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MAGNETIC FIELD MONITORING OF AREAS

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Monitoring of processes that are running in the area of interest penetrates all human activities. It is made possible by multisensors, which have remained in focus already for a long time at the department of Electronics and Informatics. Emphasis is laid both on realization of autonomous multisensoric subsystems and methodology of the measuring of events occurring in the surrounding physical fields [1,3].

Keywords: monitoring, process, area, magnetic, field, multisensors, methodology

1. 12-CHANNEL MAGNETIC FIELDS ANALYZER

Suitable space arrangement of independent magnetic sensors allows contactless detection of moving objects containing hard or soft ferromagnetic as well as processes accompanied by changes of magnetic fields generated by electric currents.

For the entire analysis of magnetic processes in the certain area it is necessary to know vectors of magnetic induction in four points (3 points within a plane and 1 outside of it) and basic x-y-z combinations of gradients. This can be obtained with appropriate arrangement of 12 independent sensors working in synchronous mode.

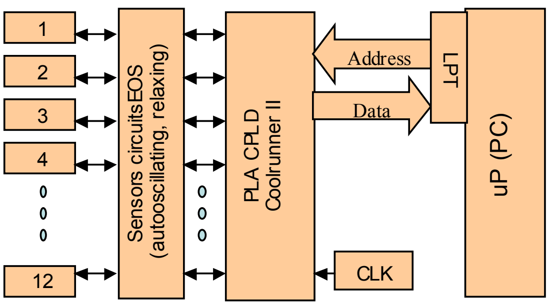

Fig.1. Flow diagram of 12-channel stationary and low frequency magnetic field analyser

Fig. 1 introduces a 12-channel stationary and low frequency magnetic field analyser. The block of sensors is build on the basis of ferrosonds in autooscillating or relaxing mode. Output PWM signals are processed with CPLD Coolrunner-II, which concurrently ensures communication with a microprocessor (or a PC).

2. AUTOOSCILLATING AND RELAXING SENSORS

Ferroprobe is the key element of autooscillating sensor as well as relaxing sensor. Magnetic field directly acts on a ferroprobe and that transforms magnetic field to an electrical signal. The principle of measurement with ferroprobe works on determination magnetic induction B_i in the ferroprobe core.

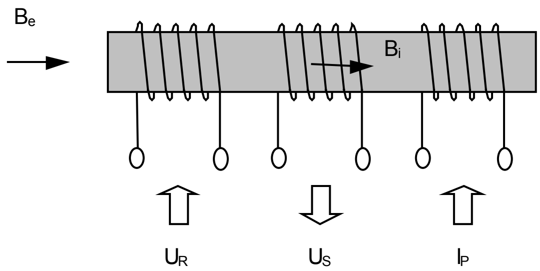

Fig. 2. Ferroprobe for autooscillating sensors with three independent coils

B_i is linearly coupled with the measured value, with induction of external magnetic field B_e. Ferroprobe is a coil with ferromagnetic core and 2 independent coils for relaxing sensors, or 3 coils for autooscillating sensors. None of the following elements of measuring chain can compensate for magnetic or electric limitations of ferroprobe (selection material of the core, the core geometry, number of coils, arrangement and geometry of the coils) [2].

Both autooscillating and relaxing sensors use transition actions on ferroprobe. In autooscillating sensors transition actions are generated with potential pulses supplied into the control coil. At the same time sensing coil response is evaluated. Premagnetization coil is used to set the proper operating point and for partially or fully compensation for the measured magnetic field. Information about measured magnetic field is included in 3 independent time periods of the output TTL signal (T, T_1, T_2) as well as in the size of premagnetization current.

Relaxing sensors utilize change of magnetic potential energy of ferroprobe core from state of technical saturation, induced by short current pulse, to a state given by external magnetic field to result in electrical work in the load of the sensing coil.

The process of the excitation of core provides stable initial conditions for the following transition action. Ferroprobe core is excited by independent coil fed by synchronized current control pulses.

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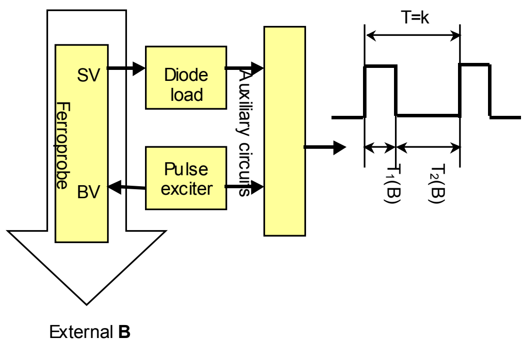

Fig. 3. Relaxing sensor flow diagram

Superposition of measured and excited magnetic value in the ferrosond core is thru electromagnetic induction transformed to a proportional electric signal. Information about measured magnetic field is included in 2 independent time periods of output TTL signal (T_1, T_2), whereas time T is constant.

