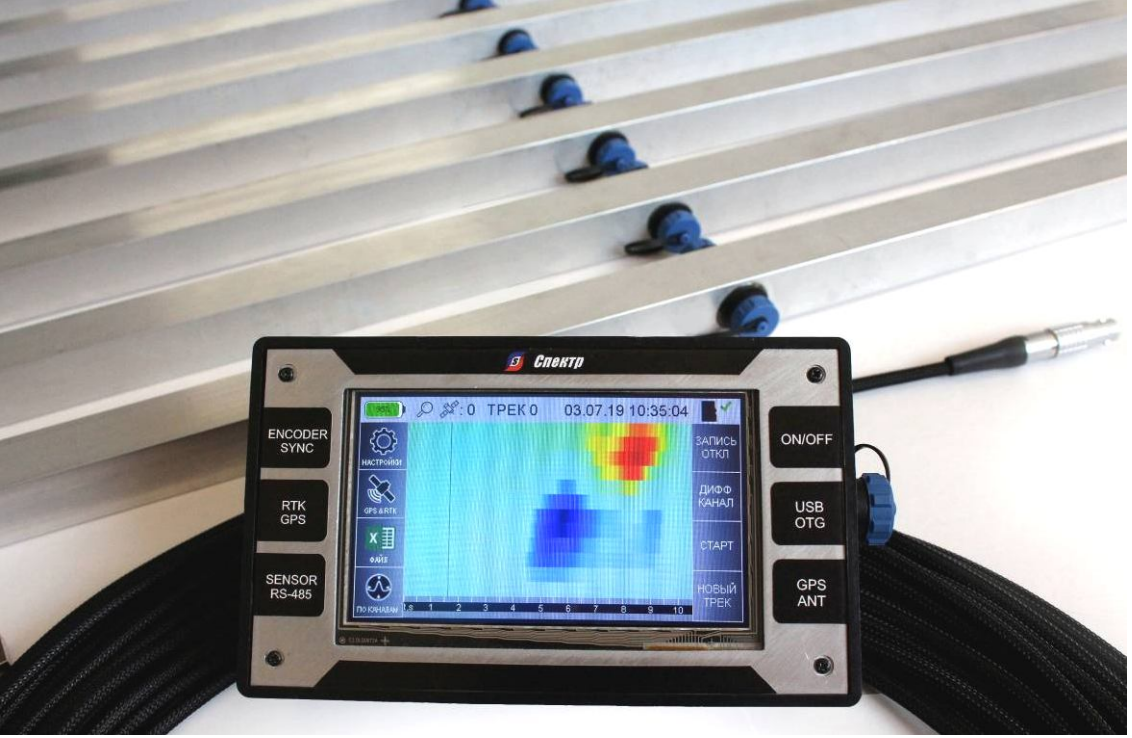


SPECTOR SCI-TECH LLC

«TRITON» MULTICHANNEL MAGNETIC FIELD MEASUREMENT SYSTEM

USER MANUAL

Ufa – Russia – 2023

CONTENTS

This user manual introduces to «Triton» multichannel magnetic field measurement system organization and operation also to establish the rules of operation, maintenance, storing and transportation that ensure «Triton» magnetic field measurement system to be ready to use every time.

1. PRIMARY APPLICATION PURPOSE AND OPERATIONAL CONDITIONS

1.1. «Triton» multichannel magnetic field measurement system designed to perform automated measurements and monitoring of Earth magnetic field vector and gradient spatial components, also to detect local magnetic perturbations on the land and in the sea.

1.2. «Triton» multichannel magnetic field measurement system can be used under the open-air environment, industrial conditions, also in laboratory.

1.3. Any sources of industrial electromagnetic interference should be moved out from magnetic field measurement system for at least 10 m distance.

1.4. According to the Russian standard GOST 14254-2015 magnetic field measurement system components have following protection degrees against the solids, liquids, and the dust penetration:

– magnetic field sensors – IP68;

– data acquisition unit – IP53.

1.5. Measurements indication:

– real-time graphic sweep of measured magnetic field vector and gradient components represented on screen as color map or individual graph on every channel by time or distance;

– displaying and recording numerical results of measurement in units of magnetic field induction vector components (nT), or units of gradient components (nT/m).

1.6. Indication output is color liquid crystal display with integrated capacitive touch screen.

1.7. According to classification system of the Russian standard GOST 15150-69 on the operation conditions multichannel magnetic field measurement system relates to the UHL 3.1 design and providing stable work under following environment conditions:

– environment temperature from – 20ºC to +70ºC,

– relative air humidity up to 98% at +25ºC,

– atmospheric pressure from 84 kPa to 106,7 kPa.

2. TECHNICAL SPECIFICATIONS

2.1. Magnetic field sensitive element:

– fluxgate, straight

2.2. Magnetic field sensor topologies provided by default:..... 3-component/gradiometer

2.3. Amount of 1/2/3-component or gradiometer sensor maintained by system simultaneously: ..... 1 – 12

2.4. Magnetic field vector components measurement range, nT:..... ±70000

2.5. Magnetic field gradient components measurement range, nT/m: ..... ±140000

2.6. Magnetic field sensing resolution, nT:..... 1 or 0.1

2.7. Measurement speed setting range, 3-component samples per second: .....0.001 – 500

2.8. Maximum length of acquisition-to-sensor cable, m (must be arranged before order): 1000

2.9. Measurement synchronization sources:

– built-in timer / external odometer (encoder)

2.10. Coordinates measurement units:

– built-in GPS/GLONASS receiver

– odometer on the base of incremental encoder

– RTK system consists of receiver and base station

2.11. RTK navigation systems supported:
– GPS and GLONASS

2.12. RTK receiver connection channel, including third party manufacturers (must be arranged before order):

– USB/RS-232, NMEA 0183 protocol

2.13. Power supply source: – 3S2P lithium accumulator

2.14. Supply current from fully-charged accumulator battery, mA: 800

2.15. Minimum time interval of magnetic field measurement system continuous working from fully-charged accumulator battery, hours: 8

2.16. Magnetic field measurement system launch time interval, in seconds, not more: 30

2.17. Minimum time interval of magnetic field measurement system continuous working, hours, at least: 8

2.18. Maximum time required to charge the accumulator battery, hours: 3

2.19. Capacity of built-in memory to record measured data, GB: 8

2.20. Minimum total duration of data could be recorded on built-in memory, hours: 300

2.21. Personal computer data exchange: ..... USB MSC

2.22. Data acquisition unit dimensions (length × width × height, mm): ..... 151×90×54

2.23. Magnetic field sensors dimensions (length × width × height, mm):
– gradiometer ..... 1020×60×30
– 3-component ..... 120×100×90

2.24. RTK system components dimensions (length × width × height, mm):
– receiver ..... 120×65×55
– base station (without tripod) ..... 170×85×55
– tripod for RTK base station ..... 1450×600×800
– tripod when folded ..... 550×100×100

2.25. Data acquisition unit weight, g: 540

2.26. Magnetic field sensors weight, g:
– gradiometer 420
– 3-component 300

2.27. RTK system components weight, g:
– receiver 230
– base station (without tripod) 1300
– tripod for RTK base station 1200

2.28. Typical GPS/GLONASS positioning error, m:
– built-in receiver ..... ±1.5
– RTK ..... ±0.01

2.29. Magnetic field sensors water resistance, m: 40

2.30. Average time of repair: 5

2.31. Full service time, years: 10

2.32. Service warranty, years: 2

3. MAGNETIC FIELD MEASUREMENT SYSTEM OVERVIEW AND CONFIGURATION

«Triton» multichannel magnetic field measurement system consists of data acquisition unit and magnetic field sensor unit network, connected to each other by flexible electric cable.

System design based on the modular principle and consists from multichannel magnetic field measurement system and coordinates measurement system (figure 3.1).

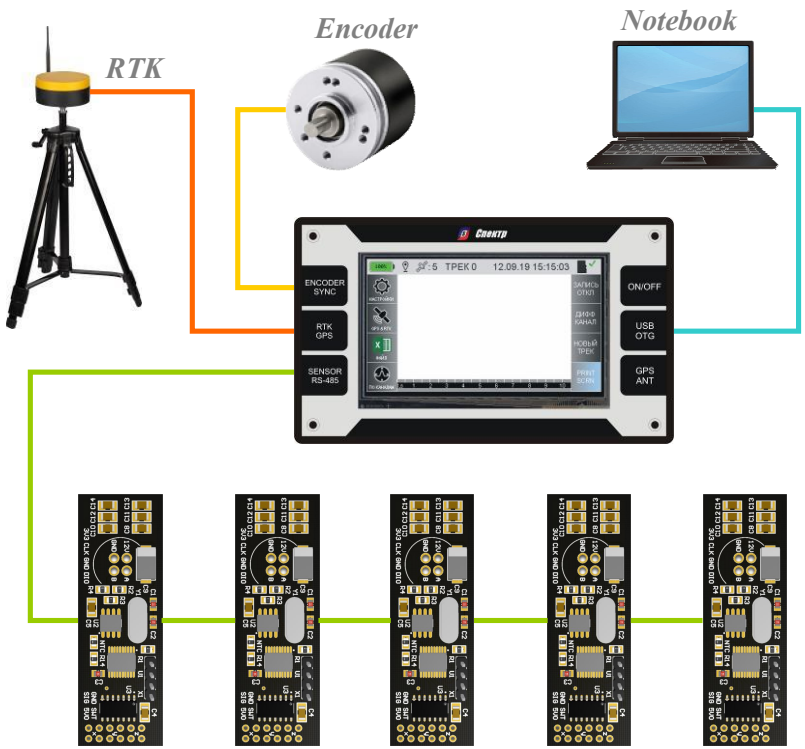


Fig.3.1. «Triton» multichannel magnetic field measurement system architecture

Multichannel magnetic field measurement system represents a linear network of 3-channel microprocessor-based fluxgate sensor signals measurement units, driven by data acquisition unit commands.

Each magnetic field measurement unit can maintain up to 3 fluxgate sensors simultaneously, allowing construct the following sensor topologies: single straight fluxgate sensor, two-element fluxgate sensor unit (compass or gradiometer), three-element fluxgate sensor unit to simultaneous measurement of 3 components of magnetic field vector.

3-component sensor (figure 3.2) designed in waterproof plastic enclosure with diagram of orthogonal magnetic field sensor axis orientation on the top side of enclosure, and a pair of waterproof circular connectors in the side of sensor enclosure.

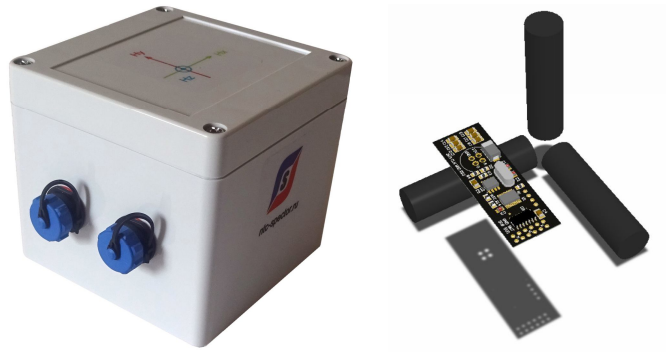


Fig.3.2. 3-component fluxgate magnetic field sensor unit

Circular connectors are identical to each other, they are used to connect sensor unit to the data acquisition unit, or to other sensor unit already connected to the acquisition unit.

2-component sensor unit looks like 3-component (figure 3.2), but differing from one by absence of one of sensing element measuring z-component of magnetic field.

Gradiometer unit is electrically equivalent to 2-component, but it has 2 fluxgate sensing elements installed along one common axe on the base distance of 1 m from each other (figure 3.3), instead of orthogonally installed fluxgate sensing elements.

Fig.3.3. Gradiometer fluxgate magnetic field sensor unit

Constructively gradiometer fluxgate magnetic field sensor unit looks as waterproof aluminum bar of 1 m length with fluxgate sensing elements on the ends; signal processing PCB and both circular connectors to connect sensor unit to the data acquisition unit, or to other sensor unit already connected to the acquisition unit, mounted in the middle part of bar.

Sensor units can be mounted on different distances from data acquisition unit and from each other (cable length

can be extended up to 1000 meters), order of sensor unit connecting to the data acquisition unit have no importance.

Position measurement system (coordinates and distance) provided by 3 independent measurement channels:

– built-in GPS/GLONASS receiver to determine the magnetic field measurement points coordinates;

– odometer connection channel to measure the distance traveled or depth of magnetic field sensor units under water;

– RTK system receiver connection channel in order to determine the magnetic field measurement point coordinates in GPS/GLONASS system with higher precision.

Results of measurements can be displayed on the screen as color map of the magnetic field measured or as convenient graphs by channel, and then recorded into the flash memory, transferred to personal computer and analyzed using «Surfer» software.

Described architecture of multichannel magnetic field measurement system allows covering a wide range of applications.

3.1. System configuration for magnetic field survey and mapping using cart or motor vehicle

To perform survey and magnetic field mapping with high resolution and precision of magnetic field anomaly location the following configuration of multichannel magnetic field measurement system should be used: 4-12 gradiometer sensor units with integrated GPS receiver, odometer and RTK system (figure 3.4).

Fig.3.4. Multichannel magnetic field measurement system configuration from 12 gradiometer fluxgate sensor units with integrated GPS receiver, odometer and RTK system

Setup of system configuration on the figure 3.4:

3.1.1. Gradiometer topology waterproof fluxgate magnetic field sensor unit set – 12 pcs.

3.1.2. Data acquisition unit.

3.1.3. Long (20m) sensor-to-acquisition unit cable.

3.1.4. Short (2m) sensor-to-acquisition unit cable.

3.1.5. Setup of 1m sensor-to-sensor cables – 11 pcs.

3.1.6. RTK system kit (base station and receiver).

3.1.7. Tripod to install RTK base station in the field.

3.1.8. Cable to connect RTK system receiver to the data acquisition unit.

3.1.9. Incremental encoder based mechanic odometer.

3.1.10. USB cable to connect the data acquisition unit to personal computer to transfer the data measured.

3.1.11. Data acquisition unit accumulator set – 2 pcs.

3.1.12. Data acquisition unit accumulator charger.

3.1.13. RTK base station accumulator set – 2 pcs.

3.1.14. RTK base station accumulator charger.

3.1.15. Box for storing and transportation.

Fig.3.5. Examples of cart constructions for survey and magnetic field mapping using vehicle or manually

To perform surveys and magnetic field mapping on big areas the gradiometer sensors should be mounded in array structure on the non-magnetic cart (figure 3.5).

Odometer should be mounted on the one of the wheels of cart to count the distance traveled. Movements of the cart can be performed both in forward and backward direction.

RTK system is usually used instead or built-in GPS receiver when higher precision of the magnetic field vector and gradient components measurement point coordinates in the absolute coordinate system GPS or GLONASS required.

Since «Triton» magnetic field measurement system is very light then survey and magnetic field mapping can be performed manually, without using motorized vehicles or any gear (figure 3.5).

3.2. System configuration to perform remote magnetometry and solve inverse problems

«Triton» multichannel magnetic field measurement system can be used to solve inverse problems of remote magnetic field sensing, such as depth and size of underground and underwater objects evaluation on magnetic field anomalies detected, etc.

An optimal spatial configuration and distance between fluxgate magnetic field sensors units are usually determined by symbolic calculating the physical models or numerical modeling of Earth magnetic field deformation on the object to be inspected.

Performing remote magnetic field sensing the measurement results are usually being recorded into built-in flash memory, and then transferred to personal computer.

To solve inverse problem of remote magnetic field sensing the magnetic field signals measured are usually analyzed on the personal computer using mathematic modeling software (e.g. MathLab, MathCad, Anaconda, etc.).

To perform remote magnetometry of the underground pipelines and stressed state analysis in real time the special configuration of magnetic field measurement system proposed on the base of «Triton» (figure 3.6).

Fig.3.6. Multichannel magnetic field measurement system configuration from eight 3-component fluxgate sensor units with integrated GPS receiver and RTK system

Setup of system configuration on the figure 3.6:

3.2.1. 3-component topology waterproof fluxgate sensor unit set – 8 pcs.

3.2.2. Data acquisition unit.

3.2.3. Short 2 meters long sensor-to-acquisition unit connection cable.

3.2.4. Setup of 0.5 meter long sensor-to-sensor connection cables – 7 pcs.

3.2.5. RTK system kit (base station and receiver).

3.2.6. Tripod to install RTK base station in the field.

3.2.7. Cable to connect RTK system receiver to the data acquisition unit.

3.2.8. USB cable to connect the data acquisition unit to personal computer to transfer the data measured.

3.2.9. Data acquisition unit accumulator set – 2 pcs.

3.2.10. Data acquisition unit accumulator charger.

3.2.11. Box for storing and transportation.

System can be supplied by special software to reconstruct distribution of residual magnetic field induction on the surface of underground steel pipeline (figure 3.7).

