

Design of a Docking PET and Field-Cycled MRI System for Small Animal Imaging

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Introduction

Efforts to combine anatomical and functional imaging modalities have resulted in the successful development and widespread use of PET/CT systems. PET/MRI would offer substantially better soft tissue contrast, provide high-resolution anatomical information and would be beneficial for longitudinal studies. Combining conventional PET and superconducting MRI faces many technical challenges, especially the incompatibilities between photomultiplier tube-based (PMT) PET detectors and high magnetic fields [1].

Current approaches to PET/MRI typically (a) modify MRI in some manner to make it compatible with conventional PET, or (b) alter PET hardware to make it compatible with conventional MRI. One approach of the second type has been to employ avalanche photodiodes (APD), which are unaffected by magnetic fields, in place of PMTs in an MR-compatible PET insert [2]. An approach of the first type is to use field-cycled (FCMRI) with a conventional PMT-based PET system [3]. Combining PET with FCMRI would enable the use of commercially available, highly optimized PET systems with little physical modification. In this abstract, the authors present their current designs for a docking PET/FCMRI system specifically based on the Siemens Inveon small-animal PET.

Methods

In FCMRI, a resistive electromagnet generates the main magnetic field and can easily be turned on or off. With the main fields on one can perform normal MR imaging, and, in a small fraction of a second, the main fields can be completely turned off. A fully-functional FCMRI system has been built (Figure 1) [4] and has generated images of good quality (Figure 2). Proof-of-principle tests have shown that linear and mesh PMTs recovered normal operation within several milliseconds of the field being turned off with no long-term effects [3,5]. In addition, the authors have shown that PMT-based PET systems can operate sequentially with an operational FCMRI system (Figure 2).

The authors are developing a PET/FCMRI system for small-animal imaging. A Siemens Inveon PET system (Siemens Medical, Knoxville, TN) has been acquired and installed within our labs. The detector consists of a ring of 16 PET modules, each consisting of a row of four LSO crystal blocks (1.59x1.59x10 mm crystals in 20x20 block) coupled to four position-sensitive PMTs. The Inveon system has a large axial FOV (12.7 cm) enabling whole-mouse imaging, and permits fast scanning due to its very high sensitivity (10%).

A larger-scale FCMRI system (Figure 3) is under development for docking with the Inveon PET system. At 60-kW-continuous operation, the main magnet produces 0.7 T, and is rough-shimmed to ~250 ppm homogeneity over a 10-cm-diameter sphere. First- and second-order resistive shims will be used to further reduce the inhomogeneity to better than 10 ppm. The main magnet wire has 7x7 mm cross-section with a 5-mm-diameter liquid cooling channel. With gradients and shims, the bore diameter is 15.9 cm. The length, diameter and mass of the system are 72.5 cm, 61 cm and approx. 900 kg, respectively. The resistance and inductance are 1.85Ω and 0.81 H.

The proposed docking geometry is shown in Figure 4, and the system is best suited for sequential PET/MRI sequences. Tumor uptake of ^{18}F -FDG in mice is on the order of 45-60 minutes for intraperitoneal injection. Therefore, an efficient sequence could conduct MR for 45 minutes while the mouse metabolizes the radiotracer and then acquire PET data for 15 minutes. The sensitivity of the Inveon system (10%) is substantially greater than that of the PET systems used in current simultaneous approaches to PET/MRI (0.23% [2]). Therefore, the proposed system can offer shorter total imaging time or lower radiation dose to the animal for longitudinal studies.

A moveable bed with 30 micron precision moves the animal between PET and MR fields of view without disturbing the position of the animal on the bed or disconnecting anaesthetic supply lines.

Discussion

The proposed PET/FCMRI approach could have several advantages over other PET/MRI approaches. While APD-based PET detectors can achieve timing and energy resolutions comparable to current PMT methods [6], as of this writing, APD-PET is still in development and there are no commercially available systems. The current approach uses the commercially available Inveon system offering state-of-the-art timing & energy resolution, high sensitivity, and highly optimized event processing hardware.

While FCMRI is less mature than conventional MRI, it is likely more critical to achieve the best possible PET resolution rather than maximize MR image quality. FCMRI image quality is more than sufficient for the anatomical detail required for image coregistration. Furthermore, FCMRI has several advantages over conventional MRI. One such advantage is the ability to dynamically vary the magnitude of the main field, offering novel T1-dispersion contrast possibilities.

Construction of the new FCMRI system and docking with the Siemens Inveon PET system will be completed soon. The final PET/FCMRI system will be relocated to a research hospital environment for performance evaluation and preclinical studies.

- [1] Gaa, J., et al. *Eur. J. Med. Res.* (2004) **9**:309-312
- [2] Judenhofer, M., et al. *Nature Med.* (2008) **14**:459-465
- [3] Handler, W., et al. *Phys. Med. Biol.* (2006) **51**:2479-2491
- [4] Gilbert, K., et al. *Phys. Med. Biol.* (2006) **51**:2825-2841
- [5] Peng H., et al. *Proc. 14th ISMRM* (2006) p1359
- [6] Grazioso, R., et al. *IEEE Trans. Nuc. Sci.* (2005) **52**:1413-1416



Figure 1. Field-cycling MRI system.

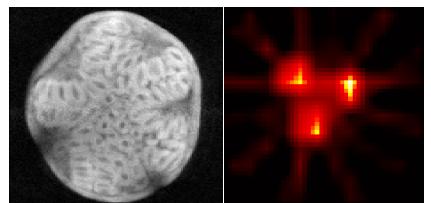


Figure 2. (left) FCMRI image of a pomegranate and (right) PET image of triangular arrangement of three point sources taken sequentially with a polarizing field of magnitude 0.3 T.

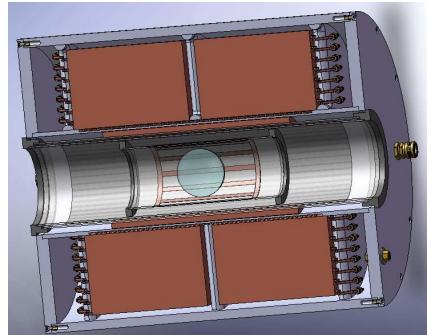


Figure 3. Cross-sectional view through the design of the FCMRI system. Shown (starting from center): 10-cm-diameter imaging volume, birdcage RF coil, RF shield, gradient set, second-order shims, main magnet. Liquid cooling inlet manifold shown on ends.

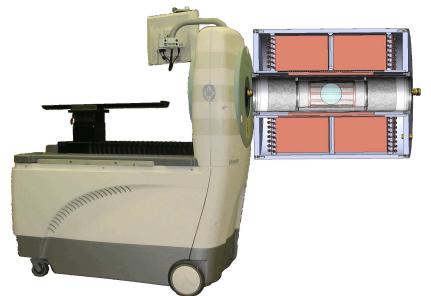


Figure 4. Docking geometry of the PET/FCMRI system. An extendible bed moves between PET and MR imaging regions with 30 micron precision.