NMR with a fast moving coil array

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NMR is typically performed with the detector and sample in a fixed relative position. In NMR well-logging, however, the tool detector is in constant motion relative to the rock formation sample. The conventional approach is to move the tool slow enough in order to be quasi-static. Fast movement causes the sample to move out of the detector coil during the CPMG acquisition and thus increase signal decay and $1/T_2$. Thus, inclusion of a second or more coils placed following the first coil could capture the signal from the escaping portion of the sample. This paper shows a multiple-coil system in order to obtain high quality NMR data at high speeds.

The new system (Fig.1) is constructed with a long magnet array (brown blocks) and four RF coils (gray boxes within the magnet). NMR experiments were performed using a Redstone spectrometer (Tecmag Inc.) with four transmit and reception RF channels for independent transmit and reception.

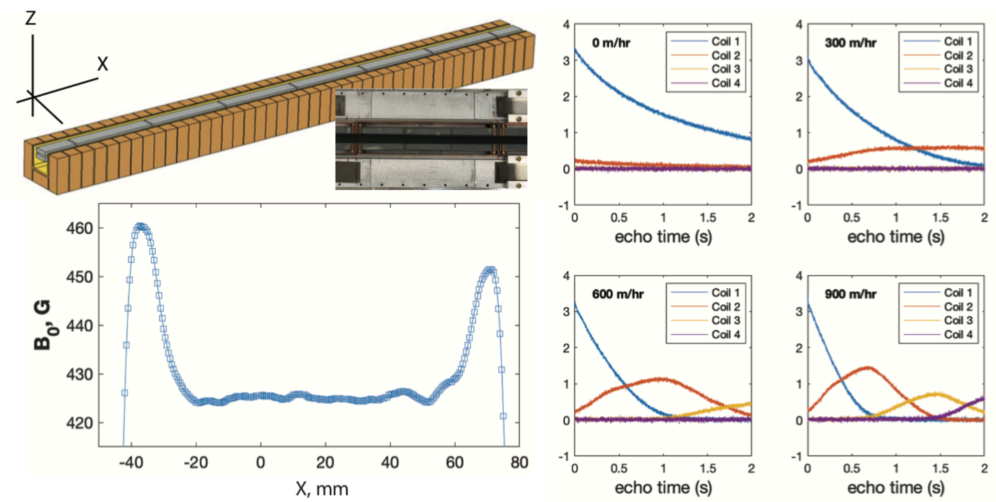

Fig. 1. Left: magnet and coil structure; The magnetic field at the sweet spot ~3.8 cm above the coil surface is uniform along the X direction within ± 1.2 G for 70-cm length. The B1 field from all coils were adjusted to be uniform ($\pm 10\%$) over the entire 4 coils. Each coil is 17 cm long. **Right**: Signals from a 13-cm long sample starting from Coil 1.

The 4 right panels show the signals from all coils at different speeds. For the static measurement, the majority of the signal appears at Coil 1 with a slight one from Coil 2. Coil 3 and 4 are too far away and thus no signal. At a 300 m/hr speed, the Coil 1 signal decays noticeably faster than the static case. The more interesting observation is the Coil 2 signal starts to rise, instead of decay. For higher speeds, for example 600 m/hr, the Coil 2 signal rises first and then falls as the sample move further out of Coil 2. Also Coil 3 start to observe signal after ~1 s when the sample enters it. For 900 m/hr, Coil 4 starts to observe signal after 1.5 s when the sample enters its area. Such complex signal behavior can be described by:

$$S^i(\tau) \sim \int dRdT_2 \Phi(R, T_2) \exp[-\frac{\tau}{T_2}] G[R - r^i(\tau)],$$

where G(R) is the coil sensitivity function and $r^i(\tau)$ is the position of Coil i at time τ. Using this equation, the multi-coil data can be analyzed to obtain accurate signal amplitude (Φ) as a 2D map of spatial coordinate and T_2. Results from samples of different amplitudes and T2 obtained at speeds up to 900 m/hr will be discussed.