J coupling effects on signal modulation at very high fields

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Introduction

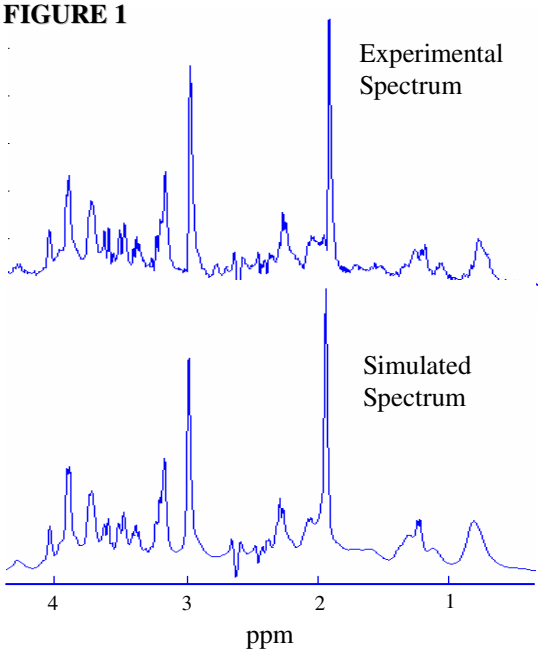
The density matrix formalism can be used to assess the evolution of strongly coupled spin systems. The majority of studies using this approach have focused on the field strengths of 1.5 and 3 T [1-3], whereas less attention has been paid to the response of strongly coupled spin systems at higher field strengths (7 and 9.4 T). The aim of the present study was to perform an analysis of the J-modulation of coupled resonances of cerebral metabolites to estimate the loss in signal intensity due to J coupling at high fields in spin-echo sequences.

Methods

Density matrix simulations [1-3] were developed to investigate the J-modulation dependence of the signal for cerebral metabolites under spin-echo excitation at the various field strengths. To this aim, the loss in signal intensity as a function of the echo time was evaluated for a number of metabolites. To validate the spin simulations, spectra were acquired from a voxel of interest in the hippocampus at TE = 2 and 20 ms in five rats, with an actively-shielded 9.4T/31cm magnet (Varian/Magnex). A novel spin-echo based pulse sequence was employed for localized MRS [4]. The Cramer-Rao lower bounds (CRB) of metabolite concentrations were obtained by spectral data analysis performed in the frequency domain using LCModel [5].

TABLE 1	**3 T**		**7 T**		**9.4 T**	
	S_{10} (%)	S_{20} (%)	S_{10} (%)	S_{20} (%)	S_{10} (%)	S_{20} (%)
Glutamate	98	94	98	83	97	76
Inositol	98	93	98	78	97	70
Glutamine	98	93	98	78	97	70
GABA	98	93	98	78	97	70
Alanine	96	84	97	87	96	86
Aspartate	98	84	96	64	96	43

FIGURE 1



Results and Discussion

At high fields (7 T and 9.4 T), the signal intensity as a function of TE displays a biphasic behaviour with minimal signal reduction up to 10 ms, followed by a steep and substantial loss at longer echo times (**Table 1**: S_{10} and S_{20} is the percentage signal intensity at 10 ms and 20 ms, respectively). At 9.4 T, the signal intensity for most metabolites is reduced to 70 %, at TE = 20 ms. The excellent agreement between simulated and experimental in vivo spectra (TE = 20 ms) validated the density matrix simulations (**Figure 1**). Data analysis of in vivo spectra (**Table 2**) shows that for coupled resonances of high concentration metabolites (Glu, Ins), the high signal-to-noise ratio compensated for the loss in signal intensity, resulting in a minor increase in CRB when TE was increased from 2 to 20 ms (for example, in Exp 2 and 3, the CRBs of Glu increases from 1% to 2 %). For metabolites with lower concentration (Gln, GABA) there was a significant increase in CRB at 20 ms. Finally, for metabolites such as alanine and aspartate, which are present in even lower concentration, the loss in signal intensity resulted in poor detectability at TE of 20 ms (for reference, the CRBs of creatine and NAA are also given). In conclusion, the results of this study show that to harness the full sensitivity gain at very high fields an echo time below 10 ms is advantageous.

References

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TABLE 2	CRB (%) at 2 ms			CRB (%) at 20 ms		
	Exp 1	Exp 2	Exp 3	Exp 1	Exp 2	Exp 3
Creatine	3	3	3	4	4	4
NAA	1	1	1	1	1	1
Glutamate	2	1	1	2	2	2
Inositol	2	2	2	3	2	3
Glutamine	4	3	5	7	6	6
GABA	7	6	7	15	14	17
Alanine	17	17	12	n. d.	n. d.	35
Aspartate	17	9	19	49	n. d.	n. d.