



# Application Note: High-Field Field-Cycler (HFFC) for Advanced Relaxometry and Spin Dynamics

## Introduction

Standard high-field NMR spectrometers are optimized for a single field strength. The HFFC adds a second dimension: field-dependent measurements from near-zero to your full magnet field, without leaving the spectrometer.

The **High-Field Field-Cycler (HFFC)**, manufactured exclusively by **Field Cycling Technology Ltd.**, is a precision add-on module designed to integrate industrial-grade mechanical control with high-field Nuclear Magnetic Resonance (NMR) spectroscopy. By enabling rapid sample shuttling within the stray field of a superconducting magnet, the HFFC allows researchers to measure field-dependent NMR parameters across a wide range of low fields — while maintaining the high resolution and sensitivity of the host spectrometer. HFFC is compatible widely with commercial systems from 300 MHz up to 1.3 GHz.

## Core Technology: High-Precision Shuttling Mechanism

The HFFC operates on a **linear motion principle with constant acceleration**, a design choice engineered to minimize mechanical vibrations and ensure the sample reaches thermal and mechanical equilibrium within milliseconds of arrival at the high-field region.

- **Rapid Shuttling:** The system achieves a minimum shuttling time of **80–100 ms for a 100 cm travel distance**.
- **Programmable Precision:** Shuttling trajectories and positions are fully customizable via intuitive software, which synchronizes motion with the NMR pulse sequence using **TTL triggers from NMR console**.
- **Safety & Reliability:** The system includes a monitoring safety system to prevent unexpected motion and is constructed from non-magnetic materials (aluminum and plastic) to ensure safe operation within the high-field environment.

## Key Advantages over Home-Built Systems

Unlike "home-built" or laboratory-scale shuttlers, the HFFC provides an industrial-grade solution that eliminates common experimental risks:

- **Hardware-Driven Stability:** A peer-reviewed study by the New York Structural Biology Center (NYSBC) validated that the HFFC delivers highly reproducible **mono-exponential relaxation curves**. This accuracy is



achieved through robust engineering rather than post-acquisition post-processing or computational modeling.

- **Seamless Integration:** The HFFC features a "**Plug-and-Play**" architecture, requiring no modifications to the magnet and fitting most commercial spectrometers (Bruker, Varian, Oxford, JEOL) and standard probeheads, including **cryoprobes**.
- **Long-Term Support:** Professional installation and warranty protect research investments, preventing the device from becoming an "orphan system" due to personnel turnover.

## Primary Scientific Applications

### Protein and Biomolecular Dynamics

The HFFC is a vital tool for studying internal molecular motions at atomic resolution. It enables site-specific  $R_1$  relaxation measurements to probe dynamics on the critical **nanosecond-to-microsecond timescale**. This is essential for investigating protein folding mechanisms, the dynamics of enzyme-bound substrates, and intrinsically disordered proteins.

### MRI Contrast Agent Relaxivity

The system opens a comparable magnetic field range for relaxivity measurements as current MRI scanners (typically 1.5 T to 7 T). Researchers use the HFFC to characterize vanadate nanoparticles and other contrast agents, validating theoretical models for **Curie and electronic spin relaxation** across middle-to-high fields.

### Shuttle-Photo-CIDNP and Photochemistry

When combined with the **Field-Cycling NMR Illuminator extension**, the HFFC facilitates advanced photochemical studies. It achieves hyperpolarization by irradiating spins at **variable stray fields** where the polarization enhancement factor is most efficient. This approach is used to study radical-pair mechanisms (RPMs), reaction kinetics, and metabolic pathways. See also: Application Note — In-situ NMR Illuminator for fixed-field systems.

## Conclusion

The HFFC unlocks field-dependent relaxometry for laboratories already equipped with a high-field spectrometer — enabling protein dynamics, contrast agent characterization, and shuttle photo-CIDNP studies without rebuilding existing infrastructure. With plug-and-play integration, hardware-driven stability, and professional long-term support, it is the most direct path to quantitative, multi-field NMR research.

### Contact Information:

For technical consultations or demonstration requests, please contact [shuttle@fcnmr.com](mailto:shuttle@fcnmr.com) or visit [www.fcnmr.com](http://www.fcnmr.com)