Turbo Spin Echo Bloch Siegert Shift B_1^+ Mapping

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Introduction

An interesting method for B_1^+ mapping based on the Bloch-Siegert (BLS) shift was recently presented (1,2) for gradient echo (FLASH) and Spin Echo (SE) sequences. This method uses off-resonant pulses before signal acquisition to encode the B_1 information into the signal phase. Fast B_1^+ mapping is possible since the repetition time has only minor influence on the quality of the phase information. In the present study, the use of BLS B_1^+ mapping was extended to CPMG-based Turbo-Spin-Echo (BLS-CPMG-TSE) imaging. For fast B_1^+ mapping phantom as well as *in vivo* 2D and 3D experiments were performed to evaluate the proposed method.

Theory

To encode the B_1^+ information into the signal phase, an initial off-resonant BLS pulse was applied between the 90° and the first 180° pulse (Fig.1a). To fulfill CPMG conditions in a TSE experiment, the same phase conditions must be present before every refocusing pulse (3). Therefore, a BLS pulse was introduced after each refocusing pulse with the same off-resonance as the initial BLS pulse. Furthermore, the power of these subsequent BLS pulses was increased to $\sqrt{2}$ times the power of the first pulse (Fig.1a/b). This was done in order to restore CPMG conditions since the phase shift introduced by the BLS pulse is proportional to the square of the B_1 field (1,2).

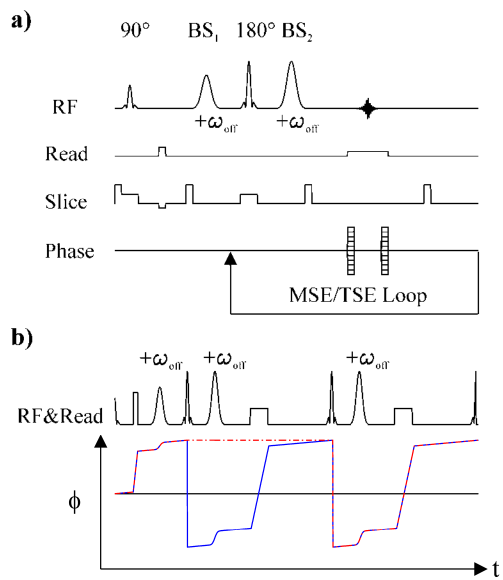

Fig.1a) Sequence diagram of the BLS-CPMG-TSE sequence. To obtain CPMG conditions the second BLS pulse used the same off-resonance frequency as the first BLS pulse to the power of $\sqrt{2}$. b) Simplified phase graph showing the phase coherency obtained from the primary echo pathway (blue) and the stimulated echo pathway (red, dashed).

Materials and Methods

BLS sequences were implemented on a 7T small animal scanner. All BLS experiments contained standard Gaussian-shaped off-resonant pulses. The BLS pulse duration (BS_{dur}) was set to 1ms. For all BLS experiments, two acquisitions with ω_{off} = +16kHz and ω_{off} = -16kHz were performed. All B_1^+ maps were calculated using the equations given in (1).

For 2D multi-slice *ex vivo* TSE experiments, the FOV included the total volume of the coil (Parameters: TE/TR = 10/30000ms; MTX = 128x128; FOV = 30x30mm^2; slices = 30; ST = 2mm). Linear and centric encoding as well as three different turbofactors (TF = 8, 16, 32) were used. For comparison, a multi-slice BLS-SE experiment with TR = 3750ms was performed as described in (1).

For *in vivo* experiments, one mouse was anesthetized with 1.5% isoflurane in a 2 L/min oxygen atmosphere. 3D TSE experiments were performed using the same BLS parameters as in the *ex vivo* experiments (Parameters: TR = 1000ms; FOV = (15x30x30)mm; MTX = 15x128x128; TF = 8, 16, 32). For comparison, SE experiments were performed. The animal experiments were performed in accordance with institutional guidelines and approved by Bavarian state authorities.

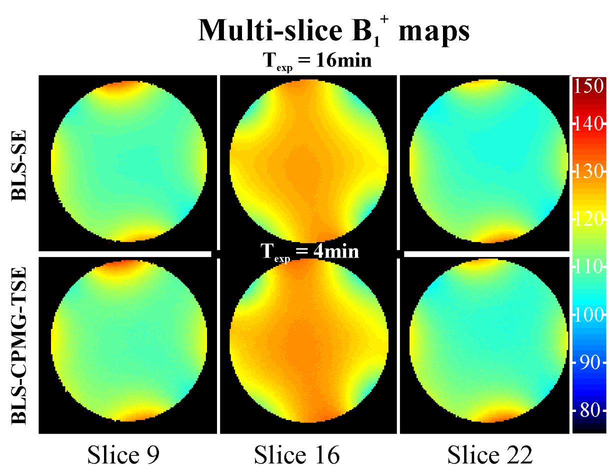

Fig.2) *Ex vivo* phantom results. Upper row: B_1^+ maps calculated from data obtained with a multi-slice BLS-SE sequence. Lower row: B_1^+ maps calculated from data obtained with the proposed multi-slice BLS-CPMG-TSE sequence. Both methods achieved excellent correlation; however, the BLS-CPMG-TSE sequence was acquired 4 times faster.

Results

Fig.2 shows the phantom experiment results. The B_1^+ values obtained from the BLS-SE experiment were in close agreement with the results from the BLS-CPMG-TSE sequence. Fig.3 shows good agreement between *in vivo* B_1^+ maps calculated from data obtained with a 3D BLS-SE sequence (Fig.3a) and a 3D BLS-CPMG-TSE sequence (Fig.3b).

Discussion and Conclusion

Using BLS-CPMG-TSE sequences decreased measurement time compared to BLS-Spin Echo was possible. This enabled fast acquisition of B_1^+ information. Furthermore, applying BLS-based spin-echo techniques minimized the influence of T_2^* effects, which are critical for gradient echo-based BLS methods at high field strengths. TSE-based BLS B_1^+ methods enable fast B_1^+ mapping although they intrinsically have high specific absorption rates (SAR). Thus, this technique is especially applicable for phantom and animal studies at high field strengths.

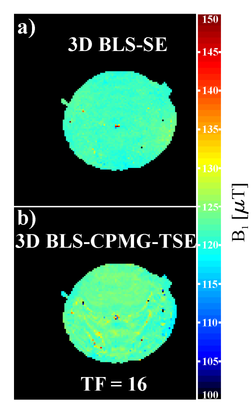

Fig.3) *In vivo* B_1^+ maps. a) B_1^+ map obtained with a 3D BLS-SE sequence. b) B_1^+ map obtained with a 3D BLS-CPMG-TSE sequence. The same image plane is shown

References

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