Proton Spectroscopy without Water Suppression using a High Dynamic Range A/D converter

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INTRODUCTION: The purpose of this work was to evaluate the application of a new high dynamic range receiver (1) to proton spectroscopy. The receiver incorporates a Linear (Milpitas, CA) 130 MSPS LTC2208 A/D converter on a Mercury (Chelmsford, MA) ECDR-GC316 16 bit card. For EPI at BW = 125 kHz, the receiver has an unprecedented dynamic range of 20 bits. This range should suffice to discriminate low level signals from naturally abundant chemicals like NAA, creatine or choline in the presence of an unsuppressed water signal. Indeed, as is seen in Fig. 1, we report success. The peak level of NAA line was about 3500 times smaller than the water level.

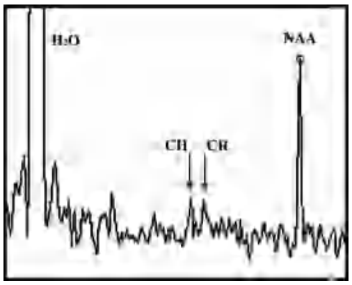

Fig. 1. *MRI spectrum averaged over volume 1.9 x 1.9 x 1 cm^3.*

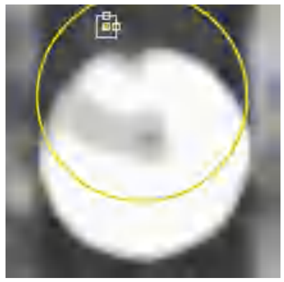

Fig. 2. *Image at NAA frequency.*

METHODS: The study was performed on a GE Signa EXCITE 3T MR scanner using a GE Model 215220 MRS phantom. Acquisition was done off-line using the Mercury card and a computer running Linux OS. The configuration was the same as described in (1). The gradient EPI sequence was used to acquire data. The time-series contained 512 images, each with a different TE, stepping by 1ms. Acquisition parameters were: TE min = 25 ms, resolution 64×64, BW = 125 kHz, FOV = 24 cm, slice 10 mm, TR 2 s. This sequence was similar to the volumetric EPI spectroscopy described in (2), but simpler because gradient rather than spin echo EPI was used and there was no necessity for water suppression. The time for single slice acquisition was correspondingly reduced. The presence of a strong water signal required low receiver gain Nevertheless, it was possible to resolve a weak NAA signal because of the high dynamic range of the digital receiver.

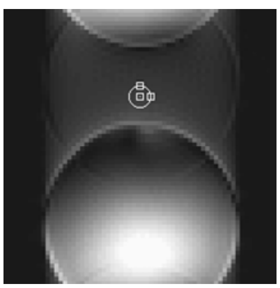

Fig. 3. *Water image at NAA offset ~350 Hz.*

RESULTS: CSI reconstruction of the entire time course was done step-by-step for each chemical shift component to correct for EPI shift in the phase-encoding direction as described in (3). The shift is about 1 pixel per 25 Hz of spectral deviation. When the frequency offset of the NAA line was applied, the water signal that was also reconstructed (out of resonance) showed an intense 25% ghost in the center as seen in the Fig 3. Basically this should not be a problem because the spectral components of water and NAA are orthogonal. In fact, after Fourier transforming the time-course, the water ghost was reduced by a factor of 50. Nevertheless the noise around the NAA line was still higher than the NAA peak itself by factor of 20. Several approaches were used to reduce noise level. The time course, Gaussian weighted, was zero-filled to increase spectral resolution 8-fold. This reduced Gibbs phenomena in spectra arising from non integer numbers of oscillations in the time-course. In addition, maxima of water peaks in re-sampled spectra along with relative shifts were saved to an array. This array is a geometrically corrected water map. Local frequency shifts were used to align spectra in all pixels. To arrive at the spectrum as in Fig. 1, the following approach was used: Instead of correcting the frequency offset (done on raw data) for each spectral component, all images were reconstructed at a water frequency offset. All water images were centered in the FOV, which reduced out-of-image ghosts to about 1%. At the same time, this approach produced NAA images that were shifted up by 14 pixels (yellow circle on Fig. 2.) This allowed us to measure spectra above the water main area. Noise in the marked area was reduced substantially. and was about two times lower than the NAA peak. Averaging over a 5x5 pixel box yielded a spectrum with reduced noise by a factor of 5, as expected (Fig 1).

DISCUSSION: Results establish that the ECDR-GC316 digital receiver has sufficient dynamic range to obtain NAA, CR and CH spectra without water suppression. But success is limited. A metabolite image is seen only in a partial-moon shaped region. The information is present in the rest of the image, but obscured by "water noise." By this term, we mean the excess noise that appears to be an effect of transmitter noise in conjunction with a strong water signal. The straightforward solution is to employ a water suppression to decrease water magnetization and reduce spectral crosstalk.. Another method is to reduce transmitter noise. All methods that use imaging time-courses, like, for example, fMRI, would benefit from reduced transmitter noise. At 3T, using a quadrature transmit head coil, only 50 W of transmit power peak are needed to rotate magnetization by 90 degree in 3 ms. High power 5 kW transmitters, which are commonly used to make these pulses, have high noise figures (NF). A specialized, low power transmitter with lower NF, dedicated to spectroscopy, would lower the stringent requirements for water suppression and make spectroscopy an easier procedure in clinical applications.

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