Rapid Optimization of Acquisition Parameters for Fast Spin Echo Imaging in RF Power Constrained Regimes

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Introduction

Fast spin echo (FSE) is a routine imaging sequence with many clinical and research applications. Unfortunately, its utility is hindered–particularly at field strengths of 3.0 T and higher–due to extreme RF power. Effective power mitigation, via prolonged RF pulse length (τ_α), or reduced pulse angle (α) is required for imaging in such regimes. Several works have described power reduction strategies via low (and modulated) refocusing angles **[1]**, low angles and long RF pulses **[2]**, or with a small number of slices and long repetition times **[3]**. To date, no framework has been presented for optimizing parameter selection for RF power reduction.

We present a simple method for selecting "low-level" acquisition parameters (refocusing angles, pulse durations, acquisition bandwidth) given a set of "high-level" user-selectable parameters (repetition time, number of slices, echo time, etc…). Our approach optimizes the signal-to-noise ratio (SNR) as a function of refocusing angle and pulse duration given a target power level. Our method is computationally efficient and applicable to a wide range of situations and field strengths. This tool is verified experimentally.

Theory and Methods

The RF power of reduced angle FSE is proportional (constant of proportionality *m*) to α^2 and inversely proportional to τ_α. The parameters α and τ_α can be independently manipulated to reduce the RF power; however, their effect on SNR must be considered.

For a fixed inter-echo spacing, a portion of this time (τ) is shared between excitation and readout, producing a tradeoff between RF power and noise levels. Echo amplitudes, neglecting relaxation, are reduced with low refocusing angles; they can be computed with the extended phase graph (EPG) algorithm **[4]**, and are denoted by $S^{(EPG)}$. The relative SNR can be approximated as

$$SNR \approx SNR_0\, S^{(EPG)} \sqrt{\tau - m\alpha^2/P},$$

where *P* is the target power level. The term in the square root represents the readout duration, which is reduced with increasing RF pulse duration, $\tau_\alpha = m\alpha^2 / P$. The above equation can be optimized numerically yielding ideal refocusing angles and pulse durations. This equation can be generalized to account for variable angle refocusing trains and tissue relaxation (not shown).

Readout profiles were collected on a 500 ml silicone oil phantom at 4.7 T. Echo spacing was 10 ms, echo train length was 24, and the effective echo was 10. Profiles were collected for α ranging between 9° and 200°. Pulse duration was varied between 300 µs and 5000 µs; acquisition bandwidth was adjusted for a 10 ms inter-echo spacing, repetition time was 2.0 s. SNR was quantified as profile height divided by the standard deviation of noise, measured from separate acquisitions with no RF and with a high receiver gain.

Results

Fig 1a displays the theoretical (lines) and experimental (symbols) SNR as functions of refocusing angle for target power levels of 1.0 W (solid line, open circles) and 0.2 W (dashed line, closed squares). Note that the optimal SNR is obtained with refocusing angles below 180°. The resulting pulse durations are shown in **Fig 1b**. **Fig 2** shows the SNR-optimal refocusing angles (solid line, open squares, left axis) and pulse durations (dashed lines, solid squares, right axis) as functions of target power for the oil phantom. Theoretical curves can be generated, and optimal values selected, in less than 5 ms.

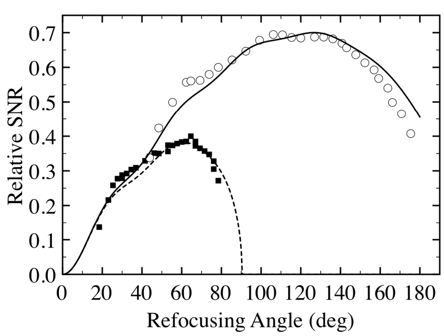

Fig 1a: Relative SNR vs. refocusing angle for target power levels of 1.0 W (solid line, circles) and 0.2 W (dashed, squares)

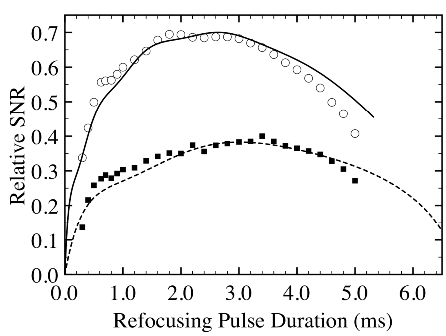

Fig 1b: Relative SNR vs. pulse lengths for power levels of 1.0 W (solid, circles) and 0.2 W (dashed, squares).

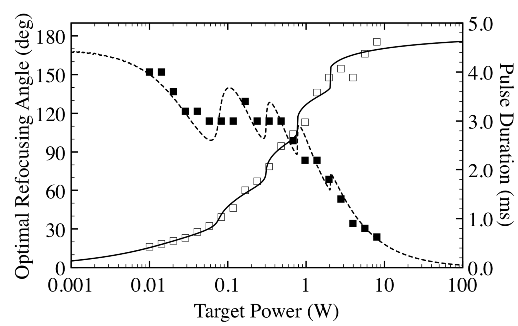

Fig 2: Optimal angles (solid line, open squares, left axis) and RF durations (dashed, closed squares, right axis) vs. power level.

Conclusions

We demonstrate that a target power level with FSE can be obtained by independent adjustment of refocusing angles and pulse durations; proper parameter selection is necessary for maximal SNR. Optimization can be achieved with the tools presented in this work. Computation time is negligible enabling integration with scanner software.

References: **[1]** Hennig J. et al. (2003). MRM, 49(3), 527-35. **[2]** Lebel R. M. et al. (2009). MRM, 62(1), 96-105. **[3]** Theysohn J. M. et al. (2009). Hippocampus, 19(1), 1-7. **[4]** Hennig J. (1988). JMR, 78(3), 397-407.