Nuclear Magnetic Resonance Program for HDice Targets

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This note describes the Nuclear Magnetic Resonance program for HDice.

Nuclear Magnetic Resonance (NMR) is the process of magnetic field absorption and re-emission of electromagnetic radiation by nuclei in certain materials. The spectroscopy associated with this phenomenon measures the overall magnetic properties of molecules, and is used for probing the hydrogen-deuterium frozen (HDice) target for ideal polarization.

Prior to running the NMR program, the Fast Resonance Scanner (FRS) program must be run to determine the RF frequency at which to probe the target for NMR analysis. The FRS program determines RF parameters for the NMR program's run conditions and calibration constants by sweeping the RF frequency at a constant magnetic field.

The LabVIEW front panel user interface requires a minimum and a maximum frequency (in KHz), number of samples, and the RF attenuation level. As the RF frequency changes, the nuclei in the target respond by emitting signals on the order of ~10^{-6} V (background), creating at resonance a pulse up to ~10^{-4} V, Fig 1; this is the frequency to use in the NMR program for further polarization analysis.

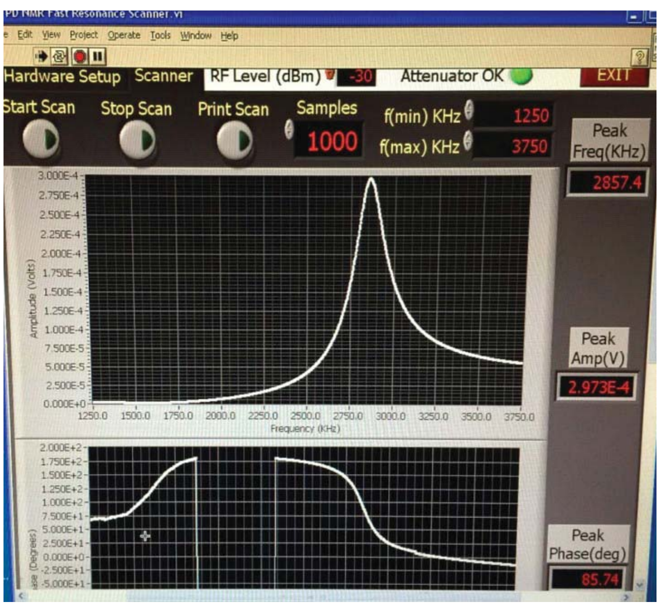
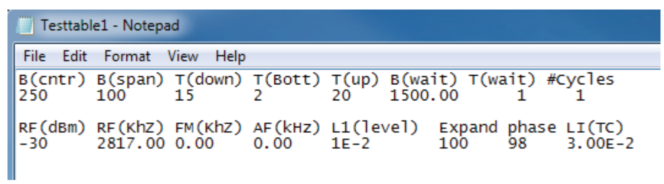


FIG. 1. Spike in FRS program while varying RF frequency, indicating ideal RF signal for NMR.

Following the run of the FRS program, the NMR program runs to measure actual NMR signals for data analysis by sweeping magnetic field at the RF frequency set by the FRS program.

At the start of the NMR program, the user must select to which dewar the program is connected. There are five dewars (PD-I, PD-II, SD, IBC-axial, and IBC-transverse), each with a different gauss per amp parameter. The power supply used in the NMR rack is configured for PD-II and requires a conversion factor to allow for the NMR program to run on other dewars without changing the physical parameters of the power supply.

The user fills out a run table as shown in Fig 2. The magnetic field value and rate in which it sweeps is defined by the run table parameters. The user enters the center field value and field span, along with the time (in seconds) to span the field across the set center value. This action happens twice, with the first span cycling the field down (time identified as Tdown) and the second cycling the field up (time identified as Tup). There are two wait values, Tbottom and Twait, which holds the power supply at a constant value to allow the RF signal to settle.


Testtable1 - Notepad

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B(cntr)	B(span)	T(down)	T(Bott)	T(up)	B(wait)	T(wait)	#Cycles
250	100	15	2	20	1500.00	1	1
RF(dBm)	RF(KhZ)	FM(KhZ)	AF(kHZ)	L1(level)	Expand	phase	LI(TC)
-30	2817.00	0.00	0.00	1E-2	100	98	3.00E-2

FIG. 2. Run table to be filled out by user.

The run table is selected and loaded from the front panel. The run table parameters are displayed in the Field Sweep tab. The times Tdown, Tbottom, Tup, and Twait, and their associated field values, are generated in a graph shown on the front panel, Fig 3.

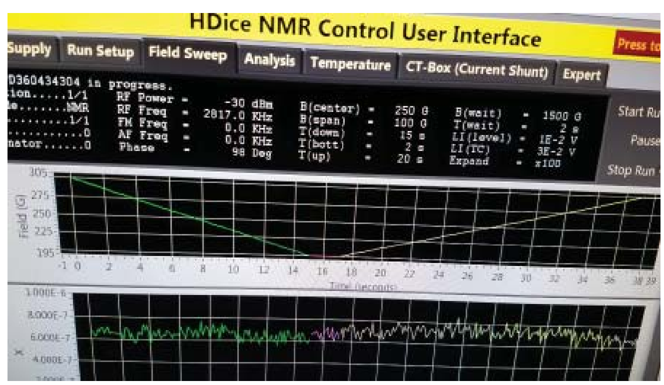

FIG. 3. Graph generated for Tdown, Tbottom, Tup, and Twait, and their associated field values.

To allow for higher precision, a CAENels Current-Transducer Box (CT-Box) was added to the data arrays. The CT-Box has an accuracy of 0.005% and gives a more accurate field reading than the power supply. The user must choose whether to record field values read by the power supply or the CT-Box before the program is run.

The lock-in amplifier records two voltage signals emitted by the nuclei (labeled X and Y). The X and Y data are recorded and saved in a file for NMR analysis. One crucial element for NMR analysis is synchronization between the lock-in amplifier and the CT-Box, meaning the data recorded by the lock-in amplifier would directly correspond to magnetic field values recorded by the CT-Box.

Synchronization between the two devices is being developed, with the CT-Box to trigger a data-recording response from the lock-in amplifier.

Once the synchronization feature is finalized, NMR data will correspond to the changing magnetic field. The data and field values will be analyzed to determine the polarization of the HDice target.