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AN ELECTROSMOG-METER – ENVIROMETER

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The paper presents an EMF – meter used to detect the magnetic component of the electromagnetic fields in the frequency range 20 Hz – 100 kHz from power lines, transformers, railway complexes, computers, etc. The developed device is based on two sensors: an inductive sensor and a direct driven fluxgate sensor. The direct driven fluxgate sensor is using $Co_{68.25}Fe_{4.5}Si_{12.25}B_{15}$ amorphous material as sensing element. This sensor has a better sensitivity in comparison with the classical ones, works in a large frequency range and exhibit good thermal stability. The increase of the working frequency range allows to measure AC magnetic fields of high frequencies. DC magnetic fields up to 200 µT can also be measured using this fluxgate sensor. The Envirometer can measure both magnetic fields up to 200 µT in 4 selectable measurement ranges with an accuracy of 3% and field frequency in 2 selectable measurement ranges.

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1. Introduction

A new kind of environmental pollution is the electromagnetic pollution, named also electrosmog. Although we can't see, hear or feel it, electrosmog is found everywhere around us. The electromagnetic pollution exists in the whole frequency range from DC fields to AC fields with frequencies up to 300 GHz. Usually there are two main types of "electrosmog": electric fields pollution and magnetic fields pollution. Magnetic fields are much more common in the common life than electric fields. To shield the magnetic fields is also more difficult than to shield the electric fields. The main sources of AC magnetic fields are electrical appliances, house wiring, power lines or underground power cables, transformers, motorized equipment, railway complexes, computers, kitchen appliances and more. Any modern electronic equipment, such as clock radios or answering machines, should have a transformer. Very recently the influence of the magnetic fields on the human health is widely investigated. Laboratory studies have shown that electromagnetic fields can affect living cells but it is unclear whether these effects are harmful. Some epidemiological studies have reported a possible link between electromagnetic fields exposure and cancer. Other studies indicate that continuous exposure to levels as low as 2 mGs may be harmful. Current researches regarding the evaluation of the electromagnetic pollution, the methods in limiting electromagnetic pollution and ways of limiting its effects on people health must provide more answers about potential health effects in the future. Until then, it is best to play it safe and know the level of electrosmog in our home and work environment. To detect and measure electrosmog (electric and electromagnetic fields) electrosmog measuring equipments for home and office are used. An Electrosmog-meter can be also known as gaussmeter, teslameter, emf-meter, ELF-meter or hf-meter/detector [1].

In this paper is presented an EMF – meter used to detect the magnetic component of the electromagnetic fields in the frequency range 20 Hz – 100 kHz. We refer especially to investigations made by us in order to obtain a performing sensor based on amorphous materials, which can be used to equip the above mentioned devices. The tests of the sensor performances are also presented. Details on the electronics of the Envirometer will be presented elsewhere.

2. Experimental

A portable device having reduced dimensions; high quality construction elements, battery included, adequate design, long lifetime and function security was developed. Taking into account the wished sensitivity, the construction parameters and the electronics were correlated with sensor excitation frequency. For this purpose it was necessary to use two sensors: one inductive sensor and one fluxgate sensor. The two sensors are dependent on the magnetic field and field frequency range.

