Dynamic control and annulment of electromagnetic pollution

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Abstract – A method and an installation for annulling the parasite alternative magnetic induction in the laboratory is presented. The installation controls the magnetic field level inside the volume where a MAT 252 mass spectrometer is situated. The field control is achieved by means of a system of a large Helmholtz coil having the spectrometer placed in their centre. A field transducer permanently measures the induction level and delivers a correction signal that monitors the compensation current intensity through the Helmholtz coil. The installation is meant to work in the laboratories situated in places where the industrial EM pollution can not be suppressed by other methods.

I. Introduction

The protection against the electromagnetic interference is recommended in the case of some special applications: tomography, spectrometry, electrocardiography, magnetoencefalography, nuclear magnetic resonance, special EM measurement, a.s.o. Different methods for suppressing the interferences are used, according to the nature of the disturbing sources and the disturbing field spectrum.

As the result of the request coming from the Institute of Geology and Geophysics of Bucharest, demanding the study of a location for a mass spectrometer type MAT 252 Finnigan, a series of measurements of the alternative magnetic field level (50 Hz) has been performed. These measurements revealed values of vertical component much higher than accepted. Analyzing the performed measurements and taking into account the producers recommendation concerning the EM interference, resulted in the necessity of diminishing the intensity of the vertical component of the magnetic flux density at the industrial frequency (50 Hz) down to the maximum admissible value of 10 mG_{pp}. The easiest but costly solution consists in the realization of a shielded room made of materials with high magnetic permeability.

The utilization of a shielded room where to place the mass spectrometer would have rised special problems connected with: room mounting, access doors, ventilation, power supply, supplementarily loading the building floor, cost price. Under these circumstances, we appealed to an apparently more complicated solution, but which shows certain advantages over the shielded room. In this connection, we conceived an installation to controll the parasite induction level and ensure a minimum disturbance level (less than 10 $mG1_{pp}$) all along the spectrometer operation, within a volume that includes both the spectrometer analyzer and collector.

II. Measuring and compensation principle

According to Faraday's law:

$$E = -\frac{d\Phi}{dt} \tag{1}$$

an alternative induction: $B = B_0 \sin\omega t$ will induce into a probe coil with N turns and the effective cross section S, an electromotive force:

$$E = S\omega B_0 \tag{2}$$

It follows hence the possibility to measure the induction by a relatively simple and well known method. For the given coil, the values of the measured induction is:

$$B_0 = \frac{E}{S\omega} \tag{3}$$

Since the probe coil has a derivative characteristics, the induced voltage will be proportional to both ω, and B_0 ; getting a dependence only on B_0 will permit the determination of induction magnitude unaffected by the pulsation. This can be achieved by using a circuit presenting a transfer-function proportional to $1/\omega$. Thus, the measuring system consists of the probe coil, an integrator or other single-pole circuit and a voltmeter (Figure 1).
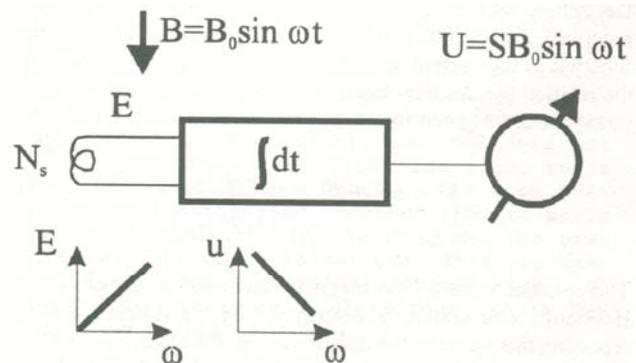

Figure 1. Measuring principle

The calibration of this system in magnetic induction units will offer it the characteristics of a magnetometer for alternative fields. Once the measurement problem solved, the compensation or annulation of the parasite induction have to be achieved. For this, the above mentioned measuring system has to be completed with a negative feed-back system presented in Figure 2.
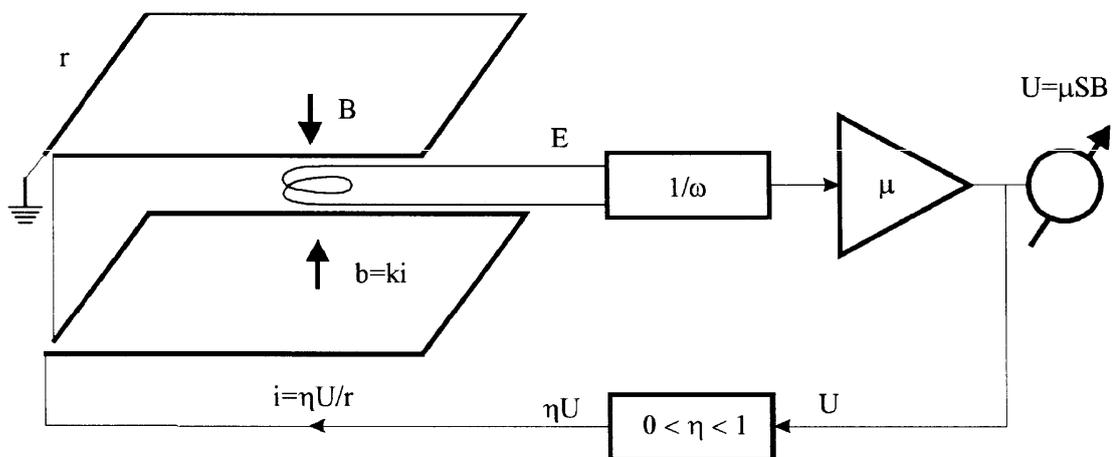