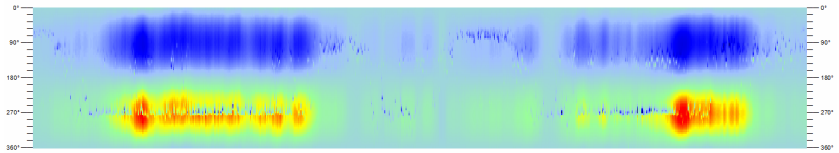


Fig.3.7. Software reconstruction of residual magnetic field distribution on the surface of underground steel pipeline

3.3. Basic configuration: portable underwater (borehole) magnetometer-gradiometer

Real-time graph indication of magnetic field vector and gradient components measured, also light weight of magnetic field measurement system providing a good advantages to use it as portable field magnetometer-gradiometer.

Basic system configuration of portable magnetometer-gradiometer with rugged magnetic field sensor can be used to make magnetic measurements deep underwater or borehole is shown in the figure 3.8.

Setup of system configuration on the figure 3.8:

Fig.3.8. Portable basic underwater (borehole) magnetometer-gradiometer system configuration

3.3.1. Gradiometer topology waterproof cylinder fluxgate magnetic field sensor unit.

3.3.2. Data acquisition unit.

3.3.3. Long (40m) sensor-to-acquisition unit cable.

3.3.4. Mmechanic odometer to measure the depth.

3.3.5. USB cable to connect the data acquisition unit to personal computer to transfer the data measured.

3.3.6 Data acquisition unit accumulator set – 2 pcs.

3.3.7. Data acquisition unit accumulator charger.

3.3.8. Transportation and storing bag.

Performing measurements under water or inside of the borehole the sensor-to-acquisition unit connection cable should be passed through the odometer mounted on the board, a plane coordinates are determined by GPS receiver built-in.

If magnetic field measurements would be performed on the land the odometer could be used to count a distance covered with built-in GPS receiver together or separately.

3.4. Acquisition unit overview

Data acquisition unit of the «Triton» multichannel magnetic field measurement system is a portable electronic device with a color touch screen on the front panel, a battery compartment on the back and connectors mounted on the sides of the case for connecting magnetic field sensor units and auxiliary measurement devices (figure 3.9).

Depending on the configuration of multichannel magnetic field measurement system selected by the Customer at the production stage, the following connectors can be installed on the left side of the control unit (figure. 3.9, from top to bottom):

3.4.1. An odometer circular connector, which is any incremental encoder operating voltage from 5 to 12 volts suitable for use. Pinout diagram of the odometer connector is shown in the figure 3.10.

3.4.3. Magnetic field sensor unit network circular connector. This connector provides the power supply to the sensor unit network with a voltage of 12 volts, and pick up the results of measurement over the differential communication line according to the RS-485 standard.

Fig.3.9. Data acquisition unit of the «Triton» multichannel magnetic field measurement system

Fig.3.10. Odometer connector pinout diagram

3.4.2. An RTK system receiver circular connector having two designs: communication according to RS-232 or USB standard (figure 3.11).

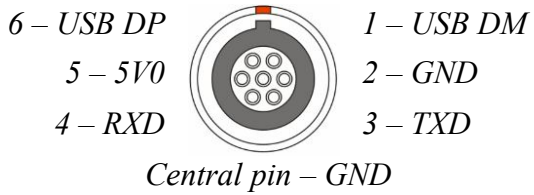


Fig.3.11. Combined RTK system connector pinout diagram

3.4.4. USB connector is mounted on the left side of the data acquisition unit to transfer the data measured to the personal computer.

3.4.5. Power switch is mounted also on the left side of the data acquisition unit of multichannel magnetic field measurement system.

3.4.6. Color liquid crystal display (LCD) with touch screen, the logo of the «Spector» Scientific and Technical Center, as well as the designation of all connectors placed on the front panel of the data acquisition unit (figure 3.12).

Fig.3.12. Front panel of the multichannel magnetic field measurement system data acquisition unit

Color LCD with touch screen is main way to exchange information and activity with device. It supply user of the multichannel system by clear intuitive interface that consists of status bar on top of the screen, graphic sweep of measured signals, automatic ruler in bottom of screen, and two groups of buttons to the left and right sides of screen used to manage system work process manually (figure 3.13).

3.4.7. Main indicators of the visual interface are located on the status bar (from left to right):

–the battery charge level indicator;

– GPS location accuracy indicator;

– number of satellites used;

– number of currently scanned profile (track);

– the current date and time indicator;

– built-in memory card status indicator.

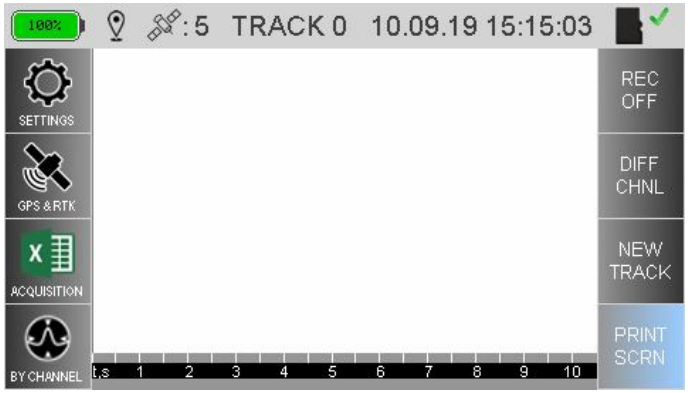


Fig.3.13. User interface of the multichannel magnetic field measurement system data acquisition unit

3.4.7.1. Battery level indicator shows the approximate percentage of the remaining battery charge as a percentage.

When the battery charge drops to a level only enough for a few minutes of operation time of the multichannel magnetic field measurement system, the battery indicator lights up in red.

When the battery charge drops to a critical level, the battery will be automatically disconnected from the power supply system of the multichannel magnetic field measurement system.

3.4.7.2. GPS location accuracy indicator has 5 states:

– unknown location, searching for a suitable satellite configuration is performing now;

– satellites found and location is fixed;

– the location is fixed in differential mode;

– the location is floating (RTK mode);

– the location is fixed with RTK precision.

3.4.7.3. Number of satellites used to calculate the current location in GPS/GLONASS coordinate system.

3.4.7.4. Number of currently scanned profile (track).

If survey performed for several passes, each pass should be numbered as in order they follows (for detailed explanation please see Sections 4.3, 7.2, and 7.3).

3.4.7.5. The current date and time indicator shows each time the current date and time from the real-time clock integrated circuit the data acquisition unit built-in.

3.4.7.6. The built-in memory card indicator has two states: the memory card is working normally (the indicator is green) and the memory card is missing or malfunction occurred (the indicator is red).

3.4.8. The graphic sweep area (figure 3.13) is used for the continuous output of the fluxgate sensors measured signals to the screen in color map or convenient graph look.

In the horizontal direction of the signal sweep, the distance traveled is counted (when synchronizing measurements from the odometer), or the time is counted (when synchronizing from the timer).

In the vertical direction of the signal sweep the magnetic field sensors are counted from 1 to 12.

By clicking on any point in the signal sweep area, the measurement process is started or stopped.

3.4.9. The cursor, which is a thin vertical line on the signal graphic sweep area, is designed to update the data on the color map and graphs by the fluxgate sensor signals measured.

When scanning in timer synchronization mode, the cursor continuously moves along the signal sweep from left to right and updates the measured data in real time (figure 3.14).

When the right edge of the signal sweep area is reached, the cursor automatically moves to the start and continues the motion from left to right again, as shown by the dashed line in the figure 3.14.

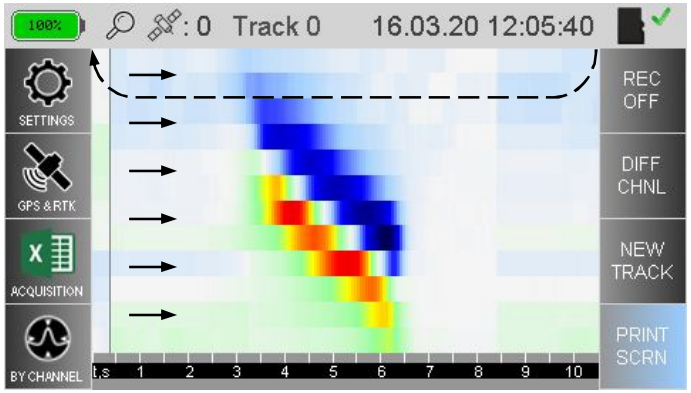


Fig.3.14. Diagram of the fluxgate sensor signals measured drawing on the signal graph sweep

Performing area survey of the magnetic field in the synchronization mode on the odometer signals, the cursor continuously moves along the sweep synchronously with the rotation of the odometer.

If the odometer is stationary, the cursor is also remains stationary until the odometer resumes rotation again.

3.4.10. Time and distance measurement ruler right on bottom of the signal graph sweep is designed to visually assess the current location, spatial orientation, shape and length of the magnetic anomalies detected.

3.4.11. The group of buttons to the left of the sweep allows access to the «SETTINGS», «GPS & RTK», «FILE» panels, and also includes the display mode of the measured components of the magnetic field vector «BY CHANNEL».

3.4.11.1. The main settings panel is consisted from two pages: «Color palette» (figure 3.15) and «Gain and offset» (figure 3.17).

The color palette is a one-dimensional function that establishes the correspondence between the magnitude of the measured signal and the color code. The «Color palette» page contains the following control elements:

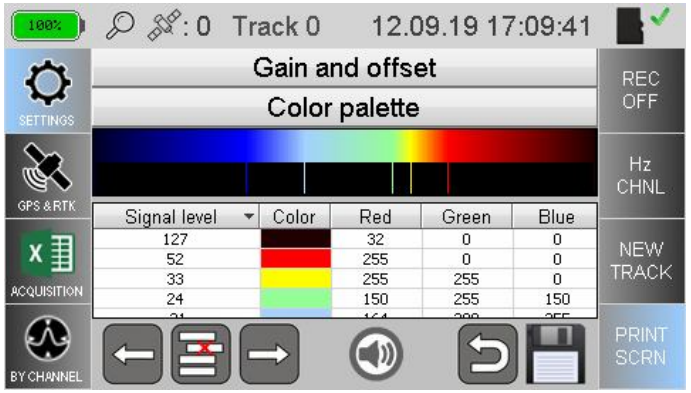


Fig.3.15. Color palette configuration panel

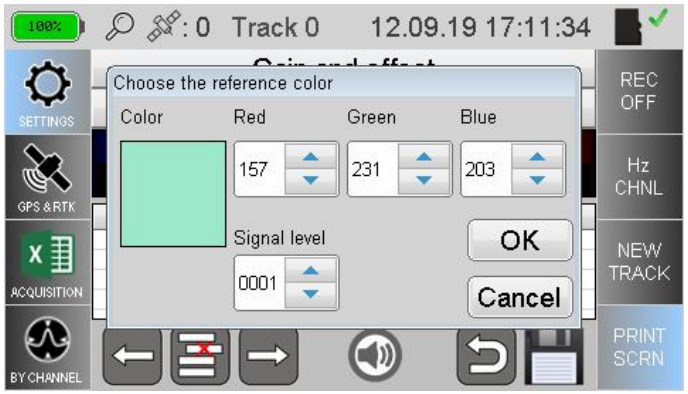


Fig.3.16. Color palette reference color set up window

– interactive color band for editing the reference colors set of the palette (figure 3.16);

– table of the reference colors, containing the attributes of all the reference colors: the signal level of the fluxgate sensor and the three basic color components in most popular and clear to understand RGB color mode;

– group of the buttons including the buttons for navigating on the reference color table «» and «», also special button to delete the reference color from palette «»;

– button to enable or disable the sound when button would pressed and touch screen would touched «»;

– group of buttons for returning to the factory settings «», and the button for saving the current settings in the non-volatile memory of the magnetic field measurement system data acquisition unit «».

Track bars on the «Gain and offset» page (figure 3.17) are used to set amplification degree and compensate the signals of fluxgate sensors measured.

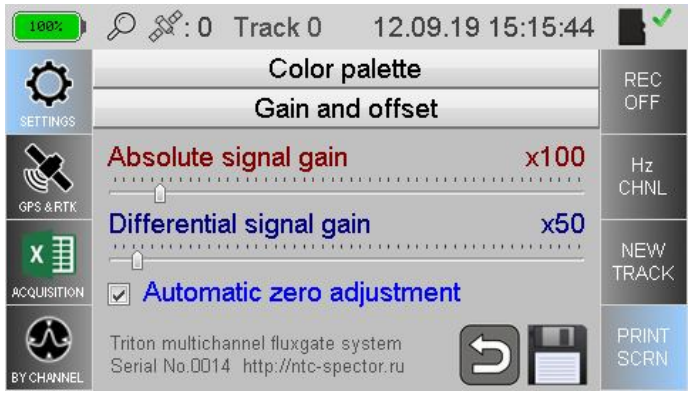


Fig.3.17. Amplification factors and zero offset adjustment panel for gradiometer (top) and 3-component topology (bottom) magnetic field sensor units

If gradiometer sensor configuration used, then amplification factors of measured signals can be adjusted for absolute and differential channel separately.

If 3-component magnetic field sensors configuration used, then amplification factors measured signals can be adjusted by common absolute signal gain track bar.

Automatic zero adjustment option subtracts non informative constant component from measured magnetic field sensors signals, passing only component consisted of informative changes of signal.

It give us possibility to set up high values of amplification factors and helps to see more details on images of measured magnetic field sensors signals on the screen of acquisition unit.

Automatic zero adjustment option calculates and updates value of constant component of measured signal on every channel every time user starts measurement process.

3.4.11.2. The «GPS & RTK» positioning systems settings panel is divided into 3 pages: «GPS coordinates and time» (figure 3.18) and two pages named «Sensor position configuration» (figure 3.19).

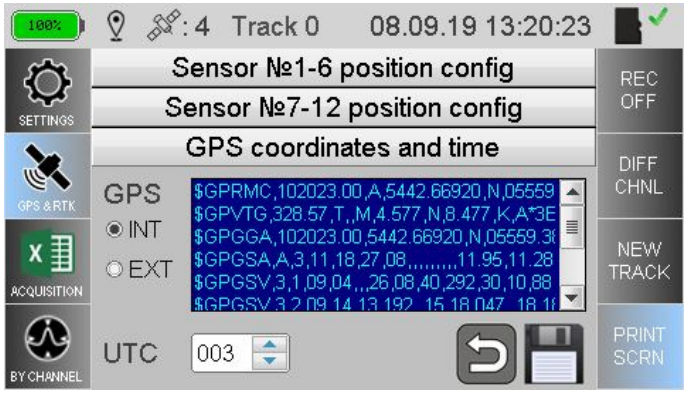


Fig.3.18. Navigation data in the window of coordinates and time settings page the navigation statuses in the status bar are based on

There is a switch on the navigation settings page to select the channel for receiving navigation data, a window for setting the time zone and a terminal window for displaying received navigation data in NMEA 0183 format. When the switch is set to the «INT» state, the navigation data are expected to be received from the integrated into the data acquisition unit navigation receiver.

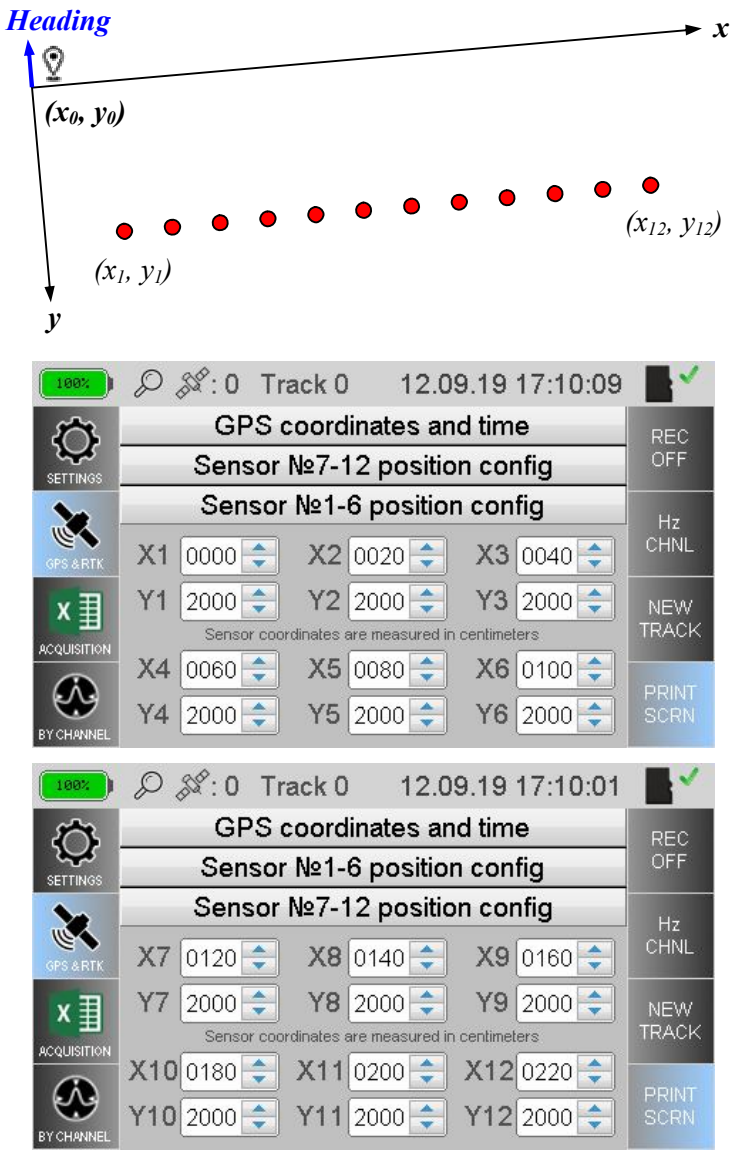


Fig.3.19. Magnetic field sensor unit positions configuration page

When the switch is set to the «EXT» state, the navigation data are expected to be received from an RTK system receiver connected to the RTK system connector.

