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A Magnetoencephalography System Having Superconductively Shielded SQUID Magnetometer

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ABSTRACT

We developed a whole-head SQUID magnetometer system having a superconductive shield to measure magnetoencephalography (MEG) signals inside a thin magnetically shielded room.

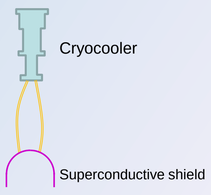
1) A robust and compact wire-wound axial magnetometer having a field sensitivity of 2 fT/√Hz at 100 Hz
2) Superconductive shield is made of 1-mm thick Pb plate with a shielding factor in the range of 20~500, depending on the position inside the helmet shield
3) Enhancement of the shielding performance can be done by introducing the inward extension at the brim
4) MEG measurement could be done with comparable signal quality with the conventional first-order axial gradiometer system, and MEG can also be measured with the MSR door open

MOTIVATION

To develop an MEG system having the following technical features :

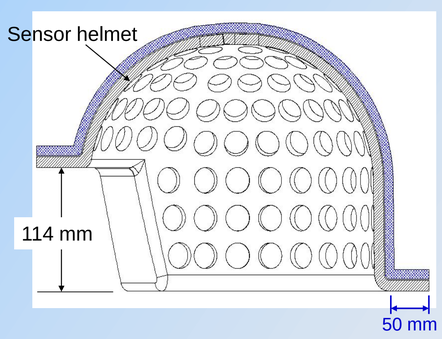
- ☞ Thinner and lighter magnetically shielded room
- ☞ Comparable signal quality with the axial gradiometer system
- ☞ Integration with cryocooler on top of the dewar

Future MEG system

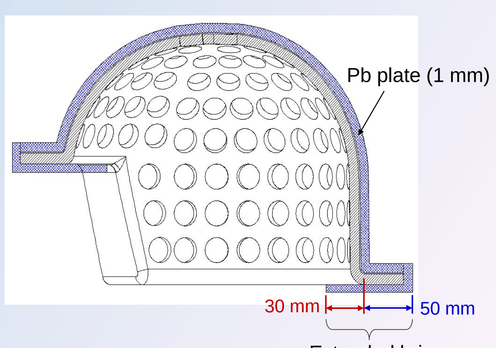


Superconductively shielded helmets

Helmet w/o inward extension



Helmet with inward extension at the brim

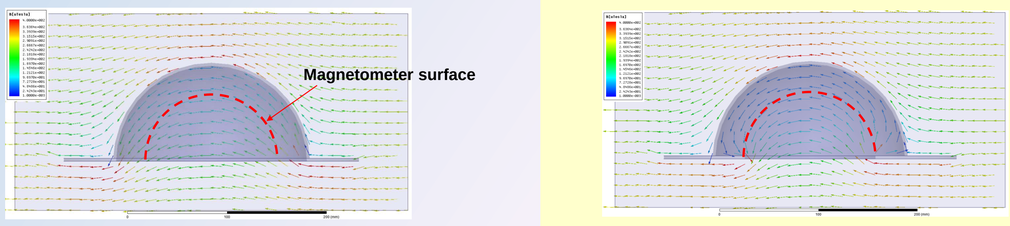


[References]
D. B. Hulsteyn et al., Rev. Sci. Instrum., 1995.
R. H. Kraus et al et al, IEEE Trans. Appl. Supercond., 1999.

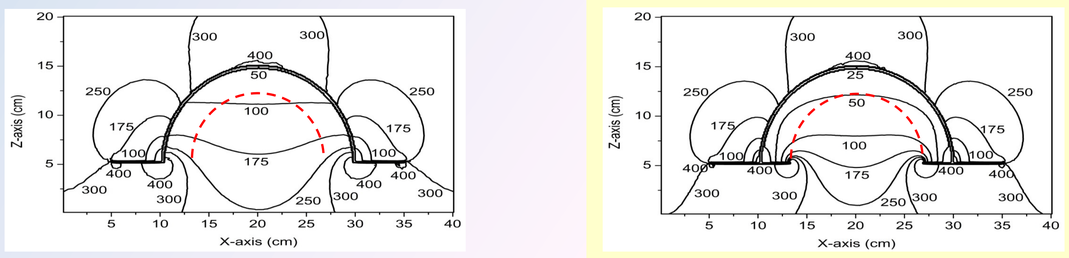
Simulation of shielding (horizontal field)

