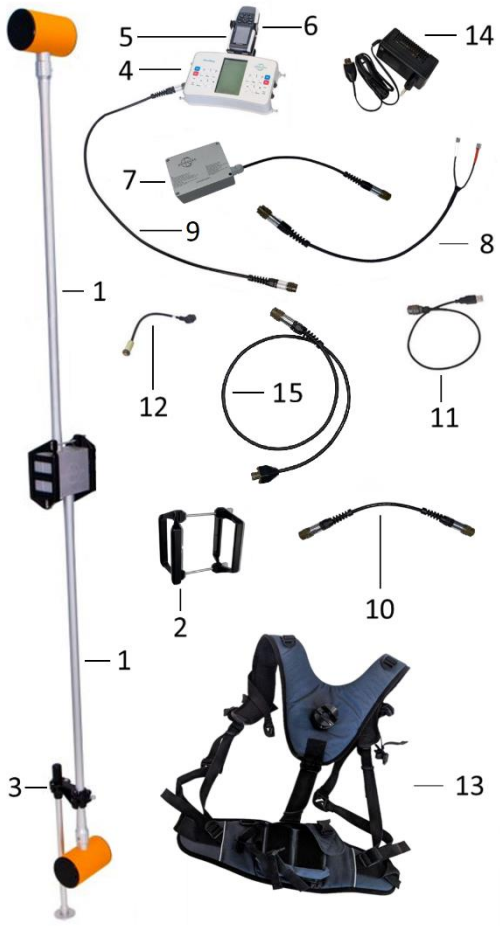
1.1.3.2 MaxiMag magnetometer with sensor on cable

Figure 2 MaxiMag magnetometer with sensor on cable

Standard delivery set of magnetometer (1 sensor) includes:

- MaxiMag console
- Overhauser sensor on cable
- OVHmag electronics unit
- Non-magnetic rod
- Rod end
- Sensor clamp
- Backpack harness
- Li-ion battery (optional)
- Charger (optional)
- Sensor cable
- USB cable
- Lead battery power cable
- Transportation case
- Operation Manual

1.1.3.3 MaxiMag magnetometer-gradiometer



1 – OVHmag digital overhauser sensor on rod;

2 – Gradiometer bracket;

3 – Gradiometer rod;

4 – MaxiMag console;

5 – External GNSS receiver (optional);

6 – External GNSS bracket (optional);

7 – Li-ion battery (optional);

8 – Lead battery power cable;

9 – Sensor cable;

10 – Short sensor cable;

11 –USB cable;

12 – GNSS receiver cable (optional);

13 – Backpack harness;

14 – Charger (optional);

15 – Battery extension cable.

Figure 3. OVHMag set on rod in gradiometer configuration

MaxiMag two-sensor gradiometer additionally includes:

- OVHmag digital overhauser sensor on rod or cable, or SmartMag digital Overhauser magnetometer
- Sensor cable
- Battery extension cable
- Gradiometer bracket
- Gradiometer rod

Multi-sensor gradiometer includes more digital OVHmag Overhauser sensors and/or digital SmartMag magnetometers and sensor cables.

1.1.3.4 SmartMag magnetometer

Figure 4 SmartMag Overhauser magnetometer

Depending on the version, the delivery includes the following accessories:

- SmartMag console with built-in GNSS receiver
- Overhauser sensor on cable
- External GNSS antenna (optional)
- Sectional non-magnetic rod with a clamp for sensor and a bracket for console
- Li-ion battery with carger (optional)
- Lead battery with charger (optional)
- USB cable
- Lead battery power cable
- SmartManager software (optional)
- Backup industrial USB Flash drive (optional)
- CAN-Ethernet interface and cable (optional)
- RS-232 - USB logger in a sealed case (optional)
- PC connection cable via RS-232 (optional)
- Transportation case
- Operation Manual

a *b* *c*

Figure 5 SmartMag magnetometer
a – walking mode, b – base station mode (before year 2023), c – base station mode (after year 2022)

SmartMag Overhauser magnetometer is transported in a plastic, sealed, shock-resistant case.

1.1.3.5 Additional options

MaxiMag and SmartMag systems have the maximum number of options included in basic configuration compared to similar systems. Nevertheless, to solve specific problems or on user's request the following items can be added to the delivery set:

- Small size overhauser sensor on cable
- External GNSS receiver
- Garmin GPS with cable and bracket
- Delta CT 12025 battery or similar
- CAN-Ethernet block
- Ethernet cable
- 100-240 VAC power supply
- Power and connection cable
- COM-USB converter
- RS-232 cable
- External logger with USB upload
- Built-in OVHmag logger with USB upload

1.1.4 Theory

To measure geomagnetic field the magnetometer uses the phenomenon of free precession of protons in a pre-polarized liquid under Earth's magnetic field impact. The polarization of the nuclei is enhanced by the Overhauser effect (dynamic polarization of the nuclei).

The Overhauser effect is a phenomenon that uses electron-proton interactions to achieve polarization of protons. To implement this effect, a specially developed liquid rich in protons that contains a free radical (an atom with an unbound electron) is used in the magnetometer. When exposed to radio frequency current unbound electrons transfer energy to neighboring protons. This allows protons' polarization without the need for a very strong magnetic field. Therefore, such sensors can generate high amplitude signals with a high signal-to-noise ratio, with only a few watts power consumption. Standard proton sensors cannot generate signals of such magnitudes and quality, even when consuming several hundred watts.

Each measurement cycle basically consists of two events:

1. Polarization - the proton rich fluid in primary transducer is affected by constant high-frequency magnetic field so that proton rotation axis turns orthogonally to the induction vector of the Earth's magnetic field.

2. Measurement - the polarization field is shut off and free precession of protons around the Earth's magnetic field vector begins. In low frequency coils of primary transducer, an electromotive force is induced in the shape of a damped sinusoid, the frequency of which is proportional to the induction of the Earth's magnetic field:

$$F = \frac{T}{\gamma},$$

where F —precession frequency,

T — magnetic field induction,

$\gamma = 23{,}4871985\ \frac{\mathrm{n}T}{Hz}$ — proton gyromagnetic ratio.

1.1.5 Packaging

The device is supplied in a shockproof plywood case. The packaging complies with safety requirements and ensures the device is water- and dust-protected.

2. Description of MaxiMag system components

Figure 6 MaxiMag Magnetometer with sensor on cable (left) and on rod (right)

1. MaxiMag console
2. External Garmin GPS Bracket (Optional)
3. Garmin GPS (Optional)
4. Garmin GPS cable (Optional)
5. Non-magnetic rod
6. Sensor clamp
7. Small size Overhauser sensor on cable (Optional)
8. OVHmag electronics unit with Optional built-in OVHmag logger with USB upload
9. Li-ion battery (Optional)
10. Sensor cable
11. USB cable
12. Lead battery power cable
13. Charger (Optional)
14. Backpack harness
15. Digital OVHmag sensor on a rod

Overhauser sensor

The sensor is designed to receive a free precession of protons signal of proton rich fluid, placed in the measured magnetic field. It contains a glass ampoule with liquid, placed in the high frequency circuit, that is covered with low frequency coils. The standard sensor body (ø70 mm) also contains shock absorbers to protect the glass ampoule from breakage. The small-sized (lightweight) version of the sensor (ø50 mm) on the cable does not have such protection but is more suitable for observations from UAVs.

Figure 7 Small-sized Overhauser sensor on cable (left) and standard on rod (right)

OVHmag electronics unit

The block serves to induce proton precession signal in the sensor and measure frequency. The device consists of a high-frequency generator, a signal generator, a microcontroller for processing the precession signal and an optional logger for saving the measurement result to the built-in microSD. The version of the unit with logger is equipped with a USB connector for downloading data to PC. Data transmission to console is done via CAN FD interface.

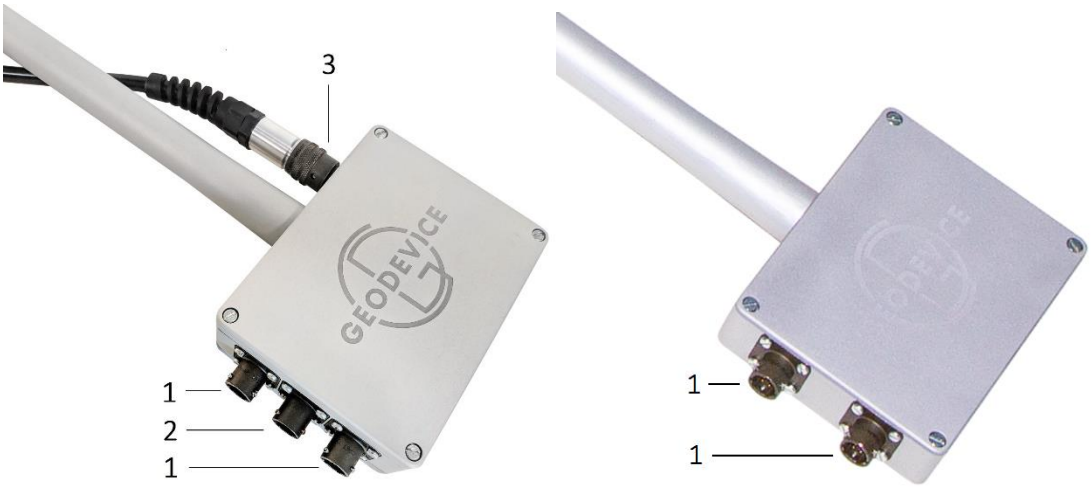


Figure 8 OVHmag electronics unit with a sensor on cable (left) and on rod (right)

1 – CAN FD + 12V / RS232 + 12V connectors (reassignable)

2 – USB connector for downloading data from the logger (optional)

3 – connector for Overhauser sensor on the cable

The logger can be used to record data without console when the OVHmag is operating as base station or to perform observations from a UAV. In this case, the data is saved to the built-in microSD card and downloaded via USB connector.

The reassignable CAN FD + 12V / RS232 + 12V connectors are configured to transmit data via CAN FD bus to MaxiMag console, CAN-Ethernet interface block or to the next OVHmag or SmartMag in chain, as well as to connect battery and provide power to devices. Switching the connectors to RS232 + 12V mode is necessary to connect digital OVHmag Overhauser sensors to external devices of a third-party manufacturer. To receive instructions on reassigning connectors, contact GEODEVICE.

MaxiMag console

MaxiMag console is designed to start measurements, visualize, and save data for further downloading on PC, dividing profiles with user guidance along them and performing many other functions. The console has a built-in modern GNSS module with antenna, which allows obtaining high-quality measurement coordinates and navigation around the site.

Figure 9 MaxiMag console

1 – external GNSS receiver or Garmin GPS connector

2 - USB connector for downloading data and uploading software updates

3 - CAN FD + 12V / RS232 + 12V connectors (reassignable)

4 - built-in LED flashlight

5 - hanger for fixing console in harness

6 - location of the built-in GNSS receiver antenna

7 – place for fastening the bracket of the Garmin GPS

Some details about the MaxiMag console:

- Dual-sided keyboard for right- and left-handed users

- Built-in bright LED light allows to navigate safely in the dark

- LCD display, equipped with a heating module, operates at temperatures as low as -40 ° C

- Advanced algorithms of signal processing and evaluation provide increased gradient stability, noise resistance and calculation of the measurement error in nT

2.1 Operating instructions for MaxiMag magnetometer

The magnetometer control panel is located on the front panel of the MaxiMag console and is presented by two-way keypad, which ensures the same ease of operation for both right- and left-handed users. This feature can also be useful when performing field works in cold weather conditions. The left and right halves of the keypad duplicate their functions and work simultaneously.

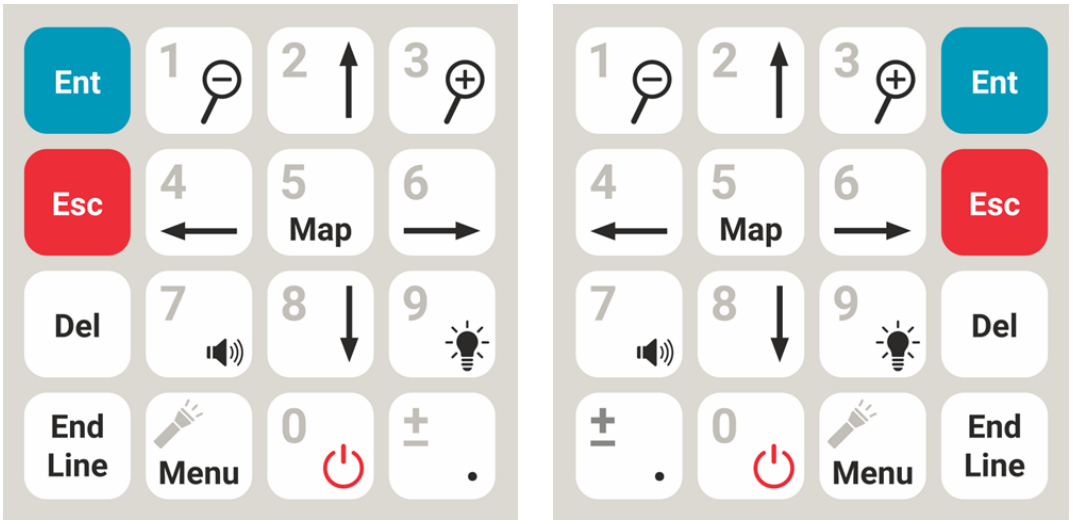


Figure 10 Two-way keypad on the console

- Start measurements. Enter the parameter editing mode. Enter the next menu level.

- Stop measurements. Exit the parameter editing mode. Return to the previous menu level.

- Enter "1". Show scale of map or graph. Decrease the parameter selected in the menu by 1 or by its specified increment.

- Enter "2". Move around the menu / map. Long press in Mobile survey mode activates quick setting of picket number for skipping, detailing or repeating measurements, where a single press rewinds the picket of the next measurement by 1 step forward.

- Enter "3". Show scale of map or graph. Increase the parameter selected in the menu by 1 or by its specified increment.

- Enter "4". Move around the menu / map. Long press in Mobile survey mode activates quick setting of picket number to skip detailing or repeat measurements, where a single press rewinds the picket of the next measurement by 0.25 steps back. Scroll through the available values of the parameter selected in the menu. Switch between data display windows in measurement modes.

- Enter "5". Map display

- Enter "6". Move around the menu / map. Long press in Mobile survey mode activates quick setting of the picket number to skip detailing or repeat measurements, where a single press rewinds the picket of the next measurement by 0.25 steps forward. Scroll through the available values of the parameter selected in the menu. Switch between data display windows in measurement modes.

- Enter "7". Long press turns on / off the sound.

- Enter "8". Move around the menu / map. Long press in Mobile survey mode activates quick setting of picket number for skipping, detailing or repeating measurements, where a single press rewinds the picket of the next measurement by 1 step back.

- Enter "9". Long press (2 sec) turns on / off the screen light.

- Enter "0". Long press (2 sec) turns on / off the device. An even longer press (7 sec) resets software.

- Enter a sign or full stop when specifying a parameter (picket, line, etc.).

- Short press in measurement mode enables measurement menu; long press in any menu turns on the flashlight.

- Erase values when setting parameters, delete the last measurement or project. In Mobile survey mode, enables a window for deleting, replacing, or repeating a measurement.

- Complete the line and go to the next one, complete measurements and exit to the main menu.

2.1.1 Commands control

The functions of the magnetometer are implemented using a microprocessor control system by making appropriate commands. To facilitate these commands, the magnetometer commands control is built on the dialog principle, where every command is selected from the menu or prompt. A complete list of commands and operations performed for the magnetometer (1 sensor connected) is shown in Figure 11 Commands control of the MaxiMag magnetometer (1 sensor connected) and for the gradiometer (2 or more sensors connected) in Figure 12 Commands control of the MaxiMag Overhauser gradiometer.

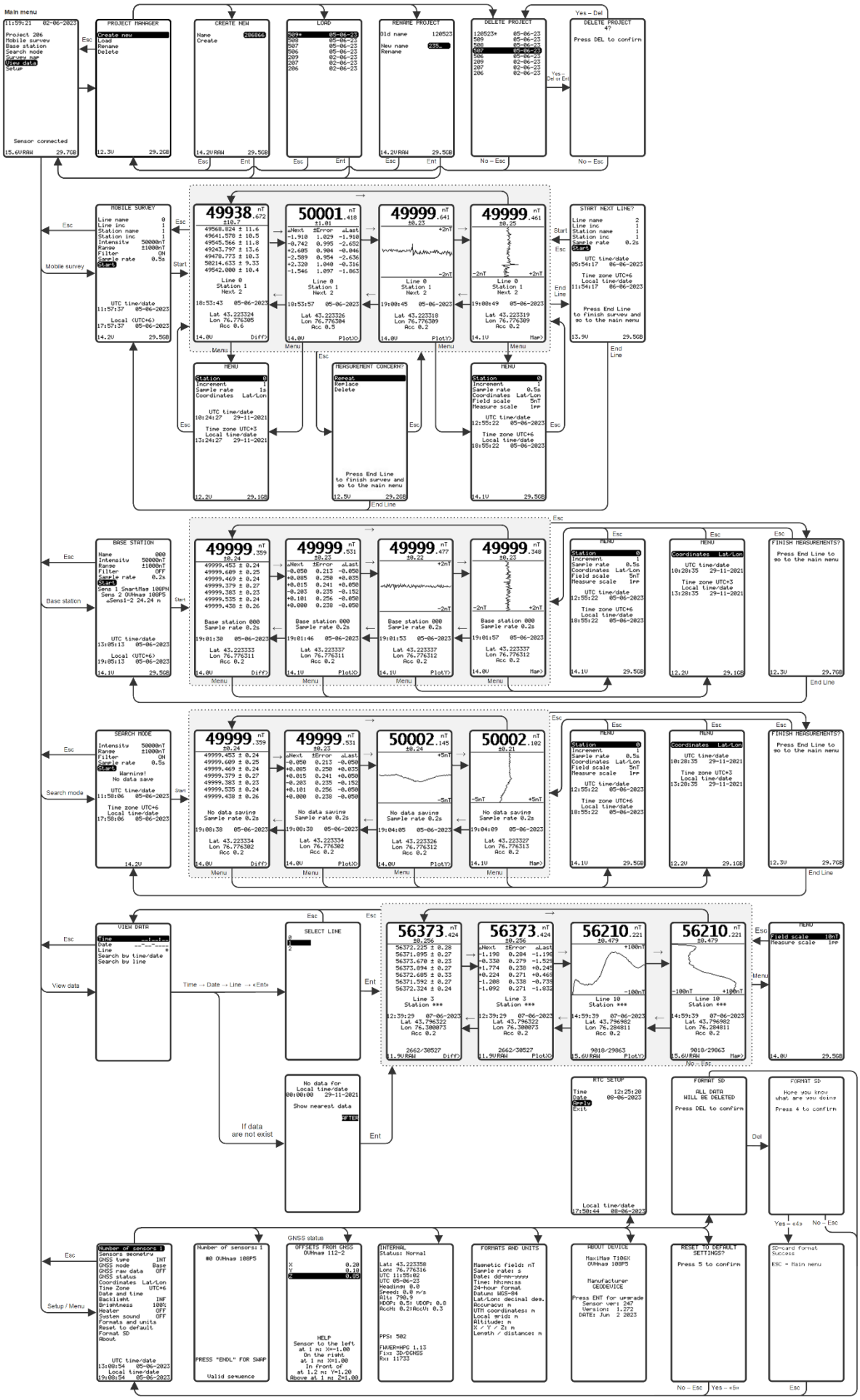


Figure 11 Commands control of the MaxiMag magnetometer (1 sensor connected)

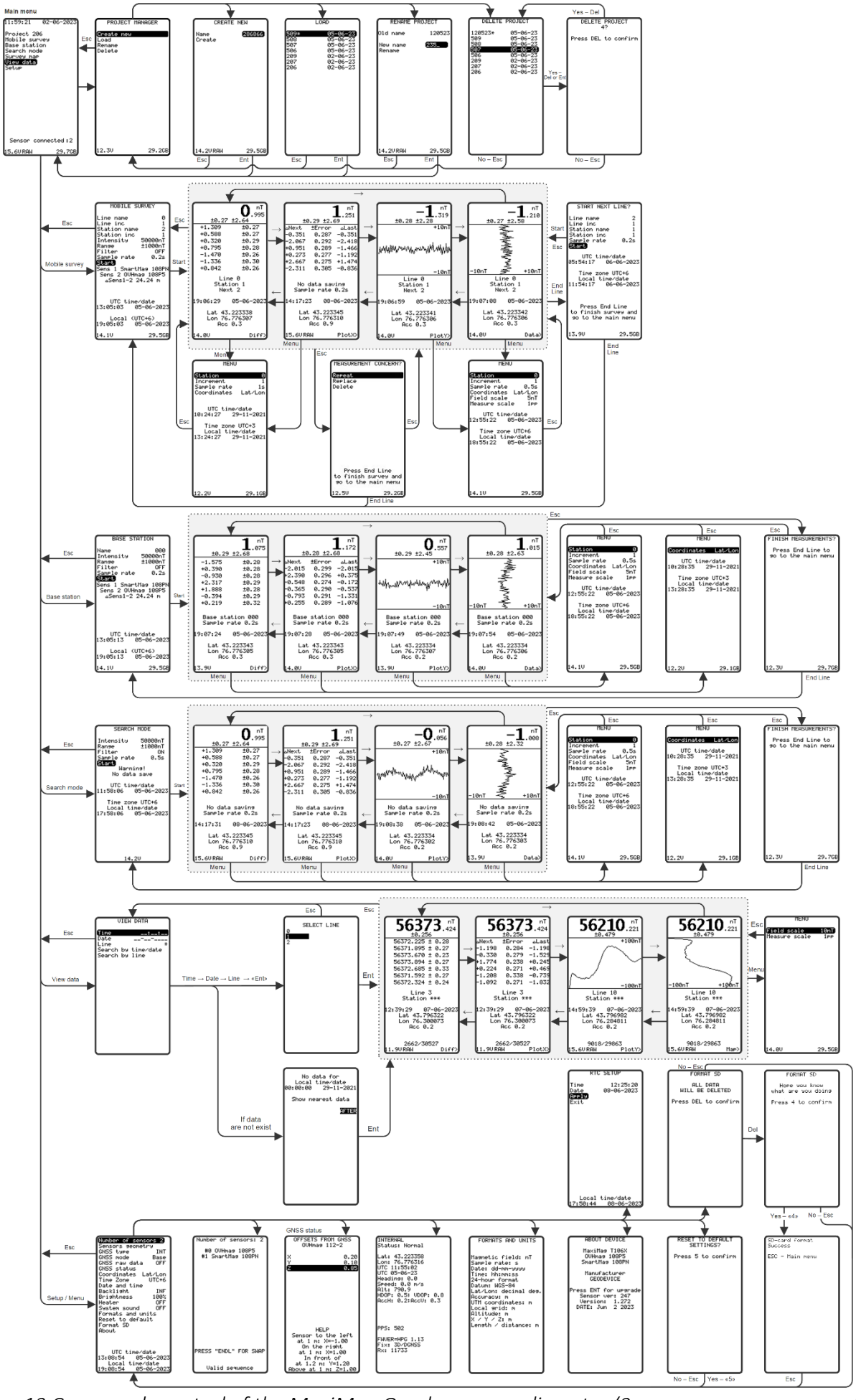


Figure 12 Commands control of the MaxiMag Overhauser gradiometer (2 or more sensors connected)

2.2 Use of MaxiMag

2.2.1 Operational limitations

MaxiMag magnetometer is designed for operation in field conditions at ambient temperatures from - 40 to + 60 ° C.

MaxiMag is a precision instrument and must be handled with care. Avoid drops and impacts when working with the device. Despite the fact that all electronic components of the magnetometer-gradiometer are sealed, it is recommended to protect the device from excessive moisture exposure whenever possible.

2.3 Preparing to use the device

2.3.1 General safety instructions on preparation for use

The magnetometer is powered by a 14.8 V Li-ion battery that is required to be operated in accordance with the attached instructions (see APPENDIX 12.3 and 12.4) or by a 12 V lead-acid battery, Delta CT 12025 type or similar. There is a special cable supplied for connecting the device to the lead-acid battery.

2.3.2 The order of actions to prepare MaxiMag magnetometer for use

1. Examine all parts of the device and make sure that:
- the magnetometer kit is complete in accordance with the manual and the type of survey to be performed;
- there is no damage on the magnetometer blocks.
- there is no damage to connecting cables and connectors.
- there is no contamination or wetting.

IT IS **PROHIBITED** TO USE THE MAGNETOMETER IF IT IS DAMAGED, WET, OR SIGNIFICANTLY CONTAMINATED.

2. If necessary, recharge the battery in accordance with the enclosed battery instructions (see APPENDIX 12.3).

THE FOLLOWING STEPS 3-5 APPLY ONLY TO THE OVHmag SENSOR ON CABLE.

3. Prepare all components of the OVHmag digital magnetometer with sensor on cable shown in Figure 13.

Figure 13 Components of the OVHmag digital magnetometer with sensor on cable a – before year 2023 modification, b – after year 2022 modification

4. Place a clamp on the Overhauser sensor and fix it in the bracket on rod (for before year 2023 modification). Remember to perform sensor orientation according to section 2.4.1.

Figure 14 Overhauser sensor on cable with bracket. Before year 2023 model

Figure 15 Overhauser sensor fixed on a rod
a – before year 2023 model, b – after year 2022 model

5. Fasten the OVHmag electronics unit to the rod and connect the Overhauser sensor cable to it.

Figure 16 OVHmag electronics unit on non-magnetic rod

Figure 17 Overhauser sensor and OVHmag electronics unit on rod

6. Fix the battery in the backpack-harness in the pocket closest to the operator's back.

Figure 18 Battery in backpack-harness

7. If magnetometer delivery set includes backpack for a harness, it can accommodate a Delta DT 1207 type battery (Figure 19). The backpack-harness has straps for backpack attachment.

Figure 19 Battery in a backpack

7. Fix the OVHmag digital Overhauser magnetometer in the backpack-harness and connect the battery to any CAN FD + 12V connector indicated in Figure 20.

Figure 20 CAN FD + 12V connectors on the side of the electronics unit for battery connection

Figure 21 Battery with power cable

Figure 22 Battery with OVHmag digital magnetometer in backpack-harness

8. Connect the sensor cable to a free CAN FD + 12V connector on OVHmag.

9. Put the backpack-harness on the operator and adjust the straps.

10. Connect the sensor control cable to any of the CAN FD + 12V connectors on the console (Figure 23).

Figure 23 CAN FD + 12V connectors for connecting sensor cable on the console

Figure 24 Sensor cable

11. When using an optional external Garmin GPS, connect the GPS cable to the connectors indicated in Figure 25 and Figure 28. Set up the GNSS signal source, to do this, go to the main menu → Setup → GNSS type and press the key Ent. Use the keys 2 ↑ or 8 ↓ to select the baud rate "EXT:9600" and press the key Ent.

