Fast slice-selective B1 mapping

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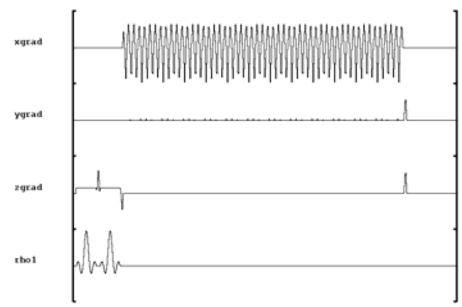
INTRODUCTION

Inhomogeneities in the RF transmit field due to wavelength effects and permittivity of tissue have hindered acceptance of whole body imaging at high field (> 3T). Recent proposed techniques to counter these effects like B_1 shimming and Transmit Sense require knowledge of the transmit RF field (B_1+). Typically the acquisition of a B_1+ field map relies on both incremental RF power adjustments with volumetric excitation profiles and fully relaxed longitudinal magnetization, which lead to long acquisition times (1). More time efficient methods have been proposed which utilize saturation pulses to overcome the long delays associated with T_1 relaxation and efficient sampling of the imaging by echoplanar techniques. A source of inefficiency remains: the profile of typical slice selective acquisitions deteriorates when the effective power deviates from the nominal power (2). The current work addresses concerns of efficiency and robustness utilizing a single polarity echoplanar imaging sequence with a 'double pulse' excitation.

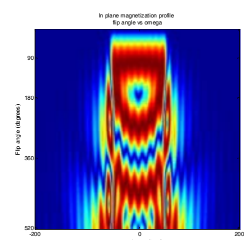
THEORY

The proposed method (figure 1) uses the same pulse twice; one time applied for pre-saturation followed by a crusher and other RF pulse for the actual excitation. The proposed method dynamically turns on and off the first pulse, yielding two images S_1 and S_2 that, neglecting T_1 relaxation, are proportional to $\sin(\alpha)$ and $\sin\alpha(x)*\cos\alpha$ for one and two RF pulses respectively. The ratio of the two images $\lambda = S_2/S_1 = \cos\alpha$ has a simple cosine dependency on flip angle α only. The readout module consisted of a zero and first moment compensated single polarity echoplanar readout train, where the echo rephasers employed maximal gradient power that could be adjusted to minimize the effect of eddy currents. No noticeable eddy current distortions remained when using a 2% longer rephaser gradient. With the experimental setup, the calculated maximal gradient switching was 132 T/s, 75% of the upper limit imposed by the IEC directive. Image reconstruction was adapted to not perform time reversal on odd views.



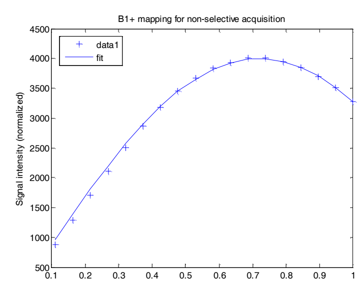
METHODS

Simulations to assess the magnetization profile were performed using the SLR forward algorithm to calculate the magnetization response of the used RF pulse (figure 2). Then experiments were performed using non-selective excitation, and slice selective excitation using a power stepped approach for both single and double pulse excitations using the sequence from figure 1. All experiments were performed using a 3T whole body scanner (GE Signa HD, slew rate 150 T/m/s, gradient strength 40 mT/m; GE Healthcare; Waukesha, WI), equipped with 8 individual RF transmit channels (patient bore of 600 mm; elements size of 190 x 560; 2 kW max forward power). The phantom used in the experiments was a 4.38" sperical phantom (T_1 ~ 215 ms). Power levels were stepped through linearly from 2kW to 0.2 kW for each acquisition. Sequence parameters were : field of view 400 mm, matrix 32x32, single shot acquisition, ramp-sampled readouts (maximum bandwidth 250 kHz), 10 mm slice thickness, 7.92 ms RF pulse width. An 8 channel receive head coil was used for signal reception. All post processing was performed using Matlab 7.1 (Mathworks, Cambridge, MA).

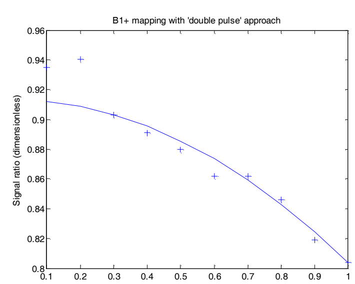


RESULTS and DISCUSSION

Flip angle results are shown for non-selective, slice selective acquisitions and the ratio of the single pulse-double pulse experiment for pixel by pixel signals at the RF hot spot. It can be seen that in the case of non-selective excitation, the signal behaviour follows the theoretical model closely. When a slice selection gradient is applied. This behaviour is changed, as predicted in the simulations. The ratio of the signals can be modeled by a simple cosine, leading to improved robustness of the method.



The proposed technique enables flip angle imaging using only one transmitter reference amplitude for all pulses applied throughout the acquisition. It therefore avoids signal inconsistencies due to varying slice profile degradation when using pulses with different B1 amplitudes. The required peak B_1 amplitude is reduced compared to other techniques that require incrementing the B_1 amplitude. This can either be used to generate higher flip angles, where the peak amplitude of the B_1 field limits the applicable flip angle or to exploit the more uniform slice profiles achieved at lower flip angles. The technique is highly time efficient because multiple slices can be interleaved for multiple transmit elements. A drawback of the proposed technique is the sensitivity to T_2*, off resonance effects and eddy currents. Using an interleaved echoplanar acquisition will deal with these effects, but at the cost of increased scan time



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2. Stollberger and Wach MRM 35 (1996): 246-251.