Precision magnetic field modelling and control for wearable MEG

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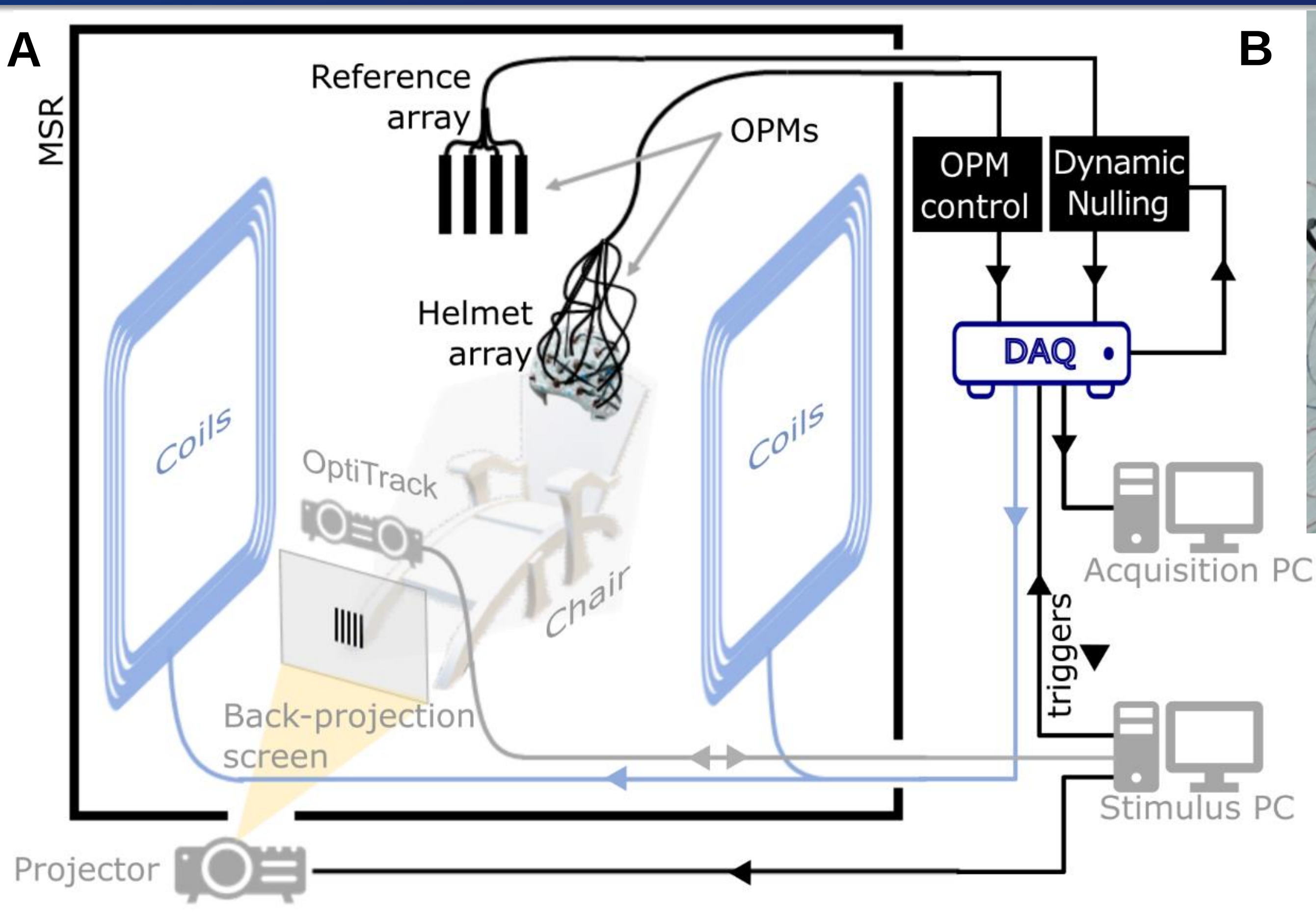
Overview

Magnetoencephalography (MEG) measures the magnetic fields generated by neuronal current flow in the brain. MEG has applications in neuroscience, mental health and pre-surgical planning for epilepsy, but presents a significant engineering challenge as the neuronal fields are a ***billion*** times smaller than that Earth's magnetic field.

