Magnetic Field Inhomogeneities Induced by PET Detector Scintillators in Dual Modality MRI/PET Systems

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Introduction: Several research groups are currently working on combined MRI/PET (positron emission tomography) scanner systems. One of the most obvious potential advantages of this combination is the ability to obtain high-resolution MR images of anatomy while simultaneously collecting the functional imaging information attainable with PET. One of the many challenges to this integration is the magnetic compatibility of the PET detector systems. In particular, the scintillator crystal materials (which stop the high energy photons produced by positron annihilation) either currently in use or proposed for future PET systems include materials with magnetic susceptibilities that range from very small (3.8 ppm for NaI) to very large (9530 ppm for GSO) [1]. These scintillators are created in ring configurations around the object under investigation. In this abstract, we investigate the field inhomogeneities that would be produced by five different scintillator materials when positioned in a standard small animal PET system configuration. By understanding the non-uniformities created by PET detectors, we can design electromagnet correction coils to minimize the magnetic interference.

Methods: A simplified geometry of a typical PET system detector ring was modeled using the FEMLAB 3.1 software package (Comsol, Burlington, MA). The scanner was assumed to have axial symmetry with rotation about the z-axis. An annular ring of scintillator material of a given susceptibility (inner radius 9.5cm; outer radius 11.5cm; thickness along the z direction of 2.0cm) was positioned within an initially uniform magnetic field of 1.0T along the z-direction. Laplace's equation for the vector potential was solved over a finite element mesh using FEMLAB and the total magnetic field obtained via the vector curl operation, and exported to MATLAB. The gradient of the z-component of the magnetic field was calculated along both the radial and the z directions. The following values were obtained from the calculated fields: field offset (ppm difference from 1.0T) at the centre of the system; maximum field perturbation (ppm) within 5cm sphere located at centre of system; maximum and average dBz/dr values (mT/m) within 5cm sphere; maximum and average dBz/dz values (mT/m) within 5cm sphere. The entire calculation was repeated for five different scintillator materials used or proposed for use in PET systems: NaI, BGO, LSO, LGSO, and GSO. The magnetic susceptibility values used for each material are listed in Table 1.

Results: Figures (2) through (4) show results for the simulation using GSO (highest susceptibility of any materials modeled) as the ring material. In Fig. (2), the contour plot of magnetic perturbation with respect to the centre of the ring is shown. It can be seen that the field is approximately within 100 ppm of the centre value within a 5cm sphere. Figures 3 and 4 show the calculated field gradients of the z field component along the z and r directions respectively. Within a 5cm sphere, the maximum gradients along either direction are approximately 5 mT/m. Table 1 below summarizes the calculated field and gradient values for all of the modeled scintillator materials.

Discussion: The Bo field offset produced at the centre of the system is not significant for any of the materials except GSO, which would produce a centre field shift of 10.8 kHz at 1.5T. The maximum local field gradients induced by NaI, BGO, and LSO are all less than 0.02 mT/m within the proposed imaging region, which would result in very small local image distortions in most pulse sequences. However, LGSO induces maximum local field gradients of more than 0.5 mT/m, while GSO produces very large maximum local field gradients of almost 8 mT/m. These gradients are large enough that significant image distortions would be expected, and in addition signal loss due to decreased T2* values would be expected. These results indicate that for the traditional scintillator materials, there is expected to be very little problem with field inhomogeneities in the MR magnetic fields. Use of LGSO appears to be feasible, whereas the use of GSO appears to represent a significant problem. The methods presented here are currently being used to analyze these same effects as a function of the system geometry.

References: [1] Yamamoto et al. IEEE Trans. Nuc. Science, Vol. 50, 2003

	Magnetic susceptibility (ppm)	Offset field Perturbation (ppm)	Maximum field perturbation (ppm)	Max(dB_z/dz) (mT/m)	Max(dB_z/dr) (mT/m)	Avg(dB_z/dz) (mT/m)	Avg(dB_z/dr) (mT/m)
NaI	3.8	-0.0679	0.0871	0.00316	0.00308	2.79e-4	1.12e-4
BGO	-19.6	0.3399	0.2644	0.01611	0.01538	0.0014	5.59e-4
LSO	-21.7	0.3882	0.3019	0.01839	0.01577	.0016	6.38e-4
LGSO	790	-14.125	18.106	0.6567	0.6396	0.0581	0.0232
GSO	9530	-169.65	217.46	7.8877	7.6833	0.6833	0.2788

Table 1. Magnetic susceptibility, maximum field perturbation, offset field perturbation, maximum gradient field along the z direction, maximum gradient field along the r direction, average of the gradient field in both z and r direction for 5 materials

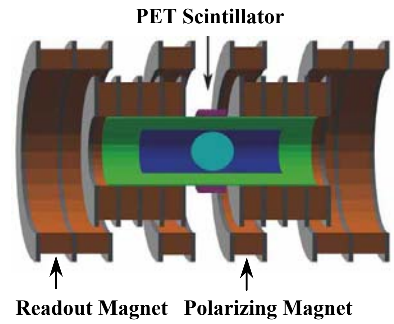

Fig.1 cutaway view of dual modality scanner

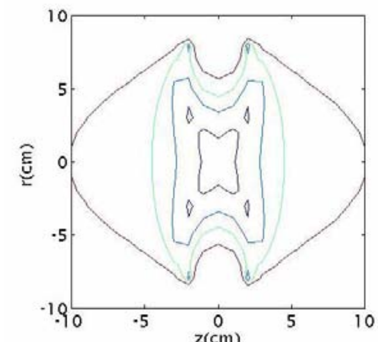

Fig.2 magnetic field perturbation contour for 10, 50, 100, 200 ppm with respect to zero perturbation at the origin

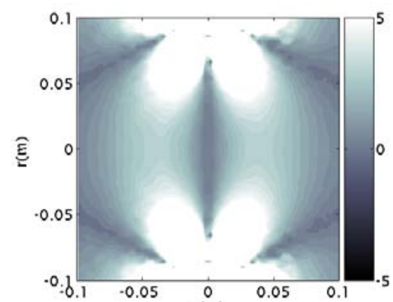

Fig.3 contour plot of abs(dB_z/dz) (mT/m)

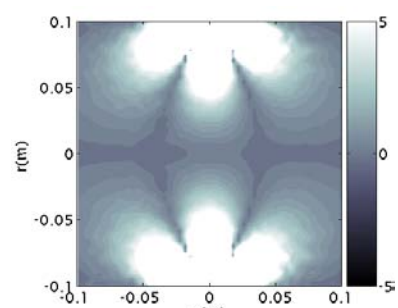

Fig.4 contour plot of abs(dB_z/dz) (mT/m)