Remote tuning and matching adjustment of intra-cavitary RF coil for integrated MR-endoscope system

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Purpose

The gastrointestinal (GI) cancer death has been ranked high, and the early detection and treatment of the GI cancer have been required. An endoscope is an invaluable imaging tool but does not provide the internal information of GI tissue. The visualization under the tissue surface is important for precise diagnosis and pre-operative planning. MRI provides high soft-tissue contrast image with arbitrary slice orientation and no ionizing radiation exposure compared to an ultrasound and X-ray CT. We have suggested an integrated MR-endoscope system to provide high quality MR images during endoscopy and navigate both MR imaging and endoscopy by showing the images by both of the modalities. This system mainly consists of two components of an RF coil available to be placed inside GI tract, and a navigation software enables to indicate the scope location with orientation inside human body in MR scanner and to show the MR images with a scope view [1, 2]. The RF coil to be inserted into the GI tract, especially the stomach, has some difficulties in preserving proper tuning and matching, controlling the coil shape and the gap between the coil and tissue surface. Therefore, the remote tuning and matching function for the RF coil to be placed inside the gastric cavity, the intra-cavitary RF coil, was developed and the performance of the remote tuning and matching function was examined with a phantom model.

Methods and Materials

The intra-cavitary RF coil was designed as a 2-turn flexible surface structure with about 40 × 50 mm square [3]. This coil was tuned in and matched to different frequency and impedance from a Larmor frequency of proton in 1.5 Tesla and 50 ohm using capacitors placed right near the coil. The coil also equipped a decoupling circuit consists of a matching capacitor, a coaxial cable for inductor and a PIN diode. The remote tuning and matching circuit was composed of variable capacitors, variable inductors and RF choke, all of which were non-magnetic devices. And the remote circuit was connected with the coil through the coaxial cable with a half wavelength ($\lambda/2$) and placed outside of a bore of 1.5T MR scanner (Signa EXCITE TwinSpeed 1.5T ver.11, GE Healthcare, USA). A Network Analyzer (8714ES, Agilent Technologies, USA) was placed the outside of MR scanner room and used to measure the frequency spectrum of the coil by connecting with a wavelength length coaxial cable between the Network Analyzer and the remote circuit. The remote tuning and matching was conducted by manually adjusting the variable capacitors and inductors after a phantom including $CuSO_4$ and NaCl was loaded on the coil inside the bore. Before and after the remote tuning and matching was done, the MR images were obtained using FSE with TR, 500 ms; TE, 18.9 ms; ET, 4; RBW, 15.6 kHz; FOV, 80 × 80 mm; slice thickness, 5 mm; acquisition matrix, 256 × 128; signal acquisition, 1. And then, a signal to noise ratio (SNR) was measured on the obtained images to assess the performance of the remote tuning and matching function.

Results

The resonant frequency and impedance of the intra-cavitary RF coil were improved from 64.405 MHz and 69 ohm to 63.865 MHz and 48 ohm respectively by applying the remote tuning and matching circuit. Figure 1 shows the impedance matching performance on Smith Chart. The quality factor of the coil before and after the achievement of the remote tuning and matching were 67.9 and 67.7 respectively. The obtained images were shown in Figure 2. The SNRs calculated at the region about 5 mm and 15 mm away from the coil surface were about 245 and 132 without the remote tuning and matching, and about 322 and 174 with the adjustment. The SNR was improved up to about 131 %.

Conclusions

The remote tuning and matching for the intra-cavitary RF coil was successfully accomplished by manually adjusting the variable capacitors and inductors, and the improvement of image quality using the remote tuning and matching function was demonstrated. This performance would be useful for imaging the GI tract by the MR-endoscope system. The feasibility of the remote tuning and matching in an animal experiment in vivo should be examined in the next step.

References

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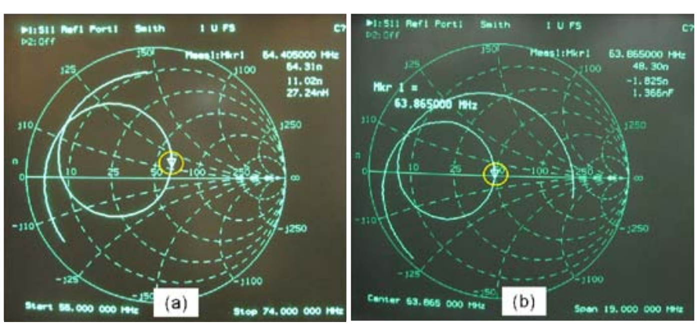

Figure 1. The frequency spectrum on Smith Chart of the intra-cavitary RF coil: (a) before and (b) after the remote adjustment of tuning and matching. Yellow circles indicate the resonance points.

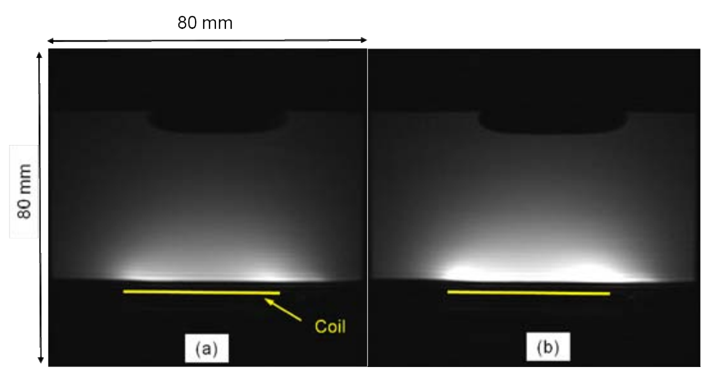

Figure 2. T1-weighted images of the phantom: (a) before and (a) after the remote adjustment of the tuning and matching of the intra-cavitary RF coil.