12. If using the built-in GNSS receiver, go to step 13.

Figure 25 GNSS connector for GPS cable connection to console

Figure 26 GPS cable

Figure 27 Garmin GPSMAP 78

Figure 28 Connector for the GPS cable on the Garmin GPSMAP 78

Turn on the GPS. ATTENTION! For correct operation of Garmin GPSMAP 78 with the MaxiMag console, set the correct interface settings (Figure 29). To do this, on your GPS go to: "PAGE" → "Main menu" → "Setup" → "System". In the system settings, select "GPS" → "Normal", "Interface" → "NMEA Input / Output". In the NMEA input / output settings, select "Auto navigation mode" →

"Off", "ID points" → "Numbers", "Precision up to minutes" → "MM.MMMM (4 digits)", "NMEA messages" → "On". In the "NMEA messages" settings, select "GSA, GSV" → "On", in the field "WPL, RTE" → "Off", in the field "Branded Garmin" → "Off".

Figure 29 Interface settings of the Garmin GPSMAP 78

12. Turn the magnetometer on by holding the button  for 1 second.

13. Wait for synchronization of initialization of the GNSS receiver to determine the coordinates and set the date and time on the MaxiMag console.

When starting up for the first time after a long period of inactivity or a significant change in the location of the device since the last measurement (more than 200 km), the GNSS receiver needs to obtain the coordinates and time from the GNSS satellites. This procedure can take up to 20 minutes, depending on the conditions of satellite signal reception. Best results are achieved in open areas without trees or buildings. The MaxiMag console must be in a horizontal position and fixed.

2.3.3 The order of actions to prepare magnetometer-gradiometer for use

MaxiMag allows you to connect an almost unlimited number of digital Overhauser sensors or SmartMag magnetometers via CAN interface cable.

Start preparing magnetometer-gradiometer with paragraphs 1-6, section 2.3.2.

2.3.3.1 Assembling several OVHmag sensors into a magnetometer-gradiometer

1. Place the two OVHmag electronics blocks so that the recesses in one box lid align with the bumps in another lid (Figure 30).

a *b* *c*

Figure 30 Assembling two OVHmag sensors into a magnetometer-gradiometer

2. Put a plastic bracket on both sides to fasten the electronics units together and tighten them together with screws (Figure 30 b).

3. Connect the two electronics units with a sensor cable (Figure 30 c).

4. Connect another sensor cable to any sensor (Figure 30 c).

5. Attach the gradiometer rod to the lower transducer (Figure 31).

a *b* *c*

Figure 31 Mounting options for gradiometer rod to
a – sensor on rod; b - sensor on cable; sensor on rod, after 2022-year model

6. Put the backpack-harness on the operator and adjust straps.

7. Connect the sensor cable (Figure 34) to any of the CAN FD + 12V connectors on the console (Figure 32).

8. Connect one end of the battery extension cable (Figure 33) to another CAN FD + 12V connector on the console (Figure 32) and connect the other end to the battery in the backpack.

Figure 32 CAN FD+12V connectors for sensor cables

Figure 33 Battery extension cable

Figure 34 Sensor cable

2.3.3.2 Assembling SmartMag Overhauser magnetometer and OVHmag sensor into a magnetometer-gradiometer

1. Place an OVHmag and SmartMag electronics blocks so that the recesses in one box lid align with the bumps in another lid.
2. Put a plastic bracket on both sides to fasten the electronics units together and tighten them together with screws (Figure 35).

Figure 35 Assembling OVHmag sensor and SmartMag into a magnetometer-gradiometer

3. Connect the OVHmag sensor and Smartmag with a sensor cable (Figure 36).
4. Connect another sensor cable to the OVHmag sensor or SmartMag (Figure 36).
5. Attach the gradiometer rod to the lower transducer (Figure 36).

Figure 36 OVHmag-SmartMag magnetometer-gradiometer assembled

6. Put the backpack-harness on the operator and adjust straps.
7. Connect the sensor cable (Figure 39) to any of the CAN FD + 12V connectors on the console (Figure 37).
8. Connect one end of the battery extension cable (Figure 38) to another CAN FD + 12V connector on the console (Figure 37) and connect the other end to the battery in the backpack.

Figure 37 CAN FD+12V connectors on the console for sensor cables

Figure 38 Battery extension cable

Figure 39 Sensor cable

2.3.3.3 Using MaxiMag as base station

1. Inspect all the parts of the device.
2. If required recharge battery, following the instructions on battery use (see APPENDIX).
3. Assemble the tripod by connecting the three non-magnetic rods ① with plastic rod ends and one with a thread ②, using connecting knob.
4. Connect sensor clamp ③ to tripod.
5. Fix sensor ④ in clamp ③.
6. Connect sensor ④ to console ⑤ using sensor cable ⑥.
7. Connect battery ⑦ to any corresponding connector on console or sensor.
8. Turn on the console by pressing  for 1 sec.
9. Wait until internal clock of console synchronizes using GNSS signal and magnetometer gets the coordinates.
10. When the system is launched after a long period of inactivity, or the start point of measurement changes significantly (more then 200 km compares to the previous one) magnetometer has to get the coordinates and time from GNSS satellites. This process can take up to 20 min depending on the reception. The best result is obtained at an open area without objects interfering with radio waves such as buildings and trees.

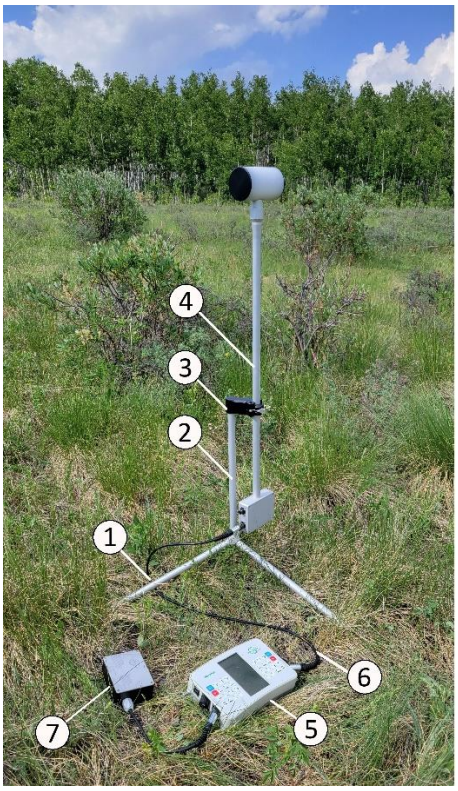


Figure 40 MaxiMag as a base station

2.4 Usage

2.4.1 Requirements and limitations

ATTENTION! Do not operate MaxiMag Overhauser magnetometer-gradiometer without reading this instruction manual. Operation of the device is allowed only after completing the steps to prepare the device for operation, described in section 2.3.

ATTENTION! The user of the magnetometer-gradiometer is not allowed to carry any objects with magnetic materials (knives, tools, coins, keys, lighters, etc.) as well as any electronic devices (radio stations, telephones, GPS, headphones, etc.). In addition, the person operating the magnetometer should not have medical implants made of magnetic materials, pacemakers, pumps, as well as earrings, piercings, etc. Clothing elements of the operator should also consist of non-magnetic materials: magnetometer readings can be influenced by metal buttons, zippers, eyelets, fasteners, carabiners, metal strings in mosquito nets, and much more. Before starting measurements, special attention should be paid to the choice of clothes and shoes.

ATTENTION! Before starting measurements, the Overhauser sensor should be oriented correctly to ensure the most efficient registration of the Earth's magnetic field. The working area of the Overhauser sensor is ± 45 degrees relative to the optimal angle between the sensor axis and the Earth's magnetic field vector (Figure 41). The optimal position is the orientation of the axis at an angle of 90 ± 5 degrees to the direction of the Earth's magnetic field vector.

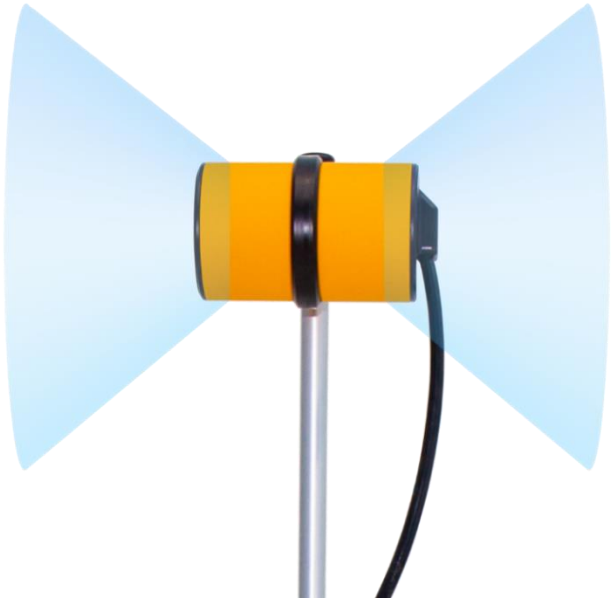


Figure 41 Visualization of the working area of the OVHmag Overhauser sensor. Areas of the magnetometer with a reduced signal-to-noise ratio are shown in blue.

The design of the bracket for attaching the sensor on cable to the rod allows orientation of the sensor axis in horizontal or vertical direction (Figure 42 and Figure 43). The sensor on rod is always perpendicular to the rod but can rotate around it.

Figure 42 Horizontally oriented sensor on cable

Figure 43 Vertically oriented sensor on cable

The need to orient both sensors depends on the area of work (Figure 44). The inclination of the Earth's magnetic field vector can be understood based on the latitude of the work site - at the equator the Earth's magnetic field vector is parallel to the Earth's surface, and at the poles it is sub-vertical (see Section 12.2.1). You can estimate the inclination of the Earth's magnetic field vector using online service https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#igrfwmm) or a smartphone app with a three-axis compass.

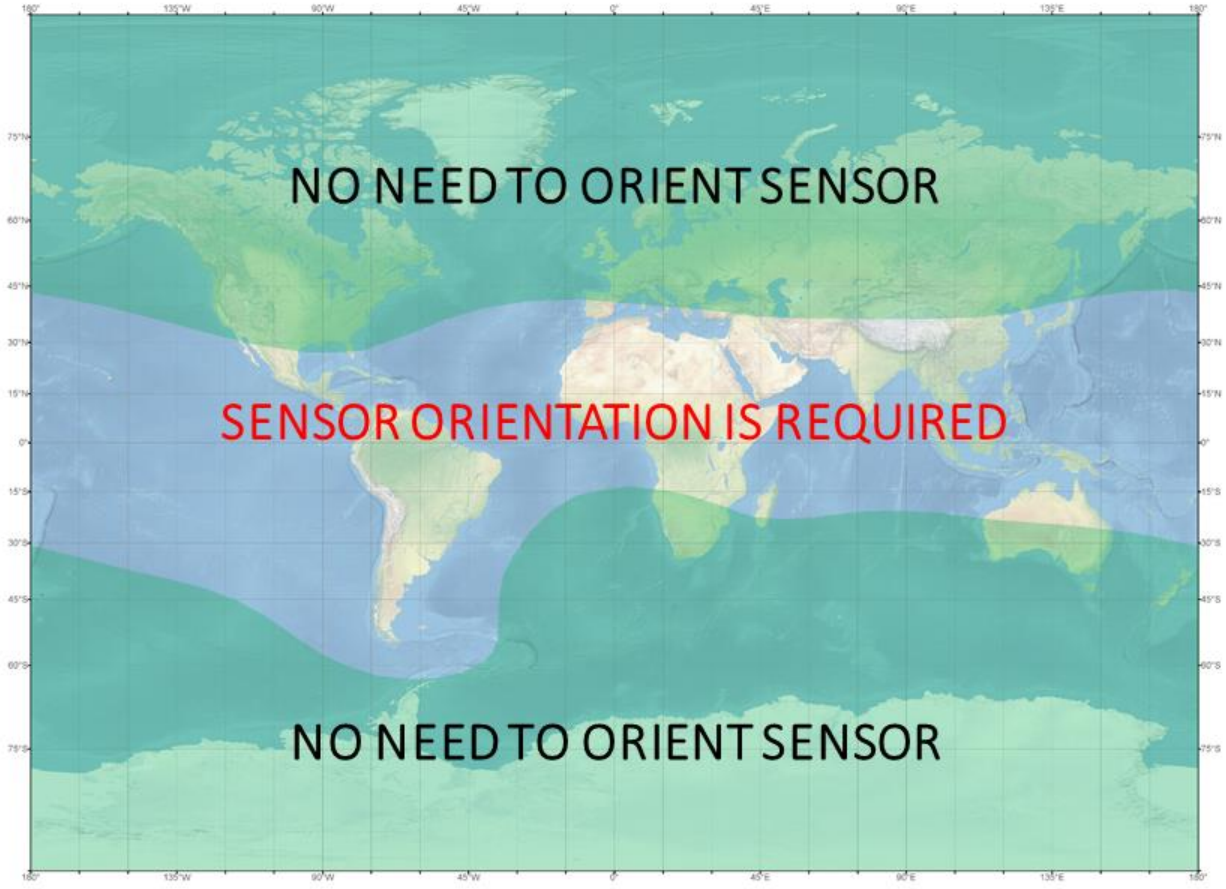


Figure 44 Map where the Overhauser sensor has to be oriented

2.4.2 Main menu

After turning the magnetometer on, the main menu appears on the display (Figure 45), indicating the name of the current project (to the right of Project), date and time, voltage of the battery or power supply and the amount of free memory, raw data recording mode from built-in GNSS receiver, the number of connected sensors. In the main menu, you can go to the project manager (Project), select the main measurement modes (Mobile survey, Base station, Search mode), creating the profile map (Survey map), view the previously measured data (View data) and go to the main instrument settings (Setup).

Information about the amount of free memory is necessary to decide if clearing memory before starting work is necessary or continuing work with the remaining memory is ok.

Measurement modes:

- Mobile survey - all options for measuring the Earth's magnetic field in motion.
- Base station - measurement in the magnetic base station mode.
- Search mode - search mode without saving data.

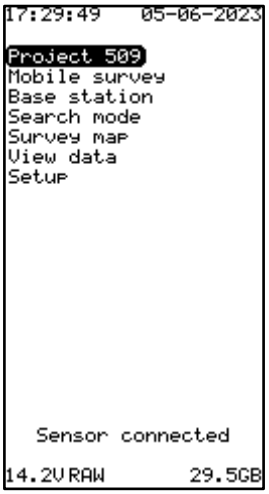


Figure 45 Main menu window

To go to any menu, select it with keys 2 ↑ or 8 ↓ and press key Ent. Go to an upper level from any menu by pressing key Esc.

2.4.3 Project Manager

To go to the project manager from the main menu, select "Project" with keys 2 ↑ or 8 ↓ and press key Ent. The project manager window will appear on the display (Figure 46).

The project manager is required to create a new project (Create new), load a project from the magnetometer memory (Load), rename the current project (Rename) or delete (Delete) a project.

The project has a unifying function for the collected data and settings for the MaxiMag console. The Project data and the configuration file are stored on the built-in microSD in the project folder. This allows to facilitate the download of the collected data and quickly and equally configure different MaxiMag consoles by simply copying the configuration files, which is especially

convenient when working on large areas where several operators work at the same time. The configuration file is named *config.dat* and is stored in binary format. When creating a new project, a new configuration file is automatically generated and inherits the characteristics of the previous project. When loading an existing project, the configuration file located in the folder of the loaded project is automatically loaded into the console. The built-in microSD card also contains the *Project.txt* file, which contains the name of the last loaded project, and that file is read each time the console is turned on.

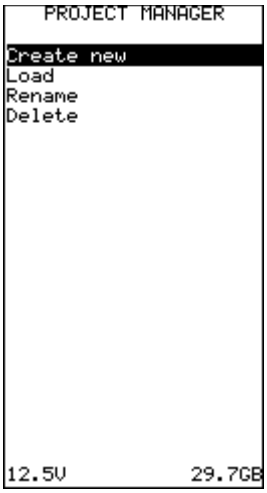


Figure 46 Project manager window

2.4.3.1 Creating a project

To create a project, use keys 2 or 8 to select “Create new” in the project manager window and press Ent. The window of creating a project will appear on the display (Figure 47) with the option to select the name of the project. To set a name, select "Name" and press the key Ent, then using numeric keypad enter the name of the new project and press key Ent.

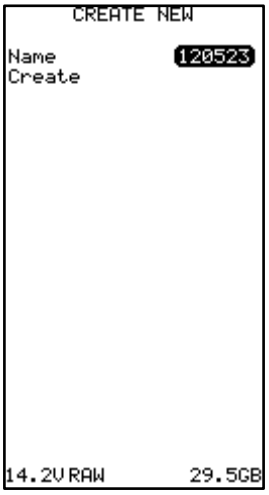


Figure 47 Create a project window

If a message “Already Exists! Press ESC” appears on the screen (Figure 48), this means a project with this name already exists and a different name is required.

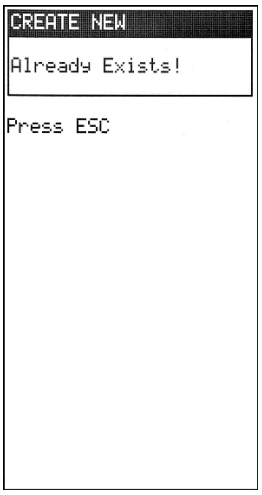


Figure 48 Error window when creating a new project

2.4.3.2 Loading a project

To load a project from the magnetometer's memory, use keys 2 ↑ or 8 ↓ to select “Load” in the project manager and press key Ent. Load a project window will appear on the display (Figure 49) with an option to select an existing project. Then select the required project and press key Ent. The symbol (*) next to the project name indicates the current project.

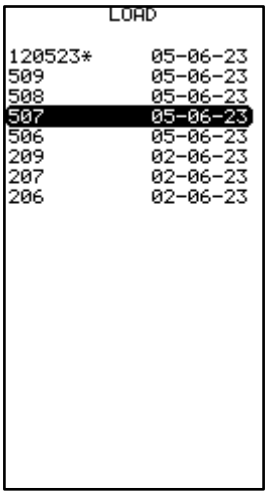


Figure 49 Window for loading an existing project from the magnetometer memory

2.4.3.3 Renaming a project

To rename a project use keys 2 ↑ or 8 ↓ to select "Rename" in the project manager and press Ent. A window for renaming the project will appear on the display (Figure 50) with the current name (Old Name) and possibility of entering a new one (New Name). To do this, select "New Name", press Ent, then using numeric keypad enter the name of the new project and press key Ent.

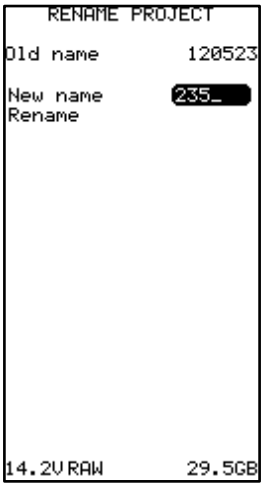


Figure 50 Window for renaming the project

2.4.3.4 Deleting a project

To delete a project from the magnetometer's memory, use keys 2 ↑ or 8 ↓ in the project manager to select "Delete" and press Ent. A window for deleting the project will appear on the display (Figure 51). To delete, select a project and press key Ent or Del. A confirmation window will appear (Figure 52). Press Del to confirm deleting, or Esc to cancel.

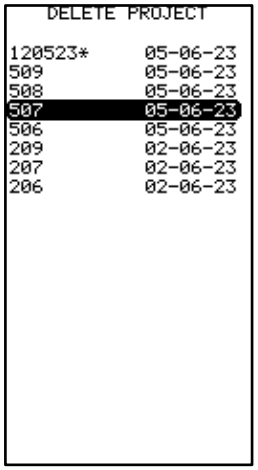


Figure 51 Deleting a project window

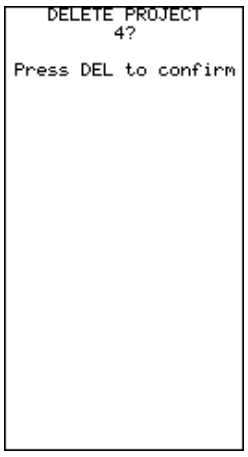


Figure 52 Confirmation of deletion window

2.4.4 Mobile survey mode

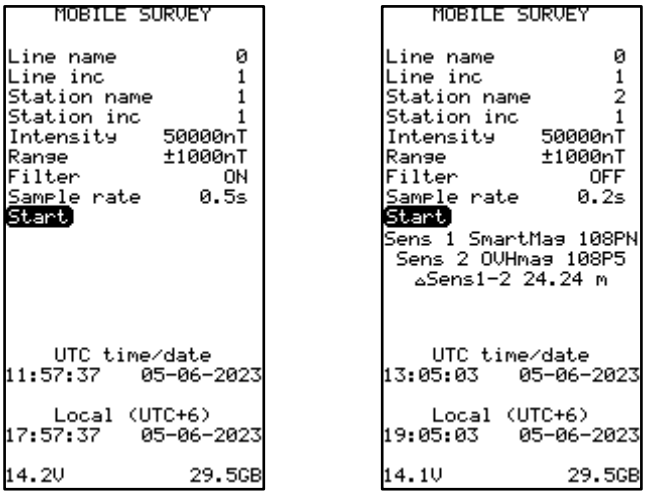
Mobile survey mode is intended for all options of the Earth's magnetic field measurements in motion. To set up and start a mode, select it using keys 2 ↑ or 8 ↓ in the main menu and press Ent. The settings window will appear on the display (Figure 53 a).

Before starting the measurements, the parameters of survey need to be configured. To do so, enter values in the following fields:

Line name	–	profile number
Line inc	–	Increment value for the next profile
Station name	–	name of the first station
Station inc	–	increment value for the next station
Intensity	–	expected value of the magnetic field
Range	–	magnetic field range limits
Filter	–	enable or disable noise filtering
Sample rate	–	OFF (fully manual), 0.2s (5 Hz), 0.25s (4 Hz), 0.5s (2 Hz), 1s (1 Hz), 2s (0.5 Hz) and 3s (0.33 Hz).

To configure each of the above parameters, select it and press key Ent, then using numeric keypad enter the name of the new project and press key Ent. Since absolutely all MaxiMag data is provided with coordinates and time, defining names of the profiles and starting station, as well as their increments, is not necessary, but can further facilitate data processing and analysis. Power consumption is higher in cycle modes compared to manually starting a single measurement (Sample rate: "OFF").

In gradiometer mode, the settings window below the "Start" item displays a list of connected sensors, their model, serial number and distance in meters between the primary converters (Figure 53 b).



a *b*

Figure 53 Mobile survey mode window
a – survey mode with one sensor; b – gradiometer mode

To start measurements, select "Start" in the mode window (Figure 53) with keys 2 ↑ or 8 ↓ and press key Ent, the measurement window (Figure 56) will appear, and the device will start the

magnetic field scanning (except for the “No” mode) and wait for the user's command to save the measurement into the memory. Scanning is performed to improve measurement accuracy. Technically, this means that the magnetometer periodically performs measurements, but does not store them in the memory until a command is received from the operator.

After turning the magnetometer on, when the GNSS receiver built into the console could not find the sufficient number of satellites to synchronize with or after losing a reliable signal during the measurement mode, a blinking message appears on the screen: “No GPS signal" (Figure 54). Wait until the console finds enough satellites to synchronize the internal clock with. The average search time for a sufficient number of satellites is up to 5 minutes.

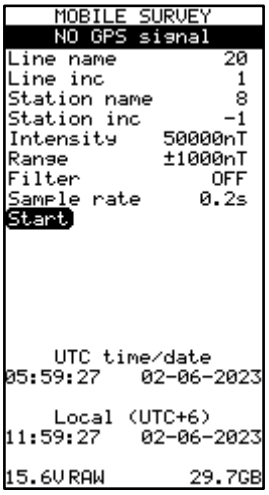


Figure 54 No GPS signal message

If period of automatic measurements is OFF, the measurements are written to the file only if key Ent is pressed. The first measurement is an estimate, it allows to correctly adjust the measurement range of the magnetometer.

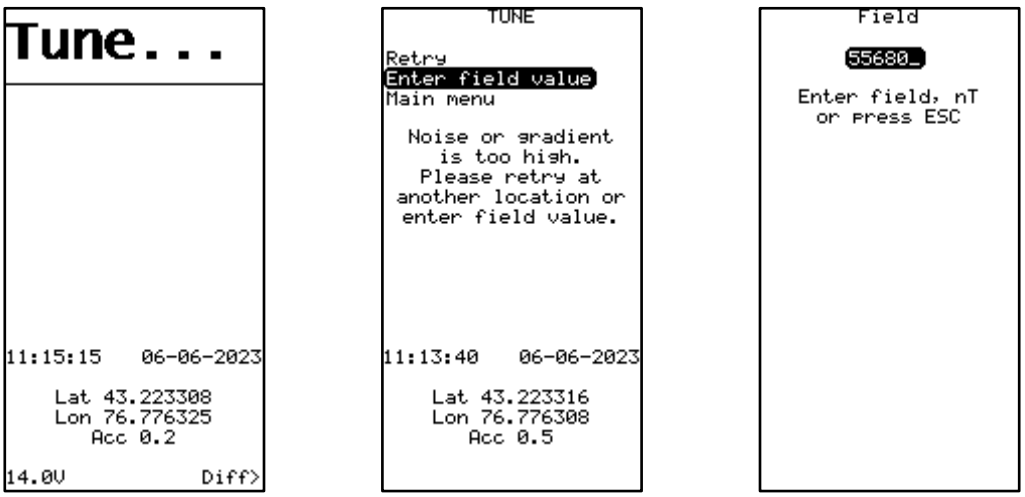
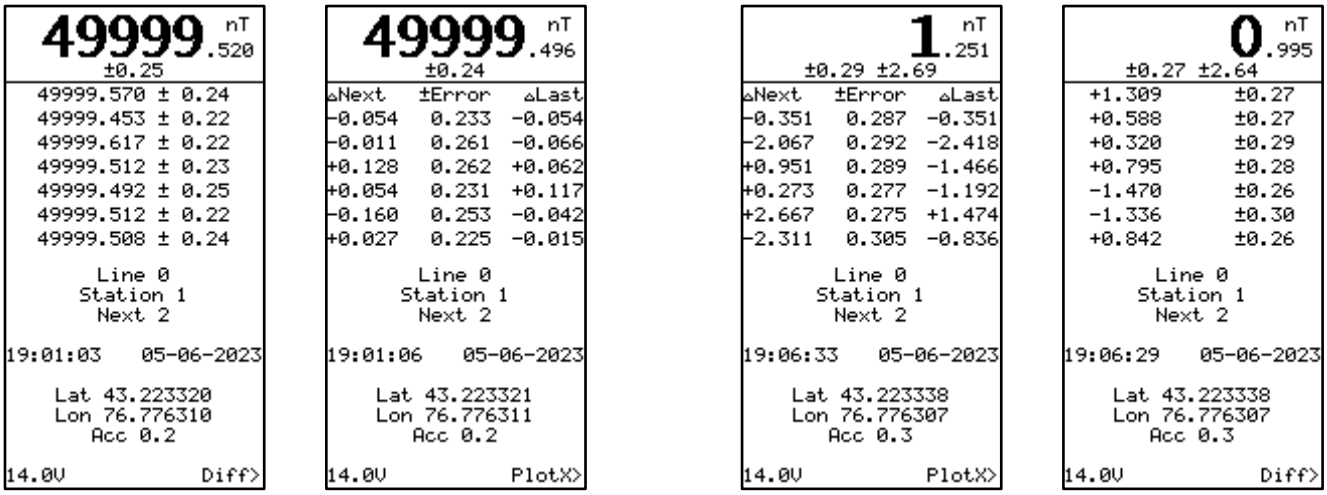


Figure 55 Evaluation measurement and TUNE menu

If magnetic field near magnetometer is inhomogeneous, then after 20 seconds of evaluation measurements, the TUNE menu appears (Figure 55) with a suggestion to repeat evaluation measurement, enter the field value in nT, or exit to the main menu.



a *b* *c* *d*

Figure 56 Measurement window in the Mobile survey mode
a,b – with one sensor; c,d – with two sensors

At the top of the screen (Figure 56), the measured field is displayed with an error in nT. Previously measured values or a table are displayed below, containing:

ΔNext - difference with the previous measurement (field increment),

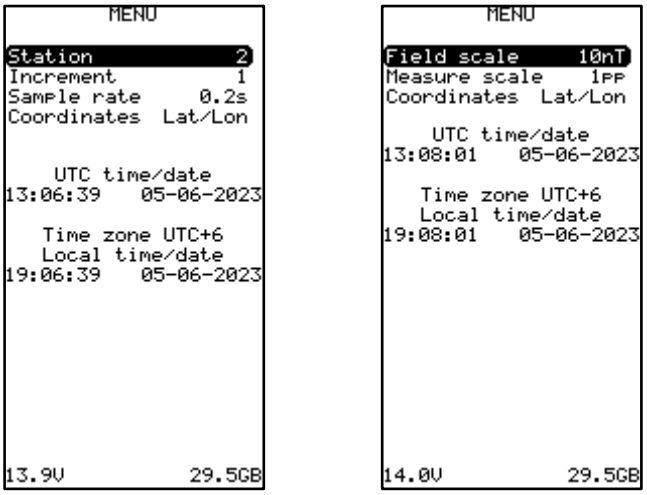
± Error - measurement error,

ΔLast - difference with the current measurement.