The buttons for returning to the factory settings «», and the button for saving the current settings in the non-volatile memory of the magnetic field measurement system data acquisition unit «» are also placed in settings panel.

On the other two pages for configuring fluxgate magnetic field sensor units position, there are 12 pairs of numeric fields for entering the coordinates of the magnetic field sensor units relative to the antenna of the GPS receiver.

The antenna of the GPS receiver integrated in the data acquisition unit is located on the left side inside the housing.

When performing an area geomagnetic survey, the GPS coordinates and the coordinates of fluxgate sensor units relative to the antenna of the GPS receiver are used to calculate the absolute coordinates of the magnetic field measurement points on the Earth surface.

The procedure how Triton calculates the absolute coordinates of measurement points in GPS and GLONASS systems is given in Section 4.2 of this manual.

3.4.11.3. Survey mode and synchronization parameters are configured on the «Synchronization» page of the «ACQUISITION» panel (figure 3.20).

The multichannel magnetic field measurement system has 2 independent sources of clock signals to synchronize the measurements, switched by the «Synchronization» selector:

– if «Odometer» option selected, then magnetic field measurements being synchronized on pulses of incremental encoder based odometer wheel connected to the data acquisition unit, the diameter of which, as well as the odometer step, depending on the diameter of the wheel, can be adjusted in existed numeric fields «Diameter» and «Encoder step»;

– if «Timer» option selected, then magnetic field measurements being synchronized on signals of the built-in timer, the response interval of which is set using the «Interval» numeric field.

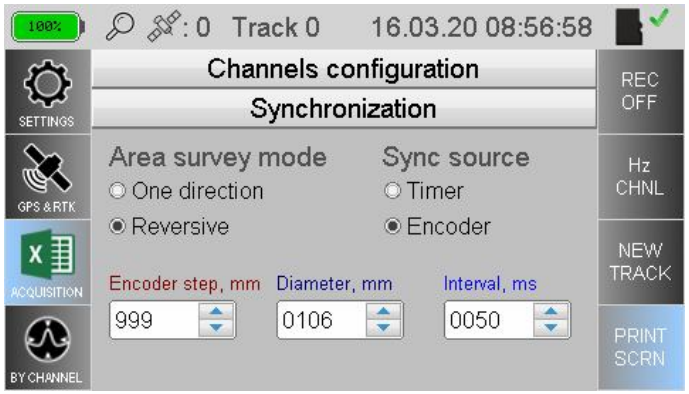


Fig.3.20. Survey mode, synchronization settings, and measurement channels configuration panel

To save survey mode and synchronization parameters in the non-volatile memory of the magnetic field measurement system data acquisition unit the button «» should be pressed; to return to the factory settings the button «» should be pressed.

3.4.11.4. Enabling and disabling the recording of fluxgate signals to file by channel is performed on the «Channel » page of the «FILE» panel (figure 3.21).

3.4.11.5. Signal graph sweep mode «BY CHANNEL» (figure 3.22) allows studying the measured signals of each fluxgate magnetic field sensor unit separately.

If system configuration is assembled from gradiometer units, the red graph corresponds to the absolute signal (projection of magnetic field vector to the axis of gradiometer), the blue graph corresponds to the differential signal (projection of magnetic field gradient to the axis of gradiometer).

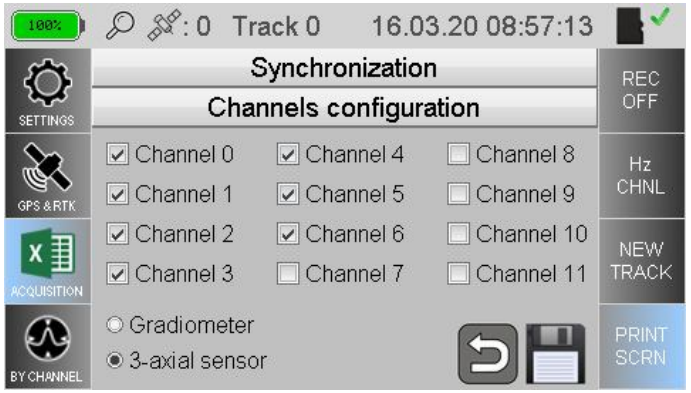


Fig.3.21. Panel for enabling and disabling recording the fluxgate magnetic field sensor signals to a file by channel

If system configuration is assembled from 3-component magnetic field sensor units, then green graph corresponds to x-component of the magnetic field vector, red to y-component, blue to z-component (figure 3.23).

Corresponding to the graph colors in the top side of 3-component magnetic field sensor axis diagram is drawn, indicating how fluxgate elements are oriented inside enclosure (figure 3.24).

Switching the measurement channels is carried out using «< PREV» and «NEXT >» buttons, while the number of current channel is displayed in bottom side of the window. Measurement channels are numbered from 0 to 11 (can be extended up to 255 if need), while the measured signals from the first fluxgate sensor are processed in the zero measurement channels, the second in the first, etc.

3.4.12. The group of buttons to the right of the sweep is designed to manage the multichannel magnetic field measurement system during the measurement process.

«RECORD» button enables and disables the recording of the current measurement results of magnetic field vector components and the gradient to the file.

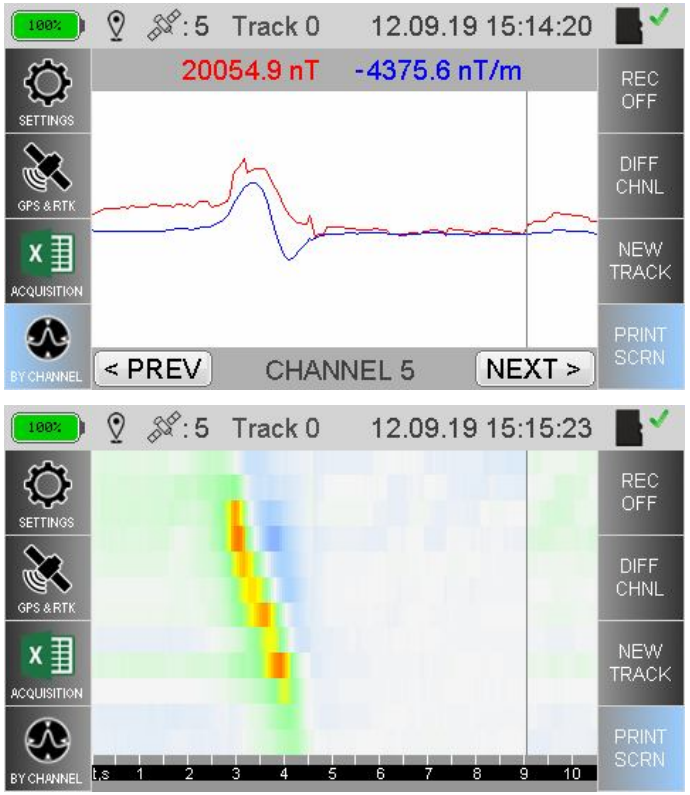


Fig.3.22. Sweep of the gradiometer magnetic field sensors signals in the «BY CHANNEL» mode (in the top) and in the normal color map sweep mode (bottom)

«CHANNEL» button switches the type of signal graph sweep by the components of magnetic field vector and the gradient: x-, y-, z-components for a 3-component sensor unit; absolute and differential component – for gradiometer sensor unit topology.

Pressing «NEW TRACK» button increase the counter of current survey profile (track) by one. If multichannel magnetic field measurement system would be powered off then turned on again, the counter of profile will be reset to 0.

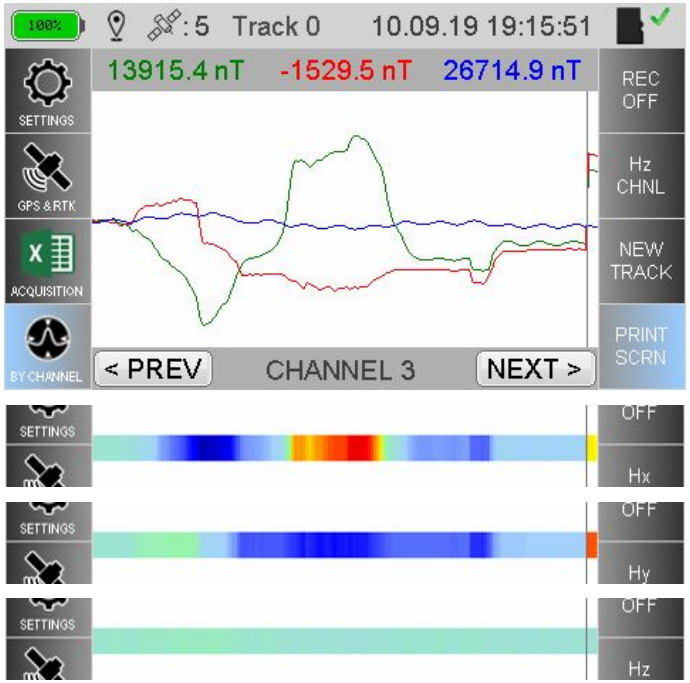


Fig.3.23. Sweep of the 3-component magnetic field sensors signals on 3-th measurement channel (4-th sensor unit)

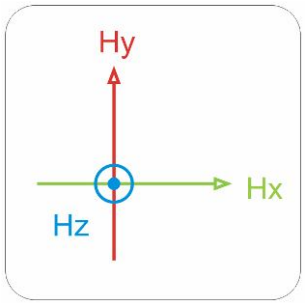


Fig.3.24. 3-component magnetic field sensor measurement axis color marking and orientation diagram

3.4.12. When «PRINT SCRN» button is pressed (in latest versions of firmware – date and time indicator should be pressed), the image is captured on the screen and saved to a file, and the date and time at the time of saving are automatically selected as the file name.

The screenshots already saved, as well as measurement results in the form of text files, can be transferred to a personal computer via USB port for further analysis using Surfer software.

To transfer the saved measurement results to a personal computer, the multichannel magnetic field measurement system has the USB Mass Storage Class standard driver. This means that when this mode is turned on, it begins to work as a standard disk device, which can be connected to a personal computer via USB port and used as a convenient USB flash disk.

«USB MSC» mode is automatically activated when a forced stop of the measurement process is performed by clicking anywhere on the graphic sweep.

When the measurement process is resumed, «USB MSC» mode is automatically turned off, while the multichannel magnetic field measurement system continues to operate normally.

4. SYSTEM ORGANIZATION AND OPERATION

The principle of the operation of «Triton» multichannel magnetic field measurement system is based on acquisition of signals of fluxgate magnetic field sensors and calculating the absolute or relative coordinates of the measurement points.

A block diagram explaining the «Triton» multichannel magnetic field measurement system operation principle is shown in the figure 4.1.

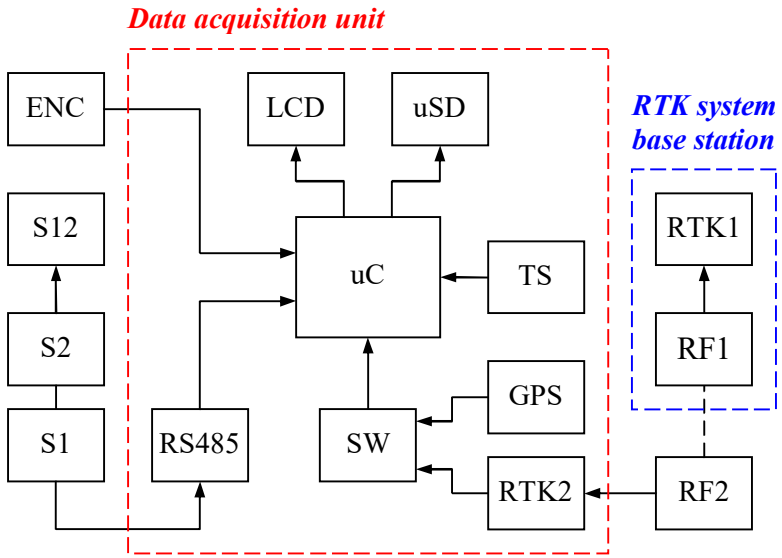


Fig.4.1. Block diagram of the «Triton» multichannel magnetic field measurement system

ENC – odometer, S1-S12 – fluxgate magnetic field sensor units with integrated processor, uC – microprocessor controller, LCD – liquid crystal display with integrated touch screen TS, uSD – memory card to save the measurement results, GPS – uBlox series basic navigation receiver, RTK1 and RTK2 – Emlid Reach series navigation receivers with RTK support, SW – logic level switch, RF1 and RF2 – RTK system base station and receiver radio modules.

Fluxgate magnetic field sensor units S1-S12, each has an integrated signal processor, perform the magnetic field vector components measurement and the gradient calculation.

S1-S12 sensor units are connected to the acquisition unit of the multichannel magnetic field measurement system by cable, this way forming RS-485 industrial standard network. Microprocessor controller uC of the data acquisition unit polls data from the sensor units in cycle, asking them on individual address inside of local network.

Topographic referencing of the magnetic field measurement results is carried out according to the odometer ENC counts, or GPS coordinates.

The multichannel magnetic field measurement system has two GPS data channels: a basic GPS/GLONASS receiver integrated into the data acquisition unit and an optional RTK system with increased accuracy, switching between ones performed by the logic level digital switch SW controlled from the «GPS & RTK» settings panel (figure 3.18).

The RTK system consists of an RTK1 base station, an RTK2 receiver connected to the data acquisition unit, and an RF1-RF2 radio channel for transmitting data from the base station to the receiver.

The measurements displayed on the color LCD, can be recorded on the built-in uSD memory card and passed to the personal computer through USB port. The multichannel magnetic field measurement system is configured and driven through the TS touch screen.

4.1. Presenting the measured magnetic field components and gradient on the color map in real time

Each of magnetic field sensors S1-S12 has an integrated microprocessor that converts the signals from the fluxgate coils captured into magnetic field vector components and gradient (nT and nT/m) measurement units, then sends them to the data acquisition unit as sequence of digital codes.

The measurement results can be recorded on the built-in memory card and displayed on the color display in digital and graphic modes, e.g. color map sweep.

To build a graph and color map sweep, excessive constant signal component compensation should be performed and optimal scaling the measured signals useful component should be performed with respect to dynamic range of the color palette (figure 4.2), then conversion into color code according to the color palette configuration performed finally.

In the horizontal direction of the signal sweep, the distance traveled is counted (when synchronizing measurements from the odometer), or the time is counted (when synchronizing from the timer). In the vertical direction of the signal sweep the magnetic field sensors are counted from 1 to 12: the top scan line corresponds to the readouts of the first sensor, the second from the top to the second, etc.

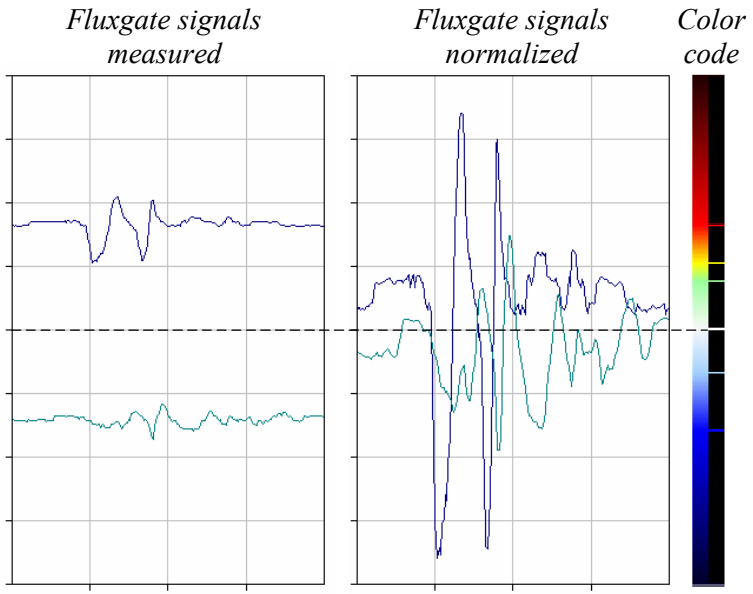


Fig.4.2. Normalization of measured signals and conversion their numerical values to the color palette codes

As an example illustration, the figure 4.3 shows the normalized signals of 12 fluxgate sensors, measured during survey of the landscape region with a magnetic field anomaly, and the color map sweep image of a magnetic field anomaly synthesized from them (figure 4.4).

