

64-channel Long-baseline Second-order Axial Gradiometer System for Magnetocardiographic Measurements

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Magnetocardiography (MCG) can provide functional information on the myocardium currents by measuring magnetic fields from the heart using a multichannel SQUID system. Since environmental noises are much larger in amplitudes than the MCG signals, and we need a magnetically shielded room (MSR) to attenuate the external noises. In order to have high shielding factors in the frequency range of MCG signals, normally 0.1 Hz – 100 Hz, we need a thick MSR made of high-permeability Mumetal plates and high-conductivity aluminum plates. Mumetal or Permalloy is an expensive material. Thus, in order to reduce the fabrication cost of MSR, we need gradiometric pickup coils to attenuate the environmental noise economically while minimizing the reduction of MCG signals due to gradiometer configuration. We fabricated a 64-channel second-order wire-wound gradiometer system for operation in a thin MSR. The gradiometers have a coil diameter of 20 mm, and wound with an NbTi wire of 0.125 mm line diameter. The gradiometers were connected to input coil pads of SQUID using an ultrasonic bonding of an annealed Nb wire. The SQUID is the double relaxation oscillation SQUID (DROS) with a high a flux-to-voltage transfers, and the DROS sensors were fabricated using the Nb/Al-oxide/Nb junction process technology. The 61 axial gradiometer bobbins were distributed in a hexagonal lattice structure with a sensor interval of 31 mm, and the 61-channel array covers about 240 mm in diameter. In addition to the 61 axial gradiometers measuring d^2B_z/dz^2 , 3 tangential gradiometers measuring d^2B_x/dz^2 were installed in the central part of the 61 axial gradiometers to measure fetal MCG signals with a minimum interference from the maternal MCG signals. Baseline of the axial gradiometers is 70 mm and the tangential gradiometers is 65 mm. The liquid He dewar has an inner diameter of 280 mm, and the cold-to-hot distance is 25 mm. The shape of dewar outer tail is a cone-shape to reduce the possibility of hitting chins of the subjects. The MCG system was operated inside a thin MSR having a 1-mm thick Mumetal and 12-mm thick aluminum.

Keywords: SQUID, gradiometer, magnetic shielding, magnetocardiography