Optimization of parameters for the distant dipolar field signal acquired in CRAZED-multiecho pulse sequence

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INTRODUCTION

The application of the signal that is formed under the influence of distant dipolar field (DDF) in most tissues is limited with its low signal level. Multiecho acquisitions, such as echo-planar or fast spin-echo imaging, in the rising period of the signal has a potential to substantially increase the total acquired DDF signal and the time efficiency in the signal acquisition [1]. The influence of closely spaced refocusing pulses in a multiecho sequence on the dipolar signal formation and the implications for practical multiecho acquisition were investigated experimentally and analyzed theoretically [1,2]. The previous works show that the phases of the refocusing pulses have significant impact on the DDF effect during the refocusing pulses, and hence the DDF signal formed. When the DDF effect during the refocusing pulses of finite duration is "canceled", the signal rises primarily during the free evolution time between the pulses in the acquisition period [1,2]. In this abstract, we extend the evaluation of the total acquired signal in a multiecho sequence (Fig. 1) with pulse sequence parameter for the CRAZED sequence. The situation when the DDF effect during the refocusing pulses is not "canceled" is also examined. It is found that the DDF signal achieves a larger value when the phase difference of the refocusing pulses in the multiecho sequence and the first rf pulse of the CRAZED sequence is closer to 90°.

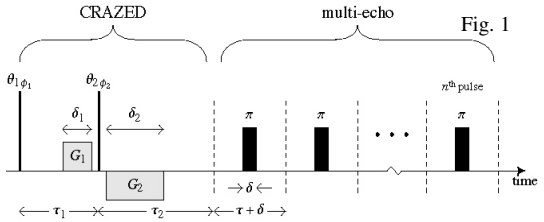

Fig. 1

THEORY

The total signal acquired from a multiple spin-echo sequence is calculated based on the first order perturbation theory developed in Ref. [2]. The multiecho sequence is taken to have a fixed duration T_{MSE} = 40 ms. The transverse relaxation times (T_2) for water, brain white matter and muscle are taken to be respectively 400 ms, 40 ms and 21 ms at B_0 = 9.4 T so that the ranges $T_2 < T_{MSE}$, $T_2 \approx T_{MSE}$ and $T_2 < T_{MSE}$ are covered with these parameters. The free evolution time (τ) between the refocusing pulses with phases ϕ and a given pulse duration δ in the multiecho sequence is given by $\tau = T_{MSE}/N_\pi - \delta$, where N_π is the number of refocusing pulses in the sequence.

RESULTS AND DISCUSSIONS

Figure 2 shows the plots of the ratio τ_{opt} per δ against τ_2 with several values of the pulse duration δ. It can be seen in the figure that, for the considered range of T_2 (water, brain white matter and swine muscle), optimal signals are obtained with $\tau_{opt}/\delta \le 1$. When $\tau_2 \approx 0$, it is found that $\tau_{opt} \approx \delta$. On the other hand, $\tau \approx 0$ when τ_2 is large, implying that highest signal-to-noise ratio is obtained when there are as many signal acquisitions as possible in this regime. The dotted lines in Fig. 2(a) are the estimations by approximating a linear rise of the signal during the free evolution period between the pulses.

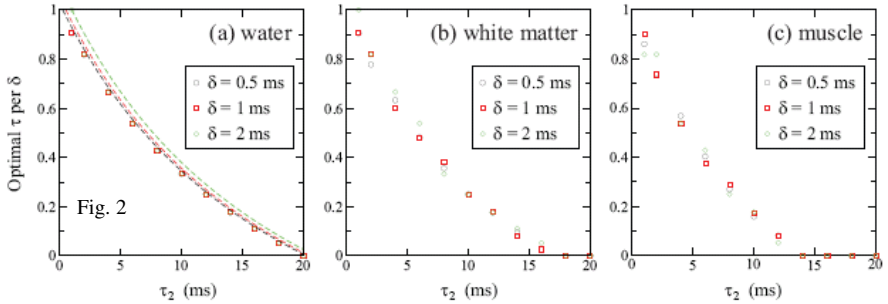

Fig. 2

Figure 3 shows the total acquired signal against τ_2 with the optimal free evolution duration and different pulse durations. The figure shows that larger total signal can be obtained with longer τ_2 even for the case of muscle with the total evolution time $\tau_2 + T_{MSE} \approx 3\ T_2$.