Optically-Pumped Magnetometers (OPMs) are an exciting and wearable alternative to the cryogenic sensors currently used in MEG. Participants can move during a scan, but **precise control and compensation of interfering magnetic fields are required** to enable such measurements.

Even in an optimised, magnetically-shielded environment (<2 nT), movement of the head-mounted OPMs generates undesirable, low frequency artefacts in MEG data. ***Here we present a method to further reduce remnant magnetic fields and improve MEG data quality.***

Methods



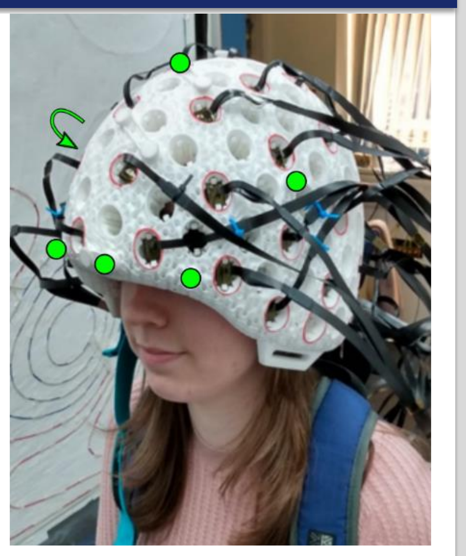


Figure 1 – *A) A diagram of the system setup. B) The OPM-MEG helmet, with marker positions for optical tracking indicated in green.*

Participants move their head while wearing the rigid OPM-MEG helmet[1], allowing the QuSpin OPMs[2] to **map the background magnetic field** as they move through it.

Movement data are recorded using optical tracking and used in combination with the OPM data to **estimate the background magnetic field coefficients**, via a spherical harmonic model.

These coefficients are fed into **bi-planar electromagnetic coils**[3] to generate an equal and opposing magnetic field, hence 'nulling' the background magnetic field for OPM-MEG experiments.

