Modelling Study of a Hybrid Loop-Sheet Coil Structure for a 8-channel Small Animal Transceive Array at 9.4T

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Introduction

When designing a small animal RF transceive array coil, RF field penetration depth and mutual decoupling of individual coil elements are two important considerations. Conventionally, loop coils are used for the construction of small animal transceive arrays. However, as the number of coil elements increases the size of each coil has to be reduced, since the available space is generally restricted, to comply with MRI-system specifications. As a result the RF penetration depth will be compromised. In this work, a 9.4T shielded 8-channel hybrid loop-sheet coil transceive array for small animal MRI is proposed to overcome the low RF penetration depth issue.

Methodology

The major constraint when designing the small animal 8-channel transceive array is the limited available space to accommodate the coil elements and decoupling circuits. In our previous studies, a loop coil-element with angularly-oriented radiating structures was presented which was capable to increase the RF penetration depth and to regulate the mutual coupling between neighbouring coils [1-2]. However, the opening angle of the loop aperture is limited to 35° (see Fig.1a and Fig.4b) [1], which is one of the limiting factors for further improvement of the RF field penetration depth. To overcome this constraint, we investigated a combination of sheet coil element [3-4] and angularly-oriented loop element. Illustrated in Fig.1b is the coil element diagram of the new design (transverse view). Angularly-oriented loop coils are used at positions 1, 3, 5 and 7, while sheet coils are used at locations 2, 4, 6 and 8. This hybrid loop-sheet coil design provides a higher degree of freedom to optimize the coil blade rotation angle and aperture size of the loop coils, for highest RF penetration depth and minimum mutual coupling between neighbouring coils.

Modelling Study and Simulation Results

Shown in Fig.2a is the modelling of the proposed hybrid coil. Depicted in Fig.2d is the optimized loop coil element. The opening angle of the loop aperture was increased to 45° considering physical constraints. In addition, when using the numerical optimization algorithm, the optimum coil blade rotation angle of 20° was obtained. Using a hybrid MoM/FEM simulation package (FEKO), a comparison of RF field penetration depth between Loop_a (previous design, Fig.2b), sheet coil element (Fig.2c) and Loop_b (Fig.2d) was undertaken. All the modelled coil elements are excited with a voltage source of 1V and a 0° phase, tuned to 400MHz and matched to 50Ω. Magnetic fields inside the FOV (transverse to the region of interest) are calculated and plotted in Fig.2e. It is shown that the calculated magnetic field at the centre of the FOV is approximately 14.7% higher than that of Loop_a, and Loop_b approximately 34.66% higher, as compared to Loop_a. These results demonstrate the potential of the proposed new design.

Conclusion

In this work, a dedicated 9.4T 8-channel hybrid loop-sheet coil transceive array for small animal MRI is modelled and studied. The array was designed within the limited space available by using a dedicated coil structure that contains loop and sheet coil elements. The hybrid design enables large aperture for the loop coil, therefore offering improved RF field penetration and coil efficiency. By using numerical modelling/simulation, we were able to determine the feasibility of the hybrid-designed and also understand its performance and field behaviour.

References