# 3D B1+ Mapping with Multi-Slab Catalyzed Steady-State Double-Angle Method

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**Introduction:** The double-angle method (DAM) can be used for $B_1^+$ mapping but requires long TR (≥ $5T_1$) to achieve complete relaxation of magnetization. Although modified DAM can allow shorter TR via reset saturation and combine with fast acquisition sequences [1], further improvements of 3D DAM are necessary. 3D multi-slab acquisition is a time efficient technique for large volume scanning [2]. In this study we present a 3D multi-slab DAM combined with multi-echo CPMG acquisition [3] and compensated catalyzation pulses at the end of each TR which drive the longitudinal magnetization into steady-state enabling short TR for fast imaging without $T_1$ bias.

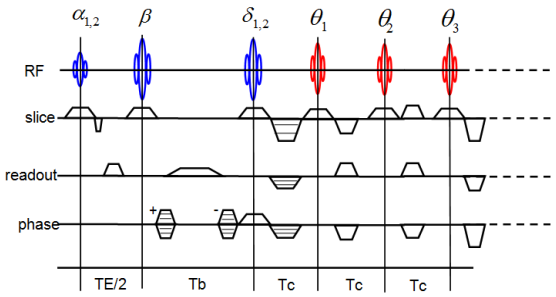
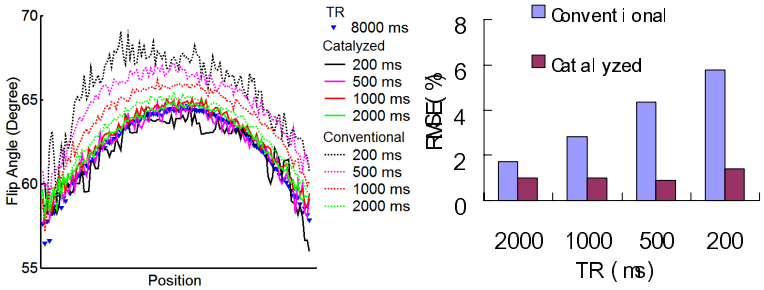



**Fig. 1**. Schematic diagram of catalyzed steady-state DAM sequence. δ: compensation pulse. θ: catalyzation pluse. Tb: refocusing and compensation pulses spacing. Tc: catalyzation pluse spacing.

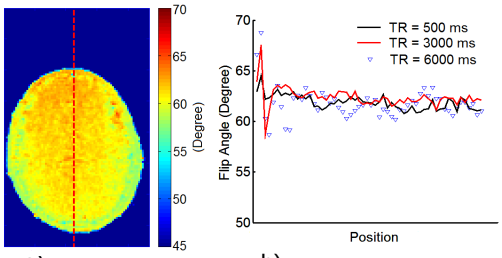
**Method:** All experiments were performed using a 1.5T clinical MRI scanner (Siemens Magnetom Sonata) with body coil transmitter. *Sequence design:* The 3D multi-slab catalyzed steady-state (MSCSS) sequence (**Fig. 1**) includes slab-selective compensated catalyzation RF pulses with crusher gradient spoilers alternating in parity and varying in gradient moment along all three axes at the end of each TR. RF spoiling scheme was also applied consecutively to each catalyzation pulse. The longitudinal magnetization will be catalyzed into the same steady-state regardless of initial excitation flip angle (FA). Gradients and RF spoiling strategies were applied between TRs, and after the second refocusing pulse to eliminate stimulated echoes [4]. All RF pulses were designed using SLR algorithm to provide a uniform profile along slice direction. Two groups of multiple interleaved 2-partition slabs with 100% spacing were acquired separately. 100% 3D slice over-sampling was applied to preclude RF transition region and side lobes. *Phantom studies:* We initially validated the accuracy of 3D MSCSS DAM in an $MgCl_2$ phantom ($T_1$ = 1200 ms). Both conventional and MSCSS TSE DAM were performed with TR = 8000, 2000, 1000, 500, and 200 ms. Other parameters included FA = 60º/120º excitation, 120º refocusing, 120º/60º compensation, 85º catalyzation, 3 catalyzation pulses, TE/Tb/Tc = 9.5/9.5/5 ms, 560 Hz/pixel BW; 280×110×40 $mm^3$ FOV, 128×50×8 matrix. The FAs from conventional and MSCSS DAM at different TR were compared to those from DAM with TR=8000 ms by calculating percentage root-mean-squared-error (RMSE) over the central line of the phantom. *Volunteer studies:* We acquired 3D $B_1^+$ maps in brain and abdomen of healthy volunteers with MSCSS TSE DAM. *In vivo* parameters: Brain: TR= 6000, 3000, 500 ms, 280×170×80 $mm^3$ FOV, 128×78×16 matrix, ETL = 3, acquisition time: 2 min 24 sec (TR = 500 ms); Abdomen: TR= 600 ms, 380×200×80 $mm^3$ FOV, 128×68×16 matrix, ETL = 5, GRAPPA acceleration factor 2, acquisition time:1 min 8 sec.




a) b)

**Fig. 2**. a) Phantom FA profiles from conventional (dotted line) and catalyzed (solid line) DAM with different TR. b) RMSE of conventional and catalyzed DAM (Phantom $T_1$ = 1200 ms)

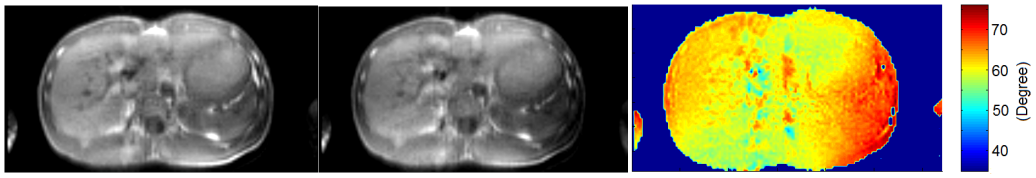
**Results:** FA profiles from conventional and catalyzed TSE DAM through the center of the phantom were compared in **Fig. 2**. While RMSE of conventional DAM increases as TR decreases, RMSE of catalyzed DAM is < 1.4% (**Fig. 2b**). **Fig. 3** shows *in vivo* $B_1^+$ map and FA profile along central line in human brain. **Fig. 4** shows representative abdominal 60º/120º TSE images and corresponding $B_1^+$ map.




a) b)

**Fig. 3**. a) The *in vivo* $B_1^+$ map of brain acquired using MSCSS DAM with TR = 500 ms. b) FA profile along central line of brain $B_1^+$ maps with different TRs.

**Conclusion:** Compensated catalyzed steady-state method removes the DAM reliance on long TR. The 3D multi-slab multi-echo acquisition accelerates imaging speed. Careful pulse design, 3D acquisition and 100% slice over-sampling improve excitation FA profile and assure better quantification accuracy. In conclusion, 3D multi-slab catalyzed steady-state multi-echo DAM provides a rapid and accurate method for large volume RF field mapping.




a) b) c)

**Fig. 4**. Abdominal MSCSS TSE images (TR =600 ms) a) 60º b)120º c) corresponding $B_1^+$ map

**References:** [1] Cunningham et al., MRM 2006 55:1326–1333 [2] Liu et al. MRM 2000 44:269–276 [3] Sled et al. MRM 2000;43:589–593 [4] Grawley et al. Mag Reson Med 1987 4:34–47