A Self-Resonant Inductively Coupled Skin Chamber Coil for High Resolution MR Imaging in Small Animals

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Introduction

The interaction of different cell types with tissue in a living animal can be studied with the help of a skin chamber that is surgically implanted under the skin. The chamber contains a reservoir where cells are kept in contact with the host animal's tissue. Direct absorption of the cells is prevented by a separation layer (e.g. collagen), but mutual infiltration of the separation layer is possible both for the animal's stroma cells as well as the target cells. In longitudinal studies the growth of different biological structures such as blood vessels can be studied in this well-defined micro-environment.

Repetitive imaging of the skin chamber is preferentially performed using MRI since it allows for non-invasive visualization of the skin chamber's interior. To achieve the high spatial resolution required for imaging of tissues in skin chambers a local rf coil is needed. In this work we propose a self-resonant, inductively coupled rf coil that is directly integrated in the implantable chamber. The coil design is optimized for minimal space requirement and ease of fabrication.

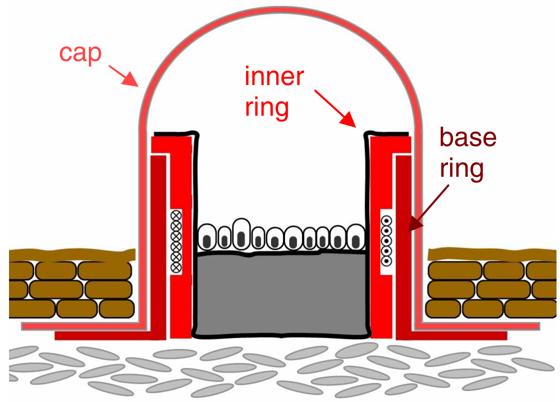

Fig 1: Cross-sectional view of a skin chamber consisting of an outer cap, a base ring and an inner ring. The coaxial cable forming the self-resonant rf coil structure is wound on the inner ring.

Materials and Methods

A commercially available skin chamber system for small animals (model 30268, Silicon Culture, Renner GmbH, Dannstadt, Germany) was used that consists of an outer cap, a base ring and an inner ring (Fig. 1). The inner ring was replaced by a custom-made coil former (PEEK, Ø = 10 mm). Six turns of a miniature coaxial cable (PicoCoax, AXON Cables, PCX42K10 AK, 50 Ω, Ø = 0.34 mm) were wound on the former and the inner conductor of one end was soldered to the outer braiding of the other. The dimensions and coil windings were chosen to achieve a self-resonant structure with a resonance frequency of 63.7 MHz [2]. Loaded and unloaded Q factors of the coil were measured with a network analyzer connected to two geometrically decoupled loop coils (S_{21}) that were placed under the skin chamber coil. During the measurements a weak coupling (< -50 dB) between all coils was maintained.

To assess the B_1 field amplification during signal transmission the skin chamber coil was imaged in a clinical 1.5 T whole body MR system (Magnetom Symphony, Siemens, Erlangen, Germany). The coil interior was filled with a physiologic saline solution doped with 1% Gd-DTPA contrast agent (Magnevist, Schering, Germany). Spoiled gradient echo images (FLASH) were acquired at different nominal flip angles between 0.25° and 50°. For each pixel in the image series a B_1 amplification factor was calculated from the ratio of the flip angle at maximum signal (i.e. the Ernst angle) versus the Ernst angle in a region outside the coil (i.e. without B_1 amplification).

A prototype skin chamber system was surgically implanted into a nude mouse. MRI was performed 3 weeks after implantation with a conventional head coil. FLASH images (TR = 141 ms, TE = 6.9 ms, FOV = 150 mm, matrix = 256^2) of the mouse were acquired at different nominal flip angles.

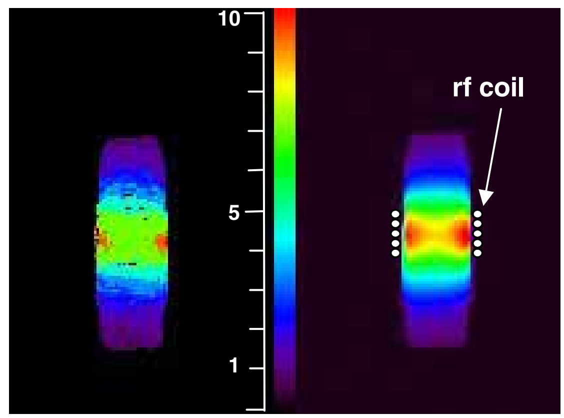

Fig. 2: Ernst angle ratio (left) and relative signal intensity at Ernst angle (right) in a small tube surrounded by the skin chamber coil. Near the coil windings an amplification of the B_1 field by a factor of 10 is seen.

Results and Discussion

The measurements of the Q factors yielded a value of 60 and 25 for the unloaded and loaded coil, respectively. The B_1 amplification maps of the coil show an amplification factor of about 10 / 8 near the coil windings / in the coil center (Fig. 2 left) which is consistent with the signal amplification at the Ernst angle (Fig. 2 right). In the animal experiment a very strong signal was seen at $\alpha = 10°$, whereas at higher flip angles saturation of the MR signal was present (Fig. 3). Both B_1 and signal amplification allowed for nearly background-free visualization of the skin chamber's interior with conventional MRI equipment.

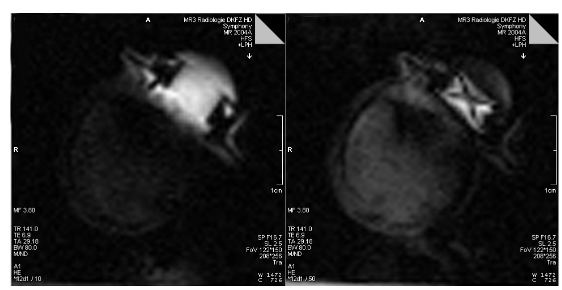

Fig. 3: FLASH image of the skin chamber acquired with a conventional human-size head coil and $\alpha = 10°$ (left) and $\alpha = 50°$ (right). At low nominal flip angles the MR signal of the mouse outside the coil is nearly completely suppressed.

References

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[3] Johns RH. QST, May 1981, 15-17.