Saturated double-angle method for rapid B1 mapping

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INTRODUCTION For in-vivo magnetic resonance imaging at high field (>= 3 T) it is essential to consider the homogeneity of the active B1 field (B1+), particularly if surface coils are used for RF transmission. A new method is presented for highly rapid B1+ magnitude mapping. It combines the double angle method with a B1-insensitive magnetization-reset sequence such that the choice of repetition time (TR) is independent of T1, and with a multi-slice segmented (spiral) acquisition to achieve volumetric coverage with high spatial resolution in a few seconds.

THEORY The spatial distribution of B1+ can be measured by mapping the flip angle. This is based on modest assumptions about the action of the excitation pulse, for example that spin-locking is not occurring during the pulse. The flip angle can be mapped by dividing image magnitudes at two flip angles and computing the inverse cosine as in [1-3], but usually a long TR must be used to avoid T1 weighting. If the T1 weighting can be equalized for the images with different flip angles, then a rapid, short TR sequence can be used.

METHODS A new pulse sequence was developed (see Fig. 1) consisting of an imaging sequence and a magnetization reset sequence [4]. The imaging sequence contains a tip pulse, readout, and gradient spoiler, while the reset sequence contains a composite 90-degree pulse (which is insensitive to both B1 variations and off-resonance) and a gradient spoiler. The flip angles prescribed are 60 and 120 degrees. Spiral readouts were chosen because of their efficiency, good flow properties, and short echo time.

A linear transmit/receive extremity coil was used to produce a B1+ map in the leg of a normal volunteer, both with the new method and the reference double-angle method with a long TR (3 s). Measurements were made of the B1+ homogeneity in a human head at 3 T using a standard bird-cage head coil for RF transmission and signal reception. Maps made with TRs ranging from 3 s to 400 ms were compared.

CONCLUSIONS By comparing maps made with different TRs and observing no difference except variations in SNR, it can be concluded that the proposed sequence achieved the desired removal of T1 effects. The saturated double angle method can yield volumetric B1+ maps of sufficient resolution in just a few seconds. This has substantial implications for high-field neuro-imaging, and enables rapid cardiac and abdominal B1+ mapping in within the duration of a breath-hold.

[1] Insko et al. JMR ser. A 103:82-95 (1993) [2] Stollberger et al. MRM 35::246-251 (1996) [3] Yarnykh et al. ISMRM Kyoto p.194 (2004) [4] Cunningham et al MRM 2006 (in revision)

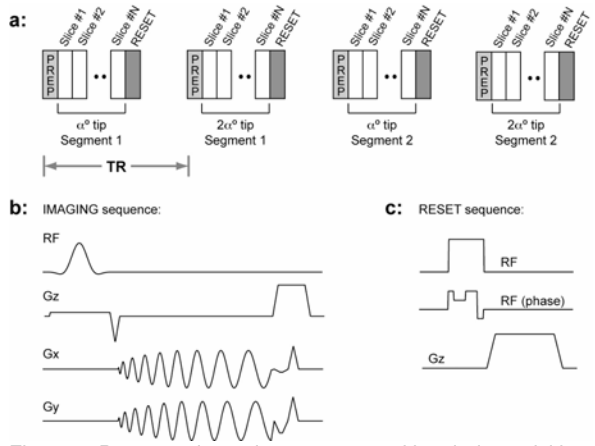

Figure 1: B1+ mapping pulse sequence with spiral acquisitions. A B1-insensitive saturation pulse is used to RESET the magnetization after each acquisition set. The acquisition of multiple slices is achieved as shown in (a). The (b) IMAGING sequence consists of a simple slice-selective excitation, followed by a short spiral readout, and a dephaser. The (c) RESET sequence consists of a B1-insensitive and non-spatially selective saturation pulse followed by a dephaser.

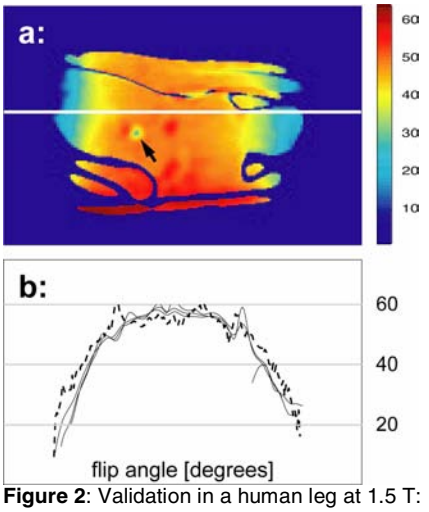

Figure 2: Validation in a human leg at 1.5 T: (a) B1+ map (b) B1+ profiles along the line shown in (a) using reference method (TR = 3 s, dashed line), and new method with TR = 1 s, 500 ms and 100 ms (solid lines). The arrow indicates a region with short T2 where an error in the B1+ map occurs. The scan time with TR of 100 ms was 1.6 s.

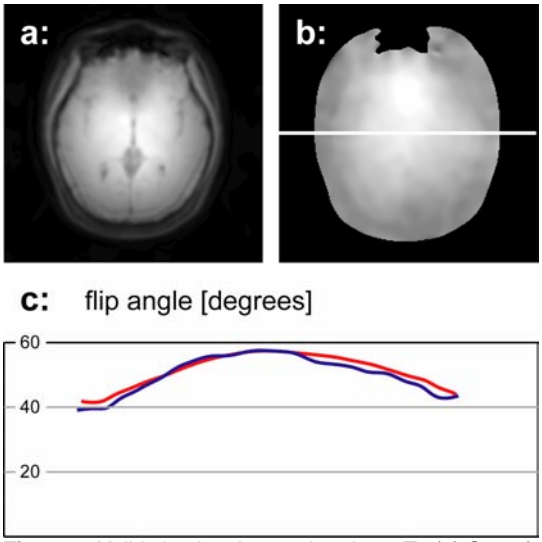

Figure 3: Validation in a human head at 3 T. (a) One of the images and (b) the computed flip angle map, and (c) plots of the flip angle variation in the left/right direction, acquired with TR of 2000 ms (red) and 400 ms (blue). The scan time with TR of 400 ms was 10 s. The images in (a,b) are from the TR = 2000 ms scan. As expected, the B1+ profile is parabolic in shape.