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Identification and elimination of spiky noise features in MRS data

Introduction

➢Spiky noise: Interfering signals with short length (some milliseconds) and high amplitudes (Fig. 1)
➢Problems:
- Highly increased noise level after stacking of repeated measurements
- Failure of harmonic noise compensation (HNC)

➢ Solution:
- Automatic identification and elimination of spiky noise features in the single records before application of HNC and stacking

➢Processing scheme:
1. De-spiking > 2. HNC > 3. Bandpass filtering > 4. Stacking > 5. Fitting, Inversion

➢Investigation:
- Usage of time domain (TD) thresholding and wavelet-based (WL-based) de-spiking
- Comparison of both methods regarding automatization and combination with HNC

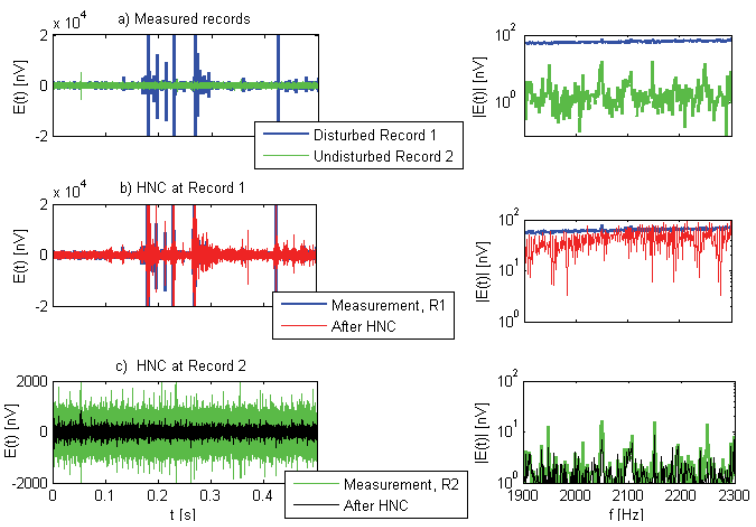

Figure 1: (a) Two example records from the same sounding, (b) Application of HNC to a disturbed record, (c) Application of HNC to an undisturbed record

Time domain (TD) thresholding

➢Identification of high amplitudes in the time series by thresholding

➢Substitution with mean voltage of remaining records, i.e. repeated measurements of the same pulse moment (Fig. 2)

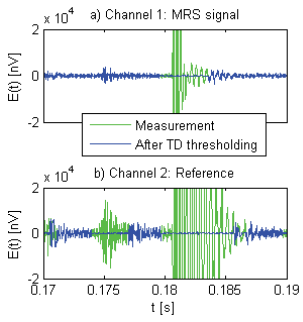

Figure 2: Application of TD thresholding method to a single record

➢User defined parameters:
1. Length of window for substitution
2. Voltage threshold (depending on noise standard deviation)

➢Combination with HNC leads to decreasing noise levels (Fig. 3 and 4)

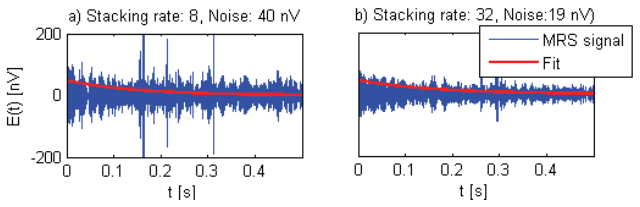

Figure 3: Resulting MRS signal after applying the TD thresholding method, after: (a) stacking 8 records, (b) stacking 32 records.

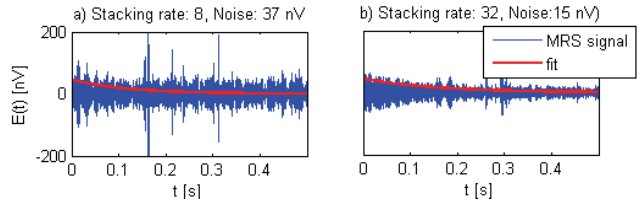

Figure 4: Resulting MRS signal after applying the TD thresholding method + HNC, after (a) stacking 8 records, (b) stacking 32 records.

Wavelet-based (WL-based) de-spiking

➢Identification of high coefficients in the WL domain

➢Isolation of interfering signal and subtraction from original time series (Fig. 5)

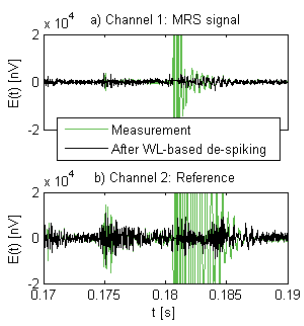

Figure 5: Application of WL-based de-spiking method to a single record

➢User defined parameters:
1. Wavelet base (Main WL and level of decomposition)
2. Threshold in WL domain (depending on standard deviation of WL coefficients)

➢Combination with HNC leads to decreasing noise levels (Fig. 6 and 7)

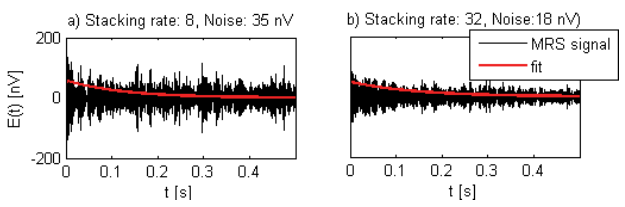

Figure 6: Resulting MRS signal after applying the WL-based de-spiking method, after: (a) stacking 8 records, (b) stacking 32 records.