Helmet w/o inward extension **Helmet with inward brim**

<Field arrow lines>



<Isofield contour lines>



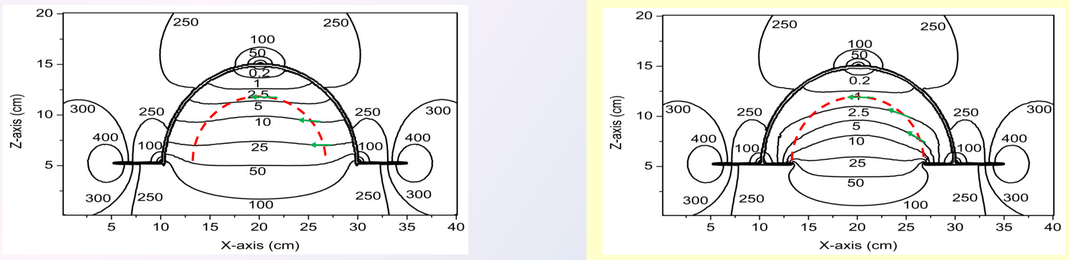
Simulation of shielding (vertical field)

Helmet w/o inward extension **Helmet with inward brim**

<Field arrow lines>

Field is weaker and its direction is more tangential to the magnetometer planes: much less noise at the magnetometers than those without inward brim.

<Isofield contour lines>



Helmet magnetometer system

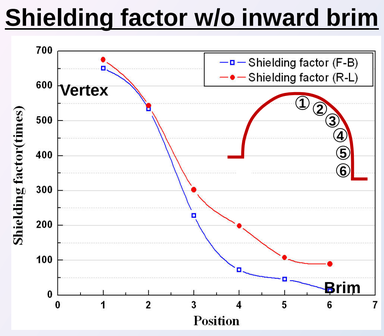
Insert

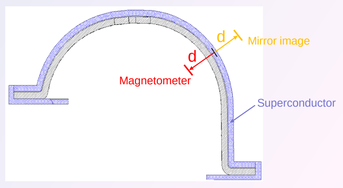
Magnetometer

- 140 magnetometers
- Pickup coil diameter of 20 mm

Sensor helmet

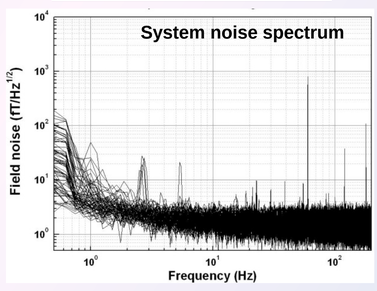
Shielding factor w/o inward brim

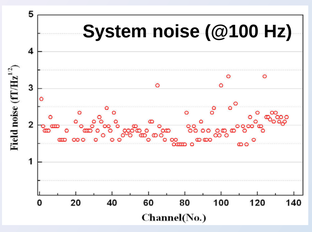




Magnetometer at a distance d from the supercon. surface
→Mirror image in the superconductive surface at –d
→SQUID output is like an axial gradiometer with a baseline of 2d

Helmet with inward brim





Comparison of MEG signals

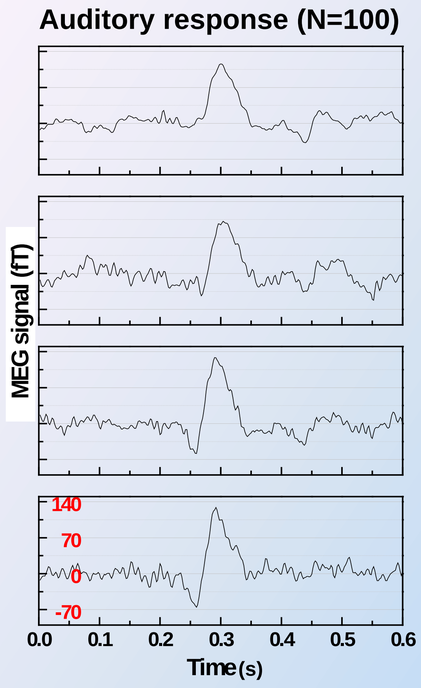
Auditory response (N=100)