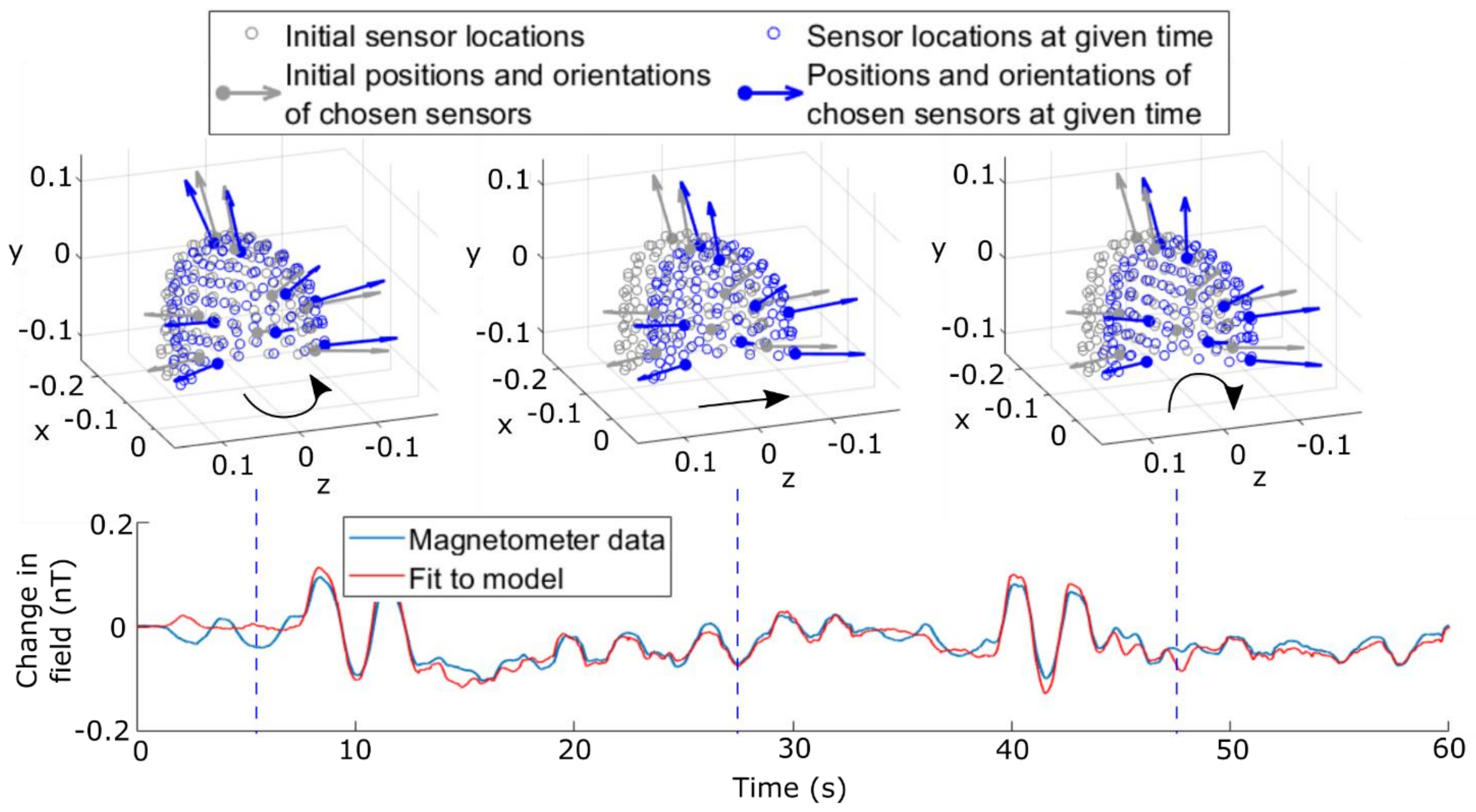


Figure 2 – *Data from an example sensor taken during movement, with the helmet position shown at three time points.*

Conclusions

Precise modelling and control of the remnant magnetic field **improves the SNR** of OPM-MEG data by a factor of 8.

Reducing motion artefacts in this way will enable **a greater range of movement during scanning**, without losing data quality.

Hence OPM-MEG would be **more suitable for patients with movement disorders**, such as Tourette's syndrome and Parkinson's disease, than traditional medical imaging techniques.

