Combination of Phased-Array Coil Signals in Localized 2D Correlated Spectroscopy: Artifacts and Remedies

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Introduction & Purpose: Multi-channel phased-array radio-frequency (RF) coils are capable of acquiring several streams of acquisitions in parallel, resulting in improved signal-to-noise ratios (SNR) and faster scan times (1,2). Data streams from these coils must be added in-phase during coil combination or risk losing signal to phase cancellation. Conventional coil combination schemes work well in one-dimensional (1D) Magnetic Resonance Spectroscopy (MRS), aligning the phase from every measurement to an arbitrary but equal value for each coil (3). Extension of the same generates multiple artificial parallel diagonals in two-dimensional (2D) localized correlated spectroscopy (L-COSY) (4), possibly due to the loss of phase information during coil combination resulting in artificial phase offsets along the F2 dimension. A major goal of this study was to investigate the source of these artifacts and develop an optimal algorithm to combine multi-channel RF coil-acquired 2D L-COSY data.

Materials & Methods: To thoroughly test the applicability of phase preservation as a means to resolve coil combination artifacts, three different coils were tested: a) 8-channel "receive" knee-array coil, b) "transmit/receive" circularly polarized (CP) extremity coil, and c) 12-channel "receive" head coil assembly. A 3T Trio-Tim MRI scanner was used for this investigation. A brain phantom containing more than 16 metabolites at physiological concentrations was tested along with other phantoms containing metabolites at higher concentrations (50-100mM). 2D L-COSY spectra were recorded predominantly from the soleus muscle of three healthy subjects (mean age = 35 years) and two diabetic patients (mean age = 58 years, mean BMI = 28, mean hemoglobin A1C of 6.5%) using the knee-array coil. 2D L-COSY acquisition parameters were as follows: TR/TE=2s/30ms, 50 $\Delta t1$ increments in the t1 dimension, 1024 complex points in the detected t2 dimension, 8 averages and 3x3x3 cm3 voxel.

Two competing methods were developed that preserve phase information during coil combination and are thus well-suited for application in 2D MRS: 1) Phase offsets are applied such that the initial phase in the first measurement from each coil is zero. Rather than repeating this process across all repetitions, as with conventional coil combination, these initial offsets are then preserved across all subsequent measurements, thus preserving phase information in the detected dimension (F2 axis). 2) The initial phases of each measurement from each coil are aligned to that from the coil with the strongest signal, rather than to a zero-offset. In this way, abrupt changes in phase over time, for example due to minute motion, are more effectively accounted for.

Results and Discussion: Figure 1 (A) shows the conventionally-processed data demonstrating multiple parallel diagonals associated with the loss of phase information. The same pattern was visible in brain and lactate phantom scans using the 12-channel head coil. These diagonals overwhelmed any off-diagonal peaks, and thus no cross-peaks were visible in these spectra. When the same data were processed with the two phase-conserving schemes, each data set showed a single diagonal, with visible cross-peaks due to intramyocellular and extramyocellular lipids (IMCL/EMCL) in the calf muscle. Diagonal peaks from fat (1.2 ppm), creatine (3.0 ppm) water (4.7 ppm) and olefinic protons (5.5 ppm) were visible in all the data sets, although their intensities were distributed across multiple diagonals in the conventionally-processed data (5). Other figures in Fig.1 show the post-processed 2D L-COSY spectra extracted from one of the eight channels (B) and all eight channels combined as discussed above (C). A data set showing a single diagonal was then zero-phased, resulting in a spectrum identical to that from a conventionally-processed scheme. Data from schemes 1 and 2 were largely similar, although the IMCL/EMCL cross-peaks were marginally better resolved in scheme 1 due to reduced t1 ridging as compared to scheme 2.

Conclusion: We have demonstrated in this pilot project that 2D L-COSY data acquired from more than one "receive" channel can be combined successfully and accurately. While artificial parallel diagonals were observed in data from conventional coil combination schemes, both new coil combination methods preserved the phase information along the t2 dimension, resulting in a single diagonal and observable cross-peaks. The advantage of the first method is that it applies phase information from all coils. The advantage of the second method is that it compensates for phase artifacts over time occurring in long 2D MRS scans. Because it did a better job of handling t1 ridging and resolving the IMCL/EMCL cross-peaks, the first method was selected as the better performer overall.

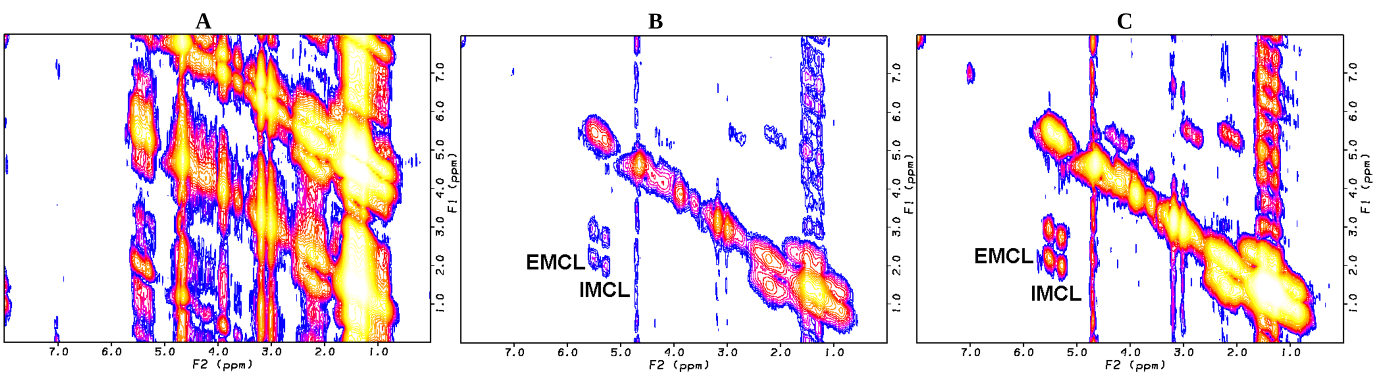

Figure 1: 2D L-COSY *in vivo* data recorded in the soleus muscle using an 8-channel knee coil "receive" assembly. (A) is conventionally-processed data. (B) and (C) are a single channel and all channels, respectively, from the same data set processed with a phase-conserving method (scheme 1).

References:

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