Placing a PET insert in the bore of a 7T magnet: Initial study of the interactions of the MRI system with the PET shielding.

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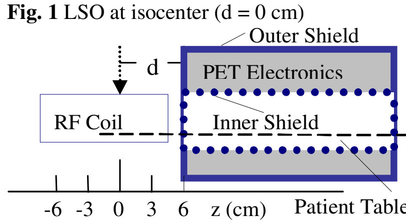
Abstract: A new PET insert is being built for simultaneous PET and MR imaging at 7T with the PET electronics placed inside the magnet bore. Results are presented for preliminary investigation of interactions between the PET shielding and the MR system. Initial concerns regarding gradient eddy currents, RF coupling, and B_0 field uniformity are explored.

Fig. 1 LSO at isocenter (d = 0 cm)



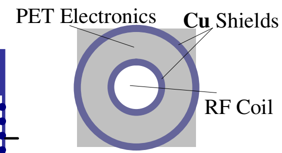


Fig.2 Cross section, outer and inner copper shield, and the PET electronics placed in between them.

Introduction: Previously, our group constructed an MRI PET insert for simultaneous MRI and PET imaging [1]. This prototype relied upon long fiber optic cables that coupled the scintillator crystals to the PET electronics outside of the magnet, a setup that is undesirable for a number of reasons including the cumbersome nature of the design and the degradation in PET performance. More recently we have pursued an alternative design, which places the PET photodetectors and electronics within the bore of the magnet [2-3]. This necessarily requires a careful examination of all potential interactions between the MRI and PET systems. Our current prototype of a simultaneous PET-MRI scanner is constructed with LSO crystals adjacent to the imaging volume and fiber optic connections with position sensitive APDs (avalanche photodiodes) placed a short axial distance away, in the bore of MRI. The PET electronics need to be shielded to operate properly. For this prototype, we chose to use copper for the shielding, because it offers thinner skin depth compared to, for example aluminum. In this work we characterize the performance of the MRI scanner with these copper shields placed in the bore. Later experiments will characterize the performance of the fully assembled PET-MRI system. Our initial concerns with placement of this shield within the bore were related to eddy currents, RF coupling, and B_0 field uniformity. Here we only focus on the effects of the shield (w/o the PET electronics).

Methods: The MRI system used for this work is a 7T (300 Mhz) Bruker Biospec magnet with Magnex MKIII gradients 180/120 mm OD/ID. We used Bruker's 35mm diameter birdcage coil. The PET electronics and shielding will be placed in the annular region outside of the RF coil and inside the gradient coil. The copper foil used for the shields in this work was 3 mils thick and 15.2 cm (6 inches) in axial length. The inner shield used had a diameter of 6.5 cm and the outer shield had a diameter of 11.8 cm. We acquired images of a uniform water phantom with standard spin echo (SE) and gradient echo (GE) sequences while placing the cylindrical copper shield at various axial locations, d (Fig 1). For each shield location we computed the RMS error compared to a reference image taken with no shield. We calculated the percentage differences relative to the image maximum. We also analyzed the SNR as a function of shield position. In addition, we used network analyzer to measure the coupling effects between the RF coil and the cylindrical shield as a function of shield position.

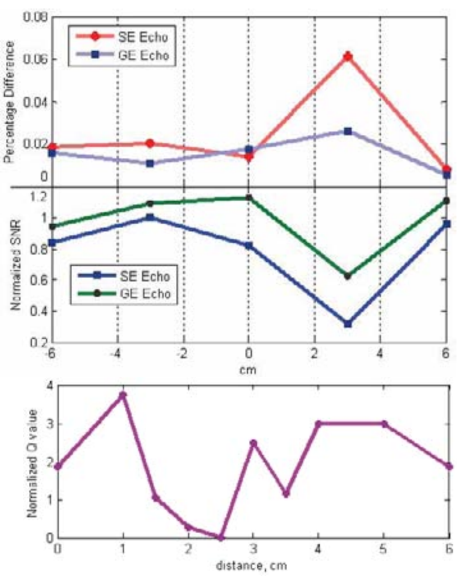


Fig. 3 Plots of RMS Error, SNR, and Q with respect to shield location d.

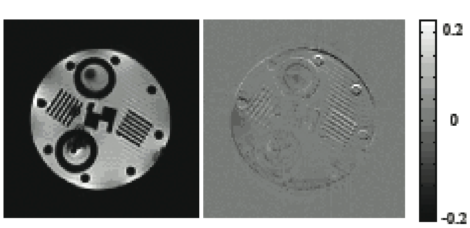


Fig. 4 GE Image (d=5 cm) and its normalized error.

Results and Discussion: Our initial experiments indicate the placement of the shield does indeed cause image distortion from field nonuniformities to varying degrees depending on the shield location. Second order shimming was required to remove these distortions. For all shield locations, careful shimming appears to satisfactorily remedy nonuniformity issues.

The axial gradient rollover points are at approximately 8 cm on either side of isocenter– right where the shields are to be positioned. If the shield is not securely fixed in place, gradient switching induces eddy currents and consequent vibration or movement of the shield. However, with the shields secured appropriately, we have not yet observed any significant image distortion. In order to quantify the subtler effects the eddy currents have on images, we show plots of the RMS difference (scaled by image max) between images taken at various shield locations and a reference image. An example image with the small diameter shield at d=5cm is shown along with a difference image in Fig 4. Edge artifacts (ringing in phase encode direction) were apparent in GE images when the shield approached or overlapped isocenter. The SE images we acquired showed less significant ringing artifacts but similar or slightly increased overall error levels and were more sensitive to RF tuning and calibration (see below).

RF coupling between the MRI coil and the PET shield is a significant concern. Although the coil has no measurable sensitivity to a phantom placed outside (radially), the coil does couple to both the small and large diameter shields. This coupling causes a detuning of the resonance (by as much as 500 kHz). In most cases, the manual adjustments on the coil were sufficient to retune and match with the shield or shields in place. One notable exception to this was when the inner edge of the small shield was at the same (or similar) axial location as the endring of the birdcage (approx +3cm). Using a network analyzer we observed that the presence of a large diameter shield positioned anywhere or a small diameter shield anywhere but in the vicinity of the endring resulted in a modest improvement in the Q of the coil. When the inner edge of the small shield was close to the endring, the Q was reduced 4-5 fold– and in one case where the tuning capacitor did not give enough leeway to tune the coil back to 300 MHz, the Q was reduced over 100-fold. A consequent reduction in SNR for these shield locations was also measured.

References: **[1]** Y. Shao, S. R. Cherry, K. Farahani, K. Meadors, S. Siegel, R. W. Silverman, and P. K. Marsden, "Simultaneous PET and MR imaging," Phys Med Biol, vol. 42, pp. 1965-70, 1997. **[2]** C. Catana, J. Stickel, M. Judenhofer, B. Pichler, and S. Cherry, "*Simultaneous PET-MRI from Detector Modules to Imaging System*," Molecular Imaging, vol. 4, No. 3, pp 259, 2005 **[3]** C. Catana, Y. Wu, M.S. Judenhofer, J. Walton, B.J. Peng, J. Willig-Onwuachi, B.J. Pichler and S.R. Cherry, "Combining PET and MRI – Challenges in Developing an MR Compatible PET insert," *Submitted*, ISMRM 2006.