Phantoms for Ultra-low Field MRI

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Purpose

The National Institute of Standards and Technology (NIST) is developing standardized, traceable phantoms for MRI to enable characterization, calibration, and validation of MR scanners, and guide their improvement.

Ultra-low field (~100 μT) MRI (ULF-MRI) is being developed as a complement to conventional (0.5-3.0 T) MRI and requires phantoms for characterization and calibration. We therefore constructed phantoms and measured them at 132 μT, 1.5 T, and 3 T. The phantoms are designed to characterize T_1 imaging on the scale of tens to hundreds of milliseconds, and resolution on the scale of millimeters.

Methods

The phantoms are squat “hockey pucks” containing cylindrical vials of contrast solutions held in place by polypropylene plates. The pucks can be filled with de-ionized water for imaging at conventional field strengths.

A suite of dilutions of $MnCl_2$ was used for T_1 contrast. As dilute salt solutions, these provide stable, linear relaxivity. A suite of dilutions of D_2O was used for proton density (PD) contrast. A resolution inset consisting of an array of holes in a polypropylene plate was used to test scanner resolution.

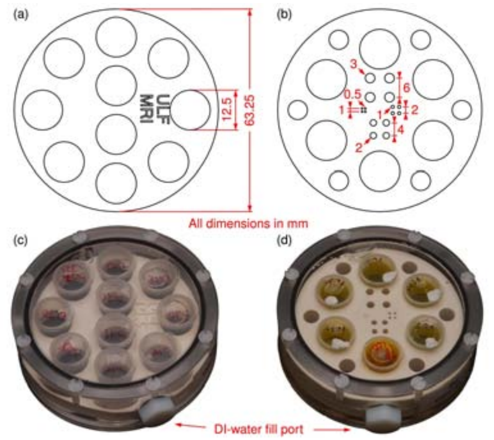

Figure 1. Schematics and photographs of NIST phantoms. Vials hold different concentrations of contrast agents and the array of holes in (b) and (d) constitutes a resolution inset.

Results

The $MnCl_2$ dilutions in the phantoms produced clinically relevant T_1 values at 132 μT (40 ms – 250 ms) as well as at 1.5 T and 3 T (roughly 400 ms – 2 s). The dilutions were well-spaced to examine the T_1 sensitivity of the scanners. The D_2O array allowed characterization of the linearity of system response. The resolution inset was appropriate for characterization of the resolution of existing ULF-MRI scanners (~ 2 mm), with headroom to track expected technological improvement.

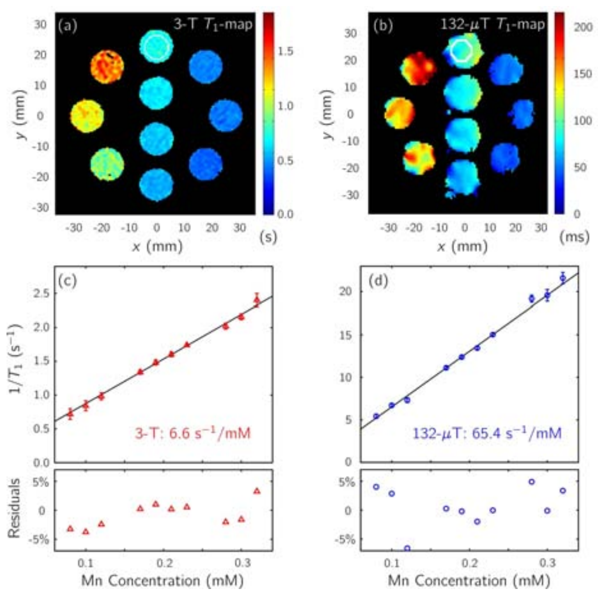

Figure 2. T_1 maps of the $MnCl_2$ phantom from a 3 T scanner and a 132 μT scanner. The subplots derive relaxivity from region-of-interest averages (e.g. white circles).

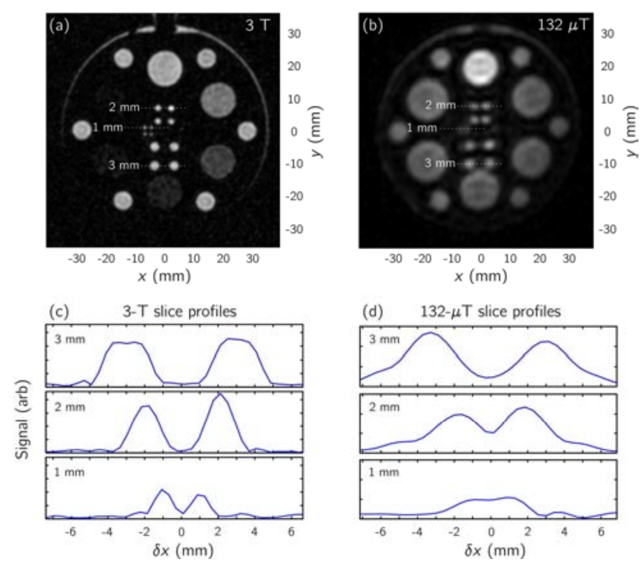

Figure 3. Images of resolution inset from a 3 T scanner and a 132 μT scanner. The subplots illustrate system resolution from cuts through the inset.

Conclusion

We confirm the utility of the phantoms for characterization of ULF-MRI systems. The phantoms can serve as common references for comparing scanner performance, both between ULF-MRI systems and between ULF-MRI and conventional clinical MRI.