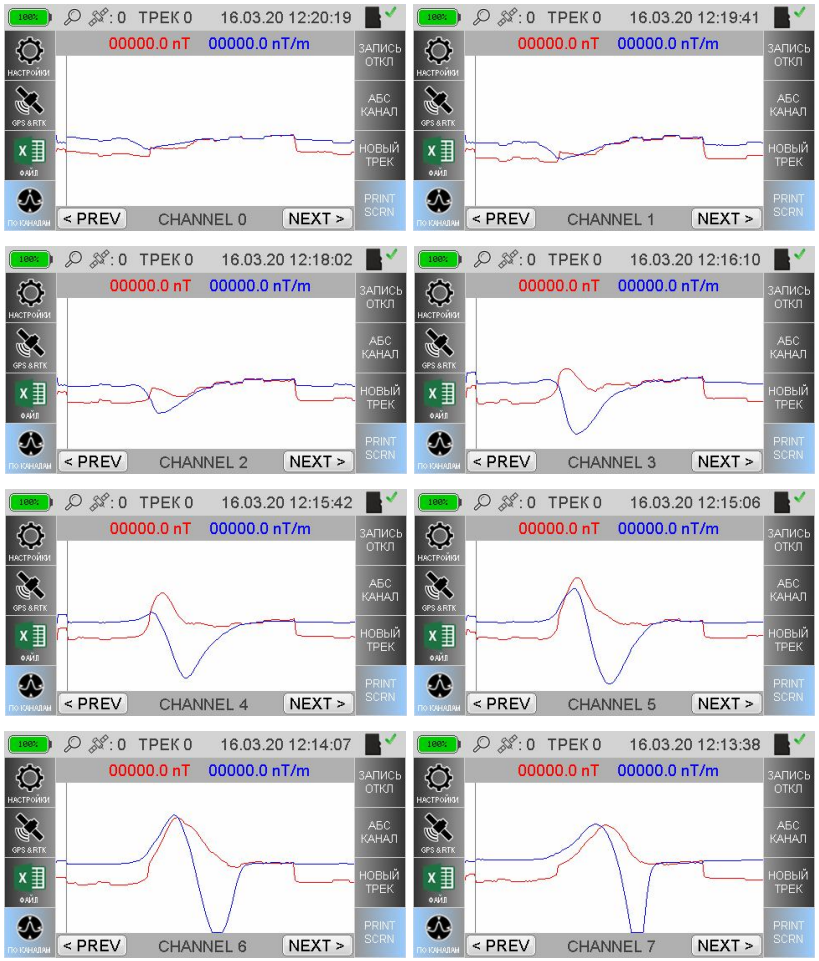


Fig.4.3. Absolute (red) and differential (blue) signals of 12-channel gradiometer on magnetic field anomaly detected

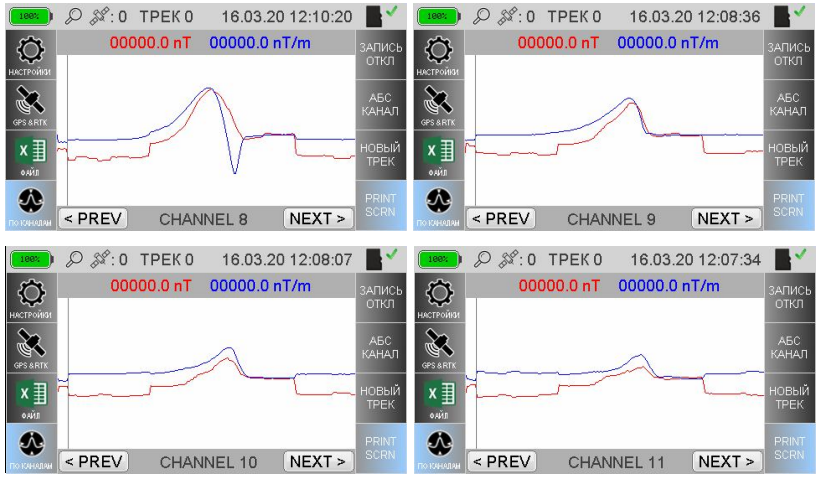


Fig.4.3. (continue) Absolute (red) and differential (blue) signals of 12-channel gradiometer configuration on magnetic field anomaly detected

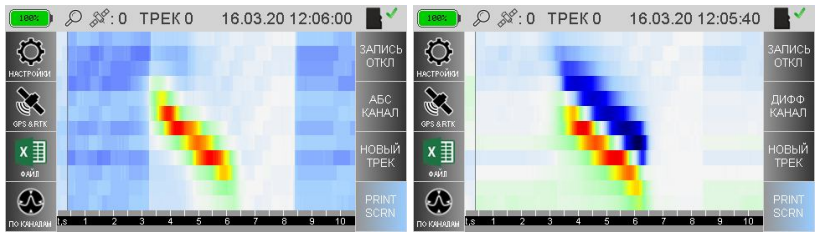


Fig.4.4. Color map image of the magnetic field anomaly on absolute (left) and differential channel (right) synthesized on measured signals shown on figure 4.3

4.2. Calculating the magnetic field measurement points coordinates in GPS/GLONASS system

In the general case, the sensor unit configuration of the magnetic field measurement system can have any shape.

For example, when automated area survey scanning is performed, the configuration consists of gradiometer topology sensor units usually installed along a straight line at regular distance from each other (figure 4.5).

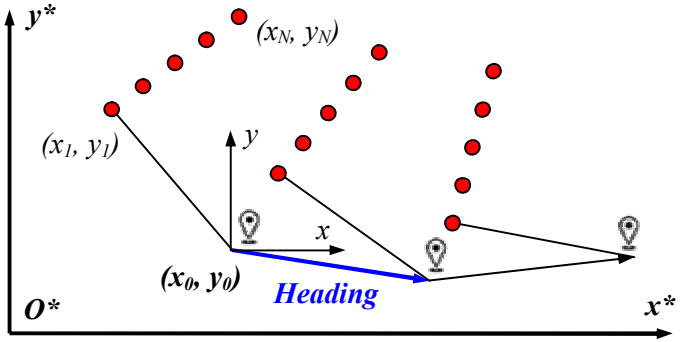


Fig.4.5. Automated area survey multichannel magnetic field measurement system configuration

The coordinates of magnetic field sensor units in the absolute system (GPS/GLONASS) are determined by vector sum of the coordinates of the magnetic field sensor units relative to the navigation receiver antenna (x_N, y_N) and the absolute coordinates of the antenna of the navigation receiver (x_0, y_0), while the scanning direction (*Heading*) also considered in given point in time.

The relative coordinate system the configuration of magnetic field sensor units determined is considered rectangular (Cartesian), while the absolute coordinates of any point on the world map are determined in a spherical (elliptical) coordinate system (figure 4.6).

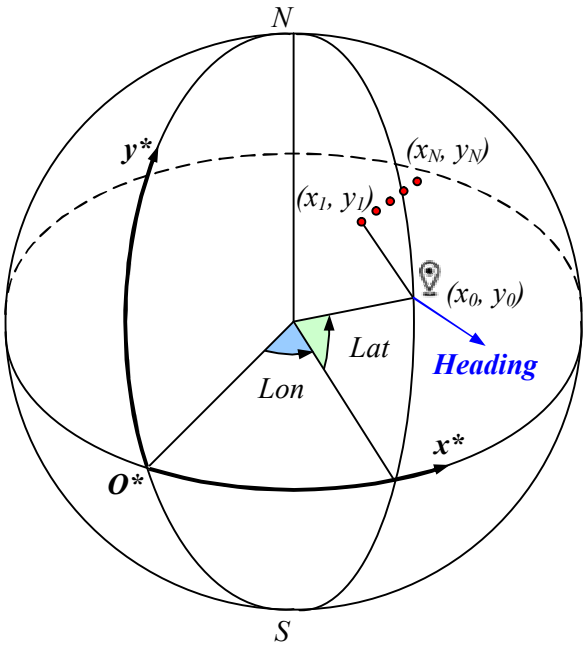


Fig.4.6. Calculating the magnetic field measurement points on the Earth surface when area survey is performed

The coordinates of the magnetic field sensor units relative to the antenna of the navigation receiver (x_N, y_N) are entered into the multichannel magnetic field measurement system through the configuration panel (figure 3.19).

The absolute coordinates of the navigation receiver antenna (x_0, y_0)) are determined automatically, and the direction of movement at each moment of time is calculated from the coordinates of the start and end points.

The listed data is sufficient to calculate the absolute coordinates of each transducer. In the middle latitudes:

$$Lat_N = Lat - \frac{180}{\pi}\arcsin\frac{y_N^*}{R_E};$$

$$Lon_N = Lon + \frac{180}{\pi}\arcsin\frac{x_N^*}{R_E}\arccos\frac{Lat}{180};$$

where (x^*_N, y^*_N) – coordinates of the magnetic field sensor units relative to the antenna of the navigation receiver in the local Cartesian system, R_E = 6372795 m – the average radius of the Earth.

$$x_N^* = \sqrt{x_N^2 + y_N^2}\cdot\cos\left(\arctan\frac{x_N}{y_N} + heading\right);$$

$$y_N^* = -\sqrt{x_N^2 + y_N^2}\cdot\sin\left(\arctan\frac{x_N}{y_N} + heading\right).$$

The coordinates of the magnetic field sensor units in the absolute coordinate system (Lat_N, Lon_N) are calculated automatically by the multichannel magnetic field measurement system, so the measurement results can be presented on a computer in the form of magnetic field maps.

4.3. Calculating the relative coordinates of magnetic field measurement points on odometer counts for surveys

The software of the multichannel magnetic field measurement system provides choice of two ways to perform survey synchronizing measurements from odometer signals: one-directional and reversive survey modes.

Examples of one-directional and reversive motion patterns of survey for 5 passes using a linear configuration of 4 magnetic field sensor units presented on figure 4.7.

For both one-directional and reversive scanning at each measurement point, the odometer readings are added to the relative coordinates Y of the configuration of the magnetic field sensor units, which are entered into the data acquisition unit settings via the user interface (figure 4.8) before the survey being started.

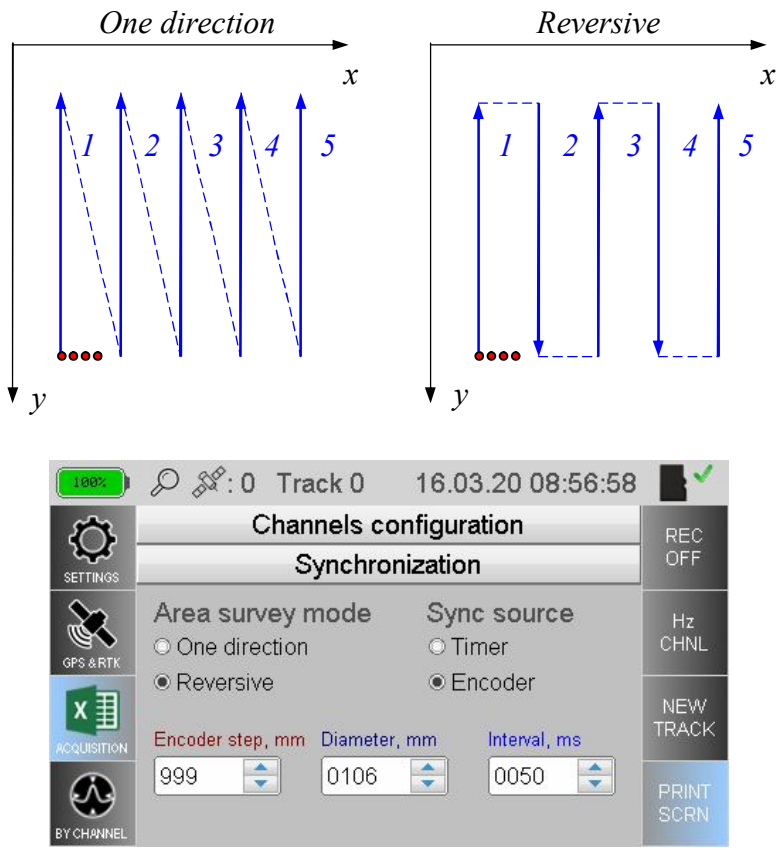


Fig.4.7. One-directional and reversive survey patterns and measurements synchronization parameters page of the «Triton» multichannel magnetic field measurement system

4.3.1. Performing the survey in one-directional mode, the count of traveled distance for each pass starts from zero, so finishing every pass you have to return to the beginning of survey, shifting to the right of the scan bandwidth.

After completing the passage, the measurements should be stopped and a new track should be started, while, according to the one-directional scan pattern, the odometer counter is automatically reset to 0.

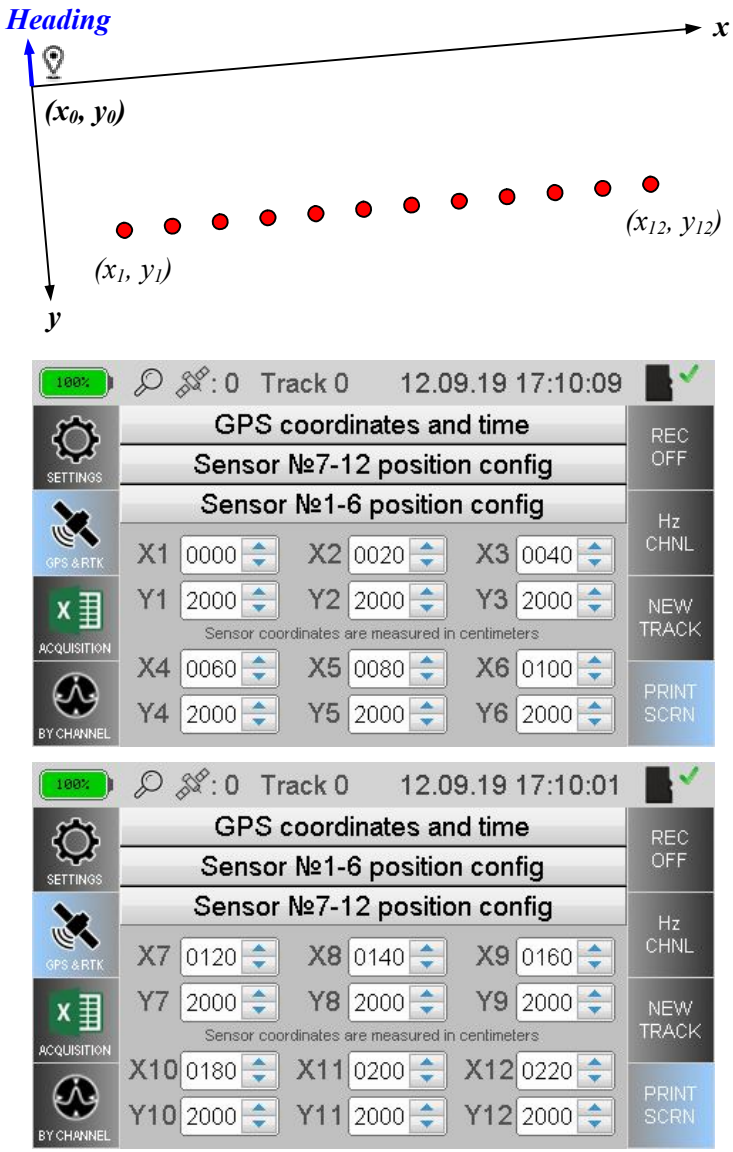


Fig.4.8. Multichannel magnetic field measurement system sensor position configuration page

4.3.2. In reversive scanning mode the distance covered for each pass starts from the last value of the previous pass. After completion of the passage there is no need to return to the beginning of the area surveying; to start the next pass, to stop the measurements is enough, then turn the scanning device in the opposite direction and start a new track.

In reversive scanning, the odometer counting direction and the configuration of the magnetic field sensor units are inverted for odd passes.

When survey is performed with referencing the measurement points to coordinates in the GPS/GLONASS system, the settings for area survey parameters (figure 4.7) does not matter, because the direction of movement in this mode is automatically determined by the GPS/GLONASS coordinates of the track points.

5. SAFETY INSTRUCTIONS

5.1. For the operation, maintenance and repair of the «Triton» multichannel magnetic field measurement system, persons are allowed only after studying the Sections 2-7 of this operating manual, as well as having been instructed in industrial and fire safety when working with electricity.

5.2. Any manipulations associated with physical contact with the battery, including replacing it, cleaning it from contamination, repairing and setting up the multichannel magnetic field measurement system, are permissible provided that the power switch is in the «OFF» position.

