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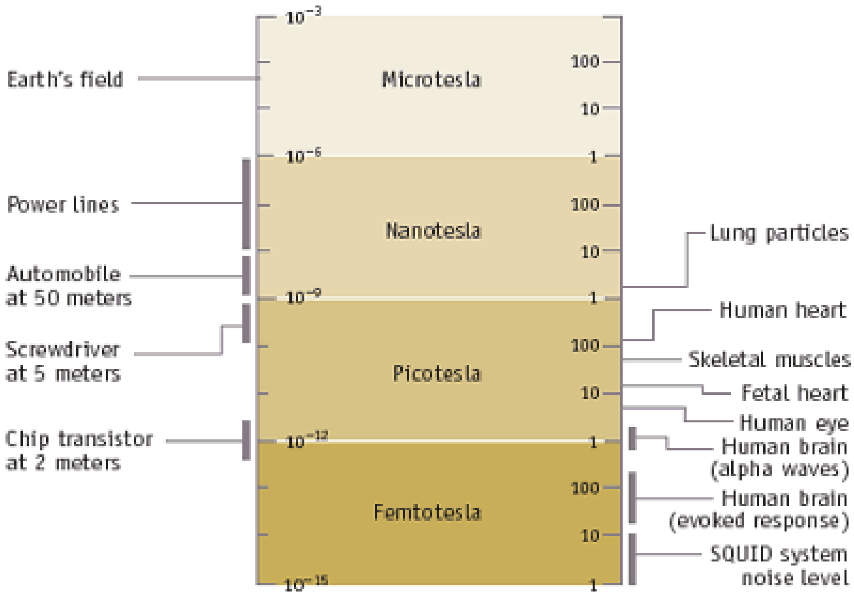
APPLICATION OF MAGNETOMETRY FOR OBJECTS IDENTIFICATION

Abstract. The paper concerns the possibility of application of magnetometry for object identification. One of the basic conditions for successful use of magnetometric methods is the magnetic contrast of solids towards surroundings. Another possible use of magnetometry is for local identification of solids in selected areas, which are situated in the local magnetic field. The magnetometer, which enables to measure up to three vector components of magnetic induciton and specialized software were used in order to perform the research. Two experiments were carried out within the research.
Keywords: magnetometry, object identification.

ZASTOSOWANIE MAGNETOMETRII DO IDENTYFIKACJI OBIEKTÓW

Streszczenie. W pracy zaprezentowano analizy dotyczące możliwości zastosowania magnetometrii do identyfikacji obiektów. Jednym z podstawowych warunków efektywnego wykorzystania metod magnetometrycznych jest pomiar tła magnetycznego obiektów w odniesieniu do otoczenia. Kolejnym możliwym zastosowaniem magnetometrii jest identyfikacja obiektów w lokalnym polu magnetycznym w wybranym obszarze. W przeprowadzonych badaniach wykorzystano magnetometr umożliwiający pomiar trzech składowych wektora indukcji magnetycznej oraz wyspecjalizowane oprogramowanie. W ramach pracy zrealizowano dwa eksperymenty naukowe.
Słowa kluczowe: magnetometria, identyfikacja obiektów.

This article points to the possible use of selected properties of solids for their identification and determination of their position if they are situated in the Earth's magnetic field with triaxial magnetometer. One of the basic conditions for succesful use of magnetometric methods is the magnetic contrast of these solids towards surroundings. Another possible use of magnetometry is for local identification of solids in selected areas, which are situated in the local magnetic field.



Picture 1. Magnetic induction of different objects [2]

Objects containing feromagnetic substances can create static as well as dynamic magnetic field. The intensity of these fields decreases with the distance from the object and vice versa. Because all of these objects are in the Earth's magnetic field, the intensity of the resulting magnetic field measured by magnetometer is given as a vector sum of the custom object fields located in the Earth's magnetic field. This vector sum is influenced by a magnetic background in the defined places.

Ferromagnetic object can have permanent magnetization or magnetization induced by the Earth's magnetic field. Permanent magnetization does not depend on the presence of an external magnetic field, therefore if an object rotates, its magnetic field will rotate too. Conversely, the induced magnetization is dependent on the direction and magnitude of the Earth's magnetic field and the magnetic properties of the object. A field created by induced magnetization will not rotate simultaneously with the object. Determining relative additions of these two kinds of magnetization is possible by a series of measurements involving an object's rotation around its axes (x, y, z).

Equipment

As was stated above, a magnetometer plays the main role in this article. Magnetometer Vema is designed for vector measurements and oscilloscopic view of the progression of magnetic induction fields as well as creating and recording data files from time and space measurements and also its analysis. Magnetometer enables to measure up to three vector components of magnetic induciton defined by user. The resolving ability of a used magnetometer reaches up to units of nT due to sensors, which are made of magneticaly soft amorphous metal alloy. The constant sampling frequency of magnetometer can be adjusted from 1kHz to 250Hz with sensitivity ≥ 2nT . The following table shows basic parameters of the mentioned device.

Table 1. Vema Magnetometer parameters [1]

Range	± 100 µT
Direct sensitivity	≥ 2,0 nT / 1kHz
Average sensitivity	≥ 0,2 nT / 5kHz
Sampling frequency	1 kHz
Frequency range	0 - 250 Hz
Offset drift	± 100 µT (after 15 min)
Linearity error	0,5%
Temperature range	+10°C - +40°C
Main power supply	230V / 50Hz / 15VA
Battery power supply	12V /500mA
Dimensions [mm]	390 x 180 x70
Weight	2,8 kg
Number of sensors	3
Interface	USB 2.0

Besides the device there is also some software equipment needed. Real time and even post-procesing evaluation of the data obtained from the magnetometer can be performed by QtVema software. The primary function of this software is to visualize the processed data to the user and also to save collected data in memory. Visualisation itself runs in osciloscopic mode on a PC connected to the magnetometer.