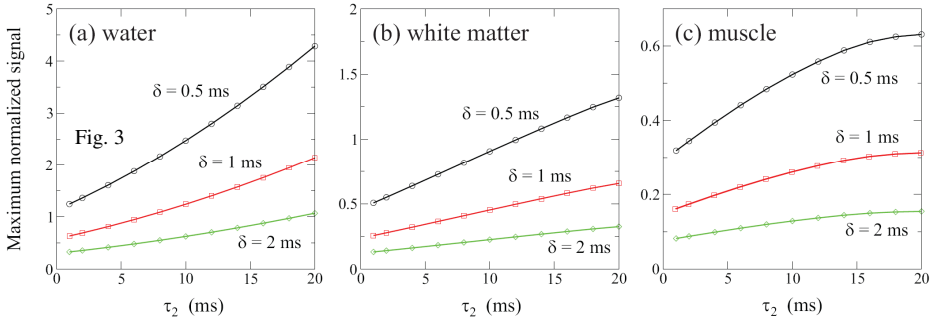

Fig. 3

The total water signal is plotted against the number of acquisition N_π in Fig. 4 with $\phi_1 = 0$, $\tau_2 = 1$ ms, different δ and phases of the refocusing pulse ϕ. It can be seen from the figure that larger total DDF signal is obtained when the phase difference is closer to 90°. This is due to the rephasing effect of the DDF during the pulse, which depends on the factor $\sin(\phi - 2\phi_1)$ as shown in previous works [2]. Similar to the case when the DDF effect during the pulse is canceled, larger signal can be obtained when a longer τ_2 is used.

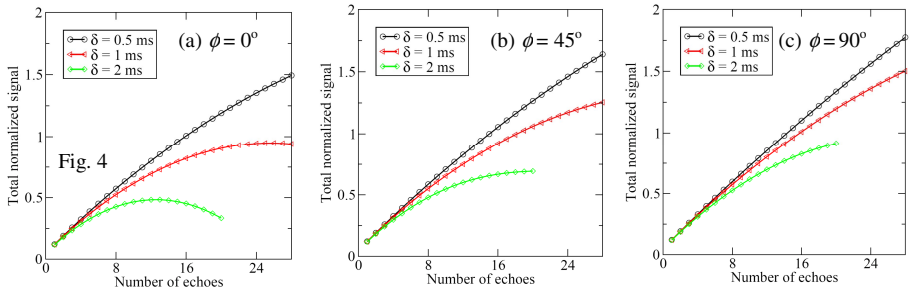

Fig. 4

In conclusions, we have studied the total signal optimization on the free evolution period between the refocusing pulses of the multiecho sequence and the second evolution period of the CRAZED sequence for a wide range of T_2. It is found that maximal total signal can be obtained with longer τ_2 even when the total evolution time $\tau_2 + T_{MSE} \approx 3\ T_2$. Also a phase difference approaching 90° gives a higher optimal signal due to the rephasing effect of the dipolar field during the refocusing pulses. The results demonstrate that although the signal is attenuated when many refocusing pulses with finite duration are used in the multiecho sequence [1], the rephasing effect by the DDF during the pulses, which is determined by the phase of the pulses, can compensate the signal loss to a certain degree.

REFERENCES

[1] S. Kennedy et al., Proc. ISMRM **13**, 2288 (2005). [2] C. K. Wong et al., J. Magn. Reson. **185**, 247 (2007).