Additional explanations of pulsed NMR for Physics 352

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The free protons in a water based liquid solution, or an oil, and many other materials, orient themselves with their magnetic moment parallel to an external and highly homogeneous magnetic field B_0 (z-direction); the fraction remaining unoriented is temperature dependent. It takes a finite time (T1) for all spins to get oriented, this time is a relaxation time, and is due to the interaction of the spins with the lattice of the medium (even if a liquid); T1 characterizes this interactions.

While aligned with B_0 the magnetic moments precess around B_0 with the Larmor frequency, $\omega_L = g\mu_{nm}H/\hbar$, $\upsilon_L = , \omega_L /2\pi$; g is the gyromagnetic factor (2.79277 for the proton), $\mu_{nm}=3.15245\ 10^{-14}$ MeVT-1, and $\hbar=6.582118\ 10^{-22}$ MeVs. For a 1T field, $\upsilon_L = 1.337574\ 10^8/2\pi = 2.12881\ 10^7$ $(s^{-1}T^{-1})$.

An RF magnetic field of strength B_1 is applied perpendicular to the B_0 field (x-direction). If the frequency is exactly equal to the Larmor frequency, this RF field will rotate all the spin around an axis perpendicular to the direction of the B_0. By adjusting the duration of application of the RF field, one can generate rotations in multiples of $\pi/2$, called, 90^o, 180^o, 270^o…a.s.o. pulses. Information about changes of orientation of the spin population is obtained from the pickup coil wrapped around the sample, with axis parallel to y-direction. This coil sees only the induction generated by magnetic moments oriented in the xy-plane.

The signals from the coil are processed to generate the RF OUT signal from the receiver. A mixer circuit adds this signal to the RF signal applied to the RF coils. When added these 2 signals should show no beats if the pickup coil is sensing the actual signal.

Measure of T1

T1 is the relaxation time for alignment of the proton magnetic moment with the B_0 field, and is called spin-lattice relaxation time (or interaction with the medium surrounding the protons in the sample). It is the time constant controlling the reestablishment of the initial alignment with the main field B_0.

It can be measured by first flipping all spins from the +z to the –z direction by applying a 180^o **A pulse**. The magnetic moments will start reorienting themselves. If then a 90^o **B pulse** is applied immediately after the A pulse, most of the magnetic moments will be flipped to the xy plane and detected by the pickup coil; as the time interval between B and A pulse is increased, the pickup coil will "see" a decreasing signal, then none if the time

corresponds to a 90^o flip, and again increasing until some time later it reaches a value equal to the zero-delay value (or initial value). This corresponds to the M_z component of the net magnetization going from $-M_z$ to 0 to $+M_z$. For this manipulation, the **scope should be triggered on the B-pulse.** The B-pulse is used to interrogate what happened to the magnetization as a function of the time after elapsed since it was flipped to $-M_z$.
There are 2 other ways to measure T1; discuss it later.

Measure of T2
T2 is the relaxation time for magnetic moments in the xy-plane, perpendicular to the main field B0, and is called spin-spin relaxation time. Such a state is the result of a 90^o flip **A pulse**. The interaction among the spins of the protons results in a dephasage, with a characteristic time called T2. It can be measured by applying a 180^o **B pulse**, while **triggering the scope on the A pulse.** The z to –z rotation resulting from the B-pulse reverses the process of dephasage and results in a spin echo when all the spin return to their initial state, to then start dephasing again. This technique compensate for the effects of field inhomogeneity. One can either measure the height of the echo pulse versus delay between A and B pulse (called τ), or applying a series a B pulses and looking directly of the decrease of the amplitude versus pulse number (that is time). You should do both and compare the results.

The mixer output gives information about the relative phase of the signal and the RF frequency; the signal itself is a rectified measure of the maximum value of the pickup signal, thus contains no phase information. A good example of use of the mixer output is observation of the change of the magnetization sign in the T1 measurement, when the mixer output signal changes sign while the polarization crosses the xy-plane.