5.3. When working with a multichannel magnetic field measurement system, it is necessary to comply with the requirements of the «Technical operation of consumer electrical facilities Rules PTE-84» and the «The operation of consumers electrical facilities safety Rules of PTB-84 ».

6. PREPARING TO WORK

Preparing of the «Triton» multichannel magnetic field measurement system to the work includes a visual inspection, assembly and switching the power on, as well as software settings adjustment.

6.1. Visual inspection, assembling, powering on

6.1.1. Connect the accumulator battery to the power connector inside of the battery compartment on the back of the data acquisition unit. Insert the accumulator battery into the compartment and snap the battery cover into place. All time while manipulations with accumulator battery performed, the power switch must kept be in the «OFF» position.

6.1.2. Perform a visual inspection of the magnetic field sensor units. If necessary, clean them from magnetic and non-magnetic particles and mud using a synthetic brush or rags.

6.1.3. Install the magnetic field sensor units on the cart and connect them to the data acquisition unit using a set of connecting cables.

6.1.4. Turn on the power of the multichannel magnetic field measurement system by setting the power switch of the power supply of the data acquisition unit to the «ON» position, marked with a dot.

6.1.5. Each time you turn it on, a short double sound alarm occurred, and then reading the settings from non-volatile memory and loading of the graphic user interface (GUI).

6.1.6. If the battery level indicator shows less than 20% and colored by red color, replace the battery immediately.

6.2. Setting the magnetic field sensor configuration up and saving it in acquisition unit memory

6.2.1. Open the sensor positions configuration page of the data acquisition unit (figure 3.19).

6.2.2. Enter the coordinates of the magnetic field sensor units relative to the antenna of the navigation system in units

of centimeters in the appropriate fields. These data will be used to determine the absolute coordinates of the magnetic field measurement points in the GPS/GLONASS system according to the method described in 4.2 of this manual.

The satellite antenna of the receiver integrated in the data acquisition unit is located in the lower right corner of housing of the data acquisition unit.

The satellite antenna of the RTK system receiver is located right under the «Spector» Sci-Tech LLC logo, on the reverse side. The satellite antenna of the base station of the RTK system is also located right under the «Spector» Sci-Tech LLC logo, on the reverse side.

When calculating the coordinates of the measurement points from the odometer readings, the relative displacements of the transducers along the scanning direction are automatically reduced to zero.

6.2.3. To save the configuration of magnetic field sensor unit positions into non-volatile memory of the multichannel magnetic field measurement system the save button «💾» is only need to be pressed.

6.3. Setting up the channels to acquire measured signals into file on acquisition unit built-in memory

6.3.1. Open the recording channels configuration page of the data acquisition unit (figure 3.21).

6.3.2. Check the boxes for those measurement channels whose signals are need to be recorded on the memory card, and then transferred to a personal computer.

Uncheck the channels whose signals should not be recorded on the memory card.

6.3.3. To save the configuration of recording of the measurement channels selected into non-volatile memory of the multichannel magnetic field measurement system the save button «💾» is only need to be pressed.

6.4. Color palette configuration to sweep signals of magnetic field sensors on screen of the acquisition unit

The information quality of color map sweep of fluxgate magnetic field sensor signals measured is determined by the color palette configuration, which is a one-dimensional function that establishes the correspondence between the measured signal value and the color code (figure 4.2).

The color palette configuration performed by setting reference points on the color palette band within the measurement range of fluxgate magnetic field sensor signals, and synthesizing reference colors at the specified points by adjusting the intensity of three basic color components:

6.4.1. Open the color palette panel (figure 3.15).

6.4.2. Specify the position of the reference color in the interactive color palette band, and the dialog box to adjust the reference color basic components will appear (figure 3.16).

6.4.3. Specify the reference color in the dialog box appeared and click «OK» button, and then color palette will be automatically recalculated in accordance with last changes in the set of reference colors.

6.4.4. If removing the reference color from the palette is required, specify it in the table of reference colors and click the button «» to delete the reference color from palette.

6.4.5. If returning to the initial (default) color palette configuration is required, press the «» button.

6.4.6. To save the color palette into non-volatile memory of the multichannel magnetic field measurement system the save button «» is only need to be pressed.

6.5. Adjusting the gain of measured signals

The fluxgate magnetic field sensors measured signals constant offset escaping and then amplification is the essence of signal normalization and is used to construct a graph and color map sweep, as shown in Section 4.1 of this manual.

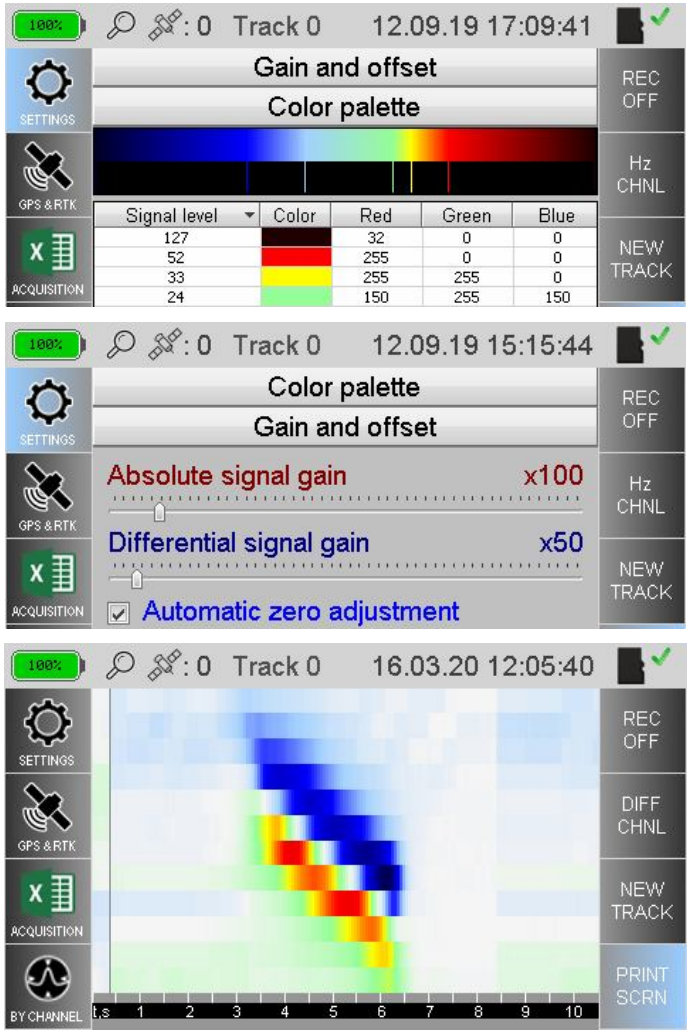


Fig.6.1. Optimal default color palette configuration, amplification factors and the zero offset magnitude

Changing the values of the amplification factors and the zero offset magnitude does not affect the values of the magnetic field vector components and gradient being recorded to the memory card.

6.5.1. Open the amplification factors and zero offset adjustment panel (figure 3.17).

6.5.2. Adjust the gain of fluxgate sensor signals using the «Differential Channel Gain» and «Absolute Channel Gain» controls (for gradiometer magnetic field sensor unit topology) or simply «Gain» (for other sensor unit topologies).

The gain can be considered to be optimal for information quality and visual convenience of a graph and color map sweep, if the largest range of the measured signals after amplification is approximately equal to the range of the color palette scale, but at the same time does not go beyond its limits (figure 6.1).

6.5.3. To save the values of the amplification factors and the zero offset magnitude just set up into non-volatile memory of the multichannel magnetic field measurement system the save button «» is only need to be pressed.

6.6. Setting up the system date and time

The date and time are used in the multichannel magnetic field measurement system when recording the measurements to file; they are also displayed in the status bar.

The system receives current date and time from the GPS/GLONASS satellite system.

Since the date and time of the satellite system are always refers to the zero time zone, according to the standard universal time coordinated UTC, the local time zone should be set to correctly display the date and time.

6.6.1. In order to set the time zone in the settings of the magnetic field measurement system, open the navigation settings panel (figure 3.18);

6.6.2. Set the time zone using the «UP» and «DOWN» buttons of the corresponding knob.

6.6.3. Save the time zone value in non-volatile memory by pressing the save button «».

6.7. Setting up the RTK system, or built-in satellite navigation signals receiver

The accuracy of the built-in navigation receiver is enough to solve most recent problems in the practice, but sometimes (for example, in archeology) the increased accuracy of the navigation system is required.

In case of such requirements, the multichannel magnetic field measurement system has the external RTK system connecting channel.

6.7.1. If accuracy of the built-in receiver will be known enough, then in order to turn it on, open the navigation settings panel and set the GPS switch to the «INT» position.

Keep the acquisition unit of multichannel magnetic field measurement system at open sky condition while optimal configuration of navigation satellites being searched.

The first order data will be obtained about the exact time and date, which will immediately appear in the status bar (figure 6.2, the first from top).

Then the navigation module will select the optimal configuration from the satellites available, which is a sign of a successful launch of navigation process. When this occurred, the number of satellites in the configuration used will appear in the status bar (figure 6.2, in the middle).

When the built-in receiver calculates the coordinates and checks their correctness, they will appear in the terminal window, while the navigation status in the status bar will change its value from «Search for location» to «Location is fixed» (figure 6.2, bottom).

6.7.2. If the absolute displacements of the system required to be measured with increased accuracy, the RTK system should be used. First of all, the RTK base station should be installed on a tripod and then powered on.

6.7.3. Connect the RTK system receiver to the data acquisition unit using the connection cable from the kit.

Fig.6.2. Navigation data output and statuses during the built-in navigation receiver launch process

6.7.4. Wait until the receiver and the base station start up and establish radio communication with each other.

6.7.5. Open the navigation settings panel, set the GPS switch to the «EXT» position and wait for the status «Location recorded with increased accuracy» RTK to appear on the status bar, like to shown in the figure 6.2.

6.8. Setting up the odometer

The data acquisition unit of the magnetic field measurement system has a connector for external odometer, which is designed to measure the relative displacements of magnetic field sensor units in space and synchronize a sweep.

To turn on the odometer, do the following:

6.8.1. Install an odometer on the cart to measure the distance traveled or the depth of the magnetic field sensor under water; connect the odometer to the acquisition unit.

6.8.2. Open the panel for set up the survey mode and measurements synchronization parameters (figure 3.20).

6.8.3. Choose the survey mode by radio button: one-directional or reversive.

6.8.4. Set the measurements synchronization channel selector to the «Odometer» position in order to take measurements at the same distance from each other.

If the measurements synchronization by timer would be selected, then the measurements will be made at regular clock intervals, while the odometer distance will still be measured according to the area survey pattern and written to a file.

6.8.5. In the lower middle window, enter the diameter of the odometer wheel in millimeters, and then select the odometer pitch (also in millimeters).

6.8.6. Save the measurements synchronization parameters and odometer parameters in non-volatile memory by pressing the save button «».

7. WORKING

Before taking measurements, the battery level should be checked by the indicator in the upper left corner of the screen. If necessary, replace or charge the battery.

Wait until the current date and time appears on the screen, while the number of visible satellites must be at least 3, and the navigation status with «Location fixed» value or «Location fixed with high accuracy» (if RTK system used to determine the location).

After performing magnetic survey, the results of measurements can be transferred to a personal computer for reporting according to requirements of regulatory documents.

7.1. Taking the magnetic field survey and mapping in GPS/GLONASS coordinates system

7.1.1. If the manual measurements of magnetic field using one magnetic field sensor unit performed, then «BY CHANNEL» sweep mode should be activated and the channel should be selected which have the sensor unit is connected.

7.1.2. If the measurements need to be performed in the area survey mode, then, select the color map mode of sweep by one of the components of the magnetic field strength vector or gradient by switching «BY CHANNEL» mode off.

7.1.3. Launch and configure the navigation system according to Section 6.7 of this manual, then start the measurement process by clicking anywhere on the sweep.

7.1.4. Perform the measurements on the region under survey and stop by pressing anywhere on the sweep again.

7.1.5. If, as a result of the measurements, no significant signals from the expected magnetic anomalies are observed, and the background color of the color map is uniform and corresponds approximately to the middle of the color palette scale, then the gain factor should be increased along the corresponding measurement channel.

If an approximately uniform or non-uniform color background is observed on the screen, which corresponds mainly to the upper or lower border of the color palette, then gain factor should be reduced and compensation (zeroing) of the measured signals should be repeated, or automatic zeroing function enabled according to Section 6.5 of this manual.

7.1.6. Repeat the measurements at the area under survey and explore the graphs measured for anomalies.

7.1.7. If necessary, a screenshots of the signals from magnetic anomalies detected can be taken, or recording the measured signals of fluxgate magnetic field sensors performed to a memory card according with Section 7.5 of this manual.

When area scanning performed with reference to the GPS/GLONASS system, the signals recording can be performed continuously, but this is not recommended, because the file size resulting may be turn out too large, which can subsequently lead to inconvenience when processing it on the computer. Therefore, it is recommended to record the signals during area survey by profiles: one profile – is a one file.

Moreover, the shapes of scan profiles and the order of their passage does not matter, because the absolute coordinates of each measurement point are calculated at each step automatically, considering the direction of movement at a given time in accordance with Section 4.2 of this manual.

7.2. Taking the magnetic field survey using odometer in one-directional survey mode

Recording of the data measured into a file during area surveying is usually performed according to profiles (tracks): one profile – is a one file. In addition, each track corresponds to one series of measurements performed along the region, from its beginning to the end.

7.2.1. Select a one-directional area scanning mode and configure its parameters according to Section 4.3 of this manual. The track counter will be automatically reset to 0.

7.2.2. Close the settings window; enable recording of the data measured to a file by pressing the «RECORD» button.

7.2.3. Start the measurements by clicking on the sweep.

7.2.4. Scan the first profile according to one-directional pattern in figure 4.7 and record the signals measured; then stop the measurements by pressing anywhere on the sweep.

7.2.5. Disable the recording of the data measured into the file by pressing the «RECORD» button again.

7.2.6. Return to the starting point of the next track (profile) according to the one-directional motion pattern in figure 4.7 and press «NEW TRACK» button.

7.2.7. Continue to follow Sections 7.2.3 – 7.2.6 until the entire area under survey has been covered.

7.3. Taking the magnetic field survey using odometer in reversive survey mode

The difference between the reversive area surveying pattern and the one-directional one is that in order to start the next measurement profile, it is not necessary to return to the beginning of the area under survey.

7.3.1. Select a reversive area scanning mode and configure its parameters according to Section 4.3 of this manual. The track counter will be automatically reset to 0.

7.3.2. Close the settings window; enable recording of the data measured to a file by pressing the «RECORD» button.

7.3.3. Start the measurements by clicking on the sweep.

7.3.4. Scan the first profile according to reversive motion pattern in figure 4.7 and record the signals measured; then stop the measurements pressing anywhere on the sweep.

7.3.5. Disable the recording of the data measured into the file by pressing the «RECORD» button again.

7.3.6. Return to the starting point of the next track (profile) according to the reversive motion pattern in figure 4.7 and press «NEW TRACK» button.

7.3.7. Continue to follow Sections 7.3.3 – 7.3.6 until the entire area under survey has been covered.

7.4. Taking the survey in borehole / underwater

7.4.1. Mount the odometer on the solid basement and fix it carefully, connect it to the data acquisition unit of the multichannel magnetic field measurement system and adjust its parameters according to Section 6.8 of this manual.

7.4.2. Pass the sensor cable through the odometer wheel so the cable length is counted when the sensor unit is dived into water or injected into the borehole.

7.4.3. Turn on the «BY CHANNELS» mode, select the channel number of the magnetic field sensor unit connected.

7.4.4. Start the measurements by clicking on the sweep.

7.4.5. Make measurements on the area under survey and stop the measurements pressing again on the sweep.

7.4.6. If, as a result of the measurements, no significant signals from the expected magnetic anomalies are observed, then the gain factor should be increased along the corresponding measurement channel.

If the graphs partially or completely extend beyond the screen, then gain should be reduced or repetitive compensation (zeroing) of the measured signals should be made.

7.4.7. Repeat the measurements at the area under survey and explore the graphs measured for anomalies.

7.4.8. In order to start record the results of magnetic field measurements into a file, the measurements should be stopped firstly by clicking anywhere on the sweep, and then a set of channels to signals from be written to the file should be configured as shown in figure 3.21.

7.4.9. Close the settings window; enable recording of the data measured to a file pressing the «RECORD» button.

7.4.10. Start the measurements clicking on the sweep.

7.4.11. Take the measurements on the area under survey, stop by pressing again anywhere on the sweep.

7.5. Recording the measured signals and making print screens on the acquisition unit built-in data storage

The «Triton» multichannel magnetic field measurement system has a high-capacity flash memory card preinstalled to store large volumes of measured data in Surfer software format, also instant screenshots.

