Optimization of a RF Coil System for, Sequential, Co-Registered Fluorine and Proton Overhauser Imaging

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INTRODUCTION/PURPOSE

Because of several biological and clinical application [1] there is a considerable interest in obtaining fluorine (^{19}F) MR imaging at very low magnetic field (10-60 mT) via the Overhauser effect. It has previously been shown that, at low magnetic field (15 mT), an Overhauser enhancement of the ^{19}F MRI signal is observed from sample regions where an interaction of the ^{19}F nucleus with a paramagnetic solute is established [2]. Recently, a prototype RF coil apparatus suitable for fixed B_0 field (59 mT) Fluorine (Proton) Electron Double Resonance Imaging was reported [3]. Our aim was to develop and optimise a RF coil system capable of, sequential, co-registered Fluorine and Proton Overhauser Imaging. We refer to these techniques respectively as fluorine-electron double-resonance imaging (FEDRI) and proton-electron double-resonance imaging (PEDRI).

METHODS AND RESULTS

Since our final goal is to obtain FEDRI images *in vivo*, we have minimized the RF power deposition in the sample during the continuous wave EPR irradiation via a Field Cycled FEDRI technique (FC-FEDRI), analogous to field-cycled PEDRI [4]. To obtain 19F and 1H images we designed an RF coil assembly (Fig.1) comprising: an Alderman-Grant resonator for EPR irradiation at the evolution field of 4.5mT (127.7 MHz); a solenoidal coil for 19F or 1H MRI acquisition at the detection field of 59mT. For the latter purpose a removable tuning/matching box, that allows the solenoid to be tuned to the 19F frequency (2.346 MHz) or the 1H frequency (2.494 MHz) without removing the sample was built and tested. Switching of the tuning box between the 19F or 1H frequency is achieved in less than 1 min. A TEMPOL solution was used to enhance the NMR signal of the 19F nuclei (FEDRI) or 1H nuclei (PEDRI) via the Overhauser effect. The apparatus equipped with a vertical field permanent magnet and a resistive magnet, allows Field-Cycling between ~0 mT and 59 mT in less than 40 ms. First, we have acquired FC-DNP spectra of a sample tube (3 ml) containing 5 mM TEMPOL free radical dissolved in trifluoroethanol (TFE) at several EPR irradiation power levels (Fig.2). From these 19F (or 1H) spectra a suitable EPR power level for enhancing the FEDRI (or PEDRI) signals was determined.

FC-FEDRI and FC-PEDRI images were obtained by using two sample tubes (3 ml) containing 5 mM and 2 mM solutions of TEMPOL dissolved in TFE, respectively. The sequentially acquired, co-registered, FC-FEDRI and FC-PEDRI images are shown in Fig.3. The measured SNR of these images was about 6. The measured FC-FEDRI and FC-PEDRI Overhauser Enhancement (OE) values were about -0.19 and -0.58, respectively.

As expected the FC-FEDRI/FC-PEDRI images show higher enhancement in the sample tube containing TEMPOL at higher concentration (left tube). In both cases the images derive from the interaction of the paramagnetic probe (TEMPOL) with the 19F or 1H nuclei contained in the same molecule (TFE).

CONCLUSIONS

We have optimized a RF coil assembly suitable for FEDRI and PEDRI studies and have demonstrated the feasibility of acquiring, sequential, co-registered FC-FEDRI and FC-PEDRI images at a constant detection field of 59mT. This work is the first methodological step toward the development of a low field scanner capable of acquiring morphological (1H) and physiological (19F) images in animal models at very low field.

REFERENCES

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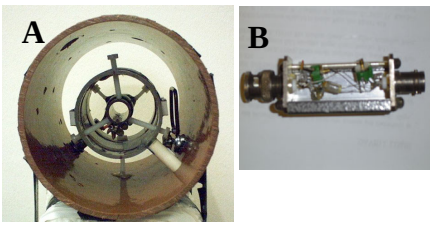

Fig. 1 A) RF coil assembly: the shield, the Aldermann Grant resonator (EPR section), the solenoidal coil (NMR section). **B)** The tuning-matching box for FEDRI or PEDRI imaging.

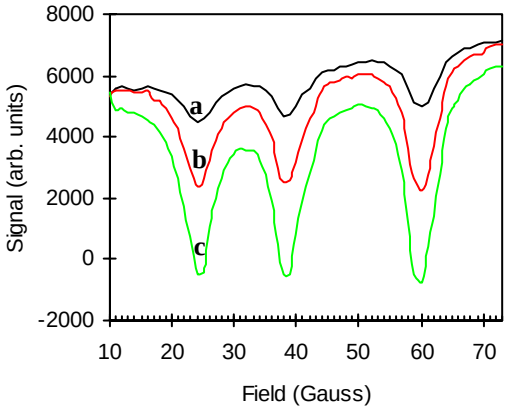

Fig. 2 FC-DNP ^{19}F spectra of a 5mM TEMPOL free radical dissolved in trifluoroethanol (TFE) collected to test the RF coil assembly at a peak EPR power of: (a) 5W; (b) 15 W; and (c) 20 W.

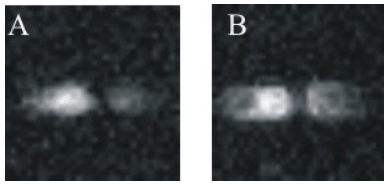

Fig. 3. (A) FC-FEDRI difference image obtained from the subtraction of EPR ON and EPR OFF data. (LEFT) 5mM and (RIGHT) 2mM solution of TEMPOL dissolved in TFE. TX EPR peak power=25 W, TEPR=400 ms, TR=1200 ms, FOV=37.5 mm, TCK=15 mm, NEX=4. **(B)** FC-PEDRI: co-registered difference image obtained in the same experimental conditions as the FEDRI in **(A)**.