A 30-Channel Phased Array for Oxygen-17 (^{17}O) Brain MRI at 7 Tesla

F. M. Meise[1], J. Groebner[1], A. M. Nagel[1], R. Umathum[1], H. Stark[2], S. H. Hoffmann[1], W. Semmler[1], and M. Bock[1]
[1]Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, [2]Stark Contrast GmbH - MR Coils Research, Erlangen, Germany

Introduction

MRI with X nuclei benefits from the increasing field strengths of modern MRI systems ($B_0 \geq 7$T). Especially with ^{17}O-MRI the cerebral metabolic rate of O_2 ($CMRO_2$) can be quantified [2], which provides direct insights into intracellular oxygen metabolism. However, to make optimal use of the higher SNR, dedicated ^{17}O coils are required which should use phased array receiver technology [1] for optimum X-nuclei SNR.
So far, volume coils are used in ^{17}O-MRI because they are easy to design and implement. To overcome the SNR limitations of these coils, we designed a ^{17}O phased array coil (^{17}O-PA) with 30 receive elements and one transmit volume coil for imaging ^{17}O the brain at 7 Tesla . With a large number of receiver elements, SNR is expected to increase significantly both in the cortex and in the center region [3]. The SNR gain can then be used in $CMRO_2$ studies to improve image resolution and/or to shorten scan times during inhalation of the ^{17}O gas.

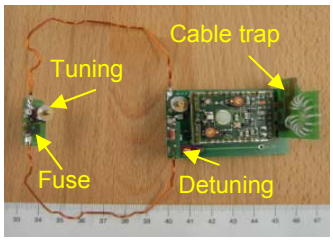

Figure 1: A single ^{17}O-PA receive element. Cable trap and detuning circuits are positioned vertically to the loop structure to minimize space requirements.

Material & Methods

Receive Elements: Thirty rectangular (66/ 90 mm × 91 mm) receive elements (Fig. 1)were built from 1mm coated copper wire. The elements were critically overlapped with their nearest neighboring elements in axial and left/ right direction (Fig. 2). All elements were tuned to the ^{17}O resonance frequency at 7 Tesla of $f(^{17}O)$ = 40.824 MHz, and decoupled to the nearest neighbors by preamplifier decoupling using low noise preamplifiers designed for a 1 Tesla MR system (Magnetom Impact, Siemens Healthcare, Erlangen, Germany). To optimize the overall receiver noise figure, preamplifiers were positioned in the loop structure. An active detuning circuit was used to detune the elements during RF excitation. For patient safety, two crossed diodes were added in case of PIN diode malfunction, and a fuse was integrated to deactivate the Rx-element permanently.
^{17}O Tx Coil: For RF excitation at the ^{17}O frequency, a circular polarized (CP) low pass birdcage resonator (340mm × 300mm) with 8 legs was built, which is activated by serial PIN-Diodes in the rods during transmit (Fig. 3).

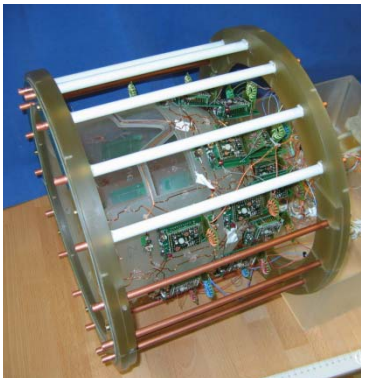

Figure 2: The ^{17}O-PA embedded in the birdcage structure.

Results and Discussion

In this work we have overcome major challenges for designing a non proton massive multi element phased array. Preamplifier decoupling of up to -40dB was achieved. In order to suppress preamplifier oscillations caused by common mode currents on the rf-cable, self shielding toroidal cable traps were placed directly at the output of the preamplifier. This resulted in a good noise correlation matrix (Fig. 4) even the preamplifiers are placed in the neighboring element. Preliminary imaging experiments (Fig. 5) showed a massive SNR increase by using phased array techniques in respect to a dedicated single channel volume coil. The resolution could easily be doubled by maintaining a superior SNR especially close to the receive elements. This improvement in imaging quality achieved by a ^{17}O phased array coil system can then be used in future patient studies to improve the image resolution or to shorten scan times during inhalation of the ^{17}O-gas.

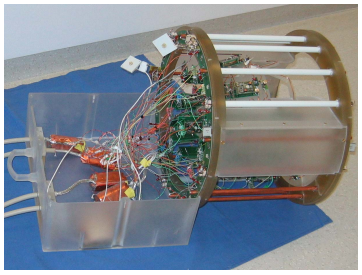

Figure 3: The ^{17}O-PA with transmit and receive electronics. The Birdcage coil can be detuned during receive to avoid coupling to the receive elements.

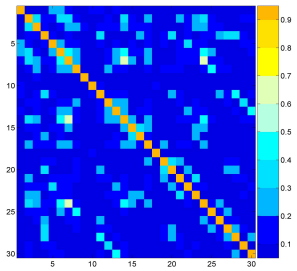

Figure 4: Noise Correlation of the ^{17}O-PA. All channels are decoupled even the preamplifiers are positioned directly in the receive elements.

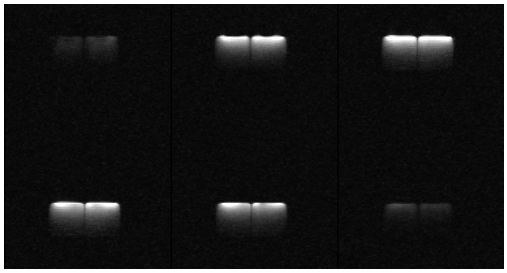

Figure 5: A massive gain in SNR was observed in a preliminary test setup with only 4 receive elements. The resolution could easily doubled while maintaining superior SNR in comparison to the existing single channel colume coil.

Acknowledgement

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References

[1] Roemer, Magn Reson Med. 1990 Nov;16(2):192-225.
[2] Zhu XH, NMR Biomed. 2005 Apr;18(2):83-103.
[3] Wiggins, Magn ResonMed 56:216–223 (2006)
[4] Hoffmann, Proc. Intl. Soc. Mag. Reson. Med. 18 (2010), #724