Solving RF Interference for a Simultaneous PET/MRI Scanner

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Abstract: Carbon fiber tubing is found to be excellent shielding against 300 MHz radiofrequency (RF) interference for the PET insert that is currently being developed for a 7T preclinical MRI system. Electrically grounding the PET detector module to the inner carbon fiber tube housing reduces low frequency RF noise. Adding thin copper (Cu) foil on the outer carbon fiber case while electrically grounding the PET module with it significantly reduced RF interference at 81 kHz.

Introduction: Two sources of RF interference need to be investigated when building a simultaneous PET/MRI system. One is RF interference generated at the Larmor frequency by the MRI RF coil, and the other is the RF generated by the switching power supply typically used in MRI gradient amplifiers. Carbon fiber (CF) has been shown to be a very effective RF shielding material at typical Larmor frequencies [1]. Reducing RF interference at lower frequencies is also extremely important because such interference can result in a baseline shift that leads to a mispositioning of PET events in detectors that utilize charge sharing positioning schemes. The MR gradients are powered by a switched power supply, which generates and radiates 81 kHz RF. This 81 kHz RF causes the flood histogram (a map of the scintillator crystal locations in the PET detector module) to be significantly degraded such that scintillator elements at the edges of the detector array cannot be resolved (Fig. 1). CF tubing is only effective at shielding against high frequencies. Thus we examined the use of Cu foil and careful grounding to reduce 81 kHz RF noise. The literature suggests that the thickness of the Cu foil is not as important as the coverage of the foil [2]. In this abstract, energy histograms obtained from the PET module further demonstrate the shielding effectiveness of CF tubing at 300 MHz. Noise spectrum measurements and analysis of flood histograms show promising RF noise reduction, and improved PET detector module performance.

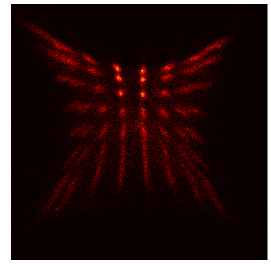

Fig. 1. Flood histogram when 81 kHz RF is not attenuated.

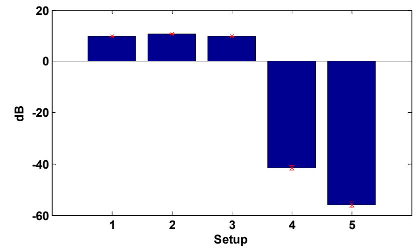

Fig. 2. 81 kHz RF signal level for different setups.

Materials and Methods: A 7T (300 MHz) Bruker Biospec MR system is used for this work. The PET detector module consists of an array of lutetium oxyorthosilicate (LSO) scintillator elements read out by a position sensitive avalanche photodiode (PSAPD). The module is constructed using one 14x14 mm^2 PSAPD to read out an 8x8 LSO array with crystal size 1.43x1.43x6 mm^3 on a pitch of 1.5 mm. The PSAPD is then AC coupled to preamplifiers. A simple CR filter composed of two resistors (50 ohms) and one capacitor (1 nF) is currently built into the PET detector module. Of the two resistors, one is the serial output resistor of the preamplifier and the other is the termination resistor of the input of NIM electronics. The PET module is placed above the uniform center of the RF coil. It is electrically grounded to a 596 mm long inner supporting CF tube with 63mm/60mm OD/ID. For experiment A, the MR gradient power supply was turned on, and 5 sets of data were recorded with different setups: 1) no shielding, no outer CF tube; 2); 151 mm long and 118 mm/115 mm OD/ID outer CF tube added; 3) outer CF tube is covered with 0.0005" thick Cu foil with 151 mm axial coverage; 4) double-sided conductive Cu tape is used to secure the Cu foil to the edges of the outer CF tube for better electrical contact and also is used on the edge of the inner CF tube, with the PET detector module electrically grounded to the Cu foil – there also is a connection between the Cu tape on the two CF tubes; 5) gradient power supply turned off. For experiment B, the PET module was placed at different locations in the MRI bore. 81 kHz interference was measured and recorded while using setup 4 from experiment A. For experiment C, the PET module was placed -33 mm away from iso-center. Four sets of energy and flood histograms were obtained from the PET module under the following conditions: 1) RF coil not powered and gradient power supply is turned off; 2) RF coil on and a single RF pulse at 300 MHz with duration of 20 µs, repetition time 500 ms, is generated, power is set at 1 dB below full power while gradient power supply is still turned off; 3) RF turned off, and gradient power turned on; 4) RF coil and gradient power are on. The reference voltage for all interference measurements is set at 100mV.

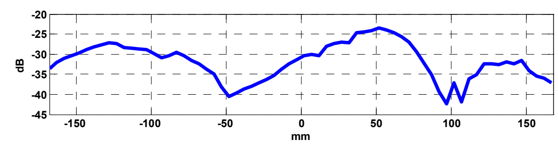

Fig. 3. 81 kHz RF signal level vs. PET module axial location.

Results and Discussion: Results of experiment A are shown in Fig. 2. 81 kHz interference cannot be reduced with simple CF shielding, Cu shielding, or simple CR filter. It can only be reduced when the PET module is electrically grounded to the inner and outer surface of the CF tube while the outside of the CF tube is covered with Cu foil. ~50 dB reduction in 81 kHz signal was achieved with this setup. A residual signal of -42dB still exists, with the baseline measure (gradient switched off) being -56 dB. Fig. 5 (experiment C) suggests that this small amount of residual interference does not affect the performance of the PET module. Results of experiment B are shown in Fig. 3. The placement of the PET module is important because 81 kHz interference varies at different locations inside the MR bore. The phenomenon likely results from the structure of the gradient coil. Results from experiment C are shown in Figs. 4 and 5. PET energy histograms are very similar for all combinations of power on/off conditions with the shielding in place. Fig. 5 confirms the previous finding that CF is very effective shielding against RF interference at 300 MHz. It also confirms that under condition 4 near ideal PET detector module performance is obtained when the PET module is placed at -33mm away from iso-center. However at other axial locations, PET detector performance is compromised by increased 81 kHz RF interference. In order for the PET detector module to work optimally at all axial locations, a higher order band-reject filter for each channel of the PET module may be needed, or low pass filters for the gradient power supply will need to be designed to filter 81 kHz RF at its source.

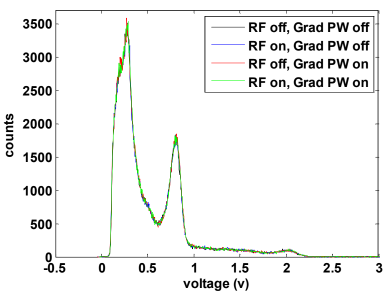

Fig. 4. Energy histogram for different configurations in experiment C.

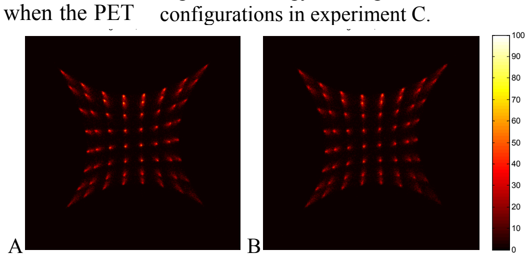

Fig. 5. Flood histograms under two different conditions. A: condition 1 – no RF or gradient power; B: condition 4 – both RF and gradient power.

References:

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[2] W. Cooper, et al, "Electrical properties of carbon fiber support systems," Nucl. Instr. and Meth in Phys. Res.; A 550;2005; 26:127-138