# An 8 Channel Transmit Receive Sodium & Nested 8 Channel Transmit Receive Proton Coil for 3.0 T Brain Imaging

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**INTRODUCTION:** Sodium MRI has the potential to provide new biochemical information on tissue viability (such as homeostasis and cell membrane integrity), which is not available with standard proton MRI, in a non-invasive and a quantitative manner[1, 2]. This information could be of importance for diagnosis and prognosis of neurodegenerative disease such as multiple sclerosis, Alzheimer's disease, or for brain cancer and chemotherapy assessment. However, the NMR sodium signal in the brain is around 10,000 times lower than the proton signal, with very short relaxation times. It is therefore necessary to use ultra short TE (UTE) acquisition sequences in conjunction with high magnetic fields and optimized dual-tuned RF coils in order to increase the SNR of the sodium images. In this work, we propose a novel dual nucleus head coil whose design incorporates 8 transmit-receive elements for sodium imaging along with 8 nested transmit-receive elements for proton imaging at 3.0 T to provide dual nucleus capability with minimal degradation of the X-nucleus performance.

**METHODS : *Design Approach*:** Traditionally for multi-nuclear imaging at 3.0T dual-tuned birdcage coils are used, though the use of high impedance trap circuits results in loss of transmit efficiency and SNR[3]. An alternative is to construct mono-resonant nested coils, but while the need for sensitivity for the X-nucleus motivates making that coil the innermost structure, it then serves as a shield for the proton coil[4]. Proton traps can be incorporated in the sodium coil, but again this impairs sensitivity. Using transmit receive elements the 23Na and 1H elements can be placed on the same former, avoiding the worst shielding problems[5]. In this work we explored a dual nuclei array using a nested configuration.

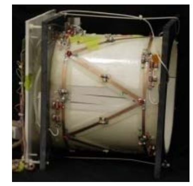
Figure 1: Nested 23Na and 1H brain array

***Sodium Transmit- Receive Array:*** The sodium transmit-receive array was built on a close fitting head shaped former (20 x 25 x 20 cm) (Fig. 1). The relatively low resonance frequency of sodium at 3.0 T (32.6 MHz) makes it a challenge to obtain favorable unloaded to loaded Q ratio. The close fitting former was chosen to obtain favorable coil to tissue coupling which in turn translates to a lower loaded Q value. The sodium array is based on a triangular array design which provides for decoupling between neighboring and next nearest neighbor coils[6] (Fig. 2). Neighboring elements were decoupled by capacitors in the shared coil rung, and next nearest neighbors by using linked inductors. An interface board (Fig. 3) consists of a 1:8 way power splitter, phase shifters and 8 T/R switches was designed and built in house and was used to drive the coils with equal power and fixed a phase offset of 45° between adjacent elements.

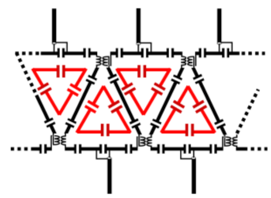
Figure 2: Coil Schematic

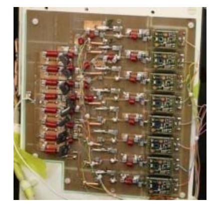
Figure 3: Interface Board

***Proton/Transmit Receive Array***: The design architecture called for 8 Tx/Rx proton elements to be nested inside the sodium elements. As a proof of principle 1 out of the 8 proton loops has been constructed (Fig. 4) to demonstrate proton imaging with minimal disturbance from the sodium elements. Sodium coils exhibit low impedance at the proton frequency and can therefore act as a shield. The proton coils were arranged concentric to the sodium coils and also shared the same former.

