Single Voxel Spectroscopy with Many-Element Coil Arrays

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Introduction

Today's state of the art MR applications are using parallel imaging techniques for accelerated clinical MR imaging [1, 2]. For this reason many-element coil arrays have been developed to balance the available signal-to-noise-ratio (SNR), noise amplification and achievable acceleration factor for clinical parallel imaging. It stands to reason that the benefits of many-element coil arrays originally developed for parallel imaging can also be used for the traditional purpose of achieving the high SNR of small individual coils over the extended field of view of a large volume resonator. As it is cumbersome in a clinical setup to change coils during a patient study, it would be advantageous if these same coils could be used for clinical MR spectroscopy in conjunction with clinical imaging. Hence this study examines the use of multi-element coil arrays, originally optimized for highly accelerated parallel imaging, for clinical high quality MR spectroscopy acquisitions. The goal is to test whether SNR in deep-lying brain regions can be preserved by appropriate combinations of many coil elements, thereby maintaining the ability to do spectroscopy while also preserving the capability for parallel imaging, e.g. in future spectroscopic imaging experiments or in combined anatomic and spectroscopic experiments. In this work, the SNR performance of different coil arrays consisting of up to 32-elements was scrutinized in phantom and in vivo MR spectroscopy studies.

Methods

All experiments were performed on a GE Signa Excite 1.5T (General Electric Healthcare Technologies, Milwaukee, WI, USA), MRI scanner equipped with a 32-channel acquisition system [3, 4] using four different coils: (i) a standard quadrature transmit/receive birdcage volume resonator, (ii) an eight-channel clinical head array (MRI Devices, Waukesha, WI, USA) and (iii) two prototype head arrays with 16 and 32 coil elements, respectively. Phantom reference data were acquired from the GE MRS HD Sphere, a 16 cm diameter spectroscopy phantom filled with Choline, Creatine, Glutamate, Lactate, myo-Inositol and NAA dissolved in a PH-buffered stock solution. A single voxel spectroscopy sequence with PRESS localization was developed, capable of running in parallel on four fully equipped 8-channel receive systems synchronized to yield the required independent 32 receive channels. Localized PRESS spectra were acquired at two different locations in the phantom, (i) at iso-center of the coil and (ii) about 50mm off-center. TE was chosen to be 35 ms, TR=2s, number of averages=128 and voxel volume=8ml. In vivo spectra were acquired in the occipital gray matter, white matter and the cortex as illustrated in Fig. 1 using identical sequence parameters. All raw data were processed off-line on a Linux PC using a dedicated software package SAGE (General Electric Healthcare Technologies, Milwaukee, WI, USA). Prior to the recombination of the spectra from each coil element, phase and frequency were individually corrected based on the unsuppressed and the residual water signal. The individual spectra from the different coil elements were recombined using unsuppressed water signal as a measure to determine coil sensitivity prior to sensitivity weighted averaging of the time domain data, attempting to replicate the optimal matched filter combination proposed by Roemer [5]. The resulting FID was reconstructed using eddy-current correction, 1.25 Hz Gauss filtering and zero-filling to 4096 points prior to the FFT. SNR was estimated based on the amplitude of the Creatine signal and the coefficient of variation of a potential noise area [6, 7]

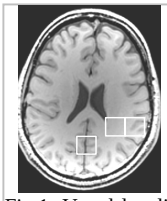

Fig.1: Voxel localization for in vivo experiments.

