S E S 2 0 1 2
Eighth Scientific Conference with International Participation
SPACE, ECOLOGY, SAFETY
4 – 6 December 2012, Sofia, Bulgaria

PORTABLE 3D MAGNETOMETER FOR LOCAL GEOMAGNETIC FIELD DISTURBANCE MEASUREMENTS

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Keywords: *Magnetic field, magneto-resistive technology, USB interface*

Abstract: *A new portable digital 3D magnetometer, based on the Anisotropic Magneto-resistive (AMR) technology is developed. The compact design makes the instrument easy in use in both the laboratory and in the field environment. Communication through a fast USB 2.0 interface allows the use of μMeter in a combination with different portable devices. Preliminary analysis of the measurement accuracy shows that the resolution of 2nT with sampling rate of 0.1Hz is achievable.*

ПОРТАТИВЕН 3D МАГНИТОМЕТЪР ЗА ИЗМЕРВАНЕ НА ЛОКАЛНИ СМУЩЕНИЯ В ГЕОМАГНИТНОТО ПОЛЕ

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Ключови думи: *Магнитно поле, магниторезистивна технология, USB интерфейс*

Резюме: *За нуждите от измерване на слаби магнитни полета в лабораторни и в полеви условия е разработен компактен и изключително лесен за ползване преносим магнитометър. Комуникацията с персоналния компютър се осъществява посредством USB 2.0 интерфейс, което прави възможно използването на магнитометъра с различни съвременни мобилни устройства. Първоначалният анализ показва постигната точност на измерванията от около 2nT при честота на самплиране 0.1Hz.*

Introduction

For the purposes of weak magnetic fields measurement in the laboratory and in the field environment a compact and extremely easy to use portable magnetometer is developed - Fig. 1. μMeter is a digital 3D magnetometer, which measures the magnitude and direction of the magnetic field intensity simultaneously on three axes x, y, z. It is based on the HMC5883L integrated circuit of the Honeywell International Inc. The device communicates with the PC via USB 2.0 interface, receives commands and sends the resulting measurement data which are displayed on the computer screen and saved on the hard disk for further processing and storage.

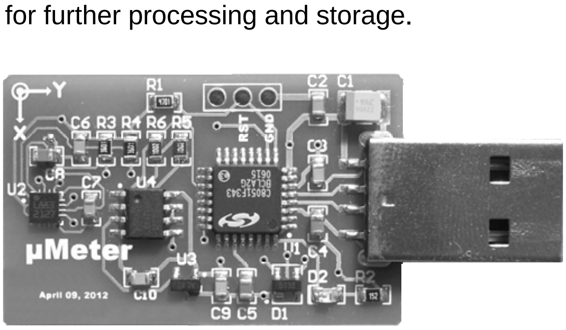

Fig. 1. μMeter

Device structure and operation

The basic scheme of the magnetometer is shown in Fig. 2. Operation of the device is controlled by a microcontroller with integrated USB module that receives information from the computer containing the parameters of the current measurement, converts them into low-level commands and send them back to the HMC5883L chip via standard I2C interface. After completion of the current measurement, HMC5883L sends raw data as 12-bit values back to the MCU that performs primary processing and along with the current temperature value, obtained from the internal temperature sensor, sends them to the PC where the graphical interface application, responsible of the magnetometer management is installed.

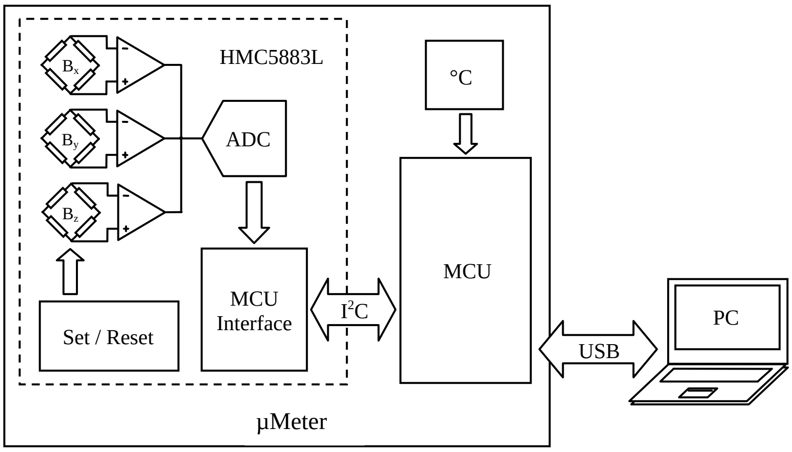

Fig. 2. Magnetometer basic scheme

Magnetometer has eight measurement ranges from ±1G to ±8G. The resolution for a single measurement (no averaging) in the most sensitive range reaches 500μG (50nT). Deviations in linearity are not to exceed 0.1% in the full-scale of the given range. Data acquisition rate reaches 200 readings per second.

