TESTING OF THE THREE AXIS MAGNETOMETERS FOR MEASUREMENTS OF THE EARTH'S MAGNETIC FIELD

Roman Szewczyk, Jacek Salach, Adam Bieńkowski, Rafał Kłoda, Marcin Safinowski

Abstract:

The paper presents experimental setup for testing of the three axis magnetoresisitive magnetometers for measurements of the magnetic field within the range of Earth's magnetic field. Measuring setup integrates three axis Helmholtz coils controlled by the specialized current source. The accuracy of magnetic field generated by the Helmholtz coils is up to 0.6% for the one direction. Presented experimental setup can be also applied for investigation and calibration of the other magnetometers utilizing magnetoresistive, Hall or fluxgate sensors.

Keywords: *magnetic sensors, Helmholtz coils, calibration.*

1. Introduction

Magnetic field occurred everywhere on the Earth, irrespective of the latitude or the longitude. The only difference is connected with its value and direction. This difference is determined by geographic location and geologic conditions. To determine the value and direction of Earth's magnetic field one has to use a magnetometer. The most used for this purpose are fluxgate magnetometers and magnetoresistive magnetometers [1], [2].

Usually measurements cover the determination of horizontal magnetic field H= and vertical magnetic field H⊥. In case like this, both declination θ and inclination φ of the magnetic field, may be calculated. Declination θ is determined as an angle between magnetic and geographic meridian, whereas inclination φ is an angle between ground level and direct of line of magnetic field at the given point.

Measurements of magnetic field are also realized in the space, near the planets in Solar System as well as on the Moon. Until now, about 200 magnetometers of different types were sent in the space [3].

To assure appropriate accuracy of magnetic field's measurement it is necessary to investigate uncertainty of magnetometers, as well as its sensibility and linearity. Helmholtz coils are the best standard for generation of the magnetic field. It should be indicated that the accuracy of Helmholtz coils depends only on the accuracy of geometry of the coils and the accuracy of the current source. This connects magnetic field standards with other standards determined as physical phenomena. One of the variants of the Helmholtz coils is three axis Helmholtz coils. In such coils, the compensation terrestrial magnetic field can be carried out as well, as it is possible to generate the arbitrary magnetic field vector.

2. Magnetoresistive sensors

Magnetoresistive sensors are used in navigation systems, in security and in measuring systems for industrial applications, especially in non-destructive testing methods. Magnetoresistive sensors, call also magnetrons, use effect of change in a resistance of ferromagnetic thin film as a function of the magnetic field. These changes are a consequence of the extension of a path of carrier charge and the scattering increase of this charge. For low values of the magnetic field this change can be described by equation (1):

$$\rho_B=\rho_0*(1+a*\mu_H^2*B) \quad (1)$$

where ρ_0 is a resistivity of the material without the magnetic field, μ_H is Hall activity charge carrier, constant a is factor describing scattering mechanism and B is magnetic flux density in the material [4].

In practice, magnetoresistor is produced during the vacuum evaporation of meander path. Therefore significant changes of resistance and high sensitivity can be obtained [4]. Most often magnetorestive sensor contains four magnetoresistors connect in Wheatstone bridge, supplied by differential power supply.

The most important advantage from magnetoresistive sensors is wide range of measuring magnetic field (up to 1mT), wide range of frequency (from DC up to 1GHz) as well as the possibility of operation in the range of temperature form –70°C up to 200°C. Moreover, magnetoresisitive sensors can be produced as small as flat devices, what make them useful for many applications.

A defect of magnetoresisitive magnetometers is necessity of use sophisticated electronic circuits, especially in configuration with compensation coil, generating magnetic field perpendicular to the sensor. Moreover, high accuracy magnetoresistive sensors are still expensive. An example of recently developed magnetoresistive magnetometer is three axis magnetometer HMR 2300, applied like reference sensor in developed experimental setup.

3. Developed testing setup for magnetometers

Figure 1 presents block diagram of the testing setup for investigation of the functional properties of magnetoresistive magnetometers.

The measuring setup covers the precision current source BOP –36A, amperometer APPA-207, three axis Helmholtz coils and reference magnetoresistive magnetometer HMR 2300. Magnetometer is connected to personal computer and works under the Labview software. Figure 2 presents visualization of three axis Helmholtz coils used in measuring setup.

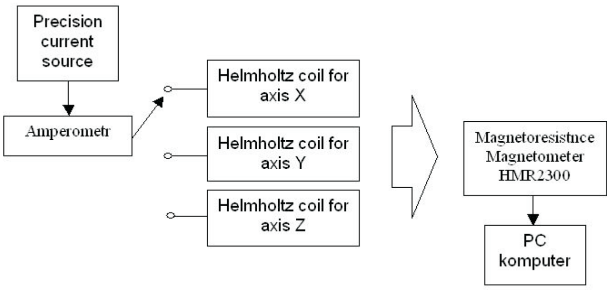

Fig. 1. Block diagram of testing setup for investigation of functional properties of magnetoresistive magnetometers.

