B0 SHIMMING FOR MAGNETIC RESONANCE ECHO PLANAR IMAGING

Echo-planar imaging (EPI) is a widely used technique in Functional Magnetic Resonance Imaging (fMRI), allowing for rapid acquisition of brain images and enabling real-time examination of brain activity.

fMRI has revolutionized our understanding of brain function and has found numerous applications in clinical settings. In disease modeling, fMRI plays a crucial role in elucidating the underlying neural mechanisms associated with conditions such as Alzheimer's disease, Parkinson's disease, schizophrenia, and depression. By examining brain activity patterns and connectivity networks, researchers can gain insights into disease progression, identify biomarkers, and develop novel therapeutic approaches. Moreover, fMRI has made significant contributions to surgical planning and guidance. It allows surgeons to map critical brain regions responsible for functions such as language, motor control, and sensory perception. By identifying these regions pre-operatively, surgeons can minimize the risk of post-operative complications and optimize surgical outcomes.

However, despite the immense potential of fMRI, the acquisition of reliable signals from certain brain regions remains **challenging**. Inhomogeneous magnetic fields pose a significant obstacle to this imaging sequence. The sensitivity of EPI to B0 inhomogeneity often leads to severe distortions or even a complete loss of signal, which cannot be recovered even through post-processing techniques.

Elara shim array for Siemens 3T head coil

Elara shim array for Philips 3T head coil

Elara shim array for all 7T NOVA head coils

Innovative Technology

To address this critical issue, we present an innovative solution: the ***Elara*** Local Shim System [1]—an advanced and innovative modular local shim coil array specifically designed to optimize magnetic field homogeneity beyond the scanner shimming routine and bring tangible value to EPI data quality.

The local shim array is lightweight, easy to set up, and designed for seamless integration with existing **3T and 7T MRI systems**. It comes equipped with amplifiers and all necessary peripherals, ensuring a user-friendly experience for researchers and clinicians. Additionally,

advanced algorithms are incorporated into the system to optimize the magnetic field, providing precise and tailored adjustments to overcome inhomogeneity challenges for EPI imaging. All of this make the Elara local shim system the first shim system capable of complete recovery of signal loss in EPI images.

n this white paper, we present a case study aimed at improving EPI data quality leveraging the advanced capabilities of the ***Elara***™ local shim system.

Case Study

To evaluate the effectiveness of the Elara Local Shim System, **two studies** on 3T and 7T MRI scanners are presented.

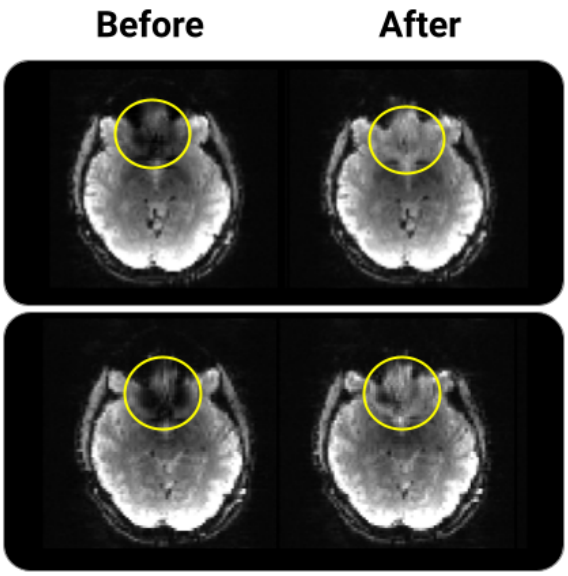
The first study [2] was conducted using a 3T Siemens Prisma MRI scanner [3] with a Siemens 32-channel head receive RF coil [3]. The specific objective of the study was to recover the **complete lack of signa**l observed in the inferior frontal and temporal regions, which are known to be particularly susceptible to inhomogeneous fields.

A dual-echo gradient echo (GRE) field mapping sequence was utilized to assess the magnetic field inhomogeneity. For EPI acquisition, an EPI sequence with a resolution of 2.5mm isotropic, TE of 30ms, and TR of 2.8 seconds was employed.

The application of enhanced shimming using the tailored *Elara* shim array resulted in remarkable improvements in signal recovery and image quality. In the inferior frontal region, a substantial signal recovery of 200% was achieved, representing a doubling of the signal intensity compared to previous attempts. Similarly, the temporal lobe exhibited an impressive signal recovery of 300%, indicating a significant enhancement in the acquired data.

Notably, the overall signal-to-noise ratio (SNR) was improved by 30%, underscoring the effectiveness of enhanced shimming in optimizing image quality and sensitivity.

These outcomes highlight the potential of this innovative solution to overcome the challenges associated with inhomogeneous fields and enhance the reliability and accuracy of EPI-based fMRI studies.

