RECEPTION SENSITIVITY INHOMOGENEITY CORRECTION AT ULTRA HIGH FIELD USING A FAST GRADIENT ECHO SEQUENCE

Franck Mauconduit[1], Aurélien Massire[2], Nicolas Boulant[2], Alexis Amadon[2], and Alexandre Vignaud[2]
[1]*Siemens Heathcare, Saint Denis, France,* [2]*CEA, DSV, I2BM, Neurospin, LRMN, Gif-Sur-Yvette, Ile de france, France*

TARGET AUDIENCE – All physicists working on ultra-high field MR systems

PURPOSE – While ultra-high field (UHF) MRI has shown great opportunities for the brain exploration, significant inhomogeneity artifacts lead to a spoiled image quality. Transmitted radiofrequency field as well as reception sensitivity need to be corrected in order to restore UHF image value. Two types of approaches have been proposed in the past: in vivo measurements of transmitted and receive field maps [1,2] and post processing alone [3,4]. Based on previous methodology[1,2], we show that a gradient recalled echo (GRE) sequence with a 9 sec acquisition time and filtering process can successfully correct the reception non-uniformities within an additionally acquired contrast weighted image.

THEORY – Theoretically, reception sensitivity is obtained using a sequence where parameters are set to cancel tissue contrast in the image. The corresponding parameters are not realistic and only a low contrast image can be acquired. Moreover, based on the assumption that the intensity non-uniformity is slowly varying spatially, the low frequency component can then be filtered from the low contrast image.
Mathematically, reception sensitivity can be expressed as:

$$R(x) = F(\ S_{LOW\ CONTRAST}(x)\ ) / T(x)$$

where T(x) is the transmission field profile, $S_{LOW\ CONTRAST}(x)$ the low contrast image at position x and F is a low pass filtering function. This method requires the acquisition of a transmission field map which is often a prerequisite at UHF. In this work, we investigate the effect of a repetition time reduction on a GRE sequence used as the low contrast image. The purpose is to achieve a reasonable inhomogeneity correction in a very short acquisition time.

METHODS – The experiment was performed on a Siemens 7T Magnetom scanner with a birdcage quadrature transmit head coil and a 32-channel receiver head coil. Informed consent of the healthy volunteer was obtained in accordance with guidelines of our institutional board. A B1 field map was measured using actual flip angle imaging (AFI) 3D sequence [5] with following parameters: matrix size = 64 x 64 x 64, resolution = 4 x 4 x 4 mm3, pulse repetition time (TR) = TR1 + TR2 = 180 msec, n = 5, prescribed flip angle = 90° and a total acquisition time of 3min16. A 3D gradient echo (3D-GRE) sequence was acquired with flip angle set to 1°, an echo time of 2 msec to minimize T2* weighting. All image parameters are identical to the AFI sequence. The 3D-GRE was repeated with the following TR: 300, 100, 50 and 10 msec leading to acquisition times of 4m34, 1m31, 46sec and 9sec respectively. A MPRAGE 1mm isotropic sequence was acquired with an inversion time of 1100 msec, a flip angle of 9° and a scan time of 6 min on which our inhomogeneity correction methodology was applied. Following the sequence acquisitions, a post processing is applied as described in figure 1. All computations were performed on Matlab (Mathworks Inc, Natick USA).

RESULTS – As shown in figure 2, the error introduced by reducing TR to 10 msec does not exceed a value of 5% compared to a TR of 300 msec. The error is slightly better and comparable for both TR = 100 msec and TR = 50 msec. Figure 3 shows that the MPRAGE image recovers a good homogeneity throughout the entire image. No difference in recovered uniformity is observed when using 3D-GRE sequence of TR = 300 msec and TR = 10 msec.

