Dual tuned, $^{13}C/^{23}Na$ low pass birdcage coil

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Introduction

RF structures that resonate at more than one frequency are becoming useful in an increasing number of MR applications. One of the most recent and promising developments in MRI, monitoring metabolism in real time through ^{13}C MRI of hyperpolarized compounds [1], relies heavily on such multi-resonant coils. Many pulse sequences need properly calibrated flip angles and a well-shimmed anatomy in order to produce high SNR, artifact-free images. Traditionally, shimming and flip angle calibration are performed in prescan, at the same frequency as the one used for imaging. In hyperpolarized agent scans, such scan preparation procedures need to be performed prior to agent injection, due to the fast decaying signal after injection. Scan preparation is difficult or impossible to achieve at the ^{13}C frequency due to the limited availability of the natural abundance ^{13}C signal, and needs to be performed at a different frequency such as that of proton or sodium. We present here simple dual tuned $^{13}C/^{23}Na$ birdcage coil which may be used in such situations, and demonstrate its performance at both the ^{23}Na and ^{13}C frequency.

Methods

A 16 rung (9 cm diameter, 18 cm length), 1.5T low-pass birdcage rat coil is presented here. The coil was nominally built to resonate between the two resonant frequencies of interest (16.06MHz for ^{13}C and 16.89MHz for ^{23}Na). Changes in the capacitor values on the rungs lying in two orthogonal planes were then made to break the symmetry of the coil and force the existence of 2 linearly polarized fields, in a manner similar to the one described in [2] for a high-pass coil. More precisely, the values of the capacitors C_4, C_8, C_{12} and C_{16} (as well as C_{14}—the balancing capacitor) were changed with respect to the other 11 equal capacitors. A 500 mL phantom, consisting of 2 concentric cylinders, containing 100mM concentrations of NaCl on the outside, and 7M ^{13}C-labeled sodium acetate on the inside was built to evaluate the performance of the coil at the two frequencies. We scanned the phantom inside this coil using a gradient echo sequence with a 40 cm FOV, 20 mm slice thickness, minimum full echo time, and TR of 50 ms (^{23}Na) or 1 second (^{13}C). To assess the homogeneity of the two modes, we acquired axial and sagittal images of 500 mL phantoms of corn oil (for ^{13}C) and 140mM sodium chloride (for ^{23}Na) using the same gradient echo imaging sequence. The phantoms filled the coil almost completely.

Results and Discussion

Figure 1 presents a plot of the reflection coefficient (S11) for the ^{13}C channel (Figure 1a) and ^{23}Na (Figure 1b), as well as the transfer function (S21) for transmitting on the ^{23}Na channel and receiving on ^{13}C. The unloaded Q of the ^{23}Na channels is 138, while the Q of the ^{13}C channel is 127. As evident from Fig. 1c, the two channels have some residual coupling; this should not present any problem *in vivo*, since the typical excitation pulses used *in vivo* do not have the bandwidth to excite both frequencies simultaneously. Figure 2 presents gradient echo images at the ^{23}Na (Fig. 2a) and ^{13}C frequencies (Fig 2b) of the concentric cylinder phantom described in Methods. Figure 3 presents representative axial and sagittal images from the sodium chloride phantom, with plots of the signal intensity measured along the indicated contour lines. The mean intensity for the axial image was 188 +/- 13, and the sagittal was 213 +/- 12. Results for the natural abundance ^{13}C images were similar, but noisier. As evident from these images, the B_1 homogeneity of these images is quite good, as no significant bias is noted at the edge of the field of view. The 5-6% standard deviation noted in the signal is a consequence of the low SNR of the low γ nuclei scans, and not of poor B_1 homogeneity. We have also verified that the coil may be operated by two different methods. In the first approach, one can connect one channel at a time through a single T/R switch. The appropriate channel is manually connected when changing the scanner transmit/receive frequency. Both channels can also be connected simultaneously through a quadrature hybrid, and switching between a mode and the other can be accomplished by simply changing the T/R frequency of the scanner. The second operation is more convenient; however, it requires using twice the amount of power (as half the power is transmitted into a non -resonant channel).

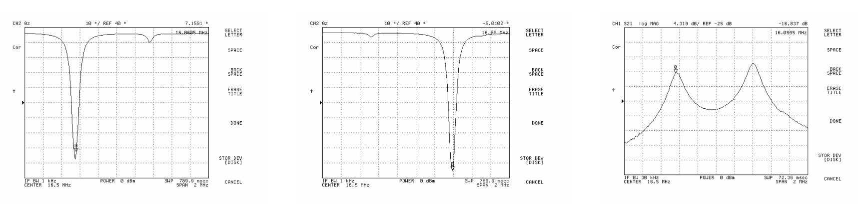
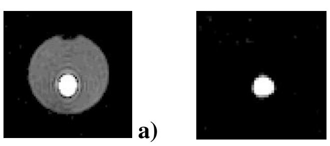
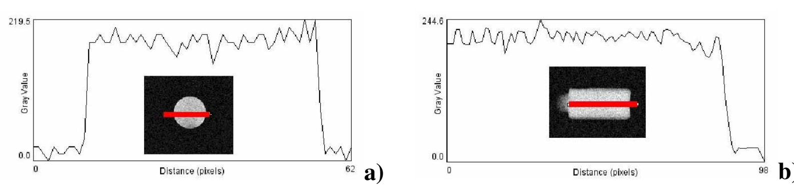


Figure 1: *S11 for the* ***a)*** *^{13}C and* ***b)*** *^{23}Na channel.* ***c)*** *S21 for the dual tuned coil*



a) b)

Figure 2: **a)** *^{23}Na and* ***b)*** *^{13}C image using the dual tuned birdcage coil*



a) b)

Figure 3: **a)** *Axial and* **b)** *Sagittal ^{23}Na images and signal intensity profiles acquired with the dual tuned birdcage coil.*

Conclusions

We have shown an implementation of a practical $^{13}C/^{23}Na$ coil, which may be useful in situations where scan setup steps for ^{13}C scans are performed at ^{23}Na frequency. This low pass birdcage coil is forced to operate in 2 linear modes tuned to the ^{13}C and ^{23}Na frequencies by a change in capacitor values on two orthogonal sets of birdcage rungs. Alternatively, a switched frequency low pass coil can be envisioned having equal capacitors for both frequencies, but slightly longer rungs for the ^{13}C frequency. The additional rung length can be added using varactor diodes. Since such a coil would retain its symmetry, this implementation would permit quadrature drive, therefore a 40% signal to noise improvement for imaging at both frequencies.

References

1. Golman et al, PNAS, **103(30),** 11270 (2006); **2.** P. Joseph et al, IEEE Trans on Med Im, 286 (1989).