Angel Winged Fast Field Cycling: Towards Point of Manufacture and Point of Sale Measurement of Authenticity and Quality

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Introduction

- Field Cycling is a powerful magnetic resonance technique which reveals important subtleties in molecular dynamics which are not available from relaxation measurements at a single field.
- The technique measures the spin lattice relaxation rate (R_1) of a sample at different values of polarizing field B_0.
- To prevent the need to retune a single probe to multiple frequencies, Fast Field Cycling (FFC) polarizes and detects at a fixed high field but switches to a lower field for an evolution time (analogous to the inversion time) in between.
- This effectively encodes the relaxation experienced at this field into the resulting signal using a single NMR frequency [1].
- Commercial systems are available but are too expensive and bulky limiting their application at the point of manufacture or sale.
- We present the first steps towards construction of a low cost FFC probe for use in determining the quality and authenticity of ingredients at the point of manufacture or food products at the point of sale.

System Design

- The system comprises two main functional parts which are shown in Figure 1:
  - A small Halbach magnet for polarisation and detection [2]
  - The angel wing magnet: a cascading array providing a linear magnetic field gradient
- The sample is shuttled between two magnetic fields using compressed air.
- The air forces the sample shuttle into the Halbach and the air is stopped to allow the sample to fall under gravity to a lower field strength
- The lower field strength is selected using an array of solenoid actuators which inserts rods to stop the fall of the sample shuttle.
- A simulated field map of the cascading magnet is shown in Figure 2, demonstrating two linear regions with different gradients.
- Rotating the angel wing assembly allows for exploration of different field strengths.

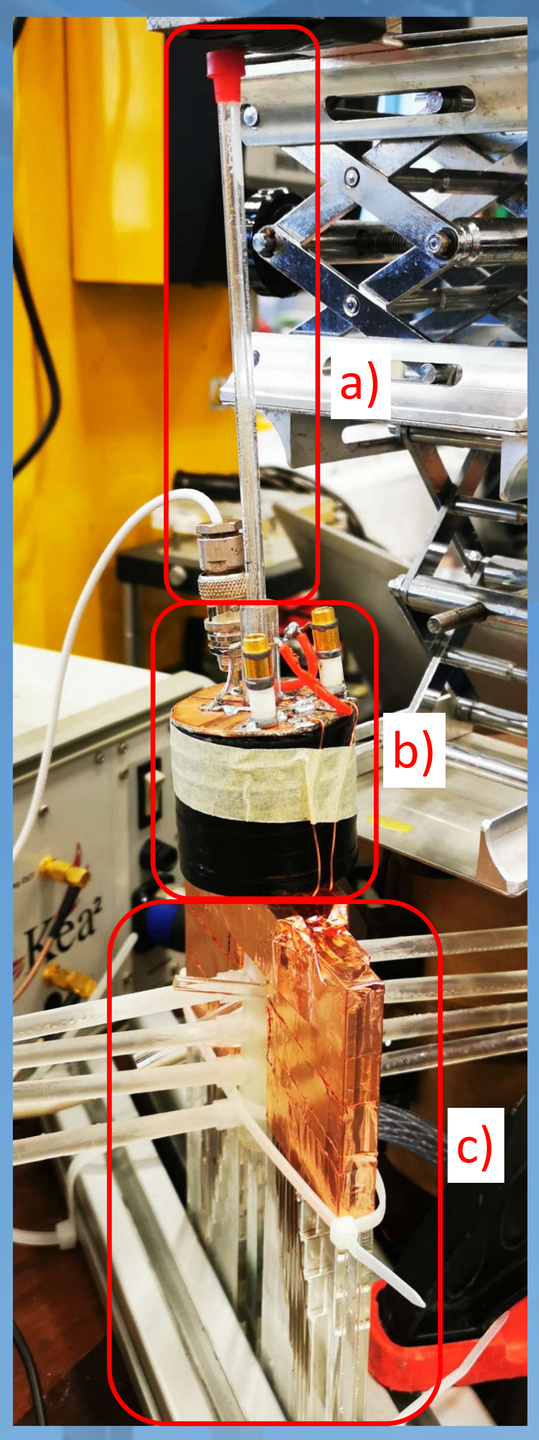

Figure 1. Photograph of the setup showing the NMR tube sample shuttle a), Halbach magnet b) and Cascading Magnet c)

