$^{19}F/^{1}H$ Double-Tuned RF Coil for ^{19}F-labeled Drug Distribution Monitoring at 7 T

Y. Otake[1], Y. Soutome[1], K. Hirata[1], and Y. Bito[1]

[1]Central Research Laboratory, Hitachi Ltd., Kokubunji-shi, Tokyo, Japan

Introduction

^{19}F MR imaging has many advantages in measuring ^{19}F-labeled drug distribution and metabolism, such as a relatively high MR signal compared to other nuclei and no background signal. Simultaneous use of $^{19}F/^{1}H$-MRI is believed to be a powerful tool for measuring distribution, efficacy, and adverse reaction to drugs because it enables anatomical and ^{19}F-labeled drug distribution information to be obtained. This imaging has been supported by using a double-tuned RF coil [1-2]. The double-tuned RF coil has a possibility that the measured ^{19}F data can be corrected using the obtained ^{1}H data. However, a conventional double-tuned RF coil has higher signal loss in two contiguous frequencies (especially with the combination of ^{19}F and ^{1}H) because a trap circuit connected to the sample coil in series has high insertion loss. Additionally, coil tuning is difficult in practical value for the capacitors and inductors at over 3 T. Therefore, the desired sensitivity cannot be obtained with a conventional coil. In this work, we have developed a highly sensitive $^{19}F/^{1}H$ double-tuned RF coil, and demonstrated ^{19}F-labeled drug distribution monitoring using a rat at 7 T.

Materials and Methods

<ins>*Coil design:*</ins> Figure 1 shows the developed highly sensitive $^{19}F/^{1}H$ double-tuned RF coil. Figure 2 (a) shows a schematic diagram of the coil. The coil was constructed with three series resonance circuits (with resonance frequencies of f_A, f_B, and f_C) each having one or more inductors (L_A, L_B, and L_C) and one or more capacitors (C_A, C_B, and C_C). The L_A and C_A were the inductor and capacitor of the sample coil. These circuits were designed to satisfy the $f_B < f_F < f_A < f_H < f_C$, where f_F and f_H are the Larmor-frequencies of ^{19}F and ^{1}H at 7 T (282 and 300 MHz, respectively). A series circuit of an inductor and a capacitor behaves like a capacitor for frequencies below the resonance frequency and like an inductor for higher frequencies. The coil behaves as shown in Fig. 2 (b) when fed by an f_F signal and as shown in Fig. 2 (c) when fed an f_H signal. The L_A is based on an 8-turn solenoid coil. Its inner diameter and length were 65 and 140 mm, respectively. The L_B and L_C were 25 and 20 nH, respectively. The C_A, C_B, and C_C were 0.19 (6 pF × 31), 17, and 6 pF, respectively. Thus, the coil can be tuned to resonate at the Larmor-frequencies of ^{19}F and ^{1}H.

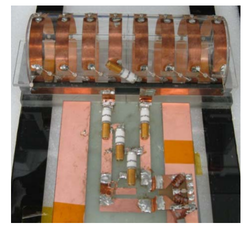

Fig. 1 Developed double-tuned RF coil.

<ins>*Simulation:*</ins> We numerically simulated the characteristics of the coil using our own program, which is based on the electromagnetic method of moments and impedance analysis [3]. This program can be used to calculate the impedance, phase, and sensitivity of the coils with the load. Coil sensitivity was calculated at the center of the coil. The load was 50 mm in diameter and 80 mm in length. The conductivity and relative permittivity of the load were 0.8 S/m and 75, respectively.

<ins>*Animal study:*</ins> PFCE (perfluoro-1, 5-crown-5-ether) nano-emulsion (20 w/v%, particle size of 100 nm), administered in a 200 mg/kg dose, was bolus injected intravenously into female Wistar rats bearing Walker 256 tumor. After injection, ^{19}F was measured cyclically to obtain the time course on a 7-T MRI (Varian, MRI System). The total measurement period was about 5 hours. ^{19}F images were obtained using the fast spin echo with FOV of 200 × 200 mm^2, matrix size of 128 × 128 without slicing, TR/TE/ETL = 2000 ms/49 ms/16, and scan time of 10 min.

