Observation of natural electro-magnetic signals using SQUID magnetometers –instrumentation and observed results–

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SUMMARY

We conducted highly sensitive observations of natural electro-magnetic (EM) signals, using a 3-axis superconducting quantum interference device (SQUID) magnetometer system developed in our laboratory. The typical system noise is 20 – 30 fT/√Hz at frequencies ranging from DC to 100 Hz. In particular, at frequencies lower than 1 Hz, the system noise is much less than that of an induction coil, which is generally used for highly sensitive observations. Therefore, we expect the SQUID magnetometer system to be capable of detecting EM signals with a high signal-to-noise ratio at extremely low frequencies.

The system comprises three thin-film SQUID magnetometers orthogonally installed in a glass fiber reinforced plastic (GFRP) cryostat filled with liquid helium, low-temperature drift readout electronics with a flux locked loop, and a data logger with a global positioning system (GPS) and telemetry function. The system operates using 12-volt batteries. The cryostat has to be refilled with liquid helium every 3–4 weeks.

We set up the system in the field and successfully confirmed the detection of natural EM signals, such as the Schumann resonance and the ionospheric Alfvén resonator.

In 2022 - 2023, we set up two SQUID magnetometer systems in Noto Peninsula, where the earthquake swarm has been still ongoing since the end of 2020, with the aim of detecting EM signals possibly related to the earthquakes. Upon comparing the signals obtained from both systems approximately 45 km apart from each other, the system located in the area closer to the epicenters detected piezomagnetic-like signals in some the earthquakes. We also analyzed the geomagnetic transfer functions during the observation period. The geomagnetic transfer functions at 0.02–0.05 Hz gradually changed from August to December 2023, before the earthquake of Mj7.6 on January 1, 2024. However, it remains unclear whether this temporal change in the geomagnetic transfer functions is related to the earthquake or not.

In this workshop, we would like to introduce the SQUID magnetometer system and discuss the observed results, focusing on the earthquakes.