

# Proton MR Spectroscopy Using Short TE PRESS without Water Suppression. In Vivo Application to Rat Brain at 7 Tesla

W. Dreher<sup>1,2</sup>, E. Küstermann<sup>1,2</sup>, and D. Leibfritz<sup>1,2</sup>

<sup>1</sup>University of Bremen, FB2 (Chemistry), Bremen, Germany, <sup>2</sup>Center for Advanced Imaging, Bremen, Germany

**Introduction:** Although several approaches have been described to avoid water suppression (WS) in localized proton MR spectroscopy (MRS) and spectroscopic imaging (SI) [1-9], WS is still a standard procedure for <sup>1</sup>H MRS and SI. However, if WS may be omitted without compromising the spectrum quality, the simultaneously acquired water signal can be used for correction procedures (line shape and phase correction or signal combination if array coils are used) and as a reference for absolute quantification. Other advantages are that (i) magnetization transfer (MT) effects on metabolite signals [10], which may be caused by WS [11], are avoided, (ii) sequential measurements may be more time efficient, and (iii) time consuming adjustments are not required. Considering the excellent performance of modern gradient systems, we investigated whether high quality short echo time (TE) PRESS spectra can be acquired without WS using an implementation without any additional sequence components or adjustments [6, 12].

**Method:** A PRESS sequence was modified to allow short TE values of TE ≥ 10 ms using optimized sinc-like RF pulses of 1.0 ms (90°) and 2.5 ms (180°) duration (cf. Fig. 1) for excellent volume definition. In order to avoid additional sequence components or adjustments, only a simple two-step scheme was applied by inverting all gradients as well as all frequency offsets of RF pulses for voxel positioning in the second step as proposed in [2,6]. Strength and order of slice selection and spoiler gradients were optimized to minimize gradient induced sideband artifacts of the dominant water signal. Outer volume suppression (OVS) was omitted because this may also give rise to MT effects. The measured data sets were processed by standard software provided by the manufacturer (Topspin 2.0) or an in-house developed program written in IDL (ITT, USA). Optionally, the water signal was extracted in the time domain by using the matrix pencil method (MPM) [13] which helped to flatten the baseline of the in vivo spectra.

**Experimental:** All experiments were performed on a Biospec USR 7T/20 animal scanner (Bruker-Biospin, Germany) equipped with standard gradients BGA-12S (12 cm inner diameter, maximum strength: 400 mT/m, slew rate: 4000 mT/m/ms). For initial phantom experiments a quadrature volume RF coil (72 mm inner diameter) was used. For further phantom measurements and all in vivo studies, a linear resonator of 72 mm inner diameter and a 4-channel array coil optimized for rat brain were used for RF transmission and RF reception, respectively. The signals of the array coil were combined online to maximize the signal-to-noise ratio (SNR). Main parameters of the PRESS sequence were: TE ≥ 10 ms, voxel size: 5x5x5 mm<sup>3</sup> (phantom) or 4x4x4 mm<sup>3</sup> (in vivo), spectral width: 4006 Hz, 2 K or 4 K complex data point, TR = 1.5 s or 3.0 s, 6 dummy scans, 64 accumulations (2 scans each with 32 accumulations using opposite gradient directions, signal addition was performed on-line). Standard EXCORCYCLE phase cycling was applied to both 180° pulses. Test measurements were performed on spherical phantoms filled with water or 50 mM aqueous solutions of metabolites (N-acetyl aspartate (NAA), glutamate (Glu), glutamine (Gln)). In vivo studies were performed on Wistar rats (250 g) anaesthetized with 1.5 % isoflurane in a 70:30 mixture of O<sub>2</sub> and N<sub>2</sub>O.