The displaying list of measurements or the table of differences are chosen in the menu (Figure 57).

In the center of the screen, the current profile (Line) and station (Station) number, as well as the number of the next station (Next) are displayed. Below are the local date and time, the coordinates of the last measurement (latitude (Lat) and longitude (Lon)), the accuracy in meters (Acc). The lower left corner shows the current voltage of the battery or power source, and on the right, there is a reminder that pressing the key 6 → will take you to the Plot mode.

The station number and increment can be changed using the data display setup. To go to the setup menu, press key Menu in the measurement window (Figure 56), and the setup window (Figure 57) will appear.



a *b*

Figure 57 Setup window in the Mobile survey mode
a – for PlotY and Diff; b – for graphs

In addition to changing the station number and increment, the setup menu also allows to change the Sample rate and Coordinates display. It also enables change of vertical scale and the distance in pixels between adjacent measurements on the screen for graphs. To configure each of the above parameters, select it and press key Ent, then use keys 2 or 8 to enter the required value.

There are two options available in the Coordinates field:

Lat / Lon - coordinates are displayed in degrees,

UTM - coordinates are displayed in the UTM system.

The following options are available in the Field scale field:

±1nT; ±2nT; ±5nT; ±10nT; ±20nT; ±50nT; ±100nT; ±200nT; ±500nT; ±1000nT; ±2000nT; ±5000nT.

The following options are available in the Measure scale field:

1pp, 4pp, 8pp.

In the lower part of the window, the global and local date and time, the voltage on the battery or the power source and the amount of free memory are indicated. While the menu is displayed, the magnetometer is in the standby mode and periodically scans the field. The return to the measurement mode is performed by pressing the button Esc.

Pressing key End Line stops the survey and goes to the menu for survey start on the next profile (Figure 58) with possibility of correcting the profile name (Line name) and its increment (Line inc), the name of the starting station (Station name) and its increment (Station inc), as well as the selection

of the period of automatic measurements (Sample rate). To configure each of the above parameters, select it and press key Ent, then using numeric keypad enter the name of the new project and press key Ent. In case of accidental access to this menu, return to the measurement mode by pressing Esc.

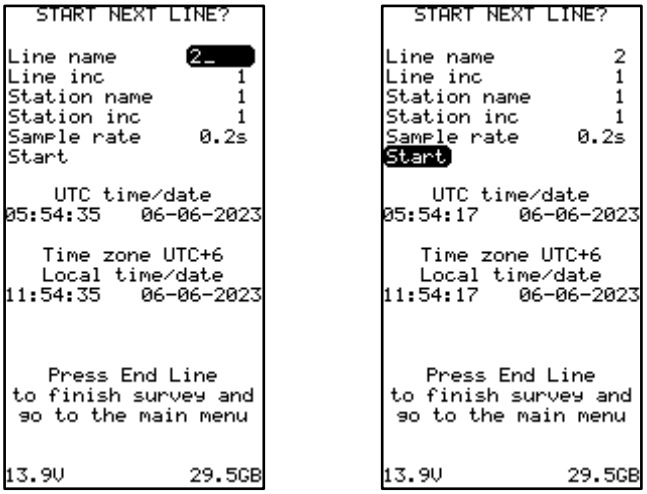
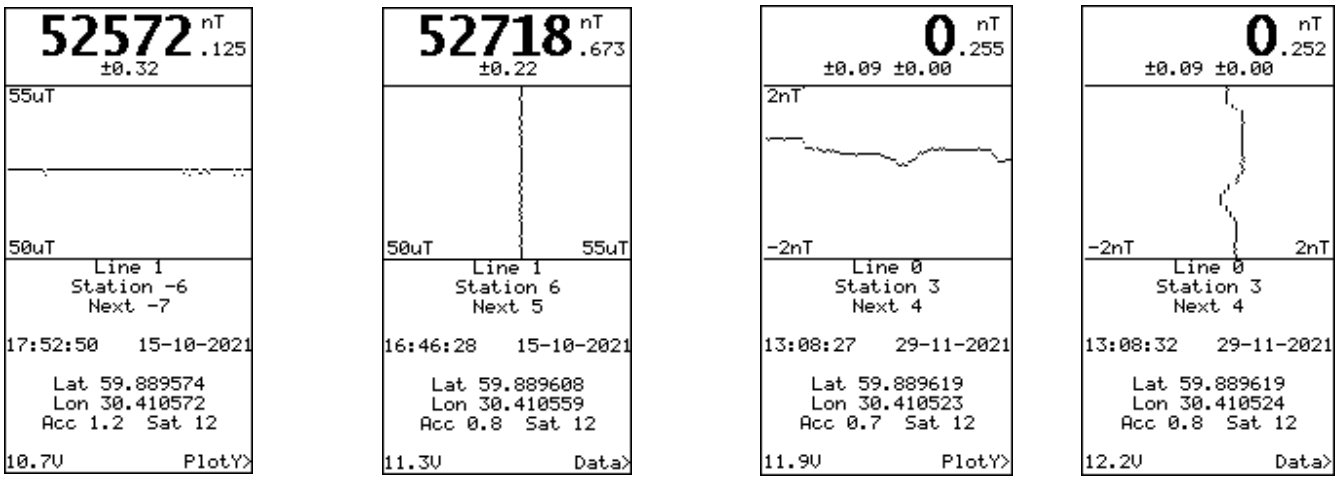


Figure 58 Start menu window for measurements on the next profile

Measurement results can also be displayed as a graph. Press key 6 → in the measurement window (Figure 56), and the graph will appear on the screen (Figure 59 a,c). Pressing 6 → again will turn the graph to vertical display (Figure 59 b,d).



a *b* *c* *d*

Figure 59 Window with a graph of measurements in the Mobile survey mode
a – horizontal display with one sensor, b – vertical display with one sensor;
c – horizontal display with two sensors; d – vertical display with two sensors

2.4.5 Base station mode

The Base station mode is designed to measure the Earth's magnetic field in the mode of base station. To switch to the mode from the main menu window select "Base station" with keys 2 ↑ or 8 ↓ and press Ent. The Base mode settings window will appear on the display (Figure 60). To

configure any of the above parameters, select it by pressing key Ent, then using numeric keypad enter the name of the new project and press key Ent. To change the scale of a graph use key 1 or 3

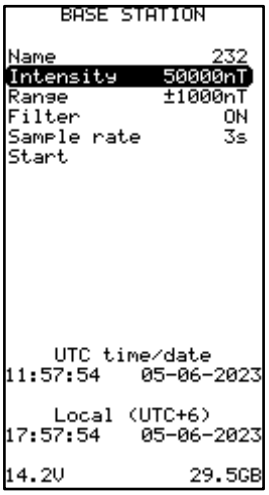
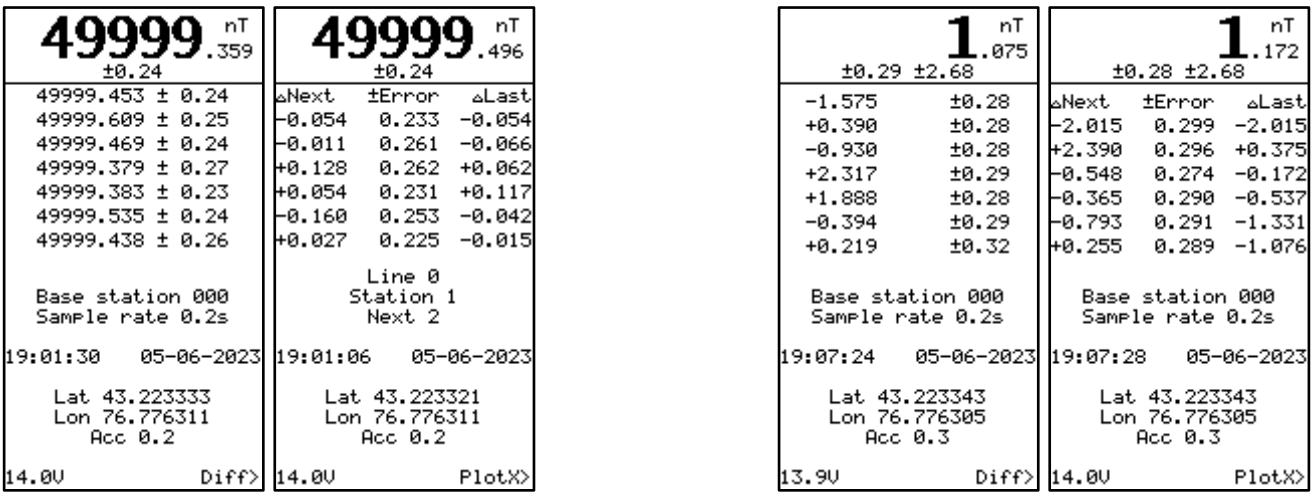


Figure 60 Base station settings window

Before starting the measurements, the parameters of survey need to be configured To do so, enter values in the following fields:

Name	–	Name of a base station
Intensity	–	expected value of the magnetic field
Range	–	magnetic field range limits
Filter	–	enable or disable noise filtering
Sample rate	–	0.2s (5 Hz), 0.25s (4 Hz), 0.5s (2 Hz), 1s (1 Hz), 2s (0.5 Hz) и 3s (0.33 Hz).

To go to measurements, select “Start” in the settings window (Figure 60) with keys 2 or 8 and press key Ent, and the measurements window will appear (Figure 61).



a *b* *c* *d*

Figure 61 Base station measurement window
a,b – with one sensor; c,d – in gradiometer mode

At the top of the screen (Figure 61 a), the measured field is displayed with an error in nT. Below are the previously measured values or a table where:

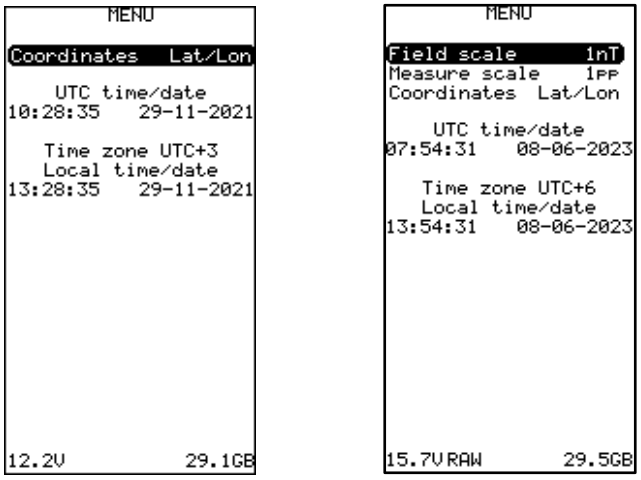
ΔNext - difference with the previous measurement (field increment),

± Error - measurement error,

ΔLast - difference with the current measurement.

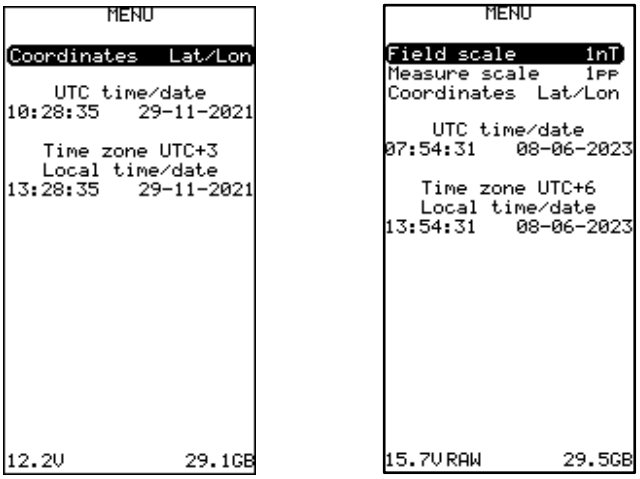
Displaying list of measurements or the table of differences are chosen in the menu.

The center of the screen displays the name of the base station (Station name) and the frequency of measurements (Sample rate). Below are the local date and time, the coordinates of the last measurement (latitude (Lat/Y) and longitude (Lon/X)), their accuracy in meters (Acc). In the lower left corner, the current voltage of the battery or power source is displayed, and in the right corner, there is a reminder that pressing key 6 → switches to the graphic display mode (Plot). To go to the setup menu, press key Menu in the measurement window (Figure 61), and the setup window (



a *b*

Figure 62) will appear.



a *b*

Figure 62 Setup window in the Base station mode
a – for PlotY and Diff; b – for graphs

To configure each of the above parameters, select it with key Ent, then use key 2 ↑ or 8 ↓ to enter the required value.

There are two options available for the Coordinates field:

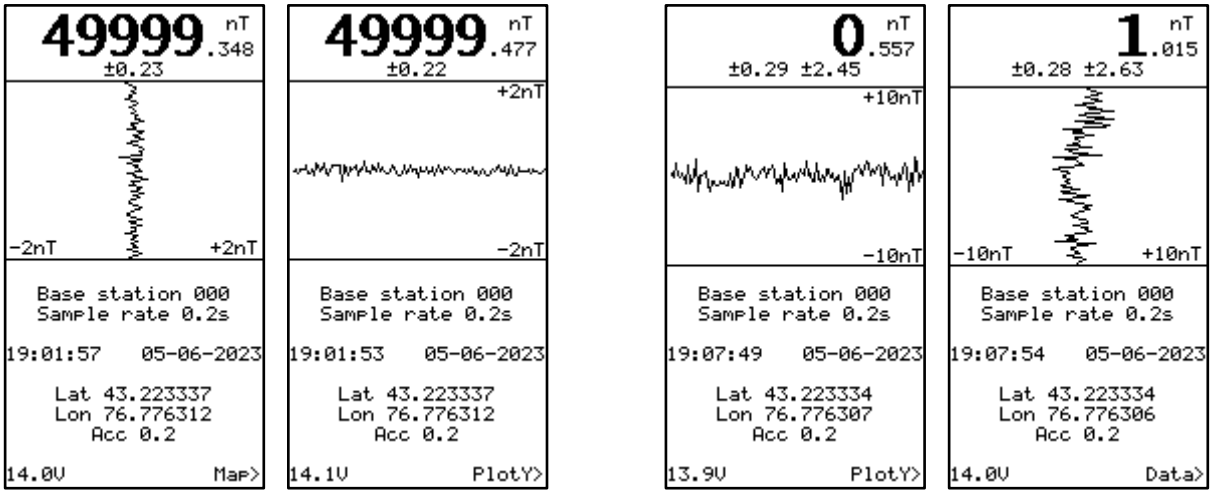
Lat / Lon - coordinates are displayed in degrees,
UTM - coordinates are displayed in the UTM system.

The following options are available in the "Field scale" field:
±1nT; ±2nT; ±5nT; ±10nT; ±20nT; ±50nT; ±100nT; ±200nT; ±500nT; ±1000nT; ±2000nT; ±5000nT.

The following options are available in the "Measure scale" field:
1pp, 4pp, 8pp.

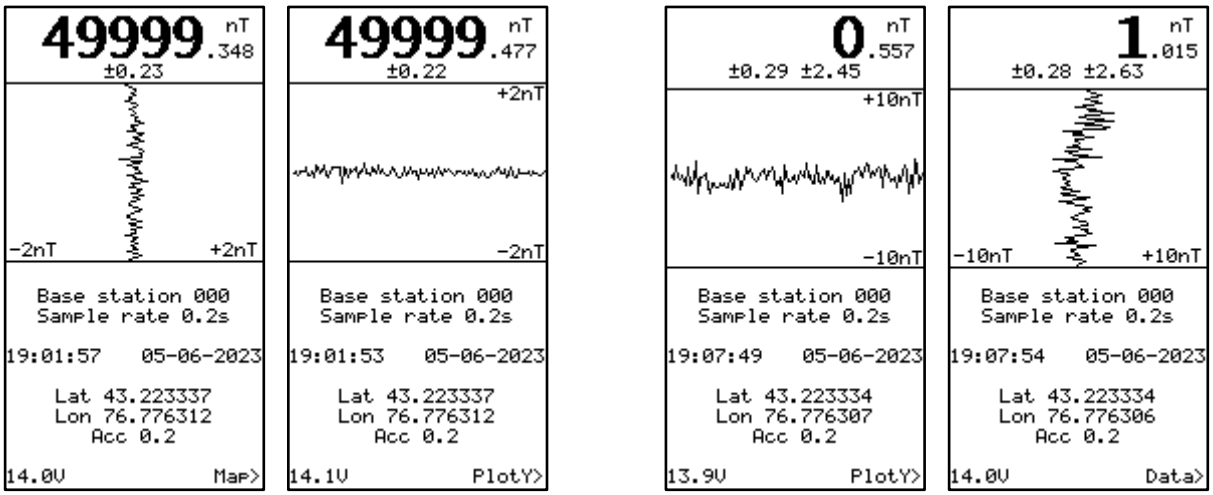
In the lower part of the window, the information is displayed indicating the global and local date and time, the voltage on the battery or power source, and the amount of free memory. Return to the measurement mode by pressing Esc.

Measurement results can also be presented as graphs. Press key 6 → in the measurement window (Figure 61 b, d), and a window with the measurement graph will appear on the screen (



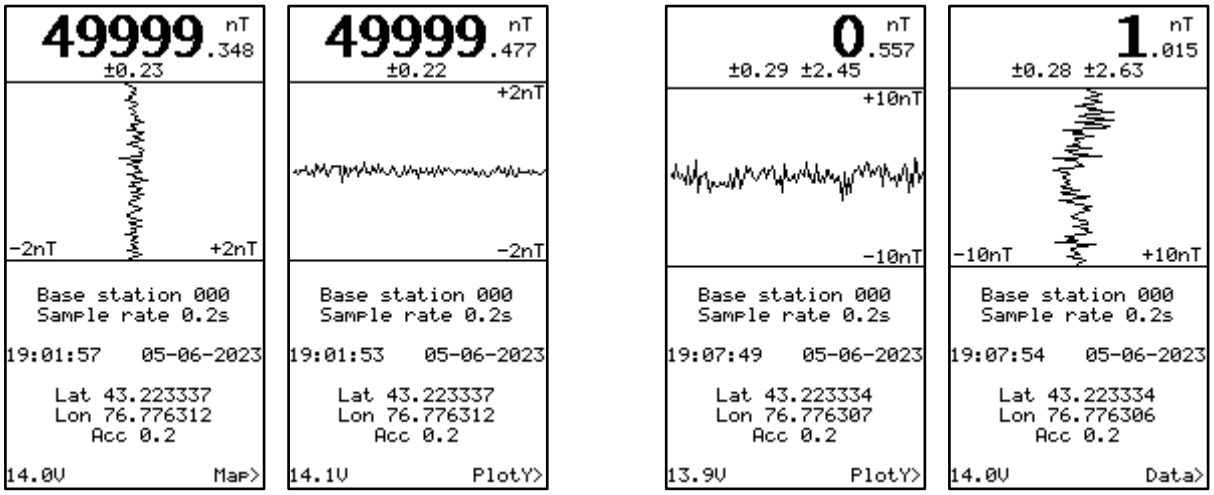
a *b* *c* *d*

Figure 63 a, c). Pressing 6 → again will change the orientation of the graph to vertical (



a *b* *c* *d*

Figure 63 b, d). To change the scale of the graphs press key 1 ⊖ or 3 ⊕.



a *b* *c* *d*

Figure 63 Window with a graph of measurements in the Base station mode
a, b – horizontal and vertical display with one sensor;
c, d – horizontal and vertical display in gradiometer mode;

2.4.6 Search mode

The Search mode is intended for measuring the Earth's magnetic field **without saving data** (search mode).

To switch to the Search mode from the main menu window, select "Search mode" with keys 2 ↑ or 8 ↓ and press key Ent. The Search mode window (Figure 64) will appear with the option to select the Sample rate period. The magnetometer has six measurement cycles (Sample rate): 0.2 s (5 Hz), 0.25 s (4 Hz), 0.5 s (2 Hz), 1 s (1 Hz), 2 s (0.5 Hz), and 3 s (0.33 Hz)). To configure that parameter, select it and press key Ent, then use 2 ↑ or 8 ↓ to enter the required value.

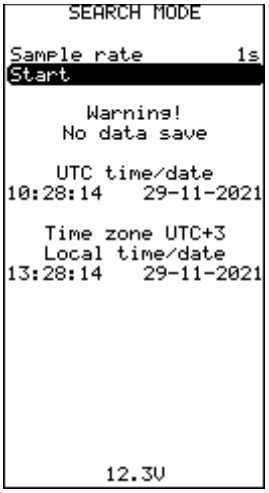
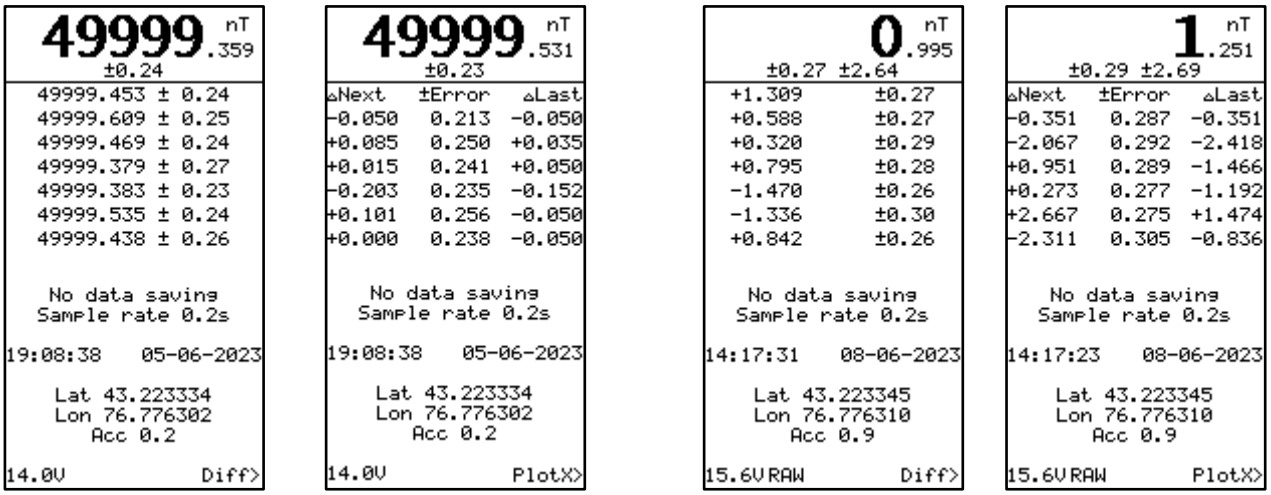


Figure 64 Search mode window

Before starting the measurements, the parameters of survey need to be configured To do so, enter values in the following fields:

Intensity	–	expected value of the magnetic field
Range	–	magnetic field range limits
Filter	–	enable or disable noise filtering
Sample rate	–	0.2s (5 Hz), 0.25s (4 Hz), 0.5s (2 Hz), 1s (1 Hz), 2s (0.5 Hz) и 3s (0.33 Hz).

To go to measurements, select “Start” in the mode window (Figure 64) with keys 2 ↑ or 8 ↓ and press Ent, the measurement window (Figure 65) will appear, and a warning that the data is not saved.



a *b* *c* *d*

Figure 65 Search mode measurement window
a,b – with one sensor; c,d – with two sensors

At the top of the screen (Figure 65 b), the measured field is displayed with an error in nT. Below there are the previously measured values or a table where:
ΔNext - difference with the previous measurement (field increment),
± Error - measurement error,
ΔLast - difference with the current measurement.

Displaying list of measurements or the table of differences are chosen in the menu (Figure 58).
The center of the screen displays frequency of measurements (Sample rate). Below there are the local date and time, the coordinates of the last measurement (latitude (Lat/Y) and longitude (Lon/X)), their accuracy in meters (Acc). In the lower left corner, the current voltage on the battery or power source is displayed, and in the right corner, there is a reminder that pressing key 6 → switches to the graphic display mode (Plot). To go to the setup menu, press key Menu in the

measurement window (Figure 65), and the setup window (

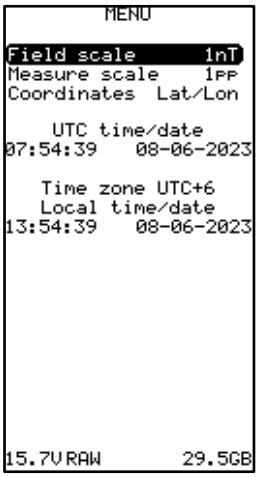


Figure 66) will appear.

