Reducing central brightening and increasing penetration depth with single-channel transmit systems at 7 Tesla using a TIAMO-like method

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Introduction

At field strengths of 7 Tesla and above, severe B1 inhomogeneities cause problems due to non-uniform contrast and SNR distributions. Most methods proposed to mitigate these problems rely on multi-channel transmit systems. On systems with a single transmit channel, one is limited to adiabatic pulses [1], unaccelerated spatially selective pulses or simply increasing the transmit voltage [2]. Recently, the TIAMO method [3,4] was introduced for multi-channel systems. In this work we propose using this method in PD- and T2-weighted spin echo imaging to homogenize head images using volume coils and increase penetration depth with surface loop coils on single-channel systems.

In the original TIAMO method, two different sets of phases and amplitudes are applied in an interleaved fashion to a multi-channel transmit array to acquire two images. These inhomogeneous images can be combined via sum of squares to achieve a more homogeneous image without complete signal dropouts. In the single-channel variant of TIAMO, we propose acquiring two images with different transmit amplitudes in an interleaved fashion. In this way the dark areas where the refocusing pulse does not achieve flip angles close to $\alpha = 180° + (n \cdot 360°)$ are in different positions in the two images. The resulting combined image should be much more homogeneous.

Materials and Methods

All imaging experiments were performed on a 7 Tesla Magnetom whole-body MR system (Siemens Healthcare Sector, Erlangen Germany). For brain imaging, a commercially available 1ch transmit/ 32ch receive head coil (Nova Medical, Inc., Wilmington MA, USA) was used. This head coil uses a circularly polarized birdcage for transmit. The second coil is a commercially available 1ch Tx/Rx loop coil (Rapid Biomedical, Rimpar, Germany). In vivo imaging with the head coil was performed in a male volunteer in axial orientation, and in vitro experiments with the loop coil were carried out in a checkerboard phantom inside a water canister.

B1 mapping was performed with a pre-saturation turbo flash sequence. For in vivo brain imaging, the transmit amplitude of the first image was set to the value at which the correct flip angle was achieved in the center of the brain; the second transmit amplitude was set to a value to achieve the correct flip angle at the point of minimum B1 in the axial slice through the brain.

In imaging with the loop coil, the transmit amplitude for the first image was set to a value so that no dark bands due to overshoots were visible (correct flip angle at the surface of the phantom). The transmit amplitude for the second image was set to 4 times this value to achieve a greater penetration depth.

Results and Discussion

Figures 1 A-C) show the results for an axial slice through the brain. While A) and B) show pronounced signal degradations, the combined image C) appears much more homogeneous. The time-averaged transmit power for image B) was 3.34 times higher than for A), resulting in a time-averaged power for image C) of 2.17 times the power of the standard image A). The increased acquisition time can be compensated by investing the higher mean SNR into higher acceleration factors with the multichannel receive array. The influence of the transmit inhomogeneity on image brightness is visibly decreased.

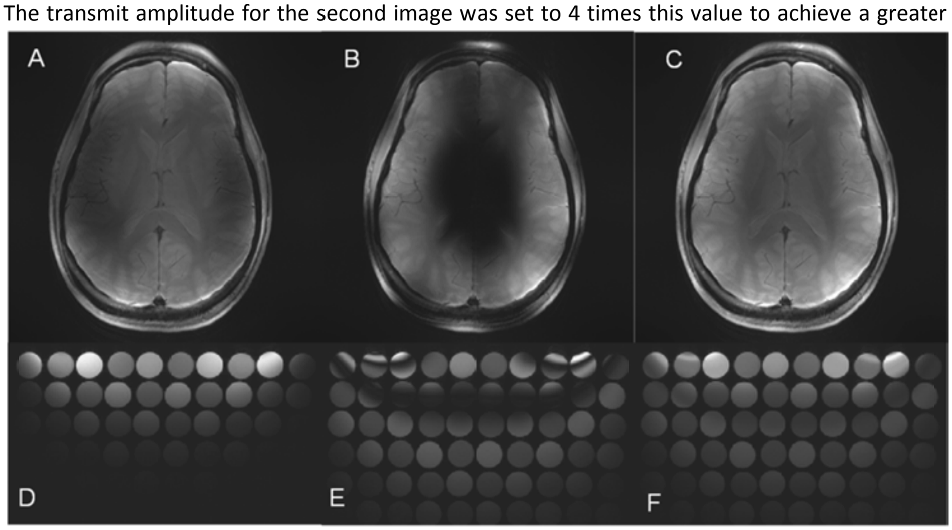

Fig. 1: A-C) PD-weighted brain images: first, second and combined image.
D-F) T2 weighted phantom images: first, second and combined images.

Figures 1 D-F) show the results for the loop coil. While D) shows a low penetration depth and E) shows distinct banding near the surface, the combined image F) combines high penetration depth with significantly reduced banding.

The time-averaged transmit power for E) was 16 times that of D), so that the time-averaged power of F) was 8.5 times that of A). Unlike adiabatic refocusing pulses which also have a high cost in terms of transmit power, this TIAMO-like method does not cause phase instability [1].

In [4] it was shown that the image contrast in PD/T2-weighted TIAMO images remains correct. The results show that this TIAMO-like method is an easy way to increase uniformity and average SNR of brain images and increase penetration depth with loop coils on a single-channel transmit system. However, the method does come at the cost of a factor 2 increase in acquisition time.

References

[1] Kalleveen et al., Proc Intl Soc MRM 2011: 600
[2] Gras et al. Proc Intl Soc MRM 2011: 4448
[3] Orzada et al., Magn Reson Med. 2010 Aug; 64(2):327-33
[4] Orzada et al., Magn Reson Med. 2011 Aug 19 (Epub)