Assessment of the SNR, G-Factor and Relative B1-Fields of Medical Radiofrequency Arrays

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Abstract

MRI relies upon a static magnetic field which creates a net magnetic moment from proton spins and radio-frequency fields are generated to excite this magnetic moment into a perpendicular plane, where it can be detected through the use of an array of conductive loops. The optimal size,shape and layout of these elements has been widely discussed in literature since the phased array's conception [1]. When designing a new coil it is useful to be able to compare several clinically relevant metrics a priori to reduce on the time and construction costs and this can be done through simulation of the receive sensitivity fields (known as B1-).

It has previously been shown that radio-frequency coils can be simulated using COMSOL Multiphysics®, and the RF module is useful for the tune and match of circular elements to the desired resonant frequency (63.86MHz at 1.5T). The advantage of a phased array comes from the recombination of individual coil's signals; a circular loop has highest sensitivity to the region less than a diameter away, which can limit the penetration depth of dense topology arrangements, however, the phase of the signals can be altered to gain an image with uniform noise. The theory for this method is well documented and simulations have been done using FDTD methods. However, COMSOL's tetrahedral mesh is useful for anatomy-conforming array designs and there is interest in a FEM solver method for medical applications. [2]

MR Imaging is accelerate through an under-sampling of frequency-space and, in practice, this under-sampling manifests itself as artefacts wrapped into a smaller field of view. The potential for such acceleration for any array design can be calculated through an extrapolation of the array noise matrix (NCM) and the fields for each element when driven by 1A. The LiveLink™ to MATLAB® module is particularly important for the automation of this calculation and for plotting the results [3].

The LiveLink™ to MATLAB® module has been used to simulate a current adult torso design - which is often employed in child imaging - and the project design paediatric coil. The designs were tuned to the correct frequency and Signal to Noise maps were generated according to the uniform noise manipulation detailed by Roemer et. al. The SENSE g-factor has been plotted for reduction factors of two and four along the x-axis.

MRI offers physiological and diagnostic advantages over other imaging techniques when

examining the paediatric population who are particularly radiation-sensitive but coil selection for reception are largely limited to adult designs. COMSOL Multiphysics® can be further used to compare existing adult designs to a new prototype infant receive coil being built as SNR and B1-field measurements cannot be ascertained quantitatively in the clinical environment. Current simulations of the adult torso array against the new design were presented here as a proof of process and this work should be extended to consider different loading conditions and potential developmental designs.

Reference

[1] P. Roemer et al. 'The NMR Phased Array' Magnetic Resonance in Medicine 16, 192-225 (1990)

[2] A. Rotislav et al. 'A Numerical Postprocessing Procedure for Analysing Radio Frequency MRI Coils' Concepts in Magnetic Resonance Part A 38A 133-147 (2011)

[3] G. Chen et al. 'An optimisation method for designing SENSE imaging RF coil arrays' Journal of Magnetic Resonance 186, 273-281 (2007)
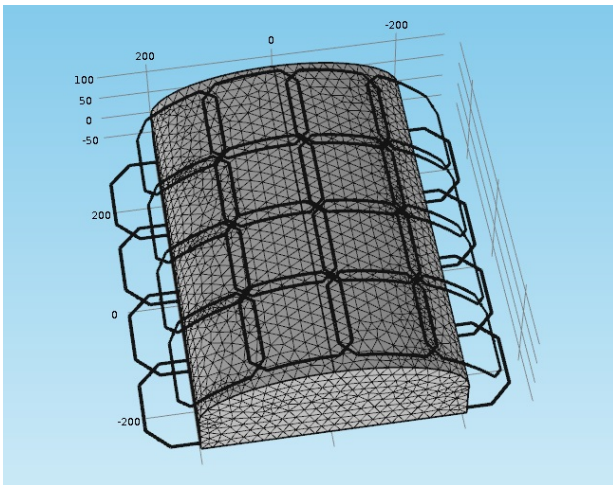
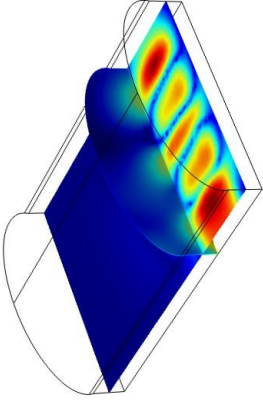# Figures used in the abstract

Figure 1

Figure 2