Figure 2. Block diagram

By adding to the integration circuit, an amplifying circuit with the gain μ, the output voltage in the system will be:

$$U = \mu SB \tag{4}$$

By means of a negative feed-back circuit, the signal resulted at the output of the amplifier μ is applied to a system of square Helmholtz coils. Taking over a fraction μU of the output signal, the current through the Helmholtz coil will be:

$$i = \eta \frac{U}{r} \tag{5}$$

where r is the Helmholtz coil resistance

This current will determine a negative feed-back magnetic induction:

$$b = ki = k\eta \frac{U}{r}, \quad k - \text{coil constant} \tag{6}$$

Depending on mutual orientation of the two coils (search and reaction), the reaction can be positive or negative. The transfer function of the system with the open reaction loop is given by the relation (4); for the closed reaction loop system, the output voltage will be given by:

$$U = \mu S(B - b) = \frac{\mu SB}{1 + \mu \eta S \dfrac{k}{r}} \tag{7}$$

The residual value of the magnetic induction in the centre of Helmholtz coil system is determined by the difference $B\text{-}b$; reporting this value to the disturbance B, the attenuation of the disturbance in the closed loop system can be established:

$$\frac{B - b}{B} = \frac{1}{1 + \mu \eta S \dfrac{k}{r}} \tag{8}$$

Considering for higher efficiency $\eta = 1$, it follows for $\mu Sk/r \gg 1$, $\dfrac{B - b}{B} = \dfrac{r}{\mu Sk}$.

III. Results

An installation for the compensation of the polluting magnetic induction has been elaborated (named "Electromagnetic field radiation controller EMC-10") with the following characteristics:
- Helmholtz coil dimensions: (3160 x 3160) mm
- controlled component: vertical
- maximum level of the compensated induction: 80 mG$_{rms}$
- working frequency: 20 Hz.. .500 Hz (3 dB)
- attenuation: 40 dB.
The residual induction control is performed with an "Electromagnetic field magnetometer type VLF-10" with the following characteristics:
- measuring range: 0-10 mG ; 0-100 mG
- precision: 1,5 %
- resolution: 0,1 mG
- probe coil constant: 10^{-2} V/HzT.
The installation for annulling the parasite alternative magnetic induction in the laboratory is presented in fig. 3.
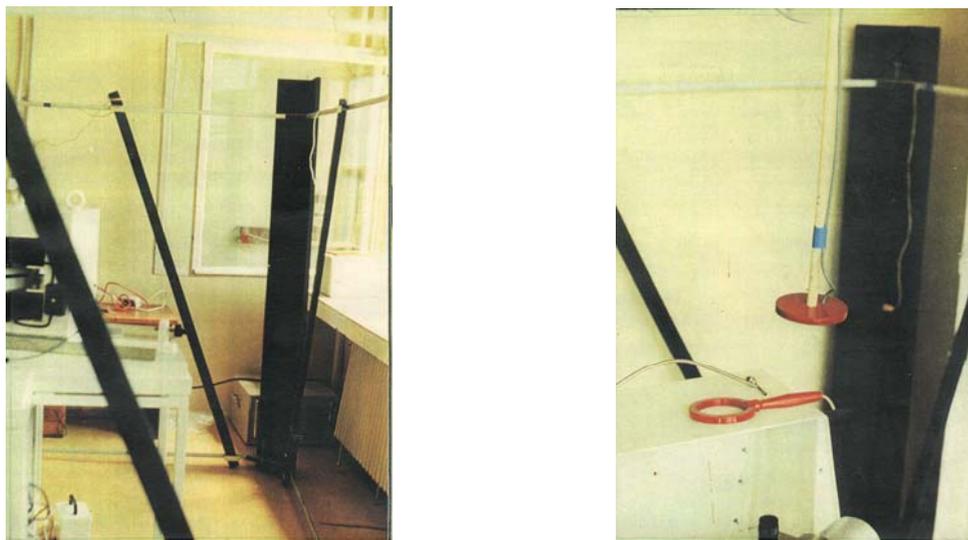

Figure 3. The installation for protection and measurement of the electromagnetic perturbations from the Institute of Geology and Geophysics of Bucharest

IV. Conclusions

The polluting magnetic inductions can be annulled by using a dynamic control installation. The installation is relatively simple, the expenses being 10 to 100 times lower than when using a magnetic screen.

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