Conventional axial gradiometer
- 1st-order gradiometer
- 50-mm baseline

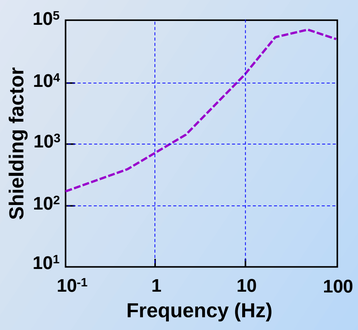
Gradiometer-in-vacuum
- Axial type 1st order gradiometer
- 50-mm baseline

Superconductive shield
- Magnetometer
- Door of MSR open

Superconductive shield
- Magnetometer
- Door of MSR closed



Shielding factors of MSR

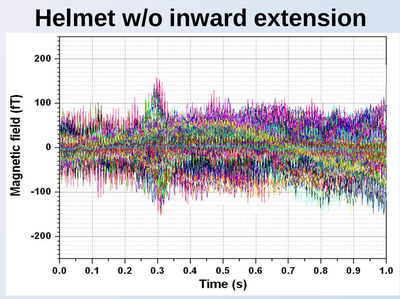


Whether MSR door is open or closed --> Signal quality of SS MEG is nearly the same

Comparison of MEG signals

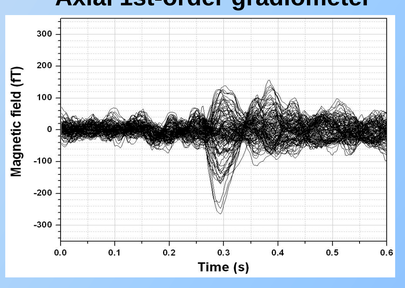
Auditory evoked signals

Helmet w/o inward extension

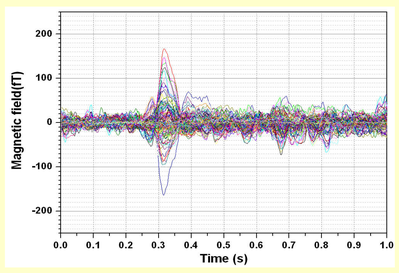


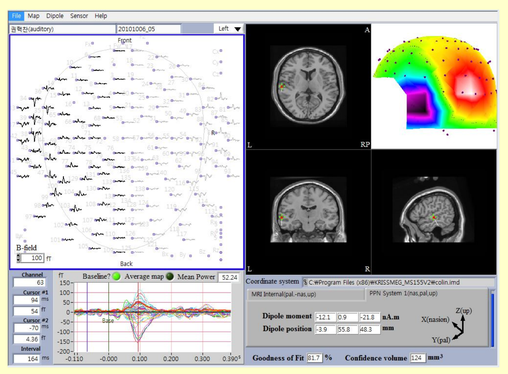
Door closed
Large 60-Hz noise at brim parts
Large MCG peaks at brim

Axial 1st-order gradiometer



Helmet with inward extension at the brim





<Acquisition>
- A/D conversion : 160-channel
- Resolution : 16 bits
- Sampling rate : 1 kHz

Auditory source is well localized!

SUMMARY

1. Advantage of superconductive shield: shielding performance is frequency independent
2. Shielding factor is in the range of 20~500 without inward extension at the brim
3. By extending the inward brim, the shielding performance and MEG signal quality improved much
4. With the inward brim, MEG can be measured with MSR door open
5. Superconductive shielding can reduce the thickness of magnetically shielded room (MSR) for an economic MEG system
6. Future development : Cryocooler-operated MEG system with thinner MSR wall thickness. The noise from the cryocooler can be reduced much by the superconductive shield