TEMPERATURE DEPENDENCE MEASUREMENT OF A FLUXGATE MAGNETOMETER

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ABSTRACT

The article presents the results of a temperature dependence measurement of a three-dimensional fluxgate magnetometer. The magnetometer has been built as a part of the research project "Determination of magnetic declination in Slovenia and comparison with global models of the earth magnetic field", started in 2007. The magnetometer is intended for long-term Earth magnetic flux density measurement. It includes a proton precession magnetometer and a three dimensional fluxgate magnetometer. The project is carried out by the Slovenian Research Agency and is funded by the Ministry of Defence.

Keywords: fluxgate magnetometer, proton magnetometer, geomagnetic field measurement

1 INTRODUCTION

The project "Determination of magnetic declination in Slovenia and comparison with global models of the earth magnetic field" started in 2007. Its main purpose is to establish a permanent system for magnetic declination measurement. An automated permanent magnetic reference point for recording of magnetic declination and absolute value of magnetic field will be set-up. In the future the connection to the global geomagnetic network is foreseen.

Geomagnetic observations and measurements in Slovenia have long tradition. In 1848 the Institute for Meteorology and Geomagnetism in Vienna was founded. After the fall of the Austro-Hungarian Monarchy it was succeeded by the Institute for Meteorology and Geodynamics in Ljubljana. Geomagnetic research in Slovenia was discontinued after the Second World War when important strategic research was transferred to military institutes in Belgrade. In the time of former Yugoslavia geomagnetic measurements in Slovenia were carried out, but measurement results are missing.

At present the geomagnetic data for Slovenia is interpolated from the World Geomagnetic Model (WGM).

A magnetometer has been built as a part of the research project. It includes a proton precession magnetometer and a three-dimensional fluxgate magnetometer. When designing the magnetometer the INTERMAGNET minimum requirements for the INTERMAGNET Magnetic Observatory have been taken into account [1].

The three components of the Earth's magnetic field are measured by an FL3-100 triaxial fluxgate magnetometer. Its zero drift is specified to be less than 0.1 nT/K. Noise spectral density is below 20 $pT/Hz^{1/2}$. The nominal scaling factor of the analogue output is 100 mV/nT. Relative scaling temperature coefficient is specified to be $+20 \cdot 10^{-6}$ 1/K typically. However, the scaling factor is temperature dependent. It could be mathematically corrected if the temperature dependence is known. In this paper a measurement system used to measure the temperature dependence of the fluxgate scaling factor is presented.

Temperature dependence of the fluxgate sensor was determined by evaluating temperature dependence of its scaling factor. The scaling factor k(T) gives the information of the sensitivity of the fluxgate sensor and is defined as the quotient between sensor output voltage U_{out} and measured magnetic flux density B_m. The temperature coefficient k_c of the fluxgate scaling factor represents the relative error of the fluxgate scaling factor depending on the temperature of the sensor. It has been determined by means of fluxgate output voltage measurement when the fluxgate sensor has been placed in a known magnetic field. The measurements were performed at different temperatures.

2 MEASUREMENT SYSTEM

Block diagram of the measurement system is presented in Figure 1.

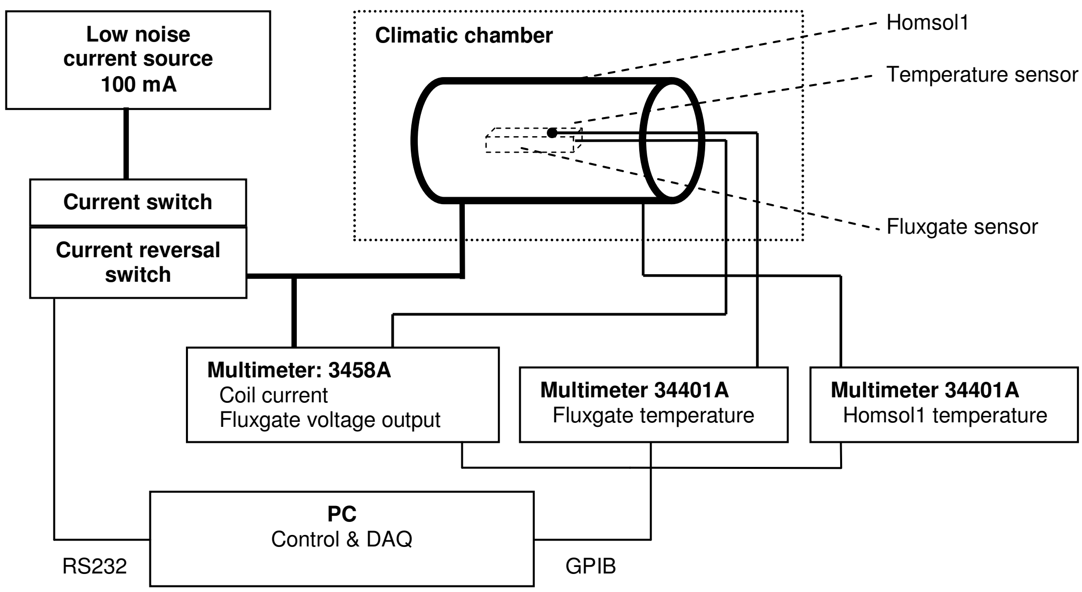

Figure 1: Schematic diagram of the measurement set-up.