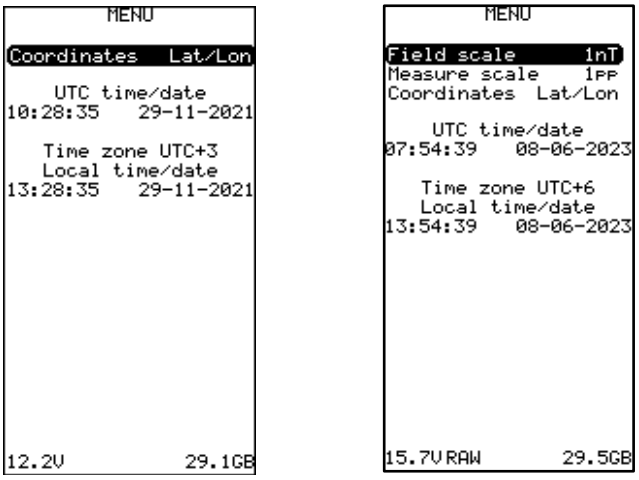


Figure 66 Search mode setup window

To configure each of the above parameters, select it with key Ent, then use key 2 ↑ or 8 ↓ to enter the required value.

There are two options available for the Coordinates field:

Lat / Lon - coordinates are displayed in degrees,

UTM - coordinates are displayed in the UTM system.

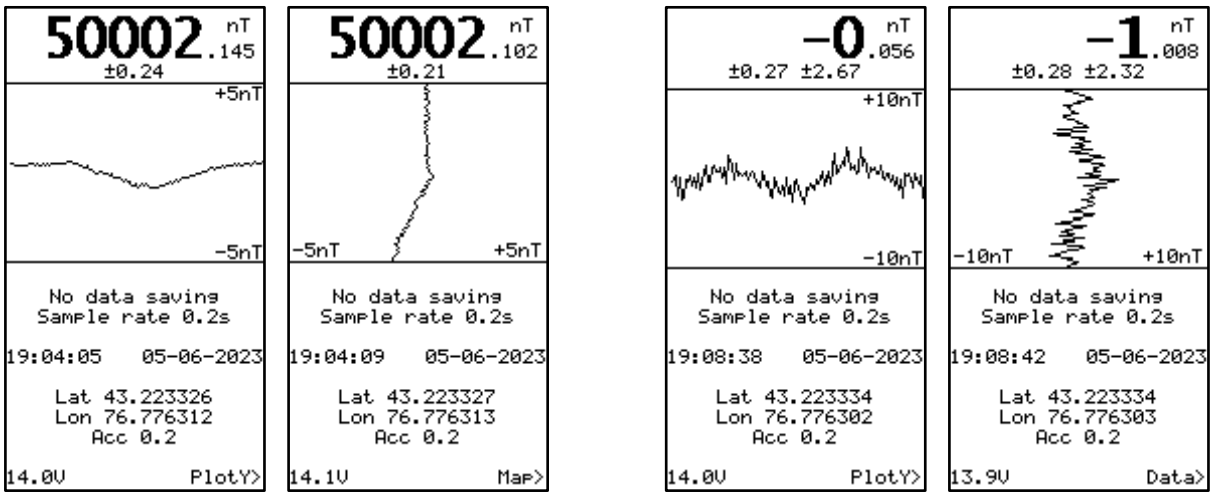
The following options are available in the "Field scale" field:

±1nT; ±2nT; ±5nT; ±10nT; ±20nT; ±50nT; ±100nT; ±200nT; ±500nT; ±1000nT; ±2000nT; ±5000nT.

The following options are available in the "Measure scale" field:
1pp, 4pp, 8pp.

In the lower part of the window, the information is displayed indicating the global and local date and time, the voltage on the battery or power source, and the amount of free memory. Return to the measurement mode by pressing Esc.

Measurement results can also be presented as graphs. Press key 6 → in the measurement window (Figure 65), and a window with the measurement graph will appear on the screen (Figure 67).



a *b* *c* *d*

Figure 67 Window with a graph of measurements in the Search mode
a – horizontal display with one sensor; b – vertical display with one sensor;
c – horizontal display in gradient mode; d – vertical display in gradient mode

2.4.7 Viewing Data

To switch to viewing data from the main menu window, select "View data" with keys 2 ↑ or 8 ↓ and press key Ent. The data viewing window will appear on the display (Figure 68) with an option to select data search by date and time or by profile number. To configure each of the above parameters, select it and press Ent, then use keys from 0 ⏻ to 9 ☀ to enter the required value.

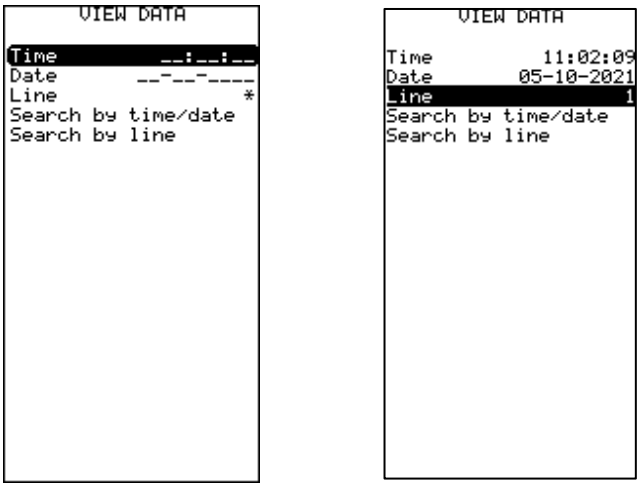
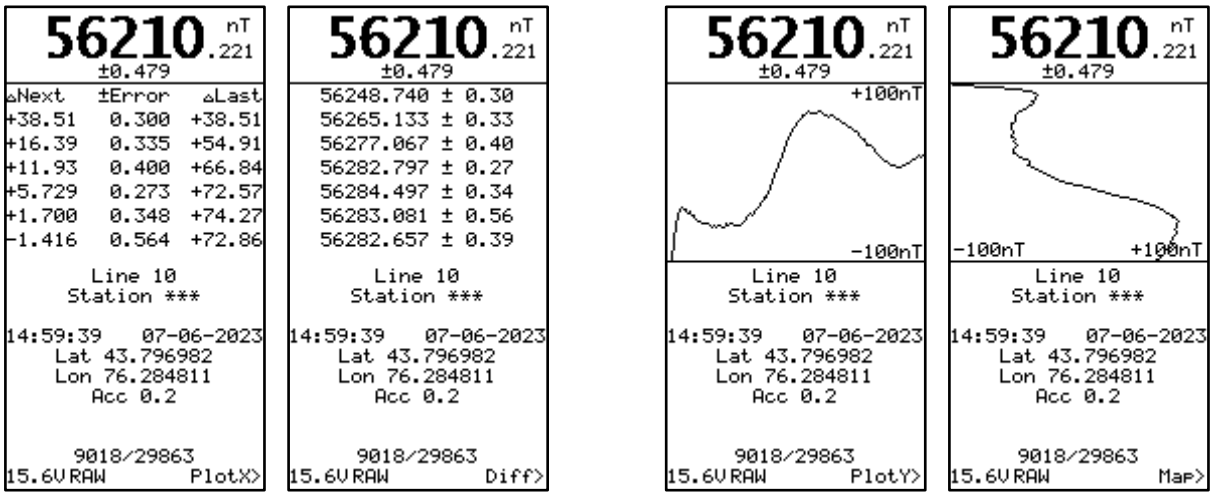


Figure 68 Viewing data window

To search data by date and time, select “Search by time / date” in the viewing window (Figure 68) with keys 2 ↑ or 8 ↓ and press key Ent; to search by profile number, select “Search by line” and press key Ent. The search will start with the message “SCAN DATA… [XX%]” displayed on the screen. If measurements are found, a window with the data found will appear (Figure 69). If the selected values are not found, the device will inform you about this and suggest the nearest available ones.

Measurement results can also be displayed as graphs. Press key 6 → in the measurement window, and a graph of measured data will appear on the screen.



a *b* *c* *d*

Figure 69 Found data window with different modes of displaying

2.4.8 Managing magnetometer settings

2.4.8.1 Setup

To go to the settings menu from the main menu window, select “Setup” using keys 2 ↑ or 8 ↓ and press key Ent, and the magnetometer setup window will appear on the display (Figure 70).

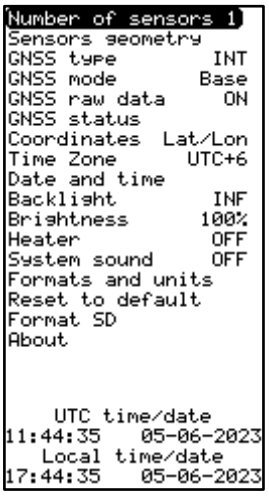


Figure 70 Setup menu window

Using this menu, you can change the settings by moving to the required menu using keys 2 ↑ or 8 ↓, and selecting it by pressing Ent. Changing values within each setting is done with keys 2 ↑ or 8 ↓. Confirmation of changes is done by pressing Ent, on the other hand pressing Esc returns the setting to the initial value.

2.4.8.2 Number of sensors

The field "Number of sensors" displays the number of sensors connected to the console, that are determined automatically. If there is more than one sensor connected, they will be displayed in order in the Sensor list window, with the designation of their order number, model, and serial number. The order in which the sensors are connected to the console does not matter. However, if a message "Invalid sequence" (Figure 71) appears on the screen, then you must press the Ent key to sort the sensors.

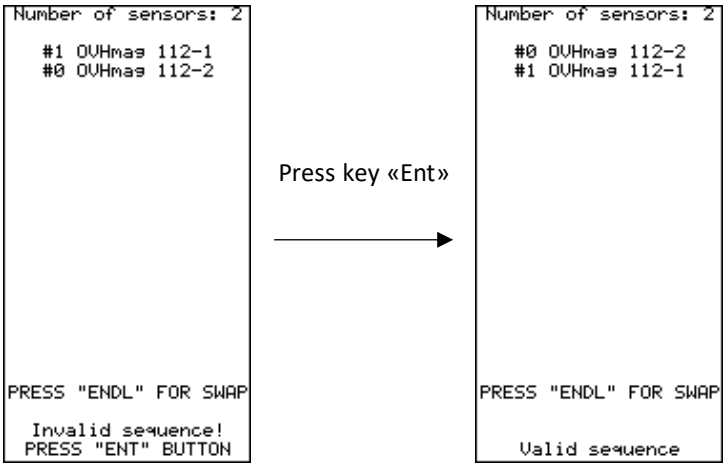
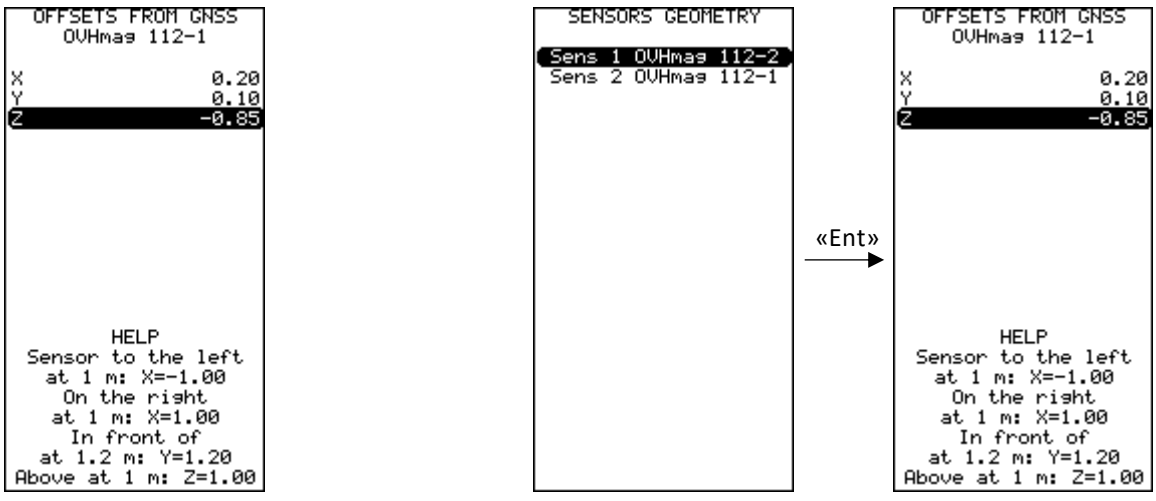


Figure 71 Gradiometer Sensor list window

2.4.8.3 Sensor geometry

To set the sensor geometry relative to the GNSS receiver, in the settings window (Figure 72) using keys 2 ↑ or 8 ↓ choose «Sensors geometry» and press the key Ent, this will open the sensor offset parameters window (Figure 72).



a *b*

Figure 72 Offset from GNSS receiver geometry setting

a – with one sensor; b – in gradient mode

To define the position of the sensor, the magnetometer has an option of setting its position relative to the GNSS receiver along three axes:

X – coordinate in meters to the left (negative values) or to the right (positive values) of the GNSS receiver relative to the direction of movement.

Y – coordinate in meters behind (negative values) or in front (positive values) of the GNSS receiver.

Z – coordinate in meters below (negative values) or above (positive values) the GNSS receiver.

2.4.8.4 GNSS type

The MaxiMag console supports an NMEA GGA message containing position, accuracy, and time information. The console has the ability to select an internal receiver (INT), an external receiver (EXT) or disable data recording from the GNSS receiver (OFF).

To receive a GGA message from an external GNSS receiver, the data transfer interface has to be changed to “NMEA” in the settings of the external GNSS receiver and set the desired speed. The same speed must be set in the settings of the MaxiMag console. To do this, in the settings window (Figure 70), use key 2 or 8 to select “GNSS type” and press the key Ent.

Using the key 2 or 8 select the data rate (Figure 73) specified in the settings of the external receiver, for example, "EXT:9600" and press the key Ent.

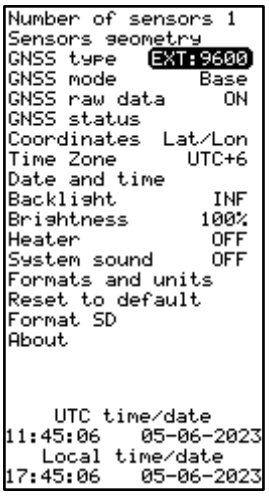


Figure 73 GNSS external source selection and speed setting

To select the GNSS receiver, in the Setup menu window (Figure 70) use keys 2 or 8, select "GNSS" and press key Ent. It is possible to select the internal receiver (INT), the external receiver (EXT), or disable data logging from a GNSS receiver (OFF).

2.4.8.5 Dynamic survey mode

The built-in GNSS receiver supports various dynamic survey modes. A well-chosen model improves the interpretation and provides more accurate position data. Setting the receiver to the wrong mode may result in poor positioning accuracy.

To select a dynamic model, in the settings window (Figure 70) use 2 ↑ or 8 ↓ to select "GNSS mode" and press Ent. Use 2 ↑ or 8 ↓ to select the dynamic mode according to the shooting mode and press the key Ent. Supported dynamic model are shown in the table below.

Table 3 – Supported dynamic model of GNSS-receiver

GNSS mode	Survey mode	Max speed, m/s
Base	Base station	10
Walking	Walking mode	30
Boat	Surveying on boat	25
ATV/Snowm	Surveying on ATV or snowmobil	100

2.4.8.6 Raw data logging from GNSS receiver

To log raw data from GNSS receiver, select "GNSS raw data" in the Setup menu window (Figure 70) using keys 2 ↑ or 8 ↓ choose “GNSS raw data” and press key Ent. When the raw data recording mode is activated, “RAW” will appear at the bottom of the main window and the Mobile survey and Base station measurement mode.

If you choose to record raw data (ON), a separate file (*.UBX) with raw data from the GNSS receiver will be written to the project folder; it can later be used in post-processing of the GNSS data if a base GNSS station is used.

2.4.8.7 Viewing GNSS data

To view the GNSS receiver information, in the settings window (Figure 70), use 2 ↑ or 8 ↓ to select “GNSS status” and press Ent, this will open a new window (Figure 74), that displays the type of receiver used (INTERNAL / EXTERNAL), the status of the receiver (Status), latitude (Lat), longitude (Lon), date, time, heading (Heading), speed between pickets (Speed), altitude (Alt), horizontal accuracy (HDOP) , vertical accuracy (VDOP), PPS signal counter (PPS), 2D/3D/3D-DGNSS Measurement Format (Fix).

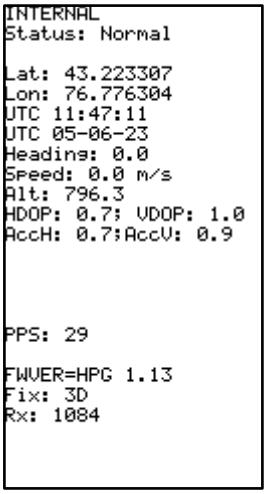


Figure 74 GNSS data view

2.4.8.8 Coordinate system

To select the coordinate system, in the settings window (Figure 70), use 2 ↑ or 8 ↓ to select “Coordinates” and press Ent, then use keys 2 ↑ or 8 ↓ to select the display option of coordinate system on the screen.

There are two options available in the "Coordinates" field:

Lat/Lon - the screen displays the coordinates in degrees,

UTM - the screen displays the coordinates in the UTM system.

2.4.8.9 Time zone

To select the time zone, in the Setup menu window (Figure 70), use keys 2 ↑ or 8 ↓, select "Time Zone" and press key Ent.

2.4.8.10 Date and time setting

To set the date and time, in the settings window (Figure 70), use keys 2 ↑ or 8 ↓ to select "Date and time" and press the key Ent. Enter the current time and date using the keyboard and press the key Ent. Use 2 ↑ or 8 ↓ to move the cursor to "Apply" line. Wait until the real time matches the one entered in the "Time" field and press the key Ent. The manually set time and date will be valid until the console is synchronizes with the precise satellite time.

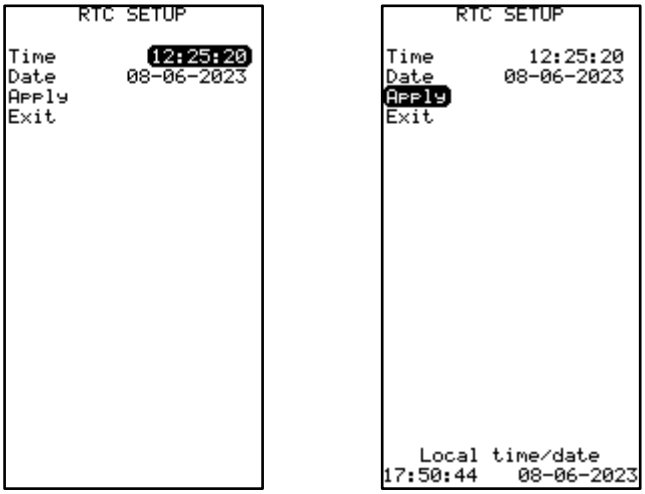


Figure 75 Time and date setting window

2.4.8.11 Backlight and brightness of the screen

To select the backlight of the screen, select "Backlight" in the Setup menu window (Figure 70) using keys 2 ↑ or 8 ↓ and press key Ent.

The Magnetometer has five screen backlight modes:

OFF – the screen backlight is turned off.

10s – the screen backlight turns off 10 seconds after the last pressing of any key.

30s – the screen backlight turns off after 30 seconds.

60s – the screen backlight turns off after 1 minute.

INF – the screen backlight is turned on constantly.

To select the brightness of the screen, in the Setup menu window (Figure 70), use keys 2 or 8 select "Brightness" and press key Ent.

2.4.8.12 Screen heating

To turn the screen heating on/off, in the Setup menu window (Figure 70), use keys 2 or 8, select "Heater" and press key Ent. When the display heating is activated, the icon is displayed.

2.4.8.13 Signal sounds

To turn on / off the signal sound of pressing the keys, in the Setup menu window (Figure 70), use keys 2 or 8, select "System sound" and press key Ent.

2.4.8.14 Formats and units of measurement

To view the information about formats and units of measure, select "Formats and units" in the Setup menu window (Figure 70) using keys 2 or 8, and press key Ent. A new window will open (Figure 76), which displays the information about the formats and units of measurement used.

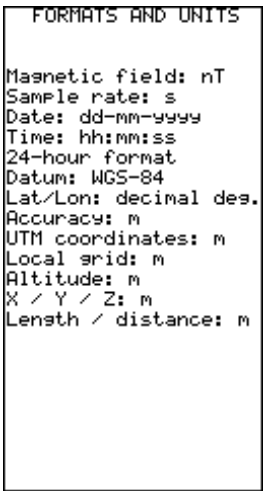


Figure 76 Formats and units of measurement viewing window

2.3.8.15 Reset the magnetometer settings to default

To reset the magnetometer settings to default, in the Setup menu window (Figure 70), use keys 2 or 8, select "Reset to default", and press key Ent. The reset confirmation window will open (Figure 77), To confirm formatting, press key 5 Map.

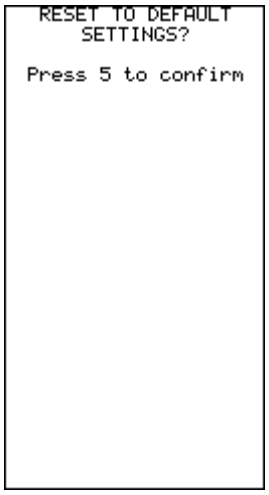


Figure 77 Magnetometer settings reset window

2.3.8.16 Deleting information from the magnetometer memory (clearing memory)

To delete information from the magnetometer memory, select "Format SD" in the Setup menu window (Figure 70) using keys 2 or 8, and press key Ent. This will open a window with confirmation of clearing the memory (Figure 78). To confirm formatting, press key Del.

Figure 78 Deleting information from the magnetometer memory window

After the memory clearing is complete, a window notifying of the successful completion of the procedure will appear on the display screen (Figure 79).

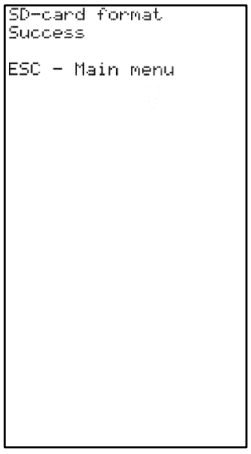


Figure 79 Window of completion of deleting information from the magnetometer memory

2.4.8.17 Device information

To view information about the device, select "About" in the Setup menu window (Figure 70) using keys 2 or 8, and press key Ent. This will open a window (Figure 80) with information about the device, namely, the serial number of the console and connected sensors, as well as the version, date, and time of the console built-in firmware.

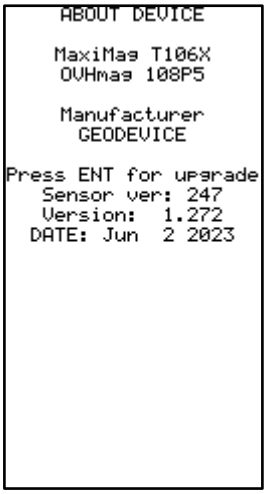


Figure 80 Device information window

3 Description of SmartMag Overhauser magnetometer components

a *b*

Figure 81 Components of SmartMag Overhauser magnetometer
a – before year 2023 model, b – after year 2022 model

1 – Overhauser sensor on flexible cable;
2 – console;
3 – external GNSS antenna (Optional);
4 – USB cable;
5 –RS-232 cable (Optional);
6 – non-magnetic rods;
7 – Li-ion battery with power cable(Optional);
8 – battery power cable;
9 – charger (Optional);
10 – tripod connecting knob;
11 – sensor bracket.

3.1 Operating instructions for SmartMag magnetometer

The magnetometer control panel is located on the front panel of the SmartMag console.

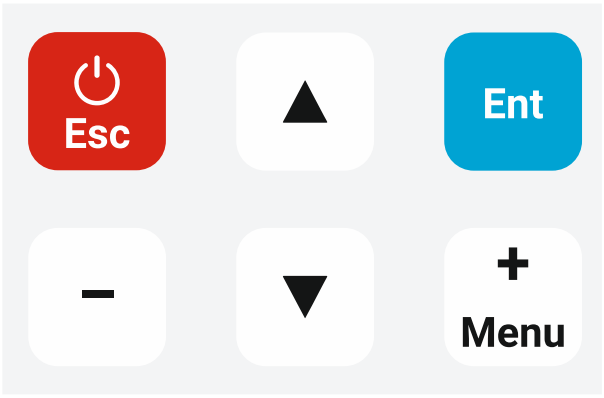


Figure 82 Main keypad of the console of SmartMag Overhauser magnetometer

- turning on / off the magnetometer, exiting to the main menu from the measurement mode and the settings menu, cancelling the action in the settings menu;

- entering a command and starting measurements;

- switching lines in the settings menu;

- going to the settings menu and selecting a value in the settings menu;

- selecting a value in the settings menu.

3.2 Use of SmartMag

3.2.1 Operational limitations

SmartMag Overhauser magnetometer is designed for operation in field conditions at ambient temperatures from - 40 to + 60 ° C.

SmartMag is a precision instrument and must be handled with care. Avoid drops and impacts when working with the device.

3.3 Preparing the device for usage

3.3.1 General safety instructions on preparation for use

The magnetometer is powered by a 14.8 V Li-ion battery that is required to be operated in accordance with the attached instructions (see APPENDIX) or by a 12 V lead-acid battery, Delta CT 12025 type or similar. There is a special cable supplied for connecting the device to the battery.

In the case of using a DC mains source, the case and the negative terminal of the source must be reliably grounded.

3.3.2 The order of actions to prepare SmartMag magnetometer for use

1. Examine all parts of the device and make sure that:
- the magnetometer kit is complete in accordance with the manual and the type of survey to be performed;
- there is no damage on the magnetometer blocks.
- there is no damage to connecting cables and connectors.
- there is no contamination or wetting.

IT IS **PROHIBITED** TO USE THE MAGNETOMETER IF IT IS DAMAGED, WET, OR SIGNIFICANTLY CONTAMINATED.

2. If necessary, recharge the battery in accordance with the enclosed battery instructions (see APPENDIX 12.3).

3. Assemble the tripod by connecting two non-magnetic rods together and attaching them to the remaining rods using the connecting element.

a *b*

Figure 83 Assembled non-magnetic tripod
a – before year 2023 model, b – after year 2022 model

4. Put the sensor bracket on the Overhauser sensor on flexible cable and fix it on the non-magnetic tripod, orienting it in the correct way (see 12.2.1).

a *b*

Figure 84 Assembled non-magnetic tripod
a – horizontal position of the sensor; b – vertical position of the sensor

a *b* *c* *d*

Figure 85 Overhauser sensor fixed on the non-magnetic tripod
a – before year 2023 model, b – after year 2022 model

5. Connect the Overhauser sensor cable to the corresponding console connector.

Figure 86 Console connector for connecting the Overhauser sensor cable

Figure 87 Overhauser sensor on flexible cable

IT IS **PROHIBITED** TO START MEASUREMENTS WITHOUT AN OVERHAUSER SENSOR CONNECTED TO THE CORRECT CONSOLE CONNECTOR.

