Phase Cycling for Semi-Laser Single Voxel Spectroscopy

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Target Audience: Radiologists and sequence developers.

Purpose: The use of adiabatic pulses for refocusing in the context of spectroscopy examinations has been shown to bring considerable benefits [1, 2, 3]. Due to a better resilience to chemical shift and to B1 inhomogeneity and their better slice profile, they provide improved quality in spectroscopy acquisitions, in particular for lactate detection at 3T, where the chemical shift artefact, combined with J-coupling effects dramatically decreases the observed lactate doublet for a standard PRESS sequence [4]. One of the disadvantages of the semi-laser single voxel spectroscopy (SVS) sequence is that since every refocusing pulse is replaced by two adiabatic full-passage (AFP) pulses, the number of unwanted coherences is increased. In order to reduce spurious echoes and contamination from outside the voxel, it is therefore necessary to devise suitable phase-cycling schemes for the semi-laser SVS sequence. In this study, we provide a generic way of building phase-cycling schemes of the excitation pulse and the four adiabatic refocusing pulses based on the phase-cycling schemes commonly used in the PRESS sequence [5, 6].

Methods: Let φ1 be the phase of the excitation pulse, φ2, φ3, φ4 and φ5 the phases of the 4 refocusing pulses in the semi-laser SVS sequence. It can be shown that the phase of the echo of interest is: φ1-2(φ2- φ3) + 2(φ5- φ4). We make the following observation: if the second and third refocusing pulses are removed, then the phase of the echo would be: φ1-2φ2 + 2φ5, which is equivalent to the phase of the echo of interest for a PRESS sequence, using the first and the fourth refocusing pulse. It is therefore straightforward to extend any phase-cycling scheme of the PRESS sequence to a phase-cycling scheme of the semi-laser sequence: first a PRESS phase-cycling scheme is chosen to cycle the phases of the excitation, the first and the fourth refocusing pulse, another standard phase-cycling scheme is chosen for the second and third refocusing pulses (say a two-step 0 deg – 180 deg phase cycling). The combination of these two cycling schemes leads to a phase cycling of the 5 pulses of the semi-laser SVS sequence. For example a 32-step phase-cycling scheme can be built by using a first sweep of the EXOR 16-step scheme for the excitation, the first and the fourth refocusing pulses with φ3 = φ4 = 0 then a second EXOR sweep with φ3 = φ4 = 180 degrees. The method is generic: a PRESS phase-cycling scheme should be combined with a phase cycling on the second and third refocusing pulses where the phases of the pulses are kept equal. The ADC phase should be the same as the one used in the PRESS scheme.

Results and Discussion: The 32-step phase-cycling scheme described above was implemented and tested in-vivo with the following parameters: TR=2s, TE=135ms, 128 averages, voxel size = 20mm x 20mm x 20mm, hyperbolic secant modulation for the AFP pulses, resulting in a measurement time of approx. 4 min. The measurement was done on a 3T scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany). The same measurement is repeated with and without phase cycling. The performance of the phase-cycling scheme is evaluated in the frontal lobe, a region where spurious echoes are a major problem due to high susceptibility [Fig. 1]. In the top and middle rows, it can be seen that the phase cycling improves the quality of the spectra in the Inositol –Creatine2 range which is affected by unwanted coherences if no phase cycling is applied. The bottom row of Fig.1 shows that massive spurious echoes could be observed upfield without phase cycling. These are significantly reduced when the phase-cycling scheme is used. In order to evaluate the reduction in contamination, a measurement was also done in a voxel close to the skull [Fig.2]. The phase-cycling technique leads to less lipid contamination.

In summary, the experimental results show that phasecycling is essential to tackle two problems related to the semi-laser SVS sequence: spurious echoes and contamination from outside the voxel. In respect to related work, where a 16-step phase cycling for the excitation and the two last refocusing pulses was proposed [3], the proposed method could be used to build phase-cycling schemes based on the PRESS schemes where the phases of all pulses could be cycled.

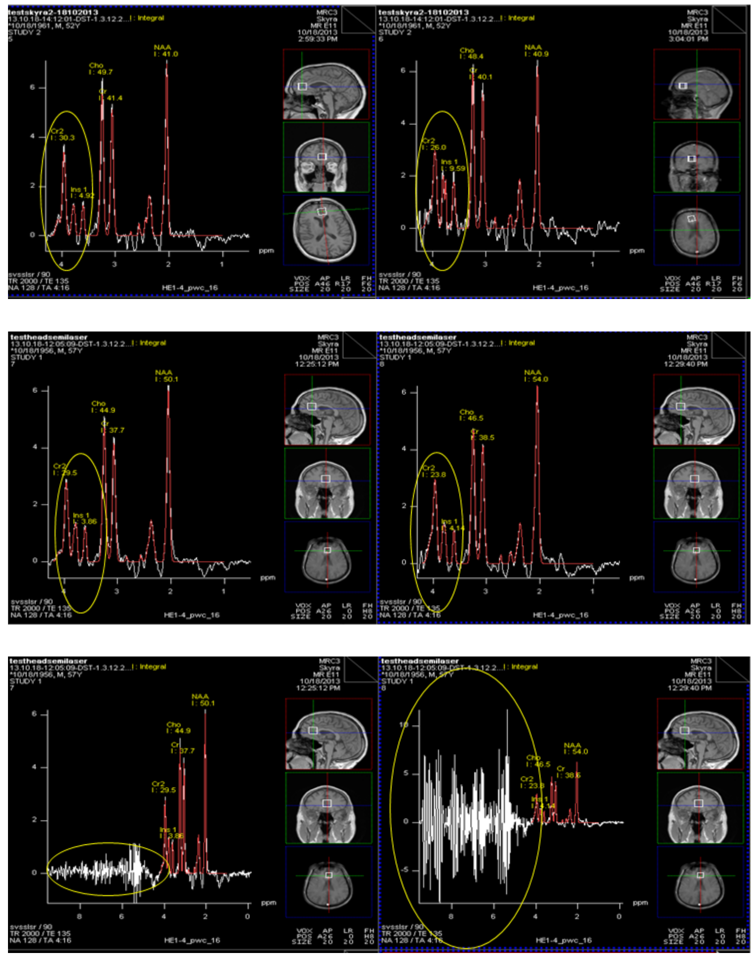

Fig. 1: Semi-laser SVS measurement (TE = 135ms) in the frontal lobe. Left column: the measurement is done with phase cycling. Right column: no phase cycling. The phase-cycling scheme reduces the spurious echoes.

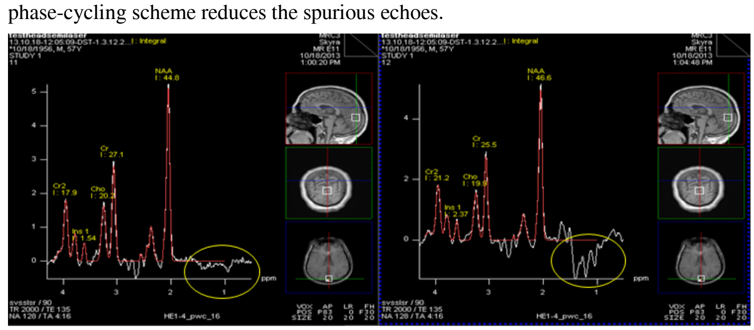

Fig. 2: Semi-laser spectrum (TE=135ms) from a voxel close to the skull. Left: with 32-step phase cycling. Right: without phase cycling. Phase cycling reduces lipid contamination.

References:

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