Geophysical Research Abstracts
Vol. 14, EGU2012-1349, 2012
EGU General Assembly 2012

Time-domain operation mode study of flux-gate magnetometer

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One of the most important parameters characterizing magnetometer quality is threshold sensitivity or own noise level (NL) of flux-gate magnetometers (FGM). The magnetic noise – fluctuations, arising by periodic magnetization of flux-gate sensor (FGS) core – determines sensitivity threshold of modern FGM. The study of NL characteristics revealed, that its spectral density b(f) consists of two parts. The first of them could be described as a “shot” noise with frequency independent power spectrum. Another one, known also as a “excess” noise, is governed by the law 1/f[U+F061]. Both parts contribute equally to the total noise at some corner frequency f0 , which for the modern FGMs lies in the proximity of 1 Hz.

In the ground geophysical surveys (geomagnetic observatories, magneto-telluric and magneto-variational soundings etc) FGMs are mainly used for measurements of DC magnetic fields and its slow fluctuations, because intensity of the geomagnetic variations falls down below FGM NL at the frequencies upper than 0.1…1 Hz. So in the operation frequency band (DC-1Hz) the FGM noise level depends on frequency and it is important to know the sources of the FGS noises in this band. From other hand reducing of the FGM noise level allow more reliable measurements of short period variations, what is important task especially for space physic community.

The magnetic noise arising during cyclic magnetization of the FGS core is a periodically non-stationary process, because the different physical processes are involved in magnetization at the different parts of hysteresis loop. So the signal detection in the frequency domain traditionally used in FGM could hardly help to study the fine structure of the magnetic noises.

In contrast, the direct digitizing of the voltage across the primary and secondary windings of FGS as well as the excitation current allows performing detailed analysis of the hysteresis loop fluctuations from cycle to cycle. In order to conduct such studies the wide-band high-resolution measurement setup was assembled and a number of FGS cores with different geometry were tested. In all cases the common behaviour of the magnetic flux non-reproducibility was revealed. At the saturated states the cycle to cycle variations of the magnetic flux through the secondary winding is minimal and often reached the noise background of the measurement setup. The intensity of the variations gradually increases as the core leaves saturated state and becomes maximal at a certain point of the hysteresis loop close to the saturated state of the opposite polarity. After this point the intensity of the cycle to cycle variations decays rapidly to the minimal value at the saturated state. The observed distribution of the magnetic noises along hysteresis loop at the high frequency cyclic excitation is proposed to use in order to optimize the signal detection procedure. As a result, for some specimens the noise level using the time-domain detection drops down around twice comparably with the usual frequency-domain detection mode at the second harmonic.

This study was supported by NASU contract N 1-711/11/1531.