AN AUTOMATIC MEASUREMENT APPARATUS FOR LOW VALUE MAGNETIC FLUX WITH HIGH RESOLUTION

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Abstract

When a low value flux is to be measured the induced signal in measuring coil would be very weak and the instrument resolution becomes very important[1]. Here a nanovoltmeter as the preamplifier is used to detect the induced signal from measuring coil and a digital integrator is followed to obtain the flux value. Thus a resolution of less than 1nWb for flux measurement is reached.

1. Introduction

In this paper an automatic measurement apparatus of high resolution for low value magnetic flux is described. A nanovoltmeter as the preamplifier is used for the induced signal from the measuring coil. Thus a high resolution of 1nWb for flux measurement is reached, which is 10times higher than the similar apparatus. At the same time, a *V/F* converter and a digital integrator are followed to obtain the flux value to avoid the returning error in the ordinary *RC* integral amplifier. This measuring system including the necessary exciting current source is operated automatically by a computer. Such a low magnetic flux measurement system may also be used for measuring low magnetic field with an adequate measuring coil. When the magnetic area of the measuring coil is about $0.2m^2$(1cm in diameter and about 4000 turns), the resolution for magnetic field detection is 5nT.

2. System Scheme

The diagram of the measuring system is shown in fig 2.1. The electromotive force in the measuring coil is induced by a varied magnetic field or a magnetic sample. Following the preamplifier, the signal is integrated in a digital integrator. A computer is used to calculate the data and controls the direction of the exciting current.

When a magnetic field is measured, the coil should be moved or reversed to obtain induced electromotive force signal. An exciting current source will be necessary, if a magnetic sample is measured.

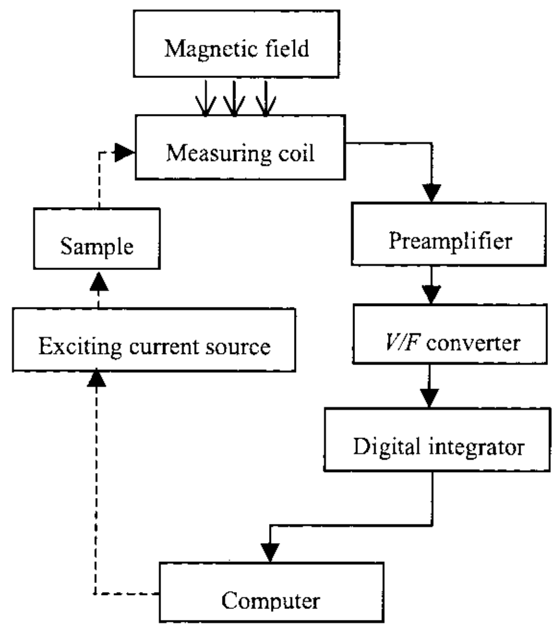

Fig 2.1 System scheme

3. Measuring-coil and Exciting Current Source

A coil is used to detect the variance of the magnetic flux. If the magnetic chain in the coil is Ψ, the induced electromotive force in the coil should be:

$$e = -\frac{d\Psi}{dt} \tag{3.1}$$

When a low value magnetic flux is to be measured, the turn number of the coil could be increased. On the other hand, the coil size is required to be smaller. Usually very thin wire should be used to make the measuring coil. In practice, a wire of diameter is 0.05mm is wound on a brass frame to form the measuring coil and its turn number is 4000. The coil diameter is 1cm; its axial length is also 1cm. Then the magnetic area of the coil is $(1933\pm1)cm^2$, which can be calibrated by the national standard of coil magnetic area.

When a weak magnetic sample is measured or the μ_0 of a ferromagnetic sample is to be determined, the measuring coil should be wound on the sample together with the exciting coil. The direction and value of the exciting current are controlled by a computer. The sweep rate of the current is also controlled by the computer to avoid eddy current. The reversed period can be extended to 1 minute.

4. Preamplifier

When the magnetic field to be measured is weak, the induced electromotive force signal in the coil may be less than 30nv. Thus a preamplifier specially designed is used to amplify this signal. The noise of the preamplifier is only 10 nV(effective value, averaged in 10 minutes) with 10 kΩ input impedance.

5. *V/F* Converter and Digital Integrator

The output of the preamplifier is converted to a frequency signal. When the input is zero, the output frequency of the converter is 5kHz. The sensitivity of the converter is 1kHz/V. the non-linearity is less than 0.1%.

The output of the *V/F* converter should be integrated. In principle, pulse galvanometer or *RC* integrator could also be used. To avoid some error such as "reverting error", a digital integrator based on the MCS monolithic computer is chosen.

For a frequency signal near 5kHz, the accuracy will be not high enough if this signal is counted only with integer number. Therefore, besides the integer part of the counting value, the fractional part is also considered in the integrator. By means of this "fractional method", the counting accuracy could be better than several parts in 10^5[2].

A low-pass filter fit in the preamplifier could cause some distortion of the wave-shape of induced voltage signal. But, it can be proved that if this filter is a linear one, this distortion will make no error for the integrator [3].

6. Automatic Control System

A computer is used to be a controller in the measuring system. It sends orders to the exciting current source and collects the data from the digital integrator through an RS-232 interface. The measuring curve and result data are displayed automatically.

7. Measuring Results and Error Analysis

The system is calibrated with a standard mutual inductor of nominal value 100μH. The current change in the primary side of the mutual inductor is:

$$\Delta I = (9.94 \pm 0.01)\text{mA} \qquad (7.1)$$

as a result, the magnetic flux change in the secondary side is:

$$\begin{aligned} \Delta\Psi &= M\Delta I \\ &= 9.94 \times 10^{-3} \times 100 \times 10^{-6} \\ &= 994 \text{ nWb} \end{aligned} \qquad (7.2)$$

It is measured 10 times continuously with the system that is shown as fig 2.1. The results are following:

Index	Result
1	990.43
2	997.96
3	990.99
4	995.26
5	996.73
6	996.24
7	993.71
8	997.00
9	992.01
10	991.14
Average	994.15±0.85

References

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[3] Zhand Zhonghua, "A Result on the Pulse Area Transform by the Linear System and its Applications", *Chinese Journal of Scientific Instrument*, Vol. 5, pp. 95-102, 1984.