Controls and Signals for the PNMR
A Conceptual Explanation

Pulsed nuclear magnetic resonance begins with the net magnetization of the protons of a sample in thermal-equilibrium in a strong magnetic field which is designated B_o. There is a net alignment of the spins with this field which is considered to be directed along the +z axis. In the TeachSpin PNMR, this is the field of the permanent magnet. The direction of the net magnetization is altered by one or more 90° or 180° rf pulses. The spins, tipped into the x-y plane, then precess around Bo creating a time varying voltage in a pick-up coil. The **pick-up coil** monitors only magnetization in the x-y plane. (See diagrams on pages A and B)

The **RECEIVER** processes the information coming from the pick-up coil. As the spins precess inside the pick-up coil, they induce a voltage which rises and falls as a sine wave with each rotation and decreases with time. This, however, is not the signal that the **DETECTOR** sends to the oscilloscope. The detector transmits only the maximum strength of the signal for each rotation. In addition, the signal has been "rectified" so that only a positive magnitude is shown each time. It is this "rectified" envelope that represents the free induction decay or FID. (If you wish to observe the sinusoidal output of the pick-up coil, it is available at the **RF OUT** of the receiver.)

The **FREQUENCY IN MHz** read-out on the right side of the PNMR gives the radio frequency (rf) pulse being used to "tip the spins" and change the direction of the net magnetization of the sample. For proper on-resonance operation, this frequency must be the same as the precession frequency of the protons in the field of the permanent magnet. (In the Magnetic Torque simulation, this is equivalent to the frequency at which the small rotating field accessory is turned by hand. When doing this by hand, on the Magnetic Torque apparatus, the person turns the small magnet assembly so that it keeps up with the precession the ball has in the field generated by the coils.)

The **MIXER** "beats" the rf pulse frequency with the actual precession frequency of the protons as sensed by the pick up coil. This allows the experimenter to see if they are the same. The **FREQUENCY ADJUST** tuning can then be used to match the frequency of the rf pulse to the proton precession frequency. The agreement drifts because the temperature of the permanent magnet is not absolutely constant. Any change in magnet temperature causes a change in the magnetic field $\mathbf{B_o}$ and thus in the precession frequency. (See diagram on page A.)

The actual proton precession frequency sensed by the pick up coil comes from the **RF OUT** on the receiver and is connected to **MIXER IN** on the mixer itself. An internal connection feeds the rf frequency of the rotating magnetic field into the mixer. **MIXER OUT** sends the difference frequency ($\omega_{rf} - \omega_{precession}$) to the oscilloscope. We put that signal on Channel 2 of the oscilloscope.

There are **two different GAIN mechanisms**.

1. The Gain of the PNMR receiver amplifies the signal coming from the pick up coil. The ability of the PNMR to magnify in this way does have a maximum. You will see a flat top on the signal if you have reached the maximum.
2. The gain on the oscilloscope is basically an enlarger which just makes the "picture" of the signal on the scope larger.

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