B_1^+ homogeneity and SAR reduction for localized excitation at 7T

B. van den Bergen[1], C. A. van den Berg[1], L. W. Bartels[2], and J. J. Lagendijk[1]

[1]Department of Radiotherapy, University Medical Center Utrecht, Utrecht, Netherlands, [2]Department of Radiology, University Medical Center Utrecht, Utrecht, Netherlands

Introduction

Due to the small wavelength at ultra-high field strengths ($B_0 \geq 7$ T), it is no longer possible to obtain a homogeneous excitation field (B_1^+) over large regions in the body for Magnetic Resonance applications. Dedicated coils are being developed for specific locations such as the knee joint [1] and breast [2], which are intended to provide a homogeneous excitation field only over the region of interest. Especially for quantitative imaging applications such as perfusion imaging in the prostate for tumor characterization is it of crucial importance that the excitation field is as homogeneous as possible.

This simulation study is intended to investigate the possibilities and limitations of such localized excitations in the pelvic region. We are interested in the B_1^+ homogeneity as function of the size of the region of interest (ROI), as function of the allowed specific absorption rate (SAR) and as function of the location of the ROI.

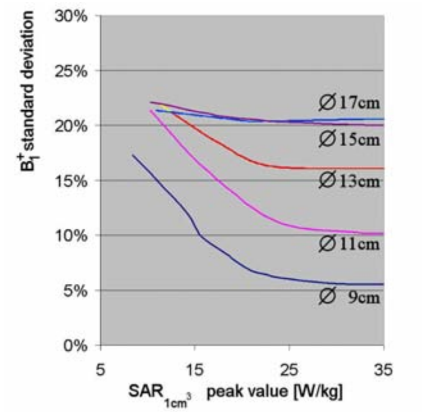

figure 1, B_1^+ standard deviation for different allowed SAR peak values for different ROI's

Methods

In order to provide a maximum understanding of the wave behavior without blurring by detailed anatomy structures, we used for our simulations an elliptical phantom with dimensions comparable to an average human and with a homogeneous filling, which is based on a volumetric averaging of a human model. Previous studies have shown that the electromagnetic fields found for such a phantom are very comparable to the fields found for detailed human anatomies [3].

The electromagnetic radio frequency (RF) fields for our simulated TEM coil were calculated with our in house developed Finite Difference Time Domain (FDTD) code [4]. The optimizations to obtain the most homogeneous B_1^+ fields for different ROI sizes, for different locations and with different SAR constraints were performed with a non-linear, constrained optimization routine, which varies the phases and amplitudes of all antenna elements to provide the best solution. The different regions of interest are black outlined in figures 2 and 3. The transverse dimensions vary as indicated, but the longitudinal thickness is always eight centimeter.

Results

Figure 1 shows that there is a trade-off between the amount of SAR that is allowed and the B_1^+ homogeneity that can be achieved with our optimizations, especially for small ROI's. The quadrature excitation solutions exceed the scale of figure 1 with a B_1^+ standard deviation of 40-50% and a SAR_{1cm3} peak value of 30-40 W/kg. The SAR is evaluated for a gradient echo sequence with a 90-degree flipangle, a pulse length of 1 ms and a repetition time of 20 ms.

The size of the region of interest plays a very important role for the homogeneity of the B_1^+ field that can be obtained. Figures 1 and 2 show that the homogeneity decreases rapidly when the ROI is enlarged. Especially when the ROI becomes comparable to the wavelength (~17 cm) of the RF waves, it is no longer possible to obtain an excitation field without 'voids'.

The transverse location of the ROI does not substantially influence the homogeneity of the B_1^+ field (figure 3), however, it does influence the SAR (not shown) due to penetration effects. More energy is required when the ROI is located in the center compared to when the ROI is located in the periphery.

Conclusions

The B_1^+ homogeneity that can be achieved is dependent on the RF wavelength, the ROI size and the allowed SAR. A solution that minimizes the SAR and also makes the B_1^+ field as homogenous as possible inside the ROI does not exist. Therefore the optimal solution will be very application dependent and it will be a trade-off between the level of SAR that is accepted on one side, and the needed B_1^+ homogeneity on the other. However, it is always possible to improve the B_1^+ homogeneity and the SAR deposition simultaneously with ~50% compared to a quadrature excitation.

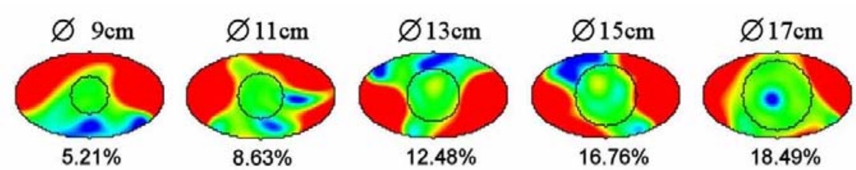

figure 2, standard deviation of the excitation field for different ROI sizes

Flipangle [degrees] 0 90 150

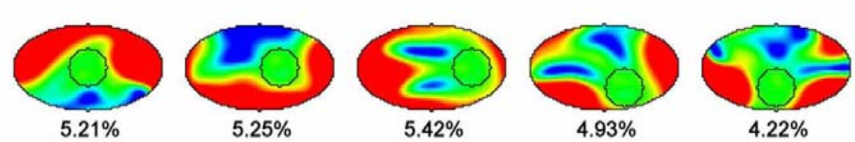

figure 3, standard deviation of the excitation field for different ROI locations

Flipangle [degrees] 0 90 150

References

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