# A Comparison of Time Domain and Frequency Domain All Rank Selection Order Statistics Filtering (ARSOS) of Single Voxel $^1$H MRS-signals

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## Introduction

In single voxel MRS, one often measures the MR-signal a number of times, *M*, and then averages these *M* signals in order to improve SNR. A new alternative to averaging is 'All Ranks Selection Order Statistic' filtering (ARSOS, *(1,2)*). ARSOS not only improves the SNR but also eliminates (motion related) outlier signals. This contribution will investigate the effect of ARSOS when applied in time- or in frequency-domain: especially the effects it has on the output noise characteristic, the output SNR, and the spectral model parameters estimated from them.

## Methods

Let **D** be the *M* x *N* signal acquisition matrix whose rows $\mathbf{r}_m$ ($1 \le m \le M$) contain the *M* complex, separately stored, time domain signals. The application of the ARSOS-filter on **D,** results in an *M* x *N* output matrix **O,** whose columns $\mathbf{c}_n$ ($1 \le n \le N$) are the rank-ordered versions of the columns of **D**. The real part and the imaginary part are rank-ordered separately. After rank-ordering the ARSOS filter eliminates the offsets. This rank-ordering/offset-correction can be applied before (TD-ARSOS) or after Fourier transformation (FD-ARSOS) i.e. in time- or in frequency-domain. The present work compares ARSOS in the two domains. Since the rank-order filter belongs to the class of non-linear filters, differences may be expected when applied in time- or frequency-domain. The effect of TD-, FD-ARSOS on the obtained fitting parameters by least squares fitting *(3)* was examined when applied in time and in frequency domain. All measurements were carried out on a 1.5T MR-scanner (PRESS 270msec) measuring a voxel of 2.0 x 2.0 x 4.0cm$^3$ in the tibialis anterior muscle during electric nerve stimulation (*4*). During this type of measurement, the electrodes may introduce spike-like artifacts in the acquired spectra if the electrodes are placed in or too close to the RF-coil. The 20 outputs of both TD- and FD-ARSOS were fitted *(3)* and of the peak-area parameter values of TMA, Cr (CH3), acetyl carnitine (AcCt) and EMCL-CH2 the average, standard deviation and coefficient of variance were determined.

## Results

Figure 1 shows 3 out of 20 outputs of the FD-ARSOS-filter on the left and the TD-ARSOS filter on the right. Displayed is the minimum, median and maximum output channel. Note the remarkable difference in minimum and maximum output signals between TD-ARSOS and FD-ARSOS outputs. Spikes visible in FD-ARSOS are missing in TD-ARSOS outputs. However, the noise levels of the TD-ARSOS output channels are significantly higher then those of FD-ARSOS. Table 1 summarizes the fitting parameter values for the time- and frequency-domain ARSOS. It is especially noteworthy that the spike-like artifact coinciding with the 3.2 ppm TMA resonance is removed in the median outputs. For TMA a large difference in CV is observed (45.5% vs. 14.1%), due to the fact that one of spike-like artifacts resonance coincides with the TMA resonance. The average, standard deviation and CV values of the other three spectral components are of comparable size.

Table 1: Average peak areas, standard deviation and coefficient of variantion (M=20)

| metabolite | frequency domain filtering | | | time domain filtering | | |
|---|---|---|---|---|---|---|
| | mean | st.dev | CV % | mean | st.dev | CV % |
| TMA | 99099 | 45067 | 45.5 | 85759 | 12092 | 14.1 |
| Cr | 139440 | 6569 | 4.7 | 152753 | 6821 | 4.5 |
| AcCt | 50544 | 6857 | 13.6 | 57406 | 6465 | 11.3 |
| EMCL-CH2 | 1811988 | 149472 | 8.2 | 1685670 | 119106 | 7.1 |

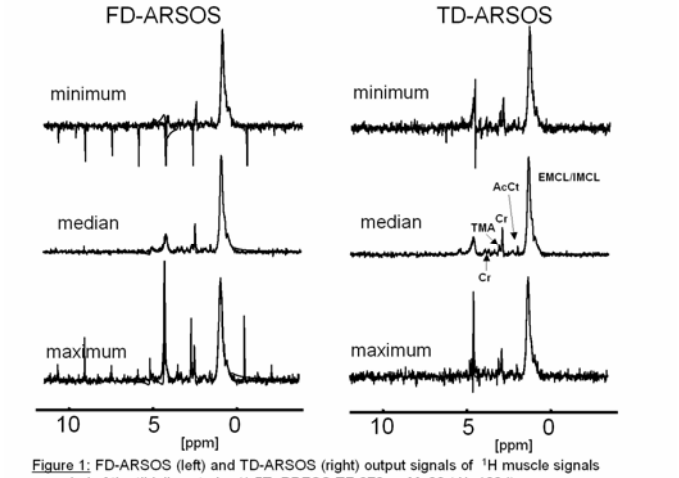


Figure 1: FD-ARSOS (left) and TD-ARSOS (right) output signals of $^1$H muscle signals recorded of the tibialis anterior (1.5T; PRESS TE 270ms M=20 / N=1024).

## Conclusion

TD-ARSOS as well as FD-ARSOS can be used to eliminate signal-artifacts related to non-stationary recording conditions, like additional disturbing RF signals picked-up by the RF-coil and patient motion. In contrast to plain signal averaging of *M* signals, which results in one SNR enhanced output signal, ARSOS filtering has *M* SNR enhanced output signals, which all can be quantified. Under stationary measuring-conditions, the variances in the parameters, obtained by *M* least square fits of the ARSOS outputs, approach the theoretical Cramér-Rao minimum variance bound. The statistical analysis of the *M* ARSOS output signals allow for signal statistical quality assessment.

**References**

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