# A Single-Shot Optimization to Achieve Homogenous 3-D Whole-Body Excitation at 3 Tesla

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**Introduction:** Utilizing higher field strengths for MRI abdominal applications would result in many substantial advantages compared to today's lower field systems [1-3]. These advantages include higher resolution, higher SNR, and reduced scan times. However, the lack of RF coils capable of producing the required $B_1^+$ field uniformities in the load is the major obstacle preventing these systems from becoming clinically feasible. In this work, utilizing the finite difference time domain (FDTD) method, we propose a phased-array 3D excitation scheme (different than the typical 2-D optimization [2] applied only over a single slice at a time) to be applied on a 3 Tesla whole-body RF coil. The proposed scheme optimizes the amplitudes and phases of the voltages applied to the coil's drive ports at a single shot to maximize the $B_1^+$ field homogeneity in the *entire 3D abdominal portion of the human body* loaded in the coil cavity.

**Methods:** A 6 mm resolution FDTD grid of a 3 Tesla TEM based [1] body coil was generated. The coil is 39 cm long, and has an outer shield diameter of 69 cm. An anatomically detailed body model of an adult male (acquired from Brooks Air Force Base) was used as the coil load. The FDTD mesh of the coil with the body loaded is shown in Fig. 1. The coil was tuned (with the body model loaded) such that mode 1 of the coil lied at the appropriate frequency for 3 T imaging (approximately 128 MHz), by altering the gap between each pair of the inner struts and measuring the coil frequency response resulting from coil excitation. Then, using a variety of numerical optimization algorithms, the amplitudes and phases of the voltages applied to the coil's 32 drive ports were optimized to produce the lowest $B_1^+$ field standard deviation through a 33 cm long abdominal portion of the loaded body. (Note that all standard deviations provided in this work have been standardized by dividing by the average of the data set; therefore, they can meaningfully be compared amongst each other.)

**Results:** Figs. 2 and 3 show the results of the 3D 32-port optimization. Fig. 2 shows the standard deviations in all axial, coronal, and sagittal slices that comprise the 3D volume, for both the optimized excitation as well as standard quadrature excitation, i.e. constant amplitudes and progressive phase shifts applied to the drive voltages (which was used as the initial condition for the coil excitation in the optimization routine). Fig. 3 shows the optimized $B_1^+$ field distributions through regular samples of axial, coronal, and sagittal slices through the 3D volume.

**Discussion and Conclusions:** From Figs. 2 and 3, it is clear that compared to standard quadrature excitation, the optimized phased-array excitation scheme is capable of significantly increasing the uniformity of the $B_1^+$ field throughout the *3D abdominal portion of the load* encapsulated within the coil cavity. The $B_1^+$ standard deviation of the entire volume resulting from standard quadrature excitation was 0.235, while the standard deviation resulting from the optimized excitation was 0.0897. These results show promising potential for using variable amplitude and variable phase optimized excitation to obtain highly homogeneous images of large volumes at 3 Tesla.

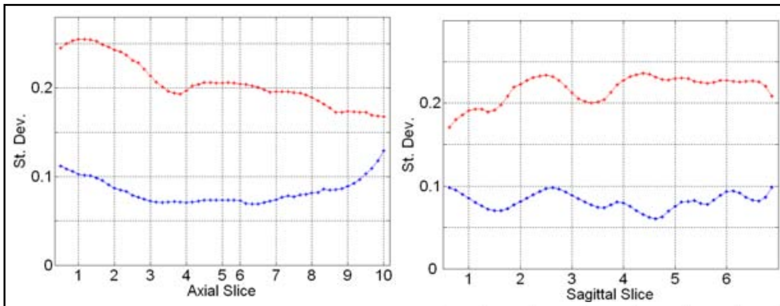


Fig. 1: 3D view of the human body mesh loaded inside TEM coil. (Note that a quarter of the outer shield has been removed in this figure to provide visual access inside.)

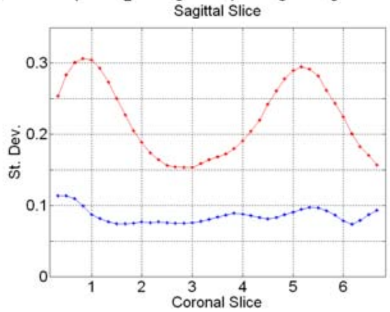


Fig. 2: Standard deviations for the optimized excitation (for maximum $B_1^+$ field homogeneity) (blue) and standard quadrature excitation (red) through of all axial (top left), sagittal (top right), and coronal (bottom right) slices that comprise the 3D abdominal volume enclosed within the coil's cavity. Note that particular slices are labeled to match the slices shown in Fig. 3.

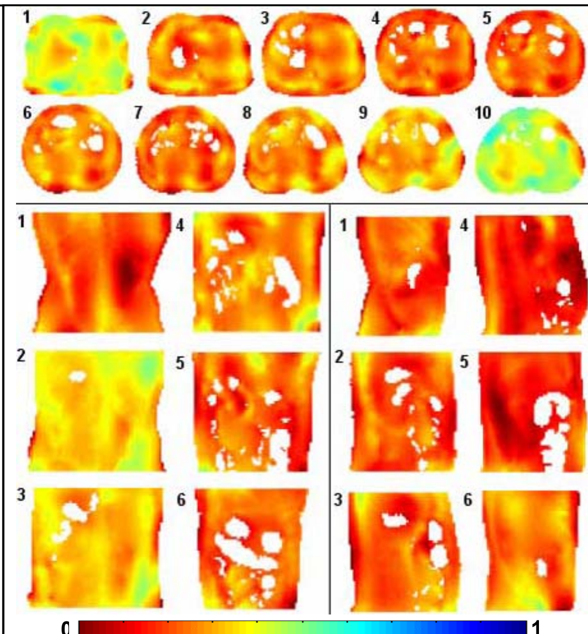

Fig. 3: Slices showing the $B_1^+$ field through the 3D abdominal volume (encapsulated within the coil, as shown in Fig. 1) that was optimized at a single shot for maximum homogeneity utilizing 32 excitation ports. Axial, coronal, and sagittal slices are shown in the specified abdominal region. The slices are numbered to correspond to the slices labeled on the x-axis of Fig. 2.

**References:**
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