Removal of Sideband Modulations in 1H MRS without Solvent Suppression

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INTRODUCTION The vast majority of in vivo proton (^{1}H) spectra make use of solvent suppression to reduce the dynamic range for the detection of signals originating from low-concentrated metabolites. Recently, we showed that it is possible to perform absolute quantification of proton spectra without water suppression in a single measurement (1). Nevertheless, the quality of the unsuppressed water spectra is largely determined by the water sidebands caused by time varying modulation of the main magnetic field due to mechanical vibrations of the gradient coils (2). The metabolites of interest can be severely obscured by the presence of the sidebands thereby degrading the spectral quantification. A variety of techniques have been proposed in order to overcome this problem such as reflecting the downfield region signals about the water frequency into the upfield region (3) and alternatively measuring the signal with positive and negative spoiler gradients (4). Unfortunately, the proposed approaches are based on some assumptions: e.g., all metabolite signals appear upfield of the water resonance or sidebands modulations arise merely from spoiler gradients. In this work, a method to remove gradient-induced sideband modulations is presented and verified by phantom experiments.

METHODS The time dependent FID signal acquired can be described as :

$$S_j(t) = A_j e^{i w_j t - t/T_{2j}} \qquad [1]$$

where A is the amplitude, $w_j = \gamma B_j$ is the angular resonance frequency and T_2 is the spin-spin relaxation time of the nucleus of interest. γ and B denote gyromagnetic ratio of the nucleus and main magnetic field, respectively. If there exists any additional time varying magnetic field perturbation, i.e $B^{\mu}(t)$, then main magnetic field and resonance frequency become $B_j = B_j + B^{\mu}(t)$ and $w_j = w_j + w^{\mu}(t)$, respectively. Equation [1] can therefore be rewritten as

$$S^{\mu}{}_j(t) = A_j e^{(i w_j t - t/T2_j + i\theta(t))} \qquad [2]$$

where $\theta(t) = \gamma B^{\mu}(t)$. As can be seen from [2], any magnetic field perturbation generates a time dependent phase shift in the FID signal. Using [1] and [2], one can write;

$$S^{\mu}{}_j(t) = S_j(t) e^{(i\theta(t))} \qquad [3]$$

The correct time signal, $S_j(t)$, can thus be found by multiplying the distorted time signal, $S^{\mu}_j(t)$, by the exponential term, that is $e^{-i\theta(t)}$, which cancels out the phase error added. The phase, $\theta(t)$, can be calculated from an another FID which is acquired using a phantom of single resonance with the same scanning parameters. The proposed method was applied in phantom measurements carried out on a 3 T MR scanner (Trio; Siemens) equipped with an 8 channel head coil. All the measurements were performed utilizing PRESS localization with the following parameters: TR/TE=1500/135ms, NEX=192, voxel size=15x15x15mm^3, 1024 data points). The FWHM of water peak was minimized to be around 12 Hz in all experiments. A 10 mM N-acetylaspartate (NAA) solution was used as phantom. The phase angle was readily calculated from the FID recorded from a distilled water phantom on an additional experiment under the same experimental conditions. Since all the spectra were recorded without water suppression, the water signal was removed from the spectra during post processing using Singular Value Decomposition (SVD) in order to resolve the sideband modulations and metabolite signal.

RESULTS AND DISCUSSION Fig 1 shows the sidebands in the spectrum obtained from NAA solution after the removal of water signal by use of SVD. Note that despite the long echo time, water side bands are still present in the spectrum, symmetrically around the central residual water frequency with inverted phase. Fig 2 shows the same spectrum after sideband removal which gives rise to a flat baseline. It is important to note that the proposed method and eddy current correction as described elsewhere [5] is different in that the present method can be used to compensate both for the water sidebands and the eddy current distortions. However, in the latter approach unsuppressed water spectrum from the same voxel is used to correct only for eddy current effects appearing in the water-suppressed spectrum. As was showed [2], in contrast to eddy currents, the amplitude of sidebands depends also on the amplitude of the modulated signal. Hence, they are mostly present in the unsuppressed water spectrum. Nevertheless, due to poor shimming which gives rise to insufficient water suppression, sidebands modulation can also be observed in the water suppressed spectrum. In this case, latter method cannot be used to remove sidebands as the superposed effect of several resonances present in the spectrum render correct phase calculation impossible. The described method however can be utilized to eliminate the gradient induced sidebands modulations as well as eddy current distortions without any of these limitations.

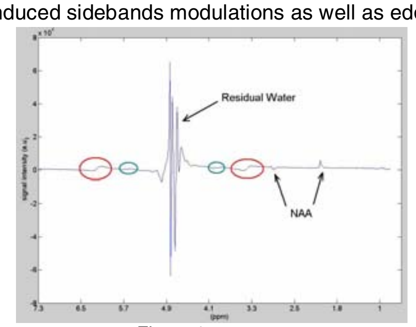

Figure 1

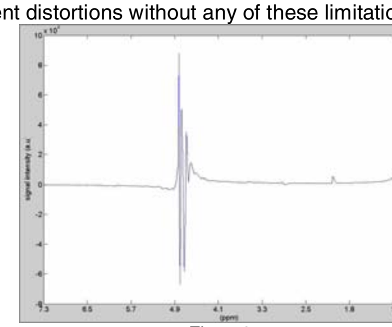

Figure2

References

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