Simple 19F /1H coil

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Introduction

The favorable properties of ^{19}F nuclei have already prompted many *in vivo* studies, in which the distribution and metabolism of injected ^{19}F labeled compounds (such as psychoactive compounds, antineoplastics, antibiotics, antihistamines and antiinflamatory drugs) were followed through MRI [1]. One of the prerequisites for *in vivo* MRI such studies is the availability of transmit and receive RF (preferably volumetric) structures, capable of providing information at the ^{1}H frequency (for anatomical localization of the structure of interest), and at the ^{19}F frequency (for following drug distribution or metabolism). While swapping of identical coils tuned to the 2 frequencies has been used in the past [2], this approach is less than desirable and requires careful registration of the two parts of the imaging study. Alternatively, dual tuned coils were also previously used [3]. Building such structures, however, is not straightforward; they usually also come with associated SNR loses, compared with single tuned volumetric coils of identical sizes [4]. While SNR loss at the ^{1}H frequency is usually not a problem, the low tissue concentration of ^{19}F labeled compounds requires the utmost efficiency in making use of the available signal. A very simple and efficient RF structure (a solenoid coupled to a square loop) is presented in this work, which can operate at both frequencies of interest through a simple opening/closing of a mechanical/electrical switch.

Methods

A solenoid transmit/receive rat coil (7 cm diameter, 13 cm length), made out of hollow copper tubing (3 mm outer diameter) was built to resonate at the ^{19}F resonance frequency at 3T. A second square loop, 7.5cm on each side, was also tuned to the same 120.08MHz frequency (Figure 1). The loop contained a switch (red arrow in Figure 1), allowing the opening or closing of the loop's electrical circuit. With the circuit open, the square loop had no influence on the solenoid coil. With the circuit closed, the two coils coupled to each other, resulting in a splitting of the initial, ^{19}F resonance, into an upfield and a downfield resonance with respect to the initial peak. The positioning of the loop was adjusted while observing the S11 curve of the solenoid coil on the network analyzer. Once the higher resonance reached 127.74MHz (^{1}H resonance frequency at 3T), the loop was affixed in place for the lifetime of the coil. The matching of the solenoid coil at the ^{1}H frequency was adjusted by changing the relative capacitance on the 4 sides of the square loop (while maintaining the total capacitance constant). As such, the coil can be operated at the ^{1}H frequency-with the switch closed- and at the ^{19}F frequency-with the switch open.

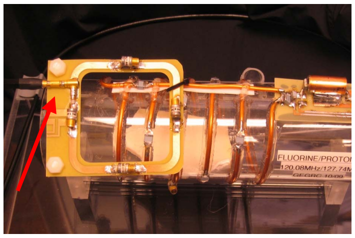

Figure 1: *Coil with switch (red arrow)*

A 60 mL cylindrical phantom, and seven 2ml phantoms filled with water/trifluoroacetic acid (TFA) were used to evaluate the performance of the coil at the two frequencies. The 7 small phantoms had TFA concentrations of 100mM, 10mM, 5mM, 1mM, 500μM and 100μM (Figure 3a- phantoms labeled 1-6). Phantom 7 contained water. The assembly of phantoms were imaged in a sagittal plane at both the ^{1}H and ^{19}F frequencies on a GE, 3T scanner. Proton imaging was performed using a spoiled gradient echo sequence with a 8 cm FOV, 20 mm slice thickness and 0.625mm in plane resolution, and TR of 100 ms, for a total imaging time of 3.3min (16 averages). The ^{19}F image was acquired using a free induction decay chemical shift imaging sequence (FIDCSI), using the same FOV and slice thickness as the ^{1}H images, 2.5mm in plane resolution, 2048 points over a 2kHz spectral bandwidth, and a repetition time of 1.1s, for a total acquisition time of 37.5min (8 averages).

Results and Discussion

Figure 2 presents a plot of the reflection coefficient (S11) of the coil with the switch closed (Figure 2a) and with the switch open (Figure 2b), displayed between 110MHz and 137.7MHz. Note that the single resonance at 120.08MHz gets split into two resonances, one at 115.8MHz, and one at 127.7MHz, following the closing of the switch. With the switch open (^{19}F operation), the unloaded Q of the solenoid coil (254) reduces to 64 after loading. With the switch closed (^{1}H operation), the unloaded Q of the solenoid coil (175) reduces to 77 after loading.

Figure 3 presents ^{1}H (Figure 3a) and ^{19}F (Figure 3b) phantom images. Although some chemical shift artifacts are visible in the proton image (in part due to small air bubbles in the phantoms), the SNR of this image (with a voxel size of 7.8 μl) is adequate for anatomical localization purposes. Preliminary comparisons of the image SNR at the ^{19}F frequency indicate similar performance for this coil with a coil used for *in vivo* studies, but single tuned for ^{19}F imaging [2]. Using the FIDCSI sequence, which allows detection of multiple spectral peaks (should such multiple peaks exist), we have shown detection of ~5mM fluorinated compound at a voxel size of 125μl (note that phantom 3 is the last one visible in our image). This detection limit may be lowered by a more efficient use of magnetization, eg, by using imaging sequences that return the magnetization to the z-axis following the play-out of the imaging gradients [5].

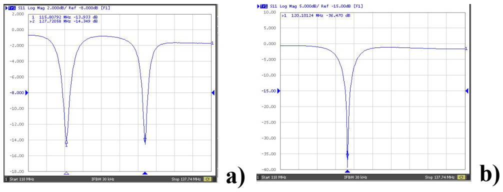

Figure 2: *S11 for the solenoid coil with the switch* ***a)*** *closed and* ***b)*** *open*

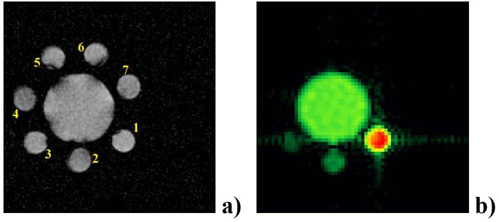

Figure 3: I*mages acquired with the solenoid coil with the switch* **a)** *closed (^{1}H image) and* ***b)*** *open (^{19}F image)*

Conclusions

An implementation of an easy to build ^{19}F/^{1}H coil, which can be useful in exams studying drug distribution and metabolism through ^{19}F MRI, was shown. The same concept of coupling of a ^{19}F tuned loop to another ^{19}F volumetric resonant structure to obtain a structure resonant at the ^{1}H frequency can be used in conjunction with any type of volumetric coil, including a more efficient birdcage coil. More elegantly, opening and closing of the loop may be obtained by biasing a PIN diode included in the loop's circuit, therefore allowing quick, interleaved ^{19}F/^{1}H acquisitions.

References

1. Reid et al, Drug Discov Today. 2008;13(11-12):473-80; **2.** Bolo et al, Neuropsychopharmacology. 2000 Oct;23(4):428-38; **3.** Murphy-Boesch et al, Magn Reson Med. 1997;37(3):321-6; **4.** Isaac et al, J Magn Res. 1990;89, 41-50; **5.** Morikawa et al, Magn Reson Med Sci. 2007;6(4):235-40.