Reconfiguration of a "standard" Biospec spectrometer for simultaneous 2-channel acquisitions: Application for mouse brain MRI and MRS

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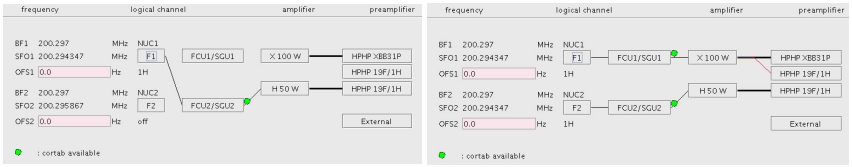
Introduction

The advantages of array coil imaging on clinical MR systems have gained relevance in many applications. In the field of small animal imaging, the interest for this concept is growing. Array-coil imaging is an advanced method to enhance the signal-to-noise ratio (SNR) using superior sensitivity of several small coil elements compared for example to a larger single element covering the same area. Another benefit of phased-array technique is the possibility to use parallel imaging techniques such as SENSE (sensitivity encoding) and GRAPPA (generalized autocalibrating partially parallel acquisitions) to increase acquisition speed. The principle of this concept is that the signals are acquired simultaneously with as many independent receiver channels [1-4]. High field MR experimental systems with multiple receiver channels are still rare and the upgrade of existing systems is relatively expensive. In this work, a "standard" 4.7T Bruker Biospec Avance II spectrometer with two broadband chains, one dedicated to proton (^{1}H), one dedicated to nuclei X (with X=^{31}P, ^{23}NA, ^{13}C, ...) was modified to allow two-channel ^{1}H acquisitions. These modifications were validated *in vitro* with phantoms as well as *in vivo* on mice brain for imaging and spectroscopy using a home-made two-channel phased array coil operating at 200 MHz.

Material and Methods

The experiments were performed on a Bruker 4.7T Biospec system (Bruker, Ettlingen, Germany). The routing which defines the connections between the hardware parts involved in the acquisition pipeline was modified to allow the acquisition of two channels simultaneously (Fig. 1). The excitation was performed using the X-nucleus amplifier, which is a broadband amplifier, and the reception was made with the standard ^{1}H-nucleus chain together with the X-nucleus chain which however was interconnected with a second proton preamplifier. The X-nucleus amplifier output was linearized, for the proton frequency, by creating a correction table (cortab) used to correct the non-linearity of the RF pulse power level versus the pulse length (Fig. 1b). The methods including the pulse programs were modified to activate the second receiver channel and to handle the sum of squares reconstruction (only for imaging). A linear 72 mm inner diameter birdcage coil (Rapid Biomedical, Würzburg, Germany), for excitation, and a home-designed two-channel phased array coil, for reception, were used. The two-channel array coil consists in two rectangular loops (12 x 16 mm^2 internal and 15 x 20 mm^2 external dimensions) build on a plastic cylinder with a 21 mm outer diameter. The two elements of the phased-array coil are decoupled using the shared inductor decoupling method. Every element has a decoupling PIN diode circuit activated during for the transmit period. The home-designed phased-array coil was compared to a single channel 15 mm diameter surface coil. For *in vitro* imaging and spectroscopy experiments, a cylindrical phantom made of eleven metabolite (aspartate (Asp), creatine (Cr), choline (Cho), γ-aminobutyric acid (GABA), glucose (Glc), glutamate (Glu), glutamine (Gln), N-acetylaspartate (NAA), taurine (Tau), lactate (Lac) and myo-inositol (Ins), 50 mM, pH = 7, 10 ml) solution was used [5]. *In vivo* experiments were performed on mouse brain. The ethical guidelines for experimental investigations with animals were followed. Gaseous anesthesia was performed on mice placed in prone position. The home-designed phased-array coil and the 15 mm surface coil were placed on top of the brain. For brain imaging an axial T2-weighted fat suppressed (FS) RARE sequence was used with the following parameters: TR/TE = 4000/75 ms; RARE factor = 8; 30 x 30 mm^2 FOV, 256 x 192 matrix, 19 slices, 1 mm slice thickness and 17 kHz receiver bandwidth. Spectroscopic acquisitions were performed using a short–echo time PRESS sequence (TE/TR=20/5000 ms, Tacq = 21 min, 4096 data-points, bandwidth of 4 kHz). The volume of interest (2.5 x 2 x2 mm^3) was centered in the right hippocampus. First- and second-order shim terms were adjusted using FASTMAP. The Spectroscopy data from the two channels were combined using Matlab 7.4 (Mathworks Inc, Natick, MA, USA) in the time domain using a sum of squares weighting function. Prior to the combination, the signals from the two channels were zero-order phase corrected. The coil intensity weighting factor, for each coil were obtained from the mean value of the four first absolute time-domain data point of the unsuppressed-water signal. The signal-to-noise ratio (SNR) was measured *in vitro* in different regions of interest and was calculated for metabolites (Cho, Cr, NAA).



