COMBINED RF/SHIM COIL FOR ULTRA-HIGH FIELD MAGNETIC RESONANCE IMAGING

Ultra-high field (UHF) MRI has emerged as a powerful imaging modality, offering unprecedented spatial resolution and exquisite tissue image quality. With advancements in technology and safety measures, UHF MRI has recently evolved from a research tool to a clinically approved imaging technique, making its way into medical centers around the world [1].

However, the unique benefits of UHF MRI are accompanied by significant challenges, particularly related to the severe inhomogeneity in the B0 and B1 magnetic fields. The non-uniformity of the magnetic field at high field strengths poses significant obstacles to achieving optimal image quality.

To overcome these challenges and unlock the full potential of UHF MRI, advanced shimming techniques, parallel transmission (PTx), and high-density RF receive arrays are required. Although each of these technologies is valuable on its own, their usability and efficiency of workflow will be diminished if they are used individually. The integration of these technologies can revolutionize UHF imaging, enabling enhanced image quality, improved accuracy, and expanded applications.

In this white paper we showcase an integrated RF/shim coil for 7T head imaging applications.

Advanced B0 shimming and RF technologies are arguably the two pivotal technologies essential for unlocking the full potential of UHF MRI.

Innovative Technology

In response to the challenges posed by B0 and B1 fields at UHF, a European consortium [2] consisting of UMCU, Wavetronica, Multiwave, and MR Shim [3] has developed an integrated 24-channel shim system within an 8Tx/64Rx RF coil [4,5]. This combined RF/Shim coil provides a comprehensive solution for UHF MRI. Careful consideration and simulations have been employed to minimize RF interference. By targeting both B0 and B1 challenges, this innovative coil design offers a streamlined and user-friendly approach to address the complexities of UHF imaging.

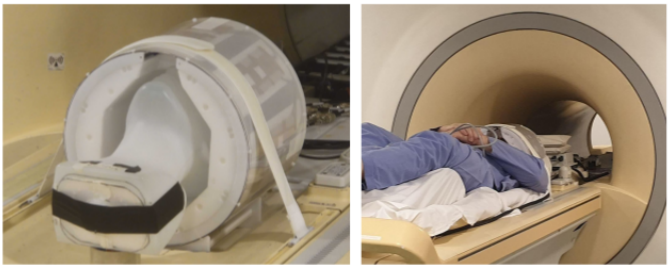
Case Study

To evaluate the effectiveness of the combined RF/Shim coil, a case study was conducted [6] using a 7T Philips Achieva MRI system [3]. The primary objective was to improve brain imaging at 7T, with a particular focus on achieving higher field homogeneity in EPI and MRSI imaging. B0 field maps, single-voxel STEAM spectra and echo planar images (EPI) were acquired using the combined RF/shim coil once with and once without using the 24-ch local shim array to assess the impact of the combined coil on image quality.

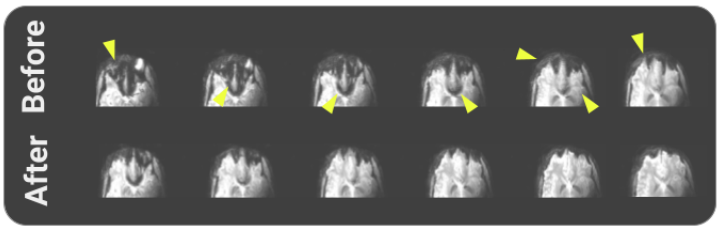
The results of the case study demonstrated an exceptional 60% improvement in B0 field homogeneity in the inferior frontal region, which is particularly susceptible to inhomogeneities at UHF. The improvement directly reflected in the single voxel spectra acquired from the challenging anatomical region in prefrontal cortex. Sharper linewidths and lower lipid contamination was observed. This improvement ensures more accurate and reliable interpretation of the data.

Overall, a 30% improvement in field homogeneity was observed throughout the whole volume of the brain, indicating the effectiveness of the combined RF/Shim coil in addressing B0 challenges. This enhanced field homogeneity leads to reduced artifacts enabling more precise localization of brain activations.

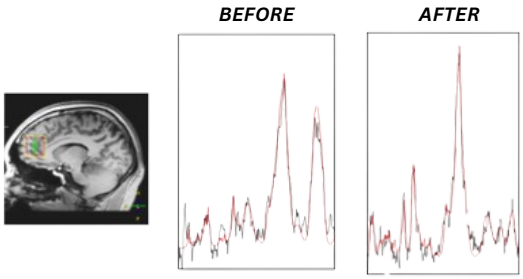
Geometric distortion artifacts in the EPI images were significantly reduced, enabling more accurate alignment of functional maps with the underlying anatomy. The reduction in distortion enhances the spatial accuracy contributing to improved investigational evaluations.
Signal loss, a common concern in UHF imaging, was effectively recovered in areas in the frontal region of the brain close to the air cavities, allowing the visualizations of parts of anatomy that would otherwise yield no signal.



Combined RF/Shim head coil



EPI images before and after the application of the 24ch local shim array integrated in the head RF coil showcasing the recovery of signal as well as less geometric distortion in challenging imaging araeas



Single voxel spectra from the prefrontal cortex with and without using the local shim array

Conclusion

The development of a combined RF/Shim coil represents a significant leap forward in addressing the B0 and B1 challenges encountered in UHF MRI. By integrating advanced shimming capabilities with high-density receive RF coils, this innovative technology offers a comprehensive solution for unlocking the full potential of UHF imaging. The case study results demonstrate the effectiveness of the combined RF/Shim coil in improving B0 field homogeneity, reducing artifacts, and enhancing image quality. These advancements pave the way for more applications of UHF MRI.

[1]https://www.siemens-healthineers.com/en-us/news magnetomterrafdaclearance.html

[2] Eurostars Project E! 113617 VM-biopsy – Rapid virtual metabolic biopsy for clinical diagnosis.

[5] 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] Chang P, et. al, "Designing a high-density combined RF/B0 shim coil for imaging the brain at 7T", Proc. Intl. Soc. Mag. Reson. Med. 29 (2021)

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

[6] Conducted at UMCU Utrecht

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