Biplanar coil cancellation system for OPM-MEG using PCB

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Optically pumped magnetometers (OPMs) are a promising sensor technology for non-invasive on-scalp measurement of human electrophysiological signals. OPM-MEG offers the potential for higher spatial resolution, naturalistic MEG studies involving movements, and higher signal-to-noise ratio (SNR) for superficial cortical sources. Despite these potential advantages, OPMs are yet to be widely adapted, in part due to the difficulty of operating the sensors in lightly shielded environments. OPM sensors need to operate in a zero background field to achieve linearity and minimize signal distortion. Several groups have proposed active field cancellation coils [1] to remove the constant and gradient components of the magnetic field. As opposed to traditional Helmholtz (or anti-Helmholtz) coil designs, these biplanar coils allow subjects to follow instructions, perform visual tasks with an unobstructed front view, as well as perform movements within a predefined region.

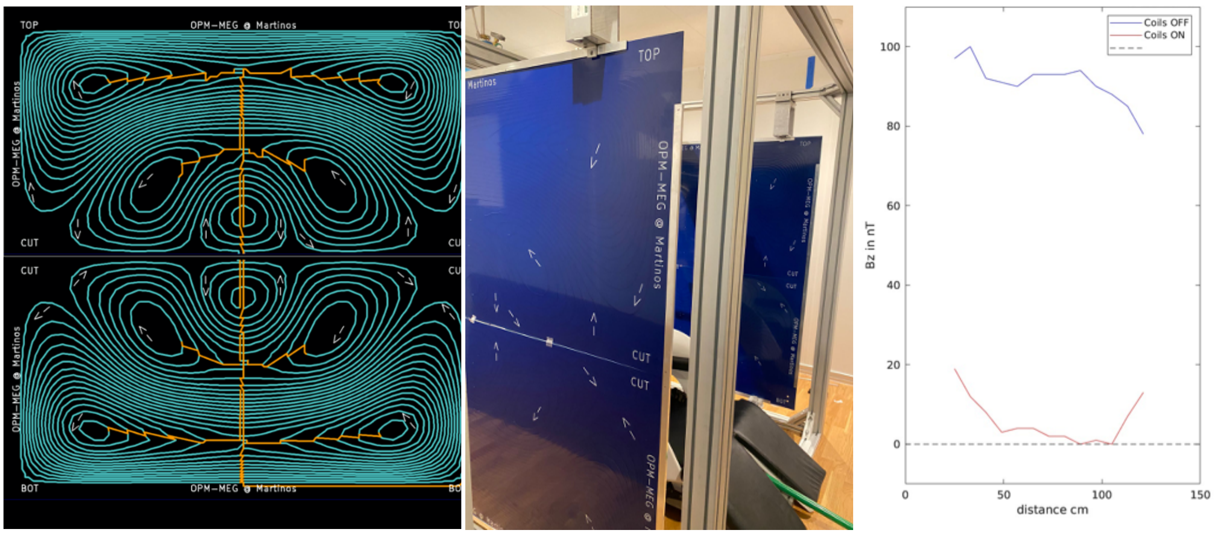

Fig 1. A. Optimized coil design for printed circuit board (PCB), and **B.** Installed PCB inside a one-layer shielded room at the Martinos Center, MGH, and **C.** Background field profile between the coil centers before and after the coils are turned on. Remnant ~6 nT/m gradient field was not canceled by this coil.

However, until now, biplanar coils were error-prone and expensive to manufacture, involving manual winding of >1000 meters of copper wire. In this work, we created a field cancellation coil on a two-layer Printed Circuit Board (PCB) for one component (floor to ceiling) of the magnetic field in a one-layer shielded room. We used the open source bfieldtools [2] package to optimize and discretize the current loops that produce a constant magnetic field in a target region. The discretized coils were connected into a continuous path (**Fig 1A, cyan: Layer1; orange: Layer 2**) using an in-house interactive interface. The coil pairs were manufactured on two 1.5 m x 0.75 m PCBs (2 oz copper) and soldered together. The PCB coils were mounted on a sliding aluminum frame for easy access to the subject during experiments (**Fig 1B**). The theoretical efficiency of the coils was 1.15 nT/mA and we obtained an efficiency of ~1 nT/mA experimentally. We measured 7 ohms resistance per coil, compared to the theoretical 5.2 ohms. Preliminary results suggest that PCB cancellation coils are more accurate than hand-wound coils and can be easily replicated and mass-manufactured at a lower cost. This innovation paves the way for cheaper and more robust commercial OPM-MEG systems.

References

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