B1 Homogenization at 3 T MRI using a 16 Rung Transmit Array

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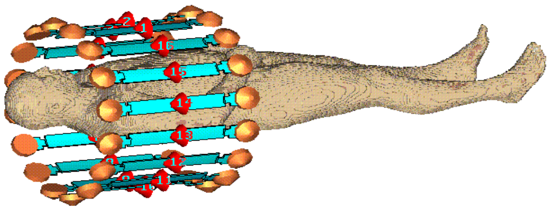
Introduction

A simulation setup comprising the human body model *HUGO*^{P} and a transmit array with 16 rungs was used to investigate the benefits of independent rung feeding, where the current in each rung can be driven with an individual phase and magnitude.



The Human Body Model (HUGO^{P}) used for the simulation within the BC resonator with independent rung feed with the chest position in isocenter. Each rung is fed in the middle and has resonant capacitors to the RF screen (not shown) at the ends.

Motivation

At high field MRI (3T and above), the homogeneity of the time-varying RF magnetic field (B1) is highly dependant on the electrical properties of the imaging object itself. Thus, it is advantageous to adapt the transmit coil properties to each individual patient and patient position in order to achieve a homogeneous excitation within the chosen field of view. On the other hand, the method used to optimize the B1 distribution should not neglect such an important issue as SAR.

Method

Adapting the current distribution for the individual rungs of a 16 channel transmit array was a straightforward optimization problem with two congruent criteria. Microwave Studio^{P}, a FDTD simulation tool was used to calculate the relevant RF parameters. The starting point was the computation of the B1 distribution within the body as induced by a body coil with conventional current distribution (equal current magnitudes and a constant phase increase). External routines computed the optimum current distribution in the rungs for a minimum standard deviation of B1 and the corresponding minimal SAR values. The simulation program was used again to calculate and plot the new, optimized B1 distribution using the improved current distribution. The optimization method can either comprise the whole slice or be focused on a special region of interest.

$$\min \begin{pmatrix} f_1(I_1,\ldots,I_{16}) \\ f_2(I_1,\ldots,I_{16}) \end{pmatrix}$$

with the secondary target

$$g(I_1,\ldots,I_{16}) \le \alpha$$

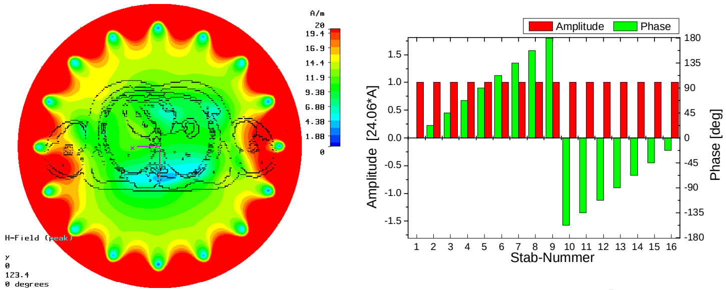
$$I_1,\ldots,I_{16} \in C$$

Optimisation targets

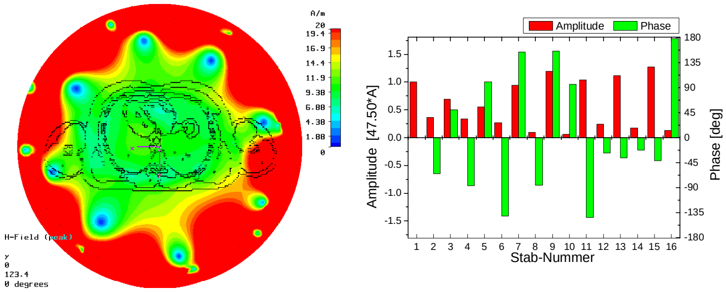
I1..I16: individual rung currents
f1: B1 homogeneity factor
f2: global SAR-Value
g: local to global SAR ratio
α: body region dependant threshold

Results

The B1 uniformity within an arbitrary chosen region of a MRI slice can significantly be improved using optimized currents in the individual coil rungs. For the example depicted below with an area comprising the upper abdominal region the standard deviation of B1 was originally 21,2%. This improved to a standard deviation of 11,5% after the optimization algorithm was applied. The total power deposition (scaled to the level needed for a 180° MRI inversion pulse) increased only by about 9% from 7410 to 8075 W.



The B1 distribution in the upper abdominal position of HUGO^{P} using evenly distributed the RF-currents (left). The rung currents (right) have all the same magnitude and a constant phase increase.



Optimized B1 distribution (left) using individual rung currents (right) computed by an external routine which minimizes the standard deviation of B1 in the abdominal region and also considers global and local SAR issues even in far off areas of the body.

Conclusion

The given example is only one from a longer series of simulations. The method is very well suited for improving the B1 homogeneity of a body coil with independent fed rungs, offering the flexibility to choose an arbitrary region of interest within the field of view. Equally good and even better results were obtained from the head region. The SAR issue was considered with a special interest due to its maximum importance for patient comfort and security. The attained homogeneity level was best in the chosen slice and slowly decayed for slices further away. Additional work is needed for volume and oblique slice optimisation with even lower SAR.

References

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