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 slowly. Fast movement causes the sample to move out of the detector coil during the CPMG acquisition and thus increase $1/T_2$. Thus, inclusion of more coils 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 receive RF channels.

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. Coils 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 moves further out of Coil 2. Also Coil 3 starts 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:

$$S^i(\tau) \sim \int dR dT_2 \Phi(R, T_2) \exp[-\frac{\tau}{T_2}] G[R - r^i(\tau)],$$

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 T_2 obtained at speeds up to 900 m/hr will be discussed.

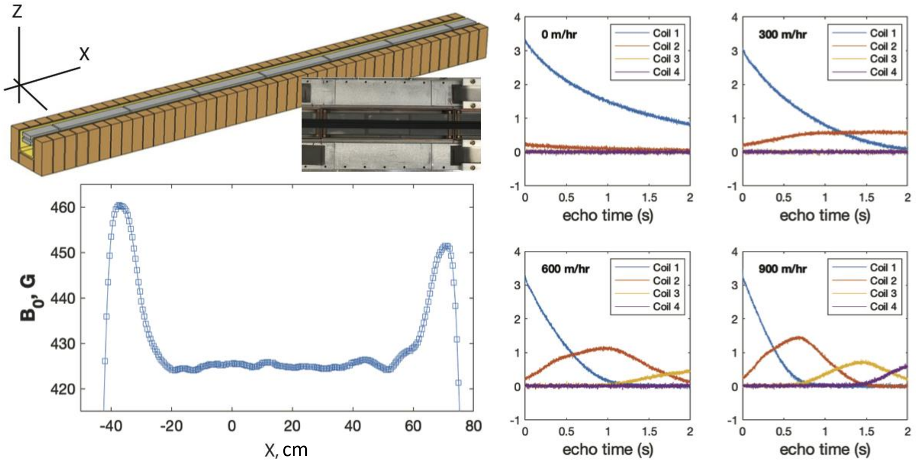

Fig. 1. Left: Magnet and coil arrays; the B_0 field at the sweet spot ~3.8 cm above the coil surface is uniform along the X direction within ± 1.2 G for 70-cm length. The B_1 field were adjusted to be uniform (± 10 %) over all 4 coils (each 17 cm long). **Right**: Signals from a 13-cm long sample starting from Coil 1.