A quiet, fast, high-resolution desktop MRI capable of imaging solids

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Purpose

We converted a low-cost NMR spectrometer into a tabletop MRI capable of quickly imaging solid structures with short T_2 decay times.

Methods

The conversion of the 0.34T NMR spectrometer (RadioProcessor Model G, iSpin-NMR, SpinCore Technologies (Gainesville Florida) into a tabletop MRI required creating gradient coils for all three axes, custom pulse sequences, and a MATLAB GUI for pulse sequence implementation and image reconstruction. The probe, included as part of the NMR spectrometer system, was a combination transmit/receive solenoid coil enclosing a cylindrical sample area of 5 mm diameter by 10 mm in height.

Gradient coils were created by two different methods: hand winding and additive manufacturing [1]. Each set of gradient coils (5 cm x 5 cm x 2 mm) was mounted on a perforated board and sandwiched the RF probe on both sides, between each permanent magnet and the probe. Initially the coils were made by hand using magnet wire and subsequently, these hand wound coils were replaced by optimized coils printed using additive manufacturing onto a thermally conductive substrate. The gradient coils were powered by class H audio amplifiers (RMX 4050HD, QSC Audio Products LLC, Costa Mesa, CA, USA).

Results

The hand wound coils were capable of delivering ~1.5 T/m gradients (ten turns, 40 Amps) within the entire sample region in all three directions. The printed coils made using additive manufacturing have a rise time under 5 microseconds and a slew rate of approximately 30 kT/m/s with a gradient strength of approximately 0.1 T/m (ten turns, 3 Amps). The printed coils excelled at producing a homogenous gradient field as determined by phase field mapping [2] and minimizing acoustic noise.

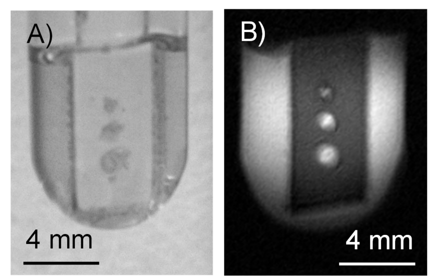

Figure 1: A) Photograph of a plastic phantom submerged in aqueous solution held within a test tube. B) 2D gradient echo MRI projection image acquired within 60 seconds.

We created a MATLAB graphical user interface to program custom pulse sequences, gather MRI data, and for image reconstruction. Custom pulse sequences were encoded in C programing language, which is easily interfaced to the SpinCore application software. The pulse sequences included: gradient echo for fast acquisitions; spin echo to minimize T_2* effects; spiral imaging for improved speed; CPMG for T_2 sample measurements; inversion recovery for T_1 sample measurements; and three dimensional volume acquisitions using a gradient or spin echo [2]. Shimming was added by additional DC offsets to each coil during the entire pulse sequence. Using gradient echo imaging, images can be obtained under one second with 50 micron resolution. Due to the quick acquisition time, quickly decaying signals, such as that from solids, can be captured and visualized.

Conclusion

Quick acquisitions of solid structures with high-resolution have been achieved with a tabletop MRI. This system will allow researchers to quickly reveal anatomical features within solid objects that were not previously imaged using conventional MRIs.

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References

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