Advanced Processing of MR Spectra Recorded Using "Maximum Echo Acquisition"

A. Henning[1], U. Dydak[1], P. Boesiger[2]

[1]Institute for Biomedical Engineering, ETH and University Zuerich, Zuerich, Switzerland, [2]ETH and University Zuerich, Zuerich, Switzerland

Introduction

One of the major problems of *in vivo* magnetic resonance spectroscopy (MRS) is the low sensitivity. Especially for the detection of low concentrated metabolites, as e.g. lactate in the healthy brain, a high signal to noise ratio (SNR) is required. Acquiring as much as possible of both the increasing as well as the decreasing part of the spin echo ("maximum echo acquisition") in localized MRS allows for an increase in SNR. Hence in "maximum echo acquisition" the acquisition starts immediately after the last localization pulse. Beside the advantage of SNR gain maximum echo acquisition is essential e.g. in fast techniques like turbo spectroscopic imaging (TSI).

Due to the time allocated for rephasing gradients or other pulses, usually the increasing part of the echo is truncated in the acquisition. Conventional processing of such truncated maximum echo data causes heavy artifacts, sinc wiggles, in the final spectra. These make correct phasing difficult and small peaks invisible. This work shows two methods to specifically solve the problem of asymmetrical truncation of the echo signal by adapted post processing.

Materials & Methods

To eliminate those artifacts, stemming from asymmetrical truncation of the echo, two different methods were developed and compared. One approach is smoothing of the truncation step in the maximum echo raw data by ***asymmetrical exponential or Gaussian filtering***. Symmetrical exponential and Gaussian filter are commonly used in the post processing of MR spectroscopy data [2]. But the application of a symmetrical filter to truncated maximum echo data leads to poorly resolved spectra, since for smoothing the step function on the truncated side a strong filter of up to 20 Hz is required. Such a filter also suppresses the tail of the echo at the decreasing side and leads therefore to tremendous line broadening. Hence asymmetrical exponential and Gaussian filter were implemented and applied to the maximum echo raw data. The step function at the increasing part of the echo signal is filtered by about 20 Hz to avoid sinc wiggles. At the same time the decreasing part of the echo is filtered by only 1 to 2 Hz to keep the resolution.

Another approach is the reconstruction of the truncated part of the signal using the ***Basic Fourier Correction algorithm (BFC) with phase reconstruction.*** In a first step the truncated maximum echo signal is Fourier transformed. Secondly the real part of the resulting spectrum is set to its magnitude and the imaginary part is set to zero. The following inverse Fourier transformation redistributes the signal symmetrically to both sides of the echo, but lowers the intensity of the redistributed sections by $\sqrt{2}$. Hence the original intensity of those regions has to be reestablished by multiplication of $\sqrt{2}$ [3]. Since the phase information gets lost by the BFC, the original phase of the raw signal needs to be re-applied to the data at the end.

Results & Discussion

Both methods have been verified using *in vitro* as well as *in vivo* data recorded on a Philips Achieva 3T scanner. ***Figure 1*** shows the performance of the ***asymmetrical exponential filter*** used to smooth brain CSI spectra (TE=144ms, 16x16 voxel). In ***Figure 2*** a maximum echo single voxel spectrum acquired on a brain phantom (TE=288ms) is shown before and after the ***BFC algorithm***.

Both algorithms lead to well resolved spectra without sinc wiggles. The metabolite ratios remain unchanged after application of either of the two methods. The BFC algorithm leads to spectra with increased SNR (***Figure 3***). But slight phase errors occur due to its reconstruction. The disadvantage of asymmetrical filtering is the resulting line shape distortion since a broader and a narrower component are overlaid.

In comparison with more complex algorithms like backwards linear prediction or maximum entropy both above presented methods are much easier to implement and to use and give comparable results.

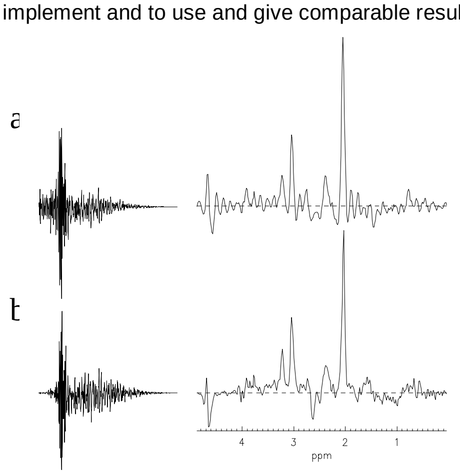

Figure 1 *Human brain CSI: a) unfiltered maximum echo and resulting spectrum with sinc wiggles, b) asymmetrically exponential filtered echo and resulting spectrum without sinc wiggles*

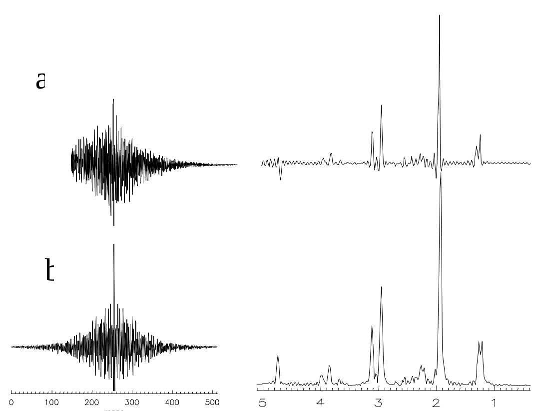

Figure 2 *Brain phantom SV: a) unfiltered maximum echo and resulting spectrum with sinc wiggles, b) maximum echo and resulting spectrum after BFC algorithm without phase reconstruction*

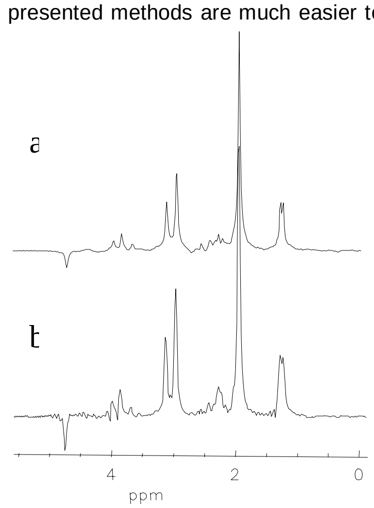

Figure 3 *The same maximum echo spectrum as in Fig.2, a: after asymmetrical filtering, b: after BFC algorithm with final phase reconstruction*

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[3] MacFall JR, et al, MRI 6: 143-155, 1988