MEASURED PARAMETERS OF THE THREE-AXIS GAUSS-METER

Tomáš Hejtmánek

Doctoral Degree Programme (1), FEEC BUT

E-mail: xhejtm07@stud.feec.vutbr.cz

Supervised by: Zdeněk Roubal

E-mail: roubalz@feec.vutbr.cz

Abstract: The purpose of this article is a measuring parameters of a gaussmeter with a three-axis measuring probe designed for magnetic field mapping. Commercially available gaussmeters have low frequency bandwidth for these purposes, and signals cannot be measured in synchronous detection mode. Therefore, a suitable magnetic field sensor was selected and one channel of the device was designed and made. In particular, the higher bandwidth for three-axis measurement and the possibility of synchronous signal detection were taken into account. Attention will also be paid to designing a suitable mechanical design of the probe and the location of the sensors. The gaussmeter will be used for magnetic impedance tomography (MIT), which is reconstruction method of conductivity image. On the proposed device was performed measurements of frequency bandwidth, noise measuring of Hall probe and measuring constants of Hall generators. The properties were evaluated and compared with parameters of commercially available Gaussmeters.

Keywords: Gaussmeter, frequency bandwidth, Hall probe noise measuring, constants of Hall cells

1 INTRODUCTION

Magnetic impedance tomography is a method of reconstituting a sample image based on the conductivity distribution on its surface, [1]. For the reconstruction to take place, it is first necessary to map the magnetic field on the surface of the sample. For this purpose, gaussmeters working on different measurement principles are used, depending on the accuracy of the measurement and the magnitude of the measured magnetic field. The basic requirements for mapping the magnetic field include, above all, the accuracy of the measurement and the smallest scanning surface, thus achieving a high spatial resolution. For laboratory measurements, the gaussmeters with Hall probes are most used. The three-axis gaussmeter in our department's magnetic field measurement laboratory can only be used for mapping under very specific conditions. Its bandwidth is limited to 400 Hz and does not allow for synchronous detection, which results in the need for measurement in a very disturbed environment or in a shielded chamber. This would be extremely disadvantageous and restrictive for future use of this method in industry, as MIT applications are expected to detect defects in metallic materials. This article deals with the design of a three-axis gaussmeter and its mechanical construction. Attention will be paid to the large frequency bandwidth and the use of synchronous detection in alternating measurements. The first step is to perform a search for a suitable Hall probe. Subsequently, design of amplifier circuits for Hall probes and AC power supplies. In the next part of the proposal the mechanical design of the sensing element and the mutual positioning of the sensors are solved, [2]. The finished gaussmetr was subjected to measurement of its actual parameters and compared with parameters of LakeShore model 460, [3].

2 MEASUREMENTS

2.1 HALL SENSOR NOISE MEASURING

Noise measurements of the Hall cells used on the HP 35660A low-frequency FFT spectral analyzer with frequency range up to 100 kHz were performed. In the measurement, Hall's cell was placed in a zero-magnetic chamber and was connected to the analyzer via the amplifier. Measurements ranged from 10 Hz to 7,4 kHz with 1, 2 and 5 mA supply currents. First, Hall sensor was replaced by a short circuit to measure the amplification string noise and correcting the measured values with the connected Hall generator. Further measurements have already been carried out with the attached sensor and the gain of the amplifiers at 86 dB. The measured values were converted to the input noise voltage in nV/√Hz, [4]. In Fig. 1 is a recalculated equivalent input noise magnetic field obtained through the sensitivity of the Hall probe. For DC power, it is preferable to select a current of 1 mA with a 1/f noise at low frequencies, as with higher excited currents. This value is also recommended by the manufacturer of Hall cells [5]. In the case of alternating excitation, it would be preferable to choose the excitation current higher, because in the white noise area we will achieve higher sensitivity at higher currents [6].