Internally HMC5883L is a complex hybrid integrated circuit comprising several distinct components: a sensor analogue part and a subsystem to manage it, 12-bit ADC, MCU interface part responsible for communication with the microcontroller - Fig. 2. The analog part consists of three separate (one for each axle) differential magneto-resistive bridges. Magneto-resistive elements are implemented as thin-film strips of nickel-iron ferromagnetic (Permalloy) material (similar to that used in the well-known magnetic tape recording) applied directly on the silicon substrate. Originally, magnetic domains in each such element are oriented in the same direction and have a given conductivity so the bridge is balanced. When external magnetic field is applied, domains reposition and thus change their resistance. As a consequence, the bridge becomes unbalanced. This change is amplified by differential amplifier and is fed to the input of the internal 12-bit ADC. So the value of imbalance, which is a function of the external magnetic field has been digitized. After each measuring cycle the magnetic domains in the resistive elements need to be repositioned towards the initial zero direction. That is what the internal Set / Reset circuit is responsible of. It creates an artificial magnetic field by short electrical current pulses in both directions and thus sets the domains in their zero direction. All this is packed into a tiny 3x3 mm plastic body, allowing the use of HMC5883L in applications with an extremely compact design.

The software is developed in C# for .NET Framework and works under MS Windows. USB protocol is conformable to Human Interface Device (HID) standard. This is an important advantage, which eliminates the need of a special driver installation. HID devices use preinstalled driver by default, available in any modern operating system. The program sets the parameters of the magnetometer operation as range, mode of averaging, single or continuous measurement. The resulting data are displayed numerically and graphically in real time. The program allows acquired data to be written in a standard text file format with the user specified path on the system local hard drive.

First measurements and results

Two data sets measured with the magnetometer are shown on Fig.3 and Fig.4. The first one demonstrates local geomagnetic field intensity during period of two days and is taken on 06-07 November

2012 in Cairns, Australia in the course of solar eclipse scientific expedition. A detailed data analysis is subject to the future work. The second one shows local geomagnetic perturbation during 01-03 December 2012 in Stara Zagora, Bulgaria. Data are taken in the center of the city, near to one of the main crossroads. Sharp peaks correspond to transitions of heavy trucks and buses in the vicinity of the instrument.

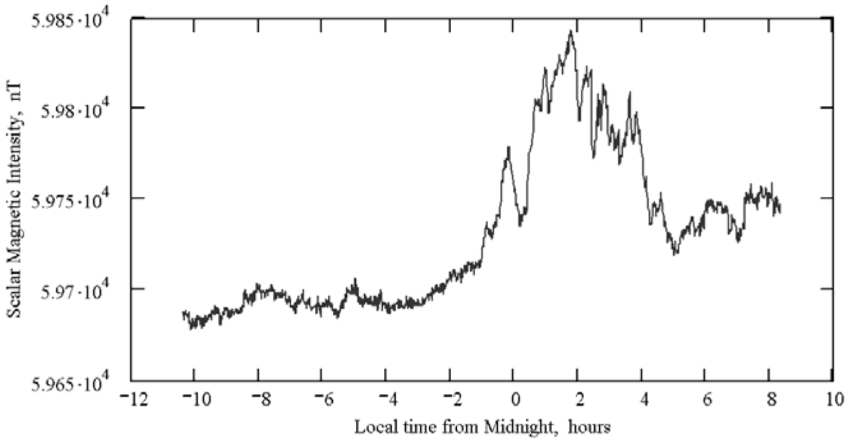

Fig. 3

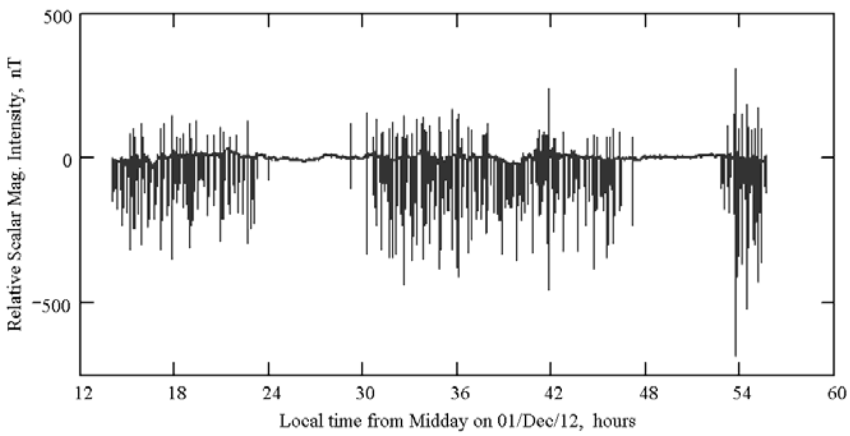

Fig. 4

Conclusion

A new portable USB digital 3D magnetometer is developed. Preliminary analysis of the measurement accuracy shows that the resolution of 2nT with sampling rate of 0.1Hz is achievable. µMeter is suitable for use in magnetic and geomagnetic studies and environmental monitoring.

As a future work we are intended to develop an accurate method for instrument calibration and to provide a detailed study of the magnetometer own noise and its properties.

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