6. Connect the battery to one of the corresponding connectors of the magnetometer.

Figure 88 Connector on the magnetometer console for connecting the battery

Figure 89 Battery with power cable

a *b*

Figure 90 Console with the Overhauser sensor and battery
a – before year 2023 model, b – after year 2022 model

8. When using an external GNSS antenna, remove the plastic plug of the sensor bracket and attach the bracket for the GNSS antenna instead of the plug (Figure 91). Connect the antenna cable to the appropriate RC connector (Figure 92). An SMA connector is used for connection. If using an internal internal GNSS antenna receiver, go to step 9.

Figure 91 External GNSS antenne (after year 2022 model)

Figure 92 Connector for the external GNSS antenna

9. Turn on the magnetometer by pressing key Esc for 1 second.

10. Wait for the synchronization of the GNSS coordinates and the RTC time using GNSS satellites data. The table below shows the light indication modes:

Light indication		Description
	Solid red	Magnetometer on. Satellites not detected.
	No light	Magnetometer on. Satellites detected and time syncronized
	Flashing green	During measurements. Magnetometer is receiving data from satellites.
	Flashing red	During measurements. Satellite reception is lost.
	Solid pink	During firmware update. Up to 1 min

When starting up for the first time after a long period of inactivity or a significant change in the coordinates of the initial point since the last measurement (more than 200 km), the magnetometer needs to obtain the coordinates and time from the GNSS satellites. This procedure can take up to 20 minutes, depending on the conditions of satellite signal reception. Best results are achieved in open areas without obstacles to radiowaves such as trees or buildings.

3.4 Usage

Operational limitations for use of SmartMag Overhauser magnetometer correspond to the section [2.4.1 Operational limitations.]

3.4.1 Commands control

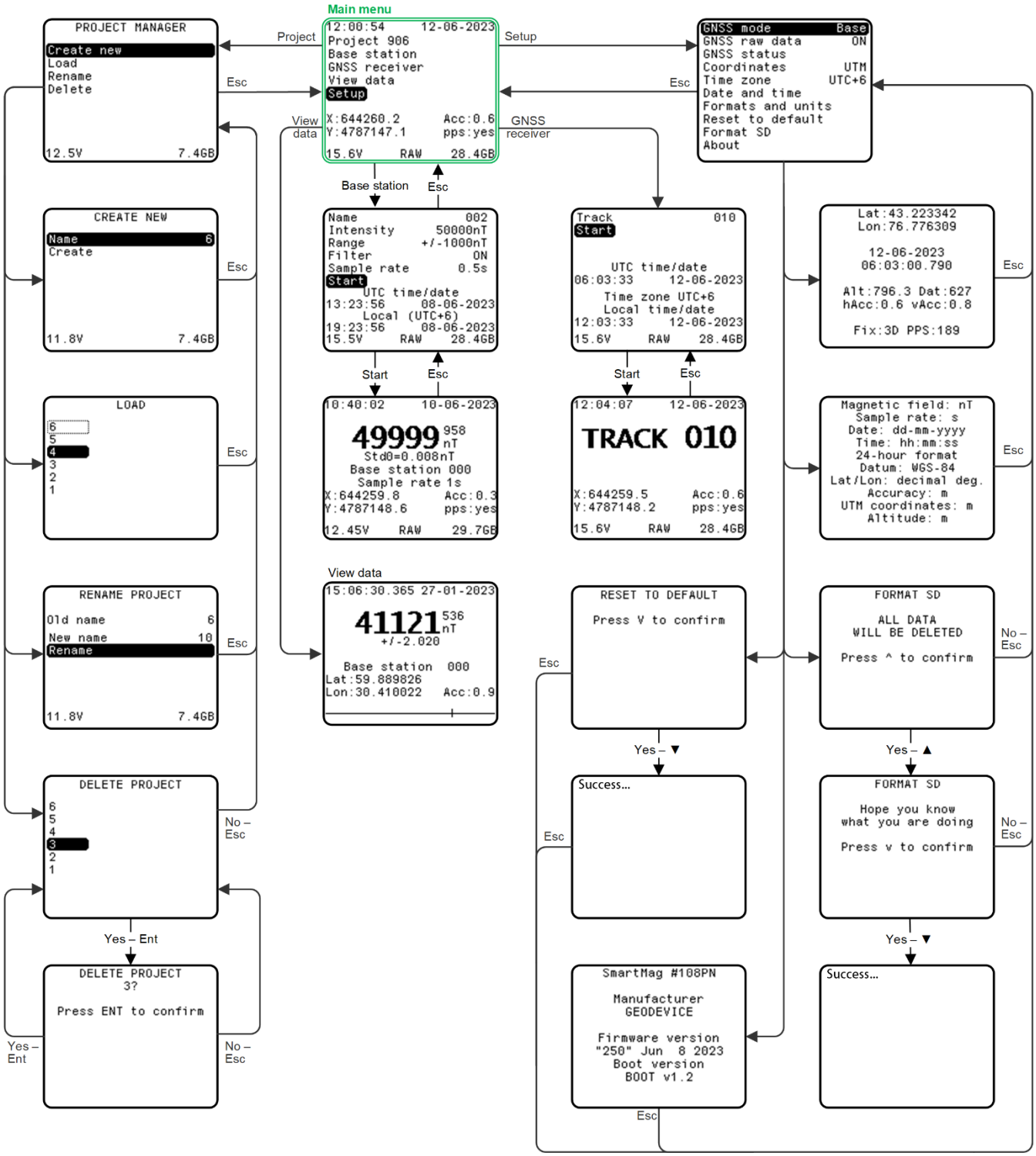


Figure 93 Commands control of the SmartMag Overhauser magnetometer

3.4.2 Initial setup window

After turning the magnetometer on, the main menu appears on the display (Figure 94) indicating the name of current project (to the right of Project), date and time, battery or power source voltage and free memory, as well as indicating GNSS data, latitude (Lat/X), longitude (Lon/Y)). The user can select one of the coordinate systems for display: Lat/Lon or UTM (X/Y).

In main menu, you can go to project manager (Project), select measurement mode (Base station), coordinate recording mode in UBX format and text format (GNSS receiver), view previously measured data (View data) and go to the main instrument settings (Setup).

Information about the amount of free memory is necessary to decide on the preliminary cleaning of memory before starting work or on continuing work with the remaining memory.

Base station – measurement in the magnetic base station mode.

To go to any menu, select it with ▲ or ▼ keys and press the key Ent. Returning to upper level from any menu is done by pressing the key Esc.

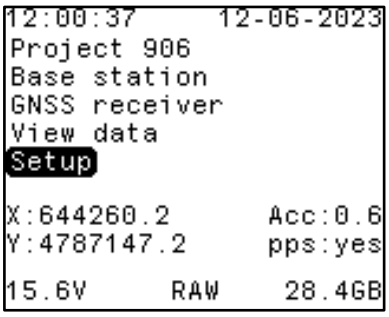


Figure 94 Initial setup window

If there is a signal from the GNSS satellite system, the date and time are synchronized automatically. To display correctly the local time, it is necessary to set the Time Zone parameter in magnetometer settings (see 3.4.10.5 Selecting the time zone). If there is no signal from the GNSS satellite system, the time is synchronized with the internal real-time clock (RTC).

3.4.3 Project manager

To switch to the project manager from the main menu window, select “Project” using ▲ or ▼ keys and press the key Ent. The Project Manager window will appear on the display (Figure 95).

The project manager is required to create a new project (Create new), load a project from the magnetometer memory (Load), rename the current project (Rename) or delete (Delete) any project.

The project has a unifying function for the collected data and settings of the SmartMag. When you create a new project, a new configuration file is automatically created that inherits the characteristics of the previous project. When loading an existing project, the console is automatically loaded with a configuration file located in the folder of the loaded project. At microSD card root folder also contains *Project.txt* file with the name of the last loaded project, that file is read each time SmartMag is turned on.

Figure 95 Project Manager window

3.4.4 Creating a project

To create a project, use ▲ or ▼ keys in the project manager to select "Create new" and press the key Ent. The project creation window will appear on the display (Figure 96) with an option to select the project name. To set a name, select "Name" and press the key Ent, then use ▲ and ▼ to enter the name of the new project.

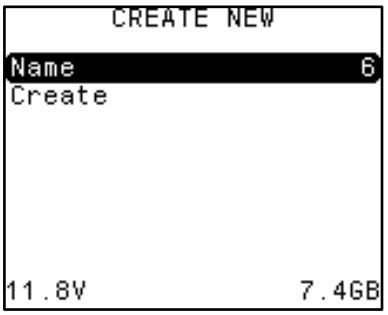


Figure 96 Window for creating a project

3.4.5 Loading a project from the magnetometer memory

To load a project from the magnetometer memory, select “Load” in the project manager using ▲ or ▼ keys and press the key Ent. The project loading window (Figure 97) will appear on the display with the option to select an existing project. Next, select the project and press the key Ent.

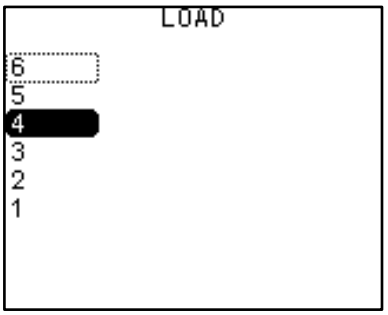


Figure 97 Window for loading an existing project from the magnetometer memory

3.4.6 Renaming a project

To rename a project, use ▲ or ▼ keys in the project manager to select "Rename" and press Ent. The window to rename a will appear on the display (Figure 98) indicating the current name (Old

Name) and the possibility to enter a new one (New Name). To do this, select "New Name", press Ent, then use ▲ or ▼ keys to enter the name of the project.

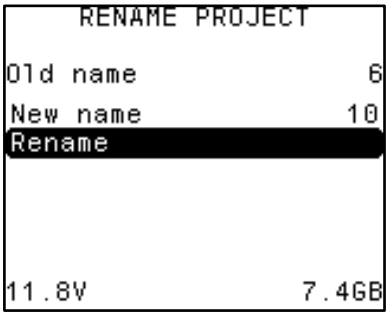


Figure 98 Rename the project window

3.4.7 Deleting a project from the magnetometer memory

To delete a project from the magnetometer memory, use ▲ or ▼ keys in the project manager to select “Delete” and press Ent. Delete a project window will appear on the display (Figure 99). To delete, select the project and press the key Ent, after which a confirmation window for deleting the project will be displayed (Figure 100). Press Ent to confirm, or Esc to cancel.

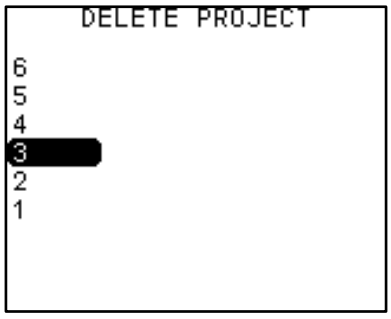


Figure 99 Delete a project window

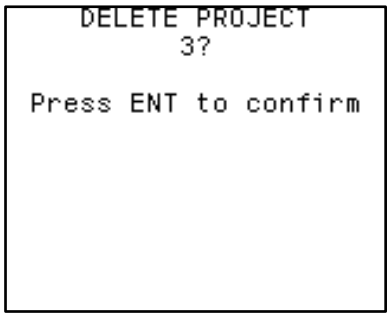


Figure 100 Window of confirmation to delete a project

3.4.8 Base station mode

IT IS **PROHIBITED** TO START MEASUREMENTS WITHOUT A CONNECTED OVERHAUSER SENSOR TO THE CORRESPONDING CONNECTOR OF CONSOLE.

The Base station mode is designed to measure the magnetic field as a base station. To switch to the mode from the main menu window, select "Base station" with ▲ or ▼ keys and press Ent.

The mode settings window will appear on the display

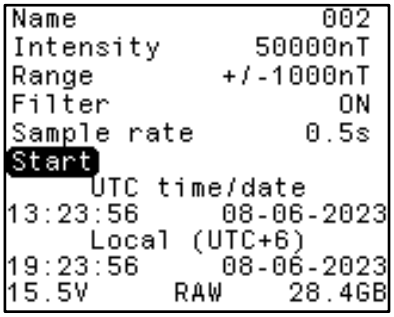


Figure 101).

Before starting the measurements, the parameters of survey need to be configured. To do so, enter values in the following fields:

Name	–	name of the base station
Intensity	–	expected value of the magnetic field
Range	–	magnetic field range limits
Filter	–	enable or disable noise filtering
Sample rate	–	0.2s (5 Hz), 0.25s (4 Hz), 0.5s (2 Hz), 1s (1 Hz), 2s (0.5 Hz) и 3s (0.33 Hz).

To set each of the above parameters, select it and press the key Ent, then use ▲ or ▼ keys to enter the value.

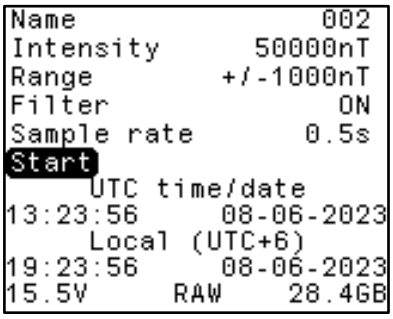


Figure 101 Base station mode window

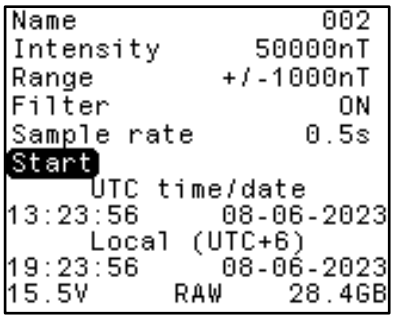
To switch to measurements, in Base station mode window (

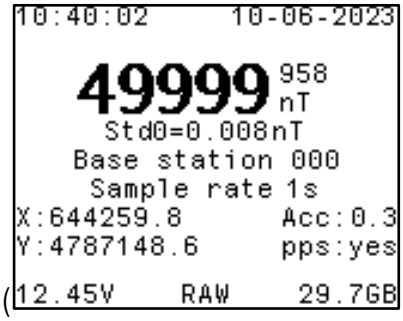
Figure 101), use ▲ or ▼ keys to select “Start” and press key Ent, and the measurement window will appear (

Figure 102).

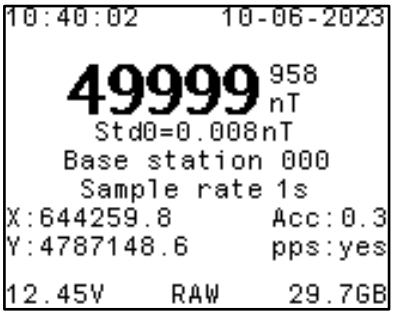


Figure 102 Base station mode measurement window

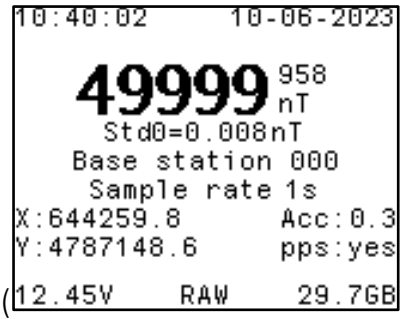
The upper part of the screen (

Figure *102*) displays the local date and time, measured field with an error in nT.

The name of the base station (Name) and the sample rate (Sample rate) are displayed in the center of the screen. The coordinates of the last measured value (latitude (Lat) and longitude (Lon)), their accuracy in meters (Acc) are displayed below. In lower left corner the current voltage of the connected battery or power source is displayed, and in right - the amount of free built-in memory.

3.4.9 GNSS receiver mode

Important! In GNSS receiver mode, the magnetometer does not measure the magnetic field.

The SmartMag magnetometer can act as a GNSS receiver for recording raw data for further conversion to RINEX format to obtain accurate tracks of magnetometric survey profiles. In addition to raw data, the magnetometer records current coordinates in a separate text file (SerNum_Tr.txt).

To switch to the mode, select "GNSS receiver" with ▲ or ▼ keys and press Ent in the main menu window. The display will show the mode settings window (Figure 103). Before starting to record a GNSS signal, specify the name of the base station (Track), to do this, select it and press the key Ent , then use ▲ or ▼ to enter the required value.

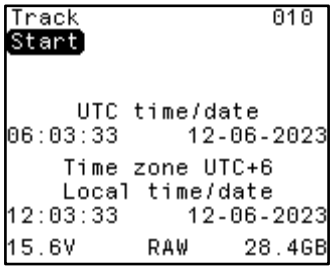


Figure 103 GNSS receiver window

To switch to recording, in the mode window (Figure 103) use ▲ or ▼ to select “Start” and press Ent, and the measurement window will appear (Figure 104).

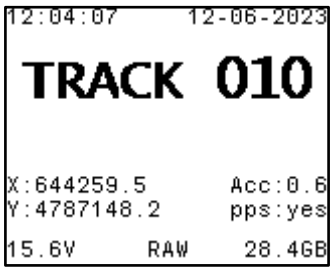


Figure 104 GNSS signal recording mode window

3.4.10 View data

To switch to data view mode from the main menu window, select “View data” using ▲ or ▼ keys and press key Ent. The data view window will appear on the display (Figure 105).

To search for data, it is necessary to select the measurement in the viewing window (Figure 105) using ▲ or ▼ keys. If there is no file with measurements in the current project, the message “No data in the project” will appear if trying to view data.

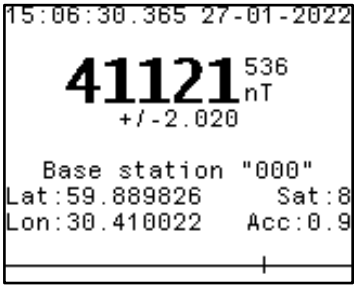


Figure 105 View data window

3.4.11 Managing magnetometer settings

3.4.11.1 Exit to the settings menu

Exit to the settings menu (Figure 106) is done by pressing + Menu. Exit to the main menu from the settings menu is done by pressing the key Esc.

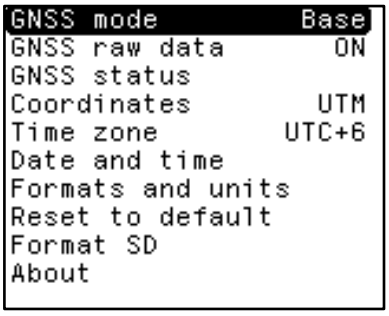


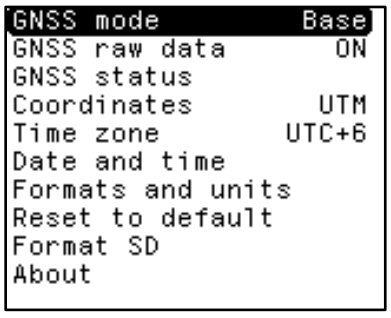
Figure 106 Settings menu

Using this menu, any of the presented settings can be changed by moving to that setting using keys ▲ ▼, and selecting it with a press of a button Ent. Changing the values within each setting is done using ▲ ▼ or + Menu – keys.

Confirmation of the changes is done by pressing a button Ent, while pressing the key Esc in the setting change mode returns the setting to its original value.

3.4.11.2 Dynamic survey mode

The built-in GNSS receiver supports various dynamic survey modes. A well-chosen model improves the interpretation by the built-in receiver and thus provides more accurate position data. Setting the receiver to the wrong mode may result in poor positioning accuracy.

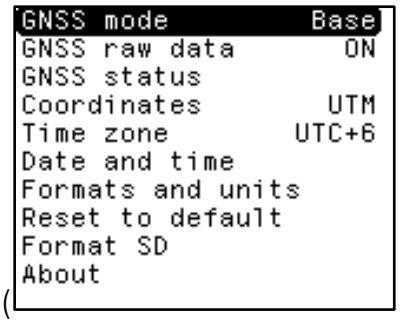


To select a dynamic mode, in the settings window (Figure 106) use ▲ or ▼ keys to select "GNSS mode" and press the key Ent. Using ▲ or ▼ select the dynamic mode according to the survey mode and press the key Ent. Supported dynamic modes are shown in the table below.

Table 4 - Supported dynamic GNSS receiver modes

GNSS mode	Survey mode	Max speed, m/s
Base	Base station	10
Walking	Walking	30
Boat	Marine	25
ATV/Snowm	Snowmobile or ATV	100

3.4.11.3 Raw data recording from a GNSS receiver



To record raw data from the GNSS receiver, in the settings window (Figure 106) use ▲ or ▼ keys to select "GNSS raw data" and press the key Ent. When the raw data recording mode is activated, the message “RAW” will appear in the lower part of the main window and the Base station and GNSS receiver measurement modes windows.

If raw data recording is selected (ON), a separate file (*.UBX) with raw GNSS data will be created in the project folder, that can be later used in post-processing of GNSS data to obtain refined coordinates of magnetometric survey tracks.

3.4.11.4 Viewing GNSS data

Viewing GNSS data can be done by pressing the button Ent in the “GNSS status” setting (Figure 107). A window will appear on the display (Figure 108Ошибка! Источник ссылки не найден.) with GNSS data in the WGS-84 system: latitude (Lat/Y), longitude (Lon/X), receiver location above the ground (Alt), Horizontal Accuracy (hAcc), Vertical Accuracy (vAcc), measurement format 2D/3D/3D-DGNSS (Fix), and PPS Signal Counter (PPS) .

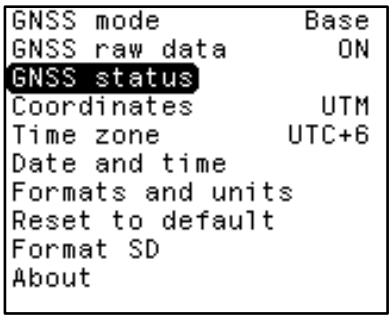


Figure 107 Viewing GNSS data

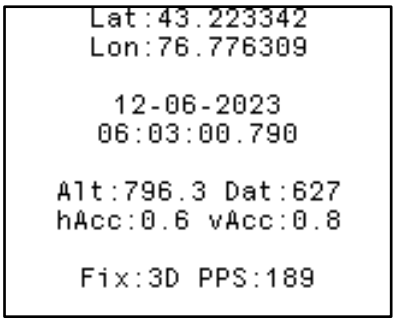


Figure 108 GNSS data window

3.4.11.5 Selecting a coordinate system

To select a coordinate system, in settings window (Figure 106), use ▲ or ▼ keys to select “Coordinates” and press key Ent, then use ▲ or ▼ keys to enter the required value.

There are two options available in the "Coordinates" field:

Lat/Lon - displays the coordinates in degrees,

UTM - displays the coordinates in UTM system.

3.4.11.6 Selecting the time zone

To select the time zone, in settings window (Figure 106), use ▲ or ▼ keys to select "Time Zone" and press key Ent.

3.4.11.7 Setting date and time

If for some reason there is no external GNSS antenna, then the time and date can be set manually. To set the date and time, in the settings window (Figure 106) use ▲ or ▼ keys to select "Date and time" and press the key Ent, then enter the current time and date using ▲ or ▼ and press the key Ent. Using ▲ or ▼ move the cursor to "Apply". Wait until real time matches the one entered in the "Time" field and press the key Ent . The manually set time and date will be valid until the console is synchronized with satellite time signal.

3.4.11.8 Information about formats and units

To view information about formats and units of measurement, in settings window (Figure 106) select “Formats and units” using ▲ or ▼ keys and press Ent, this will open a window (Figure 109Ошибка! Источник ссылки не найден.) with information on the formats and units used.

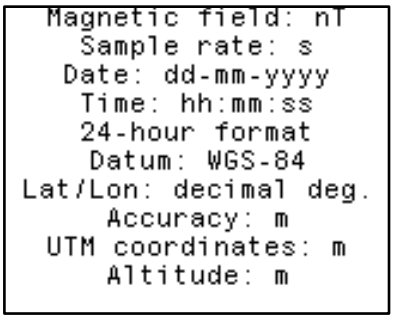


Figure 109 Window for viewing information about formats and units

3.4.11.9 Reset magnetometer settings

To reset magnetometer settings, in settings window (Figure 106), use ▲ or ▼ keys to select “Reset to default” and press Ent, this will open a window with the settings reset confirmation (Figure 110Ошибка! Источник ссылки не найден.).

To confirm formatting, press the key ▼

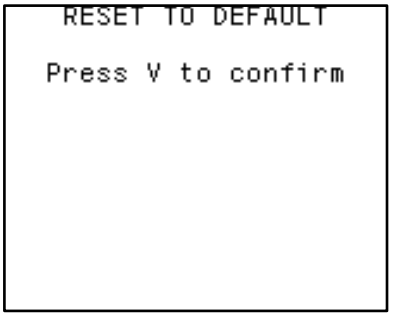


Figure 110 Reset magnetometer settings window

3.4.11.10 Memory clearing

The information recorded in the magnetometer memory is erased by pressing Ent in the “Format SD-card” setting (Figure 111). Upon **confirmation of clearing** the memory (by pressing Ent), a message will appear on the screen (Figure 112Figure 112).

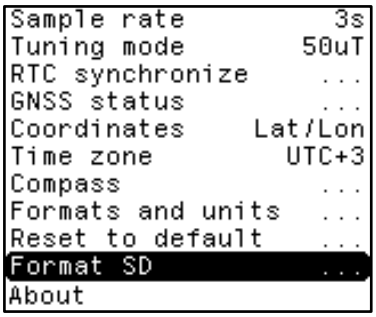


Figure 111 Deleting information from the magnetometer memory

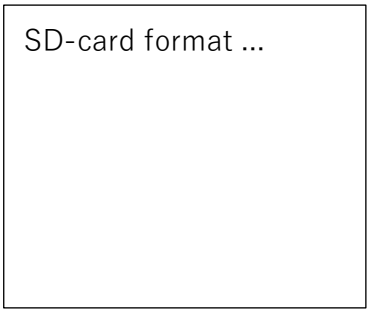


Figure 112 Clearing memory display

After clearing memory is completed, the display screen will return to initial setup window (Figure 94).

3.4.11.11 Viewing instrument information

To view information about the device, in settings window (Figure 106), use ▲ or ▼ keys to select “About” and press key Ent, this will open a window (Figure 113) with data about the device: the serial number of magnetometer and date of firmware version used.

Figure 113 Device data view window

3.5 Safety measures when using the device

When operating the device, it is necessary to comply with the requirements of the "Safety Rules for Geological Exploration"

IT IS **PROHIBITED** TO USE THE MAGNETOMETER FOR OTHER PURPOSES, IN INAPPROPRIATE CONDITIONS AND/OR ENVIRONMENT.

Handle the magnetometer with care, do not expose it to shocks, do not allow falls from a height and any external influences that can damage the device.

IT IS **PROHIBITED** TO USE THE MAGNETOMETER IF IT IS DAMAGED OR SIGNIFICANTLY CONTAMINATED.

When working in the dark, all work sites must have lighting that meets safety requirements.

