FIELD INTENSITY SHAPING PARADIGM FOR SHIMMING AND SAR CONTROL IN AN MRI SYSTEM

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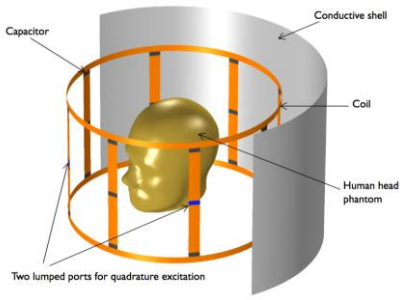
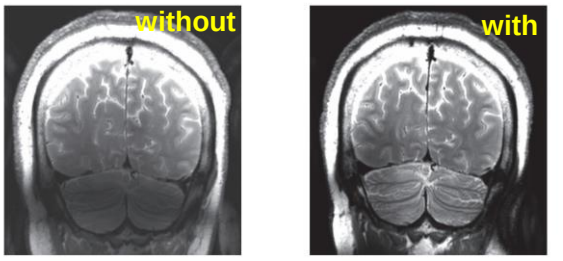
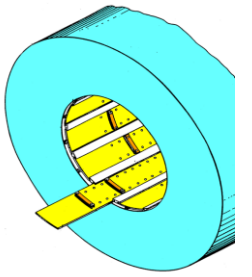
The shimming of the radiofrequency (RF) Field B_1^+ in MRI system

- There are two macro categories of shimming techniques
- **Active Shimming:** acts directly on the primary sourses (i.e. the excitations I_n) and uses small coils (or "shim-coils")





Brain imaging via MRI without and with Shimming of B1



- **Passive Shimming:** uses of iron pieces or High-permittivity, low-conductivity materials (HPMs) as shims, such as dielectric pads

A novel design metodology for active shimming

- Let $\underline{r_0}$ and $\underline{r_1}$ be the **2 control points** set in the target area

$$\min_{[I_n]} -Re\left\{B_1{}^+\left(\underline{r_0}\right)\right\}$$

subject to

$$Im\{B_1^+(\underline{r_0})\} = 0 \qquad B_1{}^+(\underline{r_0}) \geq B_{1\,des}{}^+$$

Homogeneity constraint

$$Re\left\{B_1{}^+\left(\underline{r_1}\right)\right\} = Re\left\{B_1{}^+\left(\underline{r_0}\right)\right\} * cos(\phi)$$

$$Im\left\{B_1{}^+\left(\underline{r_1}\right)\right\} = Re\left\{B_1{}^+\left(\underline{r_0}\right)\right\} * sin(\phi)$$

SAR constraint

$$SAR(\underline{r}) \leq UBS(\underline{r}) = 3.2\frac{W}{kg}$$

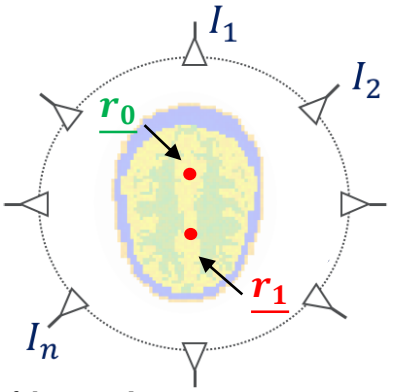
Polarization constraint

$$|B_1^-(\underline{r})|^2 \leq UBP(\underline{r}) * |B_1^+(\underline{r})|^2 = \frac{1}{2}|B_1^{+init}(\underline{r})|^2$$

CP PROBLEM

- The goal of the proposed approach is to *"determine the optimal set of* ***complex excitations coefficients*** I_n *such to produce the desired homogeneous* B_1^+ *field, while ensuring polarization purity, SAR limit and all the constraints at hand"*
- $\phi \in [-\pi,\pi]$ is an **auxiliary variable** defined as the phase shift between $B_1^+(\underline{r_0})$ and $B_1^+(\underline{r_1})$
- The **globally optimal solution** will be given by selecting the value of ϕ corresponding to the **minimum RSD** within the target area

