MR Performance Evaluation of a PET/MR With SiPM Based Time of Flight PET Detectors

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Purpose: Achieving a simultaneous PET/MR system faces many challenges for PET detector design as well as integration with the MRI. Maintaining B0 and B_1^+ homogeneity of the MR system in presence of the PET ring and minimizing RF interference between the two modalities are some of these challenges. Here we have evaluated the MR performance of an investigational PET/MR scanner with a new silicon photomultiplier-based time-of-flight (TOF) capable PET detector [1], which is mounted on the body coil [2] and inserted into a 70cm wide bore GE 3T magnet (GE Healthcare, Waukesha, WI). The MR performance of PET/MR machine is compared with a wide-bore MR system.

Methods: The MR performance has been evaluated based on the following tests: a) B0 homogeneity b) B_1^+ uniformity c) Coherent noise, and d) FBIRN test [3]. The PET/MR system was shimmed and B0 homogeneity was measured over 20 and 45 DSV (Diameter Sphere Volume). The body coil B_1^+ map on a 17cm MR Spectroscopy (MRS) sphere phantom, and on a body elliptical phantom were measured by the Adiabatic Bloch-Siegert (ABS) B_1^+ method [4] using a 6ms ABS pulse with 6μT amplitude. Maximum average B_1^+ over the MRS phantom was measured using the full 30kW power provided by the RF amplifier. A Gradient Recalled Acquisition in the Steady State (GRASS) sequence was used with no RF and the center frequency was varied from 127.628 to 127.828 MHz in increments of 25kHz. Raw data was processed to look for coherent noise artifacts. The FBIRN test was performed on a 17cm Agar sphere phantom with body transmit coil and two different receive coils: 8 channel head coil and body coil. The FBIRN test was performed weekly over a one year period on both PET/MR and wide-bore MRI scanners (SIGNA PET/MR* and MR750w, GE Healthcare, Waukesha, WI, USA) using spiral readout sequence with the following parameters: 96x96 matrix, 24cm field of view (FOV), 2400ms repetition time, 30ms echo time, 90 degree flip angle, 29 slices, 5mm thickness, 0mm spacing and 200 temporal phases. Slice number 15 was used to calculate system fluctuation, signal to noise ratio (SNR) and signal fluctuation to noise ratio (SFNR). The FBIRN tests were performed on a 17cm MRS sphere phantom with and without PET acquisition using two different receive coils: HNU (Head Neck Unit) and body coil. These tests were repeated 3 times with the following parameters: Single Shot Echo Planar Imaging, 64x64 matrix, 22cm field of view (FOV), 3100ms repetition time, 30ms echo time, 77 degree flip angle, 30 slices, 4mm thickness, 1mm spacing and 200 temporal phases. Slice number 15 was used to calculate system fluctuation, SNR and SFNR. Mean and standard deviation of each parameter were calculated using the 3 samples.

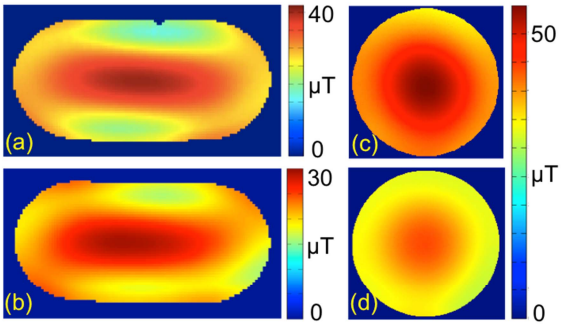

Fig 1: B_1^+ map comparison between PET/MR (a & c) and wide-bore MR (b & d). PET/MR has ~25% more peak B_1^+ due to smaller body coil. Wide bore MR B_1^+ is slightly more uniform.

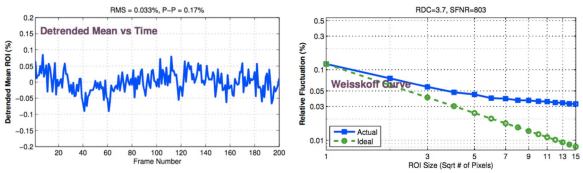

Fig 2: PET/MR FBIRN results on MRS phantom using EPI-fMRI.

	SNR	SFNR	RMS
	8 Channel Head Coil		
PET/MR	197±21	153±24	0.06±0.01
70cm Bore MR	187±13	156±9	0.06±0.01
	Body Coil		
PET/MR	58±5	57±4	0.09±0.02
70cm Bore MR	21±9	22±9	0.12±0.03

Table 1: Comparing FBIRN tests using spiral acquisition between PET/MR and wide-bore systems. PET/MR head coil is comparable to wide-bore but its body coil has a much higher SNR/SFNR compared to the wide-bore system.

	SNR	SFNR	RMS
	8 Channel Head Coil		
No PET Acq.	893±46	830±17	0.035±0.002
With PET Acq.	851±59	832±2	0.034±0.003
	Body Coil		
No PET Acq.	346±25	328±4	0.043±0.001
With PET Acq.	336±9	323±3	0.042±0.002

Table 2: Comparing PET/MR FBIRN tests with and without PET acquisition. PET acquisition only affects SNR by ~3%.

Results: The B0 homogeneity of PET/MR was in spec after shimming i.e. less than 1ppm in 20cm DSV (Diameter Sphere Volume) and less than 5 ppm in 5cm DSV. No coherent noise was detected on PET/MR scanner. Fig 1 shows the comparison of B_1^+ field between PET/MR and wide-bore MR scanner. PET MR has ~30% higher B_1^+ peak due to the smaller body coil design; however the wide bore B_1^+ uniformity is slightly better than PET/MR. The B_1^+ non-uniformity for the wide bore system were measured as 10% and 14% in sphere and elliptical phantom, while they were 11% and 18% on PET/MR respectively. Fig 2 shows an example of FBIRN test result on PET/MR machine using EPI readout. The SNR, SFNR and the RMS value of signal change over time, measured by FBIRN test are summarized in Tables 1 and 2. Table 1 shows that PET/MR body coil SNR and SFNR are more than doubled compared to the wide bore system due to the smaller size. Table 2 shows that PET acquisition has a very small effect on MR performance, i.e. ~3% drop in SNR.

Discussion: The MR performance of PET/MR machine was compared to a comparable wide-bore MR machine. We show that the MR performance is not significantly compromised after PET ring insertion. It is also shown that PET acquisition causes a small (approximately 3%) SNR decrease and no significant change in SNRF. In other words, the only tradeoff between PET/MR and a wide-bore MR is the bore size (60cm vs. 70cm); however, the smaller diameter results in better body coil SNR and SFNR as well as 30% increase in peak B_1^+ for PET/MR system.

References:

[1] C. Levin et al., SNMMI Annual Meeting, Vancouver, Jun 2013. [2] GH Glover et al., ISMRM Meeting, no.4360, Salt Lake City, Utah, May 2013. [3] GH Glover et al., JMRI, vol.36, no.1, pp. 39-54, 2012. [4] MM Khalighi et al., MRM vol.70, no.3, pp.829-835, 2013.

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