***Imaging*** Phantom and *in vivo* measurements were performed using a whole-body 3T scanner (TIM Trio, Siemens) upon approval by our local IRB and informed written consent from the participants. The dual-nuclei array was compared to a dual tuned sodium proton birdcage coil (Stark Contrast, Erlangen Germany) with dimensions of 26 cm diameter and 26 cm length via measurements in the same phantom or participant. SNR maps were derived from GRE acquisitions with both with and without RF excitation (TR/TE/Flip/BW/Slice = 50ms/2.79ms/90°/260/30mm, matrix = 64, FoV = 500mm). Anatomical images were acquired with the FLORET sequence[7] with TR/TE/Flip = 80ms/0.2ms/80°, FoV = 320mm, Nyquist resolution 5mm isotropic, acquisition time = 12:48.

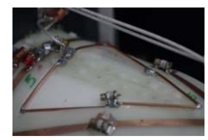
Figure 4: Nested proton loop

**RESULTS *Sodium*** In phantom experiments achieving a 90° flip angle with a 500us hard pulse required 220v for the birdcage and 235v for the 8 Channel array. The sodium array provided an SNR gain of roughly 30% over the birdcage coil at the center and a 2 fold SNR gain in periphery in phantom experiments (Fig. 5). In human experiments a 90° flip angle with a 500us hard pulse required 225v for the birdcage and 240v for the sodium array. The sodium array provided a SNR gain of 60% in the center and more than a 2 fold SNR increase in periphery in human experiments (Fig. 6). Sodium imaging using a custom FLORET sequence showed similar qualitative advantages (Fig. 7).

***Proton*** Proton imaging in the presence of the sodium array is demonstrated in figure 8.

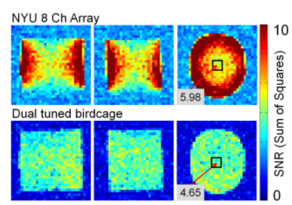

Figure 5: 23Na Phantom SNR

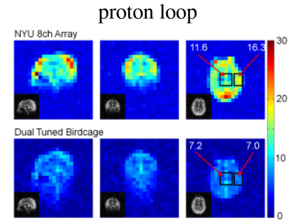

Figure 6: 23Na SNR Maps

**DISCUSSION** The first priority in the coil design was to use close fitting array elements to minimize the distance between the tissue and the sodium coils to improve the unloaded-to-loaded Q ratio and thereby achieve high SNR in the brain. We also chose to implement the sodium coil as a close fitting transmit-receive array in the hopes of increasing transmit efficiency compared to a large birdcage transmit coil. This latter goal has not so far been realized, presumably because of losses in the interface electronics and residual coupling in the array. Coupling to third and fourth order neighbors was significantly higher in this low frequency implementation of the triangle coil compared to previously demonstrated 7T designs. Nevertheless the resulting transmit receive dual-nuclei array provided substantial SNR gain in the center of the brain when compared to a dual tuned sodium birdcage coil.

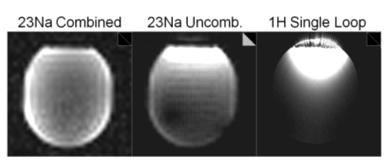

Figure 8: 23Na and 1H images

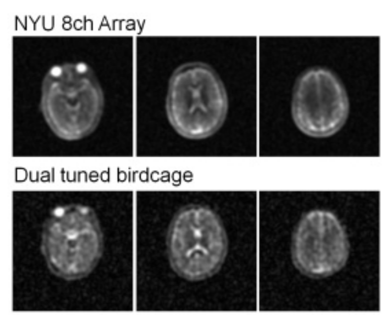

Figure 7: 23Na images with FLORET sequence

**REFERENCES** [1] Madelin G et al. JMRI 38, 511-529,2013 [2] Boada FE et al. Curr Topics Develop Biol 70, 77-101, 2005 [3] Shen GX. Magn Reson Med 1997;38:717–725 [4] Fitzsimmons J. Magn Reson Med 30:107-114 (1993) [5] Brown R. Magn Reson Med 70:259–268 (2013) [6]Wiggins GC ISMRM 2012 p309. [7] Pipe J. Magn Reson Medicine 66:1303–1311 (2011).