With reference to utilization of electric signal of ferroprobe and with reference to follow-on processing circuits is optimal to decode the time period of transition event. The diode load causes a rapid fall of core energy before it becomes exhausted and thereby it becomes ideal for low noise transformation [2]. Output pulse-width modulated signal PWM from auxiliary circuits of ferrosond is processed with programmable logic array CPLD Coolrunner-II.

3. PROGRAMMABLE LOGIC ARRAY CPLD COOLRUNNER-II

Next important task is measuring of the time periods PWM signals from ferrosonds using CPLD with maximum precision. We need to measure time of pulse T_1 and time of space T_2 of signal of a concrete ferrosond. The CPLD is provided with two independent counters on a single channel. The first counter, for the time of pulse T_1, is filled during the time of pulse and the second counter, for T_2, is filled during time of space. Increasing the filling frequency of counters will cause increase in precision of measure.

CPLD Coolrunner-II can reach almost 600 MHz filling frequency. At 600 MHz is, at 1 kHz sampling rate, resolution about 19 bits. By repeated measurements we can reach theoretical border of sensitivity 1 nT for ferrosonds, however longer time of measuring, are needed.

4. PROCESSING OF MEASURED DATA

The currently realized 4-channel stationary and low frequency (up to 500 Hz) magnetic fields analyser with 'HFT' ferrosonds [4] works with sensitivity under 6 nT. CPLD Coolrunner-II 256 operates with synchronous in all 4 channels and at the same time. The sampling rate for all channels is 1 kHz. CPLD clock are 60 MHz, it means that filling frequency of counters is 2 x 60 MHz = 120 MHz.

Data transfer to PC is provided by LPT. PC selects address with output 4 bits and data are read from CPLD by 8 input data bits. Measured values are 19bits.

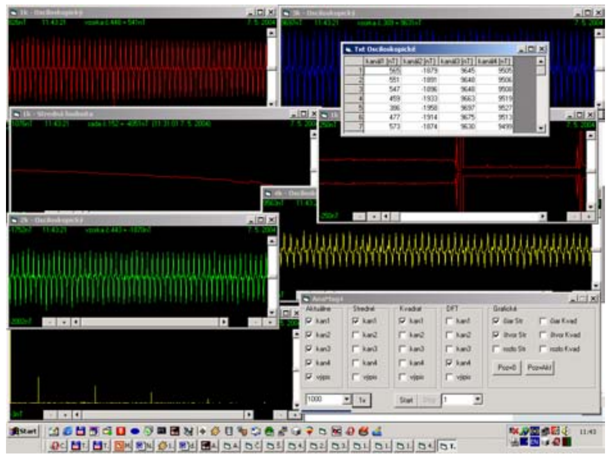

Fig.4. Anamag software

Recording, processing and visualization of measured data is ensured by a PC.

The Anamag software enabled:
- communication and recording of measured data
- computation of main statistics characteristics of measured signals
- visualization of measured and calculated characteristics of signals sensors
- generation of pictures measured magnetic fields in a plane and in a space

Main statistical characteristics, like average value, variance, standard deviation and frequency spectrum are calculated for each channel of the analyser. Oscilloscopic windows are enabled for all channels and every measured or calculated data. The software provides plane and space visualizations named 'magnetic pictures'.

'Magnetic pictures' are based on interpolations by plane or space weighting functions. The weighting function is explained in Fig. 5., where B_1 .. B_4 are measured vectors of magnetic induction in a node of a grid $\Delta_X \times \Delta_Y$. S_1 .. S_4 represent plane-weighting functions.

