Calibration of a Fast Field-Cycling NMR Relaxometer for Measurements on Biological Samples that Extend to the Ultra-Low Field Region

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Introduction

A graph of T_1 versus the applied magnetic field (known as a T_1-dispersion curve), obtained via Fast Field-Cycling (FFC) NMR and MRI techniques, can be developed into a new medical diagnostic tool thanks to the information about molecular motions that it provides[1]. For measurements at magnetic fields below 10^4 kHz (^{1}H Larmor frequency), calibration is necessary so as to compensate for the unwanted environmental magnetic fields (including the earth's field) acting on the instrument. This will extend the dispersion curves to the ultra-low field region that is not accessible with standard FFC techniques, and is expected to increase the potential of the method, allowing for the study of much slower motions than previously possible[2, 3].

Methods

The calibration involves the application of FFC techniques along with varying correction magnetic fields. During this process, the frequency by which the magnetisation precesses around the resultant field B_r (composed of the correction and environmental fields) is measured, and the magnitude of B_r is estimated via the equation: $\omega = \gamma B_r$. The acquired results are shown as graphs that plot B_r as a function of the correction field, and the environmental fields are then measured by fitting a model to these data which expresses the relation of B_r to all of its components (Equation 1). The cancellation of the environmental fields is finally achieved by adjusting appropriately opposing correction fields, based on the values estimated by the curve fitting.

$$B_r = \sqrt{(B_c^l + B_e^l)^2 + ((B_c^t \cdot \sin(\theta)) + (B_e^t \cdot \sin(\varphi)))^2 + ((B_c^t \cdot \cos(\theta)) + (B_e^t \cdot \cos(\varphi)))^2} \qquad (1)$$

where B_c^l and B_c^t are the longitudinal and transverse components of the correction fields, B_e^l and B_e^t are the longitudinal and transverse components of the environmental fields, and θ and ϕ their azimuth angles.

Results

The correction fields found by the curve fitting shown in Figure 1 were B_c^l: 500 Hz, and B_c^t: 66 Hz applied at θ: -43°. These led to dispersion curves that extended to 100-500 Hz (equivalent to 2-10 μT). In the example shown in Figure 2, the calibration revealed a segment of different slope from the rest of the curve, indicating the occurrence of slower motions.

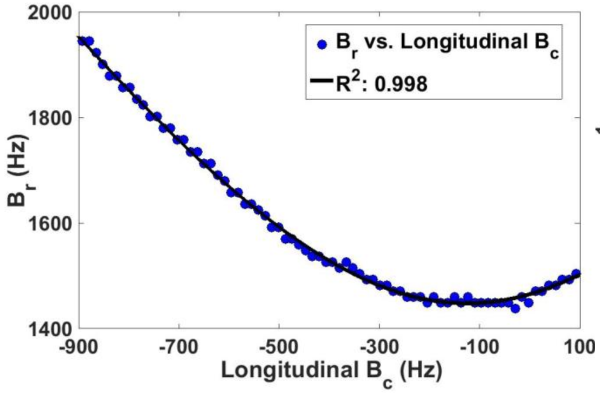

Figure 1. *Graph of B_r versus the longitudinal correction field.*

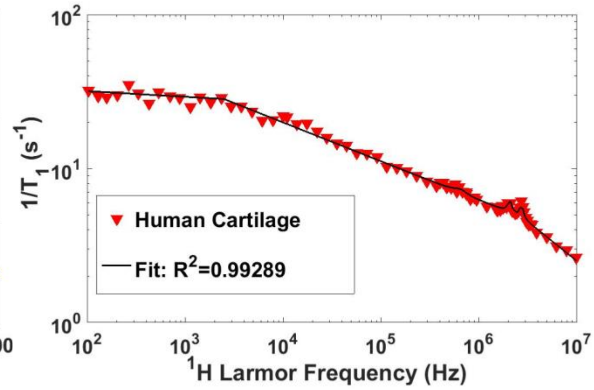

Figure 2. *$1/T_1$-dispersion curve obtained from a sample of human cartilage.*

Conclusion

FFC NMR techniques extended to the ultra-low field region can provide information on slow dynamic processes in tissues. The shape of the curves (at both low and high fields) needs further work to interpret, since they are likely to provide clinically relevant information and can form the basis of new types of contrast.

References

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