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Permalloy GMI sensor

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Abstract

GMI effect in permalloy can be used to measure DC magnetic fields. Impedance change of 50% at a field of 0.5 mT was observed at 200 kHz frequency. Magnetometer using biased two-stripe 10-cm long sensor achieved 10% linearity in open loop and 1% hysteresis error in the ±80 μT range.

Keywords: Magnetic sensors; GMI effect; Magnetometer

Giant magnetoimpedance in amorphous wires [1] is now widely exploited in the design of new magnetic field sensors [2]. It was reinvented quite recently that large variation of AC impedance with applied magnetic field can be observed also in the "conventional" soft magnetic metals such as Mo–permalloy wires [3] or mumetal strips [4]. The origins of this effect were already described in classical paper recently discovered by Sasada [5]. The aim of this work is to investigate a possible exploitation of mumetal (permalloy) strips for GMI field sensor.

The samples investigated in this work were prepared from the 0.06 mm thick tape of PY 79M kindly supplied by Kovohutě Rokycany, a.s. strips, 3 mm wide, were cut from the tape and then conventionally annealed in dry H_2 atmosphere to achieve good soft magnetic properties. The $Z(B)$ characteristics of 20 cm long strip were measured up to 1 MHz using precise LCR meter HP 4285A. Rather flat maximum of GMI sensitivity (defined here as impedance change ΔZ compared to $Z(B_{\max})$) was found for frequencies of 200–300 kHz. Dependence of GMI sensitivity on the level of measurement current (up to 20 mA) is weak.

Local minima of impedance Z were observed near to the zero magnetic field level, which can be attributed to the influence of material hysteresis, see Fig. 1.

All characteristics were measured during complete magnetization cycle, starting at relatively high field value (3 mT) in order to suppress perming effects.

A GMI sensor was built using two 10 cm long stripes of PY 79 M. The two stripes are mechanically oriented in parallel but electrically connected antiserially, Fig. 2. They were supplied by 100 kHz/30 mA rms sinewave current. The stripes were biased by the opposite DC fields of 0.25 mT to shift their working points in opposite directions to the linear parts of the $Z(B)$ characteristics. The AC voltages—proportional to the impedance of stripes—were measured with SR 830 lock-in amplifier. Since the original $Z(B)$ characteristic is symmetrical (Fig. 1), the response of the two GMI elements to the magnetic field is complementary. (See Fig. 3 for output voltages measured on both elements).

The differential voltage is shown in Fig. 4. Its response to the magnetic field is linear in the field range of ±200 μT; the achieved sensitivity is approx. 37 mV/mT.

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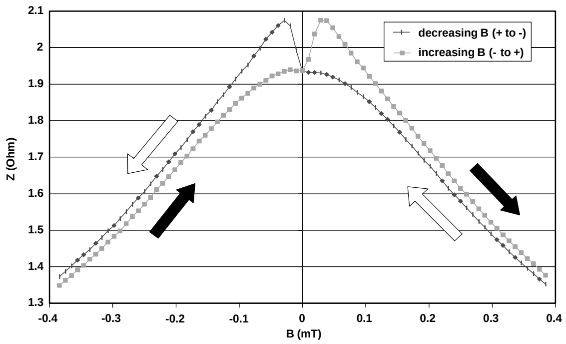

Fig. 1. Module of impedance Z for low fields (detail).

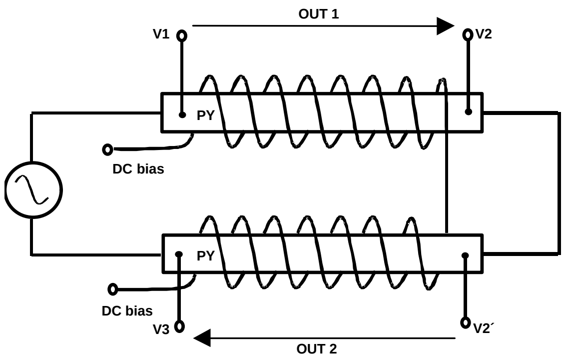

Fig. 2. The GMI sensor.