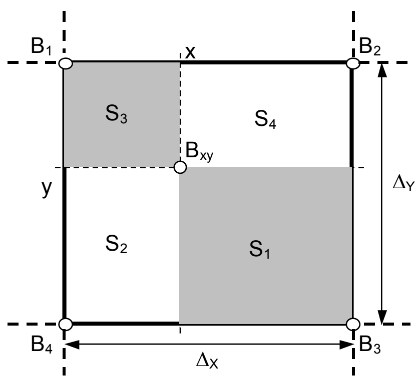

Fig.5. Computation of magnetic pictures in a plane

Magnetic field value B_{XY} in plane of sensors is calculated using the following formula.

$$B_{xy} = \frac{\sum_{i=1}^{4} S_i B_i}{\sum_{i=1}^{4} S_i} = \frac{1}{\Delta_X . \Delta_Y} \sum_{i=1}^{4} S_i B_i \qquad (1)$$

Where: $S_1 = (\Delta_X\text{-x}).(\Delta_Y\text{-y})$, $S_2 = \text{x}.(\Delta_Y\text{-y})$.

The colour scale, that can be set absolute or relative, include overall 512 levels, from scarlet (maximum positive value - north pole), over black (zero) to blue (maximum negative value - south pole).

5. RESULTS OF MEASURING

Fig. 6 describes arrangement of sensors in the lab in 5 × 5 m grid. Sensors can be placed, for example, under the ground, ceiling or walls of the room where they can be aimed in direction of the one of axes of local coordinate system or in the direction of minimum or maximum of local stationary magnetic field. It depends on the planned use and scale of measured changes.

The continuous measurement of projections of magnetic induction vectors into their axes allow us to evaluate group of events occurred in the area of interest.

Figure 8 'visualizes' changes in distribution of magnetic field, which were originated by rotation of magnetic moment carrier (magnet). The carrier is a permanent cylindrical magnet 12 cm long and 7 cm in diameter. Magnetic induction at the head of the carrier is about 0.3 T. Rotation is displayed only in range 0 - 180° and the pictures for the following two quadrants are mirrored. Pictures in Fig. 9 originate by linear shift of carrier by Fig. 7.

In both cases average values from set of actual measured samples (1 set *ie* 100 samples) were processed. Other calculated statistical characteristics of measured signal or their mutual functions can also be visualised, of course. It enables us to locate of the place of origin disturbance signal, map its movement in the area of interest, determine the size of carrier of disturbance and to activate an appropriate alarm function. Displaying magnetic fields in space by space weighting functions is very similar.

