Saturated Double Angle Method with radial sampling

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Introduction

In high-field (≥3.0T) MRI, B1+ mapping is becoming an integral part of prescan calibration. Existing B1+ mapping methods can be sorted into signal ratio methods and phase-based methods. For the signal ratio method, one of the simplest is the double-angle method (DAM), which acquires images with two flip angles, α and 2α, and a TR much larger than T1 (regularly ≥5T1), such that image signal is proportional to sin(α) and sin(2α), respectively. However, the acquisition time is regularly very long due to large T1. Saturated double-angle method (SDAM) has been proposed using a B1-insensitive reset sequence to make TR independent of T1, along with a spiral acquisition to acquire the images rapidly [1]. It is known that spiral sampling can be prone to off-resonance error. Here, a SDAM method using a non-selective magnetic perfusion preparation pulse for saturation along with radial sampling is proposed for B1+ mapping.

Methods

The pulse sequence (illustrated in figure 1) consists of a saturation pulse, followed by a saturation recovery time with a radial readout. A number of α and an equal number of 2α readouts were done in one breath-hold. For multiple breath-holds acquisitions, the readout angle was offset by a certain angle for other breath-holds.

The images acquired with α and 2α were reconstructed separately using low-pass filtered k-space (denoted as $\mathbf{I}_{\alpha}^{lp}$ and $\mathbf{I}_{2\alpha}^{lp}$). The B1+ map was generated using the equation: $\alpha = \cos^{-1}\left(\frac{\mathbf{I}_{2\alpha}^{lp}}{2\mathbf{I}_{\alpha}^{lp}}\right)$.

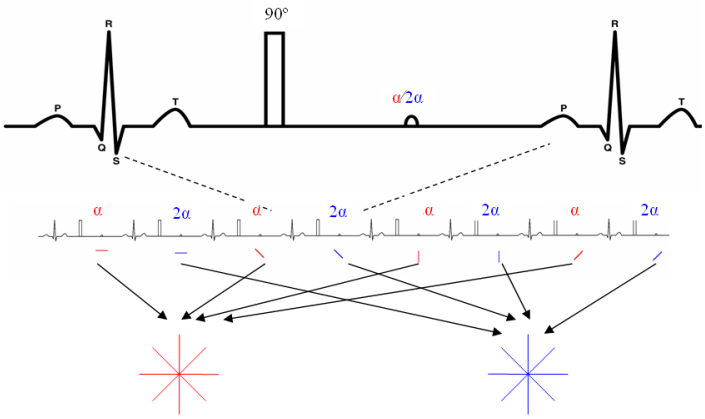

Figure 1. Pulse sequence diagram and sampling pattern for saturated double-angle method. The pulse sequence consists of a saturation pulse, followed by a saturation recovery time and a radial readout. A number of 2α and equal number of α readout were done in one breath-hold. For the other breath-holds, the readout angle was offset by a certain degree. The combined k-space data was used to reconstruct the images that were then used to determine B1 map.

Results

Figure 2 shows the phantom studies comparison between DAM and SDAM. The line profiles of both methods are shown in figure 2 (bottom), which illustrates good agreement between the two methods. Figure 3 shows an in vivo cardiac study using the radial SDAM.

Conclusion

B1+ mapping is becoming an integral part of prescan calibration in high-field MRI. The proposed SDAM with radial sampling was shown to get B1+ mapping accurately in phantom studies, and in vivo results in the heart were similar to previously reported values.

References

[1] C. H. Cunningham, J. M. Pauly, and K. S. Nayak, Magn Reson Med 55 (2006) 1326.

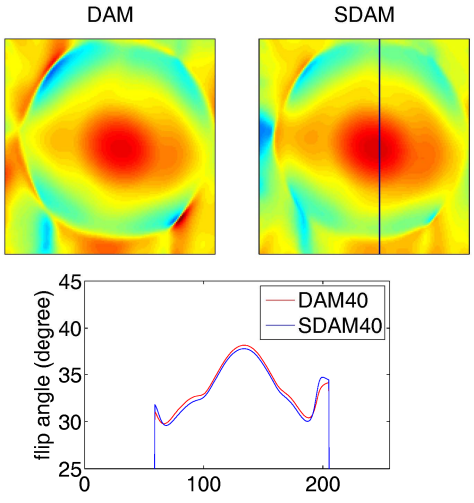

Figure 2. Phantom validation study using 48 rays, with 24 rays for each α and 2α image. (top-left) is the α flip angle image computed using DAM method; (top-right) is that using SDAM method; (bottom) is the line profile of the two top images indicated by the line in the top-right image.

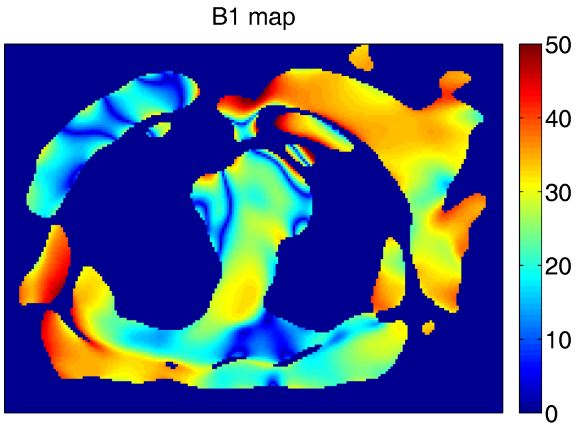

Figure 3. Cardiac B1 maps in a healthy volunteer at 3T with a prescribed flip angle of 40/80 using 40 rays, with 20 rays for each α and 2α image) acquired in two breathholds.