Measurements were performed in a climatic chamber, Weiss $SB11^{300}$. The fluxgate sensor has been placed on a ceramic plate and inserted in the coil (Homsol1). All measurements were performed on the axis "Z" of the magnetometer. The ceramic plate is used to minimize temperature dependence of the sensor fixture, see Figure 2. The coil is a single-layer solenoid coil and has 300 turns. The copper wire diameter is 1 mm. The coil is

320 mm long and it has a diameter of 150 mm. The wire is wound on a tubular ceramic former. It is enclosed in a Plexiglass casing to prevent possible geometric changes of the windings. The temperature dependence of the coils has been measured [2] in the temperature interval from 25 °C to 37 °C.

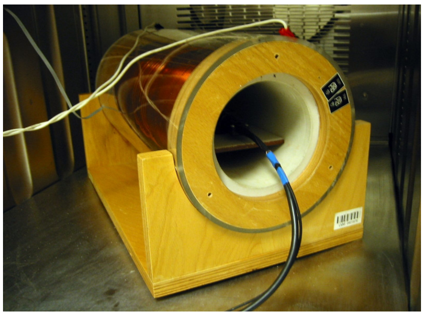

Figure 2: Fluxgate sensor placed in the coil.

To supply the coil a low-noise current source has been designed and built as the laboratory power supplies working in constant current mode (e.g. Agilent E3531A) exhibit too much noise. The current source uses a temperature stabilised low noise Zener diode as a voltage reference. A closed loop regulation system comparing the reference voltage and voltage drop across the shunt resistor is used to assure constant voltage drop on the reference shunt resistor and thus constant current across the load.

The coil and fluxgate sensor are oriented in the East–West direction. To compensate the residual Earth magnetic field the polarity of the current powering the coil is reversed. The average of the magnetic flux density measured in both directions is calculated, thus eliminating the Earth magnetic flux density contribution. We suppose that the Earth magnetic flux density is stable during the measurement procedure.

A field reversal switch consists of a power relay to reverse the current and an additional relay to switch off the solenoid coil and short-circuit the current source. Thus the transient at switch over is minimized. Both relays are controlled via USB to Serial RS232 adapter.

The temperature of the Homsol1 is monitored by measuring the resistance of the Pt100 sensor attached to the coil. The temperature of the fluxgate sensor is monitored by measuring the resistance of the NTC thermistor attached to the sensor.

The system is controlled by a personal computer, running MatLab. All measurements are stored on the hard drive for later data analysis.

Before each set of measurements the direction of the coil and fluxgate sensor is corrected to have lowest absolute magnetic flux reading with the coil disconnected from the current source. Then the climatic chamber is set to appropriate temperature and started. Measurements are performed when the temperature of the solenoid and sensor are stabilised. The climatic chamber is then switched off to minimize interference.

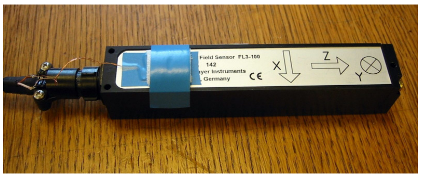

Figure 3: FL3-100 fluxgate sensor with a temperature sensor attached.

The solenoid current and fluxgate sensor output voltage are measured by Agilent 3458A multimeter. Two Agilent 34401A multimeters are used to measure the resistance of the Pt100 sensor attached to the solenoid and the resistance of the NTC sensor attached to the fluxgate sensor. The temperature sensor attached to the fluxgate sensor is isolated with a foam to prevent sensor cooling or heating by surrounding air, see Figure 3.

3 MEASUREMENTS

For one measurement of fluxgate scaling factor four measurements are performed: two current measurements (each at different current direction) and two voltage measurements. All measurements are made by the same multimeter. In addition the resistance of temperature sensors is measured with multimeters.

Measurements were performed near the anechoic chamber at the Faculty of Electrical Engineering, because there are less magnetic disturbances than in the laboratory (elevator near the laboratory premises). At the beginning of each set of measurements an autocalibration routine is performed for the Agilent 3458A. Temperature correction for Homsol1 is done by software, according to measurements from [2].

Figure 4: The low noise current source.

The current source is shown in Figure 4. Its output current is 100 mA. There is also buffered reference voltage output. Current source power supply should be stabilized for better long term stability. In Figure 5 current measurements are presented.

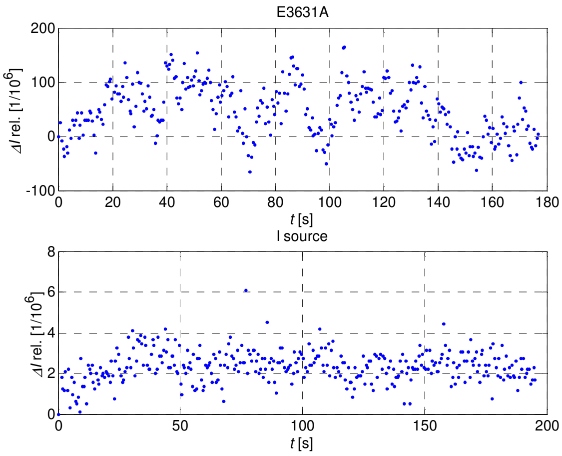

Figure 5: Comparison of relative current change: top plot: Agilent E3631A, bottom plot: 100 mA Homsol1 current source.