**Results and Discussion:** First, the strength and order of the slice selection and spoiler gradients were optimized to achieve a minimum TE of 10 ms and to reduce gradient induced sideband artifacts of the water signal so that the two-step scheme with opposite signs of all gradients allowed to suppress the remaining artifact signals below the noise level (cf. Fig.1). It was most important not to use the z-gradient as a spoiler gradient prior to data acquisition. No gradient or phase adjustments were required, contrary to earlier measurements on an older MR system where improvements could be obtained by trimming the gradients for different voxel sizes [6]. The artifact suppression was assessed on phantom measurements as shown in Fig.2. The spectrum measured on a 50 mM solution of glutamate shows no artifacts (which would occur on both sides around the water signal) in the downfield region which is void of metabolite signals. In the highfield region, the multiplets of Glu are detected with excellent lineshape and spectral resolution. Figure 3 shows an in vivo spectrum measured on the rat brain within only 3.5 minutes. Using the MAPSHIM procedure based on a B<sub>0</sub> field map, the linewidth of the water signal was 10-12 Hz. Only minor improvements were achieved by manually optimizing the shim currents. Data processing consisted of apodization with a Hanning function, FT, phase correction and water extraction by MPM. No baseline correction was applied. The good spectral resolution allows to observe e.g. the "splitting" between the CH<sub>2</sub> signals of creatine (Cr) and phosphocreatine (PCr) despite the small chemical shift difference of 0.017 ppm. A high SNR is obtained, which is also due to the use of the large water signal for a precise and efficient combination of the four receiver channels [14]. The main signals are assigned to NAA, Cr, PCr, total choline (tCho), Glx (Glu+Gln), taurine (Tau), myo-inositol (m-Ins) and Gaba. Additionally, proton signals of NH protons were clearly observed, e.g. at 7.85 ppm (NAA), which is another advantage of MRS without WS because saturation transfer is avoided as demonstrated in [8].

**Conclusion:** The current study shows that WS is indeed not required if modern hardware (particularly optimized gradients) is used and a two-step scheme with opposite gradient directions is applied to suppress the remaining gradient induced artifacts. Considering the undeteriorated spectrum quality and the various advantages of MRS without WS, WS may become obsolete in the near future for many applications of <sup>1</sup>H MRS.

**References:** [1] Hurd RE et al., MRM 40, 343(1998). [2] Kreis R et al., Proc. ISMRM, 1998, p.24. [3] van der Veen JW et al., Radiology, 217, 296(2000). [4] Serrai H et al., JMR 149, 45(2001) and JMR 154, 53(2002). [5] Clayton DB et al. JMR 153, 203(2001) and Concepts in Magn. Reson. 13, 260(2001). [6] Dong Z et al., MRM 51, 602(2004). [7] Dreher W et al., MRM 54, 190(2005) and ISMRM 2006, p.3066. [8] de Graaf RA et al., Proc. ISMRM, 2006, p.3063. [9] Dong Z et al., MRM 55, 1441(2006). [10] Dreher W et al. MRM 31, 81(1994). [11] de Graaf RA et al., MRM 41, 1136(1999). [12] Nixon TW et al, JMR 192, 209(2008). [13] Lin Y-Y et al., JMR 128, 30(1997). [14] Dong Z et al., MRI 25, 1148(2007).

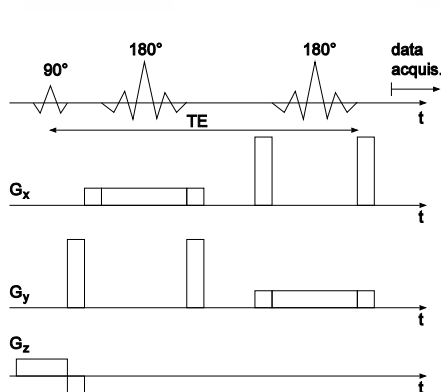


Fig.1: Scheme of optimized PRESS sequence without WS implemented at 7T (not to scale)

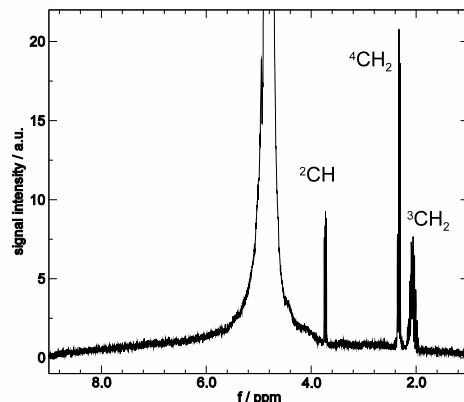


Fig.2: PRESS spectrum (TE=10 ms) without WS measured on a 50 mM glutamate solution.

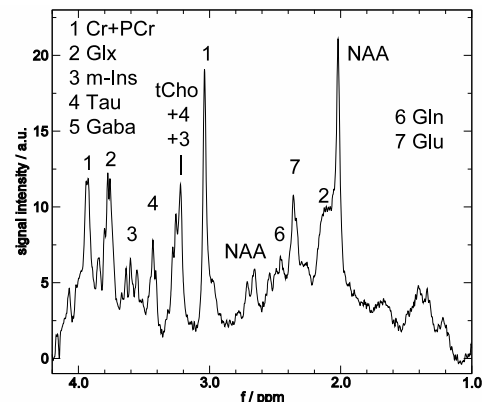


Fig.3: PRESS rat brain in vivo spectrum measured without WS (TE=10 ms).