Quantitative comparison of B_1^+ phantom measurements and FDTD B_1^+ calculations for a quadrature transmit MRI body coil.

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Introduction

The advent of modern whole-body MRI scanners with static fields up to 7 Tesla has increased the importance of RF modeling in MR imaging considerably. As the wavelength becomes comparable to the size of the human body, the dielectric interaction between the electromagnetic wave and the human tissue can no longer be neglected. In this study the goal was to investigate whether B_1^+ field calculations using the Finite Difference Time Domain (FDTD) technique corresponded quantitatively to B_1^+ phantom measurements for a whole-body coil.

Development of Methods

The measurements were performed on a clinical 1.5 Tesla (Gyroscan NT Intera, Philips Medical Systems, Best, the Netherlands) scanner with its quadrature driven transmit body coil. Using a multi-power B_1^+ mapping technique [1], the amplitude of the B_1^+ excitation field was measured inside a cylindrical phantom. This method requires the collection of several images at a broad range of flip angles, i.e. transmit powers. The MR sequence consisted of a spoiled gradient-echo sequence with TR = 1000 ms. and TE = 4.7 ms. The body coil was loaded with a perspex cylindrical phantom (diameter 20 cm, length 14 cm, wall thickness 5 mm) consisting of two equal compartments separated by a 1 mm thick perspex interface perpendicular to the cylinder axis. One compartment was filled with vegetable oil while the other compartment could be filled with distilled water or saline solutions. Their dielectric properties were determined with an impedance cell and were verified with values know from literature [2]. To reduce the total scan time, the MR T1 relaxation times of the water and saline solutions were matched to the T1 relaxation time of the vegetable oil by adding $MnCl_2{\cdot}4H_2O$ (final concentration was 95 mg/l). This resulted in a T1 for the water/saline solutions of around 220 ms while the T1 of the vegetable oil was approximately 200 ms in experiments. The effect of the $MnCl_2$ was found to be neglible on the final conductivity as expected from the low concentration

Material	Relative Dielectric Constant	Specific conduction (S/m)
Distilled water	77	0.02
NaCl sol. (5 gr/l)	77	0.70
NaCl sol. (16 gr/l)	75	2.60
Vegetable Oil	6	0.001
Perspex	3	0.005

Table 1: Dielectric properties of materials (@ 22 °C, 64 MHz)

The FDTD platform used for the simulations was originally designed in house for Hyperthermia Treatment Planning [3]. Here it was applied to perform simulations for an RF shielded Philips 64 MHz Intera body coil, the exact geometry of which was modeled. The simulated birdcage coil consisted of 16 copper rungs with length 56 cm and two end rings of diameter 62 cm. The copper RF shield had a diameter of 68 cm and length of 80 cm. In the mid-plane of the rungs, gaps were opened in which dipole sources were assigned. Their mutual phase relation was chosen such that quadrature excitation was achieved. The FDTD simulations were done at an isotropic resolution of 5 mm, applying Retarded Absorbing Boundary conditions with a time step of 8.3 ps. The magnetic field components were found to be stationary after 9000 time steps. Using equation $B_1^+ = B_{1x} + B_{1y}$ from [4], the amplitude of the rotating frame component B_1^+ was computed from steady state B_{1x} and B_{1y} components.

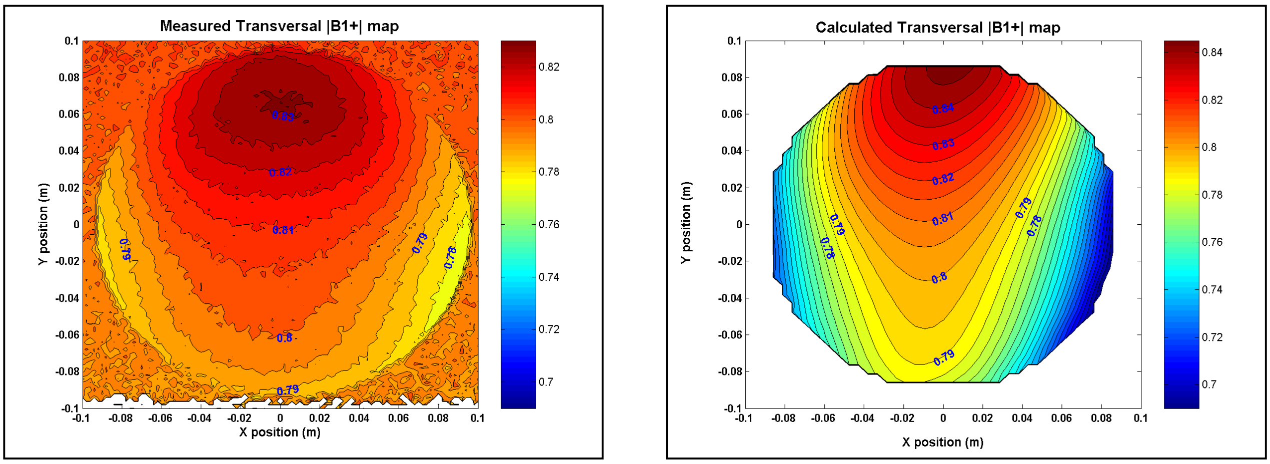

Figure 1: Measured and calculated transversal B_1^+ maps. The center of the cylinder was 4 cm off-center in AP direction.

In general, the measurements and calculations show a good qualitative and a fair quantitative correlation. As an example, in figure 1 $|B_1^+|$ measurement and calculations are depicted for a distilled water/oil phantom. The slice goes through the mid-plane of the water compartment. The calculations are scaled to the measurement by normalizing on the center values. Deviations occur at the edges of the cylinder, possibly indicating that the 5 mm calculation grid is not satisfactory.

Conclusions

The degree of quantitative correlation between FDTD $|B_1^+|$ calculations and $|B_1^+|$ measurements, show that it is feasible to do reliable FDTD calculations for whole-body coils loaded with phantoms. We hope to extend this approach in the near future towards measuring and modeling the $|B_1^+|$ field distribution inside a human cadaver.

References:

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