

A 10-channel RF coil for use in magnetic resonance guided high intensity focused ultrasound of the the brain.

Emilee Minalga¹, Robb Merrill¹, Nick Todd¹, Dennis L. Parker¹, and J. Rock Hadley¹
¹Department of Radiology, University of Utah, Salt Lake City, UT, United States

Introduction

The purpose of this work was to design a coil that allows for open ultrasound (US) access to the cranium for MR imaging during transcranial MR guided focused US (MRgHIFU) treatments. This coil provides high SNR in the brain, and keeps the majority of the coil circuitry out of the ultrasound path.

Methods

Two coil designs were investigated. Both had coil elements that were non-overlapped and capacitively decoupled in a common leg. The first design was a triangular-shaped, three-channel (3ch) phased array that fit on top of the head like a cap. The second design had 7 rectangular loops (7ch) that wrapped around the back and side of the head. Both coils were designed to integrate with the stereotactic head device without interfering with the US beam unlike clinical RF head coils. (**Fig. 1**)

Three experiments were performed in a Siemens TIM Trio 3T MRI scanner (Erlangen, Germany). Coil comparison studies were performed with the following three coils: Body coil (BC), 10-channel (3ch + 7ch) HIFU coil, and 7-channel (7ch) brain ladder coil.

Exp.1) To assess the ultrasound transparency of a single coil rung of the 3ch coil, MRI temperature maps were generated. Heating was performed using single point and circular HIFU heating trajectories in a homogeneous phantom with and without a single copper trace present in the US trajectory.

Exp.2) Signal to Noise Ratio (SNR) maps were obtained using a standard GRE pulse sequence and were performed in an environment that replicated the water membrane and stereotactic head device in Fig 1. No US transducer was present.

Exp.3) Temperature standard deviation maps were obtained using a 2D GRE sequence (TR/TE 25/10 ms, 0.8x0.8x3 mm³ spatial resolution, 20° flip angle), repeated 19 times on a human volunteer. The standard deviation of the calculated temperature through time was calculated for each pixel in the images.

Results

Exp.1) Phantom temperature measurements made with and without the copper coil rung in place showed no significant difference in the heating patterns for the single point and circular trajectories.

Exp.2) The SNR plots showed that the 10ch/7ch coils had a 185%/216% increase compared to the BC in the center of the brain and an 831%/950% increase on the sides of the brain. (**Fig. 2**)

Exp.3) Standard deviation of temperature maps showed that there was improved accuracy using MRgHIFU brain coils. The average temperature error for a small ROI in the middle of the brain at a depth of 7 cm from the top of the head was: 8.27/3.73/3.23 °C for the BC/10ch/7ch coils, respectively. (**Fig. 3**)

The 3ch and 7ch coils together had little coupling where the maximum noise coupling between any two channels was 0.5249.

Discussion and Conclusion

Both coils gave better SNR results in the central brain region compared to the BC. The 3ch coil gave better SNR at the cranium surface and the 7ch gave better SNR in the deep central portion of the brain. When combined together great coverage of the entire head region of interest was obtained. Both coils are a good trade off between design simplicity, compatibility with the stereotactic frame, and improved SNR in the brain. Transcranial MRgHIFU treatments should be significantly improved with the high SNR, better anatomical imaging and improved temperature monitoring accuracy provided by the dedicated HIFU coils.

Acknowledgments

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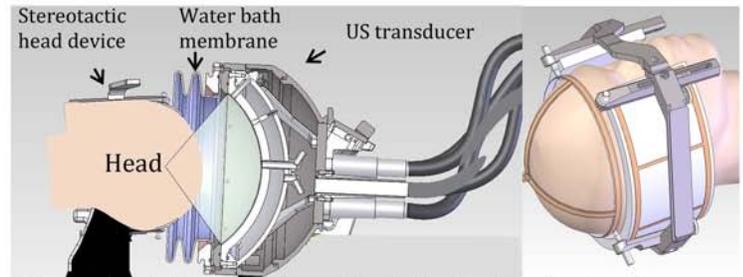


Figure 1: Solidworks schematics. Left: Design showing the complexity of the HIFU environment. Right: design of the 10-channel coil including the 3ch cap and 7ch ladder coils.

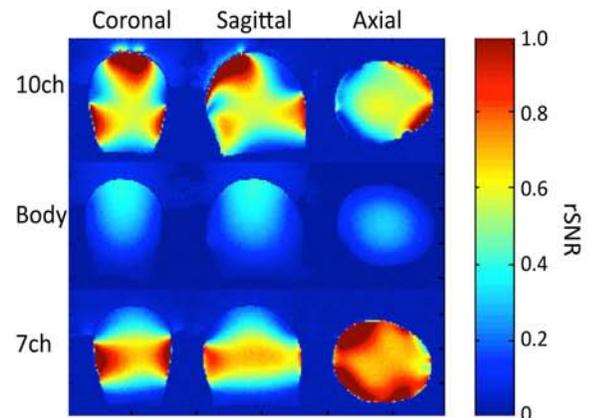


Figure 2: SNR scans using three different coil setups.

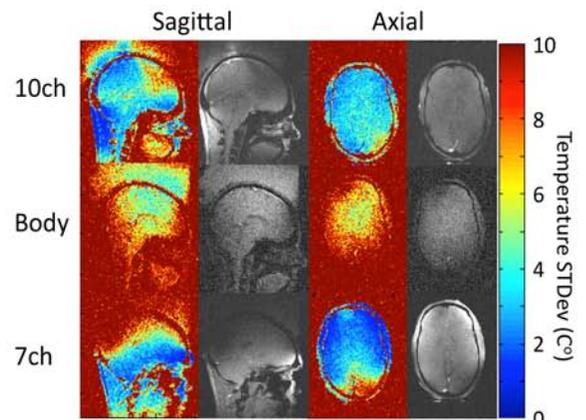


Figure 3: Standard deviation of temperature through time for a non-heating scan which are adjacent to their respective anatomy scan. Three different coil setups are used.