Flip Angle Calibration using SPAMM for Hyperpolarized 3He MRI

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Introduction:

The quality factor of the MR-coil is strongly influenced by its loading and, consequently, the flip angle created by the RF-Pulses may vary significantly. Thus, a flip angle calibration is necessary especially in case of using no-tune coils. In hyperpolarized ^{3}He MRI this procedure must be performed rapidly to guarantee the patient comfort (limited breath hold). A new calibration method based on the analysis of the phase image following a Spatial Modulation of Magnetization preparation (SPAMM) is presented in this work.

Theory and Methods:

The SPAMM [1] preparation, composed of two similar RF-Pulses separated by a gradient, creates a harmonic spatial modulation of the magnetization defined by: $M_Z(x)=M_0\cdot(1+\sin^2(\alpha_{SPAMM})\cdot(\sin(2\pi\cdot x/\lambda)-1))$ where α_{SPAMM} is the flip angle of the two RF-Pulses, x is the position along the direction of the gradient and λ the wavelength of the modulation. When α_{SPAMM} is higher than 45°, the longitudinal magnetization is periodically inverted and consequently the signal appears with a negative phase in the subsequently detected MR-image. This part with negative phase was measured and the real flip angle was calculated using an equation derived from the modulation equation under condition $M_Z(\Delta x,\alpha_{SPAMM}) < 0$. The relation between flip angle and «inverted phase» distance measured in units of modulation wavelength is shown graphically on figure 1:

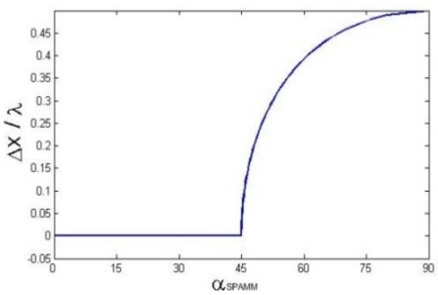

Fig. 1: Relation between the SPAMM flip angle and the measured distance divided by the wavelength of the modulation

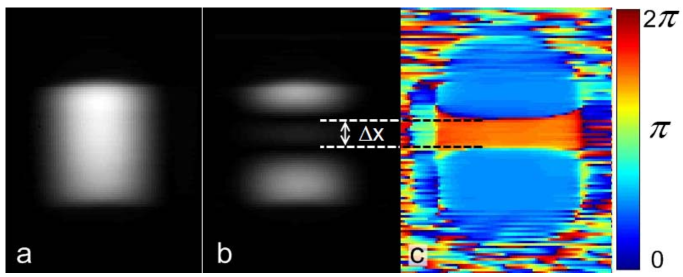

Fig. 2: (a): Reference magnitude image before SPAMM; (b): Magnitude image following SPAMM; (c) Difference between the reference phase image and the first phase image after the SPAMM

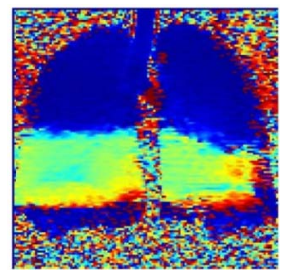

Fig. 3: calibration using SPAMM in healthy volunteer lung

The MR-images were acquired on a 1.5T MR-scanner (SIEMENS Sonata, Erlangen, Germany) using a FLASH pulse sequence with SPAMM preparation in readout direction after acquisition of the first image (Reference Image: Fig 2.a). For analysis the difference between reference and «SPAMM-prepared» phase image was used to exclude possible phase artifact (Fig. 2.c). The validation of this method was done with a 7cm birdcage coil using 50mL of Hyperpolarized ^{3}He (FLASH: α=1°; TR/TE: 6/3ms; FOV: 90*70; Matrix: 128*16) Several acquisitions were acquired with SPAMM flip angle set between 49° and 53°(λ=100mm) (cf. fig.4).

The flip angle calibration using SPAMM method was compared with a multiple acquisition of 1D projection profiles of ^{3}He-phantom with following fit of the hyperpolarized magnetization RF-decay function according to the ref [2]. Finally, the SPAMM calibration method was also tested in vivo on healthy volunteer using a 50cm double tuned (^{19}F/^{3}He) birdcage (Rapid Biomedical, Wurzburg, Germany). (TR/TE: 5.7/ 3ms FOV: 300*300 Matrix:128*64; λ=200).

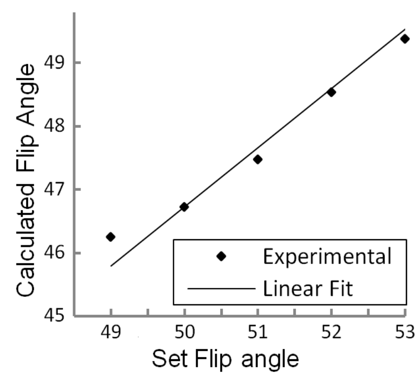

Fig.4 : Calculated from «inverted phase» distance vs. set flip angle.

Results:

As shown in figure 4, the relation between the set and calculated from SPAMM calibration flip angle is very closed to linear (Correlation coefficient R^2=0,96). Both methods show a very good agreement of determined flip angle with mean deviation less than 2 % which is smaller than the standard error of each of these methods. The volunteer experiment (fig.3) shows a good feasibility of the method for potential in vivo application including patients' studies.

Conclusion:

The advantage of presented flip-angle calibration method opposite to the ones based on rf-decay fit is that it is free of error due to the T_1 relaxation decay cause by oxygen and it does not require image processing with external software but can be done using the standard scanner interface tool and simple calculator. It however does not provide a full map of the flip angle distribution but only profile along the line perpendicular to the modulation wave's direction. The additional essential advantage is the possibility to combine calibration with positioning scout scan without acquiring extra images.

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