A Simple B_1 Correction Method for High Resolution Neuroimaging

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Introduction

Developments in multi-channel detector arrays and increases in magnetic field strength have led to at least an order of magnitude sensitivity increase in MR imaging over the last decade. This can be applied to increase spatial resolution to well below 1mm, which is expected to have a major impact for clinical diagnosis. However, non-uniformities in transmit and receive B_1 field lead to severe intensity variations over the image, complicating its interpretation. Transmit B_1 nonuniformities are partly caused by dielectric resonance and finite wavelength effects, which are difficult to quantify and correct for. Correction of reception B_1 non-uniformities, particular severe when small array elements are placed close to the object, requires a sensitivity reference map, often not available at high field. Here we present an alternative method for obtaining high resolution MRI with minimal intensity variations.

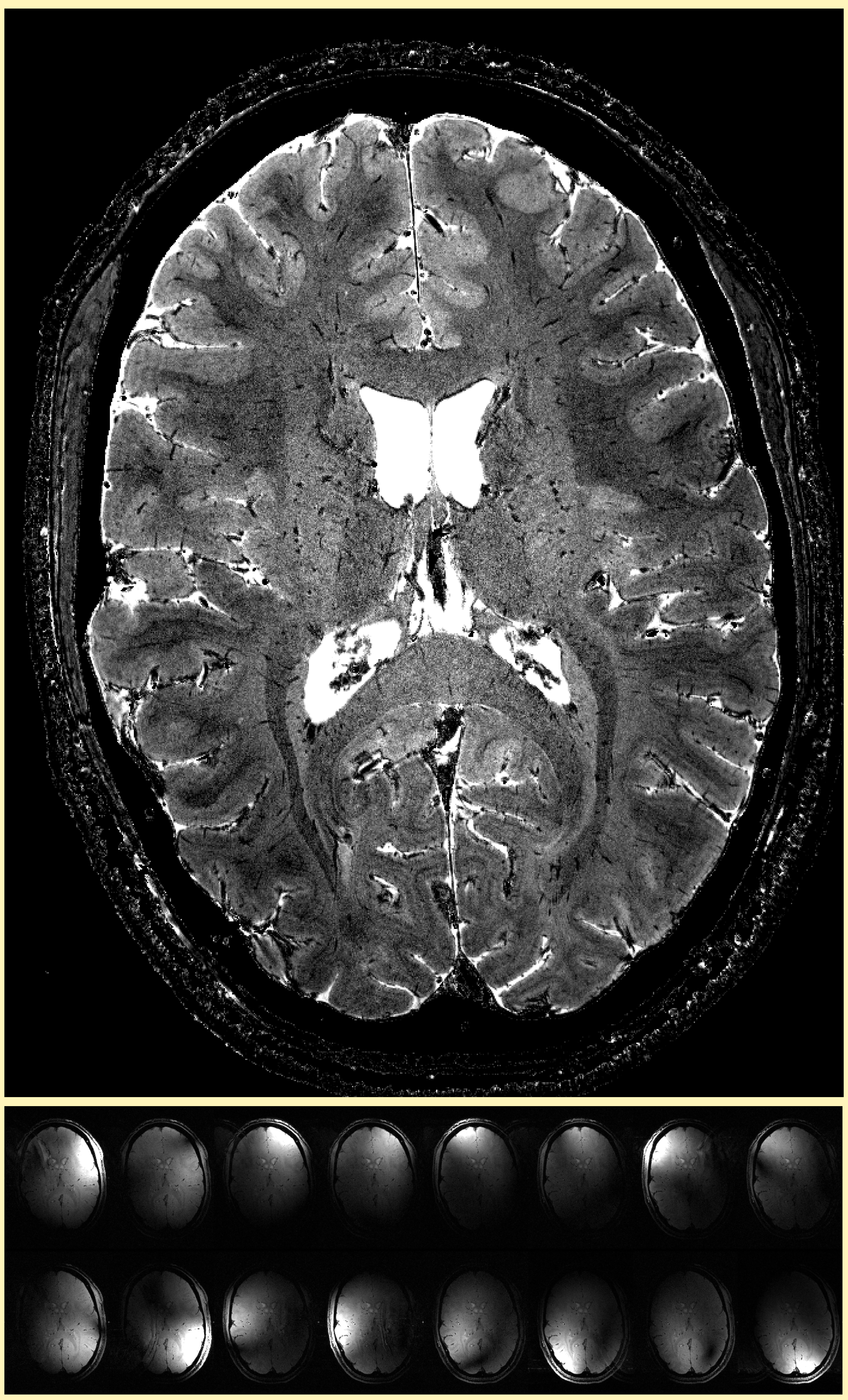
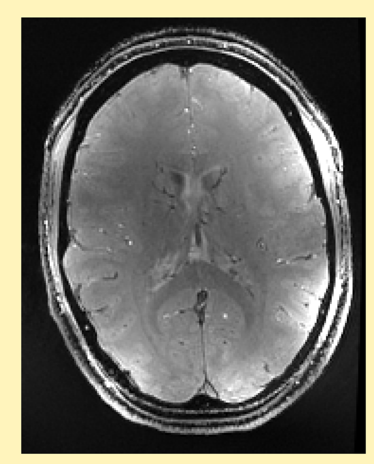
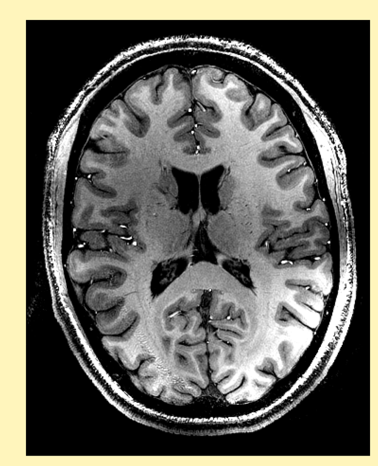


