An optimum RF shield for simultaneous MRI-PET system

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Introduction

An integrated system of magnetic resonance imaging (MRI) and positron emission tomography (PET) can be efficiently used for brain studies because it can simultaneously acquire complementary information using both MRI and PET [1, 2]. Previously, we have developed an integrated MRI-PET system using a PET insert as shown in Fig.1 [3]. To develop a robust MRI-PET system, it is important to provide MR image quality that is not influenced by the PET insert. There are many artifact sources that can deteriorate the MR image quality. For example, the coupling of RF noise between electronics in the PET system and RF coil of the MRI system can degrade the MR image quality. In addition, the center frequency of the RF coil may experience shifting due to the PET insert. In order to solve the RF noise coupling and frequency shifting problems, an appropriate RF shield should be used. For an MRI-PET fusion system with an add-on/off type PET insert, a gold-mesh tape [4] shield is proposed for the RF coil in this study. Furthermore, single-layer and double-layer type RF shields are examined to generate high-quality MR images regardless of the presence of the PET insert.

Methods

In the proposed MRI-PET system, the PET detector modules were enclosed by the RF-shielded PET gantry and the other electronics were placed in the RF shielded box to reduce the RF noise from the PET electronics. Moreover, an RF shielding has to be applied for the RF coil so that the center frequency of the RF coil is stabilized and a constant center frequency is maintained regardless of the presence of the PET gantry. Thus, a gold-mesh tape was chosen as shielding material to fully cover a homemade birdcage-type RF coil, having a diameter of 270 mm and a length of 300 mm. In Fig.2, the RF coil, RF-shielded PET gantry, cylindrical RF shields are presented. For single-layer and double-layer RF shields, simply one layer or two layers of gold-mesh tape was used to cover a homemade cylindrical RF shield case, as shown in Fig.2c. By applying the single-layer and double-layer RF shields, images were acquired at a 3T MRI system (SIEMENS Verio, Germany) with a FLASH 2D sequence using the following parameters: TR/TE = 250/2.46msec, Flip Angle = 20deg, 256x256x7, Voxel size = 1.0mm x 1.0mm x 3.0mm. We also analyzed the s11 response measured by a network analyzer to evaluate the performance of the single- and double-layer RF shields.

Results

For conventional MR imaging, the center frequency of the RF coil has to be tuned to match the center frequency of the MRI system. However, when the RF coil is surrounded by the PET gantry, the center frequency of the RF coil is no longer maintained at the pre-tuned center frequency. For conventional MR imaging, the center frequency of the RF coil has to be matched to the center frequency of the magnet, which is 123.2MHz in our Verio system. However, when the PET gantry is inserted, about 10MHz of frequency shifting occurs and the pre-tuned RF coil is no longer compatible with the MRI system. Thus, to use the RF coil for MRI-PET system, the RF coil has to be pre-tuned in the presence of the PET gantry to prevent the frequency shifting. This, in turn, produces frequency shifting of the RF coil according to the presence/absence of the PET gantry. Therefore, a proper RF shielding has to be applied so that the presence of the PET gantry does not cause shifting of the center frequency of the RF coil. By using single-layer RF shield, the frequency shift was largely reduced as shown in Fig.3a-b, as the difference of the center frequency is only about 2~3MHz according to the presence of the PET gantry. In case of the double-layered shield, better performance was observed as the center frequency was more stabilized (Fig3.c-d). Figure 4 shows images acquired with single-layer and double-layer RF shields with respect to the presence of the PET gantry model. As demonstrated by the frequency response and the acquired images, double-layer RF shield is an efficient way of shielding the RF coil to improve MR image quality.

Conclusions

Due to the conductive material of PET gantry shielding, the frequency shift of the RF coil is observed in the presence of the PET insert. To screen the RF noise from the PET components, the PET gantry of the PET detector module should be shielded and the PET electronics should be placed in the RF shield box. While both single- and double-layer RF shields improved the RF coil characteristics, the single-layer RF coil shield still showed a small amount of frequency shift in the presence/absence of the PET gantry, thereby degrading the MR image quality. From this study, we can find that proper RF shielding can keep the center frequency of the RF coil from the effect of the PET gantry and electronics. In future work, effectively stabilizing material, pattern, and method of the RF shield will be analyzed.

References

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Fig. 1. The proposed simultaneous MRI-PET System with a PET-insert. (a) Front and (b) rear views of the MRI system after placing the PET gantry and the RF coil. (c) A shield box to prevent RF noise from PET electronics.

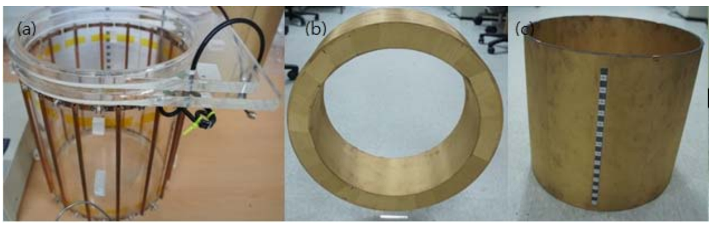

Fig. 2. (a) A homemade birdcage RF coil, (b) the PET gantry of the PET detector module, (c) the cylindrical RF shield.

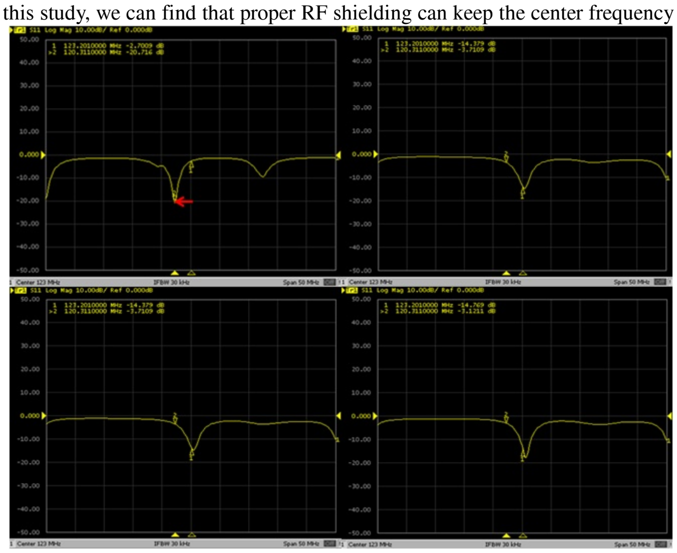

Fig. 3. The s11 responses measured by a network analyzer. The center frequency of the single-layer shielded RF coil (a) without and (b) with the PET gantry. The center frequency of the double-layer shielded RF coil (c) without and (d) with the PET gantry.

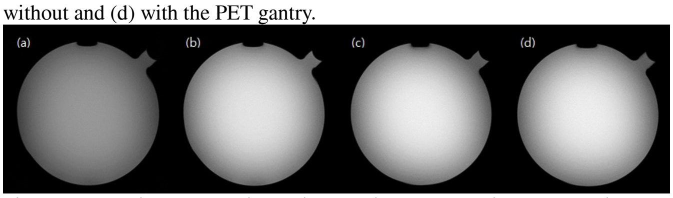

Fig. 4. MR images acquired with the single-layer shielded RF coil when the PET gantry is (a) not present and (b) present. MR images acquired with the double-layer shielded RF coil when the PET gantry is (c) not present and (d) present.