Assessment of SAR values and coil performance for an adaptive 4-channel 3T proton head coil array

G. Wuebbeler[1], F. Seifert[1], S. Junge[2], H. Rinneberg[1]
[1]Physikalisch-Technische Bundesanstalt, Berlin, Germany, [2]Bruker BioSpin MRI, Ettlingen, Germany

Introduction

At frequencies above 100 MHz the large relative permittivity and the conductivity of body tissue (skin effect) causes pronounced distortions of the spatial B1-field distribution. Knowledge of the B1 distribution is required for multichannel receive methods and for adaptive coil control schemes using multichannel RF excitations. By adjusting amplitude and phase of the RF applied to each separate coil elements the $B_1^{(+)}$ distribution can be tailored [1], e.g. for B1-shimming or focussing. For assessment of coil safety the distribution of the specific absorption rate (SAR) and, in particular, its local maxima must be known for each set of amplitude and phase parameters. Here we report on a worst case analysis of simulated RF-field data, validated by measurements, to asses safety and coil performance of a 4-channel transmit-receive head coil array operating at 125 MHz.

Methods

The measurements were performed on a 3 T whole body scanner (MEDSPEC30/100, Bruker Biospin MRI). The phased array, consisting of 4 current sheet antenna (CSA), was loaded by a cylindrical phantom (∅ 20 cm, ε=76, σ = 0.33 S/m). The transmit $B_1^{(+)}$ distribution was measured for the "birdcage" excitation of the coil array (Fig. 2, coil phases as indicated) by applying a 1ms rectangular preparation pulse followed by a gradient echo sequence to image the remaining magnetization. The power required for a 90° flip angle was determined for each pixel from the dependence of the image intensity on the amplitude of the preparation pulse. Using the calibrated transmitter power, the corresponding $|B_1^{(+)}|$ field amplitude was calculated.

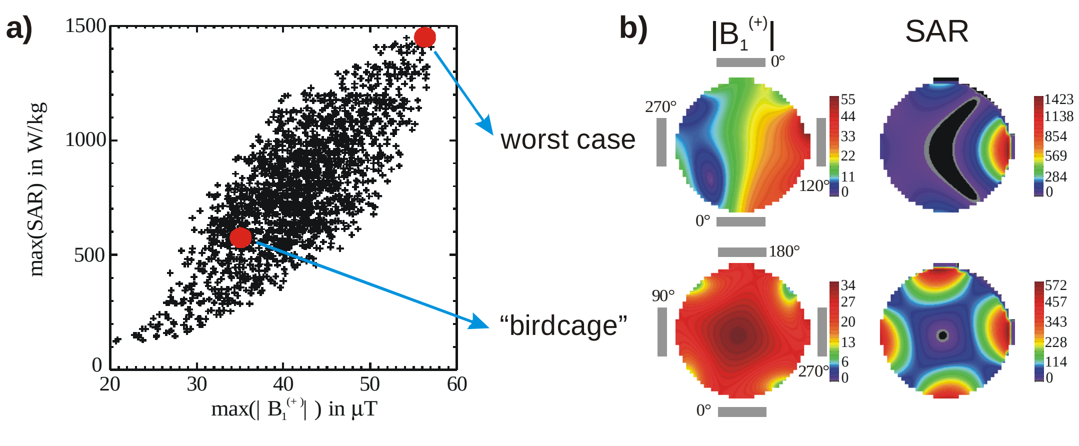
The numerical calculations were performed with the XFDTD software package (REMCOM Inc.). The model, consisting of the CSA array and the load, was implemented on a 0.5 cm grid (49x61x49) with 8 perfectly matched layers. One coil of the array was excited by a CW RF current, applied at the matched feeding port in the FDTD grid, to infer the steady state magnetic and electric fields. At each point of the FDTD-grid the complex steady state electric and magnetic field values were evaluated and calibrated to the input power. Because of the 4-fold symmetry of the arrangement, the RF-field distributions of the remaining 3 antenna were generated by rotating the electric and magnetic fields by 90°,180 ° and 270°.

For a worst case analysis the four sets of electric and magnetic field distributions were superimposed for different combinations of coil phases, varying in steps of 30° in a grid like manner. The same RF amplitude was applied to each coil element corresponding to a total power of 1 kW. From the resulting magnetic and electric fields the distributions $|B_1^{(+)}| = |B_{1x} + i\,B_{1y}|$ and $SAR = \sigma/\rho(|E_x|^2 + |E_y|^2 + |E_z|^2)$ were calculated inside the load. For each set of phases the maximum local SAR value and the maximum value of $|B_1^{(+)}|$ were determined.

Results and Discussion

Fig.1a shows the correlation between maximum local SAR values and maximum $|B_1^{(+)}|$ amplitudes inside the phantom calculated for varying coil phases. These maximum values generally do not occur at the same location inside the phantom. In Fig.1b the $|B_1^{(+)}|$ and SAR distributions at the central axial slice of the phantom are shown for two selected phase settings. The top row corresponds to the phase settings leading to the highest local SAR values (worst case). The bottom row illustrates the $|B_1^{(+)}|$ and SAR distributions for the "birdcage" excitation. Fig.2 shows the $|B_1^{(+)}|$ distribution measured at the central axial slice of the phantom for the "birdcage" excitation. The input power for each antenna was 250 W. Measured and simulated (Fig.1b, lower left corner) distributions agree quantitatively.

The large spread of maximum SAR and $|B_1^{(+)}|$ values, obtained by varying phases only, clearly demonstrates the need for an extensive safety analysis before using multi-channel transmit coils for tailoring B1 field distributions. Here we propose a worst case analysis based on superimposed simulated RF-field distributions together with corresponding measurements for model validation.



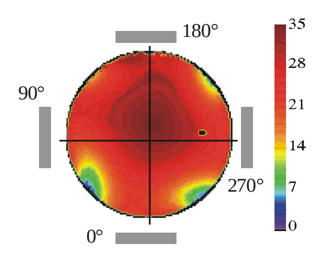


Fig. 1:a) Correlation of max(SAR) and max($|B_1^{(+)}|$) obtained for various coil phases
b) $|B_1^{(+)}|$ and SAR distribution for worst case (top) and "birdcage" (bottom) excitation

Fig. 2: Measured $|B_1^{(+)}|$ in µT for "birdcage" exitation

References

1. F. Seifert et al., Proc. Intl. Soc. Mag. Reson. Med. 10 (2002) 162