НАУКИ О ЗЕМЛЕ

MARINE COMPONENT GRADIENTOMETER

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ABSTRACT
The paper describes the design of an experimental sample of the marine component gradientometer for hydromagnetic observations, which allows to measure the gradient not only of the module of the Earth magnetic field, but also its components using rigid or flexible measuring bases of varying lengths and positions.

Keywords: magnetic field, hydromagnetic survey, magnetometer, gradientometer, magnetic sensor, towed gondola

INTRODUCTION

The gradientometric method of the Earth magnetic field (**EMF**) studying [1, 2], one of the main uses for hydromagnetic survey (**HMS**), is implemented by synchronizing measurement of the module or the component values of magnetic induction vector (**MIV**) by sensors spread to some distance ("measuring base" - **MB**), and the subsequent calculation of the field gradient in the direction of this measuring base. The ratio of module increments and MIV components to the distance between measuring points (measuring sensors) allows us to estimate the derivative fields by the vector directions that connect these measuring points. Compared to modular HMS, the gradientometric method of shooting has a higher resolution and sensitivity to the earth's local anomalous magnetic field. At the same time, its main advantage is the ability to obtain observations and data that are free from the influence of geomagnetic temporal variations [3].

The paper describes the design of an experimental sample of the marine component gradientometer (**MCG**) for hydromagnetic observations, which allows to measure the gradient not only of the module of the EMF, but also its components using rigid or flexible measuring bases of varying lengths and positions. The MCG's scheme solution allows you to control and fix the parameters of towing - speed, position and depth of immersion of towed gondolas (**TG**).

The device is designed for relative measurements of the magnetic field in space at points and gradient between them in marine conditions, including can be used effectively to search for ferromagnetic objects.

THE DEVICE DESIGN

The device includes two main parts connected by a towed cable - a fence and a board. The MCG functional scheme is presented in ***Fig.1***. The onboard part of the device includes a power supply (**PS**) and a personal computer (**PC**) and is installed on board the tow ship. The hull part of the device includes two towing cables (**TC**) and two submersible gondolas (**SG**), which are towed at a distance (to eliminate the impact of the ship's magnetic mass) at least three lengths of the tugboat's hull from its stern. At the same time, the speed of towing gondola is limited to the range of 3 to 10 knots at the allowable amplitude of sea excitement no more than 5 points.

The general appearance of individual parts of the device and the scheme of its use for hydromagnetic survey are shown respectively in ***Fig.2a*** and ***Fig.2b***. The submersible gondola is designed to be able to tow at horizons and depths of up to 130 m. The overall view of gondolas and its dimensions are shown on ***Fig.3***. The depth of immersion of each of submersible gondolas is fixed with the help of a built-in hydrostatic pressure sensor (**HPS**), which allows to have information about the course and depth of towing gondolas with an accuracy of no less than 0,2 m.