Results

Magnetic Field Compensation

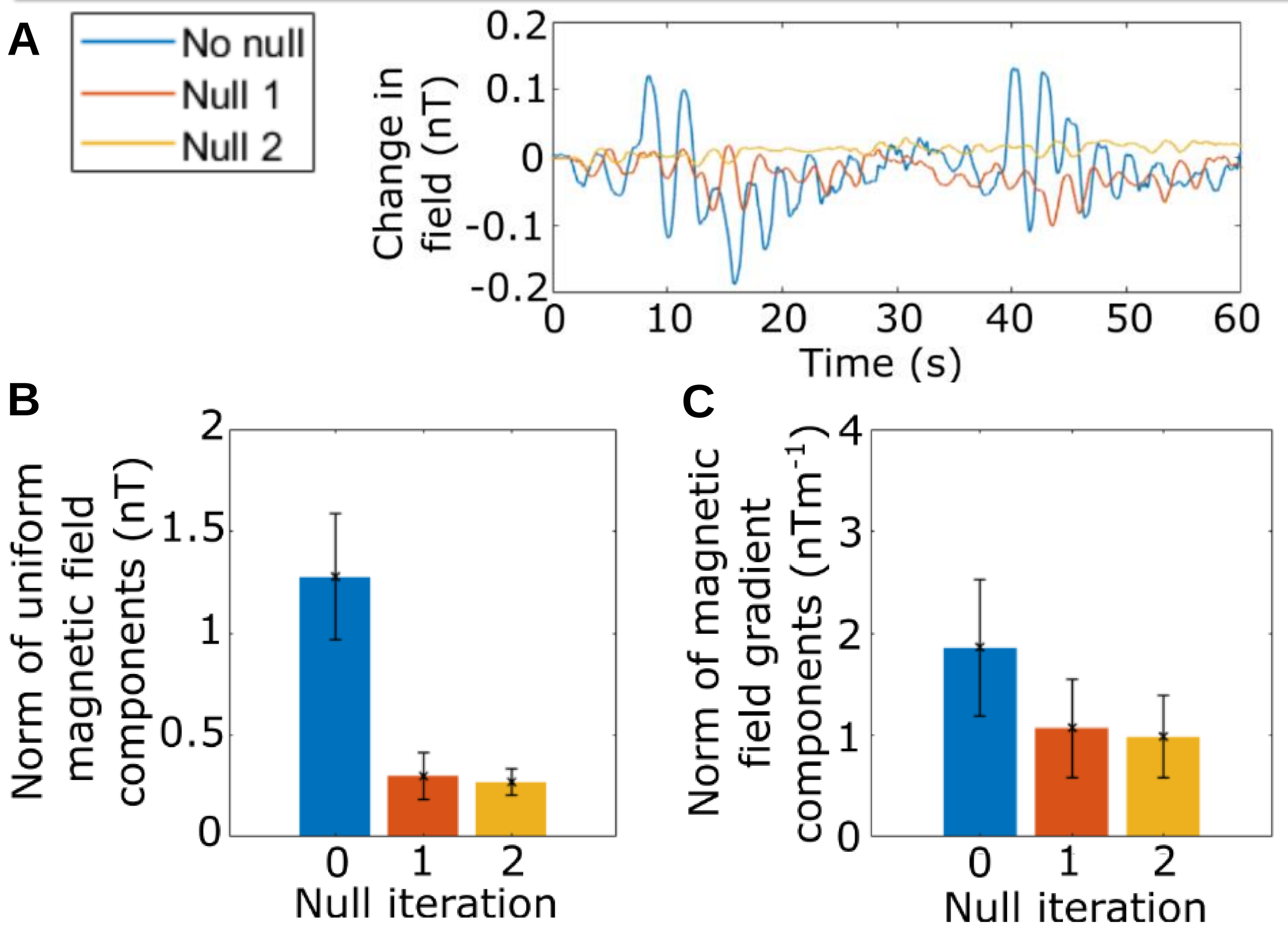


Figure 3 – *A) Data from an example sensor show the motion artefacts are reduced once the background magnetic field is compensated. B) Uniform magnetic field components are reduced by factor of 5. C) Magnetic field gradient components are also reduced by our method.*

The magnetic field mapping and nulling procedure was repeated twice to optimise the magnetic field compensation.

Over five repeat experiments, the **uniform magnetic field components were reduced from 1.3±0.3 nT to 0.27±0.06 nT**, with magnetic field gradient components also reduced. The **standard deviation of motion artefact was also decreased by a factor of 3.**

