

Multi-Coil Imaging with Algebraic Reconstruction

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INTRODUCTION: To date, MR imaging is based on spherical harmonic (SH) functions and combinations thereof. Linear field gradients corresponding to the first order SH terms allow Cartesian and radial encoding schemes and in combination with Fourier-based reconstruction provide the basis for most currently applied MR imaging techniques. Algebraic reconstruction involving second order SH terms has received some attention recently [1,2]. All of these methods share the use of low-order SH shapes.

Multi-coil (MC) magnetic field modeling has been shown to enable the flexible and accurate generation of magnetic fields for various MR applications [3]. With the MC approach, magnetic field shapes are synthesized by superposition of non-orthogonal basis fields from individual, generic coils, which is conceptually different from the conventional generation of coil-specific SH field shapes with dedicated wire patterns. After the demonstration of the benefits of MC magnetic field modeling for the homogenization of magnetic fields in the rodent and the human brain [4,5], here we present the first MC imaging application with spatial encoding fields that were not based on low-order SH shapes and coils. Instead, spatial encoding was achieved by MC magnetic fields from simple, circular coils and images were calculated by algebraic reconstruction.

METHODS: This first realization of MC imaging with algebraic reconstruction was based on a standard projection approach similar to radial imaging, however, with the linear magnetic field gradients replaced by non-SH MC fields. The spatial encoding fields were generated by a miniaturized MC setup designed for magnetic field modeling in mice [4]. In essence, 48 individual coils (diameter 13 mm, 30 turns) were placed in 6 rings of 8 coils on a cylindrical surface (diameter 32 mm) and driven with home-built amplifier electronics in the ± 1 A range at switching times of 10 μ s. A total of 125 magnetic fields spanning the -30..+30 kHz range in a not further specified fashion over a 12 mm field-of-view were synthesized with the MC setup (examples are shown in figure 1) and applied for spatial encoding. Experiments were done on a 9.4 Tesla small-bore scanner (Agilent Inc.) and based on customized methods and software. Singular value decomposition (SVD) was applied to reconstruct the acquired data on to a 40 \times 40 imaging grid.

RESULTS: MC magnetic fields have been successfully applied for MR imaging in combination with algebraic reconstruction (Fig. 2, left). Good image quality was achieved in this proof-of-principle study and all three imaged water tubes were clearly visible. For comparison, a reference image based on conventional radial imaging is shown in figure 2 (right) in which the spatial encoding fields were provided by the MR scanners' built-in gradient system. Radial images were reconstructed by filtered back-projection.

DISCUSSION: Today's MR imaging methods use low-order SH shapes or combinations thereof. Here we show that MR imaging does not rely on SH shapes and can also be achieved with random magnetic field shapes when analyzed by algebraic reconstruction. The consistency of the magnetic fields that are applied experimentally with the shapes that are assumed by the image reconstruction is essential for every algebraic method. The MC concept has been shown previously to allow the synthesis of highly predictable magnetic field shapes [3-5] which is considered key for its successful application to spatial encoding and algebraic imaging. Note that the applied MC encoding fields had significant amplitudes throughout the entire field-of-view and, therefore limited spatial specificity at the magnet's iso-center as reported for SH shapes was avoided. The shallowness of the available low-order SH terms can limit the image fidelity and the MC approach bears the potential to address this limitation through synthesis of spatially more specific magnetic field shapes. The freedom to use unconventional field shapes for spatial encoding demonstrated here together with the ability of the MC concept to reliably generate them opens the door for the optimization of additional parameters such as field efficiency with the design of spatial encoding schemes. The presented work has been limited to the proof-of-principle of MC imaging with algebraic reconstruction. Neither imaging characteristics nor efficiency considerations have been addressed in this work and will be part of future research.

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[1] MAGMA 21:5-14 (2008), [2] MRM 64:447-56 (2010), [3] JMR 204:281-289 (2010); [4] MRM 66:893-900 (2011); [5] JMR 212:280-288 (2011)

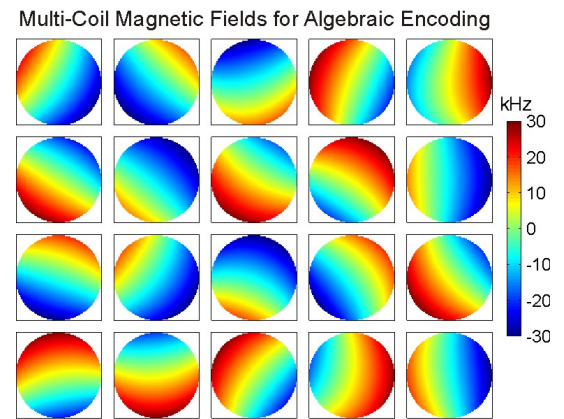


Fig. 1

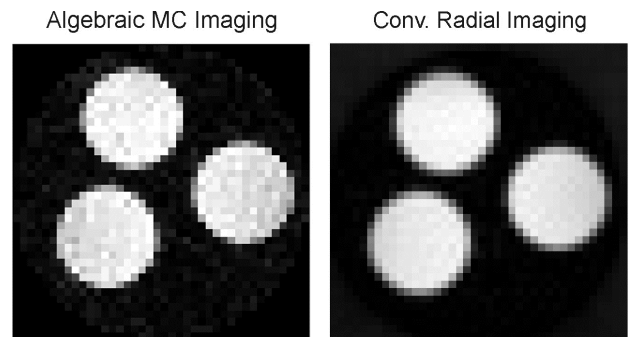


Fig. 2