The main tendencies of the magnetic sensors applications refer to the miniaturization, the increase of the sensitivity, the diminishing of the sensitivity threshold and the increase of the resolution, achieved by the lower noise level of the sensor [2-4]. The possibility to miniaturise the sensor is an advantage of the fluxgate sensors, but this has as effect the diminution of the sensor sensitivity. The effect of sensitivity reduction can be compensated using a higher exciting frequency and/or by choosing suitable solutions in order to reduce the noise level. Such a solution, proposed by Nielsen [5,6], a fluxgate sensor having the ferromagnetic core material itself as the carrier of the excitation current was chosen in order to obtain a sensor that competes favourably with traditional fluxgate sensors with respect to simplicity, miniaturization, sensitivity and noise level. A miniaturised direct driving fluxgate sensor having the sensitivity of 30 mV/μT was designed. The sensor can be characterized as an extremely simple construction consisting of one coil surrounding a hairpin-shaped piece of stress-annealed amorphous core with open magnetic paths. The sensor has the dimensions: 30 x 2 x 2 mm. The sensing element is the $Co_{68,25}Fe_{4,5}Si_{12,25}B_{15}$ ribbon 26 mm long 0.3 mm wide and 25 μm thick. The sensor includes the pick-up and feed back windings of 100 and 500 turns respectively, surrounding the hairpin shaped core. The measurements of main functional parameters of the sensor were performed in a pulse excitation field with frequency between 40 kHz and 1 MHz with the sensor situated inside a thermostatic enclosure placed in a five-layer P-80 permalloy shielding system [7].

The main electronic devices of the developed Envirometer are the frequency meter and the magnetometer but their description is not the subject of this paper.

3. Results and discussions

Using suitable heat treated $Co_{68,25}Fe_{4,5}Si_{12,25}B_{15}$ amorphous ribbons we obtained a sensitive sensor that has a magnetic behaviour in agreement with the metrological requirements of the devices for the electromagnetic pollution measurements. The sensor has the sensitivity greater than 20 mV/μT, the transfer characteristic is linear in the field range –10 μT to +10 μT, but the negative feedback increases the linearity domain of the transfer characteristic. In the field range of ±25 μT, the sensor sensitivity is of about 30mV/μT. The results regarding the magnetic behaviour of the sensor can be discussed in terms of the contribution of both the stress annealing and the driving magnetic field at the magnetization processes which take place in the used amorphous ribbon. The core materials for fluxgate applications should be magnetically soft so that low excitation currents can lead to the saturated state. If the easy axis of magnetization is parallel to the applied magnetic field, domain wall movements dominate the magnetization processes. This is the case for the as-quenched ribbon where the ribbon axis is the easy axis of magnetization. The presence of the magnetic anisotropy with the ribbon axis as a hard axis of magnetization promotes magnetization rotations rather than domain wall movements in the AC magnetization processes in fluxgate sensors [8]. This hard axis induced during the stress annealing remains if the ribbon is cooled to room temperature under applied tensile stress. The more we stabilize by pre-annealing the amorphous structure in the sample, the larger is the induced anisotropy. By the change of the magnetic anisotropy from the easy-ribbon-axis type to the hard-ribbon-axis type [9, 10], the Barkhausen noise in core material is reduced so that mainly rotations of the magnetization are responsible for magnetic behaviour of the amorphous core. On the other hand, the field induced by the AC electric current passing through the ribbon (driving magnetic field) will determine a more rectangular form of the transversal hysteresis loop, in good agreement with the change of the magnetic anisotropy from the easy-ribbon-axis type to the hard-ribbon-axis type. The good sensor sensitivity obtained at high frequencies of the driving current can be explained by the fact that the domain wall movements are effectively damped at high frequencies [11] so that mainly rotations of magnetization are responsible for magnetic behaviour of the amorphous core.

We demonstrated the possibility to use the fluxgate sensor based on $Co_{68.25}Fe_{4.5}Si_{12.25}B_{15}$ amorphous ribbons to measure the AC magnetic fields up to 200 μT in the frequency range 0 – 20 kHz.

The response of the Envirometer in the AC magnetic fields of 200 μT and 124 Hz is presented in Fig. 1. The calibration error is less than 3 %. Fig. 2 shows the Envirometer response in the AC magnetic fields of 20 μT and 124 Hz. The deviation from the expected linearity is of about 2 %.

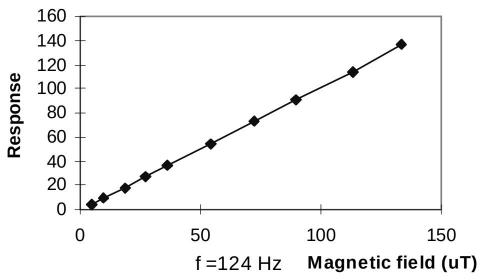

Fig. 1. The Envirometer response on the 200 μT scale with magnetic field variation.