MEG Demonstration

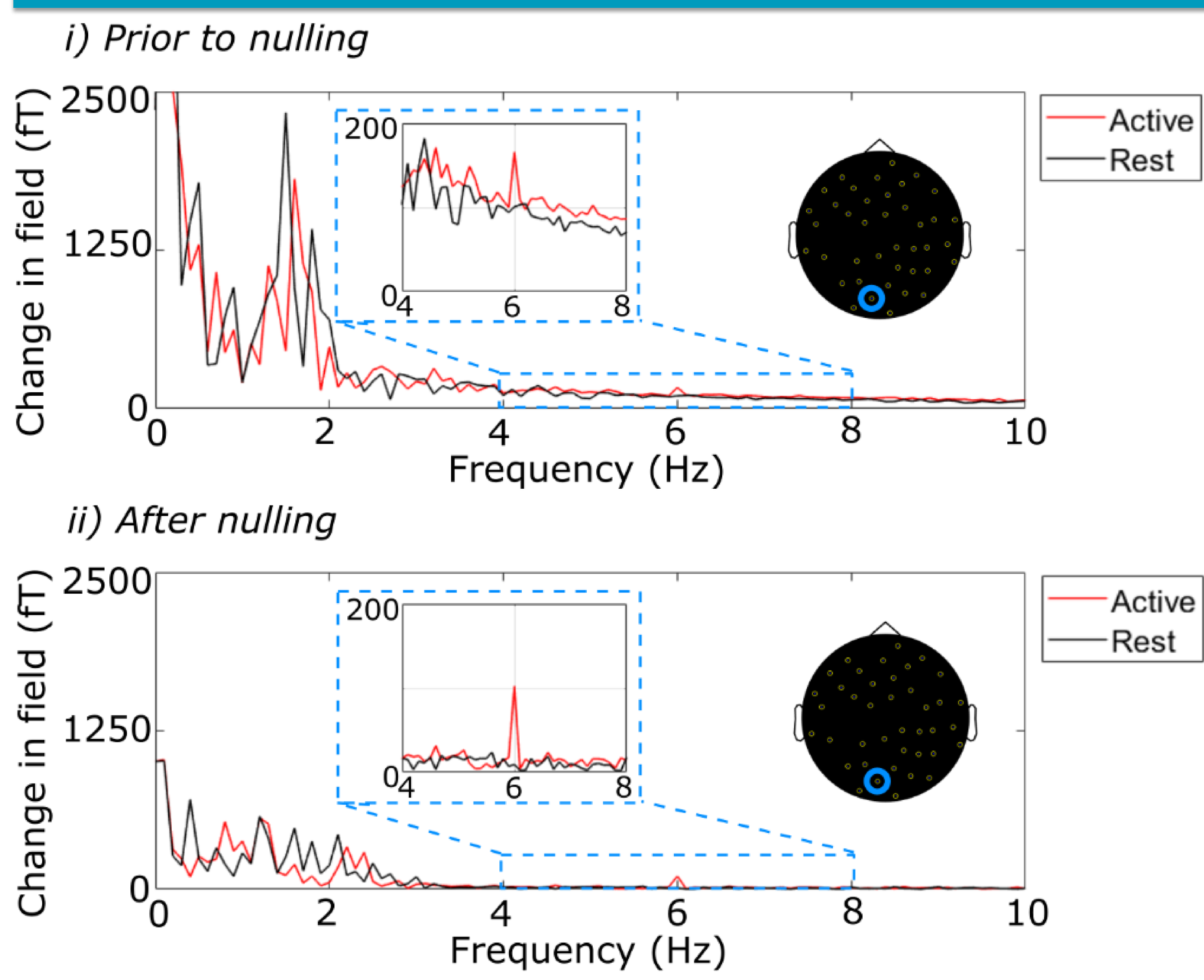


Figure 4 – *Frequency spectra of data taken from an example sensor (marked in inset diagram) over the visual cortex. Head movement generates low frequency interference (i) that is reduced when nulling is applied (ii), leading to an eight-fold increase in SNR of 6 Hz visual evoked response.*

A visual steady-state evoked response paradigm was used, where the participant viewed a 6 Hz flickering stimulus for 10 s, with a 10 s rest period thereafter. **We expect to see this flicker mimicked in the firing of neurons in the visual cortex at the rear of the brain.** 50 trials were completed and the experiment performed with and without our magnetic field nulling approach.

The **signal-to-noise ratio of the 6 Hz peak increased by a factor of 8** when nulling was applied, in addition to a **five-fold decrease in low frequency (0–2 Hz) interference**.

References:
[1] Osborne *et. al.*, Proc. SPIE **2018**. doi: 10.1117/12.2299197
[2] Hill *et. al.*, NeuroImage **2020**. doi: 10.1016/j.neuroimage.2020.116995
[3] Holmes *et. al.*, NeuroImage **2018**. doi: 10.1016/j.neuroimage.2018.07.028

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