

Adaptive combination of multichannel data for non-proton MRI

Stefan H. Hoffmann¹, Florian M. Meise^{1,2}, Armin Biller³, and Armin M. Nagel¹

¹Dpt. of Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, ²Siemens AG, Healthcare Sector, Magnetic Resonance, Erlangen, Germany, ³Dpt. of Neuroradiology, University Hospital Heidelberg, Heidelberg, Germany

PURPOSE Non-proton MRI can provide functional tissue information on cell viability (^{23}Na), pH (^{31}P) or oxygen metabolism (^{17}O). However, low *in vivo* concentrations and low NMR sensitivities of these nuclei lead to the low SNR that is characteristic for non-proton imaging. To optimize SNR phased array receiver coils that have become a standard in proton imaging are increasingly utilized also for x-nuclei (e.g. [1,2]). But to gain optimum SNR from the multichannel data acquisition an adequate reconstruction algorithm has to be applied that accounts for the sensitivity profiles of the receive coils. Compared to ^1H MRI where sum-of-squares (SoS) reconstruction is often approximately optimal because of the high SNR [3], the low SNR in non-proton MRI leads to severe noise amplification. In this work, we implemented a multichannel image reconstruction method based on the spatial matched filter of Walsh et al. [4] and compared this method with the standard SoS reconstruction of ^{23}Na data acquired with a 30-channel head coil at 3T.

METHODS ^{23}Na MRI was carried out on a 3 Tesla MR system (MAGNETOM Trio, Siemens AG, Healthcare Sector, Erlangen, Germany) using a dual tuned quadrature $^1\text{H}/^{23}\text{Na}$ birdcage coil (Rapid Biomedical GmbH, Rimpfing, Germany) with a 30-channel receive array and a birdcage volume coil for Tx/Rx. ^{23}Na data was acquired using a 3D density-adapted projection reconstruction pulse sequence [5] with an isotropic nominal spatial resolution of 4.5 mm. One data set with TR/TE = 50/0.25 ms, $T_{\text{RO}} = 20$ ms, $\theta = 76^\circ$, 5000 projections and $T_{\text{AQ}} = 4:10$ min was acquired with the receive array and the birdcage coil, respectively. Additionally, noise only data sets with identical acquisition parameters but no RF power were acquired for the calculation of SNR maps. The adaptive combination (AC) algorithm [4] for multichannel image reconstruction was implemented using Gaussian pre-filtering of the image data before the calculation of the weighting factors. The weighting factors were determined block-wise (16x16x16 pixels) and interpolated to the full image size. Image reconstruction with a zero-filling factor of 2 and calculation of the SNR maps was performed offline using custom MATLAB scripts (The Mathworks Inc, Natick, MA). The SNR maps were calculated using the bootstrapping method [6] with the mean SNR in each voxel determined from 1000 replicas of the SoS and AC reconstructed data.

RESULTS AND DISCUSSION In Figure 1 representative slices acquired with the 30-channel receive array with the SoS (Fig. 1a) and AC reconstruction (Fig. 1b) and corresponding images acquired with the birdcage volume coil (Fig. 1c) are shown. The SoS method leads to a bright noise floor because of the summation of low SNR magnitude data. In the AC data the noise amplitude is significantly reduced especially in regions of low signal intensity thus leading to a better delineation of brain structures from the background noise. In the SNR maps (Fig. 2) a significant increase (up to 2.5-fold) in SNR from AC reconstruction is found in most brain regions, despite the fact that the intrinsic noise amplification of the SoS algorithm leads to an “apparent” SNR of about 10-15 in areas of low signal intensity. The birdcage images show a reduced SNR (~ 25-45) compared to the 30-channel data especially in the cortex. But the volume coil gives a higher signal intensity in the brain center as it is expected from the homogeneous B_1 profile of the birdcage resonator.

CONCLUSION We showed that for low SNR data the AC multichannel reconstruction technique is highly beneficial in terms of noise attenuation compared to the standard SoS coil combination. Hence, an optimized multichannel reconstruction technique considering noise characteristics between the coils is especially required in non-proton MRI to achieve the full SNR advantage over single channel acquisition.

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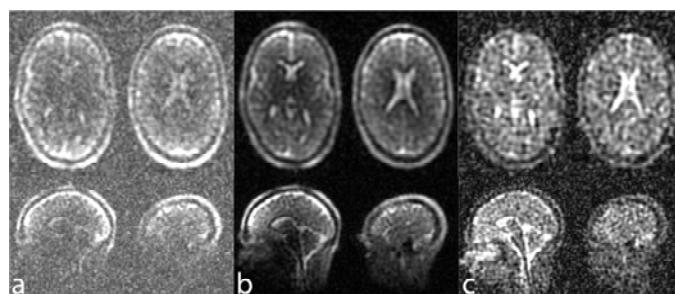


Fig.1: ^{23}Na images acquired with 30 receive channels (a,b) and corresponding images acquired with the birdcage Tx/Rx volume coil (c). The multichannel data were reconstructed by the SoS (a) and the AC (b) method, respectively.

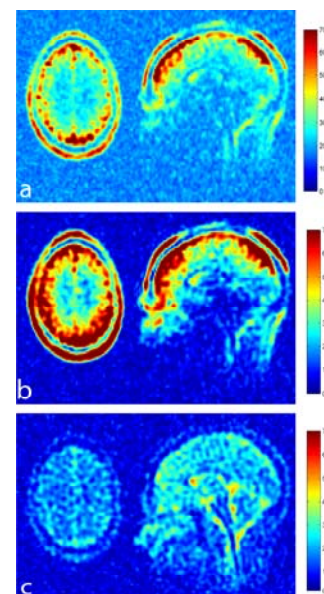


Fig.2: SNR maps of the 30-channel ^{23}Na data reconstructed by the SoS (a) and the AC (b) method. And the corresponding slices acquired with the Tx/Rx birdcage volume coil (c) with identical imaging parameters.