Figure 1.
Example of high resolution gradient echo with correction (top), the bottom images show the coil sensitivity maps used in the SENSE reconstruction. Image parameters: TR 700ms, TE 31.4ms flip angle 40, voxel dimensions 234x234x500µm^3, 3 averages in total scan time of 30 minutes.

Methods

The method is based on the acquisition of a reference map with low tissue contrast, achieved through manipulation of acquisition parameters: In T_1-weighted imaging, T_1 weighting can be reduced by changing acquisition timing or omitting the inversion pulse. In T_2^*- or T_2-weighted imaging, contrast can be reduced by shortening TE. The resolution of the reference map can be reduced to improve SNR and/or lower scan time. One caveat is that contrast dependence on flip angle should not change between reference and actual scan. The effectiveness of the proposed method is demonstrated in a number of image types: 3D MP-RAGE based T_1-weighted imaging, Turbo-FAIR perfusion imaging [1], and high resolution gradient echo anatomical scans. Experiments were performed at 7T using a 24-element receive array [2], 16 of which were selected for reception. Respiratory induced phase changes were compensated in real time [3]. Image reconstruction was performed by phase-sensitive noise weighted channel combining [4]. The reference image was smoothed by fitting its intensity with a 10th order 3D polynomial function. Intensity correction was performed by dividing the anatomical data by this smoothed and interpolated reference image. Alternatively, the intensity correction can be incorporated in the sensitivity reference for a SENSE type coil combination [5].





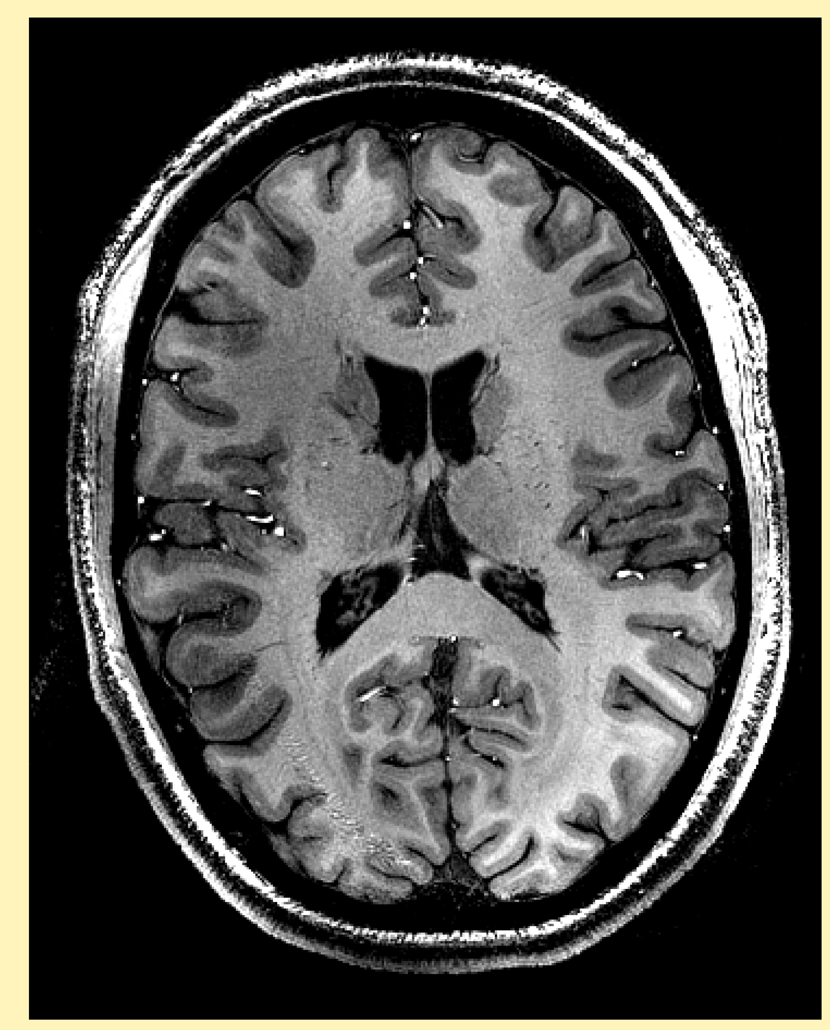
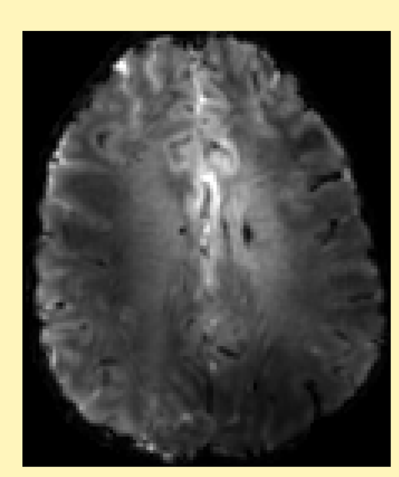
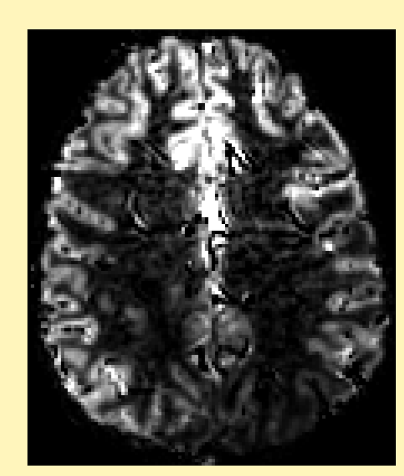