Identification process

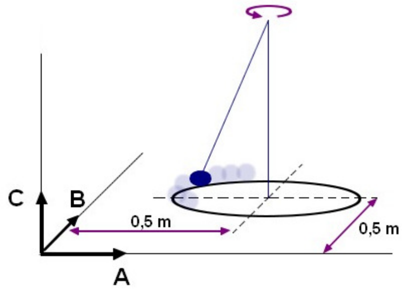
The principle of change of magnetic induction can be used in object security, because this change represents a specific state change caused by an object presence at real space (e. g. room). This state can be defined in real space $\boldsymbol{E_3}$ and specific time $\boldsymbol{t}$ by a set of values $\Omega_1 \in E_3$ (t, B_x, B_y, B_z), which is transformed (by Fourier's disctrete transformation) and provides us mediated image $\psi_1 \in$ (t,a,b,c).

For practical applications it's necessary to know the initial or referential state in the defined area [a, b, c] and time. This state is defined by a specific value, which is a function of the specific time, exact position (e. g. GPS) and properties of magnetic background $\Omega_1 \in E_3$ $(t_1, B_{a1}, B_{b1}, B_{c1})$. Then at the specific time values $\Omega_n \in E_3(t_n, B_{an}, B_{bn}, B_{cn})$ are monitored, where the resulting change is given by a difference between Ω_1 and Ωn.

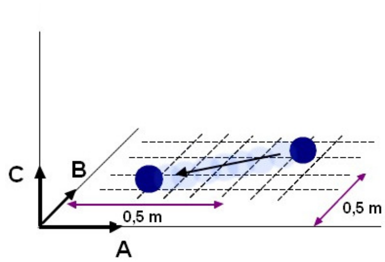
Experiments

The main objective of the first experiment was to study interactions between sources (magnetic, electromagnetic) in the defined area. The dependence of distance and induction of the selected object was monitored with regard to the characteristics of the defined area and furthermore standard electrical sources with a frequency of 50Hz were monitored, especially their first to fifth harmonics and sub-harmonics. The experiment was supposed to confirm or refute the assumption of potential influence by any other sources outside the defined area and also their influence on this area without magnetical shielding.

During the first experiment several different items were used – a neodymium ball (5mm in diameter), screw nuts (in sizes M4 and M8). The following characteristics were monitored – course of movement with regard to time, frequency spectrum, waveforms of induction in directions of the x, y, z axis and the resulting vector of magnetic flux for selected movements - cyclic and acyclic.

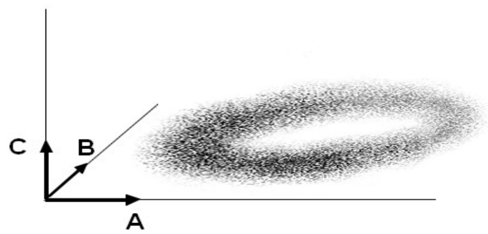


Picture 2. Cyclic movement [1, redrawed]



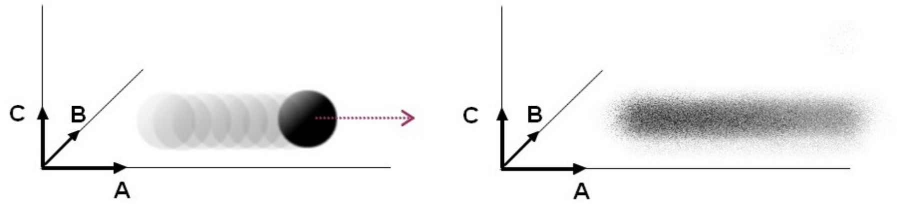
Picture 3. Acyclic movement [1, redrawed]

The second experiment was supposed to verify the possibility of determining object’s position in the defined area by measuring changes of magnetic induction in the directions of a, b, c axis. One of the main conditions was to use common metal or a ferromagnetic object –a neodymium ball and screw nuts (the same items as in the first experiment).



Picture 4. Oscilation of neodymium ball [1, redrawed]

Picture 4 is illustrating the track of the neodymium ball and the screw nut during the cyclic movement in regard to the defined area. Coloured dots indicate the change in intensity of the induction in three directions (axes a, b, c) - the darker the colour is, the higher is its intensity of the induction.



Picture 5. Rolling neodymium ball [1, redrawed]

Monitoring changes in the shape of neodymium solid and observing changes in its induction regarding to variable position (picture 5 shows a roling ball).

Evaluation

1. Sources working on 50Hz frequency generate the first to third harmonics, which must be filtered out during the measurement to obtain correct data.
2. Common metal objects are indentifiable up to distance of 2m when they are magnetized even without filtering 50Hz sources and their harmonics.
3. For rapid recognition of background and noise standard autocorrelation function can be used, which is involved in a software package.
4. To evaluate cyclic movements Fourier's discrete transformation may be used.
5. Real objects usually do acyclic movement; its evaluation should be based on time waveform.
6. Both movements - cyclic an acyclic can be monitored up to distance of ± 3m if it is performed by a feromagnetic or common metal object.
7. Even small paramagnetic objects can be monitored (their presence, shape, position) up to distance of ±1m.
8. It is possible to identify objects moving cyclically by means of recorded spectrum.
9. Objects which are not moving cyclically can be identified by means of time waveform.

Sources

[1] Oravec M. Využitite magnetometrie při identifikovaní objektov. TU Košice, 2012.
[2] Squid Magnetometry. [online] 2008, [cit. 2014-07-30]. Dostupné z: <http://www.lanl.gov/quarterly/q_spring03/magnetic_fields.shtml >