# Filter implementation into a 2D radial trajectory for sodium MRI

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## Introduction:

Large voxel sizes (>30mm$^3$) are required for sodium imaging due to its low sensitivity that can result in Gibbs ringing if no filter is used. However, noise filtering leads to non-efficient use of data in spatial/temporal aspects. SNR increase can be obtained by using a k-space trajectory with an intrinsic k-space filter [1,2]. In this work, a pre-filter (Hamming) was implemented into a 2D radial trajectory (2DRT-PRE) and compared to imaging with a post-filter (2DRT-POST) and without filtering (2DRT-W/O). It is shown that an SNR increase up to 60% can be reached by pre-filtering for sodium imaging of the human heart.

## Methods:

All measurements were performed on a 3 Tesla whole-body MR scanner (Magnetom Tim Trio, Siemens Healthcare, Erlangen, Germany). For phantom measurements, a double-resonant birdcage head coil (Rapid Biomedical GmbH, Würzburg, Germany) was used. For heart imaging, signal was acquired with an eight-channel coil array [3]. It consists of two identical parts with a transmit loop and four receive-only channels each. Only three channels were used for reconstruction to enhance SNR. Image quality was improved by using a density-adapted radial acquisition scheme [4] for post-filtering and for the case without filtering. Hamming filter was implemented because of its finite value at the maximum k-value $k_{max}$. To obtain the same resolution (FWHM), the maximum k-value must be higher for filtering: $k_{max}$(w/ filter)=α·$k_{max}$(w/o filter). The point-spread function (PSF) was simulated for the three sequences. Depending on the readout length and the transversal relaxation time ($T_{RO}$/ $T_2$*), blurring is detectable by the FWHM of the PSF for small objects.

Parameters for the phantom measurement: TR/TE=20ms/1.4ms, α=40°, averages=80, projections=320, slice thickness=10mm.

Parameters for the human heart measurement: TR/TE=20ms/1.7ms, α=55°, averages=30, projections=640, slice thickness=10mm. A time delay of 200ms was inserted after the R-wave of the healthy volunteer and 32 projections were acquired for each heart beat.

The readout parameters are shown in Table 1 to obtain an in-plane resolution of 4mm with $T_{RO}$=10ms.

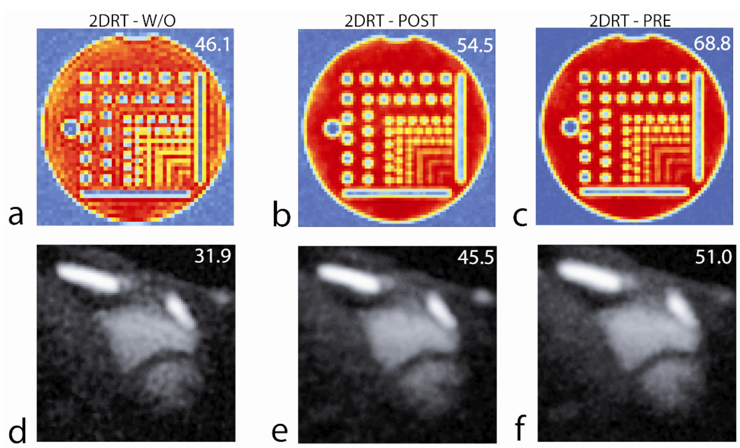


***Figure 2. a-c:*** Sodium phantom measurements with the three sequence schemes. Gibbs ringing is clearly visible for the case without filtering.
**d-f:** Sodium imaging of the human heart in short-axis view. The values in the upper right corner show the SNR of blood.

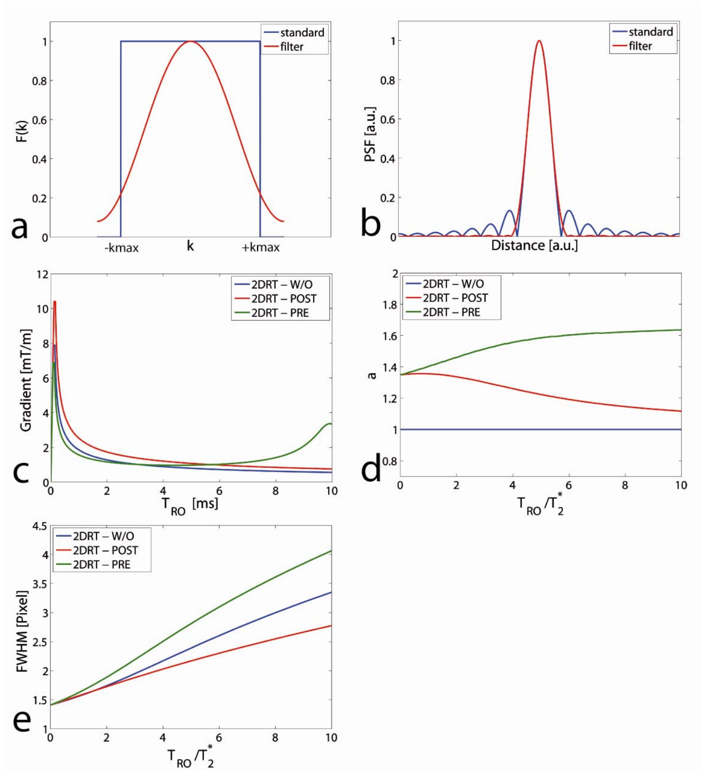


***Figure 1.*** **a:** k-space weighting without (blue) and with (red) filtering and **b:** the associated PSF. **c:** Gradient designs of all sequences. **d:** Factor on $k_{max}$ for same resolution as for the case without filtering. **e:** FWHM dependent on $T_{RO}$/ $T_2$* for α=1.35.

| | 2DRT – W/O | 2DRT – POST | 2DRT – PRE |
|---|---|---|---|
| $G_0$ [mT/m] | 7.89 | 10.4 | 6.87 |
| $t_0$ [ms] | 0.14 | 0.16 | 0.12 |
| SNR (phantom) | 46.1 | 54.5 | 68.8 |
| SNR( heart) | 31.9 | 45.5 | 51.0 |

***Table 1:*** *Gradient parameters for all readout schemes and SNR values for phantom and heart measurements. $G_0$ is the maximum gradient amplitude and $t_0$ the time where density adaption begins.*

## Results and Discussion:

The k-space weighting is shown for the case without (blue) and with (red) filtering, where the maximum k-value must be 1.35 times higher to obtain the same resolution, even without Gibbs ringing (Fig.1a+b). The gradient designs of the different readout schemes are shown in Fig.1c. For shorter transversal relaxation times $T_2$*, the maximum acquired k-value must be higher for 2DRT-PRE and lower for 2DRT-POST (Fig.2d) to obtain same resolutions. In Fig.1e, the FWHM is depicted dependent on $T_{RO}$/ $T_2$* with a constant α=1.35. All these results are valid only for point-shaped objects and differ from real measurements because the shape of the PSF is not considered. Phantom and heart measurements are shown in Fig.2. The absence of Gibbs ringing and an SNR increase is clearly visible for the filtered images. The SNR could be increased up to 60% using 2DRT-PRE.
In conclusion, the use of an implemented filter in the trajectory will improve the SNR and the shape of the PSF.

**References:**
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