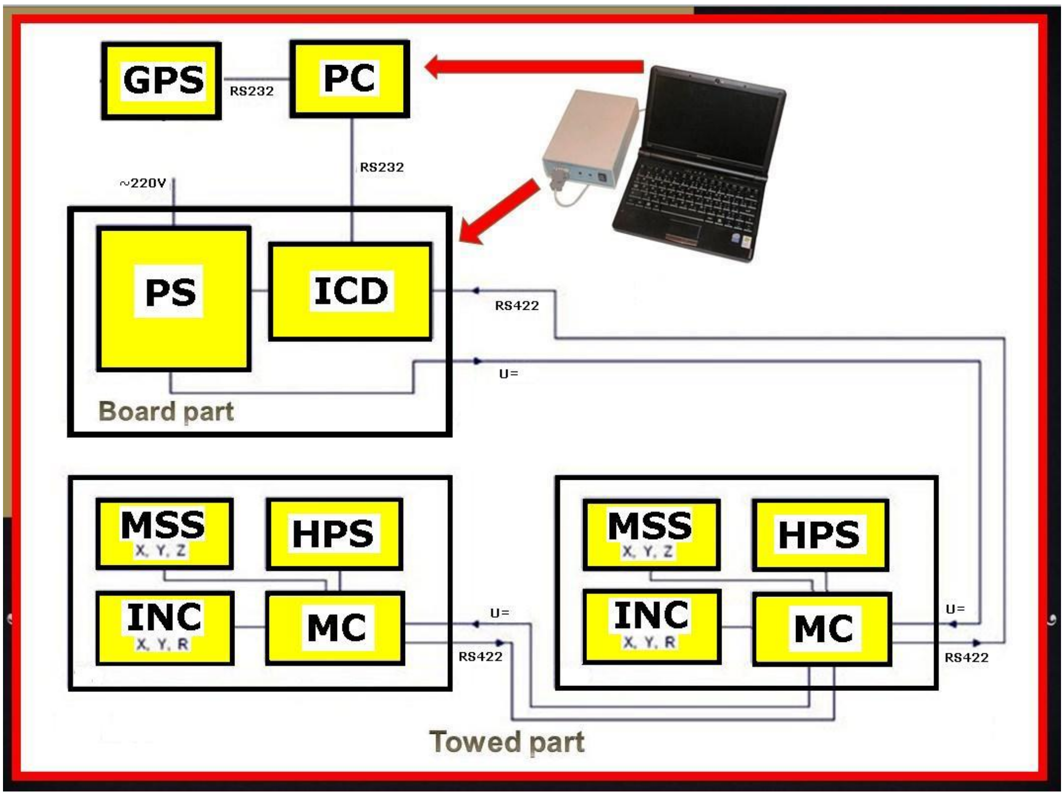

Fig.1. The MCG functional scheme.

The block-scheme of the measuring part of the MCG (*measuring module* - **MM**), which is located in each of the towed gondolas, is shown in ***Fig.3a***. The measuring module includes a microcontroller (**MC**), inclinometer (**INC**) and magnetic sensor (**MSS**). The measurement of the EMF components of the VMI and the gradient between them is carried out using (see ***Fig.1***) two analog three-component fluxgate magneto-sensitive sensors (**MSS**) such as FLC3-70 [4]. Analog signals, which come from each of the three measuring channels of both MSS corresponding to the components of the EMF, are converted (see ***Fig.3a***) into digital code using a 24-bit analog-digital converter (**ADC**).

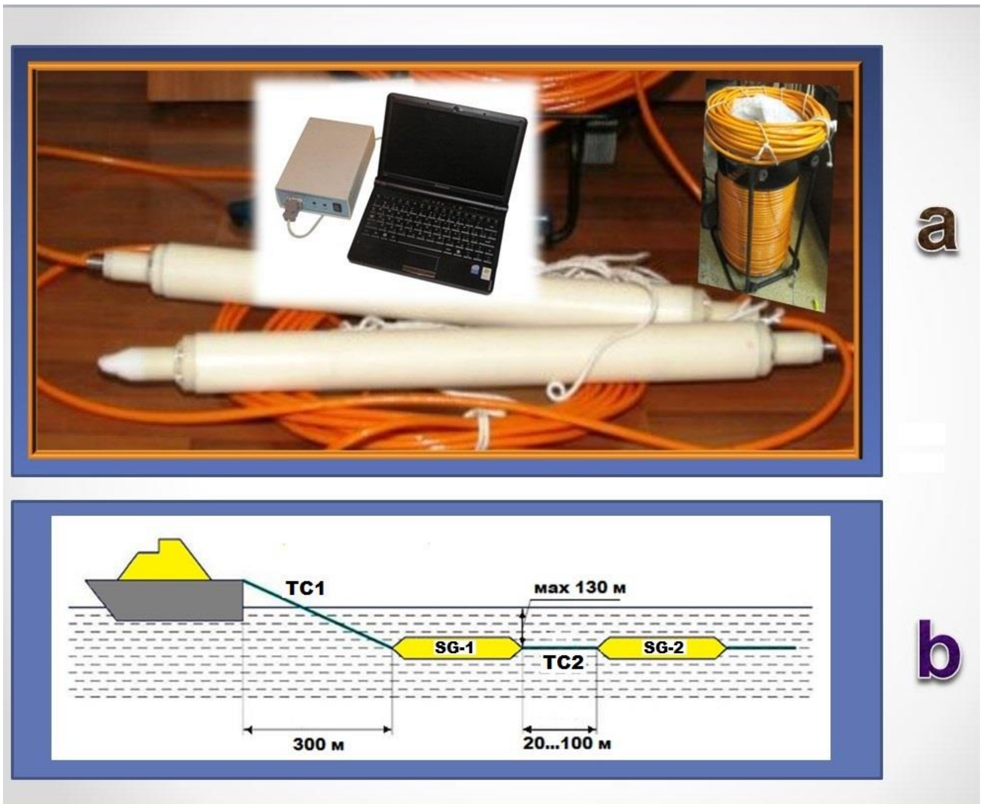

Fig.2. General view of the board and towed parts of the MCG (a) and the towing scheme (b).