3.6 Procedure at the end of work with the device

At the end of working with the device, perform the following steps:

- Finish data acquisition by pressing key Esc briefly;
- Turn off the power supply of the device by long pressing the Esc key.

ATTENTION! It is prohibited to turn off the power supply of the device during measurements! This may lead to incorrect data recording into the device memory and the subsequent impossibility to log it to a PC.

3.7 Uploading data from the magnetometer memory to a PC

3.7.1 Uploading data to PC

The magnetometers can upload data via the USB interface. To do so:

3.7.1.1 Connect the battery to any of magnetometer connectors shown in Figure 114 and Figure 115.

Figure 114 Battery connector on MaxiMag console

Figure 115 Battery connector on SmartMag electronics unit

Figure 116 Battery with power cable

3.7.1.2 Turn on the magnetometer by holding the button  or  .

3.7.1.3 Connect the USB cable (Figure 119**Ошибка! Источник ссылки не найден.**) to the connector indicated in Figure 117**Ошибка! Источник ссылки не найден.** and Figure 118**Ошибка! Источник ссылки не найден.**.

Figure 117 Connector for USB cable on MaxiMag console

Figure 118 Connector for USB cable on SmartMag electronics unit

Figure 119 USB cable

3.7.1.4 Turn on the computer and connect the magnetometer console with a USB cable. It will be recognized as USB with folders. Names of folders will be the same as names of projects. In folders there will be files with measured data in the text format .txt with a tab delimiter and a project configuration file (cfg.dat), containing all current settings in all menus for this project.

Data measured in Base station or Mobile survey modes are saved in ##### B1.txt and ##### M1.txt files respectively, where "#####" is the serial number of the console, indexes "B" or "M" indicates mode, and "1" indicates the number of sensors used. Each new measurement is saved in the file as a new line.

Data files use the following headers, separated by tabs:

- UTC_date – UTC date in dd-mm-yyyy format
- UTC_time – UTC time in hh: mm: ss.ss format
- Time_zone – time zone
- Line – profile number
- Station – station number
- Field# – field measured by sensor # (nT)
- Error# – measurement error by sensor # (nT)
- DeviceSN# – sensor serial number #
- Sens_X – X position of the sensor # relative to the GNSS antenna (m)
- Sens_Y – Y position of the sensor # relative to the GNSS antenna (m)
- Sens_Z – Z position of the sensor # relative to the GNSS antenna (m)
- Lat – latitude determined by GNSS (degrees)
- Lon – longitude determined by GNSS (degrees)
- Alt – altitude above sea level determined by GNSS (m)
- Zone – UTM zone
- Hemisphere – hemisphere
- Easting – X coordinate in Universal Transverse Mercator (m)
- Northing – Y coordinate in Universal Transverse Mercator (m)
- hAcc – horizontal accuracy determined by GNSS (m)
- vAcc – vertical accuracy determined by GNSS (m)

The ##### B1.txt files do not have the Line and Station headers, and ##### M1.txt does not use the Base header

3.7.2 Uploading real-time data

SmartMag and MaxiMag magnetometers can upload data in real time via CAN FD or RS-232 connection, to do this:

3.7.2.1 Connect the battery to connectors as shown in 3.7.1 Uploading data to a PC.

3.7.2.2 Turn on the magnetometer by holding the button Esc.

3.7.2.3 Connect CAN FD or RS-232 cable to connectors in Figure 120 and Figure 121.

Figure 120 CAN FD or RS-232 cable connector on MaxiMag console

Figure 121 CAN FD or RS-232 cable connector on SmartMag electronics unit

Figure 122 CAN FD Cable

3.7.2.4 Turn on the computer on (a PC with Windows 10 is required for correct operation) and plug the magnetometer to USB.

3.7.2.5 Download SmartManager.exe software. After launching the software, the main window of the program will appear (Figure 123).

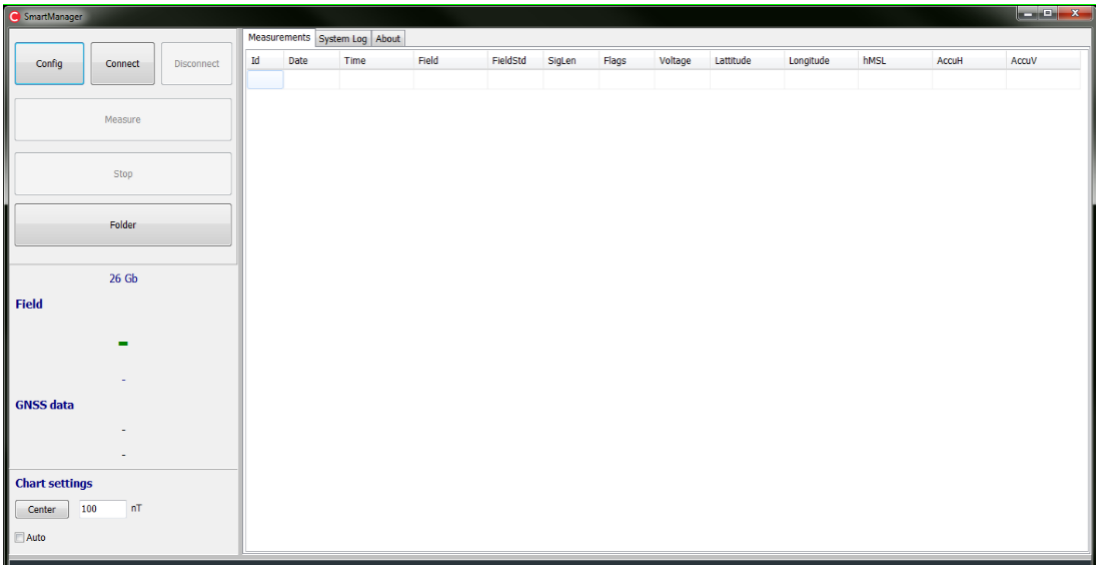


Figure 123 SmartManager Main Window

3.7.2.6 To select the connection port and data storage directory, click the "Config" button in the main program window (Figure 123). This will open a window (Figure 124) with an option to specify data storage directory, should be entered manually, as well as an option to select the magnetometer connection port. Information about remaining free memory in the selected directory (Disk Free Space) will appear on the left side of the main window. To select a port, click on the "…" button, after which a window, where you can select required port, will open (Figure 125). To confirm your selection, click the "Apply" button.

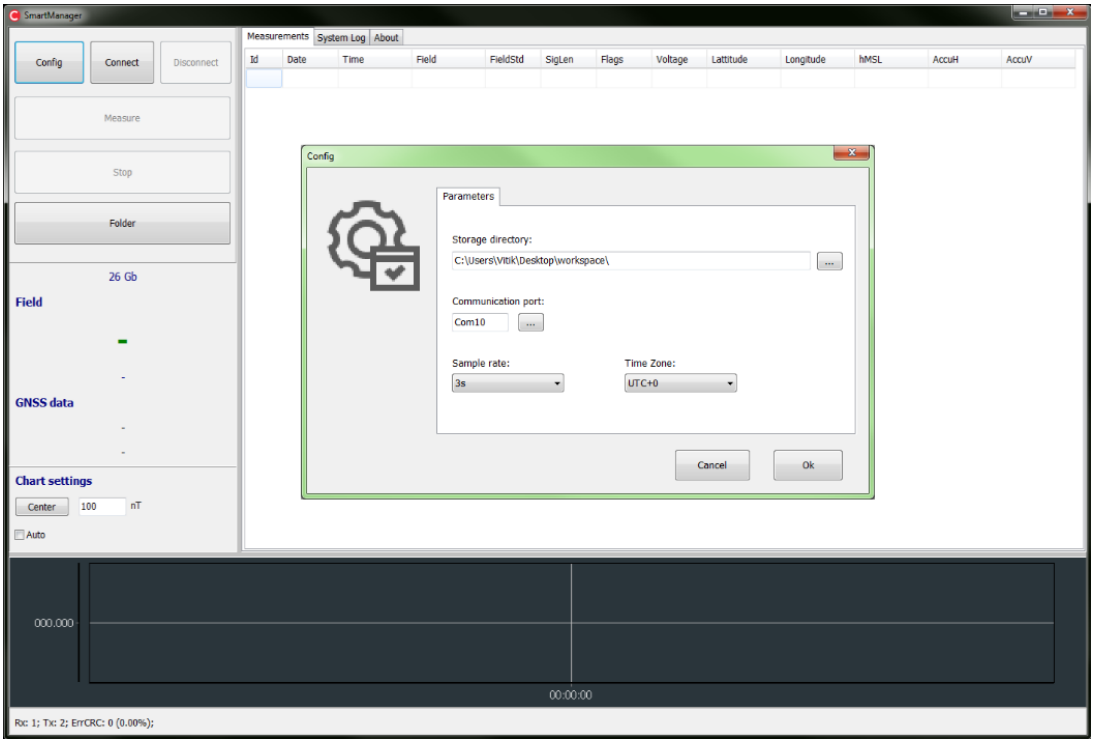


Figure 124 Selecting a connection port and storage directory

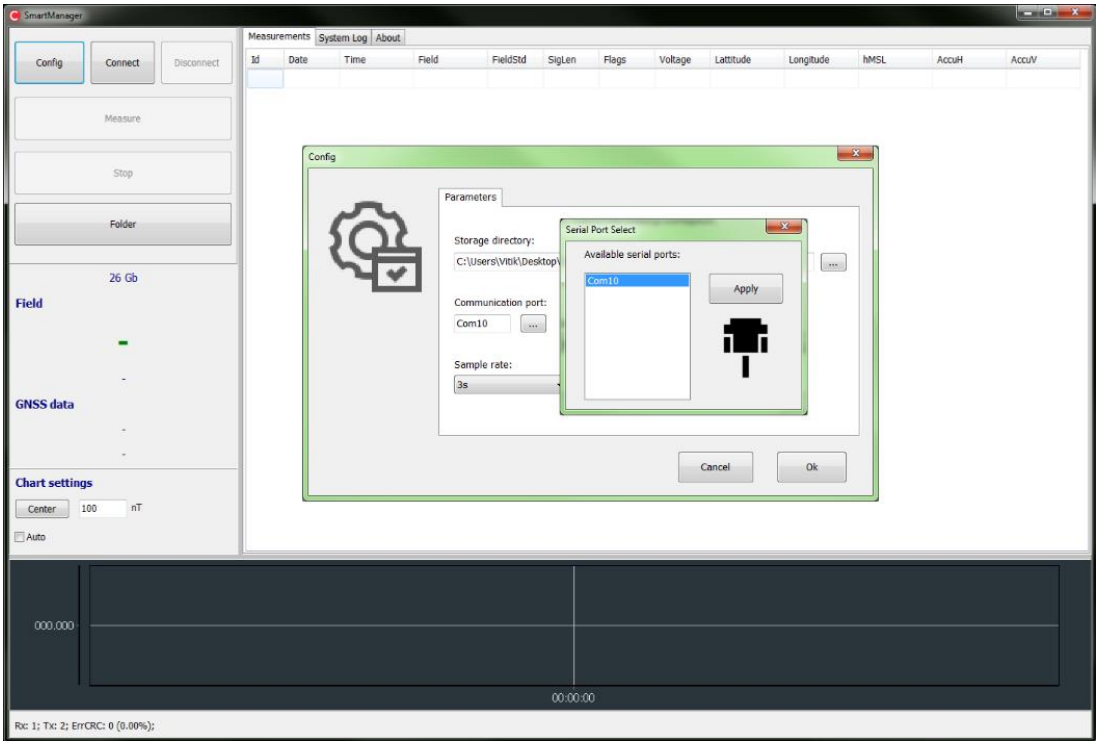


Figure 125 Connection port selection

3.7.2.7 Magnetometer connection

Turn on SmartMag by pressing Esc button. To connect the magnetometer, click the "Connect" button in the main program window (Figure 123). "Config" and "Connect" buttons will become inactive, "Disconnect" and "Measure" buttons will become active.

3.7.2.8 Starting the measurement.

To switch to the window with measurement data, open the “Measurements” tab in the main program window (Figure 126).

To start measurements, press the “Measure” button, this button becomes inactive afterwards. The magnetometer will automatically start measurements with a given cycle. The window with the measurement results will be updated (Figure 126) indicating the field value in nT, RMS error for one measurement (S1), RMS error (Sn) for a given number of n-measurements, GNSS data (date, time, latitude, longitude), and a table with data will form on the “Measurements” tab.

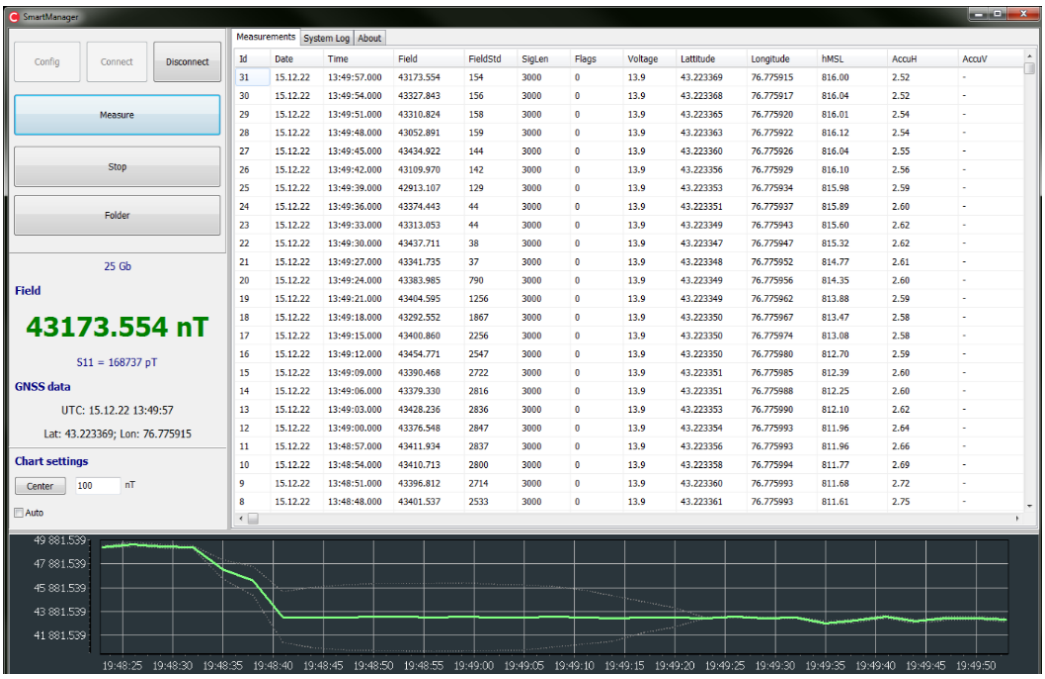


Figure 126 Starting the measurements and data window

Also, the values of the measured field are presented as a graph in the lower part of the window. X coordinates are for measured field in nT, and Y axis shows the measurement time.

In the left part of the main program window (Figure 123) Chart settings can be defined. "Center" button arranges the vertical scale of the chart relative to the average value of the field, and the range relative to the average value depends on the value specified in the editable field of the "Chart settings" menu.

To continuously change the chart scale, hold the left mouse button on the chart and adjust the required size of the zoom window by moving the mouse to the right. To set the initial scale of the graph, hold down the left mouse button and move it to the left. Automatic scaling is enabled by checking the "Auto" field.

The measurement results are saved in the selected directory (see section 3.7.2.6 To select the connection port and data storage directory, click the "Config" button in the main program window (Figure 123). This will open a window (Figure 124) with an option to specify data storage directory, should be entered manually, as well as an option to select the magnetometer connection port. Information about remaining free memory in the selected directory (Disk Free Space) will appear on the left side of the main window. To select a port, click on the "…" button, after which a window, where you can select required port, will open (Figure 125). To confirm your selection, click the "Apply" button.

) as a text file containing several columns separated by tabs. The data is represented by seven columns: Time_System – time on the PC; Time_Mag – time of the magnetometer, Field is the value of the measured field in nT; S11 is the RMS error for eleven measurements; Flag - time sync (0 - time synchronization according to the internal RTC, 1 - time synchronization according to GNSS data); Lat - latitude; Lon - longitude; U - battery voltage.

3.7.2.9 Finishing measurements

To end the measurements, press the “Stop” button in the measurement mode (Figure 126), the button then becomes inactive, the magnetometer completes the measurements and the window with the results is updated.

3.7.2.10 System Log

To go to the protocol log window, open the “System Log” tab (Figure 127) in the main program window (Figure 123).

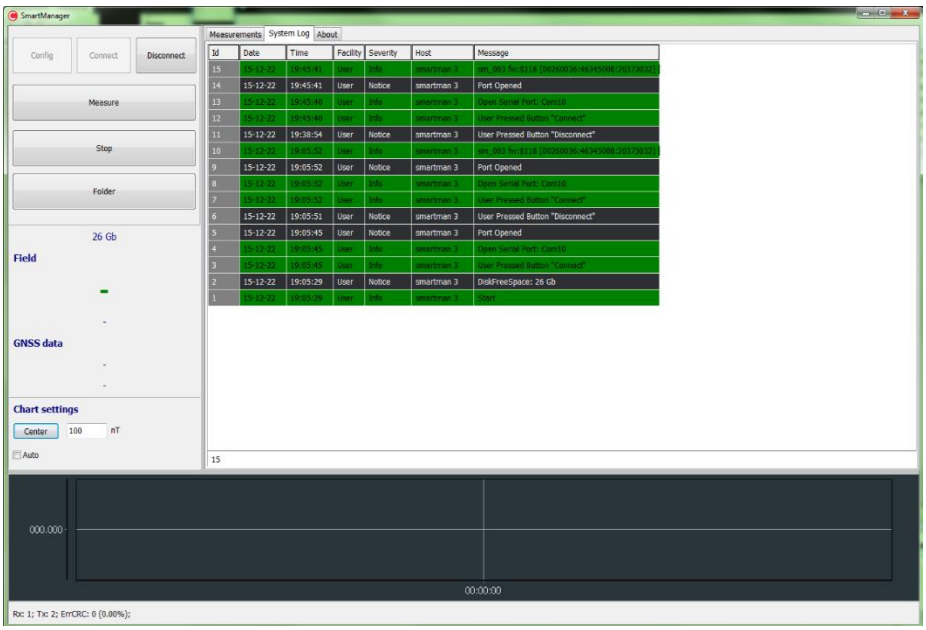


Figure 127 System Log

3.7.2.11 About

To visualize the identification data of the OVHmag and SmartMag magnetometer select the “About” tab.

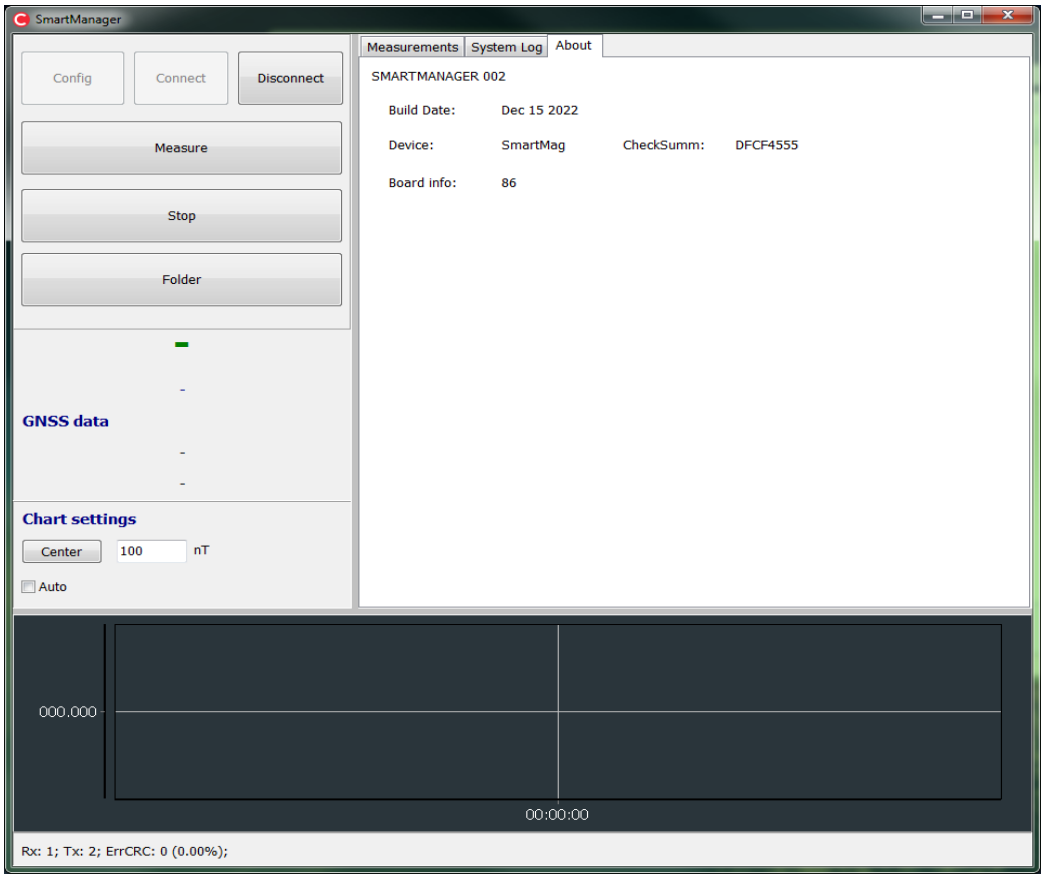


Figure 128 SmartMag info window

4 SOFTWARE UPDATE

Before updating the magnetometer software, save all files with the measurements from the MaxiMag console to your computer.

4.1. MaxiMag magnetometer software update

4.1.1 Unpack the archive with the firmware on your computer. Read the entire section before making any changes to the device!

4.1.2 Before connecting to a PC, make sure that the main menu is displayed on the screen of MaxiMag console. Then connect USB cable to the corresponding connector on the console. After the computer detects MaxiMag console, a window with the folder and data files stored (Figure 129) will appear on the computer screen, and the message “USB Mass storage …” will be displayed on magnetometer console.

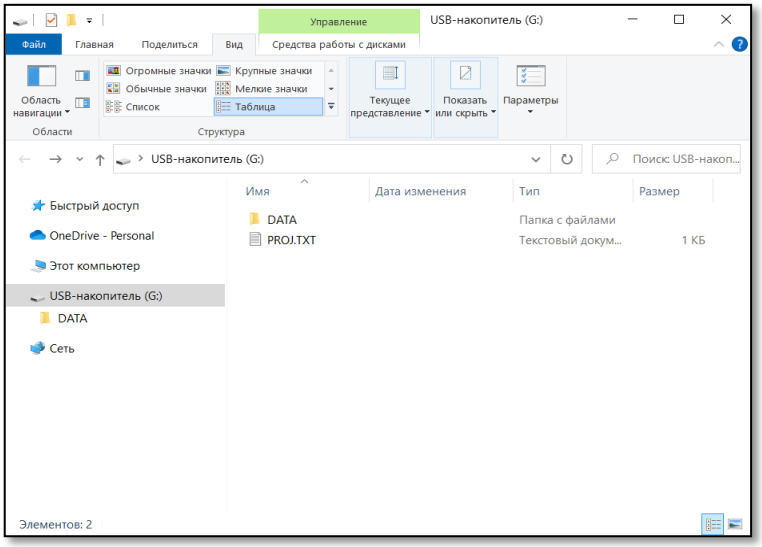


Figure 129 MaxiMag console root folder

4.1.3. Copy *upgrade.bin* file to the root folder (Figure 130). **NEVER** upload SmartMag upgrade file to MaxiMag console. This will result in fatal error. If the name of the firmware file is different from upgrade.bin, for example, "Maximag.bin", you should change the name of this file to upgrade.bin first, before copying it to root file. That can be done for security purposes.

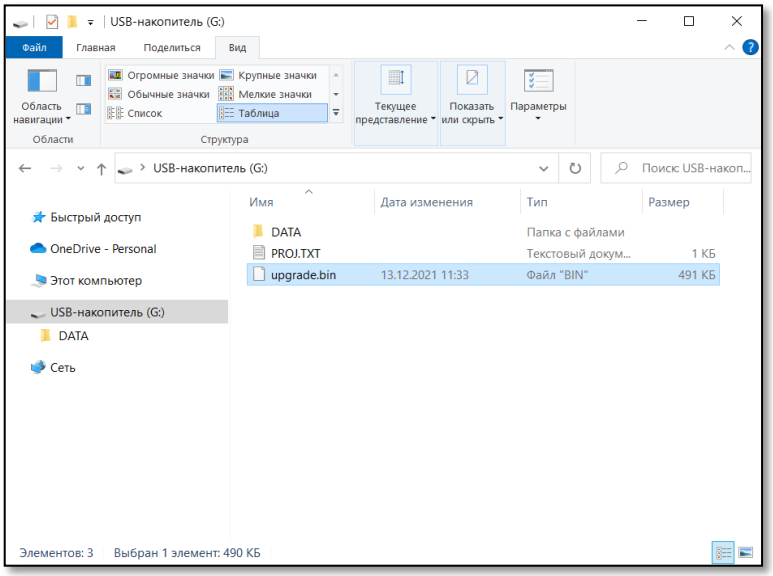


Figure 130 Root folder with firmware file

It is PROHIBITED
to unplug the battery while upgrading MaxiMag console!

4.1.4 After copying the firmware file to memory, safely disconnect the MaxiMag from the PC. To do this, in the lower right corner of the PC desktop, click the "Safely Remove Hardware" icon (Figure 131). Then click on the "Extract “MaxiMag Mass Storage”".

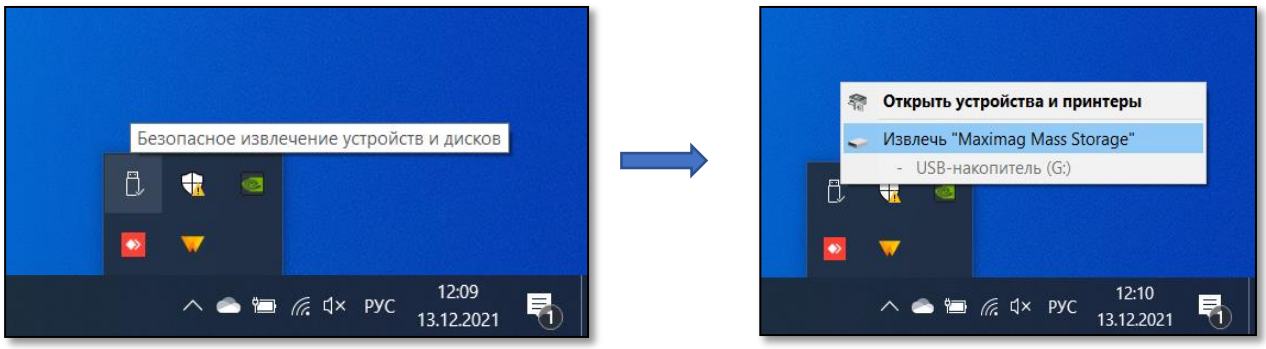


Figure 131 Safely Remove MaxiMag Hardware

4.1.5 Disconnect the USB cable from the PC. After disconnecting the cable, the software update process will start. During the update process, the MaxiMag will beep (up to 10 seconds). Wait for the software update to finish.