Measurements show good short time stability of the current source. It is important that the current fluctuations and drift are as small as possible during one measurement cycle.

In Figure 6 and 7 typical measurements are shown. These are measurement of the magnetic flux density, current and temperature. In Figure 6 absolute values of the measurements are presented. A drift, which is due to the current source long-term instability (shunt resistor temperature change) could be seen.

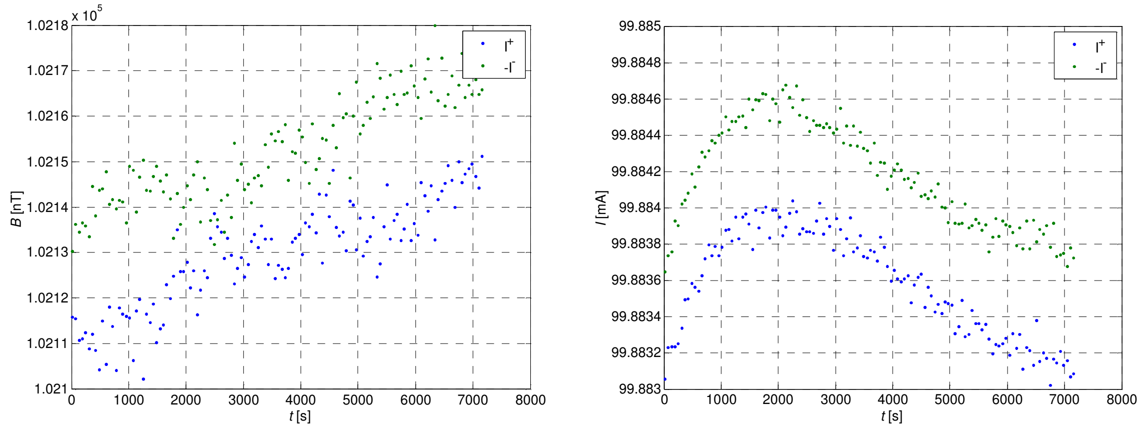

Figure 6: Absolute values of typical measurements. Left plot: magnetic flux density measured by fluxgate sensor. Right plot: Homsol1 current.

The temperature correction for Homsol1 is done after the measurement. The second order polynomial approximation is used, as presented in [2].

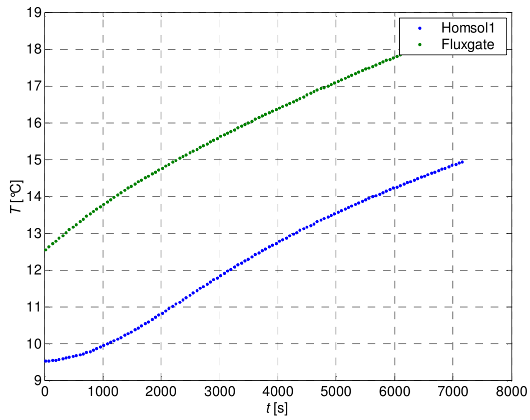

Figure 7: Temperature of the sensor and coil.

Temperature coefficient measurements data are shown in Figure 8.

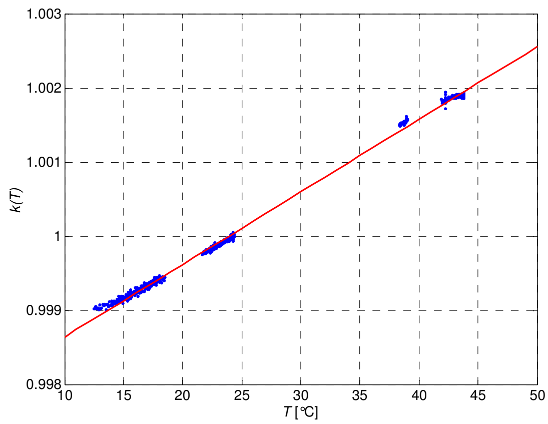

Figure 8: Fluxgate scaling factor.

By means of the least square method the linear fitting curve is calculated. The temperature dependence of the fluxgate scaling factor is $k_s = 9.8 \cdot 10^{-5}$ 1/K.

4 CONCLUSIONS

Due to time constraint only a limited number of measurements were performed. The results show large temperature dependence of the fluxgate scaling factor. Possible reasons are insufficient fluxgate sensor mechanical fixture, too fast temperature change during the measurement and unequal temperature distribution of the fluxgate sensor.

In the future new measurements are planned. A new fixture for the fluxgate sensor will be made. Also a metal box for fluxgate sensor will be considered with temperature stabilization of the sensor.

5 ACKNOWLEDGMENT

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