Entrechat Templates May Help Overcome Scepticism on Combinining Forward and Reflected EPSI Readouts

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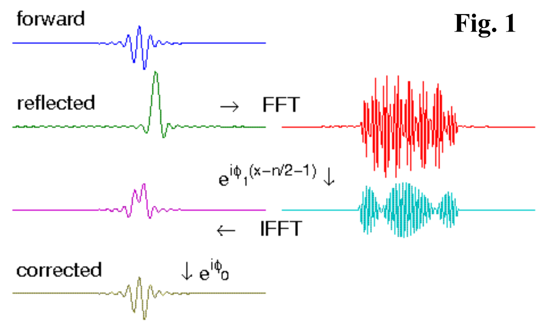
Introduction: It is widely accepted that forward and reflected readouts may not be combined into a single series of EPSI *k*-spaces [1,2]. Consequently, measurements must be repeated with opposite readout polarities to form two separate *k*-space series homogenously containing either forward or reflected ADCs. With modern hardware compensation of eddy-currents during the ramptimes of trapezoidal gradient pulses, the plateaus of the forward and reflected readouts may be assumed to be sufficiently flat for the combination of ADCs in a single *k*-space. Since the remaining echo shifting is independent of the chemical composition of the sample, the strong signal of water may be used as a probe without the need for signal accumulation. Template corrections employed for imaging with EPI enable a zero- and first-order phase correction in the half-Fourier space by comparing successive readouts obtained without phase encoding blips. Chemical shift evolution during the EPSI sequence complicates the comparison of phase from ADCs acquired at different time, and ignoring this contribution may introduce a Nyquist ghost in the FID. Crisscrossing (it. *intreciatta*, fr. *entrechat*) the acquisition of two separate template scans with opposite readout polarities permits the comparison of forward and reflected template ADCs that were acquired during two separate *TR*s but at the same time in the FID. An additional difficulty inherent to MRSI is the low spatial resolution and the use of voxels of interest combined with saturation bands. All together, they may lead to half-Fourier template lines with limited numbers of significant points from which the phase slope could be determined, or to failed unwrapping across saturated regions. In this study, we suggest to determine the echo-shifting correction by comparing forward template ADCs with corrected reflected template ADCs in *k*-space.

Fig. 1



Methods: <u>Phase correction</u> – Two separate template scans are acquired without phase encoding blips and starting with opposite readout polarities. As shown in Fig. 1, the echo of the reflected ADC is slightly shifted with respect to the forward echo. Following an FFT of the readout, a linear phase correction (φ_1) is performed with a pivot placed at the center of the Fourier transformed echo (n/2+1 in matlab convention). After the inverse FFT, the echo is phased with a constant term (φ_0) to yield a corrected reflected template ADC which is compared to the forward template ADC by a non-linear least square fit (matlab *lsqnonlin*). The starting values are obtained from a search of the index of the maximum of the magnitude echoes: $\varphi_1 = 2\pi\,(i_{\mathrm{reflected}} - i_{\mathrm{forward}})\,/\,n$, and φ_0 the phase difference between the respective maxima. In order to improve the robustness of the non-linear fit, real and imaginary parts of the template ADCs are concatenated. The parameters are determined along the FID and updated values are employed as starting values for the next template pair. Only reflected ADCs are corrected after the FFT of the readouts with both linear and constant terms. <u>Phantom</u> – A standard phantom with 20 mM sodium acetate and lithium lactate was studied at 3 T (Siemens TIM Trio, circularly polarized head coil) with an EPSI sequence, PRESS excitation, one accumulation, TR 1.7 s, TE 30 ms, 128x128 matrix, 1.7×1.7 mm^2, thickness 20 or 10 mm. <u>Volunteer</u> – A healthy women (31y) gave informed consent for a double-shot center-out EPSI [3], 12×12 matrix, 15×15×15 mm^3 voxel, 128 accumulations.

Fig. 2

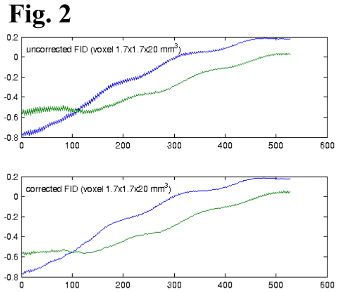


Fig. 3

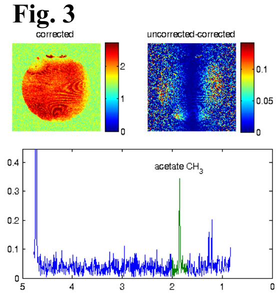


Fig. 4

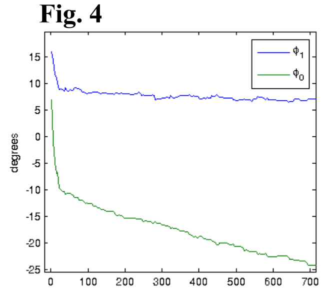
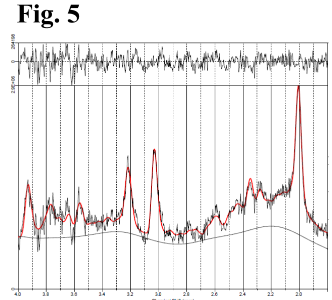


Fig. 5



Results: Fig. 2 shows an example of a Nyquist artifact (top) in the water FID of a center voxel (1.7×1.7×20 mm^3) that is well corrected by the template correction (bottom). In Fig. 3, the acetate methyl is mapped (voxel 1.7×1.7×10 mm^3). The changes with respect to an uncorrected map were less than 5%. We performed a double-shot center-out EPSI employing both phase-encoding blips and periodic phase-encoding fly-backs. The parameters of the phase correction obtained from the in-vivo *entrechat* templates are shown in Fig. 4. After an early variation of the echo-shifting and echo-dephasing during the first 20 ms of the FID, the echo-shifting stabilizes and the echo-dephasing follows a slight linear progression. In Fig. 5, a LCModel quantitation [4] of a 15 mm isotropic voxel is displayed for which the significantly determined concentrations expressed in mM were as follows: Cre 4.03 SD4%, Glu 6.30 SD11%, Glu+Gln 9.13 SD11%, mI 2.26 SD13%, NAA+NAAG 6.50 SD4%, GPC+PCh 1.02 SD7%.

Conclusion: Modern hardware eddy-current compensation permits the acquisition of EPSI data that can be corrected with a template correction to form a single *k*-space, thus eliminating the need for a second acquisition with inversed readout gradient polarities. The new *entrechat* templates provide an exact timing and phase correction which does not alter the phase of reflected ADCs. We demonstrated that the phase correction may be determined by fitting corrected reflected template ADCs with corresponding forward ADCs in *k*-space.

References: [1] Posse S. 2009 *MRM* 61:541. [2] Ebel A & Schuff N. 2007 *MRM* 58:1061 [3] Labadie, *Proc. ISMRM* 2010, p. 3384. [4] Provencher 1993 *MRM* 30:672. Acknowledgement: EU funding FAST Marie-Curie network MRTN-CT-2006-035801.