High B1-field, high bandwidth and short TE 31P and 1H MR Spectroscopy at 7T using a dedicated surface coil setup

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Introduction:
MR spectroscopy at high B_0 magnetic field strength results in high signal to noise ratios and increased spectral resolution. In reality, , MRS of the human brain may be limited in localization accuracy and sensitivity as B_1^+-field intensity may be substantially compromised. Low B_1^+-fields lead to low bandwidth RF pulses and as a consequence severe chemical shift displacement artifacts (CSDA) occur with slice selective excitation and refocusing at high field. Also long echo times are needed to reach refocusing flip angles with low B_1^+. For MRS of nuclei other than ^{1}H a high excitation bandwidth is generally required to excite all metabolites. We therefore propose the use of local transmit-receive (TxRx)-coils with a highly focused and therefore strong B_1^+ field. With this setup we demonstrate ^{1}H MR spectra obtained with a semi-LASER [1] sequence with a TE of only 17 ms and CSDA of only 3.5% ppm^{-1} and adiabatic excitation of the entire 25 ppm spectral range of ^{31}P spins in the human brain at 7T.

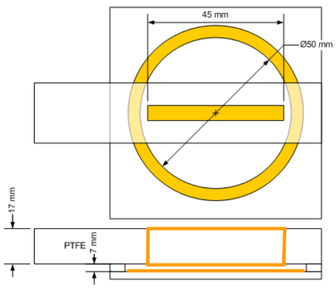

Figure 1: Schematic visualization of the coil setup.
A: the circular loop
B: the shortened stripline

Materials and methods:
A TxRx-coil was developed which consists of two elements (figure 1): a circular loop (diameter=50mm) combined with a shortened stripline (length=45mm, thickness=17mm). For multi nuclei MRS (^{1}H & ^{31}P) each element is double-tuned to enable transmit and receive both at 120.6 MHz and 298.2 MHz. Both elements were combined via a quad-hybrid and interfaced via a narrowband TxRx switch and preamplifier to a 7 Tesla whole body MR-system (Philips, Cleveland, USA) with a 4kW RF amplifier for both nuclei.
B_1^+ values were determined at a distance of 3 cm from the coil by visualization of inversion bands using a FLASH sequence with a fixed nominal flip angle. Areas of signal null were corresponding to a 180 degree excitation, which ratio to the nominal flip angle was multiplied to the nominal B_1 value to calculate the actual B_1^+ field. A ^{1}H MR spectrum was obtained with a semi-LASER sequence in a voxel of (1.5cm)^3, using 1.5 ms adiabatic inversion pulses with a bandwidth of 8.3 kHz (TE=17ms, NSA=32, TR=6s). Pulse acquire ^{31}P spectra were obtained with an adiabatic half-passage excitation pulse of only 0.8 ms, both unlocalized (NSA=64, TR=1.5s) and localized using 3D CSI (voxel size = 2x2x2cm^3 , TR=1.5s, total acquisition time = 20min).

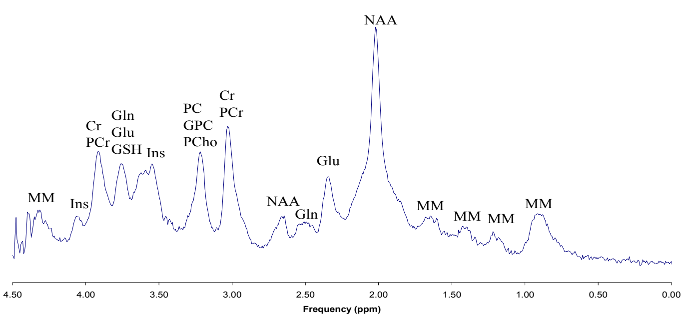

Figure 2: ^{1}H short TE spectrum, obtained with the double-tuned double-channel coil setup using a semi-LASER sequence (TE=17ms, NSA=32, TR=6s).

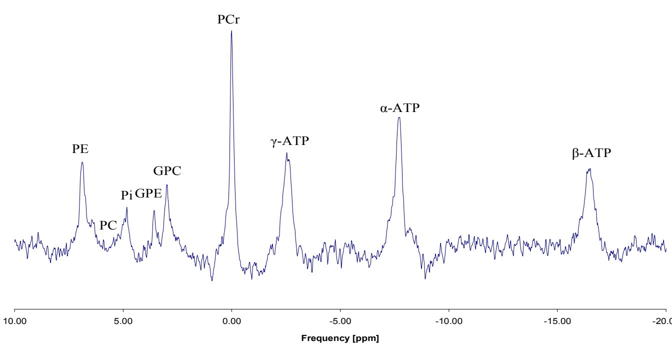

Figure 3: ^{31}P spectrum, obtained with an adiabatic half-passage pulse acquire (NSA=64, TR=1.5s, baseline filtered for short T2 components).

Results and discussion:
The perpendicular fields of both elements makes this setup inductively decoupled. The B_1^+-field at a depth of 3 cm for ^{1}H is estimated at 40 µT and the B_1^+ for ^{31}P was at similar penetration depth estimated to be 100 µT. These strong B_1 fields enable the use of high bandwidth adiabatic RF pulses. For ^{1}H adiabatic refocusing pulses (8.3 kHz) of only 1.5 ms were used leading to a very short TE of 17ms with a CSDA of only 3.5% ppm^{-1} (figure 2). For ^{31}P an AHP pulse could be used with a duration of 0.8ms resulting in excitation of the entire 25 ppm bandwidth (figures 3 and 4).

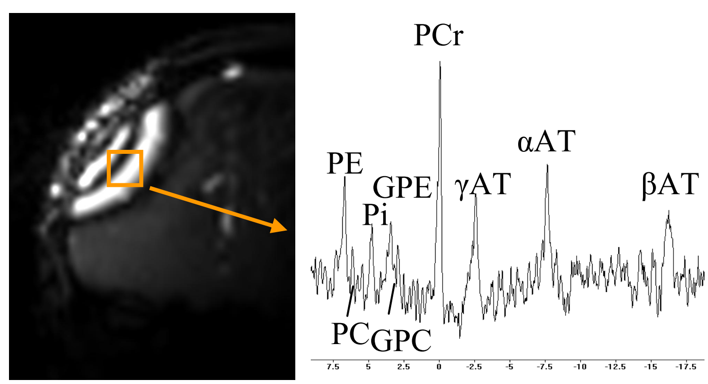

Figure 4: 31P MRSI obtained with a high bandwidth adiabatic half-passage pulse acquire 3D CSI (2x2x2cm^3, TR=1.5s, no baseline correction)The high B_1^+ field is visualized by multiple bands with signal nulling corresponding to 180, 360 etc. degree excitation.

Conclusion:
A dedicated double-tuned double-channel transmit receive surface coil setup is developed that enables the use of high B_1^+-fields in multi nuclei MRS of the human brain. The available B_1^+ field of up to 40 µT and 100 µT for respectively ^{1}H and ^{31}P allowed the use of short and high bandwidth adiabatic RF pulses, which are insensitive to the inhomogeneous nature of the B_1^+-field. Therefore accurately localized ^{1}H and ^{31}P MR spectra with high sensitivity could be obtained at 7T.

Reference:
[1] Scheenen TJ, Heerschap A, Klomp DWJ et. al. MAGMA 2008 5;21(1):95