Multi-Frequency Encoded Source Imaging for Wearable OPM-MEG

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Despite the existence of high-frequency brain signals (HFBS, ≥70 Hz) up to 8,000 Hz, it is worth noting that low-frequency brain signals (LFBS, <70 Hz) are the primary focus in clinical applications. One issue is the relative weakness of HFBS, which frequently necessitates their acquisition via intracranial recordings. Furthermore, localizing HFBS is a daunting task. Our goal was to create a novel magnetoencephalography (MEG) system that used optically pumped magnetometers (OPMs) for noninvasive detection and localization of both LFBS and HFBS.

A novel prototype of a wearable OPM MEG was constructed utilizing a helmet composed of two layers. A series of techniques, such as synthetic gradiometers (SGs), frequency-specific signal space classification (FSSSC), and artificial intelligence (AI) techniques, were devised to mitigate the effects of motion artifacts and environmental noise. Four software packages have been developed to facilitate various aspects of MEG data process, including data acquisition, paradigm design, data analysis, and source localization. To examine brain activities across a wide range of frequency bands, we have devised frequency-encoded source imaging (FESI). Both OPM MEG and superconducting quantum interference device (SQUID) MEG data were obtained from phantoms and human subjects.

MEG data showed that OPMs consistently detected HFBS. In wearable OPM MEG, SGs and FSSC significantly reduced artifacts and noise. The strength of OPM neuromagnetic signals is 3.6-9.1 times that of SQUID neuromagnetic signals. FESI successfully localized brain signals in a variety of frequency bands ranging from low to high frequencies (Fig. 1). A new OPM MEG method based on AI could analyze OPM MEG data automatically.

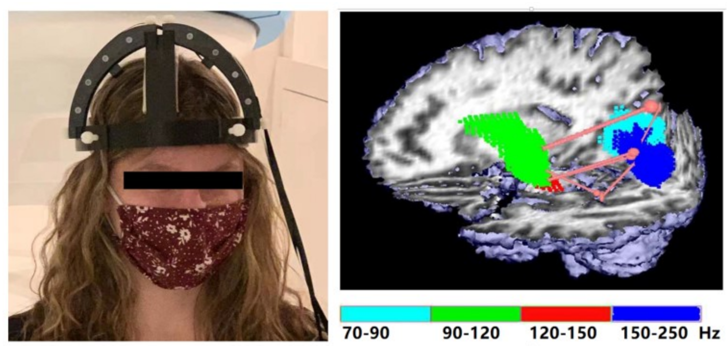

Fig. 1. A Photo of a Wearable OPM MEG Prototype and Frequency-Encoded Source Imaging from a Participant. High-frequency brain signals (HFBS, ≥70 Hz) are detectable by OPM and SQUID MEG. When extracting HFBS, a new software solution can get rid of noise and artifacts. Brain activity is only visible in one frequency band in conventional source imaging. The new FESI displays brain activity across multiple frequency bands. According to the pilot data, HFBS are localized to language areas.

The findings show that OPM MEG is wearable, non-cryogenic, low-cost, and outperforms SQUID MEG. OPM MEG can detect HFBS, and a software solution can reduce artifacts and noise significantly. FESI can detect and visualize brain activity from low to high frequency bands, as well as provide novel cross-frequency information (Fig. 1). A combination of wearable OPM-MEG and HFBS has the potential to alter the landscape of brain research. Wearable OPM MEG detection of HFBS may pave the way for future brain disorder diagnosis and treatment.