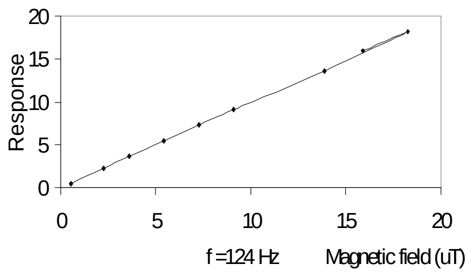

Fig. 2. The Envirometer response on the 20 μT scale with magnetic field variation.

The fluxgate sensor is also used to measure continuous magnetic fields in the range 0 – 200 μT. The scale of 200 μT DC was introduced in order to estimate the presence of eventual electromagnetic pollution sources. The UE recommendations referring to the exposure limits of electromagnetic fields indicate as exposure limits for frequencies lower than 25 Hz the field values greater than 200 μT.

Using the developed Envirometer the magnetic fields strength up 200 μT can be measured in 4 selectable measurement ranges with an accuracy of 3 % and a resolution of 0,1μT: in the range of 0 to 20 μT AC fields with inductive sensor; 0 – 20 μT AC – with fluxgate sensor; 0 – 200 μT AC – with fluxgate sensor; 0 – 200 μT DC – with fluxgate sensor. The device allows to measure in 2 selectable ranges the frequency of alternating magnetic fields: 0 – 200 Hz; and 0 – 20 kHz. Both the magnetic field ranges and the frequency ranges are in agreement with the latest UE recommendations referring to the all important exposure limits of electromagnetic fields.

The Envirometer offers the possibility to measure magnetic fields and their frequency with only one device. Despite of these functions even non-professionals can easily handle the device. The Envirometer is a portable device having reduced dimensions; high quality construction elements, battery included, adequate design, long lifetime and function security, developed for the use by administrations, industries, researches, health institutions or engaged private users.

4. Conclusions

Using suitable heat treated $Co_{68,25}Fe_{4,5}Si_{12,25}B_{15}$ amorphous ribbons, a sensitive sensor that has a magnetic behaviour in concordance with the metrological requirements of the device used for electromagnetic pollution measurements, was designed. The miniaturised direct driving fluxgate sensor having the sensitivity of 30mV/μT can be characterized as an extremely simple construction consisting of one coil surrounding a hairpin-shaped piece of stress-annealed amorphous core with open magnetic paths.

The magnetic behaviour of the sensor is discussed in the terms of the contribution of both the stress annealing and the driving magnetic field at the magnetization processes which take place in the used amorphous ribbon. The presence of the magnetic anisotropy with the ribbon axis as a hard axis of magnetization promotes magnetization rotations rather than domain wall movements in the AC magnetization process used in fluxgate sensors. The Barkhausen noise in core material is reduced, so that rotations of the magnetization are mainly responsible for magnetic behaviour of the amorphous core and a low noise sensor can be produced. At high frequencies of the driving current, good sensor sensitivity can be obtained because the domain wall movements are effectively damped at high frequencies.

The possibility to use the developed fluxgate sensor based on $Co_{68.25}Fe_{4.5}Si_{12.25}B_{15}$ amorphous ribbons to measure alternating magnetic fields up to 200 μT and frequencies of 0 – 20 kHz was demonstrated. The response of Envirometer equipped with the presented sensor deviates from the magnetic field variation only with 2 % from the expected linearity.

The Envirometer offers the possibility to measure magnetic fields strengths up to 200 µT in 4 selectable measurement ranges with an accuracy of 3 % and field frequencies in 2 selectable ranges with only one device. Both the magnetic field and the frequency ranges are in agreement with the latest UE recommendations referring to the all important exposure limits of the electromagnetic fields.

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