7.5.1. To record signals during measurements, press the «RECORD» button. The status of the button will change from «RECORDING OFF» to «RECORDING ON», and in the folder «__DATA__» a text file will be created under the name «DDMMYYYY-hhmmss.csv», where DD/MM/YYYY is the current date (day, month and year), hh:mm:ss – is time (hour, minute, second) at the begin of recording moment.

The measurement results of fluxgate sensor signals by the configuration of the recording of the measurement channels (figure 3.21), the coordinates in the GPS/GLONASS system determined, as well as the odometer counts will be recorded in the file created until the recording will not be stopped by pressing the «RECORD» button again.

7.5.2. To take a snapshot of the screen and save it on a flash memory installed inside of the data acquisition unit in the form of a raster image, press the «PRINT SCRN» button. An image file will be created under the name «DDMMYYYY-hhmmss.bmp» in the root directory, where DD/MM/YYYY is the current date (day, month and year), hh:mm:ss – is the time (hour, minute, second) at the time of taking the screenshot.

7.5.3. The universal location of the «PRINT SCRN» button on the side of the touch screen allows taking screenshots of any interface elements, including not only sweep, but also settings panels and dialog boxes. Therefore, it is reasonable that all the screenshots presented in this manual are made using the «PRINT SCRN» button.

7.6. Transferring the recorded data and printed screens from acquisition unit to personal computer, and creating the maps using Surfer and Google Earth software

Records of the magnetic field vector and gradient components signals measured, as well as screenshots of the magnetic anomalies detected, can be used in documenting the results of the magnetic survey. For this purpose, data must first be transferred to a personal computer.

7.6.1. Stop the measurements by clicking anywhere on the sweep. The data acquisition unit of the magnetic field measurement system will turn into a standard flash disk device, which can be connected to a personal computer via USB and used as a convenient USB flash disk.

7.6.2. Connect the data acquisition unit to a personal computer using the USB connection cable from the multichannel magnetic field measurement system toolkit.

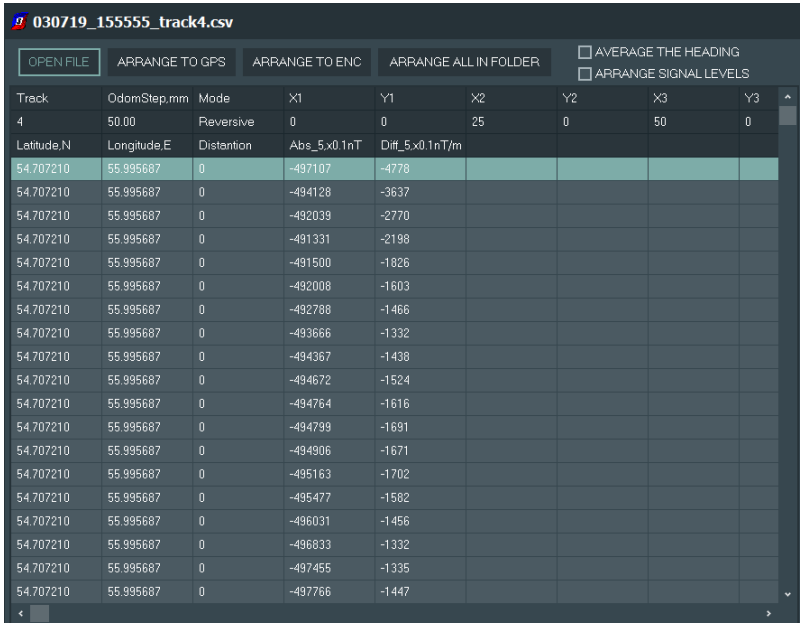
7.6.3. Wait until the operating system of the personal computer recognize the type and class of the device connected, while a new disk device called «Multichannel Fluxgate System» appears on the taskbar and in the file explorer.

7.6.4. Open this disk device in the file explorer and copy the necessary data from it in the usual way.

7.6.5. If necessary, you can delete unnecessary files from the disk, or clean it completely, or save useful information on it, for example, samples of forms and acts, photographs of detected magnetic anomalies, regulatory documents, etc.

7.6.6. At the end of the file transfer, safely remove the disk device. When the measurement process will be turned on again, the «USB Mass Storage Class» mode will be disabled automatically, while the multichannel magnetic field measurement system continues to operate normally.

7.6.7. Launch the «SurferCvt.exe» application on the computer (figure 6.3) and open one of the copied files in it by pressing the «OPEN FILE» button.



Track	OdomStep,mm	Mode	X1	Y1	X2	Y2	X3	Y3
4	50.00	Reversive	0	0	25	0	50	0
Latitude,N	Longitude,E	Distantion	Abs_5,x0.1nT	Diff_5,x0.1nT/m				
54.707210	55.995687	0	-497107	-4778				
54.707210	55.995687	0	-494128	-3637				
54.707210	55.995687	0	-492039	-2770				
54.707210	55.995687	0	-491331	-2198				
54.707210	55.995687	0	-491500	-1826				
54.707210	55.995687	0	-492008	-1603				
54.707210	55.995687	0	-492788	-1466				
54.707210	55.995687	0	-493666	-1332				
54.707210	55.995687	0	-494367	-1438				
54.707210	55.995687	0	-494672	-1524				
54.707210	55.995687	0	-494764	-1616				
54.707210	55.995687	0	-494799	-1691				
54.707210	55.995687	0	-494906	-1671				
54.707210	55.995687	0	-495163	-1702				
54.707210	55.995687	0	-495477	-1582				
54.707210	55.995687	0	-496031	-1456				
54.707210	55.995687	0	-496833	-1332				
54.707210	55.995687	0	-497455	-1335				
54.707210	55.995687	0	-497766	-1447				

Fig.6.3. Main form of the «SurferCvt» application

7.6.8. Set «AVERAGE THE HEADING» checkbox enabled if you want to enable the function of automatic averaging of heading of the profile over all points, which increases the accuracy of determining the heading by GPS coordinates if the profile was carried out along a straight path (figure 6.4).

If the area survey was performed along a curved path, then do not enable «Average the heading» checkbox, however switch it in disabled state.

7.6.9. Set «ARRANGE SIGNAL LEVELS» checkbox enabled to align the levels of absolute signals between the profiles to obtain a more uniform picture of the magnetic field in the «Surfer» software application (figure 6.5).

7.6.10. Press the «ARRANGE ALL IN FOLDER» button to convert all entries in this folder to Surfer software format. The application will open all the files in an open folder

one by one, automatically calculate the coordinates of the measurement points and combine the results. The results of the conversion of the measured data will be saved out to 4 text files (if gradiometer sensor unit configuration is used):

enc_abs_data.txt, enc_diff_data.txt – absolute value and gradient of vertical magnetic field component measurements referenced to the odometer distance covered;

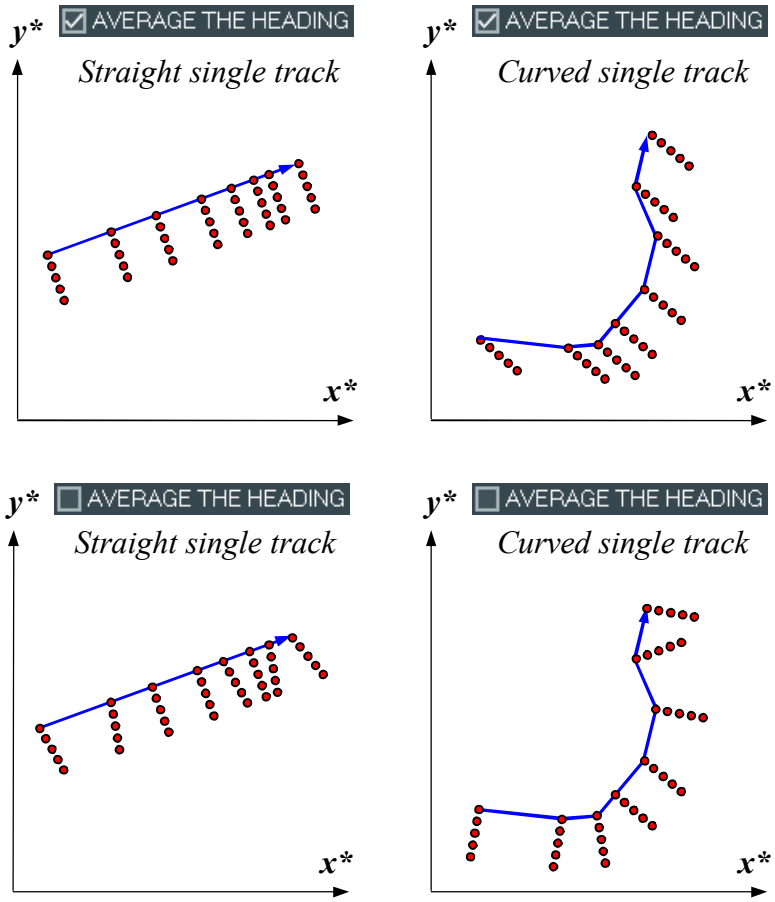


Fig.6.4. «Average the heading» function working principle

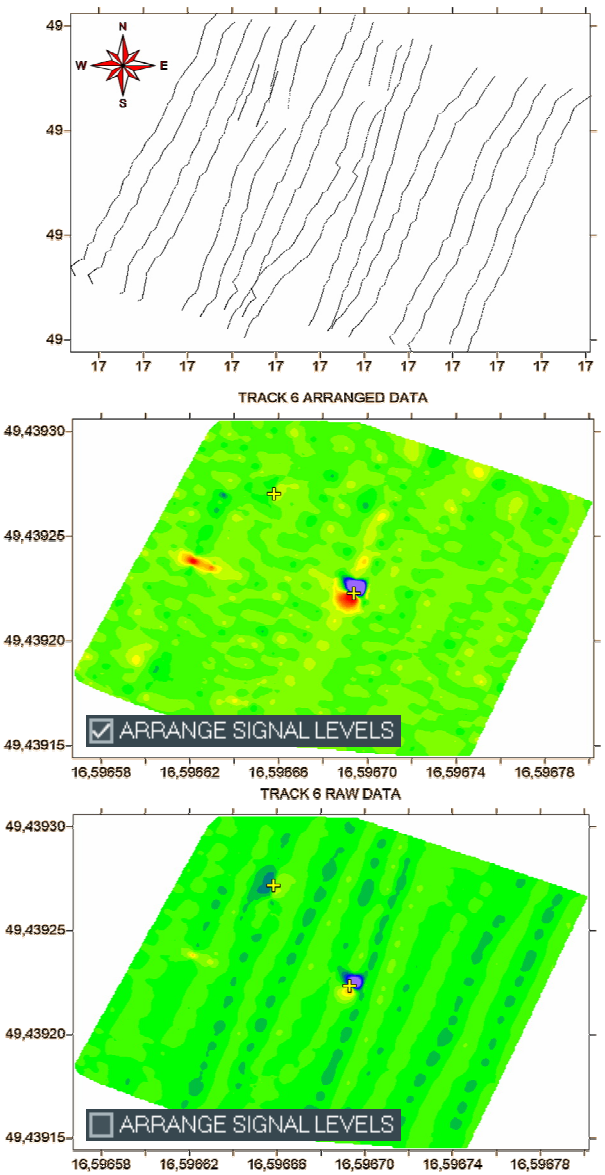


Fig.6.5. «Arrange signal levels» function working principle

gps_abs_data.txt, gps_diff_data.txt – absolute value and gradient of vertical magnetic field component measurements referenced to the GPS/GLONASS coordinates.

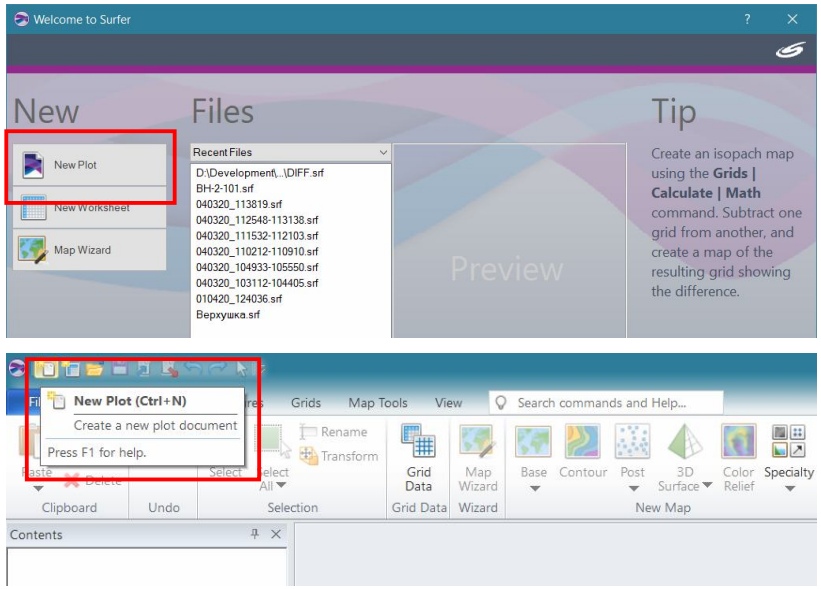
If 3-component sensor unit configuration is used then results of the conversion of the measured data will be saved out to 6 text files:

enc_Hx_data.txt, enc_Hy_data.txt, enc_Hy_data.txt – magnetic field vector components measurements referenced to the odometer distance covered;

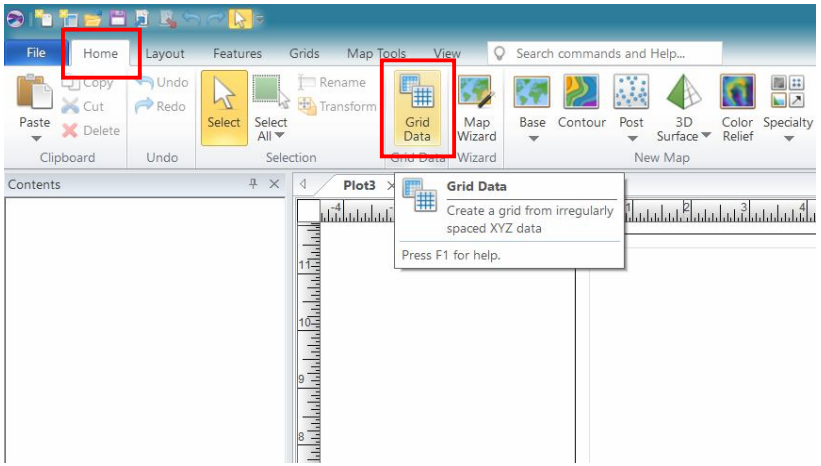
gps_Hx_data.txt, gps_Hy_data.txt, gps_Hy_data.txt – magnetic field vector components measurements referenced to the GPS/GLONASS coordinates.

The resulting files can be opened and analyzed in the Surfer software application.