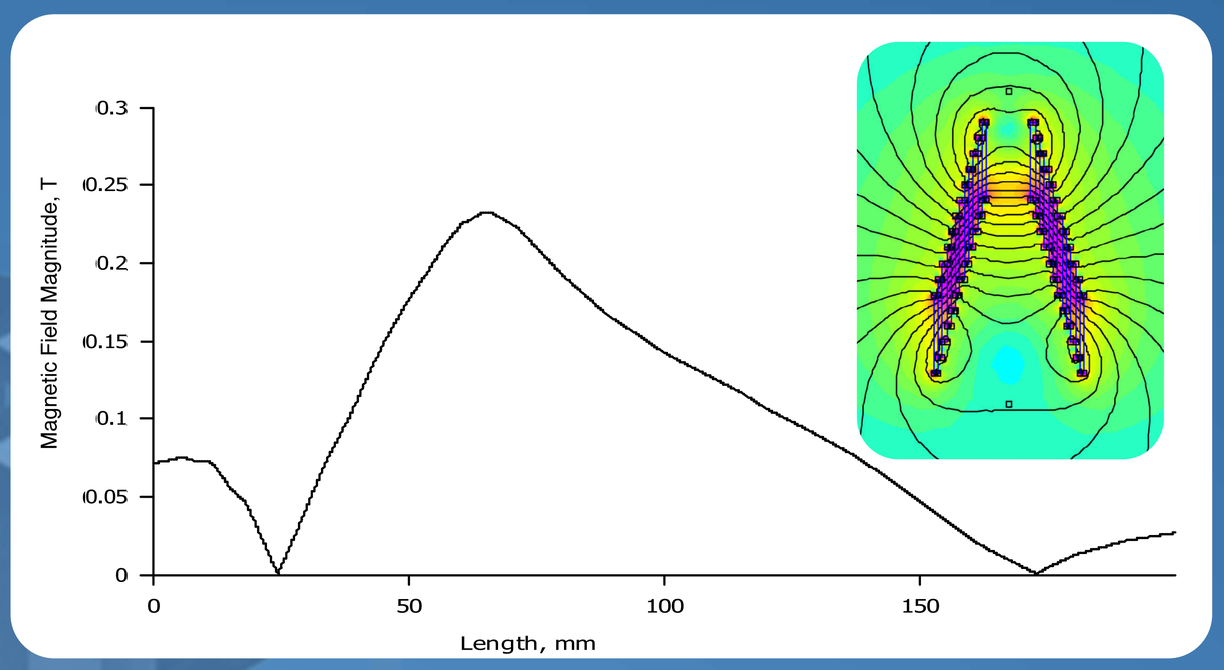

Figure 2. Plot showing field through central region. Insert shows field simulation through central slice.

Pulse Sequence

- A 180° pulse is applied at 21.4MHz while compressed air suspends the sample in the Halbach magnet.
- The air is removed and the sample dropped into the relaxation field between 20mT and 100mT for a variable duration equivalent to the inversion time in a standard inversion recovery experiment.
- Compressed air returns the sample to the Halbach and a standard CPMG pulse sequence is run to facilitate collection of the signal.

Data Processing

- Echoes from the CPMG are integrated and this integral plotted against the duration of the relaxation field.
- A monoexponential fit is used to determine R_1.
- Finally, the R_1 at different relaxation fields is plotted to provide the dispersion curve which is the desired measurement from FFC.

Results

- The system is tested on an aqueous sugar solution to verify the suitability of the technique.
- Preliminary results are shown in figure 3 and demonstrate the fundamental operation of the system.

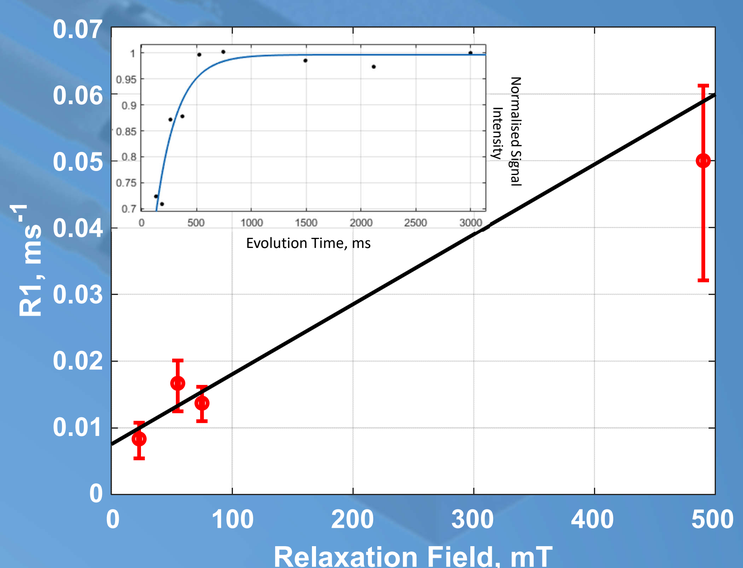

Figure 3. Preliminary dispersion curve from sugar solution. Insert is example T1 measurement

Conclusion

- The principle has been shown to work on a simple sample. The full system with pneumatic shuttling must now be demonstrated with complex samples.
- Full characterisation will now take place and the system will be used to monitor the quality of chocolate and crème fillings and to identify beet and cane sugar solutions to test for adulteration.

Acknowledgments

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References

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