A Design Tool for Optimized RF Coil Array Design

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Introduction

In this work we describe a tool to aid in the RF coil design problem of determining the optimal number of coils elements to be used in a linear coil array for imaging the carotid arteries. Each coil's radius and position in the optimal array are determined and provide a simple estimate for the optimal number of coil elements to be used for imaging a tortuous vessel structure with position dependent depth.

Methods

We assume that a linear array of variable sized circular or square loop coils is placed on the flat surface of a semi-conducting half-space over a vessel of some arbitrary depth along the length of the surface. In this 2D model we assume the low frequency limit such that coil noise is primarily caused by the electric coupling to the sample and that the magnetic fields are due to the electric currents in the coil[1]. A user defined FOV in the x-direction defines the length of the vessel segment (see Figure 1), and the vessel structure is created using spline interpolation of specified vessel-depth / x-location coordinates. Number of coil elements in each array is varied from 1 to 10. Each element in an array is varied in its diameter (from 2 to 20 cm) and position (along the length of the vessel) for all possible combinations of coil size and position. For our current studies, coils are not overlapped to simulate arrays more suitable for parallel imaging. For each element of a given array, signal sensitivity at a point in the vessel is obtained using analytical off-axis equations [3,4] for the transverse component of a B-field ($B_z + jB_y$) resulting from a unit current in the loop[2]. The estimates of the power dissipated in the sample[5], and the coil ohmic losses[6], are used together to estimate the noise for each coil. Correlated noise between coil elements is computed to obtain the noise correlation matrix, Ψ. Radiated losses are assumed to be negligible.

For each array, the average SNR along the length of the vessel is computed. The composite SNR at each point in the vessel is computed using the optimal image reconstruction algorithm for the coils in the array, $SNR_p = \sqrt{B^T \Psi_{ij}^{-1} B^*}$, where B is a matrix representing the coil sensitivities at the vessel point. For each array size (number of elements), the optimal array configuration (that with highest average SNR) is determined providing details of the best coil sizes and positions for that particular array.

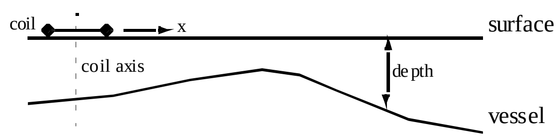

Figure 1: Carotid artery simulation model

Results

This optimization tool provides interesting information using a single circular coil array and various vessel lengths. Figure 2 shows the relationship between optimal coil radius versus vessel depth for both long and short vessels.

A carotid vessel is simulated as having a 20-30 cm length from the aortic arch to the circle of Willis. The vessel depth is 5-6 cm at the arch (x=0 cm), 2-4 cm at the bifurcation (x=12 cm), and 8-10 cm at the circle of Willis (x=25 cm). This optimization process results in the graph shown in Figure 3.

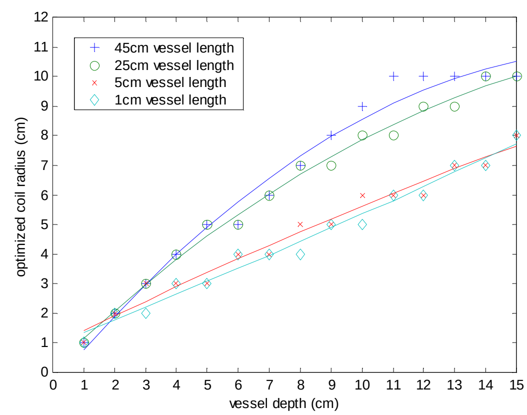

Figure 2: Optimal radius of coil vs. vessel depth

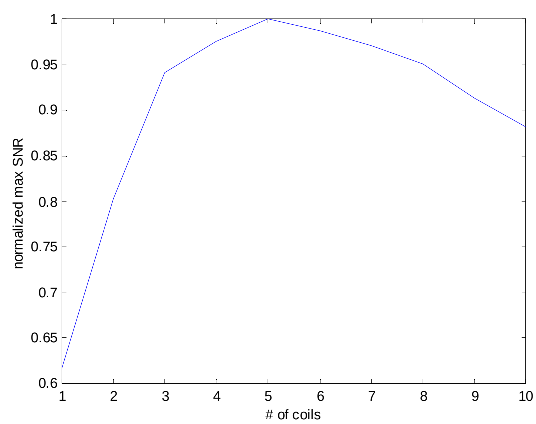

Figure 3: Example plot of normalized vessel SNR vs. number of coils used to image the carotid artery.

Discussions and Conclusions

We have developed an RF coil design tool that aids the researcher in establishing the number of coils and their approximate sizes and positions linear coil arrays for arbitrary depths along the array. Although this model is simple, it provides a good approximation of the coil array needed for imaging any given carotid artery. It provides the ability to study the variation in coil arrays that will best image various types of vessel segments (deep vs. shallow / long vs. short vessels, etc.). Finally, we note that we studied only the 2D problem of placement along the artery. The final result may include bilateral pairs of coil elements.

Acknowledgments

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