ACCELERATED B1+ MAPPING BY MODEL BASED RECONSTRUCTION

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Introduction Several high-field and parallel MRI techniques [1,2] require knowledge of the transmit RF field profiles (B_1^+). During the past years, several methods have been developed to acquire this information. When 3D maps are needed, the measurement time could become impractical. In this work, a model based reconstruction method is illustrated which reduces the measurement time in case of 3D B_1^+ mapping. Only a reduced number of transverse slices is needed as input for the reconstruction problem. Positive results from simulations and in vivo measurements confirm the validity of the method.

Methods The method was inspired by the previous work conducted in [3,4]. The idea is to describe the transmit RF fields as an expansion with respect to few basis functions, that is $B_1^+ = \Sigma_\ell c_\ell f_\ell$ with $\ell = 1,...,L$ and $L = O(10)$. After discretization we can express it in matrix/vector form $\mathbf{b_1}^+ = \mathbf{Fc}$ where $\mathbf{F}$ is the encoding matrix and $\mathbf{c}$ is the vector of complex coefficients c_ℓ. Given this 3D model, reference data ($\mathbf{b_m}$) can be acquired with a limited number of transverse slices and subsequently fitted to the model to derive ˆc solving the problem ˆc = arg $\min_c \| |\mathbf{Fc}| - \mathbf{b_m} \|$. The coefficients ˆc are then used to reconstruct B_1^+ for the missing interleaved slices. In this work, the basis functions f_ℓ are set to be spherical functions: $f_\ell = j_m(\kappa\rho) Y_n^m(\theta, \varphi)$, $0 \le n \le N$, $-n \le m \le n$, $\ell = n^2 + n + m + 1$, $\kappa = \varepsilon_0\varepsilon\mu_0\omega^2 - i\sigma\omega\mu_0$. j_m is the spherical Bessel function of the first kind and order m, while Y_n^m is the spherical harmonic of degree n and order m. These functions arise naturally as solutions of the Helmholtz equation for B_1^+ in the spherical coordinates system in case of an homogeneous medium (constant properties). The scaling factor κ depends on the value of the permittivity (ε) and the conductivity (σ). These two values were chosen by running the fitting procedure over a realistic range of (σ, ε) values and then selecting the best matching couple [3,4].

Materials Two fully simulated setups and one in vivo data set were studied. For the simulations, a 12 ch 7T TEM head coil and a 2ch 3T birdcage body coil were employed, with segmented head and abdomen models, respectively. The magnetic fields were calculated by SEMCAD (Speag, Switzerland) simulations. In vivo measurements of whole brain B_1^+ maps were acquired according to the AFI method [5]. The optimal values for the scaling factor κ were determined by: (σ, ε) = (0.1, 50) for the 7T TEM coil, (0.1, 80) for the 3T bodycoil and (0.3, 50) for the 7T birdcage coil. The fitting procedure was implemented in Matlab 7.4.0 (The MathWorks). The number of basis functions was set to be 36 (i.e. $N = 5$).

Results The reconstructed B_1^+ maps for the 3 setups are shown in Fig. 2. The slices used as input of the optimization procedure were taken from a full B_1^+ map (reference) with undersampling factor of 5 in the vertical direction for all test-cases (see Fig. 1). Only these slices need to be measured. The 4 interleaved slices are reconstructed on the basis of the ˆc found. The model is able to describe the transmit fields with a good accuracy. In case of the measured data, the beneficial effect of filtering the noise is also obtained. The overall computation time was, per data set, about one minute.

Conclusions The method described here makes use of B_1^+ measurements in a few transverse slices to reconstruct the B_1^+ fields for the slices in between. The transmit fields are represented in terms of spherical functions, which arise naturally from the solution of the Helmholtz equation in the spherical coordinate system. The 3D model accurately describes the field for a few basis functions and the weighting coefficients can be determined on the basis of the measured B_1^+ maps for the few slices. Simulations and in vivo measurements confirm the validity of the method with an acceleration factor of 5.

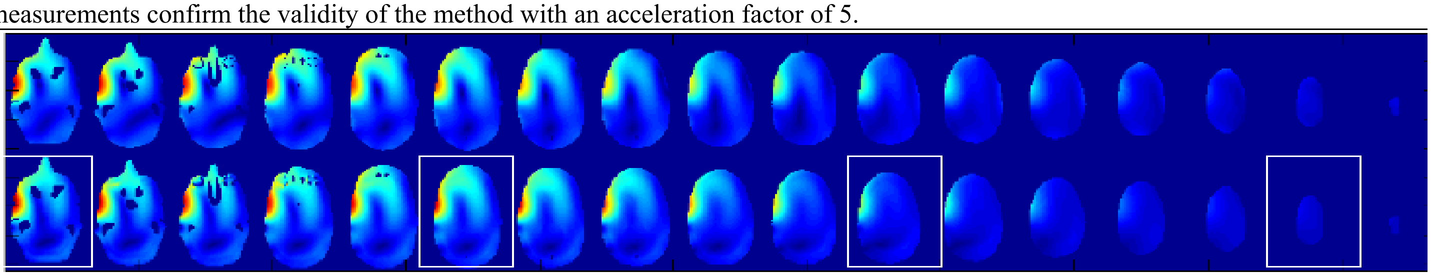

Figure 1: Reference (Bottom) and reconstructed (bottom) transverse slices for the TEM headcoil, channel 1. Slices used as input are marked.

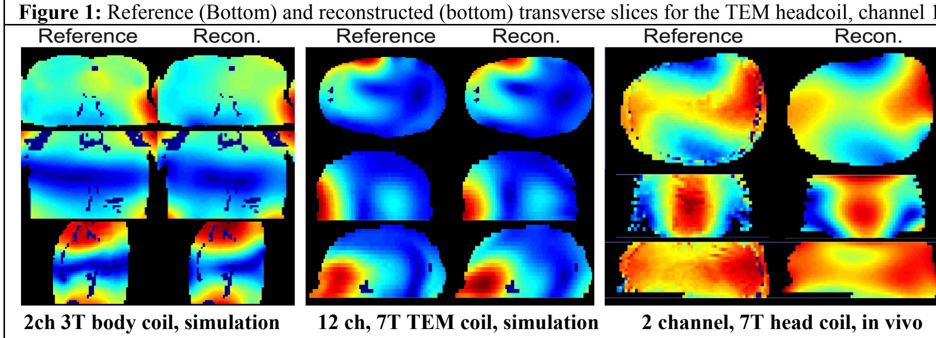

Figure 2: Reference and reconstructed B1+ maps. Visualization in the transverse, coronal and sagittal direction

References [1] Pruessmann KP et al. MRM 42:952–962 (1999) [2] Katscher U et al. MRM 49:144–150 (2003) [3] Sbrizzi A et al. ISMRM 2011 p. 3855 [4] Sbrizzi A et al. ISMRM 2011 p. 3889 [5] Yarnykh VL et al. MRM 57:192 (2007)