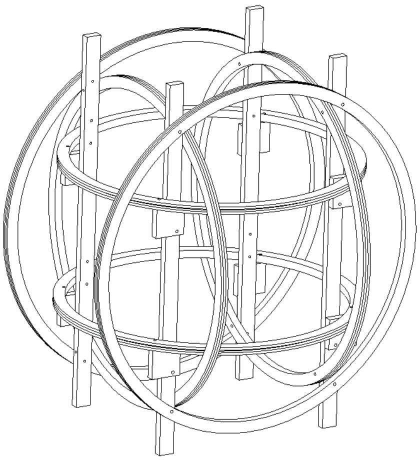

Fig. 2. Visualization of the three axis Helmholtz coils for developed experimental setup.

Helmholtz coil for experimental setup was produced during the special process covering water cutting. Water cutting process provides high precision in production of large elements, such as Helmholtz coil's bobbins.

Value of the magnetic field generated by the Helmholtz coil in its axis is given by the equation (2) [5]:

$$H = \frac{nIr^2}{2}\left\{\left[r^2 + (\frac{a}{2}+x)^2\right]^{-\frac{3}{2}} + \left[r^2 + (\frac{a}{2}-x)^2\right]^{-\frac{3}{2}}\right\} \quad (2)$$

where x is the distance from the centre of Helmholtz coils to measuring point, a is the distance between coils, n is number of turns for one coil, I is current in coils as well as r is the radius of coil. In order to generate uniform magnetic field, the distance a between coils should be equal to the radius of coil.

Table 1 presents functional parameters of Helmholtz coils developed for the measuring setup.

Tab. 1. The most important functional parameters of developed Helmholtz coils.

Oś	Radius r(m)	Coils winding turns n	Coil constant k_1(A/m / A)	Coil constant k_2(mT / A)
X	0.2230	25	80.213	100.799
Y	0.2045	25	87.469	109.917
Z	0.1860	25	96.169	120.850

Figure 3 presents window of program for acquisition and visualization of the results of magnetic field measurements using HMR2300 magnetoresistive magnetometer.

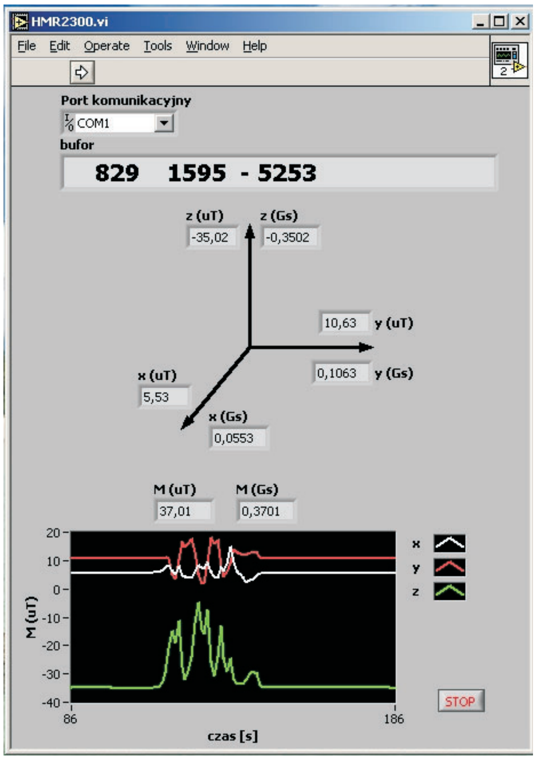

Fig. 3. Program for visualization of the results of measurements using magnetometer HMR-2300.

Presented in Figure 3 oscillation of the measuring field is the result of disturbances of Earth magnetic field through a ferromagnetic object.

4. Results of accuracy estimation

To estimate the accuracy of value of magnetic field generated by developed Helmholtz coils, following assumptions were taken:

- accuracy of coil diameter is 0.5 %,
- accuracy of current measuring is 0.2 %.

To sum up, the accuracy of generated magnetic field is about 0.6 %. This accuracy is almost the same as accuracy of the magnetoresistive magnetometer HMR-2300.

5. Conclusion

Presented experimental setup enables investigation of functional parameters of the magnetometers, in range of magnetic field up to 100 μT, what is sufficient for magnetometers operating in the range of the Earth's magnetic field. Generation of arbitrary magnetic vector is possible due to application of the three axis Helmholtz coils.

Accuracy of generated magnetic field is about 0.6 % for each axis. Such accuracy is sufficient for majority of industrial and navigational applications and sensors.

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AUTHORS

Roman Szewczyk* - Institute of Metrology and Biomedical Engineering, Warsaw University of Technology and Industrial Research Institute for Automation and Measurements - PIAP, Warsaw, Poland. E-mail: szewczyk@mchtr.pw.edu.pl

Jacek Salach - Institute of Metrology and Biomedical Engineering, Warsaw University of Technology, Warsaw, Poland. E-mail: j.salach@mchtr.pw.edu.pl.

Adam Bieńkowski - Institute of Metrology and Biomedical Engineering, Warsaw University of Technology, Warsaw, Poland. E-mail: bienko@mchtr.pw.edu.pl.

Rafał Kłoda - Institute of Metrology and Biomedical Engineering, Warsaw University of Technology and Industrial Research Institute for Automation and Measurements - PIAP, Warsaw, Poland. E-mail: rkloda@piap.pl.

Marcin Safinowski - Industrial Research Institute for Automation and Measurements - PIAP, Warsaw, Poland. E-mail: msafinowski@piap.pl.

* Corresponding author

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