Highly Accelerated Multicoil Bloch-Siegert *B1*+ Mapping Using Joint Autocalibrated Parallel Imaging Reconstruction

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Introduction High field MRI holds significant promise for many existing and new applications of MRI. One of the major technical challenges in high field imaging is inhomogeneity of the transmit RF (B_1^+) fields, which can be alleviated using parallel transmission (pTx) [1]. However, (pTx) requires B_1^+ field mapping, which must be performed during pre-scan in each subject. Ideally the fields for each element of an array could be rapidly measured over the entire imaging volume, however, even the fastest existing B1+ mapping techniques suffer from relatively long acquisition times of up to several minutes for a large number of transmit channels [2]. Previous efforts to accelerate B1+ mapping include the application of single-shot imaging [2] and compressed sensing and parallel imaging (PI) [3]. Here we present a straightforward method to accelerate Bloch-Siegert (BS) B_1^+ mapping [4] beyond the number of receive channels by performing a joint autocalibrated PI reconstruction across the transmit array.

Theory The proposed method is based on the fact that each transmit channel's BS encoding pulse imparts a unique smooth phase shift to the same underlying image. This phase shift can be mathematically absorbed into the receive sensitivities, leading to an augmented set of virtual receive channels. Thus, BS data for N_t transmit channels, each comprising data for N_r receive channels at two symmetric off-resonant frequencies (+/-), effectively comprises data from $2xN_rxN_t$ virtual receive channels. We exploit this augmented receive channel array to accelerate BS B_1^+ mapping beyond the number of physical receive channels. Furthermore, since the N_t BS datasets are acquired at different time points, we have the opportunity to improve image reconstruction quality by acquiring disjoint/staggered k-space sampling patterns for each transmit channel, the advantage of which is demonstrated here.

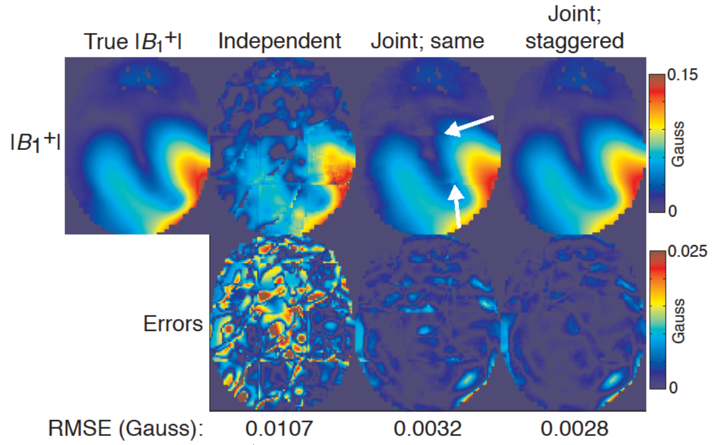

Figure 1: Reconstructed B_1^+ Maps using different reconstruction/sampling methods and the error in each. Calibration region was of size 10x10, with an acceleration of 16 (4x4) in the undersampled region. White arrows point to aliasing errors in the Joint; same pattern B_1^+ map which were removed in the Joint; staggered B_1^+ map.

Methods BS B_1^+ mapping data were synthesized from the simulated B_1^+ and B_1^- maps at 300 Mhz (7T) for an 8-channel TEM array in a human head model, calculated using CST Microwave Studio (CST AG, Darmstadt, Germany). The maps had a 24 cm FOV and 128x128 matrix size. The Cartesian SPIRiT method [5] was chosen as the PI reconstruction algorithm since it requires little modification to allow distinct k-space sampling patterns for each receive channel. Three acquisition and reconstruction scenarios were compared: (1) Independent reconstruction of each of the $2xN_t$ BS datasets with the same sampling pattern, (2) Joint reconstruction of all $2xN_t$ datasets with same sampling pattern, and (3) Joint reconstruction with same sampling across BS +/- images of each channel but staggered sampling across Tx channels. A calibration region of size 10x10 was chosen for high acceleration and since this placed considerable B1+ energy in the undersampled region, thereby rigorously testing our method. g-factor and angle-to-noise ratio maps were determined empirically using Monte Carlo simulations with 100 realizations. B_1^+ maps were combined across receive channels using an image magnitude-weighted average [4].

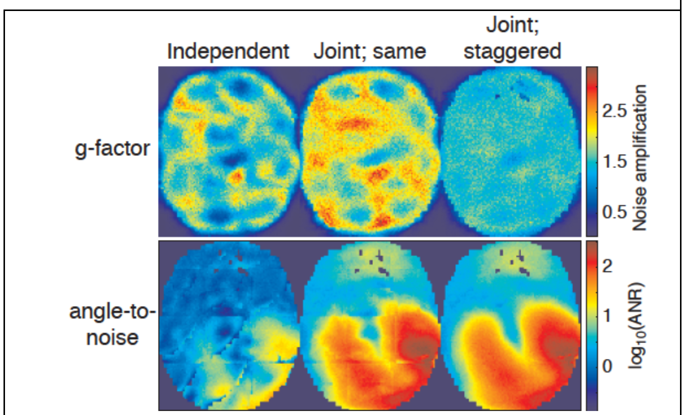

Figure 2: g-factor and angle-to-noise ratio maps using different reconstruction/sampling methods.

Results Figure 1 shows a true B_1^+ map and the maps obtained in each scenario and their errors at an acceleration of 16x. The most accurate result was obtained by using joint reconstruction with staggered sampling patterns across Tx channels. Figure 2 shows the g-factor and angle-to-noise maps for the three sampling methods. Joint reconstruction with a staggered sampling pattern had the least and most uniform g-factor. Joint reconstruction alone with the same sampling pattern increased ANR but staggering minimized residual aliasing. Figure 3 illustrates the change in RMSE values between the original B_1^+ map and the B_1^+ maps reconstructed using the three different methods. The RMSE for independent reconstruction rose steeply beyond an acceleration of 2x. But for the joint reconstructions the errors remained relatively flat with increasing acceleration.

Conclusion The proposed method enables acceleration of B_1^+ mapping beyond the number of receive channels. The method is compatible with any autocalibrating PI image reconstruction method which permits different sampling patterns for different receive channels. Experimental validation and extension to non-Cartesian trajectories are forthcoming.

References [1] W A Grissom et al. Imag Med, 2:675-93, 2010. [2] M Khalighi et al, 19th ISMRM, p. 578, 2011. [3] M Doneva et al. 18th ISMRM, p. 2833, 2010. [4] L I Sacolick et al, MRM, 63:1315-1322, 2010. [5] M Lustig et al, MRM, 64:457-471, 2010.

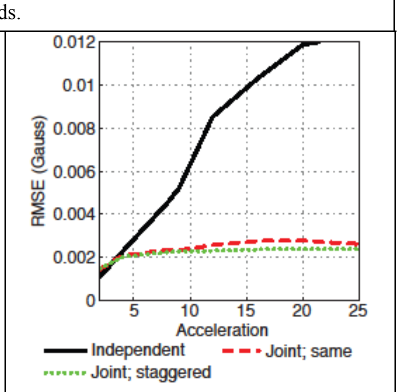

Figure 3: Error v/s Acceleration curve for the different reconstruction/sampling methods