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Measurement technology for seismomagnetic signals

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Ultra low frequency (ULF) band (0.001-3 Hz) is usually used for study of natural magnetic field variations of ionospheric and magnetospheric origin. At present this frequency range gains in importance at monitoring of lithospheric magnetic activity in seismo-hazardous areas for application to short-time earthquake (EQ) forecasting. A big number of publications confirm that ULF magnetic precursors were recorded from few weeks up to few hours before EQ.

The measurement technology of these signals has several peculiarities. First, the lithospheric ULF EQ magnetic precursors as a rule are very weak and their frequency range is overlapping with signals of magnetospheric or ionospheric origin. Second, for resolution of magnetic precursors at the background of more powerful sources it is necessary to have magnetic field sensors with wide dynamics and minimum possible spectral noise density (SND) level. Additionally, monitoring of lithospheric activity should be provided in close proximity to probable EQ area and almost in real-time regime.

For the study of ULF magnetic precursors the magnetometers with search-coil (SC) and fluxgate (FG) sensors are used. SC sensors for ULF band usually have length 0.8-1.2 m, diameter 10-15 cm and weight few kilograms with SND 0.1-200 pT/Hz$^{0.5}$ (here and further maximum SND value relates to a lower part of frequency range). FG sensors are very compact (pencil-shaped with length $\sim$ 4 cm) but have greater SND in this band (about 10-500 pT/Hz$^{0.5}$).

Next requirement, if to use SC, is that at 3-component magnetic field measurement it is necessary to provide spacing between sensors about 1-2 of their length for avoiding mutual influence between them. This requirement creates problems caused by non-rigidity of such construction and their spatial instability relatively ground surface (or horizontal plane). In addition, for such a long sensor a ratio of core length/diameter is big enough, what leads to increased SC sensor sensitivity to variety of mechanical deformations of sensor body. These factors increase the real SC SND because of induction effect in the Earth's magnetic field. Simple estimations show that sensitivity to changing of sensor axis direction can achieve a level about 250 pT for one second of arc.

To overcome majority of these problems, a specialized FG with length 10 cm has been developed. This newly developed device has SND in ULF band about 1-30 pT/Hz$^{0.5}$ and moderate consumed power. Additional merit of this sensor is extremely low noise density in the most prospective EQ magnetic precursors frequency range (0.001-0.03 Hz) – about 3-30 pT/Hz$^{0.5}$- which is less than SND for the best recent SCs. A ULF magnetometer with such a compact solid sensor unit at partial compensation of the Earth's magnetic field in the sensor volume allows drastic decreasing the mechanical artefacts influence and facilitates the constructing of measuring sites for field works.

As an example of SND necessity decrease the experimental data from seismo-hazardous region of China are discussed. It is shown that high SND of magnetometers leads to appearance of false background lithospheric signals and complicates the procedure of EQ related signals selection.

The comparison of parameter set for FG and SC has been made and a specific design of FG dedicated for seismogenic ULF signals measurements has been discussed.

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