Design and construction of an actively frequency-switchable RF coil for fast field-cycling magnetisation transfer contrast MRI

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Introduction

Magnetisation transfer contrast (MTC) is an important MR contrast generating mechanism to characterise the immobile macromolecular protons using an off-resonance pre-saturation RF pulse (or MT pulse). As the MT effect occurs by MT pulse irradiation, the condition of the MT pulse is the main source to produce MTC. MTC is normally implemented at a fixed magnetic field; however, it may provide valuable information to evaluate changes of the MT effect as a function of main magnetic field strength (B_0) [1,2]. In order to conduct field-dependent MTC experiments, we need techniques which enable both B_0 and the resonance frequency of the RF coil (f_0) to shift simultaneously during only MT pulse irradiation and return to the original condition during the MR signal acquisition. Switching of B_0 is achieved by the so-called fast field-cycling (FFC) technique [3,4], while switching of f_0 requires a special multi-tunable RF coil. Previously, this type of coil was built with double (or triple) coils, tank circuits or varactor diodes [5-7]. Their switchable frequencies were, however, limited to two (or three) values or the range of switchable frequency was limited (particularly at low field). In this work, we designed and constructed an actively frequency-switchable RF coil. The design employs PIN diodes, and enables switching the coil's resonance frequency between five levels without limitation of the switchable frequency range.

Methods

A balanced and shielded solenoid volume coil (24 turns, 145 mm diameter and 100 mm length) was designed and constructed as shown in Fig. 1. Using trimmer capacitors (Voltronics, USA) and PIN diodes (located at the tuning and the matching parts of the circuit), the overall capacitance and the matching are, respectively, controlled. In order to turn on/off the PIN diodes, a PIN diode driver circuit was designed (Fig. 2) supplying +5 V (PIN on) and -12 V (PIN off). This was modified and extended from Garbow's circuit [8]. The driver is activated by either TTL pulses provided by a commercial MRI console (SMIS Ltd, UK) or by manually-operated switches (for testing and initial setup). The TTL pulses are split by the TTL pulse divider constructed using Inverting and AND logic gates. Control of the TTL lines was included in the FFC-MTC pulse sequence code. RF chokes, bypass capacitors and blocking capacitors (C_b) were used in order to separate DC and RF.

Fig. 1

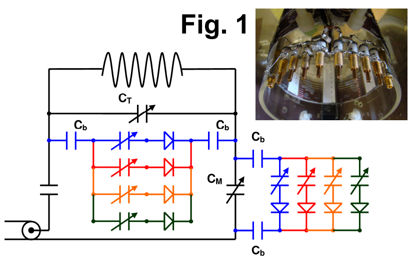
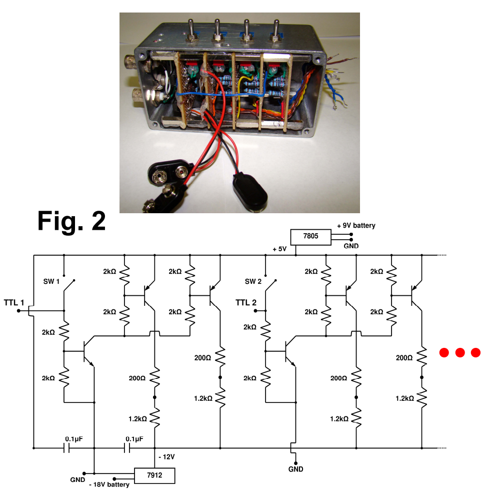


Fig. 2



Results

Fig. 3 shows snap-shots of network analyser (Agilent 8712ET) S_{11} reflection measurements obtained from the frequency-switchable resonator in five pre-determined configurations: (a) 2.5 MHz, (b) 2.38 MHz, (c) 2.26 MHz, (d) 2.14 MHz, and (e) 2.02 MHz. The pre-determined resonance frequency levels can be adjusted between 2.5 MHz and 1.5 MHz using the trimmer capacitors. However, the available f_0 range can easily be extended with additional capacitors. With all the PIN diodes set in the off state, the frequency of the coil is 2.5 MHz. f_0 is shifted to 2.38 MHz when the first set of PIN diodes is turned on. When turning on only the second set of PIN diodes, f_0 is switched to 2.26 MHz. The resonances depicted in Fig. 3 indicate excellent matching (about -40 dB reflected signal) and the unloaded Q-factor at each frequency is approximately 80.

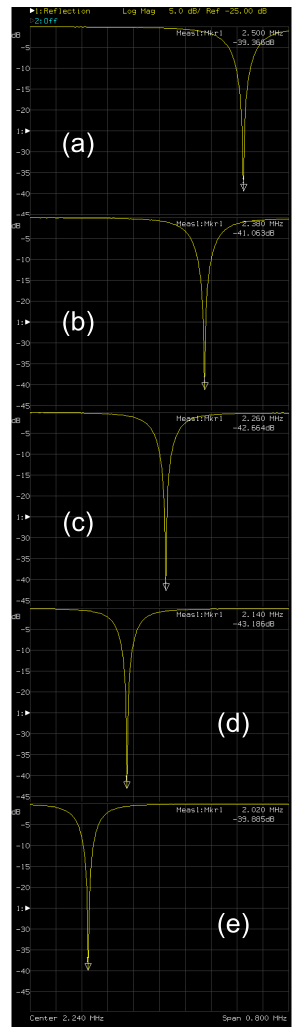


Fig. 3

Discussion

We have demonstrated a frequency-switchable (five frequencies) RF coil using PIN diodes. At the expense of decreasing the Q-factor (caused by attaching additional PIN diode circuits), more frequencies could be attained. In the future, we intend to use this RF coil with the FFC technique to conduct field-dependent MTC experiments at low field. In addition to its use for MTC, this design could also find use for multi-nuclear magnetic resonance.

References

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