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Noise Characteristics of Microwire Magnetometer

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Current trends in modernization and miniaturization of ferroprobe sensors lead to replacement of amorphous ribbon cores with magnetic microwires. The miniaturization often causes degradation in the parameters of sensors, so, considering measurement of weak magnetic fields, it is necessary to explore noise parameters, temperature drift and stability of the magnetometer output value. The article deals with analysis of microwire sensor noise characteristics based on the experimental data processing. Using one second periodograms, the linear spectral density was processed. Obtained data are compared with corresponding parameters of a relax-type ferroprobe magnetometer.

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1. Introduction

A dominating current trend in sensors development is their miniaturization. Therefore, we are developing a sensor system suitable to replace our relax-type magnetometers based on amorphous ribbon cores. Considering present development in electronics, sensors based on magnetic microwires could be the solution. They provide sufficient performance, but in significantly smaller dimensions and with lower power consumption. This fact is also important, because one of their prior application possibilities was on board of an unmanned aerial vehicle, as a precise magnetic compass with sufficient performance for inertial navigation, based on non-colinear vector fields. Therefore it was necessary to evaluate their noise parameters.

2. Function principles

The relax-type magnetometer utilizes the transition effects between positive and negative saturation. The time interval of this transition effect is measured and so provides information of the measured field. More detailed description of this principle can be found in [1, 2]. Since the latest version of the relax-type magnetometer electronics is based on the CPLD (complex programmable logic device), only minor changes in the excitation electronics and CPLD program were necessary, because of the flexibility our modular magnetometer system provides. The block diagram of our system is shown in Fig. 1.

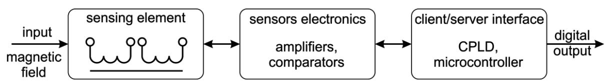

Fig. 1. Block diagram of the modular magnetometer system.

Magnetometer based on magnetic microwires utilizes also transition effects [3], but the excitation signal is tri-wave shaped instead of an impulse signal, used in the relax-type magnetometer. Induced voltage peaks occur, when the critical magnetic field of the bistable or rectangular microwire is reached and the time intervals between maximum values of the excitation field and the voltage peaks provide information about the measured field value. This principle is shown in Fig. 2.

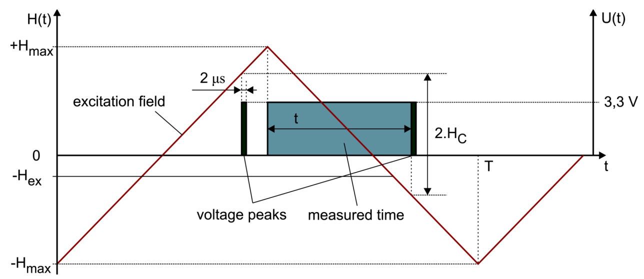

Fig. 2. Function principle of magnetometer based on bistable or rectangular magnetic microwires.

3. Magnetometers characterization

For comparison were used three types of magnetometers: relax-type VEMA-030, relax-type VEMA-040 and microwire testing VEMA-T magnetometer. Both VEMA-030 and VEMA-040 use amorphous ribbon cores made from VITROVAC 6030. Difference between them is in their electronics. The first one has electronics built-up from discrete digital components, whereas the second is based on CPLD. VEMA-030 is sampling at 500 Hz, VEMA-040 at 1 kHz with interleaved sampling. VEMA-T is a modified VEMA-040, sampling frequency is 500 Hz. Sensor used for measurements with VEMA-T has the ability to change the microwire, therefore were tested various cobalt microwire types: MW1 $Co_{70.5}Fe_{4.5}Si_{15}B_{10}$ from University of P.J. Safarik - UPJS (30 μm diameter, glass-coated), MW2 30DC2T from UNITIKA (30 μm, without glass coating),

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MW3 $Fe_{4.85}Co_{81.28}B_{3.64}Si_{6.51}Cr_{3.72}$ from Institute ELIRI (29 μm glass-coated).

All magnetometer types use slim concentric coil sensing elements, so they are vector magnetometers. Relax-type sensors have length of 80 mm and diameter of 5 mm. Microwire sensor has length of 20 mm and diameter of 2 mm.

