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A Comprehensive Approach to Decoupling in RF Coil Arrays

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The radio frequency (RF) coil is a key determinant of MR image quality, influencing factors such as signal-to-noise ratio and image uniformity. In particular, RF coil arrays can effectively improve the uniformity of the RF transmit magnetic field and reduce image acquisition time at ultra-high field strengths through parallel transmit systems and parallel imaging techniques, respectively. However, in dense RF coil arrays, each element may couple with both adjacent and non-adjacent elements. Therefore, decoupling is essential to optimize RF coil array performance and enhance MR image quality.

In general, overlapping, capacitive, and transformer (inductive) decoupling methods have been applied in RF coil arrays. Although these traditional approaches are effective in ensuring RF coil array performance, they impose certain limitations on coil arrangement and fabrication. To overcome these limitations, several alternative decoupling strategies have been proposed, such as preamplifier decoupling, induced current elimination, and the use of high-impedance or metamaterial-inspired elements. These approaches provide greater flexibility in coil geometry and have the potential to further improve RF coil array performance in ultra-high-field MRI.

In this context, three novel RF coil array designs for decoupling are introduced. Each RF coil array was designed using electromagnetic simulations, and the decoupling performance was subsequently validated through bench measurements and MRI experiments.

First, a clip-path conductor coil array for 7T MRI, which consists of a loop coil and clip-shaped additional conductor lines. By adjusting the length of the conductor lines and the capacitance of the loop coil, effective decoupling between elements can be achieved.

Second, a self-decoupling dipole array for 7T MRI, in which the proposed dipole antenna comprises a bent dipole, an FR-4 substrate, and an additional conductor line. The resonance frequency is determined by the geometrical parameters of each component, while the position of the additional conductor line enables decoupling.

Finally, a chain-shaped dipole array for 11.74T MRI, which reduces the overlap distance from 75% (conventional method) to 59% along the xy-axis, thereby allowing a greater number of channels in that direction.

Keywords: RF Coil array, Decoupling, Ultra-high field MRI