

Fast patient specific estimation of electric fields for a transmit array from B1+ measurements

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INTRODUCTION: An outstanding challenge of parallel transmission is to obtain patient specific information about the electrical fields. Previous work indicates that for a multi-channel transmission array the local SAR can behave in a very complex manner [1,2,3]. Thus, local SAR information should be available for a parallel transmission experiment on a patient specific basis. Currently, the SAR distribution is evaluated through numerical simulations for a limited range of body models. This approach has two major drawbacks: 1) the numerical simulations require long computing times and 2) they are not patient specific. In this work we describe how information about the electric fields in a body can be gained from standard transverse B1+ magnitude measurements. This approach allows a patient specific estimation of the electric fields and, in addition, requires only some seconds of computation time. The novel method is validated by means of FDTD simulations and *in vivo* measurement.

METHODS AND MATERIALS: **Methods.** The method was inspired by the following observations: 1) the transverse components of the RF field and the z-component of the corresponding electric field in a transverse slice can be approximated by a Bessel/Fourier functions expansion for a 2D domain (TM mode)[4,5]; 2) the number of modes required for a good fit is quite small, typically about 20 (Fig 1); 3) even if the permittivity, ϵ and the conductivity, σ are assumed to be constant in the whole transverse slice, the model still fits well to a fully segmented body model [5]. See Fig 1. The analytic expressions of E_z and B1+ in terms of Bessel/Fourier

modes are: $E_z(r, \theta) = -2i\mu\omega \sum_{m=-M}^M x_m J_m(\xi r) e^{im\theta}$ (1) and $B_1^+(r, \theta) = \frac{1}{2} i \xi \sum_{m=-M}^M x_m J_{m+1}(\xi r) e^{i(m+1)\theta}$ (2) where J_m denotes the first kind Bessel function of order m , ω the

frequency, μ the magnetic permeability, $\xi^2 = \epsilon\mu\omega^2 - i\omega\sigma\mu$ and x_m the (complex) expansion coefficient. The coefficients x can be calculated by fitting the Bessel-Fourier expansion for |B1+| to the data set d consisting of a transverse |B1+| field map. The obtained non linear fitting function $F(x) = ||Ex - d||$ can be minimized to find x . Substituting x into formula (1) gives the E_z field distribution. It is assumed that ϵ and σ are constant in the whole domain and to determine their numerical value, we iterate the described process over a range of realistic ϵ and σ values (Fig 1). The optimal choice of ϵ and σ is the one for which the Bessel/Fourier expansion best fits the |B1+| data.

Materials. Magnetic and electric fields for a 12 channels 7T head coil loaded with the Hugo model (Fig 2) were computed by FDTD simulations. A single transverse slice B1+ magnitude data set d was then derived. An experimental transverse |B1+| map of a volunteer's brain was obtained for each of the two channels of a 7T birdcage headcoil using the AFI method (TR1 = 50 ms, TR2 = 340 ms, 2.4 mm in plane resolution, 4 mm slice thickness). The minimization of $F(x)$ was carried out by a non linear minimization solver run with MATLAB 7.4.0. on an Intel Core Duo processor PC. The number of modes for the Bessel/Fourier expansion was set to be 21 (i.e. $M=10$). Contributions of higher order terms are not relevant for the quality of the reconstruction (Fig 1).

RESULTS: The total computation time for the calculation of x and the corresponding E_z field was about 15 seconds. The best choice of ϵ and σ resulted to be 30 and 0.5 S/m, respectively. The Bessel/Fourier model describes with good accuracy the |B1+| data set in both cases, i.e. the FDTD simulation and the experiment, resulting in a good fit of the B1+ map (see Fig 3 and 4, respectively). Similar results were obtained for other transverse slices. In the model, the anatomy is approximated as a homogeneous compartment. As a consequence, local peaks in the electric field related to anatomical heterogeneities are missed. However, the global E_z field pattern is well resolved as demonstrated by the FDTD comparison. In principle the model can be expanded to include transverse electric field components as follows from the TM model.

CONCLUSIONS: A novel approach to determine the patient specific electric fields for a transmit coil array was presented. The method combines the information obtained from a standard |B1+| measurement technique with an analytical description of the electric and magnetic fields in terms of Bessel/Fourier modes. The method relies on a transverse B1+ map as input which is most often already routinely performed in parallel transmission experiments. The major advantages of this approach are 1) the patient specific characterization and 2) the short measurement and computation times. The quality of the reconstructed E_z fields is confirmed by FDTD simulations. The resulting information about patient specific electrical fields per channel will be highly useful for parallel transmission applications. Based on the TM model, the methodology should also work for volume coils at 3 Tesla.

References: [1] Zelinsky et al. J Magn Reson Imaging 28:1005-1018(2008) [2] Sbrizzi A et al. ISMRM 2010 p. 4931 [3] Lee J et al. ISMRM 2010 p. 105 [4] van den Berg CAT et al. <http://www.staff.science.uu.nl/~bisse101/Articles/proc2007.pdf> [5] van den Bergen B et al Phys. Med. Biol. 52 (2007) 5429-5441.

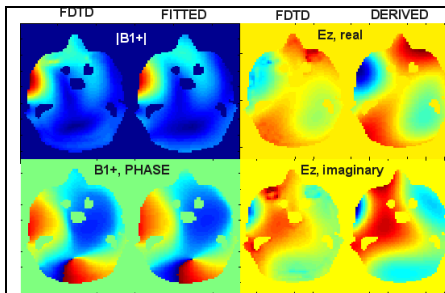
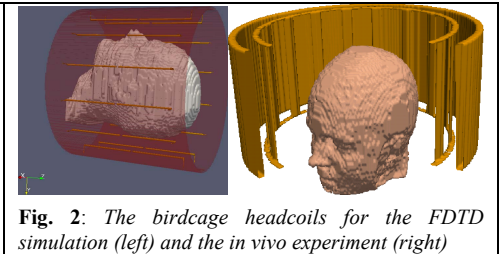
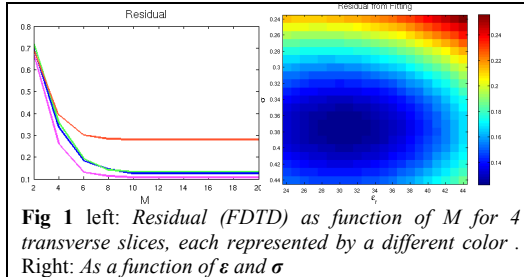


Fig. 3: Comparison between FDTD simulation and the derived maps

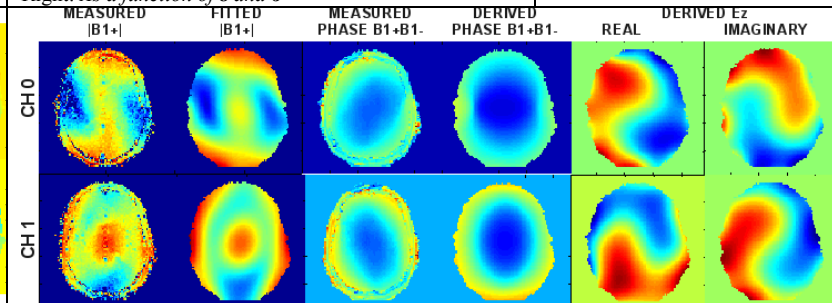


Fig. 4: Comparison between the measured data and the derived maps. Measured and derived maps for the phase of the B1+B1- product are also displayed.