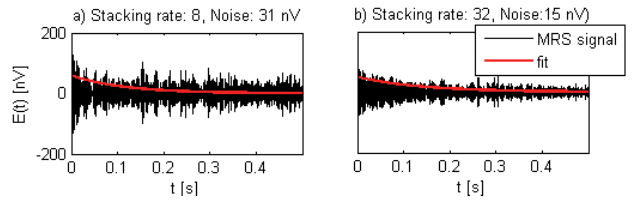

Figure 7: Resulting MRS signal after applying the WL-based de-spiking method + HNC, after (a) stacking 8 records, (b) stacking 32 records.

Isolation of spiky noise features in the Wavelet domain

1. Wavelet decomposition of MRS record, highest WL coefficients represent spiky signal (Fig. 8)
2. Determination of threshold for isolating highest coefficients
3. Wavelet reconstruction by using only the highest coefficients
4. Subtraction of isolated spiky signal from original time series

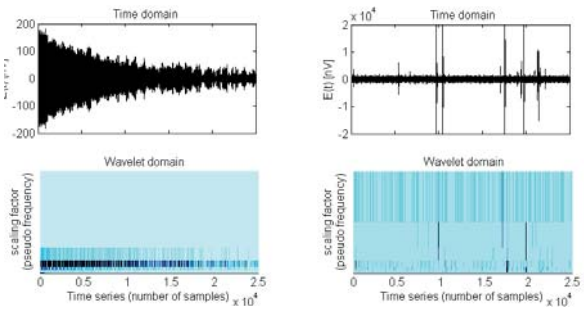

Figure 8: Representation of an MRS signal after stacking (left) and a record with spiky noise features (right) in the WL domain

➢ Using multivariate wavelet decomposition the correlation of noise between different channels is accounted for
➢ Leads to better performance, if amplitude of harmonic noise is less then 3 % of spike amplitude (Fig.9)

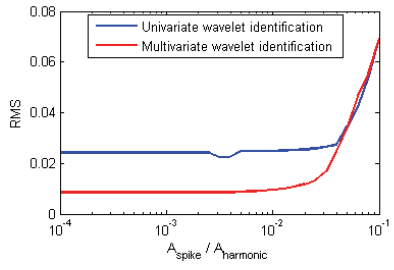

Figure 9: Performance of univariate and multivariate WL transform regarding the reconstruction of a synthetic spiky noise feature

Conclusions, Comparison of both methods

➢ Both can easily be automated and combined with HNC:

	TD thresholding approach	WL-based de-spiking
Automatization	Good, however: handle with care, user-defined parameters have great effect on performance	Excellent: user-defined parameters have minor effect on performance, default threshold: $\sqrt{\mathrm{cov}(C_L)\log(number(C_L))}$
Combination with HNC	Excellent, noise coherence between different channels is maintained during despiking	Good, however, Decision whether applying static or level-dependend thresholding affects performance, which depends on amplitude ratio between spiky and harmonic noise

➢WL-based de-spiking performs better for low stacking rates (Fig. 10)

➢Similar results for high stacking rates (Fig. 10)

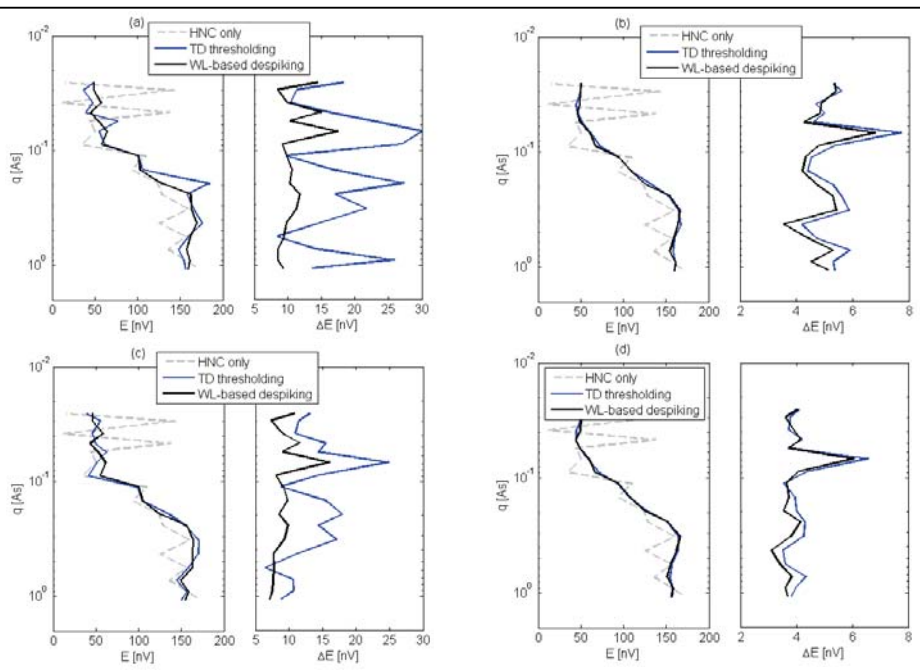

Figure 10: Results of example sounding (sounding curves E(q) and uncertainties ΔE(q)) after application of de-spiking methods, top: without HNC, bottom: with HNC, left: stacking of 8 records, right: stacking of 32 records

References:
Strehl, S., Rommel, I., Hertrich, M. and Yaramanci, U. (2006): New strategies for fitting and filtering of MRS signals. Proceedings of 3rd Magnetic Resonance Sounding International Workshop, Madrid-Tres Cantos, Spain.
Aminghafari, M., Cheze, N., Poggi, J.-M. (2006): Multivariate denoising using wavelets and principal component analysis, Computational Statistics & Data Analysis 50, 2381-2398.