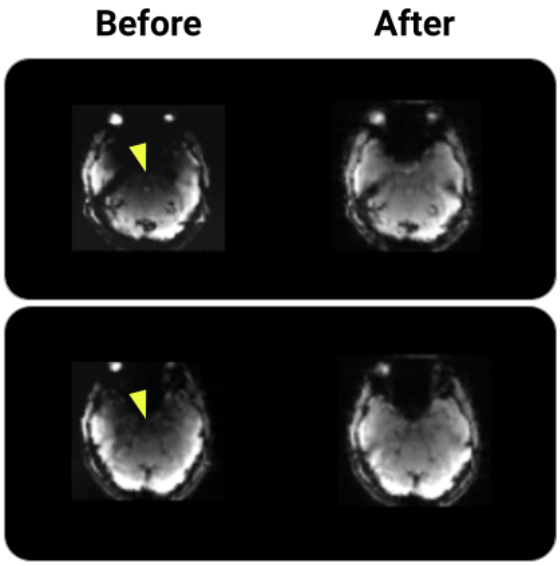


3T EPI images showcasing signal recovery in a challenging region

Recovering signal from challenging anatomical regions in EPI imaging is undeniably the toughest task in shimming.

In the second study [4], a 7T Philips Achieva [3] MRI system equipped with a 1Tx/32Rx NOVA head RF coil [3] was used. The primary objective was to improve the quality of EPI data, particularly in lower brain slices where B0 field inhomogeneity is more pronounced. EPI imaging and shimming was performed over the slab encompassing the brain region of interest and data was acquired once with and once without the local shim array.

The application of the *Elara*™ local shim System yielded significant improvements in field homogeneity, geometric distortion, signal-to-noise ratio (SNR), and artifact reduction in UHF EPI imaging. The findings from the case studies include:



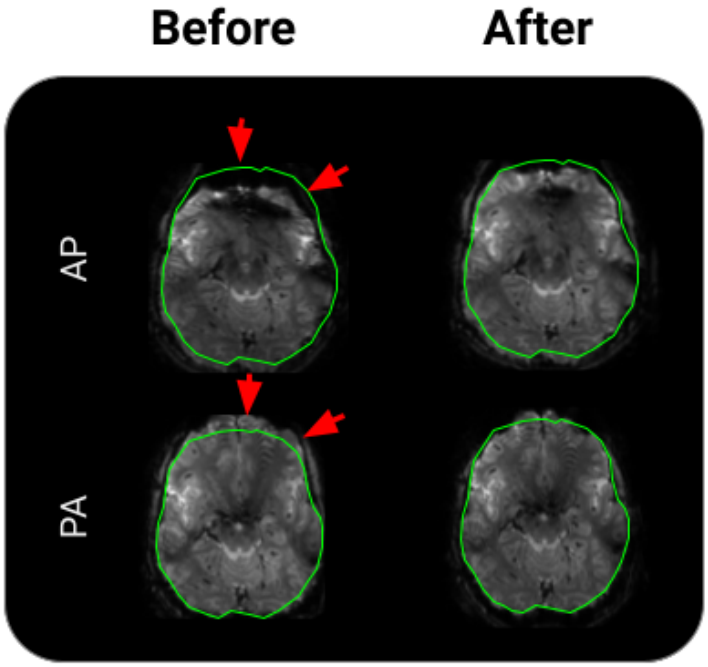
3T EPI images showcasing SNR gain in inferior temporal regions

BOLD Sensitivity loss as a result of magnetic field inhomogeneities can be addressed during data acquisition using advanced shimming methods.

- A remarkable 40% improvement in field homogeneity over the slab, indicating enhanced magnetic field uniformity throughout the brain. This improvement ensures more accurate and reliable interpretation of EPI data, especially in regions prone to susceptibility artifacts.

- Reduced geometric distortion, enabling precise anatomical localization and better alignment of functional activation maps. The reduction in distortion enhances the spatial accuracy of EPI-based analyses, contributing to more robust research and clinical evaluations.

- Increased SNR and reduced artifacts visible even after FSL top-up correction. The enhanced SNR improves the detectability of subtle brain activations and facilitates more precise characterization of brain pathology.



7T EPI images showcasing significantly less distortion after local shimming

Conclusion

The Elara Local Shim System represents a significant advancement in EPI-based imaging. The enhanced shimming capabilities reverses the effect of severe dephasing and local residual gradients in the field, resulting in high fidelity, robust and clear images inchallenging anatomical regions. As we continue to push the boundaries of fMRI research and advance clinical applications, enhanced shimming stands as a valuable tool to unlock new insights and improve patient care in the realm of brain imaging.

[1] CAUTION: Not a medical device. Limited by Federal (or United States) law to investigational use.

[2] Conducted at Uniklinikum Tübingen

[3] All product and company names are the registered trademarks of their original owners. The use of any trade name or trademark is for identification and reference purposes only.

[4] Conducted at Spinoza Centre for Neuroimaging

The local shim systems offered by MR Shim are customizable to any MRI setup or anatomical region. Dynamic and real-time shimming kits available. Learn more by visiting our website or contact us today to schedule a meeting

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