Figure 1.
MPRAGE image with correction. Voxel dimensions 468x468x1000µm^3,TI 1.1s, TR 3s , 10° flip angle, 60 sections (3D), 20 min acquisition time. The reference was an equivalent 3D gradient echo acquisition without inversion at half the in-plane resolution. The slice shown is at the same location as fig. 3.





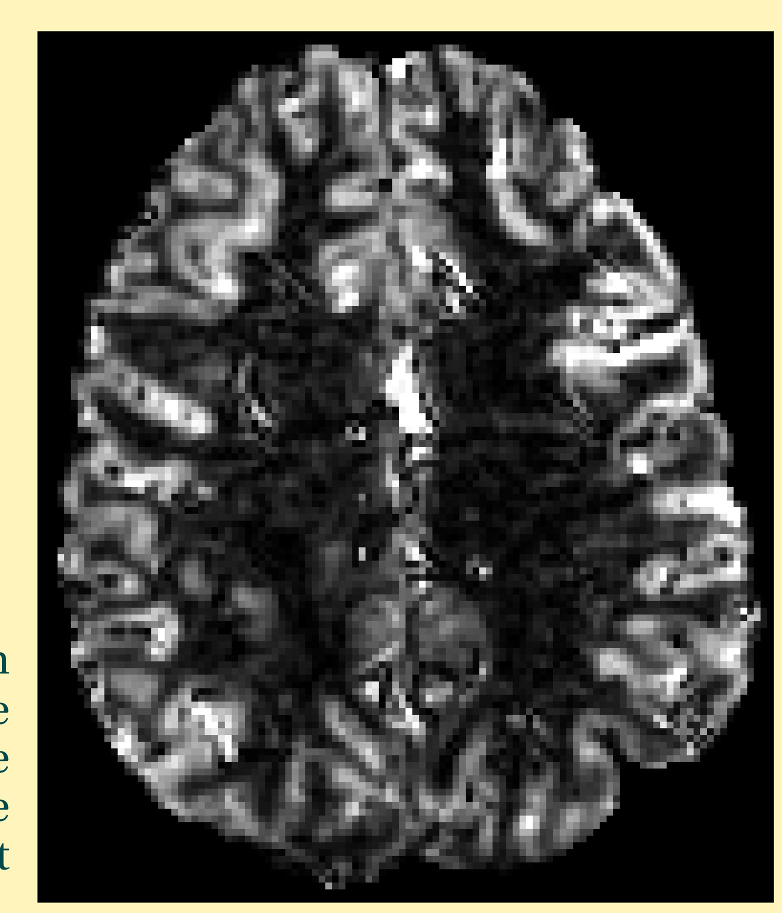


Figure 3.
High resolution TURBO FAIR perfusion (3). Voxel size 1.1x1.1x2mm^3, SENSE rate 3, FOV 240mm, TR 1s, TI 500ms, flip angle 90, 10 minutes total acquisition time. The reference is derived from images without inversion.

Results & Discussion

Examples of the effectiveness of the correction method are shown in the figures. After combining the 16 RF channels, substantial intensity variations remain. The corrected images shows notably more uniform intensity. The presented method allows for an effective and simple way to correct for intensity variations resulting from B_1 non-uniformity, at the cost of a minimal increase in scan time. Additionally, post-processing methods can be used based on low-pass filtering. However, such methods generally fail when spatial frequency of the B_1 variations approaches that of the anatomical structures. The presented method is comparable to a simplified version of the correction methods proposed in [6]. Although transmission and reception B_1 variations are not quantified here, their contribution to the image intensity can still be effectively eliminated in one step. This works as long as T_1 saturation (by readout pulse) is similar to that of reference.

Conclusion

Intensity correction of both transmit and receive B_1 inhomogeneities in high field high resolution images improves the image quality with the minimal additional cost of a (fast) low resolution reference scan.

References

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