Simultaneous Bloch Siegert B_1^+ and T_2 mapping in one experiment using a multi spin echo sequence

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Introduction

A novel method for B_1^+ mapping based on the Bloch-Siegert (BLS) shift was recently introduced (1,2). BLS-based B_1^+ mapping employs off-resonant pulses before signal acquisition to encode B_1 information into the signal phase. In the present study, BLS B_1^+ mapping was extended to CPMG-based Multi-Spin-Echo (MSE). Through only one experiment, this method simultaneously provides the data needed for B_1^+ mapping with the data necessary for T_2-quantification. *Ex vivo* phantom and *in vivo* experiments were performed to investigate the proposed method.

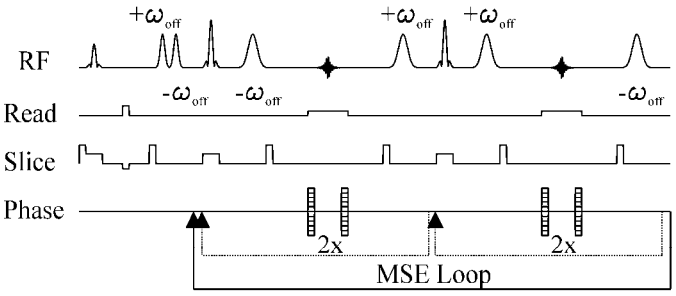

Fig.1) Sequence diagram of the modified BLS-CPMG-MSE sequence.

Theory

Two main considerations must be taken into account when CPMG-based BLS imaging is performed. **A)** For CPMG-based imaging, the same phase conditions must be given before every refocusing pulse (3). **B)** To enable the B_1^+ calculation, two phase images with opposite BLS encoding (ω_{off}= ± offset) must be acquired (1,2).
To fulfill both criteria, two BLS-pulses with the same duration and power but opposite off-resonance values were applied before the first 180° pulse. This phase state was restored by applying the same off-resonance pulses with doubled duration to each subsequent echo (Fig.1). The positive or negative BLS-phase information was encoded in the acquired data by varying which of the two BLS offset pulses was given before and which one after the readout. To obtain both BLS-phases with similar signal intensity, the positive and negative phase information was acquired in an interleaved fashion. Since only every second echo is fully refocused in a CPMG echo train, two subsequent echoes with the same BLS phase were always obtained.

Materials and Methods

The proposed BLS sequence was implemented on a 7T small animal scanner. In all BLS experiments, Gaussian-shaped off-resonant pulses were utilized. The BLS pulse duration was set to 0.5ms for the two BLS pulses before the first 180° pulse and to 1ms for all following BLS pulses. The BLS-off-resonace ω_{off} was set to = ±32kHz.

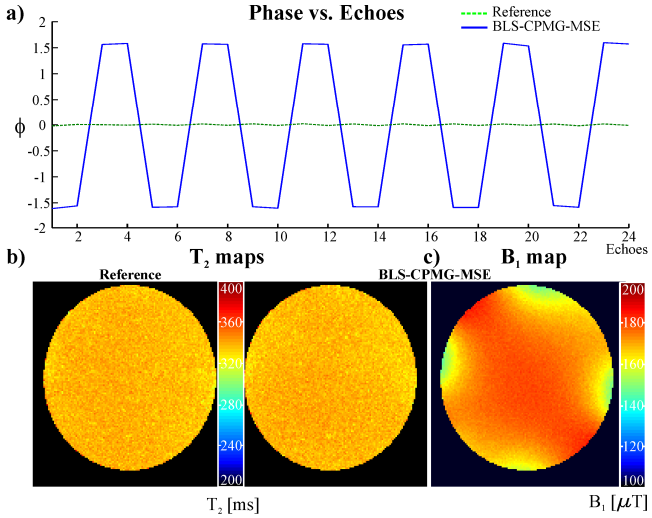

Fig.2) Results from the phantom experiments. a) The mean phase is plotted against the echo number, showing phase jumps between defined positive and negative BLS-phase due to interleaved BLS-encoding. b) T_2 maps of the reference (left) and the BLS experiment (right). Good agreement between both methods is visible. c) Calculated B_1^+ map.

For *ex vivo* 2D MSE experiments, a single slice of the phantom (1.5g hydroxyethyl cellulose dissolved in 50ml distilled water) was imaged (Parameters: Echo time/ repetition time (TE/TR) = 40/2000ms; echo images = 24; matrix size (MTX) = 128x128; field-of-view (FOV) = 30x30mm^2; slice thickness (ST) = 2mm; number of dummy scans (NDS) = 2, T_{exp} = 4min16s).
For *in vivo* experiments, one mouse was anesthetized with 1.5% isoflurane in a 2 L/min oxygen atmosphere. Using 2D MSE experiments, a single slice of the animal brain was imaged (Parameters: TE/TR = 10/2000ms; echo images = 40; MTX = 64x64; FOV = 25x25mm^2; ST = 2mm; NDS = 2; T_{exp} =2min8s).
For comparison, reference experiments were performed with same parameters but without BLS pulses. To obtain T_2 maps, the acquired data were fitted point wise to an exponential model. B_1^+ maps were calculated using equations provided in (1).

Results

Fig.2 shows the results from the phantom experiments. In Fig.2a, the mean phase of the different echo images is plotted for the reference experiment and the BLS-CPMG-MSE experiment. The phase of the reference experiments is centered between the phase values of the BLS-CPMG-MSE echo train. Fig.2b shows that T_2 values calculated out of the reference experiment (left) are in good agreement with the T_2 values calculated from the data of the BLS-CPMG-MSE experiment (right). In Fig.2c, the B_1^+ map calculated from the phase data of the BLS-CPMG-MSE experiment is shown. Fig.3 shows the result form the *in vivo* experiments. Fig.3a shows good agreement between the T_2 values calculated from the reference data (left) and the BLS-CPMG-MSE data (right). Fig.3b shows B_1^+ maps calculated from two different echo pairs of the BLS-CPMG-MSE experiment. Besides noise amplification, similar B_1^+ values were obtained.

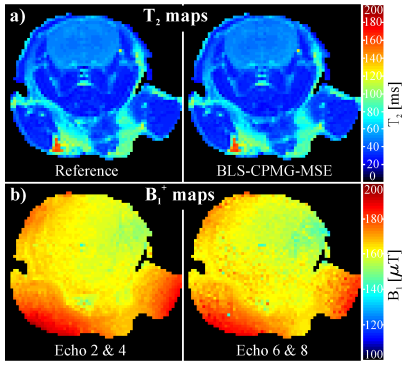

Fig.3) Results from the *in vivo* experiments. a) T_2-maps calculated from reference scan (left) and BLS-CPMG-MSE scan (right). b) B_1^+-maps calculated from different echo-images

Discussion and Conclusion

As shown the proposed BLS-CPMG-MSE sequence allowed the interleaved encoding of all necessary BLS phase information in one echo train while maintaining the CPMG conditions. Furthermore, T_2 quantification was not influenced by the BLS encoding. Thus, the proposed BLS-CPMG-MSE sequence allowed simultaneous T_2 and B_1^+ quantification in only one experiment. Hence, BLS-CPMG-MSE imaging is a promising technique for future quantitative MRI studies.

References

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