Development of a voltage-tuneable RF coil to enable double resonance experiments with Fast Field-Cycling MRI

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Fast Field-Cycling MRI (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 which is tissue dependant through rapidly switching the applied magnetic field [1]. Dispersion plots can contain features known as quadrupole peaks which are indicative of immobilised molecules and give information regarding their chemical composition and concentration [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. It is also possible that molecules displaying appropriate quadrupole and biological properties could be introduced into a patient prior to imaging; this would provide the opportunity for functional imaging.

Many double resonance experiments require the sample to be irradiated with a range of RF frequencies which can span over a few MHz. This being so, it was necessary to design and construct an RF coil and tuning circuit capable of covering this range of frequencies. Integration of a varactor diode (a component which acts as a voltage-variable capacitor) within a series-resonance circuit allowed the resonant frequency of the circuit to be selected through the application of a DC voltage across the diode. The DC voltage was selected and supplied using a 16-bit DAC715 Digital-to-Analogue Converter which was controlled using two 8-bit 74HC595 shift registers. Transistor-Transistor Logic (TTL) lines from a commercial console (MR Solutions Ltd., U.K.) facilitated the shift registers to be controlled during pulse sequences such that the coil's resonant frequency could be set prior to an irradiation pulse.

Two anti-series/anti-parallel varactor set up, as described in [6], were used in order to minimise second and third-order distortion of the varactor's capacitance caused by the applied voltage while extending the range of frequencies to which the coil could be tuned (typically 1.99 to 3.87 MHz).. 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 to block the DC and RF chokes on the control voltage lines to stop any RF. This design has allowed selection of a specific resonance frequency of an RF coil to be performed during a pulse sequence allowing for double resonance experiments to be run using a single irradiation coil.

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