A region growing algorithm for robust kt-points B1+ homogenisation at 9.4T

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Target Audience
Researchers that require uniform excitation at 7 T and above.

Purpose
B1+ homogenisation was performed at 9.4 T repeatably and robustly using a region-growing algorithm. Radiofrequency pulse amplitudes and phases for kt-points homogeneous excitation can be found with deterministic or stochastic optimisation algorithms, which regularly yield suboptimal local or unrepeatable solutions. One approach is to perform many local optimisations with randomised initial guesses, however we hypothesise that there exists a smooth continuum from the small region solution (essentially transmitter phase coherence in the centre) to the globally optimum solution for the full homogenisation volume.

Methods
Experiments were performed with a 9.4 T whole-body MRI system (Magneton 9.4T, Siemens, Erlangen) with 8 channels of parallel RF transmit and receive. Mapping the B1+ of each channel was performed with the dual refocusing echo acquisition mode (DREAM) sequence by 16 measurements with unique incremental phase rotations for each channel and the following parameters: 17 slices, T2* compensated timings, TE_{ref} = 2.22 ms, TR_{ref} = 4.44 ms, 7° degree nominal flip angle (FA) and 4 x 4 x 4 mm³ voxel size.

kt-points homogenisation RF pulses were optimised using Matlab (The Mathworks, Natick, MA) and a magnitude least squares (MLS) 4 variable exchange algorithm with phase following and Tikhonov regularisation. A target homogenisation region was defined and (Nr-1) more regions were defined to have dimensions of n/Nr times the target region, integer n = 1 to Nr. Repeatedly eroded masks could also be used.

A 160 mm diameter spherical water phantom containing 50 mM phosphate buffered saline, a formalin-fixed ex vivo human brain and a 41-year old healthy male volunteer (fully complying by the rules of the local ethics committee) were imaged using a low flip angle gradient echo sequence of the complex B1+ maps and normalised, to produce modes with complimentary interference patterns.

Results
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Discussion
Due to the shortened RF wavelength at 9.4 T, holes appear in images because of destructive B1+ interferences. In the homogenisation of B1+ using kt-points, a deterministic algorithm is often used that find suboptimal local minima that is more troublesome in phantoms and also some human heads. This problem was avoided by using a region-growing algorithm. Figures 1 and 4 demonstrate the benefit of the region growing in a phantom and a troublesome head. Flip angle calibration was shown in Fig. 2 in arbitrary units valid only for small tip angles, but extension to high tip angle is expected. This technique has also usefully been applied to “no holes” (min{1/min(B1+)}) static B1+ mapping.

Conclusion
Growing the region in kt-points results in repeatable and robust MLS optimised homogeneous excitation. It is not proven that this solution is globally optimal, but no superior solutions were found with randomised MLS or GA optimisations.

References