Results and Discussion

Phantom and in vivo spectra were successfully acquired with all coils as shown in Fig. 2. The qualitative result achieved with the standard quadrature head coil compared to the 8 and 16 channel arrays showed very little difference as shown for the phantom spectra in Fig. 3. This finding was confirmed by the comparison of the estimated SNR values obtained for the four different coils (Fig. 2). The 32-element coil array developed for highly accelerated parallel imaging yielded significantly reduced SNR showing that more development work needs to be done for this particular 32-element array design to further boost spectroscopic SNR. This study successfully demonstrates on 8- and 16-element arrays, that coil arrays optimized for accelerated imaging can preserve the SNR in a spectroscopy experiment after appropriate data recombination. A quantitative comparison of the presented results remains challenging: 1. The SNR values are approximate estimates, and can easily vary by 15-20% due to the method used. 2. The inner diameters of the coils, which are crucial performance parameters, are different for all coils. 3. All coils are tuned and matched for loading with a human head and not for the phantom. 4. Due to the differences in the coil design the noise obtained for the 32-channel coil array using narrow elements tend to be coil noise dominated, while the noise derived from the 8- and 16-element coil array is mainly patient noise dominated.

This single voxel spectroscopy study was a preliminary test showing that the benefits of many-element arrays can eventually be brought to bear for more general spectroscopic experiments with the caveat that underlying array design must be appropriate and noise must remain body-dominated or otherwise controlled. We anticipate extending the development to patient studies for the detection of brain disease, including exploration of accelerated chemical shift imaging using the many element coil arrays presented here.

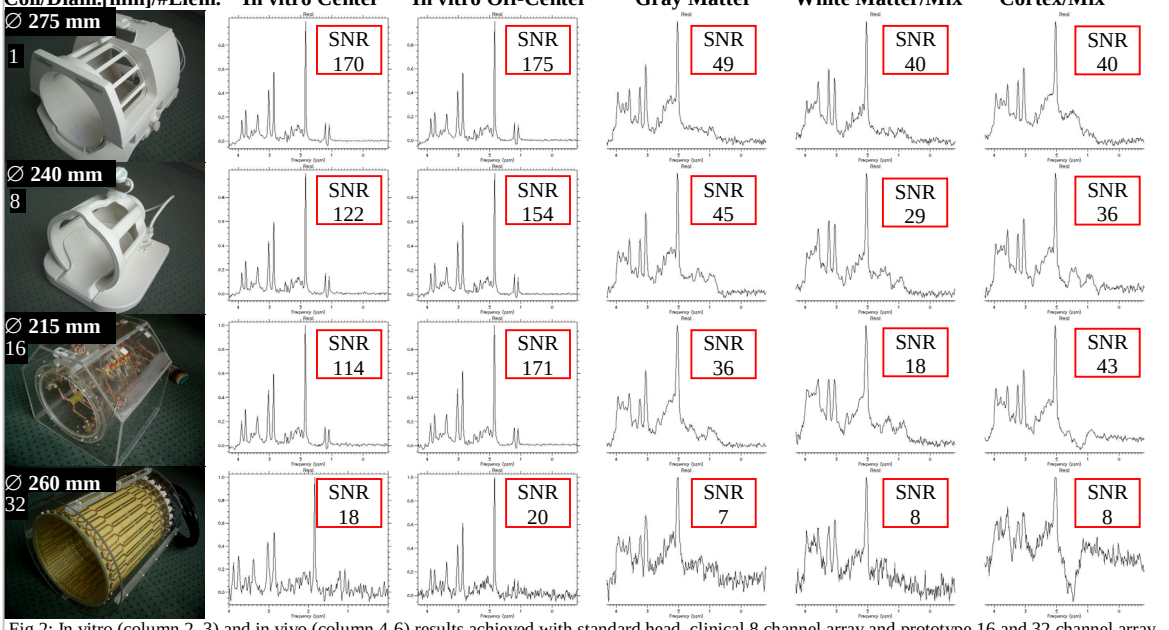

Fig.2: In vitro (column 2, 3) and in vivo (column 4-6) results achieved with standard head, clinical 8 channel array and prototype 16 and 32 channel array coil (from top to bottom).

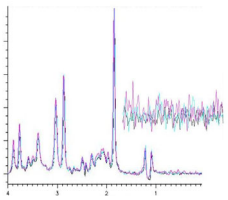

Fig.3: Signal and noise comparison for 1 (black), 8 (blue) and 16 (pink) element array coils.

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