RF shimming with implant safety control in MRI transmit arrays through second-order cone programming

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Inside a Magnetic Resonance Imaging (MRI) birdcage, the patient is subjected to the static magnetic field B_0 generated by a magnet, and the radiofrequency (RF) magnetic field B_1, usually generated by a transmit array. A common technique used in MRI to achieve a higher image quality is RF shimming. It aims to maximize the homogeneity of the B_1 field over the desired region by properly adjusting the driving excitations of channels in the MRI transmit array. Several strategies have been followed to achieve this objective. One of the most successful ones is minimizing the mean square error (MSE) of the magnitude of the B_1 field with respect to a reference value.

On the other hand, the RF magnetic field irremissibly bears an associated RF electric field, responsible for depositing RF energy in human tissues. In the case of a patient with an active medical implant, the RF energy is especially coupled through the electric field tangential to the implant. This results in a severe risk of heating the tissues around the implant and therefore, depending on the implant features, most of these patients cannot undergo an MRI diagnosis. To assess the magnitude of this risk, a four tier approach can be found in ISO/TS 10974.

In this work, a novel method to carry out the RF shimming while jointly imposing a limit on the estimated RF power deposited around a medical implant is proposed. The evaluation of the RF heating is carried out through a tier 3 compliant model of the implant. The problem is initially formulated as a complex-valued constrained MSE optimization problem. This original formulation is then recast and subsequently solved as a real-valued second-order cone programming (SOCP) problem. The convex nature of the SOCP formulation ensures the global optimum solution is reached.

Numerical simulations in SEMCAD-X are performed for different setups to check the validity of the proposed method. As expected, thanks to the proposed SOCP formulation, it will be shown how there is a tradeoff between B_1 homogeneity and RF power deposited through the implant in the surrounding tissues.