DISCUSSION – GRE sequence parameters have been chosen to minimize the tissue contrast in the image (low flip angle, short echo time). Whereas TR reduction enables a faster sequence, it also brings back tissue contrast. The low pass filter is therefore very important to remove residual tissue contrast. We show that a 10s 3D-GRE sequence is sufficient to recover high-quality homogeneity from reception non uniformities.
Although our method requires more than 3 min of acquisition including 3D-GRE and B1 field sequences, recent developments will allow us to acquire a B1 map in about 20 seconds. Subsequently the full procedure should soon take about 30 seconds to be acquired.
The standard clinical method used to correct reception inhomogeneity, known as the body coil method, is not feasible at UHF because of SAR limitations. Our work could lead to an alternate method of the standard body coil method for UHF.

REFERENCES –
[1] Milles J, et al. IEEE Trans Biomed Eng. 2006;53:885-95. [2] Wang J, et al. Magn Reson Med. 2005;53(2):408-17. [3] Vovk U., et al. IEEE Trans Med Imaging. 2007;26:405-21. [4] Zheng W, et al. Neuroimage. 2009;48(1):73-83. [5] Yarnykh VL. Magn Reson Med 2007;57:192–200.

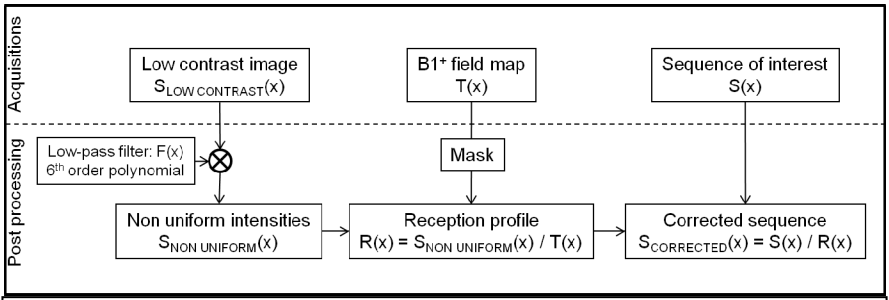

Figure 1: Flowchart of the sequence acquisition scheme and post processing algorithm used for the correction of non uniformities.

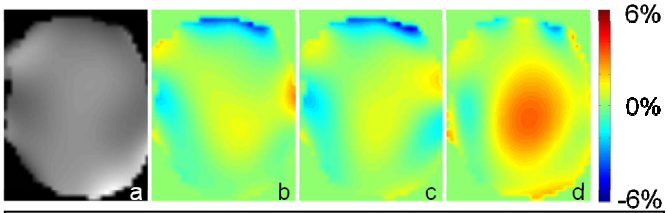

Figure 2a – Low pass filtered 3D-GRE sequence of TR = 300 msec. A 6th order polynomial fit is used to extract low frequency signal intensity. 2b,c,d – Percentage difference of filtered 3D-GRE at different TR where TR = 300 msec is chosen as a reference. Scale factor is set from -6% to +6%. b – TR = 100 msec, c – TR = 50 msec, d – TR = 10 msec.

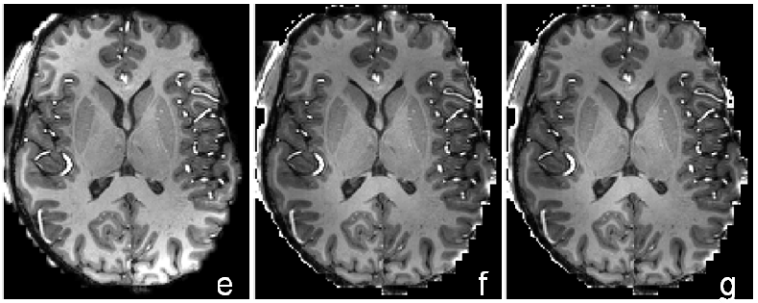

Figure 3 – a) MPRAGE image before correction f-g) Corrected MPRAGE image using a 3D-GRE sequence with TR = 300 msec and 10 msec respectively.