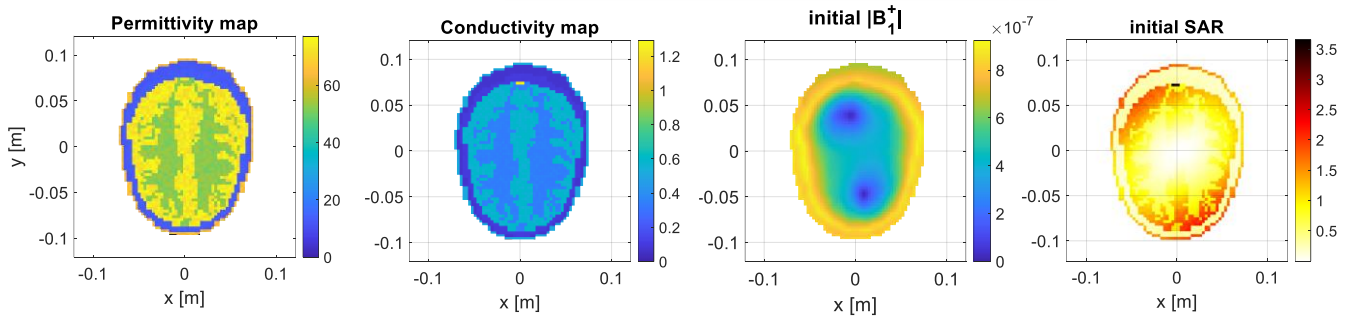
$$RSD = \frac{std\{|B_1^+(\underline{r})|\}}{mean\{|B_1^+(\underline{r})|\}}$$



I_n: set of the complex excitations

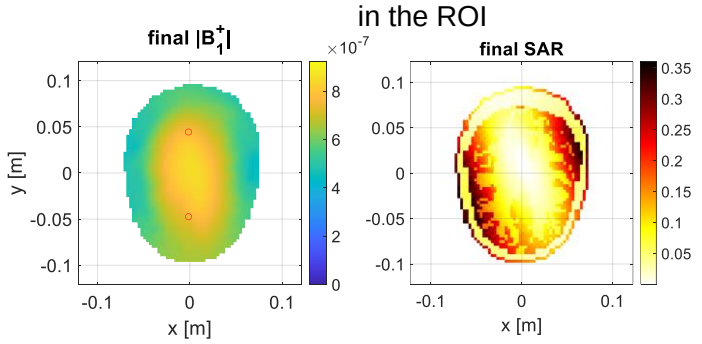
Numerical validation

Realistic 2D scenario mimicking human head



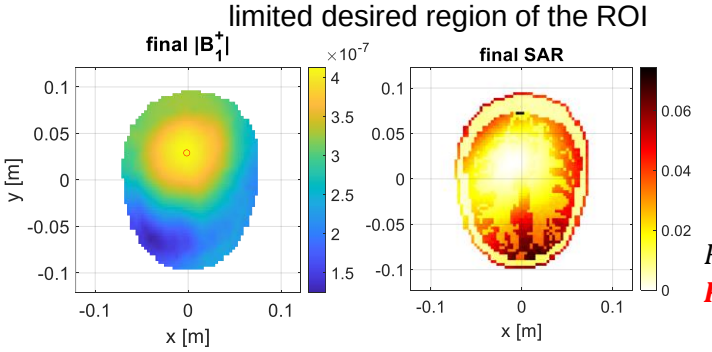
$B_0 = 3T$
$f = 128\ MHz$
$d_{ControlPoints} = \lambda_m/4$
$n_{antenna} = 16$
$I_n = I_o\, e^{-j\varphi_n}$

The use of **2 control points** allows to achieve a "shimmed" field in the ROI



$RSD_i = 0.38$
$\boldsymbol{RSD_f = 0.10}$

The use of **1 control point** allows to "shape" the field in a limited desired region of the ROI



$RSD_i = 0.36$
$\boldsymbol{RSD_f = 0.06}$

1. E. A. Attardo, T. Isernia, and G. Vecchi, Field synthesis in inhomogeneous media: joint control of polarization, uniformity and SAR in MRI B1-field, Progress In Electromagnetics Research, Vol. 118, 355-377, 2011.
2. G. G. Bellizzi, M. T. Bevacqua, L. Crocco and T. Isernia, "3-D Field Intensity Shaping via Optimized Multi-Target Time Reversal," in IEEE Transactions on Antennas and Propagation, vol. 66, no. 8, pp. 4380-4385, Aug. 2018, doi: 10.1109/TAP.2018.2841412