Three-Dimensional MR Fingerprinting (MRF) and MRF-Music Acquisitions

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Purpose: The goal of this study is to extend the MR Fingerprinting (MRF)[1] and MRF-Music[2] acquisitions to 3D. MRF is a acquisition and processing framework that utilizes pseudorandom acquisition strategies to enable simultaneous quantification of multiple important properties of a tissue. The initial application of MRF was for relaxation parameter mapping. MRF-Music is an extension of MRF, which was developed to manipulate the pseudorandom acquisitions so that the sequences have the additional feature where the gradient sounds produce music, improving patient comfort. High scan efficiency and image quality are still maintained. Both MRF and MRF-Music were originally implemented in 2D acquisitions. This study extended these two sequences to 3D in two different ways: the scans are performed with 3D slab-selective and 3D non-selective acquisitions.

Sequence Design: 3D slab-selective MRF was implemented by adding additional phase encoding gradients in the slice direction, to the original 2D MRF. For the **3D slab selective MRF-Music**, these phase encoding gradients were designed to be consist of three music segments that were optimized based on [2] for specific slab selective encoding, dephasing and rewinding. Correspondingly, VERSE RF pulses were designed for each slab selective encoding gradient within each TR, such that the slice profile was identical to that of the sinc pulse used in the MRF sequence. In order to correct for the imperfect slice profile, an AFI sequence[3] was applied to measure the slice profile from both sequences. **The 3D non-selective MRF** used a rectangular RF pulse with no concurrent slice selection gradient. A radial trajectory was rotated to uniformly cover the surface of a sphere[4]. These angles were then segmented into different numbers of images and repetitions for the MRF acquisition. For the **3D non-selective MRF-Music sequence**, instead of a radial trajectory, the music gradients were designed as the radial lines of a 3D sphere and were projected to three encoding directions by the angles from [4].

Acquisition: The 3D slab selective sequences were applied in both phantom and *in vivo* studies, with a FOV of 300x300x48 mm^3 and a matrix size of 128x128x16. For each partition, 1000 time points were acquired for the 3D-MRF sequence, and 4000 time-points were acquired for the 3D-MRF-Music sequence. The total scan times for the 3D slab selective MRF and MRF-Music were 3.6 minutes and 12.4 minutes, respectively. For the 3D non-selective MRF and MRF-Music sequences, acquisitions consisted of 1579 time points with 144 repetitions and 178 repetitions, respectively, with a time outlay of approximately 37 minutes in both cases.

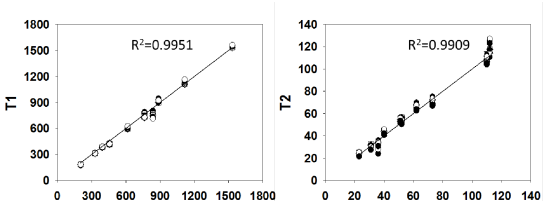

Figure 1: The comparison of the T_1 (ms) and T_2 (ms) values measured from 3D slab-selective MRF and standard methods in a phantom study.

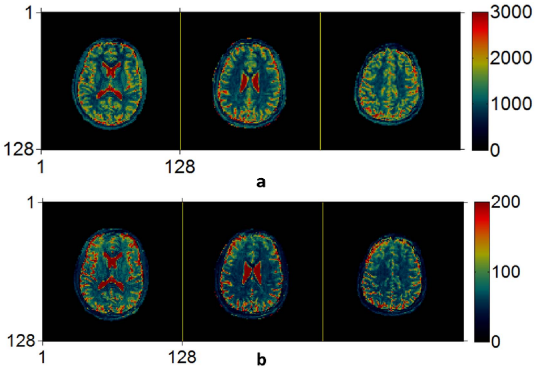

Figure 2: In vivo T_1 (a, ms) and T_2 (b, ms) maps from a 3D slab-selective MRF-Music scan. Partition No. 4, 8 and 12 are shown.

Results: Figure 1 shows the phantom results from the 3D slab-selective MRF scan. T_1 and T_2 values from the 3rd to 13th partitions are in good agreement with the values measured from the standard measurements. Figure 2 depicts T_1 and T_2 maps from the central 3 of 16 partitions from the 3D slab selective MRF-Music sequence. Due to the space constraints, only 3D non-selective MRF-Music results are shown in this abstract. The MRF-Music sequence used the encoding gradients derived from a recording of Yoyo Ma playing Bach's Cello Suite 1. Figure 3 showed an example of the T_1, T_2, off-resonance and M_0 maps in axial, sagittal and coronal views from this 3D non-selective MRF-Music scan.

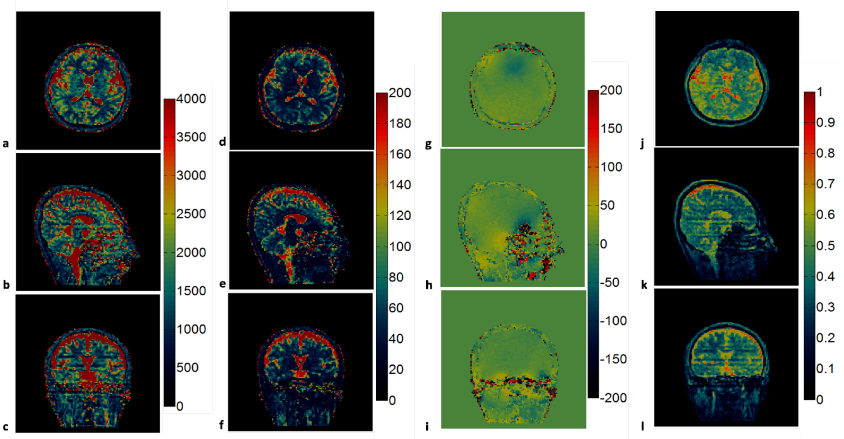

Figure 3: Examples of the T_1 (a-c, ms), T_2 (d-f, ms), off-resonance (g-i, Hz) and M_0 (j-I) maps in the axial, sagittal and coronal views from a non-selective MRF-Music scan

Conclusions: This study demonstrated the capability of obtaining 3D maps of multiple tissue properties from both MRF and MRF-Music sequences. In addition, 3D MRF-Music provided a sound similar to the original music, which could dramatically improve patient experience during MR scans. Future studies will include improvement of the sampling efficiency and image quality by optimizing the encoding gradients and reduction of the scan time.

Reference: [1] D.Ma et al. Nature (2013). [2] D.Ma et al. ISMRM,22(2014). [3]V.Yarnykh,MRM(2007). [4]D.Piccini et al. MRM (2011).[5]J.Fessler et al. IEEE Trans Sig. Proc. (2013). **Acknowledgement:** The authors would like to acknowledge funding from Siemens Healthcare and NIH grants NIH 1R01EB016728-01A1 and NIH 5R01EB017219-02.