Encoding Methods for B_1^+ Mapping in Parallel Transmission Systems at Ultra High Field

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Target Audience

MR physicists and engineers who work with ultra-high field (UHF) systems with parallel transmission (pTx).

Purpose

Decent quality complex B_1^+ maps from each of the transmit channels in a pTx system are required for various RF homogenisation methods, e.g. Transmit SENSE. However, all B_1^+ mapping methods suffer from a high degree of uncertainty in the measured flip angle when the true flip angle or the SNR is low[1, 2]. RF interferometric methods[3] have been proposed to maintain sufficient B_1^+ over most of the sample during mapping. In this study, we evaluated several interferometric encoding methods[3, 4] for individual transmit channel B_1^+ mapping at 9.4 T.

Methods

All experiments were performed with a 9.4 T human whole-body MR scanner (Magnetom 9.4 T, Siemens Medical Solutions, Erlangen, Germany) with an 8-channel transceive RF coil array operated in pTx mode. A 16 cm diameter spherical water phantom containing 50 mM phosphate buffered saline (PBS) at pH 7.2 was imaged. In vivo validation of the method was approved by the local ethics committee and the 18-year-old male volunteer who took part in the study gave written, informed consent. Individual transmit channel B_1^+ maps were obtained with the T_2- and T_2^*-compensated version of DREAM[5] with 1-channel-on (1-on), all-channels-on-except-1 (1-off), all-channels-on-1-inverted (1-inv) and RF phase encoding (PE) schemes. The encoding matrix of RF PE is defined as $(\mathbf{E})_{m,c}$,=exp[2πi(m-1)c/M], where c is the coil index and m is the m^{th} measurement out of a total of M. Qualitative and quantitative comparisons were made between each encoding method as well as their sensitivity to the initial phase setting.

Results

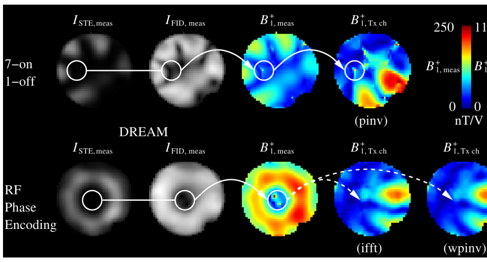

Figure 1. Graphical description of artefact propagation and suppression in DREAM. The top row shows 1-off encoding of channel 1. The bottom row shows a different initial phase setting and B_1^+ maps of channel 2 encoded by 16 PE steps. The columns, from left to right, are the stimulated echo and free induction decay magnitude images from DREAM, the reconstructed B_1^+ maps, the transmit channel B_1^+ maps decoded by either pseudo matrix inversion (pinv), inverse fast Fourier transform or weighted pinv (wpinv).

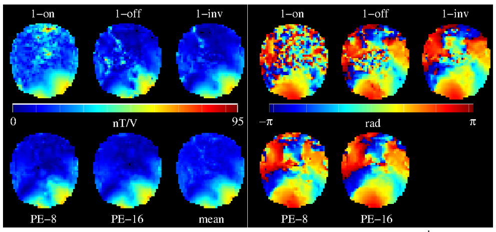

Figure 2. In vivo magnitude and phase B_1^+ maps for 1-on, 1-off, 1-inv, PE-8 and PE-16 encodings of channel 1. The mean B_1^+ magnitude map was reconstructed from all data.

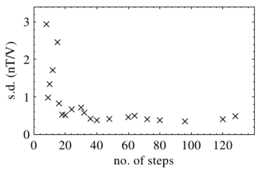

Figure 4. Standard deviations of the B_1^+ maps from the mean B_1^+ maps with different numbers of regular phase encoding steps.

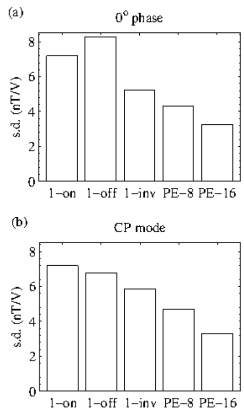

Figure 3. The standard deviations of the B_1^+ maps from the mean B_1^+ maps. Two initial phase settings, 0^o-phase and CP mode were tested in a phantom.

Discussion

In contrast to a previous study[4] at 3 T, RF phase encoding was the least susceptible to artefacts caused by RF destructive interference compared to the other three encoding methods. It was also much less dependent on the initial RF phase setting than the two other interferometric methods. This means that no prior knowledge of B_1^+ phase settings is required for B_1^+ mapping. RF phase encoding also provided a flexible way to increase the number of measurements to further increase SNR and reduce artefacts using a weighted pseudoinverse of the overdetermined system. In our experiments in vivo and phantom at 9.4 T, more than 16 PE measurements conferred little improvement in the quality of the 8 transmit maps.

Conclusion

The benefits of RF phase encoding make DREAM a fast and accurate choice for B_1^+ mapping at UHF that does not require prior knowledge of a highly efficient and homogeneous transmit mode to obtain high SNR and low artifact B_1^+ maps. This work also provides new insight into pTx B_1^+ mapping by describing the interferometric RF PE B_1^+ mapping technique as yet another k-space dimension.

References

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