Obtaining Localized Excitation in Human Abdominal Organs at 7 Tesla

T. S. Ibrahim[1], R. Abraham[2]

[1]Electrical and Computer Engineering, The University of Oklahoma, Norman, Oklahoma, United States, [2]Electrical and Computer Engineering, University of Oklahoma, Norman, OK, United States

INTRODUCTION:

An MRI system operating at 7 Tesla (classified as ultra high field MRI) could generate images with substantially higher signal-to-noise ratio than what is possible with current clinical MRI machines. Unfortunately, it is extremely difficult to design whole-body RF coils at such high fields, largely because of the complexities associated with obtaining excite/receive fields with suitable uniformity throughout loads as large as the human abdomen. In many medical applications, however, it is not necessary to image across the entire abdominal volume. Rather, images of only specific organs are necessary. In such applications [1,2], it would be beneficial to have high intensity and uniform excite field within the organ of interest, and low intensity excite field outside that organ. In this paper, using computational electromagnetics simulations, we propose a technique that is capable of maximizing the excite field in the three-dimensional volume of the human heart while simultaneously minimizing it in the surrounding tissues.

METHODS:

A finite difference time domain grid of a 32-port, 7 Tesla Transverse-electromagnetic whole-body coil was created and loaded with a human body model (acquired from the Visible Human Project). A rectangular volume was selected around the heart such that the heart would comprise 20% of the total body tissue inside the volume. Then, optimization routines were implemented in order to minimize the excite field intensity outside the heart and within the specified rectangular volume while maximizing excite field intensity inside the heart. Parameters were also input into to the optimization parameters to ensure good excite field uniformity inside the heart volume, as well.

Briefly, the optimization method was performed by first running the FDTD code 32 times after the coil was numerically tuned, each time corresponding to excitation from a different drive port. In each of these runs, the Fourier Transform (at approximately 298 MHz) of the magnetic field was calculated over the aforementioned 3-D volume that contains the heart. The superposition of these 32 3-D matrices represents the magnetic fields in the volume resulting from all 32 ports driving simultaneously. Gradient based and genetic algorithm functions were then used to determine the amplitudes and phases that should be applied to each 3-D volume such that the superposition of the 32 matrices would have 1) excellent uniformity in the heart, 2) maximized excite field intensity in the heart, and 3) minimized excite field intensity in the regions surrounding of the heart These magnitudes and phases can then be used to determine the specific excitation parameters that should be implemented on the real coil's excitation ports in order to realize the predicted optimization results.

RESULTS AND CONCLUSIONS:

When utilizing the 32-port optimized excitation mechanism, localization of the B_1^+ field over *three-dimensional volumes* of size comparable to many organs in the abdominal region can clearly be achieved. This is demonstrated in Figure 1, in which the result of performing localized RF excitation over the heart region is shown. The figure shows axial, coronal, and sagittal slices through the heart, the specified rectangular volume, and the exterior body region from eight different perspectives. Clearly, excellent B_1^+ field localization was accomplished. The average value of the B_1^+ field inside the heart over the average value of the B_1^+ field outside the heart contained inside the rectangular volume was ***4 over 1***. Such localization was also tested with success on other organs such as the pancreas and the liver. These simulation shows clear potential for utilizing optimized coil excitation to obtain images of various abdominal organs at 7 Tesla field strength.

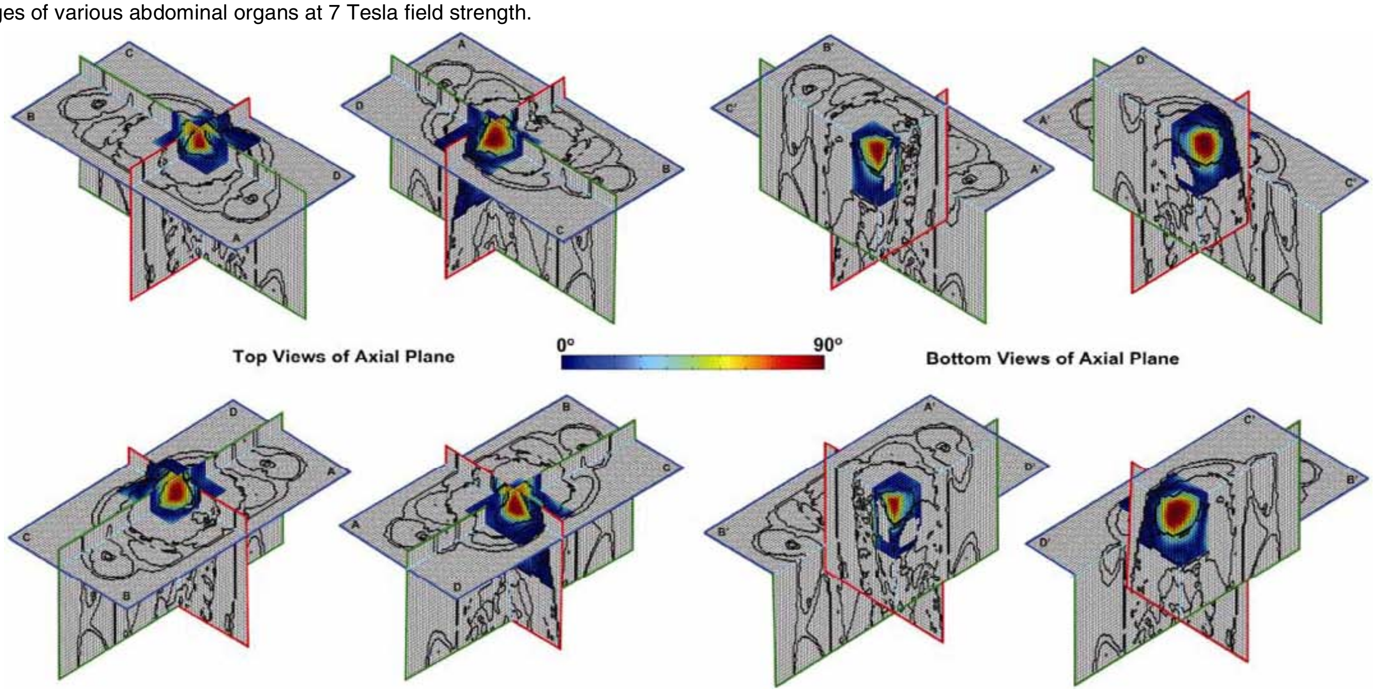

Figure 1: Axial, coronal, and sagittal slices through a specified rectangular volume that encapsulates the heart and the exterior body, showing the excite field distribution after 3-D optimization was performed to localize the excite field in the heart (by maximizing its intensity in the heart and minimizing its intensity in the surrounding tissues contained in the specified volume). Note that heart volume comprises 20% of the total volume through which the excite field is shown in these figures.

REFERENCES:

[1] Keong, B, et al., *Magn Reson Med*, (53)1251-7, 2005.

[2] Hardy, CJ, and Cline, HE, *J Magn Reson*, (82)647-654, 1989.