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

Desmond H. Y. Tse1, Michael S. Poole1, Arthur W. Magill1, Jörg Felder1, Daniel Brenner1,2, and N. Jon Shah1,3

1INM - 4, Research Centre Jülich GmbH, Jülich, Germany, 2German Center for Neurodegenerative Diseases (DZNE), Bonn, Germany, 3Department of Neurology, RWTH Aachen University, Aachen, Germany

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. RF interferometric methods have been proposed to maintain sufficient $B_1^+$ over most of the sample during mapping. In this study, we evaluated several interferometric encoding methods 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 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 $E_{m,c}=\exp[2\pi i(m-1)c/M]$, 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
In contrast to a previous study 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