A two-part inclinometer, which contains two devices to measure the angle of inclination, is used to control the spatial orientation of the MSS. Inclinometer X, Y measures deviations from the horizontal plane passing through the axial line of the gondola and perpendicular "vertical" of gondola, the R inclinometer measures the angle of tilt (*rotation*) of the gondola in the plane, perpendicular axial line. The location of the inclinometers relative to the MSS in gondola is shown in ***Fig.3b***. The inclinometers measure the angles of the roll and the different of towed gondolas, with the accuracy of these measurements being **0,1** angular degree. As shown above, digital HPS is used to control the depth of towed gondolas, which is located (see ***Fig.3g***) inside the SG at the maximum distance from the magnetic sensors. The sensitive element of HPS is connected by channel to the external environment (*water*).

Information from each towed gondolas on the sequentially RS422 interface is transmitted by cable on board the ship. Passing through the overboard interface conversion device (**ICD**), which is part of the PS (see ***Fig.1***), the data is converted to the RS232 standard and delivered to the PC. Software uses data to be collected and processed and visualized in one form or another on a PC screen. For precise time binding of current measurements, a GPS receiver is connected to the COM port of the computer.

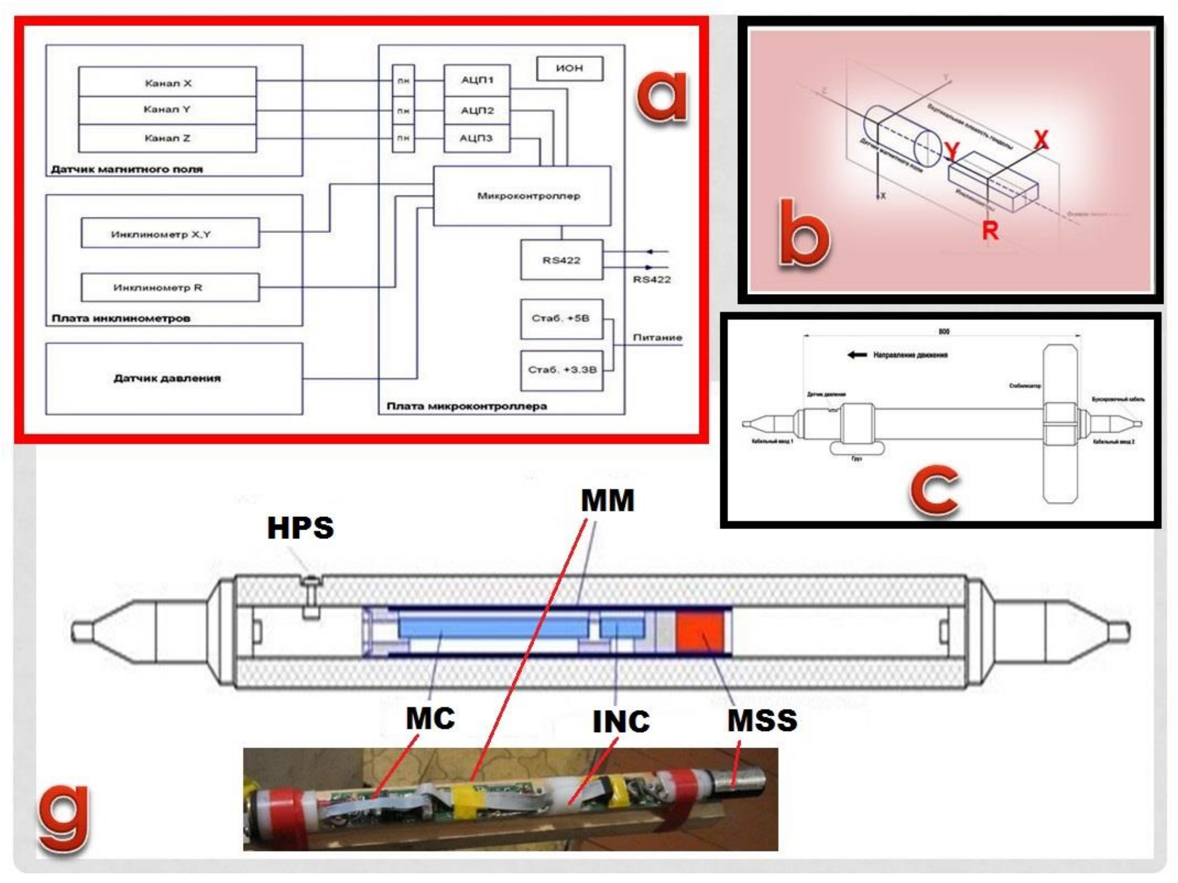

Fig.3. Block scheme the MM (a) in towed gondola (SG), reciprocal location of sensors (b) in gondolas, appearance (c) of the SG and internal location (g) of MM and MSS in the SG.

The TC uses a non-magnetic cable based on Kevlar with an increased explosive force, about 1500 kg. This cable (see ***Fig.2***) has an external diameter of 12 mm and includes two conductive veins to supply voltage power, two twisted pairs to transmit digital information. The length of the TC (**TC1**), which connects the near-boon SG with the onboard part of the device, is 300 m. To measure the horizontal gradient at HMS on different measuring bases, the MCG includes two similar cables 20 m long and 100 m long.

The design of the SG is shown in ***Fig.3c***. and consists of a non-magnetic case with removable stabilizers and cargo fixed on it. The stabilizer is designed to increase the stability of gondolas (SG) in towing, and the cargo is needed to reduce the vibrations of the gondola around the longitudinal axis and to fix the position of its vertical plane. Near towed gondola from the ships stern has two cable inputs, and the long-distance SG has one.