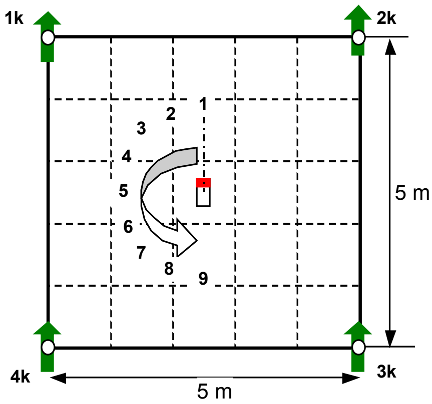

Fig. 6. Rotation of object with magnetic moment

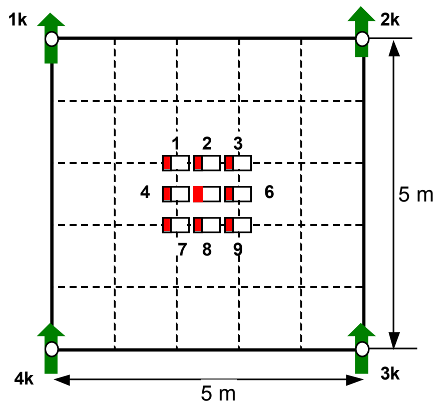

Fig. 7. Shift of object with magnetic moment

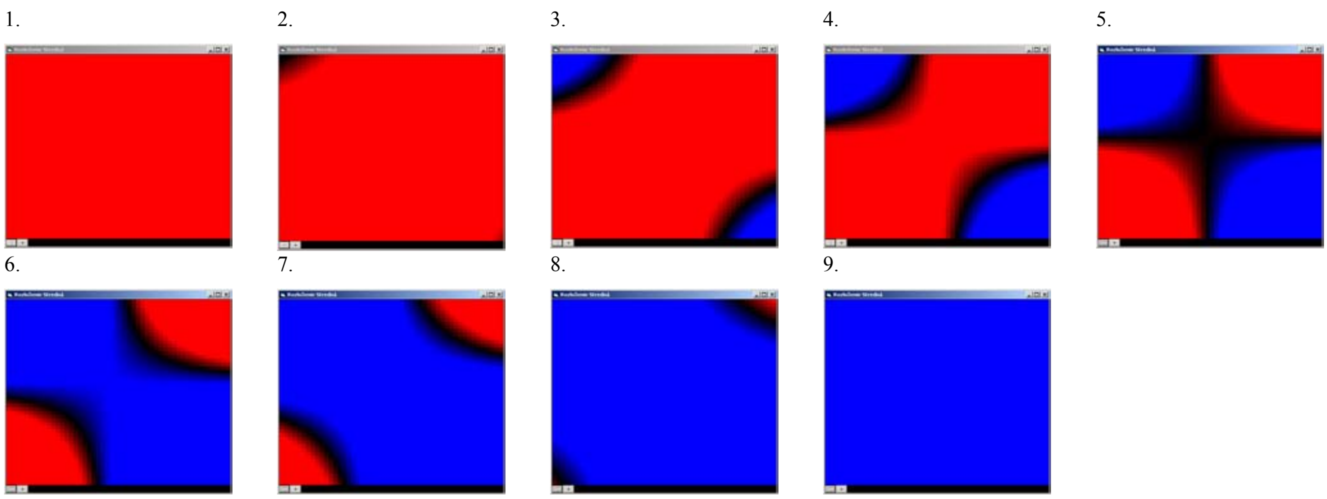

Fig. 8. Demonstration of changes in 'magnetic pictures' caused by rotation of magnetic moment carrier

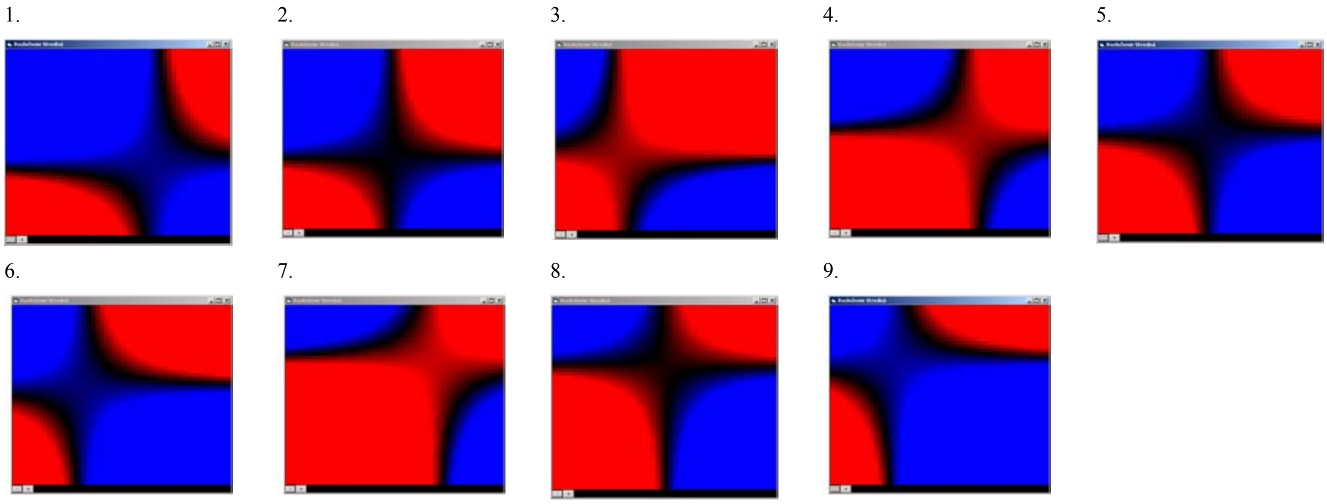

Fig. 9. Demonstration of changes in 'magnetic pictures' caused by linear shift of magnetic carrier

5. CONCLUSIONS

The results obtained in various environments suggest high information value contained in the magnetic field. Consequently there exist wide areas of application, particularly for 'intelligent objects and areas of interest'. Changes in 'the magnetic map' visualize events, which are not demonstrative in acoustic or light spectra, and therefore they are difficult to detect for human beings.

REFERENCES

[1] Hudák, J.: Magnetometria, vybrané problémy vývoja a využitia, Habilitačná práca, VLA Košice, 1999

[2] Praslička, D.: Relaxačné magnetometre, Dizertačná práca, VLA Košice, 2000

[3] Čopík, J.: Autonómny multisenzorický podsystém získavania a spracovávania informácií, Diplomová práca, VLA Košice

[4] EDIS: Hlídače feromagnetických telies, firemná literatúra, Košice, 1999

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