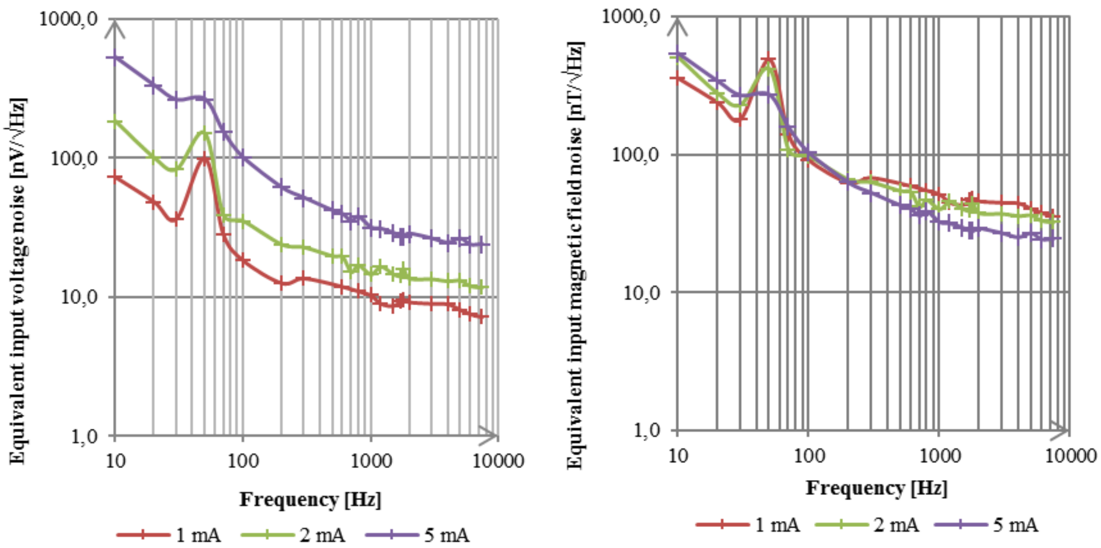

Figure 1: Hall sensor noise measurement

2.2 THREE AXIS PROBE

Based on inspiration from various probe designs, a prototype was constructed, which is depicted in Fig. 2. The core is part of the PCB, which houses three Hall cells. The carrier cube is made of 5 x 5 x 5 mm plastic material and is glued to the printed circuit board. In close proximity to the cube, there is a PT1000 sensor that measures the temperature of the Hall sensors to compensate for the temperature drift of the cells, [7].

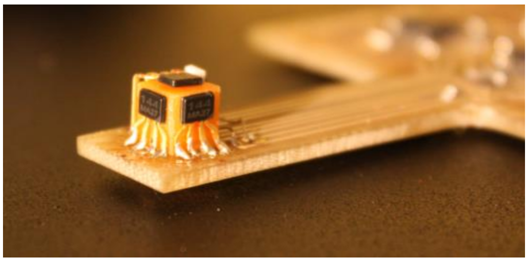

Figure 2: Three-axis probe

2.3 HALL CONSTANTS MEASURING

In order to accurately determine the magnitude of the measured magnetic field, it is necessary to know the Hall element constant. For HE144 sensors, the manufacturer gives a typical value 200 mV/T at a supply current of 1 mA, but the actual value may be in the range of 180 to 360 mV/T. Using calibration magnets with precisely defined magnetic induction magnitude, the actual values of the constants of all three sensors were measured, see Fig. 3.

