An SNR Comparison Between a Sodium Phased Array Coil and a Single Channel Coil

Amin Nazaran[1], Joshua D Kaggie[2,3], Meredith Taylor[1], Daniel J Park[1], Grayson Tarbox[1], Rexford D Newbould[4], Neal Bangerter[1], and Glen Morrell[3]
[1]*Electrical and Computer Engineering, Brigham Young University, Provo, Utah, United States,* [2]*Physics, University of Utah, Salt Lake City, Utah, United States,* [3]*Utah Center for Advanced Imaging Research, University of Utah, Salt Lake City, Utah, United States,* [4]*Imanova Centre for Imaging Sciences, London, United Kingdom*

Purpose: Sodium imaging has the potential to reduce the false positive rate in breast cancer diagnosis, and may be able to improve the ability to stage tumors [1]. However, the signal-to-noise ratio (SNR) of sodium imaging is significantly limited when compared to hydrogen imaging. This is due to sodium's lower intrinsic concentration within the body, its lower gyromagnetic ratio, and its faster signal decay rates. Coil design plays a crucial role in the overall SNR of MR imaging. Phased array coils are commonly used to improve the SNR in MRI by combining small surface loops that have higher sensitivity and smaller noise volume when compared to larger coils. Phased array coils have demonstrated their ability to improve sodium MRI at 3T. Sodium breast arrays have only recently begun to be investigated at 3T [2] and 7T [3]. We previously constructed a 3T phased array sodium breast coil [2] which had greatly improved SNR compared to single-loop designs. In order to accommodate a wider range of women being evaluated for breast cancer, we have created a new sodium phased array coil, with a large, open design that can accommodate large breast sizes. SNR is compared to a single channel sodium coil (with proton trap).

Methods

Single channel coil *(Fig. 1A)***:** The coil used for comparison has a single transmit/receive ^{1}H loop and a single transmit/receive ^{23}Na loop. The radius of the coil is 133 mm. The ^{23}Na loop contains a proton trap to decouple the sodium loop from the proton loop.

New phased array coil *(Fig. 1B-D)***:** The new phased array coil consists of 7 sodium loops that are overlapped to minimize coupling to adjacent sodium loops. Each loop has a diameter of 74 mm. The loops were mounted on a 3D printed structure that has an overall length of 264mm, width of 179mm, and depth of 73mm at the center. Transmit occurred through a large butterfly coil, with the butterfly coil bent in the center so that it operates in quadrature. A butterfly loop was used to improve the transmit efficiency of the coil through quadrature operation, instead of using a less efficient large square loop that surrounds the entire structure.

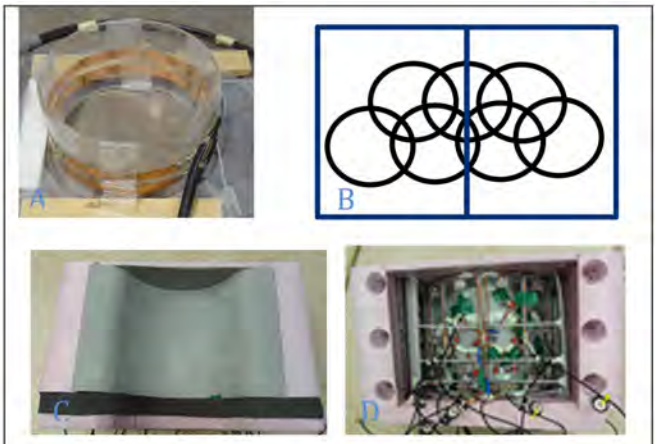

Figure 1. (A) 1 channel ^{23}Na and 1 channel ^{1}H coil; (B) **7-channel sodium receive array, surrounded by a large butterfly sodium transmit coil.** (C) **The** new phased array (top view) ; (D) The new phased array coil (bottom view).

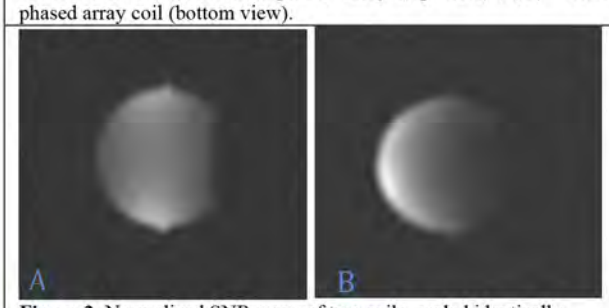

Figure 2. Normalized SNR maps of two coils, scaled identically. (A) resulted image from 1 channel ^{23}Na and 1 channel ^{1}H phased array; (B) resulted image from the new designed coil.

MRI Experiment: Experiments were done on a 3T Siemens TIM Trio MRI machine, using a spherical NaCl/$CuSO_4$ phantom. A 3D cone ultra short echo time (UTE) sequence [3] was used with scan parameters: TR=120ms, TE=0.3 ms, 2.5mm resolution, FOV=20cm, flip angle = 60 degrees, and 2 averages. A flip angle map was obtained using the dual-angle method for both coils at 30 and 60 degrees with similar scan parameters.

Results: SNR maps from both coils are shown in the Figure 2. SNR measurements from both coils in two regions of interest are in Table I. As can be seen, the new phased array design has higher SNR near the surface loops of the coil (2-3x) and has reduced SNR near the center of the phantom (50%), when compared to the single channel coil.

Table. I: SNR results comparing the two coils

Coil name	SNR at the center	SNR at the edge
Dual tune coil	67.3	60.4
Phase array coil	33.1	167.8

Discussion: The overall benefit of this larger array is that the sensitive volume of the coil is much larger than that of single channel coil, due to the much larger volume that can be contained within the coil; thephased array is 264 X 179mm^2 long/wide, while the trap coil is only 133mm in radius. In addition to the larger volume, near the surface loops the coil obtained higher SNR (2-3x) than the single channel coil. The inhomogeneous transmission of the coil causes the flip angle to decrease near the center of the coil, which resulted in a lower SNR than could be obtained if the transmission had been more homogeneous. Improvements to this coil could include the implementation of a more homogeneous transmit to enable higher SNR from the center of the coil and additional sodium loops for increased coverage.

Conclusion: This work demonstrated a new phased array sodium breast coil with a design that accommodates a wide range of breast size, suitable for typical breast cancer patients or women at risk for breast cancer. The coil obtained 2-3 times the sodium SNR near the loops when compared to a simple loop of 133mm diameter.

References

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