Comparison of different methods for B1+/flip angle and reception sensitivity mapping

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Introduction: Knowledge of transmission field B_1^+, and reception sensitivity maps is important in high field (≥3T) human Magnetic Resonance (MR) imaging for several aspects: these include post acquisition correction of intensity inhomogeneities, that may affect the quality of images, and modelling and design of radiofrequency (RF) coils and pulses [1]. Moreover, in recent works, it has been demonstrated that B_1 maps can be used for the direct calculation of tissues electrical parameters [2] and for estimating the local Specific Absorption Rate (SAR) in vivo [3]. In this study a comparison among known methods for B_1^+/flip angle and reception sensitivity mapping is introduced.

Methods: Spatial distribution of the B_1^+ field is obtained from the measurement of the actual flip angle (FA) according to well known relationship [4]. Three methods for B_1^+/actual-FA mapping are compared: a least square fitting (indicate with Fitting) from the signal theoretical equation for gradient echo (GRE) sequences [4], a double angle method (DAM) [5] and arbitrary flip angle method (AFA) [6]. The reception sensitivity maps are obtained from the signal expression for a GRE sequence and the actual FA estimated previously with DAM and AFA methods; then, they are compared with a reference reception sensitivity map obtained using a more accurate pixel-by-pixel fitting method [4]. All data were collected using a 30 cm diameter spherical dielectric phantom of saline solution (water, NaCl and $CuSO_4$) with a General Electric 3T scanner (Signa HDx 3.0T): we used the MR system body coil to collect the axial image located in the middle of the phantom (FOV=40x40 cm, matrix size=256x256, TR=800 ms, TE=3.8 ms, slice thickness= 5 mm). For the fitting method, we acquired phantom images using GRE sequence with 6 different nominal FA (30°, 60°, 90°, 120°, 150°, 180°). For estimation of B_1^+/actual-FA map using the DAM method, two nominal FA values of 60° and 120° respectively were chosen, while for the AFA method we chose FA equal to 60° and 90°. The results obtained using the fitting method are used as reference values to compare the different methods both for B_1^+/actual-FA and reception sensitivity maps evaluation.

Results: Fig. 1 shows the B_1^+/actual-FA maps obtained using the fitting method and the difference between DAM vs Fitting and AFA vs Fitting results. The B_1^+/actual-FA profiles through the sphere centre for all the maps are also shown (scale is in degrees).

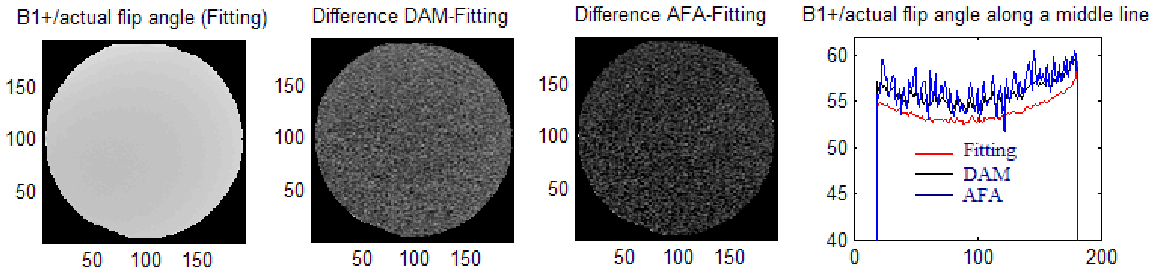

Figure 1. B_1^+/actual FA maps

Fig. 2 shows the reception sensitivity map obtained using the fitting method. Differences between the maps obtained with the different methods, DAM and AFA, are reported using the map obtained with the fitting method as reference. The reception sensitivity (normalized values) profiles through the centre of the sphere are also shown.

Discussions and Conclusions: Fitting method is considered the most accurate both for B_1^+/actual-FA and reception sensitivity maps because it uses numerous measurements points per pixel at different nominal FA values. However, its implementation requires more acquisitions with different FA values and a long time to perform the fitting. For B_1^+/actual-FA mapping, DAM and AFA methods give similar results on the homogeneous phantom, both higher with respect to fitting method results. All the maps have the expected distribution: B_1^+/actual_FA has a higher values on the surface of the conducting sphere. The max error in a central ROI of 100x100 pixels is 3.5 degrees for DAM vs Fitting and 7 degrees for AFA vs Fitting. Although AFA method produces the highest error and larger noise values, it doesn't require doubling the nominal flip angle value and hence a larger ranges of RF peak power and SAR. For the estimation of reception sensitivity map, comparing maps obtained with DAM e AFA actual FA values, it is possible to note that the results are similar and both methods underestimate the reception sensitivity values for the phantom with a maximum error of 5% for DAM and 7% for AFA, in a central ROI of 50x50 pixels. The results of our comparison suggest that, if accurate quantitative measurements are not required, AFA method is the most reasonable method thanks to its simple and fast implementation.

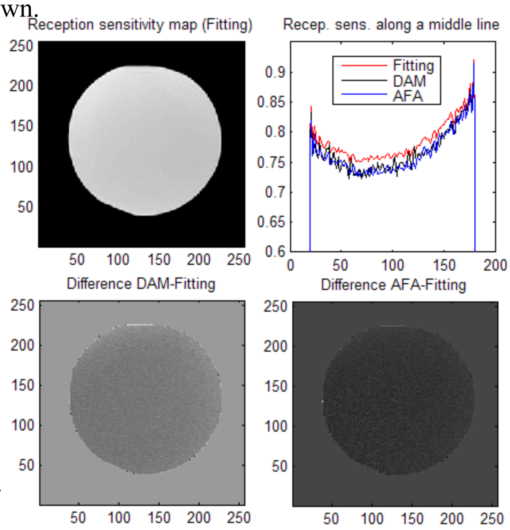

Figure 2. Reception sensitivity maps

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