A 7T Halo Loop Resonator for Registration of 31P MRSI

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Introduction

MRI images obtained at 7 Tesla from a small diameter loop-resonator can exhibit excitation and reception that are many coil diameters removed from the conducting elements of the resonator. Webb and coworkers recently demonstrated this by obtaining images of the entire human leg using an 8 cm diameter single loop ^{1}H (300 MHz) RF coil [1], and postulated the existence of traveling dielectric waves [2] as the mechanism for the extended coverage. A potentially important application for such an RF coil is when used in combination with a single-tuned heteronuclear RF coil. In such a configuration the small coil could provide high-resolution 'scout' images to improve heteronuclear acquisition planning, B_0 optimization, and post-acquisition registration with a dedicated independently acquired high-quality ^{1}H MRI dataset. Accurate coregistration is an important step to properly attribute signal to the appropriate tissue type in large heteronuclear voxels. This method does not require careful subject positioning procedures when employing separate heteronulcear and proton coils or complicated dual tuned resonators. Here, we describe the results of combining a small loop ^{1}H RF coil with a ^{31}P single tuned RF coil at 7T.

Methods

The ^{31}P resonance frequency at 7T is 3 MHz below ^{1}H at 3T. A simple retuning of an old 12 leg high pass birdcage coil for 3T ^{1}H allowed spectroscopic imaging on a Siemens 7T Tim Trio imaging system. An 8 cm loop resonator tuned to 297 MHz was constructed following the design published by Webb [1]. The loop coil can be oriented such that the loop is normal or parallel to the polarizing $\mathbf{B_0}$ field direction.

Results and Discussion

Preliminary experiments with the 8 cm loop coil were performed to assess the range of coverage that could be obtained. The first tests on a phantom consisting of a tube 1 meter in length and 9 cm in diameter containing 50 mM saline solution showed coverage expected by the familiar pattern for the RF near field produced by a thin loop when oriented both parallel and perpendicular to $\mathbf{B_0}$ and placed near the phantom. The parallel orientation, which is not normally used for MRI reception, does offer significant near field excitation from the radial components of the RF field. Only by replacing the 70 mM saline with pure water did we observe extended signal coverage beyond that expected from the near field excitation profiles. These observations are in accord with similar results that demonstrate the damping of standing wave patterns in a spherical phantom of water by the addition of saline [3].

The human body of course does not have the dielectric properties of saline and presents a more complicated geometry than a simple tube. Placement of the loop coil for acceptable ^{1}H density maps of the human head was determined experimentally. The configuration chosen is illustrated in **Figure 1**, where the loop is positioned just above the head and oriented axially. An example of a typical proton density map obtained from this configuration and used for registration of ^{31}P spectroscopic imaging is given in **Figure 2**. The image is a 2D FLASH with TE of 2.5 ms, TR of 100 ms. The resolution is 0.9mm x 0.9mm x 5mm, 32 slices with a 1 min acquisition time. The FLASH image shows extended excitation can be obtained from an axially oriented loop coil. The excitation pattern also does not show a dark central area characteristic of an excitation pattern expected from a loop where the radial component of the near field RF vanishes. The intensity remains fairly constant as a function of distance from the loop plane and remains significant even at the brain stem. A more complete analysis of the intensity variations is in progress. We note that the presence of the loop did not interfere with the operation of the ^{31}P coil, suggesting negligible coupling between both structures. This is due to the isolation produced by frequency difference as well as geometry. The small loop coil used in the configuration shown in **Figure 1** provides an important set of in situ ^{1}H MRI scout images that greatly facilitate co-registration of ^{31}P MRSI data set with high quality ^{1}H MRI acquired in an independent scanning session (see **Figure** 3 – which shows an overlay of ^{31}P MRSI data and ^{1}H MRI).

References

[1] Webb MRM 63: 297-302(2010) [2] Brunner Nature 457: 994-997(2009) [3] Yang MRM 47:982-989(2002).

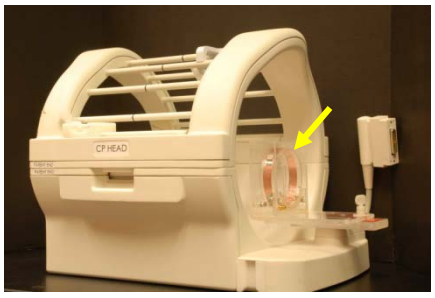

Figure 1. ^{31}P Birdcage Coil with ^{1}H Loop Coil indicated by arrow.

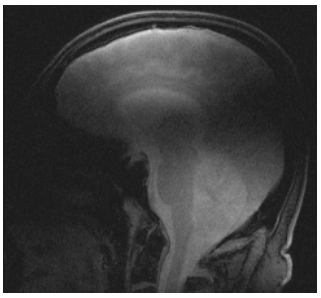

Figure 2. 2D Flash Image taken with ^{1}H loop RF coil suitable for registration.

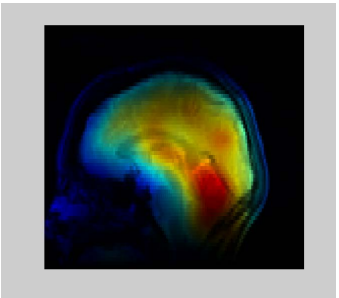

Figure 3. Post-acquisition coregistration facilitated by use of the in-situ ^{1}H scout images