Matrix Shimming for Whole Body Gradient coils

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Introduction

A resistive shim coil set integrated into the gradient coil is an important tool for high-resolution imaging, especially brain imaging. The traditional high order shim coil is composed of spherical harmonic coils and requires the individual shim coils to have crossing points which will increase the radial build dimensions. The matrix array shim coil [1, 2] reduces the radial build dimension and will permit the integration of the matrix array into a smaller radial space. The matrix array shim coil also has the potential to offer increased static magnet field corrections over the traditional shim coil design for improved image quality. A 28 channel matrix shim array coil was designed and integrated into a wide bore gradient coil to permit resistive shim corrections and improve image quality.

Matrix Shim Array Simulations

Computer simulations were executed to determine on "optimal" solution to generate higher order spherical harmonic terms while seeking to minimize the number of independent shim coils and reduce the number of independent shim coil drivers required. A matrix shim array of 7 coils around the circumference and 4 coils along the axis was determined to be a solution in this design space. The configuration is shown in Figure 1. Two of the loops are nested in each have of the gradient coil. The matrix array was used to simulate the effects on a clinical brain scan to demonstrate the performance of the new array. Figure 2 demonstrates the effect of the shim matrix on two slices near the sinus cavity of the brain. The width of the field homogeneity is shown in Figure 3 for comparison demonstrating the improved shimming capability with the matrix shim array coil over a traditional 3rd order spherical harmonic shimming capability.

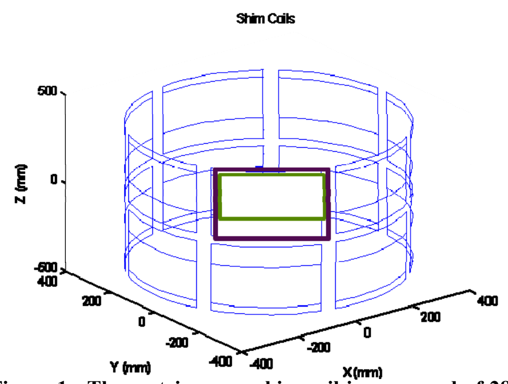

Figure 1. The matrix array shim coil is composed of 28 channels in a 7 x 4 array configuration. One coil is outlined in purple and 1 coil is outlined in green forming a pair of shim matrix coils.

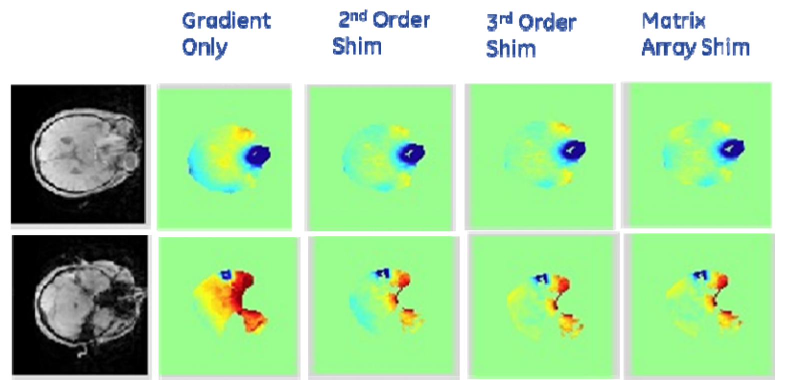

Figure 2. The magnetic field homogeneity is compared between a linear, gradient only correction and 2nd, 3rd and matrix array shim coils. The 80% width for the matrix array shim coil is superior to 3rd order corrections with spherical harmonic shim coils.

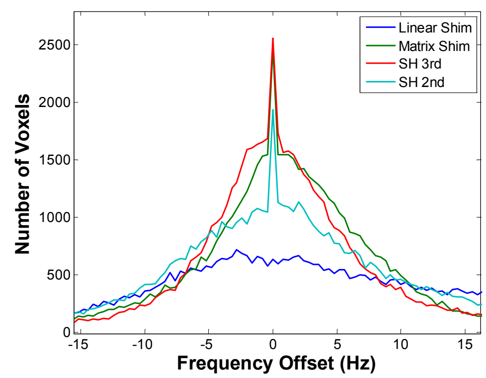

Figure 3. The 80% spectral width for the entire brain ROI reduces from 64 Hz for the linear shim, 32 Hz for the 2nd order harmonic system, 24 Hz for a 3rd order harmonic system and 22 Hz for a 28 channel matrix shim.

Matrix Shim Array Coil Integration

Each of the 7 circuit boards coils of the matrix array shim coil is constructed from a multi-layer Kapton circuit board enabling the shim coil board to be formed to the correct radius for integration into the gradient coil. The shim coil contains 6 layers of winding with each layer having 22 turns for a total of 132 turns per coil. The 7th layer of the Kapton circuit board is used for lead routing to the individual shim coils. The matrix shim coils are placed between the inner and outer gradient coils and require only 2.0 mm of radial space. One of the seven shim boards is shown in Figure 4. The shim boards are placed immediately on top of a gradient cooling circuit to provide addition cooling to the matrix array shim coils. An integrated matrix array shim set into a widebore gradient coil will be demonstrated with improved homogeneity.

Figure 4. One of the Kapton circuit boards is shown that is impregnated into a widebore gradient coil to evaluate the image quality.

1. Juchem, et al. "Dyanamic Shimming of the Human Brain at 7T". Concepts in Magnet Resonance Part B. Vol. 37B, P116-128, 2010.
2. Juchem, et al. "Magnetic field modeling with a set of individual localized coils". Journal of Magnetic Resonance. Vol. 203, P281-289, 2010.