Computer simulation and experiments of RF coil for simulataneous MRI-PET system

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Introduction

Recently, many researchers have shown interests in developing an integrated system of magnetic resonance imaging (MRI) and positron emission tomography (PET). In the integrated MRI-PET system, there can be two main problems that can deteriorate MR image quality: one is the coupling of RF noise between electronics in the PET system and RF coil of the MRI system, and the other is frequency shifting of RF coil. In order to solve the RF noise coupling and frequency shifting problems, an appropriate RF shield can be used. In this study, we propose an MRI-PET fusion system [1], which can simultaneously acquire MRI and PET images by using an add-on/off type PET insert, and a gold-mesh tape shield is used to improve the MR image quality.

Methods

The proposed MRI-PET fusion system is set up as shown in Fig.1 with a PET insert enclosed by a shield box. Since non-magnetic materials should be used as shielding material due to strong magnetic field of the MRI system, gold-mesh tape [2] was used to fully cover a homemade birdcage-type RF coil, having a diameter of 270 mm and a length of 300 mm. Fig. 2 shows the structure of the RF coil, RF shield, and PET gantry model. To reduce the RF noise from the PET electronics, all PET electronics were placed in the RF shielded box and flexible cable shielding was also applied. To evaluate the performance of the gold-mesh tape shielding, simulation was performed at XFdtd 7.2(xFDTD, Remcom, PA, USA). The stability of center frequency of the RF coil was tested by comparing simulation results acquired with and without the PET gantry. The RF coil, the RF shield, and the PET gantry geometries were defined as the same size as real structures (RF shield : dia. 319-320 mm, hei. 320 mm, PET gantry : dia. 366-520 mm, hei. 180 mm). For simulation, automatic grid region having the minimum cell size of 0.5(ratio to maximum), automatic mesh mode, and enabled XACT were used [3]. To experimentally verify the proposed method, MRI and PET images were acquired at two 3T MRI systems (SIEMENS Verio, Germany, and ISOL Forte, Korea) using the following parameters: GEMS : TR/TE = 400/7.0 msec, and SEMS : TR/TE = 600/14 msec.

Results

In the simulation, we set the center frequency of the RF coil to 123.2MHz to match the Verio system. The values of end-ring capacitors used in the simulation are slightly different from actual values, mainly due to minute difference in structure size, material property definitions and ideality. Fig. 3 represents the frequency response of two cases. The center frequency of the RF coil is not affected, whether the PET gantry is present or not, as the RF shield makes the resonant frequency of the RF coil stable. The currents of each conductive part produce an image of the original current to the conductive surface. The magnetic field between the coil and the shield is reinforced by two current sources of the RF coil and shield structures with and without PET gantry. In Fig.4, the magnetic energy concentrated between the RF coil and the RF shield can be analyzed using the magnitude map of the transverse B-field, reflecting the strength of magnetic field generated by the RF coil as explained by the theory of the mirror. Fig. 5 displays the Hoffman brain phantom images simultaneously acquired by the proposed MRI-PET fusion system. Left two images were acquired by MRI system using (a) gradient echo sequence and (b) spin echo sequence, and right two images were PET images of (c) and (d) acquired during gradient echo and spin echo MR imaging, respectively.

Conclusions

To acquire MR images with or without the PET gantry insert, the RF noise from the PET electronics should be blocked and the center frequency of the RF coil should be stabilized. The RF shield is an appropriate solution for both problems. However, if the RF shielding is not properly applied, the quality of the MR images can be degraded by interference from the PET electronics. Moreover, the resonance frequency of the RF coil is affected by mutual inductance between the MRI system and the PET electronics. Since the shift of resonance frequency of the RF coil has critical effects on MR image quality, it is important to use a proper RF shield. From this study, we have shown that the RF shield can hold the center frequency of the RF coil, whether the PET gantry is present or not. 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 MRI-PET system with a PET-insert. (a) Front and (b) rear views of the MRI-PET system, including the gantry and the RF coil. (c) A shield box to prevent RF noise from PET electronics.

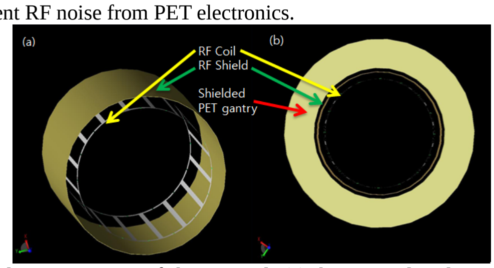

Fig. 2. Simulation structure of the RF coil. (a)The RF coil and surrounding gold shield without the PET gantry (b)The RF coil and surrounding gold shield with the PET gantry.

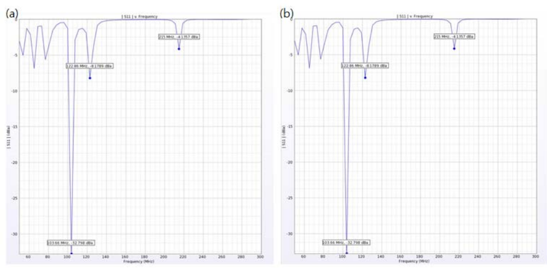

Fig. 3. The S11 responses of the simulated structures for (a) the RF coil and surrounding shield without the PET gantry model, and (b) the RF coil and surrounding shield with the PET gantry model

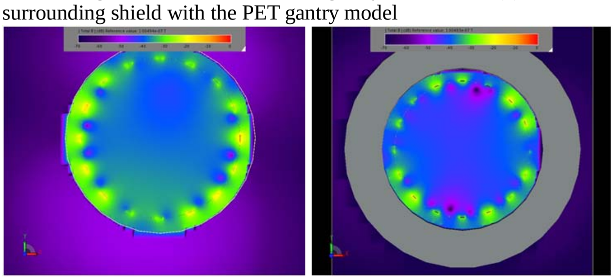

Fig. 4. The B-field magnitude map of the simulated structures. (a)The RF coil and surrounding shield without the PET gantry. (b) The RF coil and surrounding shield with the PET gantry model

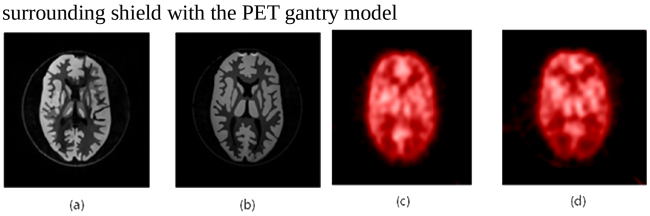

Fig. 5. Gradient(a) and Spin(b) Echo MR images, PET images(c) obtained during gradient echo MR imaging, and (d) during spin echo MR imaging, after the RF coil was retuned and rematched.