Lessons Learned in Applying Efficient B_1 Shimming Techniques at UHF

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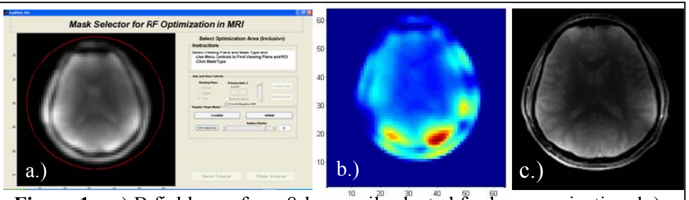


Figure 1: a.) B field map from 8-loop coil selected for homogenization. b.) Simulated optimal B_1^+ homogenization with B_1^- correction c.) Scan using optimized phase and amplitude from the tool for homogenization.

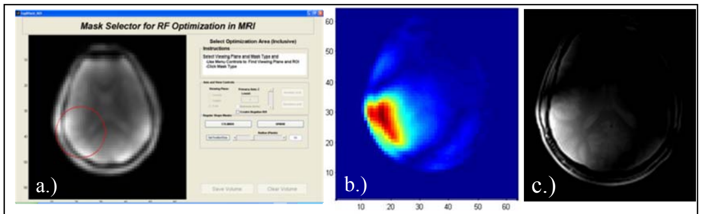


Figure 2: a.) B field map from 8-loop coil visualized w/ localized ROI selected using Software GUI b.) Simulated optimal B_1^+ localization with B_1^- Correction c.) Scan using optimized phase and amplitude from tool.

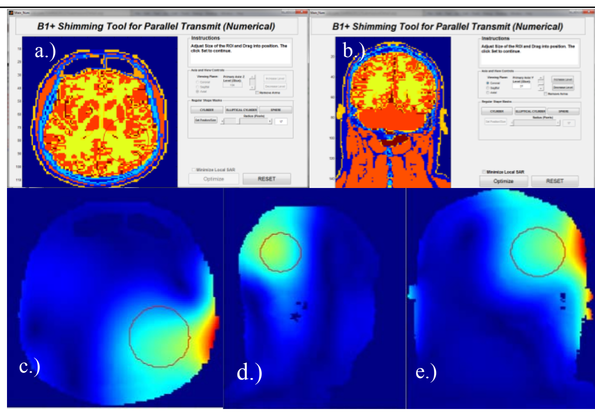
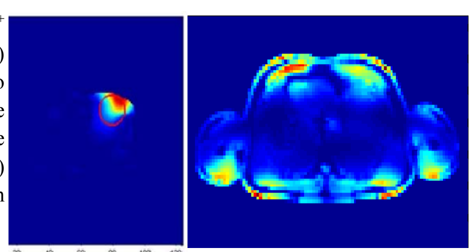


Figure 3: a.) Axial and b.) coronal view of region selection in a numerical head model. RF simulations are used for shimming, as shown in the 3D optimized B_1^+ for the spherical region displayed in c.) axial, d.) sagittal and e.) coronal planes.

Figure 4 a.) Optimized local B_1^+ field in the selected ROI b.) Associated SAR optimized to minimize local peaks. The software tool is graphically capable of selecting any ROI (shape/size) & performing pulse shimming in 3D.)



Purpose: B_1 shimming, or in electromagnetic terminology, phased array excitation, is a fundamental technique to manipulate RF fields in UHF MRI. Conventional high-field hardware, i.e. traditional coils with fixed-phase and amplitude excitation, does not, in and of itself, alleviate the problems of the increasingly (electrically) large loads at higher field strengths [1,2]. B_1 shimming, coupled with multi-channel transmit coils, provides a viable alternative in solving RF inhomogeneity issues and addressing local/global SAR considerations when compared to time-consuming pulse optimization algorithms such as TXSense [3]. However, this technique does require the clever application of widely used optimization algorithms specific to the target application. Current B_1 shimming practices with multi-channel transmit coils, pTX arrays and numerical simulations will be explored and generously supplemented by the pains experienced developing a software graphical user-interface (GUI) for intuitive, real-time RF shimming. This will also address the hot topic of RF safety for parallel transmission applications. In an electronic presentation, the audience will test-drive the simulation tool.

Outline of Content: The basic value of B_1 shimming will be demonstrated for several applications using both empirical and simulated B_1 profile information. The most prevalent of these will be improving the B_1 homogeneity over an entire 2D slice or 3D volume. An example of using a GUI to perform this operation is given in Figure 1, showing how experimentally obtained B_1 fields for individuals channels can be used to provide real-time optimization. Other applications will be introduced such as RF localization for improved local SNR (Figure 2) and B_1 optimization combined with local/global SAR constraints and/or minimization for numerical data where all field components are available Figure 3.

Numerical considerations for B_1 optimizations will then be described. Many optimization routines are available through commercial software, but all do not necessarily suited equally for the same desired shimming profile. Performance metrics such as speed and reliability will be discussed for several methods. Conventional methods include gradient and search-based solvers, but newer techniques for dealing with the numerous local minima of the problem have also been suggested [3]. The target objective function for these functions is critical to explain, especially the weighting in multi-parametric optimizations where B_1 field homogeneity and SAR are jointly considered.

Finally, practical concerns when implementing these methods in real-time will be addressed. This will span a variety of topics from operating experience, including improving the speed of computations through parallel computing to physical modifications to coil setups, such as the placement of RF splitters and phase-array cables, to achieve the desired effect of the shimming results. Particularly, the end-user functionality of the GUI will be used to help emphasize the value to immediate, real-time scanning for *in-vivo* studies at UHF. Real numerical results from experiments and FDTD simulations with a 20-Channel transmit coil using pTX for B_1 shimming will be presented as evidence.

Summary: To have the highest degree of RF control at 7T and beyond, B_1 shimming is an essential tool for MR engineering. The underlying principles are very simple; however, basic guidance can improve the speed and efficiency with which this method is applied. Instruction will also expose individuals to other B_1 shimming considerations, such as SAR measurements in numerical data. In addition, a well-informed individual should easily be able to recreate the presented GUI to facilitate their own UHF research. The intent will be to have attendees investigate the software first-hand on a laptop PC.

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