4. Measurement and results

As the first step we had to obtain a frequency characteristic of the magnetometer system. For this purpose measurements in Helmholtz coil with 1 nT/μA constant were realized. The results are shown in Fig. 3. The sensors were oriented in the direction, where zero value of the ambient magnetic field was indicated. As the stimulation signal the sinewave 0 – 250 Hz with magnetic field amplitude of 1 μT was used.

The graph shows, that the used electronics for the microwire magnetometer has a flat frequency characteristics, which makes this system sensitive to aliasing, but if we are able to exclude higher frequencies (their presence) from the measurement area, the sensed signal can be processed without the use of an equalizer.

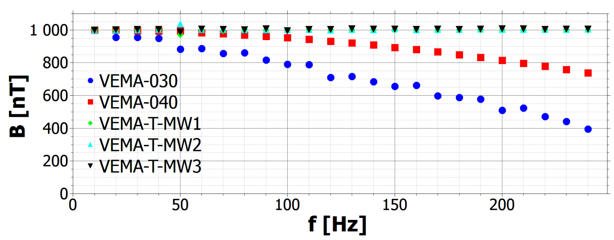

Fig. 3. Frequency characteristics.

For determination of the sensitivities of tested systems the square-wave signal with 1 μT, 0.1 Hz frequency was used . The obtained sensitivities are summarized in Table. There are different values of sensitivities, since the electronics, tri-wave generator and sensing bridge, had to be fine tuned to achieve the best signal to noise ratio for each wire.

Sensitivities. TABLE I

	VEMA-030	VEMA-040	VEMA-MW		
			UPJS	UNITIKA	ELIRI
K [nT/LSB]	3.2	2	1.7	2	1.1

Magnetic field in a laboratory is excessively complex for description with a reasonable deterministic model. It can be viewed as a stationary random process that is evaluated by a linear, time-invariant system – the magnetometer.

To determine the most suitable time period for measurements, ambient (environmental) magnetic field was monitored (Fig. 4). Based on the results, the best interval for measurements is between 8 p.m. and 5 a.m., when the ambient field could be considered as a stationary process.

Obtained results with subtracted internal electronics noise are shown in Fig. 5. The linear spectral density was processed through 500 of one second long periodograms. Compared to the values of 20 – 40 pT/$\sqrt{\text{Hz}}$ obtained for relax-type magnetometers VEMA-030 and VEMA-040, the tested microwire device has a similar sensitivity, but higher noise. The lowest noise was achieved with the microwire from UPJS.

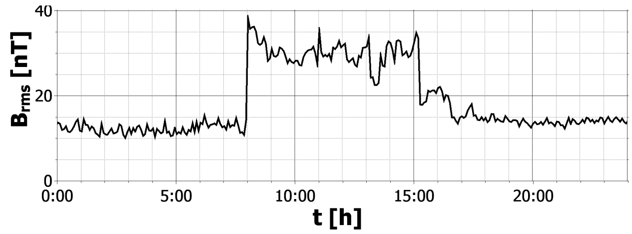

Fig. 4. 24-hour development of magnetic field.

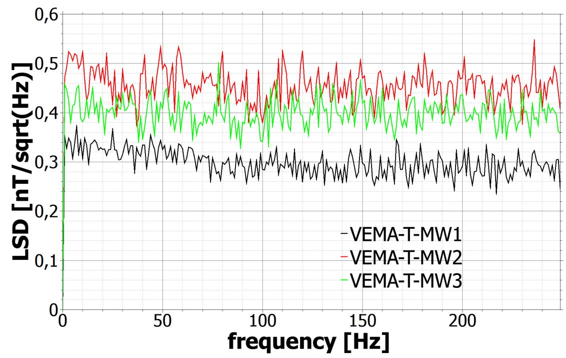

Fig. 5. Linear spectral density of VEMA-T.

5. Conclusions

The developed electronics system for a use with microwires was designed by the rule “as simple as it gets” to obtain a low cost precise device. Realized measurements proved the concept of replacing amorphous ribbons with magnetic microwires and also the necessity to improve performance of the sensing electronics, to achieve lower internal noise.

Acknowledgments

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