Cardiac Triggered B_1^+ mapping using Bloch Siegert in the heart at 3T

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Introduction:

There is a growing number of Cardiac MR (CMR) applications which could benefit of the signal to noise ratio advantage (SNR) at high magnetic fields [1-3]. However the image quality in CMR may be spoiled by effects other than SNR. The proximity of the air spaces of the lungs and the continuous motion of the heart cause strong B_0 offsets, which hamper methods such as SSFP imaging at high and ultrahigh fields [4]. Severe B_1^+ inhomogeneities present at high field strengths might affect quantitative CMR studies which require knowledge of the local applied flip angle (FA). In these cases a map of the local FA would be beneficial if not necessary. The acquisition of a FA map in the heart is challenging as most of the magntitude-based B_1^+ mapping methods rely on the knowledge of the steady state magnetization which is affected by the varying heart rates and repetition times in cardiac gated imaging [5]. On the contrary, phase-based B_1^+ mapping methods, are not affected by variation in TR/T_1. Most of them, however, use a non selective pulse for volume excitation [6-8], resulting in long acquisition times exceeding the single breath-hold period. This renders these techniques unsuitable for clinical routine imaging and makes them susceptible to respiratory motion artifacts. Realizing these limitations, this study examines the applicability of cardiac gated 2D phase-based B_1 mapping [9] with the goal to acquire a B_1^+ maps of the heart at 3T in a single breath-hold.

Materials and Methods:

Volunteer studies were performed, on a 3.0 T whole body MR system (Verio, Siemens Medical Solution, Germany). All subjects gave written informed consent. The body coil was used as transmit/receive. Volume selective B_0 shimming was performed with the shim volume confined to the heart region. The Bloch Siegert B_1 mapping method was implemented adding an off-resonance Fermi pulse to the standard 2D slice selective gradient echo sequence. The two images necessary for generating the B_1 map were interleaved. The off-resonance Fermi pulse parameters were chosen in order to reduce SAR and allow fast TRs : $\Delta\omega = \pm$ 4kHz , duration= 3.12ms; this corresponds to a nominal B_1=7.1µT, and a totalFA=340° (if that was applied on resonance). The other imaging parameters were: FA=25°, TR=40ms, TE=7.6ms, Matrix=96x96, FOV=300mm, Slice thickness=10mm. Imaging was segmented (8 segments per cardiac cycle) using acoustic cardiac gating (easyACT, MRI.Tools GmbH, Berlin, Germany) with an acquisition window of 320ms placed at an end diastolic phase. With these settings, the total acquisition time was about 20 seconds achieved in single breath-hold.

Results:

Figure 1 shows the scheme of the 2D-Bloch Siegert B_1 mapping sequence adopted in this study. The *k*-spaces for the two images $\pm\Delta\omega$ were interleaved to reduce differences due to motion. Figure 2 shows the simulated sensitivity curve of the accrual phase with the chosen parameters for the off-resonance Fermi pulse. The phase difference of the two images is considered: the curve shows a flat dependency on B_0 offsets, which eliminates the need for an additional B_0 map over the range of experienced offsets at 3T. The accrual phase for the nominal B_1 is about 38°, which is considered sufficient to estimate the B_1^+ inhomogeneities of the transmit coil. Figure 3 shows the magnitude image obtained with one of the two Bloch Siegert images, showing that the SNR in the heart is good enough to measure the phase accurately. No respiratory motion artifacts are visible as the image was acquired in one breath-hold. Figure 4 shows the B_0 map, demonstrating that the volume selective shim reduces B_0 offsets below 100Hz in the heart. Figure 5 shows the normalized B_1^+ distribution in the heart at an end diastolic phase. For the short axis view, a rather uniform excitation was found with this setup.

Discussion and Conclusions:

The Bloch Siegert B_1 mapping approach is of proven value for a broad spectrum of applications [9, 10]. Here we demonstrate the applicability of Bloch Siegert based B_1 mapping for cardiac MRI. The reduction of the duration of the Fermi pulse allowed for short TR at 3T which enabled scan times fitting in a single breath hold. However, MRI phase images are not exclusively given by the phase accrual induced by the Fermi pulse but might also include phase contributions due to blood pulsation and cardiac motion. These effects have not yet been accounted for and are currently under investigation. Nevertheless, our preliminary results do not show major changes in the calculated flip angle at the blood/myocardium interface and hence indicate that blood flow related phase contributions might be minor. We are researching methods to incorporate a systematic examination of velocity induced phase contributions to the final B1 map. The proposed approach can be extended to multi-channel cardiac coil arrays , with the ultimate goal to optimize B_1^+ homogeneity or B_1^+/SAR efficiency in cardiac MRI.

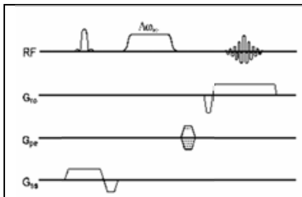

Fig.1. Scheme of the 2D Bloch Siegert B_1 mapping pulse sequence. The *k*-spaces of the two images are acquired in a interleaved manner, with $\Delta\omega$=+ or - 4kHz.

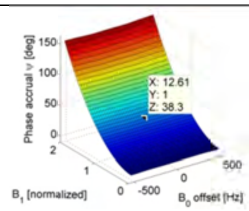

Fig.2. Curve of the sensitivity to B_0 and B_1 inhomogeneities of the adopted off-resonance Fermi pulse. The phase accrual for ΔB_0=0 and B_1=1 is ~38°. The nominal B_1=7.1µT. The curve is flat in the B_0 offset ranges experienced for cardiac MR at 3.0 T.

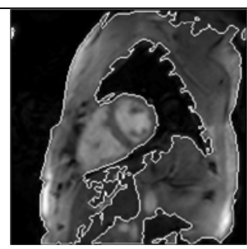

Fig.3. Magnitude image of the Bloch Siegert method, used for signal thresholding and masking. The SNR in the heart is sufficient to obtain accurate phase measurements.

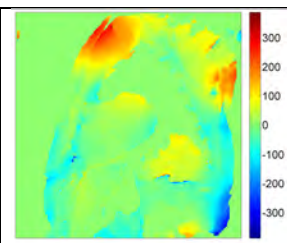

Fig.4. B_0 map of the imaged slice (short axis view). The volume selective shim reduces the frequency offsets in the heart to less than 100Hz which eliminates the need for accounting for B_0 inhomogeneities.

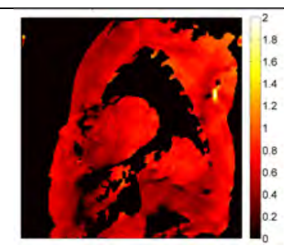

Fig.5. Normalized B_1 map of the body transmit coil in the heart using the Bloch Siegert method. The nominal value of 1 corresponds to 7.1µT. A rather uniform excitation was found for this setup.

References:

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