An Optimized 8-Channel Helmet Array for Head Imaging at 6.5 mT

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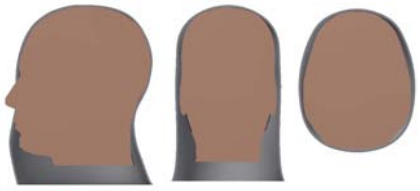
Purpose: In many traumatic brain injury situations, time-critical diagnostic imaging is needed to properly triage and begin treatment. However, in some scenarios access to conventional MRI scanners is limited, owing in part to their siting requirements. A low-field imager could enable a potentially transportable and rapidly deployable human imaging system free from many of the system requirements of high-field scanners. As preliminary steps towards low-field imaging of the human brain, previous work has developed an eight-channel array for 6.5 mT capable of imaging objects up to 15.6 cm in diameter and implemented SENSitivity Encoding (SENSE)[1]. The aim of this study was to construct an eight channel receive-only helmet array for imaging the human brain.

Methods: Previous work identified ideal coil design parameters for our low-field imager[1]. Using CAD software (Autodesk Inventor Professional 2013, Autodesk, San Rafael, CA, USA) and an anatomically correct human head model (ANSYS, Canonsburg, PA, USA) a tight fitting helmet was designed. To ensure a fit to most subjects, the model was slightly expanded in size. Approximate coil sizes and locations were estimated by tiling 8 coils across the top and back of the helmet. Separately, a 30 cm NMR transmit solenoid was also constructed.

Because high performance low-impedance pre-amps are not readily available in our frequency regime, transmit and receive coils are passively decoupled using crossed diodes in series with transmit and in parallel with receive. Active detuning solutions based around PIN diodes are not possible as the carrier lifetime of commercial PIN diodes precludes operation at 276 kHz. Therefore, receive coils are only geometrically decoupled from their nearest neighbors.



A B C

Figure 1. CAD model of the helmet fit (gray) to an anatomically correct model of a human head (peach). Views are from the sagittal (a), coronal (b) and transverse (c) planes.

Results: A helmet contoured to an anatomically and physiologically correct model of the human head was constructed. Figure 1 displays the fit of the helmet to the head model. An approximation of coil shapes and sizes was obtained by tiling 8 coils across the helmet while avoiding the flat sides by the ears as these will be perpendicular to B_0 and therefore collect minimal signal (Figure 2). The final helmet design was 3D printed (Fortus 360mc, Stratasys, Eden Prairie, MN, USA). Final coil designs were 4x14 cm and 4x12 cm (all with 24 AWG, 30 turns). Figure 3 shows the completed helmet. The final assembly of the single channel NMR transmit with the array coil is shown in Figure 4.

All coils were tuned to 276.0 kHz and were matched to at least -27 dB. Coils were geometrically decoupled from their nearest neighbors by at least -30 dB. Decoupling from next-nearest neighbors was at least -6 dB.

A B C

Figure 2. Proposed tiling of 8 receive-only coils on helmet. Coils will be 30 turns from 24 AWG copper wire. Views are from the side (a), iso (b) and top (c).

Discussion: Though previous work was performed on 8 cm coils, coverage of the head as well as penetration to the center of the brain required coil sizes be increased. The helmet was designed to fit 95% of the population. For a subject lying on their back in our very-low field imager, B_0 lies in the coronal plane. For this reason, coils are not tiled on the left and right sides of the helmet.

Conclusions: A tight-fitting 8 channel human-head receive-only imaging array was successfully designed and constructed for 276 kHz. Future work will investigate parallel imaging, SENSE reduction and incoherent undersampling strategies when imaging the human brain at very-low field.

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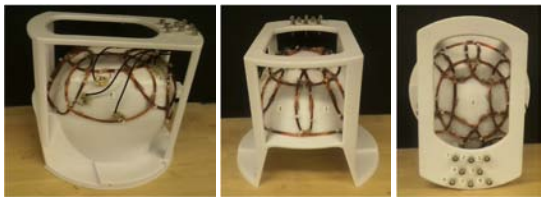

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Figure 4. Images of the 8 channel human head array. Views are from the side (a),front (b), and top (c).

Figure 3. Helmet array coil positioned inside 30 cm NMR transmit coil.

References: 1. LaPierre CD, et al. ISMRM abstract Proc. Intl. Soc. Mag. Reson. Med. 21 (2013) 2772
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