4.1.6 After successful software update, the MaxiMag console will turn on automatically and the display will show the console main menu. The version of the console software can be found by clicking "Setup" → "About", Version: X.XX.

4.1.7 After successful update of console software, magnetometer software needs to be updated too. Connect magnetometer to console using the sensor-to-console cable. Go to menu "Setup" → "About". To start updating the magnetometer software, press the Ent → End Line key, after 5 seconds, the values in “Activity” will start to increase. Wait until the values stop changing, this indicates the end of the magnetometer software update. The update can last up to 4 minutes. To exit the software update mode, press Esc.

4.1.8 The owners of magnetometer-gradiometers need to upgrade all magnetometers. For this:

• turn off the console;

• reconnect the sensor-to-console cable to the second magnetometer;

• turn on the console;
• go to the “About” menu and make sure that the serial number indicated on the body matches the number in the OVHmag line;
• update software according to 4.1.7.

4.1.9 If error occurs during the software update (an error message during the update process), contact the manufacturer immediately.

4.1.10 If after updating the software, the MaxiMag console does not work or does not work correctly, contact the manufacturer immediately.

4.2. SmartMag magnetometer software update

Before updating the magnetometer software, save all files with the measurements from the SmartMag electronics unit to your computer.

4.2.1 Unpack the archive with the firmware on your computer. Read the entire section before making any changes to the device!

4.2.2 Connect the SmartMag unit to PC according to paragraph 3.7.1. of this Manual. After the computer detects SmartMag magnetometer, a window with the folder and data files stored (Figure 132) will appear on the computer screen, and the message “USB Mass storage …” will be displayed on magnetometer.

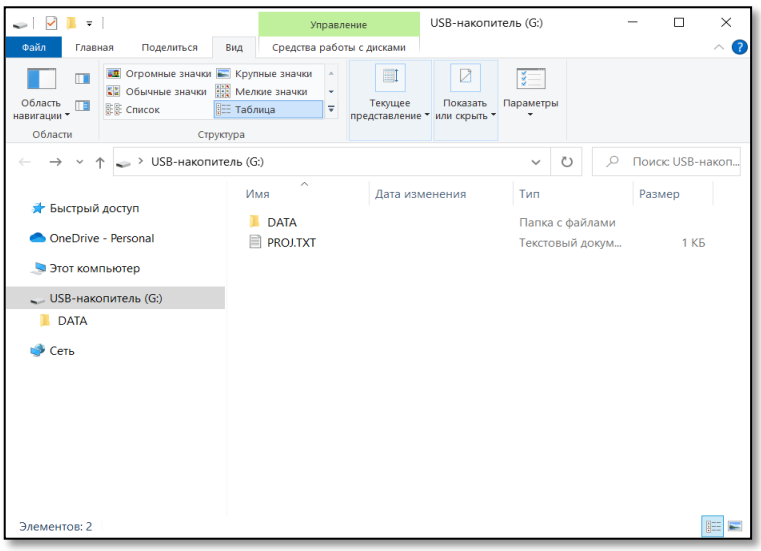


Figure 132 SmartMag root folder

4.2.3. Copy *upgrade.bin* file to the root folder (Figure 133). **NEVER** upload MaxiMag upgrade file to SmartMag unit. This will result in fatal error.

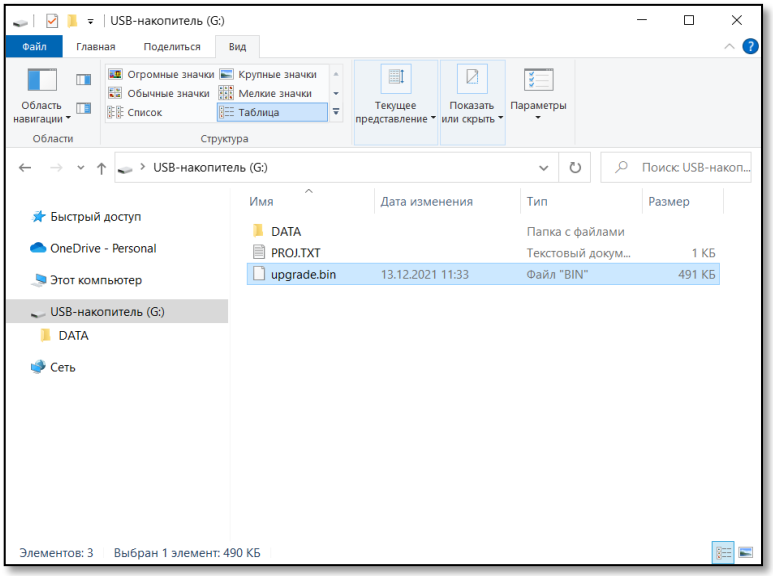


Figure 133 Root folder with firmware file

It is PROHIBITED
to unplug the battery while upgrading SmartMag magnetometer!

4.2.4 After copying the firmware file to memory, safely disconnect the SmartMag from the PC. To do this, in the lower right corner of the PC desktop, click the "Safely Remove Hardware" icon (Figure 134). Then click on the "Extract “Mag Mass Storage”".

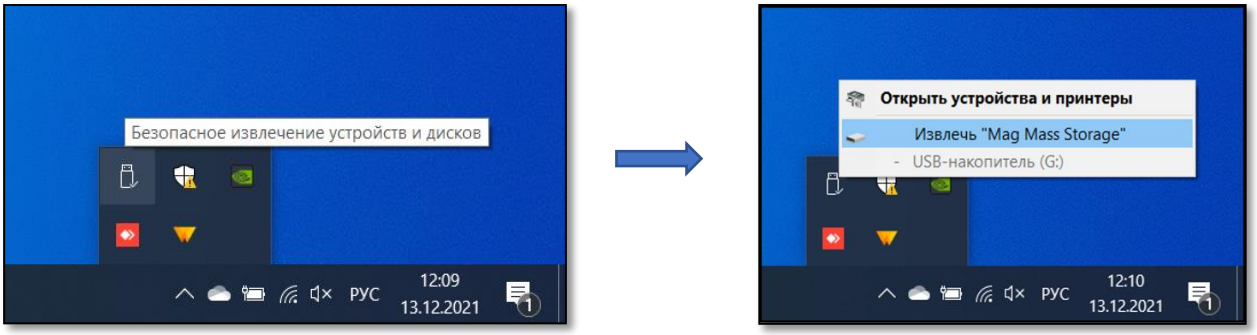


Figure 134 Safely Remove SmartMag Hardware

4.2.5 Disconnect the USB cable from the PC. After disconnecting the cable, the software update process will start. The magnetometer software update is accompanied by a color LED indication on the front panel of the magnetometer. LED glows red for 10-30 seconds.

4.2.6 After successful software update, SmartMag magnetometer will turn off automatically.

4.2.7 Turn on SmartMag magnetometer by pressing Esc. The version of software can be found in "About" menu, line FW: X.X.

4.2.8. If error occurs during the software update (an error message during the update process), contact the manufacturer immediately.

4.2.9. If after updating the software, the MaxiMag console does not work or does not work correctly, contact the manufacturer immediately.

5 ACCESSORIES

Batteries and power supply

Battery provides power to magnetometer. The standard lithium-ion battery has a 14.8 V voltage and a 4 Ah capacity. The backpack harness can also hold a 12-volt lead acid Delta CT 12025 battery or equivalent. During long-term operation as a base station, more capacious batteries with 10 ÷ 16.8 V voltages can be used. For operation in observatory conditions, an optional AC/DC 100-240 V power supply unit with frequency of 50/60 Hz can also be used. The indicated batteries are allowed for transportation by any type of vehicles, incl. avia, which is confirmed by MSDS certificates (see ANNEX pp. 12.5 and 12.6).

Charger

Serves to charge the battery from 100-240 V, 50/60 Hz AC/DC. The devices are manufactured by third party companies and come with their own detailed manuals. A brief description of the Li-ion battery charger is presented in Appendix 12.4.

Figure 135 Li-ion battery with charger on the left and Delta CT 12025 with charger on the right

Sensor cable

Serves for data and power transfer between the console and the OVHmag electronics unit or the SmartMag digital magnetometer.

GPS cable (optional)

Serves to transfer data from your Garmin GPSMAP 78 (or similar) to the console.

Garmin GPS (optional)

When ordering this option, Garmin GPSMAP 78 is supplied as default, however, it is possible to install any other navigation system with GNSS receiver that provides data transmission via NMEA 0183 protocol.

GPS is used to receive GNSS signal in order to determine the current location of the device and the exact time.

External GPS Bracket (Optional)

Attaches Garmin GPSMAP 78 (or similar) to MaxiMag console.

Non-magnetic rod

The rod provides connection between the Overhauser sensor on the cable and the OVHmag electronics unit.

Sensor clamp

Serves for fixing the Overhauser sensor on the cable to the rod.

Gradiometer bracket

Designed to fix and provide rigidity of the connection between two digital OVHmag magnetometers.

Gradiometer rod

Is intended for the lower sensor protection and support of the two-sensor gradiometer assembly when measuring the vertical gradient of the Earth's magnetic field.

USB cable

Is used to connect the MaxiMag console, SmartMag magnetometer and the optional logger built into OVHmag to a PC.

Sensor cable (for gradiometer)

Serves for interconnection of several OVHmag digital Overhauser magnetometers to ensure their power supply and data transmission. The pinout of the cable connectors is similar to that of the sensor cable.

Battery extension cable

The length of the Li-ion battery cable and the lead-acid power cable is of minimum required for the connection to the OVHmag in backpack harness. The console is powered via the sensor cable. When using the gradiometer, sensors are held in hand and the entire system is connected to the extension cable, connecting the console and the battery cable from battery placed in the harness.

Backpack harness

Provides the convenience of carrying a set of magnetometer-gradiometer during magnetic prospecting operations.

Backpack

Serves for storing things and accessories, has an internal pocket for placing a battery Delta DT 1207 formfactor.

GNSS antenna bracket

Used to attach an external GNSS antenna to the tripod of the SmartMag magnetometer.

6 ACTIONS IN EXTREME CONDITIONS

Geophysical surveys should be suspended when weather conditions degrade: visibility drops below 20 m, wind increases to stormy (over 20 m/s), severe icing, in extreme and emergency situations.

In case of emergency on site that threatens life and health of people, it is necessary to immediately evacuate to a safe place.

If smoke appears, cable sparks, unpleasant odor or signs of fire appear, immediately stop working and turn off the power of the device.

7 POSSIBLE MALFUNCTIONS AND TROUBLESHOOTING RECOMMENDATIONS.

Table 3. Possible malfunctions and troubleshooting recommendations

Appearance of the malfunction	Possible causes of the malfunction	Troubleshooting methods of the malfunction
The console display does not turn on after the power is turned on.	No power supply: 1) The battery is not connected; 2) The power cable is damaged; 3) The battery is discharged.	1), 2) Check the power supply circuit; 3) Charge the battery. If the malfunction does not disappear, contact the manufacturer
Scatter of magnetometer readings.	1) The magnetic induction converter axis is deviated significantly from the optimal position; 2) High level of electromagnetic interference or the primary transducer is close to a strongly magnetized object; 3) The battery is low.	1) Orient the primary transducer axis to the optimal position (see p. 2.3); 2) Change the magnetic induction converter position, remove the magnetized object; 3) Recharge the battery. If the malfunction does not disappear, contact the manufacturer
No response to key presses.	Low power, keyboard malfunction, processor freezes.	Check the voltage (U), and if it's between 11 and 16.8 V, turn off and on the magnetometer. Use a redundant keypad. If the malfunction does not disappear, contact the manufacturer
An error occurs when unloading data.	Data stored in the memory is corrupted due to SD card failure.	Replace the SD card, format it via the device menu. If the malfunction does not disappear, contact the manufacturer
No coordinates for 30 minutes	Satellite reception conditions are not optimal. GNSS module malfunction	Try to improve reception conditions by placing the console in an open area away from tall buildings, trees, and cliffs.

Appearance of the malfunction	Possible causes of the malfunction	Troubleshooting methods of the malfunction
		If the malfunction does not disappear, contact the manufacturer
A flashing message («ATTENTION! No PPS signal») appears in measurement mode	1) The console has not yet found enough satellites to synchronize the internal clock with. 2) Loss of reliable signal due to obstacles interfering with GNSS signal reception from satellites.	1) Wait for confident reception of the GNSS signal from the satellites. This may take up to 5 minutes. 2) Make sure that you are in a place with a clear sky. As a last resort, reset the magnetometer (turn it off and on again). If the malfunction does not disappear, contact the manufacturer
If you try to enter any of the measurement modes, a message («ATTENTION! No sensor(s) found! Check wire connection and try again») appears on the display	1) No sensor connected to the electronics unit 2) Sensor connector is not securely connected to the electronics unit connector 3) Sensor connector or sensor is defective	1) Connect the sensor to the electronics unit. If the problem is not solved, contact the manufacturer 2) Secure the sensor connector on the electronics unit by turning the sensor connector ring until you hear it click into place. 3) Contact the manufacturer
If you try to create the project a message («Already Exists! Press ESC») appears on the display	A project with that name already exists.	Set another name for the project.

8 REPAIR

In the event of failure of device operation during warranty and post-warranty, the user should contact GEODEVICE representative.

Warranty and post-warranty repairs of magnetometer are only carried out in manufacturer's facility or specialized geophysical service facility by specialists trained and certified by GEODEVICE.

IT IS PROHIBITED TO MAKE REPAIRS BY UNAUTHORISED PERSONELL.

IT IS PROHIBITED TO OPEN / DISASSEMBLE THE MAGNETOMETER, AS WELL AS TO MAKE CHANGES IN DESIGN OF THE DEVICE, TO IMPROVE IT WITHOUT AGREEMENT WITH THE MANUFACTURER.

Otherwise, the manufacturer does not guarantee the operational reliability and safety of the device, and the manufacturer's warranty obligations are terminated.

9 STORAGE

The device should be stored in the manufacturer's packaging in a warehouse environment that excludes direct exposure to atmospheric precipitation (rain, snow, fog, etc.) at temperature from + 5 to + 35 ° C and humidity from 5 to 95%.

DO NOT STORE THE MAGNETOMETER TOGETHER WITH EVAPORATING LIQUIDS, ACIDS AND OTHER SUBSTANCES THAT COULD CAUSE METAL CORROSION AND DAMAGE INSULATION.

10 TRANSPORTATION

The magnetometer can be transported by any mode of transport at ambient temperature from -40 to 60 °C and relative humidity from 5 to 95%.

Transportation must be performed in the original manufacturer's packaging in closed transport in accordance with transportation rules, operating for this kind of transport.

Care must be taken during transportation. Avoid shocks and falls from heights.

After transportation, check the device for transport damage (damages caused in the transport of the device).

DO NOT OPERATE THE DEVICE IF TRANSPORT DAMAGE IS DETECTED.

If transport damage is detected, immediately inform the representative of the manufacturer in order to clarify the possibility of further operation of the device.

11 INFORMATION ABOUT DEVICE DISPOSAL

The buyer (user) is responsible for disposal of the device after loss of its consumer properties.

DO NOT DISPOSE MAGNETOMETER WITH HOUSEHOLD WASTE.

If possible, divide the device into parts depending on the materials (plastic, rubber parts, etc.) and recycle.

Materials to be disposed in special facilities should be hand over for disposal in accordance with legislation in force at the time of disposal.

12 APPENDIX

12.1 Brief recommendations for the magnetic survey methodology

12.1.1 Installation of a base magnetic station

Base magnetic station, as a rule, is a field magnetometer installed stationary. It is set for automatic recording of the Earth magnetic field (EMF) values at a fixed time interval determined by the Methodology of works in accordance with the requirements of the Technical Assignment. The task of base magnetic station is to record variations of EMF, which are then taken into account when processing field magnetic survey data.

The choice of base magnetic station location is a very responsible task, which should be given due attention. First of all, base magnetic station should be located in the area with low field gradient (not more than 10 nT/m) away from large magnetic masses (both mobile and stationary) and sources of electromagnetic interference. Thus, the choice of base magnetic station location is carried out after preliminary survey, carried out with field magnetometers on several profiles or on a uniform network with a step of not more than 5 m. The preliminary survey area must have dimensions not less than 25*25 m. It is recommended to place base magnetic station at the distance of not less than 30-50 m from roads and trails. Base magnetic station may be placed in close proximity to the surveying site, with the maximum distance for small-scale surveying not exceeding 10-15 km.

When installing base magnetic station, the magnetometer sensor should be oriented in a way to provide the most effective registration of EMF. The sensor axis should be oriented at 90°±5° to the direction of the Earth magnetic field vector. The magnetometer sensor itself should be fixed in the way to exclude any movement during operation (wind and vibration interference). Depending on weather conditions and base magnetic station type, its installation place may be equipped with protection from exposure to precipitation, direct sunlight and wind (screens, awnings, etc.). It is recommended to start recording geomagnetic variations 1.5-2 hours before the beginning of field measurements. Capacity of batteries, by means of which base magnetic station is powered, should be sufficient to provide power supply to the station during the whole recording time, and the batteries should not work in critical modes. It is recommended to install the magnetometer control panel (and batteries) as far away from the station as possible.

During recording of geomagnetic variations it is prohibited to perform any actions with base magnetic station, as well as to approach and drive close to it. If it is necessary to carry out any manipulations with the station and/or close to it, it is necessary to record them in the logbook of recording magnetic variations or in the field logbook, indicating the exact time of these actions.

As a rule, surveying and, accordingly, recording of variations is not carried out during magnetic storms. However, if for some reason you need to make a survey at this time, it is necessary to reduce the interval between measurements to a minimum and make sure that the time of base magnetic station and field magnetometers is accurately synchronized.

When processing field survey results, the results of recording of geomagnetic variations and their registration are carried out according to standard methods.

12.1.2 Survey with field magnetometer

At the beginning of each survey day, immediately before the start of measurements and immediately after their completion at the end of the day, measurements must be taken at the reference point/profile, in accordance with the established survey methodology. The procedure for selecting a reference point/profile location is similar to the one used to determine base magnetic station location. Measurements at the control point during morning and evening control should be carried out uniformly for each instrument - by one operator, with the sensor positioned at the same height and its orientation along the same azimuth.

The operator of the magnetometer is prohibited to carry any objects containing magnetic materials (knives, tools, coins, keys, lighters, etc.), as well as any electronic devices (radios, telephones, navigators, headphones, etc.). In addition, the operator should not be a person who has medical implants made of magnetic materials, pacemakers, as well as earrings, piercings, etc. The magnetometer operator's clothing should also consist of non-magnetic materials: buttons, zippers, eyelets, clasps, carabiners, metal strings from headgear, and more may affect the magnetometer readings. Before survey starts, it is necessary to pay special attention to the choice of working clothes and shoes.

The composition of the team is determined by the relevant regulatory documents and current safety requirements. As a rule, it consists of an operator and his assistant, in exceptional cases only of an operator.

When conducting a survey, it is important to comply with the requirements of the relevant regulatory documents, operating manuals and methods of work defined in the (Geological) Terms of reference. During the survey, the field magnetometer set must be securely fixed on the operator in order to protect the device units from damage and ensure the protection of the connecting wires and connectors from jerks and strains. This is ensured with the help of special backpack harnesses included in the delivery set of the device, and in their absence with the help of improvised means. The magnetometer fixing system should not interfere with or significantly restrict the freedom of movement of the operator in order to ensure the safety of his movement around the work site. The sensor of the magnetometer is placed on a special rod which is fixed to the backpack harness or a route backpack. When installing the sensor, it is necessary to ensure that the height of its position above the level of the Earth's surface at the measurement point is constant.

12.2 Maps of magnetic inclination and total intensity of the Earth's magnetic field

12.2.1 Magnetic inclination

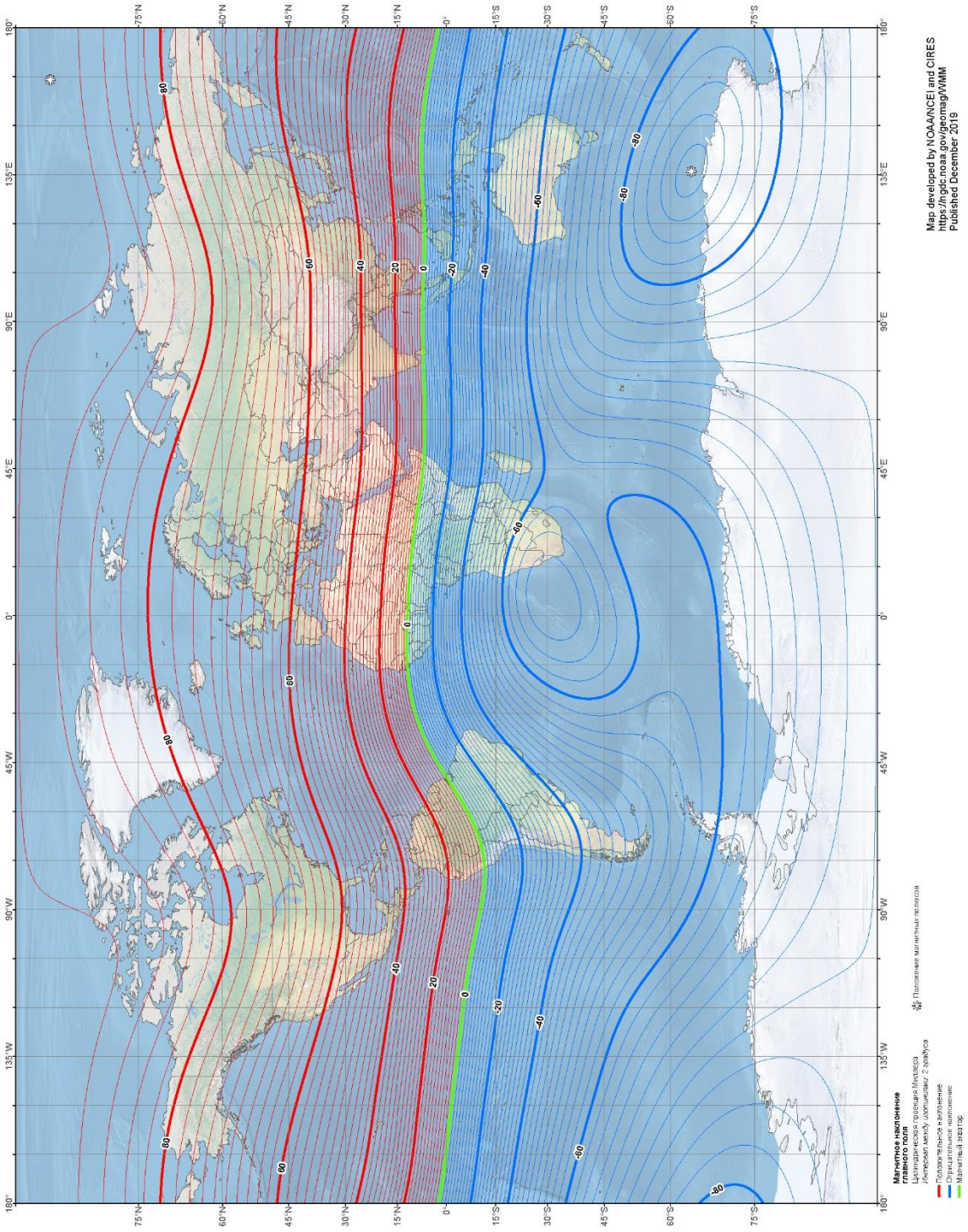


Figure 136 Map of magnetic inclination. NOAA's National Centers for Environmental Information

12.2.2 Total intensity of the Earth's magnetic field

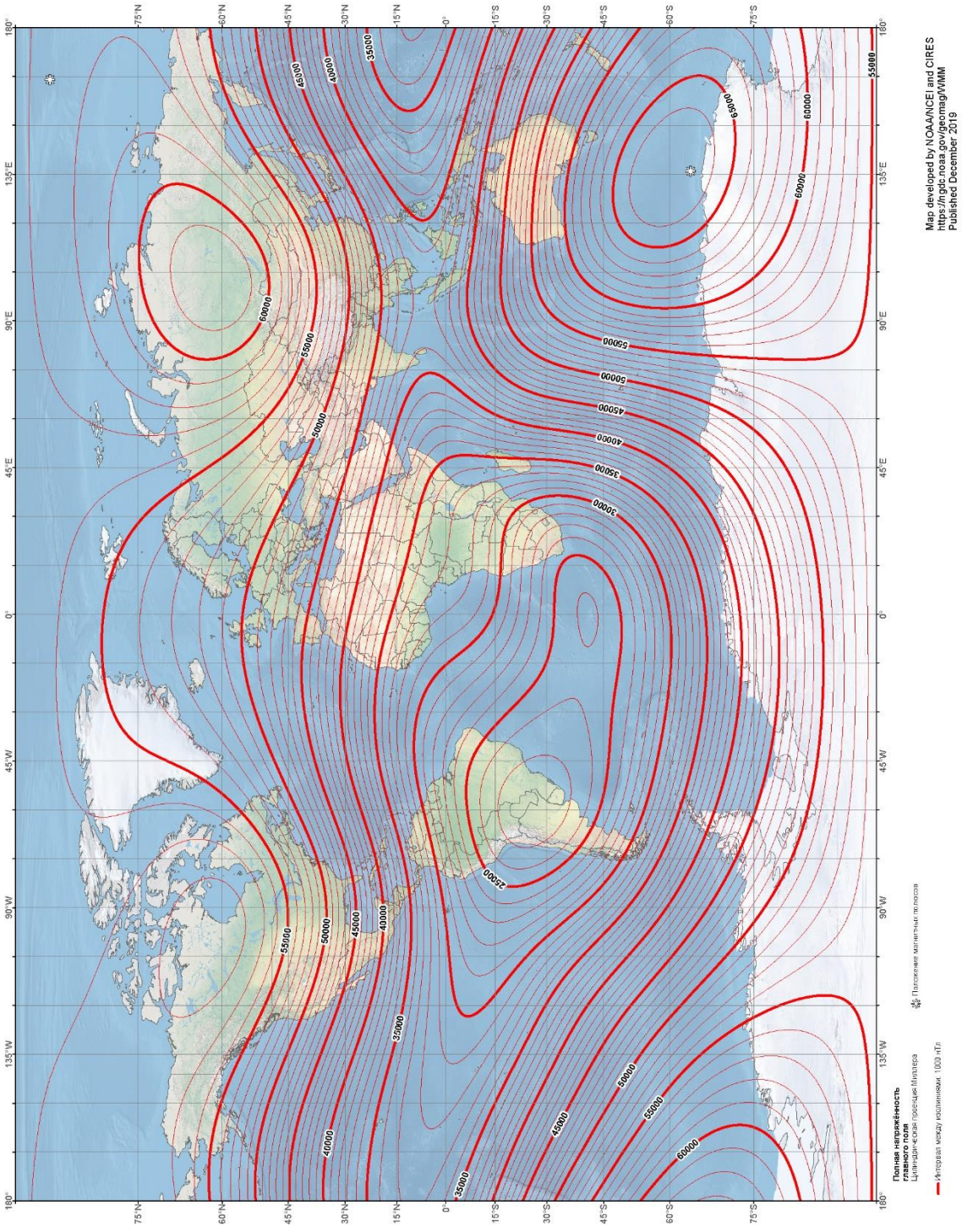


Figure 137 Map of total intensity of the Earth's magnetic field. NOAA's National Centers for Environmental Information

12.3 Rechargeable battery manual

12.3.1 Rechargeable battery type

This MaxiMag magnetometer-gradiometer includes a Li-ion rechargeable battery with a voltage of 14.8 V and a capacity of 4 Ah.

