Design of a Highly Sensitive 12-Channel Receive Coil for Tongue MRI

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Introduction

Using MRI to study the structure-function relationship of the normal and impaired human tongue presents some unique challenges. The tongue, a highly mobile and anatomically complex organ in the oral cavity, is difficult to image due to the presence of air, multiple types of other adjacent tissue, and potential voluntary and involuntary movement. Our *in vivo* tongue studies, conducted using 4-channel and 8-channel neurovascular phased array coils in a 3.0T system (GE Signa HDx), often were confronted with the issues of inadequate SNR, susceptibility artifacts, field inhomogeneity, and/or unacceptably long scan times. These coil arrays encompass a larger FOV than required and provide only a few oversized elements to cover our region of interest. Therefore, we have designed a 12-element phased array that focuses on the lower face and upper throat. Small surface coil elements were contoured to fit the lower face and follow the offset under the chin should give a higher SNR. Their better spatial differentiation should also permit a high acceleration factor with parallel imaging.

Coil Design and Construction

The desired FOV extends in the superior-inferior direction from above the hard palate down the throat to the level of the C3 vertebra and in the anterior-posterior direction, from several centimeters in front of the lips to the anterior surface of the cervical spine. Our coil configuration consists of five subgroups of elements: three longitudinal pairs and two longitudinal triplets (see Fig 1). The coils in each subgroup share a common conducting element along one edge (e-e in Fig. 1) but form two layers along the opposite side (the under layer is dotted). The top two bands of five coil elements each are mounted on a thin plastic substrate that wraps around the lower face. The third coil of each triplet extends down the side of the neck and is encased in a flexible foam cover that allows it to curve under the chin for a tighter coupling to the neck region (Fig. 1b). The overlaps between neighboring coil elements form three different areas: *a*, *b*, and *c* in Fig. 1. The contour of the coil elements were adjusted so that area *b* cancels the mutual inductive coupling between diagonal elements. The sum of the areas *a* and *b* cancel the coupling between the circumferentially adjacent coils. The overlap *c* between longitudinally adjacent coil elements is larger than that needed to cancel mutual inductive coupling. For coils spaced along the z-direction with the conventional overlap, the SNR profile shows two peaks with a valley where the coils intersect. The overlapping area c was enlarged to eliminate the valley and give a flat SNR response along the z-direction. The resulting excess mutual inductance can be canceled with the decoupling capacitor Cd placed in the common conducting element.

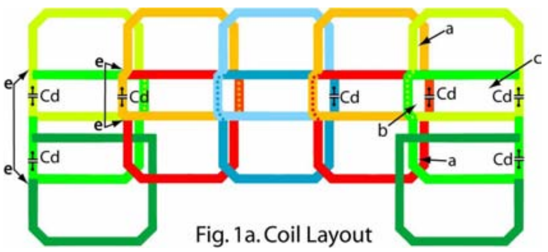

Fig. 1a. Coil Layout

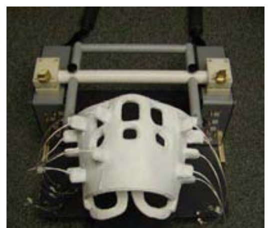
Fig. 1b. Array with Preamps


Fig. 2a. RF Trap Coaxial Inductor


Fig. 2b. Trap with Etched Capacitors

Each coil element is connected to a 27dB-gain, low–input-impedance preamplifier (Rich Spring Technologies, Arcadia, CA) located in a box on either side of the head. Each coaxial cable posed between the coil element and the preamp is fitted with an RF trap to eliminate multiple ground connections to different points on the subgroup's common conductor and to prevent spurious eddy currents in the shields of the coax. The RF trap consists of three turns of 0.040" semi-rigid coax (Fig. 2a) inside a cylindrical shell (Fig. 2b) made from double-sided Teflon circuit board. The outer surface of the Teflon is etched to form two capacitors between two outer conducting pads and the common inner pad. The outer pads are segmented into many smaller, binary weighted pads connected with small bridges. The traps were tuned to 127.72MHz by cutting a sufficient number of the bridges with a file.

The preamp boxes are mounted on a base plate that serves as the platform for an adjustable headrest padded with memory foam. Care was taken to maximize patient comfort since the MRI studies for our research protocol can require more than an hour of scan time. The two preamp boxes serve as the base of a pivoting cross bar that holds an adjustable cantilever connected to the facemask coil array. The coil array can be held close to the face or folded up and back to permit patient entry and exit. The outputs of the two preamp boxes were connected to the scanner's A and B input sockets by way of two cables that were each fitted with a single RF trap. The latter trap consists of two concentric conducting cylinders that are connected at each end by several capacitors in parallel.

Results

Initial imaging results indicate greatly enhanced SNR in the regions proximal to the new array's smaller coil elements (see representative images from one subject in Fig. 3). Relatively, the signal is weaker at the back of the tongue near the front of the upper cervical vertebrae. Our quantitative measurements of the SNR in phantoms have been compromised by the available phantoms which do not mimic the contorted contours of the anatomy of interest. The 8-channel neurovascular array and our new array are not equivalently loaded by the phantom; consequently, their noise performance was not comparable. Imaging of four human subjects with both coil arrays has been performed to obtain average signal strength for different tissue locations in the tongue. The noise levels derived from the air region outside the subject were compensated to account for the different number of coil elements in the two arrays. Fig. 4 is a plot of the scaled SNR vs. depth for both arrays for the subject in Fig.3.

(a) (b)

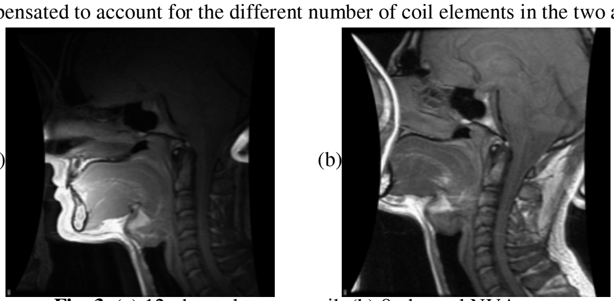
Fig. 3. (a) 12-channel tongue coil; (b) 8-channel NVArray.

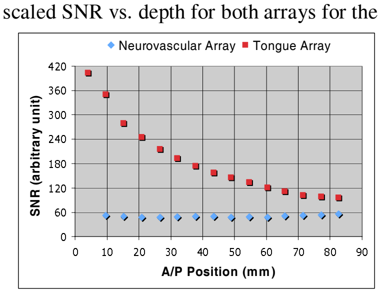

Fig. 4. SNR as a function of depth for tongue coil (red) and NVArray (blue).

Discussion

Although the current coil design presents greatly improved SNR in the anterior 2/3 of the tongue, the weak signal in the posterior region of interest renders this 12-channel tongue MRI coil less than optimal. To improve the overall signal intensity, we are adding four more coil elements to provide coverage for the posterior tongue. Our tongue coil array, though highly specialized, utilizes several new design features that can be applied to construct other complex, multiple-element coil arrays for imaging regions such as the carotid arteries, breast, axilla, and skeletal muscles in the extremities.