A Fast 3D B1 Mapping Method at 3T

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Introduction

3T scanners offer increased signal to noise compared with 1.5 T systems and are now commonplace at many research and clinical sites. Currently, a big challenge to be overcome is the heterogeneity of the B_1 field at 3 T compared to 1.5 T. There are many B_1 mapping methods published[1]. However, due to their high RF irradiation to the subjects, long acquisition times, or incapability of 3D volume coverage they are often not appropriate for many clinical and research applications. We describe an optimised B_1 mapping method at 3 T, which has a fast acquisition, is capable of 3D volume coverage, and has very low RF irradiation.

Theory and Method

Our method is based on a magnetisation preparation 3D TurboFLASH approach[2]. Before the TurboFLASH acquisition a varied hard pulse is applied, followed by a spoiling gradient to dephase the transverse component of the tipped magnetisation so that the net longitudinal magnetisation available for the TurboFLASH acquisition is modulated by $\cos(\theta(\mathbf{x}))$, where $\theta(\mathbf{x})$ is the true flip angle of the hard pulse for preparation at spatial location $\mathbf{x}$. A centre-out k-space sampling scheme is utilised within the TurboFLASH acquisition to weight the image signal intensity to the magnitude of the available longitudinal magnetisation. Acquisitions with different nominal preparation angle θ_i are then collected in order to calculate the B_1 distribution in the volume of interest. We have found that the T_1 decay during the preparation period is significant and therefore we describe the signal intensity as $S_i(\mathbf{x}) = M_0(\mathbf{x})\ (\ 1 - A\ (\ 1 - \cos(\lambda(\mathbf{x})\theta_i)\ )\ )$, where S_i is the signal intensity of each acquisition with a preparation angle θ_i. The parameters to be fitted are M_0, A and $\lambda(\mathbf{x})$, where $M_0(\mathbf{x})$ is the total magnetisation at $\mathbf{x}$, A is used to account for the decay that happens during the period of preparation, $\lambda(\mathbf{x})$ is the efficiency of the B_1 pulse at $\mathbf{x}$, and $\lambda\theta_i(\mathbf{x})$ is the true preparation angle at $\mathbf{x}$. The B_1 variation in the field is characterised by $\lambda(\mathbf{x})$.

Our method was implemented on a Philips 3 T Achieva scanner (Philips, Best, NL). We used a 3D TFE sequence to cover a volume of 240x240x126 mm^3 with a data matrix of 128x128 and 10 slices. The acquisition has a flip angle of 10 degrees, a TR of 3.5ms and TE of 0.9ms with a single shot mode of a TFE factor 102. The acquisition of each image for each θ_i takes less than 10 seconds. In the example presented we use 16 preparation nominal angles of 0, 150, 165, 180, .., 360 degrees for B_1 mapping in the head. The total acquisition time is under 4 minutes. As the Turbo FLASH flip angle is only 10 degrees, the RF irradiation is very low compared with some methods such as the 180 degree null method[3], where flip angles around 180 degrees have to be applied to the acquisition.

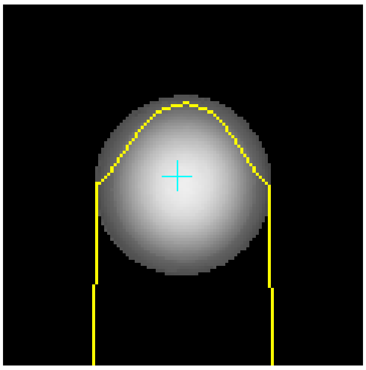

Fig.1. B_1 map through the central slice of a water bottle phantom, an intensity profile across the centre of the image is also shown.

Results

Fig.1 shows a fitted map of the efficiency $\lambda(\mathbf{x})$ from a central slice of a 15 cm diameter water bottle phantom. B_1 is stronger at the centre of the field and weaker at the edge, as expected due to standing wave effects.

We have conducted a comparison study of our method with the alternative Double Angle Method (DAM) [4], which is calculated from two images acquired with nominal flip angles of 45 and 90 degrees. The results are compared in a Bland-Atman Plot in Fig.2, where the efficiency is scaled by a factor of 1000. The plot demonstrates that our method has a maximum of around 4 % difference in calculated B_1 from the DAM method., with differences being more apparent at lower B_1.

In Fig. 3 we present an orthogonal view of a B_1 map of a brain, which is overlaid onto a structural, to demonstrate the 3D capability of our method.

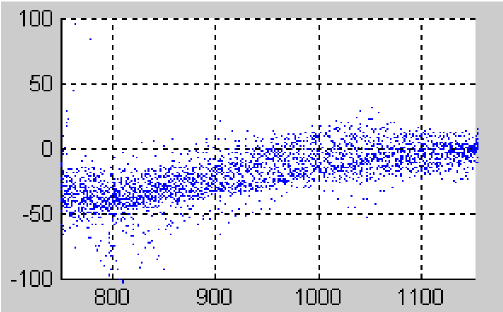

Fig.2. Comparison of our method with a DAM method using a Bland-Atman Plot, where the efficiency is scaled by a factor of 1000.

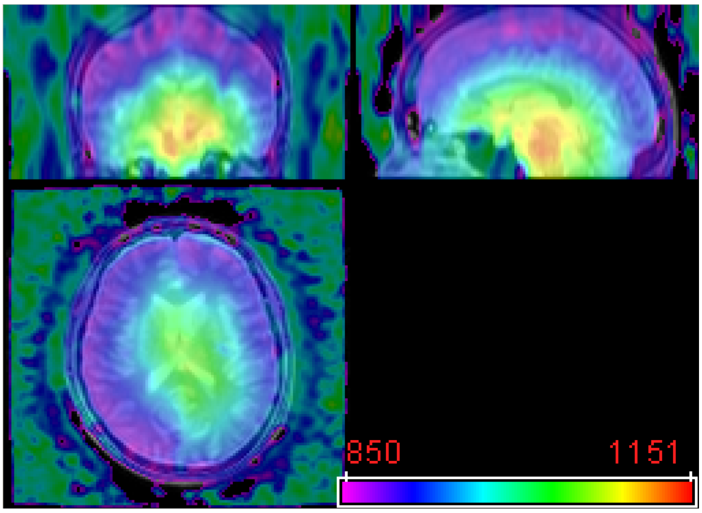

Fig. 3 Orthogonal views of a B_1 map overlaid onto a structural image of brain. The efficiency has been scaled by a factor of 1000.

Discussion

We have shown that our proposed method identifies the expected B_1 non-uniformity at 3 T in a water-filled phantom and that similar object-specific non-uniformities are identified in vivo. We have also shown that our methods produces B_1 estimates that are similar to within around 4 % to the established, but slower, DAM method. These differences may be related to small inaccuracies in our proposed method or in the DAM method, which itself produces variable estimates of B_1 efficiency under varying conditions (data not shown).We have demonstrated a fast B_1 mapping method, suitable for 3 T imaging, which has a full 3D coverage with low RF irradiation to the subject.

Acknowledgement

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References

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