2D Radial Acquisition Technique with Density Adaption in Sodium MRI

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Introduction:

In this work we propose a 2D projection reconstruction method with variable gradient amplitudes to cover the k-space uniformly, as described elsewhere for the 3D case [1]. Signal-to-noise ratio is increased and the linear form of the radial trajectory is kept contrary to the twisting radial-line (TWIRL) trajectory [2] and interleaved spiral trajectory [3]. This method can be easily implemented at the MR scanner due to the simple gradient design and lower hardware requirements in respect of slew rate. Simulations and sodium measurements of the human head are shown for the density adapted 2D radial trajectory (DA-2DRT) compared to the conventional 2D radial trajectory (2DRT).

Methods:

Sodium measurements were performed on a 3.0 Tesla clinical whole-body MR scanner (Magnetom Tim Trio, Siemens, Germany). Using a variable-rate selective excitation pulse [4] the echo time is kept as short as possible. For density adaption the readout gradient must be shaped as shown in Fig. 1 to obtain uniform k-space coverage. The radial spokes were homogeneously distributed in k-space with equally spaced azimuthal angles φ ($0 < \varphi < 2\pi$). The k-space data was reconstructed using a convolution with a Kaiser-Bessel kernel [5] (W=4.0) followed by sampling onto a Cartesian grid and a complex 2D fast Fourier transform. The received k-space signal is dependent on the sequence design due to transversal relaxation. Therefore, the point-spread function PSF(x) was simulated for trapezoidal gradients, for full density adapted gradients (which cannot be applied in practice) and for those density adapted gradients that were used for the measurements. Dependent on T_{RO}/T_2^*, the blurring is readable from the full width half maximum of the PSF and the SNR for small objects was quantified by $\mathrm{sqrt}(T_{RO})*\mathrm{PSF}(0)$. Sodium measurements of the human head were performed to compare both sequence schemes in regard to SNR and blurring caused by T_2^* decay depending on the readout window. A slice thickness of 6 mm and an in-plane resolution of 4 x 4 mm^2 were used. The echo time TE was 0.1 ms, the repetition time TR was 50 ms and a flip angle of 74° was employed to match the Ernst angle. One image was averaged over 40 measurements and the number of projections was 160 to fulfill the Nyquist criterion, resulting in a total scan time of 10 min 40 sec.

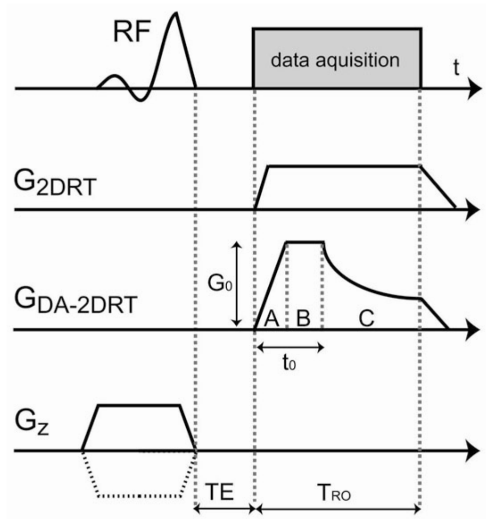

***Figure 1**: Scheme of the 2D radial sequence with (DA-2DRT) and without (2DRT) density adaption. The readout gradient of the DA-2DRT sequence is divided into three parts: A = ramp, B = trapezoidal and C = density adapted part.*

Results:

The amplitude and FWHM of the simulated PSF are shown in Fig. 2 for monoexponential T_2^* decay. The optimal readout window $T_{RO} = \alpha \cdot T_2^*$ for highest SNR (Fig. 2c) is $\alpha = 0.81$ for trapezoidal gradients, $\alpha = 1.19$ for density adapted gradients considering hardware limitations and $\alpha = 1.25$ for full density adapted gradients. The associated SNR benefit is 1.19 for the full density adapted case and 1.17 for the less density adapted case. This SNR gain is only induced by the more efficient signal acquisition under T_2^* decay. The theoretical expected SNR gain neglecting T_2^* relaxation effects is 14.5 % (15.5 % for full DA-2DRT). A total benefit in SNR of 1.37 for the fully adapted sequence and 1.34 for the less adapted sequence can be reached if the more homogeneous sampling is considered. Sodium measurements of the human head with both sampling schemes are shown in Fig. 3 for different readout window lengths. An SNR benefit is always observed for the DA-2DRT sequence in comparison to the conventional radial trajectory (brain tissue: 14 %, 18 %, 29 %, 25 % for T_{RO} = 5, 10, 20, 40 ms). At T_{RO} = 40 ms, signal extinctions appear for the non-adapted sequence due to magnetic field inhomogeneities while for the density adapted trajectory the decrease in image quality is negligible.

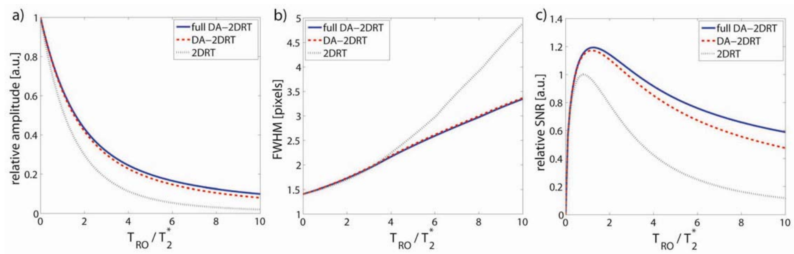

***Figure 2**: a) Amplitudes of the point-spread functions of the 2DRT, DA-2DRT and the fictional case of a full density adapted trajectory as a function of the readout duration T_{RO}/T_2^*. b) Full width half maximum of the associated point-spread functions. c) Resulting SNR for these three different trajectories.*

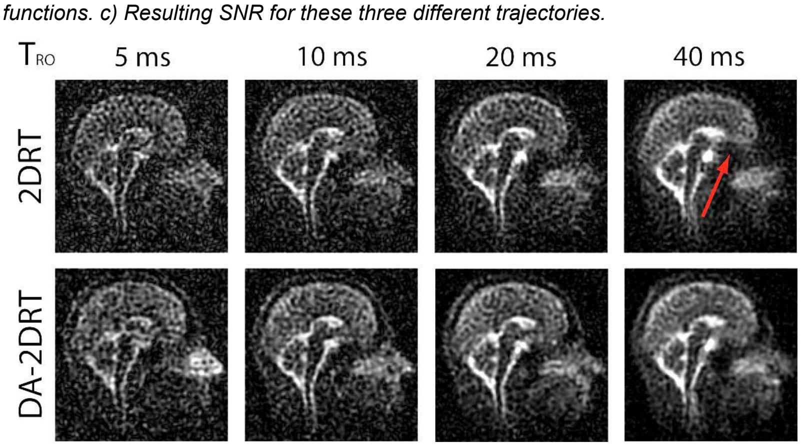

***Figure 3:** Sodium measurements of the human head with both sequence schemes and different readout lengths T_{RO}. The SNR is always higher for the density adapted sequence. Signal extinctions (red arrow) appear for the 2DRT sequence with long readout windows because of magnetic field inhomogeneities.*

Discussion:

We present a new density adapted 2D radial sampling scheme which provides higher SNR, less blurring and less artifacts in the presence of magnetic field inhomogeneities than conventional projection reconstruction methods. In addition, its straightforward trajectory form simplifies the implementation at the MR scanner when compared to spiral trajectories. This sequence is well suited for sodium MRI and other applications where short echo times are required.

References:

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