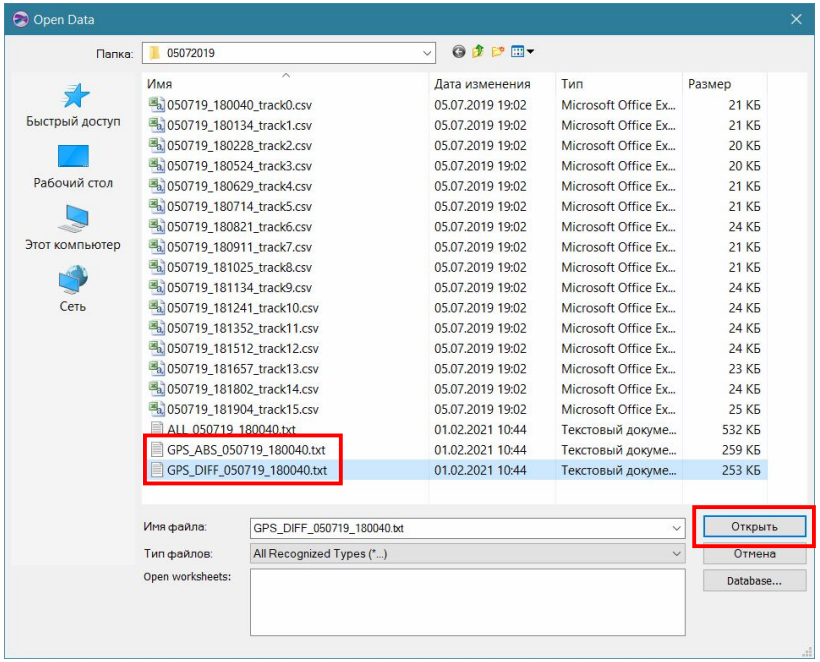
7.6.11. Launch the Surfer software application, and then choose «New Plot» in start window or control panel:



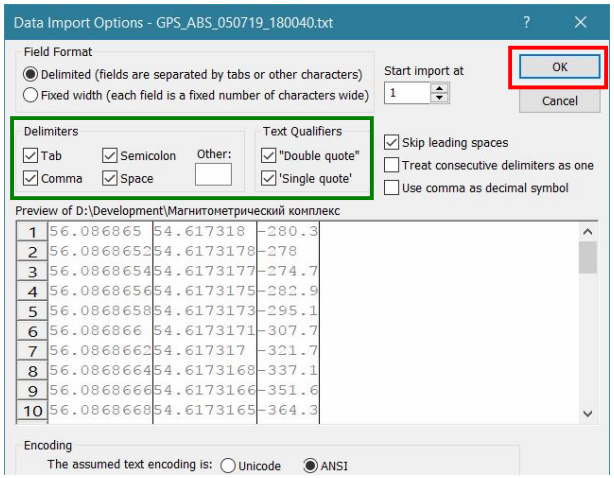
7.6.12. Choose «Home» – «Grid Data» command:



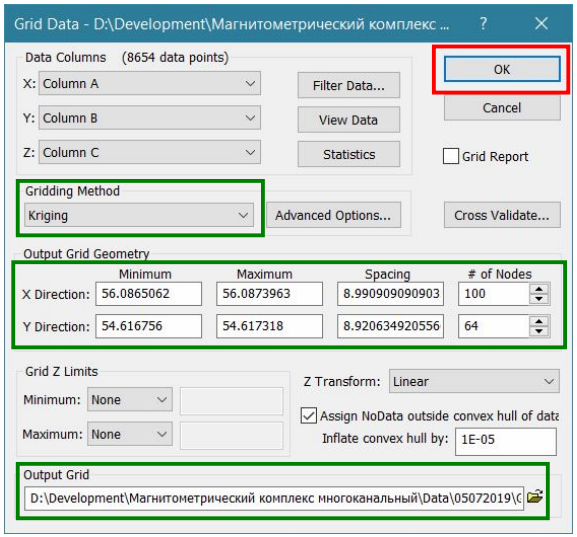
7.6.13. Choose the data file **gps_diff_data.txt** in file explorer window, and then press «Open»:



7.6.14. Import data window does not require any actions or adjustments, just press «OK»:

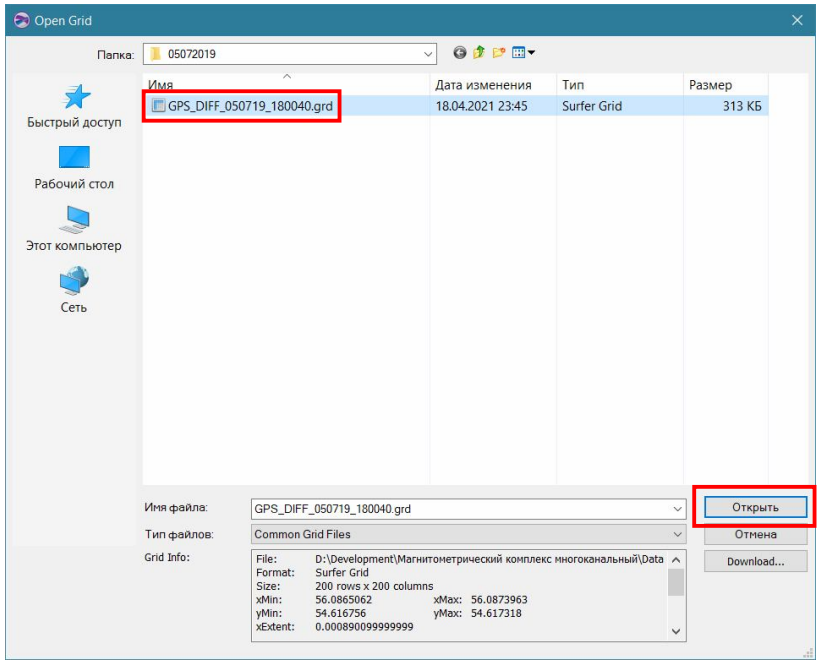


There is possibility of improve the resolution of the resulting map of the magnetic field gradient/components, by increasing the number of Nodes or choosing optimal Gridding Method, if need (however, not necessary).

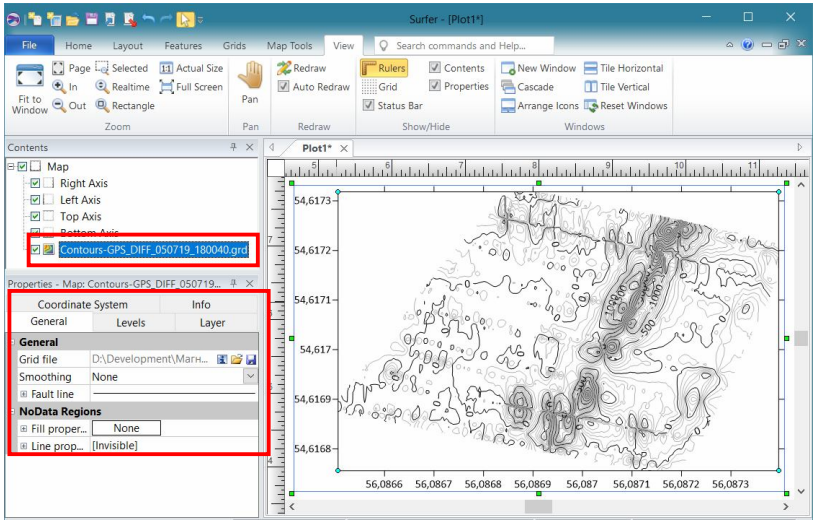


7.6.15. The grid file **gps_diff_data.grd** then appeared on specified path, which is already Surfer map. Choose «Home» – «Contour» command in order to open it:

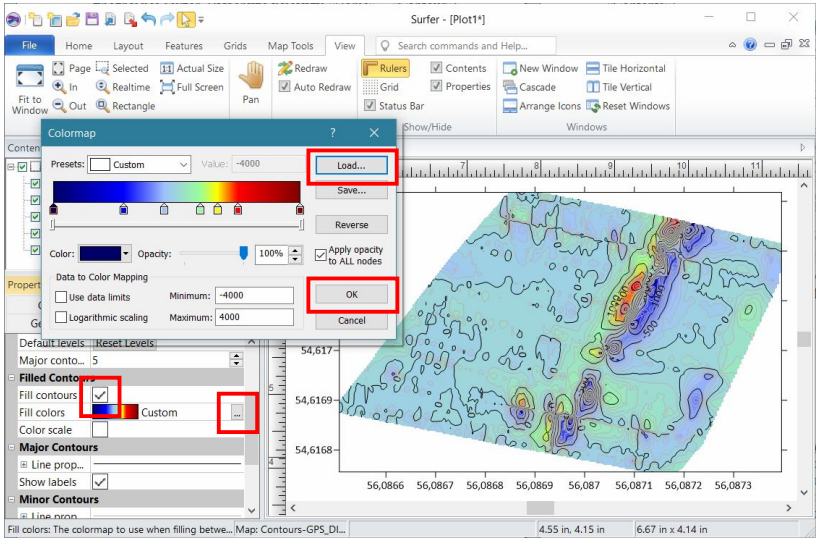
7.6.16. Choose the grid file **gps_diff_data.grd** in file explorer window, and then press «Open»:



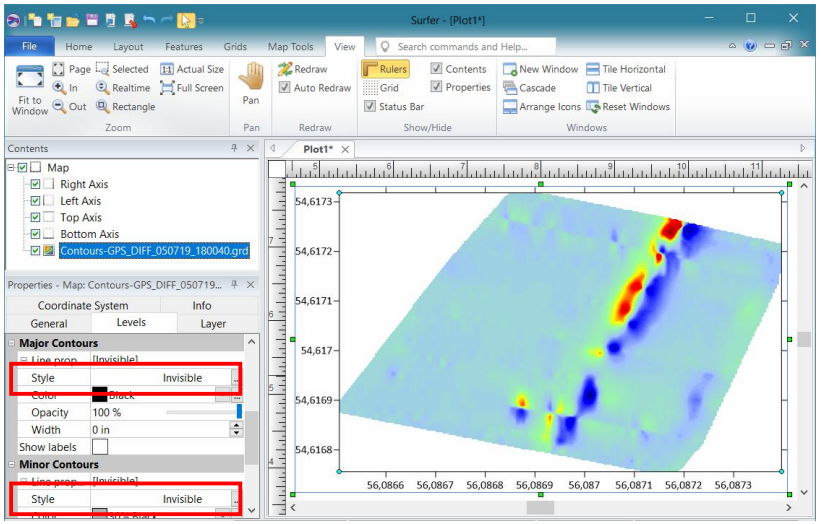
7.6.17. Go to the contour map settings by click on the appropriate item in «Contents» window:



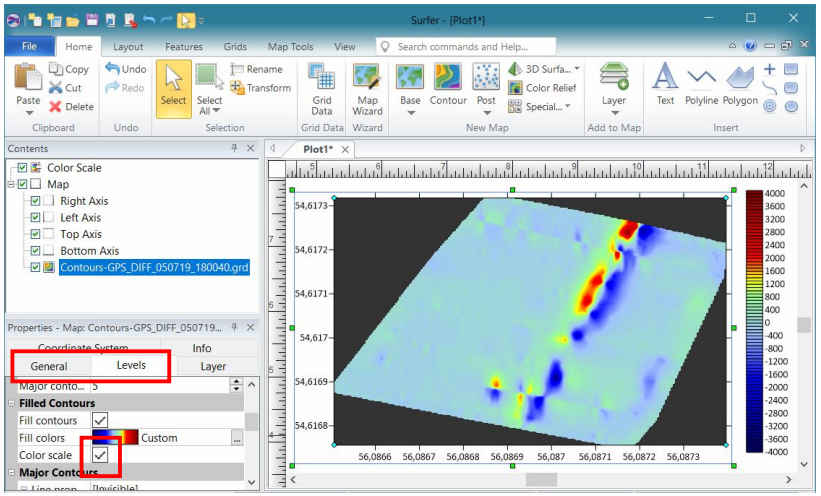
7.6.18. Set up the color palette parameters in «Levels» page: enable «Fill Contours», and then open «Fill Colors» window, choose the custom palette file or one default schemes:



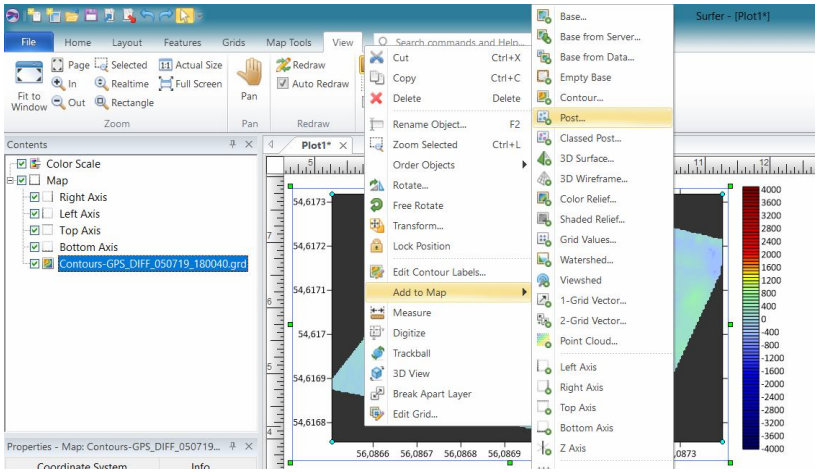
7.6.19. Contour curves can be hidden if need, by setting the «Style» property of the «Major/Minor Contours» objects to «Invisible» state:



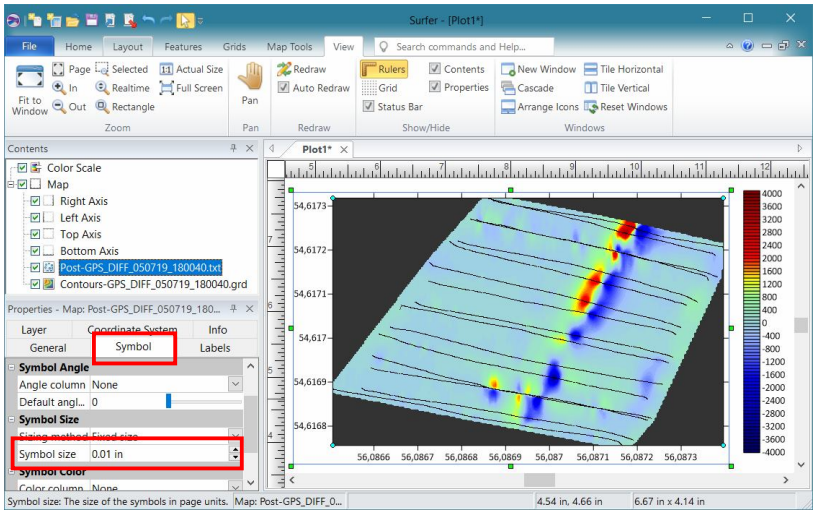
7.6.20. Also legend (page «Levels» – «Color Scale» property) and background filling (page «General» – «NoData Regions» property) can be added on the map if need:



7.6.21. Tracks and measurement points can be added to the map like top layer by right click on the diagram and choose «Add to Map» – «Post…», and then follow instructions of the master. No parameter changes and additional actions required.

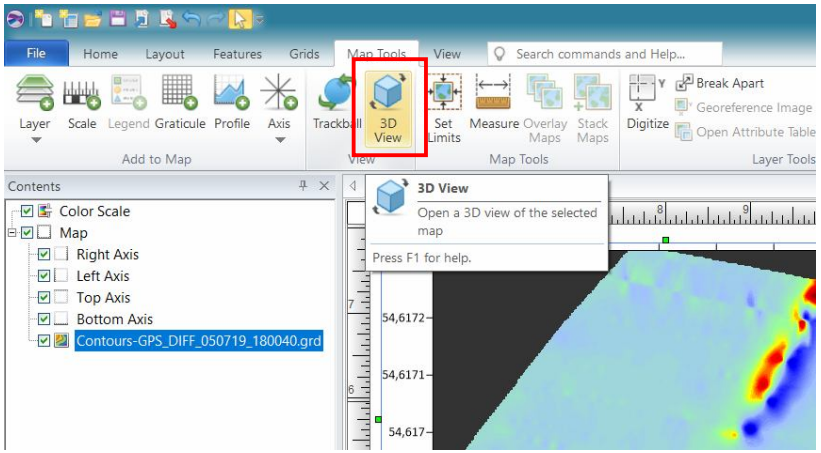


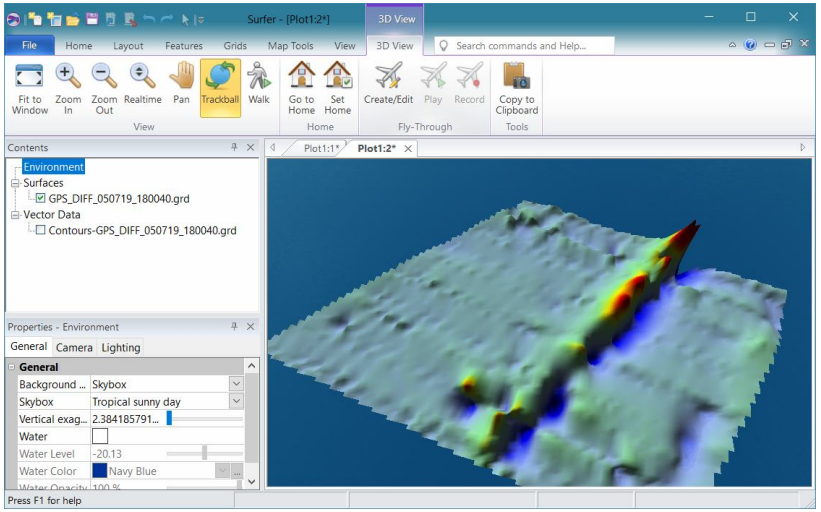
7.6.22. Adjust the optimal size of point symbol, type, color, frequency, transparency, and other properties of the Post object just created:



7.6.23. Save the Surfer magnetic field gradient map file just created applying the «File» – «Save/Save As» command.

7.6.24. In order to see the data as 3D surface, choose the «3D View» mode on the «Map Tools» control panel:

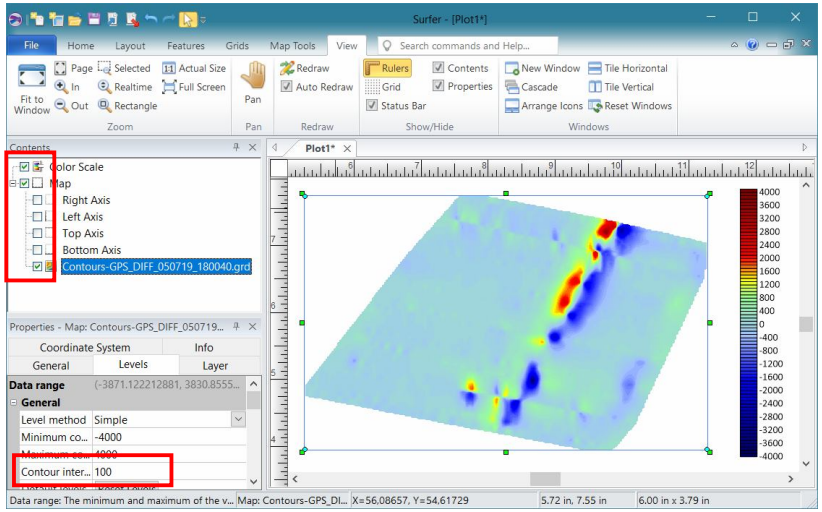




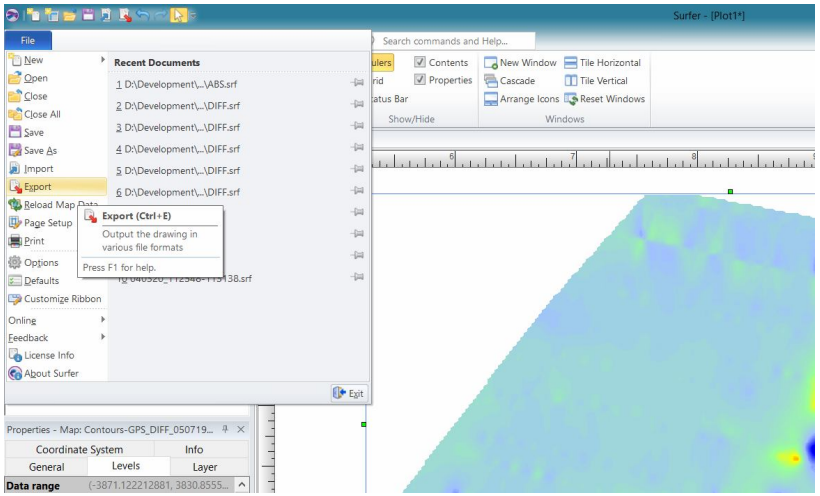
7.6.25. The same way, proceeding steps 7.6.12 – 7.6.23 on remaining data files, the maps of remaining measured magnetic field vector components H_x, H_y, H_z can be created.

