RF Shimming and SAR Considerations With an Eight-Element 3T Body Coil

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Introduction

Static RF shimming, whereby multiple transmit elements are driven with amplitude scaled and phase shifted versions of essentially the same RF signal, is seen as a potential technology for improving transmit uniformity at high field.

With RF shimming there is an opportunity for obtaining large phase differences, and hence interferences, in the signals from neighboring transmit elements, which requires a renewed look at average and local SAR increases.

Further, and somewhat counter intuitively, if one of the transmit elements fails there is the potential for the average and/or local SAR to increase [1].

In this work these effects are numerically investigated for 3T body imaging with an eight-loop body-sized transmit array.

Methods

The numerical simulations were performed using the FDTD algorithm, a "visible-man" tissue model, and frequency dependent electrical tissue properties. The visible-man model was placed with the abdomen at the coil center.

The body array consisted of eight 18cm x 56cm rectangular loops, equally spaced azimuthally, on a diameter of 61cm. The mutual inductance between elements was assumed to be negligible. The coil array was driven with four different current sets, corresponding to circular polarized, and RF shimming in the transverse, sagittal and coronal planes, respectively.

The RF shimming optimization attempted to minimize the maximum error in the magnitude of the B1 field over a single slice. This was repeated for transverse, sagittal and coronal slices. To ensure that neighboring elements did not have wildly varying phase shifts, the optimal phase was constrained to be within +/-90 deg of the value required for achieving circular polarization. Further, the maximum current in any one element was restricted to be no more than twice that of the circular polarization case. Matlab's constrained optimization routines were used.

The B1 field was normalized such that the mean of the magnitude was held constant within the "imaging" section.

Average and peak local SAR values were calculated for the full 3D visible-man structure.

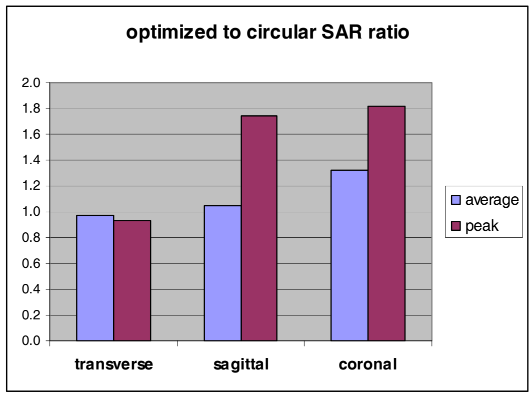
The following derived parameters were calculated: (1) The maximum increase in average and peak local SAR due to RF shimming, relative to the circular polarized case;(2) the ratio of peak to average SAR; and (3), along the lines of [1], the maximum increase in average and peak local SAR due to one transmit element failing.

Results

RF shimming in the sagittal and coronal planes resulted in a peak local SAR increase (top graph) of about 80%. For the transverse plane the SAR values remained almost unchanged.

The peak to average SAR ratio (bottom graph) was around 18 for the circular polarized and transverse optimized cases (similar to that reported by Collins [2]), but this was up to 70% higher for sagittal and coronal RF shimming; and up to ~2.2 times higher in the event that one element fails.

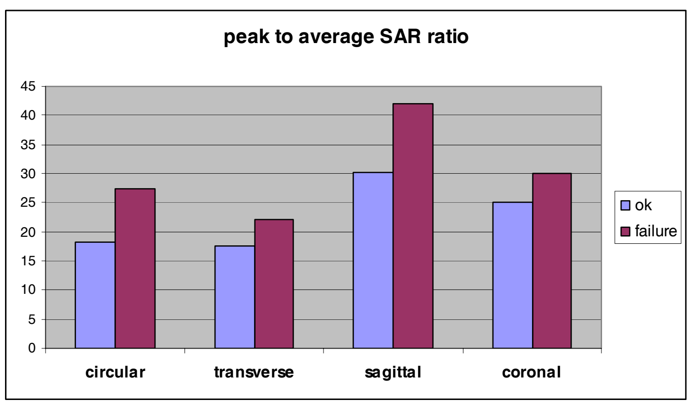
The maximum increase in average and peak local SAR due to single element failure was 20% and 48% respectively (not shown).



Discussion

Monitoring the average SAR in order to infer the peak local SAR seems a reasonable approach for transverse plane RF shimming, but is not very reliable for sagittal and coronal plane RF shimming.

Element failure can lead to large increases in peak local SAR, although the values seen here are not as large as those reported in [1] - perhaps this is due to the constraints placed within the RF shimming algorithm used.



References

[1] Graesslin et al., ISMRM, 2041 (2006)
[2] Collins et al., ISMRM, 2044 (2006)