# In Vivo Localized Correlated Spectroscopy using Spectral Spatial Coherence Transfers

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## Introduction

Two dimensional correlated spectroscopy (COSY) is an useful tool for the detection of metabolites since the spectral sparsity afforded by the extra spectral dimension enables easier identification of overlapping resonances. However, *in-vivo* 3D localized COSY [1] is particularly challenging for several reasons. Heterogeneous relaxation times in tissue confound water suppression by pre-saturation. Furthermore, to encode cross peaks of weakly coupled spin systems, both of the coupling partners of the molecule must be fully refocused. Therefore, all refocusing pulses must have high spectral bandwidth and thus have high peak power requirements. A variation of the L-COSY sequence using spectral spatial (SPSP) refocusing pulses for robust water suppression was developed and applied in this project. High bandwidth and low peak power was achieved by phase modulation of the spectral filter and using phase-matched refocusing pulses. Phantom data showed greatly increased robustness to peak B1 nonuniformity compared to CHESS. Initial *in vivo* data from a healthy volunteer shows robust water suppression and strong metabolite cross peaks.

## Methods

A localized COSY sequence was designed by playing a π/2-π-π/2 sequence with slice select gradients on orthogonal axes. The spectral spatial π and π/2 pulses were designed using a T(BW)=11 minimum phase spctral filter which was then root flipped to reduce peak power. Since the root flipping imparts a nonlinear phase to the transverse magnetization, the π and π/2 pulses were designed using the same β(ω) filter differing only by a scale factor sin(θ/2) (Figure 1). The filters were then sampled with spatially selective RF / gradient pulses and passed through the inverse SLR transform [2,3] to generate the RF waveform. The resulting transverse magnetization of this sequence is

$$M_{xy,2} = M_{xy,0}\,(\beta^*_{180})^2\,(\beta_{90})^2$$

When $\beta_{180}$ and $\beta_{90}$ differ only by a scale factor but have matched phase profiles as was performed in this study, the phase of the magnetization is unaffected. Acquisition parameters were $B_0$ = 3T, 128 indirect encodes, 1.25 kHz (indirect) and 1.0 kHz (direct) spectral widths, minimum TE = 55 ms, TR =2s. Data were zero-padded to 1024×1024, apodized by a 2 Hz filter in the direct dimension only, Fourier transformed, and displayed in magnitude mode. To test the robustness to trasmitter miscalibration, the sequence was run in a brain metabolite phantom localized to a ~100 mL ROI. The COSY was run using both spectral spatial and CHESS water suppression over a 1.5 dB range of transmitter offsets. Data were acquired in a healthy volunteer using a ~30 mL localized FOV, 8 averages per encode.

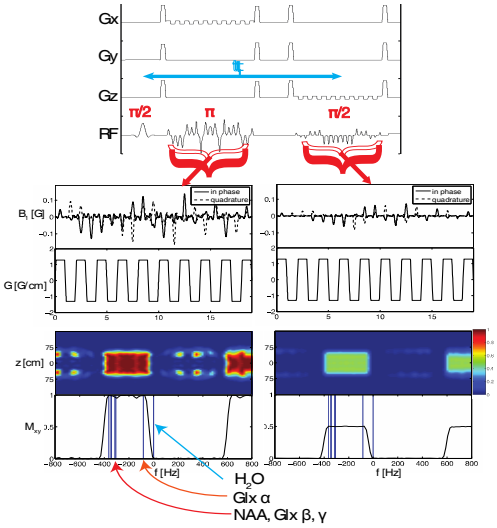


Figure 1: Pulse sequence (top), and spectral spatial π and π/2 RF and gradient waveforms (center). Simulated profiles are shown on the bottom with the location of several weakly coupled metabolites

## Results

Figure 2 shows COSY data aquired in a phantom using CHESS and spectral spatial water suppression. Spectral spatial data were essentially unchanged over a 1 dB change in transmitter scaling, while CHESS data were highly corrupted by residual water signal. This contamination impeded visibility of metabolite crosspeaks even at 0.5 dB from the calibrated value. Data from a healthy subject shows cross peak / diagnoal peak ratios of 0.58 for NAA (2.6/4.4 PPM), 0.14 for glutamine / glutamate (2.1/3.8 PPM), 0.34 for choline / inositol (3.5/4.1 PPM). Ratios were measured with respect to the upfield diagonal. Many cross peaks from the strongly coupled groups of glutamine, glutamate, and NAA are also visible in the 2.1-2.7 PPM region in both *in vivo* acquisitions and phantom experiments.

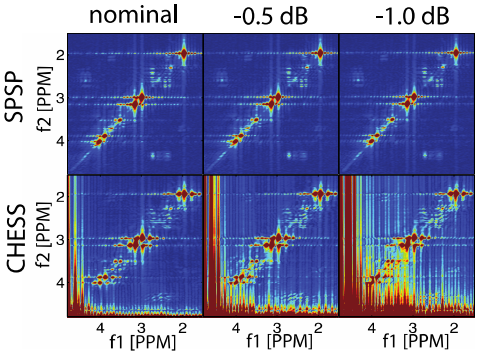


Figure 2: Spectral spatial (top) and CHESS (bottom) water suppression for COSY data in a brain metabolite phantom over a range of global transmitter strength offsets.

## Conclusion

We have demonstrated an *in vivo* COSY sequence using high bandwidth, phase modulated spectral-spatial refocusing / coherence transfer pulses. This approach provides a highly robust, B1 insensitive method for water suppression for *in vivo* correlated spectroscopy.

**References** [1] M. A. Thomas et al, MRM 46,58 (2001). [2] J. M. Pauly et al, IEEE TMI [3] A. B. Kerr et al, 16th ISMRM, 226.

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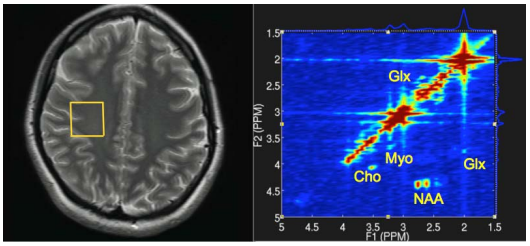


Figure 3: *In vivo* human data from an approximately 30 cc volume of a healthy volunteer.