Optimized antisymmetric composite pulses for fast proton spectroscopic imaging

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Introduction

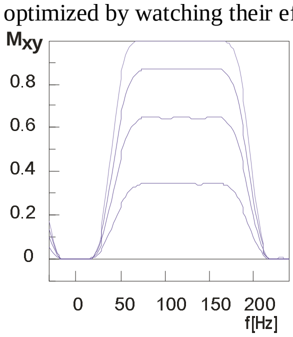
In proton MRS, a rapidly increasing interest is devoted to the development of fast SI techniques, which are capable to acquire much more clinically valuable information than single voxel techniques in the same experimental time. However, applications of fast SI techniques suffer from much greater technical difficulties. At the very short repetition times (TR) used in fast SI to attain the required spatial resolution, large technical problems are related, for instance, to the need to assure efficient and stable suppression of strong signals from water and subcutaneous lipids. To alleviate this problem, in several multiple-echo based fast SI techniques, such as spectroscopic U-FLARE [2,3], spectroscopic GRASE [4], spectroscopic RARE [5], and recently also a new steady state free precession (SSFP) based proton SI technique [6], special antisymmetric RF composite pulses have been employed for frequency selective excitation. So far, composite pulses defined as 1(x)–2t–5.4(-x)–t–5.4(x)–2t–1(x) **[A]** and 1(x)–t–1(x)–t–8(-x)–8(x)–t–1(-x)–t–1(-x) **[B]** [1] are predominantly used for the given purpose. Unfortunately, the excitation performances of these composite pulses are not fully optimal. The frequency profile of pulse **[A]** is degraded at low flip angles, commonly required in fast SI experiments. Excitation provided by pulse [**B]** is less dependent on the flip angle but the bandwidth of excitation is narrower than required.

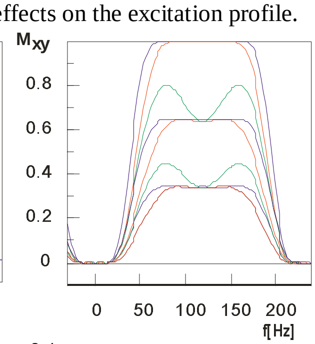
Methods

Computer simulation was used to develop new composite pulses in order to achieve excitation performance improvement upon pulses [**A]** and [**B**]. The attention was mainly paid to broadening the bandwidth of effective excitation and making it independent of the flip angle. Further, the pulses were designed to have suitable profile of the suppression. Computer simulation was also applied to optimize the shape, duration, and flip angle of presaturating CHESS pulses used to improve water (lipid) suppression.

Results

One of the best composite pulses we developed is: 5(x)–t–13(x)–t–1(x)–t–97(-x)–t–97(x)–t–1(-x)–t–13(-x)–t–5(-x) **[C]**. The excitation profiles of this pulse computed for various flip angles are shown in Fig. 1. In Fig. 2, for comparison, excitation profiles computed for pulses A, B, and C are displayed. Figure 4 gives the profiles in the zero-excitation region computed for the pulse C in which the relative flip angles generated by the first and last pulses are set to 3.5, 5, and 6.4. Fig. 5 demonstrates how the suppression profile is affected by the application of one or two 30-ms presaturation CHESS pulses with flip angles of 105° and shapes as given in Fig. 3. Both the CHESS pulse shape and the employed flip angle were computer optimized by watching their effects on the excitation profile.





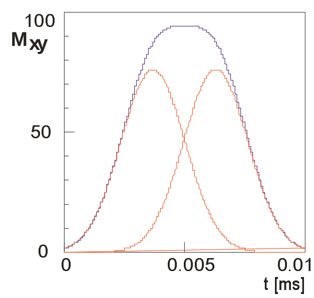
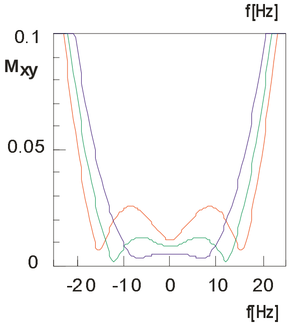


Fig. 1. Transverse magnetizations excited by pulse [C] at 20°, 40°, 60°, and 90° flip angles; t=4.2ms.

Fig. 2. Comparison of transverse magnetization profiles generated by pulses [A], [B] , and [C] at 20, 40, and 90° flip angles.

Fig. 3. Waveform of the optimized CHESS pulse created by summing two Gaussian shapes.



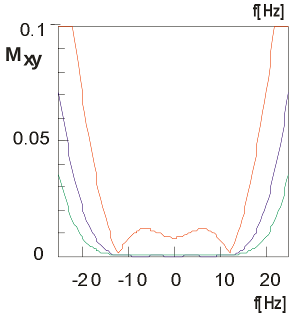


Fig. 4. Transverse magnetization profiles generated in the region with maximum suppression by the composite pulse [C] with relative magnitudes of the first and the last component hard pulses set to 3.5, 5, and 6.4. Values of T_1 = 1s and T_2 = 0.25s were used in the calculation.

Fig. 5. The effect of use of one and two CHESS pulses from Fig. 3 on the suppression profile generated by pulse [C] with relative magnitude of the first and last pulse in the composite pulse equal to 5.

Discussion and Conclusion

The results obtained by computer simulation demonstrate outstanding excitation performance of the newly developed antisymmetric composite pulse. Properly chosen relative flip angles of the component pulses make it possible to attain flip-angle independent broad excitation regions on the one hand and broad suppression region on the other hand. Large advantage of antisymmetric composite pulses is the independence of its suppression profile of the B_1 strength. Therefore, as demonstrated, the use of already one suitable CHESS pulse can substantially improve the quality of water (lipid) suppression.

Acknowledgements

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References

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