An Optically Detunable Coil for Improved Self Gating in Small Animals

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Introduction

In MRI physiological gating is typically performed with additional sensors such as breathing belts or ECG electrodes. In small animal studies, these sensors are sometimes difficult to apply, and the trigger detection can be difficult, in particular if whole body MR systems are utilized. A convenient alternative for physiologic triggering is the use of motion-dependent MR signal variations (self-gating, SG) [1, 2].

In small animal MRI the acquisition of SG-data can be challenging, if volume coils encompassing the whole animal are used. The SG signal can be increased with dedicated local coils (e.g., a heart coil); however local coils do not provide a homogeneous image of the whole animal. The combination of a heart coil and a coil that images the whole body requires additional receive channels. In this work we present a hardware solution to increase the sensitivity of the SG signal at the heart region while the image remains homogeneous.

Materials and Methods

Inductively coupled coil

For enhancement of the SG signal an inductively coupled coil (SG-Coil) [3] was built by etching a 18 mm × 10 mm loop structure on a circuit board. The coil was tuned to the proton resonance frequency at 1.5 T (i.e., 63.7 MHz), using non-magnetic capacitors (C) (Fig 1). To be able to dynamically detune the coil [4], the capacitor was shunted with two PIN-Diodes (V_2 and V_3) connected to a photo diode (V_1). Under illumination, the photo current of the photo diode, switched the PIN-diodes into the conducting state, thereby detuning the coil. To achieve a sufficiently high photo current the optical detuning signal was created by a laser diode (5mW light power) and conducted to the photo diode via an optical fiber.

Self Gating Experiments

Self Gating was performed on a 25 g mouse in a 3-turn solenoidal receive-coil built in-house (inner diameter 36 mm). The relative position of the SG-coil to the receive-coil was chosen such that only a moderate amount of coupling occurred (no split of resonance frequency). Then the chest of the mouse was positioned on the SG-coil to maximize the physiologic signal variations.

Image Acquisition

The MR pulse sequence used for the SG-experiments was a flow compensated 2D gradient echo sequence (TR/TE=14/6,06 ms, α=25°) with an additional ADC event prior to phase encoding [5]. The data from this SG-ADC event were sampled for each k-space line to determine the physiologic trigger. Gating was performed retrospectively by reordering the image data according to the periodic changes of the SG signal intensity. During rf excitation and image data readout the inductively coupled coil was detuned using a gating signal supplied by the pulse sequence (Fig. 2) allowing the acquisition of a homogeneous whole-body image (situation 1). To assess the enhancement of the SG signal by the SG coil and to determine image homogeneity MR experiments were performed with the SG-coil detuned only during rf transmission (situation 2) and with the SG-coil detuned all the time (situation 3).

Results and Discussion

The Fourier transform of the SG signal in situation 1 is shown in Fig 3. The spectral component at 5 Hz represents the expected heart frequency of the mouse. To assess the SNR in the SG data, the baseline-corrected peak integral (*S*) was compared to the standard deviation *N* of low-signal areas between 8.5-9.5 Hz/7-9 Hz for transversal/sagittal slices. Table 1 shows the calculated SNR values for the three situations and two different image orientations. In those cases where the SG-coil was tuned during the SG-ADC event (situation 1 and 2) the navigator SNR was increased by a factor of 1.7 to 2.8 compared to that of the detuned SG coil. As an example, two self-gated sagittal images for situation 1 and 2 are shown in Fig 4. With the SG-coil detuned during the imaging ADC event the image inhomogeneities are reduced.

Conclusion

An optically detunable inductively coupled coil is an effective device for improving SG in small animal experiments. The SG-coil does not need an extra receive channel and is MR safe, since no long conducting structures are necessary for connection. The device is combinable with all common SG-pulse sequences that use an additional SG-ADC event.

Acknowledgements

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References

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Situation	1	2	3
Transversal	739	887	317
Sagittal	81	100	49

Tab 1. SNR for the three trigger situations and the two different slice orientations.

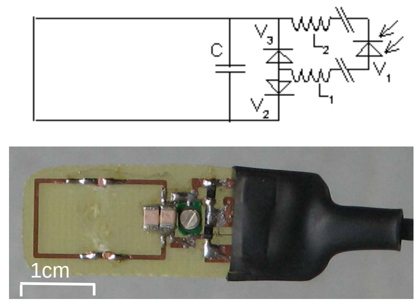

Fig 1. Top: Schematic of the inductively coupled coil with tuning capacitor C, pin diodes V_2 and V_3 for detuning, photo-diode V_1 and rf-chokes L_1 and L_2. Bottom: Photograph of the coil.

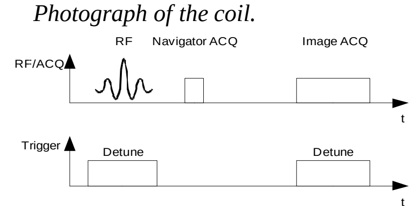

Fig 2. Sequence acquisition scheme. During the rf-pulse and the image acquisition the trigger was switched on, and detuned the inductively coupled coil.

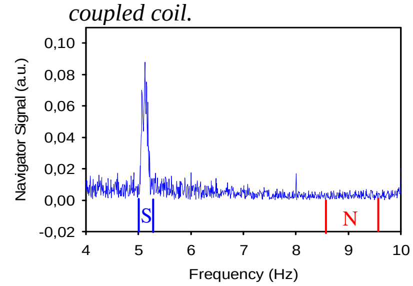

Fig 3. Part of the navigator signal in the frequency-domain (transversal slice, SG-coil on). A signal peak (S) occurs around 5 Hz while the low-signal band N was used for noise estimation and baseline calculation.

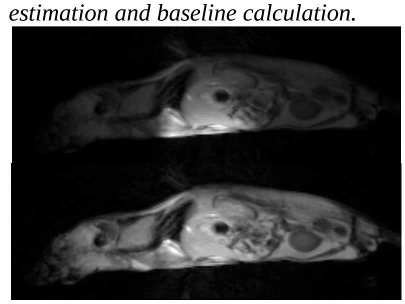

Fig 4. Self gated images of a mouse. Top: the SG-coil was switched on during signal reception, resulting in a highly inhomogeneous sample illumination (situation 2). Bottom: The SG-coil was only tuned during acquisition of the SG signal (situation 1).