a b

Fig. 1. The routing connection scheme: a) for a standard proton acquisition; b) for a two-channel proton acquisition.

Results

The images and spectra acquired with the two-channel phased-array-coil are showed in Fig. 2. The mean SNR measured at various locations was 137 ± 15 for the two-channel array-coil in comparison with a mean SNR of 117 ± 41 for the 15 mm single channel surface coil. SNR-values measured for three metabolites of interest are summarized in Table 1. Magnetic field homogeneities measured with both coils were comparable with a full width half maximum (FWHM) of 3.2 Hz (ranging 2 to 5 Hz).

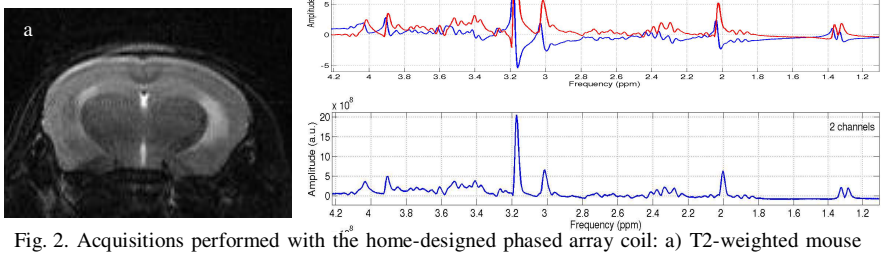


Fig. 2. Acquisitions performed with the home-designed phased array coil: a) T2-weighted mouse brain image with neurological disorders; b) Spectra acquired on the eleven metabolite solution before (top) and after (bottom) the combination.

Conclusion

Simultaneous two-channel acquisition for imaging and spectroscopy was demonstrated after reconfiguration of a standard 4.7T Biospec spectrometer. Only a second broadband RF amplifier in the proton range is mandatory. The second proton preamplifier can be optional if the two-channel amplifier decoupled phased-array coil with on board preamplifiers is used. Modifications realized for proton multiple channel acquisitions could also be applied for any X-nucleus. Compared to quadrature detection coils, two-channel coils offer the ability to use parallel acquisitions techniques. Further step will be to implement this feature and to demonstrate the interest for small animal ^{1}H imaging as well as for other nuclei such as ^{3}He hyperpolarized gas imaging.

Reference

1. Roemer PB *et al.*, Magn Reson Med 1990; 16: 192–225.
2. Gareis D *et al.*, NMR Biomed. 2007; 20: 326–334
3. Sutton BP *et al.*, Magn Reson Med 2005; 54: 9–13.
4. Griswold MA *et al.*, Magn Reson Med 2002; 47:1202–1210.
5. Cudalbu C *et al.*, C. R. Chimie 2006; 9 :534–538.

Metabolites SNR	Phased-array	Surface
Cho	317	192
Cr	111	69
NAA	113	66

Table 1. Comparison of SNR-values measured *in vitro* for three metabolites of interest.

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