Compensation of offresonance magnetization transfer artifact in SPECIAL at 7T

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Introduction: The increase in spectral separation and signal-to-noise ratio at ultra-high field (7T and higher) strength enables the detection of a large number of low concentrated or coupled spin systems aside from the big landmark peaks NAA, creatine and choline. However, their detection is complicated by relatively short T2 relaxation times at ultra-high field strength (7T). The large spectral separation and fast T2 relaxation call for a localization approach that controls the chemical shift displacement artifact while keeping echo-times short. Mlynárik et. al. [1] introduced an elegant approach combining 1D ISIS and 2D spin echo encoding for a localization scheme called SPECIAL. With this approach 3D localization can be reached by using only one slice selective refocusing pulse instead of two as in conventional localization schemes. However, besides the spatial labeling the slice selective inversion pulse used for ISIS encoding prior to the excitation also acts as a magnetization transfer pulse. It was shown among others by Wolf et.al. [2] that magnetization transfer can take place between mobile, observable protons and a bound NMR invisible proton pool. Other authors [3,4,5] demonstrated that magnetization transfer can also lead to significant changes in metabolite signals like creatine, glutamate, glutamine, lactate or myo-Inositol [6]. A similar effect can also be observed for lipids in the skull which can complicate ISIS based localization schemes for ^{1}H spectroscopy.
In this work, it is shown that the fat contamination which occurs in single voxel SPECIAL experiments without outer volumes suppression stems from magnetization transfer due to the ISIS inversion pulse. This leads to different lipid signal intensities in the alternating scans with and without ISIS pulse and therefore results in incomplete cancellation of outer volume fat. An alternative method to the often SAR demanding outer volume saturation is presented to deal with this specific artifact.

Materials & Methods: The measurements were performed on a 7T Philips MRI scanner. A 16 channel Nova head receive array combined with a head transmit volume coil (B_1 = 18μT) was used to acquire the data The ISIS scheme was implemented using a slice selective trapezoidal adiabatic inversion pulse [7] prior to a 2D selective spin echo. The spectra were obtained from a volunteer in the visual cortex with a voxel size of 20x20x20mm. 64 averages at a repetition time TR of 5000ms and a minimum TE of 15ms were acquired. During the first experiment the inversion pulse was alternately turned off and on to achieve 1D ISIS encoding and together with the 2D selective spin echo 3D volume selection in the desired region after subtraction of the two ISIS encoding steps. For the second experiment the inversion pulse was turned on during both ISIS encoding steps but its frequency offset was shifted every average such that the resulting inversion slice ended up at a location outside the subject's brain. As a consequence the SV localization is not spoiled, but the same magnetization transfer between bound water and outer volume lipids is induced leading to nearly perfect cancellation of confounding lipid signals.

Results & Discussion: Figure 1 (A) & (B) show all averages from the 2 ISIS encoding steps of the first experiment in which the ISIS pulse was turned off (red) for every second average. It is clearly visible that the fat signal shows a slight but systematic difference between the odd and the even averages. This slight change in lipid signal intensity (figure 1 (E)) lead to fat contamination in the final spectrum after the subtraction process with amplitudes that can exceed metabolite signal amplitudes.
In figure 1 (C) & (D) the lipid intensities of the individual ISIS encoding steps prior to subtraction are shown for the case a MT compensation pulse as described above was used during the second encoding step. In this case the difference between these the two averages is negligible. After subtraction the data acquired with this scheme leads to an artifact free single voxel spectrum without any lipid contamination (figure 1 (E)).

In conclusion, it could be shown that the ISIS inversion pulse prior to excitation in SPECIAL induces magnetization transfer effects between bound water and lipids, which can lead to substantial fat contamination in the final spectrum.. Beside the possibility of presaturating the fat with outer volume suppression pulses, the method proposed in this abstract showed to yield excellent results in removing magnetization transfer induced subtraction errors and depending on the type of OVS pulses used, this method might also be more SAR efficient.