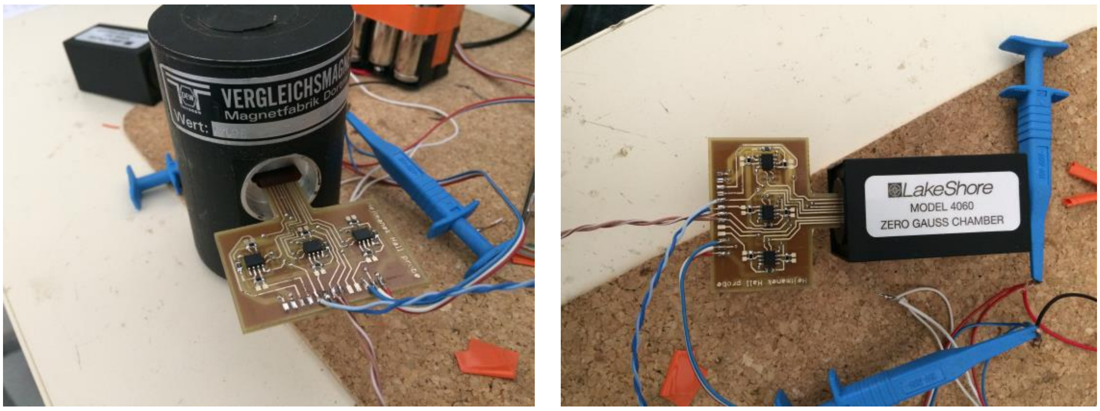

Figure 3: Measuring in calibration magnet and zero Gauss chamber

The measurement was first performed in a zero magnetic chamber to determine the offset value that was subtracted from the measured value in the calibration magnet. Hall voltage for individual magnets was measured for different gains and the resulting constant was calculated as the average value. The results show that the reported typical value almost agrees with the measured values (Tab. 1). Knowing the exact values of constants is important for processing the measured voltages and converting them into magnetic induction, [8].

B [mT]		9,9	195	990	U_H
	A_U	U_H [mV/T]			mV/T
Sensor 1	20x	208,59	207,66	202,47	**207,74**
	200x	209,48	208,66		
	2000x	209,58			
Sensor 2	20x	193,80	201,49	196,35	**199,46**
	200x	199,77	204,39		
	2000x	200,97			
Sensor 3	20x	202,35	202,50	199,35	**202,93**
	200x	205,72	201,72		
	2000x	205,98			

Table 1: Measured constants of three HE144 sensors

2.4 FREQUENCY RESPONSE MEASUREMENT

Measurement of the frequency range of a three-axis probe was assembled by a measuring apparatus consisting of a signal generator, power amplifier and Helmholtz coils, which in their center generate a homogeneous magnetic field and the Hall probe was mounted thereon, see Fig. 5. The output voltage was measured by an oscilloscope and the current flowing into the coils was measured by a current probe to the oscilloscope. It was possible to set precisely the same current value for each frequency and the magnetic field excited by the coils was thus constant. A current of 3 A was selected for the measurement and the gaussmeter range set to 3 mT. From the first measurement performed, a strong frequency dependence of the sensor was evident, which was caused by the induced voltage to the lead wires to the Hall cell, which was added to the measured Hall voltage. An adjustment was made to shorten Hall sensor solder pins and replace both power and sensing wires on the printed circuit with twisted lacquered wires. Subsequently, a second measurement was performed, and the results obtained were compared. The measured values indicate that the frequency range is approximately 1 kHz. The measurement result is on Fig. 4.

