Intro to MRI and Stray Field Imaging

(original concept by Samoilenko et al., JETP Letters, V47 (1988) p417-419)

Funny things you can do with an MAS/DAS probe

Jay Baltisberger
Basics of MRI

- Inhomogeneous broadening from internal source (CSA, Pake pattern, etc.)
- MR Imaging relies on broadening from an external source (magnetic field gradient)
- Dispersion due to gradient proportional to gradient strength

\[
\tilde{G} = \left( G_x, G_y, G_z \right) = \nabla B = \left( \frac{\partial B}{\partial x}, \frac{\partial B}{\partial y}, \frac{\partial B}{\partial z} \right)
\]
Back Projection

- One of earliest approaches
- Apply gradient in various directions and determine image from the projection onto each gradient axis
FT Approach to 1D Sample

- Simple case of plastic insert in an NMR tube
- Pulse and acquire, FT for 1D image
MRI and k-space

- This is the inverse FT of the real Cartesian space, often aligned on a grid.
- Using gradients to sample all of “k-space” is required for good image.
- Closer spacing equates to a larger area imaged.
- Longer k-space values equate to higher spatial resolution.

\[ k_i(t) = \gamma \int_{0}^{t} G_i(\tau) \, d\tau \]
Fast 2D/3D Imaging

- Echo planar imaging sequences
- Various approaches to fill “k-space”
- May involve non-regular data spacing in time
Stray Field Imaging

- Consider that a 9.41T magnet goes from 9.41T at the center to about 0.01T near the base of the shim stack.
- \( G_z = (9.41\text{T} - 0.01\text{T})/0.5\text{m} = 18.8 \text{T/m average} \)
- There will in fact be locations with a much higher gradient since the \( G_z \) will not vary linearly across this region
- Conventional gradients are 2 or more orders of magnitude less, meaning 100 times lower spatial resolution.
- Most of pictures come from Landeghem et al., JMR V211 (2011) p60-66
Basics of STRAFLI

- By having the sample in a very strong stray field gradient, a single plane will be both excited and detected and may be mapped as a function of sample location.
- Resolution limited by strength of gradient, number of excited spins and control of sample motion
Sample STRAFI image

- Step-by-step (5 µm) profile of phantom of two cream layers between 150 µm glass slides
MAS STRAFI

- MAS is equivalent to rotation about the body diagonal of a cube
- In the presence of a $G_z$, this can appear as a moving gradient in time from the same perspective
MAS STRAFI Pulse Sequence

- Stop evolution to just at the three orthogonal rotor phase positions (0°, 120° and 240°) using both π/2 and π pulses
- Sequence becomes analogous to the MAT/MAH type of experiments
- Use of π pulses renders sequence constant time and allows no loss of signal from π/2 storage pulses
Image of Phantom

- 2D Image of a water phantom used to test the $\pi$ pulse sequence
- For scale, this is done in a 4mm OD MAS rotor
- Distortions due to non-linearity of the $G_z$
Non-symmetric object in 3D

• By using variable delays along with rotor triggered pulses, a series of 2D projections of a coffee bean have been assembled

• All processing done using FT analysis, future work may involve back projection techniques mentioned earlier in the seminar
Problems

- Using RF pulses with a gradient present means dealing with large offset effects, meaning non-ideal 180 pulses to many of the spins in the sample.
- Overall the acquisition time seems to be rather long for the quality of images, mostly a function of small numbers of spins involved versus normal imaging.