RF coil design for simultaneous PET/MR

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Introduction

Combining PET and MR provides increased soft tissue contrast, reduced ionizing radiation and the possibility of genuine simultaneous measurement compared with PET/CT [1]. A current engineering challenge of simultaneous PET/MR imaging is to minimize the impact of RF coils, supporting structures and account for the γ-ray scatter and absorption due to additional material in the PET field-of-view (FOV). High signal-to-noise ratio (SNR) MR images require that the filling factor for the receiver is maximized [2]. Consequently, MR receiver coils are optimally places in close proximity to the object of interest. This causes additional scatter and absorption, reducing PET sensitivity and spatial resolution. As diagnostic decisions can be based on quantitative localized tracer uptake values, minimizing and accounting for these processes is an important issue.

MR signal intensity is independent of the γ-ray attenuation properties of a material. Segmentation based methods have been employed to assign predetermined attenuation coefficients to regions of interest seen in MR images [3]. Though suitable for tissue, the RF hardware does *not* appear in the MR image, hence segmentation methods cannot be applied. The gross impact of RF coils can be measured in the absence of the sample. However Monte Carlo simulations of coil geometries provide a method of quantifying scatter and absorption from the different components of the coil structure. Also, measurements of the impact on sensitivity and spatial resolution can be made. This also provides a design tool to optimize material choice and guide component placement.

Coil Arrangements

A. Mouse transceiver birdcage coil and shield. (Figure 1)
B. Mouse head surface coil, transmit coil and shield.
C. Mouse head surface coil and Bruker T5346 Transmit coil.
D. Unsupported copper wirecage coil.
E. Unsupported copper sheath coil.

Figure 1: Mouse transceiver coil used in [6], simulated as arrangement A. Coil is a copper foil birdcage mounted on a Teflon tube, with tuning components and solder attached.

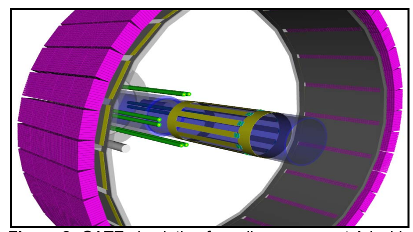

Figure 2: GATE simulation for coil arrangement A inside the FOV of the MicroPET Focus 220.

Methods and Results

Our approach uses GATE-based Monte Carlo simulations of transmission and emission processes to quantify the impacts of the various coil structures [4]. To date we have simulated five RF coils (Figures 1 and 2) in the FOV of a MicroPET Focus 220 preclinical scanner. Separate simulations were run using ^{68}Ge point sources and a cylindrical water-filled polyethylene phantom containing multiple ^{18}F line sources. We recorded the number of scatters occurring in the different coil components (Figure 3), and evaluated the effects on spatial resolution (via full width at half maximum measurements) and sensitivity (using count intensities in regions of interest).

We have also examined the impact of supporting material. The probability of a true coincidence was evaluated for several common polymers (Figure 4), as well as the sensitivity and spatial resolution impacts of having dense tuning capacitors close to the source (Figure 5).

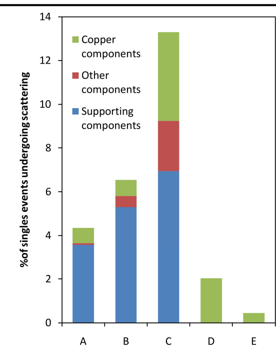

Figure 3: The relative contributions to scatter for five coil arrangements. Large contributions arise from the supporting material.

Conclusions

Placing conventional MR coils in the FOV can reduce sensitivity by up to 25% and spatial resolution by 0.5mm. This can be reduced to 2% and 0.2mm by reducing the coils to radio antennas without support, but at the expense of rigidity. Common MR materials can be responsible for >15% reduction in coincidences for thicknesses of 5mm or more. Alternative polymers may be suitable if magnetic susceptibility artifacts can be avoided. Also, dense electronic materials must be placed as far from the sources as possible to reduce sensitivity impact, and avoid reconstruction artifacts. While we have evaluated impacts of RF structures in the small animal context, Monte Carlo methods are equally applicable to human imaging. The larger coil structures have been shown to produce singles event losses of up to 17% [5].

Further Work

We plan an extensive range of PET/MR studies on a preclinical scanner [6] involving metabolic abnormalities in R6/2 HD mouse model of Huntingdons Disease, Fallypride studies of impulsive rats, cardiac studies in ApoE mouse models and FMISO and T2* mapping in stroke models of the rat. We believe that these protocols will all benefit from simultaneous imaging and we intend to continue this investigation by comparing the relative impacts of the coil designs. We will simulate PET acquisitions using the MOBY mouse phantom [7] with an emphasis on investigating the impact of coil hardware close to the subject's head. We anticipate the need to produce a precise attenuation map in order to determine accurate regional uptake values.

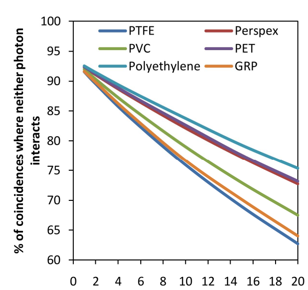

Figure 4: The probability of a true for varying thickness of several polymers.

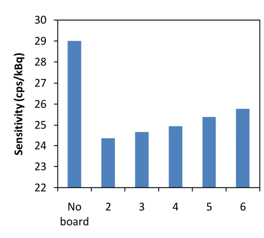

Figure 5: The reduction in sensitivity from having dense electronic materials close to the source. The effect on resolution (not shown) was a reduction of ~2%.

References

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