Obtained maps of measured magnetic field vector gradient and components can be integrated with realistic model of the Google Earth planet.

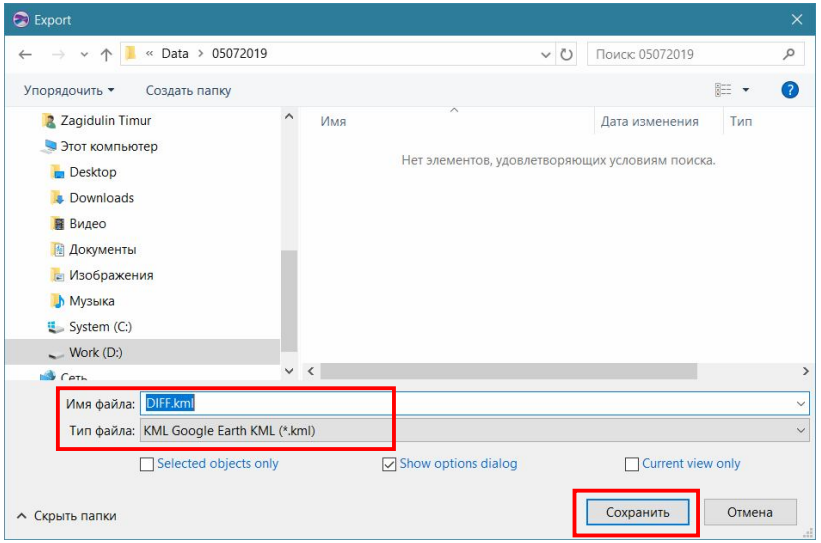
7.6.26. Before integration all unused elements should be removed from the map: axes, background filling, etc.



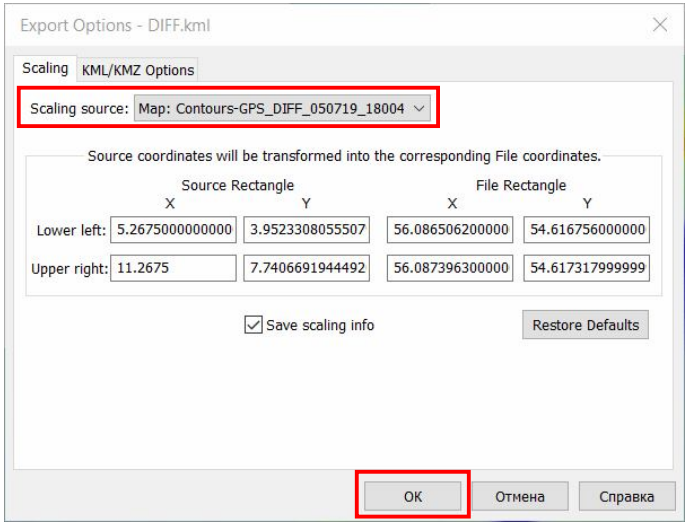
7.6.27. Choose «File» – «Export» command:



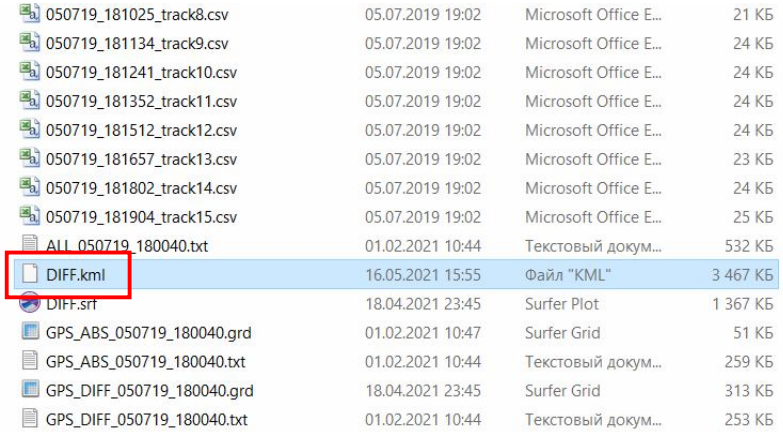
7.6.28. Enter the filename, and then choose «KML Google Earth KML» data output format, and click «Save»:



7.6.29. Select the grid file **gps_diff_data.grd** as scaling source of the output data, and then click «OK»:

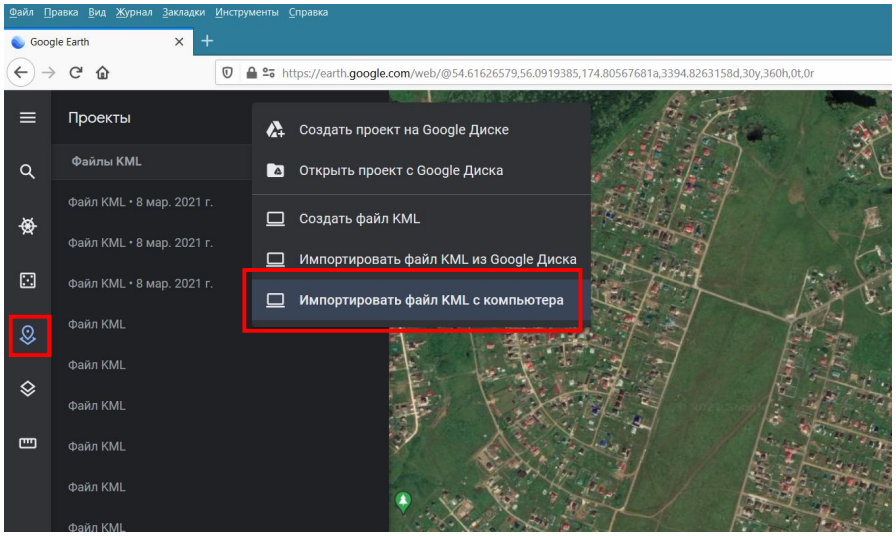


7.6.30. KML file is now ready for integration with the Google Earth realistic model of the planet.

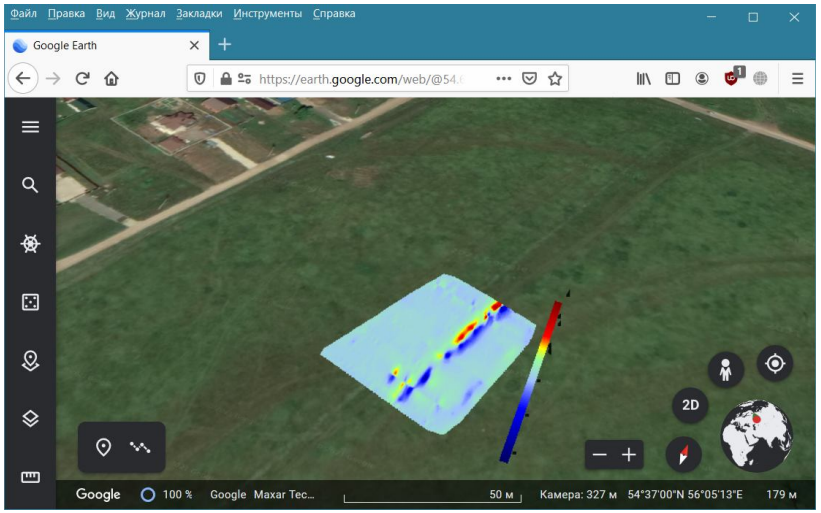


7.6.31. Open the Google Earth service in your browser on https://earth.google.com, or in desktop software application.

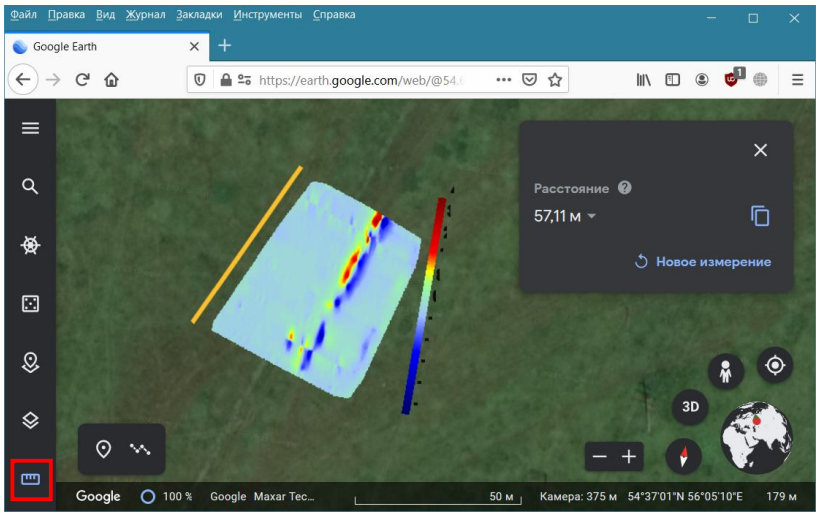
Open your projects page, choose the command «New project» – «Import KML file from computer», and finally, browse the target KML file in explorer window:



7.6.32. Result of magnetic survey data integration with the Google Earth realistic model of the planet:



7.6.33. The model obtained can be rotated to be learned from different points of view, compared with the landscape, as well as measured using built-in interactive «Ruler» tool:



7.7 Replacing and recharging accumulator battery

As the accumulator battery charge level goes low, the readouts of the charge level linear indicator in the status bar also decrease, and when the minimum acceptable threshold level is reached, the power supply of the magnetic field measurement system will be automatically turned off.

It is necessary to replace the discharged battery in time with a new one, and charge the discharged one.

7.7.1. Turn the power switch of the data acquisition unit to the «OFF» position.

7.7.2. Open the battery compartment and remove the discharged battery out, disconnect it from the power connector, charge it using the charger from the toolkit of the multichannel magnetic field measurement system.

7.7.3. Connect new battery to the power connector inside the battery compartment on the back of the data acquisition unit. Insert the battery into the compartment and snap the battery cover into place.

At the same time, the indicator of the charger will light up in red, which means that the microprocessor built into the charger has successfully tested the battery and started the process of charging it.

After the battery charging process has been successfully completed, the charger indicator light will turn green again.

7.7.4. Set the power switch of the data acquisition unit to the «ON» position, marked with a dot. The «Triton» multichannel magnetic field measurement system is ready for operation.

7.7.5. When accidental mechanical damage of the battery occurred, or its failure, it is necessary to contact the manufacturer of the multichannel magnetic field measurement system for its disposal and replacement.

8. MAINTENANCE

8.1. Maintenance of «Triton» multichannel magnetic field measurement system is only performed by technical personnel from the departments of the instrumentation workshop or similar.

8.2. Maintenance of multichannel magnetic field measurement system consists of routine inspection, preventive maintenance and routine maintenance.

8.3. The frequency of scheduled inspections is established depending on the production conditions, but at least once a month. During a routine inspection, the all mountings, the state of the controls and paintwork, the integrity of the data acquisition unit housing and magnetic field sensor units are checked.

8.4. Scheduled preventive maintenance of the multichannel magnetic field measurement system is performed after the warranty period has expired and at least once a year.

Repairing includes a visual inspection of the multichannel magnetic field measurement system, inspection of the internal state of mounted items, checking the reliability of electric contacts and joints, removing dust and dirt.

All types of work are performed, the need for which was identified during a routine inspection of the magnetic field measurement system. In case of failure of the electronic components of the magnetic field measurement system circuits, they must be replaced.

8.5. Current maintenance is performed during the operation of the magnetic field measurement system. This eliminates the malfunctions observed during the routine inspection by replacing or restoring individual parts of the magnetic field measurement system (replacing electronic components, restoring broken electrical connections, etc.).

9. TROUBLESHOOTING

Possible troubles of magnetic field measurement system and ways for to fix them are given in table 1.

Table 1.

Possible trouble	Most like reason	Way to fix
There is no information on the screen when turning on the power	The battery is low.	Replace or recharge the battery.
Saving to a memory card does not work, the memory card indicator in the status bar lights up in red	1. The file system structure is broken. 2. Missing or defective memory card in holder.	Remove the memory card and format it on the computer. Replace the memory card.
When connected to computer via USB, the data acquisition unit is not recognized	1. The process of measurement is does not stopped. 2. The file system structure is broken. 3. A break inside the USB cable occurred.	Stop the measurements clicking anywhere on the sweep. Remove the memory card and format it on the computer. Repair or replace the USB cable.

Odometer measurement synchronization does not work	1. The odometer used is broken. 2. Process of measurements is stopped.	Replace the odometer. Start the measurements clicking anywhere on the sweep.
The date and time does not displayed on the status bar At the same time, the GPS system cannot fix the location	1. If the RTK channel is on, the RTK system receiver is not connected to the acquisition unit. 2. Poor satellite signal reception due to bad weather conditions or radio frequency interference: 2.1. If the RTK channel is on, the RTK receiver is connected to the control unit. 2.2. RTK channel is disabled, built-in GPS receiver is used	Connect the RTK system receiver to the data acquisition unit. Wait for a clear weather, remove sources of radio frequency interference in the surroundings of magnetic field measurement system.
Recording on one or several channels does not work	Recording on one or several channels is disabled	Enable missing channels in the «FILE» window

Indications on one or several channels are not displayed, or disappeared after the some time	1. Scanning speed too high when synchronizing measurements on odometer signals. 2. A break inside the sensor cable. 3. One or more magnetic field sensor unit is broken.	Decrease the scan speed or increase odometer pitch. Find the cable break point and repair it. Replace broken magnetic field sensor unit.

10. STORING AND TRANSPORTATION

10.1. Transportation of the «Triton» multichannel magnetic field measurement system should strictly provided that the power switch of the on the data acquisition unit is in the «OFF» position.

At this time the accumulator battery may be contained inside the battery compartment, or outside from it.

10.2. It is allowed to transport a packaged multichannel magnetic field measurement system in closed railway carts or containers, in the cars, as well as inside of the heated compartments of aircraft.

10.3. The packed magnetic field measurement system must be fixed in vehicles, and when using open vehicles, in case of short-term transportation, they should be protected from atmospheric precipitation and water.

10.4. Placement and fastening of the packed magnetic field measurement system in vehicles should ensure their stable position, exclude the possibility of collision with other objects, as well as on the walls of the vehicle.

10.5. Transportation Conditions:

– surrounding temperature, ºC: .....from –20 to +70

– relative air humidity at +35ºC temperature, %:.....95

10.6. Multichannel magnetic field measurement system in transport packaging withstands mechanical loads with up to 15 m/s^2 acceleration at the frequency from 10 to 120 heats per minute, or 7500 hits at the same acceleration.

10.7. The packed multichannel magnetic field measurement system should be stored with the power switch on the data acquisition unit turned off, on racks in a dry room with no presence of acid, alkali and other aggressive substances in the air.

At this time, the battery may be inside the battery compartment, or separately from it.

10.8. Storage conditions regarding the impact of environment factors must comply with the requirements of Appendix "L" of the GOST 15150-69.

10.9. Placing the multichannel magnetic field measurement system in the storage should ensure its free movement and access to it.

10.10. When storing the «Triton» multichannel magnetic field measurement system for more than 6 months, it should be freed from transport packaging and kept in consumer packaging in accordance with the conditions above described.