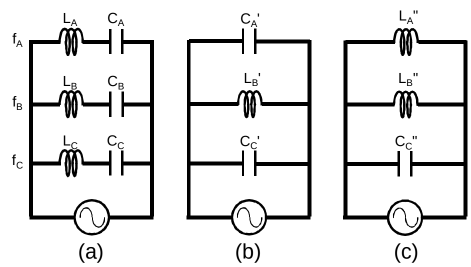

Fig. 2 Equivalent circuit schematics: (a) developed coil, (b) ^{19}F resonance mode, (c) ^{1}H resonance mode.

Results and Discussion

Figure 3 shows the simulated frequency characteristics of the developed coil with the load. Two impedance (red) peaks were observed at the Larmor-frequencies of ^{19}F and ^{1}H. The measured loaded/unloaded quality factors of ^{19}F and ^{1}H were 67/515 and 48/472. Sensitivity (green) peaks were observed at both frequencies. At this point, the coil had sensitivities at both frequencies without the trap circuit with sample coil. Additionally, the coil was allowed tuning with practical values for the capacitors and inductors. As a result, the two sensitivities of both frequencies increased more than twice a conventional dual-tuned coil.

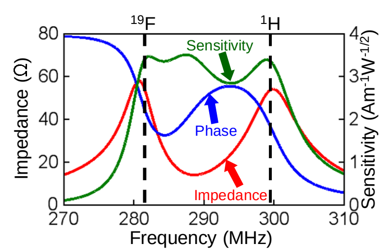

Fig. 3 Simulated frequency characteristics.

Figure 4 shows ^{1}H and ^{19}F images of the rat using the developed coil. These image shows that the coil enables measuring anatomical information by ^{1}H-MRI and the drug distribution of PFCE nano-emulsions by ^{19}F-MRI. The ^{19}F images clearly show that the ^{19}F signal intensity increased for liver and tumor tissues. It is thought that increased signal intensity shows accumulations of PFCE nano emulsion. These results suggest that this coil will be a powerful tool for measuring ^{19}F distribution monitoring.

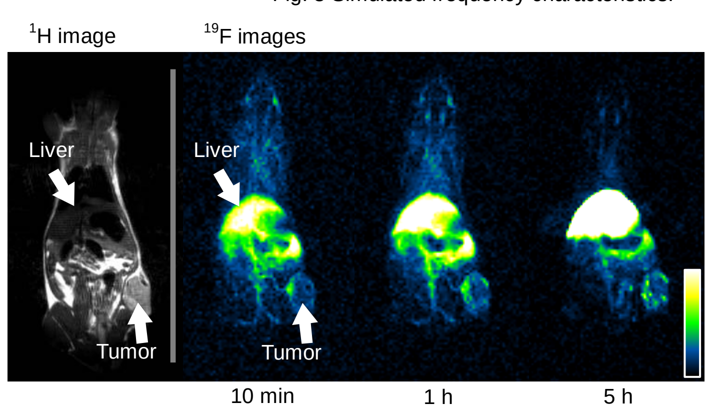

Fig. 4 ^{1}H and ^{19}F coronal images of rat.

Conclusion

We have developed a highly sensitive $^{19}F/^{1}H$ double-tuned RF coil for 7-T MRI. Using a PFCE nano-emulsion administered rat, we demonstrated that the coil can monitor ^{19}F-labeled drug distributions.

Reference

[1] Mazurkewiz C, et al., ISMRM, 2006. p. 2596.
[2] Morikawa S, et al., Magn Reson Med Sci 2007;6:235-240.
[3] Ochi H, et al., SMRM, 1992. p. 4021.