[1] Mlynárik et. al. Magnetic Resonance in Medicine 56:965–970 (2006)
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[3] deGraaf et. al. Magnetic Resonance in Medicine 41:1136–1144 (1999)
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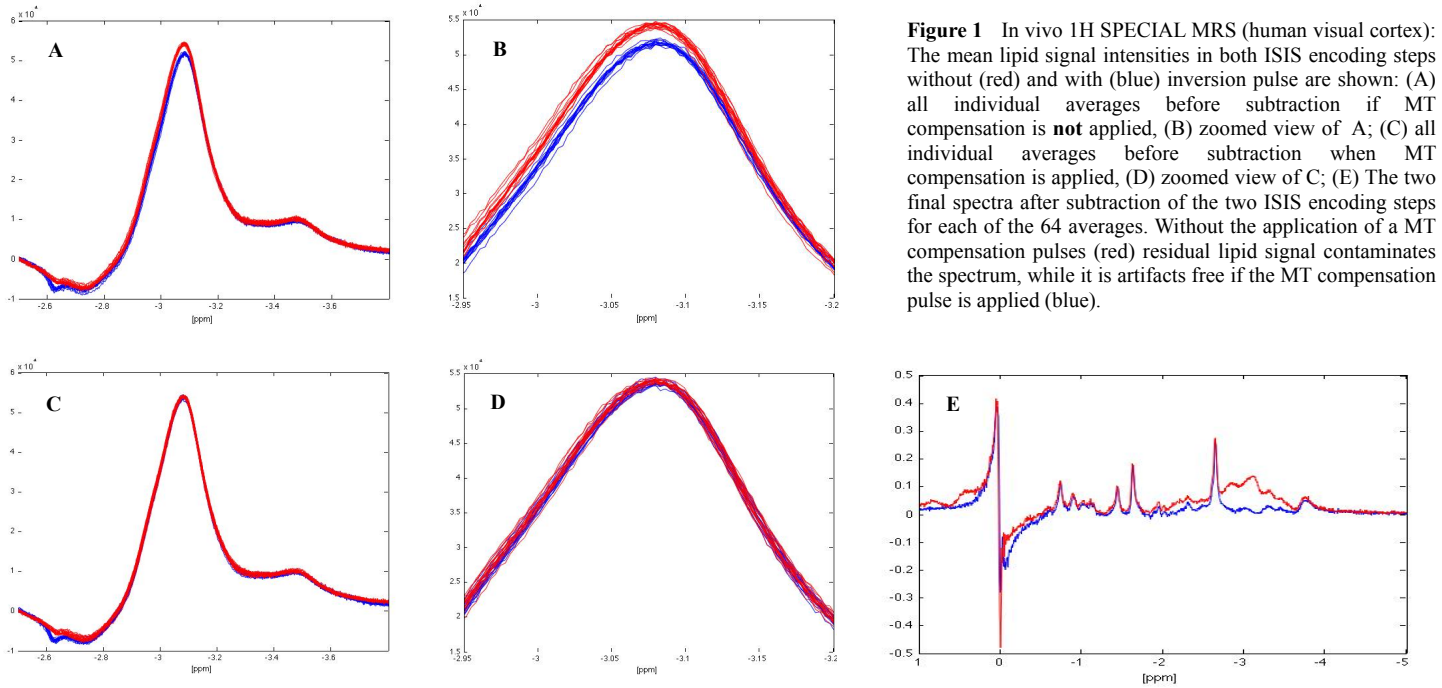

Figure 1 In vivo 1H SPECIAL MRS (human visual cortex): The mean lipid signal intensities in both ISIS encoding steps without (red) and with (blue) inversion pulse are shown: (A) all individual averages before subtraction if MT compensation is **not** applied, (B) zoomed view of A; (C) all individual averages before subtraction when MT compensation is applied, (D) zoomed view of C; (E) The two final spectra after subtraction of the two ISIS encoding steps for each of the 64 averages. Without the application of a MT compensation pulses (red) residual lipid signal contaminates the spectrum, while it is artifacts free if the MT compensation pulse is applied (blue).