B_1-insensitive slice-selective pseudo-adiabatic pulse

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Target audience

Physicists and engineers with an interest for high field MRI.

Purpose

The high interest towards high field MRI increases the need for a uniform flip angle in the presence of inhomogeneous RF fields through parallel RF transmission or single channel pulse design. The adoption and development of parallel RF transmission is hampered by the high cost of implementation and the risk that an error in B1 and B0 field maps or in the underlying wave propagation algorithm can ultimately deliver harmful SAR to the patient. On the other hand, few B1-insensitive excitation pulses offer a slice selective arbitrary flip angle [1-3]. While some rely on the adiabatic condition and therefore suffer from a long duration and SAR limitations[1,2,], others lead to a non-linear through slice phase, which can lead to signal loss if thin slices are required. In this work, we present a slice-selective pseudo-adiabatic excitation (pBIR4-S1s2) which offers a B1-insensitive excitation at an arbitrary flip angle in a comparatively short duration (<10 ms).

Methods

In the adiabatic half passage (AHP), the effective field (B_{eff}) is tipped from the longitudinal axis to the transverse plane. This vector is designed to respect the adiabatic condition so that the longitudinal magnetization will remain collinear with it throughout the whole pulse and experience a 90° nutation. Our pulse design relies on a pseudo-adiabatic condition[4] to lower the power requirement of the pulse in comparison to the full adiabatic condition. The original pseudo-adiabatic half passage (pAHP-S*n*) decomposes the AHP in *n* hard pulses (or steps) to efficiently tip the magnetization in the transverse plane. Each step consists of a 180° precession of the magnetization around a fixed effective field. With an appropriate orientation of the effective field at each step, the magnetization grazes the transverse plane at the end of the last 180° precession. For a high *n*, this approximation results in a pulse waveform and a field insensitivity profile similar to the adiabatic passage. At lower *n* (1 or 2), the pulse duration can be greatly reduced, while still preserving some of the properties of the adiabatic passage. This pAHP-S*n* can also be used as a segment of a BIR-4 pulse.

In the current slice-selective implementation, the hard RF sub-pulses of the pseudo-adiabatic pulse are replaced by slice-selective sub-pulses (SLR) of the same time-integrated areas and driven with an oscillating gradient as done previously by other groups[2,3]. The pulse design of the slice-selective pseudo-adiabatic pulse (pBIR4-S*n*s2) needs to take into account the interaction of the modulating RF frequency with the slice profile and the through slice spread of the trajectory of the magnetization during a 180° precession. Therefore, two slice selective pulses are needed per pseudo-adiabatic step. The resulting pBIR4-S1s2 design is shown in Figure 1. Magnetization response was simulated for a 7,2 ms pulse with maximum B1 of 10,6 µT (Figure 2) and the corresponding experimental slice profile and B1 homogeneity profile were measured at 3T in an oil phantom (Figure 3 and 4).

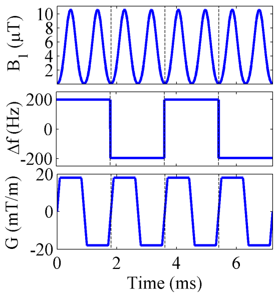

Figure 1- Pulse waveform of a pBIR4-S1s2

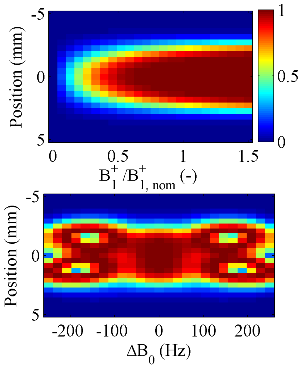

Figure 2- Performance simulations of a 90° pBIR4-S1s2 pulse

Results and discussion

The simulated performance of the slice selective 90° pulse shows the B1- and B0-insensitivity of the transverse magnetization. The center of the slice is B1-insensitive between 0.52 and 1.5 times the nominal RF amplitude. If we consider the magnetization through the whole slice, the signal was homogeneous from 0.83 to 1.5. The B0-insensitivity is preserved in the interval ±100 Hz.

Figure 3 confirms the experimental slice selection of the pBIR4-S1s2 pulse. Also, B1-mapping on a 12 cm oil phantom with a standard pulse compared to the pBIR4-S1s2 is shown in Figure 4. The pBIR4-S1s2 shows an improvement in B1-insensitivity through the whole phantom at 3T.

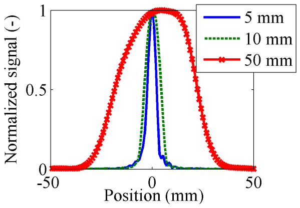

Figure 3- Experimental slice profile of the pBIR4-S1s2c

Conclusion

The slice selective pseudo-adiabatic excitation pulse is a short duration (<10 ms) pulse which offers a B1-insensitive nutation angle. It could be used in scanners without parallel RF transmission or in conjunction with this approach to achieve a higher B1 insensitivity.

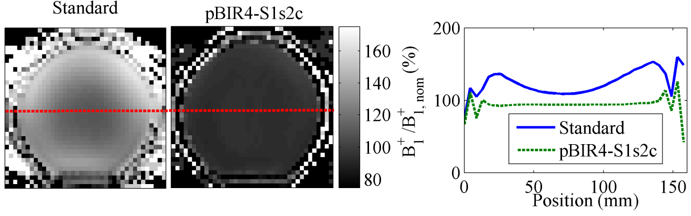

Figure 4- Dual flip angle B1+ mapping at 3T in an oil phantom

References

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