Geomagnetic field measurements using portable 3D magnetometer

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Abstract

A new portable digital 3D magnetometer, based on the Anisotropic Magnetoresistive (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 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. The instrument can be used to study the temporal variations of the geomagnetic field and their generation mechanisms in context of Space Weather Forecasting.

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 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.

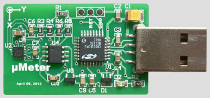

Fig. 1 Common layout of the *μMeter*

Magnetometer basic scheme

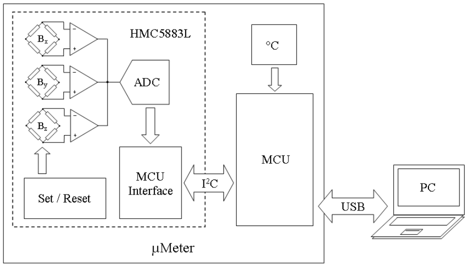

Fig. 2 *μMeter basic scheme*

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.

Software

The software is developed in C# for .NET Framework and works under MS Windows. The application main window is shown in Fig. 3.

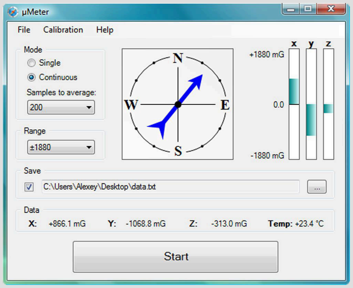

Fig. 3 *μMeter main program*

USB protocol is conformable to Human Interface Device (HID) standard. This is an important advantage, which eliminates the need of a special driver installation. 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.

Magnetic sensor internal structure

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. Initially each bridge is balanced. When an external magnetic field is applied, domains reposition and thus change their resistance, so the bridge becomes unbalanced. This change is amplified by differential amplifier and is fed to the input of the internal 12-bit ADC. Thus the value of imbalance, which is a function of the external magnetic field has been digitized. All this is packed into a tiny 3x3 mm plastic body, allowing the use of HMC5883L in applications with an extremely compact design.

First measurements

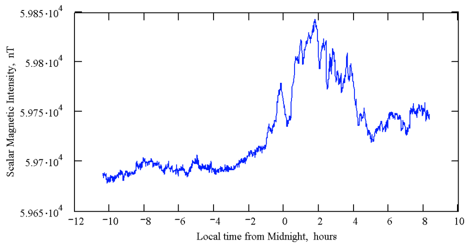

Fig. 4 Local geomagnetic field intensity during 06-07 November 2012, Cairns, Australia. A detailed data analysis is subject to the future work.

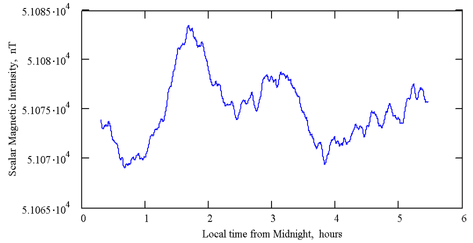

Fig. 5 Typical local geomagnetic field variations on 20 March 2013, Stara Zagora, Bulgaria. A two-poles bidirectional (zero phase shift) recursive filter is applied to the data.

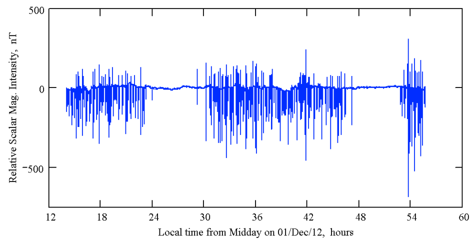

Fig. 6 Local geomagnetic perturbation during 01-03 December 2012, Stara Zagora, Bulgaria. Data are taken in the center of the city, near to one of the main crossroads. Sharp peaks correspond to transitions of heavy trucks and buses in the vicinity of the instrument.

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.

References

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Fifth Workshop - Solar Influences on the Magnetosphere, Ionosphere and Atmosphere June 3-7, 2013, Nesebar, Bulgaria