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A proposal and a feasibility study of highly sensitive geo-electromagnetic field measurements using SQUID magnetometers

KAWAI, Jun[1*], MIYAMOTO Masakazu[1], OYAMA Daisuke[1], KAWABATA Miki[1], ADACHI Yoshiaki[1], HIGUCHI Masanori[1], UEHARA Gen[1], OGATA Hisanao[1]

[1]Applied Electronics Laboratory, Kanazawa Institute of Technology

A superconducting quantum interference device (SQUID) magnetometer is well known as a highly sensitive magnetic sensor, which has a wide frequency range from DC to 10 kHz or higher with the noise level of 10^{-15} T/rtHz. This sensitivity is around 1000 times higher compared to conventional magnetic sensors such as a fluxgate magnetometer and a proton magnetometer. Is not a highly sensitive measurement using SQUID magnetometers available for geo-electromagnetic research?

There were some works on the measurements of geomagnetic fields using SQUID magnetometers in Japan. It was a challenging experiment that Kitamura first demonstrated observation of geomagnetic fields using a bulk-type SQUID magnetometer in 1978. Unfortunately, the SQUID at that time did not have enough performance for field measurements. Then, he pointed out what to improve for a SQUID system if it was applied for geo-electromagnetism. Later, some groups demonstrated measurements of ULF electromagnetic signals using portable HTS-SQUID magnetometers operating in liquid nitrogen on the purpose of detection of electromagnetic phenomenon associated with volcanism and earthquakes.(Kamata 2000, Kasai 2001, Nomura 2002, Machitani 2003) However, those measurements were sometimes affected by an ambient noise or unexpected malfunction in the system. In addition, their experiment period was not so long enough that the availability of using SQUIDs has not been presented for geo-electromagnetic measurements yet. On the other hand, LSBB in France reported that magneto-ionosphere responses in the order of 100 pT-1 nT to P-wave emissions for earthquakes were detected with a SQUID system located underground.(Waystand 2009)

We have been developing MEG (magnetoencephalography) systems with low temperature SQUIDs operating in liquid helium, which are now in practical use and available for clinical diagnosis of brain diseases and for research on brain functions. Based on the techniques we developed, we again propose a SQUID system as a new tool for stationary and highly sensitive measurements in geo-electromagnetic research. In this session, we introduce a prototype SQUID system for this purpose. The system has the frequency bandwidth of DC-500Hz and the noise level is 15 fT/rtHz at 100 Hz and 2 pT/rtHz at 0.01 Hz. The dynamic range of the detectable field is set to be 300 nTpp. The data is acquired with a 16-bit logger with the maximum sampling frequency of 1 kHz. The time is calibrated with a GPS signal. First, we plan to place this system 1 m below ground and demonstrate a continuous measurement of magnetic fields for a month or longer to seek for what is necessary for the next improvement.

We are not experts in geo-science. We look forward to some discussions and appreciate not only useful advice but also severe opinions on our idea from the point of view of experts in this session.

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Keywords: SQUID, geo-electromagnetic fields, highly sensitive measurements, superconductivity