The MCG has measuring ranges for all components of the MIV for each of the magnetometric channels from 0 to 70 mkT, with the main measurement error being no more than 5 nT, and the accuracy of the countdown, implemented with the help of ADC, is 0,1 nT. The gradient registration range between the MSS in gondolas for each of the measuring magnetometric channels ranges from 0 to 10 mkT. The range of the SG dive depth is 0 to 130 m, with the accuracy of recording the depth of the course and the dive is 0,2 m.

Fig. 4. An example of one of the options for recording a digitally sourced PC display in the HMS test mode from the MSS (measured components of EMF- X, Y, Z, and computational module - T) and inclinometers (X, Y, R) are installed in gondolas.

Information from the measuring channels of magnetometers in binary code is displayed through the sequential interface of RS422 by line of communication (two veins of the towing cable) to the onboard registration device at a speed of 115200 bod.

In the HMS process, when using ships, the device is powered by a 220 V AC network and a frequency of 50 Hz, with a capacity of no more than 50 VA. Small "*floating means*" provide the ability to power the MCG from the battery with a voltage of 10... 15 V.

The hulls of both towed gondolas, based on the polyurethane non-magnetic pipe (the thickness of the walls of the case 18 mm), have dimensions: a diameter of 70 mm and a length of 1000 mm. The mass of gondola, including those located inside it MM and MSS - is no more than 10 kg, and the total weight used in the device in various variants of the use of TC - is no more than 100 kg.

The board part of the MCG (PS and ICD, see ***Fig.1***) is 120 x 50 x 200 mm in size, and the total weight together with the personal computer is no more than 5 kg.

CONCLUSION

The MCG has undergone laboratory tests at the ISMIRAN magnetic observatory, natural and operational tests in the Black Sea waters during the HMS process. During the tests, it was practically established that the MSS used implement the calculated accuracy of measuring 1 nT in the range of 0 to 70 mkT on each measuring channel of the device.

As an example of the work of the device in ***Fig.4***, fragments of digital data registration on PCs coming from the MSS and inklinometers in test mode during the towing process of one of the SGs at HMS are presented.

The device was used in HMS for research and production work on the oceans in a number of research marine expeditions of the RAS institutes**.**

LITERATURE

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