A varactor-tuned RF coil for nuclear quadrupole double resonance with Fast Field-Cycling MRI

Nicholas R. Payne, Lionel M. Broche, P. James Ross and David J. Lurie

Aberdeen Biomedical Imaging Centre, University of Aberdeen, AB25 2ZD, Scotland, UK
www.ffc-mri.org

Fast Field-Cycling magnetic resonance imaging (FFC MRI), being developed at the University of Aberdeen, allows for an additional image contrast originating from the relationship between a spin's relaxation rate and the external field strength [1]. Features in the acquired dispersion plots, known as quadrupole peaks, have been shown to reveal information regarding the chemical composition of the sample being imaged [2]. This has applications for the in vivo detection and quantification of medical conditions such as thrombosis and osteoarthritis for which data has already been obtained by Broche et al [3-4].

Previous research has focused solely on quadrupole peaks caused by Nitrogen-14 which is a prevalent constituent of many organic molecules, especially proteins; however, there are a number of other quadrupolar nuclei which could be studied. Further to this, double resonance techniques established in solid-state nuclear magnetic resonance (NMR) could allow for much more sensitive detection [5] of relaxation caused by quadrupole interactions which would enable biologically scarcer nuclei to be utilised.

The irradiation frequencies required for double resonance experiments can span over a few MHz and, as such, it is necessary to design and construct an RF coil capable of covering this range of frequencies. Through integrating a varactor diode within a series-resonance circuit it was possible to change the RF coil's resonant frequency by applying a DC voltage across the diode. In order to vary the voltage given to the varactor a 16-bit DAC715 Digital-to-Analogue Converter was used in association with two 8-bit 74HC595 shift registers, controllable through three Transistor-Transistor Logic (TTL) lines from a commercial console (MR Solutions Ltd., U.K.). An anti-series/anti-parallel varactor set up, as described in [6], was used in order to minimise second and third-order distortion of the varactor's capacitance caused by the applied voltage. In order to use the coil and the control circuit simultaneously it was important to separate the DC control voltage and the AC used to drive the RF coil. This was achieved by placing large value capacitors (1000 pF) either side of the varactor and RF chokes on the control voltage lines. This design has allowed selection of a specific resonance frequency of an RF coil to be performed during a pulse sequence such that it can be made to match the frequency of the RF field to be irradiated.

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