Figure 138 Rechargeable battery with power cable

Table 4. Specifications, parameters, and dimensions of the rechargeable battery

Name	Value
Rated battery voltage	14.8 V
Available capacity	4 Ah
Charge mode	• with a current of no more than 4 A up to final voltage of 14.8 V in the temperature range 0 ÷ +60 ° C • with a current of no more than 0,8 A in the temperature range -20 ÷ 0 °C and +60 ÷ +85 °C • with a current of no more than 0,2 A A in the temperature range -30 ÷ -20 °C
Discharge mode	with a current of no more than 5 A up to final voltage of 10 V
Dimensions (L x W x H)	113 × 87 × 42 mm
Weight	650 g
Operating temperature range	–30 ÷ +85 °C — charge –40 ÷ +85 °C — discharge
Storage conditions	in dry, heated rooms, temperature of no more than 30 °C at 30 ± 15% state of charge of the battery (14.8 V with no load)

12.3.2 Battery charge

It is recommended to charge the battery at a temperature of 0 ÷ +60 °C using an automatic charger included in the magnetometer set (see p. 12.4)

After the charger is disconnected, a fully charged battery should have a voltage of about 14.8 V (no load).

12.3.3 Precautions

The battery must be used in compliance with all precautions provided for the work with lithium-ion batteries.

1. Protect the battery from shock and do not drop it.
2. Protect the battery against short circuits.
3. Do not use the battery with obviously non-working chargers.
4. Do not charge the battery using a charger which is not designed for this battery.
5. Do not open the battery, it may break it!
6. If the battery leaks and the electrolyte gets on the skin or in the eyes, immediately rinse the eyes and skin with clean water.
7. If you sense unpleasant smell coming from the battery, or if its color has changed, or if some special defects have appeared, unplug the charger from the mains, disconnect it from the battery, and stop using it.
8. Keep the battery away from direct sunlight, water, and various liquids.
9. Do not allow the battery contacts to come into contact with metal objects during storage.
10. Store the battery in a dry place at room temperature and out of the reach of children.
11. Do not store a fully charged or fully discharged battery for a long time. To avoid losing the battery capacity, store it with a 40% charge. When storing the battery for a long period of time, control its level of charge every six months, and if the battery is less than 30% charged, charge it up to 50%.

12.4 Li-ion battery charger manual

12.4.1 Charger type

This MaxiMag magnetometer-gradiometer includes a charger for Li-ion battery from 100-240 V, 50/60 Hz AC/DC.

Figure 139 Charger

Table 5. Specifications, parameters, and dimensions of the charger

Name	Value
Configuration	3-stage charge control
Input voltage	90 ÷ 264 AC/DC
Power supply frequency	47 ÷ 63 Hz
Pulse converter frequency	40 kHz
Maximum current	2.7 A
Output voltage unevenness	less than 100mV p-p
Dimensions (L × W × H))	107 × 67 × 36.5 mm
Weight	250 g
Operating temperature range	–20 ÷ +40 °C
Storage temperature range	–25 ÷ +85 °C
protection	Reverse polarity and short circuit

12.4.2 Battery charge and its diagram

Connect the battery to the charger, then plug it to AC power supply.

The Li-ion battery charge cycle consists of three stages (Figure 140Figure 140):

Stage 1 – Constant-current charge

The charger is in constant current mode and charges at the maximum current value indicated on the charger's body while the LED on the charger is orange. This stage allows you to quickly charge the battery until the battery voltage increases to a predetermined level.

Stage 2 – Constant-voltage charge

When the battery voltage has increased to a predetermined level, the charger switches to constant voltage mode, charging it with a decreasing charge current until the current falls below a predetermined level indicated on the charger's body. The LED on the charger is still orange. When the battery is charged to 90-95% of its full capacity, the charge current falls below the predetermined level, and the LED on the charger turns yellow, indicating that the battery is almost fully charged. Constant-voltage charging continues, and the battery is fully charged by the end of this stage.

Stage 3 – Charging is complete

When the LED on the charger turns green, this means that the battery is fully charged.

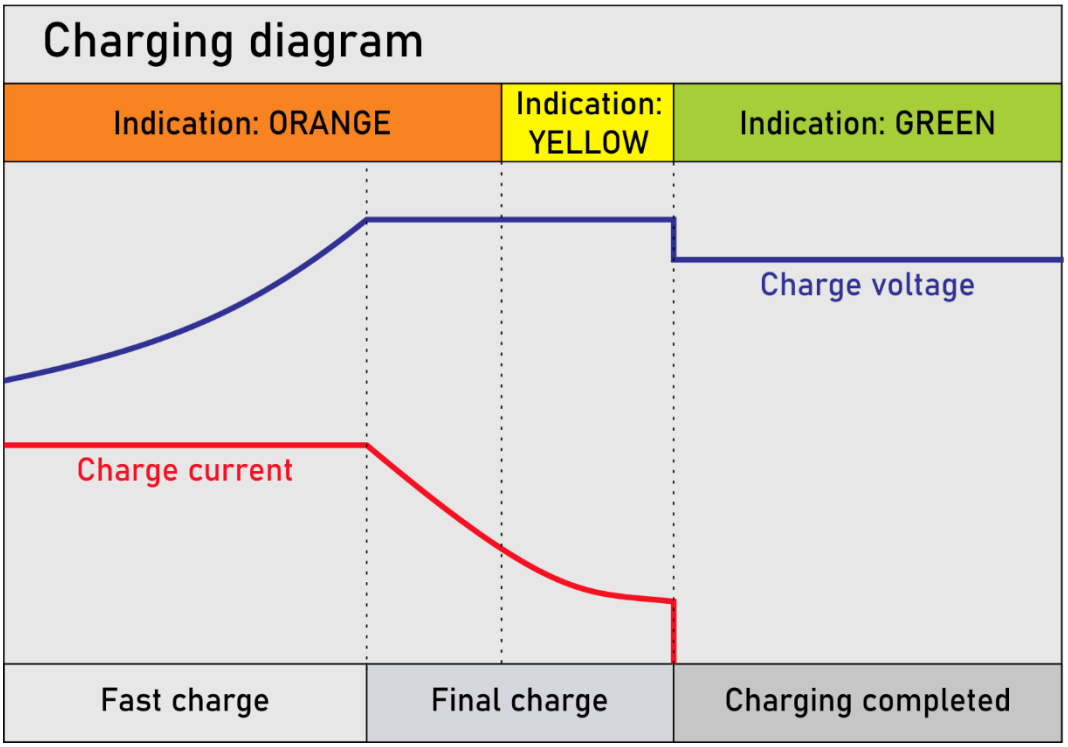


Figure 140 Charge diagram

12.4.3 Precautions

1. Use the charger indoors only and do not leave it in humid place or under the rain.

2. Unplug the charger when not in use.

3. Do not plug in the charger if damaged.

4. Do not disassemble the charger.

5. Make sure the batteries are charged at temperature range 0 ° - 60 ° C.

6. Batteries and chargers may become hot while charging. However, in case of excessive heating (when the surface is too hot to be touched with hands), as well as if there are signs of melting of the battery or the case of the charger, an unpleasant smell, or any signs of smoke, immediately disconnect the charger from AC/DC.

7. Do not place the charger on fluffy or soft surfaces.

8. Use and store the charger out of children reach. Improper handling can cause electric shock and fire.

9. Do not leave the charger or its adapter plugged in for a long time unattended, even after the end of charging.

12.5 Li-ion Battery Material Safety Data Sheet (MSDS)

Material/Product Safety Data Sheet
(MSDS-PSDS)

MP / VL products **Revision 8** **Date 02/2009**	**Lithium-Ion single cells and multi-cell battery pack**

1. Identification of the Substance or Preparation and Company		
Product	**Rechargeable lithium-ion single cells and multi-cell battery packs**	
Production sites	Saft America Inc. 313 Crescent Street Valdese North Carolina 28690 USA Tel. No. +1 (828) 874 4111 Fax No. +1 (828) 874 2431	Saft Rue Georges Leclanché BP 1039 86060 Poitiers cedex 9 FRANCE +33 (0)5 49 55 48 48 +33 (0)5 49 55 48 50
www.saftbatteries.com (section "Contact")		
Emergency contacts	+1 (703) 527 3887 (CHEMTREC U.S. Service Center) within the USA : 800 424 9300	

2. Composition and Information on Ingredients

Each cell consists of a hermetically sealed metallic container containing a number of chemicals and materials of construction of which the following could potentially be hazardous upon release.

There is no potential for exposure to these ingredients unless the cell leaks, or opens, following high temperature, mechanical or electrical abuse.

Ingredient	**Content*** (wt. %)	**CAS #**	**ACGIH (TLV)**	**OSHA (PEL)**
Lithium metal	0 *(in spite of their name, these batteries do not contain lithium metal)*			
$LiCoO_2$ *(Lithium cobalt oxide)*	19-35 %	12190-79-3	0.02 mg/m^3 8 hours as dust and fumes	5 mg/m^3 as dust and fumes
Organic solvents	12-15 % EA (*Ethyl Acetate*) EC (*Ethylene Carbonate*) DMC (*Di Methyl Carbonate*)	141-78-6 96-49-1 616-38-6	None established	None established
$LiPF_6$ *(Lithium Hexafluoro phosphate)*	≈ 3 %	21324-40-3	None established	None established

MSDS Li-ion
Rev. 8 February 2009

PVDF	< 1 %	24937-79-9	None established	None established
Copper *(Cu)*	9-18 %	7440-50-8	0.2 mg/m^3 as fume 1.0 mg/m^3 as dust and mist	0.1 mg/m^3 as fume 1.0 mg/m^3 as dust and mist
Aluminium *(Al)*	17-27 %	7429-50-5	10.0 mg/m^3, as dust	2.0 mg/m^3, as soluble salt
Graphite and Carbon	13-18%	7782-42-5 1333-86-4	3.5 mg/m^3, TWA for carbon	2.0 mg/m^3, as dust
Steel, Nickel, and inert components	Balance		Balance	

* Quantities may vary a little with cell model
ACGIH : American Council of Governmental Industrial Hygienists
TLV : Threshold Limit Value is personal exposure limit, determined y ACGIH.

3. Hazards Identification

The rechargeable lithium-ion batteries described in this Product Safety Data Sheet are sealed units which are not hazardous when used according to the recommendations of the manufacturer and as long as their integrity is maintained.

Do not short circuit, puncture, incinerate, crush, immerse in water, force discharge or expose to temperatures above the declared operating temperature range of the product. Risk of fire or explosion.

Under normal conditions of use, the active materials and liquid electrolyte contained in the cells and batteries are not exposed to the outside, provided the battery integrity is maintained and seals remain intact. Risk of exposure only in case of abuse (mechanical, thermal, electrical) which leads to the activation of safety valves and/or the rupture of the battery container. Electrolyte leakage, electrode materials reaction with moisture/water or battery vent/explosion/fire may follow, depending upon the circumstances.

4. First Aid Measures (in case of leaking or accidentally opened cells)

In case of accumulator breakage or burst, please evacuate employees from the contaminated area and ensure maximal ventilation in order to break-up corrosive gas, smoke and unpleasant odors.

If it occurs, by accident, following measures must be taken:

Inhalation	Not anticipated under normal use. Remove from exposure. Remove to fresh air. Rest and keep warm. In severe cases obtain medical attention.
Skin contact	Not anticipated under normal use. Wash off skin thoroughly with water. Remove contaminated clothing and wash before reuse. In severe cases obtain medical attention.
Eye contact	Not anticipated under normal use. Irrigate thoroughly with water for at least 15 minutes. Obtain medical attention.
Ingestion	Not anticipated under normal use. Wash out mouth thoroughly with water and give plenty of water to drink. Obtain medical attention.
Further treatment	All cases of eye contamination, persistent skin irritation and casualties who have swallowed this substance or been affected by breathing its vapours should be seen by a doctor.

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5. Fire Fighting Measures
Dry chemical type or CO_2 extinguishers, Halon, or copious quantities of water or water-based foam can be used to cool down burning Li-ion cells and batteries. During water application, caution should be exercised as burning pieces of flammable particles may be ejected from the fire. In case of fire, it is recommended to wear self-contained breathing apparatus, to avoid contact with irritant fumes. Evacuate all persons from immediate area of fire. Do not re-enter the area until it has been adequately purged of the fire vapour and extinguishing agent.

6. Accidental Release Measures
In case of electrolyte leakage from a cell or battery, do not inhale the gas as possible. Remove personnel from area. If the skin has come into contact with the electrolyte, it should be washed thoroughly with water. Using protective glasses and gloves, sand or earth should be used to absorb any exuded material. Seal leaking battery (unless hot) and contaminated absorbent material in plastic bag and dispose of as Special Waste in accordance with local regulations.

7. Handling and Storage	
Handling	Do not crush, pierce, short (+) and (-) battery terminals with conductive (i.e. metal) goods, which would end up into excessive heating. Do not directly heat or solder. Do not throw into fire. Do not mix batteries of different types and brands. Do not mix new and used batteries. Keep batteries in non conductive (i.e. plastic) trays. Do not disassemble, mutilate or mechanically abuse cells and batteries.
Storage	Store in a cool (preferably below 30°C) and ventilated area, away from moisture, sources of heat, open flames, food and drink. Keep adequate clearance between walls and batteries. Temperature above 70°C may result in battery leakage and rupture. Since short circuit can cause burn, leakage and rupture hazard, keep batteries in original packaging until use and do not jumble them.
Other	Follow Manufacturers recommendations regarding maximum recommended currents and operating temperature range. Applying pressure on deforming the battery may lead to disassembly followed by eye, skin and throat irritation. Do not immerse in water. The Li-ion cells and batteries are not designed to be recharged from external power sources besides specific Li-ion charger models approved by Saft. Connecting to inappropriate power supplies can result in fire or explosion.

8. Exposure Controls & Personal Protection	
Occupational exposure standard	See section 2

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	**Respiratory protection**	In all fire situations, use self-contained breathing apparatus.
	**Hand protection**	In the event of leaking or ruptured cells, wear gloves.
	**Eye protection**	Safety glasses are recommended in case of leaking or ruptured cells
	**Other**	In the event of leakage or ruptured cells, wear chemical apron.

9. Physical and Chemical Properties	
Note: The following points are not applicable unless in case of leaking or damaged batteries with internal components sipping out.	
Appearance	Solid object with cylindrical or prismatic shape
Odour	Odourless (unless in case of damaged product with leaking electrolyte)
pH	Not applicable
Flash point	Not applicable
Flammability	Not applicable
Relative density	> 2 g/cm^3
Solubility (water)	Not applicable, unless inner components are exposed
Solubility (other)	Not applicable

10. Stability and Reactivity	
The product is stable under conditions described in Section 7.	
Conditions to avoid.	Heating above 70°C or incinerate. Deformation. Mutilation. Crushing. Piercing. Disassembly. Short circuiting. Exposition over a long period to humid conditions.
Materials to avoid	Strong mineral acids, alkali solutions, strong oxidising materials and conductive materials
Hazardous decomposition Products	HF, CO, CO_2

11. Toxicological Information	
Signs & symptoms	None, unless battery ruptures. In the event of exposure to internal contents, corrosive fumes will be very irritating to skin, eyes and mucous membranes. Overexposure can cause symptoms of non-fibrotic lung injury and membrane irritation.
Inhalation	Lung irritant.
Skin contact	Skin irritant
Eye contact	Eye irritant.
Ingestion	Tissue damage to throat and gastro-respiratory tract if swallowed.
Medical conditions generally aggravated by exposure	In the event of exposure to internal contents, eczema, skin allergies, lung injuries, asthma and other respiratory disorders may occur.

12. Ecological Information	
Mammalian effects	None known if used/disposed of correctly.
Eco-toxicity	None known if used/disposed of correctly.
Bioaccumulation potential	None known if used/disposed of correctly.
Environmental fate	None known if used/disposed of correctly.

13. Disposal Considerations

Do not incinerate, or subject cells to temperatures in excess of 70°C. Such abuse can result in loss of seal, leakage, and/or cell explosion. Dispose of or recycle in accordance with appropriate local regulations.

14. Transport Information

Note: when manufacturing a new battery pack, one must assure that it is tested in accordance with the UN Model Regulations, Manual of Tests and Criteria, Part III, subsection 38.3

Label for conveyance	For the single cell batteries and multi-cell battery packs that are non-restricted to transport, use lithium-ion batteries inside label. For the single cell batteries and multicell battery packs which are restricted to transport (assigned to the Miscellaneous Class 9), use Class 9 Miscellaneous Dangerous Goods and UN Identification Number labels. In all cases, refer to the product transport certificate issued by the Manufacturer.
UN number	UN 3480, for Li-ion batteries transported in bulk UN 3481, for Li-ion batteries contained in equipment or packed with it
Shipping name	Lithium-ion batteries
Hazard classification	Depending on their nominal energy, some single cells and small multi-cell battery packs may be non- assigned to Class 9 (Refer to Transport Certificate)
Packing group	II
IMDG Code	9033
CAS	
EmS No.	4.1-06
Marine pollutant	No
ADR Class	Class 9

15. Regulatory Information

Regulations specifically applicable to the product:

- ACGIH and OSHA: see exposure limits of the internal ingredients of the battery in section 2.
- IATA/ICAO (air transportation): UN 3480 or UN 3481
- IMDG (sea transportation) : UN 3480 or UN 3481
- Transportation within the US-DOT, 49 Code of Federal Regulations

16. Other information

This information has been compiled from sources considered to be dependable and is, to the best of our knowledge and belief, accurate and reliable as of the date compiled.

This information relates to the specific materials designated and may not be valid for such material used in combination with any other materials or in any process. It is the user's responsibility to satisfy himself as to the suitability and completeness of this information for his particular use.

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Saft does not accept liability for any loss or damage that may occur, whether direct, indirect, incidental or consequential, from the use of this information. Saft does not offer warranty against patent infringement.

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Signature

Nicolas Paquin
Lithium Product Manager

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12.6 Lead battery Delta CT 12025 Material Safety Data Sheet (MSDS)

DELTA BATTERY

MATERIAL SAFETY DATA SHEET (MSDS)

SECTION 1--- PRODUCT AND MANUFACTURER

Product Name: Valve Regulated Lead Acid (VRLA) Batteries

DELTA Battery
2-y Yuzhnoportovy pr., 16, build 2
Moscow, 115088, Russia
Tel: (495) 785-73-87
Fax: (495) 785-73-87
Email: sales@energon.ru
Website: http://energon.ru

SECTION 2--- HAZARDOUS COMPONENTS

Components	%Wt.	TLV	LD50 Oral	LC50 Inhalation	LC50 Contact
Lead (Pb, PbO2, $PbSO_4$)	About 70%	0.050mg/m^3	< (500) mg/Kg	N/A	N/A
Sulfuric Acid	About 20%	1 mg/m^3	(2.14) mg/Kg	N/A	N/A
Fiberglass Separator	About 5%	N/A	N/A	N/A	N/A
Container (ABS or PP)	About 5%	N/A	N/A	N/A	N/A

SECTION 3--- PHYSICAL DATA

Components	Density	Melting Point	Solubility (in H2O)	Odor	Appearance
Lead	11.34	327.4°C	None	None	Silver-Gray Metal
Lead Sulfate	6.2	1170°C	40 mg/l (15°C)	None	White Powder
Lead Dioxide	9.4	290°C	None	None	Brown Powder
Sulfuric Acid	About 1.3(25℃)	About 114°C (Boiling)	100%	Acidic	Clear Colorless Liquid
Fiberglass Separator	N/A	N/A	Slight	Toxic	White Fibrous Glass Membrane
Container (ABS or PP)	N/A	N/A	NONE	No Odor	Solid Plastics

SECTION 4---PROTECTION

Exposure	Protection	Comments
Skin	Rubber gloves, Apron, Safety shoes	Protective equipment must be worn if battery is cracked or otherwise damaged.
Respiratory	Respirator (for lead)	A respirator should be worn during reclaim operations if the TLV exceeded.
Eyes	Safety goggles, Face Shield	In the UK use of this material must be assessed under the COSHH regulations.

SECTION 5--- FIRST AID MEASURES

Emergency and First Aid Procedures	Contact with internal components if battery is opened/broken.
1. Inhalation	Remove to fresh air and provide medical oxygen/CPR if needed. Obtain medical attention.
2. Eyes	Immediately flush with water for at least 15 minutes, hold eyelids open. Obtain medical attention.
3. Skin	Flush contacted area with large amounts of water for at least 15 minutes. Remove contaminated clothing and obtain medical attention if necessary.
4. Ingestion	Do not induce vomiting. If conscious drink large amounts of water/milk. Obtain medical attention. Never give anything by mouth to an unconscious person.

SECTION6--- FLAMMABILITY DATA

Components	Flash Point	Explosive Limits	Comments
Lead	None	None	
Sulfuric Acid	None	None	
Hydrogen	259℃	4% - 74.2%	Emit hydrogen only if over charged (Voltage>2.4 VPC). To avoid the chance of a fire or explosion, keep sparks and other sources of ignition away from the battery. Extinguishing Media: Dry chemical, Foam, CO2
Fiberglass Separator	N/A	N/A	Toxic vapors may be released. In case of fire: wear self-contained breathing apparatus.
ABS	None	N/A	Danger: Vapors may cause Flash Fire. Harmful or Fatal if Swallowed. Vapor Harmful.
PP	None	N/A	Temperatures over 300 °C (572°F) may release combustible gases. In case of fire: wear positive pressure self-contained breathing apparatus.

SECTION 7--- REACTIVITY DATA

Components	Lead/lead compounds
Stability	Stable
Incompatibility	Potassium, carbides, sulfides, peroxides, phosphorus, sulfurs.
Decomposition Products	Oxides of lead and sulfur.
Condition To Avoid	High temperature, Sparks and other sources of ignition.

Components	Sulfuric Acid
Stability	Stable at all temperatures
Polymerization	Will not polymerize
Incompatibility	Reactive metals, strong bases, most organic compounds
Decomposition Products	Sulfuric dioxide, trioxide, hydrogen sulfide, hydrogen
CONDITIONS TO AVOID	Prohibit smoking, sparks, etc. from battery charging area. Avoid mixing acid with other chemicals.

SECTION 8---CONTROL MEASURES

1. Store lead/acid batteries with adequate ventilation. Room ventilation is required for batteries utilized for standby power generation. Never recharge batteries in an unventilated, enclosed space.

2. Do not remove vent caps. Follow shipping and handling instructions that are applicable to the battery type. To avoid damage to terminals and seals, do not double-stack industrial batteries.

STEPS TO TAKE IN CASE OF LEAKS OR SPILLS

If sulfuric acid is spilled from a battery, neutralize the acid with sodium bicarbonate (baking soda), sodium carbon (soda ash), or calcium oxide (lime).

Flush the area with water discard to the sewage systems. Do not allow unneutralized acid into the sewage system.

WASTE DISPOSAL METHOD:

Neutralized acid may be flushed down the sewer. Spent batteries must be treated as hazardous waste and disposed of according to local state, and federal regulations. A copy of this material safety data must be supplied to any scrap dealer or secondary smelter with battery.

ELECTRICAL SAFETY

Due to the battery's low internal resistance and high power density. High levels of short circuit can be developed across the battery terminals. Do not rest tools or cables on the battery. Use insulated tools only.

Follow all installation instruction and diagrams when installing or maintaining battery systems.

SECTION9---HEALTH HAZARD DATA

LEAD: The toxic effects of lead are accumulative and slow to appear. It affects the kidneys, reproductive, and central nervous system.

The symptoms of lead overexposure are anemia, vomiting, headache, stomach pain (lead colic), dizziness, loss of appetite, and muscle and joint pain. Exposure to lead from a battery most often occurs during lead reclaim operations through the breathing or ingestion of lead dusts and fumes.

THIS DATA MUST BE PASSED TO ANY SCRAP OR SMELTER WHEN A BATTERY IS RESOLD.

SULFURIC ACID: Sulfuric acid is a strong corrosive. Contact with acid can cause severe burns on the skin and in the eyes. Ingestion of sulfuric acid will cause GI tract burns. Acid can be release if the battery case is damaged or if the vents are tampered with.

FIBERGLASS SEPARATOR: Fibrous glass is an irritant of the upper respiratory tract, skin and eyes. For exposure up to 10F/CC use MSA Comfort with type H filter. Above 10F/CC up to 50F/CC use Ultra-Twin with type H filter. NTP or OSHA does not consider this product carcinogenic.

SECTION10--- SULFURIC ACID PRECAUTIONS

Stability: Stable Substances to be avoided include water, most common metals, organic materials, strong reducing agents, combustible materials, and bases, oxidizing agents. Reacts violently with water - when diluting concentrated acid, carefully and slowly add acid to water, not the reverse. Reaction with many metals is rapid or violent, and generates hydrogen (flammable, explosion hazard).

INHALATION: Acid mist form formation process may cause respiratory irritation, remove from exposure and apply oxygen if breathing is difficult.

SKIN CONTACT: Acid may cause irritation, burns or ulceration. Flush with plenty of soap and water, remove contaminated clothing, and see physician if contact area is large or if blisters form.

EYE CONTACT: Acid may cause severe irritation, burns, cornea damage and blindness. Call physician immediately and flush with water until physician arrives.

INGESTION: Acid may cause irritation of mouth, throat, esophagus and stomach. Call physician. If patient is conscious, flush mouth with water, have the patient drink milk or sodium bicarbonate solution.

DO NOT GIVE ANYTHING TO AN UNCONSCIOUS PERSON.

SECTION11---TRANSPORTATION REGULATIONS

We hereby certify that all DELTA Rechargeable Sealed Lead Acid batteries conform to the UN2800 classification as " Batteries, wet, Non- Spillable, and electric storage" as a result of passing the Vibration and Pressure Differential Test described in DOT [49 CFR 173.159(d) and IATA/ICAO [Special Provision A67].

DELTA Batteries having met the related conditions are EXEMPT from hazardous goods regulations for the purpose of transportation by DOT, and IATA/ICAO, and therefore are unrestricted for transportation by any means. For all modes of transportation, each battery outer package is labeled "NON-SPILLABLE".

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