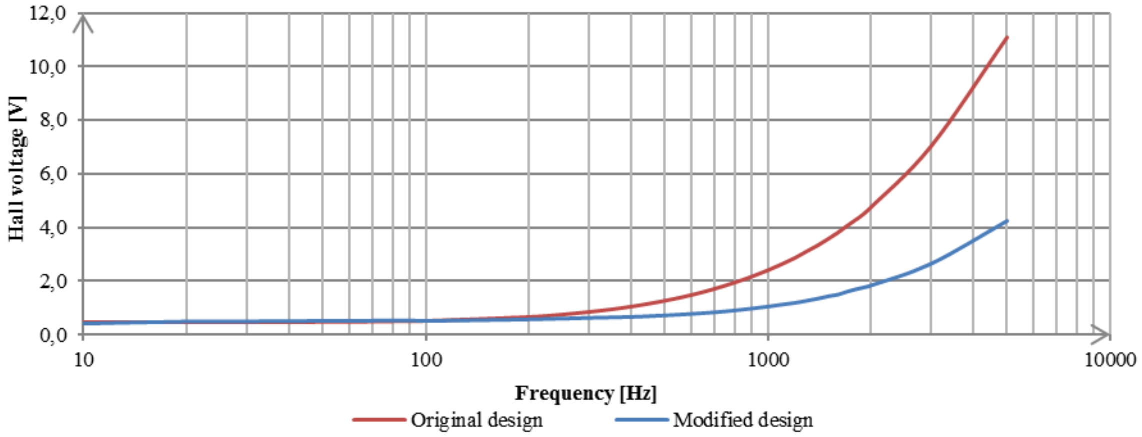

Figure 4: Frequency response of Hall probe

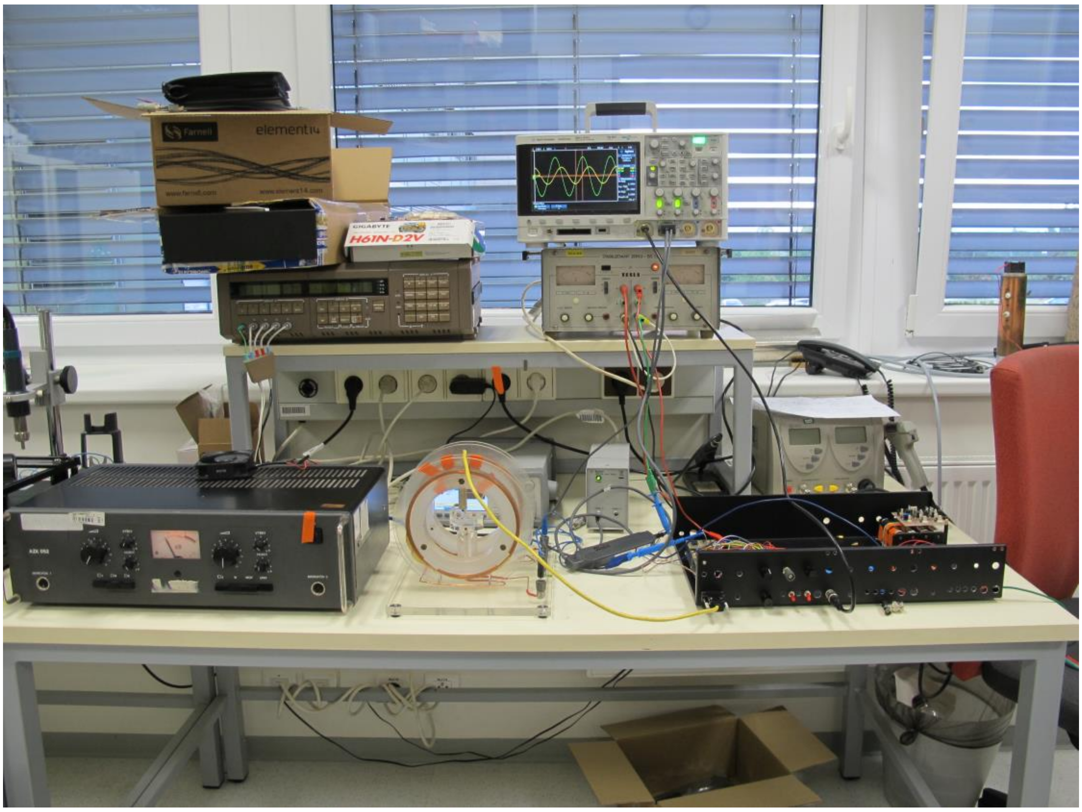

Figure 5: Frequency bandwidth measuring

3 CONCLUSION

The paper briefly deals with design of gaussmeter with triaxial probe and its use for magnetic field mapping in magnetic impedance tomography. Above all, it discusses the measured parameters of the proposed device. After construction of gaussmeter relatively extensive measurements were carried out, especially the Hall cell noise and also the measurement of constants of the used Hall generators. Chapter 2.4 describes the three-axis probe bandwidth measurement, where the initial measurement showed a three-axis probe frequency range of only 300 Hz, due to inappropriate conduction of the wires to the Hall cells. Therefore, the PCB modification was performed and the characteristic measured again. Figure 4 shows that the bandwidth has been increased to 1 kHz, which is twice as high as the LakeShore model 460.

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