Optimisation of a 32-channel Resonator for Simultaneous PET/MRI of the Head at 3.0 Tesla: Material Selection and Performance Testing

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Background:

Radio frequency resonators used in simultaneous acquisitions of positron emission tomography (PET) and magnetic resonance imaging (MRI) require special design and construction considerations to minimize photon attenuation while maintaining quality MRI images. It has been shown that resonator housing made with less than 3mm thick polycarbonate are the best choice to optimize housing structural strength versus gamma ray attenuation. However, housing geometry and type required more research as they can have important effects on reducing attenuation and PET image artefacts. In this work, we examine the effect of resonator circuit and housing materials in an effort to simultaneously minimize PET gamma ray attenuation and obtain highest MRI signal-to-noise ratio.

Methods:

Polycarbonate (PC), Derline, HDPE, and ABS-M30 materials samples were manufactured in duplicate dimensions, geometry and optimum thickness (2.5mm) as previously reported [1]. The samples were imaged on a Dual-Energy (70 /140 keV) CT scanner (Discovery STE, GE Healthcare) and monoenergetic reconstructions were derived for kVPs of 60, 80, 100, 120 and 140keV. The images were used to compute a linear attenuation coefficient map at 511keV [2]. Attenuation coefficients of the three materials were compared. For the circuit materials, three identical loops (with respect to loop diameter, components location and values) were developed. The three loops differ only in conductive material: Copper (Cu) wire (16 awg), Copper strip and Aluminum (Al) strip. MRI was performed with the loops using a 3T Biograph mMR system (Siemens AG, Healthcare Sector, Erlangen, Germany). Consecutive PET acquisitions of 20 minutes each were obtained with the elements positioned under a cylinder containing a uniformly distributed positron emitting substance. The attenuating effects of the loops on the PET signal intensity, at the region of the cylinder close to the loop, were compared. MRI signal-to-noise ratio over the whole phantom were calculated and compared for the three loops. After determining the best material for the housing a head coil with conformal geometry was constructed to accommodate 32 receivers array.

Results:

The specially treated ABS material reduced attenuation by approximately 32% from the conventional PC material; the mass of the head coil in the PET field of view was weighed and found to be 631.43g suggesting a reduction of attenuation by 175% compared to the commercially available 8 channel PET/MRI head coil. The PET signal reduction caused by the AL strip was 21.8% less than that caused by the Cu strip and 2% less than that of the Cu-wire (figure 1). The MRI SNR of Al loop was 88% higher than that obtained from the loop made of Cu-wire (figure 2).

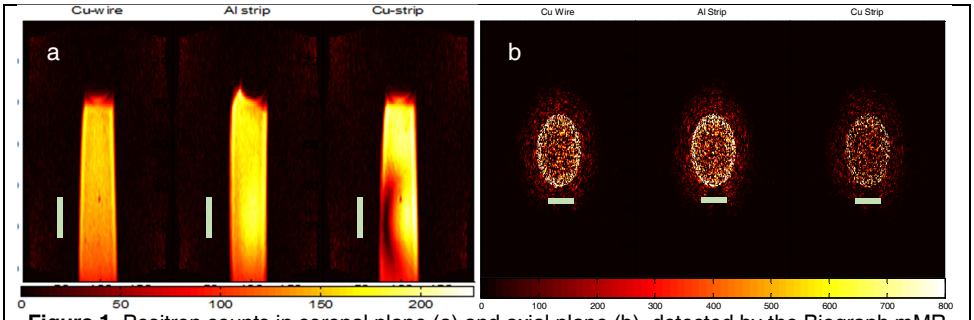

Figure 1. Positron counts in coronal plane (a) and axial plane (b), detected by the Biograph mMR with loops (presented by solid gray line) positioned under a suspended cylindrical calibration phantom.

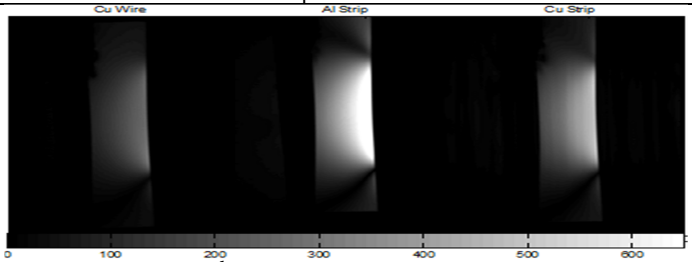

Figure 1. MRI coronal images of ^{1}H phantom acquired with the loops and plotted on the same intensity scale.

Conclusion:

Overall, the use of ABS as housing material and Al strip circuit material combined with improvements in housing geometry and weight, we estimate a reduction of PET gamma ray attenuation of over 250%, while improving MRI Signal-to-Noise ratio by factor of 1.5 of copper wire.

References:

[1] Sander C., *et al.,* DOI 10.1002/mrm, 25335 (2014)
[2] Burger C., *et al.,* 2002; 29:922-927