SFU SIMON FRASER UNIVERSITY
THINKING OF THE WORLD

262-channel helmet for comparing OPM and SQUID MEG measurements

Daniel Wijaya[1,2], Katharine Lee[2], Matt Courtemanche[2], Mark Tillotson[4] (CTF), Teresa P L Cheung[2,3]

1. Faculty of Engineering, McGill University, 2. Faculty of Applied Sciences, Simon Fraser University, 3. Surrey Memorial Hospital, Fraser Health, 4. CTF

Objectives

Create a test bed to isolate performance differences between optically pumped magnetometers (OPM) and superconducting quantum interference devices (SQUID).

Background

Optically pumped magnetometers (OPM) have progressed since their conception: they have comparable sensitivities to superconducting quantum interference devices (SQUID):

- OPM field sensitivity <15 fT/√Hz [1]. Note that OPM used had an experimental field sensitivity of<20fT/√Hz.
- CTF MEG has a sensitivity of <10fT.

OPM operate at room temperature (-30C to +60C), posing distinct advantages to SQUID [2]:

- Can position closer to patients:
  - Sensor positions can conform to head geometry; may use additive manufacturing to generate fixed form for sensor placement
  - Better SNR: brain fields strength have an inverse square relation [3].
- do not require a helium cooling system
  - Increased mobility of system [1].
  - Reduced operating cost

(a) CTF MEG (b) QUSPIN QZFM OPM

Figure 1. MEG technologies

Acknowledgments

The authors would like to acknowledge and thank NSERC CRSNG and AGEWELL for their generous support, and QUSPIN for the generous use of their sensors.

AGEWELL
NSERC CRSNG
QUSPIN

References

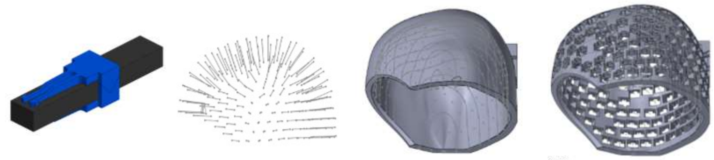
[1] QUSPIN Home. (n.d.). Retrieved from https://quspin.com/products-qzfm/

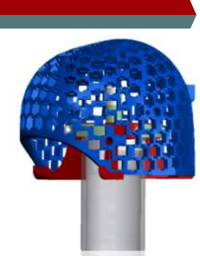
[2] Boto, E., Holmes, N., Leggett, J., Roberts, G., Shah, V., Meyer, S. S., . . . Brookes, M. J. (2018). Moving magnetoencephalography towards real-world applications with a wearable system. *Nature,555*(7698), 657-661. doi:10.1038/nature26147

[3] Boto, E., Meyer, S. S., Shah, V., Alem, O., Knappe, S., Kruger, P., . . . Brookes, M. J. (2017). A new generation of magnetoencephalography: Room temperature measurements using optically-pumped magnetometers. *NeuroImage, 149*, 404-414. doi:10.1016/j.neuroimage.2017.01.034

Methods

Design: SolidWorks API used to generate helmet shape based on geometric data of the CTF MEG. Clips were used to secure the OPM sensors to the helmet.





(a) Sensor Jacket (b) 275 Sensor Geometry (c) Helmet Shape (d) Completed Helmet (e) Experimental Setup

Figure 2. CAD models

Models were 3D printed using ABSplus-P430 thermoplastic. The manufacturing process took 233 hours and 77.57in³ of material for the components and substrate material.

(a) Helmet (b) Sensor Jacket (c) Example of Experimental Setup

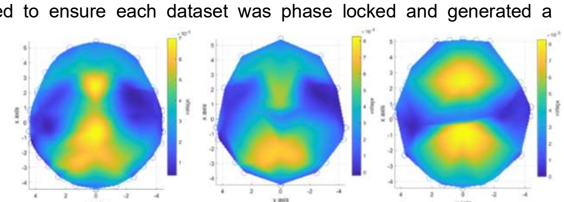
Figure 3. 3D printed components

Data Collection: Measurements of a 7Hz magnetic dipole phantom, fixed relative to the helmet, were made with two OPM sensors at 70/262 sensor locations. At each position, 10 trials of 3 seconds each were recorded at 1200 Hz. The 7Hz signal was triggered to ensure each dataset was phase locked and generated a consistent and reproducible signal.

Analysis: Data was filtered, averaged across trials, and wave centered. The maximum peak-to-peak values can be seen in figure 4.

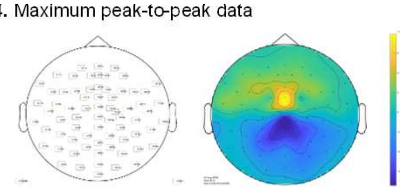
Further analysis involved using an infinite magnetic diploe equation for the forward model, followed by a dipole fit with a single dipole. Least squares was used to determine the goodness of the fit.

Initial plots and further analysis showed anomalies in sensor 1 results.



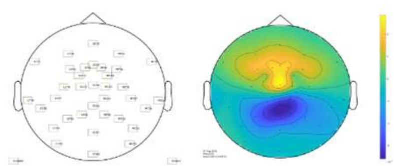
(a) Both sensors (b) sensor 1 (c) sensor 2

Figure 4. Maximum peak-to-peak data

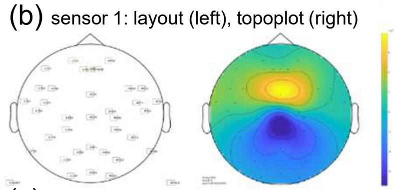


(a) Both sensors: layout (left), topoplot (right)

Figure 5. Sensor Layout and Topoplots (arbitrary polarity) [left and above]



(b) sensor 1: layout (left), topoplot (right)



(c) sensor 2: layout (left), topoplot (right)

Results

OPM helmet provided a stable test bed for comparing OPM and SQUID technologies:

- Sufficient to mount the OPM sensor.
- Sensor orientation variability, up to 1 degree during test-retest reliability measurements.

OPM and MEG localized similarly:

- Sensor 2 localized 1.0043 mm of known coordinates of the phantom dipole – consistent with MEG SQUIDS.
- Sensor 1 did not appear to function properly, and localized 13.3566 mm of known coordinates of the phantom dipole.

Conclusion

Conclusions: OPM sensors are comparable to SQUID-based MEG:

- Both OPM and SQUID sensors localize points within 2mm of their known coordinates.
- Variation of OPM sensor orientation across runs may lead to marginally lower accuracy.

Limitations:

- Incomplete sensor profile tested
- Onerous re-calibration between trials, and cross-talk results in slow data collection.
- Use of dipole phantom may not reflect more complicated magnetic profiles.

Future research:

- Improving stability of OPM sensor by reducing tolerance and lengthen sensor slots in helmet
- Patient-specific helmets to maximize SNR.
- Human testing.
- Macros or API to automate recalibration.
- Active shielding to eliminate far-field sources.

Contact - Teresa Cheung: tpc5@sfu.ca