Enabling Nuclear Quadrupole Double Resonance capabilities for Fast Field-Cycling MRI.

Nicholas R. Payne, Lionel M. Broche and David J. Lurie
Aberdeen Biomedical Imaging Centre, University of Aberdeen, AB25 2ZD, Scotland, UK
www.ffc-mri.org

Purpose / Introduction

With its ability to vary magnetic field strength, Fast Field-Cycling MRI (FFC-MRI) is able to access contrast originating from the dependence of relaxation rate on the Larmor frequency [1]. One example is the increased relaxation seen at fields in which the proton Larmor frequency matches a Nuclear Quadrupole Resonance (NQR) frequency of a coupled quadrupolar nucleus [2]. This is one form of Nuclear Quadrupole Double Resonance (NQDR) and it has proven biologically useful in the case of Nitrogen-14 [3]. There are several other NQDR techniques developed in solid-state NMR [4] which, if realised in FFC MRI, could provide more sensitive detection of quadrupole effects. These techniques involve irradiating the sample at variable or multiple RF frequencies within an experimental cycle. Therefore it has been necessary to design a system capable of providing the irradiation.

Subjects and Methods

Arrays of SVC236 varactor diodes, which function as voltage-variable capacitors, were used in place of conventional tuning and matching capacitors in an RF coil circuit. A control circuit consisting of four cascaded 74HC595 shift registers and two 16-bit DAC715 Digital-to-Analogue Converters was implemented to allow the tuned frequency to be selected by the scanner's commercial console (MR Solutions Ltd., U.K.). For maximum flexibility, a calibration procedure was designed to allow MATLAB (The MathWorks Inc., U.S., version 2013a) to calculate the critical variables used in the pulse sequence code.

Results

The RF coil system was fully integrated into the existing FFC-MRI scanner, requiring three TTL lines for control. With a carefully-selected RF coil inductance and additional levels of fixed capacitance, the system was made tuneable between 2 MHz – 3 MHz, covering the two highest NQR frequencies of Nitrogen-14 in biological samples. The minimum time between different tuning frequencies was 1.2 milliseconds.

Discussion / Conclusion

The minimum tuning time is limited by the console's available memory and processing speed and the value given is the "worst-case scenario" for the scanner in which all calculations are done within the pulse sequence. It should be noted that the tuneable range could be changed by selecting an RF coil with a different inductance. The future aims of this work are to demonstrate NQDR phenomena on an experimental FFC-MRI scanner.

References

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