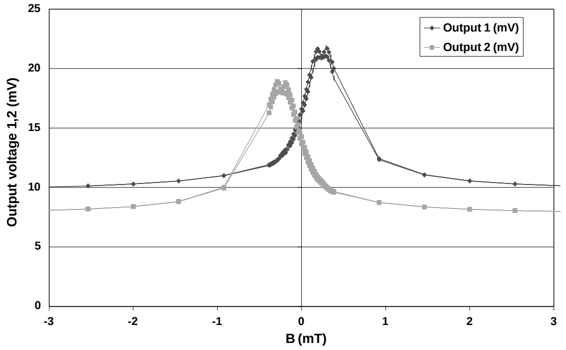

Fig. 3. Voltage vs. magnetic induction for individual outputs.

The sensor characteristic has a hysteresis of 30 μT. The conducted experiments had shown a possible application of (relatively low-cost) permalloy material for design of GMI sensor.

Simple magnetometer was built using the described sensor. The sensor is supplied by squarewave current. Excitation circuit consists of four low-resistance HEXFET switches connected to the bridge. The Microchip PIC16F84 microprocessor was used to generate four driving signals for the excitation and reference for the switching-type detector. The voltages are sensed by differential amplifiers. Block diagram of the detection circuit is shown in Fig. 5.

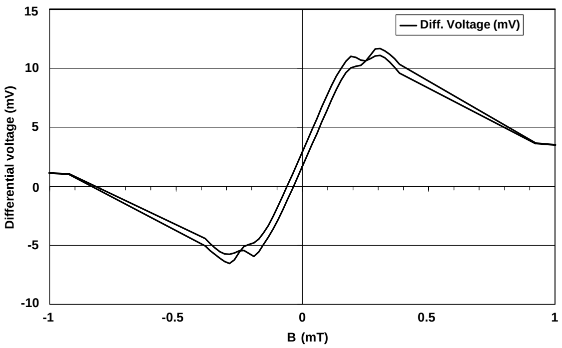

Fig. 4. Differential output voltage vs. magnetic field.

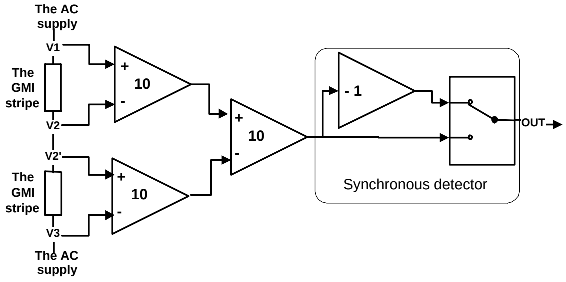

Fig. 5. Diagram of the GMI magnetometer.

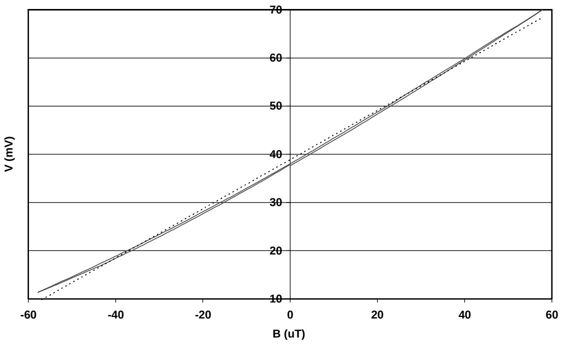

Fig. 6. GMI magnetometer characteristic.

Fig. 6 shows a magnetometer characteristic in the open loop: the achieved sensitivity is 526 mV/mT and the linearity error is 9.5% in the ±80 μT range. By optimizing the circuits and the bias value the hysteresis was suppressed below 800 nT in the ±80 μT range and 1.2 μT in the ±400 μT range. The present magnetometer resolution is 200 nT and zero stability is 1 μT.

The hysteresis may be further reduced and the stability of the offset increased by using squarewave bias field instead of DC. The linearity error can easily be suppressed by feedback compensation, which would also increase the range.

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