In vivo Parallel RF Excitation with B0 correction

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Introduction: Parallel RF excitation [1,2,3] is an emerging technology which has gained much interest in recent years. It offers the potential to address several important challenges, including RF inhomogeneity at high field, and the selection or suppression of shaped imaging volumes. Various experimental implementations of such systems has been achieved [4,5,6,7], and in this work we demonstrate the use of parallel RF excitation, with B0 inhomogeneity correction incorporated into the RF design, for human scans using both body and head excitation systems. Two types of excitation profiles were designed: a 2D spatially selective excitation, and a slice selective B1-inhomogeneity correction excitation. By incorporating B0 inhomogeneity information into the RF design, significantly improved performance was achieved.

Theory and Methods

System setup: Experiments were conducted on a Siemens Magnetom TRIO, A TIM system, equipped with an 8-channel TX Array. Two excitation coil array configurations were used: *i)* an 8-rung degenerate mode birdcage *body* coil with a 12-channel matrix head array for receive; and *ii)* an 8-rung degenerate mode birdcage *head* coil with uniform-mode body coil for receive.

B1 mapping and RF Design: For rapid B1 mapping, low voltage excitation of individual coils with uniform receive was used. The acquired maps were fitted with 3rd-order spatial polynomials. A B0 map was measured and incorporated into the RF pulse design, and used to refine the B1 phase map estimation by rewinding the B0 inhomogeneity effect on the measured B1 phase (rewinding time = TE – $T_{rf}/2$, where T_{rf} is the RF duration for B1 mapping). Parallel excitation RF pulses were designed based on the image domain approach presented by Grissom [3], including a B0 term. This method formulates the small tip approximation as: $m(x) = i\gamma m_0 \sum_{r=1}^{R} S_r(x) \int_0^T b_{1,r}(t) e^{i\gamma\Delta B_0(x)(t-T)} e^{ix\bullet k(t)} dt$, where S_r and $b_{1,r}$ are the sensitivity profile and the RF waveform for coil r, and m is the desired profile. This can be rewritten into a matrix form $m = Ab$ and solved. In this work, an LSQR-based method was used for the matrix inversion, resulting in significantly faster calculation time and lower RF energy than SVD-based methods [8]. Two types of excitation profiles were used for the design; 2D spatially selective excitation and homogeneous slice selective excitation. Spiral and spoke k-space trajectories were used for these designs [7]. To demonstrate the effect of B0 inhomogeneity, an axial section though the head with substantial B0 inhomogeneity was chosen for imaging.

Results

Body Coil Excitation: Fig1. shows the estimated B1 map of the 8-rung degenerate mode birdcage *body* coil after polynomial fitting and phase rewinding. Fig2. (top-left) shows the B0 map collected. For the body coil parallel excitation, uniform slice selective excitation of 0.5 cm, was performed using the 4-spoke design, with RF pulse duration of 3.42ms. Fig2. shows the result of the excitation without (top-right) and with B0 compensation (bottom-left). Also shown in the figure is the sharp slice selective profile achieved with this method (bottom-right).

Head Coil Excitation: 2D spatially selective excitations with spiral k-space trajectory were performed using the 8-channel parallel head coil array. Fig3. shows a 2X excitation of the “Tim Tx” logo without (left) and with (center) B0 correction. The resolution used for the design is 5 mm and the pulse duration is 2.9 ms. Also shown is a half brain excitation at 4-fold acceleration without B0 correction (right), with 5 mm design resolution, and pulse duration of 2.5 ms.

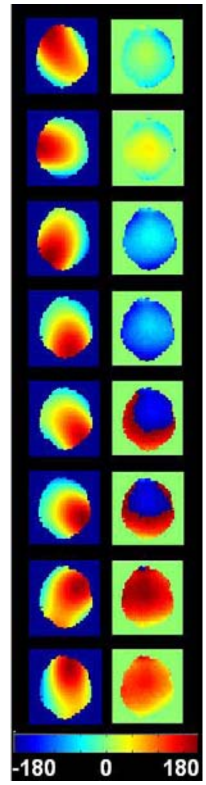

Fig. 1: Magnitude (left) and phase (right) of the 8 rung degenerate mode birdcage B1 maps.

Discussion and Conclusion

Successful implementation of 8-channel Parallel RF Excitation by body and head coil excitation for in vivo human study with B0 inhomogeneity correction has been realized. Both slice selective and 2D spatially selective excitation were created. For the slice selective excitation with no B0 correction (Fig. 2), large in-plane non-uniformity in the excitation profile is observed frontally. Significant improvement is achieved when B0 inhomogeneity is taken into account in the design. However, some residual non-uniformity can still be observed in the right part of the image, which may be due to imperfection in the B1 map estimate. For the 2D spatially selective excitation (Fig. 3) the “Tim Tx” excitation shows reduced blurring artifact when B0 correction is incorporated. Also, as expected, for the half brain excitation at 4-fold acceleration, the effect of B0 is minimal because the RF duration is relatively short. Artifacts that remain after B0 correction are likely to result from imperfection in the B1 map estimate. *In conclusion*, it has been shown that B0 correction plays an important role in improving the excitation profile in human in vivo study on an 8-channel parallel excitation system. Further effort will concentrate on methods for rapid and accurate B1 mapping for in vivo applications.

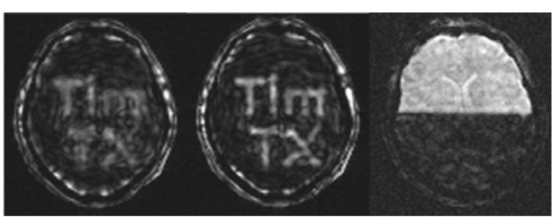

Fig. 3: 2X “Tim Tx” Excitation without (right) and with (center) B0 correction. 4X acceleration “half brain” excitation without B0 correction (left)

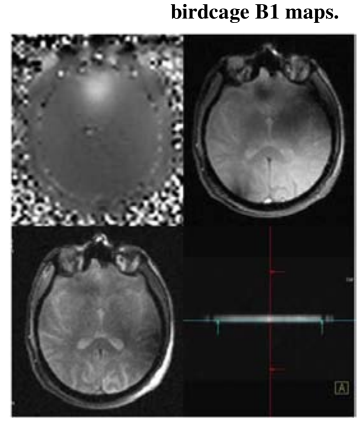

Fig. 2: B0 map (top-left), slice selective excitation without (top-right) and with (bottom-left) B0 correction. Slice profile is also shown (bottom-right)

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